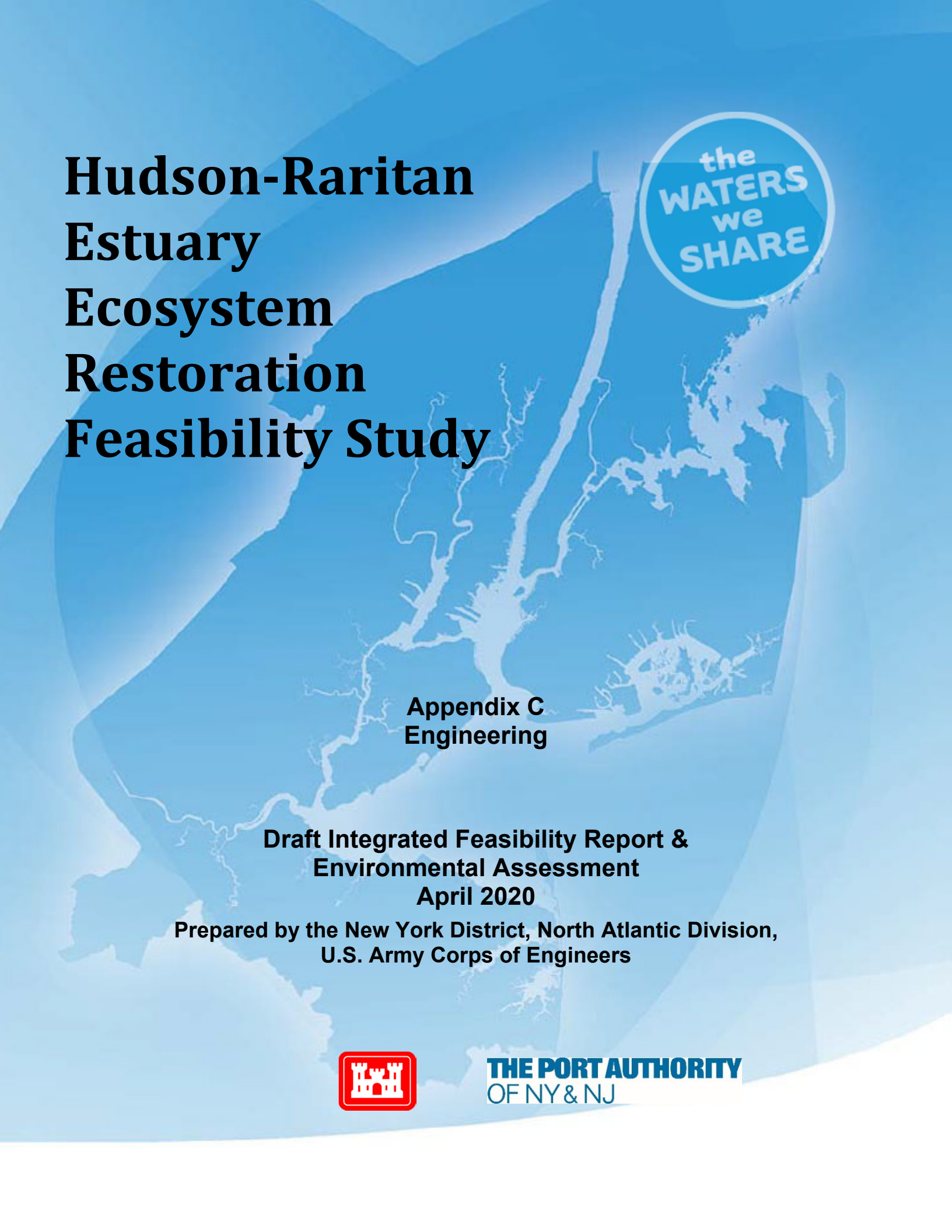
Hudson-Raritan Estuary Ecosystem Restoration Feasibility Study



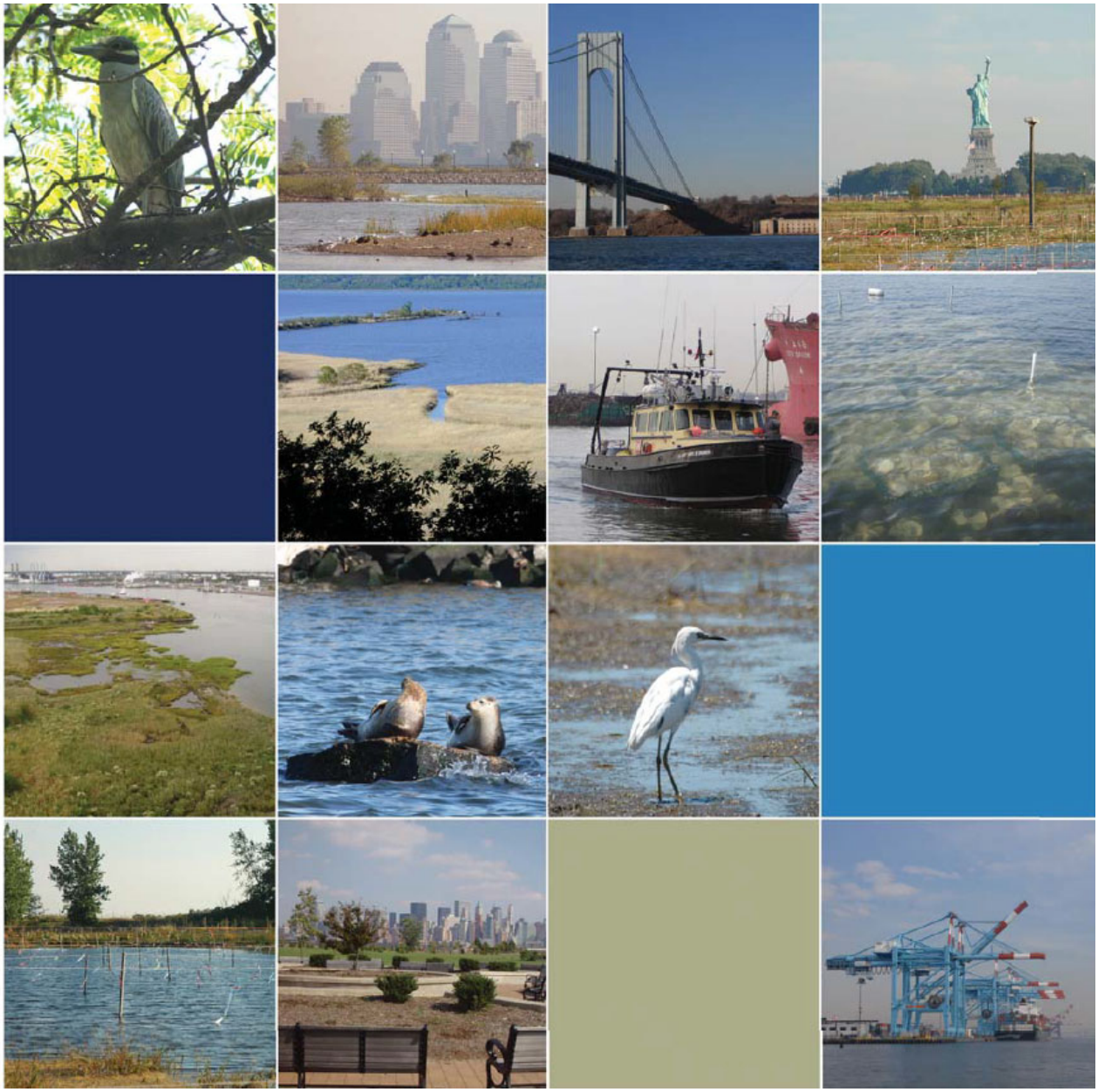
Appendix C
Engineering

Draft Integrated Feasibility Report &
Environmental Assessment
April 2020

Prepared by the New York District, North Atlantic Division,
U.S. Army Corps of Engineers

THE PORT AUTHORITY
OF NY & NJ

Hudson-Raritan Estuary Ecosystem Restoration Feasibility Study
Final Integrated Feasibility Report & Environmental Assessment



Hudson-Raritan Estuary Ecosystem Restoration Feasibility Study
Appendix C: Engineering

Table of Contents

1 Introduction 1
2 Existing Conditions 2
2.1 Jamaica Bay Planning Region 2
2.1.1 Jamaica Bay Perimeter Estuarine Sites 2
2.1.2 Dead Horse Bay 9
2.1.3 Fresh Creek 17
2.1.4 Jamaica Bay Marsh Island Sites 22
2.2 Harlem River, East River, Western Long Island Planning Region 24
2.2.1 Flushing Creek Study Area 24
2.2.2 Bronx River Study Area 30
2.3 Newark Bay, Hackensack River, Passaic River Planning Region 58
2.3.1 All Sites 58
2.3.2 Hackensack River Study Area 61
2.3.3 Lower Passaic River Study Area 67
2.4 Hudson-Raritan Estuary (HRE) Oyster Restoration Sites 72
2.4.1 All Sites 72
2.4.2 Bush Terminal Oyster Restoration Site 79
2.4.3 Head of Bay Oyster Restoration Site 79
2.4.4 Naval Weapons Station Earle Oyster Restoration Site 79
3 Design of Restoration Alternatives 79
4 Climate Change Assessment and Sea Level Change Analysis 80
4.1 Climate Change and Inland Hydrology Assessment 80
4.1.1 Site Descriptions 80
4.1.2 Phase 1: Current Climate and Climate Change Literature Review 80
4.1.3 Phase II: Vulnerability Assessment 87
4.1.4 Risk Assessment and Climate Change Conclusions 96
4.1.5 Climate Analysis References 98
4.2 Sea Level Change Analysis 100
4.2.1 HRE SLC Trends and Projections 101
4.2.2 Sea Level Change Impact Analysis 108
5 Discussion of Restoration Measures 136
5.1 Wetland Restoration/Creation 136

5.1.1 Estuarine Tidal Wetlands Restoration/Creation 136
5.1.2 Freshwater Wetland Restoration/Creation 138
5.2 Streambank Restoration 139
5.2.1 Shoreline Softening 139
5.2.2 Stacked Rock Wall with Brush Layers 140
5.2.3 Brush Mattress 140
5.2.4 Boulder Toe Revetment 140
5.3 Stream Restoration 141
5.3.1 Channel Restoration 141
5.3.2 Riverbed Restoration 141
5.3.3 Stream Naturalization and Clearing 141
5.3.4 In-Stream Structures 141
5.3.5 Sediment Forebay 141
5.3.6 Rock Vanes 142
5.3.7 J-Hooks 142
5.3.8 Bioretention Swales and Depressions 142
5.3.9 Aquatic Organism Passage (Fishway) 142
5.3.10 Weir Modification 142
5.4 Oyster Restoration 143
5.4.1 Spat on Shell 143
5.4.2 Oyster Gabions 143
5.4.3 Oyster Castles 143
5.4.4 Hanging Super Trays 143
5.4.5 Porcelain as Substrate 143
6 Quantities and Designs 143
6.1 Quantities 143
6.1.1 Excavation Volumes 143
6.1.2 Clearing and Grubbing 144
6.1.3 Plantings 144
6.1.4 Growing Medium 144
6.1.5 Shoreline Softening 144
6.1.6 Stacked Rock Wall w/Brush Layers 144
6.1.7 Brush Mattress 145
6.1.8 Boulder Toe Protection 145
6.1.9 Channel Restoration 145

6.1.10 Channel Deepening....146
6.1.11 Riverbed Restoration....146
6.1.12 Stream Naturalization and Clearing....146
6.1.13 Rock Vanes and J-Hooks....146
6.1.14 Sediment Forebay....147
6.1.15 Bioretention - Swales and Depressions....147
6.1.16 Aquatic Organism Passage....147
6.1.17 Weir Modification....147
6.1.18 Spat on Shell....147
6.1.19 Oyster Gabions....148
6.1.20 Oyster Pyramids....148
6.1.21 Hanging Super-Trays....149
6.1.22 Porcelain as Substrate....149
6.2 Designs....149
6.2.1 Jamaica Bay Planning Region....149
6.2.2 Harlem River/East River/Western Long Island Sound Planning Region....158
6.2.3 Lower Passaic River/Hackensack River/Newark Bay Planning Region....165
6.2.4 Oyster Restoration....171
7 Further Analysis and Design Development Needs....172
7.1 Jamaica Bay Marsh Islands....173
7.2 Jamaica Bay Perimeter Sites....173
7.3 Flushing Creek....173
7.4 Bronx River Sites....173
7.5 Lower Passaic Sites....174
7.6 Hackensack Sites....174
7.7 Oyster Restoration Sites....174
8 Conclusions....175
9 References....175

List of Figures

Figure 2.1: Wind Rose Plot of Resultant Wind Speed and Direction for JFK International Airport Wind Data (1984 to 2002)....8
Figure 2-2: Dead Horse Bay Tide Gauge Location....11
Figure 2-3: Dead Horse Bay Shoreline Change....14
Figure 2-4: Dead Horse Bay Shoreline Change (updated to 2016)....15
Figure 2-5: Fetch Directions for Dead Horse Bay....16
Figure 2-6: Fresh Creek Tide Gauge Location....19

Figure 2-7. Tide Gauge Locations in Elders Point and Yellow Bar, ...23
Jamaica Bay, NY (red squares). 23
Figure 2-8: Flushing Creek Tide Gauge Location 26
Figure 2-9: CSO and Dam Locations along the Bronx River 36
Figure 2-10: Locations of Sub-Watersheds within the Bronx River Basin 40
Figure 2-11: Channel Sedimentation in the Garth Woods section. 44
The new channel runs along the Bronx River Parkway. 44
Figure 2-12: Existing Stone Weir at Bronxville Lake 51
Figure 2-13: Existing Masonry Weir at Harney Road Site 55
Figure 2-14: Secaucus High School Tide Gauge 63
and Hackensack Restoration Sites. 63
Figure 2-15: Topographic and Bathymetric Surveys at Metromedia Tract site 65
Figure 2-16: Historic Map of the New York Bay Area Depicting Major Oyster Habitats in 1911. Shaded Areas Indicate the Principal Sources of Oysters 73
(Metropolitan Sewerage Commission 1911). 73
Figure 2-17: Proposed Oyster Restoration Locations 74
Figure 2-18: Bedrock Underlying the Oyster Restoration Sites 77
Figure 4-1. Location of Hutchinson River at Pelham NY Gage 01301500 88
Figure 4-2. Climate Hydrology Assessment Tool output using annual instantaneous peak discharge at Hutchinson River at Pelham, NY Gage 01301500 (HUC 0203) 89
Figure 4-3. Range of Projected Annual Maximum Monthly Streamflow in HUC 0203 (Lower Hudson-Long Island) 89
Figure 4-4. Projected Mean Annual Maximum Monthly Streamflow in HUC 0203 (Lower Hudson-Long Island) 90
Figure 4-5. Location of Second River at Belleville NJ Gage 01392500 90
Figure 4-6. Climate Hydrology Assessment Tool output using annual instantaneous peak discharge at Second River at Belleville, NJ Gage 01392500 (HUC 0203) 91
Figure 4-7. Output from Nonstationarity Detection Tool – Hutchinson River at Pelham, NY 93
Figure 4-8. Output from Nonstationarity Detection Tool – Second River at Belleville, NJ 94
Figure 4-9: Relative Sea Level Change Projections, 1992-2100, Gauge: Sandy Hook, NJ (#8531680) with Jamaica Bay Marsh Island Thresholds 102
Figure 4-10. Relative Sea Level Change Projections, 1992-2100, Gauge: Sandy Hook, NJ (#8531680) with Jamaica BayPerimeter Site Thresholds 103
Figure 4-12: Sea Level Trend and Projection (1980-2030), Gauge: Sandy Hook, NJ (#8531680) 104
Figure 4-11: Sea Level Trend and Projection, (Long Range, 1942-2100, Gauge: Sandy Hook, NJ (#8531680) 104
Figure 4-14: Sea Level Trend and Projection, (Long Range, 1942-2100), Gauge: Kings Point, NY (#8516945) 105
Figure 4-13: Relative Sea Level Change Projections, 1992-2100, Gauge: Kings Point, NY (#8516945) with Flushing Creek Thresholds 105
Figure 4-16: Relative Sea Level Change Projections, 1992-2100, Gauge: The Battery, NY (#8518750) with Oak Island Yards, Metromedia and Meadowlark Thresholds. 106
Figure 4-15: Sea Level Trend and Projection, (1980-2030), Gauge: Kings Point, NY (#8516945) 106
Figure 4-18: Sea Level Trend and Projection, (1980-2030), Gauge: The Battery, NY (#8518750) 107
Figure 4-17: Sea Level Trend and Projection, (Long Range, 1865-2100), Gauge: The Battery, NY (#8518750) 107
Figure 4-19. Duck Point Area – Tidal Elevation Curve. 132
Figure 4-20. Pumpkin Patch West Area – Tidal Elevation Curve 133

Figure 4-21. Oak Island Yards Area – Tidal Elevation Curve Analysis Extent.....134
Figure 4-22. Oak Island Yards Area – Tidal Elevation Curve 135

List of Tables

Table 1-1: Restoration Sites Recommended for Construction.....1
Table 2-1: Extreme Wind Speeds 8
Table 2-2: Dead Horse Bay North Tidal Datums, 2001 11
Table 2-3: Dead Horse Bay North Erosion Rates.....12
Table 2-4: Dead Horse Bay North Wind-Generated Wave Results Fetch 17
Table 2-5: Fresh Creek Tidal Datums, 2001.....19
Table 2-6: Jamaica Bay Tidal Datums, 2003.....24
Table 2-7: Flushing Creek Tidal Datums (2000) 26
Table 2-8: Summary of Geomorphology Bronx River Valley.....30
Table 2-9: Sub-watersheds in the Bronx River Basin.....31
Table 2-10: Area of Bronx River Basin upstream from each site 32
Table 2-11: Range of elevations for the Bronx River Basin.....32
Table 2-12: Bronx River valley characteristics for each site. 33
Table 2-13: General stratigraphy of the Bronx River north of Mosholu Parkway......34
Table 2-14: Summary of Existing Dams and Impoundments along the Bronx River 37
Table 2-15: Existing Conditions Peak Discharges in cfs at Key Points of Interest 41
Table 2-16: Dredge records provided by Westchester County, New York.....46
Table 2-17: Geomorphic Reaches.....47
Table 2-18: Secaucus High School, Tidal Datums, 2008.....64
Table 2-19: Tidal Datums within the Passaic River near the Minish Park Site.....71
Table 2-20: Proposed Oyster Restoration Sites.....75
Table 3.1 - Projected Changes in Mean Annual Temperature and Precipitation for Three Mid-Atlantic Estuaries (Najjar et al., 2009).....84
Table 3-2: Vulnerability scores for HUC 0203 (Lower Hudson and Long Island) 95
Table 3-3: Vulnerability scores for HUC 0202 (Upper Hudson) 95
Table 3-4: Dominant vulnerability indicators for the Upper and Lower Hudson/Long Island watersheds. Shown as Indicator Value/ % WOWA score.....96
Table 3-5: Accretion Increases.....109
Table 3-6 Dead Horse Bay, Projected SLC –Driven Habitat Change (Screening Phase) 110
Table 3-7 Fresh Creek, Projected SLC –Driven Habitat Change (Screening Phase).....110
Table 3-8 Duck Point, Projected SLC –Driven Habitat Change (Screening Phase).....111
Table 3-9 Stony Creek, Projected SLC –Driven Habitat Change (Screening Phase).....111
Table 3-10 Pumpkin Patch West, Projected SLC –Driven Habitat Change (Screening Phase) ...111
Table 3-11 Pumpkin Patch East, Projected SLC –Driven Habitat Change (Screening Phase) 111
Table 3-12 Elders Center, Projected SLC –Driven Habitat Change (Screening Phase) 112
Table 3-13 Flushing Creek, Projected SLC –Driven Habitat Change (Screening Phase).....112
Table 3-14 Oak Island Yards, Projected SLC –Driven Habitat Change (Screening Phase).....112
Table 3-15 Metromedia, Projected SLC –Driven Habitat Change (Screening Phase).....112
Table 3-16 Meadowlark, Projected SLC –Driven Habitat Change (Screening Phase) 113
Table 3-17: Dead Horse Bay, Projected SLC –Driven Habitat Change 114
Table 3-18: Fresh Creek, Projected SLC –Driven Habitat Change 115
Table 3-19: Duck Point, Projected SLC –Driven Habitat Change 116

Table 3-20: Stony Creek, Projected SLC –Driven Habitat Change 117
Table 3-21: Pumpkin Patch West, Projected SLC –Driven Habitat Change 118
Table 3-22: Pumpkin Patch East, Projected SLC –Driven Habitat Change 119
Table 3-23: Elders Center, Projected SLC –Driven Habitat Change 120
Table 3-24: Flushing Creek, Projected SLC –Driven Habitat Change 121
Table 3-25: Oak Island Yards, Projected SLC –Driven Habitat Change 122
Table 3-26: Metromedia, Projected SLC –Driven Habitat Change 123
Table 3-27: Meadowlark Creek, Projected SLC –Driven Habitat Change 124
Table 3- 28. Dead Horse Bay Salt Marsh, % of Design Acreage 125
Table 3-29 Dead Horse Bay Projected Year of SLC Impact (Low End) 125
Table 3-30. Fresh Creek Salt Marsh, % of Design Acreage 126
Table 3-31. Fresh Creek Projected Year of SLC Impact 126
Table 3-32. Jamaica Bay Marsh Islands Salt Marsh, % of Design Acreage 127
Table 3-33. Jamaica Bay Marsh Islands, Projected Year of SLC Impact 128
Table 3-34. Flushing Creek Salt Marsh, % of Design Acreage 129
Table 3-35. Flushing Creek, Projected Year of SLC Impact 129
Table 3-36. Oak Island Yards Salt Marsh, % of Design Acreage 129
Table 3-37. Oak Island Yards Projected Year of SLC Impact 130
Table 3-38. Metromedia Salt Marsh, % of Design Acreage 130
Table 3-39. Metromedia Projected Year of SLC Impact 130
Table 3-40. Meadowlark Salt Marsh, % of Design Acreage 131
Table 3-41. Meadowlark Projected Year of SLC Impact 131
Table 5-1: Dead Horse Bay Tidal Datums, ft NAVD88 150
Table 5-2: Dead Horse Bay Planting Elevations, ft NAVD88 151
Table 5-3: Fresh Creek Tidal Datums, ft NAVD88 152
Table 5-4: Fresh Creek Planting Elevations, ft NAVD88 152
Table 5-5: Duck Point Marsh Tidal Datums, ft NAVD88 154
Table 5-6: Duck Point Marsh Planting Elevations, ft NAVD88 154
Table 5-7: Stony Creek Marsh Tidal Datums, ft NAVD88 155
Table 5-8: Stony Creek Marsh Planting Elevations, ft NAVD88 155
Table 5-9: Pumpkin Patch West Marsh Tidal Datums, ft NAVD88 156
Table 5-10: Pumpkin Patch West Marsh Planting Elevations, ft NAVD88 156
Table 5-11: Pumpkin Patch East Marsh Tidal Datums, ft NAVD88 157
Table 5-12: Pumpkin Patch East Marsh Planting Elevations, ft NAVD88 157
Table 5-13: Elders Center Marsh Tidal Datums, ft NAVD88 158
Table 5-14: Elders Center Marsh Planting Elevations, ft NAVD88 158
Table 5-15: Flushing Creek Tidal Datums, ft NAVD88 159
Table 5-16: Flushing Creek Planting Elevations, ft NAVD88 160
Table 5-17: Oak Island Yards Tidal Datums, ft NAVD88 166
Table 5-18: Oak Island Yards Planting Elevations, ft NAVD88 167
Table 5-19: Metromedia Tidal Datums, ft NAVD88 169
Table 5-20: Metromedia Planting Elevations, ft NAVD88 169
Table 5-21: Meadowlark Marsh Tidal Datums, ft NAVD88 170
Table 5-22: Meadowlark Planting Elevations, ft NAVD88 171

Attachments

Attachment C-1	Proposed Design and Quantities
Attachment C-2	Sea Level Change: Tables and Mapping
Attachment C-3	Jamaica Bay Engineering Appendix
Attachment C-4	Bronx River: Geotechnical and Geological Report
Attachment C-5	Bronx River Geomorphic Assessment and SIAM Modeling
Attachment C-6	Bronxville Lake Hydrologic and Hydraulic Analysis
Attachment C-7	Garth Harney Hydrologic and Hydraulic Analysis
Attachment C-8	Lower Passaic River: Geotechnical and Geological Report
Attachment C-9	Meadowlark Marsh H&H Analysis
Attachment C-10	Oyster Restoration: Geotechnical Report

1 Introduction

This appendix presents supporting available technical information, including topography, bathymetry, geotechnical, hydrology & hydraulics (H&H) and modeling, which was considered during formulation of the restoration alternative plans for each site (Appendix D). Hazardous Toxic and Radioactive Waste (HTRW) and additional geotechnical data are presented in the HTRW Appendix G. Proposed designs are presented in Attachment C-1 of this appendix. A climate change and sea level change (SLC) assessment of the proposed designs was conducted and is discussed in section four. SLC results mapping is presented in Attachment C-2. This appendix presents technical information available in the literature and collected within each "Source" Study including:

- Jamaica Bay, Marine Park, Plumb Beach Ecosystem Restoration Feasibility Study;
- Flushing Creek and Bay Ecosystem Restoration Feasibility Study;
- Bronx River Basin Ecosystem Restoration Feasibility Study;
- Hackensack River Ecosystem Restoration Feasibility Study; and
- Lower Passaic River Ecosystem Restoration Feasibility Study.

Source study documentation is provided as Attachments C-3 through C-10. Specific engineering information if available is included for the following sites that are recommended in this Integrated Feasibility Report/Environmental Assessment (FR/EA) (Table 1-1).

Table 1-1: Restoration Sites Recommended for Construction

Location	Recommended Restoration	Site
Jamaica Bay Planning Region		
Jamaica Bay	Estuarine Habitat Restoration	• Dead Horse Bay • Fresh Creek
	Jamaica Bay Marsh Island Restoration	• Stony Creek • Duck Point • Elders Point Center • Pumpkin Patch West • Pumpkin Patch East
	Small-Scale Oyster Restoration	• Head of Jamaica Bay
Harlem River, East River, and Western Long Island Sound Planning Region		
Flushing Creek	Estuarine Habitat Restoration	• Flushing Creek
Bronx River	Freshwater Riverine Habitat Restoration	• Bronx Zoo and Dam • Stone Mill Dam • Shoelace Park • Bronxville Lake • Garth Woods/Harney Road
Newark Bay, Hackensack River, and Passaic River Planning Region		

Location	Recommended Restoration	Site
Hackensack River	Estuarine Habitat Restoration	• Metromedia Tract • Meadowlark Marsh
Lower Passaic River	Tier 2 Estuarine Habitat Restoration	• Oak Island Yards
	Freshwater Riverine Habitat Restoration	• Essex County Branch Brook Park
Upper Bay Planning Region		
Upper New York Bay	Small-Scale Oyster Restoration	• Bush Terminal
Lower Bay Planning Region		
Sandy Hook Bay	Small-Scale Oyster Restoration	• Naval Weapons Station Earle

2 Existing Conditions

2.1 Jamaica Bay Planning Region

2.1.1 Jamaica Bay Perimeter Estuarine Sites

The source study Engineering Appendix is provided as Attachment C-3 of this appendix and is summarized below. The source study originally evaluated and recommended (8) sites (Dead Horse Bay, Paerdegat Basin, Fresh Creek, Spring Creek South, Hawtree Point, Bayswater Point State Park, Dubos Point and Brant Point) for restoration in 2010. Six (6) were included in the initial array of sites (excluding Paerdegat Basin and Spring Creek South) and only two sites were subsequently recommended (Dead Horse Bay [North] and Fresh Creek). Information for all of these sites may be discussed below based on the interconnectivity of the sampling activities from the source study.

2.1.1.1 Topography & Bathymetry

Each of the perimeter sites within the Jamaica Bay Planning Region was surveyed in the spring of 2002. This work was accomplished by surveying multiple profile lines across the site at 100 to 200-foot intervals. The distance between surveyed points along each profile was less than 20 feet. The landward portion of the survey was completed using land-based surveying procedures, while the portions of the land that remained inundated were completed via a hydrographic survey. The landward limit of the surveys for all sites was the project limits. The seaward limit for all surveys was 300 feet from the shoreline, or the navigation channel, whichever came first. All survey data was collected with enough accuracy to produce topographic mapping with one-foot contours for use by the United States Army Corps of Engineers (USACE) in further development of the site designs.
The horizontal grid for all survey data is presented in the Long Island New York State Plane North American Datum 1983 horizontal coordinate system, and the elevations are referenced to the North American Vertical Datum 1988 (NAVD88). The use of legacy

topographic and bathymetric increases the uncertainty of the derived excavation quantities for these sites and represents an acceptable cost risk. This uncertainty is fully reflected in the cost estimate contingency of these sites and is noted in the risk register. More detailed surveys for all Jamaica Bay sites will be needed in the next phase of the study.

2.1.1.2 Navigation

A federal navigation channel is within Jamaica Bay, along both the west and south shores, with an entrance channel connecting two (2) interior channels to the Atlantic Ocean at Rockaway Inlet. North Channel is the interior channel from the Marine Parkway Bridge along the west shore of the bay and is authorized to 18 feet deep at mean low water (MLW) and 300 feet wide to Mill Basin, with a turning basin 1000 feet wide and 1000 feet long at that point. North of Mill Basin the channel continues with an authorized depth of 12 feet MLW and 200 feet wide to Fresh Creek Basin. Beach Channel, authorized to 15 feet deep MLW and 200 feet, is the interior channel from the Marine Parkway Bridge along the south shore and continues to Head of Bay. At the entrance to Head of Bay, the channel branches, going north into the Head of Bay and south, forking again into Mott Basin and Inwood Creek. The entrance channel, Rockaway Inlet, is authorized to 18 feet deep MLW and 500 feet wide from the Marine Parkway Bridge to Rockaway Point, where it expands to an authorized 20 feet deep MLW and 1000 feet wide to the ocean. The Rockaway Inlet entrance channel is generally dredged on a two (2) to three (3) year maintenance cycle. The five-year average annual commercial tonnage at Jamaica Bay Federal Navigation Channel is 678,400 tons.

2.1.1.3 Geotechnical

The Jamaica Bay sites lie within the Southern Long Island watershed, contained within the Coastal Plain Physiographic region. Surficial deposits on Long Island are glacial in origin with morainal deposits to the north and outwash deposits to the south. The surficial deposits form the unconfined aquifer and local water-bearing deposits of lesser extent, including the Jameco aquifer. These systems are underlain by the Magothy and Lloyd aquifers, which are generally confined.

2.1.1.4 Shoreline Change

Shoreline change, mainly in the form of shoreline recession, is related to the dynamics of Jamaica Bay, such as winds, waves, tides, and current effects. Wave and current actions transports the sediment along the shoreline. Water levels, mainly due to tides and elevated water levels during storms, enhance these effects by increased destructive energy levels. Other geological and coastal developments also shape the present position of the shoreline. Soil type and grain size determines the natural angle of repose, the strength of the soil to resist erosion and its deposition/suspension characteristics. Interventions on natural dynamics due to erosion control measures (coastal structures, vegetation, and other) can decrease the recession rate locally while accelerating the rate

on the adjacent shorelines. Depending on the availability of the sources in the system, a shoreline may experience both erosion and accretion due to the dynamic forces of the nature. Generally, gain of sediment in a system would translate in to shoreline accretion, whereas, loss of sediment would translate into a shoreline recession.

Dynamic shorelines exhibit both short- and long-term variations. Short-term variations can be attributed to seasonal differences in storm intensities, and localized differences in sediment type. Long-term variations (in the order of years) reflect cumulated effects. Short-term rates may be highly variable while long-term effects are averaged.

Historical shoreline change for four (4) sites, Dead Horse Bay, Brant Point, Dubos Point, and Bayswater Point State Park, was studied for the period from 1959 to 1996. The objective of this analysis was to determine a qualitative estimate of the magnitude of shoreline change occurring at the four (4) sites. The Paerdegat Basin, Fresh Creek and the northern portion of the Spring Creek site did not have visible shoreline changes, with the exception of when filling or excavation activities occurred. While the southern shorelines of Spring Creek and Hawtree Point have experienced minor erosion, the restoration goals at those sites did not involve shoreline stabilization, and most of the restoration activities concentrated on the upland habitats. This analysis found little erosion in the sites remaining in the selected plan, with the exception of Dead Horse Bay. The analysis for Dead Horse Bay was updated to include more current data and the results of this analysis is discussed below.

2.1.1.4.1 Methodology

Four (4) ortho-rectified aerial images of each of the four (4) sites were utilized for the shoreline change analysis, which were made available by the USACE. These images included 1959, 1966, 1974, and 1996 aerials spanning 37 years. The 1996 imagery was ortho-rectified by New York City Department of Environmental Protection (NYCDEP). The imagery of 1959, 1966, and 1974 were ortho-rectified based on the imagery of 1996 using ArcView® Geographic Information Systems (GIS) software. In this process, four (4) to eight (8) ground control points were selected from each image to be rectified as well as from the imagery of 1996. The control points were selected from the visible features, both in the imagery of 1996 and the imagery to be rectified, such as streets and streams. The imagery of 1959, 1966, and 1974 were then aligned to the ortho-rectified imagery of 1996 by linking each control point on the imagery of 1959, 1966, and 1974 to the corresponding point on the imagery of 1996, thus ortho-rectifying each image. The approach used for the shoreline change analysis includes the interpretation of erosion/accretion reference features located and mapped on a series of ortho-rectified aerial images.

The first step in the historical shoreline change analysis of a site is to create an imaginary baseline common to all the digital ortho-photos from which all distances can be referenced. Therefore, a segmental baseline was created on landside roughly parallel to the shoreline for each of the four (4) sites. The length of the baseline was sized to cover

the delineated areas of interest. Transects were then drawn perpendicular to the baseline across the shoreline approximately every 100 feet.

Two (2) reference features, “primary” and “secondary” lines, were initially used to assess the shoreline change for this study. These reference features and their limitations on the application to this project are defined as follows:

Water Line: The intersection of bay water with beach/land was selected as one of the reference feature used to measure the shoreline change process. This feature is the easiest to map as compared to other features. However, the position of the primary line is entirely dependent on the time that the aerial photograph was taken. That is, comparison of two (2) aerial photos taken at high and low tides could give the impression of erosion or accretion simply as the result of primary line position on a beach slope. This could potentially add up to significant errors in horizontal shoreline distance, as measured from the baseline. For example, an error could be as much as 40 to 60 feet in terms of shoreline location for a nearshore slope of 1V:20H and a two (2) to three (3) foot difference in tidal water elevation. Generally, aerial images do not include time stamps to determine the corresponding tide level at the time of photography. In some cases though, it is possible to assess whether the picture was taken during a high tide period or low tide period by comparing the aerial images with respect to shoreline features and field observations. This assessment was considered during the mapping of the primary line feature.

Vegetation Line: The secondary line was also utilized to check for changes in trends for confirmation of the primary line. The secondary line was mapped as a reference feature, which generally reflects the maximum reach of wave attack, or the vegetation line. This line was identified from the aerial photographs and digitized for analysis.

For Bayswater Point State Park, Dubos Point and Brant Point sites, the reference feature lines exhibited very similar trends for the periods considered, where shoreline recession is apparent. Since the vegetation line also corresponded to habitat maps, the vegetation line is discussed further in the shoreline change analysis, and it was used to determine erosion rates for future conditions at the site. Dead Horse Bay has only its vegetation line digitized. The remaining sites did not experience significant erosion, so the shoreline change analysis was not performed at those sites.

2.1.1.4.2 Shoreline Change Rate Analysis

Determination of a reliable shoreline change rate requires relatively long sampling intervals. By using long intervals, short-term variations due to episodic processes are smoothed. Since the earliest aerial dates back 37 years, this analysis period has precedence over the other periods with relatively shorter time spans.

A number of analytical methods are available to determine shoreline change rates at a specific site. In most cases, these rates will be site specific, especially when there are

significant variations in the shoreline position data. For this study, an end-point analysis was used in combination with the average of rates (AOR) method where applicable. End-point analysis takes the first and last points in the selected record and calculates the rate as its name implies. Results are highly dependent on the period chosen for the analysis. Therefore, variations giving rise to certain trends might be missed. The AOR method was implemented, in addition to end-point-analysis, to account for those trends with significantly longer periods (i.e. in the order of years).

When compared to 1996 photograph year, the 1959, 1966, and 1974 photographs allow for three (3) relatively long analysis periods of 37, 30, and 22 years, respectively. These periods were used for end-point analysis, and averaged for the AOR analysis. Comparisons were made and site-specific rates were determined for all periods. The AOR methodology was employed where there are large variations in the rate data. These variations could be attributed to both natural phenomenon and/or mapping errors during the reference line process.

2.1.1.5 Slope Stability Analysis

The overall slope stability was assessed for four (4) of the sites: Fresh Creek, Brant Point, Dubos Point and Bayswater Point State Park. The goal of the analysis was to identify any areas within the sites where slopes may be unstable due to steep slopes, weak soil strata and/or exposure to high tidal velocities. For the purposes of this analysis the following data were analyzed:

- Historic and recent shoreline photographic documentation (USACE, 2002);
- Project survey topography and bathymetry data (spring 2002);
- Velocity data developed by HydroQual, Inc. (USACE, 2003); and
- Geotechnical data (grain size distribution) from the HTRW testing results (USACE, 2003).

In general, there does not appear to be any areas of significant slope instability at any of the sites. Slopes are generally 1V:4H or shallower and average velocities are generally less than one (1) foot per second (fps), the maximum permissible near bottom channel velocities for fine sand.

2.1.1.6 Wave Analysis

Wave-induced effects are one of the primary factors affecting sediment transport processes in a coastal region. Waves generated by winds, as well as waves generated by the vessels traveling along the navigational channels, were considered for the sites under investigation. Vessel generated waves are of particular interest due to the potentially high volume of ship traffic passing by each site every day.

2.1.1.7 Wind Generated Wave Analysis

Site-specific wave conditions (height, period, and direction) at Dead Horse Bay, Fresh Creek, Hawtree Point, Bayswater Point State Park, Dubos Point, and Brant Point were determined using local wind data and a series of analytical models. A detailed description of the procedures used to compute wave characteristics at each of the sites is presented in this section.

Bathymetric information for the area was obtained through National Oceanographic & Atmospheric Administration (NOAA) chart (12350), and through survey transect data collected by during the Jamaica Bay “Source” Study in spring 2002.

Winds blowing across Jamaica Bay generate waves that will impact the project sites. Due to the restricted nature of the Bay, the major factors affecting the magnitude and period of the waves are the fetch length, average depth, wind speed, and wind duration. Sixteen (16) possible wind directions were considered to determine the wind-generated waves for the analysis.

Local, historic wind data collected at John F. Kennedy (JFK) International Airport (spanning from early 1980s to present) was obtained from the National Climatic Data Center. Additional information utilized during the present study included an earlier study (USACE, 1981) that utilized the JFK International Airport data as well as the some general information provided in the Coastal Engineering Manual (CEM) (USACE 2002).

Overall wind conditions during the 18-year time period for JFK International Airport are presented in Figure 2-1, which shows the distribution of wind speed (mph) data (illustrated using a wind rose plot). The color-coded sidebar indicates the magnitude of wind speed, the circular axis represents the direction of wind approach relative to North (North being 0 degrees), and the extending radial lines indicate percent occurrence within each magnitude and directional band. The most common direction of wind approach, as well as the approach direction of a significant portion of the winds, is from the southerly and northerly components of westerly directions.

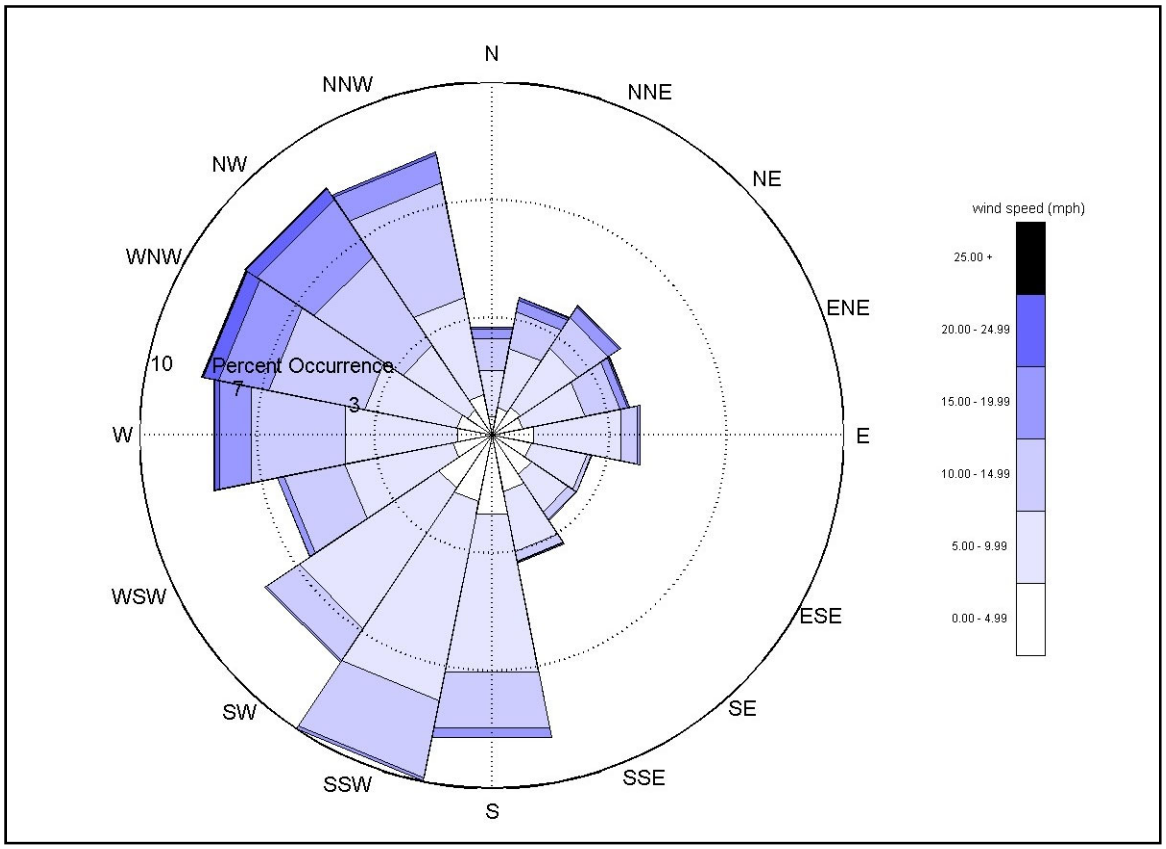


Figure 2.1: Wind Rose Plot of Resultant Wind Speed and Direction for JFK International Airport Wind Data (1984 to 2002)

To determine the extreme wave conditions for design considerations, it is necessary to associate extreme wind conditions with design return period(s). Table 2-1 summarizes the extreme wind speeds determined for this study by considering the physically possible directions. The predominant wind directions match with the directions in the wind data collected.

The proper averaging time for design and planning considerations varies dramatically as a function of wind speed and fetch length (USACE, 2002). Based on the guidance provided in the CEM, 5-, 15- and 15-min averaging time intervals were utilized for 50-year, 20-year, and 10-year winds, respectively.

Table 2-1: Extreme Wind Speeds

Return Period	Wind Speed (mph)	Averaging Time
50-year	75	5-min
20-year	59	15-min
10-year	52	15-min

The waves generated by the wind data were predicted using a computer model developed by the USACE. This computer model is part of the Automated Coastal Engineering System (ACES), published by the Coastal Engineering Research Center (USACE, 1992). The program, entitled Wind Speed Adjustment and Wave Growth, provides simplified estimates for wave growth over open-water and restricted fetches, such as Jamaica Bay, in both deep and shallow water. The ACES model addresses only wind-generated waves, and does not account for the effects of refraction, diffraction, and non-linear effects.

Wind data, along with the geometry and average water depth of the fetch, is required input to the ACES program. The fetch, or distance over which wind acts on the water, is restricted in Jamaica Bay, which in turn limits the wave generation. When all other factors are kept constant, longer fetches will generate larger waves. Therefore, each wind condition input into ACES takes into account the restricted geometry and all the fetch lengths when calculating the associated wave conditions. That is, a short fetch wind direction may generate larger waves if radially close to a longer fetch direction, other conditions being equal. Additionally, an iterative approach was used to obtain maximum fetch-limited wave conditions during the modeling process, when dealing with averaging schemes as well as the storm duration. Standard ACES output includes a spectral significant (modal) wave height (H_{mo}), peak period (T_p), and a mean wave direction (MWD) for each of the fetch bands.

Fetch directions and other related information corresponding to the specific sites under investigation, as well as results of the wind-generated wave analysis for the all sites, are presented below.

2.1.2 Dead Horse Bay

2.1.2.1 Topography and Bathymetry

Dead Horse Bay is characterized by a steep sand beach with a drainage channel that meanders through the berm, emptying a standing pool of brackish water. The pool remains undrained at low tide. The beach slope varies from a 6 percent slope from the upland, towards the drainage channel inlet, and three (3) percent in the vicinity of the inlet. The beach habitat forms roughly a 25-foot strip along the shoreline at low tide. West of the inlet a scarp begins to form, which becomes as high as 10 feet. Gerritsen Creek inlet is to the west of the site. It has been stabilized by the abutments of the Belt Parkway Bridge. The standing pool extends north into the site 400 feet. The lowest elevation of the pool is 0.0 feet, while most grades are between 1.5 to 4 feet NAVD88. Proceeding inland, the next 400-foot area is relatively flat, with grades between 5 to 7 feet NAVD88. The back portion of the site, 800 to1600 feet from the shoreline, is also relatively flat with grades 10 to 12 feet NAVD88. There is a mound in the middle of this area that reaches elevations in excess of 22 feet NAVD88.

2.1.2.2 Hydrology and Hydraulics

2.1.2.2.1 Tidal Datums

Water surface elevation data were collected at Dead Horse Bay North in October - November 2001 using a WaterLOG Model DH-21Submersible Logger Pressure Transducers. The gauge was fastened to a steel pole in the center of the impounded water along the shoreline of the proposed restoration site. In this location, impounded water precluded accurate readings at lower water levels (Figure 2-2). The tide datums extracted from these data were correlated with the long-term NOAA tide gauge at Sandy Hook, NJ (#8531680), which is appropriate for the waters of Jamaica Bay. The derived tidal datums are shown in Table 2-2. MLW and MLLW could not be calculated, presumably because of perching. The risk of reliance on this legacy data at this phase of this study is deemed to be minimal and has been noted in the risk register. More accurate tidal datums may impact excavation quantities and by extension, cost estimates.The need to collect current data (water surface elevation and other types) is discussed and emphasized in Chapter seven of this appendix.



Figure 2-2: Dead Horse Bay Tide Gauge Location

Table 2-2: Dead Horse Bay North Tidal Datums, 2001

Datum	Abbreviation	Water Surface Elevation, ft, NAVD88
Mean Higher High Water	MHHW	2.77
Mean High Water	MHW	2.17
Mean Tide Level	MTL	-0.62
Mean Low Water	MLW	X
Mean Lower Low Water	MLLW	X

2.1.2.3 Geotechnical

The soil in the area is characterized by medium, fine, well-sorted sand, with the median sand diameter of 0.226 to 0.312 millimeters (mm) for the three (3) on-shore grab samples. The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) and the New York City Soil and Water Conservation District are in the process of developing an official soil survey book and maps for New York City and for Gateway National Recreation Area (GNRA). A draft soils survey of the GNRA obtained from NRCS shows that soils within the Dead Horse Bay site include Beaches, Bigapple Coarse sand, Bigapple-Blownout land complex, Fortress sand, Hooksan fine sand, Hooksan-Dune land complex, Ipswich mucky peat, Rikers gravelly coarse sand, Breeze loamy sand, Fishkill sandy loam, and Gravesend-Oldmill coarse sand. Most of these soils series describe disturbed areas that are filled with over 40 inches of various materials that have varying drainage qualities (NRCS 2004)

2.1.2.4 Shoreline Change

Dead Horse Bay has undergone extreme changes over the last 50 years. The northern portion of the site (Dead Horse Bay North) has been influenced by the stabilization of Gerritsen Creek Inlet, and the construction of the Belt Parkway, the adjacent driving range, and the adjacent marina. The southern portion of the site lies behind a large mudflat. Dead Horse Bay South land mass was created by fill (clean and household trash) deposited there while Floyd Bennett Field was being constructed. Both portions of the site experience extremely different erosion and accretional patterns.

Overall, Dead Horse Bay North accreted between 1959 and 1996, and between 1966 and 1996. It eroded 1.93 feet/year between 1974 and 1996 (Table 2-3 and Figure 2-3). The erosion was most severe in the shoreline west of the creek outlet. This area currently has 5 to 7-foot high bluffs that have vertical faces that are most likely due to the longshore sediment transport influences of Gerritsen Creek inlet. No restoration is proposed in this section of the shoreline. The shoreline in front of the creek is highly variable, likely due to a large sediment supply coming from the bluffs, and the hydrodynamics of the creek outlet.

Table 2-3: Dead Horse Bay North Erosion Rates

	Period	Dead Horse Bay North Vegetation Line (feet/year)				
		West of Creek Outlet	East of Creek Outlet	Transition	Marina	Combined Average (All Sections)
End-point Averaging	1959-1996	1.50	1.39	4.00	1.16	1.44
	1966-1996	0.33	0.79	0.77	0.32	0.41
	1974-1996	-3.02	-1.81	-4.64	-0.52	-1.93
AVERAGE (AOR)		-0.40	0.12	0.04	0.32	**-0.03**

Given the erosion calculated along the shoreline of Dead Horse Bay North, the original analysis was updated in a qualitative manner by comparing vegetation lines for the years listed above to the vegetation lines in 2004 and 2016. Figure 2.4 illustrates the vegetation lines for 1974, 1996, 2004 and 2016 along with the project grading plan as a reference of the project extent. The erosion occurring on west of the creek continues, but it appears that the annual rate of erosion has diminished. Within the actual project area, while localized areas of erosion can be observed at some points, overall this segment of the shoreline appears to have achieved a degree of dynamic equilibrium. It is further noted that accretion appears to have taken place along significant portions of the shoreline between 1996 and 2004, an indication of natural variability at this location. The possible need for shoreline stabilization measures is discussed in sections 5.2.1.1.1 and 6.2. Finally, Dead Horse Bay is a deferred site, with a scheduled construction date of 2035. In light of this, a quantitative update to the shoreline erosion analysis is recommended for the PED phase, but not during this feasibility study phase due to the long period between study phases. If shoreline erosion proves to be a significant risk at the time of implementation, it is recommended that shoreline stabilization methods be analyzed. The cost risk for this concern is minimal, however, given the scale of this restoration effort and the minimal length of exposed shoreline.

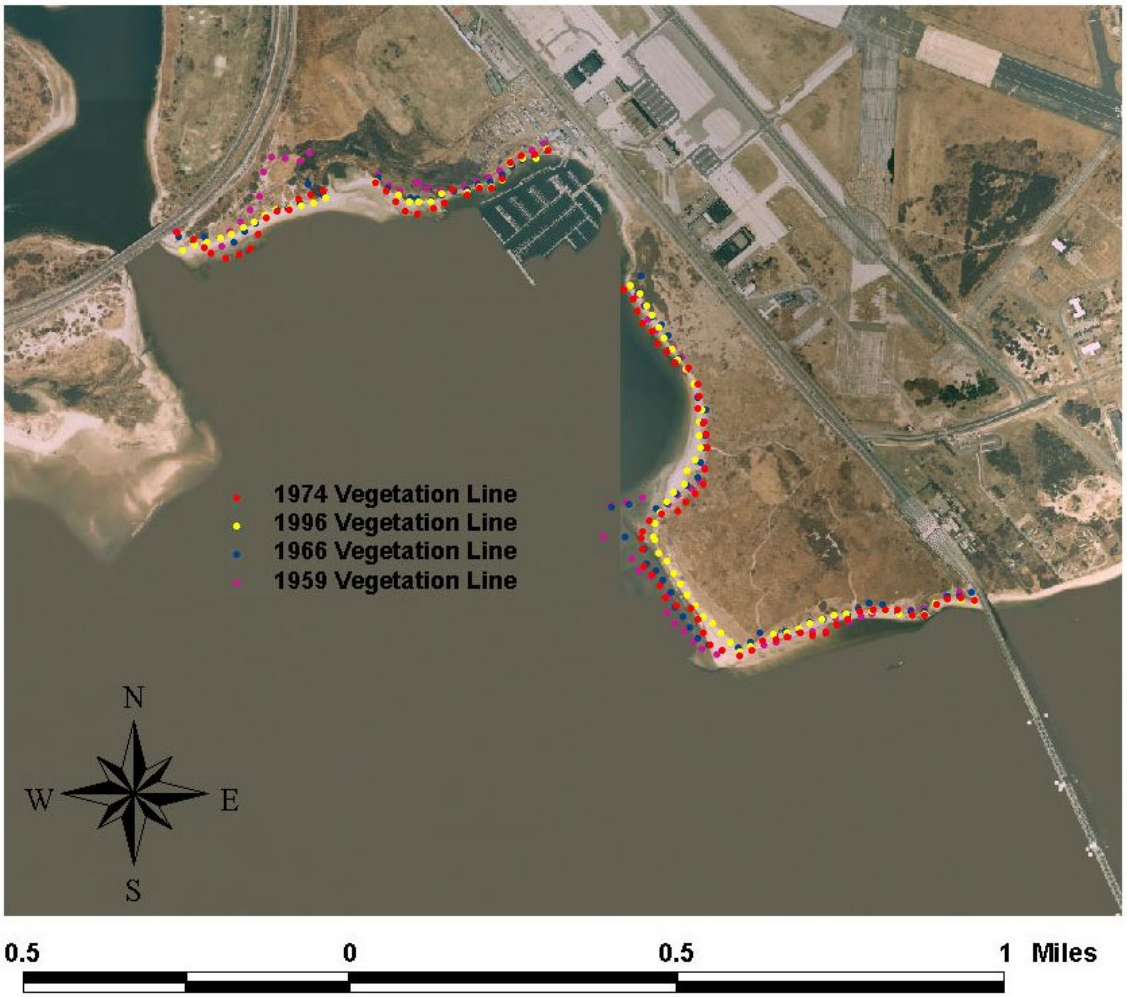


Figure 2-3: Dead Horse Bay Shoreline Change



Figure 2-4: Dead Horse Bay Shoreline Change (updated to 2016)

2.1.2.5 Wind-Generated Wave Analysis

The spectral significant wave height (H_{mo}), the peak period (T_p), and mean wave direction resulting from the ACES predictions for Dead Horse Bay is shown in Table 2-4. These results correspond to two (2) representative (reference) locations along the North and South shorelines. Figure 2-5 shows the fetch directions for wind wave generation. Three (3) different sets of results are presented corresponding to design return periods of 50-year, 20-year, and 10-year respectively. In general, for the Dead Horse Bay North site:

- The model predicts that the maximum waves will be generated when the winds are blowing from the southwest (SW) corresponding to the longest fetch direction.
- The modal wave height was estimated to be 5.4 feet, 4.7 feet, and 4.3 feet for the 50-year, 20-year and 10-year wind speeds, respectively.
- Peak periods were 4.4 seconds, 4.1 seconds, and 3.9 seconds for the 50-year, 20-year, and 10-year return-periods, respectively.
- Mean wave directions were estimated to be between 220 and 230 degrees (measured clockwise from true north) for northwesterly fetch directions.
- Southwesterly fetches will generate about 40 percent larger waves and longer periods than southeasterly fetches.

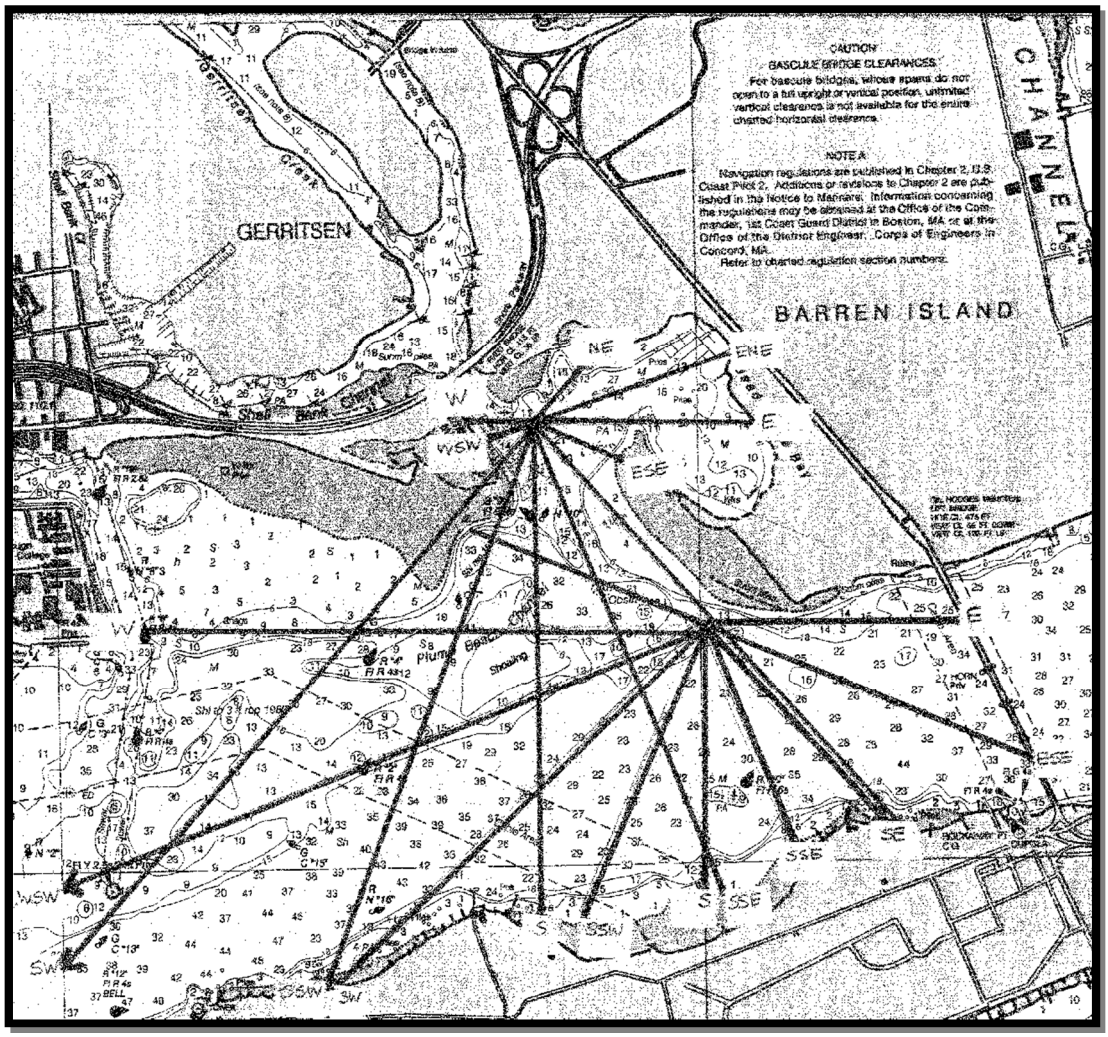


Figure 2-5: Fetch Directions for Dead Horse Bay

Table 2-4: Dead Horse Bay North Wind-Generated Wave Results Fetch

		Fetch Length	Depth	Wave Characteristics								
				50-year			20-year			10-year		
				Height	Period	MWD	Height	Period	MWD	Height	Period	MWD
No.	Direction	(mi)	(feet)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)
1	N											
2	NNE											
3	NE	0.20	15	2.6	2.7	70	2.2	2.5	70	1.9	2.4	70
4	ENE	0.55	20	2.7	2.8	76	2.3	2.6	76	2.0	2.4	76
5	E	0.60	15	3.6	3.3	133	3.1	3.1	133	2.7	2.9	133
6	ESE	0.25	20	3.9	3.4	137	3.3	3.2	137	2.9	3.0	137
7	SE	1.40	10	3.5	3.3	140	3.0	3.1	140	2.6	2.9	140
8	SSE	1.30	15	5.2	4.2	216	4.5	3.9	216	4.0	3.7	216
9	S	1.25	15	5.4	4.4	220	4.7	4.1	220	4.2	3.8	220
10	SSW	1.50	15	5.4	4.4	222	4.7	4.1	222	4.3	3.9	222
11	SW	5.00	10	5.4	4.4	224	4.7	4.1	224	4.3	3.9	224
12	WSW	0.10	10	4.5	4.2	226	4.0	3.9	226	3.6	3.7	226
13	W	0.10	10	4.5	4.2	228	3.9	4.0	228	3.6	3.7	228
14	WNW											
15	NW											
16	NNW											

MWD = Mean Wind Direction

2.1.3 Fresh Creek

2.1.3.1 Topography and Bathymetry

The upper, landward, 1300 feet of the creek has a maximum depth of -7 feet NAVD88, an average depth of -4 to -5 feet NAVD88, and average width of 300 feet. The banks are steep (close to 1V: 1H) and quickly rise to 15 feet NAVD88 on both sides of the creek.

The creek narrows to 130 feet width next 500 feet (downstream). The average depth is approximately -8 feet NAVD88, but the depth is very variable in this section of the creek, based on 2002 bathymetric data. There is an existing low marsh on southwest bank of the creek, with elevation ranges between 1 to 4 feet NAVD88. The northwest bank is steep, with grades rising above 20 feet NAVD88 less than 220 feet from the shoreline.

A mid-creek island exists in the next downstream section of the creek (or 2200 feet upstream from the Belt Parkway). The island is 50 to 150 feet wide, 800 feet long with most elevations between 2 to 3 feet NAVD88. The main channel of the creek becomes deeper in this section, with elevations dropping to -15 feet NAVD88. The remaining length of the creek out to the belt parkway has depths of approximately -10 to -13 feet NAVD88. On the bay side of the Belt Parkway Bridge depths rise to approximately -9 feet NAVD88

to form a “sill feature”, before eventually dropping to over -30 feet NAVD88 when the creek bottom meets the navigation channel in the bay.

2.1.3.2 Hydrology and Hydraulics

2.1.3.2.1 Tidal Datums

Water surface elevation data were collected at Fresh Creek in October - November 2001 using a WaterLOG Model DH-21Submersible Logger Pressure Transducer. The gauge was fastened to a steel pole, in the northern portion of the creek in the center (Figure 2-6). The tide datums extracted from these data were correlated with the long-term NOAA tide gauge at Sandy Hook, NJ (#8531680), which is appropriate for the waters of Jamaica Bay. The derived tidal datums are shown in Table 2-5. The risk of reliance on this legacy data at this phase of this study is deemed to be minimal and has been noted in the risk register. More accurate tidal datums may impact excavation quantities and by extension, cost estimates.The need to collect current data (water surface elevation and other types) is discussed and emphasized in Chapter seven of this appendix.

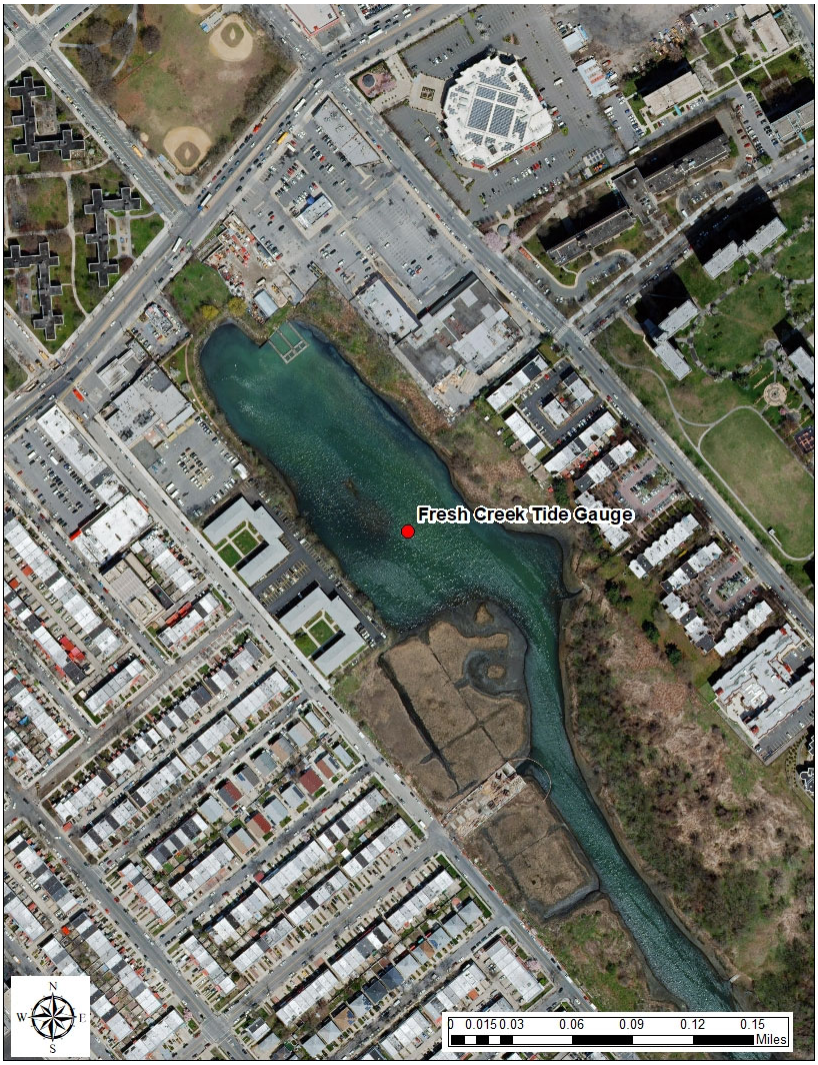


Figure 2-6: Fresh Creek Tide Gauge Location

Table 2-5: Fresh Creek Tidal Datums, 2001

Datum	Abbreviation	Water Surface Elevation, ft, NAVD88
Mean Higher High Water	MHHW	2.91
Mean High Water	MHW	2.49
Mean Tide Level	MTL	0.19
Mean Low Water	MLW	-2.5
Mean Lower Low Water	MLLW	-2.94

2.1.3.3 Geotechnical

The soil at Fresh Creek was poorly-sorted sandy-gravel, with the median diameter of 3.01 to 4.2 mm for the gravelly areas and 0.395 to 0.458 mm for the sandy grab samples. The deposition of historic fills has been irregular at this site. All samples showed significant amounts of gravel, sand and silt for all samples. Even the clay present in each sample ranged from 2 to 7 percent. In a draft soil survey for New York City, NRCS has identified the soils of the Fresh Creek site as Bigapple-Fortress series complex, Inwood-Laguardia-Ebbetts complex, Greatkills-Freshkills complex, Pavement and Buildings-Bigapple-Verazano complex, and Ipswich-Pawcatuck-Matunuck mucky peat. Both the Bigapple and Fortress series are soils consisting of sandy dredge material over 40 inches thick, which has been placed onto an area. The Inwood, Laguardia, and Ebbetts series all consist of demolished construction material mixed with various soils to create fill material. The Verazano series consists of a thick human-transported loamy layer over sandy sediments. Greatkills soils are a mixture of household garbage, construction debris and other discarded materials layered with natural soil fill. Freshkills soils are only household landfill capped with a thin layer of loamy soils. Ipswich, Pawcatuck, and Matunuck are all tidal marsh soils, differing in the thickness of the organic layer before reaching sand (NRCS 2004).

2.1.3.4 Slope Stability Analysis

The shoreline slope stability analysis for Fresh Creek showed generally stable slopes with most slopes shallower than 1V:4H, with a few isolated areas where the slopes were in the 1V:2H range. Average velocities for incoming tides ranged from 0.6 fps to 1.1 fps and average velocities for outgoing tides ranged from 0.4 fps to 1.0 fps. Geotechnical data indicates that the upper most 5 to 26 feet of material in the area consists of fine to coarse sands and general fill/debris, which is generally underlain by an older organic silty clay meadow mat strata.

2.1.3.5 Water Quality Modeling

Jamaica Bay is a heavily impacted estuary located within the boundaries of New York City. Some areas of Jamaica Bay and the basins that are tributary to it experience hypoxic or anoxic conditions. These low dissolved oxygen levels can have a profound effect on the biota that live within the bay. Fresh Creek has a large sewage treatment plant and combined sewage overflows (CSOs) at the head of the creek. A hydrodynamic/water quality model of Fresh Creek was developed in this 2002 “source” study to assess how planned bathymetric alterations will affect habitat in these areas. Water quality modelling was conducted in 2002 and was executed using an existing Hydroqual North Channel Model (NCM), which encompasses Paerdegat Basin, Fresh Creek, Hendrix Creek and Bergen Basin. This model uses the Estuarine Coastal and Ocean Model (semi-implicit) (ECOMsi) as the hydrodynamic model and Row Column Advanced Ecosystems Modeling Program (RCA) for the water quality model. The NCM, along with the Jamaica bay Eutrophication Model (JEM) (used at other sites), were designed to analyze several state

and federal projects. While the water quality modeling done for Fresh Creek is considered to be valid supporting technical information, it is not considered critical to the development of the Fresh Creek Site and has no impact on the selection of the selected plan. This modelling effort wsa not updated as the model will not serve any future project purpose.

This modeling analysis consisted of developing models for Fresh Creek to evaluate up to six (6) bathymetric alteration scenarios in each tributary and their effect on habitat. The NYCDEP has facility upgrade plans to abate CSOs at the Fresh Creek sewage treatment plant. These improvements were considered in determining the scenarios. A North Channel Model (NCM) was created within the existing Jamaica Bay Eutrophication Model (NYC DEP, 2002) which included Fresh Creek, as well as Hendrix Creek and Bergen Basin. The alternatives that were analyzed are listed below. The six (6) scenarios in Fresh Creek included bathymetric changes and the incorporation of the CSO facility plans at both of the tributaries. The Fresh Creek scenarios to be evaluated included:

1. Existing conditions with the natural sill in place;
2. Existing conditions with CSO improvements;
3. Existing conditions without the natural sill in place and with CSO improvements;
4. Upstream half-filled to MLW, lower half as is, without the sill and with CSO improvements;
5. Upstream half as is, lower half filled to 4 feet below MLW or as is (whichever is less), without the sill and with CSO improvements; and
6. Upstream half as is, lower half hued to 8 feet below MLW or as is (whichever is less), without the sill and with CSO improvements.

All of the runs were based on 1988 meteorological, tidal, and loading conditions. Bathymetric conditions were based on the latest available data.

In general, the flood tide velocities are greater than then ebb tide velocities. Removal of the sill at the mouth of the creek does little to affect the velocities in the upper half of the creek and reduces the velocities at the mouth. Scenario 4 increases the velocities in the half of the creek except for the head. Scenarios 5 and 6 increase the maximum flood velocities to a small extent near the mouth, but the velocities are reduced in the upper half of the creek. The shear stresses generally remained below 1.0 dyne/centimeter(cm)^2 until the scenarios where portions of the creek were filled. When the creek was filled to MLW in the upper half (Scenario 4), the shear stresses increased to as high as 4.1 dyne/cm^2 during August. This shear stress would cause resuspension of material and bed loading of sandy material. Filling the lower portion of the creek in Scenario 5 resulted in occasional shear stresses greater than 1.0 dyne/cm^2. The average shear stresses remain below 0.5 dyne/cm^2 for all of the scenarios indicating, that the creek would remain a depositional area.

The dissolved oxygen (DO) in Fresh Creek is computed to be lowest at the head end and in the deeper portion near the mouth under calibration conditions. The facility plan results

in improved DO along the entire creek with the largest improvements occurring in the upper portions. Removing the sill results in small changes in the average DO and the effect is slightly lower DO levels in most of the creek. Filling the upper portion of the creek results in higher DO concentrations in the upper half of the creek and slightly lower DO levels near the mouth of Fresh Creek. Filling the lower half of the creek has the opposite effect with improved DO near the mouth and slightly lower concentrations in portions of the upper end. The minimum DO concentrations are essentially anoxic in all of the scenarios. Each scenario generally results in higher minimum DO concentrations, but the DO levels do occasionally decline to hypoxic levels. Most of the improvement to the upper half of the creek is due to the implementation of CSO controls and that filling the upper portion of the creek provides only a marginal improvement. The most effective scenario for increasing the DO concentration near the mouth is Scenario 5. Under Scenario 5 conditions Fresh Creek is computed to have a DO concentration greater than 3.0 milligrams per liter (mg/L) greater than 90 percent of the time for most of the creek during July and August. The results indicate that some bathymetric alterations would improve the DO concentrations in Fresh Creek. In general, some level of filling near the mouth of the creek would improve DO levels and as a consequence aquatic habitat. Filling portions Fresh Creek would mostly like result in bringing this tributary closer to its historical depth and bring the creek back to a more natural state.

2.1.4 Jamaica Bay Marsh Island Sites

Site-specific field data were not collected at the proposed Jamaica Bay Marsh Islands (including Stony Creek Marsh, Duck Point Marsh, Elders Point Center, Pumpkin Patch East, and Pumpkin Patch West). Data collected for Elders Point East, Elders Point West and Yellow Bar Hassock were utilized to prepare the concept designs.

2.1.4.1 Topography and Bathymetry

Bathymetric data used in the development of the five (5) conceptual island design alternatives was a composite set that included data collected in 2008 and 2009, using single beam and multi-beam sonar. Some of the data was collected at 1-meter resolution and sampled to a 5-meter resolution. The data was projected to UTM Zone 18N with a vertical datum of NAVD88. The data can be downloaded from the NPS Integrated Resource Management Applications website at the following link: https://irma.nps.gov/DataStore/Reference/Profile/2204843.

The use of low-resolution topographic and bathymetric increases the uncertainty of the derived material placement quantities for these sites and represents a significant cost risk. This uncertainty is, however, fully reflected in the cost estimate contingency of these sites. The need for more accurate topographic and bathymetric data is further discussed and stressed in section seven of this appendix.

For the Elders Center Site, a composite topographic surface was created which combined the final survey data from the constructed islands at Elders Point East and Elders Point West

2.1.4.2 Hydrology and Hydraulics

2.1.4.2.1 Tidal Datums

Water surface elevation data were collected at four locations within Jamaica Bay in October - November 2003 (Figure 2-7). The gauges were subsurface absolute pressure-based, temperature-corrected devices with internal batteries and memory. They were secured to the seafloor using ground anchors as deep as possible. The time histories of pressure were collected at a sample interval of 180 seconds from October 9 to December 4, 2003. At each gauge location, a one-inch diameter PVC pipe was jetted into the bottom, extending approximately 3 feet above mean low water (MLW). The top of the pipes were determined using RTKGPS relative to NAVD88. These pipes allowed a direct measurement of the water level relative to NAVD88 just after the gauges were deployed and again just before they were retrieved.

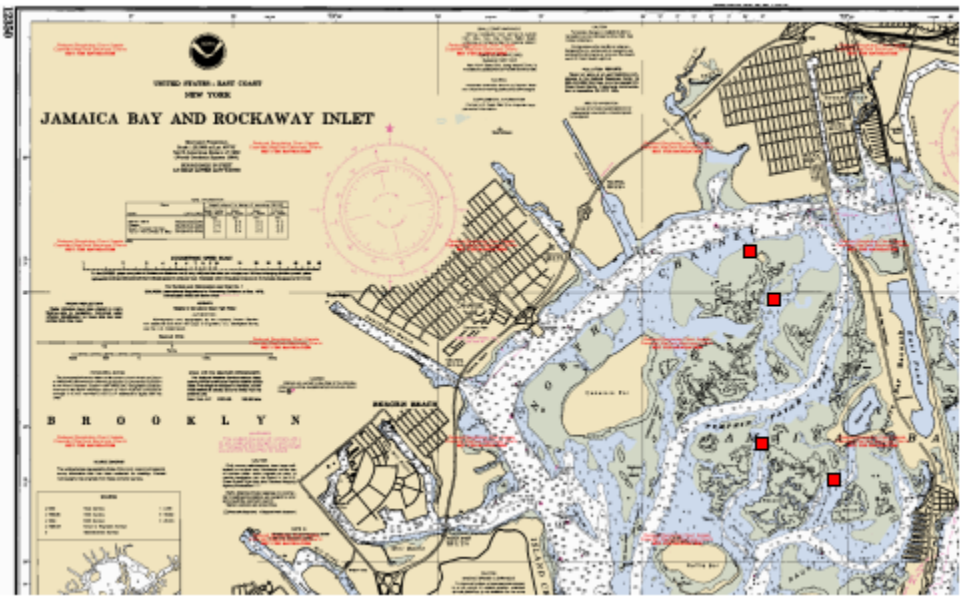


Figure 2-7. Tide Gauge Locations in Elders Point and Yellow Bar, Jamaica Bay, NY (red squares).

The time histories from the gauges were reviewed and two separate files were created for each gauge. The first file was the time history for the entire time period that the gauge was in the water. The second file was a time history from 10/11/2003 to 11/8/2003, which is a 29-day file when there was very little storminess. Because Jamaica Bay is very responsive to storms and fronts, especially those with a strong northerly component that blows water out of the bay, the 29-day file was selected for analyzing tidal datums and tidal constituents. Data later in the deployment included some significant low water events that were frequent because the deployment was in the late fall when northerly wind conditions are common.

Given the age of the data and the need to establish vegetation community elevations and conduct Sea Level Change analysis in an expedited manner for the five proposed marsh island sites within Jamaica Bay it was decided to take the average datum values for these four gauges for correlation with the long-term NOAA tide gauge at Sandy Hook, NJ (#8531680), which is appropriate for the waters of Jamaica Bay. The derived tidal datums are shown in Table 2-6

Table 2-6: Jamaica Bay Tidal Datums, 2003

Datum	Abbreviation	Water Surface Elevation, ft, NAVD88
Mean Higher High Water	MHHW	2.73
Mean High Water	MHW	2.31
Mean Tide Level	MTL	-0.32
Mean Low Water	MLW	-2.95
Mean Lower Low Water	MLLW	-2.99

2.1.4.3 Geotechnical

No geotechnical information was collected for any of the five (5) proposed marsh island sites; however, borings were collected during the design phases for the previously constructed marsh islands, including Elders Point East and Elders Point West, and Yellow Bar Hassock. The subsurface conditions for the five (5) proposed islands were assumed to be similar to those of the islands that were constructed. Geotechnical borings will be collected at each of the proposed islands during the PED phase.

Subsurface conditions at Yellow Bar Hassock, for example, consisted of a very soft silt-clay layer that ranged in depth from approximately 1 to 10 feet. The areas of thicker depth were more susceptible to natural settlement. It was anticipated that sand placement during construction would result in primary (immediate) and secondary (long-term) settlement. An initial sand loss rate of 50 percent was expected during construction; at some locations, actual losses approached 70 percent. Losses were due largely to compression of the substrate, and to a lesser extent, wind and waves.

2.2 Harlem River, East River, Western Long Island Planning Region

2.2.1 Flushing Creek Study Area

Existing conditions data was collected for the Flushing Creek “Source” Study between 2002 and 2004 and more recently conducted (2012-2014) by NYCDEP as work in kind.

2.2.1.1 Topography & Bathymetry

To establish a basis for the conceptual designs, field surveys were conducted for the shoreline properties and within the Flushing Creek. The bathymetric surveys were performed in July 2012 by Gahagan & Bryant Associates. The land survey was performed by M.J. Engineering and Land Surveying, P.C. during several site visits in 2013. The horizontal coordinate system used for the geometric model and the design plans is the New York State Plane, North American Datum of 1983 (NAD83) Long Island Lambert Zone 3104, in units of feet. The bathymetric surveys reveal water depths within the study area as typically shallow, between -1 and -9 feet NAVD88. A notable exception is a scour hole near an outfall along the east bank that has a depth of approximately -25 ft, NAV88. This bathymetric was used in conjunction with topographic LiDAR data for the development of conceptual designs and quantity take-offs. The use of LIDAR and legacy bathymetric data increases the uncertainty of the derived excavation quantities for this site and represents an acceptable cost risk. This uncertainty is fully reflected in the cost estimate contingency of these sites and is noted in the risk register.

2.2.1.2 Hydrology and Hydraulics

2.2.1.2.1 Tidal Datums

Water surface elevation data were collected at four locations in the Flushing Bay and Creek vicinity in support of the Flushing Bay and Creek Project from 03 June 2000 to 31 August, 2000. Data was collected with Coastal Macrotides Instruments. The instruments record external pressure, temperature and internal battery voltage. Data was collected at six minute intervals. Gauge locations are indicated in Figure 2-8. The single gauge installed in Flushing Creek (Gauge ID # NBB) was used to derive tidal datums for this site. The data was originally referenced to NGV29 and was converted to NAVD88 (Table 2-7) The risk of reliance on this legacy data at this phase of this study is deemed to be minimal. More accurate tidal datums may impact excavation quantities and by extension, cost estimates. *T*his uncertainty is fully reflected in the cost estimate contingency of these sites and has been noted in the risk register. The need to collect current data (water surface elevation and other types) is discussed and strongly emphasized in Chapter seven of this appendix.



Figure 2-8: Flushing Creek Tide Gauge Location

Table 2-7: Flushing Creek Tidal Datums (2000)

Datum	Abbreviation	Water Surface Elevation, ft, NAVD88
Mean Higher High Water	MHHW	3.57
Mean High Water	MHW	3.21
Mean Tide Level	MTL	-0.2
Mean Low Water	MLW	-3.6
Mean Lower Low Water	MLLW	-3.88

2.2.1.3 Geotechnical

A geotechnical study was performed for the NYCDEP by the AECOM/HydroQual Joint Venture under the Citywide Dredging Engineering Design Contract Services Contract for New York City. Shallow marine sediments were sampled and sediments were field-tested in-situ for shear strength at twelve locations in August 2013 and were analyzed at a laboratory. Information of deeper geologic materials was gathered from prior studies by New York State Department of Transportation (various) and USACE (2004).
The subsurface investigation found that the shallow depths within the project area majorly consist of very soft, black organic silt (presumed CSO sediments) with occasional natural silt or clay material near the bottom. The thickness of the CSO and natural deposit varies from approximately 3 to 35 feet. Test data shows the CSO deposits to be highly compressible with low shear strength.
Underlying the organic materials is a silt and sand mixture layer, generally consisting of various amounts of silt, sand and clayey silt mixture. This in turn overlies a fairly dense sand layer over glacial till.

2.2.1.4 Water Quality Modeling

Flushing Bay is a moderately stratified and partially mixed estuary that is part of the HRE. Flushing Bay exchanges water with the East River which is in contact with both the Atlantic Ocean and Long Island Sound. Flushing Bay is considered a dynamic and well-mixed system. However, the mixing is significantly reduced in the inner bay. The flushing half-life varies from one tidal cycle at mid-bay to six (6) tidal cycles in Flushing Creek. The salinity of the bay ranges from 22 to 24 parts per thousand (ppt).

Tidal range in Flushing Bay is approximately seven (7) feet. Mean tide ranges within Flushing Creek at the Northern Boulevard Bridge are reported to be 6.8 feet at mean tide and 8.0 feet at spring tide. The system receives freshwater (non-saline) flow from CSO discharges, direct rainfall runoff, and discharge through the tide gate from Meadow and Willow lakes. The bay and creek are Class I waters per the NYSDEC. The best intended usages for this classification are secondary contact recreation and fishing.

Water quality throughout Flushing Bay and Creek typically exhibit low levels of dissolved oxygen and anoxia, and high levels of bio-chemical oxygen demand. Sediments are organics-rich with a low level of benthic community diversity. Exposed intratidal mudflats generate hydrogen sulfide gas. Water and sediment quality investigations were conducted to provide the data needed to calibrate and verify an enhanced mathematical model to be used to evaluate restoration alternatives. Water and sediment quality modeling were conducted in two (2) phases.

The Phase I modeling effort focused on dissolved oxygen levels, hydrogen sulfide production, and the impacts of potential removal of the breakwater. The effect of breakwater removal on water quality was found to be minimal. Phase II modeling focused on sediment quality based on recent work by NYCDEP in other bays throughout the city.

These bays were found to have a negative relationship between the levels of total organic carbon within the sediments and the number of benthic taxa within the sediments. The higher the percentage of total organic carbon in the sediments, the lower the overall benthic diversity will be in the sediments.

2.2.1.4.1 Phase I Modeling and Results

Phase I modeling results indicated that no ecological benefits related to improved levels of dissolved oxygen or hydrogen sulfide would be generated by breakwater removal. Based on these results, NYCDEP proposed to extend the modeling effort (Phase II) to assess whether removal of the breakwater would provide a significant benefit to the ecosystem. The evaluation of decreasing the deposition of fine grained organic-rich sediments in inner Flushing Bay was conducted in Phase II. NYCDEP also proposed to assess the potential benefits of dredging organic-rich sediments in the inner bay. The dredged areas would be capped with clean sediments. This would reduce sediment total organic carbon concentrations.

Hydrodynamic characteristics of Flushing Bay and Creek are affected by the fast moving East River and a sill at the confluence between Flushing Bay and the East River. The tidal range throughout the system is spatially uniform, but tidal flow is attenuated the father away from the East River. Flushing Bay and Creek are depositional areas that exhibit low bottom shear stress.

Phase I water quality modeling projections were used to assess the water quality impact of breakwater removal. Breakwater removal was evaluated by comparing dissolved oxygen levels under the no-breakwater scenario, to the baseline conditions. The removal of the breakwater allows the higher salinity East River water to pass directly into and out of the inner bay. The inner bay is less diluted by Flushing Creek than under baseline conditions. The average dissolved oxygen levels in inner bay and breakwater area are higher than average dissolved oxygen levels in the East River. Under baseline conditions, removal of the breakwater causes a very slight decrease in dissolved oxygen levels in the inner bay. The effect of deeper water in the area of the former breakwater would slightly decrease re-aeration, which would also tend to lower dissolved oxygen levels.

The Phase I modeling projections indicate that hydrogen sulfide production would be reduced under the no-breakwater scenario. This result is based on the assumption that the bay bottom re-contouring associated with breakwater removal reduces the elevation of adjacent mudflats such that the sediments are no longer exposed at low tides. Although breakwater removal would have beneficial impacts to local hydrogen sulfide production, there are no ecosystem benefits to hydrogen sulfide reductions. Breakwater removal would have no impact on hydrogen sulfide production at other mud flat areas, such as in the inner bay in the vicinity of the World's Fair Marina, and upstream along Flushing Creek.

2.2.1.4.2 Phase II Modeling and Results

Phase I modeling results indicated that no ecological benefits related to improved levels of dissolved oxygen or hydrogen sulfide would be generated by breakwater removal. Based on these results, NYCDEP proposed to extend the modeling effort (Phase II) to assess whether removal of the breakwater would provide a significant benefit to the ecosystem. The evaluation of decreasing the deposition of fine grained organic-rich sediments in inner Flushing Bay was conducted in Phase II. NYCDEP also proposed to assess the potential benefits of dredging organic-rich sediments in the inner bay. The dredged areas would be capped with clean sediments. This would reduce sediment total organic carbon concentrations.

Phase II modeling included a full breakwater removal scenario. Full breakwater removal indicated minor hydrodynamic impacts to the bay and only minor impacts to sheer stress on the bay bottom that would affect sediment deposition. Deposition areas remained similar under the no-breakwater scenario as compared to baseline conditions. Overall the Phase II model results indicate that breakwater removal would not decrease the deposition of fine grained organic-rich sediments to Flushing Bay. Also, removal of the breakwater would not reduce concentrations of total organic carbon in sediments.

The Phase II modeling effort did indicate that removal of existing sediments and replacement with clean sediments would significantly improve benthic taxa. This improvement is based on studies of sediments throughout bays in New York City. These studies have shown that a high total organic carbon level in sediments is correlated with low benthic species diversity. Operation of the Flushing Bay storage facility will greatly reduce CSO discharge volume, biological oxygen demand, and total suspended solids loading into the creek and bay. Modeling conducted in Phase II indicates that removal of existing sediments and replacement with clean sediments in the inner bay and at areas along the creek would provide improved conditions. These improvements would last for many years before total organic carbon builds back up to a new equilibrium condition.

The extent of habitat benefits based on removal of existing sediments and replacement with clean sediments will be estimated determined during this study. The goal is to guide the selection of areas that would be most beneficial to dredge. The following factors need to be evaluated to extend the life of benthic habitat improvements: NYCDEP's review of sediment quality data shows that settlement of CSO solids is spatially variable, with the highest settlement volume occurring at local outfall locations. The farther from an outfall, the longer the improvement would last. The impact of spatial variability is important. The reduction in total organic carbon loading associated with improvements to CS4 will reduce levels in Flushing Creek, reducing future levels of total organic carbon in sediments. The improvements in dissolved oxygen associated with improvements to CS4 are expected to continue. It is assumed that total organic carbon will reach a new equilibrium. The ambient level of dissolved oxygen will be higher than those in the observed relationship between total organic carbon and taxa diversity; and NYCDEP is developing a comprehensive waste water control plan for Flushing Bay that will include

non-structural recommendations and best management practices alternatives that are will build on the benefits of the project.

The legacy water quality modeling results reported here for Flushing Creek were not used in development or screening of alternatives or in any aspect of the decision making process of this study.

2.2.2 Bronx River Study Area

2.2.2.1 All Bronx River Sites

2.2.2.1.1 Topography and Watershed Characteristics

The drainage area of the Bronx River is approximately 24,260 acres (55.2 square miles). Roughly 83 percent of the watershed is located in Westchester County and the remaining 17 percent is located in Bronx County. The River is approximately 23 miles long. It flows from Kensico Lake (Reservoir) in the north to Hunts Point in the East River. At the same time, it is strongly controlled by the bedrock. The present areas of investigation include a total of nine (9) sites in Westchester and Bronx Counties.

A significant portion of available land in the watershed of the Bronx River has already been developed. Generally, the degree of development increases as one proceeds downstream from Westchester County into Bronx County, particularly in the vicinity of the cities of Yonkers and Mount Vernon and Villages of Bronxville and Tuckahoe.

With urbanization comes the construction of buildings, roadways, parking lots, etc. These impervious surfaces have a dramatic impact on the Bronx River, particularly in the more urbanized lower watershed, where there is more than 25 percent impervious cover over more than half of the land area. Impervious ground surfaces deflect rainfall, rather than absorb it into the ground. Natural areas, which include parks and non-residential areas within the Bronx River watershed, typically exhibit imperviousness of 10 to 15 percent due to paved areas within parks (e.g. paths and trails) and active recreation fields (e.g. baseball fields and cricket pitches). While most of the watershed is already developed, impervious area in the Bronx River watershed is projected to increase in the future due to higher density redevelopment and implementation of existing plans to widen roadways. The topography is dominated by several NNE-SSW trending valleys and their associated ridges. Table 2-8 list general characteristics of the Bronx River. The river flows 15 miles through Westchester County and 8 miles through the Bronx. Westchester County hosts 65 percent of the river's length and 85 percent of the river's watershed. Table 2-9 lists 19 sub-watersheds that make up the Bronx river basin. 12 of these are tributary watersheds that comprise 62 percent of the Bronx River Basin. Table 2-10 shows the drainage areas upstream of the investigation sites.

Table 2-8: Summary of Geomorphology Bronx River Valley

Bronx River Basin Ranges	
River length total	~23 miles
River length total Westchester County	~15 miles
River length total Bronx County	~8 miles
Total basin area	56.3 sq miles
Bronx River valley area	21.3 sq miles
Tributary area	35.0 sq miles
Range of elevations	<0 to 270ft
Slopes	2 to 155 ft/mile
Low-flow channel width	20 to 250
Present-day width of river flood plain	50 to 620ft
Pre-railroad width of river flood plain	70 to 3,000ft
Roadway bridge crossings	66
Zoo tram bridges	2
Railroad bridges	6
Pedestrian bridges	~10
Dams	8

Table 2-9: Sub-watersheds in the Bronx River Basin

	Sub-watershed	Type	County	Drainage Area
1	Kensico Reservoir	Tributary	Westchester	12.42
2	Clove Brook	Tributary	Westchester	1.32
3	Davis Brook	Tributary	Westchester	2.14
4	Upper Bronx River Basin	Bronx River	Westchester	5.02
5	White Plains Reservoirs	Tributary	Westchester	0.90
6	Manhattan Park Brook	Tributary	Westchester	3.31
7	Fulton Brook	Tributary	Westchester	0.98
8	Hartsdale Brook	Tributary	Westchester	1.21
9	Fox Meadow Brook	Tributary	Westchester	1.45
10	Middle Bronx River	Bronx River	Westchester	5.08
11	Troublesome brook	Tributary	Westchester	2.69
12	Sprain Brook	Tributary	Westchester	3.91
13	Grassy Sprain Brook	Tributary	Westchester	2.66
14	Grassy Sprain Brook	Tributary	Westchester	1.97

15	Lower Bronx River Basin	Bronx River	Westchester	3.26
16	Parkland	Bronx River	Bronx	3.58
17	Bronx Gardens/Zoo	Bronx River	Bronx	1.30
18	West Farms	Bronx River	Bronx	1.53
19	Estuary	Bronx River	Bronx	1.58

Table 2-10: Area of Bronx River Basin upstream from each site

Site	Drainage area upstream of site (sq miles)	Additional drainage area to site (sq miles)
Westchester County Center	18.18	4.44
Garth Woods/Harney Road	26.69	
Crestwood Lake	31.07	2.69
Bronxville Lake	34.63	
Muskrat Cove	48.33	
Shoelace Park	49.73	1.58
Snuff Mill (Stone Mill) Dam	52.15	
Bronx Zoo and Dam	52.57	
Bronx River Park	53.26	

The Kenisco Dam was built across the Bronx River. Kenisco Lake flows in the Bronx River. Elevation of the Bronx River below Kensico Lake is +270 feet. The Bronx River flows into the East River at sea level. At that point the river bed is below sea level. Table 2-11 shows the ranges of elevations and average slopes for all the sites. Table 2-12 shows the approximate widths of the low-flow river and flood plain for each site. The river valleys are relatively narrow.

Table 2-11: Range of elevations for the Bronx River Basin

Site	Range of river elevations		Site river length (feet)	Average slope (feet/mile)
	Upstream (feet)	Downstream (feet)		
Westchester County Center	177	174	2,620	6.0
Garth Woods/Harney Road	125	109	1,988	42.5
Crestwood Lake	98	94	2,442	4.3
Bronxville Lake	91	83	4,165	10.1
Muskrat Cove	58	56	1,350	7.8
Shoelace Park	51	48	6,757	2.3

Snuff Mill (Stone Mill) Dam	48	38	344	153.7
Bronx Zoo and Dam	29	21	1,256	33.6
Bronx River Park	16	9	905	40.8

Table 2-12: Bronx River valley characteristics for each site. Note that the pooled area of Harney Road reach is listed separately from Garth Woods reach.

	Low-flow channel widths		Estimated present-day flood plain width		Estimated pre-railroad flood plain width		Island dimension (visible in 2014)	
	Min (feet)	Max (feet)	Min (feet)	Max (feet)	Min (feet)	Max (feet)	Length (feet)	Width (feet)
Westchester County Center	18	50	140	460	800	3,000	220[a]	135
Garth Woods	25	95	200	265	380	410	325[b]	130
Harney Road	50	95	100	260	250	620	30 [c]	8
Crestwood Lake	82	250	280	620	500	1,400	80[d]	640
Bronxville Lake	90	250	180	300	410	580	440	50
Muskrat Cove	60	85	150	210	400	575	n.a	n.a
Shoelace Park	50	90	90	400	400	850	n.a	n.a
Snuff Mill Dam	50	30	50	50	70	50	70	
Bronx Zoo and Dam	50	130	350	390	430	750+	140	65
Bronx River Park	30	50	50	60	550	650	n.a	n.a

a. Tree covered island in braided reach
b. High-flow island formed when apparent abandoned stream is full.
c. Gravel and cobble bar south of weir.
d. Largest of four (4) sediment islands as of July 2014.

The main bedrock types in the river basin consist of the Cambrian-Ordovician Inwood Marble, Hartland formation schist and gneiss, and the Proterozoic Fordham Gneiss and Yonkers Gneiss. Table 2-13 summarizes the stratigraphy of the Bronx River north of the Mosholu Parkway.

Table 2-13: General stratigraphy of the Bronx River north of Mosholu Parkway.

Age	Description
Holocene	Modern river sediments
Holocene	Fill and man-made structures
Holocene	Thin soils
Holocene	Fluvial sediments
Pleistocene	Pleistocene glacial lake clays and silts
Pleistocene	Pleistocene glacial outwash deposits
Pleistocene	Pleistocene glacial moraine tills
Cambrian-Ordovician	Inwood marble
Cambrian-Ordovician	Hartland formation
Proterozoic	Yonkers gneiss
Proterozoic	Fordham gneiss

2.2.2.1.2 Hydrology & Hydraulics

Precipitation in the Bronx River watershed is approximately 46 inches per year. For watersheds in their natural state, rainwater is absorbed into the soil, where it infiltrates to the groundwater or is conveyed slowly through the subsurface to stream channels. Impervious surfaces prevent rainwater infiltration and thus the degree of runoff is increased. In addition to the increase in runoff volume, urbanized watersheds such as the Bronx River convey stormwater to the main channel through sewers and drains, which is a much faster process than would naturally happen. This disturbed flow pattern of increased peak discharge rates and higher total discharge volumes results in flash floods, erosion, increased water temperatures, low base flow and increased sediment runoff from the surrounding watershed, all of which correlate to low habitat value.

The Bronx River has an average base flow (in dry weather conditions) of approximately 10 to 20 cubic feet per second. According to the FEMA Flood Insurance Study (FIS) for New York conducted in 2001, the 10-year and 100-year frequency discharge at the USGS gage at Bronxville (#01302000) are 1,875 cubic feet per second (cfs) and 3,358 cfs, respectively. Flow characteristics are generally flashy, with most events transpiring within a 24 hour period (USAERDC-CHL, 2007). Recent one-year storm hydrographs indicate that most runoff is conveyed to the channel over a short period of time.

Today much of the river has been straightened. Dams and other impoundments, many of which were originally created to serve as settling basins for sediment in the water column, alter the overall hydrology of the river by acting as detention areas and limiting connectivity between river sections and isolating different parts of the watershed

that might otherwise be connected by and influence each other by a free-flowing river. Lack of proper maintenance has resulted in siltation and the formation of small islands within many of the impoundment areas. Most impoundment areas are now silted in and relatively shallow, with depths of the smaller impoundments ranging from 0.0 to 5.0 feet. Crestwood Lake and Bronxville Lake have a sediment depth greater than 4.0 feet. The locations of dams, weirs and other impoundments are shown on Figure 2-9. Table 2-14 provides a summary of these features, listing both name references and numeric designations for consistency with other reports and studies prepared on the Bronx River.

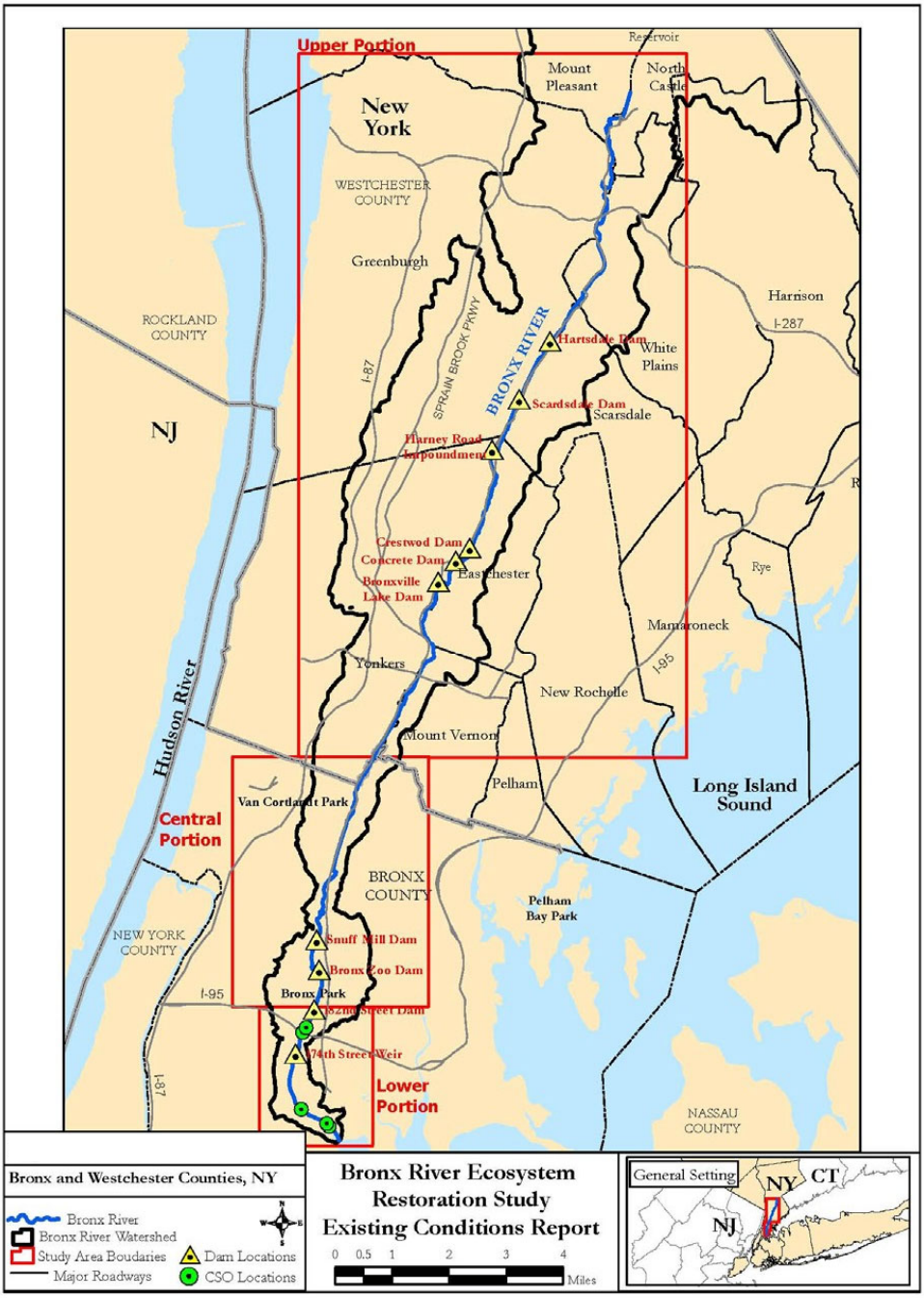


Figure 2-9: CSO and Dam Locations along the Bronx River

Table 2-14: Summary of Existing Dams and Impoundments along the Bronx River

Name/Identification	Location	Watershed
Dam 1 / 174th Street Weir	Estuary/lower portion of Bronx River, Bronx County	Estuary
Dam 2 / 182nd Street Dam	Near downstream extent of Bronx Zoo, Middle portion of Bronx River, Bronx County	West Farms / Bronx Gardens/Zoo
Dam 3 / Bronx Zoo Dam	Bronx Zoo, Middle portion of Bronx River, Bronx County	Bronx Gardens/Zoo
Dam 4 / Snuff Mill Dam	NY Botanical Garden, Middle Portion of Bronx River, Bronx County	Bronx Gardens/Zoo
Dam 5 / Bronxville Lake Dam	Westchester County	Bronx River Middle
Dam 6 / Concrete Dam	Westchester County	Bronx River Middle
Dam 7 / Crestwood Dam	Westchester County	Bronx River Middle
Dam 8 / Harney Road Impoundment	Westchester County	Bronx River Middle
Dam 9 / Scarsdale Dam	Westchester County	Bronx River Middle
Dam 10 / Hartsdale Dam	Westchester County	Hartsdale Brook
Fisher Lane Impoundment	Westchester County	Bronx River Upper
Green Acres Impoundment	Westchester County	Bronx River Upper
Ardsley Road Impoundment	Westchester County	Bronx River Upper

2.2.2.1.2.1 Hydrologic Modeling Using HEC-1

A HEC-1 Model was developed to quantify the existing conditions hydrology for the Bronx River Watershed. Though this legacy model was developed in 2005, the results do provide useful information on a broad level and served as input for (preliminary) HEC_RAS modeling. The risk of reliance on these legacy model results, as well as the 2005 HEC-RAS modeling results discussed later in this section was considered to be minimal given the preliminary level of detail for the proposed designs for the Bronx River. The uncertainty inherent in this low level of detail is fully reflected in the cost estimate contingency for each sites proposed design. More detailed H&H modeling is recommended for many of the Bronx River sites during the PED phase. Refer to the full Model report, available online, for more detailed information, including key assumptions

in determining impervious area, unit hydrograph parameters, Muskingum routing parameters, base flow parameters, and the adopted HEC-1 input parameters.

The USACE Generalized Stream Network Option of the HEC-1 Flood Hydrograph Package was used to hydrologically model the Bronx River watershed and its tributaries for the "source" study. The Bronx River watershed was divided into 55 sub-basins for HEC-1 modeling purposes, based on study needs, location of major and minor tributaries, USGS gaging stations, and points of interest on the Bronx River.

2.2.2.1.2.2 Urbanization

An upward trend of annual and partial peak flow data from the USGS streamflow gage at Bronxville, NY was observed when it was plotted versus time in years elapsed since data collection began in November 1943. This was assumed to be due mostly to the post World War II historic urbanization (development of suburbs) in the Bronx River watershed.

2.2.2.1.2.3 Base Flow Parameters

Base flow is defined as flow in the stream occurring before and after a rainfall-runoff flood, consisting of both stored water coming out of the ground between the surface and the water table, and from the water table itself, into the stream, under gravity. Base flow parameters were determined for each of six (6) major historic floods modeled.

2.2.2.1.2.4 Major Historic Flood Reproductions

The six (6) major historic floods were modeled with HEC- 1 and are listed below along with the rationale for their selection (in parentheses) and peak discharge, as recorded by the USGS gage at Bronxville, NY. Since the USGS gage was discontinued prior to the April 2007 nor'easter, no discharge data is available for that flood event at the USGS gage at Bronxville.

- June 15 1969 (former flood of record; full discharge hydrograph available from 1971 USACE COE report): 1,580 cfs.
- June 19-20, 1972 (current flood of record; about a 50 year frequency flood, full discharge hydrograph available from 1976 USACE COE report): 2,500 cfs.
- September 25, 1975 (Tropical Storm Eloise): 2,190 cfs.
- November 7-8, 1977 ("Election Day" nor'easter flood): 1,630 cfs
- April 9-10, 1980 (intense spring flood): 2,060 cfs
- April 4-5, 1984 (second-largest historic flood in adjacent Saw Mill River basin): 1,620 cfs

Note: The HEC-1 model run for the April 2007 northeaster was calibrated using the USGS gage at Bronx Botanical Garden. This calibrated model run calculated a peak discharge at the USGS gage at Bronxville of 3,120 cfs. This discharge surpasses the 2500 cfs recorded at this gage during the observed flood peak of June 1972. The Bronxville USGS

gage has been discontinued since 1989, therefore the calculated model value could not be confirmed by observed gage data. It should be further noted that this model run was done after the existing conditions hydrology appendix was completed.

Three (3) Bronx River stream gages, located in Bronxville, the Bronx Botanical Gardens, and Burke Avenue in Williamsbridge, were used to calibrate the model. HEC-HMS was used to calibrate and test HEC-1 files for six (6) historic and nine (9) specific hypothetical frequency floods. Once this calibration was accomplished, the HEC-1 models of the specific-frequency hypothetical floods, along with the historic flood HEC-1 models, were considered to be an acceptable existing conditions hydrologic, or rainfall-runoff, model of the Bronx River watershed, suitable for use in the study of water quality, sedimentation, and other parameters to be considered in future studies of proposed ecosystem restoration plans of improvement. Flows from the HEC-1 model were used in the HEC-RAS model for sediment analysis, but not to calibrate water surfaces along the Bronx River. It was determined that calibration of the HEC-RAS model and updating the historical flood events within the HEC-1 model was not necessary because typical streambank restoration projects do not significantly change channel morphology or significantly alter water surface elevations. The flows from the HEC-1 model were therefore, determined to be acceptable. Table 2-15 summarizes existing conditions peak discharges at key points of interest along the Bronx River.

Locations of sub-watersheds for the tributaries mentioned in Table 2-15 are shown on Figure 2-10.

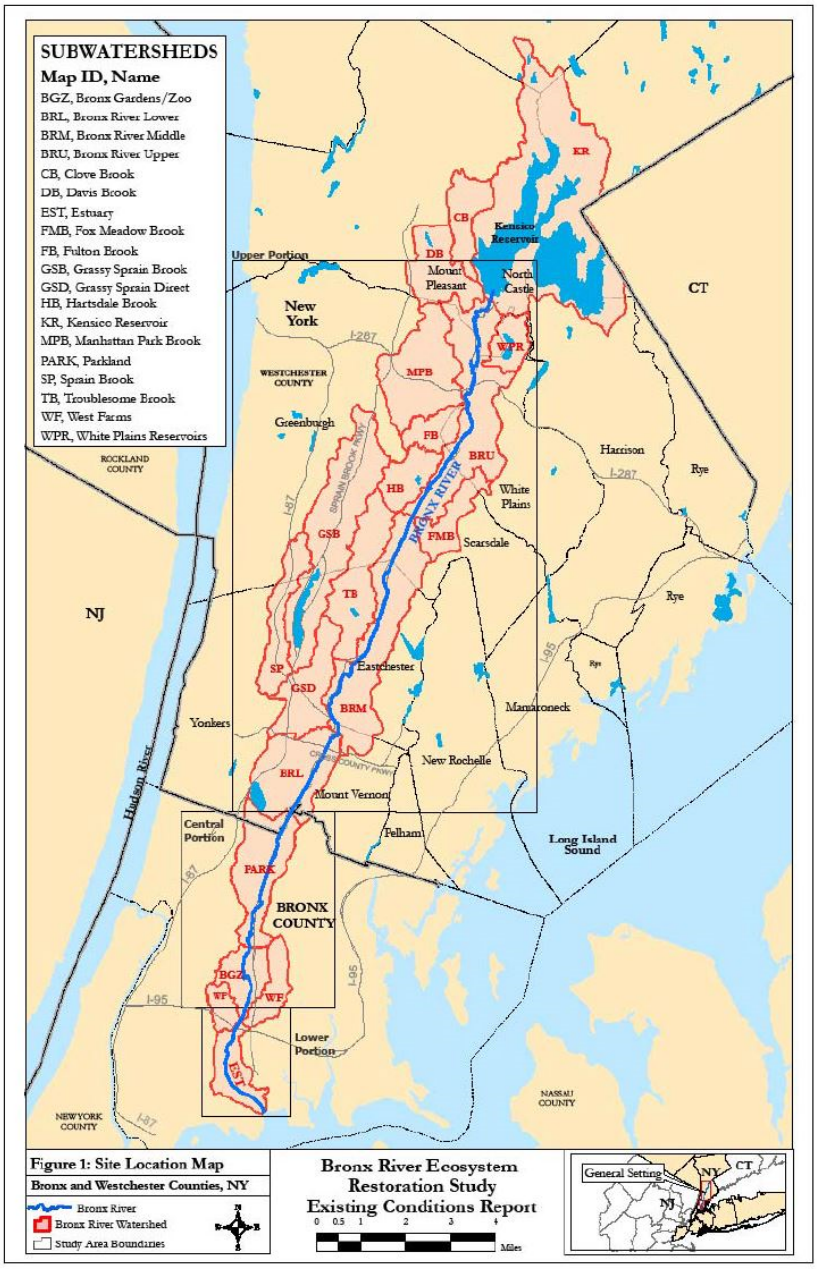


Figure 2-10: Locations of Sub-Watersheds within the Bronx River Basin

Table 2-15: Existing Conditions Peak Discharges in cfs at Key Points of Interest

Description of Location	HEC-1 ISTAQ	Contributing Drainage Area (sq. mi.)	Flood Frequency in Years									
			1	2	5	10	25	50	100	250	500	Jun-72
Bronx River : at Kensico Dam Plaza and Bronx River Parkway Traffic Circle.	C1	0.275	230	250	300	330	380	420	460	510	550	100
Downstream of first right bank tributary	C5	3.8	760	840	1040	1190	1400	1560	1720	1930	2110	910
Downstream of Fulton Brook	C12	9.56	1190	1420	1820	2120	2480	2780	3090	3490	3760	1820
Downstream of Davis Brook	C16	10.47	1140	1370	1740	2040	2380	2670	2970	3370	3660	1900
Upstream of Troublesome Brook	C26	17.17	750	900	1130	1320	1550	1750	1940	2220	2440	1880
Upstream of grassy Sprain Brook	C28	20.4	830	990	1250	1450	1690	1910	2110	2420	2660	1960
Sprain Brook at mouth	S32	3.95	270	330	420	490	580	650	730	830	910	630
Grassy Sprain Brook at mouth	C34	6.04	420	500	630	740	860	960	1060	1200	1310	970
Bronx River: USGS gage at Bronxville	302000	26.5	1070	1290	1620	1880	2200	2490	2750	3150	3460	2500
At Westchester County-Bronx NYC Border	R20	31.42	950	1140	1430	1660	1930	2180	2400	2760	3030	2190
USGS gage # 01302015 Bronx River at Williams Bridge (Burke Avenue Bridge)	BURKE	33.24	890	1060	1330	1550	1800	2030	2230	2570	2820	2010
USGS gage # 01302020 Bronx River at NY Botanical Garden at Bronx,NY	BTANIC	34.47	890	1070	1340	1550	1810	2040	2230	2570	2820	2010
At East 180th St. bridge (head of tide)	R23	35.97	880	1050	1310	1520	1770	2000	2190	2520	2760	1950
At East 174th St. Bridge	C46	38.55	890	1060	1320	1540	1790	2020	2200	2540	2790	1970
Bronx River at mouth (East River)	BRNXMO	39.94	860	1020	1280	1480	1720	1940	2110	2540	2680	1860

2.2.2.1.2.5 Conclusions

Model calibrations show reasonable agreement with actual observed storm events. Numerous impoundments have affected the overall hydrology of the river by acting as detention areas and limiting connectivity between river sections. The disturbed flow pattern of increased peak discharge rates and higher total discharge volumes generally results in flash floods, erosion, increased water temperatures, low base flow and increased sedimentation, all of which correlate to low habitat value. Hydraulic models can be utilized to assess improved conditions alternatives that involve possible changes to the hydrologic regime.

The model results reported here were conducted for a flood control study conducted in 2007. The results, despite the age, do provide useful information on a broad level and served as input for HEC_RAS modeling. Preliminary HEC-RAS modeling was conducted for selected sites as needed and are discussed in a site specific manner below. More detailed H&H modeling is recommended for many of the Bronx River sites during the PED phase.

2.2.2.1.3 Geotechnical

The Bronx River Geotechnical and Geological Report is provided as Attachment C-4 of this report and is summarized below.

2.2.2.1.3.1 Regional Geology

The course of the Bronx River, like most rivers in the Manhattan Prong, follows a narrow band of weak Inwood marble. The river follows the southwesterly trend of the marble and then turns southward to empty into the East River at the apex of the Long Island Sound. Many believe that prior to the Pleistocene Period, the Bronx River was a pre- glacial stream that wound its way from its source in present-day upstate New York to the present Long Island Sound. When a glacier came through the Bronx, approximately 240,000 years ago, it blocked part of the original path of the Bronx River and subsequently reshaped and modified the path of the River (Van Driver, Roadside Geology of New York, 1985).

2.2.2.1.3.2 Regional Soils

The natural surficial material in Bronx County is predominantly glacial till that consists of a mixture of clay, silt, sand, gravel, and boulders. Freshwater and tidal marsh deposits, consisting predominantly of organic silt and clay, commonly overlie the glacial deposits. The glacial deposits are commonly underlain by bedrock. Miscellaneous (artificial) fill deposits in the Bronx contain mixtures of glacial soil, riprap (i.e., large blocks of rubble rock), building-demolition rubble (e.g., glass, wood, brick and concrete), and cinders. (*Reconnaissance Soil Survey of the Boroughs of New York* to be published by the United States Department of Agriculture, Natural Resources Conservation Service)

Soils in the area of the study area belong to the LaGuardia and Ebbets Series soil classification and consist of very deep, well-drained soils with moderate permeability. These soils occur in and near major urbanized areas of New York City and are formed from construction debris intermingled with fill soil materials. Fill materials ranges in thickness from approximately 3.3 to 6.7 feet. The transported construction debris may include pieces of plastic, glass, rubber, bricks, lumber, asphalt, coal ash, unburned coal, gypsum board, concrete, and steel. LaGuardia Soils contained greater than 35 percent of transported construction debris. Ebbets Soils contain between 10 percent and 35 percent of transported construction debris. The transported natural soil material may originate from any geological deposit ranging from till, outwash, alluvium, coastal plains sediments or residuum, usually from a local source.

2.2.2.1.3.3 Sediment Impact Assessment Model (SIAM)

The Sediment Impact Assessment Model (SIAM) provides a framework to combine hydrology, hydraulics, and sediment supply into a geomorphic assessment and rehabilitation design for the reaches along the Bronx River. It is an important tool in the evaluation of the physical support structure for habitats, ecosystems and ecosystem services. The geomorphic Assessment and SIAM Modeling Report is provided as Attachment C-5 of this report.

A key component of the SIAM is its ability to assess short-term changes in sediment delivery and the potential morphological response to sediment management features such as bank stabilization, grade control structures, flow control, land treatments, or any other measure that alters the flow and/or sediment regime. Sediment is a significant pollutant in streams and a contributing agent in many others. SIAM is an important tool in assessing impacts, stability and sustainability by showing areas of accretion, degradation and equilibrium along defined reaches to evaluate restoration scenarios.

The erosion of channel banks is exacerbated during periods of elevated flows. As stream energy works to erode particles from channel banks, the particles are carried downstream. In locations where flows have decreased sufficiently, these particles are later re-deposited. This process of erosion and deposition is occurring in the Bronx River study area. Sedimentation and associated channel aggradation fosters a state of continued instability in the channel.

Problem areas with regard to sedimentation in limited segments of the Bronx River Basin have been reported by several local planning entities in recent years (USACE 1999, WCDOP 2000, Bronx River Alliance 2006). Watershed problems associated with sedimentation and channel instability (Figure 2-11) often require a system-wide analysis to adequately identify the causes and effects of the problems and to formulate

potential solutions.



Figure 2-11: Channel Sedimentation in the Garth Woods section. The new channel runs along the Bronx River Parkway.

2.2.2.1.3.3.1 SIAM Study Objectives

Recognizing the importance of conducting such a comprehensive and system-wide analysis in the Bronx River Study Area, in 2006, the US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL) in Vicksburg, Mississippi studied both the Westchester and Bronx County portions of the Bronx River in detail. The study was conducted in two (2) phases: a geomorphic assessment (to identify sediment sources), and a sediment assessment (to estimate sediment loads) using the SIAM model. The portion of the Bronx River downstream of Dam 1 is in the tidal zone of the East River and was not included in the assessments. The remainder of this section presents an overview of the analysis of sedimentation trends based on two (2) study phases. See full report --"Geomorphic Assessment and Sediment Impact Assessment for the Bronx River, New York – Final Report" (USACE-CHL, March 2007) for more details.

2.2.2.1.3.3.2 Geomorphic Assessment – Sediment Sources and Geomorphic Reaches

The baseline geomorphic assessment consisted of data gathering, field investigations, and data analysis. This was conducted primarily to determine the existing sources and characteristics of sediment within the project area and to assess the overall stability of the stream/watershed in the project area. The baseline geomorphic assessment also provides the foundation for the more quantitative SIAM analysis.

Bed material samples were also collected during the field investigation and the samples were sieved in the laboratory to develop bed material gradations along the Bronx River (See Technical Appendices). In general, the bed material is very coarse in the steeper reaches of the river, consisting of gravels and cobbles. No analyses were conducted to determine the mineralogical characteristics of the sediments to determine the sources of origin.

2.2.2.1.3.3.3 Sediment Sources

An attempt was made to identify sediment sources and estimate sediment loads within the watershed. These estimates serve as the basis for the SIAM sediment load input data. Based on the data collection effort, there is limited published quantitative data on bank and watershed sediment supply for this basin. Five (5) potential sediment sources were evaluated: stream banks, tributaries, watershed (upland), railroad grades, and re-suspension of sediment from the channel.

The results from the geomorphic assessment indicate that the Bronx River is stable in plan form and profile. No significant indicators of channel incision were observed on a broad reach-based macroscopic level, and no active channel migration was observed. Bank erosion observed during the field investigation was significant in localized stretches primarily in tight curvature bends with little existing vegetation. However, based on defined reach lengths, the average bank incision rates were not significant when evaluated over greater distances. Reaches where bank stabilization measures, both hard and soft, currently exist appear to be performing satisfactory. Although difficult to quantify, recession rates at bank erosion sites were estimated to be on the order of 2 inches annually on average. Results from the SIAM computations indicate that control of bank erosion sediment sources has little overall impact on the average annual bed material sediment balance of the system. In consideration of all observations and data, there is evidence to suggest that while localized bank caving exists or once existed, on a reach-based average the banks are not considered a significant contributor to the larger sediment deposits in the Bronx River.

Given that bank erosion is not considered a reach-based average significant contributor of sediment, it appears that the primary source of sediment deposited in the pools is mainly from the watershed. It is unclear, however, whether the watershed contribution was greater in years past when urban development was more active than at the present. Sediment generation within the watershed was observed at localized gullies formed by concentrated run-off from parking lots, roadways and walking paths adjacent to the river, as well as railroad embankments immediately adjacent to the river. Observations of sediment delivered from tributaries also suggest that the watershed contributes sediment. In particular, the Westchester County Center tributary was noted as a substantial contributor of sediment to the system, but the sediment load could not be quantified since sediment sampling gages or other flow gages do not exist in the basin. Estimating the annual sediment yield from the watershed areas was difficult due to the unavailability of published data, and development of watershed yield models was beyond the scope of

this study. Estimates of watershed sediment loads for the SIAM computations were estimated from study results of a similar urbanized area. SIAM computation scenarios assuming 25 percent and 50 percent control of watershed sediment sources show modest reductions in bed material supply for the reaches ranging from 100 to 200 tons/year. Dredging records were provided for two (2) locations within the Bronx River Basin, Crestwood Lake and Bronxville Lake. Dredge volumes excavated during these maintenance events are shown in Table 2-16.

Table 2-16: Dredge records provided by Westchester County, New York

Dredge Year	Dredge Volumes in cubic yards (CY)	
	Crestwood Lake	Bronxville Lake
1980/1981	13,000 (approx)	---
1993	13,000	---
2001/2002	46,000	25,000
2006	17,000	---

The pool areas located throughout the system serve as sediment traps, and apparently have done so for many years. The dredge records for Crestwood Lake provide temporal information as well as sediment volume data. The dredge records for Bronxville Lake provide volume for only a single dredging event. A calculation of deposition rates can therefore only be done for Crestwood Lake. The dredge volumes for Crestwood Lake were converted to average annual deposition by dividing the volumes by the number of years between dredging events. This assumes that the dredged volume represents the total deposition that occurred over the entire time span. Using this method the average annual deposition between 1981 and 1993 (12 years) is 1,083 CY/year, between 1993 and 2002 (9 years) is 5,111 CY/year, and between 2002 and 2006 (4 years) is 4,250 CY/year.

The computed average annual deposition volumes were converted to average annual tons/year by using an assumed sediment deposit unit weight of 90 pounds/cubic foot. The computed average annual sediment deposition in tons/year for the three (3) time periods is 1,316 tons/year, 6,210 tons/year, and 5,164 tons/year, respectively. The average of the three (3) time periods is 4,230 tons/year. Field observations show that sands and fine gravels deposit in the upper reaches of the pooled areas, while the fine sands and silts deposit in the lower reaches. Sediment depths were in excess of 4 feet, but it was difficult to determine actual depths from the available dredging records and the lack of historic channel surveys. Sediment deposition immediately upstream of most of the major impoundment dams and weirs was level or near level with the crest of the dam/weir. In some of the larger impoundments, sizable middle bars or low islands have developed and been vegetated. SIAM computations also verify these deposition areas. The primary areas of deposition that were identified are Fisher Lane (Reach 2), Ardsley Road (Reach 8), Harney Road (Reach 10), Crestwood Lake (Reach 12), Bronxville Lake (Reach 14), and Dams 2 (Reaches 21) in the Bronx Park. Depths of annual deposition

estimated from SIAM results for these areas range from approximately 0.1 to 0.2 feet to 1.8 feet per year; however, the depth of 1.8 feet is probably excessive based on observations of existing pools, and an average annual depth of deposition of 0.1 to 0.2 feet is considered more reasonable. An important but unknown aspect of the pool areas is the possibility for deposited sediments to re-suspend during major flood events. The degree to which this may occur should be investigated with a more detailed numerical sediment transport model such as HEC-RAS Sediment Transport or Adaptive Hydraulic Model (ADH).

2.2.2.1.3.3.4 Geomorphic Reaches

The Bronx River study area was divided into 26 geomorphic reaches, primarily based on information from the field investigation and the data search. Factors considered in the identification of the geomorphic reaches included plan form determined from aerial photography, channel slope determined from the HEC-RAS geometry data, sediment transport characteristics, tributary locations, and channel structures (dams). The geomorphic reaches provide the basis for organizing the SIAM model reach structure and input data. The limits of each reach are presented in Table 2-17.

By definition, a through-put reach simply “flushes” all sediments that enter to the next reach downstream, effectively transporting the material as wash load. Of the 26 geomorphic reaches used in the assessment, ten were identified as through-put reaches (Reaches 3, 4, 5b, 7a, 7b, 9, 11, 13b, 15, and 19).

The geomorphic assessment did not reveal any significant indicators of active channel incision along the study reach. The primary reason for this vertical stability is the coarse gravel and cobble bed material found through most of the area, as well as the periodic grade control provided by the dams. This lack of vertical incision also contributes to the overall stability of the stream banks in the study area. Overall, bank erosion in the study area is limited to a few isolated areas, and estimated erosion rates are very low (2 inches per year). No active bank line meanders or other indicators of recent changes in channel location were observed, indicating that the position of the river has changed little over the recent years, at least by natural processes. In consideration of the significant amount of sediment deposits observed in the pool areas and the observed stability of the channel banks, the assessment is that the channel banks are a minor to insignificant contributor of sediment to the deposits in the pools.

Table 2-17: Geomorphic Reaches

Reach	Description
1	From Kensico Dam to the upper end of Fisher Lane Pool
2	From the upper portion of Fisher Lane pool to Fisher Lane.
3	From Fisher Lane to Cemetery Road

Reach	Description
4	From Cemetery Road to the Bronx River Parkway (BRP) bridge downstream of I-287
5a	From the BRP bridge below I-287 to the third BRP crossing above Hartsdale Station
5b	From the third BRP crossing above Hartsdale Station to the second BRP crossing above Hartsdale Station
6	From the second BRP bridge above Hartsdale Station to the dam near Green Acres
7a	From the Green Acres dam to approximately 2,200 feet above the first Metro North crossing above Crane Road
7b	From approximately 2,200 feet above the first Metro North crossing above Crane Road to the Metro North crossing
8	From the Metro North crossing above Crane Road to the Ardsley Road dam
9	From the Ardsley Road dam to approximately 1,250 feet above Harney Road dam.
10	From approximately 1,250 above Harney Road dam to Harney Road dam
11	From Harney Road dam to approximately 5,000 feet above Crestwood dam
12	From approximately 5,000 feet above Crestwood dam to Crestwood dam
13a	From Crestwood dam to the concrete weir upstream of Scarsdale Road
13b	From the concrete weir upstream of Scarsdale Road to the BRP exit ramp downstream of Scarsdale Road
14	From the BRP exit ramp downstream of Scarsdale Road to Bronxville dam
15	From Bronxville dam to Sprain Brook confluence
16a	From Sprain Brook confluence to Cross County Parkway
16b	From Cross County Parkway to Nereid Avenue
17	From Nereid Avenue to Gun Hill Road
18	From Gun Hill Road to Dam 4
19	From Dam 4 in the Bronx Park to just upstream of Fordham Road
20	From just upstream of Fordham Road to Dam 3 in the Bronx Park
21	From Dam 3 in the Bronx Park to Dam 2 in the Bronx Park
22	From Dam 2 in the Bronx Park to Dam 1 near 174th Street
Note	Area downstream of Dam 1 is tidal and was not included in the assessment

Numerous small dams or weirs are located throughout the study reach. These dams form pools which act as sediment traps, and sediment deposits of 4 feet or more were observed in most of the pools. It was not possible to determine how long these deposits have existed or how quickly the pools originally filled due to (1) the lack of historical channel surveys, and (2) the limited data presented in the dredging records. The assessment that the channel banks are not a significant source of sediment to the pools suggests that the material came from the watershed and/or the tributaries. It is not known if the material has been delivered consistently over the years, or if yields were greater during years of the heaviest development of the watershed. The data collection effort located no reliable published estimates of the loading from any of these sources. Therefore, it is difficult to quantify the relative magnitudes of these sources with any certainty. Re-suspension of in-channel sediment deposited in the pools may also be a significant source, but the relative contribution of this potential source is uncertain without conducting more advanced computer models to determine the flow conditions that result in re-entrainment of the sediment.

2.2.2.1.3.3.5 Sediment Impact Assessment

The sediment impact assessment for the Bronx River was conducted using the SIAM model. Using sediment data and other information garnered in the geomorphic assessment phase, the SIAM model was used to determine the sediment continuity for each geomorphic reach. The SIAM model was constructed from the 1970s HEC-2 model and the 2005 HEC-RAS model provided by NAN, and covered the study area from Dam 2 in Bronx Park to Kensico Dam.

SIAM is a reach-based sediment accounting model that has been embedded in the Hydraulic Design module of HEC-RAS, and provides an expedient means of determining average annual sediment impacts for stream networks. It provides a framework to combine sediment sources and computed sediment transport capacities in order to evaluate sediment balances and downstream sediment yields for different alternatives. The model uses the 1-dimensional hydraulic computations from HEC-RAS to compute average annual sediment transport capacity for each reach, and sediment continuity is determined by comparing the capacity to the sediment supply for each reach. Computations are made by grain size, allowing the fate of a particular size particle to be traced. The SIAM model is currently available in HEC-RAS Version 4.0.

SIAM input data for each sediment reach consists of five (5) key input parameters for each reach: bed material composition, hydrology/flow duration, sediment properties, sediment loading from local sources and reach average hydraulic parameters. Detailed, reach-specific results of the SIAM computations for bed material local balance, wash load, and bed material supply for each scenario are shown in the Tables of the Technical Appendices. Sedimentation affects critical life stages of aquatic species such as fish, mollusks, and crustaceans.

2.2.2.1.3.3.6 SIAM Results

In general, the results of the SIAM computations were considered reasonable and representative of conditions documented not only by the geomorphic assessment, but also by NAN observations noted in the restoration project scoping document. In this section, results of the SIAM model are presented in question and answer format.

2.2.2.2 Bronx Zoo and Dam

2.2.2.2.1 Topography and Bathymetry

The landscape surrounding the Bronx Zoo and Dam site is generally flat and occupied with roadways, parking lots, and the installations of the Bronx Zoo. The over-widened channel experiences stagnation and constricted flow. Within the Bronx Zoo and Dam site, the river flow is affected by a dam system consisting of two (2) dams abreast of each other, separated by a mid-stream island. Upstream of the dams, the majority of the wetlands consist of narrow strips of emergent vegetation along the banks of the river. Downstream of the dam, wetlands are limited and consist of very small (approximately 10 square feet) discontinuous pockets of emergent vegetation adjacent to the shoreline.

2.2.2.2.2 Geotechnical

Sediment analysis at the Bronx Zoo and Dam site showed that over half of the sediment collected was medium size sand, 31.44 percent was coarse sand and 16.33 percent was fine gravel. Fine sand as well as silt clay were also present in lower quantities. No coarse gravel was present.

2.2.2.3 Shoelace Park

2.2.2.3.1 Topography and Bathymetry

Shoelace Park is surrounded by dense, urban development. The west side of the site largely consists of the Bronx River Parkway's roadway embankment. The eastern side of the site is parkland, predominantly consisting of maintained lawns that rise on a slope of notable steepness (approximately 25- to 30-percent grade) to roughly 60 feet in elevation from the river channel. In the extreme northern and southern portions of the site, deciduous woodlots occur. Along the banks of the river, dense pockets of Japanese knotweed are present. In some areas, New York City Department of Parks and Recreation (NYC Parks) has removed or partially removed this invasive species; some of this removal work was observed during the site visit. Erosion gullies were frequently observed on the upland slope. The sandy-bottom channel is generally one (1) to three (3) feet deep with limited riffles and pools. The banks are nearly vertical in some locations and the faces of the banks are sparsely vegetated.

2.2.2.3.2 Geotechnical

Sediment analysis at Shoelace Park revealed that the bottom substrate was dominated by medium sand, accounting for 60.12% of the total substrate composition. Fine sand was the second most common substrate, accounting for 36.46% of the dry sample. Coarse sand accounted for fewer than 3% of the total bottom habitat and only trace amounts of silt clay, and fine gravel were present. No coarse gravel was present.

2.2.2.4 Bronxville Lake

The Bronxville Lake site is located along the Bronx River, in the Village of Bronxville and the City of Yonkers, Westchester County, NY. The site is bounded by the Bronx River Parkway to the west, Tuckahoe Road to the north, Metro North Railroad to the east and private properties to the south. At this location, the Bronx River flows through a broad valley (~400 feet wide), the sides of which are twenty to forty (20-40) feet high. The weir across the River at the southern end of the site creates a broad and shallow lake in the southern two-thirds (2/3) of the proposed Bronxville Lake site. The stone weir is 48 feet wide and approximately 5.5 feet high at the highest elevation and the Bronxville Lake as approximate surface area of 7 acres. Figure 2-12 shows the stone weir controlling the lake. The lake is surrounded by a park, which is part of the Bronx River Parkway Reservation and is maintained by the Westchester County Department of Parks, Recreation, and Conservation. The park consists largely of maintained lawns with trees, with several pockets of emergent wetlands that are landscaped and mowed.

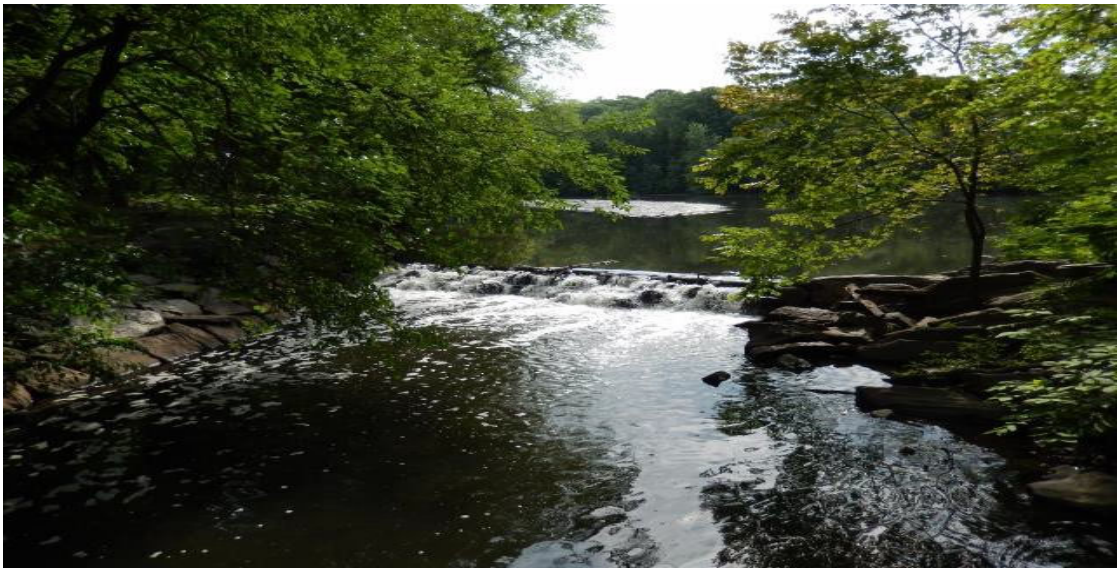


Figure 2-12: Existing Stone Weir at Bronxville Lake

2.2.2.4.1 Topography and Bathymetry

A field survey performed for Bronxville Lake on October 23, 2015. Data collection included five (5) east/west cross-sections (bathymetric & topographic) across the Bronxville Lake, and a weir survey consisting of an upstream cross-section, a downstream cross-section

and the top of the weir section. The coordinate system used for data acquisition is the New York State Plane (NAD1983) NY EAST horizontal and NAVD88 vertical datum.
The field data collected during this effort included:

- Lake/channel bathymetry;
- Riparian/floodplain topography (over bank grades along the cross-sections);
- Sediment thickness in lakes;
- Location/presence of thalweg;
- Weir dimensions and materials;
- Topography/bathymetry immediately upstream and downstream of existing weir;
- Field photographs;
- Changes in slope, top of bank, toe of bank, thalweg, water's edge, and limits of existing path; and
- Sediment depth across the section within lake/channel boundaries using appropriate sediment probe.

A number of data sources were reviewed to provide an understanding of the existing and pre-existing site characteristics. These included:

- Federal Emergency Management Agency's (FEMA) 2007 Flood Insurance Study (FIS) HEC-RAS hydraulic models;
- FEMA Hydraulic model back up GIS data including Topographic (TIN), Survey and Cross-section geometry;
- NYD – Provided 1M DEM for project area;
- USGS 1:24,000 Quadrangles;
- NYSOGS 2013 Orthoimagery; and
- FEMA Flood Insurance Study (Westchester County).
-

2.2.2.4.2 Hydrology and Hydraulics

2.2.2.4.2.1 Existing Hydrologic Models

Existing hydrologic analyses available from FEMA Flood Insurance Study (FIS) and USACE-NYD Bronx River SIAM model were used for the Bronx River H&H analyses. The Bronx River has a contributing area of approximately 34 square miles at Bronxville Lake that includes developed and undeveloped area in central Westchester County. The effective FEMA 2007 hydrologic analysis was based on an updated Log-Pearson type – III analysis on Bronxville gage located just downstream of the Bronxville Lake site. Peak flows for the 10 year, 50 year, 100 year and 500 year flood events established by FEMA and used in the effective FEMA HEC-RAS model, were directly incorporated into the current project model without any changes.

USACE-NYD had developed a detailed HEC-1 model for the Bronx River watershed as a part of the Bronx River" Source*"* Study in July 2010. The HEC-1 model was calibrated for the rainfall events and used to predict hypothetical peak discharges for 1 year, 2 year, 5 year, 10 year, 25 year, 50 year, 100 year, 250 year and 500 year

events. From these models, this analysis utilized the hypothetical peak flood volumes and the nodes where the rate of flow changes to determine the flood volumes at the cross section locations. The risk of reliance on these legacy model results, as well as the 2005 HEC-RAS modeling results discussed later in this section was considered to be minimal given the preliminary level of detail for the proposed designs for the Bronx River. The uncertainty inherent in this low level of detail is fully reflected in the cost estimate contingency for each sites proposed design. More detailed H&H modeling is recommended for this site during the PED phase

2.2.2.4.2.2 Hydraulic Model

The existing FEMA model was used as a basis for this analysis. The FEMA model was developed on the latest GIS-based hydraulic analysis platform, using the USACE's HECGeoRAS and HEC-RAS model interfaces. In order to set up the base analysis for this project, the effective FEMA model was imported in the USACE HEC-RAS version 4.1 and ran using the steady state hydraulic analysis. The backup FEMA GIS data along with FEMA's Topographic data (TIN) were used to develop project specific data at Bronxville Lake..

The general steps followed in the development of the project specific analyses at Bronxville Lake are summarized below. The field survey was imported in ARCGIS map and the survey shapefiles for the project area were extracted. Initial project setup was performed using effective FEMA data, field survey and other recent basemap data. The project specific cross-section location plan along with field survey data is provided in Attachment C-6. After initial set up of the hydraulic analysis, the channel cross-sections from Bronxville site were removed manually from the HEC-RAS model and Bronx River GIS dataset. New cross-sections based on the field survey were added in GIS for the data processing.

The cross-section geometry for the HEC-RAS hydraulic model was developed from two (2) data sources, surveyed cross-sections and FEMA Bronx River TIN elevation data. No changes were made to the existing cross-sections and structure on the Bronx River outside the project area within the Bronx River Model and database. The weir profile was then modified in HEC-RAS to match the recently surveyed data and field observations. Upon completion of the geometric data input of the model the Channel Manning's n values and in-effective flow areas were updated on each affected cross-sections following the guidance provided in the HEC-RAS user's manual. Two (2) different models scenario with FEMA and USACE-NYD hydrology were simulated to evaluate different flow conditions through the lake and establishment of the base flood elevations for the selected frequencies. The result of the hydraulic analysis using USACE-NYD hydrology is provided in Attachment C-6.

2.2.2.4.2.3 Model Results

As part of Bronxville Lake investigation, the following items were reviewed and evaluated using the field survey data and the H&H model results. The HEC-RAS summary output

table, cross-sections and flood profiles for 1 year through 500 year simulation run are provided in Attachment C-6.

Stream Thalweg**:** The stream thalweg represents the existing channel invert along the stream through the site. A GIS feature line representing the location of existing stream invert was developed using the field survey and ArcGIS application. At Bronxville Lake, the existing thalweg line is mostly in the center of the stream/lake in the north and central portion of the Bronxville Lake. However, in the southern portion of the lake, the thalweg shifts close to the left overbank in the weir vicinity. The maximum depth surveyed is approximately 6.5 feet +/- closer to the weir (XS#19575.24), whereas a minimum depth of 3.5 feet +/- was observed at the upper portions of the lake (XS#20678.07).

Channel Banks**:** The average bottom of the bank elevations along the Bronxville Lake is 85.0 feet +/- whereas the average top of the bank elevation ranges from 87.3 to 87.8 feet. A GIS feature line representing the edge of banks is plotted on the map in Attachment C-6.

Sediment Depths**:** The maximum sediment depth (refusal depth) observed ranged from 3 to 7 feet.

Bank Full Flows**:** Based on hydraulic model simulations, the average bank full flood event is a 1 year flood with an average maximum depth of 6 feet along the cross-section.

Extreme Floods: Bronxville Lake and the adjacent park land would be submerged in flood event greater than the 5-year recurrence interval level. During extreme flood events such as the 500-year interval, the predicted flood depth varies spatially from approximately 8 to 12 feet above the normal lake surface.

Channel Velocities**:** The channel velocity along the Bronxville Lake varies from below 1 feet/sec at the widest portion of the lake to approximately 3.5 feet./sec at the weir.

2.2.2.5 Garth Woods/Harney Road

The Harney Road site (downstream portion of combined Garth Woods/Harney Road site) located along the Bronx River in the City of Yonkers and Town of Eastchester, Westchester County, NY. The site is bounded by the Bronx River Parkway to the east and west, Garth Woods to the north, and Harney Road at the south side of the lake. At the Harney Pond site, the river flows through a broad valley (~400 to 600 feet wide), the sides of which are approximately 20 feet in elevation. The channel in this site is over-widened and shallow, with a ponded area upstream of the weir located immediately south of Harney Road bridge. A paved path and park on the east side of the river are part of the Bronx River Parkway Reservation maintained by the Westchester County Department of Parks, Recreation, and Conservation. The concrete weir is 50 feet wide and approximately 5.0 feet high at the highest elevation and the ponded area at Harney Road

has an approximate surface area of 2.0 acres. Figure 2-13 shows the masonry weir controlling the ponded area.



Figure 2-13: Existing Masonry Weir at Harney Road Site

2.2.2.5.1 Topography and Bathymetry

A field survey was performed for the Bronx River Garth Woods/Harney Road site on October 22, 2015 (focusing on Harney Road only). Data collection included five (5) east/west cross-sections (bathymetric & topographic) across the Harney Pond, and a weir survey consisting of an upstream cross-section, a downstream cross-section and the top of the weir section. The coordinate system used for data acquisition is the New York State Plane (NAD1983) NY East horizontal and NAVD88 vertical datum.
The field data collected during this effort included:

- Lake/channel bathymetry;
- Riparian/floodplain topography (over bank grades along the cross-sections);
- Sediment thickness in lakes;
- Location/presence of thalweg;
- Weir dimensions and materials;
- Topography/bathymetry immediately upstream and downstream of existing weir;
- Field photographs;

- Changes in slope, top of bank, toe of bank, thalweg, water's edge, & limits of existing path; and
- Sediment depth across the section within lake/channel boundaries using appropriate sediment probe (n/a for Garth Woods).

A number of other topographic data sources were reviewed to provide an understanding of the existing and pre-existing site characteristics. These included:

- Federal Emergency Management Agency's (FEMA) 2007 Flood Insurance Study (FIS) HEC-RAS hydraulic models;
- FEMA Hydraulic model back up GIS data including Topographic (TIN), Survey and Cross-section geometry;
- NYD – Provided 1M DEM for project area;
- USGS 1:24,000 Quadrangles;
- NYSOGS 2013 Orthoimagery; and
- FEMA Flood Insurance Study (Westchester County).

2.2.2.5.2 Hydrologic Models

Existing hydrologic analyses available from FEMA FIS and USACE-NYD Bronx River SIAM model were used for the Garth Woods/Harney Road H&H analysis. The Bronx River has a contributing area of approximately 29 square miles at Harney Road site that includes developed and undeveloped area in central Westchester County.
The effective FEMA 2007 hydrologic analysis was based on an updated Log-Pearson type – III analysis on Bronxville gage located just downstream of the Bronxville Lake site. Peak flows for the 10 year, 50 year, 100 year and 500 year flood events established by FEMA and used in the effective FEMA HEC-RAS model were directly incorporated into the current project model without any changes.

USACE-NYD had developed a detailed HEC-1 model for the Bronx River watershed as a part of the Bronx River "Source" Study in July 2010. The HEC-1 model was calibrated for the rainfall events and used to predict hypothetical peak discharges for 1 year, 2 year, 5 year, 10 year, 25 year, 50 year, 100 year, 250 year and 500 year. USACE-NYD provided the A/E with the HEC-1 model and the SIAM HEC-RAS model for possible use and guidance. From these models, this analysis utilized the hypothetical peak flood volumes and the nodes where the rate of flow changes to determine the flood volumes at the cross section locations. Though this legacy model was developed in 2005, the results do provide useful information on a broad level and served as input for (preliminary) HEC_RAS modeling. More detailed H&H modeling is recommended for many of the Bronx River sites during the PED phase.

2.2.2.5.2.1 Hydraulic Model

The existing FEMA model was used as basis for this analysis. The FEMA model was developed on the latest GIS-based hydraulic analysis platform, using the USACE's

HECGeoRAS and HEC-RAS model interfaces. In order to set up the base analysis for this project, the effective FEMA model was imported in the USACE HEC-RAS version 4.1 and ran using the steady state hydraulic analysis. The backup FEMA GIS data along with FEMA's Topographic data (TIN) were used to develop project specific data at Crestwood Lake. The general steps followed in the development of the project specific analyses at Harney Road are summarized below.

The field survey was imported in ARCGIS map and the survey shapefiles for the project area were extracted. Initial project setup was performed using effective FEMA data, field survey and other recent basemap data acquired. The project specific cross-section location plan along with field survey data is provided in Attachment C-7. After initial set up of the hydraulic analyses the channel cross-section were removed manually from the HEC-RAS model and Bronx River GIS dataset. New cross-sections based on the field survey were developed in GIS for the data processing.

The cross-section geometry for the HEC-RAS hydraulic model was developed from two (2) data sources, surveyed cross-sections and FEMA Bronx River TIN elevation data. No changes were made to the existing cross-sections and structure on the Bronx River outside the project area within the Bronx River Model and database. The weir profile was then modified in HEC-RAS to match the recently surveyed data and field observations. Upon completion of the geometric data input of the model the Channel Manning's n values and in-effective flow areas were updated on each affected cross-sections following the guidance provided in the HEC-RAS user's manual.

Two (2) different models scenario with FEMA and USACE-NYD hydrology were simulated to evaluate different flow conditions through the lake and establishment of the base flood elevations for the selected frequencies. The result of the hydraulic analyses using USACE-NYD Hydrology is provided in Attachment C-7.

2.2.2.5.2.2 Model Results

As part of the H&H evaluation for the Harney Road site, the following items were reviewed and evaluated using the field survey data and the H&H model results. The HEC-RAS summary output table, cross-sections and flood profiles for 1 year through 500 year simulation run is provided in Attachment C-7.

Stream Thalweg**:** The stream thalweg represent the existing channel invert along the stream through the site. A GIS feature line representing the location of existing stream invert was developed using the field survey and ArcGIS application. At Harney Road the existing thalweg line is in the center of the stream/pond for the north portion and moves closer to the left overbank in central portion of Harney Road. However in the southern portion of the pond it shifts to the center as passes beneath Harney Road. The maximum depth on the pond observed from the survey data is approximately 10.5 feet closer to the weir (XS#35451.72), whereas a minimum depth of approximately 2.5 feet was observed at the middle portions of the pond (XS#35892.15).

Channel Banks**:** The average bottom of the bank elevations along the Harney Pond is approximately 112.0 feet, whereas average top of the bank elevations are in the range of 113.9. to 117.5 feet. A GIS feature line representing the edge of banks is plotted on the Cross-Section Location Map.
Sediment Depths**:** The maximum sediment depth (refusal depth) observed is in the range of 1 to 3 feet.
Bank Full Flows**:** Based on the hydraulic model simulations, the average bank full flood event is 1 year flood with an average maximum depth along the cross-section of 5 feet, with the maximum depth at cross section 35432.17 of 8.6 feet.
Extreme Floods**:** Harney Road and the adjacent park land would be submerged during the flood event greater than the 5 year recurrence interval level. During extreme flood events such as the 500-year interval, the predicted flood depth varies spatially from approximately 8 to 11.5 feet, with the maximum depth of 13.5 feet at cross-section 35432.17.
Channel Velocities**:** The channel velocities along the Harney Road are mostly between 2 feet/ sec and 3 feet /sec at all of the cross-sections with exception of 4.5 feet. /sec at the weir.

2.3 Newark Bay, Hackensack River, Passaic River Planning Region

2.3.1 All Sites

2.3.1.1 Geotechnical

The Lower Passaic Geotechnical and Geological Report is provided as Attachment C-8 of this report.The Passaic and Hackensack Rivers flow into the northern end of Newark Bay at the Kearny Point site in Newark Bay, the lower 14 miles of the Hackensack River, and the lower Passaic River are tidal. The upper Hackensack River is dammed north at the Oradell Dam. The Passaic River has multiple dams, the most downstream of which is Dundee Dam.

The underlying bedrock of all three (3) water bodies consists of the Newark Series Triassic-Jurassic sedimentary rocks deposited in the Newark Basin and intrusive and volcanic Jurassic igneous basalts and diabases. The igneous rocks and the surrounding contact metamorphic rocks are the most resistant, and form ridges. The least resistant are the fine-grained sedimentary rocks of the Passaic Formation. These shales and siltstones underlie valleys. The eastern edge of the Newark Bay watershed is underlain by the Lockatong Formation, whereas the rest is underlain either by the Passaic Formation or the igneous dikes and sills that cross-cut the Passaic Formation.

Newark Bay, the lower 14 miles of the Hackensack River, the lower 1 mile of the Passaic River, northern Arthur Kill, and associated wetlands lie in a subtle valley between north-east trending ridges. The eastern ridge is the Palisades diabase. The western limit of the valley is formed by small ridges underlain by the Passaic Formation shales and

sandstones. The eastern edge of the valley is underlain by the Lockatong Formation. The remaining majority is underlain by the shale-dominated Passaic subunits. This valley is tidally influenced and includes the Meadowlands between the Passaic and Hackensack Rivers.

The main strike of the strata is 36° east of north and beds dip 15° to the northwest. The area consists of buried northeast trending ridges and valleys of bedrock. The top of rock is mantled by Pleistocene Glacial till. The valleys are filled with Pleistocene glacial lake deposits, the majority of which are varved clays and silts. Locally, these are interbedded with glacial lake delta deposits of sands and tills. The clay unit may be as thick as 200feet. These lake deposits are interbedded with tills and are overlain by outwash silts and sands. The Pleistocene outwash sands transition to Holocene fluvial and estuarine sands that grade vertically into finer estuarine silts and clays and marsh deposits. In the last few hundred years, much of the low-lying marsh and shallow waters areas have been filled to build up the land for roads, railroads, industrial sites, airports, and port facilities. Bridges are generally built where bedrock is shallow.

Locally, either bedrock or Pleistocene sediments are exposed in Newark Bay and in the Hackensack River. In Newark Bay, these units were uncovered by dredging, whereas in the Hackensack River, the units were uncovered both by dredging and by river currents eroding overlying sediments. Such scouring is deep at bridges.
The movement and storage of groundwater in this area occurs primarily in the interconnected network of openings that form along joints, fractures, and other channels in the Passaic Formation.

The shallower upper Pleistocene and Holocene silts and sands in addition to the historic fill form shallow groundwater aquifers that are generally laterally discontinuous. Where bedrock is deep, the relatively impermeable, Pleistocene varved clays and silts are thick and create barriers atop the bedrock aquifers. Where rock is shallow, the Pleistocene clay and silt may be thin or completely eroded and bedrock aquifers are more vulnerable to infiltration and contamination from the surface.

Much of the contaminated sediment and groundwater is in the shallower aquifers. The historic fill was usually placed for industrial use and is commonly found at the surface of contaminated sites.

2.3.1.2 Hydrodynamics

The Passaic River, along with the Hackensack River and Newark Bay, is one of the most complex estuarine systems in the United States. The system is connected to two (2) tidal straits, named the Kill van Kull and the Arthur Kill. These straits connect Newark Bay and the Passaic and Hackensack Rivers with the Upper New York Bay and Raritan Bay, through which tides, originating in the Atlantic Ocean, enter the system. The bathymetry of the Passaic-Hackensack-Newark Bay system is characterized by deep shipping channels along the center of both the Arthur Kill and the Kill van Kull, as well as the west

side of Newark Bay through the center of both the Lower Passaic and Hackensack Rivers, with shallower side banks. The USACE maintains the navigability of the channels in order to support New York-New Jersey Port operations. The shipping channels, maintained by the USACE to facilitate the movement of container ships in and out of Newark Bay, added additional complexity to the dynamics of the system. The shipping channels in Newark Bay and the Kills are relatively deep (11 -15 m) with respect to the near-shore depths, significant variability in depths across the channels. The average depth of the shipping channel in the Arthur Kill is about 11 meters MSL, while the average shipping channel depth in the Kill van Kull and Newark Bay are 15 m MSL. These channels play an important role in transporting saline water from the ocean into the system.

The hydrodynamics of the Passaic-Hackensack-Newark Bay system is predominantly controlled by three (3) forcing mechanisms, freshwater flows (buoyancy sources), tides, and winds. Two (2) major sources of freshwater inflows, the Passaic and Hackensack Rivers, contribute to the salinity gradients in the system. By far, the largest freshwater contribution is from the Passaic River. The long-term daily average flow measured at Little Falls is about 29 m^3/sec (1,000 cfs) and the maximum flow during this 21-year period was approximately 500 m3/sec (18,000cfs) in April 1984. In contrast the average flow in the Hackensack River is only 1.6 m^3/sec (56 cfs) and a maximum flow of approximately 158 m3/s (5,500 cfs) was measured in September 1999 during Hurricane Floyd. The salinity dynamics in the system are mostly controlled by the freshwater flows from the Passaic and Hackensack Rivers and the saltier ocean waters that enter the system through the Kill van Kull and the Arthur Kill. During most low to moderate flow periods, the salinity front stays within upper Newark Bay and the Lower Passaic and Hackensack Rivers. However, during extreme high flow periods the front is pushed further downstream to the Arthur Kill and the Kill van Kull. Salinity is, in general, higher during the time of low freshwater flow and is also more uniform both vertically and horizontally throughout the system than during the time of high freshwater flow. Freshwater flows emanating from the Passaic River stay along the western edge of Newark Bay, creating cross channel salinity gradients (Pence, 2004). The deep shipping channels in the system act as conveyances of denser and saltier ocean water to upper Newark Bay and to the Lower Passaic and Hackensack Rivers.

Tidal currents in Newark Bay and in the Passaic and Hackensack Rivers are found to be moderate, with maximum amplitudes of 0.5 m/sec. Most of the time, the surface and bottom tidal currents are of equal magnitude and are in phase in Newark Bay. However, during high-flow periods the surface currents, directed towards the ocean (ebb currents), become much stronger than the bottom currents, indicating the presence of strong vertical shear (Pence, 2004). During high freshwater flow, classical two-layer estuarine circulation is observed during flood tides, with surface currents flowing seaward and bottom currents flowing upstream. The net flow along the side banks is downstream, with an increased magnitude under higher freshwater flow conditions.

Strong and persistent wind events in Newark Bay can have a strong effect on the circulation in the estuary, and in some extreme cases can disrupt the normal pattern of

estuarine circulation. Modeling analysis (Pence, 2004, Pecchioli et al., 2006) suggests that strong winds from the west will flush water and water borne constituents from Newark Bay out through the Kill van Kull, with weaker flow in through the Arthur Kill. Model computations indicate that this flow pattern changes direction when strong winds blow from the east, i.e., flow enters the Kill van Kull from the upper portion of New York/New Jersey Harbor and then enters Newark Bay (Pecchioli et al., 2006). The full hydrodynamic modeling report can be found at www.ourpassaic.org (USEPA, 2008).

2.3.2 Hackensack River Study Area

2.3.2.1 All Hackensack River Sites

2.3.2.1.1 Surface Water

The Hackensack River, running 11.5 miles within the Meadowlands, is the central feature of the Hackensack Meadowlands. The quantity and quality of surface water in the Meadowlands is influenced by such factors as tidal flow, precipitation, permitted discharges, and the release or detainment of freshwater from the Oradell Reservoir. Surface water features of the Meadowlands District are characterized by the many streams, creeks, and smaller channels and ditches that drain the area. Salinity in the Hackensack River ranges from 0 to 16 parts per thousand; the reach of the river from the mouth upriver to Cromakill Creek is a moderate salinity (mesohaline) zone supporting both marine and estuarine invertebrates, fish, and turtles, while the reach of the river above Cromakill Creek to just upriver of Hackensack is a low salinity (oligohaline) zone supporting both estuarine and freshwater invertebrates, fish, and turtles.

Approximately 90 percent of the 30.4 square-mile Hackensack River watershed within the Meadowlands drains through the Newark Bay at Kearny Point. There are 17 major tributaries to the Hackensack River that form several sub-watersheds. The major tributaries include Penhorn Creek, Losen Slote, Anderson Creek, Sawmill Creek, Kingsland Creek, Berry's Creek Canal, Bashes Creek, Moonachie Creek, Mill Creek, Cromakill Creek, Bellman's Creek, Overpeck Creek, Berry's Creek, Peach Island Creek, West Riser Ditch, and East Riser Ditch.

In the past, the Hackensack River and its tributaries have been altered to meet specific needs. The river has been dredged to handle barge traffic and ditches and canals have been dug to control the flow of water into the tidal marshes. Currently, the USACE is tasked at maintaining a shipping channel at an average depth of 12 feet.

2.3.2.1.2 Hydrology & Hydraulics

2.3.2.1.2.1 Tidal Datums

Water surface elevation data were collected at the Metromedia and Meadowlark sites from 07 August 2008 to 07 November 2008. The derived tidal datums from this effort were

however deemed to be in error as the results did not correlate well with published NOAA datums for Hackensack River (Station ID # 8530278). Water surface elevation data from a tide gauge installed at the Secaucus High School wetland restoration site was used in lieu of the site specific data as it is o-n close proximity to both Hackensack River restoration sites and correlates well with published NOAA data. The location of this tide gauge in relation to the two restoration sites is indicated in Figure 2-14. Tidal Datums derived from this data are presented in Table 2-18. The risk of reliance on this at this phase of this study is deemed to be minimal. It is strongly recommended that multiple gauges be installed at each site during PED phase analysis. More accurate tidal datums may impact excavation quantities and by extension, cost estimates. This uncertainty is fully reflected in the cost estimate contingency of these sites and has been noted in the risk register. The need to collect current data (water surface elevation and other types) is discussed and strongly emphasized in chapter seven of this appendix.



Figure 2-14: Secaucus High School Tide Gauge and Hackensack Restoration Sites.

Table 2-18: Secaucus High School, Tidal Datums, 2008

Datum	Abbreviation	Water Surface Elevation, ft, NAVD88
Mean Higher High Water	MHHW	3.07
Mean High Water	MHW	2.71
Mean Tide Level	MTL	0.08
Mean Low Water	MLW	-2.54
Mean Lower Low Water	MLLW	-2.7

2.3.2.2 Metromedia Tract

The Metromedia Tract is an approximately 67-acre site located within the Hackensack Meadowlands in Carlstadt, NJ. The site is undeveloped and surrounds the Metromedia broadcast radio towers, and is largely dominated by common reed. The Metromedia Tract is a poorly drained, frequently flooded marsh that is located above peat, muck, and some fill material (gravel and debris). The marsh deposits are approximately 10 feet thick. The closest known contamination site is 1,400 feet southeast of the border of the Metromedia Tract site.

2.3.2.2.1 Topography and Bathymetry

Topographic and bathymetric surveys were conducted in 2008 by Rogers Surveying, PLLC, of Staten Island, NY (Figure 2-15.) The Metromedia Tract site is generally flat with existing elevations generally between 2 and 3 ft, NAVD88.

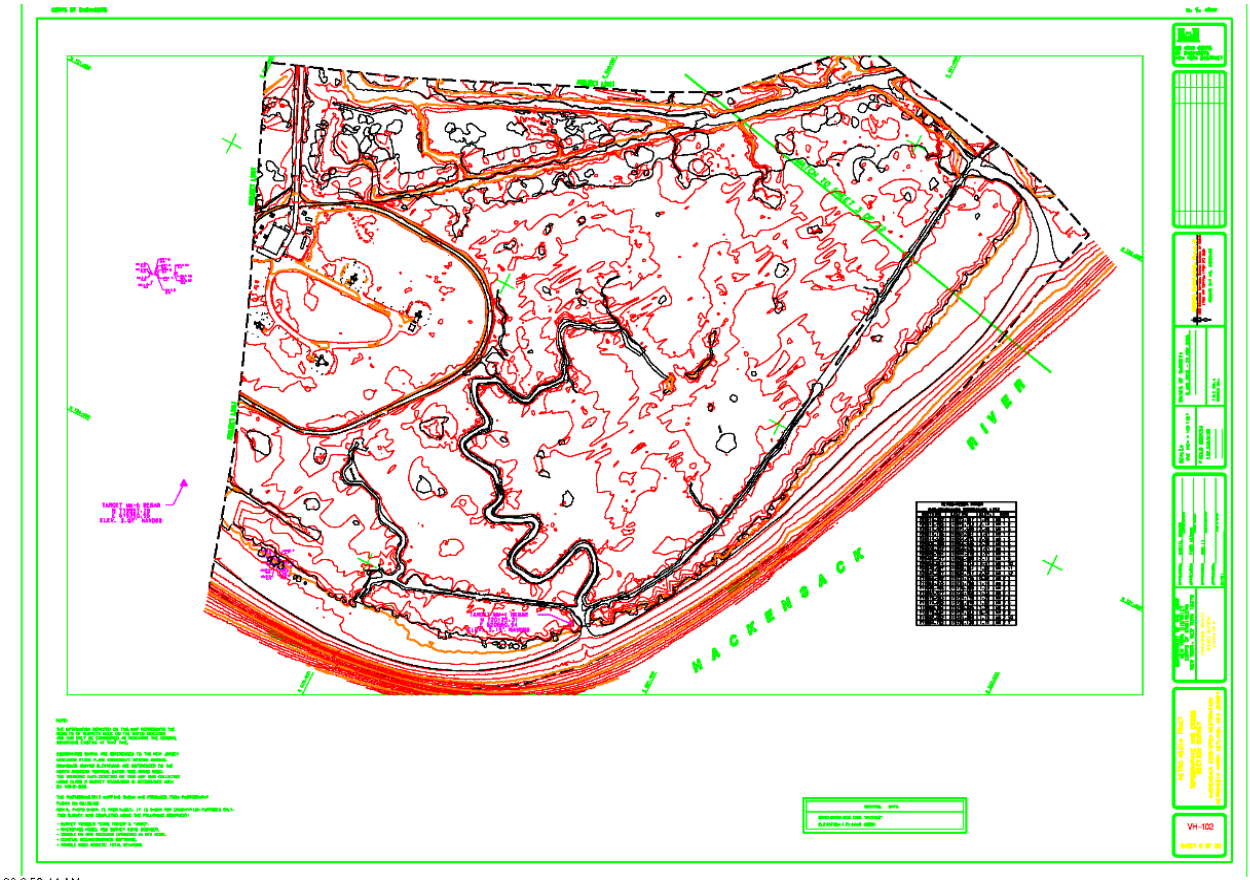


Figure 2-15: Topographic and Bathymetric Surveys at Metromedia Tract site

2.3.2.2.2 Geotechnical

The surface expression of the Holocene estuarine salt-marsh deposits at the Metromedia Tract site consists of mucky peat underlain by muck, silt, or sand. The distribution of the sand is likely defined by tidal tributaries. Areas farther away from the historic channels are characterized by less sand and silt. This is documented by the USDA NRCS Soil Survey Geographic (SSURGO) database, which identifies that the soil unit at the site is composed of three (3) soil types: Westbrook, Ipswich, and Sandyhook.

Each type is 64 percent organic matter and the remainder is composed of clay, silt and sand. Each type makes up 30 percent of the overall composition. The Westbrook and Ipswich types originated from partly decomposed herbaceous organic material (marsh plants), whereas the Sandyhook type came from sandy estuarine deposits.

2.3.2.3 Meadowlark Marsh

The approximately 85-acre Meadowlark Marsh is located within the Hackensack Meadowlands in Ridgefield, Bergen County, New Jersey. It is fed by the Hackensack

River through Bellman's Creek and the Vince Lombardi channel (tributaries to the Hackensack River) and is confined on the west and east by the New Jersey Turnpike – Eastern Spur and Westside Avenue/New Jersey Transit Rail Line, respectively. The site is a poorly drained, frequently flooded marsh that is located above mucky peat and some sand. While there are groundwater contamination sites nearby, the extent of the effects of contamination on the health of Meadowlark Marsh is unknown.

2.3.2.3.1 Topography and Bathymetry

Topographic and bathymetric surveys were conducted in 2008 by Rogers Surveying, PLLC, of Staten Island, NY (Figure 2-17.) The Meadowlark Tract site is generally a complex site characterized by extensive marsh that is directly adjacent to Bellman's Creek along the south as well as areas of Marsh on the North, chiefly characterized by its impaired hydrology that is bisected by a natural gas line. Elevations generally range from 2 to 3 ft, NAVD88, throughout the sites marshes. The northern and southern portions of the site are separated by a 100 foot wide raised dirt path (7 to 10 ft, NAVD88) that s electrical towers and ends in an upland forest on the west side, directly adjacent to the NJ turnpike. The buried natural gas line that connects the two northern sections generally has an elevation of 6 ft, NAVD88.

2.3.2.3.1.1 Hydrodynamic Modeling

The Meadowlark H&H Modeling Letter report is provided as Attachment C-9 of this Engineering Appendix. Using the baseline studies performed for the Evaluation of Planned Wetlands (EPW) in 2015 and the H&H water surface elevation data collected by USACE in 2008, a two-dimensional hydraulic/hydrodynamic model using Surface-water Modeling Systems (SMS) Coastal Modeling System (CMS) was established to assess the existing site conditions and three (3) conceptual designs to restore H&H ecological function to the Meadowlark Marsh site. The CMS model was used in place of the RMA2 platform as CMS uses a finite element size and pattern within the two-dimensional grid, which results in a more stable simulation. RMA2 does not use a finite element size, which can significantly decrease the stability of the two-dimensional model and cause it to fail. In addition, compared to RMA2, CMS provides a better platform for the modeling of culvert structures, several of which are present at Meadowlark Marsh. The platform switch was presented to the USACE after review of their RMA2 model of the Hackensack Meadowlands. In the provided USACE RMA2 model, only one element represented the entire Meadowlark Marsh site. The significant alterations required to modify this would most likely cause the model to fail due to the large size of the model. Therefore, the need for a new Meadowlark Marsh model was identified instead of using the RMA2 model provided.

2.3.2.3.1.1.1 Simulation Period

The simulation period for all three (3) models was for a 30-day period (one month) between the months of September and October 2008. Start dates varied based on peak

tides (existing conditions and Alternative C began on September 13, 2008 with a peak tide at 2.964 Feet NAVD88, Alternatives A and B began on September 19, 2008 with a peak tide of 3.388 Feet NAVD88), but ran for a duration of 30 days to verify a full tidal lunar period under normal conditions. The modeling of Alternatives A and B began after the completion of modeling the existing conditions and Alternative C, and were modeled at a point in time with a higher tide to insure the start of the more detailed Alternative simulations. The first 12 hours of this simulation were omitted in the evaluation of the results as the model takes a designated amount of time to ramp up into a simulation. This "ramping period" is specified in the model parameters and can be adjusted based on the results, if needed, to allow for more or less time to calibrate the simulation process.
These months were selected for the simulation time frame as they contained some of the highest water surface elevation data at the beginning of the cycle period for the data collected. By using this time period, the model has a greater success rate in running as it considers most of the site as wet or underwater during its ramping period.

2.3.2.3.1.1.2 Model Analysis

The H&H analysis indicates that the proposed conceptual restoration alternatives will provide sufficient tidal inundation, drainage, and the hydraulic/hydrodynamic capacity to the interior marsh to support a native tidal salt marsh, including low marsh, high marsh and scrub-shrub marsh. Additional details on the H&H evaluation of Meadowlark Marsh alternatives can be found in Appendix C-7.

2.3.2.3.2 Geotechnical

The surface expression of the Holocene estuarine salt-marsh deposits at the Meadowlark Marsh site consists of soils of mucky peat underlain by muck, silt, or sand. The distribution of the sand is likely defined by tidal tributaries. The further away from the historic channels, the less sand and silt. This is documented by the USDA NRCS soil survey database, SSURGO, which identifies that the soil unit at the site is composed of three (3) soil types: Westbrook, Ipswich, and Sandyhook. Each type is 64 percent organic matter, and the remainder consists of clay, silt, and/or sand. Each type makes up 30 percent of the overall composition.

2.3.3 Lower Passaic River Study Area

2.3.3.1 All Lower Passaic River Sites

2.3.3.1.1 Geotechnical

Till, glacial deltaic deposits, and glacial outwash terrace deposits are located upland from the Lower Passaic River. The surface soils near the river are often disturbed by human activities, such as placement of fill material. The Riverhead-Dunellen soil series (which consists of a sandy loam) dominates the riverbanks of the Lower Passaic River above River Mile 5 (RM5). The Wetherfield Urban land-Boonton soil series (which consists of

deep, moderately-well and well drained soils that form in till on uplands) dominates the riverbanks below RM5.

2.3.3.1.2 Hydrodynamics

The hydrodynamics of the Passaic-Hackensack-Newark Bay system is predominantly controlled by three (3) forcing mechanisms, freshwater flows (buoyancy sources), tides, and winds. Two (2) major sources of freshwater inflows, the Passaic and Hackensack Rivers, contribute to the salinity gradients in the system. By far, the largest freshwater contribution is from the Passaic River. The long-term daily average flow measured at Little Falls is about 29 m^3/sec (1,000 cfs) and the maximum flow during this 21-year period was approximately 500 m^3/sec (18,000cfs) in April 1984. In contrast the average flow in the Hackensack River is only 1.6 m^3/sec (56 cfs) and a maximum flow of approximately 158 m^3/s (5,500 cfs) was measured in September 1999 during Hurricane Floyd. The salinity dynamics in the system are mostly controlled by the freshwater flows from the Passaic and Hackensack Rivers and the saltier ocean waters that enter the system through the Kill van Kull and the Arthur Kill. During most low to moderate flow periods, the salinity front stays within upper Newark Bay and the Lower Passaic and Hackensack Rivers. However, during extreme high flow periods the front is pushed further downstream to the Arthur Kill and the Kill van Kull. Salinity is, in general, higher during the time of low freshwater flow and is also more uniform both vertically and horizontally throughout the system than during the time of high freshwater flow. Freshwater flows emanating from the Passaic River stay along the western edge of Newark Bay, creating cross channel salinity gradients (Pence, 2004). The deep shipping channels in the system act as conveyances of denser and saltier ocean water to upper Newark Bay and to the Lower Passaic and Hackensack Rivers.

Tidal currents in Newark Bay and in the Passaic and Hackensack Rivers are found to be moderate, with maximum amplitudes of 0.5 m/sec. Most of the time, the surface and bottom tidal currents are of equal magnitude and are in phase in Newark Bay. However, during high-flow periods the surface currents, directed towards the ocean (ebb currents), become much stronger than the bottom currents, indicating the presence of strong vertical shear (Pence, 2004). During high freshwater flow, classical two-layer estuarine circulation is observed during flood tides, with surface currents flowing seaward and bottom currents flowing upstream. The net flow along the side banks is downstream, with an increased magnitude under higher freshwater flow conditions.

Strong and persistent wind events in Newark Bay can have a strong effect on the circulation in the estuary, and in some extreme cases can disrupt the normal pattern of estuarine circulation. Modeling analysis (Pence, 2004, Pecchioli et al., 2006) suggests that strong winds from the west will flush water and water borne constituents from Newark Bay out through the Kill van Kull, with weaker flow in through the Arthur Kill. Model computations indicate that this flow pattern changes direction when strong winds blow from the east, i.e., flow enters the Kill van Kull from the upper portion of New York/New Jersey Harbor and then enters Newark Bay (Pecchioli et al., 2006).

2.3.3.2 Essex County Branch Brook Park

Branch Brook Park's 30-acre freshwater system is 5 miles from the Newark Bay and is located within the northeast flyway for migratory birds. This site contains of approximately 4,200 linear feet of Branch Brook and adjacent parkland. The surrounding environment consists primarily of commercial and residential developments and roadways. The site includes a day-lighted section of Branch Brook as well as three (3) larger pond features (Branch Brook Lake, Clarks Pond, and an unnamed pond) that were created with weirs. Branch Brook Park was established by Essex County as the first county park in the nation. The park is notable as having the largest collection of cherry blossom trees in the United States. The park is four (4) miles long and a quarter mile wide and includes open grassland with patches of forest stands that line Branch Brook. A narrow band of forested wetlands is found along the stream of this site. Two (2) emergent wetland areas are found in the northern section of this site. Uplands within the site are primarily mowed areas indicative of a park setting. The stream and adjacent forest areas experience considerable amounts of anthropogenic trash. The ponds suffer from algal blooms and eutrophication indicative of excess nutrient inputs. The park acts as a habitat island in highly developed and densely populated urban setting. However, the understory of the upland and wetland forested habitats of the site are dominated by nonnative, invasive vegetation, limiting ecological value.

2.3.3.2.1 Hydrology & Hydraulics

Branch Brook Park is primarily located within the Passaic River Lower (Newark Bay to Saddle) sub-watershed, and the Passaic River Lower (4th St. Bridge to Second River) subsubwatershed. The headwaters for the First River are located within Branch Brook Park and thus are a significant contributor to the water quality and quantity of the Passaic River. Second River, connecting to the Passaic River) flows to and through the Extension of the park in the north, and was channelized during the development of the Extension (Rhodeside & Harwell, Inc. et. al. Volume 3.). The hydrology of Branch Brook Park is highly manipulated, with a networking of stormwater systems conveying surface water to the lakes, ponds and streams within the Park and a recirculation system that moves water from the downstream areas back up to North Brook. The recirculation system was designed to offset challenges posed by an inadequate water supply to the Park's water features, which persists today. While several studies of Branch Brook Park have been conducted, most hydrologic studies have focused on characterizing the water quality and quantity issues that persist within the Park's waterways. Data regarding the fluctuation of shallow groundwater during the growing period and bio-benchmark studies, which would be necessary to inform the design of freshwater wetland restoration, have not been conducted and will be needed to advance designs at this site.

2.3.3.2.2 Geotechnical

The Essex County Branch Brook Park site's Holocene swamp deposits consist of organic silts and organic silty clays. This is corroborated by the USDA NRCS SSURGO database

which identifies five (5) soil types present at the site: Boonton Red Sandstone Lowland with 0-8 percent slope, Boonton Red Sandstone Lowland with 8-15 percent slope, Udorthents Boonton red sandstone lowland substratum, Udorthents loamy fill substratum, and Urban land Boonton red sandstone lowland substratum. Both Boonton red sandstone lowland types come from coarse loamy till derived from sandstone and shale, both Udorthents types come from loamy material transported by human activity, and the Urban land soil type originates from surfaces covered by man-made structures such as pavement, concrete, and buildings that are underlain by disturbed and natural soil material.

2.3.3.3 Oak Island Yards

This site is located along approximately 900 feet of Newark Bay and is bordered by a shipping container yard, railroad tracks, and a HESS petroleum tank farm. A semi-tidal ditch with a tide gate is located adjacent to the site, below the railroad track embankment on the southeast border of the site. Since the date of the project mapping aerial photo, the shipping container storage yard has been extended southeast to within approximately 100 feet of the pond and runs the full width of the northwestern boundary of the site. Also, a considerable amount of rock and gravel fill has been placed onsite since the aerial photo was taken. Rock fill extends from the shipping containers all the way to the river along the southeast portion of the site and has also been placed in the river. The majority of the site contains riprap fill material preventing vegetation growth. Where vegetation does grow within the upland and wetlands areas, it is dominated by nonnative invasive vegetation.

2.3.3.3.1 Topography and Bathymetry

Oak Island Yards is located along approximately 900 feet of Newark Bay and is bordered by a shipping container yard, railroad tracks, and a HESS petroleum tank farm. A semi-tidal ditch with a tide gate is located adjacent to the site, below the railroad track embankment on the southeast border of the site. A pond surrounded by common reed is present in the center of the site. A small remnant smooth cordgrass marsh and panne measuring approximately 50 feet by 100 feet is present at the northeast corner of the site. A forested wetland area is located in the northeast portion of the site beyond the shoreline. A majority of the banks of Newark Bay at the site contain mounds of boulders and riprap fill material.

2.3.3.3.2 Hydrology & Hydraulics

2.3.3.3.2.1 Tidal Datums

As part of the prior study, tidal data was collected for approximately seven (7) weeks, from October 4, 2002 to November 22, 2002, in 10-minute intervals within the Passaic River near the Minish Park site (Table 2-19). Utilizing this data, the site tidal datum was established and compared to the Kearny Point and Belleville NOAA-NOS Epoch datum's for the observed inundation period, which verified the data integrity. A summary of the

data collected in 2002 and a comparison to the NOAA-NOS Epoch datum used in 2002, as well as the current NOAA-NOS Epoch datum, is provided in the table below. Data collected in 2002 was collected in the National Geodetic Vertical Datum of 1929 (NGVD29). This was converted to North American Vertical Datum of 1988 (NAVD88) using the USACEs' Coprscon 6.0.1 datum conversion computer program, and was determined as NAVD88 = NGVD29 - 1.122 FEET. The information in the table below is provided in NAVD88 for consistency of the project design. The risk of reliance on this data at this phase of this study is deemed to be minimal. It is strongly recommended that multiple gauges be installed at this site during PED phase analysis. More accurate tidal datums may impact excavation quantities and by extension, cost estimates. This uncertainty is fully reflected in the cost estimate contingency of these sites and has been noted in the risk register. The need to collect current data (water surface elevation and other types) is discussed and strongly emphasized in chapter seven of this appendix.

Table 2-19: Tidal Datums within the Passaic River near the Minish Park Site

	Minish Park Passaic River	Kearny Point Passaic River	Belleville Passaic River	Belleville Passaic River	Kearny Point Hackensack River
	Berger	NJDEP/NOAA-NOS	NJDEP/NOAA-NOS	NJDEP/NOAA-NOS	NJDEP/NOAA-NOS
	Observed	Epoch	Epoch	Epoch	Epoch
Datum	Oct 2002 – Nov 2002	1960-1978	1960-1978	1983-2001	1983-2001
MHWS	3.33				
MHHW	2.92	2.62	2.85	3.06	2.7
MHW	2.63	2.29	2.48	2.72	2.38
MTL	-0.02	-0.33	-0.33	-0.08	-0.23
MLW	-2.67	-2.95	-3.15	-2.88	-2.84
MLLW	-2.94	-3.19	-3.41	-3.13	-3.08
MLWS	-3.34				

2.3.3.3.3 Geotechnical

The Oak Island Yards site's Holocene estuarine salt-marsh deposits consist of clay and silty sands. This is corroborated by the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) Soil Survey Geographic (SSURGO) database, which identifies the Udorthents soil unit, a loamy fill substratum, as being the dominant soil unit at the site. The Udorthents series is the product of past dredge-and-fill activities, and so the parent material of this complex is loamy-skeletal human-transported material.

2.4 Hudson-Raritan Estuary (HRE) Oyster Restoration Sites

2.4.1 All Sites

Historically, Upper and Lower New York Bay were known for its oysters, which covered an extensive area along the shoreline (Figure 2-16). Around the 1770s, 765 million oysters per year were harvested from the waters of New York Bay (Sanderson 2016). Since then, oysters have nearly disappeared due to overharvesting, water quality deterioration, sedimentation, and other factors. Restoring the oyster population in New York Bay is considered to be advantageous for both ecosystem health and protecting New York City's shoreline.



Figure 2-16: Historic Map of the New York Bay Area Depicting Major Oyster Habitats in 1911. Shaded Areas Indicate the Principal Sources of Oysters (Metropolitan Sewerage Commission 1911).

Three (3) sites have been recommended for small-scale oyster restoration within multiple planning regions (Table 2-20 and Figure 2-17). All sites are in tidal waters of the Hudson Raritan Estuary, and border man-made structures and altered shorelines. Nearby soils on land are described, as they are potential sediment sources.



Figure 2-17: Proposed Oyster Restoration Locations

Table 2-20: Proposed Oyster Restoration Sites

Oyster habitat	Planning Region	Sub-watershed/water body
Bush Terminal	Upper Bay	Upper New York Bay/ Bay Ridge Channel
Head Jamaica of Bay	Jamaica Bay	Hook Creek-Head of Bay
Naval Weapons Station Earle	Lower Bay	Compton Creek-Sandy Hook Bay

2.4.1.1 Geological

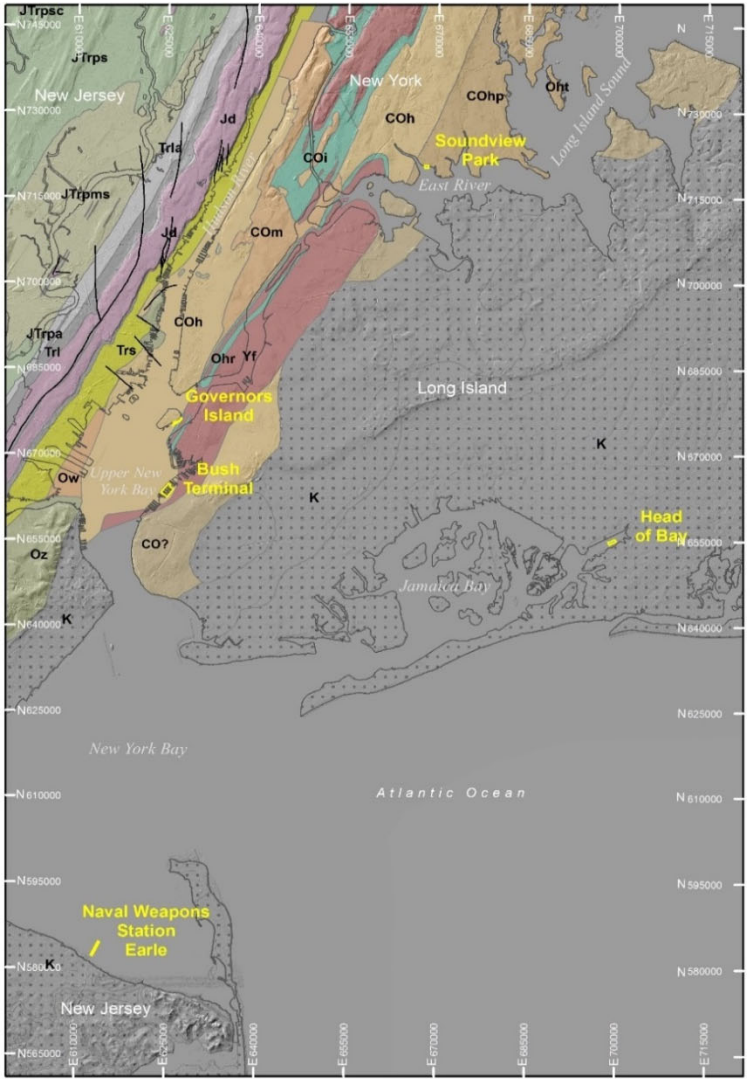
The Oyster Restoration Geotechnical and Geological Report is provided as Attachment C-10 of this report and is summarized below. Figure 2-18 shows the map of bedrock underlying the oyster restoration sites. e4sciences compiled and modified this map based on numerous sources including the bedrock geology maps of the NJDEP Geological Survey and the New York State Geological Survey. The NYS bedrock geological map and compilations incorporating it are either out of date or have not accepted revisions in the New York City area based on mapping and numerous publications by Baskerville (e.g., Baskerville, 1994, USGS map), Merguerian (e.g. Merguerian and Baskerville, 1987), Sanders (e.g. Merguerian and Sanders, 1991) and Moss (e.g. Moss and Merguerian, 2010). e4 modified the map in Figure 2-18 with the above mentioned revisions based on e4sciences' local knowledge, much of which is related to USACE-NAN contracts. Key USACE reports are included in the references.

Figure 2-19 shows the map of surficial geology encompassing the oyster habitat restoration sites. The southern termination of the last Pleistocene glacier (Wisconsin) is marked by the glacial terminal moraine (Qwtm) extending along Staten Island and Long Island. North of this, Pleistocene glaciers have scraped down to bedrock or to the semi-consolidated Tertiary and Cretaceous Coastal Plain Group sediments. North of the terminal moraine, Pleistocene glacial tills drape the bedrock and glacial lake sediments filled valleys. As the glacier receded, it also deposited a blanket of outwash sands and silts that "washed out" from the glaciers. These Pleistocene sediments overlie Coastal Plain Group strata.

On land, north of the terminal moraine, Holocene sediments are predominantly fluvial, estuarine, and marine deposits. The Holocene sediments are thin and true soils are relatively thin. Underwater, north of the Terminal moraine, the Holocene coarser sediments are marine reworked Pleistocene sands and gravels. The fine-grained sediments are estuarine deposits. In the Hudson River channel, these Holocene deposits are up to 300 feet thick. At the oyster habitat restoration sites, Holocene deposits are relatively thin (0 to 20 feet). Black silt deposited during is deposited in lows and current shadows.

On land, south of the terminal moraine, there are minor Holocene sediments and true soils may be thick. Underwater Holocene deposits are predominately sands and marsh deposits. Sands are reworked out wash sands and Coastal Plain Group strata. At Jamaica Bay Holocene sediments are estimated to be 20-feet thick.

The New Jersey coast south of New York Bay is predominantly erosive. On land, the soils have variable thicknesses and lie on the Coastal Plain Group deposits. Holocene stream deposits are relatively minor. Underwater along the New Jersey Coast the Holocene is dominated by reworked sands of the Coastal Plain Group. All of the oyster habitat restoration sites are adjacent to built-up shorelines and are in channels with varying degrees of marine vessel traffic. Naval Weapons Station Earle and Governors Island sites are adjacent to active piers. The Bush Terminal site is in an underwater field of pier “ruins” adjacent to piers that have been re-purposed as a park.



Bedrock Geology

Geologic Age	Label	Unit	Rock or Sediment Type
Cretaceous	K	Coastal Plain Group	clay, silt and sand
Jurassic	Jd	Palisade Diabase	diabase
Lower Jurassic Upper Triassic	JTrp: JTrpsc	Passaic Formation	shale and conglomorate
	JTrp: JTrpms		shale and silstone
	JTrp: JTrps		shale and sandstone
	JTrp: JTrpa		shale with silstone and sandstone
Upper Triassic	Trl	Lockatong Formation	argillite
	Trla		sand stone
Triassic	Trs	Stockton Formation	sandstones and shales
Ordovician	Oz	Serpintinite	serpintinite
	Ow	Walloomsac Formation	graphite schist
Cambrian-Ordovician	COh: COh	Hartland Formation	gneiss and schist
	COh: COhp		
	COm	Manhattan	schist
	COi	Inwood Marble	marble
	CO?		undifferentiated metamorphics
PreCambrian	Yf	Fordham Gneiss	gneiss

Fault Lines
Oyster Sites

0 7,500 15,000 30,000 45,000 60,000 Feet

Figure 2-18: Bedrock Underlying the Oyster Restoration Sites

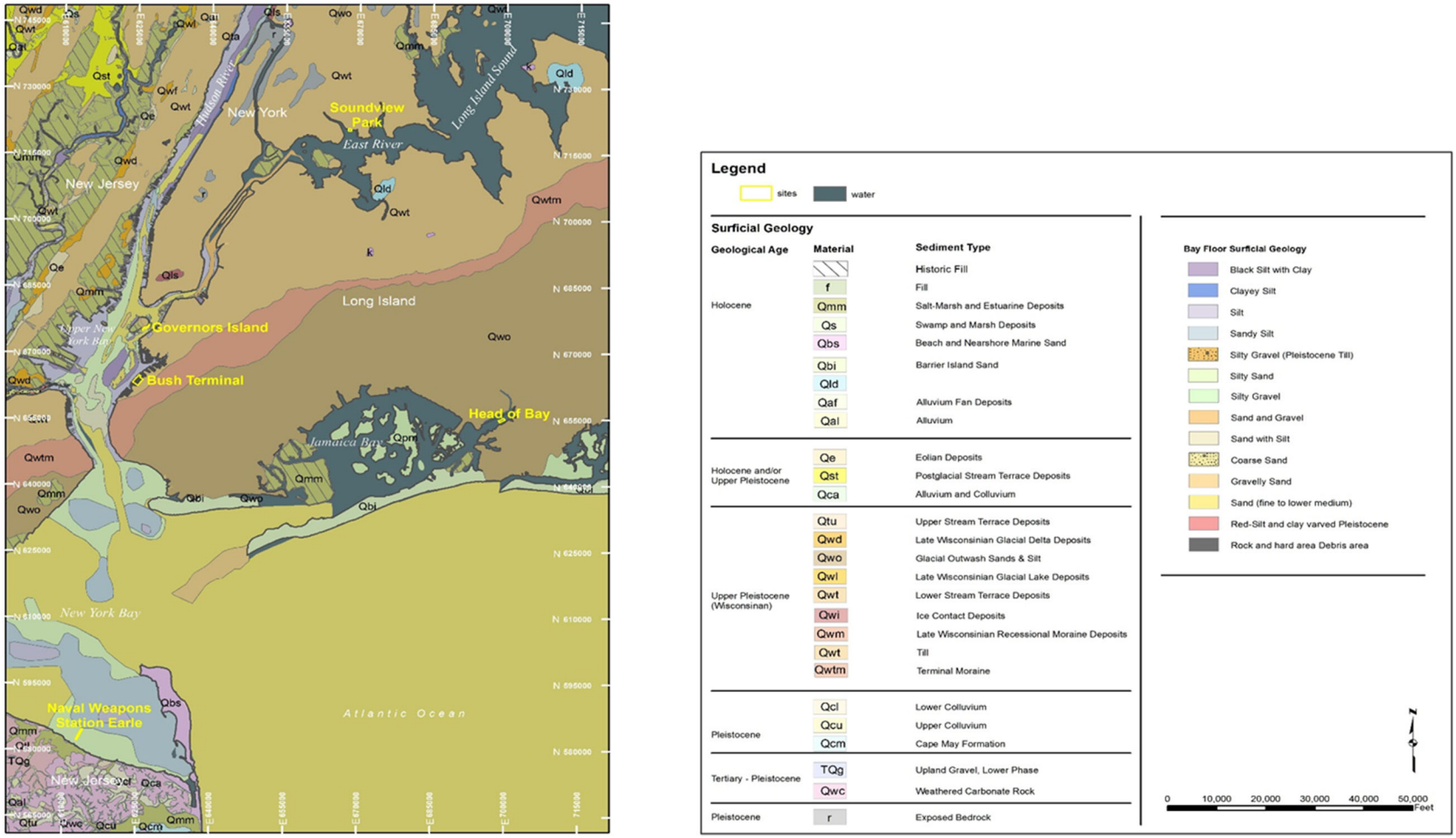


Figure 2-19: Surficial geology map and the New York oyster ecosystem restoration site

The NY land-based surficial geology is modified from NYSGS surficial geology map (Caldwell 1989), the NJ land-based surficial geology is from NJDEP Gelogical Survey surficial geology map of New Jersey (DGS07-2). The water-based NYNJ Harbor bay and river floor geology map was compiled for an ongoing USACE-NAN project (e4sciences, 2016). NYSGS geology boundaries were modified to align with orthoimagery (NYSDOP 2014, NJGIN 2015, USGS EROS 2014)

2.4.2 Bush Terminal Oyster Restoration Site

2.4.2.1 Geotechnical

The Bush Terminal oyster restoration site includes pier ruins between the Bay Ridge Channel and the re-purposed Bush Terminal Pier Park. Bedrock (Hartland Formation) is greater than 120 feet deep. Overlying the rock is a thick sequence of Pleistocene sediments dominated by glacial lake clay and silt. This is overlain by Holocene sands and Holocene black silt. The surface of Bush Terminal Piers Park is made up of the Laguardia soil unit, which is an artifactual coarse sandy loam (fill).

2.4.3 Head of Bay Oyster Restoration Site

2.4.3.1 Geotechnical

The Head of Bay oyster restoration site is part of the Hook Creek-Head of Bay sub-watershed within the larger Jamaica Bay watershed system. The site is adjacent to JFK International Airport where construction started in the 1940s. The site is underlain by estuarine sands and over 100-foot-thick glacial-outwash deposits, which are on top of older Pleistocene sediments and Cretaceous Coastal Plain Sediments. The top of crystalline rock is over 600feet deep. The surface of the Queens County north shore of Jamaica Bay in the Head of Bay area is made up of the Jamaica sand soil unit.

2.4.4 Naval Weapons Station Earle Oyster Restoration Site

2.4.4.1 Geotechnical

The Naval Weapons Station Earle oyster habitat restoration site is part of the Sandy Hook-Staten Island sub-watershed within the larger Monmouth watershed system. The site is underlain by the Cretaceous Coastal Group sand, silt and clay.

3 Design of Restoration Alternatives

Concept level designs and quantities were developed for all alternatives for 33 HRE candidate restoration sites. Designs and design summaries for all alternatives can be found in Appendix D: Plan Formulation. Costs for all alternatives can be found in Appendix I: Cost Engineering.

4 Climate Change Assessment and Sea Level Change Analysis

4.1 Climate Change and Inland Hydrology Assessment

A qualitative climate change assessment for the HRE Ecosystem Restoration Feasibility Study was performed in accordance with Engineering and Construction Bulletin: Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects (ECB 2018-14, USACE, September 2018). The focus of this assessment is the inland hydrology/nonstationarity of the Bronx River in New York and the Branch Brook (aka First River) in New Jersey.

4.1.1 Site Descriptions

4.1.1.1 Bronx River

The Bronx River, a tributary to the Long Island Sound and Hudson River estuary systems, is 23 miles long and flows southward through both suburban and highly urban communities in the Westchester and Bronx Counties. For much of its length, the river runs through numerous parks and parallels and intersects the Bronx River Parkway and the Metro North Harlem commuter rail line. The river is mostly fresh water, with tidal influences in the most downstream section of the river where it exchanges flow with the East River and the Long Island Sound. The following five (5) restoration sites are located within the Bronx River watershed: Bronx Zoo and Dam, Stone Mill Dam, Shoelace Park, Bronxville Lake and Garth Woods / Harney Road.

4.1.1.2 First River

The First River is a subterranean river through Newark, NJ and the first main tributary of the Passaic River. The headwaters for the First River are located within Branch Brook Park and from there it flows underground parallel to Seventh Avenue and Clay Street, discharging into the Passaic River in the vicinity of the Clay Street Bridge. The Essex County Branch Brook Park restoration site is located within the First River watershed.

4.1.1.3 Initial Scoping

There are three phases as outlined in ECB 2018-14 for the qualitative analysis of inland hydrology: Initial Scoping, Vulnerability Assessment and Risk Assessment. For this project, it was determined that the following climate variables were the most relevant to the analysis: temperature, precipitation and streamflow.

4.1.2 Phase 1: Current Climate and Climate Change Literature Review

The entire project site is located in the New York City metropolitan area within two states (New York and New Jersey) in the Northeast of the United States, which is generally characterized by a fairly diverse climate, with cold winters and semi-humid summers. In New York City, the average annual mean temperature is near 55°F. The summer conditions prevail from late May

through late September. Unlike the other parts of the state, the New York City area has rather warm summers by comparison, with some periods of high, uncomfortable humidity. Temperatures of 107°F have been observed in New York City. Winter-like conditions prevail from December through March with subzero minima in two or three winters out of 10 and the low temperature generally near -5°F. Characterized by cold winters and hot summers, New York experiences stable and evenly distributed rainfall throughout the year with an average annual precipitation about 46 inches.

As per ECB 2018-14, the following documents were reviewed to summarize the current climate, observed climate trends and projected climate trends in the project area.

- Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions - Mid-Atlantic Region 02. Civil Works Technical Report, CWTS-2015-09 (USACE, 2015)

- Climate Science Special Report: Fourth National Climate Assessment, United States Global Change Research Program (USGCRP) report (USGCRP, 2018).

The first report (hereinafter referred to as USACE (2015)) is 1 of 21 regional climate syntheses prepared at the scale of 2-digit USGS Hydrologic Unit Codes (HUC) across the US. This report summarizes observed and projected climate trends for Water Resources Region 02, the Mid-Atlantic Region which encompasses the states of New York and New Jersey. It is the primary source used in this literature review.

The second report (hereinafter referred to as NCA4) was incorporated in the review only in terms of updated findings as the USACE (2015) already referenced the 3rd National Climate Assessment. Findings of importance for the HRE study area are summarized below.

4.1.2.1 Temperature Trends

A literature review on observed and projected temperature trends in the Mid-Atlantic Region and specially, in New York State, is presented in the following subsections.

4.1.2.1.1 Observed Temperature Trends

Most of the studies of historical temperature data revealed a general warming trend for the Mid-Atlantic Region, especially for the northern portion of the region (i.e., New York State). Some studies broke down the temperature trend by season while others focused on average annual temperature or other climate indicators. Wang et al. (2009) conducted a study to examine historical climate trends for the period 1950 – 2000 across the continental U.S. and indicated a warming trend of up to 1.8 ^{o}F for most of the region for spring, summer and winter. A later study by Meehl et al. (2012) also indicated a warming summer (up to 1.8 ^{o}F) for the northern portion of the region for the period 1950 – 1999. The third NCA report cites a nearly 2 ^{o}F increase in average annual temperature between 1895 and 2011 for the northeast region. Results by

Huntington et al. (2009) showed a 1 – 3 °C (1.8 – 5.4 °F) increase in average annual temperature in the twentieth century for the northern portion of the region.

For the winter months, the effects of "warming hole" (i.e., lack of significant warming, or even a net cooling) has been observed in the eastern United States. This was demonstrated in both studies of Meehl et al. (2012) and Westby et al. (2013), contradicting the findings of Wang et al. (2009) who showed a warming trend in winter temperatures.

A more regional study was conducted by Cook et al. (2010) to analyze a new homogeneous climate record (1896 - 2006) for Mohonk Lake watershed in southern New York, about 100 miles north of the HRE study area. Statistically significant ($p < 0.05$) increasing trends were identified in minimum, maximum and mean annual temperature as well as in the occurrence of extreme hot days (as defined as either 90%, 95% or 99% thresholds calculated over the entire period) for the watershed area. There appears to be no evidence of the "warming hole" as described above. Similar results were presented by Burns et al. (2007) who revealed a statistically significant increasing trend in mean air temperature in the Catskill Mountains in southern New York. Both studies quantified an average rate of increase in mean temperature of approximately 0.18 °F per decade. Additionally, Anandhi et al. (2013) analyzed changes in daily minimum temperatures, specifically the occurrences of frost, in the Catskill Mountains. The results showed statistically significant increasing trends in annual average daily minimum temperature and corresponding decreasing trends in the number of frost days. The results are in agreement with those of earlier studies by Cook et al. (2010) and Burns et al. (2007).

The NCA4 reported observed changes in annual average temperature for the Northeast region as 1.43 °F. Changes are the difference between the average for present-day (1986–2016) and the average for the first half of the last century (1901–1960). The observed changes in annual average maximum temperature and annual average minimum temperature for the Northeast region are 1.16 °F and 1.70 °F, respectively. Overall, a large number of studies as cited in the literature indicated significant warming trends in the Mid-Atlantic Region, especially in southern New York State where the HRE study area is located.

4.1.2.1.2 Projected Temperature Trends

The projected climate trends are estimated using Global Circulation Models (GCMs) which are widely accepted representing the best available science to predict climate trends.
Liu et al. (2013) investigated the maximum air temperature projections in the Mid-Atlantic Region using a single GCM and assuming an A2 greenhouse gas emissions (worst case scenario). The results show a projected increase in winter and spring maximum air temperature of about 3.6 °F for a 2055 planning horizon as compared to a baseline period of 1971 – 2000. Temperature increases of up to 6.3 °F from 1985 to 2055 were projected for summer and autumn seasons.
Model projections from a study conducted by Scherer and Diffenbaugh (2014) using a multi-member ensemble GCM indicate steadily increasing air temperature for the Mid-Atlantic Region throughout the 21st century for both summer and winter season. The results are consistent with those of Liu et al. (2013).

Kunkel et al. (2010) studied changes in temperature extremes using two different downscaled GCMs. For Mid-Atlantic Region, the results reveal a 7.2 to 9 ^{o}F increase in three-day heat wave temperature and a 40 to 60 day increase in the annual number of heat wave days for the 2090's. A period was considered a heat wave if the following criteria were met: (i) the daily mean temperature was above the 97.5 percentile threshold for at least 3 days during the period; (ii) the average daily mean temperature during the entire period exceeded the 97.5 percentile threshold; and (iii) the daily mean temperature exceeded the 81 percentile threshold for every day of the period.

At a local scale, Matonse et al. (2013) quantified the impacts of projected climate change on a portion of New York City's West of Hudson (WOH) watershed, in proximity to the HRE study area. Results show projected increases in monthly average temperature ranging from 1.8 to 7.2 ^{o}F for 2055 and from 3.6 to 10.8 ^{o}F for 2090, with the largest increases projected for July, August, December and January. Samal et al. (2012) focused on reservoir thermal impacts of climate change on the Cannonsville Reservoir located in the same WOH watershed. Similar results were achieved, projecting an increase in annual average air temperature of approximately 5.4 to 9 ^{o}F for a 2081-2100 planning horizon compared to historical baseline (1966-2004).

In another study of a similar geographic area, Anandhi et al. (2013) investigated mean monthly daily minimum temperatures in the Catskill Mountain region in New York State. Results show a significant increase in mean daily temperature in the range of approximately 1.8 to 18 ^{o}F for two planning horizons: 2045 – 2065 and 2080 – 2010 as compared to the baseline data (1960 – 2008), with the greatest increases projected for the winter months.

Hudson River Estuary was one of the three Mid-Atlantic watersheds from a study by Najjar et al. (2009) to evaluate the climate change. As shown in Table 4-1, the projection ensemble from seven GCMs quantifies a nearly 5.2 ^{o}F increase in average temperature by mid-21st century and an approximately 9 ^{o}F increase by the end of the century as compared to historical baseline (1971 – 2000).

Table 4-1: Projected Changes in Mean Annual Temperature and Precipitation for Three Mid-Atlantic Estuaries (Najjar et al., 2009)

	2010-2039	2040-2069	2070-2099
Temperature (°F)			
Chesapeake Bay	2.2 ± 0.5	4.9 ± 1.8	8.5 ± 3.6
Delaware Bay	2.2 ± 0.5	5.2 ± 1.8	8.8 ± 3.2
Hudson River Estuary	**2.2 ± 0.7**	**5.2 ± 1.6**	**9.0 ± 3.1**
Precipitation (%)			
Chesapeake Bay	1 ± 2	2 ± 7	3 ± 12
Delaware Bay	0 ± 2	3 ± 4	4 ± 7
Hudson River Estuary	**1 ± 4**	**5 ± 3**	**5 ± 4**

The findings from the third NCA report are consistent with the model projections presented above. For the Mid-Atlantic Region, the report predicts an increase in the frequency, intensity and duration of heat waves. More specifically, the projections indicate an increase in annual average temperature of 4.5 to 10 °F and an increase in extreme heat days (over 90 °F) by more than 60 days per year by the mid-21st century, compared to the end of last century.
Similarly, the NCA4 report (USGCRP, 2018) stated that projected changes in annual average temperature for the Northeast region range from 4.0 to 9.1 °F. Changes are the difference between the average for mid-century (2036–2065) or late-century (2071–2100) and the average for near-present (1976–2005) under the higher scenario (RCP8.5) and a lower scenario (RCP4.5). Overall, the literature review on the effects of climate change indicates a strong consensus that air temperature will increase throughout the 21st century in the Mid-Atlantic Region including the HRE Study Area.

4.1.2.2 Precipitation

A literature review on observed and projected precipitation trends in the Mid-Atlantic Region and specially, in New York State, is presented in the following subsections.

4.1.2.2.1 Observed Precipitation Trends

Grundstein (2009) identified statistically significant ($p < 0.05$) increasing trends in soil moisture and total annual precipitation for the northern portion of the Mid-Atlantic Region over the past century (1895 – 2006), including several sites in New York and New Jersey.
As described in Section 4.1, a study by Wang et al. (2009) quantified generally positive trends in annual precipitation for spring, summer and fall for Mid-Atlantic Region, while mostly negative trends were quantified for winter precipitation.

A study by Wang and Zhang (2008) focused on the changes in the frequency of the 20-year maximum daily precipitation event. For the Mid-Atlantic Region, significant changes of approximately 25 – 100% in the recurrence of this type of storm were quantified for the period from 1977 to 1999 as compared to the period 1949 to 1976.

Based on the NCA4 report (USGCRP, 2018), for heavy precipitation events above the 99th percentile of daily values, observed changes for the Northeast average 38% when measured from 1901, and 55% when measured with the more robust network available from 1958.
A number of studies cited in the USACE (2015) included analyses specifically for the Mid-Atlantic Region as follows:

- The third NCA report cites an approximately 10% increase in average annual precipitation between 1895 and 2011 and a substantial increase in the amount of precipitation resulting from extreme heavy events (defined as the heaviest 1% of all daily events).
- Small et al. (2006) utilized Hydro-Climatic Date Network (HCDN) data from 1948 to 1997 and identified statistically significant increasing trends in fall precipitation for multiple locations in the region. However, there were even more locations with no statistically significant trends in fall precipitation. For total annual precipitation, no statistically significant trends were quantified for the Mid-Atlantic Region.
- Burns et al. (2007) identified statistically significant ($p < 0.05$) increasing trends in annual precipitation for half of their climate stations in the Catskill Mountains in southern New York with quantified average rates of increase in the range of 79 to 263 mm per fifty years of record.
- Warrach et al. (2006) investigated annual precipitation totals for a climate station in Hudson Highlands in southern New York State and found no significant annual trends for the period 1900 to 2000. Instead, seasonal trends were detected including decreasing winter and summer monthly precipitation totals.
- Cook et al. (2010) identified statistically significant ($p < 0.05$) increasing trends in total three-month autumn (September to November) precipitation for Mohonk Lake watershed in southern New York, with an overall rate of change of nearly 1mm per year.
- Results from Brown et al. (2010) quantified statistically significant increasing trends in the number of annual extreme wet (> 95th percentile) days since 1950, in a number of sites in the Mid-Atlantic Region.
- Kunkel et al. (2009) indicated no significant trends in the occurrence of extreme high (> 90th percentile) snowfall years in the Mid-Atlantic Region, but significantly increasing trends in the occurrence of extreme low snowfall (< 10th percentile) years.
- Results from Nguyen and DeGaetano (2012) showed statistically significant ($p < 0.05$) increasing trends in frequency and magnitude of high precipitation (2-day rainfall totals > 2 inches) events in the Mid-Atlantic Region for a period of 1948 to 2007.

Overall, an increasing trend in terms of both annual total precipitation and occurrence and magnitude of storm events has been identified in the literature for the Mid-Atlantic Region including the HRE Study Area.

4.1.2.2.2 Projected Precipitation Trends

Like projections for the country, projections of precipitation trends in the Mid-Atlantic Region vary from study to study and from model to model and generally lack consensus among studies or across models. Therefore, this literature review is focused on the projections on more of a regional scale, relevant to the HRE Study Area.

As described in Section 4.1.2, the study by Matonse et al. (2013) also investigated precipitation projections on the WOH watershed in New York City area. Results indicate generally increasing monthly average precipitation values with a higher variability than temperature projections. Similarly, the projections presented in the study by Samal et al. (2012) on show future increases in average precipitation for Cannonsville Reservoir on the order of 15 to 20% fora 2081-2100 planning horizon, compared to historical baseline (1966-2004).

As shown in Table 4-1, results from a study by Najjar et al. (2009) indicate an average 5% increase in annual precipitation for the middle and end of the 21st century projections in the Hudson River Estuary, as compared to historical baseline (1971-2000). The uncertainty in the HRE projection is relatively low, compared to those of the other 2 study areas.
Overall, reasonable consensus exists in the literature that total annual precipitation will increase throughout the 21st century for the Mid-Atlantic Region. However, projections do vary among models with considerable uncertainty.

4.1.2.3 Hydrology

A literature review on observed and projected hydrology/streamflow trends in the Mid-Atlantic Region and specially, in New York State, is presented in the following sub-sections.

4.1.2.3.1 Observed Streamflow Trends

The USACE (2015) cited several studies of trends and nonstationarity in streamflow data for the Mid-Atlantic Region. A summary of these studies is as follows:

- Xu et al. (2013) investigated trends for multiple stream gages and found no statistically significant ($P < 0.05$) trends in either annual streamflow or baseflow for any of the stations in the Mid-Atlantic Region.
- Kalra et al. (2008) analyzed historical streamflow (1952 – 2001) for a large number of stations and none of the stations exhibited statistically significant ($P < 0.05$) trends for annual or seasonal streamflow.
- A study by Small et al. (2006), using HCDC data for the period 1948 – 1997, did not identify any statistically significant trends in annual flow for any of the stations studied.
- Patterson et al. (2012) identified statistically significant ($P < 0.05$) decreasing trends in streamflow for a number of flow stations in the southern portion of the Mid-Atlantic Region (Virginia) for the period 1934 to 1969. A small number of stations exhibited significant decreasing tends for the more recent period (1970 – 2000).

Overall, no significant trends in historical streamflow have been identified in the literature for the Mid-Atlantic Region, despite the increased precipitation and the occurrence of extreme storm events.

4.1.2.3.2 Projected Streamflow Trends

Similar to projections of precipitation trends in the Mid-Atlantic Region, projections of streamflow trends also vary with significant uncertainties due to the introduction of hydrologic models in the climate model. Therefore, this literature review is focused on the projections on more of a regional scale, relevant to the HRE study area.

Pradhanang et al. (2013) utilized a combination of GCM output and water balance hydrologic modeling to project streamflow changes for West Branch of Delaware River in the WOH watershed. Model projections show a decreased snow pack and earlier snow melt, resulting in higher flows during the winter and lower flows during the spring runoff period. Results also indicate increased stream flashness with larger and more abrupt changes in streamflow in the study watershed.

Mukundan et al. (2013) conducted a study on the effects of projected changes in winter streamflow on stream turbidity for Esopus Creek in the WOH watershed. The results indicate decreased snowpack, earlier snow melt peak runoff and increased winter rain and streamflow, which is consistent with the results of Pradhanang et al. (2013).

A study by Matonse et al. (2013) on the WOH watershed, as described in previous sections, projects an overall increase in median flow, decreased snowpack and earlier snow melt, for the latter half of the 21st century as compared to a recent historical baseline period.
Overall, there is moderate consensus that streamflow will increase in the HRE study area in the 21st century due to projected decreased snow pack and earlier snow melt and as a result of increased precipitation.

4.1.3 Phase II: Vulnerability Assessment

4.1.3.1 Climate Hydrology Assessment Tool (CHAT)

This assessment focused on observed and projected trends in two study watersheds of interest using various climate tools. The USACE Climate Hydrology Assessment Tool (CHAT) was used to provide information on historic trends in observed data as well as qualitative information on projected climate conditions at the watershed scale (Hydrologic Unit 4, HUC-4).

4.1.3.1.1 Bronx River Watershed

The USACE Climate Hydrology Assessment Tool detects trends in observed annual maximum daily flow from the selected USGS gage, as well as projected future trends in annual maximum monthly flow for the selected HUC-4 watershed. The Bronx River watershed is in HUC 0203: Lower Hudson-Long Island. The Bronx River at NY Botanical Garden gage 01302020 only contains limited data of 5 years from 2007 to 2011 when it was used in the CHAT tool; therefore, this gage is not suitable for analysis. An analogous stream in the same HUC 0203 watershed, the Hutchinson River, was selected instead. The data from the USGS gage 01301500 at Pelham, NY (Figure 4-1), which extend from 1944 to 2011, was used in the CHAT analysis.

It should be noted that the assessment results of the analogous stream may not be translatable to the actual stream.

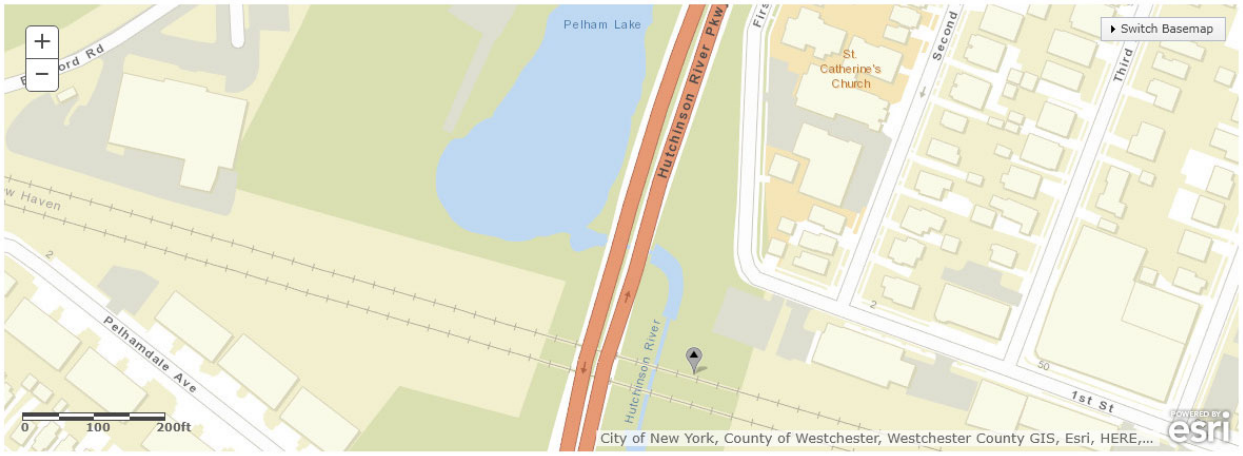


Figure 4-1. Location of Hutchinson River at Pelham NY Gage 01301500

4.1.3.1.1.1 Observed Peak Streamflow

The USACE CHAT tool was used to assess historical trends in peak instantaneous stream flow at the gage (Figure 4-2). The trendline p-value is 0.074 which is slightly larger than the accepted threshold for statistically significance of 0.05. Therefore, there may be an increasing trend in the historically observed peak flow data over the period of record 1944-2009, but the trend is not statistically significant. The reason for this may be due to the lack of data between 1990 and 2008.

4.1.3.1.1.2 Projected Peak Streamflow

The CHAT tool was used to investigate future changes in mean monthly stream flows in hydrologic unit code 0203, which encompasses the HRE study watershed. Figure 4-3 shows the range of projected, unregulated, annual maximum monthly flows computed by 93 different combinations of GCM outputs generated using different concentration pathways of greenhouse gas emissions. Climate-changed hydrology is generated for a period of 1999-2099 for the HUC Basin 0203 (Lower Hudson-Long Island).

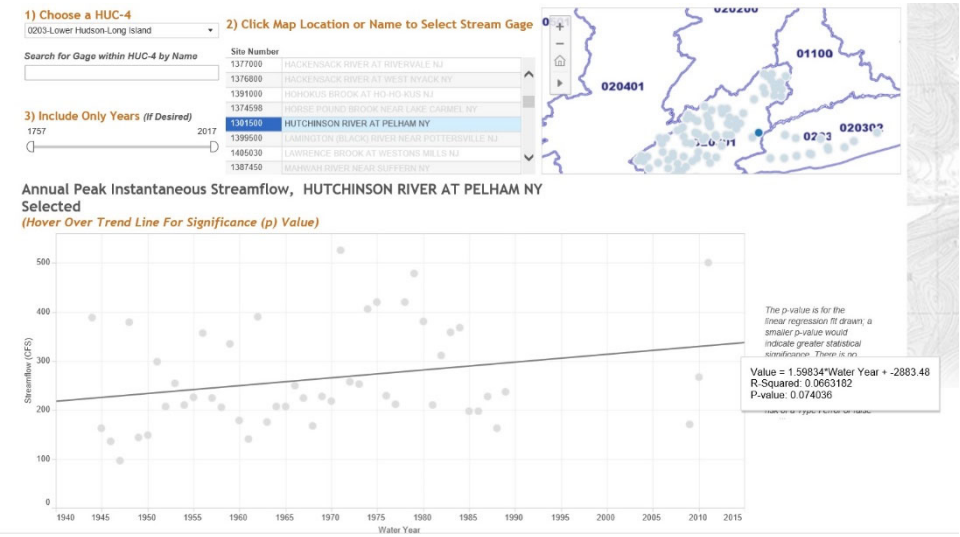


Figure 4-2. Climate Hydrology Assessment Tool output using annual instantaneous peak discharge at Hutchinson River at Pelham, NY Gage 01301500 (HUC 0203)

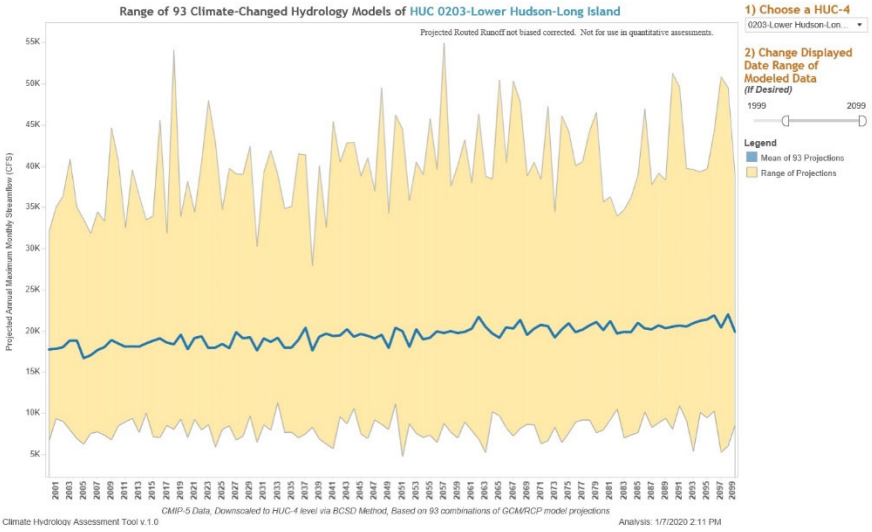


Figure 4-3. Range of Projected Annual Maximum Monthly Streamflow in HUC 0203 (Lower Hudson-Long Island)

A statistical analysis of the projected hydrology for 2000-2099 indicates a statistically significant linear trend of increasing mean annual maximum monthly flows (Figure 4-4). This increase is statistically significant (p-value < 0.05) and suggests the potential for future increases in streamflow relative to current conditions. This trend is somewhat consistent with the literature review (see Section 4.3.2).

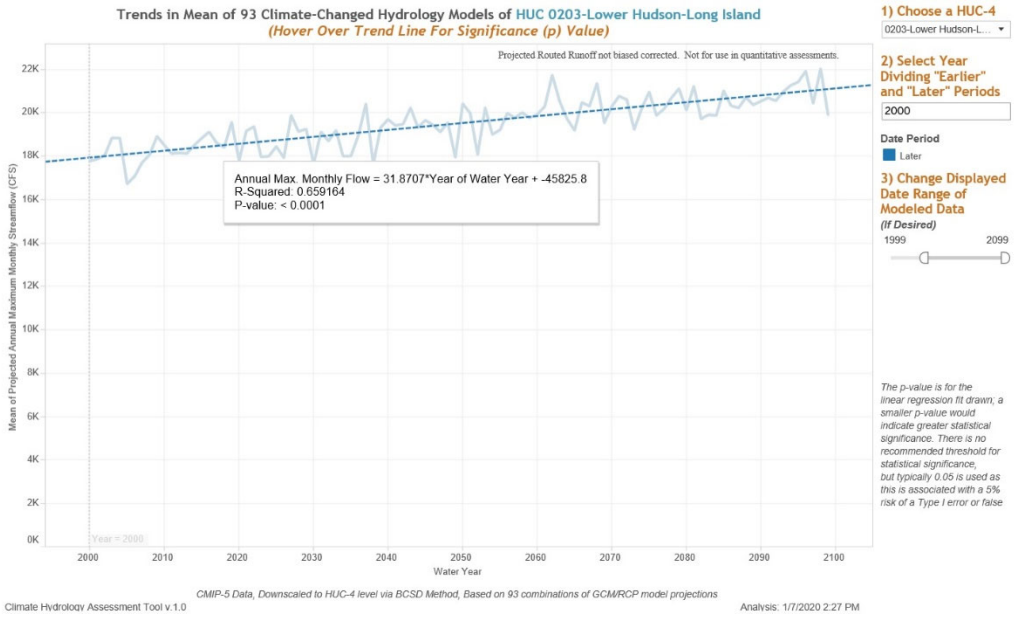


Figure 4-4. Projected Mean Annual Maximum Monthly Streamflow in HUC 0203 (Lower Hudson-Long Island)

4.1.3.1.2 First River Watershed

The First River is also located in HUC 0203: Lower Hudson-Long Island. Due to the lack of gaging stations in the watershed, an analogous stream, the Second River, which runs through the northern border of Branch Brook Park and parallel to the First River, was selected for the analysis. The data from the USGS gage 01392500 at Belleville, NJ (Figure 4-5), which extend from 1937 to 2012, was used in the CHAT analysis. Again, it should be noted that the results from the assessment of Second River may not be translatable to the actual stream.

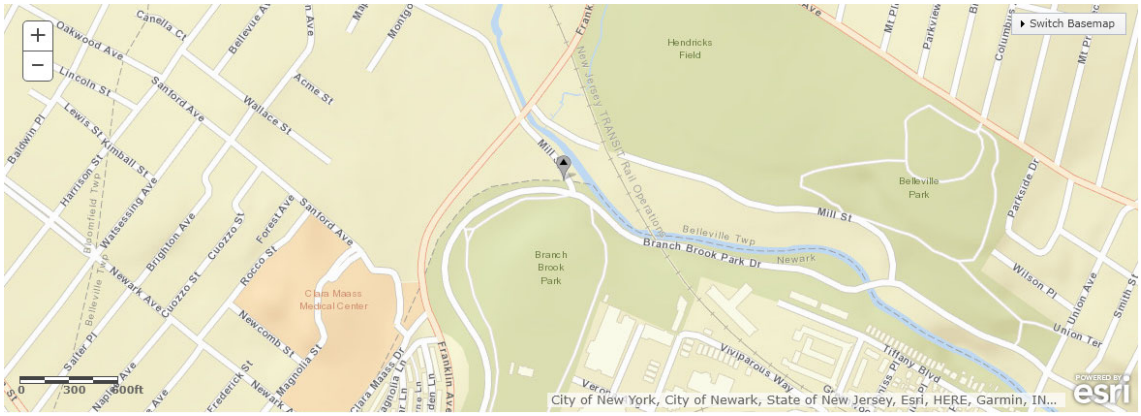


Figure 4-5. Location of Second River at Belleville NJ Gage 01392500

4.1.3.1.2.1 Observed Peak Streamflow

The USACE CHAT tool was used to assess historical trends in peak instantaneous stream flow at Gage 01392500 (Figure 4-6). The trendline p-value is less than 0.0001, which indicates a statistically significant increasing trend in the historically observed peak flow data over the period of record 1937-2012.

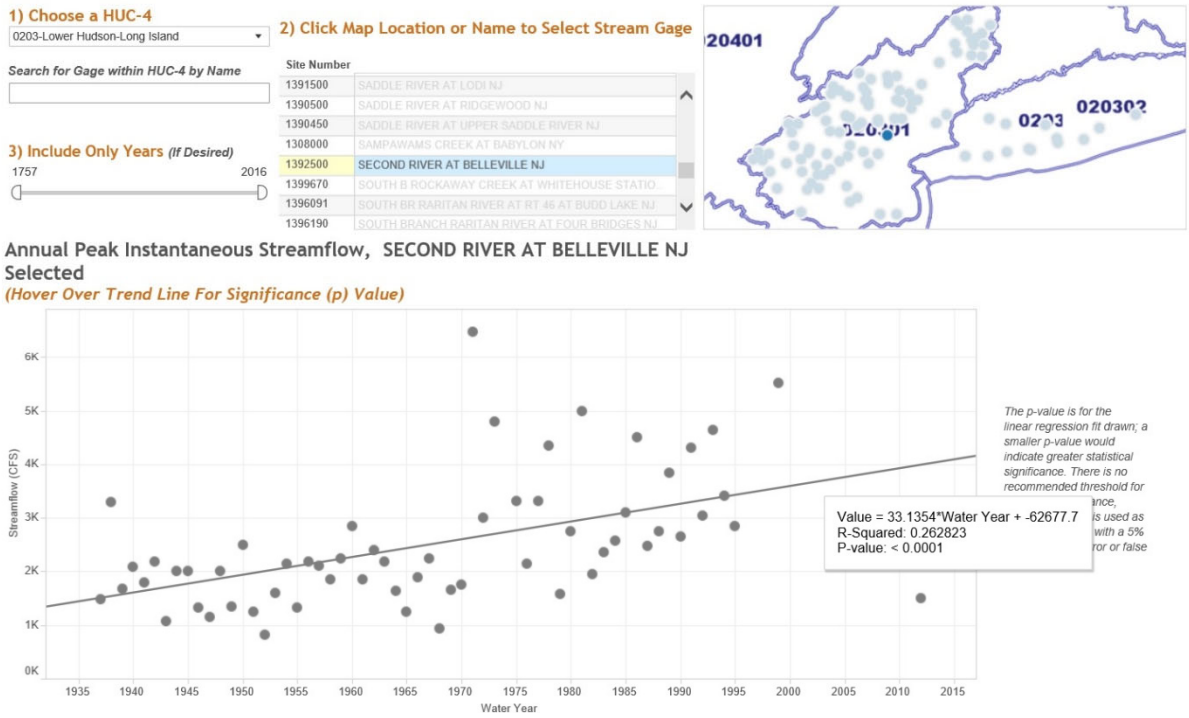


Figure 4-6. Climate Hydrology Assessment Tool output using annual instantaneous peak discharge at Second River at Belleville, NJ Gage 01392500 (HUC 0203)

4.1.3.1.2.2 Projected Streamflow Trends

The projected future trends in either mean monthly stream flows or mean annual maximum monthly flows are the same as in the analysis for the Bronx River watershed (See Section 4.1.2 and Figures 4-3 and 4-4).

4.1.3.2 Nonstationarity Detection Tool

4.1.3.2.1 Bronx River Watershed

As explained in previous sections, the Hutchinson River at Pelham NY gage 01301500 with a drainage area of 6.0 square miles was examined in the Nonstationarity Detection Tool. The statistical methods collectively identified nonstationarities in two different years: 1969 and 1970, for the period of record 1944-2011. The nonstationarities were identified using the Lombard Wilcoxon Method for 1969 and three methods (Cramer-Von-Mises, Pettitt, and Mann-Whitney)

for 1970. It should be noted that there are missing data points in the period of record selected, which may cause potential issues with the changepoints detected. The Cramer-Von-Mises Method detected a change in the underlying distribution of the data, while the Lombard Wilcoxon, the Pettitt and Mann-Whitney Methods detected a change in the average value, or mean, of the data. None of the statistical methods detected abrupt or smooth changes in the data.

The criteria for a "strong" nonstationarity are that there are: 1) a minimum of three nonstationarity detection methods (more than one test flagging a nonstationarity targeted at the same statistical property); 2) robustness in detection of changes in statistical properties (tests flagging nonstationarities targeted at different statistical properties); and 3) relatively large change in the magnitude of a dataset's statistical properties (mean or standard deviation). Although there are 3 detection methods that identified nonstationarity in Year 1970, they all targeted the same statistical property, i.e., mean of the data. Therefore, the detection is not considered a "strong" nonstationarity.

Based on these criteria, neither the 1969 nor 1970 event is considered a strong change point. Neither event meets the criteria for consensus, robustness, and magnitude, and are not considered statistically significant.

4.1.3.2.2 First River Watershed

Similar to the case for the Bronx River, the Second River at Belleville NJ gage 01392500 with a drainage area of 11.6 square miles was examined using the Nonstationarity Detection Tool. The statistical methods collectively identified nonstationarities in three different years: 1967, 1969 and 1970, for the period of record 1937-2012. The nonstationarities were identified using the Energy Divisive Method for 1967, Lombard Wilcoxon Method for 1969 and five methods (Cramer-Von-Mises, Kolmogorov-Smirnov, Lepage, Pettitt, and Mann-Whitney) for 1970.

It should be noted that there are missing data points in the period of record selected, which may cause potential issues with the changepoints detected. For 1967, the Energy Divisive Method detected a change in the underlying distribution of the data. For 1969, the Lombard Wilcoxon Method detected a change in the mean value of the data. For 1970, the Cramer-Von-Mises, Kolmogorov-Smirnov, and Lepage Methods all detected distributional changes of the data, while the Pettitt and Mann-Whitney Methods detected a change in the mean value of the data. None of the statistical methods detected abrupt or smooth changes in the data.

Based on the criteria described above, the 1970 event is considered a strong change point. However, it may not warrant a full detailed analysis due to missing data points.

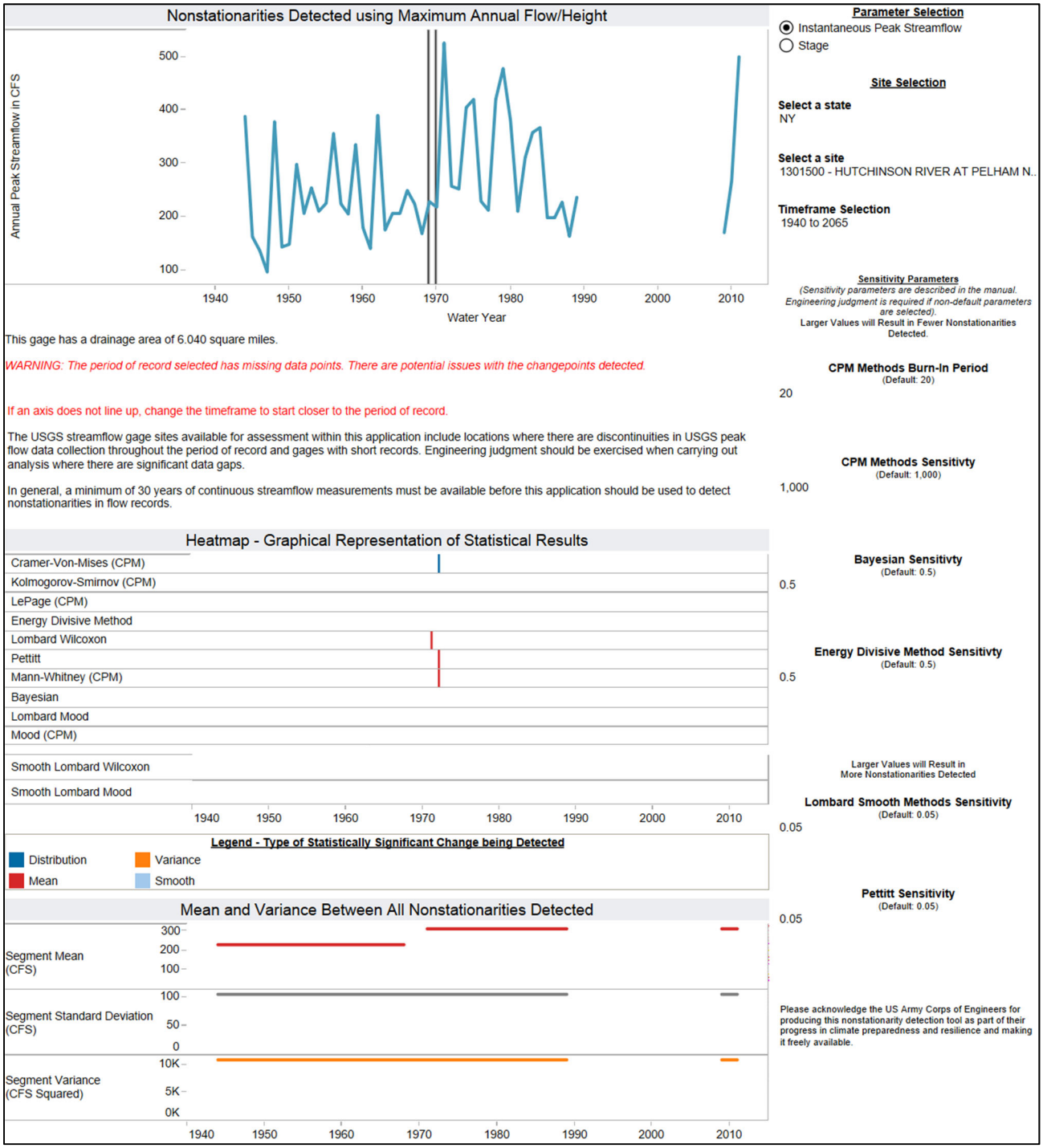


Figure 4-7. Output from Nonstationarity Detection Tool – Hutchinson River at Pelham, NY

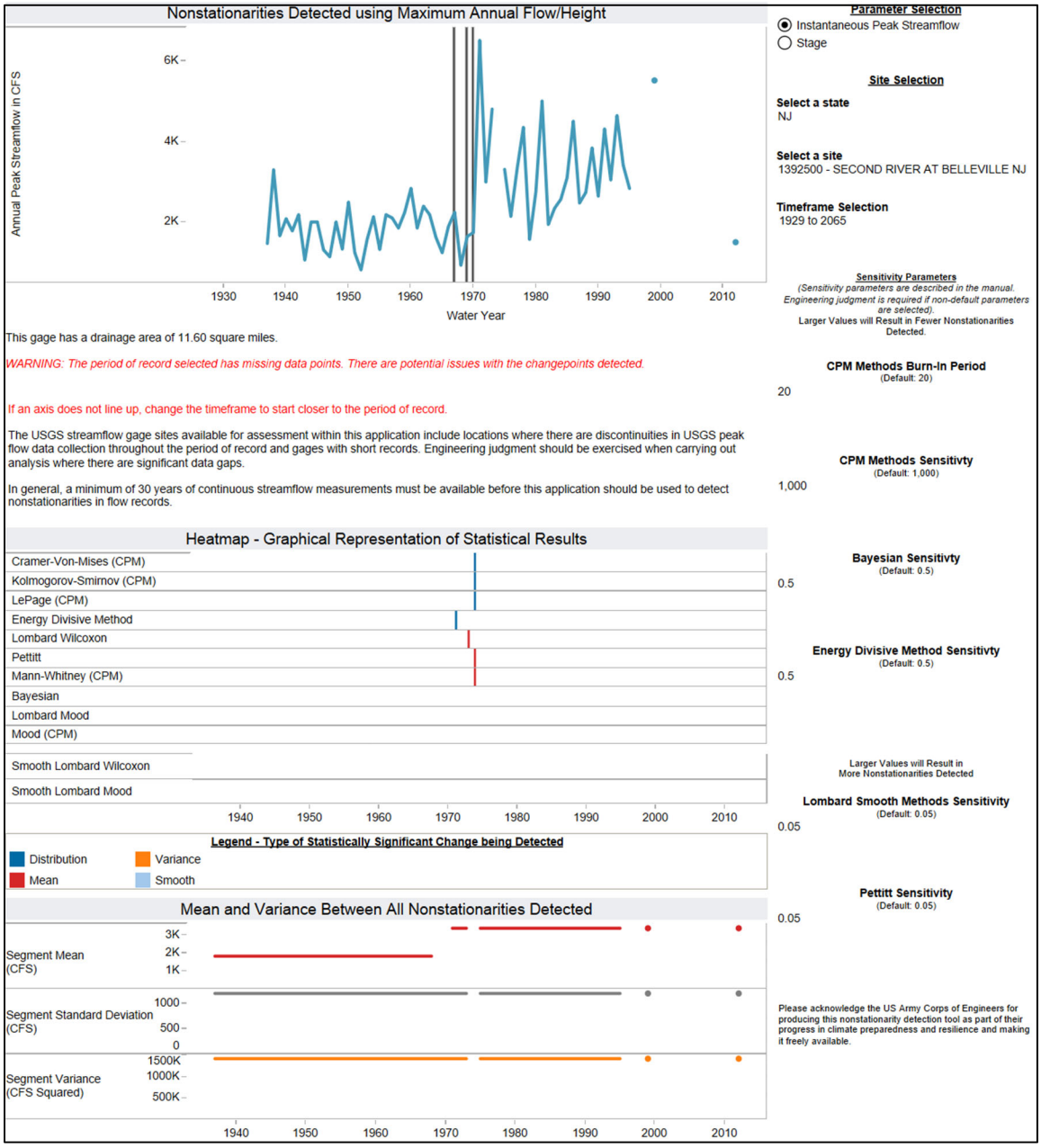


Figure 4-8. Output from Nonstationarity Detection Tool – Second River at Belleville, NJ

4.1.3.3 Vulnerability Assessment Tool

The USACE Vulnerability Assessment tool is necessary to help guide adaptation planning and implementation so that USACE can successfully perform its missions, operations, programs, and projects in an increasingly dynamic physical, socioeconomic, and political environment. This tool provides indicators to develop vulnerability scores specific to each of the watersheds located within the contiguous United States.

A Vulnerability Assessment was conducted in the USACE North Atlantic Division (NAD), and within the New York District (NAN). Tables 4a and 4b lists the vulnerability scores for the Flood Risk Reduction Business Line for HUC 0203 (Lower Hudson/Long Island) and HUC 0202 (Upper Hudson), respectively, as well as the ranges of scores nationally, and within NAD and NAN for scenario changes in Tables 4a and 4b. As shown in the table, this watershed vulnerability of the Flood Risk Reduction business line is ranked the highest within the ranges NAN and NAD for all scenarios (wet and dry). When comparing these scores nationally, the HUC 0203 watershed falls within the middle for dry scenarios and below average for wet scenarios. Further analysis using the VA tool characterizes the HUC 0202 and 0203 watersheds as vulnerable for all scenarios for the Flood Risk Reduction Business Line when compared to the rest of the nation (top 20%).

Table 4-2: Vulnerability scores for HUC 0203 (Lower Hudson and Long Island)

Scenario/Epoch	WOWA Score	National Range	NAD Range	NAN Range
Dry 2050	44.364	35.15 to 70.08	40.01 to 53.37	44.364 to 53.373
Wet 2050	48.664	39.80 to 92.85	43.12 to 56.91	48.141 to 56.915
Dry 2085	45.319	35.15 to 70.08	40.01 to 53.37	44.364 to 53.373
Wet 2085	49.687	39.80 to 92.85	43.12 to 56.91	48.141 to 56.915

Table 4-3: Vulnerability scores for HUC 0202 (Upper Hudson)

Scenario/Epoch	WOWA Score	National Range	NAD Range	NAN Range
Dry 2050	52.48	35.15 to 70.08	40.01 to 53.37	44.364 to 53.373
Wet 2050	54.419	39.80 to 92.85	43.12 to 56.91	48.141 to 56.915
Dry 2085	53.373	35.15 to 70.08	40.01 to 53.37	44.364 to 53.373
Wet 2085	56.915	39.80 to 92.85	43.12 to 56.91	48.141 to 56.915

The VA tool analyzed changes that were centered on two epochs, 2050 (2035-2065) and 2085 (2070-2099) grouping those epochs in “wet” and “dry” scenarios. Projections with total runoff values above the median value for the set are grouped as "wet", and ones with total runoff values below the median are grouped as "dry". All results were then given in scenario-epochs; Dry-2050, Dry-2085, Wet-2050, and Wet-2085. Several indicators localized within NAN were used to determine the overall climate risk score. These indicators include: Acres of Urban Area within 500-Year Floodplain (590), Flood Magnification Factor (568C/568L), and Percent Change in Runoff divided by Percent Change in Precipitation (277), and Annual Coefficient of Variant (CV) of Unregulated Runoff (175C).

The indicator that dominates vulnerability in the Lower Hudson (0203) is Indicator # 590 (Acres of urban area within the 500-yr floodplain) which contributes approximately 49% for both dry epochs, and 46% to 47% for both wet epochs. Meanwhile, the indicator that dominates

vulnerability in the Upper Hudson (0202) is Indicator #568C (Flood magnification, including freshwater inputs) which contributes approximately 49% to 50% for both dry epochs, and 51% to 52% for both wet epochs. The use of this tool suggests that "dry" scenario-epochs are vulnerable and considerations should be given to projects located within the urbanized 500-year flood plain area as well as areas in which it is anticipated that flooding will be magnified. Table 4C provides absolute values of the dominant indicators for both.

Table 4-4: Dominant vulnerability indicators for the Upper and Lower Hudson/Long Island watersheds. Shown as Indicator Value/ % WOWA score

	Scenario/ Epoch	Indicator #568C: Flood magnification, including freshwater inputs	Indicator #590 (Acres of urban area within the 500-yr floodplain
Upper Hudson (0202)	Dry 2050	21.92/49.41%	
	Wet 2050	24.79/50.94%	
	Dry 2085	22.67/50.02%	
	Wet 2085	25.67/51.67%	
Lower Hudson and Long Island (0203)	Dry 2050		25.75/49.06%
	Wet 2050		25.75/47.32%
	Dry 2085		26.25/49.19%
	Wet 2085		26.25/46.12%

The results of the VA tool analysis indicate that the HUCs 0202 and 0203 watershed are vulnerable to impacts to the Flood Risk Reduction Business Line and should be taken in consideration during the planning process and in communication with the local sponsor.

4.1.4 Risk Assessment and Climate Change Conclusions

A qualitative climate change assessment of inland hydrology for the HRE study area was conducted in accordance with ECB 2018-14 using both literature reviews and statistical tools that evaluate observed and future climate trends. The climate change literature reviews indicate significant warming trends in the observed temperatures for the Mid-Atlantic region including the HRE study area. There is a strong consensus that temperatures will increase throughout the 21st century. Historical data reveal an increasing trend in terms of both annual total precipitation and occurrence and magnitude of storm events for the Mid-Atlantic Region. Reasonable consensus exists in the literature that total annual precipitation will increase in the next century with significant uncertainty. No statistically significant trends in historical streamflow data have been identified in the literature. However, there is moderate consensus that streamflow will increase in the HRE study area in the 21st century due to projected decreased snow pack and earlier snow melt and as a result of projected increased precipitation.

The USACE Climate Hydrology Assessment Tool points towards increased streamflow trends for both streams (Hutchinson River and Second River), which were analyzed as analogous

streams to the actual streams in the HRE Study Area (Bronx River and First River). The Nonstationarity Detection Tool (NSD) was used to detect abrupt and slowly varying changes (nonstationarities) in observed, annual instantaneous peak discharges. The NSD results indicate a detection of nonstationarity for both analogous streams, but the detection does not warrant a full detailed analysis due to missing data points. It should be noted that the assessment results of the analogous streams may not be translatable to the actual streams.

Qualitatively, the project sites within both Bronx River watershed and First River watershed (Branch Brook Park) will likely be impacted by climate change, especially by the increasing precipitation and streamflow trends which may cause extensive flooding around the area. The projected mean annual maximum monthly streamflow for both rivers is project to increase by 10% by 2080 compared to the current condition. The impacts from climate change can be characterized as minimal to moderate as there is considerable model uncertainty with respect to the magnitude, frequency and timing of these changes. Climate change impacts and possible adaptive responses are briefly discussed below for each site in the Bronx River and for Branch Brook Park. The need to consider climate change impacts in future design development is also discussed in section seven of this appendix (Further Analysis and Design Development Needs).

- Bronx Zoo and Dam - There are no projected impacts to the proposed Fishway at Bronx Zoo and Dam. The Boulder Diversion barrier that guides aquatic organisms to the fishway may be subject to displacement and may need periodic replacement. Bioswale function may be impaired by increased sediment loading. The restoration of emergent wetlands is a central feature to this restoration effort and protection measures have been implemented in the form of boulder toe revetments. Increased hydrologic loading may result in displacement of this protection and the need for reinforcement and maintenance of this feature may be needed during the project's life-cycle.
- Stone Mill Dam - There are no projected impacts to the proposed Fishway at Stone Mill Dam. The Boulder Diversion barrier that guides aquatic organisms to the fishway may be subject to displacement and may need periodic replacement.
- Shoelace Park – Proposed streambank restoration measures at Shoelace Park were selected to cover a range of cots and effectiveness. Further analysis is needed during the PED phase and should consider possible increases in hydrologic loading. All proposed techniques include a boulder toe revetment at a minimum to provide protection to restored riparian wetlands. Cross-vanes, J-Hook vanes and bed material may be displaced or eroded due to increased hydrologic loading. The sizing of materials for these features should be analyzed during the PED phase and consider climate changes driven increases. Bioswale function may be impaired by increased sediment loading.
- Bronxville Lake - The sediment forebay at the northern edge of this site will serve to decrease velocities and lessen the impact of climate-driven increases in streamflow. The frequency of needed maintenance of this feature may increase as a result of greater sediment loading. Bioswale function may be impaired by increased sediment loading.
- Garth Harney – the future sustainability of the emergent wetlands proposed at this site should be subject to further analysis during the PED phase and the inclusion of a

boulder toe revetment should be considered. This protection was not deemed to be necessary for current conditions but it is acknowledge that more in-depth PED phased analysis me result in design changes. This uncertainty has been fully incorporated into the cost estimate contingency for this site. Cross-vanes and bed material may be displaced or eroded due to increased hydrologic loading. The sizing of materials for these features should be analyzed during the PED phase and consider climate changes driven increases. Bioswale function may be impaired by increased sediment loading.

- Branch Brook Park -Proposed streambank restoration measures at Branch Brook Park should be considered preliminary given the relatively low level of analysis and detail for the proposed designs. Further analysis is needed during the PED phase and should consider possible increases in streamflow. More robust streambank restoration techniques may be deemed necessary at selected locations within this site. This uncertainty has been fully incorporated into the cost estimate contingency for this site.

It is noted that the level of detail for the proposed designs for the Bronx River Sites and for Branch Brook Park is relatively low. A more in-depth investigation of existing and future with project Hydrology & Hydraulics at each site is needed and is discussed in section seven. Analysis at this phase should consider climate driven changes in conditions and inform design development of all features.

.

4.1.5 Climate Analysis References

1. Anandhi, A., Zion, M.S., Gowda, P.H., Pierson, D.C., Lounsbury, D., Frei, A. (2013) Past and future changes in frost day indices in Catskill Mountain region of New York. Hydrological Processes 27, 3094-3104.
2. Brown, P.J., Bradley, R.S., Keimig, F.T. (2010) Changes in extreme climate indices for the Northeastern United States, 1870-2005. Journal of Climate 23, 6555-6572.
3. Burns, D.A., Klaus, J., McHale, M.R. (2007) Recent climate trends and implications for water resources in the Catskill Mountain region, New York, USA. Journal of Hydrology 336, 155-170.
4. Cook, B.I., Cook, E.R., Anchukaitis, K.J., Huth, P.C., Thompson, J.E., Smiley, S.F. (2010) A homogeneous record (1896-2006) of daily weather and climate at Mohonk lake, New York. Journal of Applied Meteorology and Climatology 49, 544-555.
5. Grundstein, A. (2009) Evaluation of climate change over the continental United States using a moisture index. Climatic Change 93, 103-115.
6. Huntington, T.G., Richardson, A.D., McGuire, K.J., Hayhoe, K. (2009) Climate and hydrological changes in the northeastern United States: Recent trends and implications for forested and aquatic ecosystems. Canadian Journal of Forest Research 39, 199-212.
7. Kalra, A., Piechota, T.C., Davies, R., Tootle, G.A. (2008) Changes in U.S. streamflow and Western U.S. snowpack. Journal of Hydrologic Engineering 13, 156-163.
8. Kunkel, K.E., Liang, X.-Z., Zhu, J. (2010) Regional climate model projections and uncertainties of U.S. summer heat waves. Journal of Climate 23, 4447-4458.

9. Kunkel, K.E., Palecki, M.A., Ensor, L., Easterling, D., Hubbard, K.G., Robinson, D., Redmond, K. (2009) Trends in twentieth-century U.S. extreme snowfall seasons. Journal of Climate 22, 6204-6216.
10. Liu, Y., Goodrick, S.L., Stanturf, J.A. (2013) Future U.S. wildfire potential trends projected using a dynamically downscaled climate change scenario. Forest Ecology and Management 294, 120-135.
11. Matonse, A.H., Pierson, D.C., Frei, A., Zion, M.S., Anandhi, A., Schneiderman, E., Wright, B. (2013) Investigating the impact of climate change on New York City's primary water supply. Climatic Change 116, 437-456.
12. Meehl, G.A., Arblaster, J.M., Branstator, G. (2012) Mechanisms contributing to the warming hole and the consequent U.S. East-west differential of heat extremes. Journal of Climate 25, 6394-6408.
13. Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., (2014) Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.
14. Mukundan, R., Pierson, D.C., Wang, L., Matonse, A.H., Samal, N.R., Zion, M.S., Schneiderman, E.M. (2013) Effect of projected changes in winter streamflow on stream turbidity, Esopus Creek watershed in New York, USA. Hydrological Processes 27, 3014-3023.
15. Najjar, R., Patterson, L., Graham, S. (2009) Climate simulations of major estuarine watersheds in the Mid-Atlantic region of the US. Climatic Change 95, 139-168.
16. Nguyen, L.T., DeGaetano, A.T. (2012) A climatology of 500-hpa closed lows and associated precipitation in the northeastern United States. Journal of Applied Meteorology and Climatology 51, 3-15.
17. Patterson, L.A., Lutz, B., Doyle, M.W. (2012) Streamflow Changes in the South Atlantic, United States During the Mid- and Late 20th Century. Journal of the American Water Resources Association 48, 1126-1138.
18. Pradhanang, S.M., Mukundan, R., Schneiderman, E.M., Zion, M.S., Anandhi, A., Pierson, D.C., Frei, A., Easton, Z.M., Fuka, D., Steenhuis, T.S. (2013) Streamflow responses to climate change: Analysis of hydrologic indicators in a new york city water supply watershed. Journal of the American Water Resources Association.
19. Samal, N.R., Pierson, D.C., Schneiderman, E., Huang, Y., Read, J.S., Anandhi, A., Owens, E.M. (2012) Impact of climate change on Cannonsville reservoir thermal structure in the New York City water supply. Water Quality Research Journal of Canada 47, 389-405.
20. Scherer, M., Diffenbaugh, N. (2014) Transient twenty-first century changes in daily-scale temperature extremes in the United States. Climate Dynamics 42, 1383-1404.
21. Small, D., Islam, S., Vogel, R.M. (2006) Trends in precipitation and streamflow in the eastern U.S.: Paradox or perception? Geophysical Research Letters 33.
22. USACE (2015) Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions – Water Resources Region 02, Mid-Atlantic. Civil Works Technical Report, CWTS-2015-09, USACE, Washington, DC.
23. USGCRP (2018) Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E.

Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018
24. Wang, H., Schubert, S., Suarez, M., Chen, J., Hoerling, M., Kumar, A., Pegion, P. (2009) Attribution of the seasonality and regionality in climate trends over the United States during 1950-2000. Journal of Climate 22, 2571-2590.
25. Wang, J., Zhang, X. (2008) Downscaling and projection of winter extreme daily precipitation over North America. Journal of Climate 21, 923-937.
26. Warrach, K., Stieglitz, M., Shaman, J., Engel, V.C., Griffin, K.L. (2006) Twentieth century climate in the New York Hudson Highlands and the potential impacts on eco-hydrological processes. Climatic Change 75, 455-493.
27. Westby, R.M., Lee, Y.-Y., Black, R.X. (2013) Anomalous temperature regimes during the cool season: Long-term trends, low-frequency mode modulation, and representation in CMIP5 simulations. Journal of Climate 26, 9061-9076.
28. Xu, X., Scanlon, B.R., Schilling, K., Sun, A. (2013) Relative importance of climate and land surface changes on hydrologic changes in the U.S. Midwest since the 1930s: Implications for biofuel production. Journal of Hydrology 497, 110-120.

4.2 Sea Level Change Analysis

A climate assessment for sea level change (SLC) was conducted for the eleven tidally influenced HRE sites in accordance with Engineer Regulation (ER) 1100-2-8162, “Incorporating Sea Level Change in Civil Works Programs,” and Engineer Pamphlet (EP) 1100-2-1, “Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation.” ER 1100-2-8162 and EP 1100-2-1 provide guidance for incorporating the direct and indirect physical effects of projected future SLC across the project life cycle in managing, planning, engineering, designing, constructing, operating, and maintaining the USACE projects and systems of projects. Planning studies and engineering designs over the project life cycle, for both existing and proposed projects, will consider alternatives that are formulated and evaluated for the entire range of possible future rates of SLC.

SLC has been a persistent trend for decades in the United States and elsewhere in the world. Observed and reasonably foreseeable global SLR means that local sea levels will continue to rise beyond the end of this century. In most locations, global SLR results in local relative SLR, which has already caused impacts such as flooding and coastal shoreline erosion to the nation's assets located at or near the ocean. These impacts will continue to change in severity. Along the U.S. Atlantic Coast alone, almost 60 percent of the land that is within a meter of sea level is planned for further development. Wise decision-making requires adequate information on the potential rates and amount of SLC. Accordingly, the risks posed by SLC motivate decision-makers to ask: “What is the current rate of SLC, and how will that impact the future conditions that affect the performance and reliability of my infrastructure, or the current and future residential, commercial, and industrial development?” To better empower data-driven and risk-informed decision-making, the USACE has developed two web-based SLC tools: the Sea Level Change Curve Calculator and the Sea Level Tracker. Both tools provide a consistent and repeatable method to visualize the dynamic nature and variability of coastal water levels at tide gauges, allow comparison to the USACE projected SLC scenarios, and support simple

exploration of how SLC has or will intersect with local elevation thresholds related to infrastructure (e.g., roads, power generating facilities, dunes), and buildings. Taken together, decision-makers can align various SLR scenarios with existing and planned engineering efforts, estimating when and how the sea level may impact critical infrastructure and planned development activities (USACE, 2018b).

Both the Sea Level Change Curve Calculator and the Sea Level Tracker are designed to help with the application of the guidance found in ER 1100-2-8162 and EP 1100-2-1. The tools use equations in the regulation to produce tables and graphs for the following three SLC scenarios:

1. Baseline (or "low") estimate, which is based on historic SLR and represents the minimum expected SLC.
2. Intermediate estimate.
3. High estimate, representing the maximum expected SLC.

The calculator accepts user input—including project start date, selection of an appropriate NOAA long-term tide gauge, and project life span—to calculate projected SLCs for the respective project. The Sea Level Tracker has more functionality for quantifying and visualizing observed water levels and SLC trends and projections against existing threshold elevations for critical infrastructure and other local elevations of interest (USACE, 2018b). The start date used by the calculator is 1992, which corresponds to the midpoint of the current National Tidal Datum Epoch of 1983-2001.

4.2.1 HRE SLC Trends and Projections

The HRE restoration sites within the Jamaica Bay Planning Region (Dead Horse Bay, Fresh Creek, Duck Point Marsh Island, Stony Creek Marsh Island, Pumpkin Patch East and West Marsh Islands and Elders Center) were analyzed using data from the NOAA Sandy Hook, NJ (#8531680) tide gauge. Flushing Creek, located on the north shore of Long Island, was analyzed using data from the NOAA Kings Point, NY (# 8516645) tide gauge. The HRE restoration sites within the Lower Passaic River/Hackensack River/Newark Bay Planning Region (Oak Island Yards, Metromedia and Meadowlark) were analyzed using data from the NOAA the Battery NY (#8531680) tide gauge.

Figures 4-9 through 4-18 illustrate the following:

- Estimated relative SLC projections from 2020 to 2100 for each gauge used in this study, calculated with the USACE Sea Level Change Curve Calculator (Figures 4-9, 4-10, 4-13 and 4-16.) and plotted against the tidal wetland range for each group (low marsh low elevation to scrub/shrub high elevation). Each figure notes the projected construction start dates for each site and the full period of analysis for the group. Elevation changes due to accretion, which is modeled in the sea level change analysis discussed in this appendix are not represented here. (The analysis assumes a total of 0.25 ft of accretion for analysis of the low curve and 0.62 ft for the intermediate and high curve.) Note that all elevations are typically presented relative to NAVD88 with the exception of Flushing Creek, where

elevations are referenced to local mean sea level due to the fact that NAVD88 elevations for the Kings Point NOAA gauge are not available.

- Observed water levels and SLC trends and projections for each gauge, calculated using the USACE Sea Level tracker tool, showing the full data record and projections to 2100 (Figures 4-11, 4-14 and 4-17.)
- Observed water levels and SLC trends and projections for each gauge, calculated using the USACE Sea Level tracker tool, showing the recent trend and near-term projection (Figures 4-12, 4-15 and 4-18.)
-

The sea level change curve calculator data tables, with annual intervals, for each of these gauges are provided in Attachment C-2, Tables 1 through 3. These tables were used in projecting changes in habitat elevation ranges for each site.

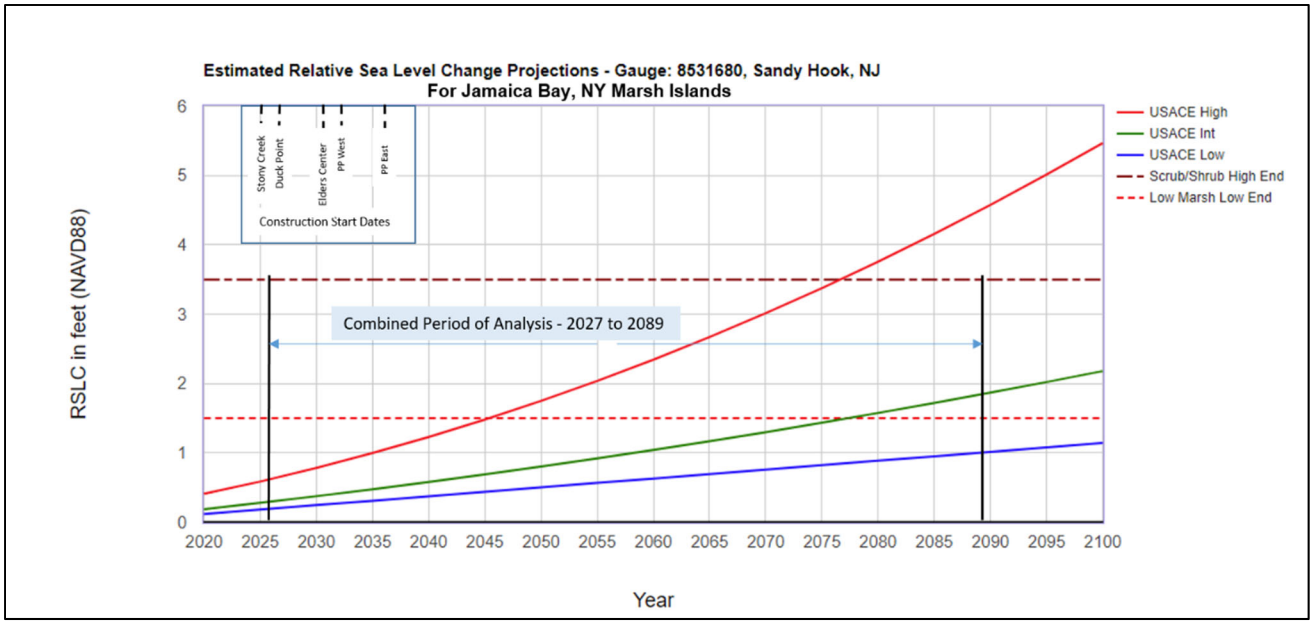


Figure 4-9: Relative Sea Level Change Projections, 1992-2100, Gauge: Sandy Hook, NJ (#8531680) with Jamaica Bay Marsh Island Thresholds

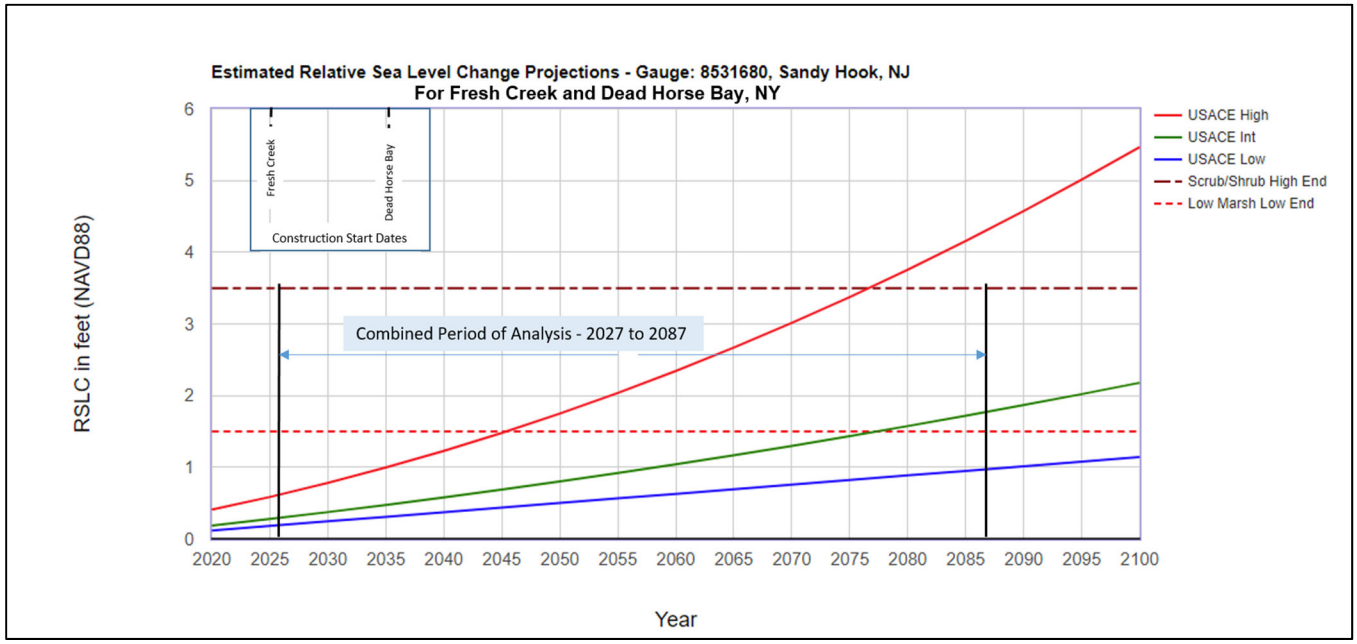


Figure 4-10. Relative Sea Level Change Projections, 1992-2100, Gauge: Sandy Hook, NJ (#8531680) with Jamaica BayPerimeter Site Thresholds

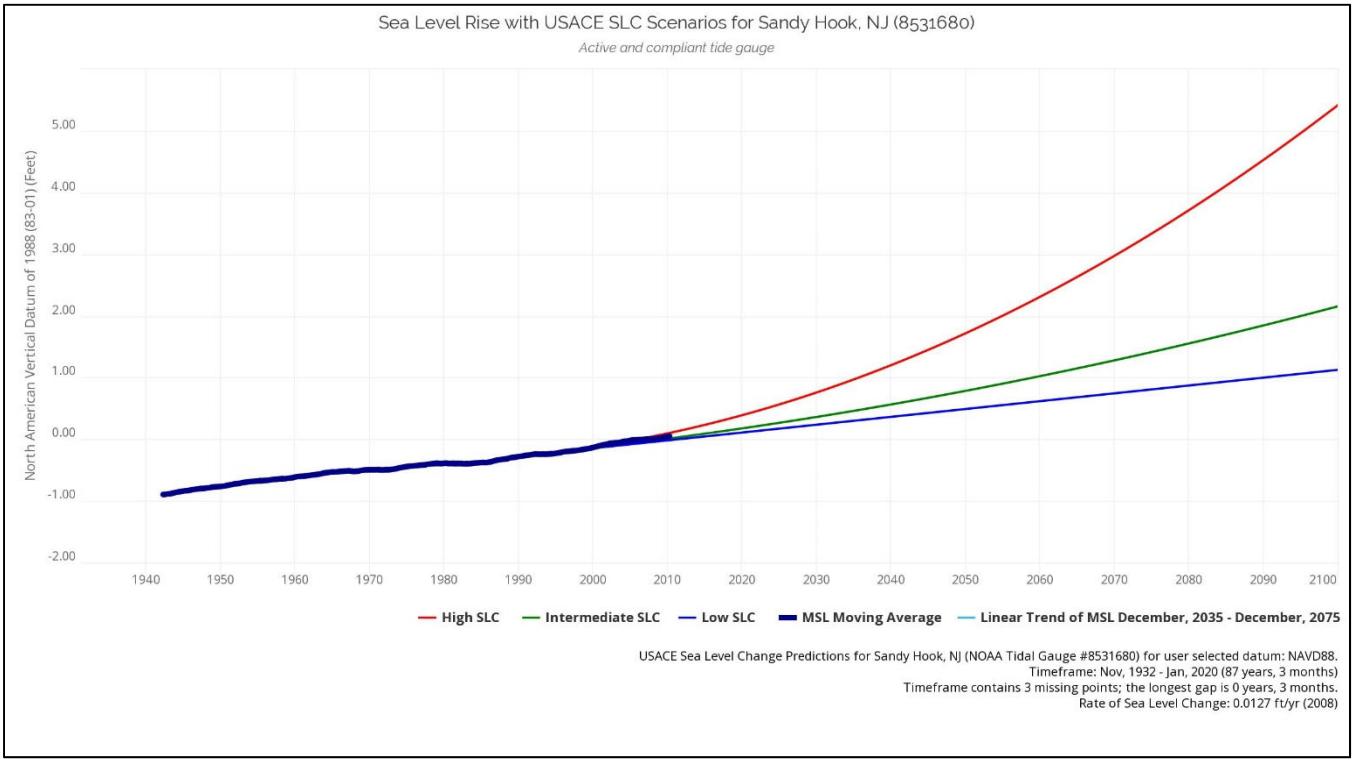


Figure 4-11: Sea Level Trend and Projection, (Long Range, 1942-2100, Gauge: Sandy Hook, NJ (#8531680)

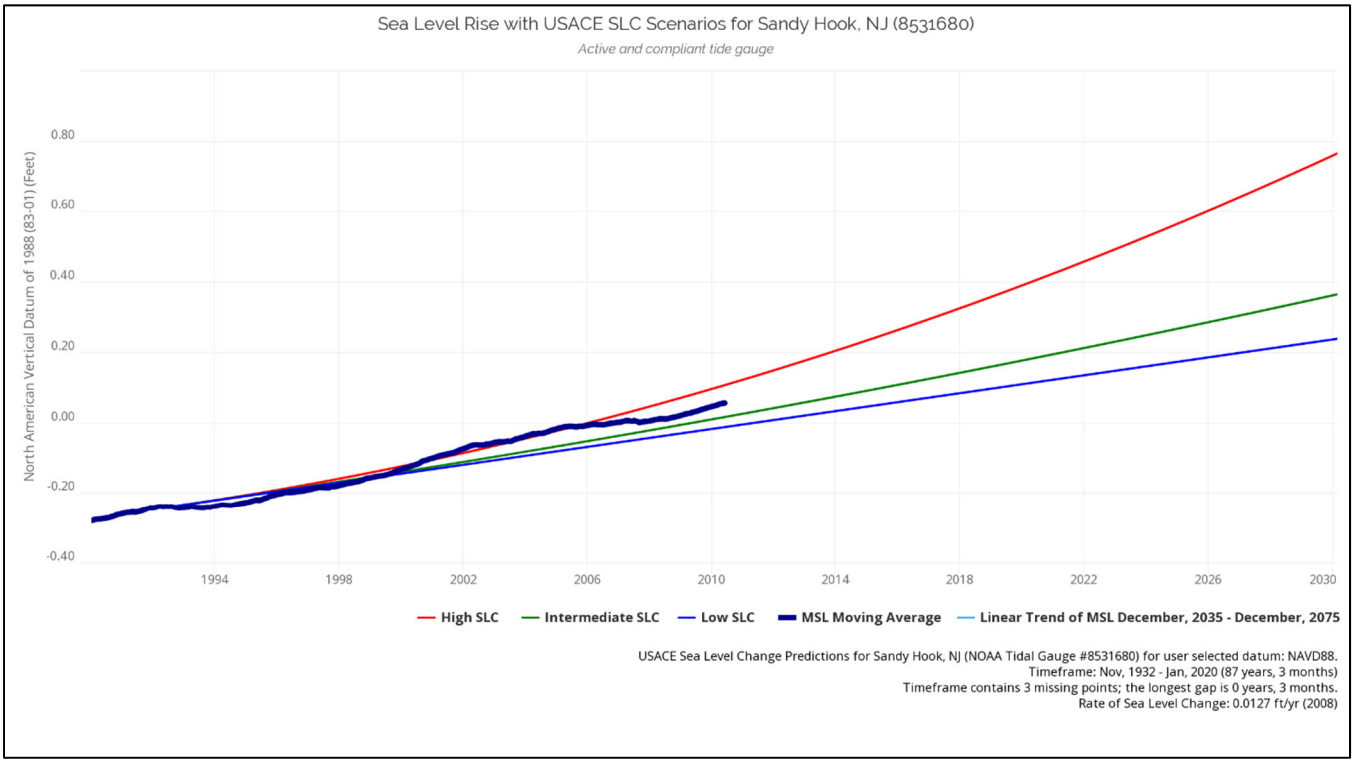


Figure 4-12: Sea Level Trend and Projection (1980-2030), Gauge: Sandy Hook, NJ (#8531680)

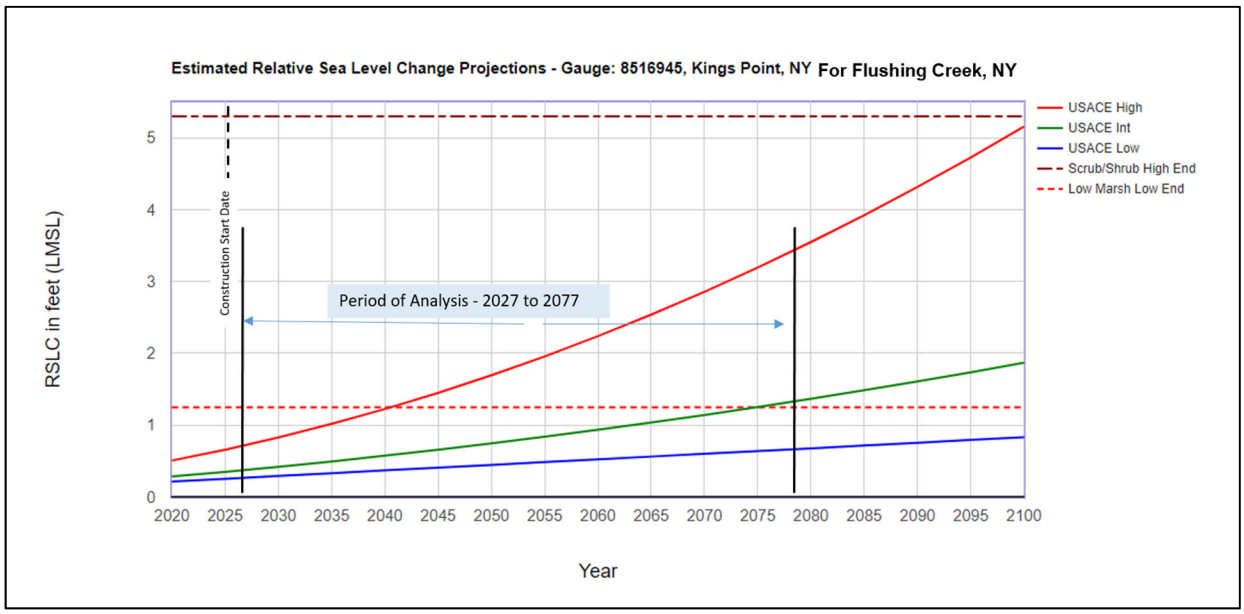


Figure 4-13: Relative Sea Level Change Projections, 1992-2100, Gauge: Kings Point, NY (#8516945) with Flushing Creek Thresholds

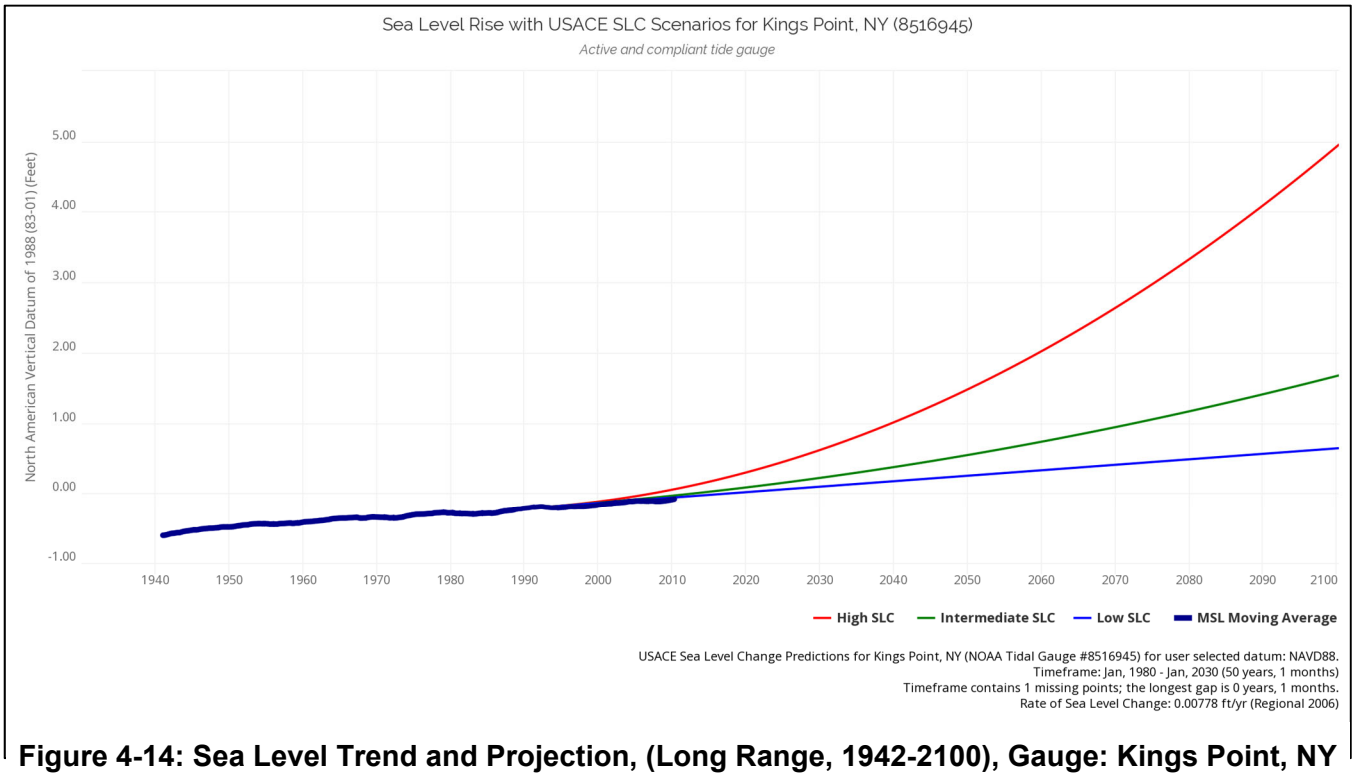


Figure 4-14: Sea Level Trend and Projection, (Long Range, 1942-2100), Gauge: Kings Point, NY (#8516945)

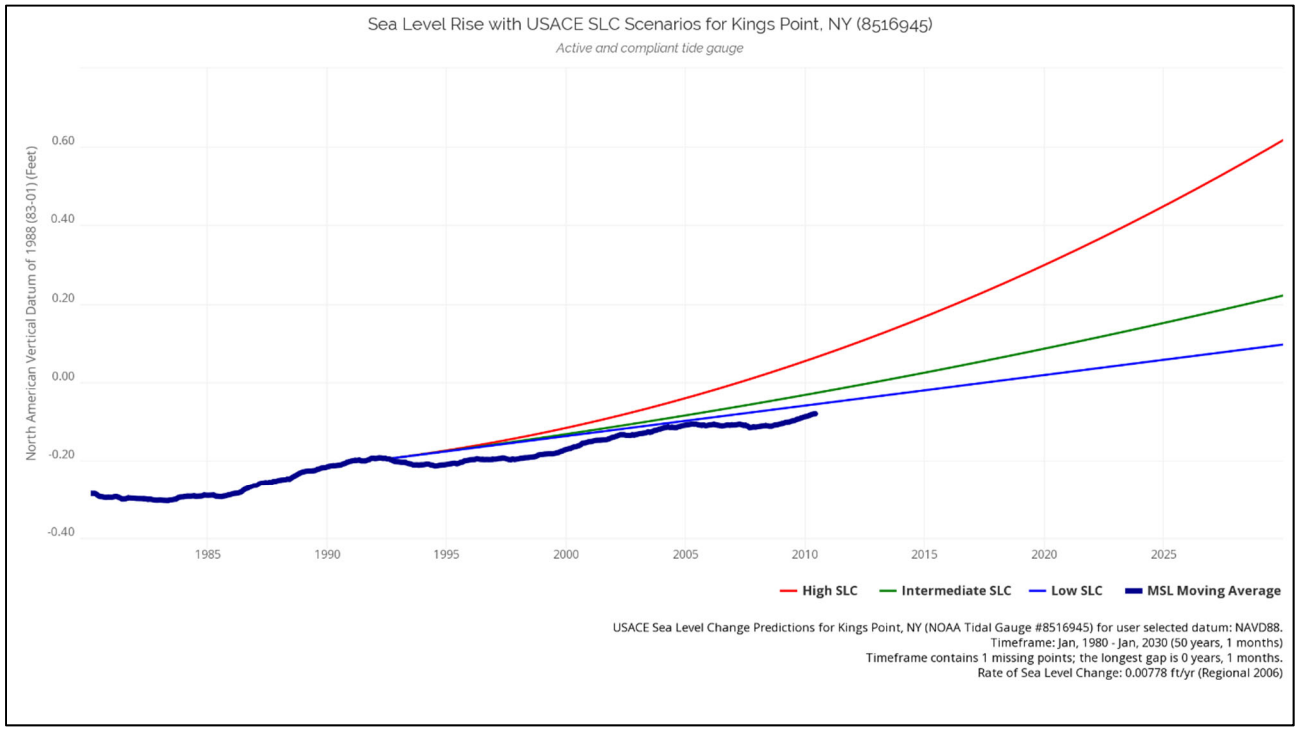


Figure 4-15: Sea Level Trend and Projection, (1980-2030), Gauge: Kings Point, NY (#8516945)

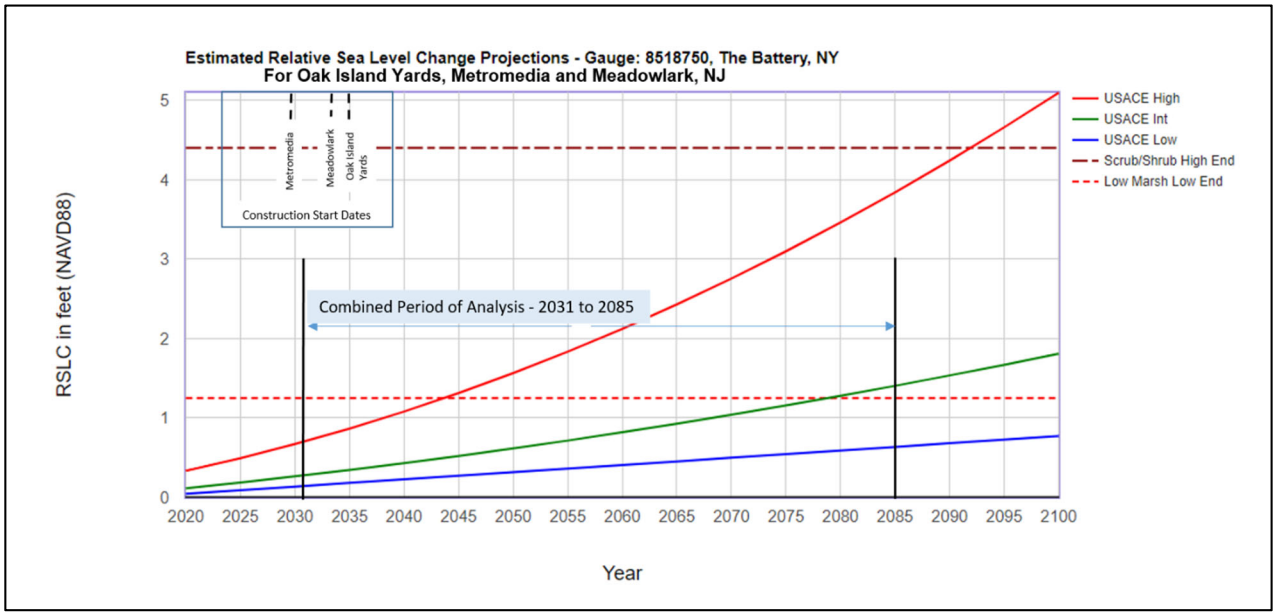


Figure 4-16: Relative Sea Level Change Projections, 1992-2100, Gauge: The Battery, NY (#8518750) with Oak Island Yards, Metromedia and Meadowlark Thresholds.

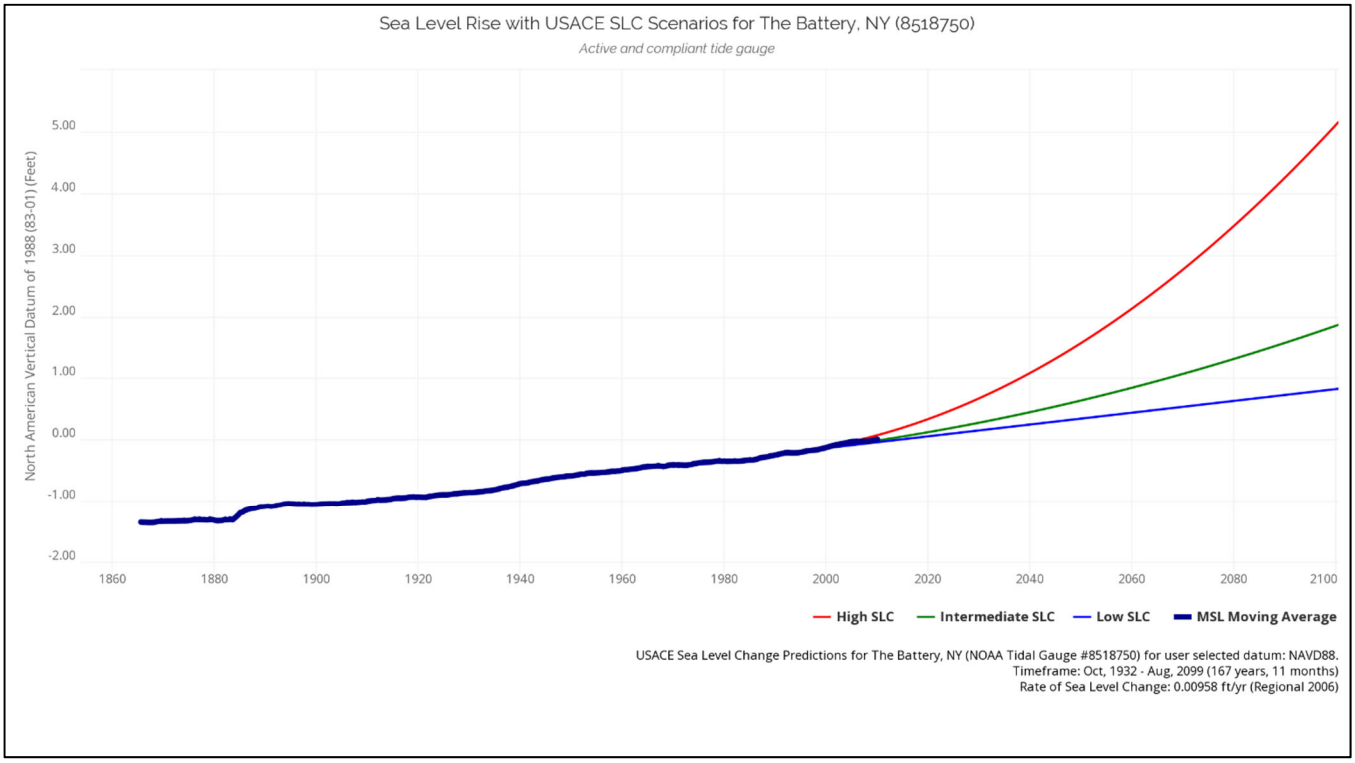


Figure 4-17: Sea Level Trend and Projection, (Long Range, 1865-2100), Gauge: The Battery, NY (#8518750)

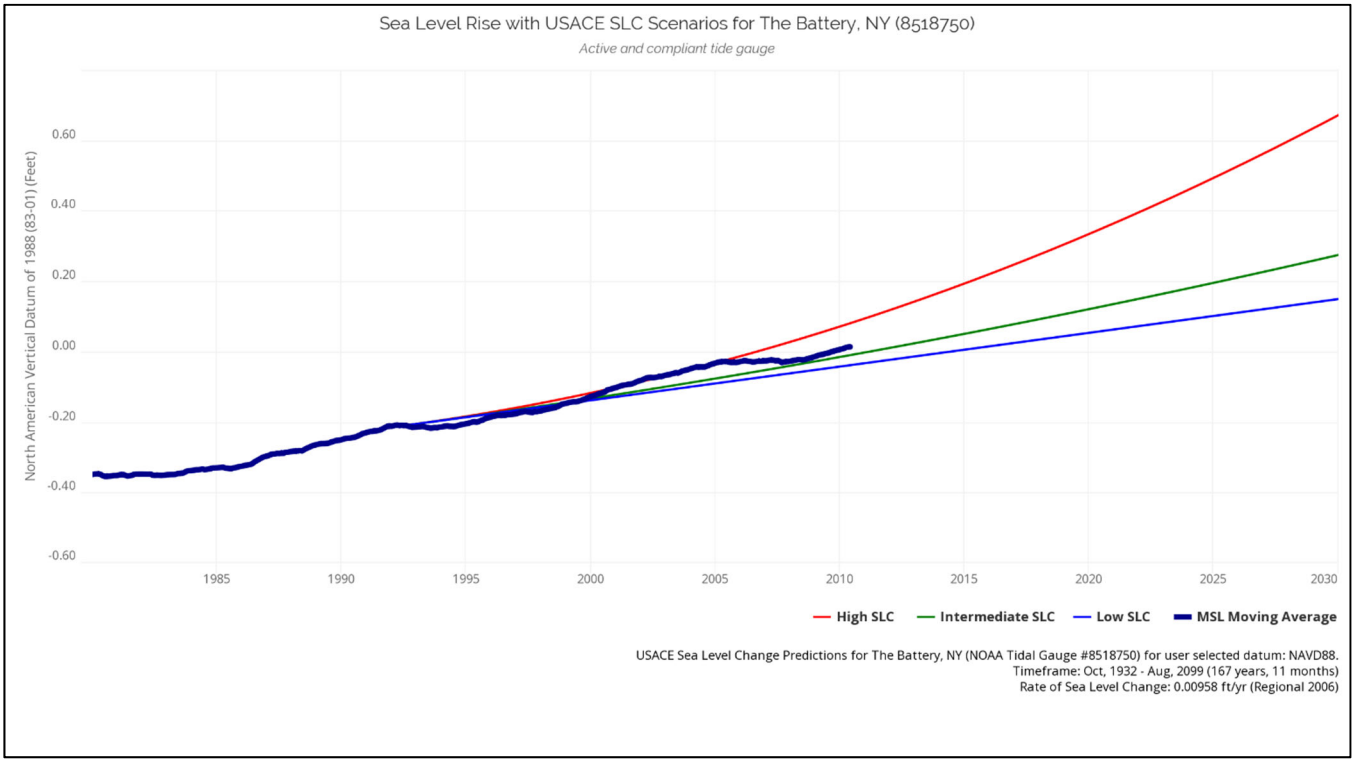


Figure 4-18: Sea Level Trend and Projection, (1980-2030), Gauge: The Battery, NY (#8518750)

4.2.2 Sea Level Change Impact Analysis

4.2.2.1 Raster Design Surface

A GIS analysis of potential impacts at each of the tidally influenced HRE sites was conducted. Site designs were based on local tide gauge datums correlated to the appropriate NOAA long term gauge (Engineering Appendix Chapter 2.) Proposed design grading plans were typically developed in the Microstation Inroads environment. These grading plans were converted to an ArcGIS polyline feature class format and an elevation raster surface was developed from the polylines. To ensure that this surface correctly matched the intended design, this "Year 0" surface was converted to a polygon feature class and the acreages of habitat communities of this output were compared to the proposed design acreages. If the output did not match the intended design acreages, contour line information was added to the polyline grading plan to correct for interpolation variances between the Microstation and ArcGIS environments. This provided an accurate baseline for projected sea level change analysis.

4.2.2.2 Assumed Accretion Rates

Accretion represents a critical component in marsh resiliency, which along with migration, allows marshes to adapt to rising sea levels. Field studies conducted within Jamaica Bay by the National Park Service have generally found that accretion rates at the reference marsh (Joco Marsh) were below sea level rise rates while the accretion rates at a restored site were above. Reed et al. (2008) conducted a comprehensive literature review of published, and in some cases unpublished, reports of recent and historical accretion rates for the Mid-Atlantic. The review found that rates in New York varied between 2 to 5 mm/year and from 3.8 mm/yr to more than 13 mm/yr in New Jersey. The report also notes high accretion rates (up to10 mm/yr) documented at newly restored sites in Delaware, presumably as a result of the site "building quickly toward an equilibrium tidal elevation." Hill (2015) concluded that the present average rate of accretion in Jamaica Bay is 2.5- 5 mm/yr.

An annual accretion rate of 3.75 mm/yr was used in this analysis for the intermediate and high SLC curves. A lower rate, 2.8 mm/yr, was used for the low SLC curve, as the annualized rate of sea level rise for the low curve can approach, or be greater than 3.75 mm/yr. These two rates were thought to be reasonably conservative while still capturing some of the impact of this important marsh evolution process. This conservative aspect increases over the span of the analysis given the fact that the accretion rate is static while the sea level change rates are generally rising. Finally, while the use of a single rate across 11 sites in a wide variety of settings is of course a gross generalization, it was nonetheless deemed sufficient for the resolution of this study.

4.2.2.3 Accreted Elevation Surface Creation.

Year 20 and year 50 accreted elevation surfaces were created. The appropriate rate was multiplied by 20 and 50 and the resulting values, expressed in feet, were added to the Year 0

elevation surface. The values used in the creation of these new elevation surfaces are shown in Table 4-5.

Table 4-5: Accretion Increases

Accretion rate (mm/yr)		Year 20 accretion (feet)	Year 50 accretion (feet)
2.8 (Low curve)		0.18	0.46
3.75 (Intermediate and High Curve)		0.25	0.62

4.2.2.4 Habitat Reclassification

Future habitat vegetation ranges were then calculated by applying the magnitude of SLC change indicated in the sea level change curve calculator data tables for the appropriate time point (Year 20 or 50) and SLC curve (low, intermediate, high), to the original vegetation ranges. These future habitat classifications were then used to classify the Year 20 and Year 50 raster surfaces, and new integer rasters were created using the reclassify tool. The reclassified rasters were then converted to polygon feature classes and the total acreages for each habitat zone were calculated. A total of 66 new surfaces and polygons were created representing projected habitat acreages for years 20 and 50 for each of the 3 SLC curves.

4.2.2.5 Constraints and Assumptions

The following constraints and assumptions were used in the analysis and presentation of the resulting data:

1) The low marsh habitat range was constrained to the original low marsh habitat limit. The accretion factor results in areas outside of the original planting area reaching elevations that would support low marsh growth. This results in a considerable amount of horizontal expansion of the low marsh. These areas were not included in the final results. This represents natural recruitment outside of the original planting areas. While this is perfectly plausible and has in fact been observed in the restored marsh islands of Jamaica Bay, it resulted in large added areas for the marsh islands that were considered too speculative.
2) The habitat range labeled as “Shallows” refers to the area between MTL and the low end of the low marsh habitat range. This habitat generally trends downward as MTL rises.
3) For Year 50, areas below MTL are not presented. At the start of the analysis period, areas such as “Shallows”, the area between MTL and the low end of the low marsh habitat range, represent important areas of restoration that provide the foundation of the restored ecosystem. These areas are not however represented in Year 50 as they represent those areas overtaken by rising sea levels.
4) Minor changes to channel acreages were not included. The resolution of the rasters were not detailed enough to accurately capture minute changes in habitat along the channel walls. The channel areas were therefore considered static unless the results were significant, generally only seen in year 50.

4.2.2.6 Results

4.2.2.6.1 Analysis of Alternatives

The method describe above used to model the impacts of sea level change on all HRE tidally influenced site alternatives. At this stage of the feasibility study, many of the proposed alternative did not have grading plans. The analysis therefore involved the development of concept level grading plans for each alternative. Only the intermediate curve was used for this alternatives analysis. The resulting outputs were then used to model future benefits, an important element in the screening of the alternatives. The results of this initial analysis also greatly informed the detailed design of the selected alternatives as the resiliency of the designs were improved as a result of the insights gained. Similarly, the results of this current analysis also inform the future development of the proposed designs. The acreage results of the SLC analysis of alternatives, along with the Future without project (FWOP) acreages are provided in Tables 4-6 through 4-16. Only the selected alternative was analyzed for Dead Horse Bay and Fresh Creek, as these plans have already been approved. A total of three alternatives each for fourteen sites were analyzed. Only those sites that remain a part of the recommend plan are presented here. This analysis focused on habitats within the tidal range. The presented acreages therefore represent only a portion of the full restoration effort.

Table 4-6 Dead Horse Bay, Projected SLC –Driven Habitat Change (Screening Phase)

DEAD HORSE BAY SEA LEVEL CHANGE, INTERMEDIATE CURVE (SELECTED ALTERNATIVE ONLY)						
	YEAR 2		YEAR 20		YEAR 50	
	FWOP	Selected Alternative	FWOP	Selected Alternative	FWOP	Selected Alternative
Low Marsh	2.7	31	2.7	32.78	2.67	31.51
High Marsh	0	7	0	5.16	0	5.43
Tidal Channel	0	4	0	3	0	4

Table 4-7 Fresh Creek, Projected SLC –Driven Habitat Change (Screening Phase)

FRESH CREEK SEA LEVEL CHANGE, INTERMEDIATE CURVE (SELECTED ALTERNATIVE ONLY)						
	YEAR 2		YEAR 20		YEAR 50	
	FWOP	Selected Alternative	FWOP	Selected Alternative	FWOP	Selected Alternative
Low Marsh	11.78	13.6	9.58	12.52	7.36	12.71
High Marsh	0	2.5	0	2.33	0	1.94
Basin/ Shallow Water	44.81	42.4	44.81	42.4	44.81	42.4

Table 4-8 Duck Point, Projected SLC –Driven Habitat Change (Screening Phase)

FLUSHING CREEK SEA LEVEL CHANGE, INTERMEDIATE CURVE												
	YEAR 2				YEAR 20				YEAR 50			
	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3
Low Marsh	5.02	5.36	8.75	10.49	5.02	5.52	9.02	10.77	5.02	6.25	10.28	12.1
High Marsh	2.84	2.26	3.84	4.02	2.84	2.17	3.64	3.86	2.84	1.7	2.74	3.09
Scrub Shrub	2.05	1.09	1.52	2.28	2.05	1.05	1.47	2.19	2.05	0.88	1.26	1.83

Table 4-9 Stony Creek, Projected SLC –Driven Habitat Change (Screening Phase)

STONY CREEK SEA LEVEL CHANGE, INTERMEDIATE CURVE												
	YEAR 2				YEAR 20				YEAR 50			
	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3
Low Marsh	10	26	28.35	22.89	7	30.1	27.6	23.1	0	32	21.7	18.8
High Marsh	0	22.5	11.3	8.45	0	18.2	6.7	4.6	0	12.2	3.5	2.5
Scrub Shrub	0	0.7	0	0	0	0.7	0	0	0	0.7	0	0

Table 4-10 Pumpkin Patch West, Projected SLC –Driven Habitat Change (Screening Phase)

PUMPKIN PATCH WEST LEVEL CHANGE, INTERMEDIATE CURVE												
	YEAR 2				YEAR 20				YEAR 50			
	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3
Low Marsh	0	10.8	13.71	18.1	0	12.3	10	18.5	0	11.3	11.5	15.8
High Marsh	0	5.5	8.61	10.3	0	2.9	7.3	8.5	0	1.5	4.8	5.7
Scrub Shrub	0	0	0.9	1.2	0	0	0.9	1.2	0	0	0.9	1.2

Table 4-11 Pumpkin Patch East, Projected SLC –Driven Habitat Change (Screening Phase)

PUMPKIN PATCH EAST SEA LEVEL CHANGE, INTERMEDIATE CURVE												
	YEAR 2				YEAR 20				YEAR 50			
	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3
Low Marsh	0	18.4	12.44	15.58	0	21.3	13.2	14.5	0	22.8	12.3	12.4
High Marsh	0	15.5	7.72	10.5	0	12.4	6.8	9.6	0	7.2	4.4	7.5
Scrub Shrub	0	0	1.23	3.13	0	0	1.23	3.13	0	0	1.23	3.13

Table 4-12 Elders Center, Projected SLC –Driven Habitat Change (Screening Phase)

ELDERS CENTER SEA LEVEL CHANGE, INTERMEDIATE CURVE												
	YEAR 2				YEAR 20				YEAR 50			
	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3
Low Marsh	0	8.5	9.51	21.64	0	8.9	9.4	19.6	0	10	8.7	17.7
High Marsh	0	6.6	6.91	10.9	0	6.3	7.7	11.1	0	3.8	5.5	8.2
Scrub Shrub	0	0	1.86	1.41	0	0	1.86	1.41	0	0	1.86	1.41

Table 4-13 Flushing Creek, Projected SLC –Driven Habitat Change (Screening Phase)

FLUSHING CREEK SEA LEVEL CHANGE, INTERMEDIATE CURVE												
	YEAR 2				YEAR 20				YEAR 50			
	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3
Low Marsh		5.36	8.75	10.49		5.52	9.02	10.77		6.25	10.28	12.1
High Marsh		2.26	3.84	4.02		2.17	3.64	3.86		1.7	2.74	3.09
Scrub Shrub		1.09	1.52	2.28		1.05	1.47	2.19		0.88	1.26	1.83

Table 4-14 Oak Island Yards, Projected SLC –Driven Habitat Change (Screening Phase)

OAK ISLAND YARDS SEA LEVEL CHANGE, INTERMEDIATE CURVE												
	YEAR 2				YEAR 20				YEAR 50			
	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3
Low Marsh	0.09	6.68	5.05	4.7	0.11	7.21	3.4	4.2	0.18	7.67	3.56	4.28
High Marsh	0.43	0.85	2.34	2.04	0.45	0.53	2.22	1.96	0.46	0.29	1.78	1.7
Scrub Shrub	0	0.44	0.99	2.21	0	0.34	0.99	2.21	0	0.11	0.99	2.21

Table 4-15 Metromedia, Projected SLC –Driven Habitat Change (Screening Phase)

METROMEDIA SEA LEVEL CHANGE, INTERMEDIATE CURVE												
	YEAR 2				YEAR 20				YEAR 50			
	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3
Low Marsh	37.43	38	43.1	50.6	43.65	40.16	46.74	51.99	58.33	42.32	43.68	55.59
High Marsh	25.24	4.8	4.5	4.1	19.93	5.64	4.26	4.99	6.34	10.09	7.76	2.98
Scrub Shrub		5.3	11.8	3.5		5.3	11.8	3.5		5.3	11.8	3.5

Table 4-16 Meadowlark, Projected SLC –Driven Habitat Change (Screening Phase)

MEADOWLARK SEA LEVEL CHANGE, INTERMEDIATE CURVE												
	YEAR 2				YEAR 20				YEAR 50			
	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3	FWOP	Alt 1	Alt 2	Alt 3
Low Marsh	46.88	55.03	58.79	53.2	52.17	54.34	57.78	52.08	63.75	52.08	54.24	48.45
High Marsh	31	6.43	5.04	4.94	26.3	6.28	5.24	5.67	15.42	5.93	5.98	7.5
Scrub Shrub		8.67	7.89	8.59		8.67	7.89	8.59		8.67	7.89	8.59

4.2.2.6.2 Analysis of Detailed Designs.

Acreage changes for Years 20 and 50, as well is the original design acreages are presented in Tables 4-17 through 4-27. The changes are also presented as a percent of the original design acreages to better facilitate comparison between sites and SLC rates. Maps of each output are presented in Attachment C-2. The results show the benefit of limiting the low end of the low marsh range to approximately one foot above MTL. The low end of the low marsh habitat range does not migrate upward until MTL becomes equal to or greater than this elevation. Generally speaking, the lack of impact on the low end and SLC driven high to low marsh conversion on the low/high marsh zone (as well as scrub/shrub to high marsh conversion) yield increases in low marsh acreages without dramatic losses in high marshes until later years under the SLC intermediate and high curve scenarios. Performance of sites under the high curve scenario do, however, vary considerably.

Table 4-17: Dead Horse Bay, Projected SLC –Driven Habitat Change

DEAD HORSE BAY SEA LEVEL CHANGE

LOW CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Channel	2.31	2.41	2.41	**Channel**	100.00%	104.33%	104.33%
Low Marsh	19	19.39	19.63	**Low Marsh**	100.00%	102.05%	103.32%
High Marsh	5.4	5.47	5.43	**High Marsh**	100.00%	101.30%	100.56%
Scrub/ Shrub	6.2	5.72	5.60	**Scrub/ Shrub**	100.00%	92.26%	90.32%
Upland	8.00	7.94	7.83	**Upland**	100.00%	99.25%	97.88%

INTERMEDIATE CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Channel	2.31	2.42	2.42	**Channel**	100.00%	104.76%	104.76%
Low Marsh	19	22.01	25.48	**Low Marsh**	100.00%	115.84%	134.11%
High Marsh	5.4	4.37	4.63	**High Marsh**	100.00%	80.93%	85.74%
Scrub/ Shrub	6.2	5.45	4.83	**Scrub/ Shrub**	100.00%	87.90%	77.90%
Upland	8.00	6.91	3.94	**Upland**	100.00%	86.38%	49.25%

HIGH CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Channel	2.31	2.26	18.88	**Channel**	100.00%	97.84%	817.32%
Low Marsh	19	26.52	20.01	**Low Marsh**	100.00%	139.58%	105.32%
High Marsh	5.4	4.53	0.57	**High Marsh**	100.00%	83.89%	10.56%
Scrub/ Shrub	6.2	5.38	0.72	**Scrub/ Shrub**	100.00%	86.77%	11.61%
Upland	8.00	3.08	1.65	**Upland**	100.00%	38.50%	20.63%

Table 4-18: Fresh Creek, Projected SLC –Driven Habitat Change

FRESH CREEK SEA LEVEL CHANGE							
LOW CURVE							
Habitat Acreage Change					**% of Design Acreage**		
	Design (Year 0) acres	**Year 20**	**Year 50**			**Design (Year 0)**	**Year 20**	**Year 50**
Channel	45.08	45.08	45.08		**Channel**	100.00%	100.00%	100.00%
Low Marsh	16.10	16.59	15.48		**Low Marsh**	100.00%	103.04%	96.15%
High Marsh	4.40	4.21	4.48		**High Marsh**	100.00%	95.68%	101.82%
Scrub/ Shrub	3.50	3.12	3.86		**Scrub/ Shrub**	100.00%	89.14%	110.29%
Upland	10.70	10.54	10.28		**Upland**	100.00%	98.50%	96.07%
INTERMEDIATE CURVE							
Habitat Acreage Change					**% of Design Acreage**		
	Design (Year 0)	**Year 20**	**Year 50**			**Design (Year 0)**	**Year 20**	**Year 50**
Channel	45.08	45.08	45.08		**Channel**	100.00%	100.00%	100.00%
Low Marsh	16.10	18.09	18.65		**Low Marsh**	100.00%	112.36%	115.82%
High Marsh	4.40	3.91	4.03		**High Marsh**	100.00%	88.85%	91.64%
Scrub/ Shrub	3.50	3.18	2.57		**Scrub/ Shrub**	100.00%	90.81%	73.56%
Upland	10.70	10.20	10.19		**Upland**	100.00%	95.32%	95.23%
HIGH CURVE							
Habitat Acreage Change					**% of Design Acreage**		
	Design (Year 0) acres	**Year 20**	**Year 50**			**Design (Year 0)**	**Year 20**	**Year 50**
Channel	45.08	47.87	51.24		**Channel**	100.00%	106.19%	113.66%
Low Marsh	16.10	17.76	13.49		**Low Marsh**	100.00%	110.31%	83.79%
High Marsh	4.40	2.37	0.60		**High Marsh**	100.00%	53.86%	13.64%
Scrub/ Shrub	3.50	2.92	1.07		**Scrub/ Shrub**	100.00%	83.43%	30.57%
Upland	10.70	8.12	6.34		**Upland**	100.00%	75.89%	59.25%

Table 4-19: Duck Point, Projected SLC –Driven Habitat Change

DUCK POINT SEA LEVEL CHANGE

LOW CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	7.57	7.57	7.56	**Shallows**	100.00%	100.00 %	99.87%
Channel	1.03	1.12	1.12	**Channel**	100.00%	108.74 %	108.74 %
Low Marsh	24.90	24.81	24.96	**Low Marsh**	100.00%	99.64%	100.24 %
High Marsh	5.60	9.38	9.29	**High Marsh**	100.00%	167.50 %	165.89 %
Scrub/ Shrub	8.10	4.36	4.30	**Scrub/ Shrub**	100.00%	53.83%	53.09%

INTERMEDIATE CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	7.57	5.86	3.27	**Shallows**	100.00%	77.41%	43.20%
Channel	1.03	1.10	1.16	**Channel**	100.00%	106.80 %	112.62 %
Low Marsh	24.90	27.21	35.06	**Low Marsh**	100.00%	109.28 %	140.80 %
High Marsh	5.60	7.96	2.66	**High Marsh**	100.00%	142.14 %	47.50%
Scrub/ Shrub	8.10	3.39	0.78	**Scrub/ Shrub**	100.00%	41.85%	9.63%

HIGH CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	7.57	1.19	0.00	**Shallows**	100.00%	15.72%	0.00%
Channel	1.03	1.11	0.00	**Channel**	100.00%	107.77 %	0.00%
Low Marsh	24.90	35.81	9.27	**Low Marsh**	100.00%	143.82 %	37.23%
High Marsh	5.60	2.17	0.00	**High Marsh**	100.00%	38.75%	0.00%
Scrub/ Shrub	8.10	0.59	0.00	**Scrub/ Shrub**	100.00%	7.28%	0.00%

Table 4-20: Stony Creek, Projected SLC –Driven Habitat Change

STONY CREEK SEA LEVEL CHANGE

LOW CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	8.67	8.64	8.38	**Shallows**	100.00%	99.65%	96.66%
Channel	1.43	1.48	1.49	**Channel**	100.00%	103.50%	104.20%
Low Marsh	26	26.05	29.23	**Low Marsh**	100.00%	100.19%	112.42%
High Marsh	22.5	22.45	20.65	**High Marsh**	100.00%	99.78%	91.78%
Scrub/ Shrub	3.49	3.41	2.08	**Scrub/ Shrub**	100.00%	97.71%	59.60%

INTERMEDIATE CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	8.67	7.12	4.37	**Shallows**	100.00%	82.12%	50.40%
Channel	1.43	1.48	1.49	**Channel**	100.00%	103.50%	104.20%
Low Marsh	26	32.95	43.04	**Low Marsh**	100.00%	126.73%	165.54%
High Marsh	22.5	17.39	8.56	**High Marsh**	100.00%	77.29%	38.04%
Scrub/ Shrub	3.49	3.32	0.00	**Scrub/ Shrub**	100.00%	95.13%	0.00%

HIGH CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	8.67	0.00	0.00	**Shallows**	100.00%	0.00%	0.00%
Channel	1.43	1.48	0.00	**Channel**	100.00%	103.50%	0.00%
Low Marsh	26	47.00	16.48	**Low Marsh**	100.00%	180.77%	63.38%
High Marsh	22.5	7.02	0.00	**High Marsh**	100.00%	31.20%	0.00%
Scrub/ Shrub	3.49	0.00	0.00	**Scrub/ Shrub**	100.00%	0.00%	0.00%

Table 4-21: Pumpkin Patch West, Projected SLC –Driven Habitat Change

PUMPKIN PATCH WEST SEA LEVEL CHANGE

LOW CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	3.88	3.89	3.87	**Shallows**	100.00%	100.26%	99.74%
Channel	0.74	0.81	0.81	**Channel**	100.00%	109.46%	109.46%
Low Marsh	13.70	13.54	13.55	**Low Marsh**	100.00%	98.83%	98.91%
High Marsh	8.61	8.65	8.56	**High Marsh**	100.00%	100.46%	99.42%
Scrub/ Shrub	0.90	0.91	0.91	**Scrub/ Shrub**	100.00%	101.11%	101.11%

INTERMEDIATE CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	3.88	3.47	2.92	**Shallows**	100.00%	89.43%	75.26%
Channel	0.74	0.81	0.81	**Channel**	100.00%	109.46%	109.46%
Low Marsh	13.70	16.35	21.07	**Low Marsh**	100.00%	119.34%	153.80%
High Marsh	8.61	6.65	1.92	**High Marsh**	100.00%	77.24%	22.30%
Scrub/ Shrub	0.90	0.00	0.00	**Scrub/ Shrub**	100.00%	0.00%	0.00%

HIGH CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	3.88	0.00	0.00	**Shallows**	100.00%	0.00%	0.00%
Channel	0.74	1.67	0.00	**Channel**	100.00%	225.68%	0.00%
Low Marsh	13.70	19.67	1.11	**Low Marsh**	100.00%	143.58%	8.10%
High Marsh	8.61	1.35	0.00	**High Marsh**	100.00%	15.68%	0.00%
Scrub/ Shrub	0.90	0.00	0.00	**Scrub/ Shrub**	100.00%	0.00%	0.00%

Table 4-22: Pumpkin Patch East, Projected SLC –Driven Habitat Change

PUMPKIN PATCH EAST SEA LEVEL CHANGE

LOW CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	5.22	5.16	5.19	**Shallows**	100.00%	98.85%	99.43%
Channel	0.58	0.63	0.63	**Channel**	100.00%	108.62%	108.62%
Low Marsh	15.60	15.61	15.59	**Low Marsh**	100.00%	100.06%	99.94%
High Marsh	10.10	10.47	10.44	**High Marsh**	100.00%	103.66%	103.37%
Scrub/ Shrub	3.10	2.75	2.73	**Scrub/ Shrub**	100.00%	88.71%	88.06%

INTERMEDIATE CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	5.22	3.87	2.29	**Shallows**	100.00%	74.14%	43.87%
Channel	0.58	0.63	0.63	**Channel**	100.00%	108.62%	108.62%
Low Marsh	15.60	17.87	23.20	**Low Marsh**	100.00%	114.55%	148.72%
High Marsh	10.10	9.01	5.63	**High Marsh**	100.00%	89.21%	55.74%
Scrub/ Shrub	3.10	1.95	0.00	**Scrub/ Shrub**	100.00%	62.90%	0.00%

HIGH CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	5.22	0.00	0.00	**Shallows**	100.00%	0.00%	0.00%
Channel	0.58	3.37	0.00	**Channel**	100.00%	581.03%	0.00%
Low Marsh	15.60	17.83	1.84	**Low Marsh**	100.00%	114.29%	11.79%
High Marsh	10.10	4.01	0.00	**High Marsh**	100.00%	39.70%	0.00%
Scrub/ Shrub	3.10	0.00	0.00	**Scrub/ Shrub**	100.00%	0.00%	0.00%

Table 4-23: Elders Center, Projected SLC –Driven Habitat Change

ELDERS CENTER SEA LEVEL CHANGE

LOW CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	5.49	3.69	4.96	**Shallows**	100.00%	67.21%	90.35%
Channel	0.95	1.08	1.09	**Channel**	100.00%	113.68%	114.74%
Low Marsh	15.2	17.03	16.37	**Low Marsh**	100.00%	112.04%	107.70%
High Marsh	10.9	10.79	12.08	**High Marsh**	100.00%	98.99%	110.83%
Scrub/ Shrub	1.4	1.36	0.00	**Scrub/ Shrub**	100.00%	97.14%	0.00%

INTERMEDIATE CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	5.49	3.89	1.84	**Shallows**	100.00%	70.86%	33.52%
Channel	0.95	1.08	1.09	**Channel**	100.00%	113.68%	114.74%
Low Marsh	15.2	17.79	24.31	**Low Marsh**	100.00%	117.04%	159.93%
High Marsh	10.9	10.52	4.01	**High Marsh**	100.00%	96.51%	36.79%
Scrub/ Shrub	1.4	0.00	0.00	**Scrub/ Shrub**	100.00%	0.00%	0.00%

HIGH CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	5.49	0.00	0.00	**Shallows**	100.00%	0.00%	0.00%
Channel	0.95	1.03	0.00	**Channel**	100.00%	108.42%	0.00%
Low Marsh	15.2	25.13	3.03	**Low Marsh**	100.00%	165.33%	19.93%
High Marsh	10.9	2.88	0.00	**High Marsh**	100.00%	26.42%	0.00%
Scrub/ Shrub	1.4	0.00	0.00	**Scrub/ Shrub**	100.00%	0.00%	0.00%

Table 4-24: Flushing Creek, Projected SLC –Driven Habitat Change

FLUSHING CREEK SEA LEVEL CHANGE

LOW CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	1.37	1.33	1.33	**Shallows**	100.00%	97.08%	97.08%
Low Marsh	9.76	9.96	10.25	**Channel**	100.00%	102.05%	105.02%
High Marsh	2.47	2.49	2.45	**Low Marsh**	100.00%	100.81%	99.19%
Scrub/Shrub	1.53	1.41	1.39	**High Marsh**	100.00%	92.16%	90.85%
Upland	3.97	4.16	3.90	**Scrub/ Shrub**	100.00%	104.79%	98.24%

INTERMEDIATE CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	1.37	1.33	1.33	**Shallows**	100.00%	97.08%	97.08%
Low Marsh	9.76	10.54	11.86	**Channel**	100.00%	107.99%	121.52%
High Marsh	2.47	2.17	1.45	**Low Marsh**	100.00%	87.85%	58.70%
Scrub/Shrub	1.53	1.23	0.79	**High Marsh**	100.00%	80.39%	51.63%
Upland	3.97	4.08	3.92	**Scrub/ Shrub**	100.00%	102.77%	98.74%

HIGH CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Shallows	1.37	1.10	2.84	**Shallows**	100.00%	80.29%	207.30%
Low Marsh	9.76	11.91	12.20	**Channel**	100.00%	122.03%	125.00%
High Marsh	2.47	1.43	0.29	**Low Marsh**	100.00%	57.89%	11.74%
Scrub/Shrub	1.53	0.76	0.30	**High Marsh**	100.00%	49.67%	19.61%
Upland	3.97	3.92	3.48	**Scrub/ Shrub**	100.00%	98.74%	87.66%

Table 4-25: Oak Island Yards, Projected SLC –Driven Habitat Change

OAK ISLAND YARDS SEA LEVEL CHANGE

LOW CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Channel	1.36	1.31	1.31	**Shallows**	100.00%	96.32%	96.32%
Low Marsh	5.32	5.45	5.59	**Channel**	100.00%	102.44%	105.08%
High Marsh	0.85	0.85	0.81	**Low Marsh**	100.00%	100.00%	95.29%
Scrub/Shrub	0.44	0.44	0.42	**High Marsh**	100.00%	100.00%	95.45%
Upland	2.85	2.85	2.85	**Scrub/ Shrub**	100.00%	100.00%	100.00%

INTERMEDIATE CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Channel	1.36	1.36	1.36	**Shallows**	100.00%	100.00%	100.00%
Low Marsh	5.32	5.85	6.31	**Channel**	100.00%	109.96%	118.61%
High Marsh	0.85	0.53	0.29	**Low Marsh**	100.00%	62.35%	34.12%
Scrub/Shrub	0.44	0.34	0.11	**High Marsh**	100.00%	77.27%	25.00%
Upland	2.85	2.82	2.75	**Scrub/ Shrub**	100.00%	98.95%	96.49%

HIGH CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Channel	1.36	1.88	7.09	**Shallows**	100.00%	138.24%	521.32%
Low Marsh	5.32	5.80	1.61	**Channel**	100.00%	109.02%	30.26%
High Marsh	0.85	0.22	0.13	**Low Marsh**	100.00%	25.88%	15.29%
Scrub/Shrub	0.44	0.11	0.30	**High Marsh**	100.00%	25.00%	68.18%
Upland	2.85	2.71	2.13	**Scrub/ Shrub**	100.00%	95.09%	74.74%

Table 4-26: Metromedia, Projected SLC –Driven Habitat Change

METROMEDIA SEA LEVEL CHANGE

LOW CURVE

Habitat Acreage Change			
	Design (Year 0) acres	Year 20	Year 50
Shallows	6.51	7.36	5.59
Channel	2.79	2.86	2.75
Low Marsh	26.50	28.54	32.78
High Marsh	9.40	7.58	6.05
Scrub/Shrub	14.80	14.22	13.85
Upland	4.10	3.87	3.28

% of Design Acreage			
	Design (Year 0)	Year 20	Year 50
Shallows	100.00%	113.06%	85.87%
Channel	100.00%	102.51%	98.57%
Low Marsh	100.00%	107.70%	123.70%
High Marsh	100.00%	80.64%	64.36%
Scrub/Shrub	100.00%	96.08%	93.58%
Upland	100.00%	94.40%	80.00%

INTERMEDIATE CURVE

Habitat Acreage Change			
	Design (Year 0) acres	Year 20	Year 50
Shallows	6.51	7.87	7.23
Channel	2.79	2.82	2.95
Low Marsh	26.50	31.91	36.51
High Marsh	9.40	5.56	9.83
Scrub/Shrub	14.80	13.72	6.01
Upland	4.10	3.16	1.78

% of Design Acreage			
	Design (Year 0)	Year 20	Year 50
Shallows	100.00%	120.89%	111.06%
Channel	100.00%	101.08%	105.73%
Low Marsh	100.00%	120.42%	137.77%
High Marsh	100.00%	59.11%	104.57%
Scrub/Shrub	100.00%	92.70%	40.61%
Upland	100.00%	77.07%	43.41%

HIGH CURVE

Habitat Acreage Change			
	Design (Year 0) acres	Year 20	Year 50
Shallows	6.51	7.90	0.00
Channel	2.79	2.93	0.00
Low Marsh	26.50	36.99	40.15
High Marsh	9.40	10.17	0.00
Scrub/Shrub	14.80	5.57	0.00
Upland	4.10	1.55	0.00

% of Design Acreage			
	Design (Year 0)	Year 20	Year 50
Shallows	100.00%	121.35%	0.00%
Channel	100.00%	105.02%	0.00%
Low Marsh	100.00%	139.58%	151.51%
High Marsh	100.00%	108.19%	0.00%
Scrub/Shrub	100.00%	37.64%	0.00%
Upland	100.00%	37.80%	0.00%

Table 4-27: Meadowlark Creek, Projected SLC –Driven Habitat Change

MEADOWLARK SEA LEVEL CHANGE

LOW CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Channel	4.60	4.63	4.42	**Channel**	100.00%	100.65 %	96.09%
Low Marsh	56.20	56.49	56.94	**Low Marsh**	100.00%	100.52 %	101.32%
High Marsh	6.50	6.42	6.32	**High Marsh**	100.00%	98.77%	97.23%
Scrub/Shrub	5.30	5.37	5.37	**Scrub/Shrub**	100.00%	101.32 %	101.32%
Upland	0.70	0.70	0.7	**Upland**	100.00%	100.00 %	100.00%

INTERMEDIATE CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Channel	4.60	4.60	4.60	**Channel**	100.00%	100.00 %	100.00%
Low Marsh	56.20	57.39	62.04	**Low Marsh**	100.00%	102.12 %	110.39%
High Marsh	6.50	5.38	5.94	**High Marsh**	100.00%	82.77%	91.38%
Scrub/Shrub	5.30	5.21	0.00	**Scrub/Shrub**	100.00%	98.30%	0.00%
Upland	0.70	0.70	0.70	**Upland**	100.00%	100.00 %	100.00%

HIGH CURVE

Habitat Acreage Change				% of Design Acreage			
	Design (Year 0) acres	Year 20	Year 50		Design (Year 0)	Year 20	Year 50
Channel	4.60	4.63	58.70	**Channel**	100.00%	100.65 %	1276.09 %
Low Marsh	56.20	64.27	16.72	**Low Marsh**	100.00%	114.36 %	29.75%
High Marsh	6.50	6.45	0.00	**High Marsh**	100.00%	99.23%	0.00%
Scrub/Shrub	5.30	0.00	0.00	**Scrub/Shrub**	100.00%	0.00%	0.00%
Upland	0.70	0.00	0.00	**Upland**	100.00%	0.00%	0.00%

4.2.2.7 Discussion

Results for each site are discussed below. A simplified metric, the percent of combined low and high marsh acreage relative to the design totals is presented as this provides a summary of overall performance. The year that MTL eclipses the low end of the low marsh range for each curve is also presented. For the low curve, this year is always outside the planning

horizon. It should be noted that the marsh habitats will have accrued considerable acreage in the preceding years, both through high to low marsh conversion and scrub/shrub to high marsh conversion, so this year merely represents the onset of marsh loss at the low end of the low marsh range. The net marsh acreage (and benefits) will remain higher than year 0 for some time due to this accrual. As expected, sites that are naturally afforded a gentle slope toward undeveloped upland areas perform better than those that do not. The discussions focus on the continued presence of low and high marsh, which will develop at the expense of high elevations communities if available. All sites perform well under the low SLC curve scenario, which is to be expected given the fact that the accretion rate is near, but less than, the low SLC rate. Sites also perform well under the intermediate SLC scenario. For the high SLC scenario, sites perform well at year 20 and most sites perform well at year 50, with exceptions that are then further analyzed.

4.2.2.7.1 Dead Horse Bay

Though the potential for migration at Dead Horse Bay is limited by the relatively steep slopes of the upper elevation habitats, the site affords ample room for wetland migration. This, along with the relatively high elevation for the low marsh vegetation range, results in projected overall good sustainability characterized by overall natural salt marsh expansion and negative impacts delayed until the later years of the project life cycle and only under the high curve.

Table 4- 28. Dead Horse Bay Salt Marsh, % of Design Acreage

Dead Horse Bay Salt Marsh (Low Marsh + High Marsh), % of Design Acreage			
	Design (Year 0)	**Year 20**	**Year 50**
Low Curve	100.00%	101.89%	102.70%
Intermediate Curve	100.00%	108.11%	123.40%
High Curve	100.00%	127.25%	84.34%

Table 4-29 Dead Horse Bay Projected Year of SLC Impact (Low End)

Projected Year of SLC impact	
Low Curve	Outside of Planning Horizon
Intermediate Curve	2078 (project year 41)
High Curve	2047 (project year 10)

4.2.2.7.2 Fresh Creek

Similar to Dead Horse Bay, Fresh Creek affords a reasonable amount of room for natural wetland migration and a relatively high low/marsh habitat range, resulting in good sustainability and natural marsh expansion. Marsh loss in the later years of the project life-cycle under the high curve is more marked and impacts the primary low marsh creation area at the head of the creek.

Table 4-30. Fresh Creek Salt Marsh, % of Design Acreage

Fresh Creek Salt Marsh (Low Marsh + High Marsh), % of Design Acreage			
	Design (Year 0)	**Year 20**	**Year 50**
Low Curve	100.00%	101.46%	97.37%
Intermediate Curve	100.00%	107.32%	110.63%
High Curve	100.00%	98.20%	68.73%

Table 4-31. Fresh Creek Projected Year of SLC Impact

Projected Year of SLC impact	
Low Curve	Outside of Planning Horizon
Intermediate Curve	2067 (project year 41)
High Curve	2049 (project year 20)

4.2.2.7.3 Jamaica Bay Marsh Islands

The five marsh islands of Jamaica Bay are discussed as a group given the similarities of environment, design approach ad projected performance. Unlike coastal sites, the marsh islands are limited in their ability to migrate toward upland elevations. Another fundamental difference is the somewhat lower design elevations. Having a relatively high existing conditions elevation at coastal sites both increases the sites' sustainability and reduces costs when excavation/ re-grading is needed to achieve lower design elevations, as is typical. For marsh islands, higher design elevations require more material, which results in higher costs. The trade-off between site resiliency and costs must therefore be carefully considered. The Marsh Islands show excellent performance under the low and intermediate curve scenarios. This is largely a result of providing an adequate amount of scrub/shrub area to allow for upward migration, however limited. The marsh islands perform less well under the high curve scenario and are projected to retain between 5% to 30% of the marsh design acreage. The percentage of remaining design marsh elevation at year 20 under the high curve scenario is generally excellent (from 85% to 124.5%). This indicates that the SLC driven deterioration largely takes place in the latter years of the project life cycle. To better understand project performance under the high curve scenario, area-tidal elevation curves were developed for selected sites that did not perform well year 50 under the high curve. This analysis is discussed in the next section.

Table 4-32. Jamaica Bay Marsh Islands Salt Marsh, % of Design Acreage

Duck Point Salt Marsh (Low Marsh + High Marsh), % of Design Acreage

	Design (Year 0)	Year 20	Year 50
Low Curve	100.00%	112.10%	112. 30%
Intermediate Curve	100.00%	115.31%	123.67%
High Curve	100.00%	124.52%	30.39%

Stony Creek Salt Marsh (Low Marsh + High Marsh), % of Design Acreage

	Design (Year 0)	Year 20	Year 50
Low Curve	100.00%	100.00%	102. 85%
Intermediate Curve	100.00%	103.79%	106.39%
High Curve	100.00%	111.38%	33.98%

Pumpkin Patch West Salt Marsh (Low Marsh + High Marsh), % of Design Acreage

	Design (Year 0)	Year 20	Year 50
Low Curve	100.00%	99.46%	99.10%
Intermediate Curve	100.00%	103.09%	103.05%
High Curve	100.00%	94.22%	4.98%

Pumpkin Patch East Salt Marsh (Low Marsh + High Marsh), % of Design Acreage

	Design (Year 0)	Year 20	Year 50
Low Curve	100.00%	101.48%	101.28%
Intermediate Curve	100.00%	104.59%	112.18%
High Curve	100.00%	84.98%	7.16%

Elders Center Salt Marsh (Low Marsh + High Marsh), % of Design Acreage

	Design (Year 0)	Year 20	Year 50
Low Curve	100.00%	106.59%	109.00%
Intermediate Curve	100.00%	108.47%	108.51%
High Curve	100.00%	107.32%	11.61%

Table 4-33. Jamaica Bay Marsh Islands, Projected Year of SLC Impact

Projected Year of SLC impact	
Duck Point	
Low Curve	Outside of Planning Horizon
Intermediate Curve	Outside of Planning Horizon
High Curve	2057 (project year 28)
Stony Creek	
Low Curve	Outside of Planning Horizon
Intermediate Curve	Outside of Planning Horizon
High Curve	2056 (project year 27)
Pumpkin Patch West	
Low Curve	Outside of Planning Horizon
Intermediate Curve	Outside of Planning Horizon
High Curve	2059 (project year 24)
Pumpkin Patch East	
Low Curve	Outside of Planning Horizon
Intermediate Curve	Outside of Planning Horizon
High Curve	2062 (project year 27)
Elders Center	
Low Curve	Outside of Planning Horizon
Intermediate Curve	Outside of Planning Horizon
High Curve	2058 (project year 23)

4.2.2.7.4 Flushing Creek

Flushing Creek affords a reasonable amount of room for natural wetland migration and a relatively high low marsh habitat range, resulting in good sustainability and natural marsh expansion. The project shows excellent performance under all three SLC scenarios. Sea level change calculated for the NOAA gauge at Kings Point, NY also rises at a somewhat lower rate than what is calculated at Sandy Hook, NJ and The Battery, NY, which are the two other reference gauges used in this analysis. It is also noted that the overall accretion rate assumed for this site likely overstates the actual accretion rate for this relatively sheltered creek, which would reduce project performance somewhat.

Table 4-34. Flushing Creek Salt Marsh, % of Design Acreage

Flushing Creek Salt Marsh (Low Marsh + High Marsh), % of Design Acreage			
	Design (Year 0)	**Year 20**	**Year 50**
Low Curve	100.00%	101.80%	103.84%
Intermediate Curve	100.00%	103.92%	108.83%
High Curve	100.00%	109.08%	102.13%

Table 4-35. Flushing Creek, Projected Year of SLC Impact

Projected Year of SLC impact	
Low Curve	Outside of Planning Horizon
Intermediate Curve	2079 (project year 50)
High Curve	2050 (project year 23)

4.2.2.7.5 Oak Island Yards

Oak Island Yards is a relatively constrained site, with steep slopes surrounding the area of low marsh on all three sides. Though the site performs well under the low and intermediate SLC curve scenarios, and well at Year 20 under the high curve scenario, it retains only 28.20 % of the design acreage at year 50 under the high SLC curve scenario. The inability to migrate inland negatively affects the sustainability of the low and high marsh acreage. The low end of the low marsh elevation range is 1.25 ft, which is relatively low when compared to the approach used at other tidally influenced sites, particularly given the high MTL projected for the time of construction (0.6 ft NAVD88.) As with the marsh islands, the performance at year 50 under the intermediate curve and at year 20 under the high curve indicate that the performance deteriorates in the latter years under the high curve scenario. Raising the lower edge of the low marsh vegetation range during the PED phase is recommended to improve project performance during the latter years of the project life cycle. Doing so will also lower construction costs by reducing excavation volumes. An area-tidal elevation curve was developed for Oak Island Yards and is discussed in the next section.

Table 4-36. Oak Island Yards Salt Marsh, % of Design Acreage

Oak Island Yards Salt Marsh (Low Marsh + High Marsh), % of Design Acreage			
	Design (Year 0)	**Year 20**	**Year 50**
Low Curve	100.00%	102.11%	103.73%
Intermediate Curve	100.00%	103.40%	106.97%
High Curve	100.00%	97.57%	28.20%

Table 4-37. Oak Island Yards Projected Year of SLC Impact

Projected Year of SLC impact	
Low Curve	Outside of Planning Horizon
Intermediate Curve	2070 (project year 33)
High Curve	2057 (project year 20)

4.2.2.7.6 Metromedia

The designs for this site perform well under all SLC scenarios, even though the site is not afforded the opportunity to migrate inland. This projected performance is simply attributed to good design. The site contains ample areas of scrub/shrub and maritime upland, thereby giving both low and high marsh room to migrate. Given the fact that restoration at this site entails excavation and onsite placement, the projected performance also indicates an efficient design that makes good use of excavated material placed onsite while also creating large areas of low marsh.

Table 4-38. Metromedia Salt Marsh, % of Design Acreage

Metromedia Salt Marsh (Low Marsh + High Marsh), % of Design Acreage			
	Design (Year 0)	**Year 20**	**Year 50**
Low Curve	100.00%	107.20%	121.30%
Intermediate Curve	100.00%	104.36%	129.08%
High Curve	100.00%	131.36%	111.84%

Table 4-39. Metromedia Projected Year of SLC Impact

Projected Year of SLC impact	
Low Curve	Outside of Planning Horizon
Intermediate Curve	2073 (project year 42)
High Curve	2050 (project year 19)

4.2.2.7.7 Meadowlark

As with Oak Island Yards, it is recommended that the lower edge of the low marsh vegetation range for this site be raised during the PED phase, thereby improving performance and reducing excavation costs. Meadowlark is a particularly complex site, with complex hydrology. Further study is needed and, given the constrained hydrology of the site, a more detailed hydrodynamic modeling effort is recommended. Modeling, and a better understanding of the tidal dynamics of this site, may allow for an optimization of more detailed designs with regards to sea level change.

Table 4-40. Meadowlark Salt Marsh, % of Design Acreage

Meadowlark Salt Marsh (Low Marsh + High Marsh), % of Design Acreage			
	Design (Year 0)	Year 20	Year 50
Low Curve	100.00%	99.92%	99.07%
Intermediate Curve	100.00%	89.75%	50.34%
High Curve	100.00%	112.79%	26.67%

Table 4-41. Meadowlark Projected Year of SLC Impact

Projected Year of SLC impact	
Low Curve	Outside of Planning Horizon
Intermediate Curve	2081 (project year 46)
High Curve	2055 (project year 20)

4.2.2.8 Area -Tidal Elevation Curves

To better understand project performance during the latter years under the high curve, area – elevation curves were developed for three sites, Duck Point, Pumpkin Patch East and Oak Islands Yards, that did not a large percentage of saltmarsh remaining by year 50. The projected year of SLC impact for the high curve has a mean value of 21.9 years. As previously noted, the restored sites have generally expanded salt marsh acreage at this point due to high to low marsh and scrub/shrub to high marsh conversion. This indicates that good performance well beyond year 20 despite the low percentage of remaining salt marah at year 50. It was decided that analyzing three sites using this approach was sufficient given the similarities of the trends seen in the prior analysis.

4.2.2.8.1 Method

The year 50 raster elevation surfaces were used in this analysis. High curve MTL levels for project years 10 through 60 were calculated in five year increments based on the sea level rise calculator output. The area above each of these datums was calculated using the ArcGIS Surface Volume tool, which measures the volume and area above or below a user input value. These output acreages were then converted to percentages of the original area and are presented as a curve in the figures below. It should be noted that this approach shows the change in total restored area as opposed to changes in individual habitat communities calculated in the sea level change impact analysis. It is also noted that the total acreage incudes shallows and channels, areas that are not planted.

4.2.2.8.2 Duck Point

Prior analysis indicated that SLC impacts to the low end of the low marsh elevation range at Duck Point begin in project year 28 (2057) and that the site has 127.25% of the salt marsh design

acreage at this point in time. The area-tidal elevation curve (Figure 4-18) supports these findings and indicates that the site retains 96% of the original area when measured against the year 20 MTL. The site continues to perform well through year 40, at which time the percent of restored area above MTL decreases to only 72%. After year 40 (2069), the acreage above MTL begins to diminish rapidly and reaches 37% by year 50 (2079), the end of the planning horizon.

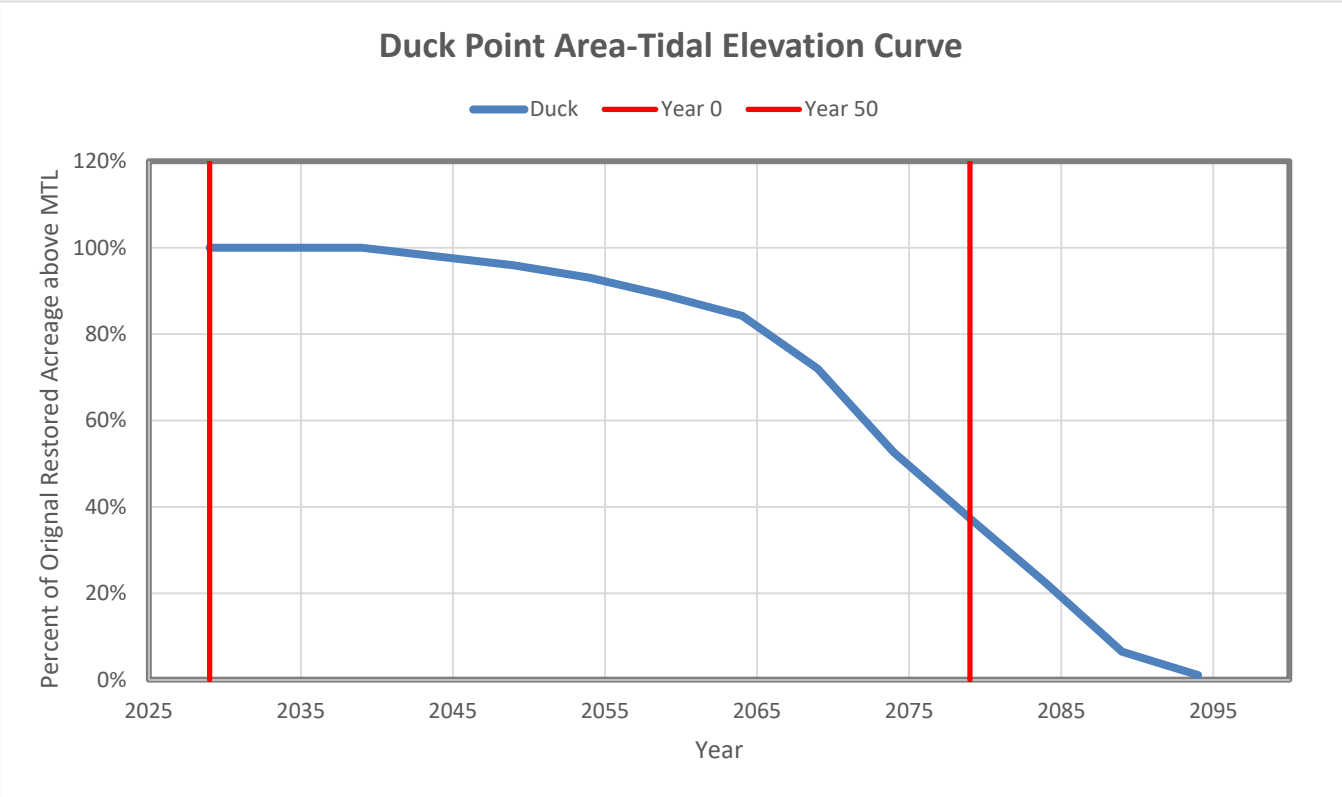


Figure 4-19. Duck Point Area – Tidal Elevation Curve.

4.2.2.8.3 Pumpkin Patch West

Prior analysis indicated that SLC impacts to the low end of the low marsh elevation range at Pumpkin Patch West begin in project year 24 (2059) and that the site has 127.25% of the salt marsh design acreage at his point in time. The area-tidal elevation curve (Figure 4-19) supports these findings and indicates that the site retains 96% of the original area when measured against the year 20 MTL. While this percentage is identical to what was seen at Duck Point, the decline at Pumpkin Patch West is somewhat more rapid. The site retains 35% of the original restored

acreage at year 35 (2070) and then 53% at year 40 (2075). As with Duck Point, acreage diminishes rapidly and reaches 21% at year 50 (2085.)

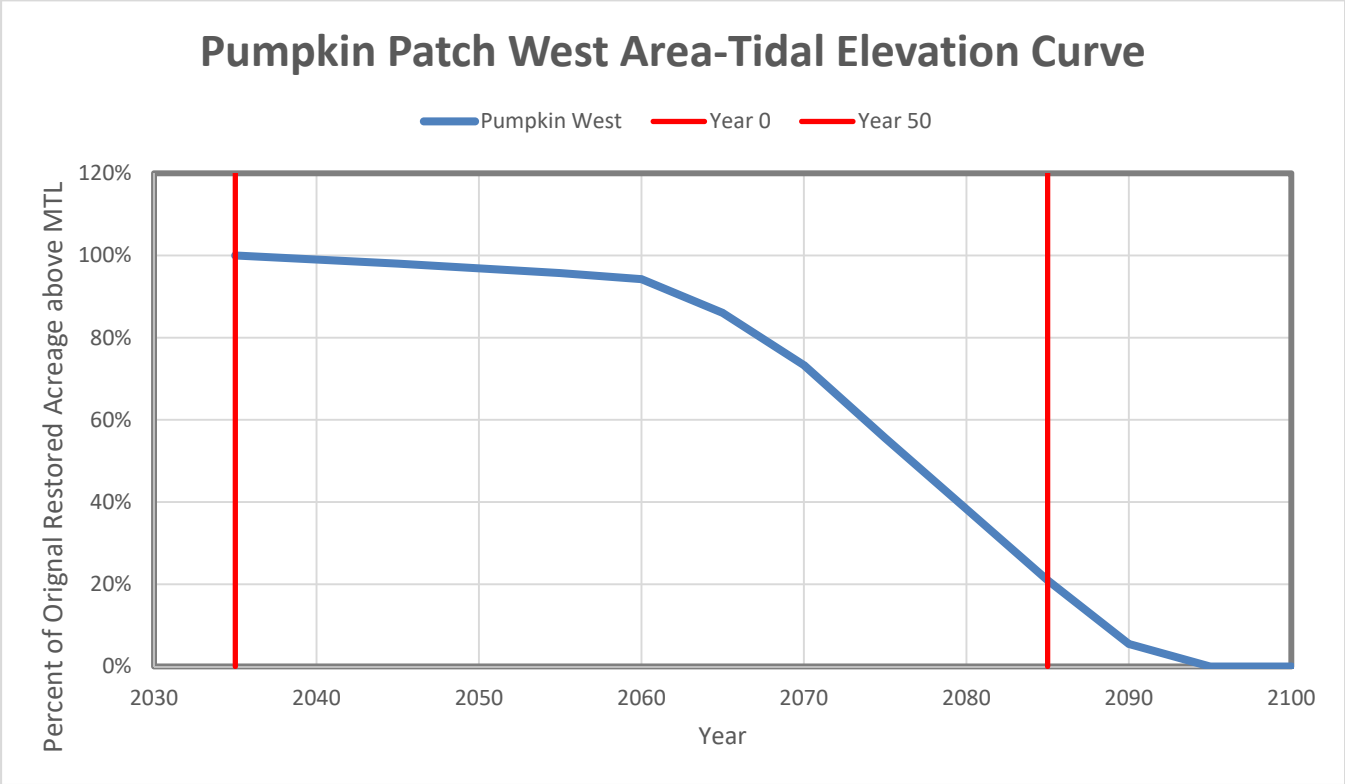


Figure 4-20. Pumpkin Patch West Area – Tidal Elevation Curve

4.2.2.8.4 Oak Island Yards.

Oak Island Yards has a significant upland component along the landward edge. This area was not considered in this area- elevation analysis as they are well above the tidal range and would skew the results. The area of analysis is indicated in Figure 4-20.



Figure 4-21. Oak Island Yards Area – Tidal Elevation Curve Analysis Extent.

Prior analysis indicated that SLC impacts to the low end of the low marsh elevation range at Oak Island Yards begin in project year 20 (2057) and that the site has 97.57% of the salt marsh design acreage at this point in time. The area-tidal elevation curve (Figure 4-21) supports this finding and indicates that the site will retain 100% of the total design salt marsh acreage in Year 20 (2057) and 99% in Year 25 (2062.) the acreage above MTL then begins to diminish rapidly and reaches 22% by year 50 (2087.) The decrease in acreages at this site after year 20 is most the most pronounced and is a reflection of the constrained nature of this site, where this is little room for marsh migration. It is recommended that the 1) the low end of the low marsh range at this site be raised from 1.25 to 1.5 or 1.6 ft NAVD88 and 2) a greater percent of the primary salt marsh area here be allocated to high marsh. Doing these measures will both increase the site

resiliency and decrease excavation costs as the restoration of this site involves considerable lowering of the existing condition elevations.

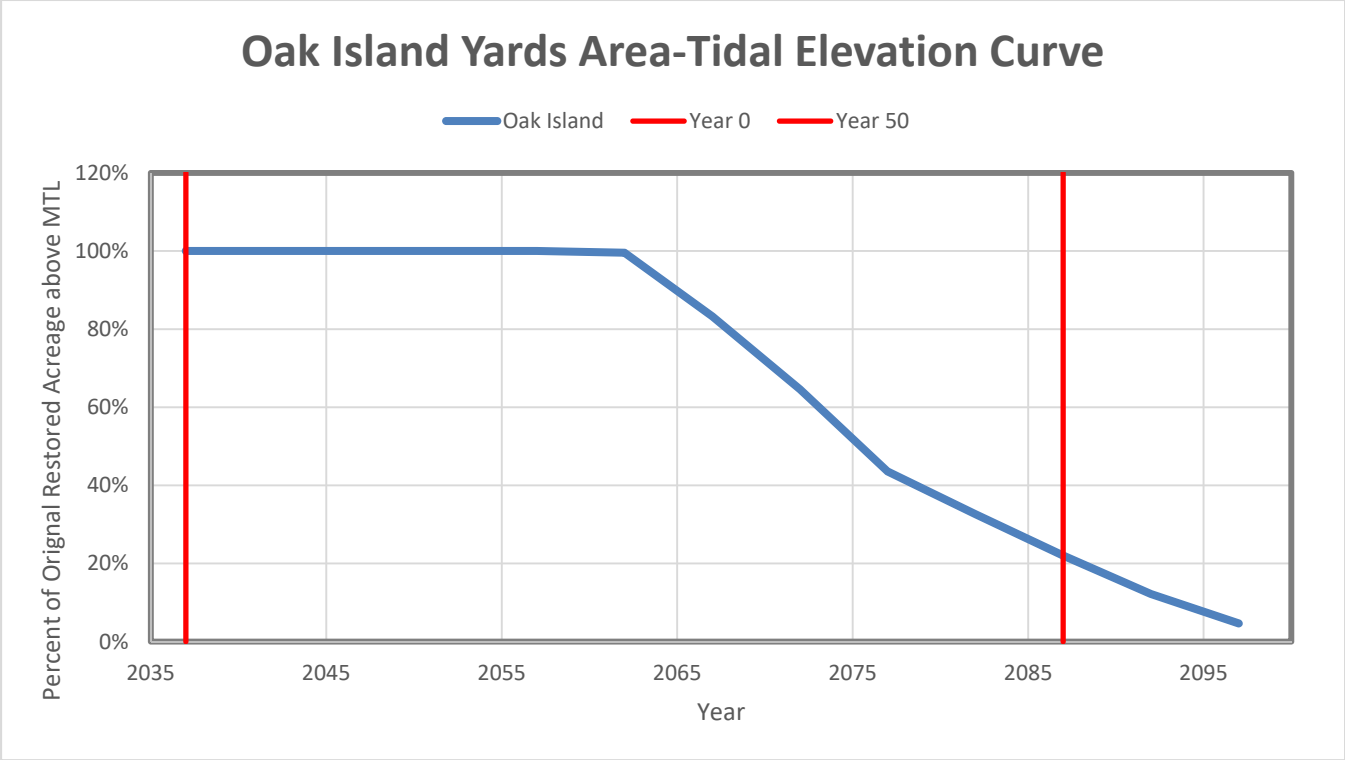


Figure 4-22. Oak Island Yards Area – Tidal Elevation Curve

4.2.2.9 Conclusion

This sea level rise analysis indicates that a high degree of resilience has been incorporated into these designs. All sites perform well under the low and intermediate curves and most perform well under the high curve. The initial analysis conducted for site alternatives informed the detailed design executed at this stage of this feasibility study and the present analysis both confirms the performance of the designs and provides insight on how designs may be improved during the PED phase (A discussion on future development is included below in this document) particularly for those sites that did not perform well during the later years of the high curve. Though there were a number of sites that did not perform well during the latter years under the high curve (generally, years 30 to 50) the risk for these sites is deemed to be low given the wide range of possible future SLC rates. The sites perform well, with some exceptions for the most extreme projected SLC rates. Giiven the fact that the typical marsh range is approximately 3 ft (MLW to MHHW) and the 50 year rise in water surface elevations under the high curve is nearly 3 ft (2.79 ft from 2030 to 2080 at Sandy Hook, high curve) negative impacts under this scenario are simply unavoidable.

5 Discussion of Restoration Measures

5.1 Wetland Restoration/Creation

5.1.1 Estuarine Tidal Wetlands Restoration/Creation

5.1.1.1 Invasives Species Removal and Control

In the context of Estuarine Tidal Wetlands, invasive species removal primarily involves the removal of *phragmites australis* and serves as a precursor to wetland restoration actions. The elimination of Phragmites is accomplished through a combination of measures. Herbicide applications as approved by the regulatory agencies for use near regulated waters will be applied in the late summer/early fall to maximize effectiveness on target species and avoid impacts to native vegetation. This is followed by mowing and the removal of the phragmites root mat during clearing and grubbing. The restoration of low marsh in itself often serves as a control as increased periods of inundation often preclude the reestablishment of Phragmites from surviving rhizomes. This however is not true for the upper elevations range of the salt marsh. Here it is critical to remove as much of the root mat as practicable. Finally, repeated and targeted herbicide applications are needed and constitute an important element of the maintenance and adaptive management strategies for these sites.

5.1.1.2 Salt Marsh Restoration/Creation

Estuarine Tidal Wetlands Restoration/Creation is proposed for many sites. This will typically occur in areas that have been overcome with invasive species such as *phragmites australis*. Clearing and grubbing will remove much of the Phragmites root mat and this material will be removed offsite. One foot of clean growing medium will be placed prior to planting. In some instances (Marsh Islands and in select intratidal mudflat areas of Flushing Creek), low marsh restoration/creation will occur through the placement of clean sand to elevations appropriate for Low Marsh.

5.1.1.2.1 Low Marsh

Low marsh typically grows in the elevation range between MTL and MHW, with a higher success rate toward the upper bounds of that range. Elevation ranges for low marshes were therefore set to 0.75 to 1.5 foot above MTL, thus enhancing success rates and providing a measure of resilience to sea level change. Low marsh will be planted with spartina alterniflora. Plugs/peat pots will propagated at a nursery using local plant stock, and will be spaced at on on-center distance of two feet. Plug and peat pots will be hand planted.

5.1.1.2.2 High Marsh

High marsh plantings will include grasses and shrubs. Distichlis spicata and spartina patens plugs/peat pots will be propagated at a nursery using local plant stock, and will be spaced at on on-center distance of 2 feet. Shrubs may include *Baccharis halimfolia, Iva frutescens and myrica*

penslvanica, and will typically be planted at a rate of 100 shrubs per acre, or at an on-center spacing of approximately 12 feet.

Herbivory fencing will be used to protect the low and high marsh zones from grazing by geese and other waterfowl. Six-foot high construction fence will be used to create 50' x 50' cells within the low and high marsh zones. Cells should be constructed in groups of no more than six or eight, and should be separated by a two feet wide walkway to access the cells for proper monitoring.

5.1.1.3 Scrub-Shrub Restoration/Creation

Scrub-shrub creation is proposed for Tidal Salt Marsh sites. The proposed areas will be cleared and grubbed of all existing invasive species, re-graded and planted with native salt-tolerant species appropriate for a scrub-shrub vegetation community. One to two feet of clean growing medium will be placed prior to planting. Grass plugs (Ammophila breviligulata) will be planted at a rate of 4,840 plants per acre, or at an on-center spacing of approximately three feet. Forbs will be planted at a rate of 1,452 plants per acre, or an on-center distance of approximately 5 feet. Whip shrubs and gallon-size shrubs will be planted at a rate of 680 shrubs per acre. Approximately 50% of Scrub-Shrub areas will be planted with whip shrubs and 50% will be planted with gallon-size shrubs mixed evenly among the three species, which include Baccharis halimfolia, Iva frutescens and myrica penslvanica. Whip shrubs and gallon-size shrubs will be intermixed evenly and planted 8 feet on-center over the entire area. Scrub-shrub planting also includes seeding of the area with a warm season/ grassland native seed mix at a rate of 10 to 15 pounds per acre.

5.1.1.4 Maritime Forest Restoration/Creation

Upland areas of Estuarine Tidal Wetlands will often serve as placement sites for excavated material and will be restored to habitat communities that enhance a sites resiliency and sustainability by inhibiting the reinvasion of unwanted species and an appropriately graded upper boundary that promotes wetland migration of tidal wetlands in response to sea level change.
Proposed areas will be cleared and grubbed of all existing invasive species, re-graded and planted with native salt-tolerant species. Two feet of clean growing medium will be placed prior to planting. Ferns and forbs will be planted 3 feet on center; gallon-size shrubs, including *Baccharis halimfolia*, Iva *frutescens* and *myrica penslvanica*, will be planted 8 feet on center and will be evenly mixed among the 3 species. Three types of trees will be planted, including 1-ft to 4-ft canopy trees, 5-ft to 6-ft whip canopy trees and 1-gallon understory trees. All trees will be planted at 10 feet on center, evenly mixed among the 3 types, as directed by the on-site biologist. The particular species of ferns, forbs and canopy trees will be determined during the next phase of the project. Maritime forest planting also includes seeding of the area with a warm season/ grassland native seed mix at a rate of 10 to 15 pounds per acre.

5.1.1.5 Tidal Channel Creation/ Restoration

Tidal channels will be restored and/or created where appropriate. Channels will enable tidal exchange within the sites, helping to sustain the planted wetlands and other vegetation communities. Tidal channel inverts are set at an elevation below MTL to ensure flow more than 50% of the time.

5.1.2 Freshwater Wetland Restoration/Creation

Wetlands provide several ecological benefits including wildlife habitat, floodwater retention, carbon sequestration and improved water quality. Present designs were developed without the benefit of site-specific hydraulic modeling or water budgets. Because the success of wetlands is tied directly to hydrologic conditions, the localized hydrology should be thoroughly investigated during the design phase of study for each site.

5.1.2.1 Emergent Wetlands Restoration/Creation

The restoration/creation of emergent wetland assumes excavation to an appropriate elevation, here estimated to be between the 1-yr flood elevation and 1 foot below. Following clearing and grubbing the areas will be re-graded and topped with 6 inches of topsoil prior to being planted with appropriate native wetland vegetation. All material from clearing and grubbing will removed offsite. Where warranted, tie protection measures will be taken (discussed below).

5.1.2.2 Forested and Scrub-Shrub Wetland Restoration/Creation

Riparian scrub-shrub is found along edges of lakes and streams with sandy soils, and is characterized by large native shrubs that have adapted to high moisture levels and frequent flooding. Scrub-shrub includes many flowering plants that provide nectar, seeds and insect foods needed by bird species that nest and seek cover there.

Construction requires excavation to an appropriate elevation to support the forested/scrub-shrub wetlands, assumed to be between the 1-yr and 5-yr flood elevations for scrub-shrub and between the 5-yr and 10-yr flood elevations for forested wetland. The areas will be planted with native vegetation. A thorough hydrographic study of the area should be conducted during the next phase of study to ensure proper design elevations.

5.1.2.3 Wet Meadow Restoration/Creation

Wet meadows are a type of marsh that commonly occur in poorly drained areas such as shallow lake basins, low-lying farmland and the land between shallow marshes and upland areas. For most of the year wet meadows are without standing water. During periods of high rainfall, wet meadows collect runoff and their vegetation remove excess nutrients, acting as a natural filter. This nutrient rich environment provides vital food and habitat for many insects, amphibians, retiles, birds and mammals. Wet Meadow restoration/creation assumes excavation to an elevation that will allow continual soil saturation from groundwater. After excavation is completed

the area will be planted with native vegetation. A thorough investigation of localized hydrology should be conducted during the next phase of study to refine proper design elevations.

5.1.2.4 Invasives Species Removal/Native Plantings

Invasive species vegetation competes directly with desirable native species for sunlight, moisture, nutrients and space. Some species have aggressive root systems that spread long distances from a single plant, which can grow so densely that they smother the root systems of surrounding vegetation. The spreading of invasive species results in the decrease in plant diversity and the degradation of wildlife habitat.

The removal of invasive species serves as a preliminary activity for many restoration measures or may be executed for specific areas, followed by the planting of native vegetation. Removal can be accomplished by utilizing mechanical, chemical, and biological controls. Mechanical control involves cutting or pulling of plant material. Chemical control involves acute application of herbicides to target invasive plants. Herbicide treatment should be timed appropriately to maximize effectiveness on target species and avoid impacts to native vegetation.

5.2 Streambank Restoration

Restoring a shoreline can provide numerous benefits including bank stabilization, increased opportunity for vegetation growth, reduced erosion potential, and protection from the impacts associated with sea level rise and storm surge. The shoreline restoration techniques proposed vary from hard armoring approaches such as Stacked Rock Walls with Brush Layers to softening bank slopes and establishing vegetation. The type of technique ultimately depends on the topography and bathymetry of the immediate area. Dramatic changes in elevation over a short distance require a hard engineering approach, while softer approaches can be utilized when the elevation change is less dramatic or there is space available to move landward to soften the slope. Armored approaches may be avoided by softening bank slopes to a maximum of five feet horizontal to one foot vertical and establishing vegetation; however, in high energy systems, an energy dissipater should be included along the water's edge.

Site specific hydraulics is also of paramount importance and will be further investigated during the PED phase of each site. The restoration approaches proposed here capture a wide range of costs and effectiveness, seeking to balance effectiveness and ecological lift. Further study may indicate alternative techniques but it is expected that any changes would be a matter of degree in terms of cost, effectiveness of stabilization and ecological lift relative to the proposed approaches.

5.2.1 Shoreline Softening

In areas where armoring structures cannot be removed, shorelines can be softened by adding structural features that support terrestrial and aquatic species and desirable ecological functions. Timber, live stakes, root wads, and vegetative mats are natural shoreline softening materials (NYSDEC, 2016).

This technique is presently proposed at only one site, where there is an existing hard bank stabilization structure (Garth Woods/Harney Road). Holes will be drilled into the existing structure, into which live stakes, such as willow, will be placed. The cut ends of the stakes must be anchored into the soil behind the existing structure so that it can take root in the soil behind the existing hardened structure. The technique may be advanced at other locations where further study indicates that it is not advisable to remove existing hard bank stabilization due to bank stability concerns.

Holes will be drilled in rows spaced 2 feet vertically along the length of the hardened structure. The holes in each row are spaced 2 feet apart; rows are staggered for maximum coverage. It is assumed that the bottom row is planted at an elevation between the base flow elevation and the 2-year flood elevation. The number of live stakes required is increased by 10% to allow for a minimal expected degree of mortality.

5.2.2 Stacked Rock Wall with Brush Layers

Stacked rock walls are appropriate where a low wall may be required to stabilize the toe of a slope. Live branch cuttings can be placed in the spaces between the rocks as they are placed. The cut ends of the branches should extend into the backfill behind the wall. A toe trench will be excavated into the channel bed at the base of the stream bank and will be filled with rock. Up to four rows of stacked rock will be used, the first of which will be excavated into the toe of the slope inland of the toe trench. Typical rock diameter will be 3 feet. The bank behind the rock wall will be excavated to a stable slope; that volume of material will be replaced with a granular filter to promote drainage. A geotextile will underlay the bottom of the footer rock and it will extend up to the top of the bank behind the stacked rocks, separating the rock from the granular material. The geotextile will be keyed into the top of the bank. 6 inches of topsoil will be placed on the disturbed surface behind the rock wall. The area will be planted with appropriate vegetation.

5.2.3 Brush Mattress

A brush mattress is a combination of live stakes, live fascines, and branch cuttings installed to cover and stabilize streambanks. Brush mattresses are used to form an immediate, protective cover over the streambank. A thick mat of dormant cuttings is placed on the bank and held down with stakes. The goal of a brush mattress is to create structural streambank protection that will eventually root and provide vegetative stabilization. This technique is often used in conjunction with other methods such as live stakes and stone toe protection.

5.2.4 Boulder Toe Revetment

A Boulder Toe Revetment is a low boulder wall and footing constructed for the purpose of infrastructure and bank protection, and creating a shear stress relief bench within a channel feature. Applications include the ability to maintain bankfull or base flow channel dimensions within a high-stress or entrenched channel environment. This measure also includes a geotextile

fabric layer which will underlay the bottom of the footer rock that will extend up to the top of the bank behind the stacked rock to prevent soil movement into and through the feature.

5.3 Stream Restoration

5.3.1 Channel Restoration

There are a number of benefits to channel restoration, which can include habitat enhancement for native fish species, restoration of hydrologic function within the channel and the reduction of downstream sediment deposition. Here, channel restoration includes the removal of existing material (sediment build-up) from the channel bottom, the narrowing of over-widened channels, possible deepening to promote greater circulation within the channel and the restoration of natural channel dimensions. Replacement material is based on flow-velocity.

5.3.2 Riverbed Restoration

Restoration of a riverbed with stone reduces erosion of the streambed and provides valuable habitat for numerous beneficial organisms. It also provides a valuable substrate for use by desirable fish species to spawn. This measures may also include the creation of sustainable riffle/pool complexes.

5.3.3 Stream Naturalization and Clearing

Stream naturalization and clearing refers to the widening of overly narrowed channels. This measure will involve excavation along the stream banks, where necessary, to remove overgrowth and to grade the stream bank to better support various vegetation communities and establish sustainable flow velocities.

5.3.4 In-Stream Structures

In-stream structures encompass measures designed to achieve a range of improvements including sediment control, grade control, the creation of riffle-poll complexes and bank stabilization.

5.3.5 Sediment Forebay

The movement of sediment within a stream channel is a natural and necessary process that helps to maintain stream stability and habitat. It may become a problem when the supply of sediment exceeds the ability of the stream to transport it. Excess sediment within a stream often leads to deposition within the channel. The resulting aggradation tends to hasten the widening of the channel and can exacerbate bank erosion. Reducing the rate of sediment supply can be achieved with an in-stream sediment forebay, where excess sediments are trapped. As forebays are only useful when they are not full, it is necessary to occasionally remove trapped sediments in order to maximize the forebay's utility.

5.3.6 Rock Vanes

A rock vane is a low profile in-stream structure that decreases shear stress, velocity and stream power in the near-bank region by redirecting energy toward the center of the channel.. The structures establish riffle-pool complexes, may establish grade control, and reduce bank erosion. Pools provide deep slow-moving water in which fish can rest and are also a place for organic material to deposit. Riffles generate faster moving water that create habitat for mayflies, stoneflies and caddisflies, where they hide in the gravel bottom.

Each rock vane arm will be angled 20 to 30 degrees from the upstream bank and shall span approximately one third of the channel bankfull width with the throat of the cross vane occupying the center third of the bankfull channel width. Rock vane stones shall be rectangular and blocky in shape such that they are stackable, and should be of sufficient size to resist displacement based on an site-specific design storm event (to be determined in the PED phase.) Footer rocks should be large enough to achieve the desired height when installed in the stream.

5.3.7 J-Hooks

A J-hook vane is a single arm low profile grade control structure that decreases shear stress, velocity and stream power in the near-bank region, while also increasing energy in the center of the channel to promote pool development. It is typically built on the outside of meander bends and can be used to promote stream sinuosity as well as achieve the benefits detailed of a rock vane structure. General material specifications for J-hooks are similar to those of rock vanes.

5.3.8 Bioretention Swales and Depressions

Bioretention basins and swales are landscaped depressions that filter solids and pollutants that might otherwise be carried to a river or stream. Trapping sediments before they can reach a water body can help to reduce the degradation of habitat for fish and other organisms.

5.3.9 Aquatic Organism Passage (Fishway)

A technical fishway is proposed at two locations. An aluminum fish passage structure will be constructed within a concrete frame that will allow fish species to travel upstream. A temporary cofferdam will be constructed to divert the stream flow while the fishway is being constructed. Boulders will be placed in the stream at the base of the fishway to guide fish into the structure. Boulders will also be placed downstream of the eastern spillway to further encourage fish to enter the structure.

5.3.10 Weir Modification

Two existing weirs will be lowered to promote fish passage. The extent of lowering will be determined through more detailed hydraulic modeling to establish an optimum height that facilitates fish passage while supporting upstream restored wetlands.

5.4 Oyster Restoration

5.4.1 Spat on Shell

Spat on shell is deployed on the bathymetric surface by first laying a bed of rock or rubble, on top of which is placed a veneer layer of mollusk shell. Spat is cast so that is settles on the shell where it can take hold. Spat-on-shell alone is suitable for use in lower energy environments with firm substrate. It can also be used in combination with other restoration techniques that adequately shelter the material from strong currents and smothering by sediments, and prevent its sinking into loose substrate.

5.4.2 Oyster Gabions

Gabions are wire cages filled with oyster shell that has been pre-seeded with spat; the cages are then placed on the bathymetric surface. Gabions, when deployed in groups, can help to create a reef structure and are more resistant to oyster poaching.

5.4.3 Oyster Castles

Oyster “castles” are small masonry blocks that have many nooks where oysters can attach themselves. The overall dimensions of the castles used at the Head of Jamaica Bay and Earle Naval Station sites are 12” long x 8” wide x 12” high. “Pyramids” are created by stacking and interlocking 30 oyster castles, having a base of 16 castles, a second row of 9 castles, a third row of 4 castles and topped with a single castle. The pyramids are then treated with shell that has been pre-seeded with spat.

5.4.4 Hanging Super Trays

Hanging super trays are mesh crates that are suspended in the water column, either by means of floats or cable, and are filled with shell seeded with spat. They are typically placed above a bed of shell or rubble. As water circulates through the trays, the spat gradually disperses into the water column and settles onto the prepared bed below.

5.4.5 Porcelain as Substrate

NY Department of Environmental Protection has approved the use of crushed porcelain as a substrate for oyster colonies when possible. Porcelain is crushed and repurposed from discarded fixtures such as toilets and sinks, which keeps these items out of landfills.

6 Quantities and Designs

6.1 Quantities

6.1.1 Excavation Volumes

Typically, designs and grading plans were developed using Bentley MicroStation InRoads, v. SS2. Quantities were taken from the surfaces created in InRoads. Regarding those sites for which further analysis is needed to better establish design details, quantities were developed in an ArcGIS environment using simple volume calculations (area x depth). Excavated quantities were calculated in cubic yards.
Grading was measured in total acres of disturbance where any earthwork and final contouring of the sites was required.

6.1.2 Clearing and Grubbing

Clearing and grubbing, the removal of unwanted surface and subsurface material, is planned for all areas wetland and upland restoration. Clearing and grubbing quantities where derived by means of simple (area x depth) volumetric calculations using the site-specific depths. All material from this activity will removed offsite to prevent the reestablishment of unwanted species.

6.1.3 Plantings

Quantities for plantings were developed using the spacings recommended by the study team biologist. Based on these spacings, quantities were calculated on a per acre basis.

6.1.4 Growing Medium

Volumes of Growing Medium, the site-specific appropriate material (typically sand or topsoil) for promoting vegetation growth, where derived by means of simple (area x depth) volumetric calculations using the site-specific depths.

6.1.5 Shoreline Softening

Shoreline softening quantities were developed by calculating the number of holes to be drilled and the number of live stakes to be installed along the linear feet of streambank where this action is planned. It is assumed that holes are drilled in rows spaced two feet vertically along the length of the hardened structure. The holes in each row are spaced two feet apart; rows are staggered for maximum coverage. The number of live stakes required is increased by 10% to allow for a minimal expected degree of mortality.

6.1.6 Stacked Rock Wall w/Brush Layers

Stacked rock walls with brush layering are useful along steep slopes that require stabilization. Gabions can also be used when the rock size needed is not locally available. The rock size is conservatively based on the highest shear stress along the shoreline within the appropriate reach in the 2005 SIAM HEC-RAS model (Rosgen). The trench stone size is conservatively based on the maximum velocity within the channel reach using the Ibash equation (USDA 1996). Rock density for the stacked rocks is assumed to be 165 lbs/cf. A 10% void ratio is assumed for the toe trench stone, resulting in 148.5 lbs/cf. The trench has an assumed area of three feet x three feet. The quantity of toe trench stone needed is increased by 10% to account for minor

losses during placement. Density of the granular fill behind the rock wall is assumed to be 165 lbs/cf. The quantity of granular fill needed is increased by 10% to account for minor losses during placement.

Live stakes are planted 2 feet apart between each course of rock; rows of vegetation are staggered for maximum coverage. The number of live stakes required is increased by 10% to allow for a minimal expected degree of mortality.
It is assumed that 30 linear feet/foot of geotextile will be needed per linear foot of shoreline. The quantity of geotextile is increased by 10% for expected damage and other losses during placement.

It is assumed that grass will be planted at the top of the slope behind the last course of rock. A six inch depth of topsoil is assumed for a distance of 10 feet behind the rock wall. The quantity of topsoil needed is increased by 20% to account for losses during placement.

6.1.7 Brush Mattress

Brush Mattress is used in conjunction with stone toe protection. A geotextile will underlay the stone trench and rock wall, and extend behind the top course of rock. Brush Mattress quantity development assumes that live cuttings will be layered in bundles at a rate of 15 branches per linear foot (ERDC TN-EMRRP-SR-23). The cuttings will be secured with coir twine, which will be held in place with stakes spaced 12 inches apart. It is assumed that the coir twine will be deployed at a rate of 20 feet per linear feet of shoreline. The quantity of cuttings will be increased by 10% to account for a minimal expected degree of mortality.

6.1.8 Boulder Toe Protection

Boulder toe size is conservatively based on the highest shear stress along the shoreline within the appropriate reach in the 2005 SIAM HEC-RAS model. The trench stone size is conservatively based on the maximum velocity within the channel reach using the Ibash equation (USDA 1996). Rock density for the stacked rocks is assumed to be 165 lbs/cf. A 10% void ratio is assumed for the toe trench stone, resulting in 148.5 lbs/cf. The trench has an assumed area of 3 feet x 3 feet. The quantity of toe trench stone needed is increased by 10% to account for minor losses during placement. Density of the granular fill behind the rock wall is assumed to be 165 lbs/cf. The quantity of granular fill needed is increased by 10% to account for minor losses during placement.

It is assumed that 30 linear feet/foot of geotextile will be needed per linear foot of shoreline. The quantity of geotextile is increased by 10% for expected damage and other losses during placement.

6.1.9 Channel Restoration

Channel restoration will include the excavation of existing channel bottom material (assumed to be silt) and its replacement with angular stone. At Shoelace Park, existing material will be

excavated to an assumed depth of 1 foot, which will be removed offsite and a 1-foot depth of angular stone will be placed at the channel bottom. At Bronxville Lake, existing material will be excavated to an assumed depth of 7 feet and replaced with 2 feet of angular stone, for a net excavated depth of 5 feet. Stone size is conservatively based on the maximum velocity within the Shoelace Park channel reach using the Ibash equation (USDA 1996). The assumed density of the angular stone is 165 lbs/cf with an assumed void ratio of 10%, for a net density of 148.5 lbs/cf.

6.1.10 Channel Deepening

The volume of material excavated for channel deepening, a measure to be implemented at Branch Brook Park, was developed with an assumed depth of two feet. Approximately 55,000 cubic yards of material will be hydraulically excavated from a channel area of 17 acres. The material will be stockpiled onsite and allowed to drain, after which it will be removed from the site

6.1.11 Riverbed Restoration

River bed restoration includes excavation within the stream but outside of the limits of the channel, and can include cutting into the stream banks. Bed restoration at Bronxville Lake was based on a very rough graphical layout of the site using one-foot contour topographic maps available from ESRI. Excavated bed material will be removed offsite. In areas where the bed is excavated to create widened but flat areas outside the channel, a one-foot layer of angular stone will be placed to create suitable fish habitat. Cross-sections were assumed based on the graphical site layout and proposed planting communities.

6.1.12 Stream Naturalization and Clearing

Stream naturalization at the Branch Brook Park site is based on a coarse graphical layout of the site and one-foot contour topographic mapping available from ESRI. A two-foot excavation depth was assumed over the area of naturalization. It is assumed that excavated material will be removed offsite.

6.1.13 Rock Vanes and J-Hooks

The rock size for vanes and J-hooks are conservatively based on the highest shear stress along the shoreline within the appropriate reach in the 2005 SIAM HEC-RAS model. Two layers of rock were assumed; a base layer and a top layer. It is assumed that the base layer has two rows of rock and that the top layer has one row. The length of the vanes and hooks are dependent on the width of the channel. Channel widths are based on representative cross-sections found in the HEC-RAS model for each reach.

The length of the vane and j-hook tie-ins are assumed to be ¼ the width of the channel. It is assumed that the tie-ins also have two layers of rock. Rock density for the vanes, j-hooks and tie-ins is assumed to be 165 lbs/cf.

In-stream excavation for the placement of the rock assumes a depth and width slightly larger than the diameter of the rock for ease of maneuverability and placement. It is assumed that all excavated material will be removed from the site.

6.1.14 Sediment Forebay

Forebay placement at the Bronxville Lake site was based on a coarse graphical layout of the site using one-foot contour topographic maps available from ESRI. The length and shape of the forebay correspond roughly with the elevation 83-foot (NAVD88) contour. Cross-sections of the forebay were assumed based on the graphical site layout and available topography. On average, it is assumed that one to two feet of bed material will be excavated and removed from the site. Sediment will be trapped behind a downstream rock berm/weir which will prevent it from continuing downstream to the proposed channel and bed restoration areas. The top elevation of the berm will be determined during the design phase, but should be able to pass the base flow.

6.1.15 Bioretention - Swales and Depressions

Excavation for bioretention swales assumes an excavation depth of 6.5 feet followed by backfilling with one foot of washed stone underdrain material, two feet of clean filter medium and 0.5 feet of mulch for a net excavated depth of three feet. For simplicity, quantities were developed by assuming a square or rectangular area and excavating the volume of a uniform inverted truncated pyramid

6.1.16 Aquatic Organism Passage

Passages are proposed for both the Bronx Zoo Dam site and the Stone Mill Dam site. The designs and quantities for the passages at the two sites are as proposed by the NY City Parks Department. Corps responsibility at the Stone Mill Dam site includes providing a rock substrate at the entrance and exits of the fish passage. Assumed areas at these locations are to be excavated to a depth of two feet and then backfilled with angular stone. A D_{50} of one foot is assumed in order to provide a desirable substrate to attract fish.

6.1.17 Weir Modification

Weir modifications are proposed at the Garth Harney and Bronxville Lake sites. Lengths of the weirs were measured from aerial photography; heights and construction materials are assumed. It was assumed that the weirs would be lowered by two feet, but this may vary based on more detailed development of design criteria.

6.1.18 Spat on Shell

Spat-on-shell is proposed for all three oyster restoration sites. At Bush Terminal, spat-on-shell will be used both inside the gabions and as a substrate placed across the entire footprint of the site. Each of the 2’ x 2’x 2’ gabions will be completely filled with spat-on-shell (0.3 cubic yards per unit). After the gabions are placed, an 18-inch depth of spat-on-shell will be deposited around

the gabions and across the entire footprint of the project area. (It is assumed that the shell is pre-seeded with spat.) The spat-on-shell will be deployed from a boat, likely with the use of a moveable chute or other similar method to ensure accuracy of placement.

At Earle Naval Weapons Station, spat-on-shell will be used both inside gabions and on the surfaces of the oyster pyramids. The 4.25' x 4.25' x 4.25' gabions will be ¾-filled with shell. It is assumed that 1/3 of this volume will be pre-seeded with spat. Oyster pyramids at Earle will occupy the interior of the project site. Because of the sandy substrate, it is assumed that the bottom course of castle blocks will settle, leaving only the top three courses of castle blocks for each pyramid exposed. The exposed castle blocks will have been pre-seeded with spat-on-shell prior to placement. To quantify the volume of spat-on-shell needed, it is assumed that the exposed surfaces of the castle blocks (neglecting cut-out notches) will be covered with a three inch thick layer.

At the Head of Jamaica Bay site, spat-on-shell will be used as a substrate, within gabions and within the hanging super-trays. Each of the 2' x 2' x 2' gabions will be completely filled with shell. It is assumed that ¼ of this volume will be pre-seeded with spat-on-shell. It is assumed that each supertray will be ½-filled with shell pre-seeded with spat. It is assumed that each pyramid will be pre-seeded with three cubic feet of spat-on-shell covered evenly across the exposed faces of the castle blocks. Once the gabions and pyramids are placed, a 12-inch thick substrate layer will be deposited around these features within the remaining footprint of the project area. 75% of this layer will be a mixture of shell and spat-on-shell, 25% of which will be spat-on-shell. The final quantities of spat-on-shell include an additional 10% to account for some losses during placement.

6.1.19 Oyster Gabions

At both the Bush Terminal and Head of Jamaica Bay sites, the gabions (2' x 2' x 2') will be filled on land and will be deployed by boat 10 feet on-center, at a rate of 34 units per acre.
At the Earle Naval Weapons Station site, the gabions (4.25' x 4.25' x 4.25') will be placed 44 feet on-center on the outside perimeter along the two long sides of the project site (approximately 2,422 linear feet on each side).

6.1.20 Oyster Pyramids

Oyster pyramids at the Earle Naval Weapons Station site will occupy the interior of the project area. The pyramids will be placed in groups of 30. Within each grouping, the pyramids will be placed in five rows of six each, spaced 12 feet apart. Each grouping of 30 pyramids will be spaced 40 feet apart. Because of the sandy substrate, it is assumed that the bottom course of castle blocks will sink, leaving only the top three courses of castle blocks for each pyramid exposed. The pyramids are placed at a rate of 101 per acre.

Pyramids at the Head of Jamaica Bay site are generally bounded by gabions. The pyramids are spaced 25 feet on-center at a rate of 15 pyramids per acre.

At both of these sites, rows of pyramids are staggered to allow maximum coverage and to provide more protection from substrate erosion against the currents. It is anticipated that pyramids will be assembled prior to placement. Pyramids will be lowered from a boat by means of a crane or similar apparatus, and guided and placed by an experienced diver.

6.1.21 Hanging Super-Trays

Hanging super-trays are proposed for the Head of Jamaica Bay site only. They will be either hung from cables or floated from the surface. Smaller trays were proposed for the site, but larger units can also be considered. The units will be spaced two feet apart along the cables; the cables will be spaced 40 feet apart. Spacing of the cables toward the center of the project area should allow for suitable dispersion of spat across the project area. Hanging the trays closer to the edges of the site would create the potential for greater loss of spat outside the project area. The trays will be half full with pre-seeded spat-on-shell.

6.1.22 Porcelain as Substrate

Porcelain substrate is proposed only for the Head of Jamaica Bay site at the request of the NY Department of Environmental Conservation (NYSDEC). The substrate at this site will be a blend of shell, spat-on-shell and porcelain. Porcelain will account for 25% of the total substrate.

6.2 Designs

Detailed designs were developed for each site using a combination of site-specific data and professional expertise. Specifically, historical investigations, data derived from site surveys, field observations, and digital spatial data, such as topography derived from LiDAR and habitat community mapping, in conjunction with scientific and engineering expertise and professional judgment coalesced to form the alternatives presented. Design criteria and assumptions made as part of the study are discussed below. Designs and quantity tables are presented in Attachment C-1.

6.2.1 Jamaica Bay Planning Region

6.2.1.1 Jamaica Bay Perimeter Sites

6.2.1.1.1 Dead Horse Bay Proposed Design

6.2.1.1.1.1 Design Summary

Restoration measures to be executed at Dead Horse Bay include invasives species removal, salt marsh restoration, scrub-shrub restoration, Maritime Forest restoration and tidal channel creation. The proposed design requires the excavation of approximately 483,090 cubic yards (cy) of material over an area of approximately 40.9 acres. Approximately 46,710 cy of material from clearing and grubbing operations will be removed offsite. Clearing and grubbing will be executed to a depth of nine inches. The remaining 436,380 cy of material will be placed at the Dead Horse Bay South site in coordination with the a potential NPS remedial action. The design

will create 19.0 acres of low marsh, 5.4 acres of high marsh, 6.2 acres of scrub-shrub vegetation and 8.00 acres of upland.

A constructed tidal channel will extend through the entire project site and will have a length of approximately 3,240 linear feet. The bottom elevation of the channel will be constructed below MTL to ensure flow more than 50% of the time. The existing narrow width and steep elevations within the site limited the ability to create a sinuous main channel, but small sinuous tributaries were added to the main channel close to its mouth and also at its farthest reach. The tidal channel will help sustain the planted wetlands and scrub-shrub vegetation communities.
Two jetties were originally proposed to protect the mouth of the tidal channel. This feature was removed during the detailed design phase as it was concluded that the tidal prism at this location will be more than sufficient in maintaining the inlet opening naturally. While it is also concluded that shoreline erosion at this area has largely equilibrated, further and more in-depth study of shoreline erosion and inlet stability at this location as well as the possible need for soft engineering approaches to shoreline stabilization, is recommended during the PED phase. This elements were not considered during this phase given the scale of the issue and the minimal cost impact added measures might have.

Dunes have been removed from the original design because the limits of the project area were reduced. Also, the updated design focused on taking advantage of the existing lower elevations to create the tidal channel and marsh areas rather than cutting into higher elevations. This approach helped to reduce the amount of excavation needed.

Planting elevations were developed from tidal datums derived from water surface elevation data collected October - November 2001. Given the age of the water surface elevation data and the lack of a full signal it is recommended that additional data be collected during the PED phase for this site. Uncertainty associated with the derived tidal datums may impact design elevations, and by extension, excavation quantity. The level of uncertainty is considered to be appropriate for this stage of this study and has been fully considered in the site's cost estimate contingency. PED phase data collection, analysis and design development needs are further discussed in Section 7 of this appendix.

Construction at Dead Horse Bay is scheduled to begin in 2035. The first year after the completion of construction, 2037, is therefore taken to be Year Zero in all sea level change analysis and the establishment of planting elevations. The 2001 tidal datums were then projected to the future base year of 2037 based on the intermediate sea level rise curve at the NOAA tide gauge at Sandy Hook, NJ (#8531680.) These datums, as well as project year 20 and 50 datums (intermediate curve) are shown in Table 6-1.

Table 6-1: Dead Horse Bay Tidal Datums, ft NAVD88

Datum	*2001*	*2037 (Yr 0)*	*2057 (Yr 20)*	*2087 (Yr 50)*
MHHW	*2.77*	*3.40*	*3.86*	*4.67*
MHW	*2.17*	*2.80*	*3.26*	*4.07*
MTL	*-0.62*	*0.01*	*0.47*	*1.28*

Tidal datums were then translated into planting elevations (Table 6-2). For Dead Horse Bay, the lower elevation for low marsh was set at approximately 1.6 foot above MTL. This relatively high lower level both decreases excavation costs and increases the sustainability of the design by providing a future margin of sustainability in that it is assumed that low marsh plantings will remain viable at elevations above MTL. Low marsh habitat will therefore not be impacted at the lower end until MTL has surpassed 1.6 ft, NAVD88. High Marsh elevations begin at the projected MHW datum and Scrub-shrub was set at a maximum elevation of 1 foot above high marsh; upland was set to be at or above the highest scrub elevation.

Table 6-2: Dead Horse Bay Planting Elevations, ft NAVD88

	Design Elevations (2035)	
	Low	*High*
Low marsh	*1.6*	*2.8*
High marsh	*2.8*	*3.4*
Scrub	*3.4*	*4.4*
Upland	*4.4*	*Above*

6.2.1.1.2 Fresh Creek Proposed Design

Restoration measures to be executed at Fresh Creek include invasives species removal, salt marsh restoration, Scrub-shrub restoration, Maritime Forest restoration and tidal channel creation/restoration. The proposed design requires the total excavation of approximately 193,200 cy of material over an area of approximately 34.8 acres. Approximately 42,000 cy will be removed off site, resulting from clearing and grubbing operations. Approximately 151,000 cy will be placed within the project area, in areas to be converted to Maritime Forest, and when appropriate, at the head of the Creek for the creation of new low marsh and along the channel bottom.

The existing channel has a very deep pit toward its mouth, reaching a depth of almost -20 feet NAVD88. Hydraulically place fill of clean dredge materials will be used to raise the basin grades, thereby reducing water volume and promoting optimal circulation by enhancing tidal exchange. Offshore dredged disposal material will be delivered to the site by a work barge being pushed by a tugboat. The fill would be pumped from the barge onto the bottom of the basin, and then an excavator mounted on a separate work barge would grade the fill. There is a bridge located at the mouth of the basin with vertical clearance at 21 feet and horizontal clearance at 43 feet. Navigation charts show the depth to bottom underneath the bridge at 9 to 11 feet, so vessel passage under the bridge will need to be coordinated with the tidal cycle.

The channel shall be re-contoured to an even -10.0 ft. After initial re-contouring the channel will then be capped with 3 feet of clean sand which will bring the final elevation to -10.0 ft NAVD88. The total length of the tidal channel will be approximately 7,500 linear feet. The channel bottom at the upper reach will gradually slope up from the existing grade and flatten out at an elevation below MTL. The design will create approximately 16.1 acres of low marsh, 4.4 acres of high marsh, 3.5 acres of scrub-shrub and 10.7 acres of maritime forest in addition to the 45.8 acres of restored channel. The areas of low and high marsh have increased over the previous design.

Additionally, the overall footprint of the project area has decreased so as not to encroach on privately-owned property.

Planting elevations were developed from tidal datums derived from water surface elevation data collected October - November 2001. Given the age of the water surface elevation data and the inadequacy of spatial coverage for this site, it is recommended that additional data be collected during the PED phase. Uncertainty associated with the derived tidal datums may impact design elevations, and by extension, excavation quantity. The level of uncertainty is, however, considered to be appropriate for this stage of this study and has been fully considered in the site's cost estimate contingency. PED phase data collection, analysis and design development needs are further discussed in Section 7 of this appendix.

Construction at Fresh Creek is scheduled to begin in 2027. The first year after the completion of construction, 2029, is therefore taken to be Year Zero in all sea level change analysis and the establishment of planting elevations. The 2001 tidal datums were then projected to the future base year of 2029 based on the intermediate sea level rise curve at the NOAA tide gauge at Sandy Hook, NJ (#8531680.) These datums, as well as project year 20 and 50 datums (intermediate curve) are shown in Table 6-3.

Table 6-3: Fresh Creek Tidal Datums, ft NAVD88

Datum	*2001*	*2029 (Yr 0)*	*2049 (Yr 20)*	*2079 (Yr 50)*
MHHW	*2.91*	*3.38*	*3.81*	*4.57*
MHW	*2.49*	*2.96*	*3.39*	*4.15*
MTL	*0.19*	*0.66*	*1.09*	*1.85*

Tidal datums were then translated into planting elevations (Table 6-4). For Fresh Creek, the lower elevation for low marsh was set at approximately 0.85 foot above MTL, thereby providing a future margin of sustainability in that it is assumed that low marsh plantings will remain viable at elevations above MTL. The low marsh low elevation is assumed to remain viable until MTL has surpassed 1.5 ft, NAVD88. High Marsh elevations begin at the projected MHW datum (approximately) and Scrub-shrub was set at a maximum elevation of 1 foot above high marsh; upland was set to be at or above the highest scrub elevation.

Table 6-4: Fresh Creek Planting Elevations, ft NAVD88

	Design Elevations (2027)	
	Low	*High*
Low marsh	*1.5*	*3.0*
High marsh	*3.0*	*3.5*
Scrub	*3.5*	*4.5*
Upland	*4.5*	*Above*

6.2.1.2 Jamaica Bay Marsh Islands

Restoration measures to be executed at the Jamaica Bay Marsh Islands consist of salt marsh restoration, scrub-shrub restoration and tidal channel creation/restoration. Five Jamaica Bay

marsh island restorations will be restored using dredged material from periodic channel maintenance operations conducted by the NY District throughout New York Harbor and the NY Bight area. The marsh island sites were designed to take advantage of the existing bathymetry when placing dredged material during construction, ensuring that most material is placed in shallow areas within the 1974 footprint of each island, which is the boundary set by the NYSDEC and National Parks Service.

Appropriate heavy equipment will be taken to the islands by barge or other sea-worthy vessel. Material will be hydraulically dredged from the appropriate channel maintenance operation at the time of construction and will be transported by barge to a location offshore of the island to be constructed. The material will be pumped from the barge to the existing island, at first to create a large berm into which the remaining material will be pumped so that it can drain. A bulldozer will continue to push the drained material into a stockpile so that it can later be used during rough grading operations. More than one stockpile location will likely be created on each island.

Grading will continue until the design elevations are within vertical tolerance, at which time the areas will be planted by hand. Based on prior marsh restoration construction efforts and lessons learned, a 60% settlement rate is assumed in material volume calculations.

Designs include the construction of waterfowl barrier fencing within the low and high marsh ranges. Based on discussions with the National Parks Service, this fencing may not be necessary. A final determination will be made during the final design phase.

6.2.1.2.1 Duck Point Marsh Proposed Design

The proposed design at Duck Point Marsh will require the placement of approximately 213,780 cubic yards (cy) of dredged material over a footprint of approximately 62.6 acres. The design will create approximately 24.9 acres of low marsh, 5.6 acres of high marsh and 8.1 acres of scrub-shrub. Three tidal channels are proposed, totaling approximately 2,730 l.f., which will be extended into the site to better sustain the planted vegetation.

The “Atoll Terrace” was removed from the original design as it was not cost effective. Additionally, the area of low marsh increased while the area of high marsh decreased. The updated design also adds scrub-shrub. A sea level change analysis of the original design revealed that the sustainability of Duck Point would be limited. Adding higher elevations ensures sustainability as high marsh and scrub shrub are gradually converted to lower vegetation communities.

Planting elevations were developed from tidal datums derived from water surface elevation data collected October - December 2003. The average datum values from four tide gauges were used as the basis for design datums for all five proposed marsh island restorations (section 2.1.4.2.1) Construction at Duck Point is scheduled to begin in 2027. The first year after the completion of construction, 2029, is therefore taken to be Year Zero in all sea level change analysis and the establishment of planting elevations. The 2001 tidal datums were then projected to the future

base year of 2029 based on the intermediate sea level rise curve at the NOAA tide gauge at Sandy Hook, NJ (#8531680.) These datums, as well as project year 20 and 50 datums (intermediate curve) are shown in Table 6-5.

Table 6-5: Duck Point Marsh Tidal Datums, ft NAVD88

Datum	*2003*	*2029 (Yr 0)*	*2049 (Yr 20)*	*2079 (Yr 50)*
MHHW	*2.73*	*3.17*	*3.6*	*4.36*
MHW	*2.31*	*2.75*	*3.18*	*3.94*
MTL	*-0.32*	*0.12*	*0.55*	*0.69*

Tidal datums were then translated into planting elevations (Table 6-6). For Duck Point Marsh, the lower elevation for low marsh was set at approximately 1.4 foot above MTL, thereby providing a future margin of sustainability in that it is assumed that low marsh plantings will remain viable at elevations above MTL. The low marsh low elevation is assumed to remain viable until MTL has surpassed 1.5 ft, NAVD88. High Marsh elevations and Scrub-shrub for the marsh islands begin at a relatively low level based on lesson learned from prior projects. Doing so also decreases material costs. As with all salt marsh restoration efforts within the HRE project, a transition zone between low and high marsh and high marsh and scrub-shrub should introduced by mixing species +/- 0.25 ft at the habitat elevation borders.

Table 6-6: Duck Point Marsh Planting Elevations, ft NAVD88

	Design Elevations (2027)	
	Low	*High*
Low marsh	*1.5*	*2.3*
High marsh	*2.3*	*3.0*
Scrub-Shrub	*3.0*	*Above*

6.2.1.2.2 Stony Creek Marsh Proposed Design

The proposed design at Stony Creek will require the placement of approximately 151, 360 cubic yards (cy) of dredged material over a footprint of approximately 69.6 acres. The design will create approximately 26.0 acres of low marsh, 22.5 acres of high marsh and 3.4 acres of scrub-shrub. Five tidal channels are proposed, totaling approximately 4,640 l.f., which will be extended into the site to better sustain the planted vegetation. Scrub shrub was added to the original design to allow for greater sustainability of the marsh as higher vegetation communities are converted to lower vegetation communities in response to sea level change.

Planting elevations were developed from tidal datums derived from water surface elevation data collected October – December 2003. The average datum values from four tide gauges were used as the basis for design datums for all five proposed marsh island restorations (section 2.1.4.2.1)

Construction at Stony Creek is scheduled to begin in 2025. The first year after the completion of construction, 2027, is therefore taken to be Year Zero in all sea level change analysis and the establishment of planting elevations. The 2003 tidal datums were then projected to the future

base year of 2027 based on the intermediate sea level rise curve at the NOAA tide gauge at Sandy Hook, NJ (#8531680.) These datums, as well as project year 20 and 50 datums (intermediate curve) are shown in Table 6-7.

Table 6-7: Stony Creek Marsh Tidal Datums, ft NAVD88

Datum	*2003*	*2027 (Yr 0)*	*2047 (Yr 20)*	*2077 (Yr 50)*
MHHW	*2.73*	*3.13*	*3.55*	*4.31*
MHW	*2.31*	*2.71*	*3.13*	*3.89*
MTL	*-0.32*	*0.08*	*0.50*	*1.26*

Tidal datums were then translated into planting elevations (Table 6-8). For Stony Creek Marsh, the lower elevation for low marsh was set at approximately 1.4 foot above MTL, thereby providing a future margin of sustainability in that it is assumed that low marsh plantings will remain viable at elevations above MTL. The low marsh low elevation is assumed to remain viable until MTL has surpassed 1.5 ft, NAVD88. High Marsh elevations and Scrub-shrub for the marsh islands begin at a relatively low level based on lesson learned from prior projects. Doing so also decreases material costs. As with all salt marsh restoration efforts within the HRE project, a transition zone between low and high marsh and high marsh and scrub-shrub should introduced by mixing species +/- 0.25 ft at the habitat elevation borders.

Table 6-8: Stony Creek Marsh Planting Elevations, ft NAVD88

	Design Elevations (2025)	
	Low	*High*
Low marsh	*1.5*	*2.3*
High marsh	*2.3*	*3.0*
Scrub-Shrub	*3.0*	*Above*

6.2.1.2.3 Pumpkin Patch West Marsh Proposed Design

The proposed design at Pumpkin Patch West will require the placement of approximately 327,690 cubic yards (cy) of dredged material over a footprint of approximately 32.9 acres. The design will create approximately 13.7 acres of low marsh, 8.61 acres of high marsh and 0.9 acres of scrub-shrub. Three tidal channels are proposed, totaling approximately 2,040 l.f., which will be extended into the site to better sustain the planted vegetation.

The areas of both low marsh and high marsh have increased from the original design, and scrub shrub was added. Higher elevations will allow for greater sustainability of the marsh as higher vegetation communities are converted to lower vegetation communities in respone to sea level change.

Planting elevations were developed from tidal datums derived from water surface elevation data collected October – December 2003. The average datum values from four tide gauges were used as the basis for design datums for all five proposed marsh island restorations (section 2.1.4.2.1). Construction at Pumpkin Patch West Marsh is scheduled to begin in 2033. The first year after the completion of construction, 2035, is therefore taken to be Year Zero in all sea level

change analysis and the establishment of planting elevations. The 2003 tidal datums were then projected to the future base year of 2035 based on the intermediate sea level rise curve at the NOAA tide gauge at Sandy Hook, NJ (#8531680.) These datums, as well as project year 20 and 50 datums (intermediate curve) are shown in Table 6-9.

Table 6-9: Pumpkin Patch West Marsh Tidal Datums, ft NAVD88

Datum	*2003*	*2035 (Yr 0)*	*2055 (Yr 20)*	*2085 (Yr 50)*
MHHW	*2.73*	*3.29*	*3.74*	*4.54*
MHW	*2.31*	*2.87*	*3.32*	*4.12*
MTL	*-0.32*	*0.24*	*0.69*	*1.49*

Tidal datums were then translated into planting elevations (Table 6-10). For Pumpkin Patch West Marsh, the lower elevation for low marsh was set at approximately 1.25 foot above MTL, thereby providing a future margin of sustainability in that it is assumed that low marsh plantings will remain viable at elevations above MTL. The low marsh low elevation is assumed to remain viable until MTL has surpassed 1.5 ft, NAVD88. High Marsh elevations and Scrub-shrub for the marsh islands begin at a relatively low level based on lesson learned from prior projects. Doing so also decreases material costs. As with all salt marsh restoration efforts within the HRE project, a transition zone between low and high marsh and high marsh and scrub-shrub should introduced by mixing species +/- 0.25 ft at the habitat elevation borders.

Table 6-10: Pumpkin Patch West Marsh Planting Elevations, ft NAVD88

	Design Elevations (2033)	
	Low	*High*
Low marsh	*1.5*	*2.3*
High marsh	*2.3*	*3.0*
Scrub-Shrub	*3.0*	*Above*

6.2.1.2.4 Pumpkin Patch East Marsh Proposed Design

The proposed design at Pumpkin Patch East will require the placement of approximately 351,960 cubic yards (cy) of dredged material over a footprint of approximately 40.5 acres. The design will create approximately 15.6 acres of low marsh, 10.10 acres of high marsh and 3.10 acres of scrub-shrub. Three tidal channels are proposed, totaling approximately 1530 l.f., which will be extended into the site to better sustain the planted vegetation.

The area of low marsh and high marsh decreased slightly from the original design, and scrub shrub was added. This will allow for greater sustainability of the marsh as higher vegetation communities are converted to lower vegetation communities in response to sea level change. Planting elevations were developed from tidal datums derived from water surface elevation data collected October – December 2003. The average datum values from four tide gauges were used as the basis for design datums for all five proposed marsh island restorations (section 2.1.4.2.1).

Construction at Pumpkin Patch East Marsh is scheduled to begin in 2037. The first year after the completion of construction, 2039, is therefore taken to be Year Zero in all sea level change analysis and the establishment of planting elevations. The 2003 tidal datums were then projected to the future base year of 2039 based on the intermediate sea level rise curve at the NOAA tide gauge at Sandy Hook, NJ (#8531680.) These datums, as well as project year 20 and 50 datums (intermediate curve) are shown in Table 6-11.

Table 6-11: Pumpkin Patch East Marsh Tidal Datums, ft NAVD88

Datum	*2003*	*2039 (Yr 0)*	*2059 (Yr 20)*	*2089 (Yr 50)*
MHHW	*2.73*	*3.38*	*3.83*	*4.66*
MHW	*2.31*	*2.96*	*3.41*	*4.24*
MTL	*-0.32*	*0.33*	*0.78*	*1.61*

Tidal datums were then translated into planting elevations (Table 6-12). For Pumpkin Patch East Marsh, the lower elevation for low marsh was set at approximately 1.2 foot above MTL, thereby providing a future margin of sustainability in that it is assumed that low marsh plantings will remain viable at elevations above MTL. The low marsh low elevation is assumed to remain viable until MTL has surpassed 1.5 ft, NAVD88. High Marsh elevations and Scrub-shrub for the marsh islands begin at a relatively low level based on lesson learned from prior projects. Doing so also decreases material costs. As with all salt marsh restoration efforts within the HRE project, a transition zone between low and high marsh and high marsh and scrub-shrub should introduced by mixing species +/- 0.25 ft at the habitat elevation borders.

Table 6-12: Pumpkin Patch East Marsh Planting Elevations, ft NAVD88

	Design Elevations (2037)	
	Low	*High*
Low marsh	*1.5*	*2.3*
High marsh	*2.3*	*3.0*
Scrub-Shrub	*3.0*	*Above*

6.2.1.2.5 Elders Center Marsh Proposed Design

The proposed design at Elders Center will require the placement of approximately 284,020 cubic yards (cy) of dredged material over a footprint of approximately 41.7 acres. The design will create approximately 15.2 acres of low marsh, 10.90 acres of high marsh and 1.40 acres of scrub-shrub. Four tidal channels are proposed, totaling approximately 2,500 l.f., which will be extended into the site to better sustain the planted vegetation.

The areas of both low marsh and high marsh have increased from the original design, and scrub shrub was added. Higher elevations will allow for greater sustainability of the marsh as higher vegetation communities are converted to lower vegetation communities in response to sea level change.

Planting elevations were developed from tidal datums derived from water surface elevation data collected October – December 2003. The average datum values from four tide gauges were

used as the basis for design datums for all five proposed marsh island restorations (section 2.1.4.2.1).

Construction at Elders Center Marsh is scheduled to begin in 2031. The first year after the completion of construction, 2033, is therefore taken to be Year Zero in all sea level change analysis and the establishment of planting elevations. The 2003 tidal datums were then projected to the future base year of 2033 based on the intermediate sea level rise curve at the NOAA tide gauge at Sandy Hook, NJ (#8531680.) These datums, as well as project year 20 and 50 datums (intermediate curve) are shown in Table 6-12.

Table 6-13: Elders Center Marsh Tidal Datums, ft NAVD88

Datum	*2003*	*2033 (Yr 0)*	*2053 (Yr 20)*	*2083 (Yr 50)*
MHHW	*2.73*	*3.25*	*3.74*	*4.48*
MHW	*2.31*	*2.83*	*3.32*	*4.06*
MTL	*-0.32*	*0.2*	*0.69*	*1.43*

Tidal datums were then translated into planting elevations (Table 6-14). For Elders Center Marsh, the lower elevation for low marsh was set at approximately 1.3 foot above MTL, thereby providing a future margin of sustainability in that it is assumed that low marsh plantings will remain viable at elevations above MTL. The low marsh low elevation is assumed to remain viable until MTL has surpassed 1.5 ft, NAVD88. High Marsh elevations and Scrub-shrub for the marsh islands begin at a relatively low level based on lesson learned from prior projects. Doing so also decreases material costs. As with all salt marsh restoration efforts within the HRE project, a transition zone between low and high marsh and high marsh and scrub-shrub should introduced by mixing species +/- 0.25 ft at the habitat elevation borders.

Table 6-14: Elders Center Marsh Planting Elevations, ft NAVD88

	Design Elevations (2031)	
	Low	*High*
Low marsh	*1.5*	*2.3*
High marsh	*2.3*	*3.0*
Scrub-Shrub	*3.0*	*Above*

6.2.2 Harlem River/East River/Western Long Island Sound Planning Region

6.2.2.1 Flushing Creek Proposed Design

Restoration measures to be executed at Flushing Creek include invasives species removal, salt marsh restoration, scrub-shrub restoration and Maritime Forest restoration. The design of the Flushing Creek site minimizes the volume of excavated material to be taken offsite while maximizing the area of restored salt marsh. Much of the low marsh restoration is achieved through the conversion of select areas of intratidal mudflats, a nuisance source of hydrogen sulfide gas, by the placement of clean growing media to the low marsh design elevations. These designs also considered the gradual migration of plant communities in response to relative sea level change over time. Clearing and grubbing will be executed to a depth of one foot. One foot

of clean growing media will be placed in low and high marsh and two feet of clean growing media will be placed in the upland areas.

The proposed design requires the excavation of approximately 39,000 cubic yards (cy) of material over an area of approximately 20 acres. Approximately 12,200 cy of material from clearing and grubbing operations will be removed offsite. The remaining 27,000 cy of material will be placed within the project area, in areas to be converted to Maritime Forest. The design will create approximately 9.76 acres of low marsh, 2.47 acres of high marsh, 1.8 acres of scrub-shrub and 3.89 acres of maritime forest. A 2 foot layer of clean growing media will be placed in upland areas. Much of the low marsh restoration is achieved through the conversion of select areas of intratidal mudflats, a nuisance source of hydrogen sulfide gas, by the placement of clean growing media to the low marsh design elevations.

During construction a turbidity curtain will be deployed along the shoreline of Flushing Creek. The curtain will trap sediments from the site as it is disturbed during excavation and grading activities, and it prevents the sediments from entering the river.

Planting elevations were developed from tidal datums derived from water surface elevation data collected June - August 2000. Given the age of the water surface elevation data it is recommended that additional data be collected during the PED phase. Uncertainty associated with the derived tidal datums may impact design elevations, and by extension, excavation quantity. The level of uncertainty is considered to be appropriate for this stage of this study and has been fully considered in the site's cost estimate contingency. PED phase data collection, analysis and design development needs are further discussed in Section 7 of this appendix.

Construction at Flushing Creek is scheduled to begin in 2025. The first year after the completion of construction, 2027, is therefore taken to be Year Zero in all sea level change analysis and the establishment of planting elevations. The 2000 tidal datums were projected to the future base year of 2027 based on the intermediate sea level rise curve at the NOAA tide gauge at Kings Point, NY (#8516945.) These datums, as well as project year 20 and 50 datums (intermediate curve) are shown in Table 6-15.

Table 6-15: Flushing Creek Tidal Datums, ft NAVD88

Datum	*2000*	*2027 (Yr 0)*	*2047 (Yr 20)*	*2077 (Yr 50)*
MHHW	*3.57*	*3.88*	*4.19*	*4.80*
MHW	*3.21*	*3.52*	*3.83*	*4.44*
MTL	*-0.02*	*0.29*	*0.60*	*1.21*

Tidal datums were then translated into planting elevations (Table 6-16). For Flushing Creek, the lower elevation for low marsh was set at approximately 1.25 foot above MTL. This relatively high lower level increases the sustainability of the design by providing a future margin of sustainability in that it is assumed that low marsh plantings will remain viable at elevations above MTL. Low marsh habitat will therefore not be impacted at the lower end until MTL has surpassed 1.25 ft, NAVD88. High Marsh elevations begin at the projected MHW datum and Scrub-shrub

was set at a maximum elevation of 1 foot above high marsh; upland was set to be at or above the highest scrub elevation.

Table 6-16: Flushing Creek Planting Elevations, ft NAVD88

	Design Elevations (2025)	
	Low	*High*
Low marsh	*1.25*	*3.5*
High marsh	*3.5*	*4.3*
Scrub-Shrub	*4.3*	*5.3*
Maritime Forest	5.3	Above

6.2.2.2 Bronx River

6.2.2.2.1 Bronx Zoo and Dam Proposed Design

Restoration measures to be executed at Bronx Zoo and Dam include the installation of a technical fishway and associated elements such as a boulder diversion barrier, an exit pool and upstream rapids, emergent wetlands restoration with bolder toe protection, forested/scrub-shrub wetlands, bioretention swales and depressions and invasive species removal with native plantings.

A cast-in-place controlled concrete fishway channel is proposed on the west bank of the Bronx River directly adjacent to the natural spillway of the Bronx Zoo Dam. The fishway will facilitate fish species passage upstream. The fishway will be partially below grade, placed into the bedrock at this location and will be 165 ft in length. The fishway will have 30 ft of embedded Aluminum Denil Steeppass and will also feature embedded stone set in a semi-random pattern into the concrete footing to create velocity variation within the fishway. A boulder diversion barrier will be constructed directly downstream to guide fish into the fishway and an exit pool and rapids shall be constructed at the upstream exit of the fishway. Construction will involve excavation of bedrock and earth. Temporary cofferdams will be constructed to divert the stream flow while the fishway is being constructed.

NYC Parks has developed 90% Plans and Specifications for these features and these plans have been adopted and advanced for this site. A preliminary review of the designs was conducted during the feasibility phase but a more comprehensive one should take place during PED phase to verify the technical and structural soundness of the plan. Similarly, the quantity take-offs adopted were reviewed and found to be accurate.

In addition to the stream improvements summarized above, the proposed design features further restoration elements. Approximately 1.16 acres of emergent wetlands will be created. In existing land area to be converted to emergent wetlands, the first 12” of earth will be excavated and removed offsite. 6” of clean growing medium will be placed prior to planting native vegetation. In areas along the shoreline where emergent wetlands are proposed, it will be necessary to construct cofferdams within the stream to block flow. A stacked rock wall will be constructed within the cofferdam, behind which will be backfilled with up to 2 feet of fill. 6” of topsoil will be

placed in these newly-created areas, which will be planted with appropriate native vegetation. This rock wall is a new feature from the original design. It was determined that emergent wetlands would have a minimal chance of success due to the high velocities in the river at that location. The rock wall will provide protection to these wetlands. The rock wall also provides a measure of resiliency against projected climate driven changes in hydraulic loading.

Approximately 0.48 acres of forested/ scrub-shrub wetlands are proposed at the Bronx Zoo and Dam site. Nine inches of cleared and grubbed material will be excavated and removed offsite. 6" of clean growing medium will be placed prior to the areas being planted with native forested/scrub-shrub vegetation.

Approximately 0.42 acres of invasive species vegetation will be removed from the site and planted with native vegetation. Nine inches of cleared and grubbed material will be removed offsite followed by the placement of 6" of clean growing medium and the planting of appropriate native species vegetation.

A small area of approximately 1100 square feet will be used to trap sediments prior to entry into the stream. This area will be excavated to a depth of 3 feet, backfilled with 2 feet of a soil medium suitable to promote drainage and then topped with 6" of mulch. These bioswales are new features that were suggested by the NYC Parks Department, who determined that their strategic placement would help to reduce sediment from entering the river.

As noted in Section 4.1.4, future with project conditions may result in increased streamflow as a result of climate change. These changes may in turn impact some of the proposed design features such as the emergent wetlands with toe revetment protection proposed here. Future condition changes may also result in higher and more frequent maintenance and adaptation needs. These considerations should be analyzed during PED phase analysis (see Section 7)

6.2.2.2.2 Stone Mill Dam Proposed Design

Restoration measures to be executed at Stone Mill Dam include the installation of a technical fishway and associated elements such as a boulder diversion barrier, an exit pool and invasive species removal with native plantings.

A cast-in-place controlled concrete fishway channel is proposed on the east bank of the Bronx River directly adjacent to the Stone Mill Dam spillway. The fishway will facilitate fish species passage upstream. The fishway will be below grade and placed into the bedrock at this location and will be approximately 255 ft in length. A galvanized steel grating will be installed on top of the fishway channel. The fishway will have 35 ft of embedded Aluminum Denil Steeppass and will also feature embedded stone set in a semi-random pattern into the concrete footing to create velocity variation within the fishway. A boulder diversion barrier will be constructed directly downstream to guide fish into the fishway and an exit pool shall be constructed at the upstream exit of the fishway. Construction will involve excavation of bedrock and earth. Temporary cofferdams will be constructed to divert the stream flow while the fishway is being constructed. Approximately 1390 square feet of existing vegetation will be disrupted during construction and

will be replanted with native vegetation and a portion of a stone screenings footpath will be relocated to accommodate the fishway installation.

NYC Parks has developed 90% Plans and Specifications for these features and these plans have been adopted and advanced for this site. A preliminary review of the designs was conducted during the feasibility phase but a more comprehensive one should take place during PED phase to verify the technical and structural soundness of the plan. Similarly, the quantity take-offs adopted were reviewed and found to be accurate.

In addition to the stream improvements summarized above, the proposed design features invasive species removal with native planting in an area of approximately 200 square feet. The total area will be cleared and grubbed to a depth of 9” and that material will be disposed of offsite. 6” of clean growing medium will be placed, and the areas will be planted with appropriate native species vegetation.

6.2.2.2.3 Shoelace Park

Restoration measures to be executed at Shoelace Park include forested/scrub-shrub restoration, invasives removal with native plantings, bioretention swales and depressions, Stacked Rock walls with brush layers, boulder toe revetments with brush mattresses, shoreline softening, riverbed restoration, and cross and J-hook rock vanes. Approximately 243,785 square feet of channel will be restored, which will include the placement of 11 rock vanes and 10 rock J-hooks placed alternately and evenly spaced along approximately 3900 linear feet of channel. One foot of existing bed material will be excavated from the channel and removed offsite. Angular rock with a diameter of approximately 4 inches will be placed on the channel bed.

The channel has a width of approximately 65 feet. Each rock vane will span the width of the channel, with each end of the vane tied into the stream bank. Each vane will have a base of 2 rows of footer rock that will be excavated into the streambed, upon which one row of vane rock will be placed. The top elevation of the vane will be set below the base flow of the stream.

Each J-hook will span 2/3 the width of the channel, with one end being tied into the stream bank. As with the rock vanes, each J-hook will have a base of 2 rows of footer rock that will be excavated into the streambed, upon which one row of vane rock will be placed. The top elevation of the J-hook will be set below the base flow of the stream.

A stacked rock wall is proposed for approximately 3900 feet along the right bank, adjacent to the Bronx River Parkway. A toe trench will be excavated into the channel bed at the base of the stream bank. It is assumed that this toe trench have a width of three feet and a depth of three feet; it will be filled with four-inch diameter angular rock. The rock wall is estimated to have four rows of stacked rock, the first of which will be excavated into the toe of the slope inland of the toe trench. The diameter of the stacked rock will be three feet. The bank behind the rock wall will be excavated to a stable slope; that volume of material will be replaced with a granular filter to promote drainage. A geotextile will underlay the bottom of the footer rock and it will extend up to the top of the bank behind the stacked rocks, separating the rock from the granular material.

The geotextile will be keyed into the top of the bank. Six inches of topsoil will be placed on the disturbed surface behind the rock wall. The area will be planted with appropriate vegetation. The rock wall also provides a measure of resiliency against projected climate driven changes in hydraulic loading.

A boulder toe revetment is proposed for approximately 3515 linear feet along the left bank of the river. A brush mattress, consisting of planting live cuttings to establish stabilizing vegetation, is proposed for the area behind the boulder revetment. A toe trench will be excavated into the channel bed at the base of the stream bank. It is assumed that this toe trench have a width of three feet and a depth of three feet; it will be filled with four-inch diameter angular rock. It is assumed that the rock wall will have two rows of stacked rock, the first of which will be excavated into the toe of the slope inland of the toe trench. A geotextile will underlay the bottom of the footer rock and it will extend up to the top of the bank behind the stacked rocks. The geotextile will be keyed into the top of the bank. Six inches of topsoil will be placed on the disturbed area behind the rock wall for an assumed width of seven feet. Live stakes will be planted in this area at a rate of 12” center-on-center. The original plan called for the use of a rock wall to stabilize almost all of shoreline. It was determined that the use of brush mattresses would be more cost effective, would allow for a “softer” stabilization and erosion control technique and would still provide a measure of resiliency against projected climate driven changes in hydraulic loading. NYC Parks has already implemented some stabilization features at Shoelace Park. Therefore, the length of shoreline requiring stabilization has been reduced by approximately 20%, which results in a greater cost savings.

Approximately 47,920 square feet in areas on both sides of the river will be converted to forested/scrub-shrub wetlands. Nine inches of cleared and grubbed material will be excavated and removed offsite. Six inches of clean growing medium will be placed prior to the areas being planted with native forested/scrub-shrub vegetation. Five areas totaling approximately 90,305 square feet will be used to trap sediments prior to their being able to enter the stream. These areas will be excavated to a depth of three feet, backfilled with two feet of a soil medium suitable to promote drainage and then topped with six inches of mulch.

A total area of approximately 57,820 square feet will be planted with native vegetation. It is assumed that the removal of invasive species vegetation will be required in an area of approximately 9,900 square feet. The total area will be cleared and grubbed to a depth of 9” and that material will be disposed of offsite. six inches of topsoil will be placed, and the areas will be planted with appropriate native species vegetation.

6.2.2.2.4 Bronxville Lake

Restoration measures to be executed at Bronxville Lake include emergent wetland restoration, forested/scrub-shrub restoration, invasives removal with native plantings, bioretention swales and depressions, riverbed and channel restoration, weir modification and an in-stream sediment forebay. Approximately 1,415 linear feet of channel will be restored within Bronxville Lake. The restored channel will have bottom width of 20 feet with 3H:1V side slopes. The channel will be

excavated to a depth of seven feet after which two feet of bank run gravel will be placed on the channel bottom, for a net excavated depth of five feet.

Approximately 28,100 cubic yards of material will be excavated from the streambed and banks to restore the channel bed and create elevations suitable for native vegetation. This material will be disposed of offsite. Approximately 0.86 acres of emergent wetland and 2.49 acres of forested/scrub-shrub wetland will be created. Six inches of clean growing medium will be placed in these areas prior to planting with native species. As opposed to the proposed design of other sites that feature the restoration of emergent wetlands, the emergent wetlands proposed here are not protected by a boulder toe revetment. The inclusion of the sediment forebay, discussed below, will mitigate stream velocities, thus providing a measure of resilience projected climate driven changes in hydraulic loading. It is also noted that the proposed design features significant areas of forested/scrub-shrub wetland, which will be inherently more resistant. A four foot excavation depth is assumed in areas of bed restoration. These areas will be backfilled with one foot of bank run gravel, yielding a net excavation of three feet.

Four small areas totaling approximately 23,504 square feet will be used to trap sediments prior to entry into the stream. These areas will be excavated to a depth of three feet, backfilled with two feet of a soil medium suitable to promote drainage and then topped with six inches of mulch. An in-stream sediment forebay of approximately 0.3 acres will be excavated immediately upstream of Bronxville Lake. A temporary cofferdam will be constructed prior to excavation, and a rock berm will span the downstream width of the forebay to trap excess sediments. The design includes a suggested access point for periodic maintenance dredging.

A total of 1.39 acres of invasive species vegetation will be removed and replanted with appropriate native vegetation. A six inch layer of appropriate growing medium will be placed prior to planting.

6.2.2.2.5 Garth Woods / Harney Road

Restoration measures to be executed at Garth Harney include emergent wetland restoration, scrub-shrub restoration, wet meadow restoration, invasives removal with native plantings, bioretention swales and depressions, riverbed and channel restoration, weir modification, shoreline softening, and rock cross vanes. Approximately 37, 340 square feet of channel will be restored, which will include the placement of 10 rock vanes evenly spaced along 945 linear feet of channel. A two-foot depth of existing bed material will be excavated and replaced with bank run gravel.

The channel has a width of 40 feet. Each rock vane will span the width of the channel, and each end of the vane will be tied into the stream bank. Each vane will have a base of two rows of footer rock that will be excavated into the streambed, upon which one row of vane rock will be placed. The top elevation of the vane will be set below the base flow of the stream.
A wet meadow is proposed for the Garth Harney site to the west of the western spur of the Bronx River Parkway. An area of approximately 1.67 acres will be cleared and grubbed to a depth of 9”. It is assumed that an additional 33” of excavation will be required to create an elevation

suitable for a wet meadow. This area will be topped with six inches of growing medium and planted with appropriate native vegetation. An appropriate seed mix will be applied.
A total area of approximately 0.82 acres of emergent wetlands will be created on either side of the river. The area will be cleared and grubbed to a depth of nine inches; that material will be removed offsite. An additional 33" of material will be excavated, the area then topped with six inches of growing medium for a net excavation depth of three feet. Appropriate native emergent wetland vegetation will be planted.

A small area of approximately 1420 square feet will be used to trap sediments prior to entry into the stream. This area will be excavated to a depth of three feet, backfilled with two feet of a soil medium suitable to promote drainage and then topped with six inches of mulch. Approximately 200 linear feet of shoreline is hardened with concrete to prevent erosion on the right bank, south of Strathmore Road. It is proposed that this area be "softened" using live branches. This will require drilling through the concrete and inserting the live stakes into the drill holes. The cut end of the live stake should extend into the soil behind the concrete so it can take root. It is assumed that 5 rows of holes drilled 2 feet apart will be necessary to completely treat the existing concrete.
A small area of approximately 1700 square feet along the left bank at the northernmost reach of the project area will be converted to a scrub-shrub wetland. Nine inches of cleared and grubbed material will be removed from the site; the area then will topped with 6" of appropriate growing medium. Appropriate native plants and shrubs will be planted and an appropriate seed mix will also be applied.

A total area of approximately 22,365 square feet will be planted with native vegetation. It is assumed that the removal of invasive species vegetation will be required in an area of approximately 2,285 square feet. The total area will be cleared and grubbed to a depth of 9" and that material will be disposed of offsite. Six inches of an appropriate growing medium will be placed, and the areas will be planted with appropriate native species vegetation.

The original plan included constructing culverts under the Bronx River Parkway to deliver water to the proposed wet meadow on the west side of the parkway. It has since been determined that the groundwater elevation and the amount of runoff at this location are such that a wet meadow can be supported without the need to deliver additional hydration through a series of culverts.

6.2.3 Lower Passaic River/Hackensack River/Newark Bay Planning Region

6.2.3.1 Lower Passaic River

6.2.3.1.1 Oak Island Yards Proposed Design

The Oak Island Yards site was designed to minimize the volume of excavated material to be taken offsite while maximizing the area of vegetation to be planted. Designs also considered the gradual migration of plant communities in response to relative sea level change over time. The proposed design is smaller relative to the TSP plan. The footprint was narrowed along the north and south boundaries in keeping with the natural contours of the area. The footprint was

narrowed along the landward edge due to the high elevations found here. Design so increased the cost efficiency of the project as excavation for the purpose of creating salt marsh in these high elevation areas would be prohibitively expensive. One foot of clean growing media will be placed in low and high marsh and two feet of clean growing media will be placed in the upland areas. Clearing and grubbing is assumed to be to a depth of one foot.

Restoration measures to be executed at Oak Island Yards include invasive species removal, salt marsh restoration, scrub-shrub restoration, maritime forest restoration, and tidal channel/pond creation. The proposed design requires the excavation of approximately 111,800 cubic yards (cy) of material over an area of approximately 11 acres. Approximately 11,000 cy of material from clearing and grubbing operations and 76,700 cy from excavation will be removed offsite. The remaining 24,500 cy of material will be placed within the project area, in areas to be converted to Maritime Forest. The design will create approximately 5.32 acres of low marsh, 0.85 acres of high marsh, 0.44 acres of scrub-shrub and 2.85 acres of maritime forest. A two-foot layer of clean growing media will be placed in upland areas.

A constructed tidal channel will extend through the entire project site and a 0.45 acre tidal pond will be constructed on the north end of the site. Site channels will have a total length of approximately 1,400 linear feet. The bottom elevation of the channel will be constructed below MTL to ensure flow more than 50% of the time. The tidal channel will help sustain the planted wetlands and scrub-shrub vegetation communities.

During construction a turbidity curtain will be deployed along the shoreline of Newark Bay. The curtain will trap sediments from the site as it is disturbed during excavation and grading activities, and prevent the sediments from entering the bay. Planting elevations were developed from tidal datums derived from water surface elevation data collected for the Minish Park project in October - November, 2002. Site specific water surface elevation data will be needed to further refine site specific tidal datums for this site. Uncertainty associated with the tidal datums used may impact design elevations, and by extension, excavation quantity. The impact of this uncertainty is considered to be minimal though, and appropriate for this stage of this study. PED phase data collection, analysis and design development needs are further discussed in Section 7 of this appendix.

Construction at Oak Island Yards is scheduled to begin in 2035. The first year after the completion of construction, 2037, is therefore taken to be Year Zero in all sea level change analysis and the establishment of planting elevations. The 2002 tidal datums were projected to the future base year of 2037 based on the intermediate sea level rise curve at the NOAA tide gauge at The Battery, NY (#8518750) These datums, as well as project year 20 and 50 datums (intermediate curve) are shown in Table 6-17.

Table 6-17: Oak Island Yards Tidal Datums, ft NAVD88

Datum	*2002*	*2037 (Yr 0)*	*2057 (Yr 20)*	*2087 (Yr 50)*
MHHW	*2.92*	*3.52*	*3.97*	*4.78*
MHW	*2.63*	*3.25*	*3.70*	*4.51*
MTL	*-0.02*	*0.6*	*1.05*	*1.86*

Tidal datums were then translated into planting elevations (Table 6-18). For Oak Island Yards, the lower elevation for low marsh was set at approximately 1.25 foot above MTL. This relatively high lower level increases the sustainability of the design by providing a future margin of sustainability in that it is assumed that low marsh plantings will remain viable at elevations above MTL. Low marsh habitat will therefore not be impacted at the lower end until MTL has surpassed 1.25 ft, NAVD88. High Marsh elevations begin at the projected MHW datum (approximate) and scrub-shrub was set at a maximum elevation of 0.65 foot above high marsh; upland was set to be at or above the highest scrub elevation.

Table 6-18: Oak Island Yards Planting Elevations, ft NAVD88

	Design Elevations (2035)	
	Low	*High*
Low marsh	*1.25*	*3.2*
High marsh	*3.2*	*3.6*
Scrub-Shrub	*3.6*	*4.25*
Maritime Forest	4.25	Above

6.2.3.1.2 Branch Brook Park

Restoration measures to be executed at Branch Brook Park, NJ include emergent wetland restoration, forested/scrub-shrub restoration, invasives removal with native plantings, channel deepening and stream naturalization and clearing. Approximately 4800 linear feet of channel will be restored within Branch Brook Park by deepening the channel, widening overly narrowed segments, removing overgrowth and establishing emergent wetlands along the stream banks. Approximately 55,000 cubic yards of material will be hydraulically excavated from a channel area of 17 acres. The material will be stockpiled onsite and allowed to drain, after which it will be removed from the site.

Approximately 10.25 acres of emergent wetlands are proposed. Nine inches of cleared and grubbed material will be excavated and removed offsite. Six inches of clean growing medium will be placed prior to the areas being planted with native forested/scrub-shrub vegetation.
Approximately 8.8 acres of forested/scrub-shrub wetlands are proposed. Nine inches of cleared and grubbed material will be excavated and removed offsite. Six inches of clean growing medium will be placed prior to the areas being planted with native forested/scrub-shrub vegetation.
Approximately 8.91 acres of invasive species vegetation will be removed from the site and planted with native vegetation. Nine inches of cleared and grubbed material to be removed offsite, six inches of clean growing medium and the planting of appropriate native species vegetation.

This plan differs from the original by reducing the area of emergent wetlands by approximately 30% while also increasing the area of invasive species removal and native plantings by approximately 30%. These changes have resulted in a more cost efficient project and greater cost savings.

6.2.3.2 Hackensack River

6.2.3.2.1 Metromedia

The Metromedia site was designed to minimize the volume of excavated material to be taken offsite while maximizing the area of vegetation to be planted. Designs also considered the gradual migration of plant communities in response to relative sea level change over time. One foot of clean growing media will be placed in low and high marsh and two feet of clean growing media will be placed in the upland areas. Clearing and grubbing is assumed to be to a depth of one foot.

Restoration measures to be executed at the Metromedia site include invasives species removal, salt marsh restoration, scrub-shrub restoration, Maritime Forest restoration and tidal channel creation. The proposed design requires the excavation of approximately 38,000 cy of material over an area of approximately 67.3 acres. Excavation assumes clearing and grubbing to a depth of six inches, and the material will be removed offsite and taken to an appropriate upland disposal facility. The design will create approximately 26.5 acres of low marsh, 11.7 acres of high marsh, 9.7 acres of scrub-shrub and 4.1 acres of maritime forest. A one foot layer of clean growing media will be placed in the high marsh and upland areas. The design includes the excavation of new tidal channels and the enhancement of existing tidal channels, totaling approximately 6,270 linear feet. During construction a turbidity curtain will be deployed along the shoreline of the Hackensack River. The curtain will trap sediments from the site as it is disturbed during excavation and grading activities, and it prevent the sediments from entering the river.

Planting elevations were developed from tidal datums derived from water surface elevation data collected at the Secaucus High Wetlands site in January 2008. Uncertainty associated with the tidal datums used may impact design elevations, and by extension, excavation quantity. The level of uncertainty is considered to be appropriate for this stage of this study and has been fully considered in the site's cost estimate contingency. PED phase data collection, analysis and design development needs are further discussed in Section 7 of this appendix. Additional, water surface elevation data should be collected at multiple locations for this site during the PED phase. PED phase data collection, analysis and design development needs are further discussed in Section 7 of this appendix.

Construction at the Metromedia site is scheduled to begin in 2029. The first year after the completion of construction, 2031, is therefore taken to be Year Zero in all sea level change analysis and the establishment of planting elevations. The 2008 tidal datums were projected to the future base year of 2031 based on the intermediate sea level rise curve at the NOAA tide gauge at the Battery, NY (#8518750). These datums, as well as project year 20 and 50 datums (intermediate curve) are shown in Table 6-19.

Table 6-19: Metromedia Tidal Datums, ft NAVD88

Datum	*2008*	*2031 (Yr 0)*	*2051 (Yr 20)*	*2081 (Yr 50)*
MHHW	*3.07*	*3.47*	*3.9*	*4.68*
MHW	*2.71*	*3.11*	*3.54*	*4.32*
MTL	*0.08*	*0.48*	*0.91*	*1.69*

Tidal datums were then translated into planting elevations (Table 6-20). For Metromedia, the lower elevation for low marsh was set at approximately 0.8 foot above MTL. This provides a future margin of sustainability in that it is assumed that low marsh plantings will remain viable at elevations above MTL. Low marsh habitat will therefore not be impacted at the lower end until MTL has surpassed 1.3 ft, NAVD88. The High Marsh elevations begin at the approximate projected MHW datum and Scrub-shrub was set at a maximum elevation of one foot above high marsh; upland was set to be at or above the highest scrub elevation.

Table 6-20: Metromedia Planting Elevations, ft NAVD88

	Design Elevations (2029)	
	Low	High
Low marsh	1.3	2.8
High marsh	2.8	3.3
Scrub-Shrub	3.3	4.3
Maritime Forest	4.3	Above

6.2.3.2.2 Meadowlark

The Meadowlark site was designed to minimize the volume of excavated material to be taken offsite while maximizing the area of vegetation to be planted. Designs also considered the gradual migration of plant communities in response to relative sea level change over time. One foot of clean growing media will be placed in low and high marsh and two feet of clean growing media will be placed in the upland areas. Clearing and grubbing is assumed to be to a depth of one foot.

Restoration measures to be executed at the Metromedia site include invasives species removal, salt marsh restoration, scrub-shrub restoration and tidal channel creation. The proposed design requires the excavation of approximately 64,400 cubic yards (cy) of material over an area of approximately 71.5 acres. This plan reduces the area of the TSP by approximately 16% so as not to encroach on privately-owned land. The excavated material includes approximately 53,600 cy resulting from clearing and grubbing operations. This material will be removed offsite and taken to an appropriate upland disposal facility. Clearing and grubbing is assumed to be to a 6" depth. The remaining 10,800 cy of excavated material will be redistributed onsite to create the higher elevations of high marsh and scrub-shrub. Approximately 11,800 cy of material will need to be brought to the site, which will be used to bring lower areas up to the design grade. The design will create approximately 56.2 acres of low marsh, 6.5 acres of high marsh and 4.2 acres of scrub-shrub. A 1 foot layer of clean growing media will be placed in the high marsh and upland areas.

A broken culvert at the western edge of the middle of the site is restricting tidal flow and will have to be replaced. For this stage of the design, a 6-foot concrete box culvert, approximately 50 feet long was assumed. This culvert will have to be properly sized during the design phase of this study.

The design will create approximately 7,700 linear feet of new or enhanced tidal channels throughout the site. The site is divided into the distinct sections; the north, middle and south. The tidal channels in the southern section of the site will originate directly from Bellman's Creek. The northern tidal channels are fed through an offsite tidal channel that runs parallel to the southbound lane of the NJ Turnpike. The channel enters the site through a culvert and flows into the northern third of the site. This culvert will need repair as it is currently not functional but it is assumed that it will not need replacement. The tidal channels from this northern section will feed the middle section of the site through the newly-replaced culvert.

During construction a turbidity curtain will be deployed along the shoreline of Bellman's Creek at the southern boundary of the site. The curtain will trap sediments from the site as it is disturbed during excavation and grading activities, and prevent the sediments from entering Bellman's Creek.

Planting elevations were developed from tidal datums derived from water surface elevation data collected at the Secaucus High Wetlands site in January 2008. Uncertainty associated with the tidal datums used may impact design elevations, and by extension, excavation quantity. The level of uncertainty is considered to be appropriate for this stage of this study and has been fully considered in the site's cost estimate contingency. PED phase data collection, analysis and design development needs are further discussed in Section 7 of this appendix. Additional, water surface elevation data should be collected at multiple locations for this site during the PED phase. PED phase data collection, analysis and design development needs are further discussed in Section 7 of this appendix.

Construction at the Meadowlark site is scheduled to begin in 2033. The first year after the completion of construction, 2035, is therefore taken to be Year Zero in all sea level change analysis and the establishment of planting elevations. The 2008 tidal datums were projected to the future base year of 2035 based on the intermediate sea level rise curve at the NOAA tide gauge at the Battery, NY (#8518750). These datums, as well as project year 20 and 50 datums (intermediate curve) are shown in Table 6-21.

Table 6-21: Meadowlark Marsh Tidal Datums, ft NAVD88

Datum	*2001*	*2035 (Yr 0)*	*2055 (Yr 20)*	*2085 (Yr 50)*
MHHW	*3.07*	*3.55*	*4.00*	*4.80*
MHW	*2.71*	*3.19*	*3.64*	*4.44*
MTL	*0.08*	*0.56*	*1.01*	*1.81*

Tidal datums were then translated into planting elevations (Table 6-22). For Meadowlark, the lower elevation for low marsh was set at approximately 0.85 foot above MTL, thereby providing a future margin of sustainability in that it is assumed that low marsh plantings will remain viable

at elevations above MTL. The low marsh low elevation is assumed to remain viable until MTL has surpassed 1.4 ft, NAVD88. High Marsh elevations begin at the projected MHW datum (approximately) and Scrub-shrub was set at a maximum elevation of one foot above high marsh; upland was set to be at or above the highest scrub elevation.

Table 6-22: Meadowlark Planting Elevations, ft NAVD88

	Design Elevations (2033)	
	Low	*High*
Low marsh	*1.4*	*2.9*
High marsh	*2.9*	*3.4*
Scrub	*3.4*	*4.4*
Upland	*4.4*	*Above*

6.2.4 Oyster Restoration

6.2.4.1 Naval Station Earle

Restoration measures to be executed at the Naval Station Earle Oyster Restoration site include Oyster Pyramids, Oyster Castles and Oyster Gabions. Approximately 10 acres of oyster habitat will be created at the Earle Naval Station site. The restoration site will be situated beneath an existing pier and will consist of a combination of gabions and pyramids. Groups of pyramids will be grouped within the interior of the site, around which gabions will form a protective perimeter. A total of 1010 oyster pyramids, each consisting of 30 oyster castles, will be placed in groups of 30. Each group will consist of five staggered rows of six pyramids. Rows are spaced 12 feet apart and pyramids are spaced 14.25 feet edge-to-edge from the base layer within each row. It is assumed that the base layer of each castle will settle into the sand substrate, leaving the top three layers exposed and available for oyster growth. It is assumed that each pyramid will be treated with three cubic feet of spat-on-shell.

A total of 102 gabions will be placed along the outside longer edges of the site, which are each approximately 2,420 linear feet. The gabions (4.25’ x 4.25’ x 4.25’) will be placed apart 44 feet edge-to-edge. It is assumed that each gabion will be ¾-filled, 2/3 of which will be shell-only and the remaining 1/3 will be spat-on-shell.

The original plan called for spat on shell as a substrate. Discussions with experts from ERDC resulted in determining that this location has currents that are too strong for such a substrate. Instead, the large perimeter gabions help to mitigate the currents and protect the interior pyramids.

6.2.4.2 Bush Terminal

Restoration measures to be executed at the Bush Terminal Oyster Restoration site include a Spat-on Shell rock or rubble bed Oyster Pyramids and Oyster Gabions. Approximately 31.9 acres of oyster habitat will be created at the Bush Terminal. One thousand one hundred 2’x2’x2’ gabions will be deployed throughout the site at a rate of approximately 35 per acre, spaced at

10 feet on-center. Each gabion will be filled with 0.30 cubic yards of spat-on-shell. A bed of spat-on-shell will be placed around the gabions at a depth of 18 inches. The original plan also included hanging super-trays, but were removed after discussions with the NYSDEC.

6.2.4.3 Head of Jamaica Bay

Restoration measures to be executed at the Head of Jamaica Bay Oyster Restoration site include a Spat-on Shell rock or rubble bed, Oyster Pyramids, Oyster Gabions and Hanging Super-Trays. Approximately 10.1 acres of oyster habitat will created at the Head of Jamaica Bay site. The site will use a combination of gabions, pyramids and hanging super-trays. In general, gabions will form perimeters around groups of pyramids, which will be surrounded by a bed of spat-on-shell.

A total of 150 pyramids, each consisting of 30 castles, will be placed in offset rows set 25 feetapart; individual pyramids will be spaced 25 feet on-center. It is assumed that each pyramid will be treated with three cubic feet of spat-on-shell.

A total of 340 gabions (2'x2'x2') will be spaced at 10 feet on-center and at a distance of 40 feet from the rows of pyramids. It is assumed that the gabions will be filled with 75% shell only and 25% spat-on-shell. The gabions and pyramids will be surrounded by a bed of mixed shell, porcelain and spat-on-shell. It is assumed that the substrate will consist of 50% shell-only mixed with 33% crushed porcelain, and overlain with 17% spat-on-shell. This mixed-material bed will be placed to a depth of 12 inches.

Two rows of hanging super-trays will be suspended by cables, spaced 40 feet part, down the center of the 1200-foot length of the oyster bed. Each cable will carry 235 three-foot trays. The trays will be spaced two feet apart along the cables and will be half-filled with spat-on-shell.
The original plan called for floating oyster bags over a hard substrate. This plan changed after discussions with the NYSDEC, and now included gabions, pyramids and super-trays. The use of crushed porcelain as a percentage of the substrate is also a new feature, and helps to reduce the cost of the final plan.

7 Further Analysis and Design Development Needs

In this section, PED phase analysis and design development needs are discussed for each individual site. Cost for these activities have been fully considered in the PED phase costs presented in Appendix I. Study and implementation risks are more fully discussed in Section 4.13.2 of the main report. These considerations were also fully considered in the project risk register, cost estimates and schedules. The proposed designs are largely based on limited and/or legacy data which increases the risk and uncertainty inherent in these designs. This risk and uncertainty is further increased by the long duration between this report and the projected Pre-Construction and Engineering Design (PED) phase for many of these sites. PED phase analysis for many sites will therefore often encompass all aspects of data collection and analysis needed to implement the proposed designs.

7.1 Jamaica Bay Marsh Islands

Hydrodynamic modeling, to better understand site specific physical processes and sediment transport is recommended for the five proposed marsh island restoration sites. It is expected that a preexisting, calibrated CMS model of Jamaica Bay will be available as a result of studies being conducted for a different project (NY & NJ Harbor & Tributaries Focus Area Feasibility Study [HATS]) and should be leveraged in modeling each of the islands.

An existing conditions topographic survey will be required for each of the islands, as well as bathymetric surveys taken far enough off-shore as to capture at least 100 feet seaward of where the design elevation will meet the existing grade. Channels in near proximity to a given site may also need surveying if the representation within the HATS model is deemed to be insufficient. Proposed marsh island designs were based largely on tide data that were collected generally from 2001 to 2003. For this reason, new tide data should be collected during the future design period(s). Updated bio-benchmarking data collection will also be required, which will be used in conjunction with the updated tide data to verify the vegetation community ranges. The design should be adjusted as necessary to incorporate any elevation changes. Tide gauge data will also be used for model calibration and current data collection should also be considered. Geotechnical data collection and analysis should be conducted to better understand settlement at each site.

7.2 Jamaica Bay Perimeter Sites

For both the Fresh Creek and Dead Horse Bay sites, existing conditions topographic and bathymetric surveys will be needed, in addition to bio-benchmarking data collection. It is strongly recommended that updated tide data should be collected and used in conjunction with the bio-benchmarking data to verify vegetation community ranges. The designs should be adjusted as necessary to incorporate any elevation changes. At Dead Horse Bay, a study of shoreline erosion should be conducted to determine whether protection at the mouth of the tidal channel will be necessary. Here again, it is strongly recommended that updated tide data should be collected. Channel stability and the optimization of sediment transport into the site, to facilitate accretion, should be investigated using a hydrodynamic model. Dlope stability must be considered in the design of this site.

7.3 Flushing Creek

Updated bathymetric and topographic survey data will be necessary. It is strongly recommended that updated tide data should be collected and used in conjunction with the bio-benchmarking data to verify vegetation community ranges. A settlement analysis of mudflat areas to be converted to low marsh is also recommended.

7.4 Bronx River Sites

An updated hydraulic model should be developed for the Bronx River to more accurately assess stream velocities, shear stresses, water surface elevations and other parameters for all

proposed sites. PED phase hydraulic analysis should also consider projected climate driven changes in hydraulic loading. Proposed design elements should be verified against the updated model to confirm appropriate sizing of in-stream and shoreline features. Further analysis during the PED phase may indicate that alternative techniques are more appropriate. As previously noted, the selected techniques are based on limited data but are deemed to be sufficiently representative of the needed restoration measures. A more in-depth analysis of local sediment transport rates and patterns may be warranted. Updated existing conditions topographic and localized bathymetric data should be collected at each of the sites. Geotechnical data should be collected as needed.

7.5 Lower Passaic Sites

For the Oak Island Yard site, existing conditions topographic and bathymetric surveys will be needed, in addition to bio-benchmarking data collection. Updated tide data should be collected and used in conjunction with the bio-benchmarking data to verify vegetation community ranges. The designs should be adjusted as necessary to incorporate any elevation changes. Geotechnical data should be collected and a slope stability analysis will be required. The sea level analysis conducted in this study suggests that the low end of the low marsh design elevations should be raised to increase resiliency.

For Branch Brook, a hydraulic model should be developed to more accurately assess stream velocities, shear stresses, water surface elevations and other parameters. PED phase hydraulic analysis should also consider projected climate driven changes in hydraulic loading. Proposed design elements should be verified against the updated model to confirm appropriate sizing of in-stream and shoreline features. Further analysis during the PED phase may indicate that alternative techniques are more appropriate. As previously noted, the selected techniques are based on limited data but are deemed to be sufficiently representative of the needed restoration measures. Existing conditions topographic and bathymetric data as well as geotechnical data should be collected.

7.6 Hackensack Sites

For both the Metromedia and Meadowlark sites, existing conditions topographic and bathymetric surveys will be needed. It is strongly recommended that updated tide data should be collected and used in conjunction with the bio-benchmarking data to verify vegetation community ranges. At Meadowlark, a utility survey will be needed to better understand the condition and function of all culverts on the site. It is noted that a natural gas line also traverses the site and the site hosts electrical towers. Hydrodynamic modeling is necessary to advance designs at this site and may help in improving the resiliency of the site. The sea level analysis conducted in this study suggests that the low end of the low marsh design elevations should be raised to increase resiliency if possible.

7.7 Oyster Restoration Sites

Prior to construction of the oyster sites, it will be necessary to verify that the marine environment at each of these sites will still be suitable for oyster sustainability. This may include updated tidal current and turbidity data, and biometric data such as salinity, temperature and dissolved oxygen, which should be confirmed by the project biologist.

8 Conclusions

The observations and data collected as well as engineering judgment summarized in this report were used to prepare alternatives and detailed designs for 20 HRE sites. The level of available data, analysis and design detail for these design vary considerably based on the extent and applicability of prior efforts in pre-existing source studies. This fact, as well as the long duration between this report and the projected Pre-Construction and Engineering Design (PED) phase for many of these sites, increase the risk and uncertainty inherent in the proposed designs. These risk are fully documented in the risk register and are discussed in further detail in Section 4.13.2 of the main report. This uncertainty has also been fully considered in the cost estimate contingency for each site. PED phase analysis and design development needs are summarized in Section 7 of this appendix. These considerations also informed the development of each designs O&M contingency costs. In all instances, and in keeping with civil works transformation principles, the designs and quantities are of sufficient detail to support risk informed study decisions as well as confidence in the base cost estimate, schedule, project benefit calculations, and design performance.

9 References

Allen, H.H & Fischenich, C. (2001). *Brush Mattresses for Streambank Erosion Control*. (ERDC TN-EMRRP-SR-23). US Army Corps of Engineers Research and Design Center, Environmental Laboratory. Vicksburg, MS. Retrieved from: https://www.spa.usace.army.mil/Portals/16/docs/civilworks/regulatory/Stream%20Information%20and%20Management/ERDC%20Brush%20Mattresses.pdf

Evergreen Environmental LLC. *Evergreen Mill Creek Point Mitigation Bank Prospectus,* July 2014, Retrieved from: https://www.nan.usace.army.mil/Portals/37/docs/regulatory/publicnotices/2014/Sept%202014/Evergreen%20Mill%20Creek%20Point%20Mitigation%20Bank%20Prospectus%20Text(1).pdf

Hill, T.D. & S.C. Anisfield. (2015). *Sea Level Rise and Sediment: Recent Salt Marsh Accretion in the Hudson River Estuary*. Section II: 1-32 pp. In D.J. Yozzo, S.H. Fernald and H. Andreyko (eds.), Final Reports of the Tibor T. Polgar Fellowship Program, 2013. Hudson River Foundation.

JMT & HAKS (2015). *In-Stream Structures Details and Construction Guidelines.* Prepared for the Philadelphia Water Department. Retrieved from: http://archive.phillywatersheds.org/doc/In-stream%20Structures%20and%20Details_Final.pdf

Little, C.D. & Biedenharn, D.S. (2007) *Geomorphic Assessment and Sediment Impact Assessment for Bronx River, New York*. US Army Corps of Engineers Research and Design Center, Environmental Laboratory, Coastlal and Hydraulics Laboratory. Vicksburg, MS.

Lyn, D.A. & Newton, J.F. (2015). *Approaches to the design of biotechnical streambank stabilization: Volume I – A guide to the literature Joint Transportation Research Program Publication* No. FHWA/IN/JTRP-2015/14). West Lafayette, IN: Purdue University. http://dx.doi.org/10.5703/1288284315998

NOAA. (2003). *Computational Techniques of Tidal Datums Handbook*. Silver Spring, MD: US Department of Commerce, Center for Operational Oceanographic Products and Services.

NOAA. (2013). *Estimating Vertical Land Motion from Long-Term Tide Gauge Records*. Silver Spring, MD. US Department of Commerce, National Ocean Service Center Operational Oceanographic Products and Services.

Tabak, N.M. & Laba, M., Spector, S. (2016). *Simulating the Effects of Sea Level Rise on the Resilience and Migration of Tidal Wetlands along the Hudson River*. PLoS ONE 11(4): e0152437. Doi: 1371/journal.pone.0152437

Reed, D.J., D.A. Bishara, D.R. Cahoon, J. Donnelly, M. Kearney, A.S. Kolker, L.L. Leonard,R.A. Orson, and J.C. Stevenson. 2008. *Site-Specific Scenarios for Wetlands Accretion as Sea Level Rises in the Mid-Atlantic Region*. Section 2.1 in: Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1, J.G. Titus and E.M. Strange (eds.). EPA 430R07004. U.S. EPA, Washington, DC.

Swanson, R.I. & Wilson, R.E. (2008) *Increased Tidal Ranges Coinciding with Jamaica Bay Development Contribute to Marsh Flooding*. Journal of Coastal Research, (24)6, 1565-1569. West Palm Beach, Florida, ISSN 0749-0208

USACE New York District. (2003). *Jamaica Bay Ecosystem Restoration Project. Jamaica Bay Conceptual Plan Report, Final.* New York, NY

USACE New York District. (2003). *Jamaica Bay Ecosystem Restoration Project. Conceptual Plan Report – Final*. New York, NY.

USACE New York District & New York City Department of Environmental Protection. (2006). *Jamaica Bay Ecosystem Restoration Project. Draft Feasibility Report. Engineering Appendix.* New York, NY.

USACE New York District. (2016). *Bronx River Ecosystem Restoration Feasibility Study, Preliminary Cost Estimates with Abbreviated Risk Analysis*. New York, NY.

USACE. (v. 2017.55). Sea Level Change Curve Calculator. Retrieved from USACE: http://corpsmapu.usace.mil

US Army Corps of Engineers. (2017). Guidance for Detection of Nonstationarities in Annual Maximum Discharges. (ETL 1000-2-3).

US Army Corps of Engineers, CECW-EC. (2018). *Guidance for Incorporation Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs and Projects*. (Engineering and Construction Bulletin No. 2018-14)

US Army Corps of Engineers, CECW-EC. (2018). *Using Non-NOAA Tide Gauge Records for Computing Relative Sea Level Change*. (Engineering and Construction Bulletin No. 2018-3).

US Army Corps of Engineers. 2018. ECB-2018-2: Implementation of Resilience Principles in the Engineering & Construction Community of Practice, dated 25 Jan 2018

US Army Corps of Engineers 2019a. ER-1100-2-8162: Incorporating Sea Level Change In Civil Works Programs, dated 15 June 2019

US Army Corps of Engineers 2019b. EP-1100-2-1: Procedures to Evaluate Sea Level Change: Impacts, Responses, And Adaptation, dated 20 June 2019.

USACE New York District. (2017). *Hudson-Raritan Estuary Ecosystem Restoration Feasibility Study, Draft Integrated Feasibility Report & Environmental Assessment.* New York, NY.

USEPA. Wet Meadows (n.d.). Retrieved from https://www.epa.gov/wetlands/wet-meadows

USDA, Invasive Plants (n.d.). Retrieved from https://www.fs.fed.us/wildflowers/invasives/index.shtml

USDA Natural Resources Conservation Service, Lake County Planning Building and Development Department & Lake County Stormwater Management Commission. (2002). *Streambank and Shoreline Protection Manual.* Retrieved from www.co.lake.il.us\stormwater

US Department of Agriculture, National Engineering Handbook. (2007). *Vegetated Rock Walls*, (Technical Supplement 14M).

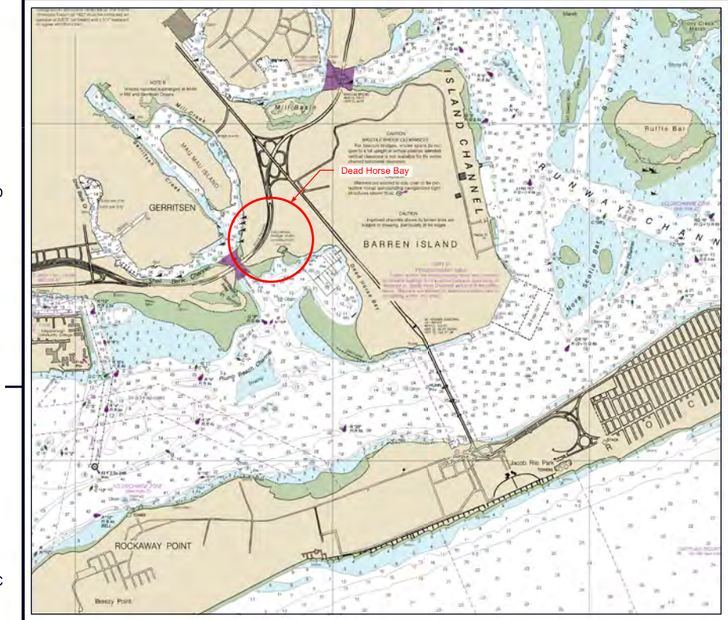
US Department of Agriculture, National Engineering Handbook. (2007). Stone Sizing Criteria, (Technical Supplement 14M).

U.S. Department of the Interior, Bureau of *Reclamation*. (2016). *Reclamation: Managing Water in the West. Rock Weir Design Guidance.* Retrieved from https://www.usbr.gov/tsc/techreferences/mands/mands-pdfs/RockWeirDesignGuidance_final_ADAcompliant_031716.pdfUniversity of North Carolina Stream Restoration Institute & North Carolina Sea Grant. (n.d.). *Stream Restoration: A Natural Channel Design Handbook*

Washington Department of Forestry. (2004). *In-Stream Detention Basins.* Retrieved from https://people.wou.edu/~taylors/g407/restoration/WA_Dept_Forestory_2004_Sediment_Detention_Basins.pdf

Attachment C-1
HRE
Proposed Design and Quantities

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\JamBay Perimeter Sites\Dead_Horse\MicroStation\DHB_selected_design.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\JamBay Perimeter Sites\Dead_Horse\MicroStation\Pen Tables\DHB_planting_plan_pen_table.tbl MAY 2009 NYD BORDER



Location map (n.t.s.)



Legend

- Low marsh: 19.0 acres, Elev. 1.6 ft to 2.8 ft
- Upland: 14.0 acres, Elev. 3.4 ft and above
- High marsh: 5.4 acres, Elev. 2.8 ft to 3.4 ft
- New tidal channel: 2.31 acres

1. Construction to begin in 2034 with 3-year duration. (Completion by 2037.)
2. Vegetation ranges based on tide data collected in 2001; projected to 2037 at the intermediate rate of sea level rise.

Not to standard scale

Coordinate system is NY State Plane, Long Island

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

Dead Horse Bay Perimeter Site

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

DESIGNED BY: GSW
DWN BY: GSW
SUBMITTED BY: GSW
FILE NAME:
SIZE: ANSI D
CKD BY:
PLOTTED BY:
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 1/5/2019

DEAD HORSE BAY
WETLAND RESTORATION

PLANTING PLAN

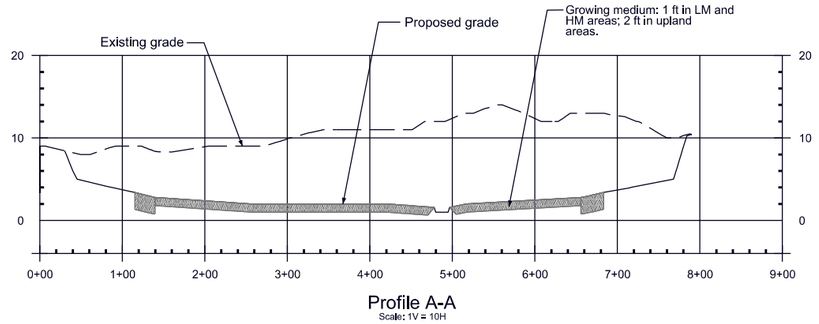
NEW YORK

JAMAICA BAY

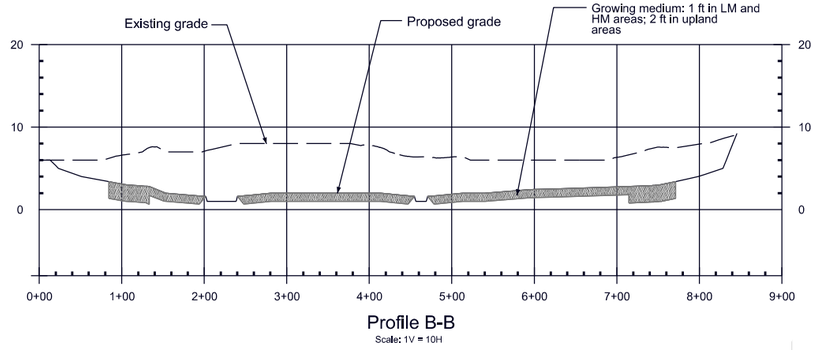
SHEET REFERENCE NUMBER

SHEET OF

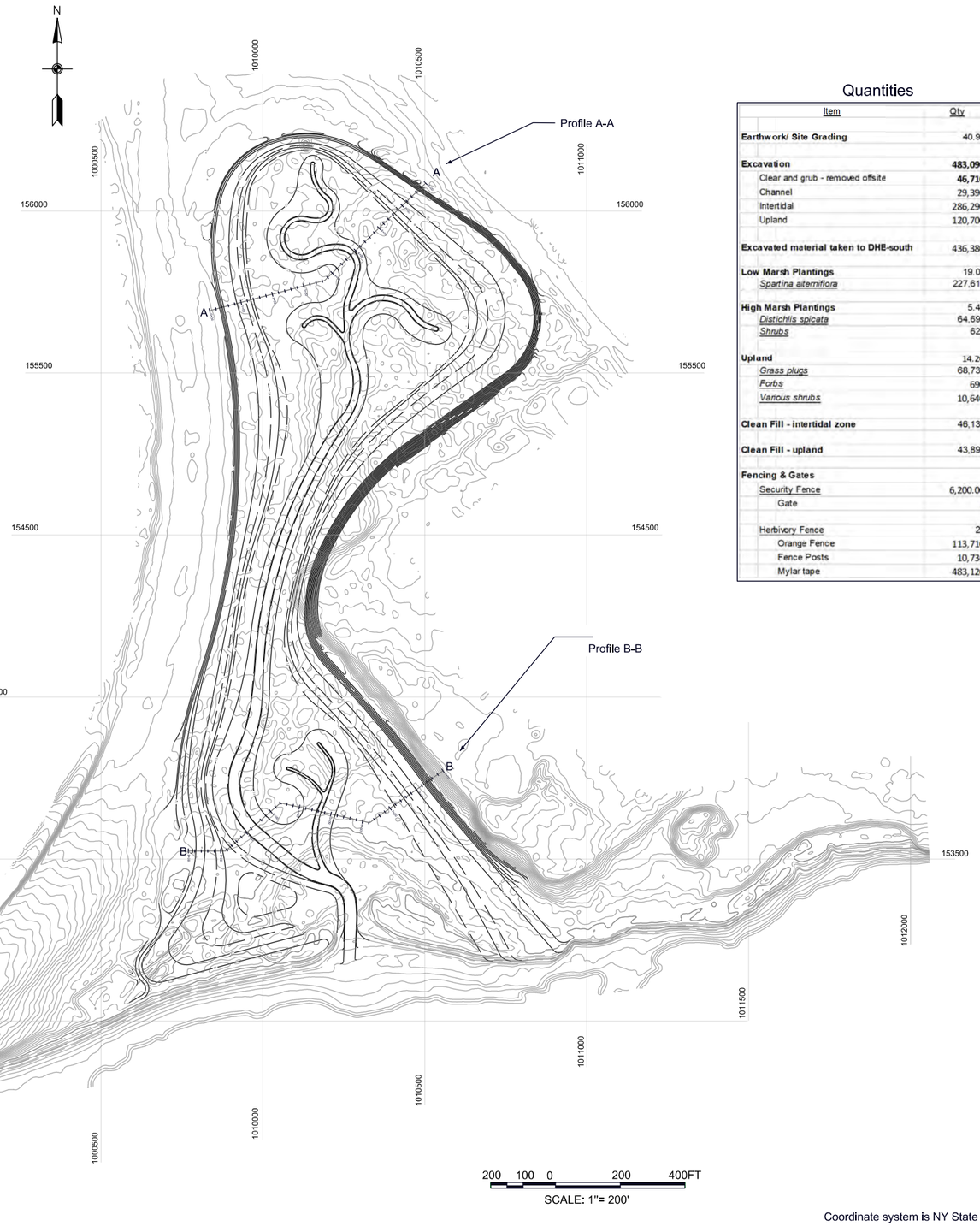
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\JamBay Perimeter Sites\Dead_Horse\MicroStation\DHB_selected_design.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\JamBay Perimeter Sites\Dead_Horse\MicroStation\Pen Tables\DHB_grading_plan_pen_table.tbl MAY 2009 NYD BORDER



Profile A-A
Scale: 1V = 10H



Profile B-B
Scale: 1V = 10H



Coordinate system is NY State Plane, Long Island

Quantities

Item	Qty	UOM
Earthwork/ Site Grading	40.90	AC
Excavation	**483,090**	CY
Clear and grub - removed offsite	**46,710**	CY
Channel	29,390	CY
Intertidal	286,290	CY
Upland	120,700	CY
Excavated material taken to DHE-south	436,380	CY
Low Marsh Plantings	19.00	AC
Spartina alterniflora	227,610	EA
High Marsh Plantings	5.40	AC
Distichlis spicata	64,690	EA
Shrubs	620	EA
Upland	14.20	AC
Grass plugs	68,730	EA
Forbs	690	EA
Various shrubs	10,640	EA
Clean Fill - intertidal zone	46,130	CY
Clean Fill - upland	43,890	CY
Fencing & Gates		
Security Fence	6,200.00	LF
Gate	1	EA
Herbivory Fence	24	AC
Orange Fence	113,710	LF
Fence Posts	10,736	EA
Mylar tape	483,120	LF

US Army Corps of Engineers
New York District

APPD.
DATE
DESCRIPTION
MARK
APPD.
DATE
DESCRIPTION
MARK

DESIGNED BY: GSW
DWN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
SIZE: ANSI D
FILE NAME:
PLOTTED BY:
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 6/2/2015

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

DEAD HORSE BAY
WETLAND RESTORATION

GRADING PLAN

NEW YORK

JAMAICA BAY

SHEET REFERENCE NUMBER

SHEET OF

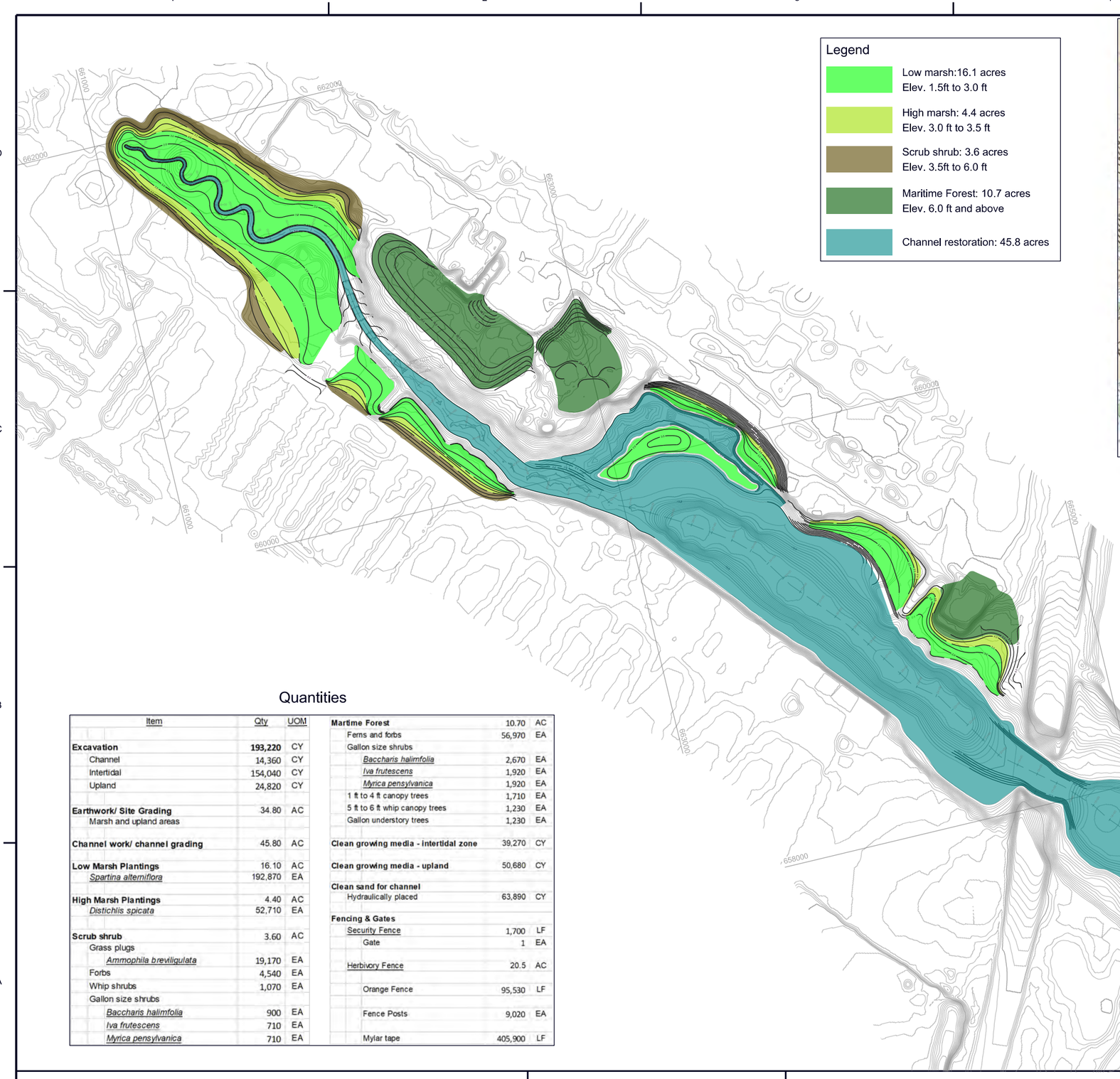
WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

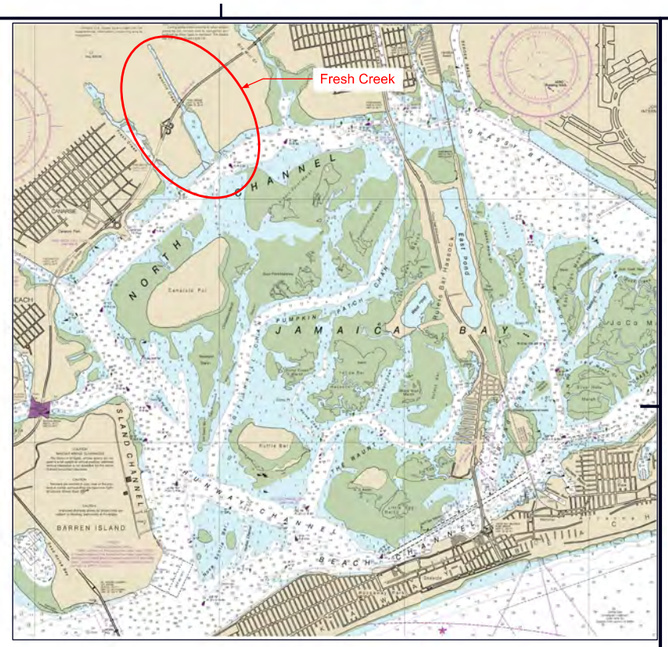
ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

Dead Horse Bay Perimeter Site

Dead Horse Bay Quantities

Item	Qty	UOM
Earthwork/ Site Grading	40.90	AC
Excavation	483,090	CY
Clear and grub - removed offsite	46,710	CY
Channel	29,390	CY
Intertidal	286,290	CY
Upland	120,700	CY
Clearing and Grubbing	38.60	AC
Excavated material taken to DHB-south	436,380	CY
Low Marsh Plantings	19.00	AC
Spartina alterniflora	227,610	EA
High Marsh Plantings	5.40	AC
Distichlis spicata	64,690	EA
Shrubs	620	EA
Upland	14.20	AC
Grass plugs	68,730	EA
Forbs	690	EA
Various shrubs	10,640	EA
Clean Fill - intertidal zone	46,130	CY
Clean Fill - upland	43,890	CY
Fencing & Gates		
Security Fence	6,200.00	LF
Gate	1	EA
Herbivory Fence	24	AC
Orange Fence	113,710	LF
Fence Posts	10,736	EA
Mylar tape	483,120	LF





Location Map (n.t.s)

Quantities

Item	Qty	UOM
Excavation	**193,220**	CY
Channel	14,360	CY
Intertidal	154,040	CY
Upland	24,820	CY
Earthwork/ Site Grading	34.80	AC
Marsh and upland areas		
Channel work/ channel grading	45.80	AC
Low Marsh Plantings	16.10	AC
Spartina alterniflora	192,870	EA
High Marsh Plantings	4.40	AC
Distichlis spicata	52,710	EA
Scrub shrub	3.60	AC
Grass plugs		
Ammophila breviligulata	19,170	EA
Forbs	4,540	EA
Whip shrubs	1,070	EA
Gallon size shrubs		
Baccharis halimfolia	900	EA
Iva frutescens	710	EA
Myrica pensylvanica	710	EA

Martime Forest	10.70	AC
Ferns and forbs	56,970	EA
Gallon size shrubs		
Baccharis halimfolia	2,670	EA
Iva frutescens	1,920	EA
Myrica pensylvanica	1,920	EA
1 ft to 4 ft canopy trees	1,710	EA
5 ft to 6 ft whip canopy trees	1,230	EA
Gallon understory trees	1,230	EA
Clean growing media - intertidal zone	39,270	CY
Clean growing media - upland	50,680	CY
Clean sand for channel		
Hydraulically placed	63,890	CY
Fencing & Gates		
Security Fence	1,700	LF
Gate	1	EA
Herbivory Fence	20.5	AC
Orange Fence	95,530	LF
Fence Posts	9,020	EA
Mylar tape	405,900	LF

Not to Standard Scale

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

Fresh Creek Perimeter Site

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DRN BY: GSW
CKD BY:
SUBMITTED BY: GSW
SIZE: ANSI D
PLOTTED BY:
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
PLOT DATE: 6/17/2019

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

FRESH CREEK
WETLAND RESTORATION
JAMAICA BAY

PLANTING PLAN

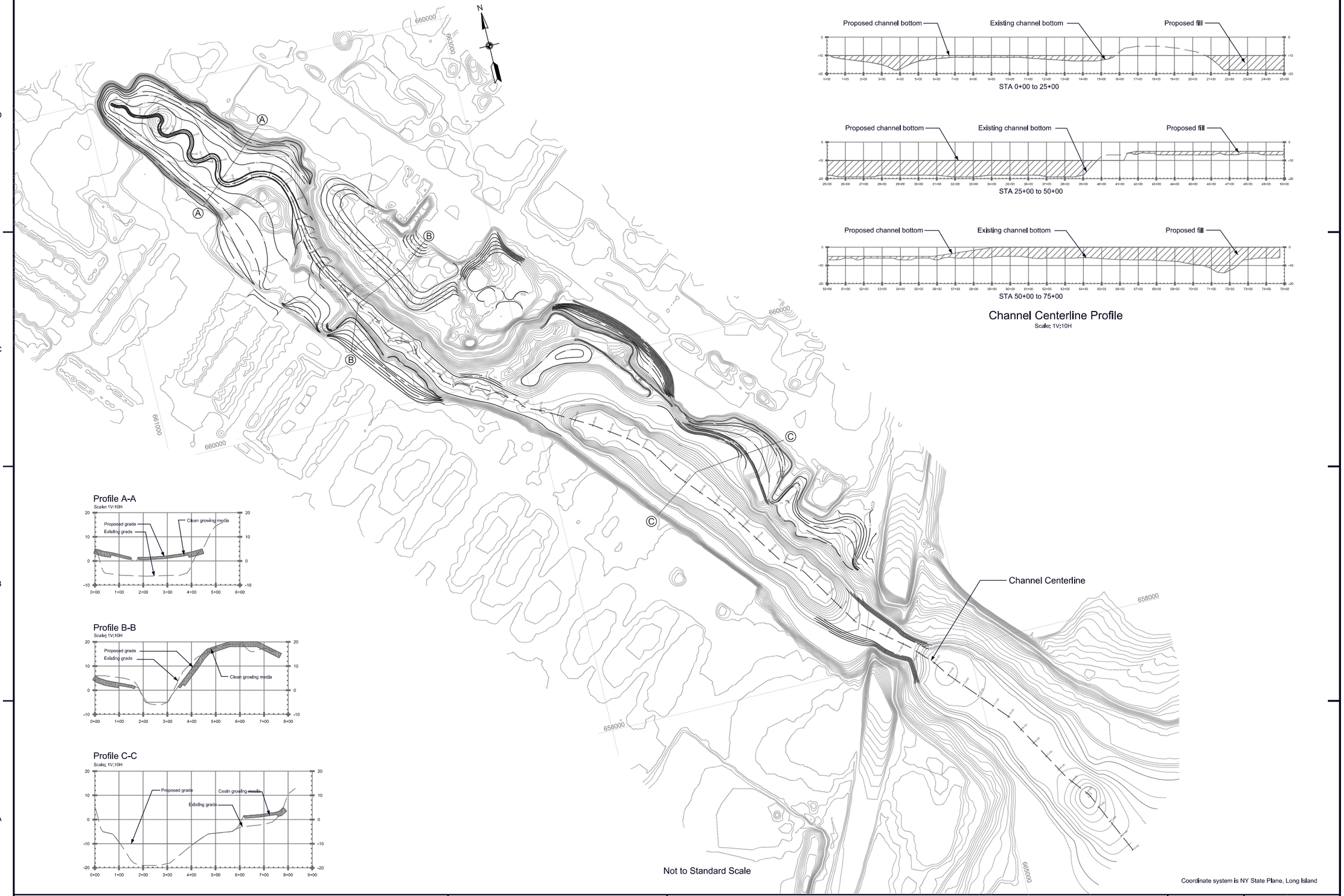
NEW YORK

SHEET REFERENCE NUMBER

SHEET OF

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\JamBay Perimeter Sites\Fresh_Creek\MicroStation\Fresh_Creek_design.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\JamBay Perimeter Sites\Fresh_Creek\MicroStation\Pen tables\Fresh_planting_plan_pen_table.tbl MAY 2009 NYD BORDER

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\JamBay Perimeter Sites\Fresh_Creek\MicroStation\Fresh_Creek_design.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\JamBay Perimeter Sites\Fresh_Creek\MicroStation\Pen tables\Fresh_grading_plan_pen_table.tbl MAY 2009 NYD BORDER



Channel Centerline Profile

Scale: 1V:10H

Profile A-A

Scale: 1V:10H

Profile B-B

Scale: 1V:10H

Profile C-C

Scale: 1V:10H

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DRN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
PLOTTED BY:
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
PLOT DATE: 8/2/2019
SIZE: ANSI D

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

FRESH CREEK
WETLAND RESTORATION

GRADING PLAN

JAMAICA BAY
NEW YORK

SHEET REFERENCE NUMBER

SHEET OF

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

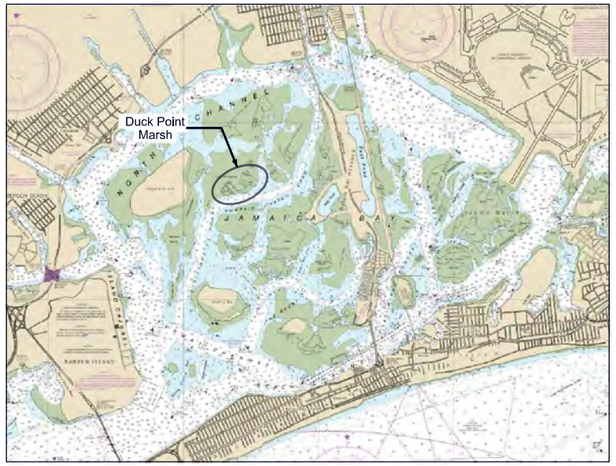
ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

Fresh Creek Perimeter Site

Fresh Creek Quantities		
Item	**Qty**	**UOM**
Excavation	193,220	CY
Channel	14,360	CY
Intertidal	154,040	CY
Upland	24,820	CY
Earthwork/ Site Grading	34.80	AC
Marsh and upland areas		
Clearing and Grubbing	34.80	AC
Marsh and upland areas		
Channel work/ channel grading	45.80	AC
Low Marsh Plantings	16.10	AC
Spartina alterniflora	192,870	EA
High Marsh Plantings	4.40	AC
Distichlis spicata	52,710	EA
Scrub shrub	3.60	AC
Grass plugs		
Ammophila breviligulata	19,170	EA
Forbs	4,540	EA
Whip shrubs	1,070	EA
Gallon size shrubs		
Baccharis halimfolia	900	EA
Iva frutescens	710	EA
Myrica pensylvanica	710	EA
Martime Forest	10.70	AC
Ferns and forbs	56,970	EA
Gallon size shrubs		
Baccharis halimfolia	2,670	EA
Iva frutescens	1,920	EA
Myrica pensylvanica	1,920	EA
1 ft to 4 ft canopy trees	1,710	EA
5 ft to 6 ft whip canopy trees	1,230	EA
Gallon understory trees	1,230	EA
Clean growing media - intertidal zone	39,270	CY
Clean growing media - upland	50,680	CY
Clean sand for channel		
Hydraulically placed	63,890	CY
Fencing & Gates		
Security Fence	1,700	LF
Gate	1	EA
Herbivory Fence	20.5	AC
Orange Fence	95,530	LF
Fence Posts	9,020	EA
Mylar tape	405,900	LF

MAY 2009 NYD BORDER

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Duck\MicroStation\Duck_planting.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Duck\MicroStation\Pen tables\Duck_planting_plan_pen_table.tbl



Legend

- Low marsh: 24.9 ac
  Elev 1.5 ft to 2.6 ft
- High marsh: 5.6 ac
  Elev 2.6 ft to 3.0 ft
- Scrub shrub: 8.1 ac
  Elev 3.0 ft and above

Note:

Construction to begin in 2024 with 3-year construction duration (completion in 2028).

N

166000
165000
1024000
1025000
1026000

200 100 0 200 400FT

SCALE: 1"= 200'

US Army Corps
of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DRN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
SIZE: ANSI D
PLOTTED BY:
PLOT DATE: 9/13/2019

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

DUCK POINT MARSH
WETLAND RESTORATION

PLANTING PLAN

NEW YORK

JAMAICA BAY

SHEET REFERENCE NUMBER
L-001
SHEET 1 OF 2

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

DUCK POINT MARSH

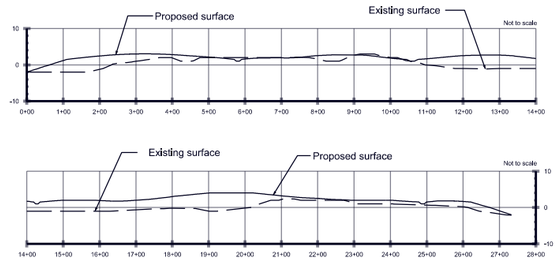
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Duck\MicroStation\Duck_grading.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Duck\MicroStation\Pen tables\Duck_grading_plan_pen_table.tbl
MAY 2009 NYD BORDER

Quantity Take-Off

Low Marsh Plantings	24.9	AC
Spartina alterniflora	298,280	EA
High Marsh Plantings	5.6	AC
Distichlis spicata	67,090	EA
Scrub-shrub	8.10	AC
Various plantings	10,790	EA
Clean Fill	213,780	CY

Baseline Profile

1V:10H



N

200 100 0 200 400FT

SCALE: 1"= 200'

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DRAWN BY: GSW
CHKD BY: GSW
SUBMITTED BY: GSW
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
PLOTTED BY:
PLOT DATE: 3/13/2019
SIZE: ANSI D

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

DUCK POINT MARSH
WETLAND RESTORATION

GRADING PLAN

JAMAICA BAY

NEW YORK

SHEET REFERENCE NUMBER
G-001
SHEET 2 OF 2

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

DUCK POINT MARSH

Duck Point Quantities

Item	Qty	UOM
Earthwork/ Site Grading	62.6	AC
Low Marsh Plantings	24.9	AC
Spartina alterniflora	298,280	EA
High Marsh Plantings	5.6	AC
Distichlis spicata	67,090	EA
Scrub-shrub	8.10	AC
Various plantings	10,790	EA
Clean Fill	213,780	CY
Fencing & Gates		
Construction (Orange) Fence	11,830	LF
Herbivory Fence	30.5	AC
Orange Fence	142,130	LF
Fence Posts	13,420	EA
Mylar tape	603,900	LF

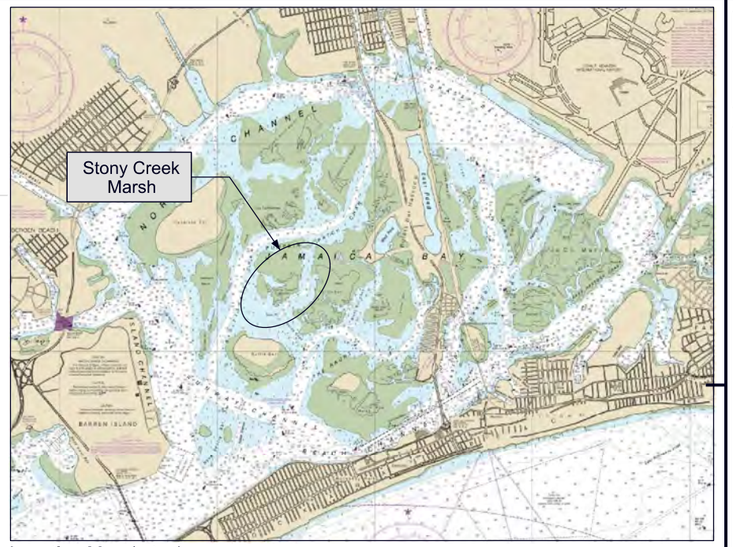
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Stony Creek\MicroStation\Stony_Creek_design.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Stony Creek\MicroStation\Pen tables\Stony_planting_plan_pen_table

1 2 3 4 5

D C B A

1024000 1025000 1026000

162500 161500 160500



Location Map (n.t.s.)

Legend

- Low marsh: 26.0 ac
  Elev 1.5 ft to 2.5 ft
- High marsh: 22.5 ac
  Elev 2.5 ft to 3.5 ft
- Scrub shrub: 3.4 acres
  Elev 3.5 ft and above

Note:
Construction to begin in 2024 with 3-year construction duration. (Completion by 2027.)

150 75 0 150 300 FT
SCALE: 1" = 150'

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

STONY CREEK MARSH

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DRN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
FILE NAME:
SIZE: ANSI D
PLOTTED BY:
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 9/25/2019

U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

STONY CREEK MARSH
WETLAND RESTORATION

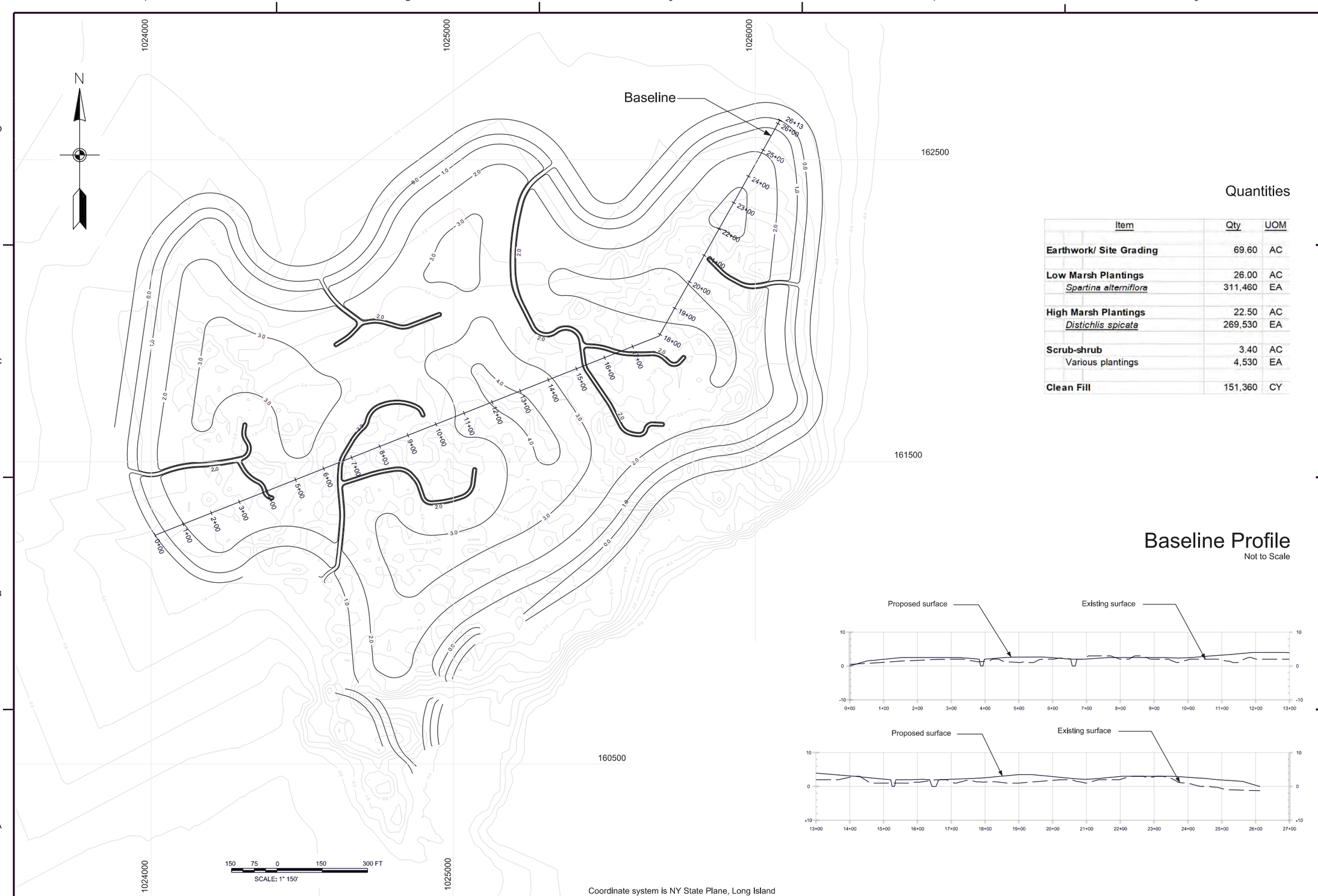
PLANTING PLAN

NEW YORK

JAMAICA BAY

SHEET REFERENCE NUMBER
L-001
SHEET 1 OF 2

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Stony Creek\MicroStation\Stony_Creek_design.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Stony Creek\MicroStation\Pen tables\Stony_grading_plan_pen_table.tb..



Coordinate system is NY State Plane, Long Island

Quantities

Item	Qty	UOM
Earthwork/ Site Grading	69.60	AC
Low Marsh Plantings	26.00	AC
Spartina alterniflora	311,460	EA
High Marsh Plantings	22.50	AC
Distichlis spicata	269,530	EA
Scrub-shrub	3.40	AC
Various plantings	4,530	EA
Clean Fill	151,360	CY

Baseline Profile

Not to Scale

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

STONY CREEK MARSH

US Army Corps of Engineers
New York District

APPR. | DATE | DESCRIPTION | MARK

DESIGNED BY: GSW | DATE:
DWN BY: GSW | CKD BY: | SOLICITATION NO.:
SUBMITTED BY: GSW | CONTRACT NO.:
FILE NAME: | PLOTTED BY: | PLOT DATE: 9/25/2019
SIZE: ANSI D

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

STONY CREEK MARSH
WETLAND RESTORATION
GRADING PLAN
JAMAICA BAY
NEW YORK

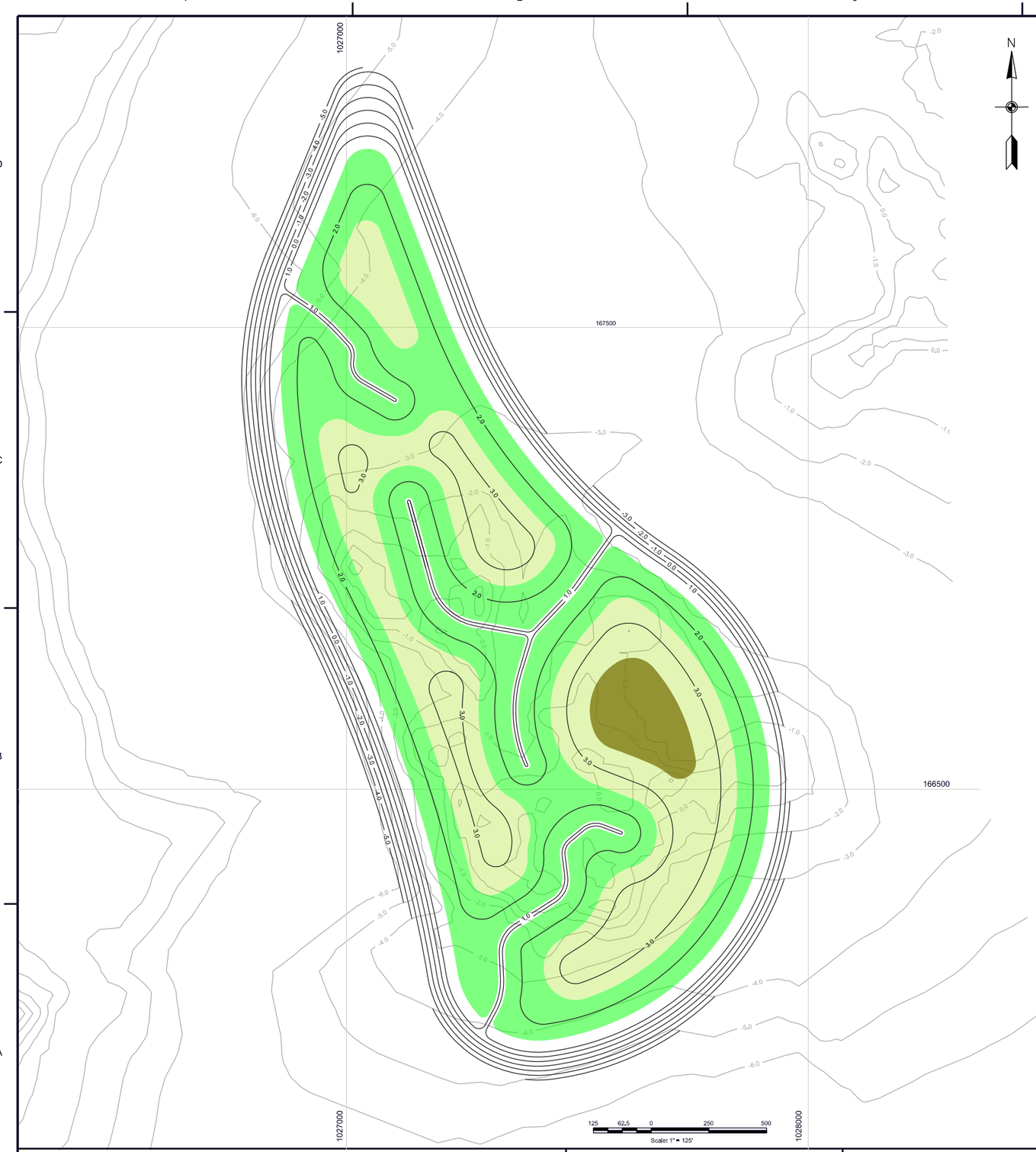
SHEET REFERENCE NUMBER
G-001
SHEET 2 OF 2

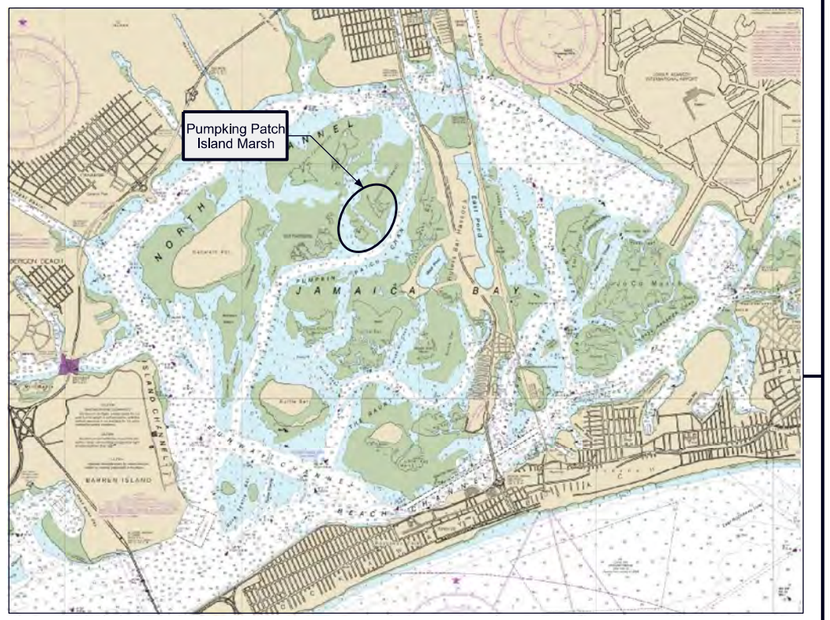
Stony Creek Quantities

Item	Qty	UOM	
Earthwork/ Site Grading	69.60	AC	
Low Marsh Plantings	26.00	AC	
Spartina alterniflora	311,460	EA	2ft c-c
High Marsh Plantings	22.50	AC	
Distichlis spicata	269,530	EA	2ft c-c
Scrub-shrub	3.40	AC	
Various plantings	4,530	EA	6ft c-c
Clean Fill	151,360	CY	
Fencing & Gates			
Construction (Orange) Fence	13,570	LF	
Herbivory Fence	48.50	AC	
Orange Fence	226,010	LF	
Fence Posts	21,340	EA	
Mylar tape	960,300	LF	

MAY 2009 NYD BORDER

S:\CRB\JBopportunities\MicroStation\Final feasibility plans\Pumpkin Patch E&W\Pumpkin_Patch_Designs.dgn
S:\CRB\JBopportunities\MicroStation\Final feasibility plans\Pumpkin Patch E&W\Pen tables\Pumpkin West planting_plan_pen_table.tbl





Location Map (n.t.s.)

Legend

- Low marsh: 13.7 ac
  Elev 1.5 ft to 2.5 ft
- High marsh: 8.6 ac
  Elev 2.5 ft to 3.5 ft
- Scrub shrub: 0.9 ac
  Elev 3.5 ft and above

US Army Corps
of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DRN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
FILE NAME:
SIZE: ANSI D
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOTTED BY:
PLOT DATE: 07/12/2018

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

PUMPKIN PATCH WEST ISLAND
WETLAND RESTORATION

PLANTING PLAN

NEW YORK

JAMAICA BAY

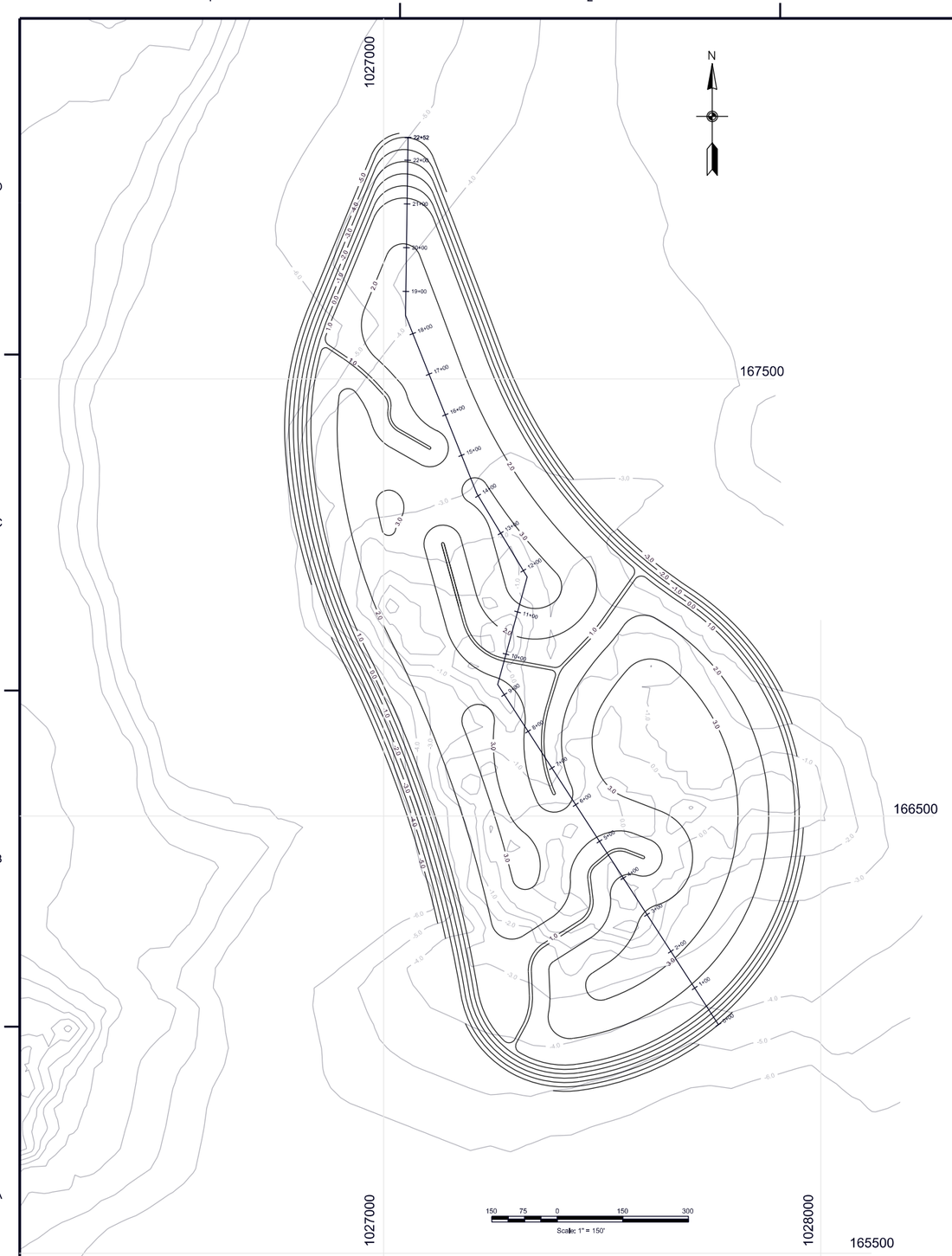
SHEET REFERENCE NUMBER
L-001
SHEET 1 OF 2

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

PUMPKIN PATCH WEST

L-001



Quantities

Item	Qty	UOM
Earthwork/ Site Grading	32.9	AC
Low Marsh Plantings	13.7	AC
Spartina alterniflora	164,270	EA
High Marsh Plantings	8.61	AC
Distichlis spicata	103,150	EA
Scrub-shrub	0.90	AC
Various plantings	1,200	EA
Clean Fill	327,690	CY

Baseline Profile

Not to scale



WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

PUMPKIN PATCH WEST

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DWN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
FILE NAME:
SIZE: ANSI D
PLOTTED BY:
PLOT DATE: 6/4/2019
DATE:
SOLICITATION NO.:
CONTRACT NO.:

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

PUMPKIN PATCH WEST MARSH
WETLAND RESTORATION

GRADING PLAN

NEW YORK

JAMAICA BAY

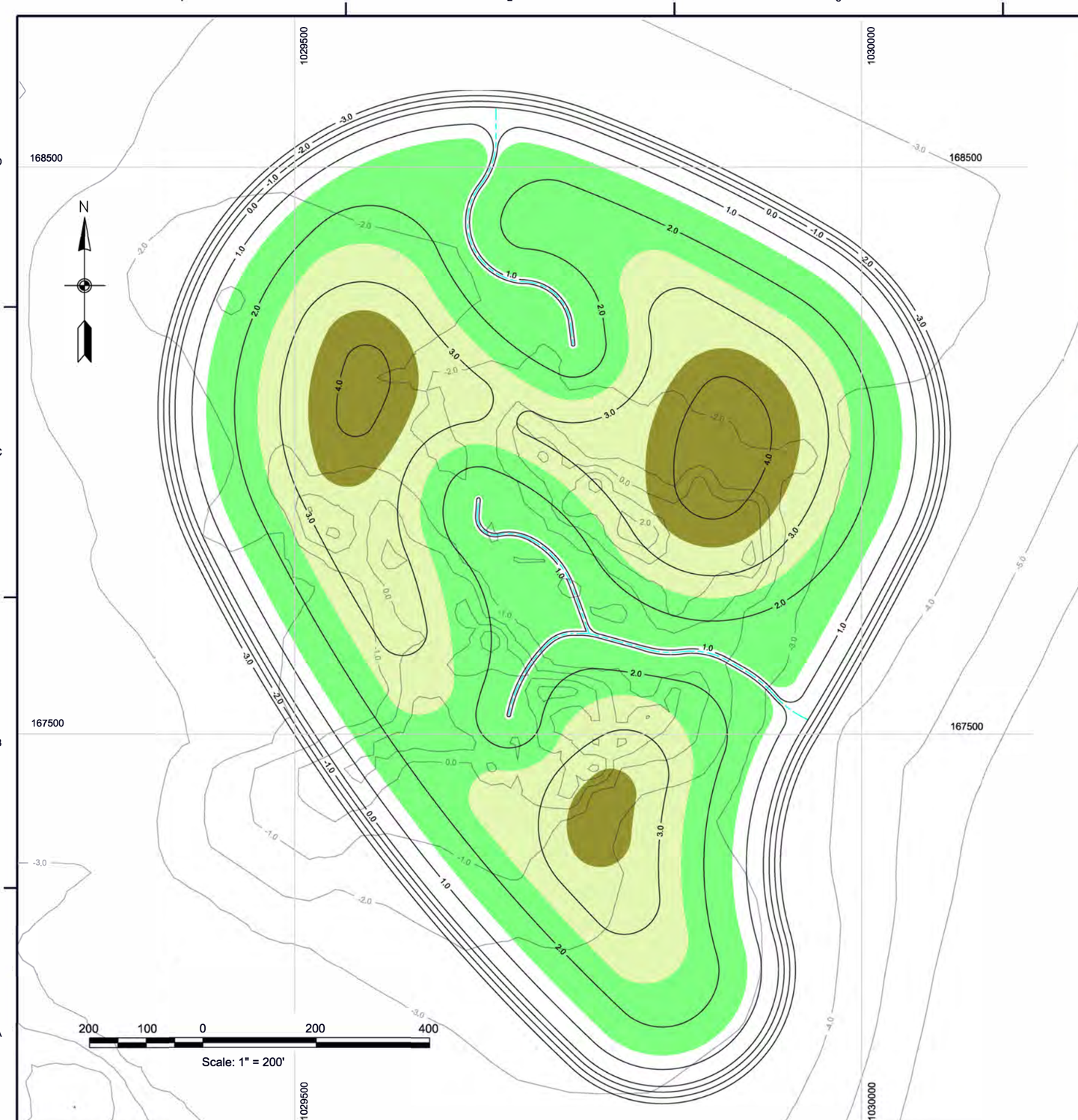
SHEET REFERENCE NUMBER
G-001

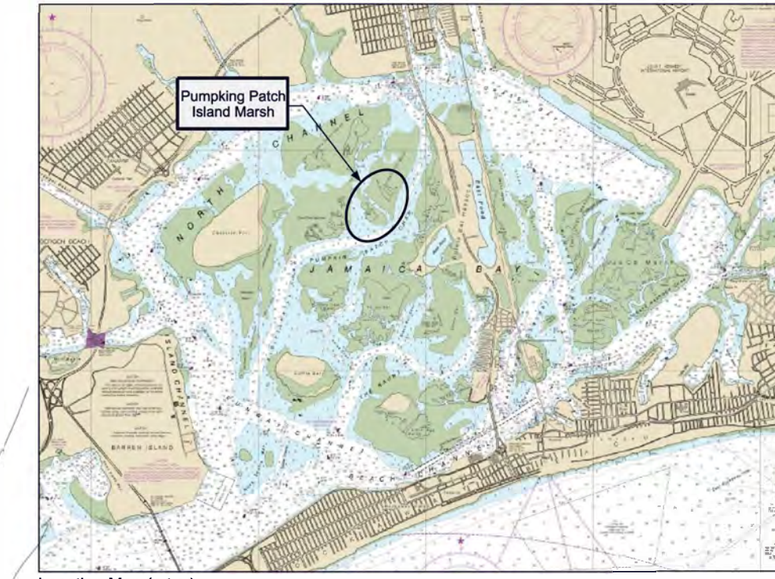
SHEET 2 OF 2

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Pumpkin_Patch_Designs.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Pumpkin Patch E&W\MicroStation\Pumpkin_Patch_Designs.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Pumpkin Patch E&W\MicroStation\Pen tables\Pumpkin West_grading_

Pumpkin Patch West Quantities

Item	Qty	UOM	
Earthwork/ Site Grading	32.9	AC	
Low Marsh Plantings	13.7	AC	
Spartina alterniflora	164,270	EA	2ft c-c
High Marsh Plantings	8.61	AC	
Distichlis spicata	103,150	EA	2ft c-c
Scrub-shrub	0.90	AC	
Various plantings	1,200	EA	6ft c-c
Clean Fill	327,690	CY	
Fencing & Gates			
Construction (Orange) Fence	8,480	LF	
Herbivory Fence	22.3	AC	
Orange Fence	104,030	LF	
Fence Posts	9,830	EA	
Mylar tape	442,000		





Location Map (n.t.s.)

Legend

- Low marsh: 15.6 ac
  Elev 1.5 ft to 2.5 ft
- High marsh: 10.1 ac
  Elev 2.5 ft to 3.5 ft
- Scrub shrub: 3.1 ac
  Elev 3.5 ft and above

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW | DATE:
DWN BY: GSW | CKD BY: | SOLICITATION NO.:
SUBMITTED BY: GSW | CONTRACT NO.:
FILE NAME:
SIZE: ANSI D | PLOTTED BY: | PLOT DATE: 11/20/2018

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

PUMPKIN PATCH EAST MARSH
WETLAND RESTORATION

PLANTING PLAN

JAMAICA BAY NEW YORK

SHEET REFERENCE NUMBER
L-001
SHEET 1 OF 2

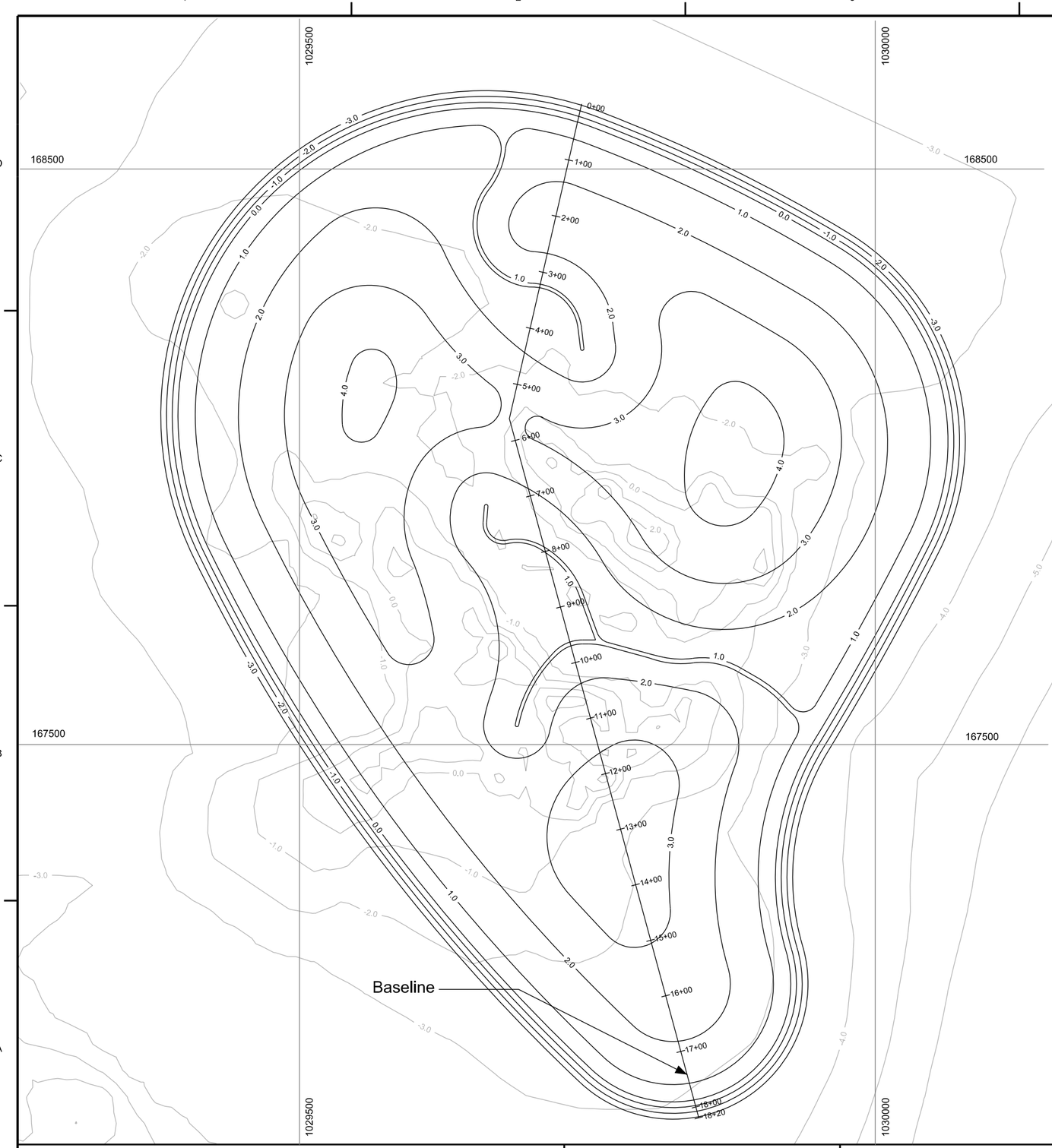
WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE, ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

PUMPKIN PATCH EAST

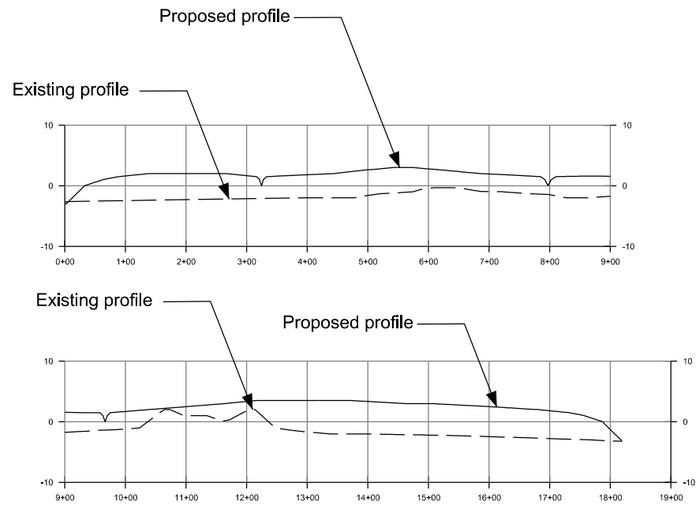
L:\HRE-Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Pumpkin Patch E&W\MicroStation\Pumpkin_Patch_Designs.dgn
L:\HRE-Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Pumpkin Patch E&W\MicroStation\Pen tables\Pumpkin East_planting_

L:\HRE-Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Pumpkin Patch E&W\MicroStation\Pumpkin_Patch_Designs.dgn
L:\HRE-Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Pumpkin Patch E&W\MicroStation\Pen tables\Pumpkin East_grading_f



Quantities

Item	Qty	UOM
Earthwork/ Site Grading	40.5	AC
Low Marsh Plantings	15.6	AC
Spartina alterniflora	186,580	EA
High Marsh Plantings	10.10	AC
Distichlis spicata	120,990	EA
Scrub-shrub	3.10	AC
Various plantings	4,130	EA
Clean Fill	351,960	CY



Baseline Profile

Not to scale

200 100 0 200 400

Scale: 1" = 200'

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DWN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
SPEC: MSD
PLOTTED BY:
PLOT DATE: 17/5/2018

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

PUMPKIN PATCH EAST MARSH
WETLAND RESTORATION

GRADING PLAN

NEW YORK

JAMAICA BAY

SHEET REFERENCE NUMBER
G-001
SHEET 2 OF 2

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

PUMPKIN PATCH EAST

Pumpkin Patch East Quantities

Item	Qty	UOM	
Earthwork/ Site Grading	40.5	AC	
Low Marsh Plantings	15.6	AC	
Spartina alterniflora	186,580	EA	2ft c-c
High Marsh Plantings	10.10	AC	
Distichlis spicata	120,990	EA	2ft c-c
Scrub-shrub	3.10	AC	
Various plantings	4,130	EA	6ft c-c
Clean Fill	351,960	CY	
Fencing & Gates			
Construction (Orange) Fence	7,190	LF	
Herbivory Fence	25.7	AC	
Orange Fence	119,650	LF	
Fence Posts	11,300	EA	
Mylar tape	508,370	LF	

L:\HRE-Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Elders CenterMicroStation\EldersCenterDesign.dgn
L:\HRE-Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Elders CenterMicroStation\Pen tables\Elders_planting_plan_pen_table.tbl May 2009 NYD BORDER

1 2 3 4 5

D C B A

N

1026000

1025000

170500

169500



Location Map (n.t.s.)

Legend

- Low marsh: 15.2 ac
  Elev 1.5 ft to 2.5 ft
- High marsh: 10.9 ac
  Elev 2.5 ft to 3.5 ft
- Scrub shrub: 1.4 ac
  Elev 3.5 ft and above

NOT TO STANDARD SCALE

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE, ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

ELDERS CENTER MARSH

US Army Corps of Engineers
New York District

DESCRIPTION | DATE | APPR | MARK

U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

DESIGNED BY: GSW | DATE:
DWN BY: GSW | CKD BY: | SOLICITATION NO.:
SUBMITTED BY: GSW | CONTRACT NO.:
FILE NAME:
SIZE: ANSI D | PLOTTED BY: | PLOT DATE: 11/20/2018

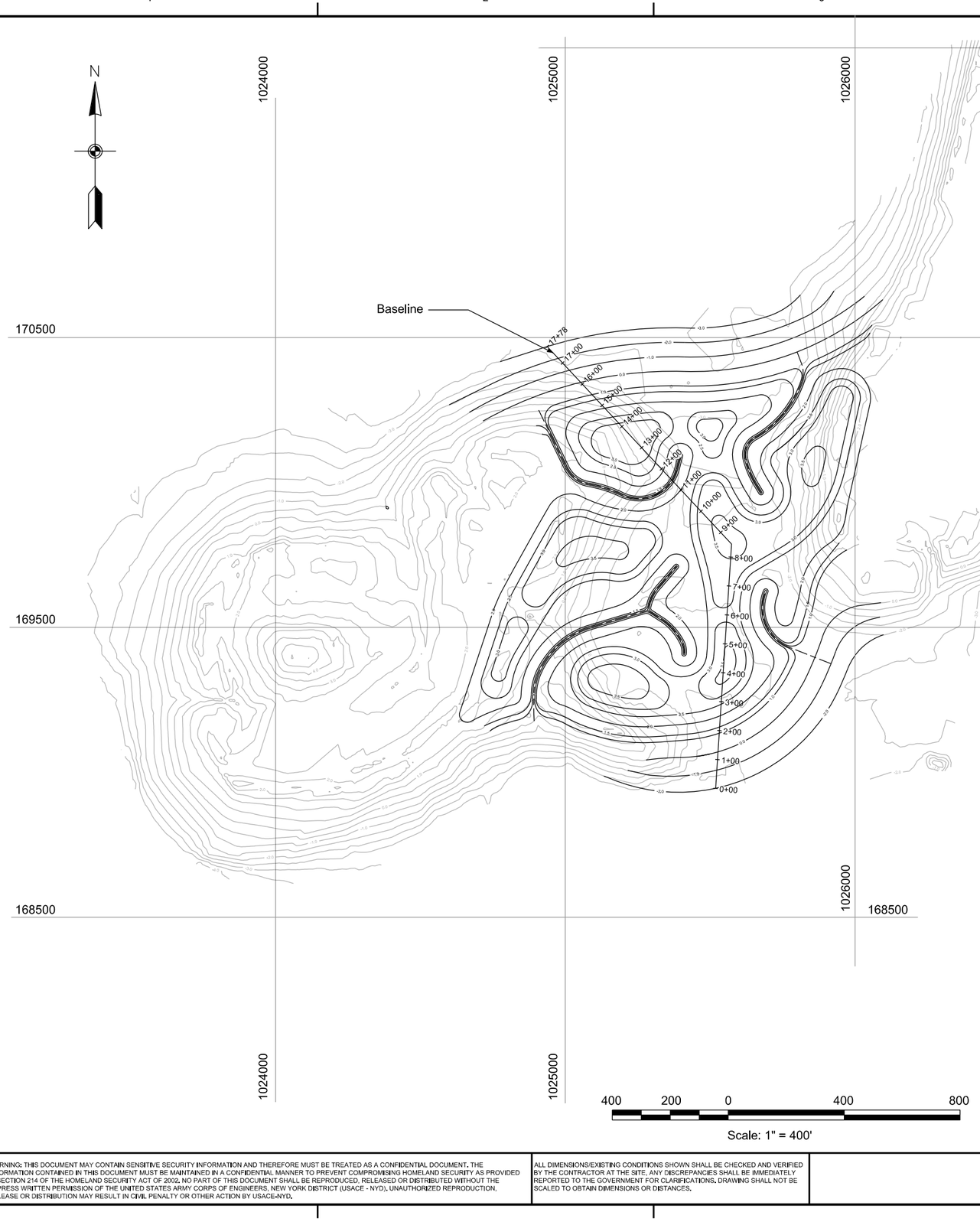
ELDERS CENTER MARSH
WETLAND RESTORATION

PLANTING PLAN

NEW YORK
JAMAICA BAY

SHEET REFERENCE NUMBER
L-001
SHEET 1 OF 2

L:\HRE-Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Elders Center\MicroStation\EldersCenterDesign.dgn
L:\HRE-Overall\Feasability_Detailed_Design\Detailed_Designs\Jamaica Bay Marsh Islands\Elders Center\MicroStation\Pen tables\Elders_grading_plan_pen_table.tbl MAY 2009 NYD BORDER

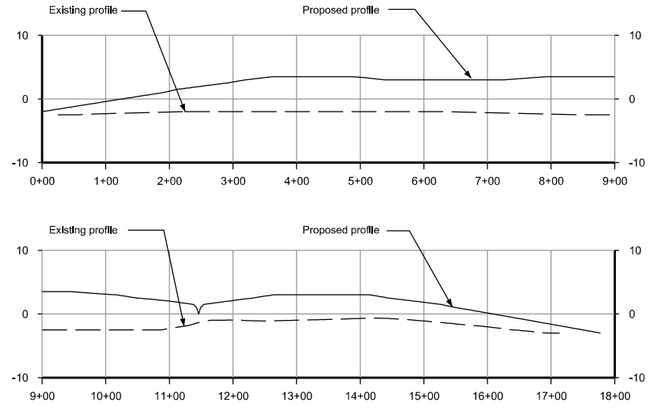


Quantities

Item	Qty	UOM	
Earthwork/ Site Grading	41.7	AC	
Low Marsh Plantings	15.2	AC	
Spartina alterniflora	182,020	EA	2ft c-c
High Marsh Plantings	10.90	AC	
Distichlis spicata	130,580	EA	2ft c-c
Scrub-shrub	1.40	AC	
Various plantings	1,870	EA	6ft c-c
Seed	1.0	TON	
Clean Fill	284,900	CY	

Baseline Profile

Not to scale



WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

ELDERS CENTER MARSH

US Army Corps of Engineers
New York District

DESCRIPTION | DATE | APPR.

DESIGNED BY: GSW
DWN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
PLOTTED BY:
PLOT DATE: 17-Dec-2018
USES ANSI D

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

ELDERS CENTER MARSH
WETLAND RESTORATION

GRADING PLAN

NEW YORK

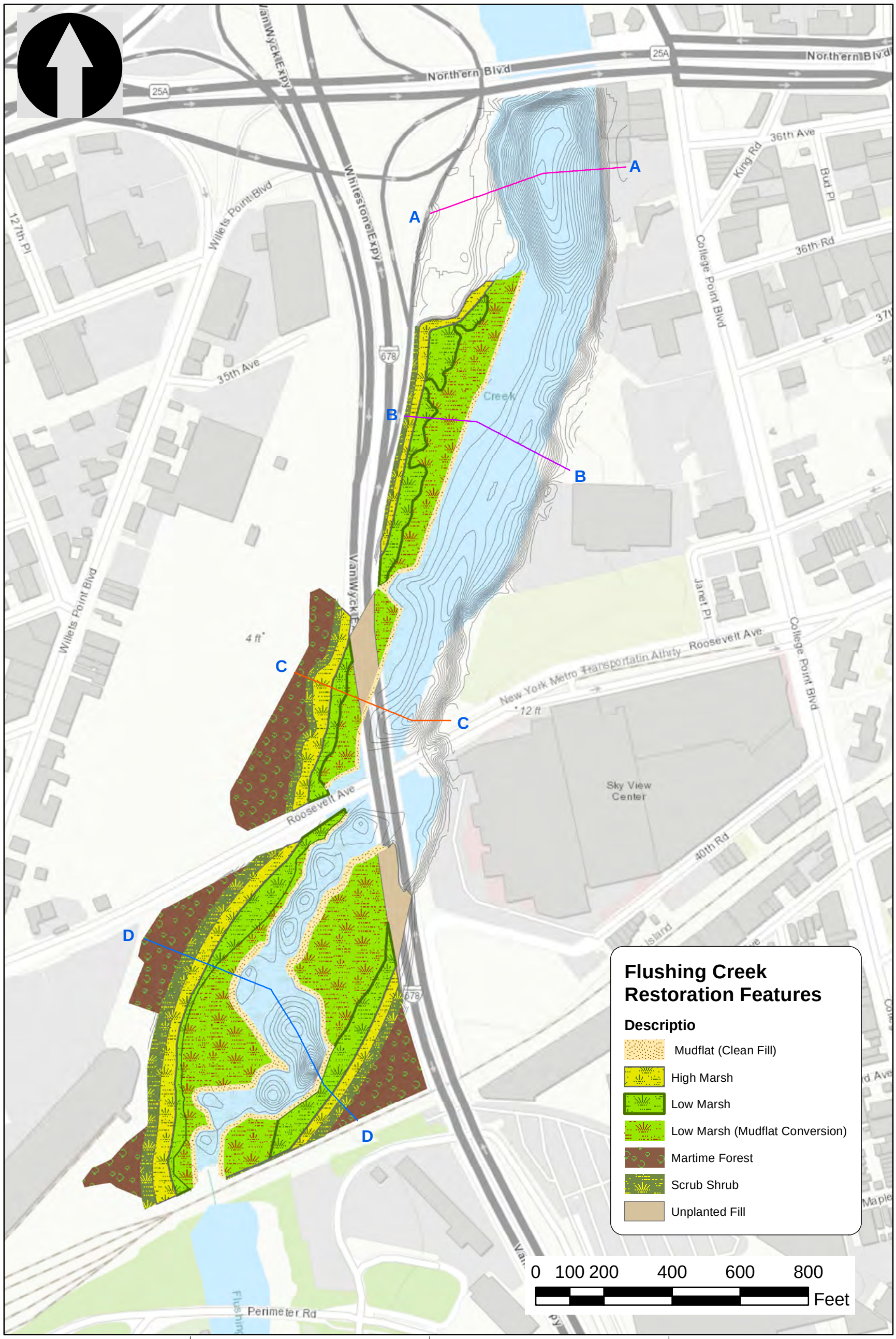
JAMAICA BAY

SHEET REFERENCE NUMBER
G-001

SHEET 2 OF 2

Elders Center Quantities

Item	Qty	UOM	
Earthwork/ Site Grading	41.7	AC	
Low Marsh Plantings	15.2	AC	
Spartina alterniflora	182,020	EA	2ft c-c
High Marsh Plantings	10.90	AC	
Distichlis spicata	130,580	EA	2ft c-c
Scrub-shrub	1.40	AC	
Various plantings	1,870	EA	6ft c-c
Seed	1.0	TON	
Clean Fill	284,900	CY	
Fencing & Gates			
Construction (Orange) Fence	7,710	LF	
Herbivory Fence	26.1	AC	
Orange Fence	121,610	LF	
Fence Posts	11,490	EA	
Mylar Tape	516,680	LF	



Flushing Creek

FLUSHING CREEK

Detailed Design for USACE Features

QUEENS NEW YORK

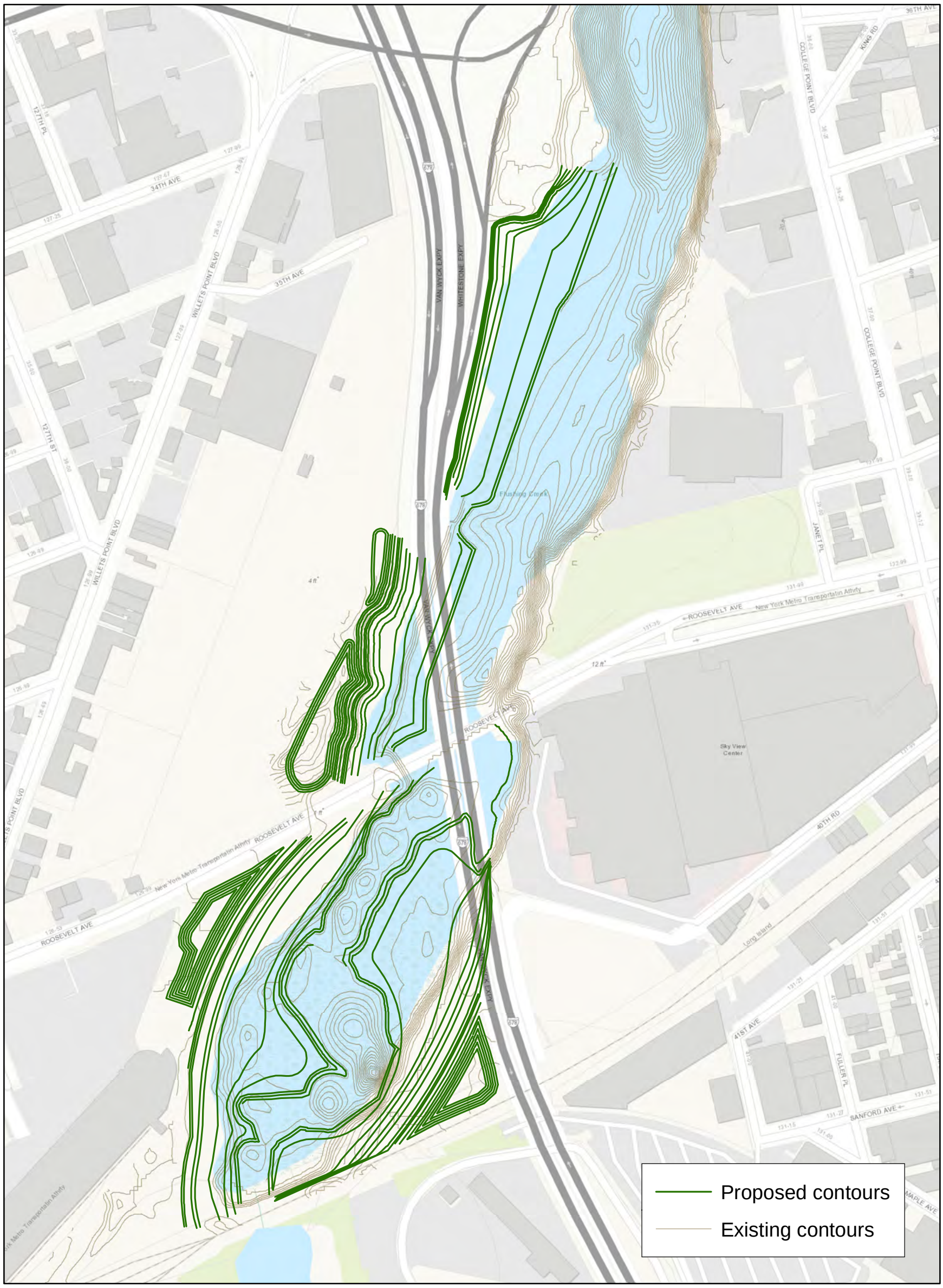
U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

US Army Cors of Engineers
New York District

Map created 16 Sep 2019, e3enhgsw
Source: ESRI

L:\HRE_OverallFeasability_Detailed_Designs\Flushing_Bay\GIS\Detailed_Design_Final\HRE_FlushingCreek_Sep19__Layout1.mxd



Flushing Creek

FLUSHING CREEK

Grading Plan

QUEENS NEW YORK

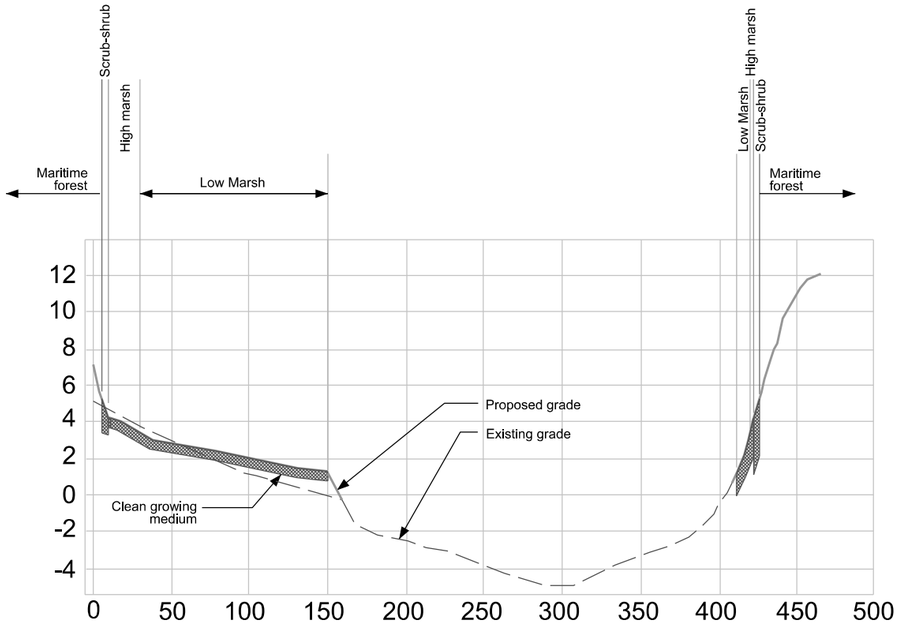
U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

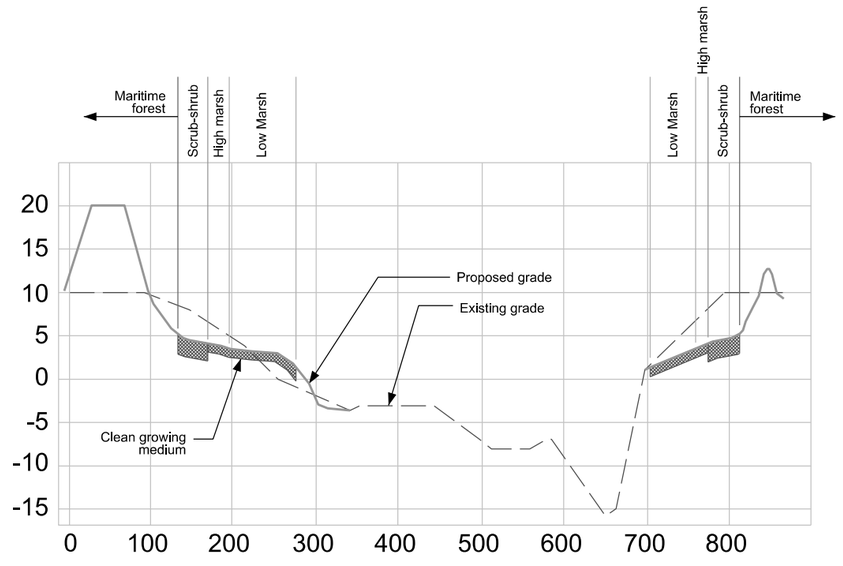
US Army Corps of Engineers
New York District

Map created 09 Jan 2020, e3enhgsw
Source: ESRI

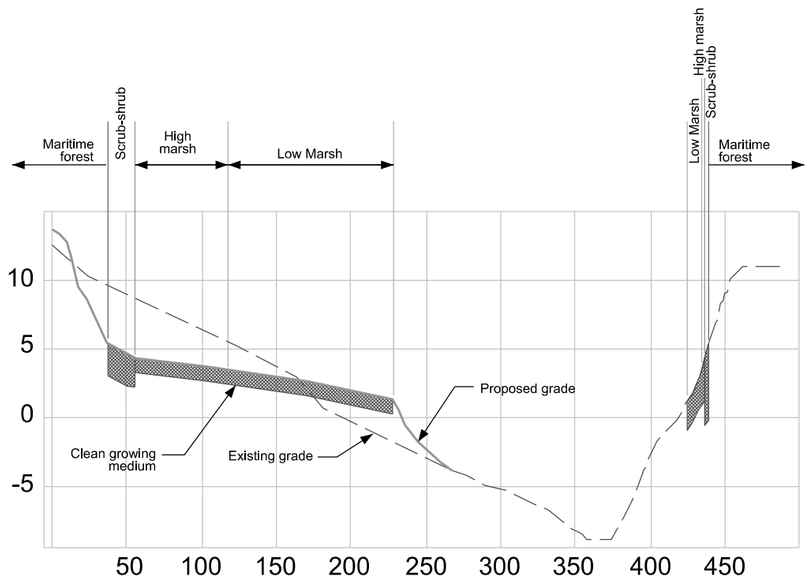
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Flushing_Bay\GIS\Detailed_Design_Final\HRE_FlushingCreek_Sep19__Layout1.mxd



X-Section AA



X-Section CC



X-Section BB

See grading plan for cross-section locations

Flushing Creek

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR
MARK	DESCRIPTION	DATE	APPR

DESIGNED BY: GSW
DRWN BY: GSW
SUBMITTED BY: GSW
FILE NAME:
SIZE: ANSI D
DATE:
CKD BY:
SOLICITATION NO.:
CONTRACT NO.:
PLOTTED BY:
PLOT DATE: 8/7/2019

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-ENH

FLUSHING CREEK
ECOSYSTEM RESTORATION

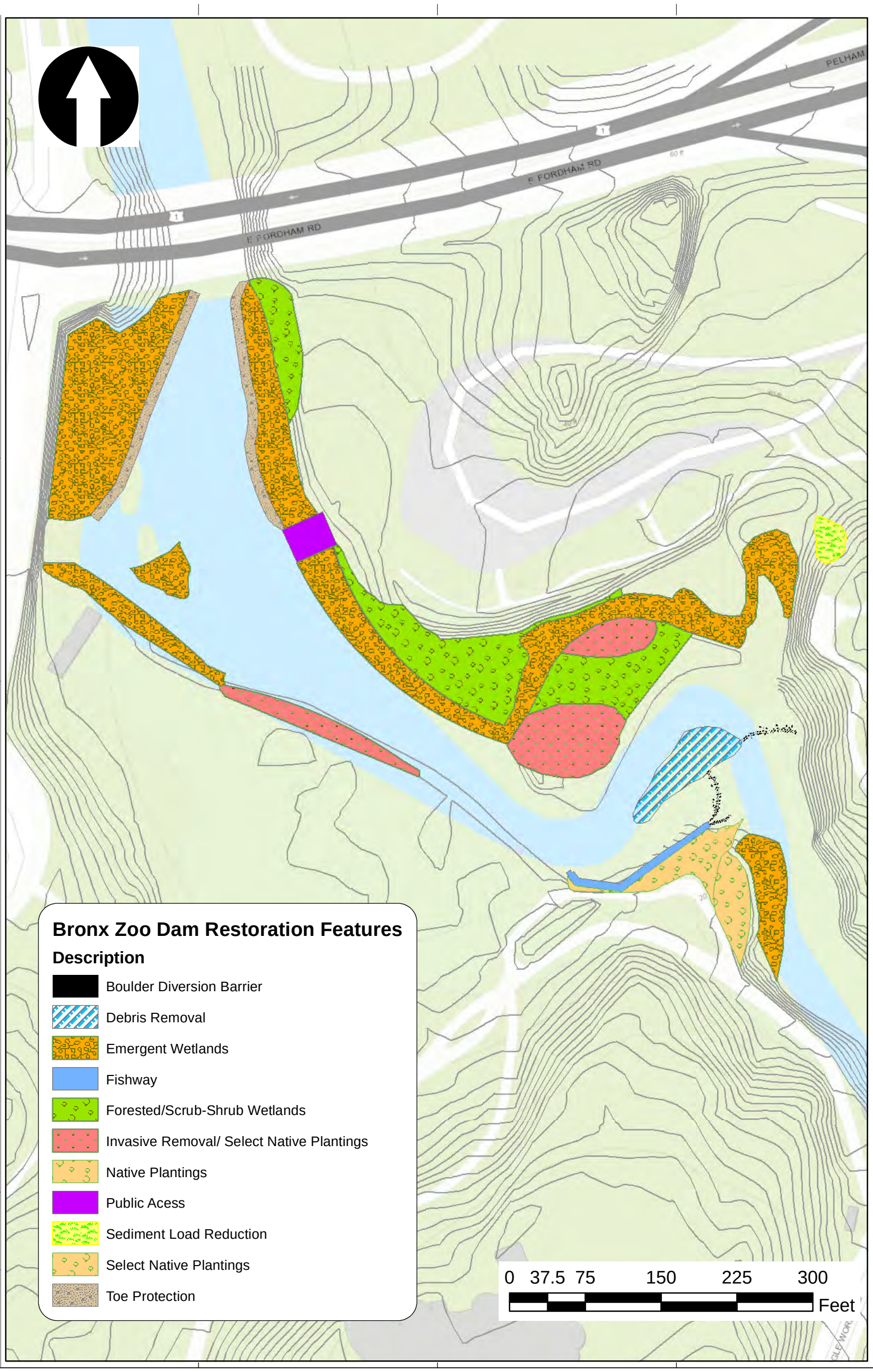
Cross-Sections

NEW YORK
QUEENS

SHEET REFERENCE NUMBER

SHEET OF

Flushing Creek Quantities				
Item			Qty	UOM
Excavation			39,015	CY
		Offsite Disposal	12,200	CY
		Volume to be place upland	26,815	CY
Site Clearing and Grubbing			8.29	AC
Earthwork/ Site Grading			20.10	AC
Low Marsh Plantings			9.76	AC
	Spartina alterniflora		116,920	EA
High Marsh Plantings			2.47	AC
	Distichlis spicata		29,590	EA
Scrub Shrub			1.80	AC
	Forbs		2,880	EA
	Gallon size shrubs			
		Baccharis halimfolia	450	EA
		Iva frutescens	530	EA
		Myrica pensylvanica	530	EA
	Native grass seeding		30	LB
Martime Forest			3.89	AC
	Ferns and forbs		20,720	EA
	Gallon size shrubs			
		Baccharis halimfolia	970	EA
		Iva frutescens	970	EA
		Myrica pensylvanica	970	EA
	1 ft to 4 ft canopy trees		630	EA
	5 ft to 6 ft whip canopy trees		630	EA
	Gallon understory trees		630	EA
	Native grass seeding		60	LB
Clean Fill			**72,636**	**CY**
	Mudfalt converesion		42,432	
	Intertidal zone		13,414	CY
	Upland		11,750	CY
	Uplanted Fill		5,040	CY
Fencing & Gates				
	Security Fence		5,100.00	LF
		Gate	4	EA
	Herbivory Fence		12.23	AC
		Orange Fence	57,000	LF
		Fence Posts	5,381	EA
		Mylar tape	242,154	LF



Bronx Zoo Dam

BRONX ZOO DAM

Detailed Design for USACE Features

BRONX NEW YORK

U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

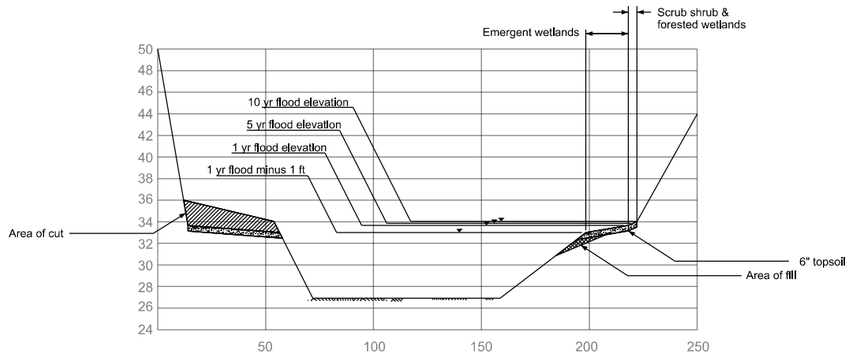
CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

US Army Corps of Engineers
New York District

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Bronx_Zoo_Dam\GIS\HRE_BronxZooDam_12Aug19__Layout1.mxd

MAY 2009 NYD BORDER

L:\HRE_Overall\Feasability_Detailed_Design\Bronx_Sites\Bronx_Zoo_design.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Bronx_Zoo_Dam\Microstation\Bronx_Zoo_design.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Bronx_Zoo_Dam\Microstation\BZD_pen_table.tbl

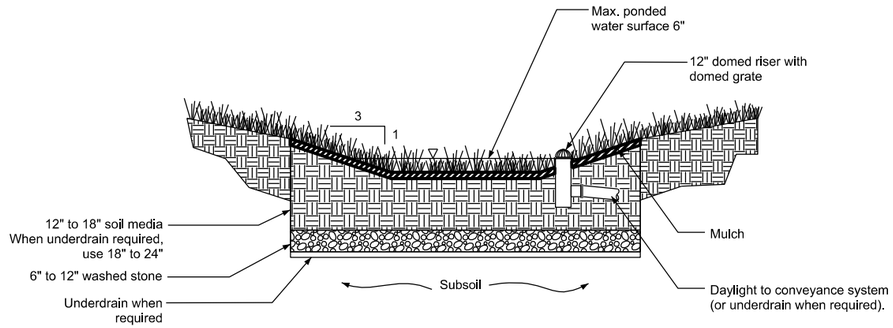


Typical Cross-Section

n.t.s.

Notes:

1. It is assumed that emergent wetlands will be planted between 1-yr flood elevation and 1 ft below 1-yr flood elevation.
2. It is assumed that scrub-shrub and forested wetlands will be planted between 5-yr flood elevation and 10-yr flood elevation.

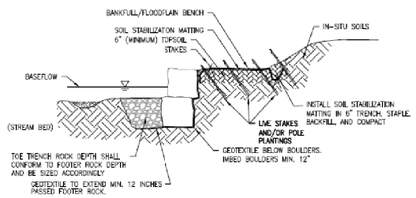


Typical Bioswale - Profile

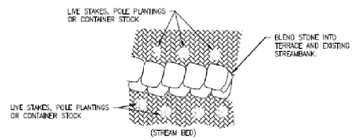
n.t.s.

Source: NY State Stormwater Manual
January 2015

BOULDER TOE REVETMENT - SECTION VIEW



BOULDER TOE REVETMENT - PLAN VIEW



Boulder Toe Revetment Detail

n.t.s.

Detail adapted from In-Stream Structures, Details and Construction Guidleines, prepared for the Philadelphia Water Department, September 2015

Quantities

ITEM DESCRIPTION	QTY	UOM
General Requirements		
MOBILIZATION (N.T.E. 6% OF TOTAL OF ALL OTHER ITEMS)		LUMP SUM
CONSTRUCTION SIGN ON FENCE	1	EACH
CONSTRUCTION FENCE 8'-0" HT.	575	LINEAR FOOT
MAINTENANCE & PROTECTION OF TRAFFIC - TYPE C	1	LUMP SUM
TEMPORARY SNOW FENCE BOUNDARY	575	LINEAR FOOT
TEMPORARY WOODEN TREE GUARD W/TREE WRAP	10	EACH
PROTECT EXIST. TREE ROOTS W/WOODCHIPS 6' DEPTH	800	SQUARE FOOT
PROTECT EXIST. TREE ROOTS W/PL:YWOOD OR MATS	3000	SQUARE FOOT
Removals (General)		
REMOVALS (N.T.E.$)	1	EACH
STUMP REMOVAL OVER 6" TO 12" DIA.	9	EACH
TREE REMOVAL OVER 6" TO 12" DBH	7	EACH
Site Work		
CLEAR AND GRUB	1	LUMP SUM
ROCK EXCAVATION	600	CUBIC YARD
HAND AND/OR PNEUMATIC EXCAVATION	5	CUBIC YARD
EARTH MOVING OPERATIONS	300	CUBIC YARD
STRIP, STORE & SPREAD EXISTING TOPSOIL	50	CUBIC YARD
Erosion Control and Containment		
STABILIZED CONSTRUCTION ENTRANCE	300	SQUARE YARD
TEMPORARY SILT FENCE	80	LINEAR FOOT
Masonry - Concrete		
CONTROLLED CONCRETE (f'c = 4,000 psi)	115	CUBIC YARD
Reinforcement		
STEEL BAR REINFORCEMENT	18500	POUND
Landscape - General		
SHREDDED BARK MULCH	285	SQUARE YARD
PREPARATORY PRUNING OF TREE OVER 6" TO 12" DBH	10	EACH
ACCESS ROAD	1	LUMP SUM
SHREDDED STRAW	180	SQUARE YARD
SEEDING	180	SQUARE YARD
WATER CONTROL	1	LUMP SUM
FISH LADDER	1	LUMP SUM
FORM LINER	350	SQUARE YARD
BOULDERS	230	TON
TOPSOIL	120	CUBIC YARD
DENIL ALUMINUM STEEPPASS (3 SECTIONS - 22"W x 27" H x 120"L)	30	LF

Plantings	QTY	UOM	Container/Size
TREES/SHRUBS			
SHADBLOW SERVICEBERRY	2	EACH	6'-7' HEIGHT
WINTERBERRY	14	EACH	30"-36" HEIGHT
COMMON WITCH HAZEL	3	EACH	30"-36" HEIGHT
MOUNTAIN LAUREL	12	EACH	30"-36" HEIGHT
HERBACEOUS PLANTINGS			
WHITE WOOD ASTER	198	EACH	1 GALLON, 12 " O.C.
CHRISTMAS FERN	126	EACH	1 GALLON, 24 " O.C.
NEW YORK FERN	111	EACH	1 GALLON, 18 " O.C.
New England Restoration Mix Seed	1450	SQ FT	

US Army Corps
of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DWN BY: GSW
CKD BY:
SUBMITTED BY: GSW
FILE NAME:
SIZE: ANSI D
PLOTTED BY:
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 1/7/2020

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

BRONX ZOO DAM
STREAM & ECOSYSTEM RESTORATION

DETAIL SHEET

NEW YORK

BRONX

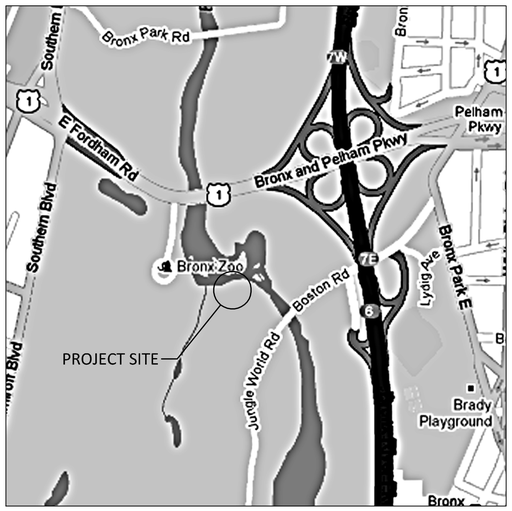
SHEET REFERENCE NUMBER

SHEET OF

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

Bronx Zoo Dam



NORTH

LOCATION PLAN

NOT TO SCALE

THIS PROJECT WAS FUNDED BY AN AGREEMENT AWARDED BY THE ENVIRONMENTAL PROTECTION AGENCY TO THE NEW ENGLAND INTERSTATE WATER POLLUTION CONTROL COMMISSION IN PARTNERSHIP WITH THE NEW YORK-NEW JERSEY HARBOR & ESTUARY PROGRAM.

New York - New Jersey Harbor & Estuary Program
www.harborestuary.org

NEIWPCC

CITY OF NEW YORK
PARKS & RECREATION
OLMSTED CENTER
FLUSHING MEADOWS - CORONA PARK
FLUSHING, NEW YORK 11368

PARKS & RECREATION

NANCY PRINCE — DEPUTY CHIEF OF DESIGN

THERESE BRADDICK — DEPUTY COMMISSIONER

MITCHELL J. SILVER — COMMISSIONER

CONTRACT DRAWINGS FOR

ANADROMOUS FISHERIES RESTORATION LOCATED IN THE WILDLIFE CONSERVATION SOCIETY'S BRONX ZOO ON THE BRONX RIVER

PREPARED BY:
MILONE & MACBROOM, INC.

MILONE & MACBROOM®
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

BOROUGH OF THE BRONX
CONTRACT NO. XXXX-XXXX

LIST OF STANDARD DETAIL SHEETS APPLICABLE BUT NOT INCLUDED

SHEET TITLE	DETAIL SHEET NO.	REV. DATE

LIST OF DRAWINGS

1. TITLE SHEET
2. OVERALL EXISTING CONDITIONS PLAN
3. SITE EXISTING CONDITIONS MAP
4. EXISTING SPILLWAY - PLAN AND PROFILE
5. CONSTRUCTION ACCESS AND STAGING
6. REMOVALS, WATER CONTROL, AND SEDIMENT AND EROSION CONTROL
7. SITE REMOVALS PLAN
8. PROPOSED FISHWAY - PLAN
9. PROPOSED FISHWAY - PROFILE
10. PROPOSED FISHWAY - CROSS SECTIONS (1)
11. PROPOSED FISHWAY - CROSS SECTIONS (2)
12. STRUCTURAL PLAN & ELEVATIONS
13. PROPOSED FISHWAY - CROSS SECTIONS
14. RESTORATION PLAN
15. SEDIMENT AND EROSION CONTROL NOTES AND DETAILS
16. DETAILS
17. GENERAL NOTES

XXXX-XXXX



GENERAL NOTES:

1. ALL CONTOURS AND ELEVATIONS ARE BASED UPON AN ASSUMED DATUM.
2. THE CONTRACTOR SHALL VERIFY ALL EXISTING SITE CONDITIONS, BOTH ABOVE AND BELOW THE SURFACE. ANY DISCREPANCIES BETWEEN INFORMATION SHOWN ON THE DRAWINGS AND ACTUAL FIELD CONDITIONS SHALL BE BROUGHT TO THE ATTENTION OF THE RESIDENT ENGINEER AND NRG IN WRITING, PRIOR TO COMMENCING WORK.
3. TOPOGRAPHY IS BASED UPON SURVEY PERFORMED BY MANUEL ELKEN, CO., P.C. CONSULTING ENGINEERS, LAFAVE, WHITE, McGIVERN, LLC, AND R.B.A. ENGINEERS-ARCHITECTS-PLANNERS AND SUPPLEMENTED BY MILONE & MACBROOM, INC. IN MARCH 2006.
4. FEMA 100-YEAR FLOODPLAIN BOUNDARY FROM FLOOD INSURANCE RATE MAP NUMBER 3604970082F AND 3604970101F, REVISED THROUGH SEPTEMBER 5, 2007.
5. ALL CONTRACTORS ARE REQUIRED TO VISIT THE SITE AND ATTEND THE PRE-BID MEETING PRIOR TO SUBMITTING BIDS.
6. THE CONTRACTOR IS RESPONSIBLE FOR WATER CONTROL DURING THE PROJECT. THE CONTRACTOR SHALL COORDINATE THE WATER CONTROL OF THE DAM AREA WITH THE ENGINEER. THERE SHALL BE NO CLAIMS FOR EXTRA COMPENSATION DUE TO WATER LEVELS RISING FROM NATURAL EVENTS, SUCH AS STORMS, ETC.
7. THE CONTRACTOR AND HIS JOB SUPERINTENDENT SHALL BE RESPONSIBLE FOR COMPLYING WITH THE JOB SPECIFICATIONS. THE CONTRACTOR SHALL DESIGNATE A SUPERINTENDENT AT THE START OF CONSTRUCTION AND THE CONTRACTORS SUPERINTENDENT SHALL BE ON-SITE AT ALL TIMES DURING CONSTRUCTION.
8. THE CONTRACTOR SHALL PROVIDE FIELD SURVEYING SERVICES TO ESTABLISH AND RECORD GRADES, LINES, AND ELEVATIONS.
9. NO CONSTRUCTION VEHICLES SHALL BE STORED, SERVICED, WASHED OR FLUSHED IN A LOCATION WHERE LEAKS, SPILLAGE, WASTE MATERIALS, CLEANERS, OR WATERS WILL BE INTRODUCED OR FLOW INTO WETLANDS, WATERCOURSES, OR ACTIVE PARK AREAS.
10. THE CONTRACTOR SHALL MAINTAIN ALL STREETS, SIDEWALKS, AND WALKWAYS IN THE AREA FREE OF SOIL, MUD AND CONSTRUCTION DEBRIS.
11. THE PROJECT SITE IS SUBJECT TO FLOODING. THE CONTRACTOR SHALL MONITOR WEATHER FORECASTS AND REMOVE EQUIPMENT FROM FLOOD PRONE AREAS IN THE EVENT OF FLOOD WARNINGS. THE UNITED STATES GEOLOGICAL SURVEY OPERATES STREAM FLOW GAUGE #01302020 ON THE BRONX RIVER NEAR THE NEW YORK BOTANICAL GARDENS. THE WEBSITE FOR THE GAGE IS: HTTP://WATERDATA.USGS.GOV/NWIS/RT
12. THE PROJECT SITE HAS EXTENSIVE PEDESTRIAN USAGE. THE CONTRACTOR MUST STRICTLY ADHERE TO APPROVED ACCESS ROUTES AND WORKING HOURS.
13. THE CONTRACTOR SHALL SUBMIT A SEQUENCE OF CONSTRUCTION THAT MINIMIZES NOISE, DUST, POLLUTION, AND PUBLIC INCONVENIENCE.
14. ALL STORAGE AND ACCESS ROUTES, PEDESTRIAN FENCES/BARRIERS, WORKING HOURS, AND LIMITS OF CLEARING MUST BE APPROVED BY THE WILDLIFE CONSERVATION SOCIETY (WCS), NATURAL RESOURCES GROUP (NRG), AND THE RESIDENT ENGINEER (RE) PRIOR TO BEGINNING ANY OTHER SITE WORK.
15. THE RESIDENT ENGINEER WILL BE DESIGNATED AS A REPRESENTATIVE FROM THE WILDLIFE CONSERVATION SOCIETY AND THE DEPARTMENT OF PARKS AND RECREATION WHO WILL CONTACT AND GET APPROVAL FROM THE DEPARTMENT OF PARKS AND RECREATION.
16. INFORMATION REGARDING THE LOCATION OF EXISTING UTILITIES HAS BEEN BASED UPON AVAILABLE INFORMATION AND MAY BE INCOMPLETE, AND WHERE SHOWN SHOULD BE CONSIDERED APPROXIMATE. THE LOCATION OF ALL EXISTING UTILITIES SHOULD BE CONFIRMED PRIOR TO BEGINNING CONSTRUCTION. CALL DIG SAFELY NEW YORK "811". ALL UTILITY LOCATIONS THAT DO NOT MATCH THE VERTICAL OR HORIZONTAL CONTROL SHOWN ON THE PLANS SHALL BE BROUGHT TO THE ATTENTION OF THE RE FOR RESOLUTION.

LEGEND

- EXISTING CONTOUR (50)
- EDGE OF ROAD
- EDGE OF WATER
- TREELINE
- EXISTING FENCING
- EDGE OF WETLAND
- EXPOSED LEDGE
- EXISTING STORM DRAIN PIPE
- PROPERTY LINE
- FEMA 100-YR FLOODPLAIN (FP)
- EXISTING LIGHT POLE
- EXISTING TREE (SIZE VARIES)
- EXISTING TREE STUMP
- EXISTING CATCH BASIN
- EXISTING STORM DROP GRATE
- EXISTING SIGN
- EXISTING HYDRANT
- EXISTING PARKING CURB STOPS

GRAPHIC SCALE
10 0 10 20
(IN FEET)
1 inch = 20 ft.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE
BRONX ZOO DAM
FISH PASSAGE AND SITE IMPROVEMENTS

DRAWING TITLE
OVERALL EXISTING CONDITIONS MAP

DESIGNED BY	DRAWN BY	CHECKED BY
EUAG	BAM	JGM/RG/SK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO.
B-SCAN	SCALE 1"=20	DRAWING NO. 02
	DATE	CONTRACT NUMBER

SHEET NO. 02 OF 17 SHEETS

STONE MASONRY WALL WITH CONCRETE CAP APPROXIMATELY FLUSH WITH SURROUNDING GRADE

EXISTING CANOE PORTAGE

PORTAGE SIGNAGE (ON BANKS)

WARNING/DIRECTIONAL SIGN (ON BANK)

NON-FUNCTIONING LOW-LEVEL OUTLET CONCRETE HOUSING WITH SLUICE GATE

EAST SPILLWAY CREST ELEV. 30' ± AND VARIES CONCRETE OVER BEDROCK

WARNING/DIRECTIONAL SIGN (IN WATER)

BRONX RIVER

1/04

WEST SPILLWAY CREST ELEV. 30' ± AND VARIES CONCRETE OVER BEDROCK SEE EXISTING SPILLWAY-PROFILE

IMPOUNDMENT SILTY SAND BED WITH EXPOSED BEDROCK

EXISTING PEDESTRIAN PATHWAY

EXISTING PEDESTRIAN PATHWAY

EXISTING WATERCOURSE EDGE

EXISTING WATERCOURSE EDGE

APPROXIMATE LOCATION OF STORMWATER PIPING, LOCATION PROVIDED BY WCS

APPROX. LOCATION OF EXISTING USGS KIOSK

BRONX RIVER

LEGEND

- EXISTING CONTOUR
- EDGE OF ROAD
- EDGE OF WATER
- TREELINE
- EXISTING FENCING
- EDGE OF WETLAND
- EXPOSED LEDGE
- EXISTING STORM DRAIN PIPE
- PROPERTY LINE
- FEMA 100-YR FLOODPLAIN
- EXISTING LIGHT POLE
- EXISTING TREE (SIZE VARIES)
- EXISTING TREE STUMP
- EXISTING CATCH BASIN
- EXISTING STORM DROP GRATE
- EXISTING SIGN
- EXISTING HYDRANT
- EXISTING PARKING CURB STOPS
- EXISTING TREE STUMP

GRAPHIC SCALE
10 0 10 20
(IN FEET)
1 inch = 20 ft.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

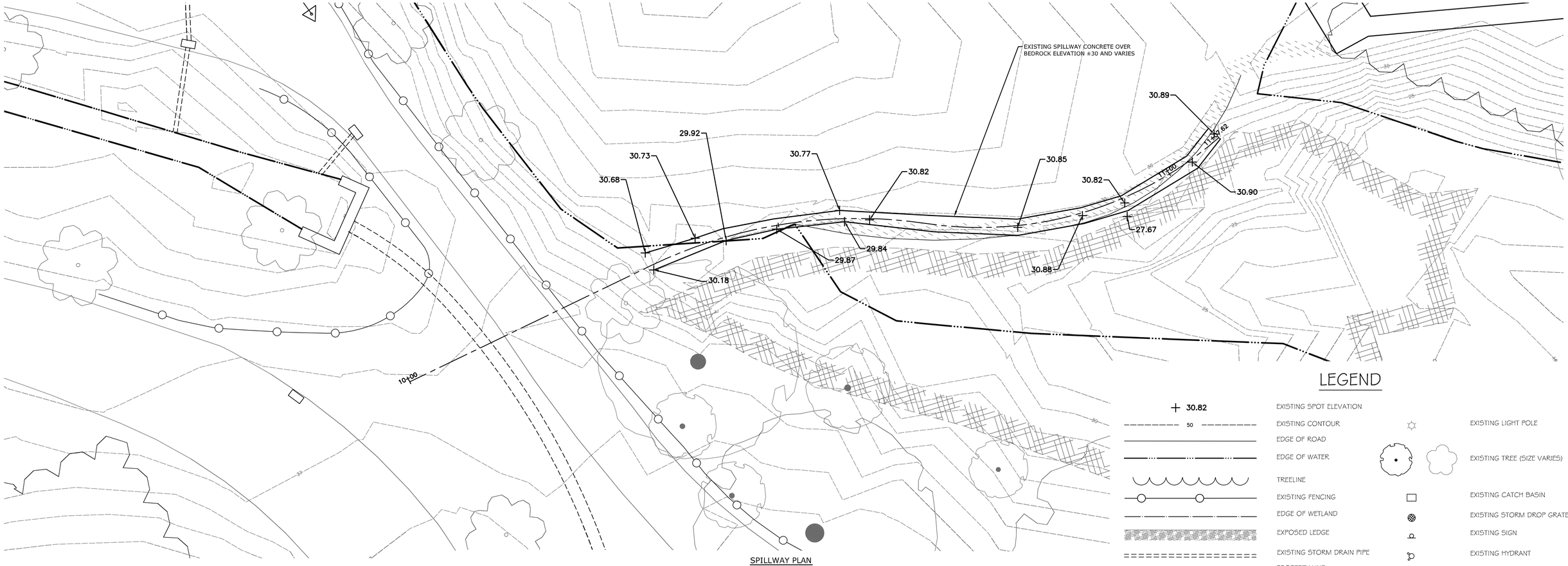
City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE
BRONX ZOO DAM
FISH PASSAGE AND SITE IMPROVEMENTS

DRAWING TITLE
SITE EXISTING CONDITIONS MAP

DESIGNED BY	DRAWN BY	CHECKED BY
ELAG	BAM	JGM/RGSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. CONTRACT NUMBER
B-SCAN	SCALE 1"=20'	DRAWING NO. 03
	DATE	

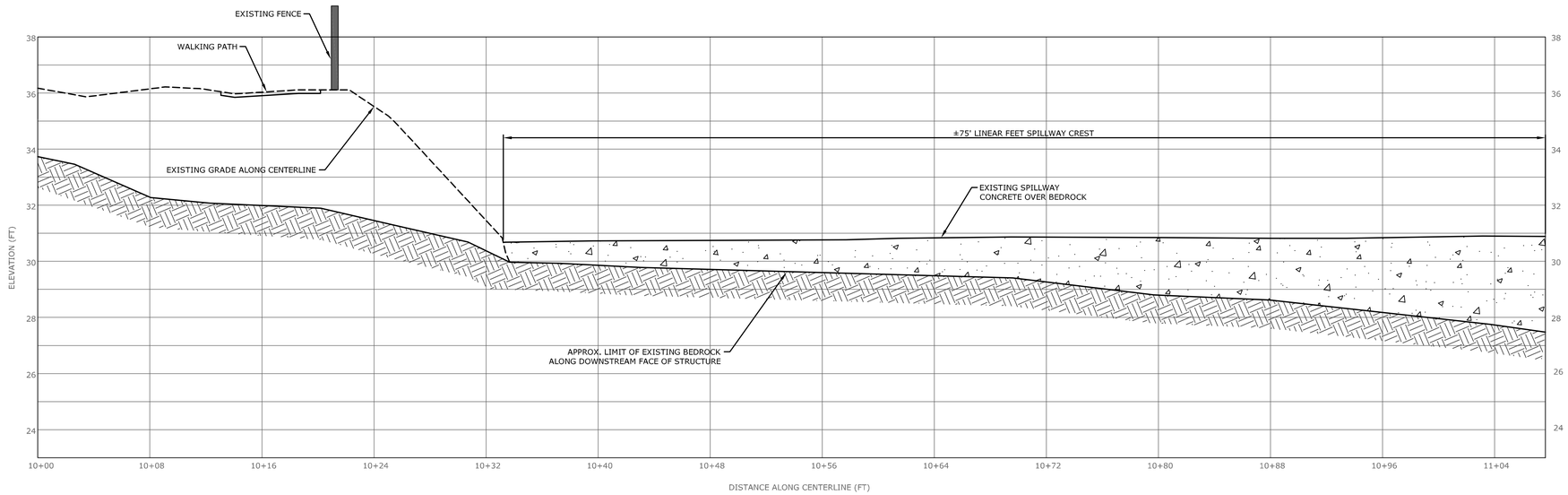
SHEET NO. 03 OF 17 SHEETS



SPILLWAY PLAN
SCALE: 1" = 5'

LEGEND

30.82	EXISTING SPOT ELEVATION
50	EXISTING CONTOUR
	EDGE OF ROAD
	EDGE OF WATER
	TREELINE
	EXISTING FENCING
	EDGE OF WETLAND
	EXPOSED LEDGE
	EXISTING STORM DRAIN PIPE
	PROPERTY LINE
FP FP	FEMA 100-YR FLOODPLAIN
	CONCRETE DAM
	EXISTING LIGHT POLE
	EXISTING TREE (SIZE VARIES)
	EXISTING CATCH BASIN
	EXISTING STORM DROP GRATE
	EXISTING SIGN
	EXISTING HYDRANT
	EXISTING PARKING CURB STOPS



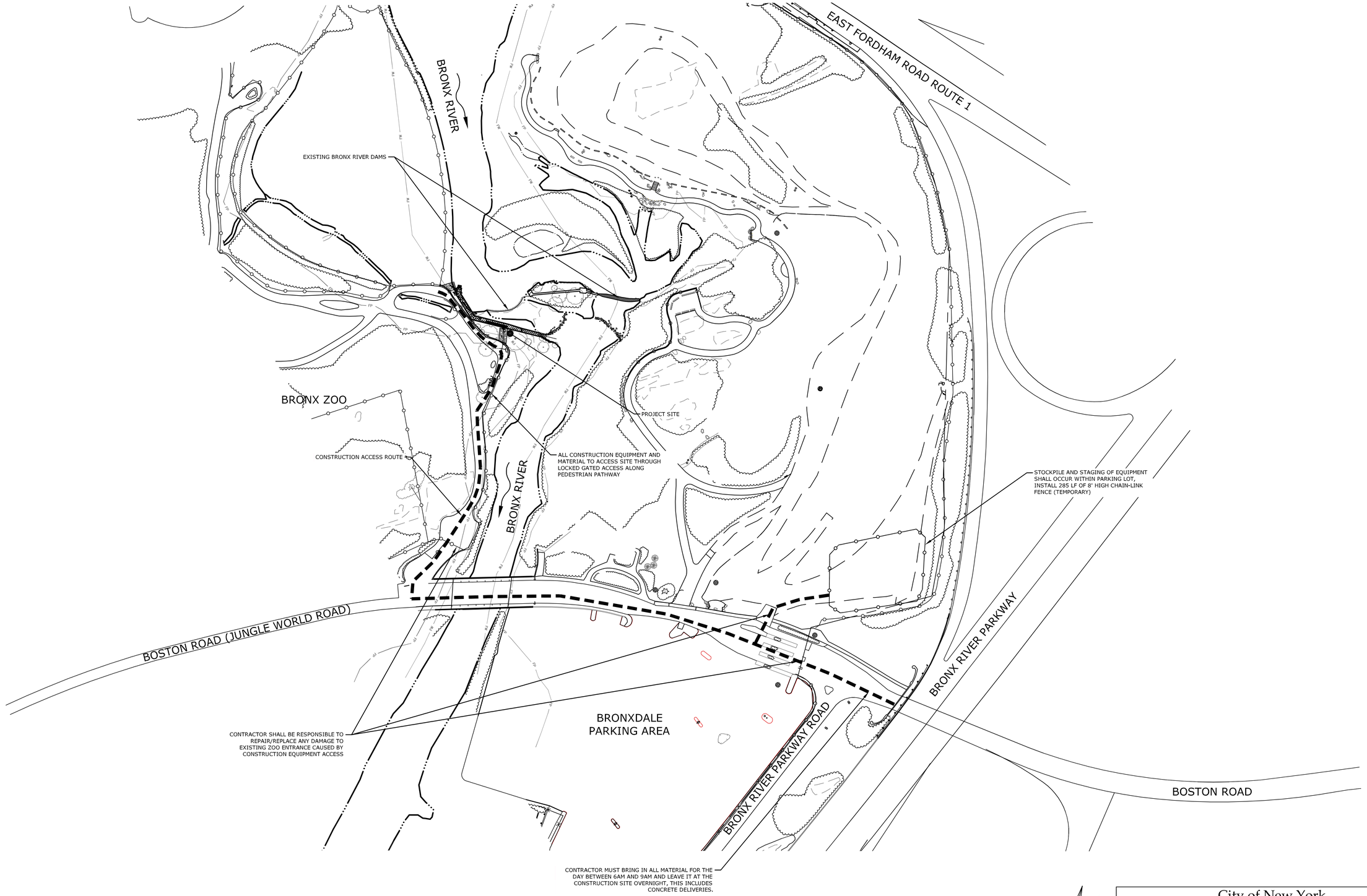
1/04 SPILLWAY CENTERLINE PROFILE
SCALE: 1" = 4' H, 1" = 2' V

GRAPHIC SCALE
2.5 0 2.5 5
(IN FEET)
1 inch = 5 ft.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: BRONX ZOO DAM FISH PASSAGE AND SITE IMPROVEMENTS		
DRAWING TITLE: EXISTING SPILLWAY - PROFILE		
DESIGNED BY: EJAG	DRAWN BY: BAMORM	CHECKED BY: JGMNRG/SK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. CONTRACT NUMBER
B-SCAN	SCALE: AS NOTED; DATE:	DRAWING NO. 04
		SHEET NO. 04 OF 17 SHEETS



LEGEND

CONSTRUCTION ACCESS ROUTE

CONSTRUCTION NOTES:

1. PRIOR TO PERFORMING ANY WORK WITHIN THE BRONX ZOO LIMITS, CONTRACTOR SHALL COORDINATE WORK PLAN WITH THE NATURAL RESOURCES GROUP AND WCS. THESE GROUPS SHALL BE NOTIFIED OF ANY PROPOSED WORK A MINIMUM OF 48-HOURS IN ADVANCE, AND SHALL INCLUDE ANY AND ALL CONSTRUCTION ACTIVITIES.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

GRAPHIC SCALE
30 0 30 60
(IN FEET)
1 inch = 60 ft.

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE
BRONX ZOO DAM
FISH PASSAGE AND SITE IMPROVEMENTS

DRAWING TITLE
CONSTRUCTION ACCESS AND STAGING

DESIGNED BY	DRAWN BY	CHECKED BY
EJAG	BAM	JGM/RGSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO.
B-SCAN	SCALE 1"=10' / DATE	DRAWING NO. 05

CONTRACT NUMBER

SHEET NO. 05 OF 17 SHEETS

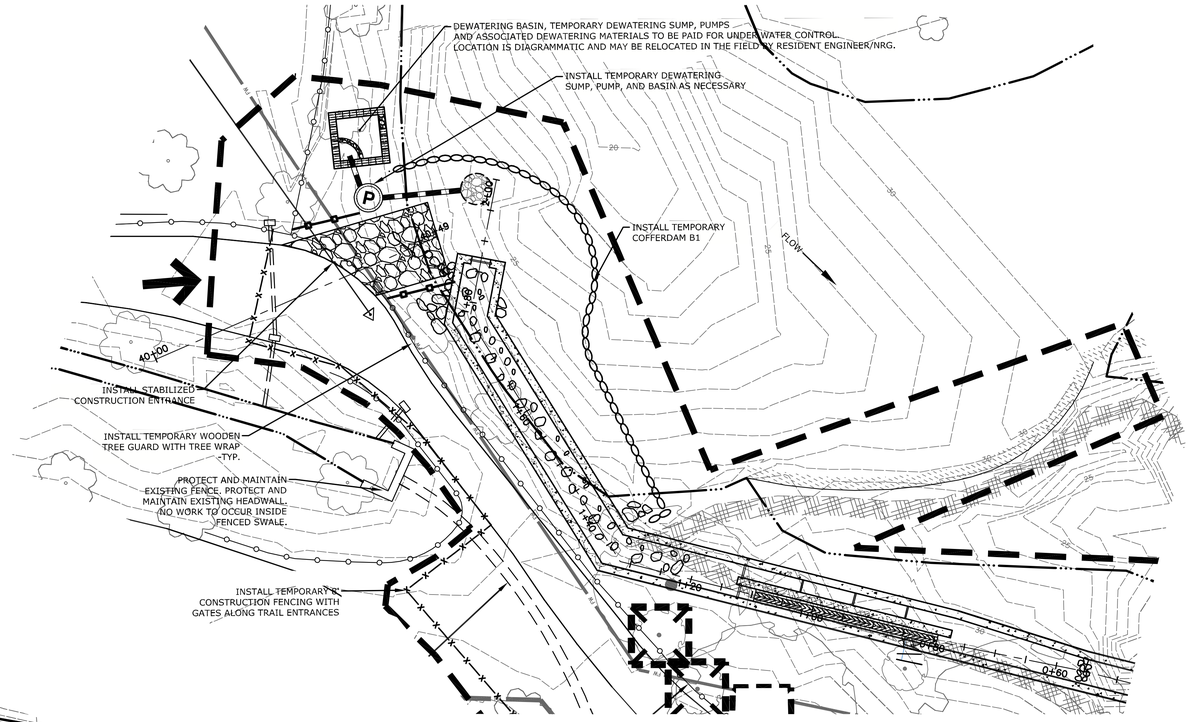
LEGEND

- CONTRACT LIMIT LINE
- EXISTING TIMBER BARRIER RAIL
- EXISTING STEEL PICKET FENCE (4FT)
- EXISTING PIPE RAIL FENCE (TWO RAIL)
- WHITE PICKET CONSTRUCTION FENCE WITH LOCKING GATE
- STABILIZED CONSTRUCTION ENTRANCE (1 / 15)
- CATCH BASIN SILT SACK - INLET PROTECTION (4 / 15)
- TEMPORARY SILT FENCE AND TEMPORARY STRAW BALE SILT CONTROL (2 / 15) (3 / 15)
- TEMPORARY DEWATERING PUMP
- EXISTING TREE (SIZE VARIES)
- CONSTRUCTION ACCESS ROUTE
- TEMPORARY DEWATERING BASIN (15 / 15)
- TEMPORARY WOODEN TREE GUARD WITH TREE WRAP (5 / 15)
- TEMPORARY COFFERDAM (8 / 15) (9 / 15)
- TREE TO BE REMOVED
- FENCE TO BE REMOVED
- STONE SCREENINGS FOOTPATH TO BE REMOVED
- TREE TRUNK PROTECTION
- EXPOSED LEDGE

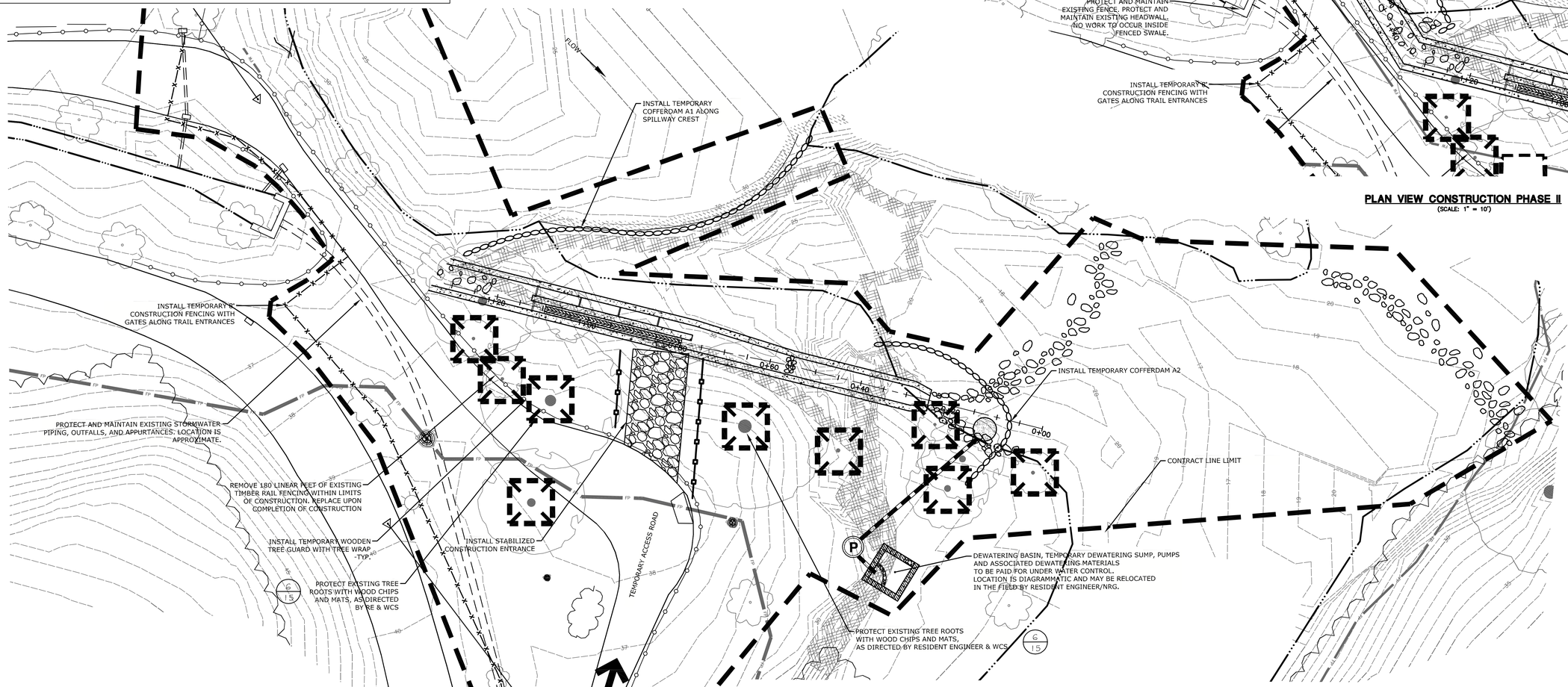
SAFETY PLAN

THE SAFETY PLAN CONSISTS OF TWO ELEMENTS, THE FIRST INVOLVING THE CONSTRUCTION SITE AND WORKER AND PUBLIC SAFETY. THE SECOND COMPONENT FOCUSES ON DOWNSTREAM AREAS, WHICH IS ADDRESSED UNDER THE EMERGENCY ACCESS PLAN.

1. THE CONTRACTOR SHALL INSTALL TEMPORARY FENCING AND SUITABLE BARRICADES AS WELL AS LOCKED GATES TO PREVENT PUBLIC ACCESS TO THE CONSTRUCTION SITE.
2. THE CONTRACTOR SHALL INSTALL CHAIN LINK FENCING AROUND THE PERIMETER OF THE CONSTRUCTION STAGING AREA.
3. THE CONTRACTOR SHALL PROVIDE EMERGENCY CONTACT PHONE NUMBERS TO LOCAL EMERGENCY DEPARTMENTS (POLICE, FIRE, EMS, ETC.) AS WELL AS THE ENGINEER AND OWNER.
4. APPROPRIATE LOCAL EMERGENCY RESPONSE PERSONNEL SHALL BE PROVIDED KEYS TO ALL ACCESS GATES.
5. THE CONTRACTOR SHALL NOT ALLOW THE GENERAL PUBLIC ONTO THE CONSTRUCTION SITE.
6. ALL PERSONS ON THE SITE, INCLUDING CONSTRUCTION CREWS, RESTORATION SYSTEMS, REPRESENTATIVES OF THE ENGINEER AND THE OWNER, AUTHORIZED VISITORS, AND OTHERS MUST WEAR ORANGE REFLECTIVE VESTS AND HARD HATS.
7. THE CONTRACTOR SHALL POST EMERGENCY PHONE NUMBERS FOR POLICE, FIRE, AND MEDICAL SERVICES AT THE CONSTRUCTION SITE.
8. THE CONTRACTOR SHALL KEEP A FIRST-AID KIT ON THE SITE AT ALL TIMES.
9. THE CONTRACTOR SHALL POST "KEEP OUT" AND/OR OTHER CAUTIONARY SIGNS ON THE SAFETY FENCING SITUATED AROUND THE PERIMETER OF THE WORK AREA.
10. THE CONTRACTOR SHALL MAINTAIN A SAFETY BOAT AND RESCUE PERSONNEL ON SITE IN ACCORDANCE WITH OSHA REQUIREMENTS
11. PROVIDE FLAGGERS WHEN CROSSING PUBLIC AREAS WITH VEHICLES OR CONSTRUCTION EQUIPMENT.



PLAN VIEW CONSTRUCTION PHASE II
(SCALE: 1" = 10')



PLAN VIEW CONSTRUCTION PHASE I
(SCALE: 1" = 10')

CONSTRUCTION SEQUENCE

PHASE I

1. REMOVE AND STORE EXISTING FENCE WITHIN CONTRACT LINE LIMITS.
2. INSTALL SEDIMENT AND EROSION CONTROLS AS SHOWN ON THE PLANS.
3. CLEAR SLOPE FOR TEMPORARY ACCESS AS SHOWN.
4. INSTALL TEMPORARY ACCESS RAMP TO CHANNEL.
5. INSTALL TEMPORARY COFFERDAMS A1 AND A2.
6. DEWATER WORK AREA WITH PUMPS AS NECESSARY.
7. EXCAVATE EARTH AND BEDROCK TO LIMITS SHOWN ON THE PLANS.
8. CONSTRUCT FISHWAY CHANNEL.
9. INSTALL STEEP-PASS SECTIONS AND WEIR BOARDS.
10. REMOVE COFFERDAMS A1 AND A2.

PHASE II

1. CLEAR SLOPE FOR TEMPORARY ACCESS AS SHOWN.
2. INSTALL SEDIMENT AND EROSION CONTROLS AS SHOWN ON THE PLANS.
3. INSTALL TEMPORARY ACCESS RAMP TO CHANNEL.
4. INSTALL TEMPORARY COFFERDAM B1.
5. DEWATER WORK AREA WITH PUMPS AS NECESSARY.
6. EXCAVATE EARTH AND BEDROCK TO LIMITS SHOWN ON THE PLANS.
7. CONSTRUCT EXIT POOL, AND RAPIDS UPSTREAM OF SPILLWAY.
8. REMOVE COFFERDAMS B1.
9. REMOVE SEDIMENT AND EROSION CONTROLS.
10. REPLACE EXISTING SECTIONS OF FENCE THAT WERE REMOVED.
11. RESTORE SITE AS SHOWN ON RESTORATION PLAN.

STAGING & ACCESS NOTES:

1. THE CONTRACTOR SHALL INSTALL CONSTRUCTION FENCE AND GATES AROUND THE PERIMETER OF THE CONSTRUCTION ZONE TO PREVENT PUBLIC ACCESS TO THE CONSTRUCTION SITE FOR THE DURATION OF THE CONTRACT, OR AS DIRECTED BY RESIDENT ENGINEER.
2. CONTRACTOR IS RESPONSIBLE FOR FULLY REMOVING ALL TEMPORARY ACCESS MATERIALS AND REPAIRING ANY DAMAGE THAT MAY OCCUR FROM ACCESS ROAD MATERIALS BEING MOBILIZED UNDER A FLOOD EVENT, AT NO ADDITIONAL COST TO THE CITY.
3. CONTRACTOR IS RESPONSIBLE TO REPAIR ANY DAMAGE TO ALL EXISTING PAVEMENTS, CURBS, WALL, OR ITEMS AS DETERMINED BY RESIDENT ENGINEER TO REMAIN, AT NO ADDITIONAL COST TO THE CITY.
4. NO CONSTRUCTION VEHICLES SHALL BE STORED, SERVICED, WASHED, OR FLUSHED IN A LOCATION WHERE LEAKS, SPILLAGE, WASTE MATERIALS, CLEANERS, OR WATERS WILL BE INTRODUCED OR FLOW INTO WETLANDS, WATERCOURSES, OR ACTIVE PARK AREAS.
5. CONTRACTOR MUST BRING IN ALL MATERIAL FOR THE DAY BETWEEN 6AM AND 9AM AND LEAVE IT AT THE CONSTRUCTION SITE OVERNIGHT, THIS INCLUDES CONCRETE DELIVERIES.

EMERGENCY ACTION PLAN

1. THE CONTRACTOR SHALL MONITOR LOCAL WEATHER FORECASTS, PRECIPITATION, RIVER STAGE, AND FLOW RATES ON A DAILY BASIS. THE CONTRACTOR IS RESPONSIBLE TO ADJUST WORK SCHEDULES AND REMOVE EQUIPMENT FROM THE RIVER PRIOR TO RAINFALL EVENTS THAT MAY CAUSE RISING WATER LEVELS. IN THE EVENT OF MORE THAN ONE INCH OF RAIN IN A 24-HOUR PERIOD, OR THE FORECAST OF A TROPICAL STORM OR HURRICANE, ALL EQUIPMENT, FLOATABLES, FUEL, AND OTHER POSSIBLE CONTAMINANTS ARE TO BE MOVED OUT OF THE FEMA DESIGNATED 100-YEAR FLOODPLAIN.
2. PRIOR TO INITIATING WORK, THE CONTRACTOR SHALL INSPECT DOWNSTREAM AREAS TO IDENTIFY ZONES THAT COULD POTENTIALLY BE FLOODED WITHIN OR NEAR THE CHANNEL IN THE EVENT OF AN UNEXPECTED WATER RELEASE.
3. THE CONTRACTOR SHALL NOTIFY LOCAL EMERGENCY DEPARTMENTS (FIRE, POLICE, EMS, ETC.) AT THE COMMENCEMENT OF WORK, AND AFTER ANY STOPPAGE OF WORK AND REMOBILIZATION.
4. THE CONTRACTOR SHALL NOTIFY LOCAL EMERGENCY PERSONNEL IN THE EVENT OF MEDICAL EMERGENCIES OR FLOOD RELATED PROBLEMS.
5. THE PROJECT SITE IS SUBJECT TO FLOODING. THE CONTRACTOR SHALL MONITOR LOCAL WEATHER FORECASTS, PRECIPITATION, RIVER STAGE, AND FLOW RATES ON A DAILY BASIS. THE CONTRACTOR IS RESPONSIBLE TO ADJUST WORK SCHEDULES AND REMOVE EQUIPMENT FROM FLOOD PRONE AREAS IN THE EVENT OF FLOOD WARNINGS. IN THE EVENT OF MORE THAN ONE (1) INCH OF RAIN IN A 24-HOUR PERIOD, OR THE FORECAST OF A TROPICAL STORM OR HURRICANE, ALL EQUIPMENT, FLOATABLES, FUEL, AND OTHER POSSIBLE CONTAMINANTS ARE TO BE MOVED OUT OF THE FEMA-DESIGNATED 100-YEAR FLOODPLAIN .

CONSTRUCTION NOTES

1. TREES TO BE PROTECTED & REMAIN AS INDICATED. REFER TO SHEET 07.
2. FINAL DESIGN SHALL INCLUDE CENTERLINE STAKE OUT, SUPPLEMENTAL SURVEY, AND PROBES OF CURRENT SEDIMENT CONDITIONS.
3. LOCATION OF TURBIDITY CURTAIN TO BE DETERMINED IN FIELD TO MAXIMIZE DOWNSTREAM PROTECTION. TURBIDITY CURTAIN SHALL BE CLEANED AS NEEDED AND MAINTAINED DAILY.
4. SEE TREE INVENTORY ON SHEET 07 FOR DETAILED INFORMATION ABOUT TREE REMOVALS AND PROTECTION.

GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: BRONX ZOO DAM FISH PASSAGE AND SITE IMPROVEMENTS		
DRAWING TITLE: SITE PREPARATION AND WATER CONTROL		
DESIGNED BY: EJAG	DRAWN BY: BAM	CHECKED BY: JSWNRGSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. CONTRACT NUMBER
B-SCAN	SCALE: 1"=10' / DATE:	DRAWING NO. 06
		SHEET NO. 06 OF 17 SHEETS

TREE #	SPECIES	D.B.H. (INCHES)	TOTAL TREE HEIGHT (FT)	CROWN HEIGHT (FT)	CROWN WIDTH (FT)	AGE CLASS (Y <20% M 20-80% OM >80% of Life Expectancy)	PRUNING ANSI A-300: Cleaning	Raising	Reducing	Restoring	Structural	Thinning	Limb Tying	REMOVAL (condition)	REMOVAL (design)	REMOVAL (stump only)	TRANSPLANT	CONDITION: ROOTS Structure (1-4)	ROOTS Health (1-4)	ROOTS Subtotal (2-8)	TRUNK Structure (1-4)	TRUNK Health (1-4)	TRUNK Subtotal (2-8)	SCAFFOLD BRANCHES Structure (1-4)	SCAFFOLD BRANCHES Health (1-4)	SCAFFOLD BRANCHES Subtotal (2-8)	SMALL BRANCHES (1-4)	BUDS & FOLIAGE (1-4)	SUBTOTAL (32)	COMMENTS
1	OAK, NORTHERN RED	24	48	18	20	OM												4	4	8	4	4	8	4	4	8	4	4	32	
2	MAPLE, RED	18	45	30	35	OM												3	4	7	4	4	8	4	4	8	4	4	31	
3	TULIP TREE	6	20	6	6	Y												4	4	8	1	3	4	2	4	6	4	4	26	
5	MAPLE, NORWAY	24	60	45	35	M									X			4	4	8	3	4	7	3	4	7	4	4	30	Caliper based restitution
6	OAK, NORTHERN RED	10	35	10	15	M									X			3	4	7	4	4	8	4	4	8	4	4	30	NYC tree valuation restitution
6	OAK, NORTHERN RED	8	35	10	15	M									X			3	4	7	4	4	8	4	4	8	3	4	30	NYC tree valuation restitution
6	OAK, NORTHERN RED	10	35	10	15	M									X			3	4	7	4	4	8	4	4	8	3	4	30	NYC tree valuation restitution
7	MULBERRY, WHITE	8	20	10	5	Y									X			4	4	8	2	2	4	4	4	8	4	4	28	Caliper based restitution
8	OAK, NORTHERN RED	29	65	40	25	OM												4	4	8	4	4	8	4	4	8	4	4	32	
9	MULBERRY, WHITE	8	22	10	6	Y									X			4	4	8	4	3	7	4	4	8	4	4	31	Caliper based restitution
10	MAPLE, NORWAY	7	20	2	5	Y									X			3	4	7	4	4	8	4	4	8	4	4	31	Caliper based restitution
11	OAK, NORTHERN RED	34	50	35	27	OM												4	4	8	4	4	8	4	4	8	4	4	32	
13	MAPLE, NORWAY	10	28	3	12	M												4	4	8	4	4	8	4	4	8	4	4	32	
14	MAPLE, NORWAY	17	50	10	25	M									X			4	2	6	4	4	8	4	4	8	2	4	28	Removal pending site access
16	OAK, NORTHERN RED	17												X						0			0			0			0	Dead tree
17	ALDER, EUROPEAN	10	45	3	6	M												3	4	7	4	4	8	4	4	8	4	4	31	
18	MAPLE, RED	3				Y								X						0			0			0			0	Clear and grub
19	MAPLE, NORWAY	3				Y								X						0			0			0			0	Clear and grub
20	ASH, OTHER	6	20	10	8	Y									X			3	4	7	4	4	8	4	4	8	3	4	30	NYC tree valuation restitution
21	ASH, OTHER	7	24	2	12	Y												4	4	8	2	4	6	4	4	8	4	4	30	
22	TREE OF HEAVEN	14	50	12	12	OM									X			4	4	8	4	4	8	4	2	6	2	2	26	Caliper based restitution
23	BIRCH, OTHER	8	20	4	15	Y												4	4	8	3	4	7	4	4	8	4	4	31	
24	ALDER, EUROPEAN	5	9	3	8	Y												4	4	8	2	4	6	4	4	8	4	4	30	
25	MAPLE, NORWAY	5	12	3	6	Y									X			4	4	8	4	4	8	4	4	8	4	4	32	Caliper based restitution
26	OAK, OTHER	4	18	2	5	Y												4	4	8	4	4	8	4	4	8	4	4	32	
27	OAK, OTHER	4	12	6	6	Y												4	4	8	4	3	7	2	4	6	4	4	29	
28	MULBERRY, WHITE	10												X						0			0			0			0	Shaft

#6: 10" QUERCUS RUBRA TO REMOVE, TREE AND STUMP COMPLETE TYPICAL

#5: 24" ACER PLATANOIDES TO REMOVE

#11: 35" QUERCUS RUBRA TO REMAIN

#10: 7" CARYA GLABRA TO REMOVE

#13: 10" ACER PLATANOIDES TO REMAIN

#15: 11" ULMUS AMERICANA TO REMAIN, BX ZOO TREE TAG #2283

#16: 17" DEAD TREE TO REMOVE, BX ZOO TREE TAG #2282

#17: 9" ALNUS GLUTINOSA TO REMAIN

#14: 17" ACER PLATANOIDES TO REMAIN

AREA OF REMOVAL REQUIRED FOR FISH STEEPPASS CONSTRUCTION. EARTH AND ROCK EXCAVATION REFER TO SHEET 09 PROPOSED FISHWAY PROFILE.

#7: 8" MORUS ALBA TO REMAIN

#9: 8" MORUS ALBA TO REMAIN

#4: 48" STUMP TO REMOVE

#8: 29" QUERCUS RUBRA TO REMAIN

#1: 22" QUERCUS RUBRA TO REMAIN

18" DEADSHEAD TO REMOVE

#2: 18" ACER SACCHARUM TO REMAIN & PROTECT

PROTECT AND MAINTAIN EXISTING STORMWATER PIPING, OUTFALLS, AND APPURTENANCES. LOCATION SHOWN IS APPROXIMATE.

#12: 28' STUMP TO REMOVE

REMOVE AND RESET USGS KIOSK

REMOVE 180 LF TIMBER RAIL FENCE

LEGEND

- EXISTING CONTOUR
- EDGE OF ROAD
- EDGE OF WATER
- TREELINE
- EXPOSED LEDGE
- FEMA 100-YR FLOODPLAIN
- EXISTING LIGHT POLE
- EXISTING TREE (SIZE VARIES)
- TREE STUMP OR SHAFT
- TEMPORARY WOODEN TREE GUARD WITH TREE WRAP
- TREE REMOVAL
- BEDROCK AND/OR EARTH REMOVAL

NOTES:

1. EROSION, WATER, AND SEDIMENT CONTROL MEASURES SHALL BE INSTALLED PRIOR TO ANY REMOVALS OCCURRING. REFER TO SHEET 6.
2. REFER TO REMOVAL NOTES, SHEET 17.

GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

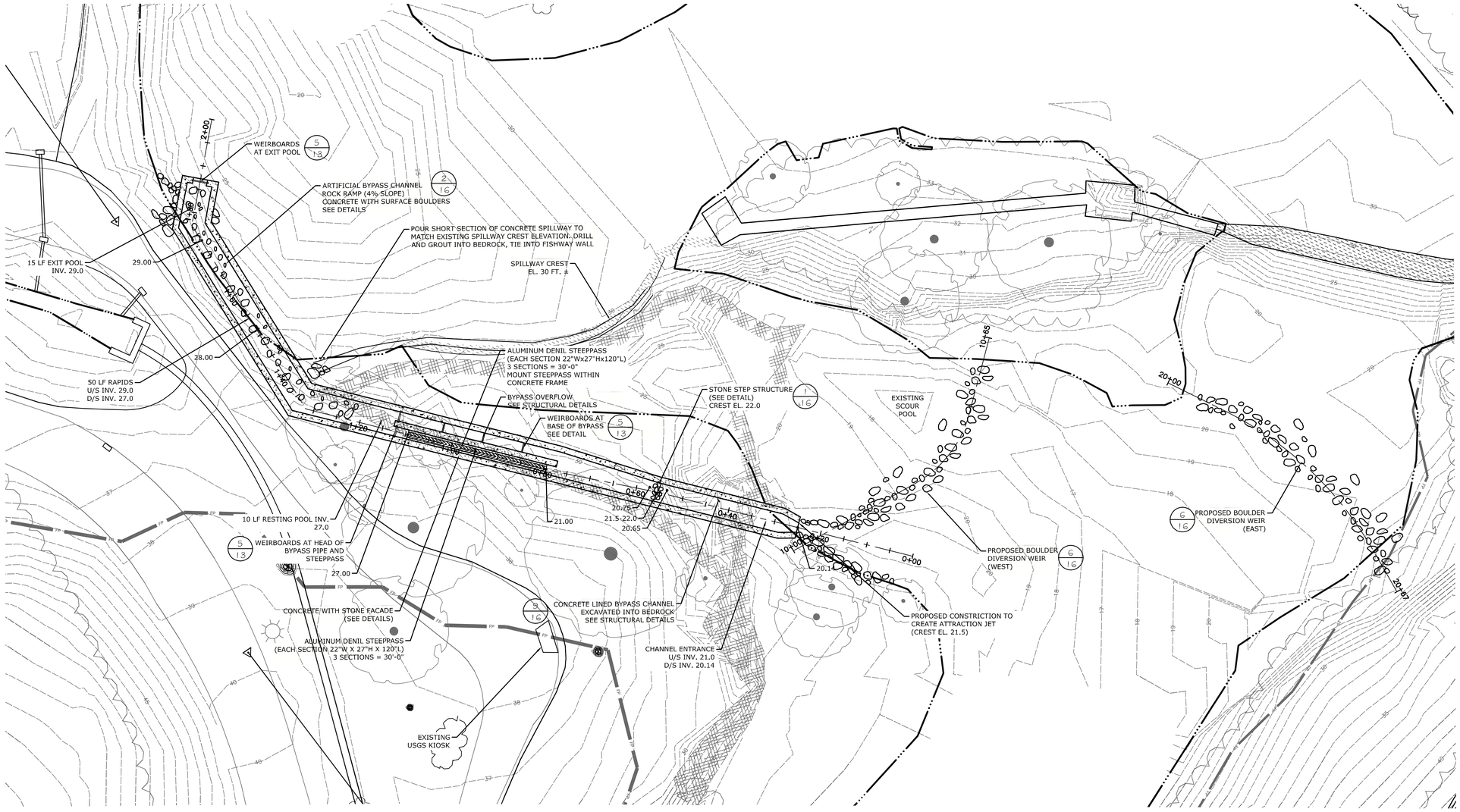
PROJECT TITLE
BRONX ZOO DAM
FISH PASSAGE AND SITE IMPROVEMENTS

DRAWING TITLE
SITE REMOVALS PLAN

DESIGNED BY	DRAWN BY	CHECKED BY
EJAG	BAM	JGMMRGSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO.
B-SCAN	SCALE 1"=10' / DATE	DRAWING NO. 07

CONTRACT NUMBER

SHEET NO. 07 OF 17 SHEETS



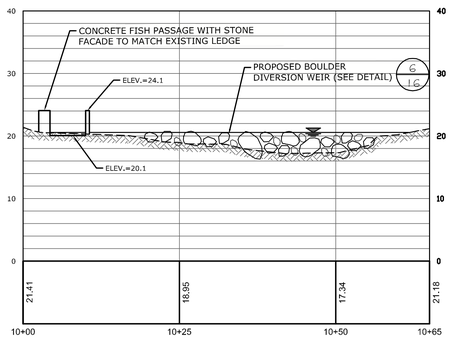
PROPOSED FISHWAY - PLAN VIEW
(SCALE: 1" = 10')

LAYOUT & MATERIALS NOTES:

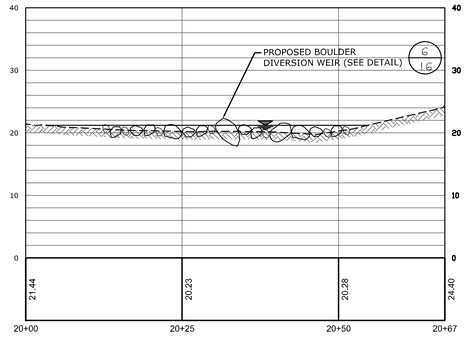
1. THE CONTRACTOR SHALL VERIFY ALL EXISTING SITE CONDITIONS, BOTH ABOVE AND BELOW THE SURFACE. ANY DISCREPANCIES BETWEEN INFORMATION SHOWN ON THE DRAWINGS AND ACTUAL FIELD CONDITIONS SHALL BE BROUGHT TO THE ATTENTION OF THE RESIDENT ENGINEER AND PARKS IN WRITING, PRIOR TO COMMENCING WORK.
2. LOCATIONS OF EXISTING TREES SHALL BE VERIFIED IN THE FIELD.
3. NO CHANGES SHALL BE MADE TO THE DESIGN OR LAYOUT WITHOUT THE WRITTEN APPROVAL OF THE ENGINEER. LAYOUT THE WORK AS DIMENSIONED ON THE PLANS. WRITTEN DIMENSIONS SHALL GOVERN. DO NOT SCALE DISTANCES.
4. CONTRACTOR SHALL LAYOUT AND STAKE IN THE FIELD THE ALIGNMENT OF ALL PATHS, PAVEMENTS AND TRAILS FOR REVIEW BY THE ENGINEER. ADJUSTMENTS MAY BE MADE ONLY AS DIRECTED BY THE LANDSCAPE ARCHITECT. CONTRACTOR MAY NOT PROCEED WITH CONSTRUCTION OF IMPROVEMENTS UNTIL HE HAS RECEIVED THE FINAL APPROVAL OF THE LAYOUT FROM THE LANDSCAPE ARCHITECT AND RESIDENT ENGINEER.
5. NEW CURBS, WALLS, AND PAVEMENTS SHALL BE BUILT TO A SMOOTH EVEN FINISH WITH A CONSISTENT TOP AND PROFILE WITHOUT WAVES OR IRREGULARITIES. ANY WORK NOT MEETING THIS QUALITY STANDARD SHALL BE REPLACED AT THE CONTRACTOR'S EXPENSE.
6. THE CONTRACTOR SHALL EXERCISE CARE DURING EXCAVATION OPERATIONS TO AVOID DISTURBING ADJACENT FACILITIES, SUB GRADE STRUCTURES AND TREES. ALL DAMAGE RESULTING FROM THE CONSTRUCTION SHALL BE THE CONTRACTORS RESPONSIBILITY AND SHALL BE REPAIRED AT NO EXPENSE TO THE WCS, THE CITY, AND THE DEPARTMENT OF PARKS AND RECREATION. ALL REPAIR WORK SHALL BE TO THE SATISFACTION OF THE RESIDENT ENGINEER, THE DEPARTMENT OF PARKS AND RECREATION, AND THE WCS. PLANTED AREAS DISTURBED BY HIS WORK SHALL BE RESTORED AS DIRECTED BY THE ENGINEER OR ENGINEERS REPRESENTATIVE.
7. NO HEAVY MACHINERY, EQUIPMENT OR STOCKPILING OF MATERIAL IS PERMITTED WITHIN THE DRIP LINES OF EXISTING TREES.
8. THE CONTRACTOR SHALL TAKE SPECIAL CARE TO PROTECT ALL EXISTING TREES AND THEIR ROOT SYSTEM. EXCAVATIONS WITHIN THE DRIP LINES OF TREES SHALL BE KEPT TO A MINIMUM AND SHALL BE COMPLETED BY HAND ONLY AND SHALL BE PERFORMED IN THE PRESENCE OF THE RESIDENT ENGINEER. AT NO ADDITIONAL EXPENSE TO THE CITY. ROOTS OVER 2" DIAMETER SHALL NOT BE DISTURBED AND BRIDGE CURBS SHALL BE CONSTRUCTED WHERE NECESSARY.
9. IN AREAS WHERE NEW PAVEMENTS FALL WITHIN THE DRIP LINE OF EXISTING TREES, THE CONTRACTOR SHALL MINIMIZE EXCAVATIONS AT TREE ROOTS BY REDUCING THE AMOUNT OF FOUNDATION MATERIAL AS DIRECTED BY ENGINEER.

GRADING NOTES:

1. THE CONTRACTOR SHALL VERIFY ALL EXISTING TOPOGRAPHIC INFORMATION. ANY DISCREPANCIES BETWEEN THE SURVEY AND EXISTING CONDITIONS, BETWEEN PLANS AND SPECIFICATIONS, OR BETWEEN DIFFERENT PLANS SHALL BE BROUGHT TO THE ATTENTION OF THE RESIDENT ENGINEER AND D.P.R. IN WRITING PRIOR TO COMMENCING WORK.
2. ALL PAVEMENTS SHALL BE INSTALLED TO SMOOTH EVEN GRADE WITH NO PATCHING, IRREGULARITIES, OR BIRDBATHS.
3. ALL NEW PAVEMENTS SHALL MEET EXISTING PAVEMENTS AND GRADES FLUSH AND EVENLY.
4. ALL CURBS SHALL BE INSTALLED TO SMOOTH EVEN GRADES AS INDICATED WITH NO PATCHING OR IRREGULARITIES.
5. THE CONTRACTOR SHALL USE EXTREME CARE TO PROTECT EXISTING TREES AND THEIR ROOTS. EXCEPT AS NOTED, ELEVATIONS AROUND EXISTING TREES SHALL REMAIN THE SAME. MODIFY TRENCHES OR CHANNELS TO AVOID REMAINING TREES AND THEIR ROOTS. ONLY HAND EXCAVATE AS NECESSARY WITHIN THE DRIP LINES OF TREES AS DIRECTED BY THE RESIDENT ENGINEER.
6. THE CONTRACTOR SHALL EXERCISE EXTREME CARE DURING EARTHWORK OPERATIONS, TO AVOID DISTURBING ADJACENT FACILITIES AND OR SUB GRADE STRUCTURES. ALL DAMAGE RESULTING FROM CONSTRUCTION SHALL BE THE CONTRACTOR'S RESPONSIBILITY AND SHALL BE REPAIRED AT NO EXPENSE TO PARKS & RECREATION OR THE CITY OF NEW YORK. ALL REPAIR WORK SHALL BE DONE TO THE SATISFACTION OF THE RESIDENT ENGINEER AND/OR AGENCY HAVING JURISDICTION.
7. ALL GRADES SHOULD BE VERIFIED IN FIELD BY FISHWAY CONSTRUCTION ENGINEERING SPECIALIST.



WEST



EAST

PROPOSED BOULDER DIVERSION WEIRS SECTION VIEW

(SCALE: 1" = 10'H)
1" = 10'V

LEGEND

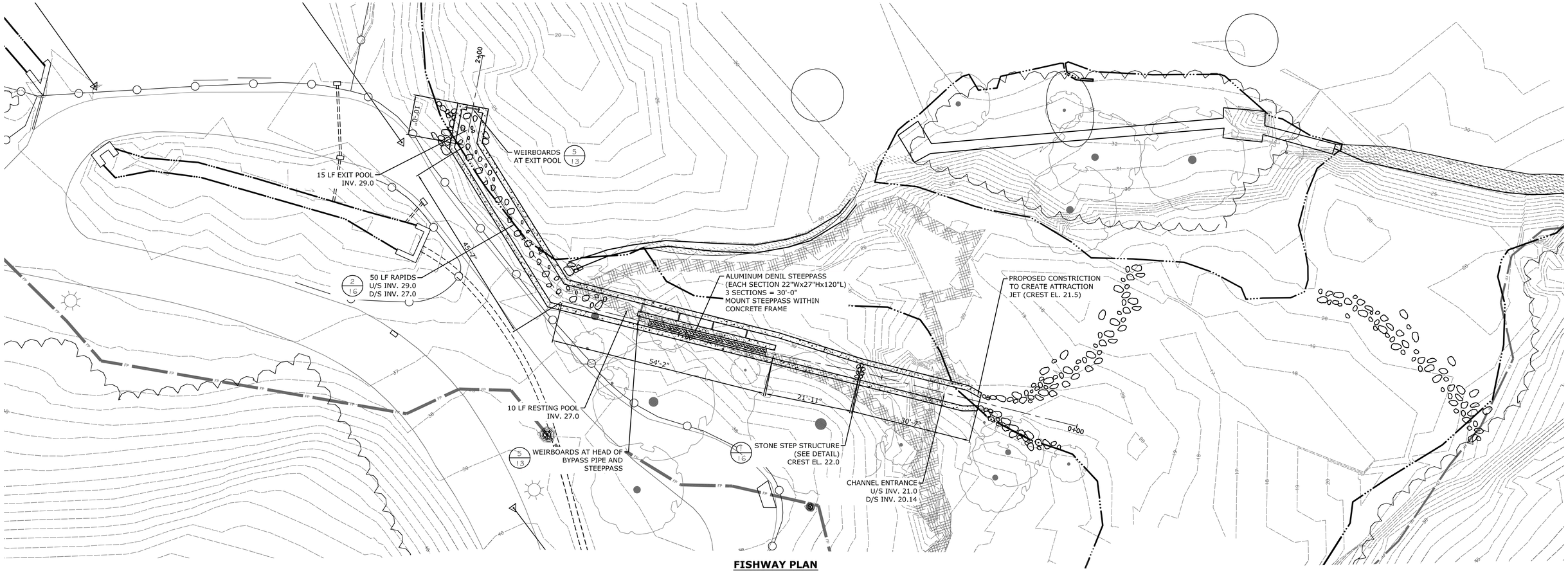
- EXISTING CONTOUR
- EDGE OF ROAD
- EDGE OF WATER
- TREELINE
- EXISTING FENCING
- EDGE OF WETLAND
- EXPOSED LEDGE
- EXISTING STORM DRAIN PIPE
- PROPERTY LINE
- FEMA 100-YR FLOODPLAIN
- EXISTING LIGHT POLE
- EXISTING TREE
- BOUNDER DIVERSION WEIR (4/16, 5/16, 6/16)
- ALUMINUM DENIL STEEPPASS (7/16, 8/16)
- RAPIDS SURFACE BOULDERS (2/16)
- REINFORCED CONCRETE

GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

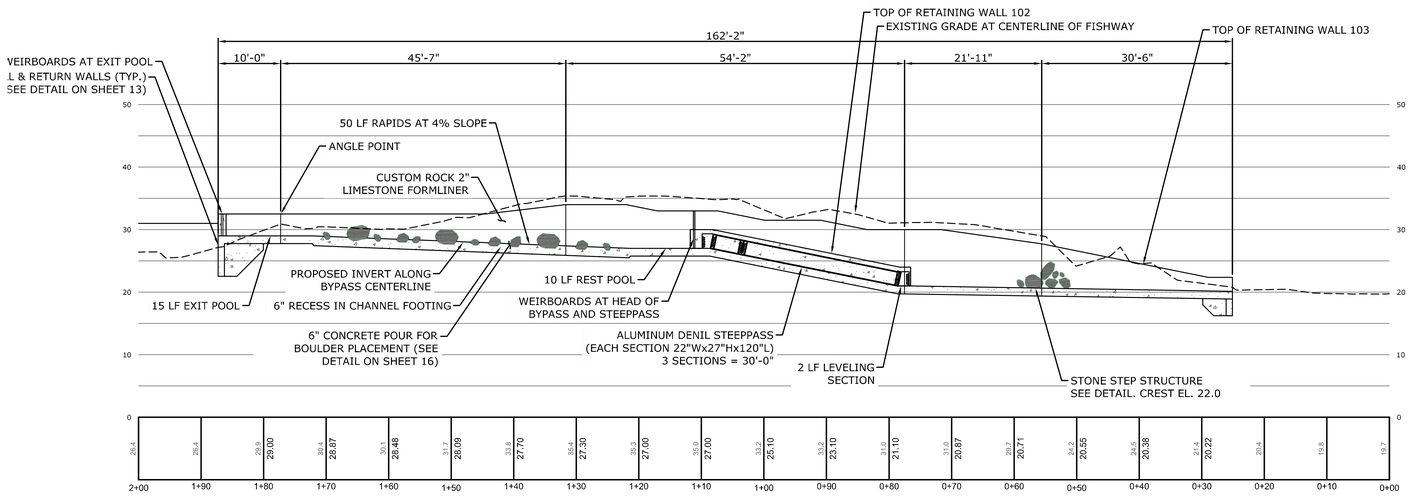
MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: BRONX ZOO DAM FISH PASSAGE AND SITE IMPROVEMENTS		
DRAWING TITLE: PROPOSED FISHWAY - PLAN		
DESIGNED BY: ELIAS	DRAWN BY: BAM	CHECKED BY: JGM/RGSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. CONTRACT NUMBER
B-SCAN	SCALE 1"=10' / DATE	DRAWING NO. 08
		SHEET NO. 08 OF 17 SHEETS



FISHWAY PLAN
SCALE: 1" = 10'-0"



FISHWAY PROFILE
SCALE: 1" = 10'-0"

LEGEND

- EXISTING CONTOUR (50)
- EDGE OF ROAD
- EDGE OF WATER
- TREELINE
- EXISTING FENCING
- EDGE OF WETLAND
- EXPOSED LEDGE
- EXISTING STORM DRAIN PIPE
- PROPERTY LINE
- REINFORCED CONCRETE
- EXISTING LIGHT POLE
- EXISTING TREE (SIZE VARIES)
- EXISTING TREE STUMP
- EXISTING CATCH BASIN
- EXISTING STORM DROP GRATE
- EXISTING SIGN
- EXISTING HYDRANT

GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

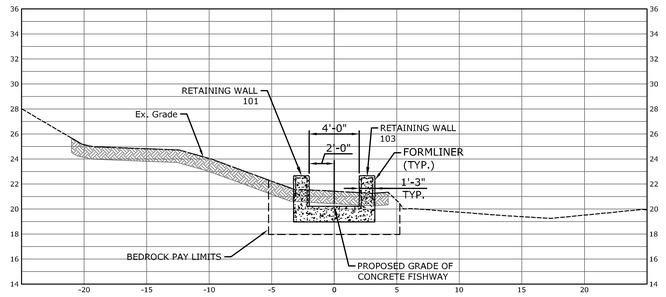
City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE
BRONX ZOO DAM
FISH PASSAGE AND SITE IMPROVEMENTS

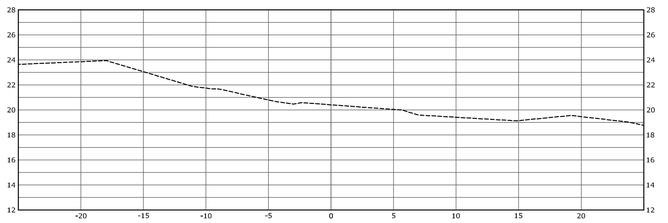
DRAWING TITLE
PROPOSED FISHWAY - PROFILE

DESIGNED BY EL/AG	DRAWN BY SEP/BAW	CHECKED BY JGM/RG/SK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. CONTRACT NUMBER
B-SCAN	SCALE AS NOTED / DATE	DRAWING NO. 09

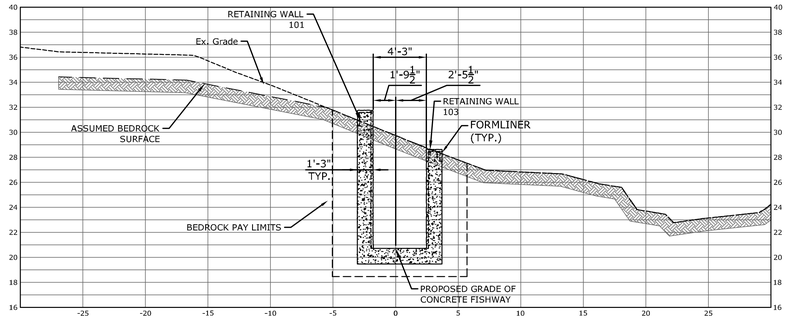
SHEET NO. 09 OF 17 SHEETS



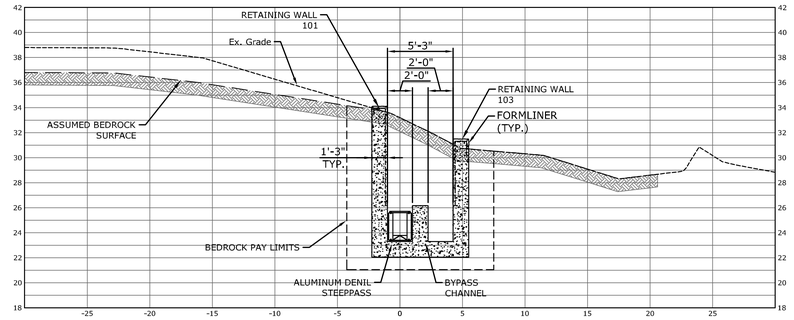
0+30



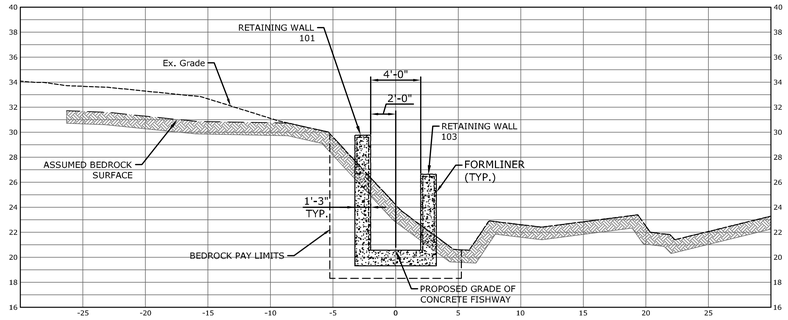
0+20



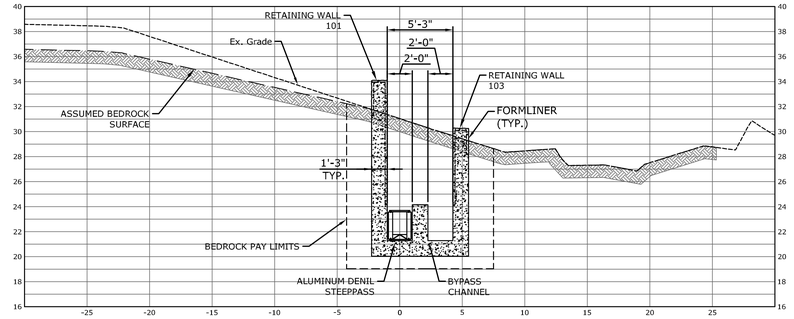
0+60



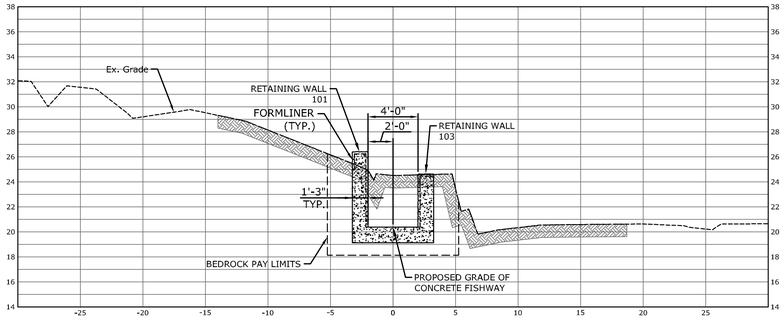
0+90



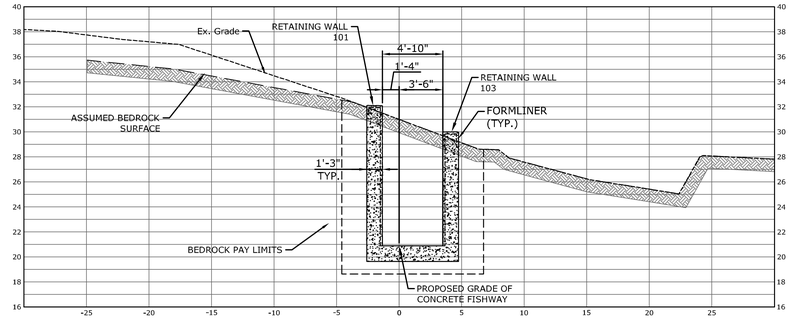
0+50



0+80



0+40



0+70

LEGEND

EXISTING GRADE (EARTHEN)

ASSUMED GRADE (BEDROCK)

PROPOSED CONCRETE FISHWAY

CONSTRUCTION NOTES

1. CONTRACTOR TO COMPLETE BORINGS EVERY 50' TO DETERMINE SUBSURFACE MATERIAL AND BEDROCK ELEVATION.
2. ENGINEER TO FIELD VERIFY ALIGNMENT/LAYOUT AFTER CONTRACTOR STAKEOUT. ENGINEER TO ADJUST STAKEOUT AS NECESSARY.

GRAPHIC SCALE
10 0 10 20
(IN FEET)
1 inch = 20 ft.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

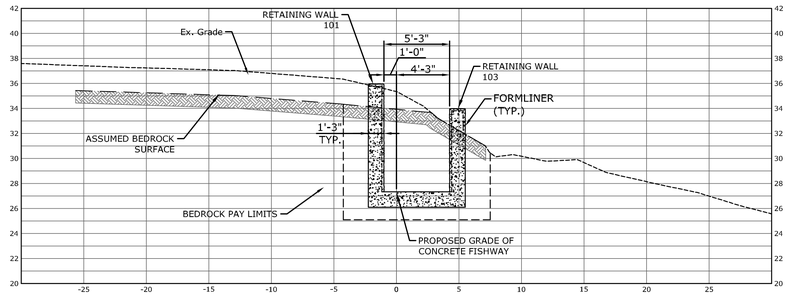
City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE
BRONX ZOO DAM
FISH PASSAGE AND SITE IMPROVEMENTS

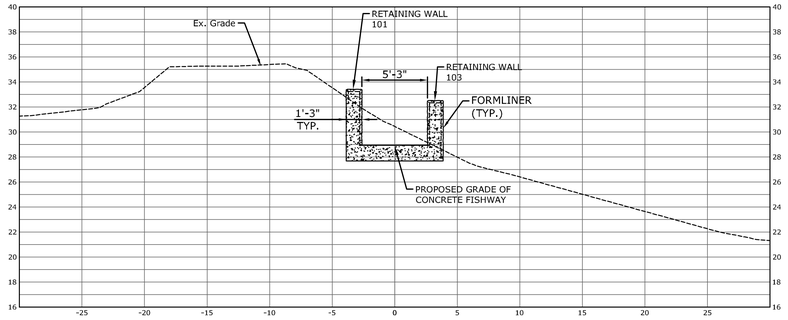
DRAWING TITLE
PROPOSED FISHWAY - CROSS SECTIONS (1)

DESIGNED BY	DRAWN BY	CHECKED BY
EL/AG	BAM	JGM/NRG/SK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. CONTRACT NUMBER
B-SCAN	SCALE 1"=20 / DATE	DRAWING NO. 10

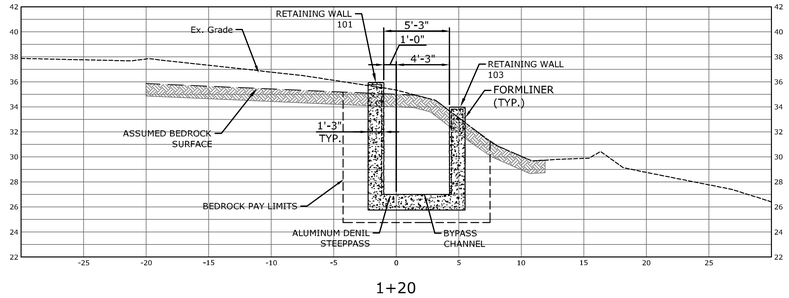
SHEET NO. 10 OF 17 SHEETS



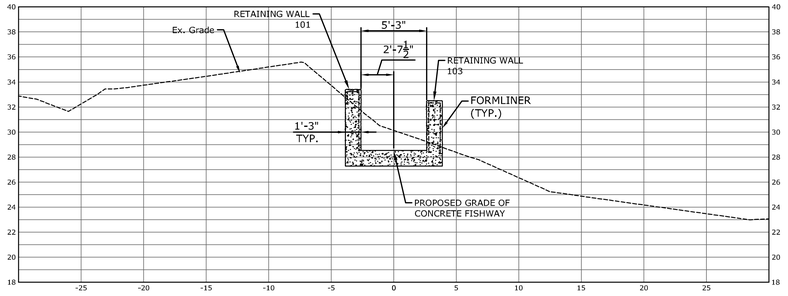
1+30



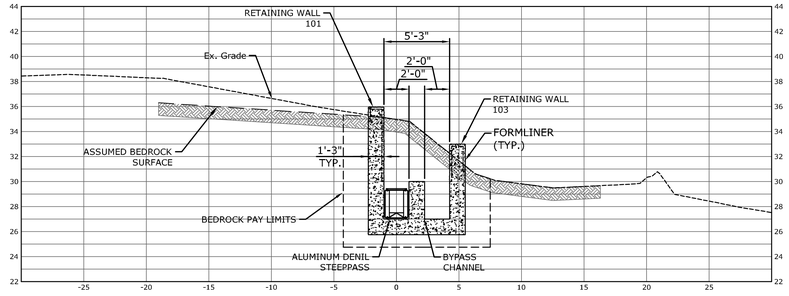
1+70



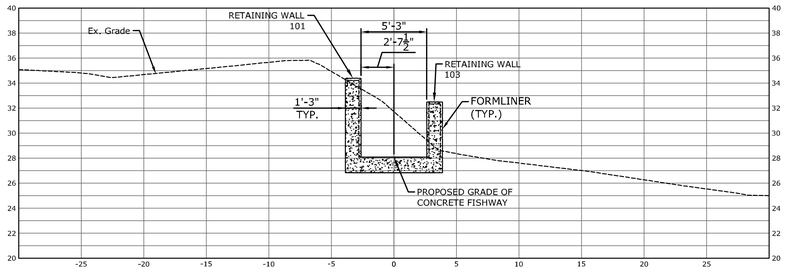
1+20



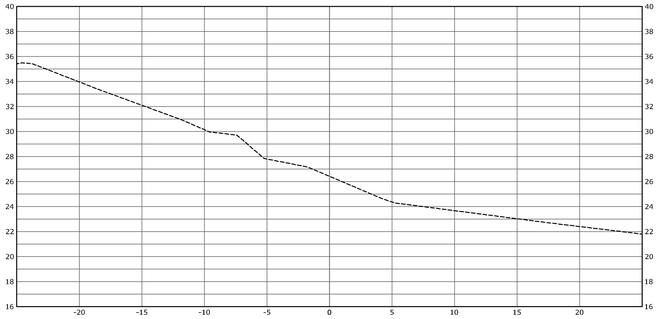
1+60



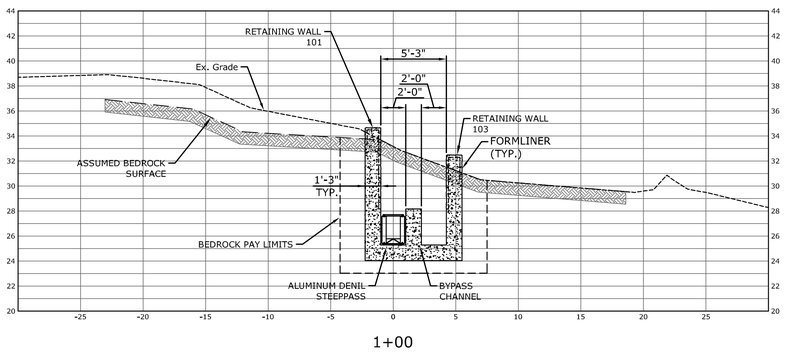
1+10



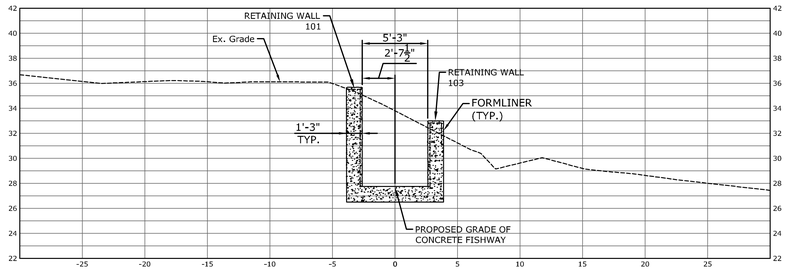
1+50



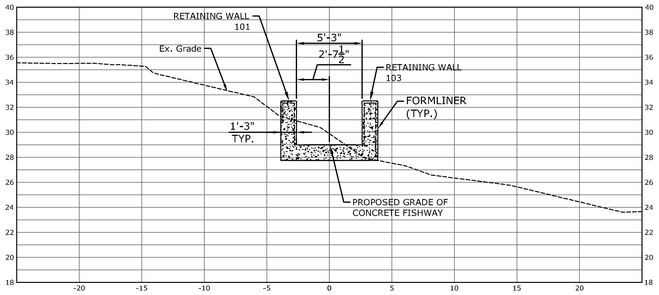
1+90



1+00



1+40



1+80

LEGEND

EXISTING GRADE (EARTHEN)

ASSUMED GRADE (BEDROCK)

PROPOSED CONCRETE FISHWAY

CONSTRUCTION NOTES

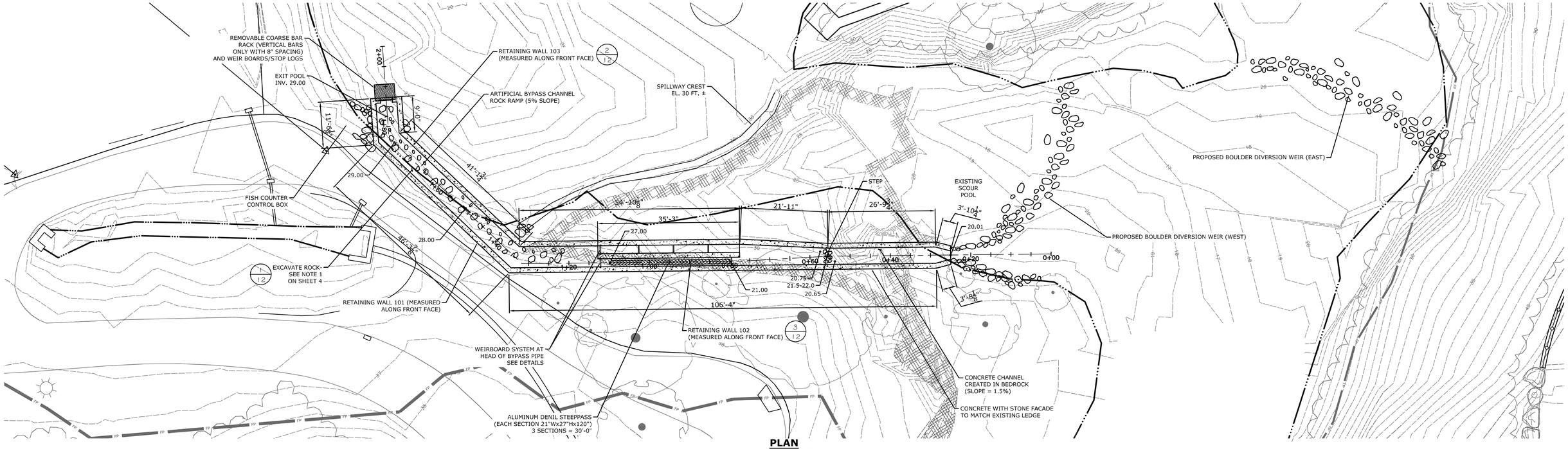
1. CONTRACTOR TO COMPLETE BORINGS EVERY 50' TO DETERMINE SUBSURFACE MATERIAL AND BEDROCK ELEVATION.
2. ENGINEER TO FIELD VERIFY ALIGNMENT/LAYOUT AFTER CONTRACTOR STAKEOUT. ENGINEER TO ADJUST STAKEOUT AS NECESSARY.

MILONE & MACBROOM®
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

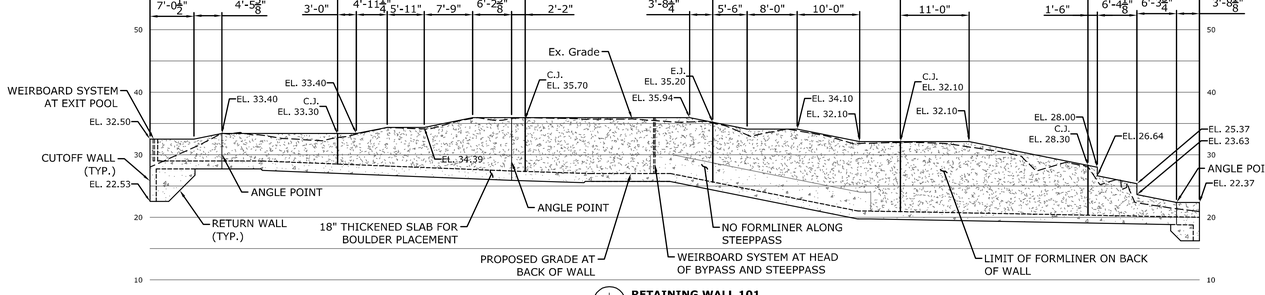
GRAPHIC SCALE
10 0 10 20
(IN FEET)
1 inch = 20 ft.

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

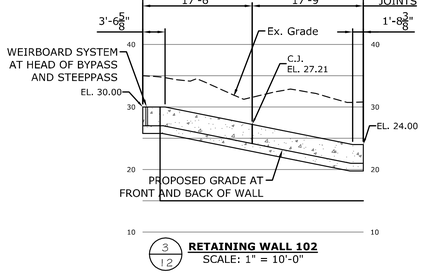
PROJECT TITLE: BRONX ZOO DAM FISH PASSAGE AND SITE IMPROVEMENTS			
DRAWING TITLE: PROPOSED FISHWAY - CROSS SECTIONS (2)			
DESIGNED BY: EL/AG	DRAWN BY: BAM	CHECKED BY: JGM/RGSK	
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR	
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO.	
B-SCAN	SCALE: 1"=20'	DRAWING NO.: 11	CONTRACT NUMBER
	DATE:		SHEET NO. 11 OF 17 SHEETS



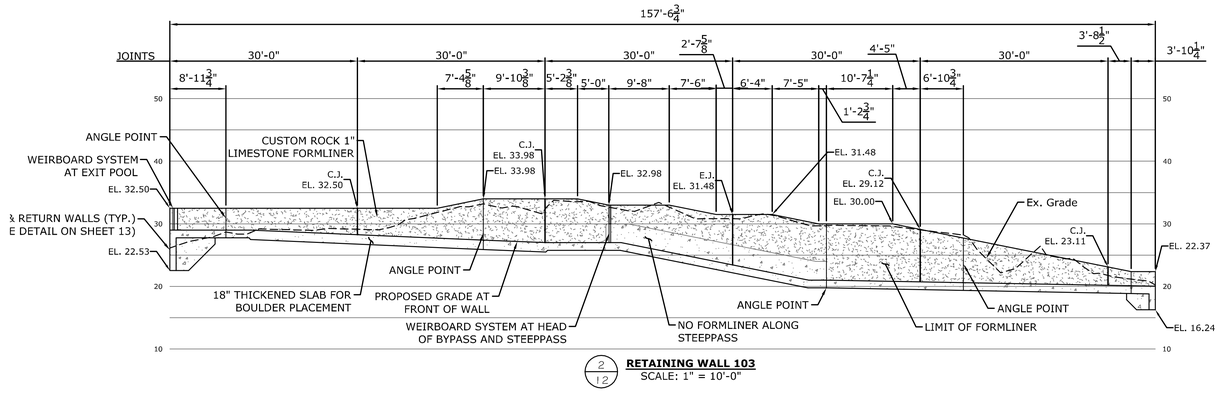
PLAN
SCALE: 1"=10'-0"



1 / 12 **RETAINING WALL 101**
SCALE: 1" = 10'-0"



3 / 12 **RETAINING WALL 102**
SCALE: 1" = 10'-0"



2 / 12 **RETAINING WALL 103**
SCALE: 1" = 10'-0"

LEGEND

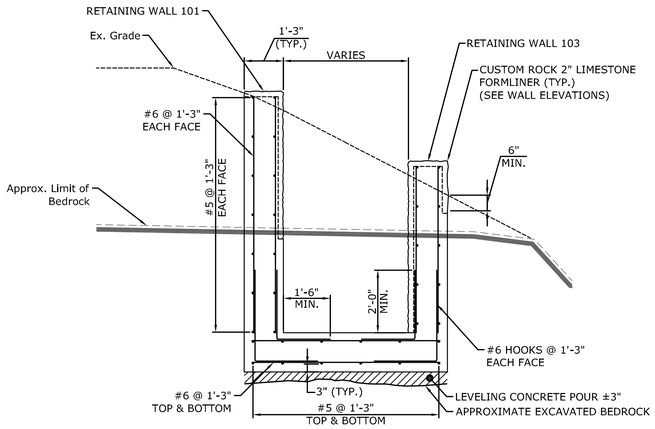
- 50 — EXISTING CONTOUR
- EDGE OF ROAD
- EDGE OF WATER
- TREELINE
- EXISTING FENCING
- EDGE OF WETLAND
- FP — FP — FEMA 100-YR FLOODPLAIN
- EXPOSED LEDGE
- EXISTING STORM DRAIN PIPE
- PROPERTY LINE
- EXPOSED LEDGE
- EXISTING LIGHT POLE
- EXISTING TREE
- EXISTING CATCH BASIN
- EXISTING STORM DROP GRATE
- EXISTING SIGN
- EXISTING HYDRANT

GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

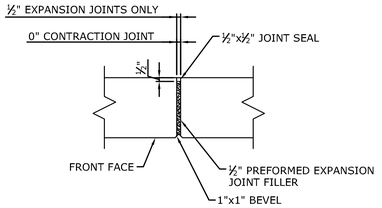
MILONE & MACBROOM®
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE	BRONX ZOO DAM FISH PASSAGE AND SITE IMPROVEMENTS
DRAWING TITLE	STRUCTURAL PLAN & ELEVATIONS
DESIGNED BY: EVAG	DRAWN BY: SEP/DRM
CHECKED BY: JGM/RGSK	
REVIEWED-TEAM LEADER	FORESTRY:
APPROVED-DIRECTOR	
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER
CONTRACT NO.	CONTRACT NUMBER
B-SCAN	SCALE: 1"=10'
DRAWING NO.	12
DATE	
SHEET NO. 12 OF 17 SHEETS	



1/13 **RETAINING WALLS 101 & 103 - TYPICAL SECTION**
SCALE: ½" = 1'-0"



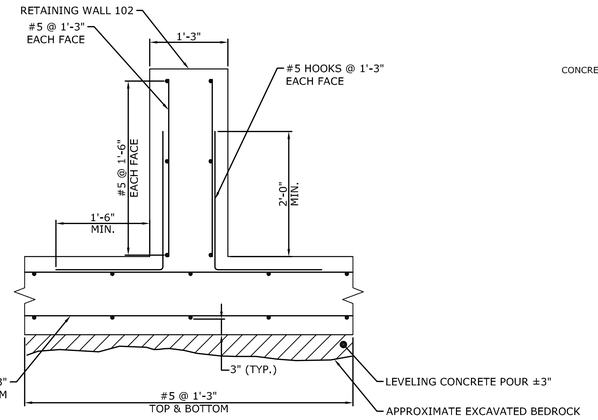
NOTES:

1. JOINT SEAL TO EXTEND FROM TOP OF FOOTING TO TOP OF WALL.

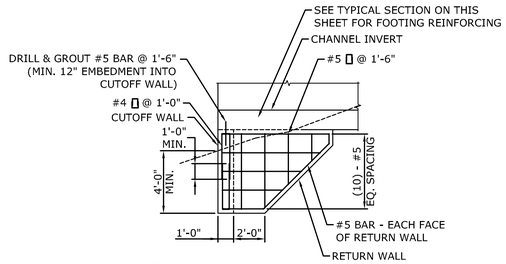
2. NO REINFORCEMENT SHALL PASS THROUGH EXPANSION OR CONTRACTION JOINT.

3. REINFORCEMENT SHALL PASS THROUGH CONSTRUCTION JOINTS.

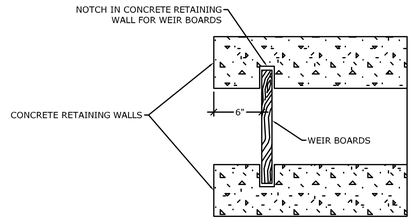
4/13 **CONTRACTION & EXPANSION JOINT DETAIL**
NOT TO SCALE

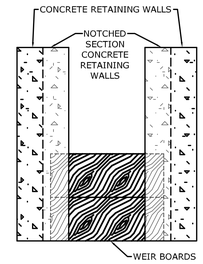


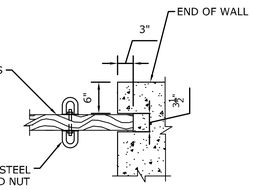
2/13 **RETAINING WALL 102 - TYPICAL SECTION**
SCALE: 1" = 1'-0"



3/13 **CUTOFF WALL & RETURN WALL DETAIL**
SCALE: ¼" = 1'-0"







WEIR BOARD DETAIL
SCALE: 1" = 1'-0"

NOTE: PROVIDE A SET OF FIVE (5) 3"x6" OAK WEIR BOARDS AT EACH LOCATION. DETAIL APPLICABLE FOR ALL WEIR BOARD LOCATIONS.

5/13 **WEIR BOARDS**
NOT TO SCALE

CONSTRUCTION NOTES

1. CONTRACTOR TO COMPLETE BORINGS EVERY 50' TO DETERMINE SUBSURFACE MATERIAL AND BEDROCK ELEVATION.

2. ENGINEER TO FIELD VERIFY ALIGNMENT/LAYOUT AFTER CONTRACTOR STAKEOUT. ENGINEER TO ADJUST STAKEOUT AS NECESSARY.

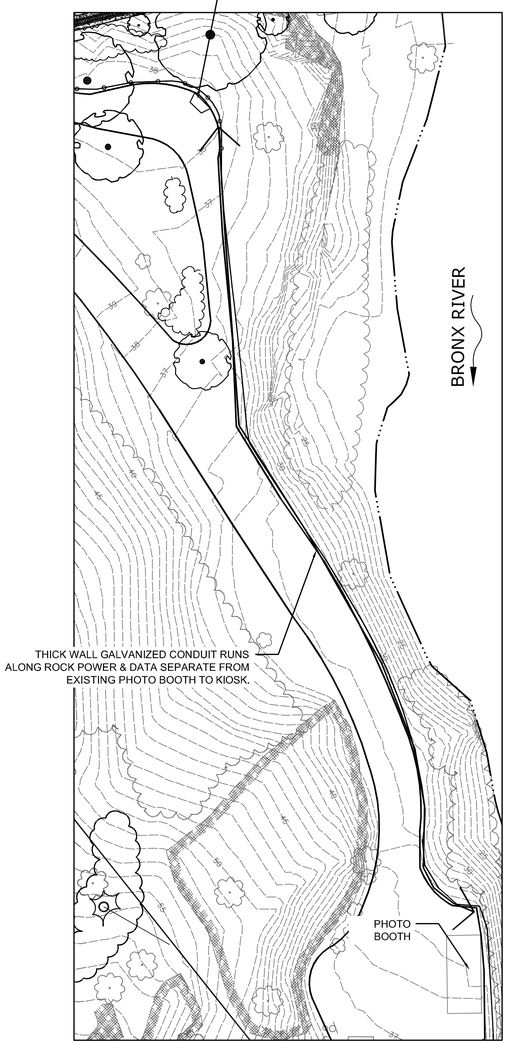
MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

GRAPHIC SCALE
10 0 10 20
(IN FEET)
1 inch = 20 ft.

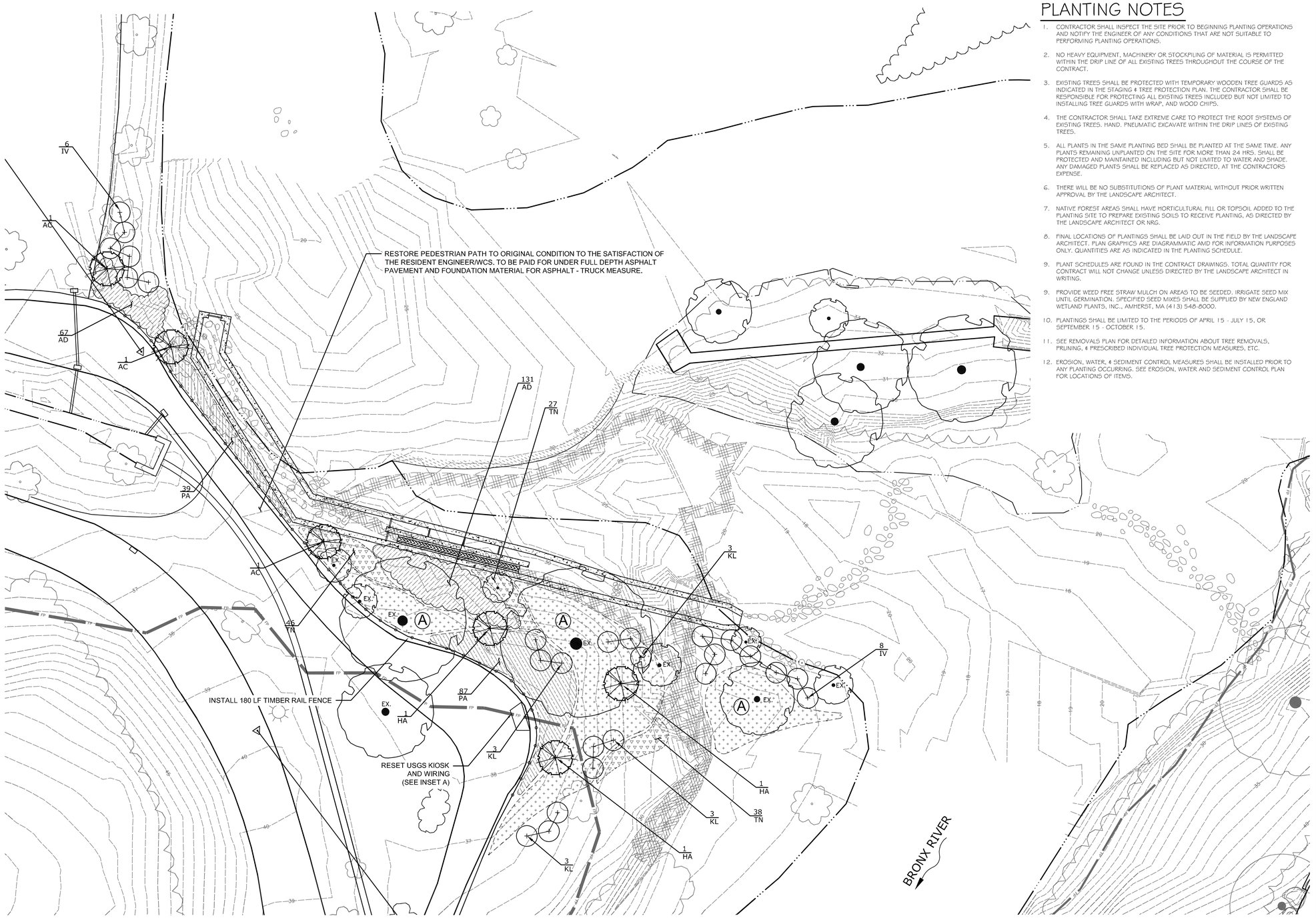
City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: BRONX ZOO DAM FISH PASSAGE AND SITE IMPROVEMENTS		
DRAWING TITLE: STRUCTURAL DETAILS		
DESIGNED BY: EL/AG	DRAWN BY: BA/WDR/	CHECKED BY: JGM/RG/SK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. CONTRACT NUMBER
B-SCAN	SCALE: AS SHOWN / DRAWING NO.: 13 / DATE	SHEET NO. 13 OF 17 SHEETS

ENGINEER SEAL - PANEL DISCIPLINE - PANEL NAME - DRAWING NAME - DATE - PLOTTED BY - PLOT TIME - PLOT SCALE - PLOT STYLE - XREFS - IMAGES



INSET A
SCALE: 1"-20'



PLANTING NOTES

1. CONTRACTOR SHALL INSPECT THE SITE PRIOR TO BEGINNING PLANTING OPERATIONS AND NOTIFY THE ENGINEER OF ANY CONDITIONS THAT ARE NOT SUITABLE TO PERFORMING PLANTING OPERATIONS.
2. NO HEAVY EQUIPMENT, MACHINERY OR STOCKPILING OF MATERIAL IS PERMITTED WITHIN THE DRIP LINE OF ALL EXISTING TREES THROUGHOUT THE COURSE OF THE CONTRACT.
3. EXISTING TREES SHALL BE PROTECTED WITH TEMPORARY WOODEN TREE GUARDS AS INDICATED IN THE STAGING & TREE PROTECTION PLAN. THE CONTRACTOR SHALL BE RESPONSIBLE FOR PROTECTING ALL EXISTING TREES INCLUDED BUT NOT LIMITED TO INSTALLING TREE GUARDS WITH WRAP, AND WOOD CHIPS.
4. THE CONTRACTOR SHALL TAKE EXTREME CARE TO PROTECT THE ROOT SYSTEMS OF EXISTING TREES. HAND, PNEUMATIC EXCAVATE WITHIN THE DRIP LINES OF EXISTING TREES.
5. ALL PLANTS IN THE SAME PLANTING BED SHALL BE PLANTED AT THE SAME TIME. ANY PLANTS REMAINING UNPLANTED ON THE SITE FOR MORE THAN 24 HRS. SHALL BE PROTECTED AND MAINTAINED INCLUDING BUT NOT LIMITED TO WATER AND SHADE. ANY DAMAGED PLANTS SHALL BE REPLACED AS DIRECTED, AT THE CONTRACTORS EXPENSE.
6. THERE WILL BE NO SUBSTITUTIONS OF PLANT MATERIAL WITHOUT PRIOR WRITTEN APPROVAL BY THE LANDSCAPE ARCHITECT.
7. NATIVE FOREST AREAS SHALL HAVE HORTICULTURAL FILL OR TOPSOIL ADDED TO THE PLANTING SITE TO PREPARE EXISTING SOILS TO RECEIVE PLANTING, AS DIRECTED BY THE LANDSCAPE ARCHITECT OR NRG.
8. FINAL LOCATIONS OF PLANTINGS SHALL BE LAID OUT IN THE FIELD BY THE LANDSCAPE ARCHITECT. PLAN GRAPHICS ARE DIAGRAMMATIC AMD FOR INFORMATION PURPOSES ONLY. QUANTITIES ARE AS INDICATED IN THE PLANTING SCHEDULE.
9. PLANT SCHEDULES ARE FOUND IN THE CONTRACT DRAWINGS. TOTAL QUANTITY FOR CONTRACT WILL NOT CHANGE UNLESS DIRECTED BY THE LANDSCAPE ARCHITECT IN WRITING.
9. PROVIDE WEED FREE STRAW MULCH ON AREAS TO BE SEEDED. IRRIGATE SEED MIX UNTIL GERMINATION. SPECIFIED SEED MIXES SHALL BE SUPPLIED BY NEW ENGLAND WETLAND PLANTS, INC., AMHERST, MA (413) 548-8000.
10. PLANTINGS SHALL BE LIMITED TO THE PERIODS OF APRIL 15 - JULY 15, OR SEPTEMBER 15 - OCTOBER 15.
11. SEE REMOVALS PLAN FOR DETAILED INFORMATION ABOUT TREE REMOVALS, PRUNING, & PRESCRIBED INDIVIDUAL TREE PROTECTION MEASURES, ETC.
12. EROSION, WATER, & SEDIMENT CONTROL MEASURES SHALL BE INSTALLED PRIOR TO ANY PLANTING OCCURRING. SEE EROSION, WATER AND SEDIMENT CONTROL PLAN FOR LOCATIONS OF ITEMS.

PLANTING SCHEDULE

TREES/ SHRUBS	QTY	KEY	BOTANICAL	COMMON	SIZE	COMMENTS
	2	AC	Amelanchier canadensis	Shadblow Serviceberry	6'-7' HT.	FULL & DENSE
	3	HA	Hamamelis virginiana	Common Witchhazel	30"-36" HT.	FULL & DENSE
	14	IV	Ilex verticillata	Winterberry	30"-36" HT.	FULL & DENSE
	12	KL	Kalmia latifolia	Mountain Laurel	30"-36" HT.	FULL & DENSE
HERBACEOUS PLANTINGS	QTY	KEY	BOTANICAL	COMMON	SIZE	COMMENTS
	198	AD	Aster divancatus	White Wood Aster	1 GAL.	PLANT 12" O.C.
	126	PA	Polystichum acrostichoides	Christmas Fern	1 GAL.	PLANT 24" O.C.
	111	TN	Thelyptens noveboracensis	New York Fern	1 GAL.	PLANT 18" O.C.

ABBREVIATIONS

REV.	= REVISION	B&B	= BALL AND BURLAP
QTY.	= QUANTITY	GAL.	= GALLON
SPR.	= SPREAD	CAL.	= CALIPER
HT.	= HEIGHT	CONT.	= CONTAINER
MIN.	= MINIMUM	TYP.	= TYPICAL

SEED SCHEDULE

ZONE A

New England Semi-shade Grass and Forbs Mix
Application Rate: 30 lbs/ acre 1450 sf/ lb

As manufactured by:
New England Wetland Plants, Inc.
820 West St. Amherst, MA 01002
(413) 548-8000

LEGEND

EXISTING CONTOUR
EDGE OF ROAD
EDGE OF WATER
TREELINE
EXPOSED LEDGE
FEMA 100-YR FLOODPLAIN
EXISTING LIGHT POLE
EXISTING TREE (SIZE VARIES)

GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE
BRONX ZOO DAM
FISH PASSAGE AND SITE IMPROVEMENTS

DRAWING TITLE
RESTORATION PLAN

DESIGNED BY EU/AG	DRAWN BY BAM	CHECKED BY JGM/MRGSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. CONTRACT NUMBER
B-SCAN	SCALE 1"=10' / DATE	DRAWING NO. 14

SHEET NO. 14 OF 17 SHEETS

PROJECT DESCRIPTION

THE BRONX RIVER OFFERS A UNIQUE OPPORTUNITY TO PROVIDE IMPROVED AQUATIC HABITAT WITH DIADROMOUS FISH PASSAGE IN AN URBAN SETTING. THE GOAL IS TO RESTORE THE BRONX RIVER BY MAKING UPSTREAM HABITAT ACCESSIBLE TO RIVER HERRING. SPECIFICALLY CONSTRUCTING A FISHWAY WITHIN THE NATURAL BEDROCK ABUTMENT ALONG THE WESTERN PORTION OF THE SPILLWAY. THE APPEARANCE OF SUCH A STRUCTURE IS TO BE CONSISTENT WITH THE NATURAL AND BUILT FEATURES OD THE ADJACENT LANDSCAPE.

SITE DESCRIPTION

THE PROJECT SITE IS LOCATED DOWNSTREAM OF NY ROUTE 1 (EAST FORDHAM ROAD) AT WHICH POINT THE BRONX RIVER BECOME BRAIDED. A NATURAL WATERFALL OCCURS AT THE SITE TO BOTH SIDES OF A VEGETATED CENTER BAR. THE NATURALLY OCCURRING BEDROCK CREATES THESE FALLS AND BECOME AN IMPASSABLE POINT FOR FISH MIGRATION.

PROPOSED IMPROVEMENTS

THE WEST BANK COMPOSED OF BEDROCK IS THE SELECTED LOCATION OR INCORPORATE A FISH PASSAGE STRUCTURE FOR ACCESS FURTHER UPSTREAM. THE STRUCTURE WOULD BE LOCATED BELOW CURRENT GRADE TO MINIMIZE ITS APPEARANCE AND MAINTAIN A NATURAL LANDSCAPE CONSISTENT WITH THE CURRENT CONDITIONS OF THE SITE.

PLANNED EROSION AND SEDIMENT CONTROL PRACTICES

1. RIVER ACCESS ROADS WITH STABILIZED CONSTRUCTION ENTRANCES WILL BE CONSTRUCTED OFF OF THE PEDESTRIAN WALKING PATH BRANCHING OFF TOWARDS BRONX RIVER.
2. CONSTRUCTION ROAD STABILIZATION: THE CONSTRUCTION ACCESS ROADS WILL BE CONSTRUCTED AFTER THE REMOVAL OF TOPSOIL AND WILL BE SLOPED TOWARDS THE RIVER AND THE ROW OF SILT FENCE.
3. SILT FENCE WILL BE INSTALLED ALONG THE CONSTRUCTION ACCESS ROAD AND AROUND ANY STOCKPILE AREAS.
4. SUMP PIT: A SUMP PIT WILL BE UTILIZED TO DEWATER THE WORK AREA IF GROUNDWATER IS ENCOUNTERED.
5. SURFACE STABILIZATION: STABILIZATION OF THE SURFACE WILL BE ACCOMPLISHED WITH VEGETATION AS SPECIFIED ON THE SITE PLAN.

EROSION CONTROL NOTES

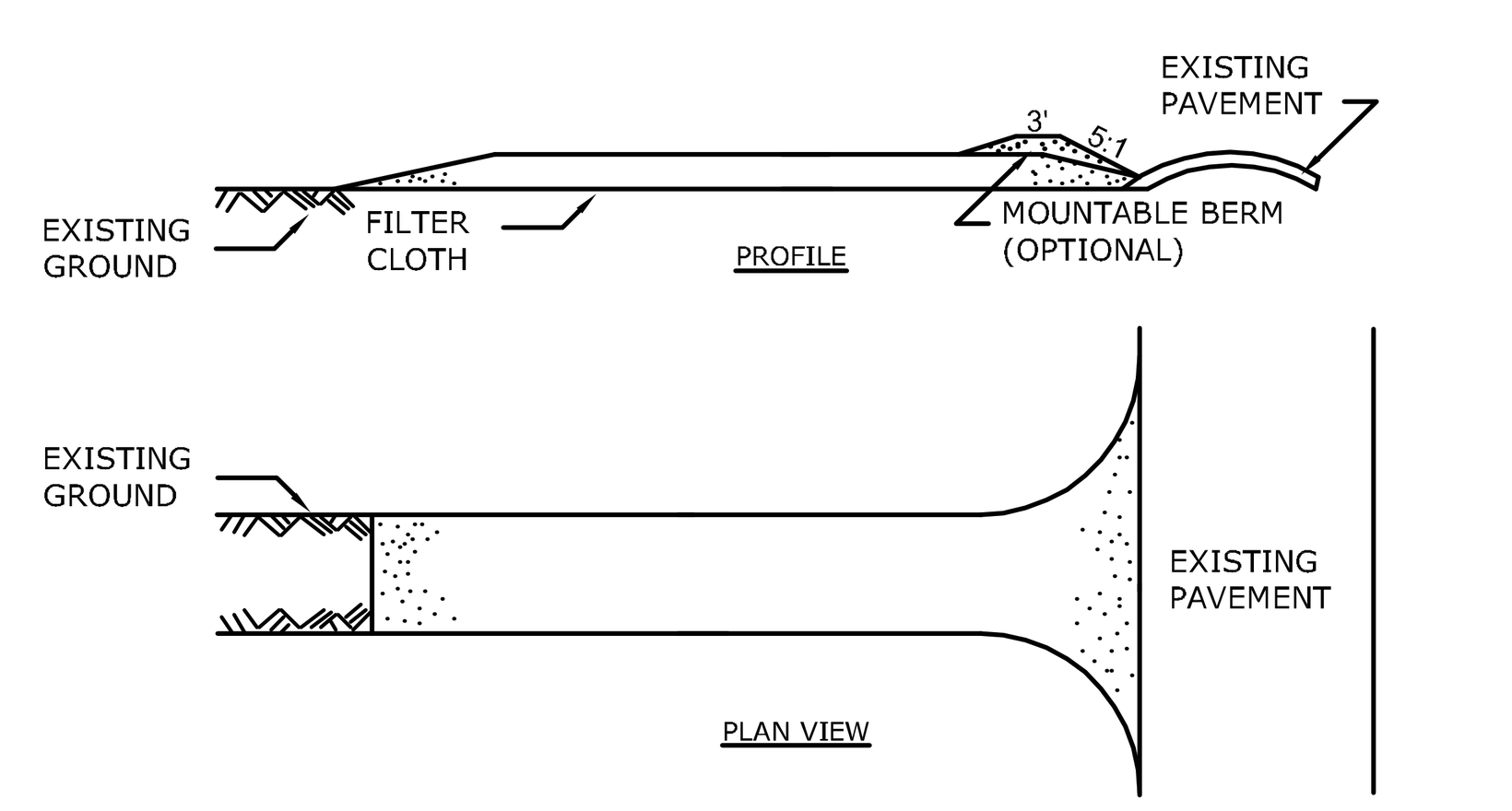
1. ALL VEGETATIVE AND STRUCTURAL EROSION AND SEDIMENT CONTROL PRACTICES WILL BE CONSTRUCTED IN ACCORDANCE WITH THE "NEW YORK STATE STANDARDS AND SPECIFICATIONS FOR EROSION AND SEDIMENT CONTROL."
2. A COPY OF THE APPROVED EROSION AND SEDIMENT CONTROL PLAN SHALL BE MAINTAINED ON THE SITE AT ALL TIMES.
3. ALL WETLANDS SHALL BE AVOIDED AND PROTECTED FROM CONSTRUCTION ACTIVITIES WITH SEDIMENT CONTROL MEASURES WHERE NECESSARY AS DETERMINED BY THE PROJECT ENGINEER.
4. CLEARING OF NATIVE VEGETATION FOR CONSTRUCTION ACCESS SHOULD BE MINIMIZED.
5. TEMPORARY ACCESS AREAS SHALL BE BORDERED WITH SILT FENCE. SEE PLANS AND DETAILS.
6. STOCKPILE AREAS TO BE ENCLOSED BY SILT FENCE.
7. AN EROSION CONTROL BLANKET SHALL BE PLACED OVER ANY DISTURBED AREAS WITH A SLOPE GREATER THAN OR EQUAL TO 3:1 TO PREVENT EROSION.
8. THE CONTRACTOR IS RESPONSIBLE FOR THE MAINTENANCE OF ALL SOIL EROSION AND SEDIMENT CONTROL MEASURES. THE CONSTRUCTION INSPECTOR WILL VERIFY THE MAINTENANCE WEEKLY AND AFTER RAIN EVENTS.
9. THE FINAL LOCATION OF THE TEMPORARY HAUL ROADS SHALL BE DETERMINED PRIOR TO CONSTRUCTION. THE HAUL ROAD SHALL BE CONSTRUCTED WITH PROPER EROSION CONTROLS, INCLUDING SILT FENCE WHERE NECESSARY, AND A STABILIZED CONSTRUCTION ENTRANCE. RESTORATION OF THE DISTURBED AREA SHALL BE COORDINATED WITH THE PROPERTY OWNER.
10. TEMPORARY SEED SHALL BE NEW ENGLAND EROSION CONTROL/RESTORATION MIX FOR DRY SITES, APPLIED AT THE RATE OF 35LBS PER ACRE.

STOCK PILING NOTES

1. TEMPORARY STOCKPILE AND STAGING AREAS TO BE FLAGGED BY CONTRACTOR PRIOR TO CONSTRUCTION AND APPROVED BY THE NEW YORK CITY DEPARTMENT OF PARKS AND RECREATION AND THE PROJECT ENGINEER.
2. NO CONSTRUCTION VEHICLES SHALL BE STORED, SERVICED, WASHED OR FLUSHED IN A LOCATION WHERE LEAKS, SPILLAGE, WASTE MATERIALS, CLEANERS, OR WATERS WILL BE INTRODUCED OR FLOW INTO WETLANDS OR WATERCOURSES. AN EMERGENCY MANAGEMENT PLAN AND SPILL KIT WILL BE MAINTAINED ON SITE AT ALL TIMES. IN THE EVENT OF AN ACCIDENTAL RELEASE, IMMEDIATELY STOP CONSTRUCTION WORK, CONTAIN THE SPILL, AND NOTIFY THE CITY, APPROPRIATE AUTHORITIES AND PROJECT ENGINEER.
3. THE CONTRACTOR SHALL MAINTAIN ALL STREETS, SIDEWALKS, AND WALKWAYS IN THE AREA FREE OF SOIL, MUD AND CONSTRUCTION DEBRIS. CONSTRUCTION ENTRANCES MUST BE MAINTAINED AT EACH ACCESS POINT. SEE PLANS AND DETAILS.
4. THE PROJECT SITE IS SUBJECT TO FLOODING. THE CONTRACTOR SHALL MONITOR WEATHER FORECASTS AND STABILIZE THE CONSTRUCTION SITE AND REMOVE EQUIPMENT FROM FLOOD PRONE AREAS IN THE EVENT OF FLOOD WARNINGS. WORK SHOULD BE PERFORMED DURING LOW WATER.
5. ALL STORAGE AND ACCESS ROUTES, PEDESTRIAN FENCES/BARRIERS, WORKING HOURS, AND LIMITS OF CLEARING SHALL BE APPROVED BY THE NEW YORK CITY DEPARTMENT OF PARKS AND RECREATION, LANDOWNERS AND THE PROJECT ENGINEER.

EROSION CONTROL MAINTENANCE INTERVALS

EROSION CONTROL MEASURE	CONTROL OBJECTIVE	INSPECTION/MAINTENANCE	FAILURE INDICATORS	REMOVAL
SILT FENCE	- INTERCEPT, AND REDIRECT/DETAIN SMALL AMOUNTS OF SEDIMENT FROM SMALL DISTURBED AREAS. - DECREASE VELOCITY OF SHEET FLOW. - PROTECT SENSITIVE SLOPES OR SOILS FROM EXCESSIVE WATER FLOW.	INSPECT AT LEAST ONCE A WEEK AND WITHIN 24 HOURS OF THE END OF A STORM WITH A RAINFALL OF 0.5 INCHES OR MORE. ACCUMULATED SEDIMENT MUST BE REMOVED ONCE ITS DEPTH IS EQUAL TO ½ THE TRENCH HEIGHT. INSPECT FREQUENTLY DURING PUMPING OPERATIONS IF USED FOR DEWATERING OPERATIONS.	- PHYSICAL DAMAGE OR DECOMPOSITION - EVIDENCE OF OVERTOPPED OR UNDERCUT FENCE - EVIDENCE OF SIGNIFICANT FLOWS EVADING CAPTURE - REPETITIVE FAILURE	SILT FENCE MAY BE REMOVED AFTER UPHILL AND SENSITIVE AREAS HAVE BEEN PERMANENTLY STABILIZED.
STABILIZED CONSTRUCTION ENTRANCE	- REDUCE THE TRACKING OF SEDIMENT OFF-SITE ONTO PAVED SURFACES.	INSPECT AT THE END OF EACH WORK DAY AND IMMEDIATELY REPAIR DAMAGES. PERIODIC ADDITION OF STONE, OR LENGTHENING OF ENTRANCE MAY BE REQUIRED AS CONDITIONS DEMAND. ALL SEDIMENT SPILLED, DROPPED, WASHED, OR TRACKED ONTO PAVED SURFACES AS A RESULT OF INEFFICIENCY OF CONSTRUCTION ENTRANCE SHALL BE IMMEDIATELY REMOVED.	- SEDIMENT IN ROADWAY ADJACENT TO SITE	CONSTRUCTION ENTRANCE MAY BE REMOVED ONCE THE SITE HAS BEEN PERMANENTLY STABILIZED, AND ALL OTHER SECTIONS OF ROADWAY HAVE BEEN PERMANENTLY PAVED.



1/15 STABILIZED CONSTRUCTION ENTRANCE

NOT TO SCALE

CONSTRUCTION SPECIFICATIONS

1. STONE SIZE - USE 2" STONE, OR RECLAIMED OR RECYCLED CONCRETE EQUIVALENT.

2. LENGTH - NOT LESS THAN 50 FEET (EXCEPT ON A SINGLE RESIDENCE LOT WHERE A 30 FOOT MINIMUM LENGTH WOULD APPLY).

3. THICKNESS - NOT LESS THAN SIX (6) INCHES.

4. WIDTH - TWELVE (12) FOOT MINIMUM, BUT NOT LESS THAN THE FULL WIDTH AT POINTS WHERE INGRESS OR EGRESS OCCURS. TWENTY-FOUR (24) FOOT IF SINGLE ENTRANCE TO SITE.

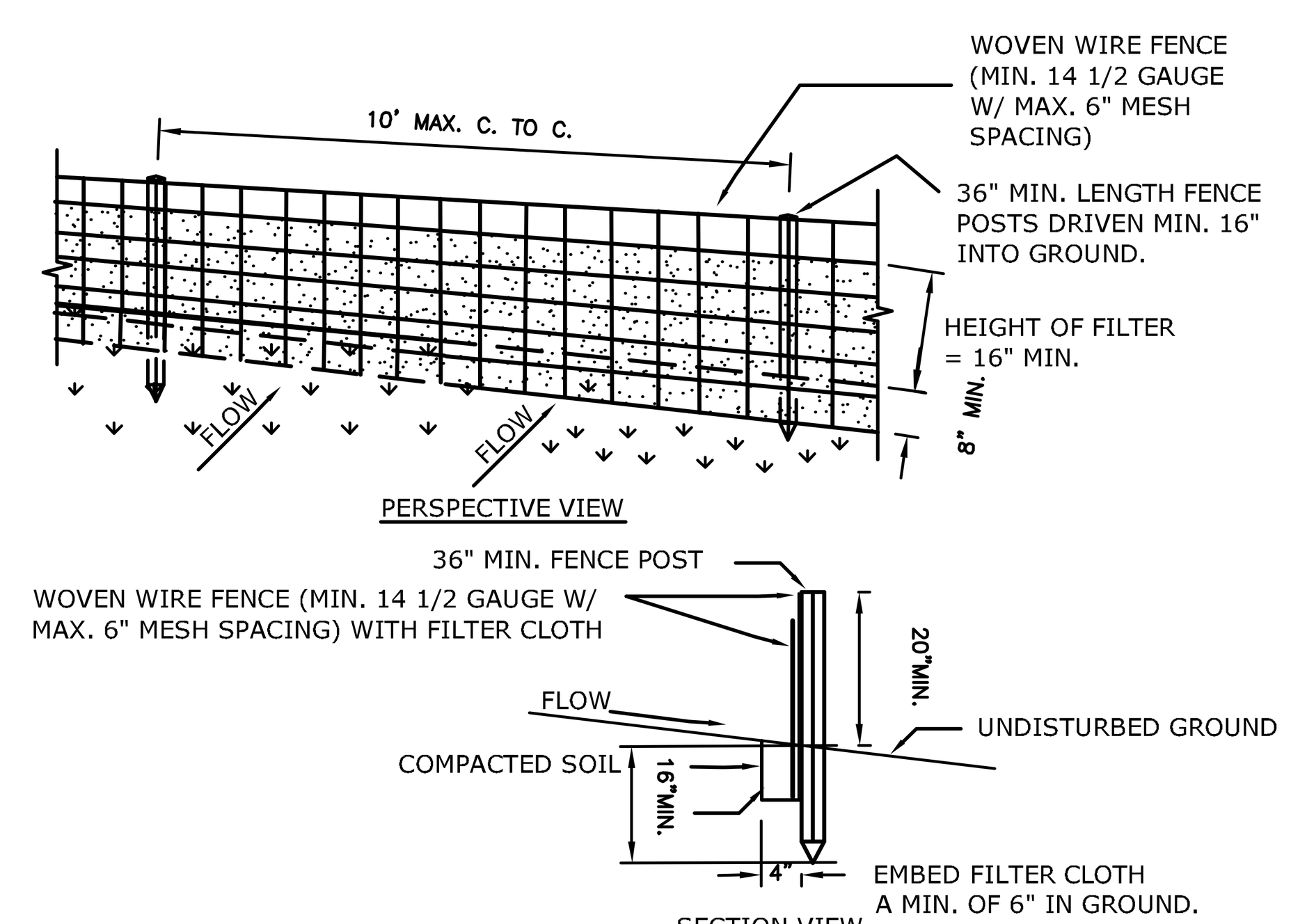
5. FILTER CLOTH - WILL BE PLACED OVER THE ENTIRE AREA PRIOR TO PLACING OF STONE.

6. SURFACE WATER - ALL SURFACE WATER FLOWING OR DIVERTED TOWARD CONSTRUCTION ENTRANCES SHALL BE PIPED ACROSS THE ENTRANCE. IF PIPING IS IMPRACTICAL, A MOUNTABLE BERM WITH 5:1 SLOPES WILL BE PERMITTED.

7. MAINTENANCE - THE ENTRANCE SHALL BE MAINTAINED IN A CONDITION WHICH WILL PREVENT TRACKING OR FLOWING OF SEDIMENT ONTO PUBLIC RIGHTS-OF-WAY, ALL SEDIMENT SPILLED, DROPPED, WASHED OR TRACTED ONTO PUBLIC RIGHTS-OF-WAY MUST BE REMOVED IMMEDIATELY.

8. WHEN WASHING IS REQUIRED, IT SHALL BE DONE ON A AREA STABILIZED WITH STONE AND WHICH DRAINS INTO AN APPROVED SEDIMENT TRAPPING DEVICE.

9. PERIODIC INSPECTION AND NEEDED MAINTENANCE SHALL BE PROVIDED AFTER EACH RAIN.



2/15 SILT FENCE

NOT TO SCALE

CONSTRUCTION SPECIFICATIONS

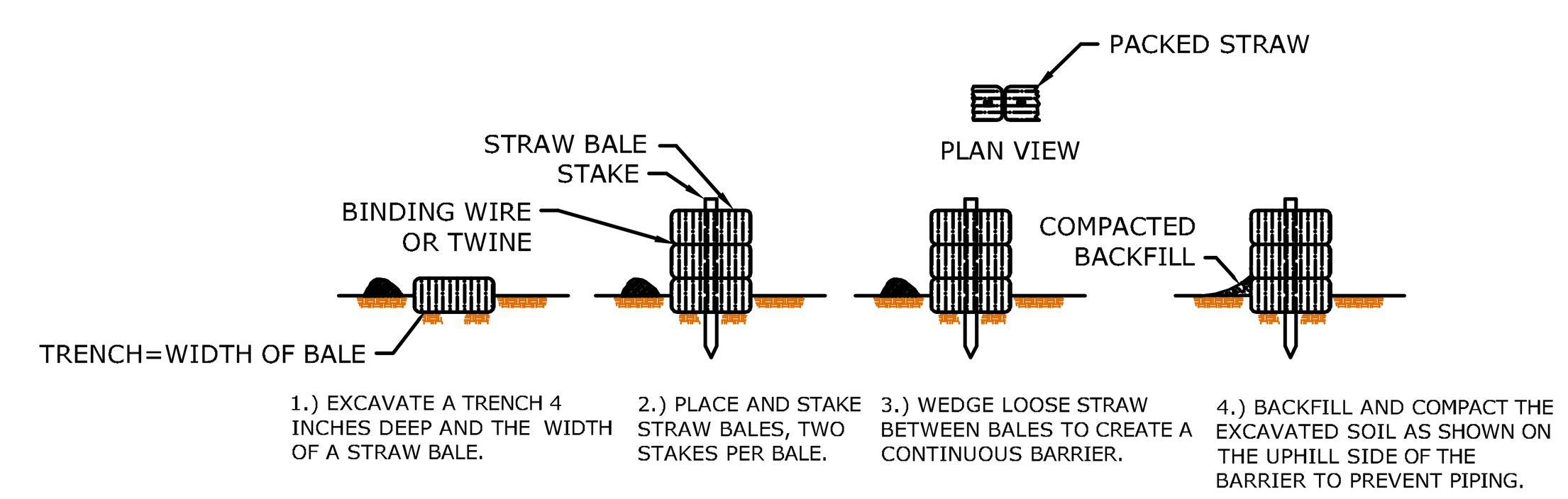
1. WOVEN WIRE FENCE TO BE FASTENED SECURELY TO FENCE POSTS WITH WIRE TIES OR STAPLES. POSTS SHALL BE STEEL EITHER "T" OR "U" TYPE OR HARDWOOD.

2. FILTER CLOTH TO BE TO BE FASTENED SECURELY TO WOVEN WIRE FENCE WITH TIES SPACED EVERY 24" AT TOP AND MID SECTION. FENCE SHALL BE WOVEN WIRE, 12 1/2 GAUGE, 6" MAXIMUM MESH OPENING.

3. WHEN TWO SECTIONS OF FILTER CLOTH ADJOIN EACH OTHER THEY SHALL BE OVER- LAPPED BY SIX INCHES AND FOLDED. FILTER CLOTH SHALL BE EITHER FILTER X, MIRAFI 100X, STABILINKA T140N, OR APPROVED EQUIVALENT.

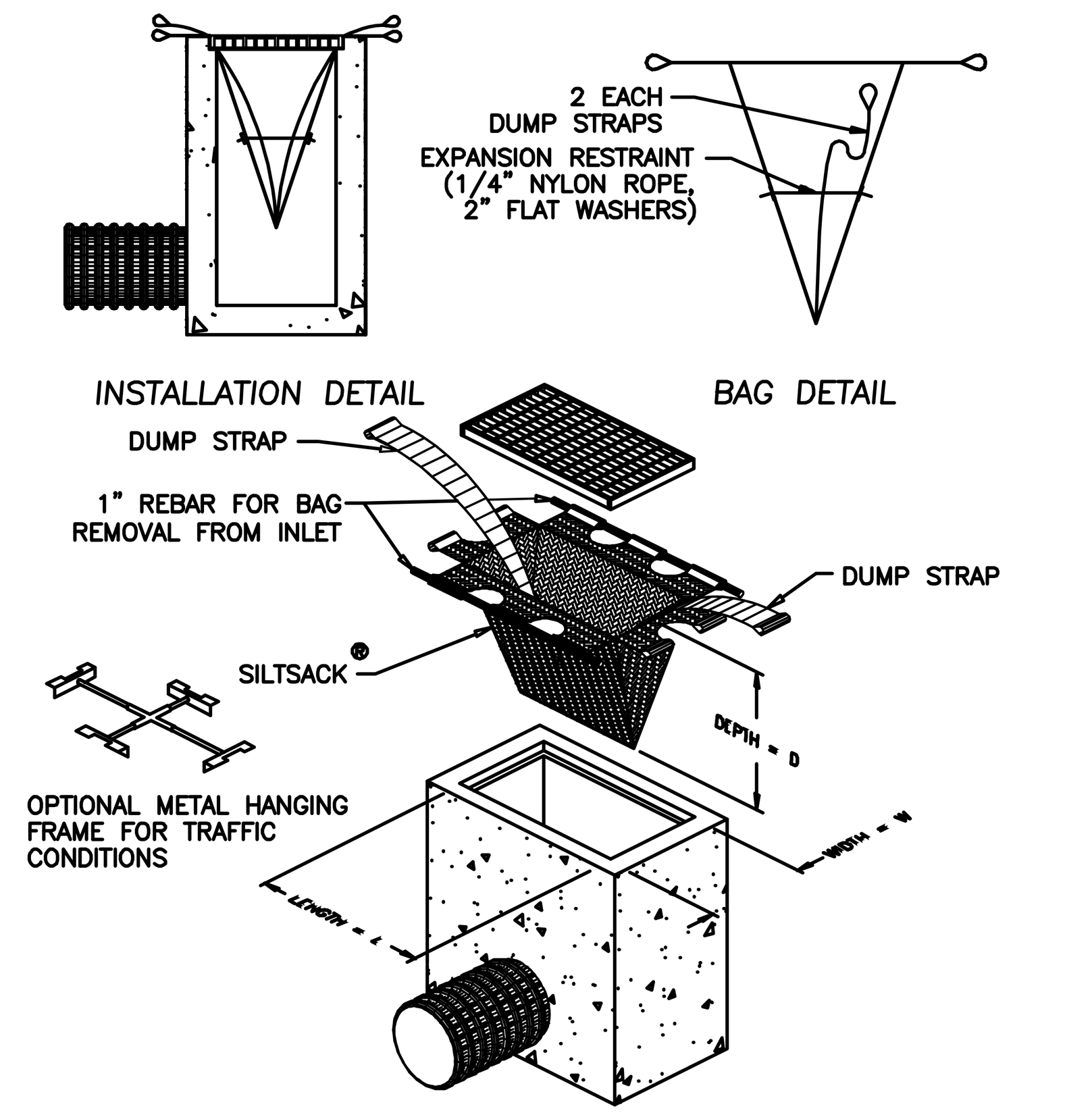
4. PREFABRICATED UNITS SHALL BE GEOFAB, ENVIROFENCE, OR APPROVED EQUIVALENT.

5. MAINTENANCE SHALL BE PERFORMED AS NEEDED AND MATERIAL REMOVED WHEN "BULGES" DEVELOP IN THE SILT FENCE.



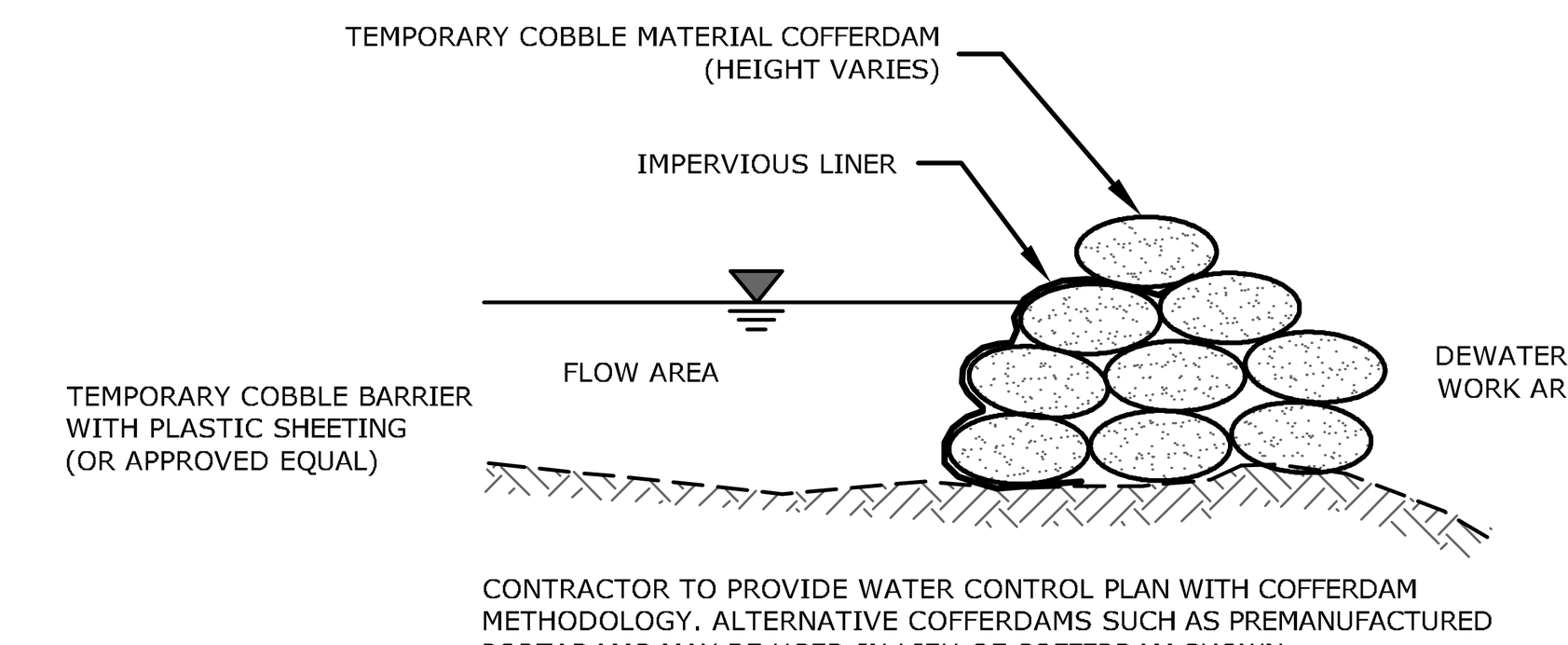
3/15 PLACEMENT AND CONSTRUCTION OF A STRAW BALE SILT CONTROL

NOT TO SCALE



4/15 INLET PROTECTION DETAIL

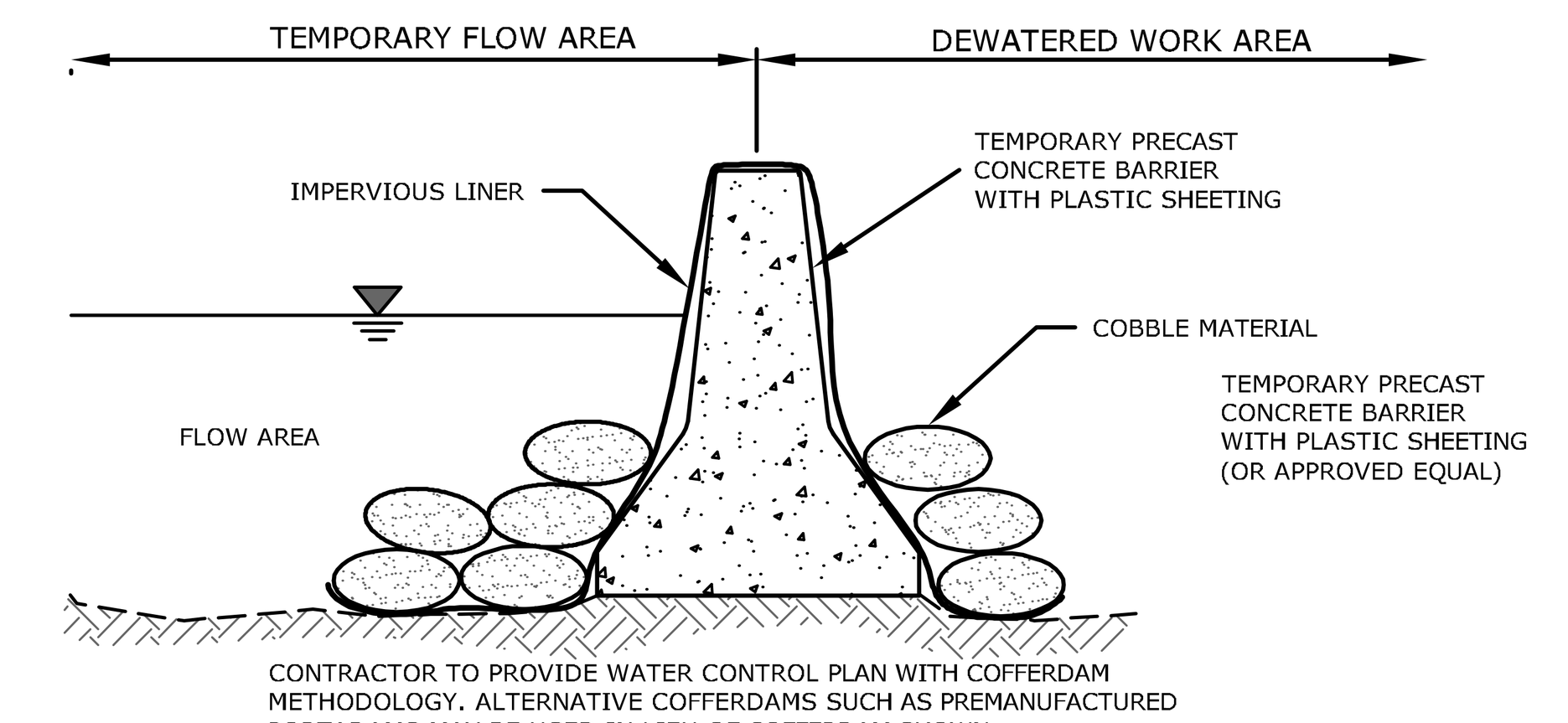
N.T.S.



CONTRACTOR TO PROVIDE WATER CONTROL PLAN WITH COFFERDAM METHODOLOGY. ALTERNATIVE COFFERDAMS SUCH AS PREMANUFACTURED PORTADAMS MAY BE USED IN LIEU OF COFFERDAM SHOWN.

8/15 TEMPORARY COFFERDAM DETAIL

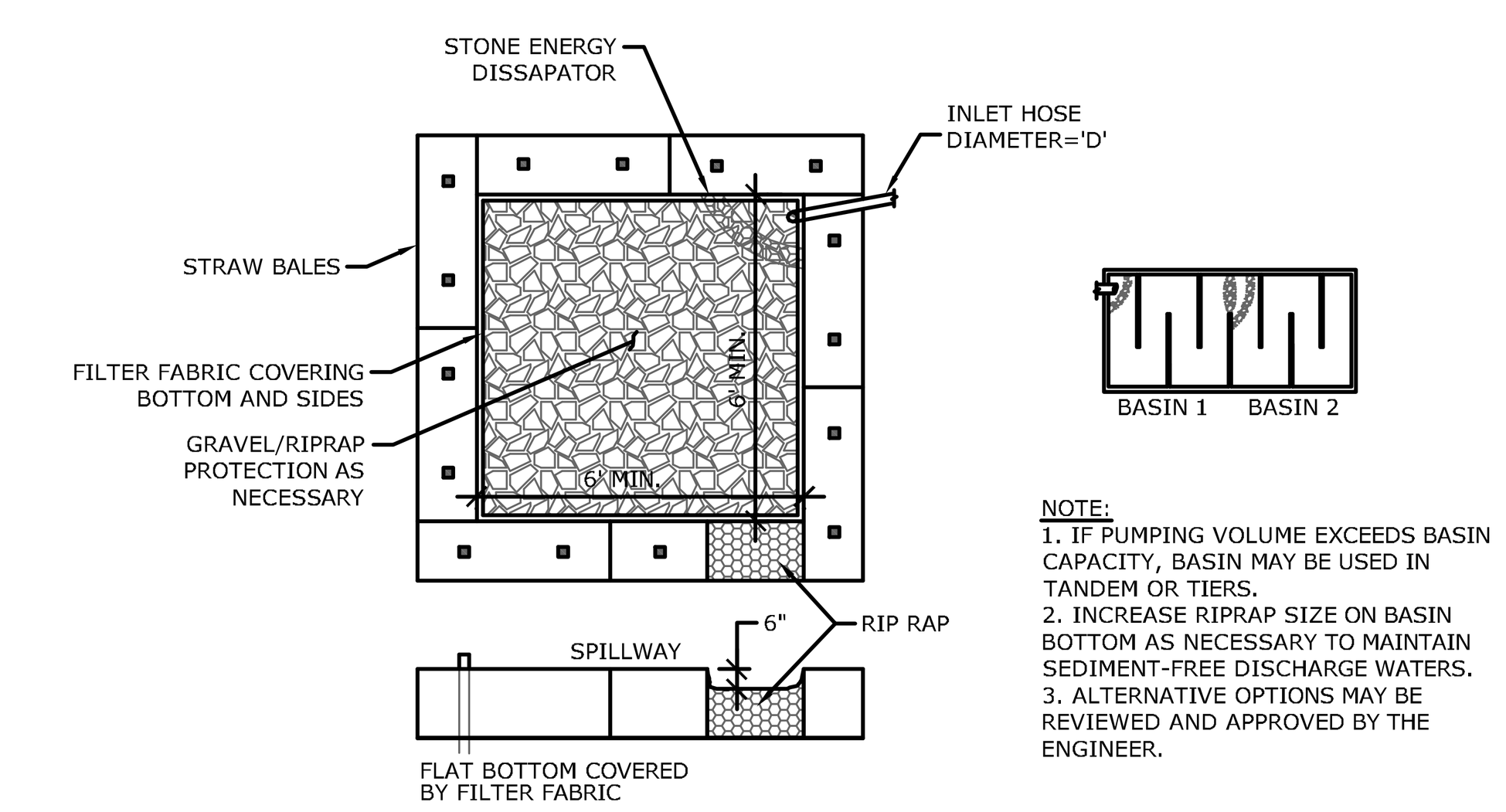
N.T.S.



CONTRACTOR TO PROVIDE WATER CONTROL PLAN WITH COFFERDAM METHODOLOGY. ALTERNATIVE COFFERDAMS SUCH AS PREMANUFACTURED PORTADAMS MAY BE USED IN LIEU OF COFFERDAM SHOWN.

9/15 TEMPORARY CONCRETE BARRIER COFFERDAM DETAIL

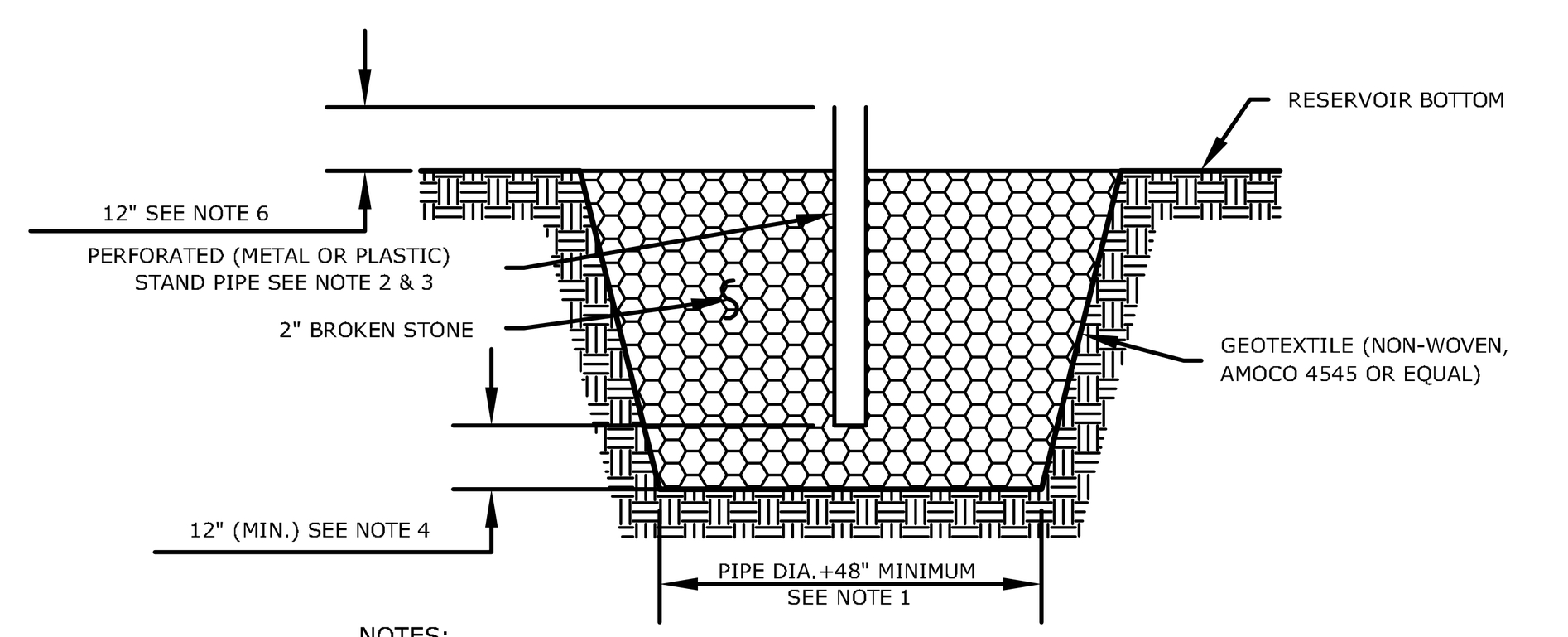
N.T.S.



NOTE:
1. IF PUMPING VOLUME EXCEEDS BASIN CAPACITY, BASIN MAY BE USED IN TANDEM OR TIERS.
2. INCREASE RIPRAP SIZE ON BASIN BOTTOM AS NECESSARY TO MAINTAIN SEDIMENT-FREE DISCHARGE WATERS.
3. ALTERNATIVE OPTIONS MAY BE REVIEWED AND APPROVED BY THE ENGINEER.

10/15 DEWATERING BASIN

N.T.S.

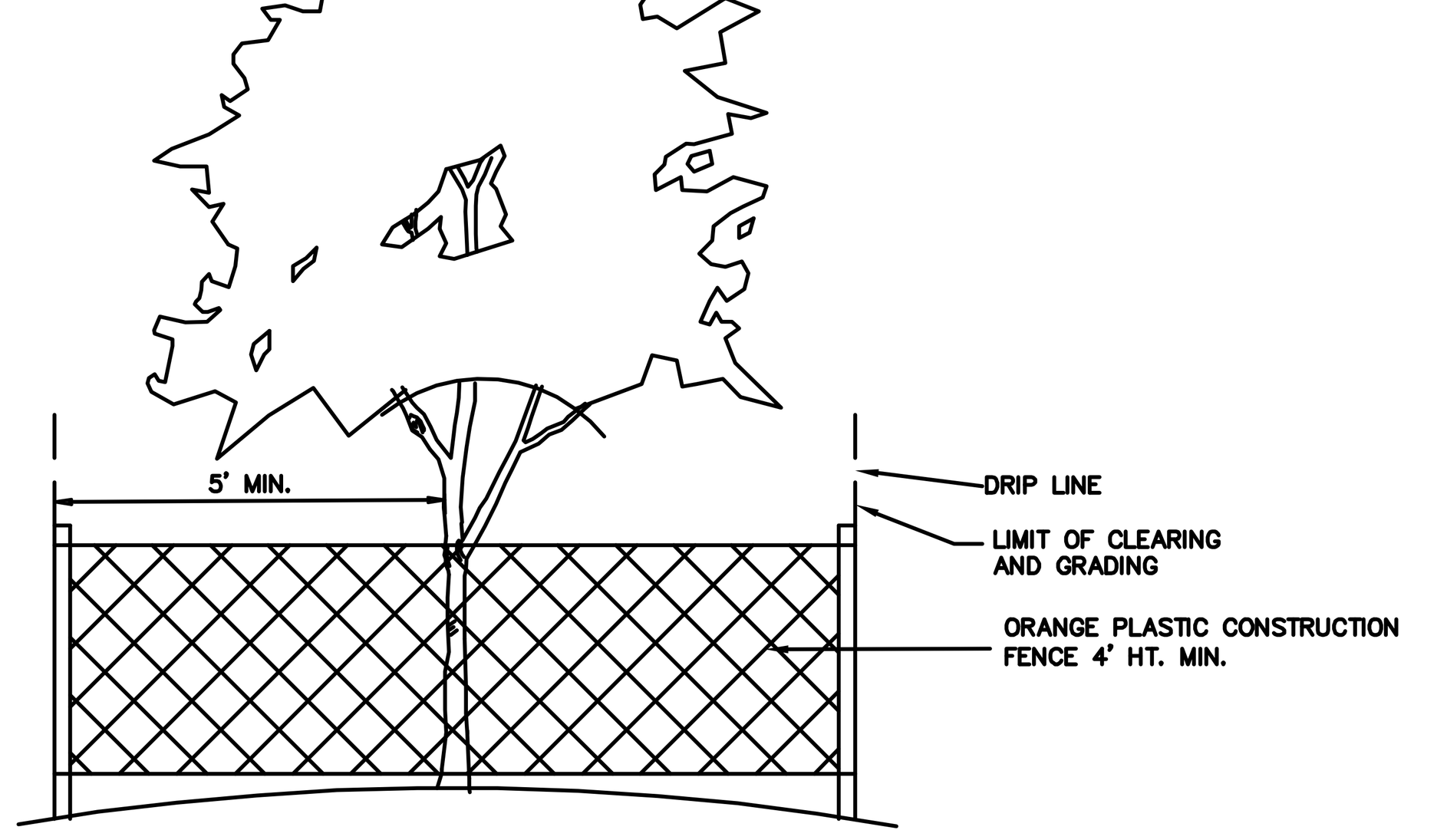


NOTES:

1. OVERALL SUMP PIT DIMENSIONS TO BE COMPATIBLE WITH ANTICIPATED SEEPAGE RATES AND PUMP TO BE USED.
2. THE STAND PIPE DIAMETER AND NUMBER OF PERFORATIONS TO BE COMPATIBLE WITH THE PUMP SIZE BEING USED.
3. PERFORATIONS IN THE STANDPIPE TO BE EITHER CIRCULAR OR SLOTS, PERFORATION SIZE SHALL NOT EXCEED 1/2" DIAMETER.
4. 2" BROKEN STONE SHALL EXTEND A MINIMUM OF 12" BELOW THE BOTTOM OF THE STANDPIPE.
5. A PROPERLY DESIGNED GEOTEXTILE TO BE PLACED BETWEEN THE EXISTING SOILS AND THE CRUSHED STONE BACKFILL.
6. THE STANDPIPE SHALL EXTEND A MINIMUM OF 12" ABOVE THE SURROUNDING GROUND.

11/15 TEMPORARY DEWATERING SUMP

N.T.S.

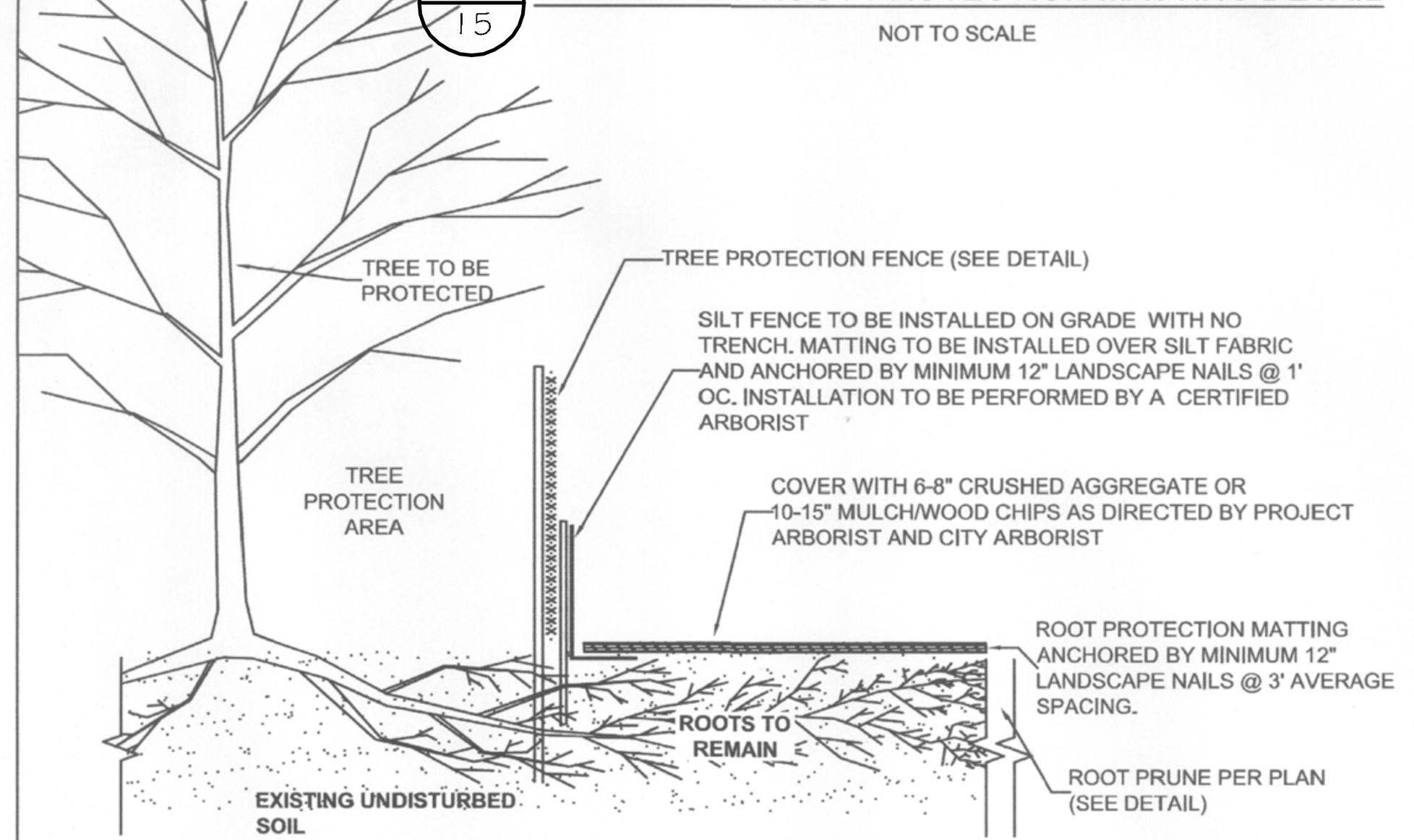


5/15 TREE PROTECTION DETAIL

N.T.S.

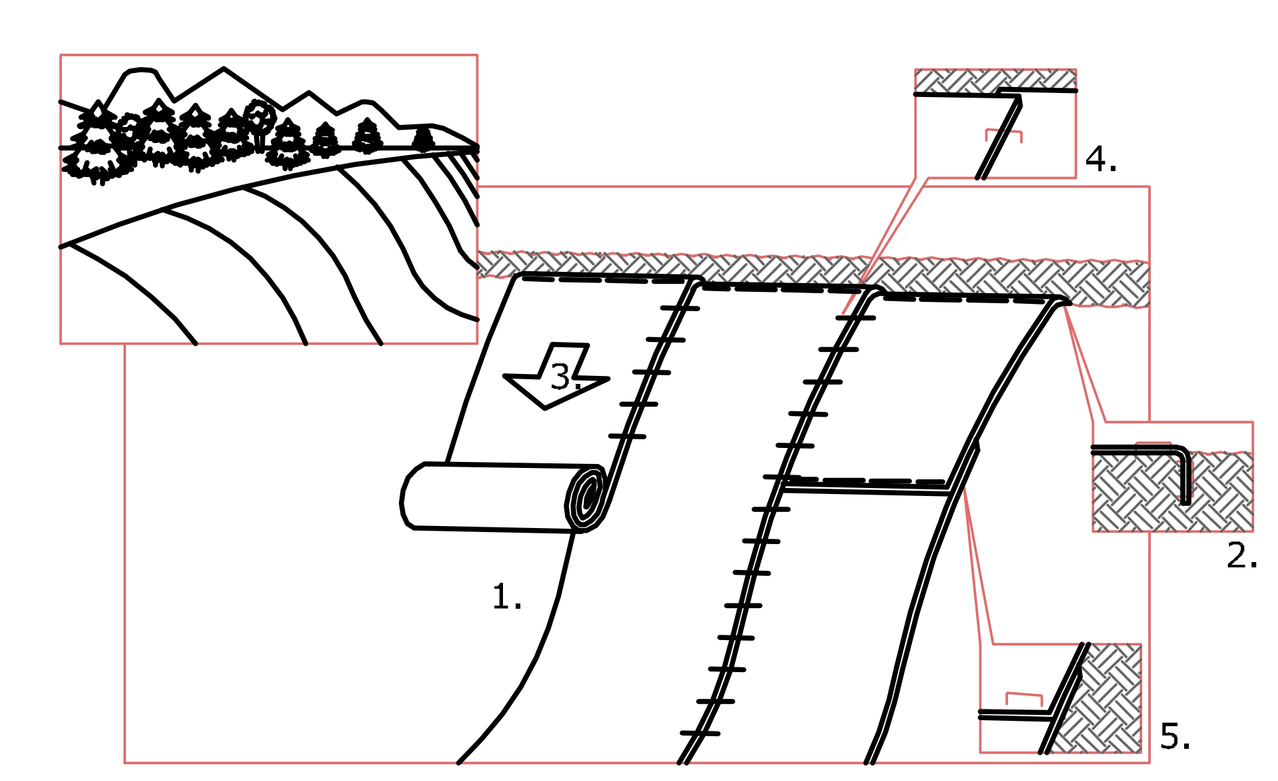
6/15 TEMPORARY ROOT PROTECTION MATTING DETAIL

NOT TO SCALE



NOTES:
1. MATTING MATERIAL SHALL BE DOUBLE SIDED GEOCOMPOSITE, GEONET CORE WITH NON–WOVEN COVERING (SUCH AS TENAX TENDRAIN 750/2) OR APPROVED EQUIVALENT.
2. RPM SHALL BE INSTALLED BY A CERTIFIED ARBORIST EXPERIENCED IN RPM INSTALLATION.
3. RPM SHALL BE REMOVED PROMPTLY AFTER CONSTRUCTION. REMOVAL OPERATIONS SHALL NOT DAMAGE TREES TO REMAIN OR COMPACT SOILS PROTECTED BY THE RPM. EQUIPMENT USED TO REMOVE RPM SHALL NOT TRAVEL OR WORK ON UNPROTECTED SOILS.

REV. 07/17/08

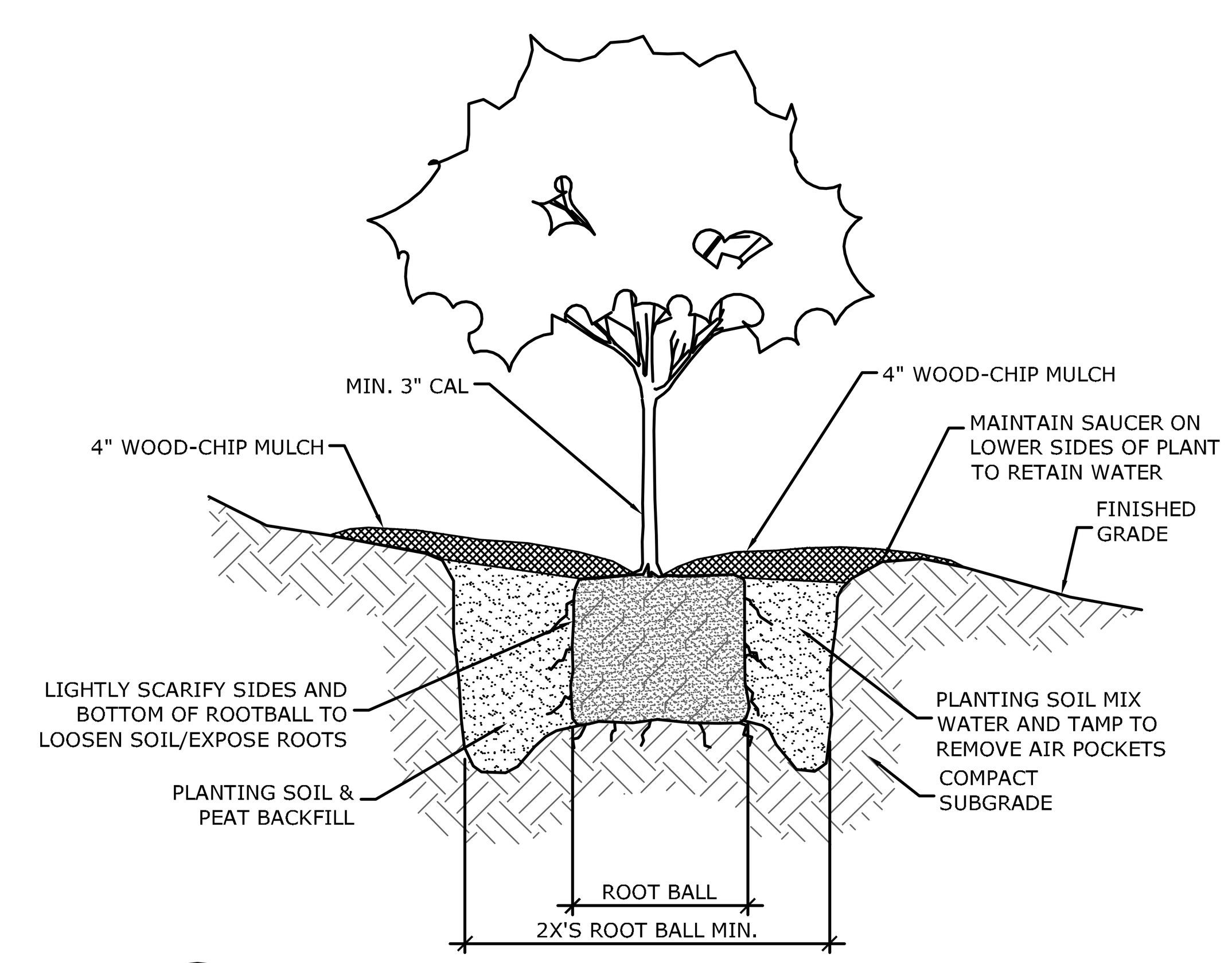


1. PREPARE SOIL BEFORE INSTALLING BLANKETS, INCLUDING APPLICATION OF LIME, FERTILIZER, AND SEED. NOTE: WHEN USING S150, DO NOT SEED PREPARED AREA. S150 MUST BE INSTALLED WITH PAPER SIDE DOWN.
2. BEGIN AT THE TOP OF THE SLOPE BY ANCHORING THE BLANKET IN A 6" DEEP BY 6" WIDE TRENCH. BACKFILL AND COMPACT THE TRENCH AFTER STAPLING.
3. ROLL THE BLANKETS DOWN THE SLOPE IN THE DIRECTION OF THE WATER FLOW.
4. THE EDGES OF PARALLEL BLANKETS MUST BE STAPLED WITH APPROXIMATELY 2" OVERLAP.
5. WHEN BLANKETS MUST BE SPLICED DOWN THE SLOPE, PLACE BLANKETS END OVER END (SHINGLE STYLE) WITH APPROXIMATELY 6" OVERLAP. STAPLE THROUGH OVERLAP AREA, APPROXIMATELY 12" APART.

REFER TO GENERAL STAPLE PATTERN GUIDE IN NORTH AMERICAN GREEN CATALOG FOR CORRECT STAPLE PATTERN RECOMMENDATIONS FOR SLOPE INSTALLATIONS.

7/15 APPLICATION OF EROSION CONTROL BLANKET ON SLOPES

NOT TO SCALE



12/15 POTTED TREE/SHRUB PLANTING DETAIL

NOT TO SCALE

NOTE MULCHING OF PLANT BEDS:
UNLESS OTHERWISE DIRECTED SHREDDED MULCH SHALL BE PLACED TO A LIMIT OF ONE FOOT BEYOND THE CENTER OF THE OUTERMOST SHRUBS IN SHRUB BED.

TRUE NORTH
BRONX NORTH

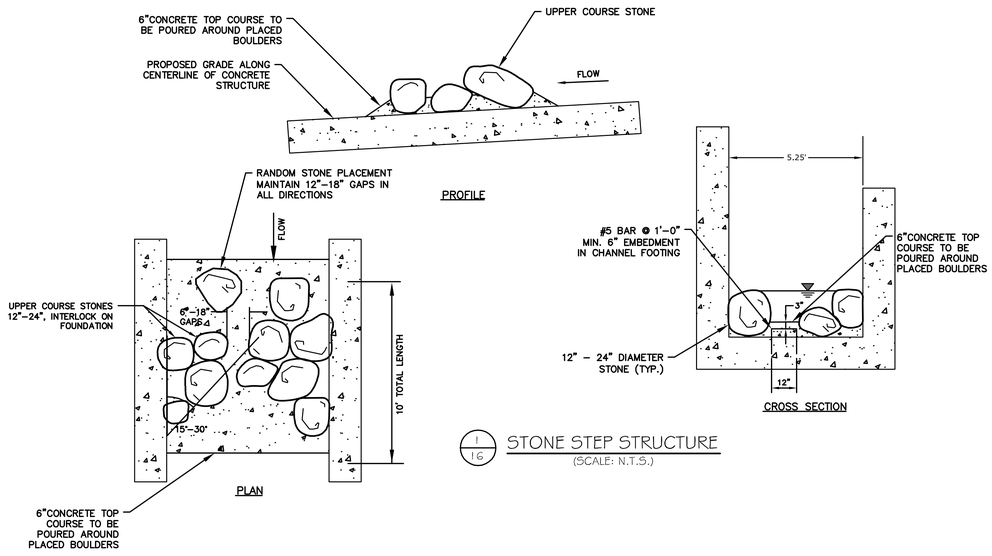
MILONE & MACBROOM®
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

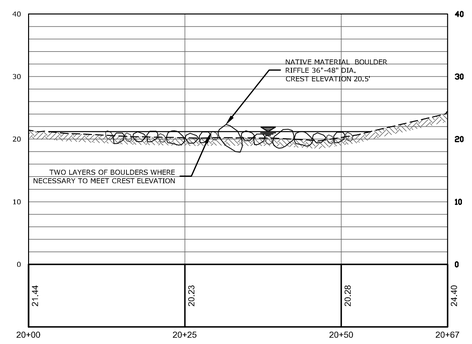
PROJECT TITLE: BRONX ZOO DAM FISH PASSAGE AND SITE IMPROVEMENTS

DRAWING TITLE: SEDIMENT AND EROSION CONTROL NOTES AND DETAILS

DESIGNED BY: EL/AG	DRAWN BY: BAM	CHECKED BY: JGM/NRG/SK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. CONTRACT NUMBER
B-SCAN	SCALE / DATE / DRAWING NO. 15	SHEET NO. 15 OF 17 SHEETS



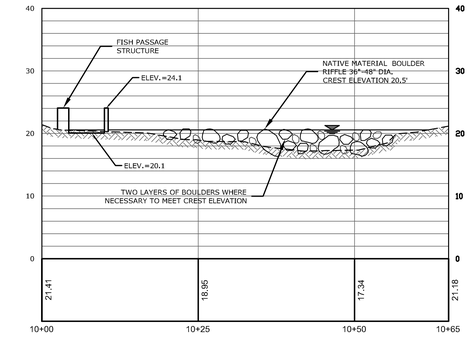
1/16 STONE STEP STRUCTURE
(SCALE: N.T.S.)



ELEVATION VIEW

4/16 BOUNDARY DIVERSION WEIR (EAST)
SCALE: 1"=10'

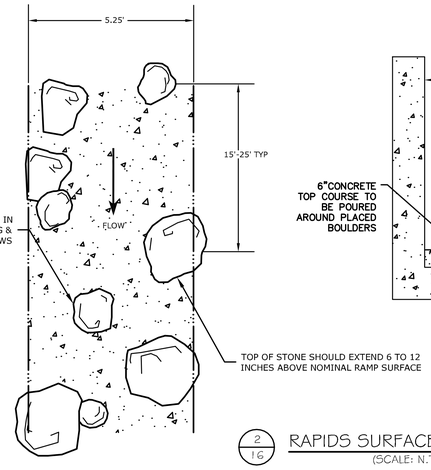
1) WHERE POSSIBLE ON SITE BOULDERS SHOULD BE USED FROM BLASTING OF FISH PASSAGE STRUCTURE.
2) TWO LAYERS OF ROCK OR MORE MAY BE NECESSARY IN THE CHANNEL TO REACH THE REQUIRED CREST ELEVATION.

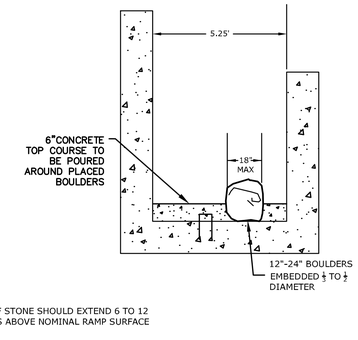


ELEVATION VIEW

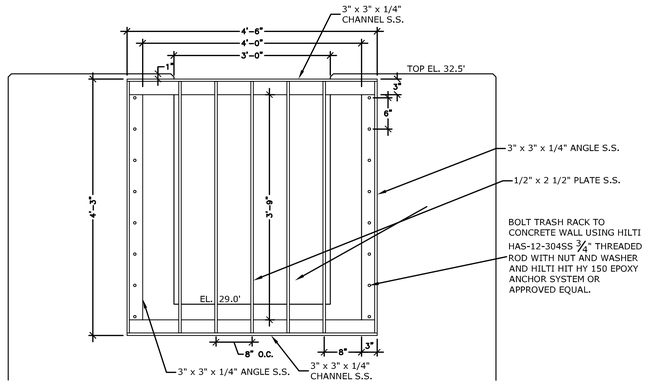
5/16 BOULDER DIVERSION WEIR (WEST)
SCALE: 1"=10'

1) WHERE POSSIBLE ON SITE BOULDERS SHOULD BE USED FROM BLASTING OF FISH PASSAGE STRUCTURE.
2) TWO LAYER OF ROCK OR MORE MAY BE NECESSARY IN THE CHANNEL TO REACH THE REQUIRED CREST ELEVATION.

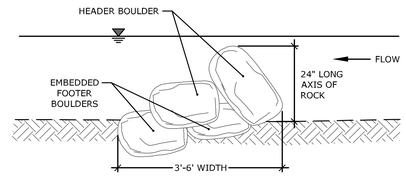




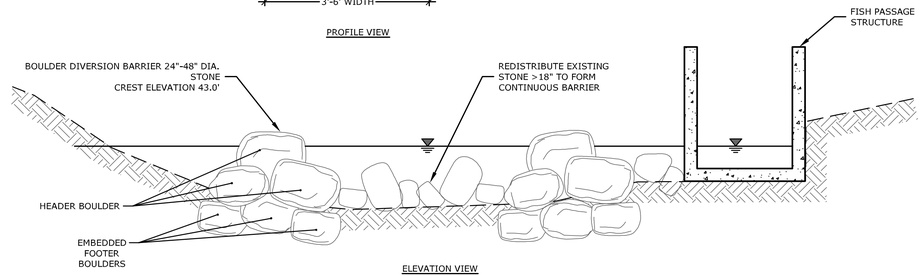
2/16 RAPIDS SURFACE BOULDERS
(SCALE: N.T.S.)



3/16 TRASH RACK DETAIL AT FISHWAY EXIT
N.T.S.



PROFILE VIEW

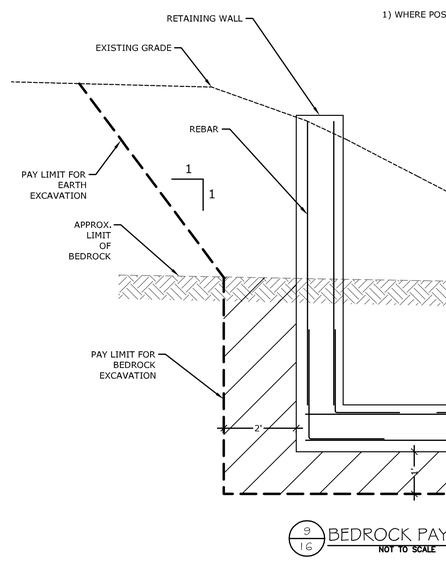


ELEVATION VIEW

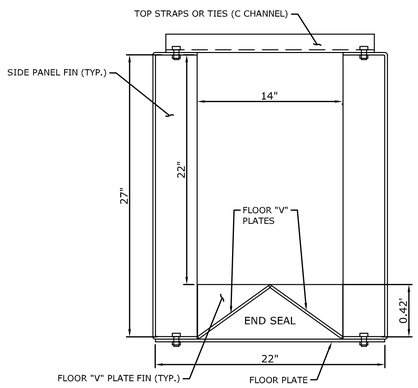
6/16 BOULDER DIVERSION WEIR
NOT TO SCALE

1) WHERE POSSIBLE ON SITE BOULDERS SHOULD BE USED FROM BLASTING OF FISH PASSAGE STRUCTURE.

NOTES:
1 USE 12" TO 24" INCH DIAMETER ROUNDED BOULDERS.
2. PLACE BOULDERS IN EACH OF THE FIVE SECTIONS OF THE RAMP. POSITION BOULDERS WITH THE LONG AXIS OF EACH BOULDER PARALLEL TO THE CHANNEL FLOW DIRECTION. THE FINISHED ELEVATION OF THE BOULDERS SHALL BE DETERMINED IN THE FIELD BY THE ENGINEER.
3. PLACE BOULDERS APPROXIMATELY THREE TO FIVE FEET APART IN THE DOWNSTREAM DIRECTION.
4. NO MORE THAN 1.5 FEET OF THE TOTAL 4 FOOT WIDTH SHALL BE BLOCKED WITH ANY ROCK PLACEMENT.
5. PLACE BOULDERS TO CREATE DEFINED LOW FLOW CHANNEL. FINAL BOULDER PLACEMENT SHALL BE DETERMINED BY THE ENGINEER IN THE FIELD.
6. POUR 6" TOP COURSE OF CONCRETE AFTER FINAL ROCK PLACEMENT.

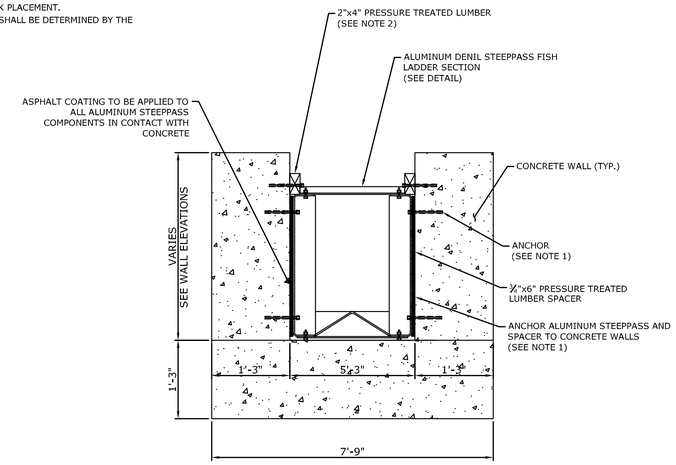


9/16 BEDROCK PAY LIMITS
NOT TO SCALE



END VIEW - ELEVATION

7/16 STEEPPASS SCHEMATIC ELEVATION (END VIEW)
NOT TO SCALE



8/16 TYPICAL PROPOSED FISHWAY SECTION AT ALUMINUM STEEPPASS
NOT TO SCALE

NOTES:
1. SECURE STEEPPASS AND LUMBER SPACER TO THE CONCRETE SIDE WALL WITH HILTI HIT HY 150 EPOXY ANCHOR SYSTEM WITH HAS-R-304SS ¾" THREADED ROD AND 4½" MINIMUM EMBEDMENT. TWO BOLTS PER SPACER AS INDICATED ABOVE.
2. BOLT 2"x4" PRESSURE TREATED LUMBER ON TOP OF STEEPASS TO BLOCK GAP BETWEEN STEEPASS AND WALL. THE 2"x4" IS TO RUN THE FULL LENGTH OF THE STEEPASS AND TO BE BOLTED TO THE SIDE WALL WITH HILTI HIT HY 150 EPOXY ANCHOR SYSTEM WITH HAS-SS ½" THREADED ROD AND 4½" MINIMUM EMBEDMENT. BOLTS TO BE LOCATED 2' O.C. OR APPROVED EQUAL.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: BRONX ZOO DAM FISH PASSAGE AND SITE IMPROVEMENTS		
DRAWING TITLE: DETAILS		
DESIGNED BY: EJAG	DRAWN BY: BAM	CHECKED BY: JGM/RGJSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO.
B-SCAN	SCALE / DATE	DRAWING NO.: 16
		CONTRACT NUMBER
		SHEET NO. 16 OF 17 SHEETS

TREE PROTECTION NOTES:

1. IT IS THE CONTRACTOR'S RESPONSIBILITY TO CHECK AND VERIFY ALL SITE CONDITIONS, BOTH ABOVE AND BELOW THE SURFACE, PRIOR TO COMMENCING WORK. ANY DISCREPANCIES BETWEEN INFORMATION SHOWN ON THE DRAWINGS AND ACTUAL FIELD CONDITIONS SHOULD BE BROUGHT TO THE ATTENTION OF THE AGENCY IN WRITING, PRIOR TO THE COMMENCEMENT OF WORK.

2. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE PROTECTION AND PRESERVATION OF ALL EXISTING TREES THAT ARE TO BE RETAINED WITHIN CONTRACT LIMIT LINE. CONTRACTOR SHALL PROTECT EXISTING VEGETATION, AS PER ARTICLE 12, SECTION A, "PRESERVING NATURAL FEATURES."

3. THE RESIDENT ENGINEER SHALL NOTIFY LANDSCAPE CONSTRUCTION AT (XXX) XXX-XXXX AT LEAST 48-HOURS PRIOR TO THE COMMENCEMENT OF ANY TREE PROTECTION, PRUNING, TREE REMOVALS, EXCAVATIONS WITHIN DRIPLINES, DECOMPACTION, TOPSOIL, AND PLANTING WORK.

4. WHEN A TREE PROTECTION DEFICIENCY, AS DETERMINED BY THE DIRECTOR OF LANDSCAPE CONSTRUCTION, IS IDENTIFIED, IT MUST BE REMEDIED WITHIN 24-HOURS OF THE AGENCY'S NOTIFICATION BY THE CONTRACTOR. FAILURE TO CORRECT THE DEFICIENCY WITHIN THIS TIMEFRAME WILL RESULT IN LIQUIDATED DAMAGES. (AS PER GENERAL CONDITIONS, SPECIAL PROVISIONS, SECTION C, ARTICLE 14 "TREE WORK".)

5. ANY DAMAGE TO EXISTING TREES DURING CONSTRUCTION SHALL BE THE CONTRACTOR'S RESPONSIBILITY. THE CONTRACTOR SHALL MITIGATE SUCH DAMAGED TREES TO THE SATISFACTION OF THE AGENCY, AT THE CONTRACTOR'S EXPENSE. (AS PER GENERAL CONDITIONS, SPECIAL PROVISIONS, SECTION C, ARTICLE 14 "TREE WORK" - "REMEDIATION")

6. TREES WITHIN THE CONTRACT LIMIT LINE ARE TO RECEIVE AT LEAST ONE (1") INCH (THE EQUIVALENT OF 750 GALLONS OF WATER PER 1,000 SQUARE FEET OF TREE PROTECTION ZONE) OF WATER PER WEEK BETWEEN THE MONTHS OF MARCH AND OCTOBER, AS DIRECTED BY THE DIRECTOR OF LANDSCAPE CONSTRUCTION OR NRG REPRESENTATIVES. IF RAINWATER IN ANY GIVEN WEEK IS BELOW THIS QUANTITY, THE CONTRACTOR MUST SUPPLEMENT THE AMOUNT RECEIVED BY UTILIZING SOAKER HOSES OR AS DIRECTED BY THE AGENCY. IF A WATER SOURCE IS UNAVAILABLE AT THE SITE, THE CONTRACTOR MUST PROVIDE TREE IRRIGATION BAGS TO APPLY THE REQUISITE AMOUNT OF WATER. (AS PER GENERAL CONDITIONS, SPECIAL PROVISIONS, SECTION C, ARTICLE 14 "TREE WORK")

7. PREPARATORY PRUNING WORK SHALL BE PERFORMED WHEN DIRECTED BY THE DIRECTOR OF LANDSCAPE CONSTRUCTION OR HIS REPRESENTATIVE. THIS WORK SHALL BE PERFORMED IN ACCORDANCE WITH ANSI A300 STANDARDS AND BY A QUALIFIED ARBORIST. THE CONTRACTOR SHALL NOTIFY THE DIRECTOR LANDSCAPE CONSTRUCTION (XXX) XXX-XXXX AND JAMES LEMYRE, DIR. OF BRONX FORESTRY (718) 430-1820, AT LEAST 48-HOURS PRIOR TO THE COMMENCEMENT OF ANY PRUNING WORK. (ITEM "PREPARATORY PRUNING OF TREE OVER 6" TO 12" DBH")

8. ANSI PRUNING TYPES SPECIFIED ON TREE PROTECTION SCHEDULE AND TREE DIAMETERS AT BREAST HEIGHT ARE TO BE CONFIRMED BY THE DIRECTOR OF LANDSCAPE CONSTRUCTION OR HIS REPRESENTATIVE BEFORE PRUNING WORK IS PERFORMED.

9. TEMPORARY WOODEN TREE GUARDS WITH WRAP FOR INDIVIDUAL TREES SHALL BE MAINTAINED THROUGHOUT THE COURSE OF THE CONTRACT. (ITEM "TEMPORARY WOODEN TREE GUARDS WITH WRAP")

10. TEMPORARY WOODEN TREES GUARDS AND TEMPORARY SNOW FENCE BOUNDARIES ARE NOT TO BE REMOVED UNTIL DIRECTED BY THE DIRECTOR OF LANDSCAPE CONSTRUCTION OR HIS REPRESENTATIVE.

11. THE CONTRACTOR SHALL TAKE EXTREME CARE TO PROTECT THE ROOT SYSTEMS OF EXISTING TREES. BULK MATERIAL, EQUIPMENT, OR VEHICLES SHALL NOT BE STOCKPILED OR PARKED WITHIN THE DRIPLINE OF ANY TREE, OR WITHIN 10 FT. OF THE TRUNK (WHICHEVER IS GREATER) TO MINIMIZE SURFACE AND SUBSURFACE ROOT AND SOIL COMPACTION. THIS APPLIES TO ALL AREAS WITHIN OR OUTSIDE THE CONTRACT LIMIT LINE.

12. IF STOCKPILING OCCURS WITHIN THE DRIPLINE, A STOP WORK ORDER SHALL BE ISSUED IMMEDIATELY. WORK SHALL NOT RE-COMMENCE UNTIL ALL STOCKPILED MATERIAL IS REMOVED FROM THE ZONE AND TREE REMEDIATION IS SATISFIED.

13. AS SHOWN ON THE PLANE, THE ROOT ZONE OF A TREE SHALL BE COVERED WITH MULCH TO A DEPTH OF AT LEAST SIX (6") INCHES AND/OR WITH PLYWOOD/MATS IN ORDER TO PROTECT ROOTS FROM DAMAGE CAUSED BY HEAVY EQUIPMENT. SUCH COVERING SHALL BE MAINTAINED DURING THE COURSE OF CONSTRUCTION AND REMOVED BY HAND OR AS SPECIFIED BY THE DIRECTOR OF LANDSCAPE CONSTRUCTION, THE RESIDENT ENGINEER, OR NRG REPRESENTATIVE. (ITEM "PROTECT EXIST. TREE ROOTS W/WOODCHIPS 6" DEPTH" AND "PROTECT EXIST. TREE ROOTS W/PLYWOOD")

14. ANY EXCAVATION WITHIN THE DRIPLINE, OR ELSEWHERE ON SITE, AS INDICATED ON TREE PROTECTION PLAN, SHALL BE DONE BY HAND OR PNEUMATIC EXCAVATION AND TIN THE PRESENCE OF THE DIRECTOR OF LANDSCAPE CONSTRUCTION OR HIS REPRESENTATIVE AND THE RESIDENT ENGINEER. (ITEM "HAND AND/OR PNEUMATIC EXCAVATION") ROOTS OVER ONE (1") INCH IN DIAMETER SHALL NOT BE CUT WITHOUT THE WRITTEN PERMISSION OF THE BOROUGH DIRECTOR OF FORESTRY.

15. THE CONTRACTOR SHALL EXERCISE EXTREME CARE IN REMOVING CONCRETE OR ASPHALT WITHIN THE DRIPLINE OF EXISTING TREES - LIFTING RATHER THAN DRAGGING PIECES OF PAVING. TOOLS FOR THIS ACTIVITY SHALL BE APPROVED BY THE DIRECTOR OF LANDSCAPE CONSTRUCTION AND THE RESIDENT ENGINEER PRIOR TO THE START OF EXCAVATION.

16. THE EXCAVATION AREA WITHIN THE DRIPLINE SHALL BE BACKFILLED IMMEDIATELY AND/OR ROOTS SHALL BE KEPT CONSTANTLY MOIST WITH BURLAP COVERED WITH WHITE PLASTIC AND CHECKED A MINIMUM OF TWO (2) TIMES A DAY, ONCE IN THE MORNING AND ONCE IN THE AFTERNOON, FOR A MAXIMUM OF FORTY-EIGHT (48) HOURS, UNTIL BACKFILL IS COMPLETE AS DIRECTED BY THE DIRECTOR OF LANDSCAPE CONSTRUCTION AND THE RESIDENT ENGINEER. IF DIRECTED, SOAKER HOSES SHALL BE INSTALLED TO FACILITATE PROPERLY MOIST CONDITIONS. NO POOLING OF WATER OR CONTINUOUS RUNNING WATER SHALL OCCUR WITHIN THE DRIP LINE OF EXISTING TREES OR WITHIN THE TREE PROTECTION ZONES OTHER THAN THAT DURING THE IRRIGATION PROCESS. (AS PER GENERAL CONDITIONS, SPECIAL PROVISIONS, SECTION C, ARTICLE 14 "TREE WORK")

17. IF ROOTS ARE TO BE EXPOSED FOR A PERIOD GREATER THAN 48-HOURS, THE EXPOSED AREA SHALL BE COVERED WITH AT LEAST 6-INCHES OF MULCH AND MAINTAINED DURING THE COURSE OF CONSTRUCTION UNTIL THE AREA CAN BE PROPERLY BACKFILLED. (AS PER GENERAL CONDITIONS, SPECIAL PROVISIONS, SECTION C, ARTICLE 14 "TREE WORK")

18. ALL EXCAVATION AND PLANT INSTALLATIONS WITHIN THE DRIPLINE OF TREES ARE TO BE PERFORMED BY HAND AND NOT WITH AUGERS TO MINIMIZE SOIL DISTURBANCE AND ROOT DAMAGE. PLANTS SHALL NOT BE PLACED WITHIN THREE (3') FEET OF THE TREE TRUNK.

STAGING & ACCESS NOTES:

1. THE CONTRACTOR SHALL INSTALL CONSTRUCTION FENCE AND GATES AROUND THE PERIMETER OF THE CONSTRUCTION ZONE TO PREVENT PUBLIC ACCESS TO THE CONSTRUCTION SITE FOR THE DURATION OF THE CONTRACT, OR AS DIRECTED BY RESIDENT ENGINEER.

2. CONTRACTOR IS RESPONSIBLE FOR FULLY REMOVING ALL TEMPORARY ACCESS MATERIALS AND REPAIRING ANY DAMAGE THAT MAY OCCUR FROM ACCESS ROAD MATERIALS BEING MOBILIZED UNDER A FLOOD EVENT, AT NO ADDITIONAL COST TO THE CITY.

3. CONTRACTOR IS RESPONSIBLE TO REPAIR ANY DAMAGE TO ALL EXISTING PAVEMENTS, CURBS, WALL, OR ITEMS AS DETERMINED BY RESIDENT ENGINEER TO REMAIN, AT NO ADDITIONAL COST TO THE CITY.

4. NO CONSTRUCTION VEHICLES SHALL BE STORED, SERVICED, WASHED, OR FLUSHED IN A LOCATION WHERE LEAKS, SPILLAGE, WASTE MATERIALS, CLEANERS, OR WATERS WILL BE INTRODUCED OR FLOW INTO WETLANDS, WATERCOURSES, OR ACTIVE PARK AREAS.

5. THE PROJECT SITE IS SUBJECT TO FLOODING. THE CONTRACTOR SHALL MONITOR LOCAL WEATHER FORECASTS, PRECIPITATION, RIVER STAGE, AND FLOW RATES ON A DAILY BASIS. THE CONTRACTOR IS RESPONSIBLE TO ADJUST WORK SCHEDULES AND REMOVE EQUIPMENT FROM FLOOD PRONE AREAS IN THE EVENT OF FLOOD WARNINGS. IN THE EVENT OF MORE THAN ONE (1) INCH OF RAIN IN A 24-HOUR PERIOD, OR THE FORECAST OF A TROPICAL STORM OR HURRICANE, ALL EQUIPMENT, FLOATABLES, FUEL, AND OTHER POSSIBLE CONTAMINANTS ARE TO BE MOVED OUT OF THE FEMA-DESIGNATED 100-YEAR FLOODPLAIN.

6. THE UNITED STATE GEOLOGICAL SURVEY OPERATES STREAM FLOW GAUGE #01302020 ON THE BRONX RIVER NEAR THE NEW YORK BOTANICAL GARDENS (NYBG), APPROXIMATELY 1.25 MILES UPSTREAM FROM THE PROJECT SITE. THE WEBSITE FOR THE GAUGE IS: http://waterdata.usgs.gov/ny/nwis/uv/?site_no=01302020&PARAmeter_cd=00065,00060

7. PRIOR TO INITIATING WORK, THE CONTRACTOR SHALL INSPECT DOWNSTREAM AREAS TO IDENTIFY ZONES THAT COULD POTENTIALLY BE FLOODED WITHIN OR NEAR THE CHANNEL IN THE EVENT OF AN UNEXPECTED WATER RELEASE.

8. THE CONTRACTOR SHALL PROVIDE EMERGENCY CONTACT PHONE NUMBERS TO ENGINEER, NRG, AND DPR PRIOR TO WORK COMMENCING.

9. THE CONTRACTOR SHALL POST EMERGENCY PHONE NUMBERS FOR POLICE, FIRE, AND MEDICAL SERVICES AT THE CONSTRUCTION SITE.

10. THE CONTRACTOR SHALL KEEP A FIRST AID KIT ON SITE AT ALL TIMES.

11. PROVIDE FLAGGERS WHEN CROSSING PUBLIC SIDEWALK AREAS WITH VEHICLES OR CONSTRUCTION EQUIPMENT.

12. CONTRACTOR SHALL PROVIDE SIGNAGE DIRECTING PUBLIC TO TEMPORARY PLAYGROUND ACCESS ALONG BOSTON ROAD, PAID FOR UNDER MOBILIZATION.

EROSION & WATER CONTROL NOTES:

1. WATER & EROSION CONTROL MEASURES SHALL BE IN PLACE PRIOR TO ANY WORK OCCURRING ON THE ADJACENT STRUCTURES TO BE RECONSTRUCTED/CONSTRUCTED.

2. THE CONTRACTOR IS RESPONSIBLE FOR WATER CONTROL DURING THE PROJECT. THE CONTRACTOR SHALL COORDINATE THE WATER CONTROL OF THE DAM AREA WITH THE RESIDENT ENGINEER AND NRG.

3. IN GENERAL, ALL CONSTRUCTION ACTIVITIES SHALL PROCEED IN SUCH A MANNER SO AS TO NOT POLLUTE ANY WETLANDS, WATERCOURSE, WATERBODY, AND CONDUIT CARRYING WATER, ETC. THE CONTRACTOR SHALL LIMIT, INSOFAR AS POSSIBLE, THE SURFACE WARE OF EARTH MATERIALS EXPOSED BY CONSTRUCTION METHODS AND IMMEDIATELY PROVIDE PERMANENT AND TEMPORARY POLLUTION CONTROL MEASURES TO PREVENT CONTAMINATION OF ADJACENT WETLANDS, WATERCOURSE, AND WATERBODIES, AND TO PREVENT, INSOFAR AS POSSIBLE, EROSION ON THE SITE.

4. THE CONTRACTOR SHALL BE REQUIRED TO COMPLY WITH ALL APPLICABLE PROVISIONS OF THE "NYS STANDARDS AND SPECIFICATION FOR EROSION AND SEDIMENT CONTROL."

   THE MEASURES FOR THE CONTROL OF EROSION AND SEDIMENTATION ARE UNDERTAKEN CONSISTENT WITH THE NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION "GUIDELINES FOR URBAN EROSION AND SEDIMENT CONTROL," AS AMENDED, OR ITS EQUIVALENT SATISFACTORY TO THE PLANNING BOARD.

5. SILT FENCE SHALL BE INSTALLED AND LOCATED ALONG THE PROPOSED LIMIT OF DISTURBANCE AREAS, AT THE TOP OF SLOPE ALONG THE SHORELINE AND AROUND TOPSOIL STOCKPILE AREA AS DIRECTED BY THE RESIDENT ENGINEER/NRG AND SHOWN ON THE DRAWINGS.

6. STRAW BALES SHALL BE INSTALLED ALONG THE UPSTREAM SIDE OF ALL SILT FENCING.

7. SURFACE STABILIZATION SHALL BE ACCOMPLISHED WITH VEGETATION AND EROSION CONTROL FABRIC AS SHOWN IN EROSION CONTROL AND PLANTING PLANS.

8. DEWATERING SHALL OCCUR AS NECESSARY TO PROVIDE DRY WORKING CONDITIONS DURING CONSTRUCTION/RECONSTRUCTION OF STRUCTURES, AS DIRECTED BY THE RESIDENT ENGINEER AND NRG. DEWATERED PERIOD SHALL BE MINIMIZED AS MUCH AS POSSIBLE, WEATHER AND WATER FLOW DEPENDING. CONTRACTOR'S WATER CONTROL PLAN SHALL INDICATE THE PROPOSED PERIOD OF TIME FOR DEWATERING, FOR APPROVAL BY DPR. IN THE EVENT OF A HIGH FLOW-PRODUCING STORM, THE CONTRACTOR MAY REMOVE AND THEN REPLACE THE WATER CONTROLS WITH APPROVAL OF DPR, AT NO ADDITIONAL COST TO THE CITY, TO PREVENT DAMAGE TO SUCH CONTROLS, EXISTING STRUCTURES, AND NEWLY CONSTRUCTED WORK.

9. THE CONTRACTOR WILL BE RESPONSIBLE FOR THE PROPER CONSTRUCTION STABILIZATION AND MAINTENANCE OF ALL TEMPORARY EROSION AND SEDIMENTATION CONTROL MEASURES AND RELATED ITEMS INCLUDED WITHIN THIS PLAN. THE PROPER CONSTRUCTION AND STABILIZATION OF PERMANENT CONTROL MEASURES INCLUDED IN THE PLAN FOR THE DURATION OF THE CONTRACT, AND THE REINSTALLATION OF WATER CONTROL STRUCTURES AT NO ADDITIONAL COST TO THE CITY. THERE SHALL BE NO CLAIMS FOR EXTRA COMPENSATION DUE TO WATER LEVELS RISING FROM NATURAL EVENTS, SUCH AS STORMS, ETC. DPR WILL BE RESPONSIBLE FOR THE MAINTENANCE OF ALL PERMANENT CONTROL MEASURES.

10. SOIL SEDIMENT REMOVED FROM ANY TEMPORARY EROSION CONTROL MEASURE, DURING REGULAR MAINTENANCE, WILL BE INCORPORATED BACK INTO THE EARTHWORK AS FILL/SOIL ON-SITE. SOIL SEDIMENT MATERIAL SHALL BE DISTRIBUTED ON-SITE WITHOUT CHANGING DRAINAGE PATTERNS DURING A SPECIFIC CONSTRUCTION STAGE, TO BE PAID FOR UNDER THE RESPECTIVE EROSION CONTROL ITEMS AND AS DIRECTED BY NRG.

11. ALL EROSION AND SEDIMENT CONTROL PRACTICES WILL BE CHECKED FOR STABILITY AND OPERATION FOLLOWING EVERY RUNOFF-PRODUCING RAINFALL, BUT IN NO CASE LESS THAN ONCE A WEEK, AS SPECIFIED. ANY NEEDED REPAIRS WILL BE MADE IMMEDIATELY TO MAINTAIN ALL PRACTICES AS DESIGNED. REPAIRS TO EROSION AND WATER CONTROL SHALL BE INCLUDED IN THE PAYMENT FOR THE ITEM AT NO EXTRA COST.

12. SEDIMENT WILL BE REMOVED FROM BEHIND SEDIMENT FENCING WHEN IT BECOMES ABOUT 0.5 FEET DEEP AT THE FENCE. THE SEDIMENT FENCE SHALL BE REPAIRED AS NECESSARY TO MAINTAIN A BARRIER.

13. ALL SEEDED AREAS WILL BE FERTILIZED, RESEEDED AS NECESSARY, AND MULCHED ACCORDING TO THE PLANTING PLAN. SEE SPECIFICATION FOR RATES OF FERTILIZATION, AND SEED COVERAGE, ETC.

REMOVAL NOTES:

1. SEE EXISTING CONDITIONS PLANS FOR ALL EXISTING SURVEY AND TOPOGRAPHICAL DATA AND LEGEND.

2. IT IS THE CONTRACTOR'S RESPONSIBILITY TO VERIFY ALL EXISTING SITE CONDITIONS, BOTH ABOVE AND BELOW THE SURFACE, PRIOR TO COMMENCING WORK. ANY DISCREPANCIES BETWEEN THE INFORMATION SHOWN ON THE DRAWINGS SHALL BE BROUGHT TO THE ATTENTION OF THE RESIDENT ENGINEER AND DPR IN WRITING PRIOR TO COMMENCING WORK.

3. THE CONTRACTOR SHALL COMPLY WITH ALL APPLICABLE CODES AND REGULATIONS GOVERNING THIS WORK. THE CONTRACTOR SHALL COORDINATE DEMOLITION WITH APPLICABLE AGENCIES, UTILITY COMPANIES, AND/OR SUB-CONTRACTORS.

4. IT IS MANDATORY, AS PER NYS INDUSTRIAL CODE RULE 53, FOR THE CONTRACTOR TO NOTIFY NEW YORK CITY/LONG ISLAND ONE-CALL CENTER, 36-35 BELL BOULEVARD, SUITE 202, BAYSIDE, NY 11361, TEL 800.272.4480, FAX 718.631.6723, EMAIL B5CHUETT@1-CALL.COM, IN ADDITION TO ALL UNDERGROUND FACILITY OPERATORS IN THE AREA WHO ARE NOT ONE-CALL MEMBERS, NOT LESS THAN TWO (2) FULL BUSINESS DAYS AND NOT MORE THAN TEN (10) FULL BUSINESS DAYS BEFORE COMMENCING EXCAVATION. THE ONE-CALL CENTER IS ALWAYS OPEN. THE ONE-CALL CENTER WILL THEN NOTIFY MEMBER FIRMS WITH OPERATIONS IN THE SITE AREA OF THE CONTRACTOR'S PENDING EXCAVATION OPERATIONS. THE CONTRACTOR WILL RECEIVE A NOTIFICATION TICKET FROM THE ONE-CALL CENTER WHICH SHOULD BE PRESENTED TO THE RESIDENT ENGINEER AS PROOF OF THE CALL. THERE IS NO CHARGE FOR THIS SERVICE. THIS PROCESS ENSURES THAT UTILITY SERVICE LINES ARE PROPERTY MARKED PRIOR TO EXCAVATION TO MINIMIZE FACILITY DAMAGE, ON THE JOB INJURIES, AND CONTRACTOR'S LIABILITY. MORE INFORMATION ABOUT THE ONE-CALL CENTER IS AVAILABLE ONLINE AT HTTP://WWW.NYC1I CALLDSI.COM, WHICH INCLUDES A DESCRIPTION OF THE INFORMATION THAT CONTRACTOR WILL NEED WHEN MAKING THE CALL.

5. IT SHALL BE THE CONTRACTOR'S RESPONSIBILITY TO REPAIR ANY DAMAGE AND/OR RESTORE ANY INTERRUPTION TO ANY UTILITY SERVICE THAT MAY BE CAUSED BY THE CONTRACTOR'S CONSTRUCTION OR EQUIPMENT, AT THE CONTRACTOR'S EXPENSE, WITH NO ADDITIONAL EXPENSE TO THE CITY OF NEW YORK.

6. ALL EXISTING SEWER, GAS, WATER, AND ELECTRIC UTILITY LINES, AS WELL AS STRUCTURES WITHIN THE CONTRACT AREA SHALL REMAIN, UNLESS REMOVAL OF SAME IS SPECIFICALLY NOTED. ALL STORM DRAINAGE PIPES TO BE ABANDONED OR REMOVED ARE NOTED ON THE PLANS. IF ABANDONED PIPES ARE ENCOUNTERED DURING EXCAVATION, THEN THE CONTRACTOR SHOULD REMOVE PIPE IN AREA OF EXCAVATION AND PLUG AT EACH END OF EXCAVATION. CONTRACTOR SHOULD CONFIRM PIPE IS ABANDONED BEFORE ATTEMPTING THIS OPERATION.

7. THE CONTRACTOR IS TO USE CARE DURING CONSTRUCTION TO AVOID DISTURBING OR DAMAGING ADJACENT ABOVE-GRADE OR SUBGRADE STRUCTURES, FACILITIES, CURBS, PAVEMENT, AND PERIMETER FENCING. ANY DAMAGE RESULTING FROM THIS WORK WILL BE RESTORED TO THE SATISFACTION OF DPR AT THE CONTRACTOR'S EXPENSE.

8. WHERE NEW CONSTRUCTION ABUTS EXISTING PAVEMENTS, CURBS, OR WALLS, THE EXISTING MATERIALS SHALL BE CLEANLY SAWCUT TO PROVIDE A CLEAN, NEAT MATCH AND A SMOOTH, FLUSH TRANSITION, AS DIRECTED BY THE RESIDENT ENGINEER. ALL SAWCUTTING SHALL BE DONE TO NEAT, STRAIGHT, AND ACCURATE LINES. CONTRACTOR SHALL PROVIDE EXPANSION JOINTS (TIE ROAD AND/OR SLIP JOINT) WHERE OLD AND NEW CURBS MEET.

9. THE CONTRACTOR SHALL REPLACE ANY EXISTING CURBS, FENCING OR PAVEMENTS THAT WERE INTENDED TO REMAIN BUT ARE DAMAGED OR DISTURBED DURING CONSTRUCTION. IF REPLACEMENT IS NECESSARY, IT SHALL BE DONE AT THE CONTRACTOR'S EXPENSE, TO THE SATISFACTION OF DPR AND THE RESIDENT ENGINEER.

10. THE CONTRACTOR SHALL TAKE EXTREME CARE TO PROTECT THE ROOT SYSTEMS OF EXISTING TREES. BULK MATERIAL, EQUIPMENT, OR VEHICLES SHALL NOT BE STOCKPILED OR PARKED WITHIN THE DRIPLINE OF ANY TREE. SEE EROSION & SEDIMENT CONTROL, TREE PROTECTION, & ACCESS/STAGING PLAN FOR DETAILS AND LOCATIONS OF PROTECTIVE MEASURES.

11. SEE EROSION & SEDIMENT CONTROL, TREE PROTECTION, & ACCESS/STAGING PLAN FOR ADDITIONAL NOTES REGARDING PROTECTION, PRUNING AND DECOMPACTION OF EXISTING TREES.

12. WHEN NECESSARY, THE CONTRACTOR SHALL ALWAYS EXCAVATE BY HAND WITHIN THE DRIPLINE OF EXISTING TREES, OR AS DIRECTED BY THE RESIDENT ENGINEER.

13. IN AREAS DESIGNATED FOR EXCAVATION, ALL EXISTING PAVEMENTS, CURBS, AND CATCH BASINS SHALL BE REMOVED ACCORDING TO THE PLANS AND SPECIFICATIONS, AND AS DIRECTED BY THE RESIDENT ENGINEER.

14. THE CONTRACTOR SHALL DISPOSE OF ALL ITEMS AND MATERIALS REMOVED AND NOT SALVAGED, INCLUDING ALL EXCAVATED MATERIAL, OFF-SITE AND IN A LEGAL MANNER.

15. THE CONTRACTOR IS RESPONSIBLE FOR OBTAINING ALL NECESSARY PERMITS FROM THE APPROPRIATE AGENCIES PRIOR TO COMMENCING WORK.

16. THE CONTRACTOR SHALL REMOVE, EXCAVATE, AND DISPOSE OF ALL MATERIALS ACCORDING TO SPECIFICATION.

MATERIALS NOTES:

1. TOPOGRAPHICAL DATA OF EXISTING CONDITIONS AND UTILITIES ARE FROM A SURVEY BY DPR IN-HOUSE SURVEY TEAM. SEE THE 'EXISTING CONDITIONS' PLAN INCLUDED IN THIS SHEET SET FOR DETAILS.

2. THE CONTRACTOR SHALL VERIFY ALL EXISTING SITE CONDITIONS, BOTH ABOVE AND BELOW THE SURFACE. ANY DISCREPANCIES BETWEEN INFORMATION SHOWN ON THE DRAWINGS AND ACTUAL FIELD CONDITIONS SHALL BE BROUGHT TO THE ATTENTION OF THE RESIDENT ENGINEER AND PARKS IN WRITING, PRIOR TO COMMENCING WORK.

3. LOCATIONS OF EXISTING TREES SHALL BE VERIFIED IN THE FIELD.

4. NO CHANGES SHALL BE MADE TO THE DESIGN OR LAYOUT WITHOUT THE WRITTEN APPROVAL OF THE LANDSCAPE ARCHITECT. LAYOUT THE WORK AS DIMENSIONED ON THE PLANS FOR APPROVAL OF LANDSCAPE ARCHITECT PRIOR TO THE PLACEMENT OF CONCRETE. WRITTEN DIMENSIONS SHALL GOVERN. DO NOT SCALE DISTANCES.

5. CONTRACTOR SHALL LAYOUT AND STAKE IN THE FIELD THE ALIGNMENT OF ALL CURBS, PAVEMENTS AND OTHER IMPROVEMENTS FOR REVIEW BY THE LANDSCAPE ARCHITECT. ADJUSTMENTS MAY BE MADE ONLY AS DIRECTED BY THE LANDSCAPE ARCHITECT. CONTRACTOR MAY NOT PROCEED WITH CONSTRUCTION OF IMPROVEMENTS UNTIL HE HAS RECEIVED THE FINAL APPROVAL OF THE LAYOUT FROM THE LANDSCAPE ARCHITECT.

6. ALL NEW CURBS AND PAVEMENTS SHALL MEET EXISTING CURBS & PAVEMENTS IN A SMOOTH FLUSH CONDITION UNLESS NOTED OTHERWISE.

7. NEW CURBS, WALLS, AND PAVEMENTS SHALL BE BUILT TO A SMOOTH EVEN FINISH WITH A CONSISTENT TOP AND PROFILE WITHOUT WAVES OR IRREGULARITIES. ANY WORK NOT MEETING THIS QUALITY STANDARD SHALL BE REPLACED AT THE CONTRACTOR'S EXPENSE.

8. THE CONTRACTOR SHALL EXERCISE CARE DURING EXCAVATION OPERATIONS TO AVOID DISTURBING ADJACENT FACILITIES, SUB GRADE STRUCTURES AND TREES. ALL DAMAGE RESULTING FROM THE CONSTRUCTION SHALL BE THE CONTRACTOR'S RESPONSIBILITY AND SHALL BE REPAIRED AT NO EXPENSE TO THE CITY AND DPR. ALL REPAIR WORK SHALL BE TO THE SATISFACTION OF THE RESIDENT ENGINEER AND DPR. PLANTED AREAS DISTURBED BY HIS WORK SHALL BE RESTORED AS DIRECTED BY THE LANDSCAPE ARCHITECT.

9. NO HEAVY MACHINERY, EQUIPMENT OR STOCKPILING OF MATERIAL IS PERMITTED WITHIN THE DROP LINES OF EXISTING TREES.

10. THE CONTRACTOR SHALL TAKE SPECIAL CARE TO PROTECT ALL EXISTING TREES AND THEIR ROOT SYSTEM. EXCAVATIONS WITHIN THE DRIP LINES OF TREES SHALL BE KEPT TO A MINIMUM AND SHALL BE COMPLETED BY HAND ONLY AND SHALL BE PERFORMED IN THE PRESENCE OF THE RESIDENT ENGINEER, AT NO ADDITIONAL EXPENSE TO THE CITY. ROOTS OVER 2" DIAMETER SHALL NOT BE DISTURBED AND BRIDGE CURBS SHALL BE CONSTRUCTED WHERE NECESSARY.

11. IN AREAS WHERE NEW PAVEMENTS FALL WITHIN THE DRIP LINE OF EXISTING TREES, THE CONTRACTOR SHALL MINIMIZE EXCAVATIONS AT TREE ROOTS BE REDUCING THE AMOUNT OF FOUNDATION MATERIAL AS DIRECTED BY ENGINEER.

12. WHERE CONC. CURB IS REQUIRED FOR FENCING, THE APPROPRIATE STANDARD DPR DETAIL SHALL BE DEFERRED TO.

13. DPR/NATURAL RESOURCES GROUP (NRG) SHALL COORDINATE THE ACCESS TO ZOO/WCS PROPERTY FOR CONTRACTOR PRIOR TO START OF CONSTRUCTION. CARE SHOULD BE TAKEN BY THE CONTRACTOR TO KEEP PROPERTIES SECURED AT ALL TIMES. CONTRACTOR SHALL SUPPLY A SUPERVISOR OR SECURITY GUARD THROUGHOUT THE DURATION OF THE CONTRACT THAT SECURES THE CONSTRUCTION AREAS DURING BUSINESS HOURS, AS REQUIRED BY WCS/BRONX ZOO WHEN PERFORMING WORK ON THAT LAND.

14. LOCATION OF CONSTRUCTION FENCE SHOWN IS SUGGESTED. FINAL LOCATION SHALL BE DETERMINED BY CONTRACTOR FOR APPROVAL OF RESIDENT ENGINEER.

MILONE & MACBROOM®
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: BRONX ZOO DAM FISH PASSAGE AND SITE IMPROVEMENTS		
DRAWING TITLE: GENERAL NOTES		
DESIGNED BY: ELAG	DRAWN BY: BAM	CHECKED BY: JGM/RGSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO.
B-SCAN	SCALE / DATE	DRAWING NO. 17
		CONTRACT NUMBER
		SHEET NO. 17 OF 17 SHEETS

Bronx Zoo Dam Quantities
US Army Corps of Engineers Features

Item			Qty	UOM
INVASIVE SPECIES REMOVAL W/ SELECT NATIVE PLANTINGS				
	Clearing & grubbing/ Excavation		450	CY
	Clean soil		270	CY
	Plantings			
		Sassafras	70	EA
		Sassafras albidium		
		Red oak	70	EA
		Quercus rubra		
		White oak	70	EA
		Quercus alba		
SELECT NATIVE PLANTING				
	Clearing & grubbing/ Excavation		230	CY
	Common fill		140	CY
	Topsoil		140	CY
	Plantings			
		Sassafras	40	EA
		Sassafras albidium		
		Red oak	40	EA
		Quercus rubra		
		White oak	40	EA
		Quercus alba		
EMERGENT WETLANDS				
	Clearing & grubbing/ Excavation		1,840	CY
	Common fill		1,110	CY
	Top soil		1,110	CY
	Plantings			
		Cinnamon fern	2,170	EA
		Osmundastrum cinnamaeum		
		Sedge	8,680	EA
		Carex stricta		
		Arrow arum	8,680	EA
		Peltandra virginica		
		Bulrush	8,680	EA
		Scripus atrovirens		
		Common rush	8,680	EA
		Juncus effuses		
		Broad leafed cattail	3,860	EA
		Typha latifolio		
FORESTED SCRUB/SHRUB WETLAND CREATION				
	Clearing & grubbing/ Excavation		800	CY
	Common fill		383	CY
	Top soil		500	CY
	Trees			
		Arrowwood	70	EA
		Viburnum dentatum		
		Elderberry	70	EA
		Sambucus spp.		
		Buttonbush	70	EA
		Cephalanthus accidentalis		
		Serviceberry	70	EA
		Amalenchier spp.		
		Red osier dogwood	436	EA
		Cornus stolonifera		
		Willow	436	EA
		Salix (sp.)		
		Red maple	35	EA
		Acer rubrum		
		Sweet gum	35	EA
		Liquidambar styraciflua		
		Pin oak	35	EA
		Quercus palustris		
	Seed Mix			
		Wet meadow seed mix	20	LB
SEDIMENT LOAD REDUCTION				
	Bioswales			
		Total excavation	220	CY
		Soil medium	200	CY
		Mulch	50	CY
		Stone for underdrains	50	CY
		Bank run gravel	90	Tons
STEPPED ROCK WALL				
	Rock		560	Tons
	Excavation for rock		2,200	CY
	Live willow cuttings		4,320	EA
	Geotextile		1,430	SY

Bronx Zoo Dam Quantities NYC Parks 100% Design			
ITEM DESCRIPTION		**QTY**	**UOM**
General Requirements			
MOBILIZATION (N.T.E. 6% OF TOTAL OF ALL OTHER ITEMS)			LUMP SUM
CONSTRUCTION SIGN ON FENCE		1	EACH
CONSTRUCTION FENCE 8'-0" HT.		575	LINEAR FOOT
MAINTENANCE & PROTECTION OF TRAFFIC - TYPE C		1	LUMP SUM
TEMPORARY SNOW FENCE BOUNDARY		575	LINEAR FOOT
TEMPORARY WOODEN TREE GUARD W/TREE WRAP		10	EACH
PROTECT EXIST. TREE ROOTS W/WOODCHIPS 6' DEPTH		800	SQUARE FOOT
PROTECT EXIST. TREE ROOTS W/PL:YWOOD OR MATS		3000	SQUARE FOOT
Removals (General)			
REMOVALS (N.T.E.$)		1	EACH
STUMP REMOVAL OVER 6" TO 12" DIA.		9	EACH
TREE REMOVAL OVER 6" TO 12" DBH		7	EACH
Site Work			
CLEAR AND GRUB		1	LUMP SUM
ROCK EXCAVATION		600	CUBIC YARD
HAND AND/OR PNEUMATIC EXCAVATION		5	CUBIC YARD
EARTH MOVING OPERATIONS		300	CUBIC YARD
STRIP, STORE & SPREAD EXISTING TOPSOIL		50	CUBIC YARD
Erosion Control and Containment			
STABILIZED CONSTRUCTION ENTRANCE		300	SQUARE YARD
TEMPORARY SILT FENCE		80	LINEAR FOOT
Masonry - Concrete			
CONTROLLED CONCRETE (f'c = 4,000 psi)		115	CUBIC YARD
Reinforcement			
STEEL BAR REINFORCEMENT		18500	POUND
Landscape - General			
SHREDDED BARK MULCH		285	SQUARE YARD
PREPARATORY PRUNING OF TREE OVER 6" TO 12" DBH		10	EACH
ACCESS ROAD		1	LUMP SUM
SHREDDED STRAW		180	SQUARE YARD
SEEDING		180	SQUARE YARD
WATER CONTROL		1	LUMP SUM
FISH LADDER		1	LUMP SUM
FORM LINER		350	SQUARE YARD
BOULDERS		230	TON
TOPSOIL		120	CUBIC YARD
DENIL ALUMINUM STEEPPASS (3 SECTIONS - 22"W x 27" H x 120"L)		30	LF
TREES/SHRUBS			
SHADBLOW SERVICEBERRY		2	EACH
	Amelanchier canadensis		
WINTERBERRY		14	EACH
	Ilex verticillata		
COMMON WITCH HAZEL		3	EACH
	Hamamelius virginiana		
MOUNTAIN LAUREL		12	EACH
	Kalmia latifolia		
HERBACEOUS PLANTINGS			
WHITE WOOD ASTER		198	EACH
	Aster divaricatus		
CHRISTMAS FERN		126	EACH
	Polystichum acrostichoides		
NEW YORK FERN		111	EACH
	Thelypteris noveboracensis		
New England Restoration Mix Seed		1450	SQ FT

ITEM DESCRIPTION	QTY	UOM
CLEARING AND GRUBBING	10	CY
TOPSOIL	10	CY

PLANTINGS	QTY	UOM
SASSAFRAS	1	EA
Sassafras albidium		
RED OAK	1	EA
Quercus rubra		
WHITE OAK	1	EA
Quercus alba		
ARROWWOOD	5	EA
Viburnum dentatum		
SHADBLOW SERVICEBERRY	5	EA
Amalenchier canadensis		
RED OSIER DOGWOOD	10	EA
Cornus stoloniferia		
CHANNEL EXCAVATION	80	CY
ANGULAR STONE FOR CHANNEL BOTTOM (D_{MIN} = 1.0 FT)	150	TON
DENIL STEEPPASS FISH LADDER	35	LF

See NYC Parks
100% design package

Additional features, USACE

- Invasive species removal with native plantings
- Stream bottom improvements
- NYC Parks fish passage design

25 12.5 0 25 50 75 100 Feet

US Army Corps
of Engineers
New York District

STONE MILL DAM
NEW YORK BOTANICAL GARDENS
Detailed Design for USACE Features
BRONX NEW YORK

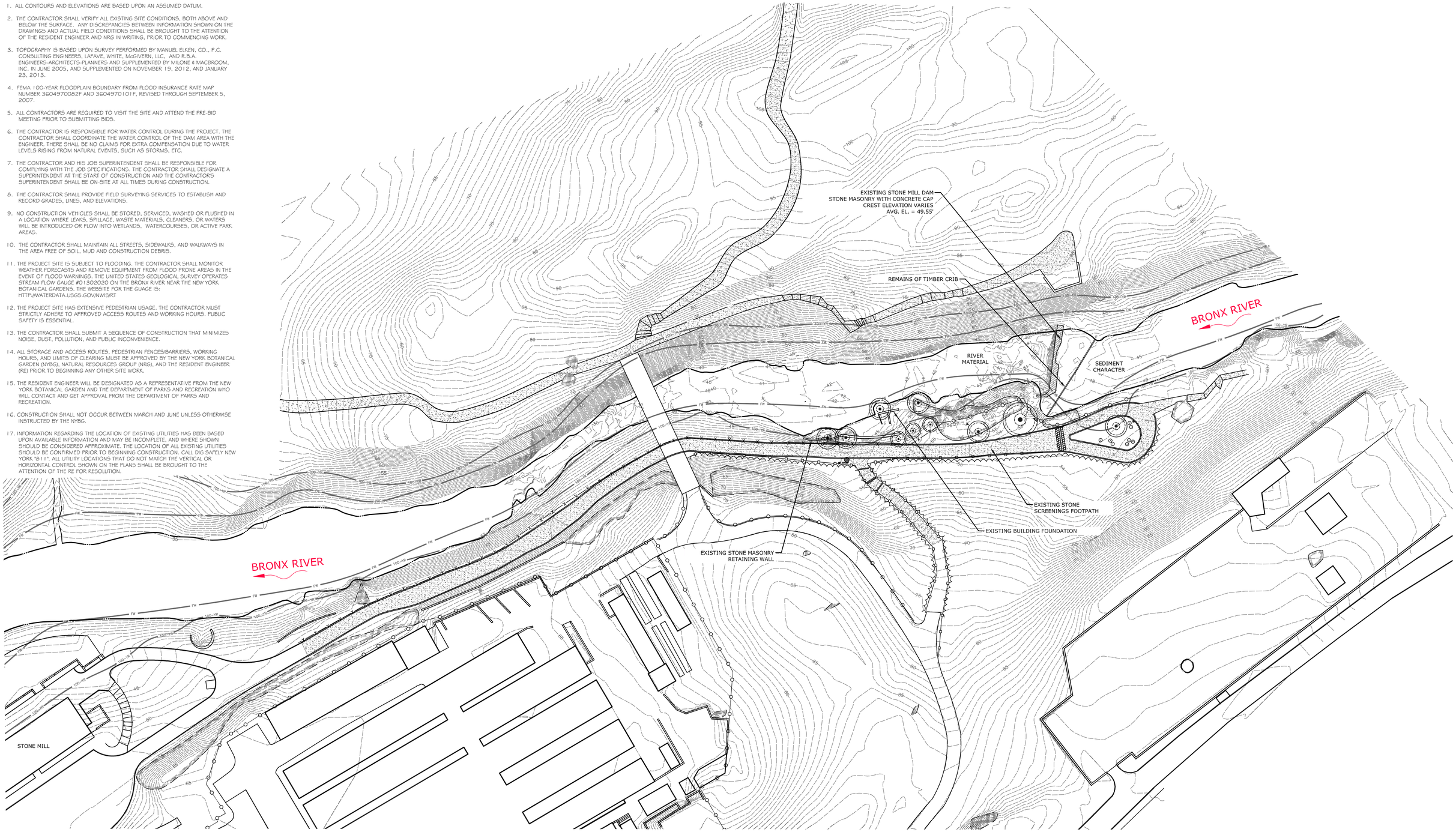
STONE MILL DAM

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Stone_Mill_Dam\GIS\Stone Mill Dam.mxd


PROJECT SITE
Bronx Park
Bronx Zoo
Bronxwood
Bronxdale
Parkside Housing Project
Allerton Battfields
Fordham University
Jack Coffey Field
Botanical Garden
Our Lady of Mt Carmel Church
Arthur Avenue Caterers
Belmont
Pelham Pkwy N
Pelham Pkwy S
Bronx and Pelham Pkwy
Fordham Rd
E 187th St
Southern Blvd
Boston Rd
Bronx Park E
White Plains Rd
Waring Ave
Allerton Ave
Burke Ave
Adee Ave
Arrow Ave
Britton St
Mace Ave
Astor Ave
Morris Park
Brady Ave
Dr Theodore A Kazimiroff Blvd
Bronx River Pkwy
Bronx Park Rd
Bronx Park E
Bronx River
Bronx Zoo
Pelham Pkwy
Bronx Park Rd
Bronx River
Bronx Park E
Bronx Park E
Boston Rd
Bronx Park E
White Plains Rd
Bronx Park E
Bronx River
Bronx Park E
Bronx River
Bronx Park E
Bronx River

GENERAL NOTES:

1. ALL CONTOURS AND ELEVATIONS ARE BASED UPON AN ASSUMED DATUM.
2. THE CONTRACTOR SHALL VERIFY ALL EXISTING SITE CONDITIONS, BOTH ABOVE AND BELOW THE SURFACE. ANY DISCREPANCIES BETWEEN INFORMATION SHOWN ON THE DRAWINGS AND ACTUAL FIELD CONDITIONS SHALL BE BROUGHT TO THE ATTENTION OF THE RESIDENT ENGINEER AND NRG IN WRITING, PRIOR TO COMMENCING WORK.
3. TOPOGRAPHY IS BASED UPON SURVEY PERFORMED BY MANUEL ELKEN, CO., P.C. CONSULTING ENGINEERS, LAFAVE, WHITE, McGIVERN, LLC, AND R.B.A. ENGINEERS-ARCHITECTS-PLANNERS AND SUPPLEMENTED BY MILONE & MACBROOM, INC. IN JUNE 2005, AND SUPPLEMENTED ON NOVEMBER 19, 2012, AND JANUARY 23, 2013.
4. FEMA 100-YEAR FLOODPLAIN BOUNDARY FROM FLOOD INSURANCE RATE MAP NUMBER 36047970082F AND 36047970101F, REVISED THROUGH SEPTEMBER 5, 2007.
5. ALL CONTRACTORS ARE REQUIRED TO VISIT THE SITE AND ATTEND THE PRE-BID MEETING PRIOR TO SUBMITTING BIDS.
6. THE CONTRACTOR IS RESPONSIBLE FOR WATER CONTROL DURING THE PROJECT. THE CONTRACTOR SHALL COORDINATE THE WATER CONTROL OF THE DAM AREA WITH THE ENGINEER. THERE SHALL BE NO CLAIMS FOR EXTRA COMPENSATION DUE TO WATER LEVELS RISING FROM NATURAL EVENTS, SUCH AS STORMS, ETC.
7. THE CONTRACTOR AND HIS JOB SUPERINTENDENT SHALL BE RESPONSIBLE FOR COMPLYING WITH THE JOB SPECIFICATIONS. THE CONTRACTOR SHALL DESIGNATE A SUPERINTENDENT AT THE START OF CONSTRUCTION AND THE CONTRACTORS SUPERINTENDENT SHALL BE ON-SITE AT ALL TIMES DURING CONSTRUCTION.
8. THE CONTRACTOR SHALL PROVIDE FIELD SURVEYING SERVICES TO ESTABLISH AND RECORD GRADES, LINES, AND ELEVATIONS.
9. NO CONSTRUCTION VEHICLES SHALL BE STORED, SERVICED, WASHED OR FLUSHED IN A LOCATION WHERE LEAKS, SPILLAGE, WASTE MATERIALS, CLEANERS, OR WATERS WILL BE INTRODUCED OR FLOW INTO WETLANDS, WATERCOURSES, OR ACTIVE PARK AREAS.
10. THE CONTRACTOR SHALL MAINTAIN ALL STREETS, SIDEWALKS, AND WALKWAYS IN THE AREA FREE OF SOIL, MUD AND CONSTRUCTION DEBRIS.
11. THE PROJECT SITE IS SUBJECT TO FLOODING. THE CONTRACTOR SHALL MONITOR WEATHER FORECASTS AND REMOVE EQUIPMENT FROM FLOOD PRONE AREAS IN THE EVENT OF FLOOD WARNINGS. THE UNITED STATES GEOLOGICAL SURVEY OPERATES STREAM FLOW GAUGE #01302020 ON THE BRONX RIVER NEAR THE NEW YORK BOTANICAL GARDENS. THE WEBSITE FOR THE GUAGE IS: HTTP://WATERDATA.USGS.GOV/NWIS/RT
12. THE PROJECT SITE HAS EXTENSIVE PEDESTRIAN USAGE. THE CONTRACTOR MUST STRICTLY ADHERE TO APPROVED ACCESS ROUTES AND WORKING HOURS. PUBLIC SAFETY IS ESSENTIAL.
13. THE CONTRACTOR SHALL SUBMIT A SEQUENCE OF CONSTRUCTION THAT MINIMIZES NOISE, DUST, POLLUTION, AND PUBLIC INCONVENIENCE.
14. ALL STORAGE AND ACCESS ROUTES, PEDESTRIAN FENCES/BARRIERS, WORKING HOURS, AND LIMITS OF CLEARING MUST BE APPROVED BY THE NEW YORK BOTANICAL GARDEN (NYBG), NATURAL RESOURCES GROUP (NRG), AND THE RESIDENT ENGINEER (RE) PRIOR TO BEGINNING ANY OTHER SITE WORK.
15. THE RESIDENT ENGINEER WILL BE DESIGNATED AS A REPRESENTATIVE FROM THE NEW YORK BOTANICAL GARDEN AND THE DEPARTMENT OF PARKS AND RECREATION WHO WILL CONTACT AND GET APPROVAL FROM THE DEPARTMENT OF PARKS AND RECREATION.
16. CONSTRUCTION SHALL NOT OCCUR BETWEEN MARCH AND JUNE UNLESS OTHERWISE INSTRUCTED BY THE NYBG.
17. INFORMATION REGARDING THE LOCATION OF EXISTING UTILITIES HAS BEEN BASED UPON AVAILABLE INFORMATION AND MAY BE INCOMPLETE, AND WHERE SHOWN SHOULD BE CONSIDERED APPROXIMATE. THE LOCATION OF ALL EXISTING UTILITIES SHOULD BE CONFIRMED PRIOR TO BEGINNING CONSTRUCTION. CALL DIG SAFELY NEW YORK "811". ALL UTILITY LOCATIONS THAT DO NOT MATCH THE VERTICAL OR HORIZONTAL CONTROL SHOWN ON THE PLANS SHALL BE BROUGHT TO THE ATTENTION OF THE RE FOR RESOLUTION.



LEGEND

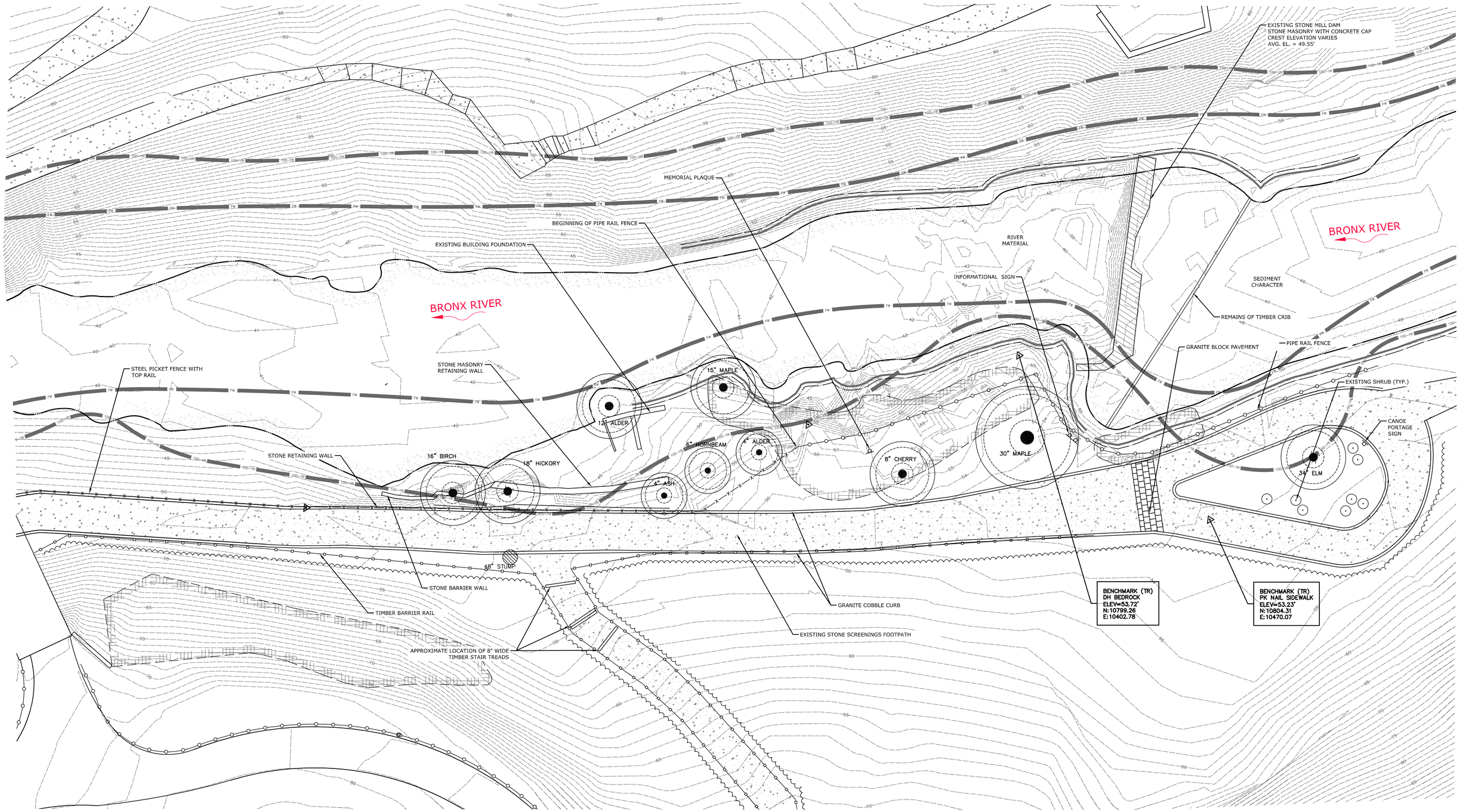
- EXISTING CONTOUR (50)
- EDGE OF ROAD
- COBBLE STONE BAND
- EDGE OF WATER
- EXISTING FENCING
- EDGE OF WETLAND
- EXPOSED LEDGE
- EXISTING STORM DRAIN PIPE
- PROPERTY LINE
- FEMA FLOODWAY (FW)
- FEMA 100-YEAR FLOODPLAIN (100-YR)
- EXISTING LIGHT POLE
- EXISTING TREE (SIZE VARIES) — ABSOLUTE ROOT ZONE / DRIP LINE
- EXISTING CATCH BASIN
- EXISTING STORM DROP GRATE
- EXISTING SIGN
- EXISTING HYDRANT
- GRANITE BLOCK PAVEMENT

GRAPHIC SCALE
15 0 15 30
(IN FEET)
1 inch = 30 ft.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: FISH PASSAGE STRUCTURE AROUND THE STONE MILL DAM		
DRAWING TITLE: OVERALL EXISTING CONDITIONS PLAN		
DESIGNED BY: EL/AG	DRAWN BY: DRM	CHECKED BY: JGM
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO.
B-SCAN	SCALE: 1"=30'	DRAWING NO.: 02
	DATE: 2/26/2014	XXXX-XXXX
		SHEET NO. 02 OF 15 SHEETS



LEGEND

- EXISTING CONTOUR (50)
- EDGE OF ROAD
- GRANITE COBBLE CURB
- EDGE OF WATER
- EDGE OF WETLAND
- EXPOSED LEDGE
- PROPERTY LINE
- FEMA FLOODWAY (FW)
- FEMA 100-YEAR FLOODPLAIN (100-YR)
- STEEL PICKET FENCE (4FT)
- PIPE RAIL FENCE (TWO RAIL)
- TIMBER BARRIER RAIL (ONE RAIL)
- STONE SCREENINGS FOOTPATH
- EXISTING TREE (SIZE VARIES) — ABSOLUTE ROOT ZONE / DRIP LINE
- SHRUB
- SIGN

GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York Parks & Recreation

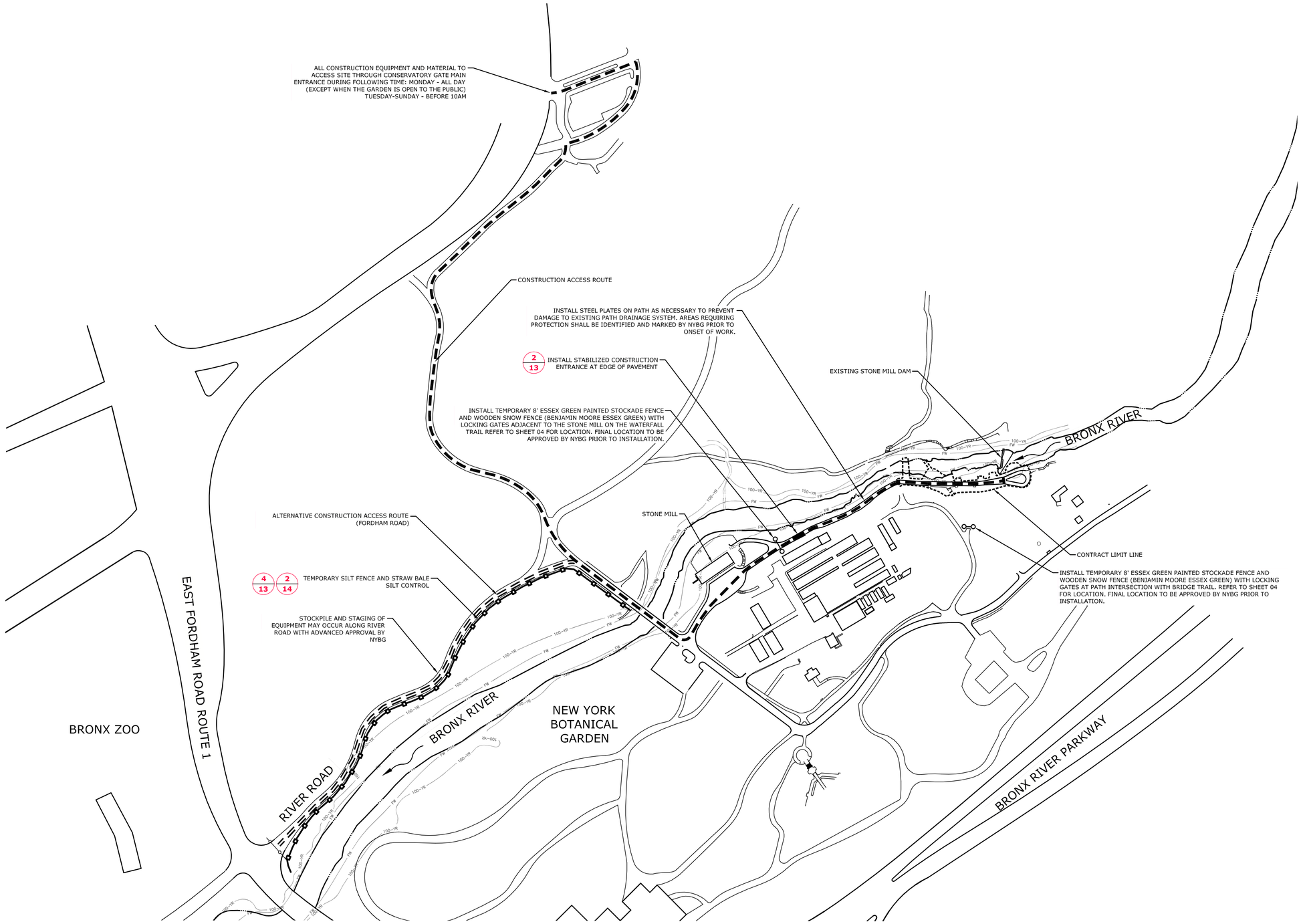
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: FISH PASSAGE STRUCTURE AROUND THE STONE MILL DAM

DRAWING TITLE: EXISTING CONDITIONS PLAN

DESIGNED BY	DRAWN BY	CHECKED BY
EL/AG	DRM	JGM
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO.
B-SCAN	SCALE 1"=10'	DRAWING NO. 03
	DATE 2/26/2014	XXXX-XXXX

SHEET NO. 03 OF 15 SHEETS



LEGEND

- EXISTING CONTOUR (50)
- EDGE OF ROAD
- EDGE OF WATER
- TREELINE
- EXISTING FENCING
- EDGE OF WETLAND
- EXPOSED LEDGE
- EXISTING STORM DRAIN PIPE
- PROPERTY LINE
- FEMA FLOODWAY (FW)
- FEMA 100-YEAR FLOODPLAIN (100-YR)
- EXISTING LIGHT POLE
- EXISTING TREE (SIZE VARIES) (ABSOLUTE ROOT ZONE / DRIP LINE)
- EXISTING CATCH BASIN
- EXISTING STORM DROP GRATE
- EXISTING SIGN
- EXISTING HYDRANT

CONSTRUCTION NOTES:

1. PRIOR TO PERFORMING ANY WORK WITHIN THE NEW YORK BOTANICAL GARDEN LIMITS, CONTRACTOR SHALL COORDINATE WORK PLAN WITH THE NATURAL RESOURCES GROUP AND BOTANICAL GARDEN STAFF. THESE GROUPS SHALL BE NOTIFIED OF ANY PROPOSED WORK A MINIMUM OF 48-HOURS IN ADVANCE, AND SHALL INCLUDE ANY AND ALL CONSTRUCTION ACTIVITIES.
2. THERE IS AND SHALL BE NO POWER OR WATER UTILITIES LOCATED ON SITE.
3. NO ORANGE MESH CONSTRUCTION FENCING IS ALLOWED.
4. MUD ON TRUCKS MUST BE WASHED CLEAN BEFORE RE-ENTERING ROADWAY.
5. VEHICLES MOVING THROUGH SITE DURING BUSINESS HOURS REQUIRE SECURITY ESCORT.
6. CONSTRUCTION ROUTES MUST BE SWEPT CLEAN ALONG THE ENTIRE ROUTE AFTER EACH VEHICLE PASSES.
7. MATERIALS AND EQUIPMENT STORAGE AND STOCKPILE AREA ALONG RIVER ROAD AT ALL TIMES IS TO BE KEPT NEAT AND TIDY TO THE SATISFACTION OF THE OWNER.
8. RIVER ROAD TO BE RESTORED TO ITS PRECONSTRUCTION CONDITION, FOLLOWING COMPLETION OF CONSTRUCTION.
9. COORDINATE WITH NYBG REGRADING LOCATIONS OF SUBSURFACE PATH DRAINAGE STRUCTURES TO BE PROTECTED FOR THE DURATION OF CONSTRUCTION. AREAS TO BE IDENTIFIED AND MARKED BY NYBG PRIOR TO ONSET OF WORK. ANY DAMAGE TO DRAINAGE STRUCTURES TO BE REPAIRED/REPLACED TO THE OWNER'S SATISFACTION AT THE CONTRACTORS EXPENSE.
10. NO WORK TO OCCUR BETWEEN NOVEMBER 1 AND NOVEMBER 15 TO ALLOW FOR CANOE PORTAGE THROUGH THE PROJECT SITE. THE SITE SHALL BE SECURED, AND TEMPORARY FENCING ERECTED TO ALLOW FOR PEDESTRIAN ACCESS WITH CANOES FROM UPSTREAM OF THE DAM TO THE STONE MILL.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

GRAPHIC SCALE
60 0 60 120
(IN FEET)
1 inch = 120 ft.

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE
FISH PASSAGE STRUCTURE
AROUND THE STONE MILL DAM

DRAWING TITLE
CONSTRUCTION ACCESS AND STAGING

DESIGNED BY EL/AG	DRAWN BY DRM	CHECKED BY JGM
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. XXXX-XXXX
B-SCAN	SCALE 1"=120	DRAWING NO. 04
	DATE 2/25/2014	

SHEET NO. 04 OF 15 SHEETS

PROJ NAME:

PROJ #:

TREE #	SPECIES	D.B.H. (INCHES)	TOTAL TREE HEIGHT (FT)	CROWN HEIGHT (FT)	CROWN WIDTH (FT)	AGE CLASS (Y-<20%, M-20-80%, OM->80% of Life Expectancy)	PRUNING ANSI A-300: Cleaning	Raising	Reducing	Restoring	Structural	Thinning	Limb Tying	REMOVAL (condition)	REMOVAL (design)	REMOVAL (stump only)	TRANSPLANT	CONDITION ROOTS: Structure (1-4)	Health (1-4)	Subtotal (2-8)	TRUNK: Structure (1-4)	Health (1-4)	Subtotal (2-8)	SCAFFOLD BRANCHES: Structure (1-4)	Health (1-4)	Subtotal (2-8)	SMALL BRANCHES (1-4)	BUDS & FOLIAGE (1-4)	SUBTOTAL (32)	COMMENTS
1	ELM, AMERICAN	34	70	45	35	OM												4	4	8	4	4	8	4	4	8	3	4	31	
2	MAPLE, SUGAR	30	45	25	30	OM												4	3	7	1	2	3	4	4	8	4	4	26	
3	CHERRY, BLACK	8	20	10	8	M												4	4	8	4	4	8	4	4	8	2	4	30	
4	ASH, OTHER	4	20	12	5	Y												4	4	8	4	4	8	4	4	8	4	4	32	Note: there was another tree here that was removed and a stump remains, there is now a 3" Ash tree
5	MAPLE, RED	15	50	30	15	M												4	4	8	2	4	6	4	4	8	4	4	30	
6	ALDER, EUROPEAN	12	30	15	10	M												4	4	8	4	4	8	4	4	8	4	4	32	
7	HICKORY, OTHER	18	55	20	9	M												3	4	7	4	4	8	4	4	8	4	4	31	
8	BIRCH, OTHER	16	40	20	15	M									X			2	3	5	4	3	7	4	3	7	4	4	27	Removal pending site access
9	HORNBEAM, EUROPEAN	6	15	5	6	M												3	4	7	4	4	8	4	4	8	4	4	31	
10	ALDER, EUROPEAN	4	12	12	7	Y												2	4	6	4	2	6	4	4	8	4	4	28	

LEGEND

- CONTRACT LIMIT LINE
- EXISTING TIMBER BARRIER RAIL
- EXISTING STEEL PICKET FENCE (4FT)
- EXISTING PIPE RAIL FENCE (TWO RAIL)
- ESSEX GREEN PAINTED STOCKADE FENCE WITH LOCKING GATE
- STABILIZED CONSTRUCTION ENTRANCE
- CATCH BASIN SILT SACK - INLET PROTECTION
- TEMPORARY SILT FENCE AND TEMPORARY STRAW BALE SILT CONTROL
- EXISTING TREE (#1; DRIP LINE; ABSOLUTE ROOT ZONE)
- CONSTRUCTION ACCESS ROUTE
- TEMPORARY SEDIMENT TRAP
- TEMPORARY WOODEN TREE GUARD WITH TREE WRAP
- TEMPORARY COFFERDAM
- STABILIZED CONSTRUCTION ENTRANCE
- TREE TO BE REMOVED
- FENCE TO BE REMOVED
- STONE SCREENINGS FOOTPATH TO BE REMOVED

SAFETY PLAN

THE SAFETY PLAN CONSISTS OF TWO ELEMENTS, THE FIRST INVOLVING THE CONSTRUCTION SITE AND WORKER AND PUBLIC SAFETY. THE SECOND INVOLVED DOWNSTREAM AREAS, WHICH ARE ADDRESSED UNDER THE EMERGENCY ACCESS PLAN.

1. THE CONTRACTOR SHALL INSTALL TEMPORARY FENCING AND SUITABLE BARRICADES AS WELL AS LOCKED GATES TO PREVENT PUBLIC ACCESS TO THE CONSTRUCTION SITE.
2. THE CONTRACTOR SHALL INSTALL TEMPORARY 8' ESSEX GREEN PAINTED STOCKADE FENCE AND WOODEN SNOW FENCE (BENJAMIN MOORE ESSEX GREEN) AROUND THE PERIMETER OF THE CONSTRUCTION STAGING AREA.
3. THE CONTRACTOR SHALL PROVIDE EMERGENCY CONTACT PHONE NUMBERS TO LOCAL EMERGENCY DEPARTMENTS (POLICE, FIRE, EMS, ETC.) AS WELL AS THE RE, OWNER, AND NRG.
4. APPROPRIATE LOCAL EMERGENCY RESPONSE PERSONNEL SHALL BE PROVIDED KEYS TO ALL ACCESS GATES.
5. THE CONTRACTOR SHALL NOT ALLOW THE GENERAL PUBLIC ONTO THE CONSTRUCTION SITE.
6. ALL PERSONS ON THE SITE, INCLUDING CONSTRUCTION CREWS, RESTORATION SYSTEMS, REPRESENTATIVES OF THE ENGINEER AND THE OWNER, AUTHORIZED VISITORS, AND OTHERS MUST WEAR ORANGE REFLECTIVE VESTS AND HARD HATS.
7. THE CONTRACTOR SHALL POST EMERGENCY PHONE NUMBERS FOR POLICE, FIRE, AND MEDICAL SERVICES AT THE CONSTRUCTION SITE.
8. THE CONTRACTOR SHALL KEEP A FIRST-AID KIT ON THE SITE AT ALL TIMES.
9. THE CONTRACTOR SHALL POST "KEEP OUT" AND/OR OTHER CAUTIONARY SIGNS ON THE SAFETY FENCING SITUATED AROUND THE PERIMETER OF THE WORK AREA.
10. THE CONTRACTOR SHALL MAINTAIN A SAFETY BOAT AND RESCUE PERSONNEL ON SITE IN ACCORDANCE WITH OSHA REQUIREMENTS.
11. THE CONTRACTOR SHALL PROVIDE FLAGGERS WHEN CROSSING PUBLIC AREAS WITH VEHICLES OR CONSTRUCTION EQUIPMENT.
12. WATER CONTROL DETAILS SUPPLIED ON THIS SHEET ARE SUGGESTED MATERIALS/METHODS ONLY AND NOT FOR CONSTRUCTION WITHOUT ENGINEER'S STAMP AND SIGNATURE THROUGH THE SUBMITTALS PROCESS. SEE SPECIFICATIONS FOR FURTHER INFORMATION ON RESTRICTIONS AND SUBMITTAL REQUIREMENTS. CONTRACTOR SHALL SUBMIT WATER CONTROL PLAN DETAILING PROPOSED METHOD OF WATER CONTROL, INCLUDING SIZES, TYPES, AND CONSTRUCTION DETAILS OF PROPOSED METHODS, FOR APPROVAL BY RE AND NRG.

EMERGENCY ACTION PLAN

1. THE CONTRACTOR SHALL MONITOR LOCAL WEATHER FORECASTS, PRECIPITATION, RIVER STAGE, AND FLOW RATES ON A DAILY BASIS. THE CONTRACTOR IS RESPONSIBLE TO ADJUST WORK SCHEDULES AND REMOVE EQUIPMENT FROM THE RIVER PRIOR TO RAINFALL EVENTS THAT MAY CAUSE RISING WATER LEVELS. IN THE EVENT OF MORE THAN ONE INCH OF RAIN IN A 24-HOUR PERIOD, OR THE FORECAST OF A TROPICAL STORM OR HURRICANE, ALL EQUIPMENT, FLOATABLES, FUEL, AND OTHER POSSIBLE CONTAMINANTS ARE TO BE MOVED OUT OF THE FEMA DESIGNATED 100-YEAR FLOODPLAIN.
2. BRONX RIVER STAGE AND FLOW NOTES: THE CONTRACTOR SHALL MONITOR RIVER FLOW RATES AS LISTED AT THE UNITED STATES GEOLOGICAL SURVEY WEB SITE: http://waterdata.usgs.gov/ny/nwis/uv/?site_no=01302020
3. PRIOR TO INITIATING WORK, THE CONTRACTOR SHALL INSPECT DOWNSTREAM AREAS TO IDENTIFY ZONES THAT COULD POTENTIALLY BE FLOODED WITHIN OR NEAR THE CHANNEL IN THE EVENT OF AN UNEXPECTED WATER RELEASE.
4. THE CONTRACTOR SHALL NOTIFY LOCAL EMERGENCY DEPARTMENTS (FIRE, POLICE, EMS, ETC.) AT THE COMMENCEMENT OF WORK, AND AFTER ANY STOPPAGE OF WORK AND REMOBILIZATION.
5. THE CONTRACTOR SHALL NOTIFY LOCAL EMERGENCY PERSONNEL IN THE EVENT OF MEDICAL EMERGENCIES OR FLOOD RELATED PROBLEMS.

CONSTRUCTION NOTES

1. LOCATION OF OIL BOOM TO BE DETERMINED IN FIELD TO MAXIMIZE DOWNSTREAM PROTECTION. OIL BOOM SHALL BE CLEANED AS NEEDED AND MAINTAINED DAILY.
2. CONTRACTOR TO SUBMIT A CONSTRUCTION SCHEDULE TO THE RE, NRG, AND NYBG FOR ACCEPTANCE PRIOR TO INITIATING WORK.
3. ALL SIGNAGE USED SHALL BE CONSISTENT WITH THE NYBG STANDARDS AND A MOCKUP OF APPEARANCE AND TEXT IS REQUIRED FOR APPROVAL PRIOR TO FABRICATION.
4. THE CONTRACTOR SHALL TAKE SPECIAL CARE TO PROTECT ALL EXISTING TREES AND THEIR ROOT SYSTEMS. EXCAVATIONS WITHIN THE DRIP LINES OF TREES SHALL BE KEPT TO A MINIMUM AND SHALL BE COMPLETED BY HAND ONLY AND SHALL BE PREFORMED IN THE PRESENCE OF THE RE, AT NO ADDITIONAL EXPENSE TO THE NYBG. ROOTS OVER 2" DIAMETER SHALL NOT BE DISTURBED AND BRIDGE CURBS SHALL BE CONSTRUCTED WHERE NECESSARY.

CONSTRUCTION SEQUENCE

THIS PROPOSED SEQUENCE OF CONSTRUCTION IS PROVIDED FOR GENERAL INFORMATION ONLY. THE OVERALL SEQUENCE OF CONSTRUCTION IS TO BE DETERMINED AND SUBMITTED BY THE CONTRACTOR AND APPROVED BY THE ENGINEER.

1. OBTAIN ANY NECESSARY PERMITS AND SUBMIT SCHEDULES, PLANS AND PRODUCT INFORMATION, INCLUDING THE WATER CONTROL PLAN AND EMERGENCY OPERATION PLAN DURING CONSTRUCTION TO THE ENGINEER FOR REVIEW, 30 DAYS PRIOR TO INITIATION OF CONSTRUCTION.
2. INSTALL TEMPORARY SEDIMENTATION AND EROSION CONTROLS AS SHOWN ON PLANS, PRIOR TO ANY REMOVALS OCCURRING. INSTALL PEDESTRIAN FENCES/BARRICADES AND CAUTION SIGNS.
3. INSTALL STABILIZED CONSTRUCTION ENTRANCE TO SITE. INSTALL TREE PROTECTION AND CLEAR/GRUB AREAS AS INDICATED ON THE PLANS.
4. INSTALL FLOATING OIL BOOM.
5. INSTALL UPSTREAM AND DOWNSTREAM COFFERDAM AS SHOWN ON PLANS, AND INSTALL DEWATERING PUMPS AND SETTLING BASINS FOR WORK AREAS.
6. CONSTRUCT PROPOSED CONCRETE WALLS AND FISHWAY EXIT POOL AS SHOWN ON THE PLANS. INSTALL PRE-MANUFACTURED ALUMINUM STEEP-PASS FISH LADDER.
7. CONSTRUCT CAST-IN PLACE CONCRETE FISHWAY SECTIONS, FISHWAY ENTRANCE, FISHWAY TURN POOL WALLS, AND FISHWAY SIDEWALLS.
7. INSTALL GRATING AND RAILING ABOVE FISHWAY, AND WEIR BOARDS AT FISHWAY ENTRANCE POOL AS SHOWN ON THE PLANS.
9. INSTALL BOULDER CLUSTERS IN CHANNEL IN THE WET AS SHOWN ON PLANS.
10. REMOVE ALL WATER CONTROL MEASURES.
11. INITIATE FLOW TO FISHWAY. ADJUST WEIR BOARDS IF NECESSARY AT THE DIRECTION OF THE ENGINEER AND OWNER.
12. REMOVE CONSTRUCTION ENTRANCE PAD AND SEDIMENTATION AND EROSION CONTROLS.
14. RESTORE SITE AS NECESSARY, REFER TO THE RESTORATION PLAN. RESTORE SITE TO ORIGINAL CONDITION, AND REPLANT DISTURBED AREAS.

GRAPHIC SCALE 5 0 5 10 (IN FEET) 1 inch = 10 ft.

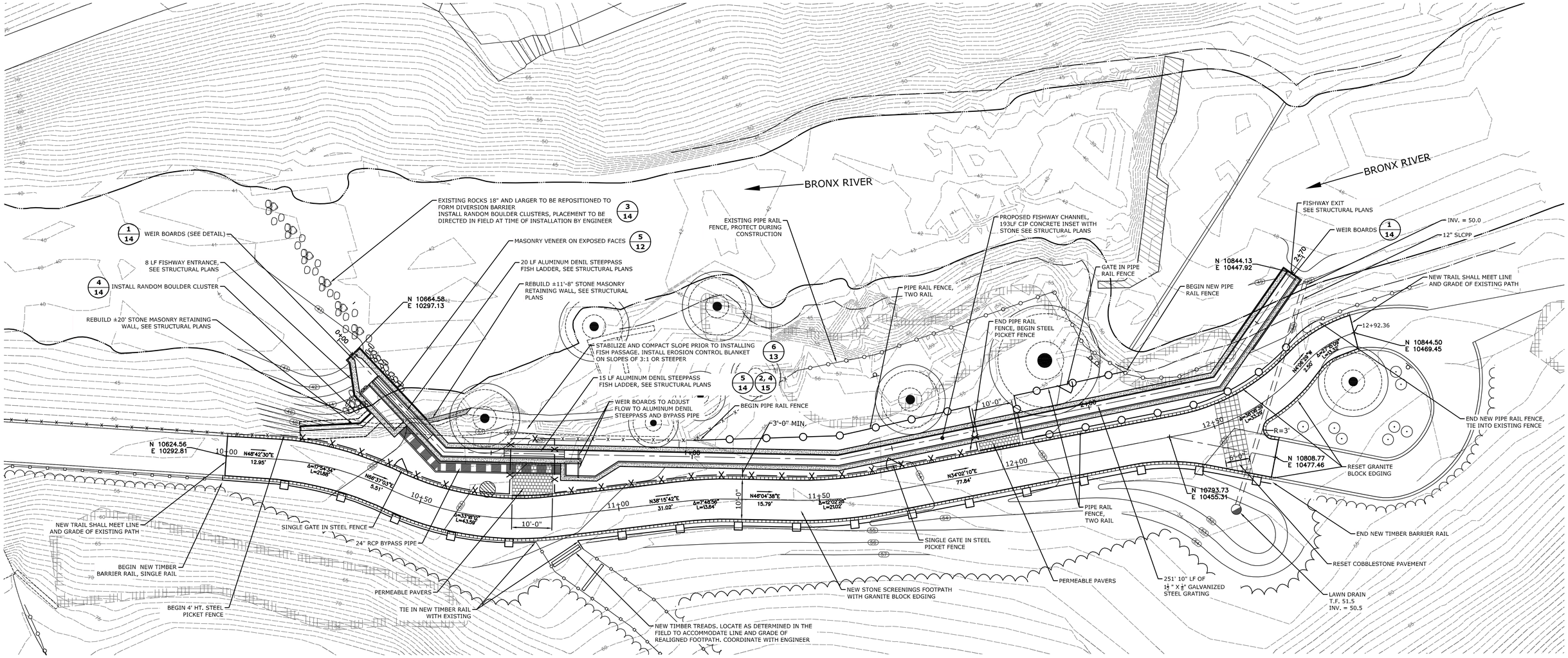
MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: FISH PASSAGE STRUCTURE AROUND THE STONE MILL DAM

DRAWING TITLE: REMOVALS, WATER CONTROL, AND SEDIMENT AND EROSION CONTROL

DESIGNED BY	DRAWN BY	CHECKED BY
EI/AG	GDW	JGM/NRG/SK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. XXXX-XXXX
B-SCAN	SCALE 1"=10' / DATE 2/28/2014 / DRAWING NO. 05	SHEET NO. 05 OF 15 SHEETS



PROPOSED FISHWAY - PLAN VIEW
(SCALE: 1" = 10')

LEGEND

- EXISTING CONTOUR (50)
- EDGE OF ROAD
- GRANITE BLOCK EDGING
- EDGE OF WATER
- EDGE OF WETLAND
- EXPOSED LEDGE
- PROPERTY LINE
- EXISTING STEEL PICKET FENCE (4FT)
- EXISTING PIPE RAIL FENCE (TWO RAIL)
- EXISTING TIMBER BARRIER RAIL (ONE RAIL)
- FEMA FLOODWAY (FW)
- FEMA 100-YEAR FLOODPLAIN (100-YR)
- PROPOSED 4' HT. STEEL PICKET FENCING
- PROPOSED DOUBLE PIPE RAIL FENCING
- PROPOSED TIMBER BARRIER RAIL FENCING
- PROPOSED TREELINE
- STONE SCREENINGS FOOTPATH
- PROPOSED PERMEABLE PAVERS
- RESET GRANITE BLOCK PAVEMENT
- EXISTING TREE (ABSOLUTE ROOT ZONE, DRIP LINE)
- SHRUB
- SIGN

LAYOUT & MATERIALS NOTES:

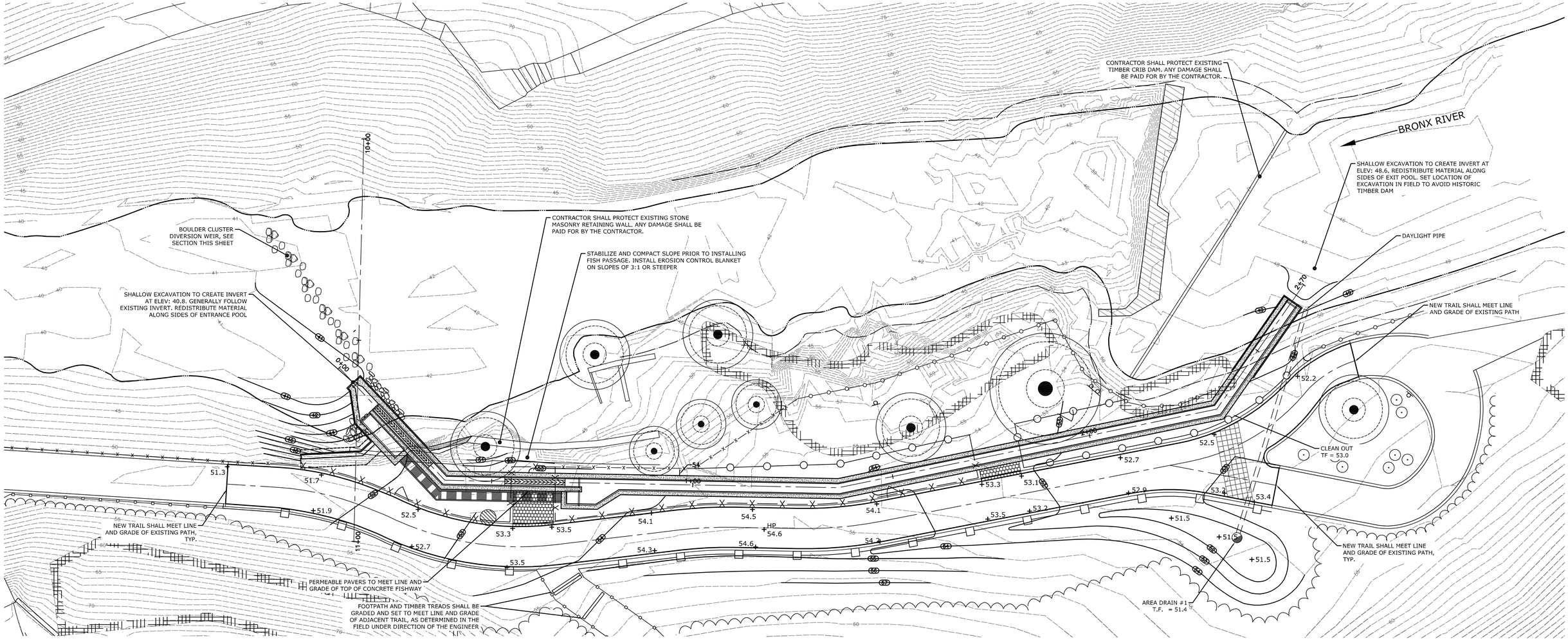
1. EXISTING SURVEY AND TOPOGRAPHICAL DATA TAKEN FROM MILONE & MACBROOM SURVEY, DATED MAY 2009.
2. THE CONTRACTOR SHALL VERIFY ALL EXISTING SITE CONDITIONS, BOTH ABOVE AND BELOW THE SURFACE. ANY DISCREPANCIES BETWEEN INFORMATION SHOWN ON THE DRAWINGS AND ACTUAL FIELD CONDITIONS SHALL BE BROUGHT TO THE ATTENTION OF THE RESIDENT ENGINEER AND NRG IN WRITING, PRIOR TO COMMENCING WORK.
3. LOCATIONS OF EXISTING TREES SHALL BE VERIFIED IN THE FIELD.
4. NO CHANGES SHALL BE MADE TO THE DESIGN OR LAYOUT WITHOUT THE WRITTEN APPROVAL OF THE RESIDENT ENGINEER. LAYOUT THE WORK AS DIMENSIONED ON THE PLANS. WRITTEN DIMENSIONS SHALL GOVERN. DO NOT SCALE DISTANCES.
5. ALL VISIBLE CONCRETE USED ON SITE SHALL BE PIGMENTED A LIGHT GRAY THAT IS CONSISTENT WITH THE GRAY UTILIZED IN THE GARDEN. THE CONTRACTOR SHALL SUBMIT A COLOR SAMPLE TO THE NYBG, NRG, AND RESIDENT ENGINEER FOR APPROVAL PRIOR TO INSTALLATION.
6. CONTRACTOR SHALL LAYOUT AND STAKE IN THE FIELD THE ALIGNMENT OF ALL PATHS, PAVEMENTS AND TRAILS FOR REVIEW BY THE RESIDENT ENGINEER. ADJUSTMENTS MAY BE MADE ONLY AS DIRECTED BY THE RESIDENT ENGINEER. CONTRACTOR MAY NOT PROCEED WITH CONSTRUCTION OF IMPROVEMENTS UNTIL HE/SHE HAS RECEIVED THE FINAL APPROVAL OF THE LAYOUT FROM THE RESIDENT ENGINEER.
7. CONTRACTOR SHALL SUPPLY THE NYBG, NRG, AND RESIDENT ENGINEER WITH A MOCKUP OF THE REBUILT EXISTING STONE RETAINING WALL FOR APPROVAL PRIOR TO RECONSTRUCTION. THE CONTRACTOR SHALL ALSO SUBMIT THE NAME/FIRM OF THE STONE MASON TO BE USED TO THE NYBG, NRG, AND RESIDENT ENGINEER FOR APPROVAL.
8. ALL NEW GRANITE BLOCK LANDSCAPE EDGING SHALL MEET IN A SMOOTH FLUSH CONDITION UNLESS OTHERWISE NOTED.
9. NEW CURBS, WALLS, AND PAVEMENTS SHALL BE BUILT TO A SMOOTH EVEN FINISH WITH A CONSISTENT TOP AND PROFILE WITHOUT WAVES OR IRREGULARITIES. ANY WORK NOT MEETING THIS QUALITY STANDARD SHALL BE REPLACED AT THE CONTRACTOR'S EXPENSE.
10. THE CONTRACTOR SHALL EXERCISE CARE DURING EXCAVATION OPERATIONS TO AVOID DISTURBING ADJACENT FACILITIES, SUB GRADE STRUCTURES AND TREES. ALL DAMAGE RESULTING FROM THE CONSTRUCTION SHALL BE THE CONTRACTOR'S RESPONSIBILITY AND SHALL BE REPAIRED AT NO EXPENSE TO THE NYBG AND THE DEPARTMENT OF PARKS AND RECREATION. ALL REPAIR WORK SHALL BE TO THE SATISFACTION OF THE RESIDENT ENGINEER AND NRG. PLANTED AREAS DISTURBED BY HIS WORK SHALL BE RESTORED AS DIRECTED BY THE RESIDENT ENGINEER AND NRG.
11. NO HEAVY MACHINERY, EQUIPMENT OR STOCKPILING OF MATERIAL IS PERMITTED WITHIN THE DRIP LINES OF EXISTING TREES.
12. THE CONTRACTOR SHALL TAKE SPECIAL CARE TO PROTECT ALL EXISTING TREES AND THEIR ROOT SYSTEM. EXCAVATIONS WITHIN THE DRIP LINES OF TREES SHALL BE KEPT TO A MINIMUM AND SHALL BE COMPLETED BY HAND ONLY AND SHALL BE PERFORMED IN THE PRESENCE OF THE RESIDENT ENGINEER, AT NO ADDITIONAL EXPENSE TO THE NYBG. ROOTS OVER 2" DIAMETER SHALL NOT BE DISTURBED AND BRIDGE CURBS SHALL BE CONSTRUCTED WHERE NECESSARY.
13. IN AREAS WHERE NEW PAVEMENTS FALL WITHIN THE DRIP LINE OF EXISTING TREES, THE CONTRACTOR SHALL MINIMIZE EXCAVATIONS AT TREE ROOTS BY REDUCING THE AMOUNT OF FOUNDATION MATERIAL AS DIRECTED BY RESIDENT ENGINEER.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

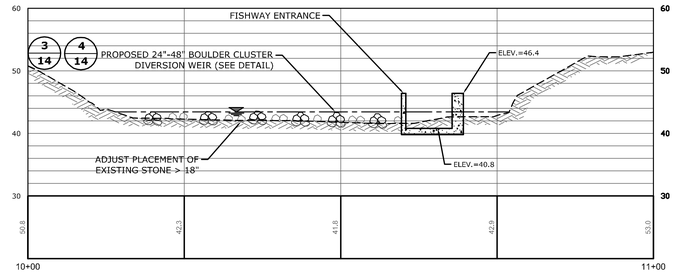
GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: FISH PASSAGE STRUCTURE AROUND THE STONE MILL DAM		
DRAWING TITLE: LAYOUT PLAN		
DESIGNED BY: EL/AG	DRAWN BY: SEP	CHECKED BY: JGM/RGSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO.: XXXX-XXXX
B-SCAN	SCALE: 1"=10'	DRAWING NO.: 06
	DATE: 2/28/2014	SHEET NO. 06 OF 15 SHEETS



PROPOSED FISHWAY - PLAN VIEW
(SCALE: 1" = 10')



PROPOSED BOULDER CLUSTER DIVERSION WEIR SECTION VIEW
(SCALE: 1" = 10'(H) 1" = 10'V)

LEGEND

- EXISTING CONTOUR (50)
- EDGE OF ROAD
- GRANITE BLOCK EDGING
- EDGE OF WATER
- EDGE OF WETLAND
- EXPOSED LEDGE
- PROPERTY LINE
- EXISTING STEEL PICKET FENCE (4FT)
- EXISTING PIPE RAIL FENCE (TWO RAIL)
- EXISTING TIMBER BARRIER RAIL (ONE RAIL)
- FEMA FLOODWAY (FW)
- FEMA 100-YEAR FLOODPLAIN (100-YR)
- PROPOSED 4' HT. STEEL PICKET FENCING
- PROPOSED DOUBLE PIPE RAIL FENCING
- PROPOSED TIMBER BARRIER RAIL FENCING
- PROPOSED TREELINE
- STONE SCREENINGS FOOTPATH
- PROPOSED PERMEABLE PAVERS
- RESET GRANITE BLOCK PAVEMENT
- EXISTING TREE (ABSOLUTE ROOT ZONE, DRIP LINE)
- SHRUB
- SIGN

GRADING NOTES:

1. ALL PATHWAYS SHALL BE INSTALLED TO SMOOTH EVEN GRADE WITH NO PATCHING, IRREGULARITIES, OR DEPRESSIONS.
2. ALL GRADES SHOULD BE VERIFIED IN FIELD BY FISHWAY CONSTRUCTION ENGINEERING SPECIALIST.
3. CONTRACTOR SHALL PROVIDE FIELD SURVEYING SERVICES TO ESTABLISH AND RECORD GRADES, LINES, AND ELEVATIONS FOR APPROVAL BY NRG. FINAL ELEVATIONS FOR ALL CAST-IN-PLACE INSTALLATIONS OF FISHWAY SHALL BE VERIFIED BY RE, NRG, AND FISHWAY SPECIALIST (COORDINATED BY NRG) DURING INSTALLATION OF FORMWORK AND PRIOR TO PLACEMENT OF CONCRETE. NRG RESERVES THE RIGHT TO ADJUST LAYOUT AND ELEVATIONS IN THE FIELD TO ENSURE PROPER FUNCTIONING OF FISHWAY, AT NO ADDITIONAL COST TO NYGB.

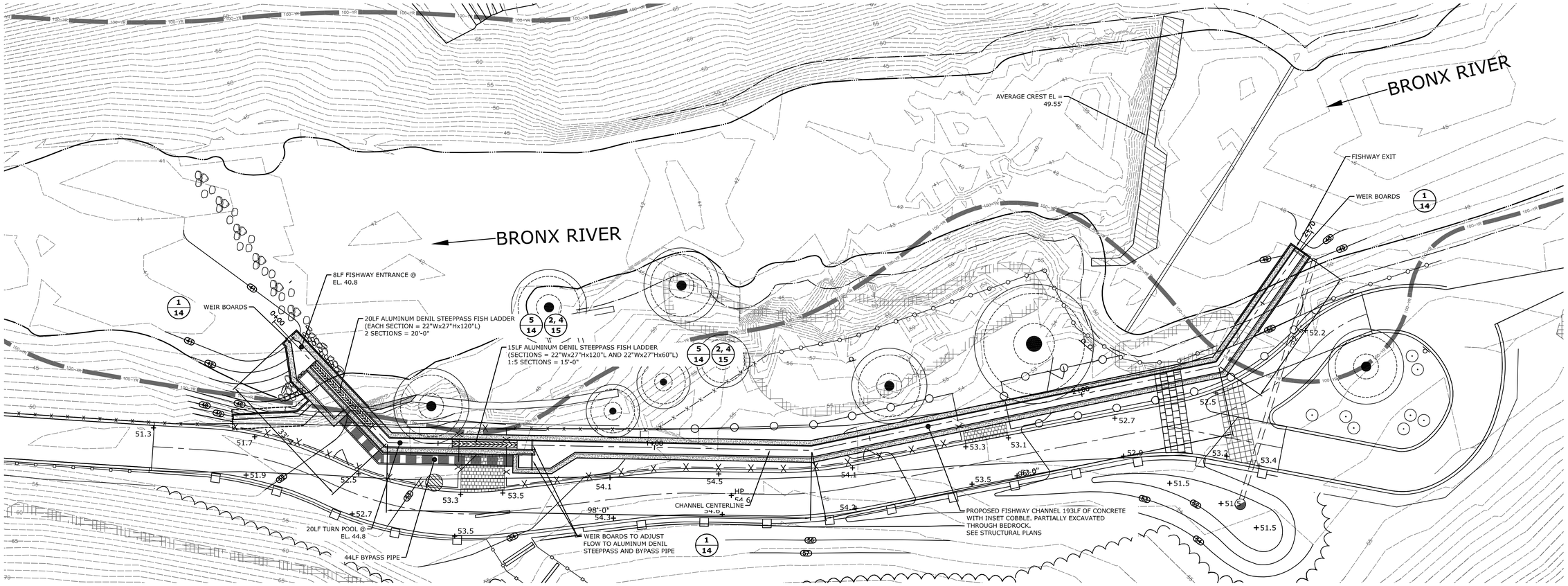
GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

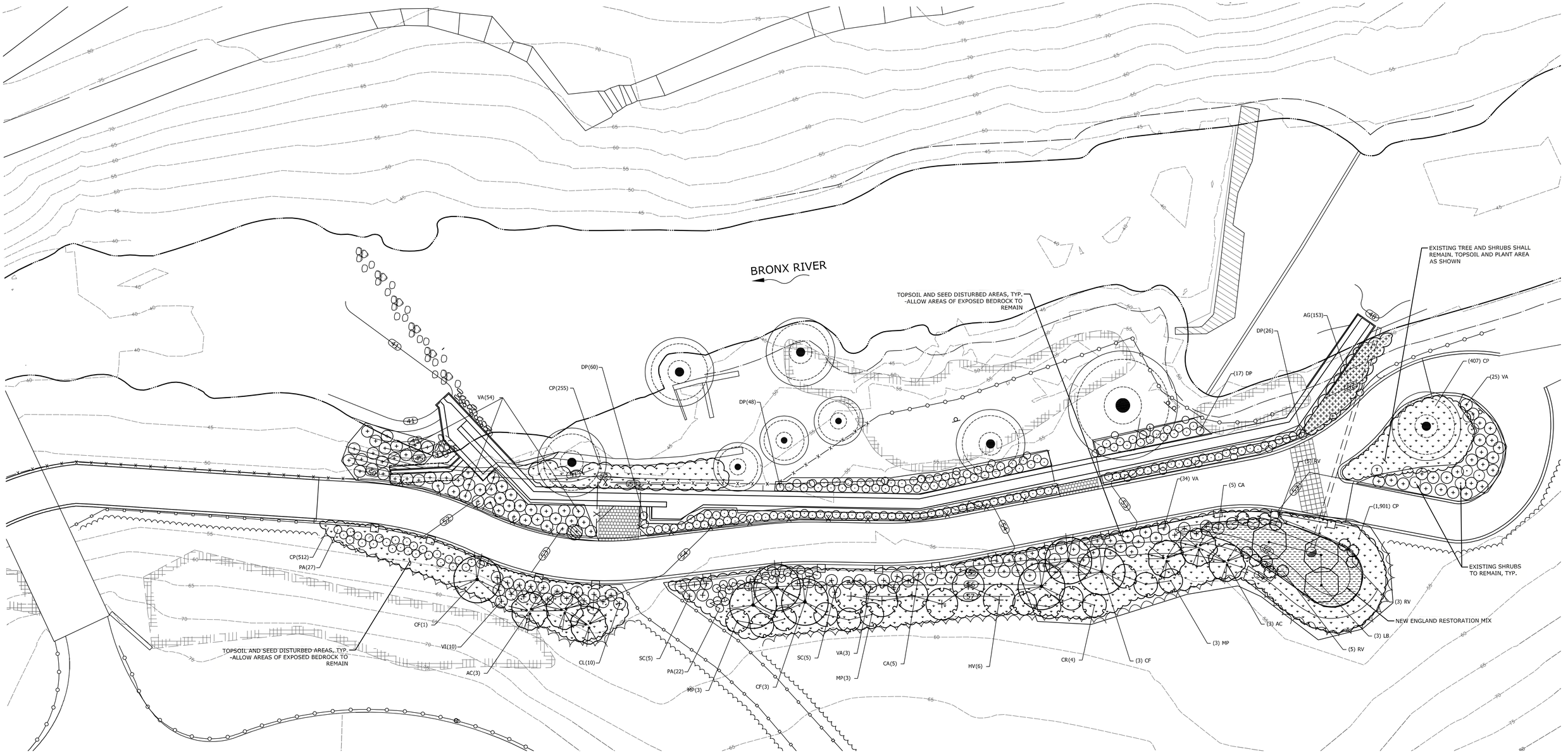
MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: FISH PASSAGE STRUCTURE AROUND THE STONE MILL DAM		
DRAWING TITLE: GRADING PLAN		
DESIGNED BY: EL/AG	DRAWN BY: SEP	CHECKED BY: JGM/RGSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. XXXX-XXXX
B-SCAN	SCALE 1"=10' / DATE 2/25/2014	DRAWING NO. 07

SHEET NO. 07 OF 15 SHEETS


BRONX RIVER
BRONX RIVER
AVERAGE CREST EL = 49.55'
FISHWAY EXIT
WEIR BOARDS
1/14
8LF FISHWAY ENTRANCE @ EL. 40.8
WEIR BOARDS
1/14
20LF ALUMINUM DENIL STEEPPASS FISH LADDER (EACH SECTION = 22"Wx27"Hx120"L) 2 SECTIONS = 20'-0"
5/14
2, 4/15
15LF ALUMINUM DENIL STEEPPASS FISH LADDER (SECTIONS = 22"Wx27"Hx120"L AND 22"Wx27"Hx60"L) 1:5 SECTIONS = 15'-0"
5/14
2, 4/15
20LF TURN POOL @ EL. 44.8
44LF BYPASS PIPE
WEIR BOARDS TO ADJUST FLOW TO ALUMINUM DENIL STEEPPASS AND BYPASS PIPE
1/14
CHANNEL CENTERLINE
PROPOSED FISHWAY CHANNEL 193LF OF CONCRETE WITH INSET COBBLE, PARTIALLY EXCAVATED THROUGH BEDROCK. SEE STRUCTURAL PLANS
98'-0"
51.3
51.7
51.9
52.5
52.7
53.5
53.3
54.1
54.5
54.1
53.3
53.1
52.7
52.2
52.5
53.4
53.4
51.5
51.5
51.5
+1.00
+1.00
+1.00



RESTORATION PLANTINGS

TREES	QTY	BOTANICAL NAME	COMMON NAME	SIZE	COMMENTS
AC	6	Amelanchier canadensis	Canadian Serviceberry	7'/8' HT.	MULTI-STEM
CF	7	Cornus florida	Eastern Dogwood	1.5"-2.0" Cal.	SINGLESTEM

SHRUBS & PERENNIALS	QTY	BOTANICAL NAME	COMMON NAME	CONT.	COMMENTS
CR	4	Cornus racemosa	Gray Dogwood	#2	FULL & DENSE
DP	151	Dennstaedtia punctilobula	Hay-scented Fern	#1	FULL & DENSE
HV	6	Hamamelis virginiana	Common Witch Hazel	#3	FULL & DENSE
MP	9	Morella Pensylvanica	Northern Bayberry	#2	FULL & DENSE
LB	3	Lindera benzoin	Spicebush	#2	FULL & DENSE
PA	49	Polystichum acrostichoides	Christmas Fern	#1	FULL & DENSE
RV	13	Rhododendron viscosum	Swamp Azalea	#2	FULL & DENSE
VA	116	Vaccinum angustifolium	Lowbush Blueberry	#2	FULL & DENSE
VI	10	Viburnum acerifolium	Mapleleaf viburnum	#2	FULL & DENSE
CL	10	Clethra Anifolia	Summersweet	#2	FULL & DENSE
SC	10	Sambucus Canadensis	American Elderberry	#2	FULL & DENSE
CA	10	Corylus Americana	American Hazelnut	#2	FULL & DENSE

GROUND COVERS	QTY	BOTANICAL NAME	COMMON NAME	CONT	SPACING
AG	153	Acorus gramineus	Sweet flag	flat	12" o.c.
CP	3,075	Carex pensylvanica	Pennsylvania Sedge	flat	12" o.c.

New England Restoration Mix, AS SUPPLIED BY NEW ENGLAND WETLAND PLANTS, INC., SEE NOTES

ABBREVIATIONS
QTY = QUANTITY
HT. = HEIGHT
CAL. = CALIPER
CONT. = CONTAINER
TYP. = TYPICAL

PLANTING NOTES

1. THE CONTRACTOR SHALL VERIFY THE LOCATION OF ALL UNDERGROUND UTILITIES PRIOR TO EXCAVATING PLANT PITS.
2. THE LANDSCAPE CONTRACTOR SHALL PROVIDE A 6" MINIMUM DEPTH OF TOPSOIL FOR ALL LAWN PLANTED AREAS AS NECESSARY TO ESTABLISH.
3. ALL PLANTING BEDS SHALL HAVE 12" MINIMUM DEPTH OF TOPSOIL.
4. THE LANDSCAPE CONTRACTOR SHALL PROVIDE A 4" MIN. DEPTH OF SHREDDED MULCH OVER ALL PLANTING BEDS AND TREE PLANTINGS. NO DYED MULCH. ALL PLUGS SHALL BE LIGHTLY MULCHED WITH 2"-3" OF SHREDDED NON-DYED BARK MULCH.
5. ALL PLANT MATERIAL IS SUBJECT TO INSPECTION AND APPROVAL BY THE LANDSCAPE ARCHITECT/ENGINEER PRIOR TO AND AFTER PLANTING.
6. PLANT SPECIES MAY BE ADJUSTED BASED ON AVAILABILITY AT TIME OF PLANTING. ALL PLANT MATERIAL SUBSTITUTIONS ARE SUBJECT TO REVIEW AND APPROVAL BY THE LANDSCAPE ARCHITECT, RESIDENT ENGINEER, NYBG, AND NRG.
7. ALL PLANT MATERIALS SHALL CARRY A FULL GUARANTEE FOR A PERIOD OF ONE YEAR FROM THE DATE OF ACCEPTANCE, TO INCLUDE PROMPT TREATMENT OR REMOVAL AND REPLACEMENT OF ANY PLANTS FOUND TO BE IN AN UNHEALTHY CONDITION BY THE LANDSCAPE ARCHITECT RESIDENT ENGINEER, NYBG, AND NRG. ALL REPLACEMENTS SHALL BE OF THE SAME KIND AND SIZE OF PLANTS SPECIFIED IN THE PLANT LIST.
8. MAINTENANCE SHALL BEGIN IMMEDIATELY AFTER PLANTING AND SHALL CONTINUE UNTIL ACCEPTANCE BY THE LANDSCAPE ARCHITECT/ENGINEER. MAINTENANCE SHALL INCLUDE WATERING, MULCHING, TIGHTENING & REPLACING OF GUYS, REPLACEMENT OF SICK OR DEAD PLANTS, RESETTING PLANTS TO PROPER GRADE OR UPRIGHT (PLUMB) POSITION, RESTORATION OF SAUCERS, AND ALL OTHER CARE NEEDED FOR PROPER GROWTH OF THE PLANTS.
9. WHERE A SIZE RANGE IS SPECIFIED AT LEAST 50% OF PLANTS PROVIDED SHALL BE OF THE LARGER SIZE.
10. CONTRACTOR TO REMOVE TREE STAKES AFTER ONE GROWING SEASON.
11. QUANTITY AND PLACEMENT OF PLANTS ARE APPROXIMATE AND ARE SUBJECT TO FINAL PLACEMENT IN THE FIELD BY THE DIRECTING LANDSCAPE ARCHITECT/ENGINEER.
12. NATIVE GRASS SEED MIXES AS SUPPLIED BY NEW ENGLAND WETLAND PLANTS, INC. 820 WEST STREET, AMHERST, MA 01002 (413)548-8000.
13. CAREX PENNSYLVANICA PLANTS SHALL BE PLUGS.
14. ALL HERBACEOUS PLUG PLANTINGS SHALL BE PLANTED BY HAND.
15. PLANTINGS SHALL BE LIMITED TO THE PERIODS OF APRIL 15 - JULY 15, OR SEPTEMBER 15 - OCTOBER 15.
16. ALL PLANTINGS ARE TO BE PLANTED ONLY AFTER STABILIZATION OF CONTRIBUTING DRAINAGE AREAS.
17. IT IS RECOMMENDED THAT A WETLAND SCIENTIST FROM MILONE AND MACBROOM INC. BE ON-SITE DURING LAYOUT AND PLANTING OF PLUGS TO IDENTIFY ACCURATE LOCATIONS FOR SPECIFIC PLANT SPECIES TO ENSURE A HIGH SURVIVAL RATE.
18. TOPSOIL TO CONTAIN 12% ORGANIC CONTENT (BY WEIGHT), AMEND SOIL WITH ORGANIC MATTER (LEAF COMPOST).
19. IN AREAS OF LEDGE ALL PLANT PITS SHALL BE OVER EXCAVATED IN DEPTH AND WIDTH.
20. SITE SHALL BE INSPECTED AND APPROVED BY NYBG STAFF AT COMPLETION OF RESTORATION.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

City of New York Parks & Recreation

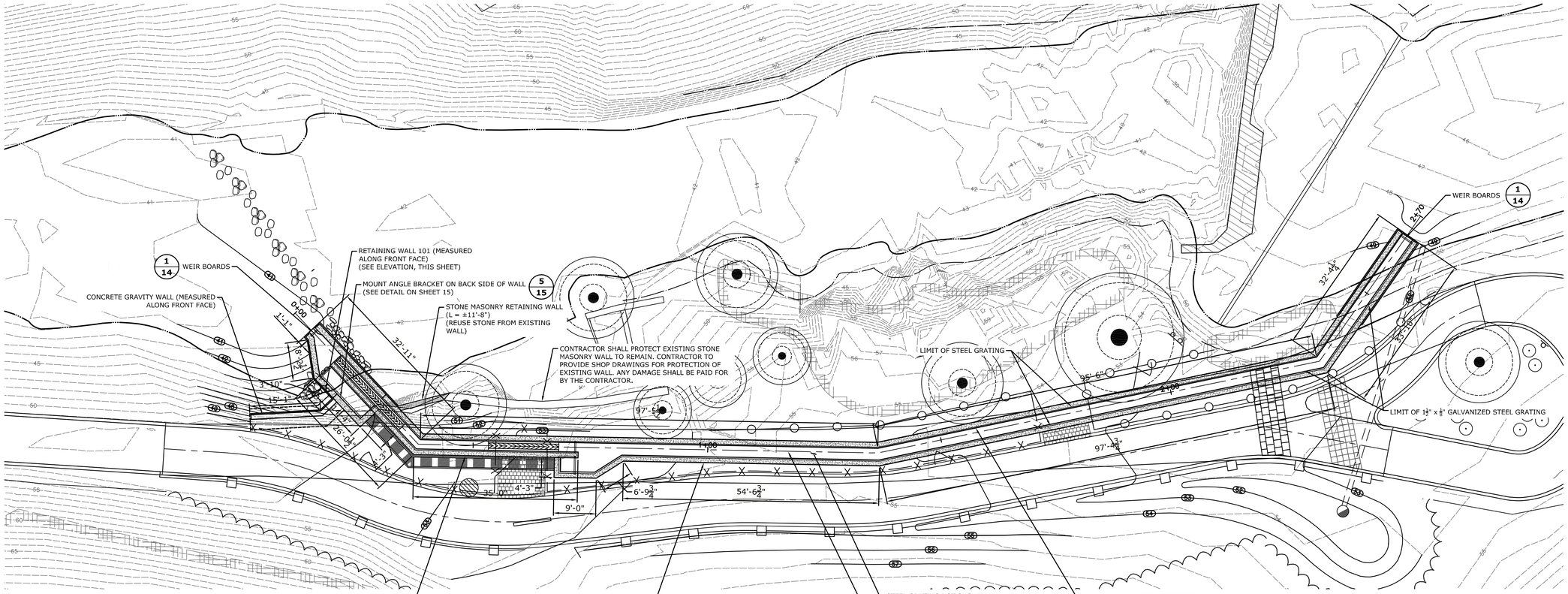
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE
FISH PASSAGE STRUCTURE AROUND THE STONE MILL DAM

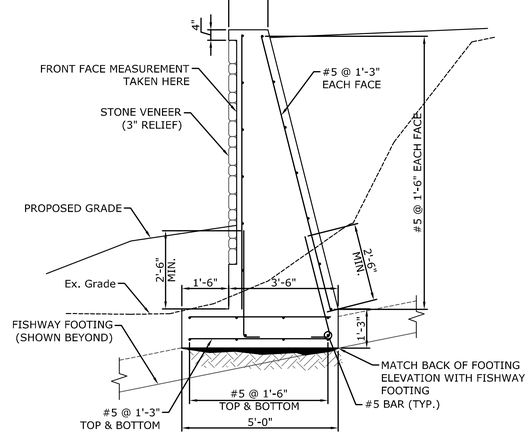
DRAWING TITLE
RESTORATION PLAN

DESIGNED BY	DRAWN BY	CHECKED BY
ELAG	GDW	JGM/MRG/SK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO.
B-SCAN	SCALE 1"=10'	DRAWING NO. 09
	DATE 2/28/2014	XXXX-XXXX

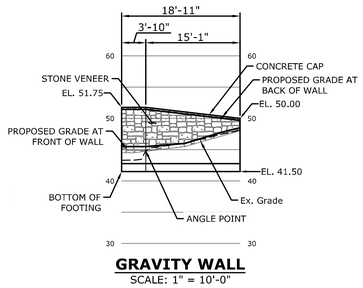
SHEET NO. 09 OF 15 SHEETS



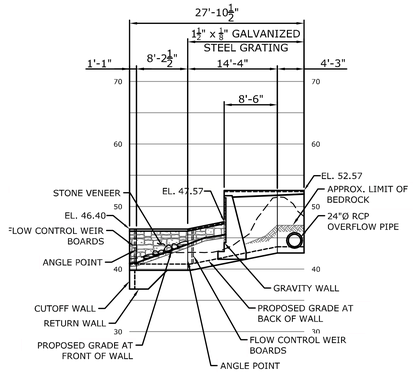
PLAN



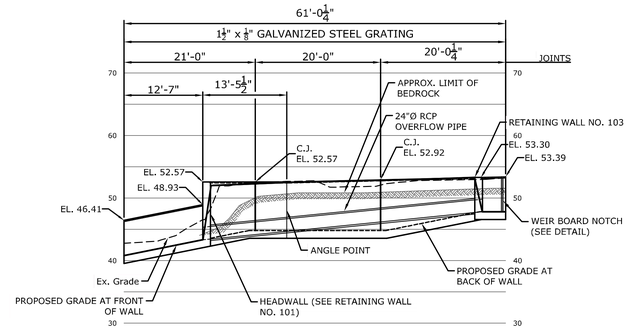
GRAVITY WALL TYPICAL SECTION
SCALE: ½" = 1'-0"



GRAVITY WALL
SCALE: 1" = 10'-0"



RETAINING WALL 101
SCALE: 1" = 10'



RETAINING WALL 102
SCALE: 1" = 10'

NOTE: FOR CHANNEL INVERTS SEE PROFILE ON SHEET 08

LEGEND

- EXISTING CONTOUR (50)
- EDGE OF ROAD
- EDGE OF WATER
- TREELINE
- EXISTING FENCING
- EDGE OF WETLAND
- EXPOSED LEDGE
- PROPERTY LINE
- REINFORCED CONCRETE
- EXISTING LIGHT POLE
- EXISTING TREE (ABSOLUTE ROOT ZONE, DRIP LINE)
- EXISTING SIGN

NOTES:

1. CONTRACTOR SHALL SUBMIT REBAR SCHEDULE FOR ALL REINFORCEMENT WITHIN CONTRACT. SEE SPECIFICATIONS FOR SUBMITTAL DETAILS.
2. REBAR SHALL BE EPOXY COATED.
3. A LEVELING COURSE OF FLOWABLE FILL SHALL BE PLACES BETWEEN BEDROCK AND PROPOSED TOOTING.
4. WHERE ROCK IN NOT ENCOUNTERED AN 8" DEEP COURSE OF PROCESSED AGGREGATE SHALL BE INSTALLED AS BEDDING MATERIAL FOR PROPOSED FOOTING.

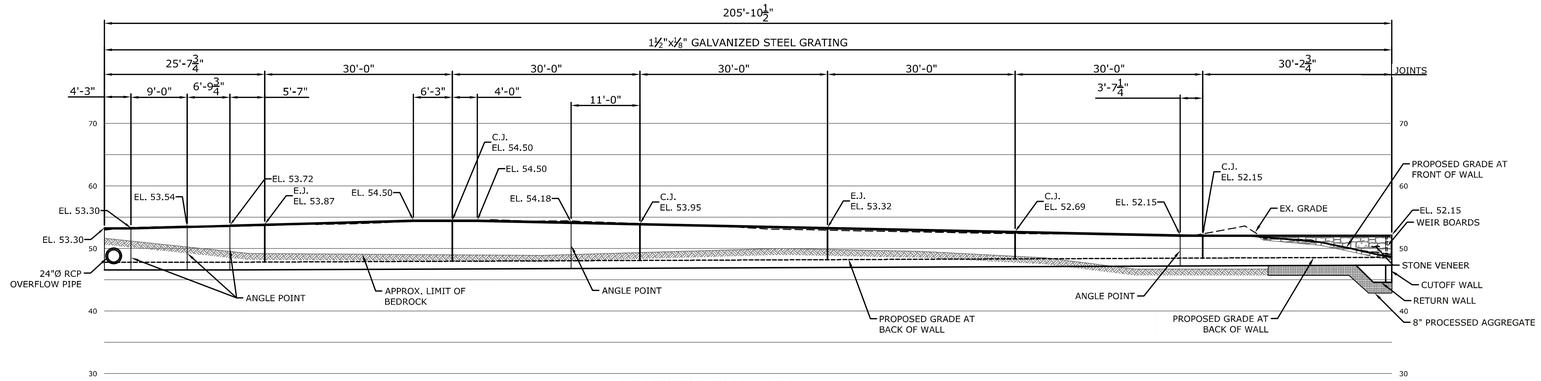
GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

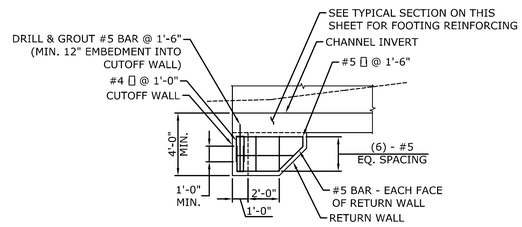
PROJECT TITLE: FISH PASSAGE STRUCTURE AROUND THE STONE MILL DAM		
DRAWING TITLE: RETAINING WALL PLAN & ELEVATIONS		
DESIGNED BY: SEP	DRAWN BY: SEP	CHECKED BY: JGM/RGSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. XXXX-XXXX
B-SCAN	SCALE: 1"=10' / DATE: 2/28/2014	DRAWING NO. 10
		SHEET NO. 10 OF 15 SHEETS

PLOTTED BY: Stephen Pelletier 2/28/2014 - 08:57:00 AM
G:\Projects\NYC Parks\Olmsted Center\Fish Passage\Drawings\Retaining Wall Plan & Elevations.dwg



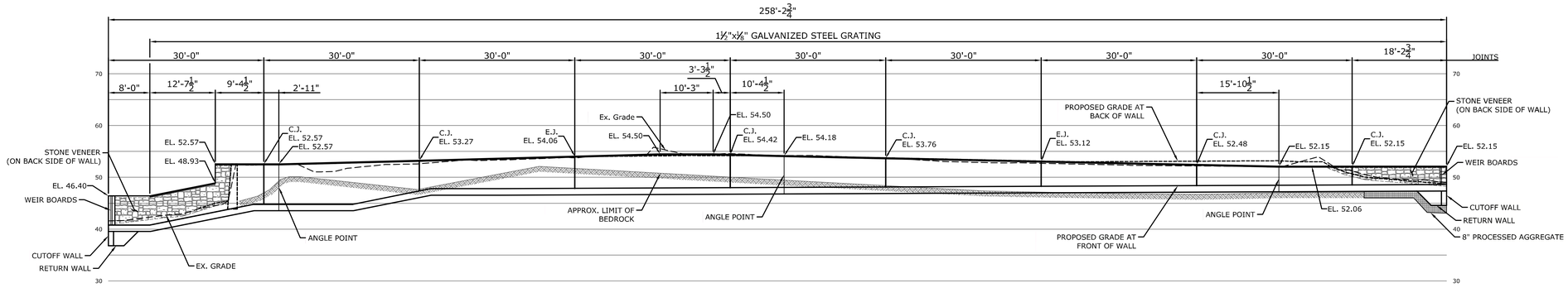
RETAINING WALL 103

SCALE: 1" = 10'



CUTOFF WALL & RETURN WALL DETAIL

SCALE: ¼" = 1'-0"



RETAINING WALL 104

SCALE: 1" = 10'

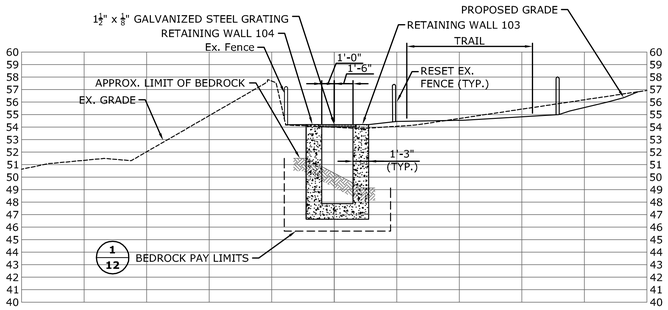
NOTE: FOR CHANNEL INVERTS SEE PROFILE ON SHEET 08

GRAPHIC SCALE
5 0 5 10
(IN FEET)
1 inch = 10 ft.

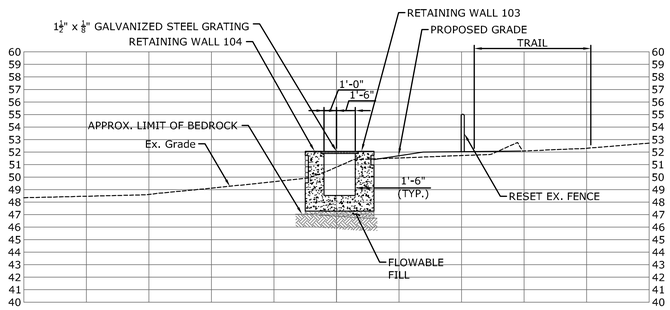
MILONE & MACBROOM®
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

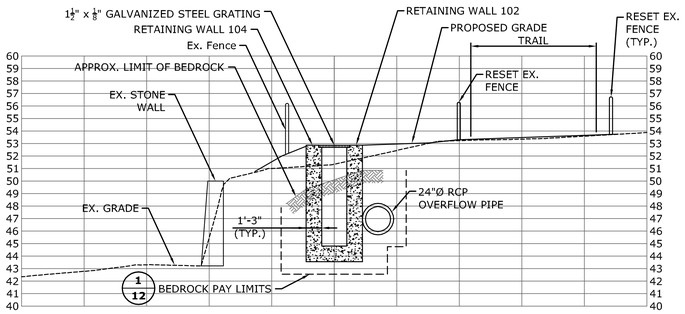
PROJECT TITLE: FISH PASSAGE STRUCTURE AROUND THE STONE MILL DAM		
DRAWING TITLE: RETAINING WALL ELEVATIONS		
DESIGNED BY: ELAG	DRAWN BY: SEP	CHECKED BY: JGM/RGSK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. XXXX-XXXX
B-SCAN	SCALE: 1"=10' / DRAWING NO.: 11 / DATE: 2/28/2014	SHEET NO. 11 OF 15 SHEETS



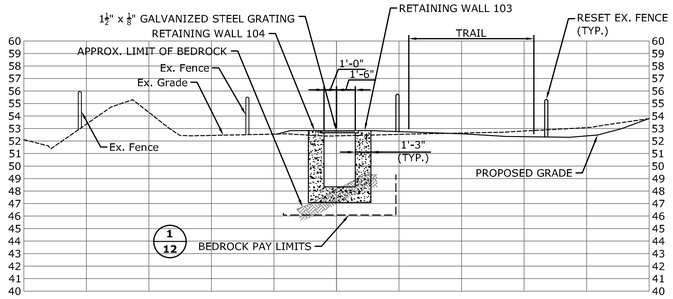
1+00



2+50

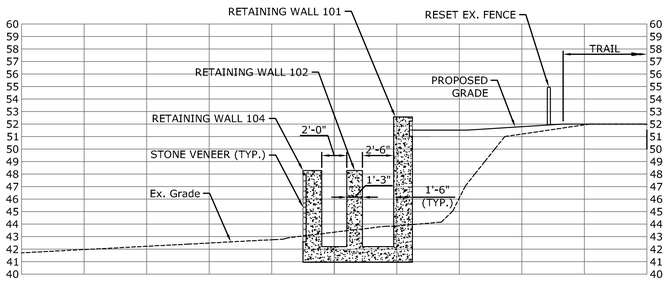


0+50

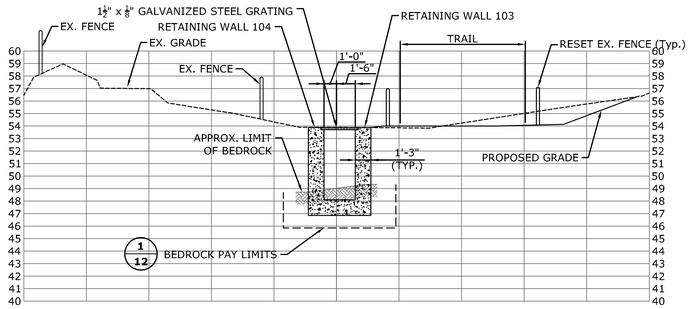


2+00

NOTE: CONTRACTOR SHALL PROTECT EXISTING STONE MASONRY WALL TO REMAIN. CONTRACTOR TO PROVIDE SHOP DRAWINGS FOR PROTECTION OF EXISTING WALL. ANY DAMAGE SHALL BE PAID FOR BY THE CONTRACTOR.

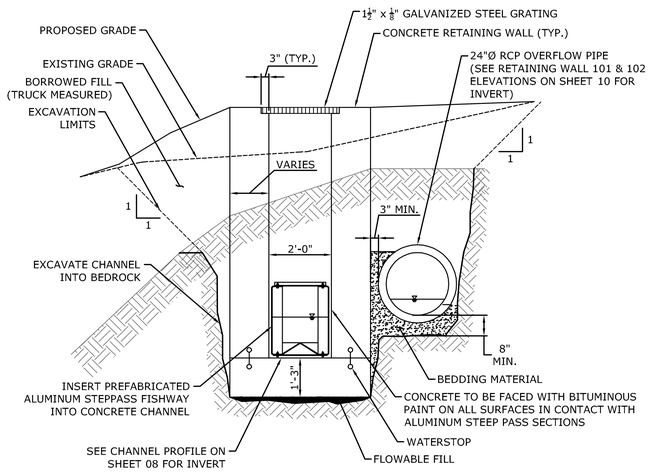


0+20

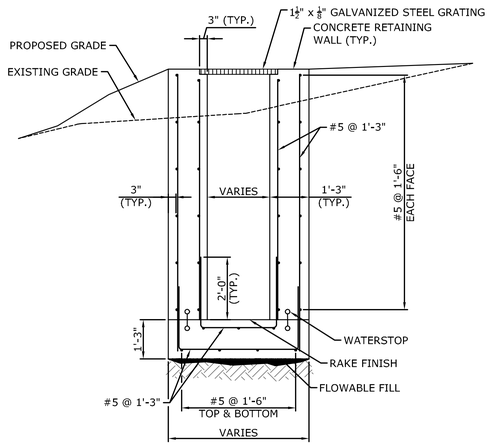


1+50

CROSS SECTIONS
SCALE: 1" = 5'-0"

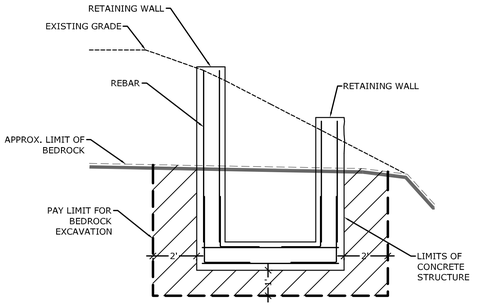


TYPICAL SECTION: FISH LADDER AND BYPASS CHANNEL
SCALE: ½" = 1'-0"

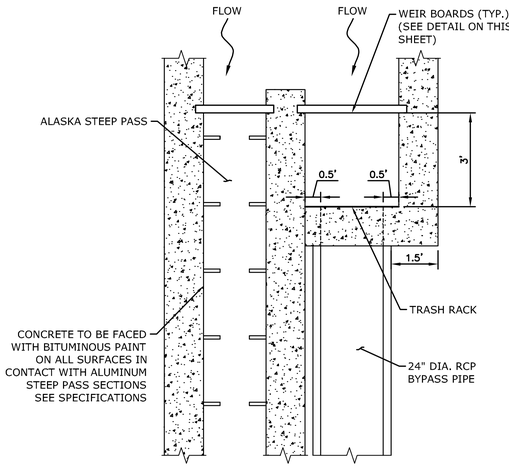


TYPICAL SECTION
SCALE: ½" = 1'-0"

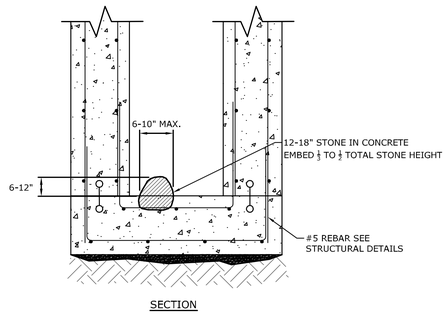
NOTE: TYPICAL SECTIONS ARE LOOKING U/S.



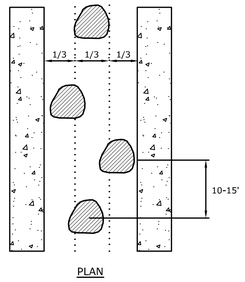
1 BEDROCK PAY LIMITS
NOT TO SCALE



2 BYPASS PIPE JUNCTION PLAN DETAIL
SCALE: ½" = 1'-0"



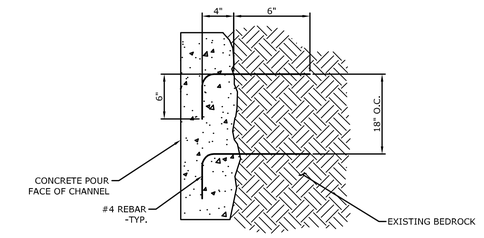
SECTION



PLAN

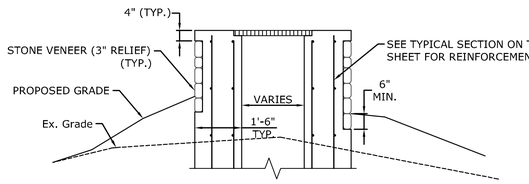
3 FISHWAY STONE
NOT TO SCALE

1) USE 12" TO 18" STONES.
2) DO NOT BLOCK MORE THAN 10" HORIZONTALLY ACROSS FISHWAY WITH EACH STONE PLACEMENT.
3) ORIENT STONE WITH LONG AXIS PARALLEL TO FLOW.
4) EMBED STONES IN CONCRETE ⅓ TO ⅔ OF TOTAL STONE HEIGHT.
5) INSTALL STONES 10' TO 15' APART ON CENTER, INSTALL 15 STONES TOTAL.
6) STONES TO BE ROUNDED. NO RIPRAP, CONCRETE, OR BEDROCK ALLOWED.
7) STONES TO BE RANDOMLY PLACED TO THE LEFT, CENTER, AND RIGHT THIRDS OF THE FISHWAY ALONG ITS LENGTH.
8) STONES TO BE PLACED AT THE DIRECTION OF THE CONSTRUCTION ENGINEER.
9) INDIVIDUALLY PLACED STONES TO BE SET ⅓ TO 1 HOUR AFTER CONCRETE POURED TO PROVIDED SUFFICIENT TIME FOR THE CONCRETE TO CURE/HARDEN.

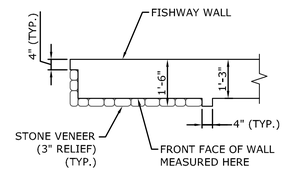


4 CONCRETE REINFORCEMENT ANCHORS
NOT TO SCALE

1) ANCHORS TO BE INSTALLED WHERE CONCRETE POUR IN BEDROCK IS REQUIRED.



5 TYPICAL SECTION WITH STONE VENEER
SCALE: ½" = 1'-0"



5 STONE VENEER PLAN VIEW
SCALE: ½" = 1'-0"

MILONE & MACBROOM

99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE	FISH PASSAGE STRUCTURE AROUND THE STONE MILL DAM
DRAWING TITLE	PROPOSED FISHWAY - CROSS SECTIONS
DESIGNED BY: EVAG	DRAWN BY: SEP
CHECKED BY: JGM/RG/SK	
REVIEWED-TEAM LEADER	FORESTRY:
APPROVED-DIRECTOR	
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER
CONTRACT NO. XXXX-XXXX	
B-SCAN	SCALE
DRAWING NO. 12	
DATE 2/28/2014	
SHEET NO. 12 OF 15 SHEETS	

PROJECT DESCRIPTION

THE BRONX RIVER OFFERS A UNIQUE OPPORTUNITY TO PROVIDE IMPROVED AQUATIC HABITAT WITH DIADROMOUS FISH PASSAGE IN AN URBAN SETTING. THE GOAL IS TO RESTORE THE BRONX RIVER BY MAKING UPSTREAM HABITAT ACCESSIBLE TO RIVER HERRING. SPECIFICALLY CONSTRUCTING A FISHWAY WITHIN THE NATURAL BEDROCK ABUTMENT ALONG THE WESTERN PORTION OF THE SPILLWAY. THE APPEARANCE OF SUCH A STRUCTURE IS TO BE CONSISTENT WITH THE NATURAL AND BUILT FEATURES OF THE ADJACENT LANDSCAPE.

SITE DESCRIPTION

THE SNUFF MILL DAM IS A NATIONAL HISTORIC LANDMARK, LOCATED AT THE UPSTREAM END OF A STEEP BEDROCK GORGE, WITHIN THE NEW YORK BOTANICAL GARDENS. IT IS SURROUNDED BY NATURAL VEGETATION AND BEDROCK OUTCROPS. A MATURE TREE CANOPY EXISTS ON BOTH SIDES OFF THE STRUCTURE, WITH VALUABLE SHADE PROTECTION. WITHIN THE NEW YORK BOTANICAL GARDEN, THE SNUFF MILL DAM IS REFERENCED AS THE "WATERFALL", AND IS HIGHLY VISIBLE FROM THE NEARBY DOWNSTREAM FOOTBRIDGE.

PROPOSED IMPROVEMENTS

THE SOUTHERN BANK COMPOSED MOSTLY OF BEDROCK IS THE SELECTED LOCATION OR INCORPORATE A FISH PASSAGE STRUCTURE FOR ACCESS FURTHER UPSTREAM. THE 210 FOOT LONG STRUCTURE WOULD BE LOCATED BELOW CURRENT GRADE TO MINIMIZE ITS APPEARANCE AND MAINTAIN A NATURAL LANDSCAPE CONSISTENT WITH THE CURRENT CONDITIONS OF THE SITE. A SET OF ADJUSTABLE TIMBER WEIRS WILL SPAN THE FISHWAY ALLOWING THE REDIRECTION OF HIGH FLOWS FROM THE FISH LADDER TO THE ATTRACTION WATER FLOW CHANNEL. THE MAJORITY OF THE FISHWAY WILL RUN UNDER THE EXISTING PEDESTRIAN PATH. AS SUCH THE PROPOSED PATH WILL BE REALIGNED TO GO AROUND THE FISHWAY WITH SEVERAL VIEWING LOCATIONS.

PLANNED EROSION AND SEDIMENT CONTROL PRACTICES

1. STABILIZED CONSTRUCTION ENTRANCES WILL BE CONSTRUCTED ALONG THE PEDESTRIAN WALKING PATH ADJACENT TO THE BRONX RIVER.
2. CONSTRUCTION ROAD STABILIZATION: THE CONSTRUCTION ACCESS PAD WILL BE CONSTRUCTED AFTER THE REMOVAL OF STONE DUST AND WILL BE SLOPED TOWARDS THE RIVER AND THE ROW OF SILT FENCE.
3. SILT FENCE WILL BE INSTALLED ALONG THE CONSTRUCTION ACCESS ROAD AND AROUND ANY STOCKPILE AREAS.
4. SUMP PIT: A SUMP PIT WILL BE UTILIZED TO DEWATER THE WORK AREA IF GROUNDWATER IS ENCOUNTERED.
5. SURFACE STABILIZATION: STABILIZATION OF THE SURFACE WILL BE ACCOMPLISHED WITH VEGETATION AS SPECIFIED ON THE SITE PLAN.

EROSION CONTROL NOTES

1. ALL VEGETATIVE AND STRUCTURAL EROSION AND SEDIMENT CONTROL PRACTICES WILL BE CONSTRUCTED IN ACCORDANCE WITH THE "NEW YORK STATE STANDARDS AND SPECIFICATIONS FOR EROSION AND SEDIMENT CONTROL."
2. A COPY OF THE APPROVED EROSION AND SEDIMENT CONTROL PLAN SHALL BE MAINTAINED ON THE SITE AT ALL TIMES.
3. ALL WETLANDS SHALL BE AVOIDED AND PROTECTED FROM CONSTRUCTION ACTIVITIES WITH SEDIMENT CONTROL MEASURES WHERE NECESSARY AS DETERMINED BY THE PROJECT ENGINEER.
4. CLEARING OF NATIVE VEGETATION FOR CONSTRUCTION ACCESS SHOULD BE MINIMIZED.
5. TEMPORARY ACCESS AREAS SHALL BE BORDERED WITH SILT FENCE. SEE PLANS AND DETAILS.
6. STOCKPILE AREAS TO BE ENCLOSED BY SILT FENCE.
7. AN EROSION CONTROL BLANKET SHALL BE PLACED OVER ANY DISTURBED AREAS WITH A SLOPE GREATER THAN OR EQUAL TO 3:1 TO PREVENT EROSION. SEE PLANS AND DETAILS.
8. THE CONTRACTOR IS RESPONSIBLE FOR THE MAINTENANCE OF ALL SOIL EROSION AND SEDIMENT CONTROL MEASURES. THE CONSTRUCTION INSPECTOR WILL VERIFY THE MAINTENANCE WEEKLY AND AFTER RAIN EVENTS.
9. THE FINAL LOCATION OF THE TEMPORARY HAUL ROADS SHALL BE DETERMINED PRIOR TO CONSTRUCTION. THE HAUL ROAD SHALL BE CONSTRUCTED WITH PROPER EROSION CONTROLS, INCLUDING SILT FENCE WHERE NECESSARY, AND A STABILIZED CONSTRUCTION ENTRANCE. RESTORATION OF THE DISTURBED AREA SHALL BE COORDINATED WITH THE PROPERTY OWNER.
10. TEMPORARY SEED SHALL BE NEW ENGLAND EROSION CONTROL/RESTORATION MIX FOR DRY SITES, APPLIED AT THE RATE OF 35LBS PER ACRE.

CONSTRUCTION SEQUENCE

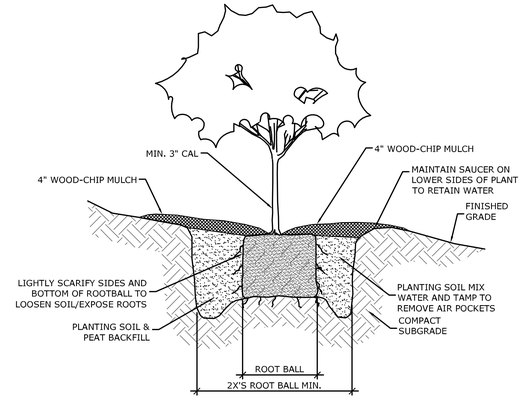
1. REMOVE AND STORE EXISTING FENCE WITHIN CONTRACT LINE LIMITS.
2. INSTALL TEMPORARY CONSTRUCTION FENCE/GATE AS SHOWN ON THE PLANS.
3. CLEAR SLOPE FOR TEMPORARY ACCESS AS SHOWN.
4. INSTALL SEDIMENT AND EROSION CONTROLS AS SHOWN ON THE PLANS.
5. REMOVE EXISTING FLAGGED TREES WITHIN IMPACTED AREAS.
6. INSTALL TEMPORARY COFFERDAMS.
7. DEWATER WORK AREA WITH PUMPS AS NECESSARY.
8. EXCAVATE BEDROCK TO LIMITS SHOWN ON THE PLANS.
9. INSTALL STEEP-PASS SECTIONS.
10. REMOVE COFFERDAMS.
11. REPLACE EXISTING SECTIONS OF FENCE THAT WERE REMOVED.
12. RESTORE SITE AS SHOWN ON RESTORATION PLAN.

STOCK PILING NOTES

1. TEMPORARY STOCKPILE AND STAGING AREAS TO BE FLAGGED BY CONTRACTOR PRIOR TO CONSTRUCTION AND APPROVED BY THE NEW YORK CITY DEPARTMENT OF PARKS AND RECREATION, THE NYBG, AND THE PROJECT LANDSCAPE ARCHITECT/ENGINEER.
2. NO CONSTRUCTION VEHICLES SHALL BE STORED, SERVICED, WASHED OR FLUSHED IN A LOCATION WHERE LEAKS, SPILLAGE, WASTE MATERIALS, CLEANERS, OR WATERS WILL BE INTRODUCED OR FLOW INTO WETLANDS OR WATERCOURSES. AN EMERGENCY MANAGEMENT PLAN AND SPILL KIT WILL BE MAINTAINED ON SITE AT ALL TIMES. IN THE EVENT OF AN ACCIDENTAL RELEASE, IMMEDIATELY STOP CONSTRUCTION WORK, CONTAIN THE SPILL, AND NOTIFY THE CITY, APPROPRIATE AUTHORITIES AND PROJECT LANDSCAPE ARCHITECT/ENGINEER.
3. THE CONTRACTOR SHALL MAINTAIN ALL STREETS, SIDEWALKS, AND WALKWAYS IN THE AREA FREE OF SOIL, MUD AND CONSTRUCTION DEBRIS. CONSTRUCTION ENTRANCES MUST BE MAINTAINED AT EACH ACCESS POINT. SEE PLANS AND DETAILS.
4. THE PROJECT SITE IS SUBJECT TO FLOODING. THE CONTRACTOR SHALL MONITOR WEATHER FORECASTS AND STABILIZE THE CONSTRUCTION SITE AND REMOVE EQUIPMENT FROM FLOOD PRONE AREAS IN THE EVENT OF FLOOD WARNINGS. WORK SHOULD BE PERFORMED DURING LOW WATER.
5. ALL STORAGE AND ACCESS ROUTES, PEDESTRIAN FENCES/BARRIERS, WORKING HOURS, AND LIMITS OF CLEARING SHALL BE APPROVED BY THE NEW YORK CITY DEPARTMENT OF PARKS AND RECREATION, LANDOWNERS AND THE PROJECT LANDSCAPE ARCHITECT/ENGINEER.

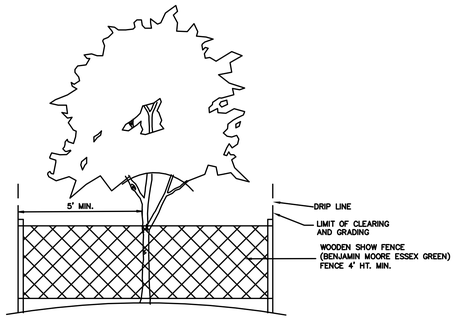
EROSION CONTROL MAINTENANCE INTERVALS

EROSION CONTROL MEASURE	CONTROL OBJECTIVE	INSPECTION/MAINTENANCE	FAILURE INDICATORS	REMOVAL
SILT FENCE	- INTERCEPT, AND REDIRECT/DETAIN SMALL AMOUNTS OF SEDIMENT FROM SMALL DISTURBED AREAS. - DECREASE VELOCITY OF SHEET FLOW. - PROTECT SENSITIVE SLOPES OR SOILS FROM EXCESSIVE WATER FLOW.	INSPECT AT LEAST ONCE A WEEK AND WITHIN 24 HOURS OF THE END OF A STORM WITH A RAINFALL OF 0.5 INCHES OR MORE. ACCUMULATED SEDIMENT MUST BE REMOVED ONCE ITS DEPTH IS EQUAL TO ½ THE TRENCH HEIGHT. INSPECT FREQUENTLY DURING PUMPING OPERATIONS IF USED FOR DEWATERING OPERATIONS.	- PHYSICAL DAMAGE OR DECOMPOSITION - EVIDENCE OF OVERTOPPED OR UNDERCUT FENCE - EVIDENCE OF SIGNIFICANT FLOWS EVADING CAPTURE - REPETITIVE FAILURE	SILT FENCE MAY BE REMOVED AFTER UPHILL AND SENSITIVE AREAS HAVE BEEN PERMANENTLY STABILIZED.
STABILIZED CONSTRUCTION ENTRANCE	- REDUCE THE TRACKING OF SEDIMENT OFF-SITE ONTO PAVED SURFACES.	INSPECT AT THE END OF EACH WORK DAY AND IMMEDIATELY REPAIR DAMAGES. PERIODIC ADDITION OF STONE, OR LENGTHENING OF ENTRANCE MAY BE REQUIRED AS CONDITIONS DEMAND. ALL SEDIMENT SPILLED, DROPPED, WASHED, OR TRACKED ONTO PAVED SURFACES AS A RESULT OF INEFFICIENCY OF CONSTRUCTION ENTRANCE SHALL BE IMMEDIATELY REMOVED.	- SEDIMENT IN ROADWAY ADJACENT TO SITE	CONSTRUCTION ENTRANCE MAY BE REMOVED ONCE THE SITE HAS BEEN PERMANENTLY STABILIZED, AND ALL OTHER SECTIONS OF ROADWAY HAVE BEEN PERMANENTLY PAVED.

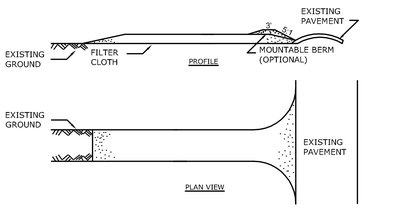


7 POTTED TREE/SHRUB PLANTING DETAIL
NOT TO SCALE

NOTE MULCHING OF PLANT BEDS:
UNLESS OTHERWISE DIRECTED SHREDDED MULCH SHALL BE PLACED TO A LIMIT OF ONE FOOT BEYOND THE CENTER OF THE OUTERMOST SHRUBS IN SHRUB BED.



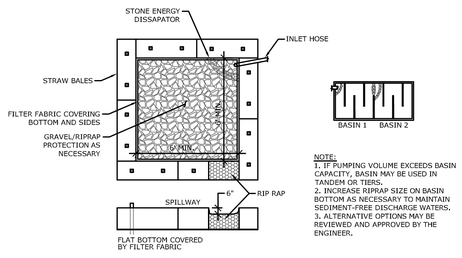
1 TREE PROTECTION DETAIL
N.T.S.



2 STABILIZED CONSTRUCTION ENTRANCE
NOT TO SCALE

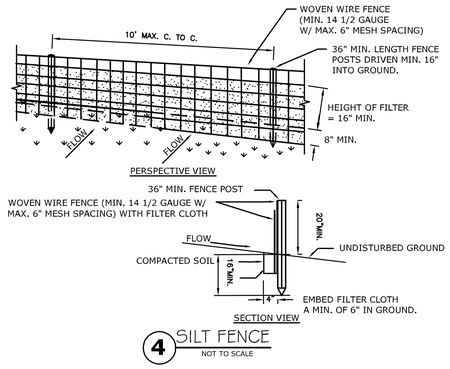
CONSTRUCTION SPECIFICATIONS

1. STONE SIZE - USE 2" STONE, OR RECLAIMED OR RECYCLED CONCRETE EQUIVALENT.
2. LENGTH - NOT LESS THAN 50 FEET (EXCEPT ON A SINGLE RESIDENCE LOT WHERE A 30 FOOT MINIMUM LENGTH WOULD APPLY).
3. THICKNESS - NOT LESS THAN SIX (6) INCHES.
4. WIDTH - TWELVE (12) FOOT MINIMUM, BUT NOT LESS THAN THE FULL WIDTH AT POINTS WHERE INGRESS OR EGRESS OCCURS. TWENTY-FOUR (24) FOOT IF SINGLE ENTRANCE TO SITE.
5. FILTER CLOTH - WILL BE PLACED OVER THE ENTIRE AREA PRIOR TO PLACING OF STONE.
6. SURFACE WATER - ALL SURFACE WATER FLOWING OR DIVERTED TOWARD CONSTRUCTION ENTRANCES SHALL BE PIPED ACROSS THE ENTRANCE. IF PIPING IS IMPRACTICAL, A MOUNTABLE BERM WITH 5:1 SLOPES WILL BE PERMITTED.
7. MAINTENANCE - THE ENTRANCE SHALL BE MAINTAINED IN A CONDITION WHICH WILL PREVENT TRACKING OR FLOWING OF SEDIMENT ONTO PUBLIC RIGHTS-OF-WAY, ALL SEDIMENT SPILLED, DROPPED, WASHED OR TRACTED ONTO PUBLIC RIGHTS-OF-WAY MUST BE REMOVED IMMEDIATELY.
8. WHEN WASHING IS REQUIRED, IT SHALL BE DONE ON A AREA STABILIZED WITH STONE AND WHICH DRAINS INTO AN APPROVED SEDIMENT TRAPPING DEVICE.
9. PERIODIC INSPECTION AND NEEDED MAINTENANCE SHALL BE PROVIDED AFTER EACH RAIN.



NOTE:
1. IF PUMPING VOLUME EXCEEDS BASIN CAPACITY, BASIN MAY BE USED IN TANDEM OR TIERS.
2. INCREASE RIPRAP SIZE ON BASIN BOTTOM AS NECESSARY TO MAINTAIN SEDIMENT-FREE DISCHARGE WATERS.
3. ALTERNATIVE OPTIONS MAY BE REVIEWED AND APPROVED BY THE ENGINEER.

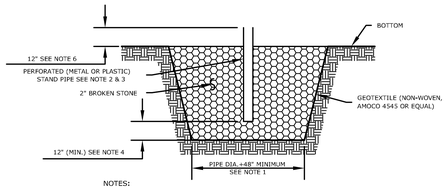
3 DEWATERING BASIN
N.T.S.



4 SILT FENCE
NOT TO SCALE

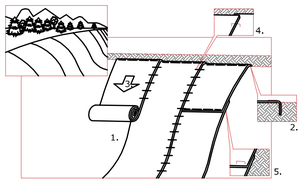
CONSTRUCTION SPECIFICATIONS

1. WOVEN WIRE FENCE TO BE FASTENED SECURELY TO FENCE POSTS WITH WIRE TIES OR STAPLES. POSTS SHALL BE STEEL EITHER "T" OR "U" TYPE OR HARDWOOD.
2. FILTER CLOTH TO BE TO BE FASTENED SECURELY TO WOVEN WIRE FENCE WITH TIES SPACED EVERY 24" AT TOP AND MID SECTION. FENCE SHALL BE WOVEN WIRE, 12 1/2 GAUGE, 6" MAXIMUM MESH OPENING.
3. WHEN TWO SECTIONS OF FILTER CLOTH ADJOIN EACH OTHER THEY SHALL BE OVERLAPPED BY SIX INCHES AND FOLDED. FILTER CLOTH SHALL BE EITHER FILTER X, MIRAFI 100X, STABILINKA T140N, OR APPROVED EQUIVALENT.
4. PREFABRICATED UNITS SHALL BE GEOFAB, ENVIROFENCE, OR APPROVED EQUIVALENT.
5. MAINTENANCE SHALL BE PERFORMED AS NEEDED AND MATERIAL REMOVED WHEN "BULGES" DEVELOP IN THE SILT FENCE.



NOTES:
1. OVERALL SUMP PIT DIMENSIONS TO BE COMPATIBLE WITH ANTICIPATED SEEPAGE RATES AND PUMP TO BE USED.
2. THE STAND PIPE DIAMETER AND NUMBER OF PERFORATIONS TO BE COMPATIBLE WITH THE PUMP SIZE BEING USED.
3. PERFORATIONS IN THE STANDPIPE TO BE EITHER CIRCULAR OR SLOTS, PERFORATION SIZE SHALL NOT EXCEED 1/2" DIAMETER.
4. 2" BROKEN STONE SHALL EXTEND A MINIMUM OF 12" BELOW THE BOTTOM OF THE STANDPIPE.
5. A PROPERLY DESIGNED GEOTEXTILE TO BE PLACED BETWEEN THE EXISTING SOILS AND THE CRUSHED STONE BACKFILL.
6. THE STANDPIPE SHALL EXTEND A MINIMUM OF 12" ABOVE THE SURROUNDING GROUND.

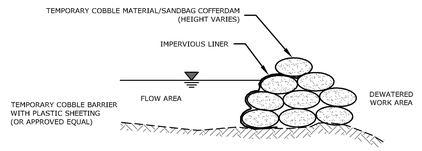
5 TEMPORARY DEWATERING SUMP
N.T.S.



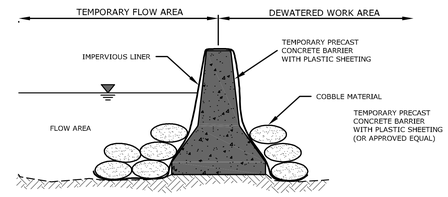
1. PREPARE SOIL BEFORE INSTALLING BLANKETS, INCLUDING APPLICATION OF LIME, FERTILIZER, AND SEED. NOTE: WHEN USING S150, DO NOT SEED PREPARED AREA. S150 MUST BE INSTALLED WITH PAPER SIDE DOWN.
2. BEGIN AT THE TOP OF THE SLOPE BY ANCHORING THE BLANKET IN A 6" DEEP BY 6" WIDE TRENCH. BACKFILL AND COMPACT THE TRENCH AFTER STAPLING.
3. ROLL THE BLANKETS DOWN THE SLOPE IN THE DIRECTION OF THE WATER FLOW.
4. THE EDGES OF PARALLEL BLANKETS MUST BE STAPLED WITH APPROXIMATELY 2" OVERLAP.
5. WHEN BLANKETS MUST BE SPLICED DOWN THE SLOPE, PLACE BLANKETS END OVER END (SHINGLE STYLE) WITH APPROXIMATELY 6" OVERLAP. STAPLE THROUGH OVERLAP AREA, APPROXIMATELY 12" APART.

REFER TO GENERAL STAPLE PATTERN GUIDE IN NORTH AMERICAN GREEN CATALOG FOR CORRECT STAPLE PATTERN RECOMMENDATIONS FOR SLOPE INSTALLATIONS.

APPLICATION OF EROSION CONTROL BLANKET ON SLOPES
6
NOT TO SCALE



8 TEMPORARY COFFERDAM DETAIL
N.T.S.



TEMPORARY CONCRETE BARRIER COFFERDAM DETAIL
9
N.T.S.

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

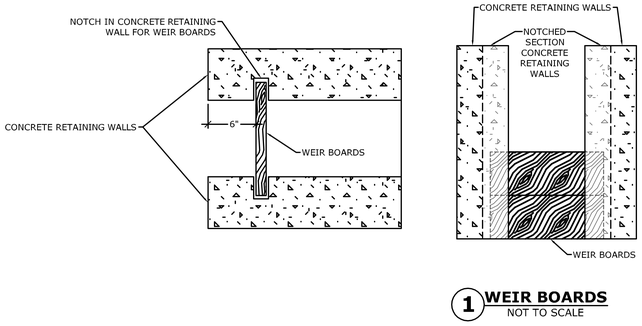
PROJECT TITLE
FISH PASSAGE STRUCTURE
AROUND THE STONE MILL DAM

DRAWING TITLE
SEDIMENT AND EROSION CONTROL NOTES AND DETAILS

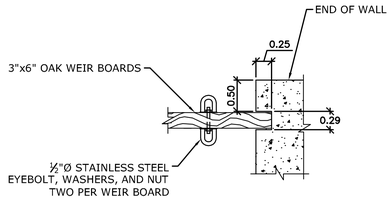
DESIGNED BY	DRAWN BY	CHECKED BY
ELIAG	GDW	JSM/NRG/SK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO.
B-SCAN	SCALE	DRAWING NO.
	DATE 2/28/2014	13

XXXX-XXXX

SHEET NO. 13 OF 15 SHEETS

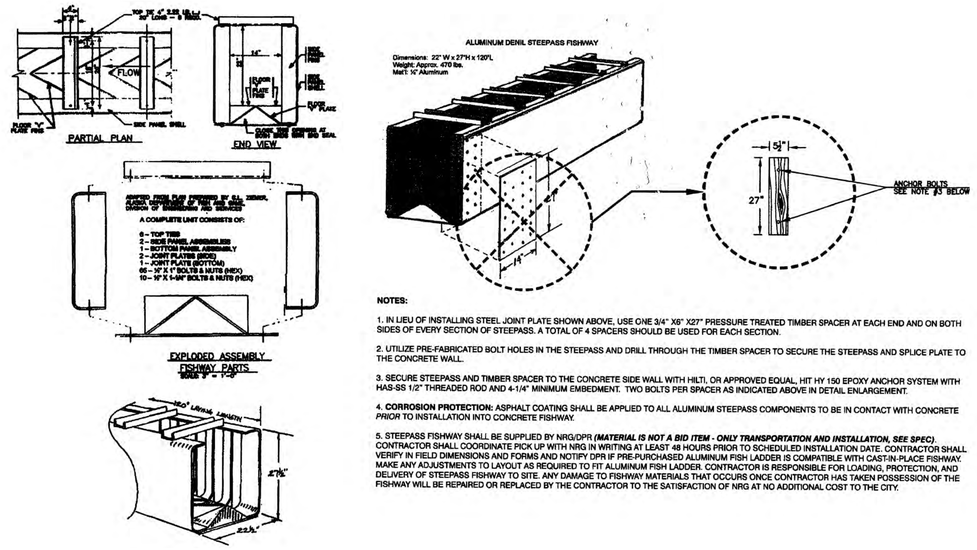


1 WEIR BOARDS
NOT TO SCALE



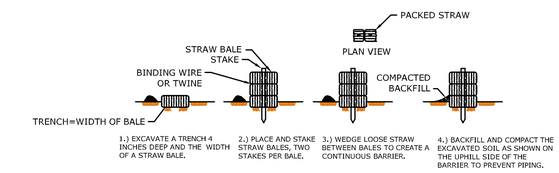
WEIR BOARD DETAIL
SCALE: 1" = 1'-0"

NOTE: PROVIDE A SET OF FIVE (5) 3"x6" OAK WEIR BOARDS AT EACH LOCATION. DETAIL APPLICABLE FOR ALL WEIR BOARD LOCATIONS.

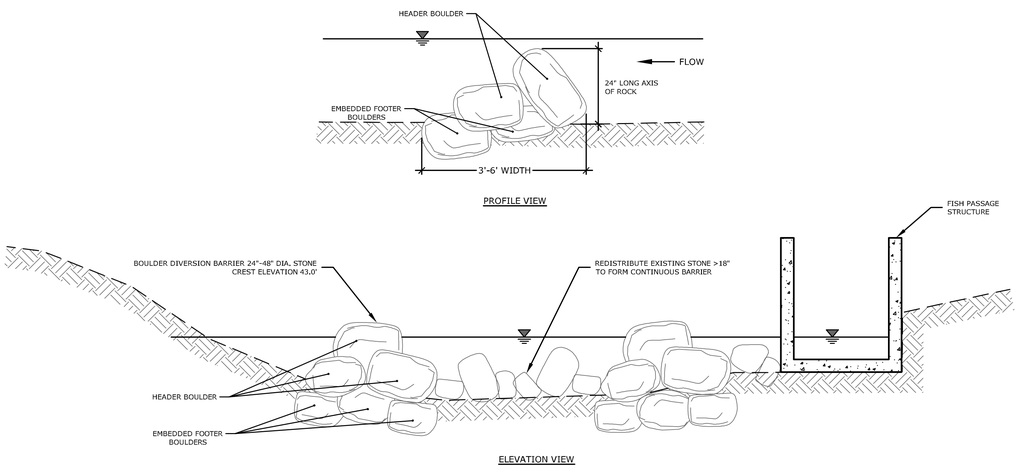


5 ALUMINUM DENIL STEEP PASS DETAILS
NOT TO SCALE

1) GRAY ANODIZED PAINTED FINISH TO MATCH EXISTING ROCK.
2) SAMPLE COLOR CHIPS REQUIRED.
3) REMOVE TOP CROSSBARS AFTER INSTALLATION, IF FEASIBLE.

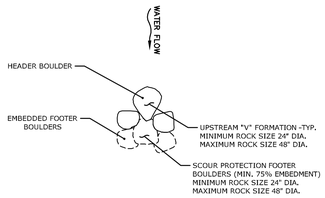


2 PLACEMENT AND CONSTRUCTION OF A STRAW BALE SILT CONTROL
NOT TO SCALE



3 BOULDER CLUSTER DIVERSION BARRIER
NOT TO SCALE

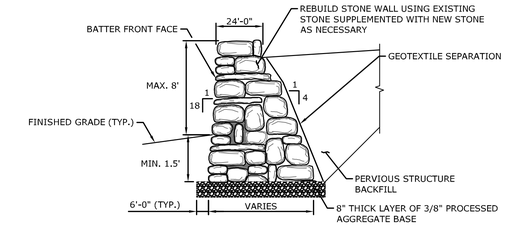
1) WHERE POSSIBLE ON SITE BOULDERS SHOULD BE USED FROM BLASTING OF FISH PASSAGE STRUCTURE.
2) REFER TO PLAN FOR FOR LAYOUT AND SPACING OF BOULDER CLUSTERS FOR VELOCITY DIVERSION BARRIER.



4 BOULDER CLUSTER
NOT TO SCALE

NOTES:

1. 3 BOULDERS PER BOULDER CLUSTER, PLUS 3 SCOUR PROTECTION FOOTER BOULDERS.
2. POSITION BOULDER GROUPS IN AN UPSTREAM "V" FORMATION.
3. INDIVIDUAL BOULDERS PLACED IN THE STREAM SHOULD BE 24" TO 48" IN DIAMETER.
4. POSITION BOULDERS WITH THEIR LONG AXIS PARALLEL TO THE STREAM FLOW.
5. INSTALL FOOTER BOULDER TO WEDGE HEADER BOULDER IN PLACE FROM DOWNSTREAM.
6. INSTALL HEADER BOULDERS AT A LOW PROFILE SUCH THAT THEY ARE PARTIALLY SUBMERGED DURING NORMAL SPRING FLOW. INSTALL SUCH THAT ⅓ TO ¼ OF ROCK DIAMETER IS BURIED IN STREAM CHANNEL.
7. FINISHED ELEVATION OF THE BOULDERS WILL BE DETERMINED IN THE FIELD.



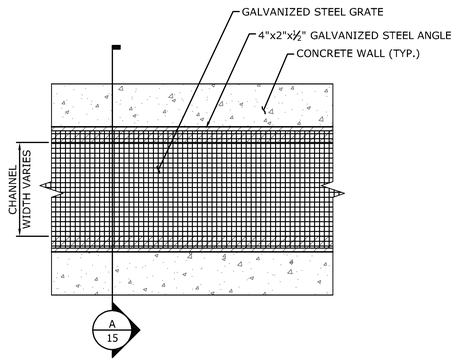
TYPICAL RETAINING WALL SECTION
NOT TO SCALE

MILONE & MACBROOM
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: FISH PASSAGE STRUCTURE AROUND THE STONE MILL DAM		
DRAWING TITLE: DETAILS		
DESIGNED BY: EJAG	DRAWN BY: GDW	CHECKED BY: JGM/RG/SK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. XXXX-XXXX
B-SCAN	SCALE / DATE: 2/28/2014	DRAWING NO.: 14

SHEET NO. 14 OF 15 SHEETS

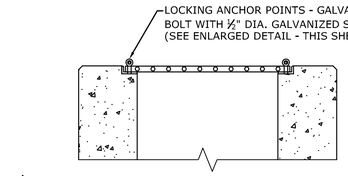


GALVANIZED STEEL GRATING DETAIL - PLAN

SCALE: ¾" = 1'-0"

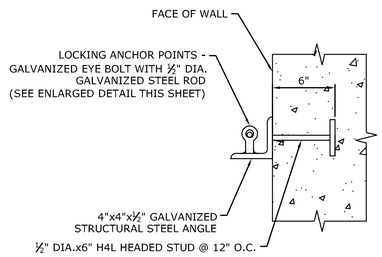
NOTE

1. NO ANGLE IS TO BE PLACED AT VERTICAL NOTCHES IN CONCRETE SUCH AS WEIR BOARD LOCATIONS.



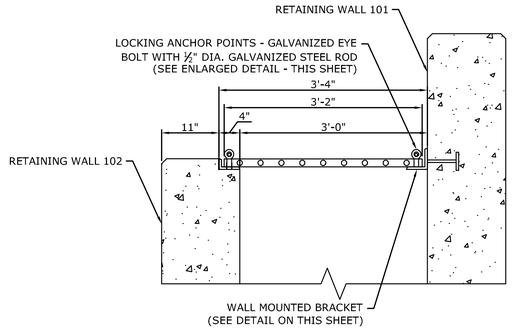
GALVANIZED STEEL GRATING DETAIL SECTION "A"

SCALE: ¾" = 1'-0"



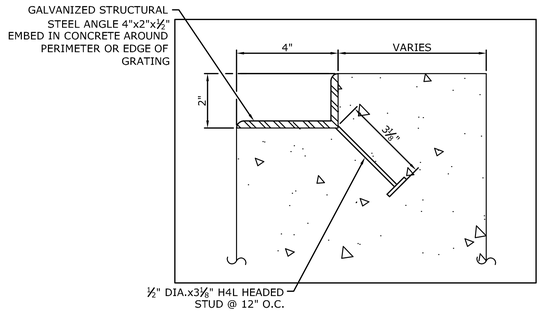
5 WALL MOUNTED ANGLE BRACKET

SCALE: 2" = 1'-0"



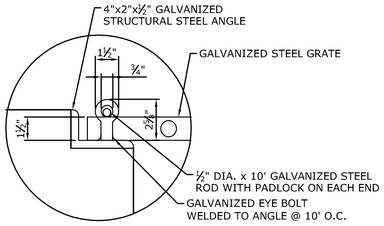
5 WALL MOUNTED ANGLE BRACKET - TYPICAL SECTION

SCALE: 1" = 1'-0"



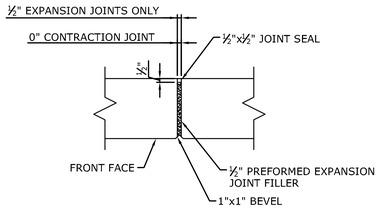
1 STRUCTURAL ANGLE DETAIL

NOT TO SCALE



3 ENLARGED DETAIL 1/2" DIAMETER STEEL ROD

SCALE: 3" = 1'-0"



NOTES:

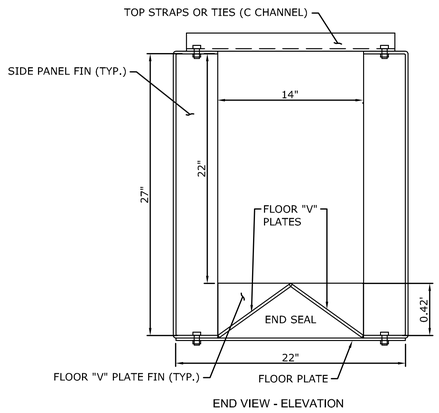
1. JOINT SEAL TO EXTEND FROM TOP OF FOOTING TO TOP OF WALL.

2. NO REINFORCEMENT SHALL PASS THROUGH EXPANSION OR CONTRACTION JOINT.

3. REINFORCEMENT SHALL PASS THROUGH CONSTRUCTION JOINTS.

6 CONTRACTION & EXPANSION JOINT DETAIL

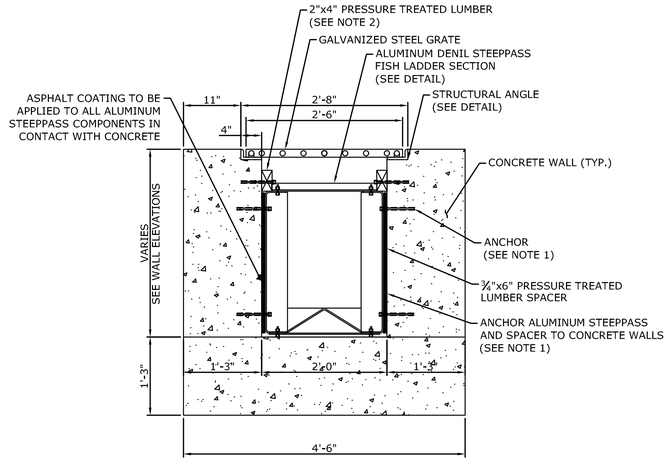
NOT TO SCALE



END VIEW - ELEVATION

2 STEEPASS SCHEMATIC ELEVATION (END VIEW)

NOT TO SCALE



4 TYPICAL PROPOSED FISHWAY SECTION AT ALUMINUM STEEPASS

NOT TO SCALE

NOTES:

1. SECURE STEEPASS AND LUMBER SPACER TO THE CONCRETE SIDE WALL WITH HILTI HIT HY 150 EPOXY ANCHOR SYSTEM WITH HAS-R-304SS ½" THREADED ROD AND 4½" MINIMUM EMBEDMENT. TWO BOLTS PER SPACER AS INDICATED ABOVE.
2. BOLT 2"x4" PRESSURE TREATED LUMBER ON TOP OF STEEPASS TO BLOCK GAP BETWEEN STEEPASS AND WALL. THE 2"x4" IS TO RUN THE FULL LENGTH OF THE STEEPASS AND TO BE BOLTED TO THE SIDE WALL WITH HILTI HIT HY 150 EPOXY ANCHOR SYSTEM WITH HAS-SS ½" THREADED ROD AND 4½" MINIMUM EMBEDMENT. BOLTS TO BE LOCATED 2' O.C. OR APPROVED EQUAL.

NOTES:

1. EXPOSED EDGES OF CONCRETE FISHWAY SHALL BE BEVELED 1" X 1" UNLESS DIMENSIONED OTHERWISE..

2. WHERE FOOTINGS ARE SHOWN ON BEDROCK, IF BEDROCK IS AT AN ELEVATION LOWER THAN SHOWN OR NOT FOUND, THE ENGINEER SHALL BE NOTIFIED IN WRITING BY THE CONTRACTOR. EXISTING ELEVATIONS SHALL BE PROVIDED AND SUPPLIED IN AFOREMENTIONED DOCUMENTATION.

MILONE & MACBROOM

99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

City of New York
Parks & Recreation

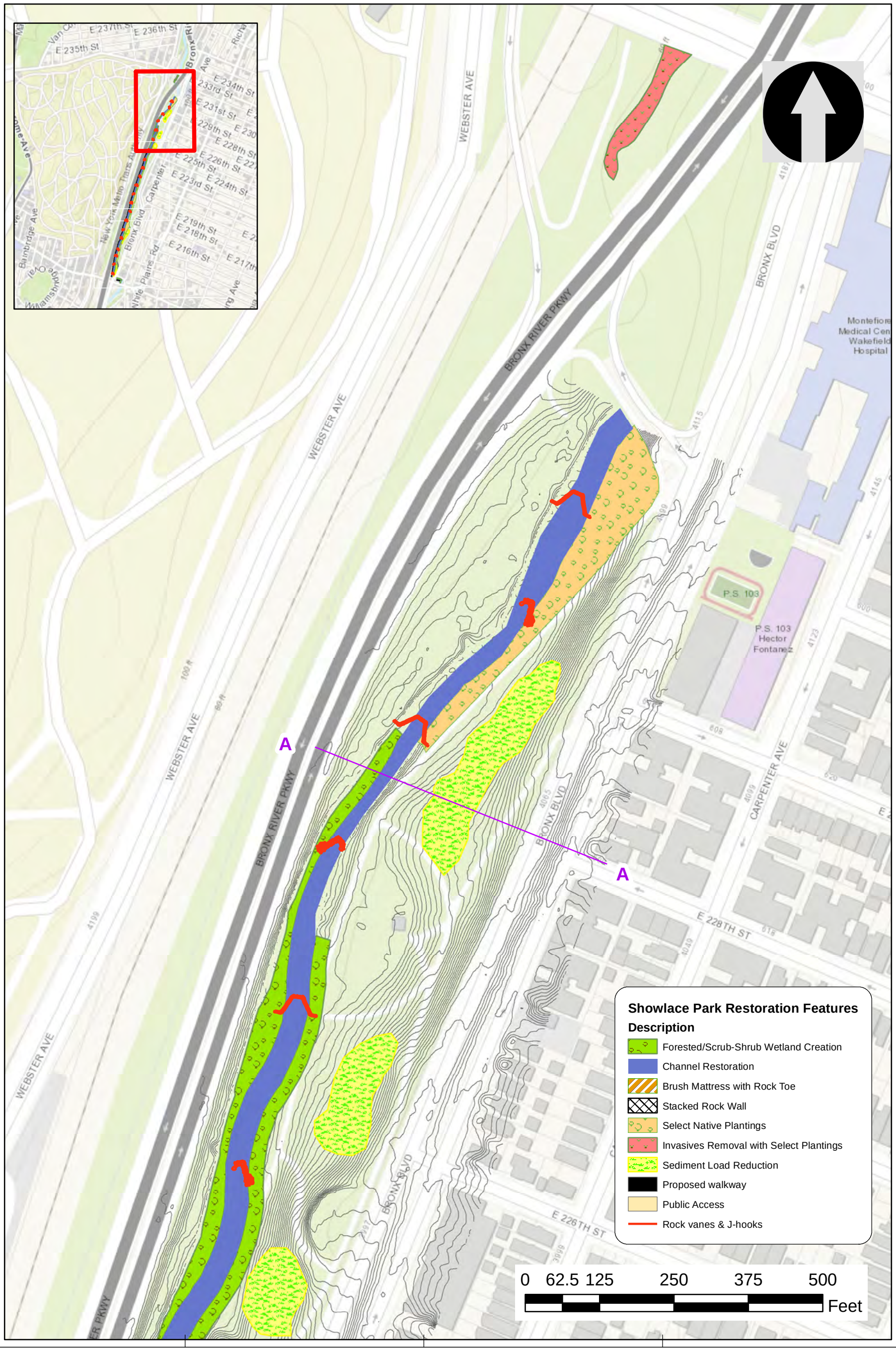
Olmsted Center
Flushing Meadows Corona Park
Flushing, New York 11368

PROJECT TITLE: FISH PASSAGE STRUCTURE AROUND THE STONE MILL DAM		
DRAWING TITLE: DETAILS		
DESIGNED BY: EJAG	DRAWN BY: GDW	CHECKED BY: JGM/MRG/SK
REVIEWED-TEAM LEADER	FORESTRY:	APPROVED-DIRECTOR
APPROVED-CHIEF OF DESIGN	APPROVED-CHIEF ENGINEER	CONTRACT NO. XXXX-XXXX
B-SCAN	SCALE / DATE: 2/28/2014	DRAWING NO.: 15
		SHEET NO. 15 OF 15 SHEETS

Stone Mill Dam Quantitites US Army Corps of Engineers Features			
Item		Qty	UOM
CLEARING AND GRUBBING		10	CY
TOPSOIL		10	CY
PLANTINGS			
SASSAFRAS		1	EA
	Sassafras albidium		
RED OAK		1	EA
	Quercus rubra		
WHITE OAK		1	EA
	Quercus alba		
ARROWWOOD		5	EA
	Viburnum dentatum		
SHADBLOW SERVICEBERRY		5	EA
	Amalenchier canadensis		
RED OSIER DOGWOOD		10	EA
	Cornus stoloniferia		
CHANNEL EXCAVATION		80	CY
ANGULAR STONE FOR CHANNEL BOTTOM		150	TON
DENIL STEEPPASS FISH LADDER		35	LF

Shoelace Park NYC Parks 100% Design		
Item	Qty	UOM
General Requirements		
MOBILIZATION (N.T.E. 6% OF TOTAL OF ALL OTHER ITEMS)	1	LS
CONSTRUCTION SIGN ON FENCE	3	EA
CONSTRUCTION FENCE 8'-0" HT.	310	LF
TEMPORARY SNOW FENCE BOUNDARY	310	LF
MAINTENANCE & PROTECTION OF TRAFFIC - TYPE C	1	LS
TEMPORARY WOODEN TREE GUARD W/TREE WRAP	7	EA
PROTECT EXIST. TREE ROOTS W/WOODCHIPS 6' DEPTH	1,850	SF
TEMPORARY STRAW BALE SILT CONTROL	320	LF
TEMPORARY SILT FENCE	320	LF
STABILIZED CONSTRUCTION ENTRANCE	70	SY
EROSION CONTROL BLANKET	50	SY
STUMP REMOVAL OVER 6" TO 12" DIA.	1	EA
TREE REMOVAL OVER 6" TO 12" DBH	1	EA
ITEMIZED REMOVALS (N.T.E $)	1	LS
CLEAR AND GRUB	1	LS
STRIP, STORE & SPREAD EXISTING TOPSOIL	85	CY
ROCK EXCAVATION	270	CY
HAND AND/OR PNEUMATIC EXCAVATION	10	CY
EARTH MOVING OPERATIONS	410	CY
CONTROLLED LOW STRENGTH MATERIAL (flowable fill)	25	CY
CONTROLLED CONCRETE (f'c = 4,000 psi)	265	CY
STEEL BAR REINFORCEMENT	24,000	LB
REMOVE & RESET STEEL FENCE PANEL	75	LF
REMOVE & RESET STEEL FENCE POST	20	EA
REMOVE PIPE RAIL FENCE - TWO RAIL	55	LF
PAINT STEEL FENCE 4'-0" HT.	75	LF
SINGLE GATE FOR STEEL FENCE 4'-0" HT	2	EA
SINGLE GATE FOR PIPE RAIL FENCE - TWO RAIL	1	EA
TIMBER BARRIER RAIL - ONE RAIL TYPE A	285	LF
STEEL FENCE 4'-0" HT.	185	LF
PIPE RAIL FENCE - TWO RAIL	170	LF
POLYETHYLENE CORRUGATED PIPE, 12" DIA	65	LF
CATCH BASIN - D.E.P. TYPE 2	1	EA
TOPSOIL FOR SEEDED AND SODDED AREAS	10	CY
SHREDDED BARK MULCH	760	SY
STONE SCREENING FOOTPATH	375	SY
TOPSOIL FOR PLANTING PITS AND BEDS	255	CY
REMOVE AND RESET GRANITE BLOCK PAVEMENT	20	SY
REMOVE AND RESET GRANITE CURB	670	LF
PREPARATORY PRUNING OF TREE OVER 6" TO 12" DBH	7	EA
TEMPORARY ACCESS ROAD	1	LS
SHREDDED STRAW MULCH	60	SY
SEEDING RESTORATION	60	SY
WATER CONTROL	1	LS
INSTALL FISH LADDER AND ACCESSORIES	1	LS
GALVANIZED STEEL GRATING	900	SF
REBUILD STONE MASONRY WALL	65	SF
MASONRY VENEER	30	SY
BOULDER CLUSTERS	20	TON
STONE IN FISHWAY	15	EA
TIMBER BRIDGE TIES	5	EA
PERMEABLE PAVERS	20	SY
RIP-RAP	10	CY
24" RCP	50	LF
FOUNDATION MATERIAL FOR CONCRETE (TRUCK MEASURE)	15	CY
TOPSOIL	250	CY

Plantings		Qty	UOM
GROUND COVER			
PENNSYLVANIA SEDGE		3045	EA
	Carex pensylvanica		
SWEET FLAG		153	EA
	Acorus gramineus		
SHRUBS AND PERENNIALS			
GREY DOGWOOD		4	EA
	Cornus racemosa		
HAY-SCENTED FERN		151	EA
	Dennstaetia punctilobula		
COMMON WITCH HAZEL		6	EA
	Hamamelius virginiana		
NORTHERN BAYBERRY		9	EA
	Morella pensylvanic		
SPICEBUSH		3	EA
	Linera benzoin		
CHRISTMAS FERN		49	EA
	Polystichum acrostichoides		
SWAMP AZALEA		13	EA
	Rhododendronviscosum		
LOWBUSH BLUEBERRY		116	EA
	Vaccinum angustifolium		
MAPLELEAF VIBURNUM		10	EA
	Viburnim acerifolium		
SUMMERSWEET		10	EA
	Clethra Alnifolia		
AMERICAN ELDERBERRY		10	EA
	Sambucus canadensis		
AMERICAN HAZELNUT		10	EA
	Corylus americana		
TREES			
CANADIEN SERVICEBERRY		6	EA
	Amelanchier canadensis		
EASTERN DOGWOOD		7	EA
	Cornus florida		
New England Restoration Mix Seed		500	SF



Shoelace Park

Sheet 3 of 3

Shoelace Park
Ecosystem Restoration

Detailed Design for USACE Features

QUEENS NEW YORK

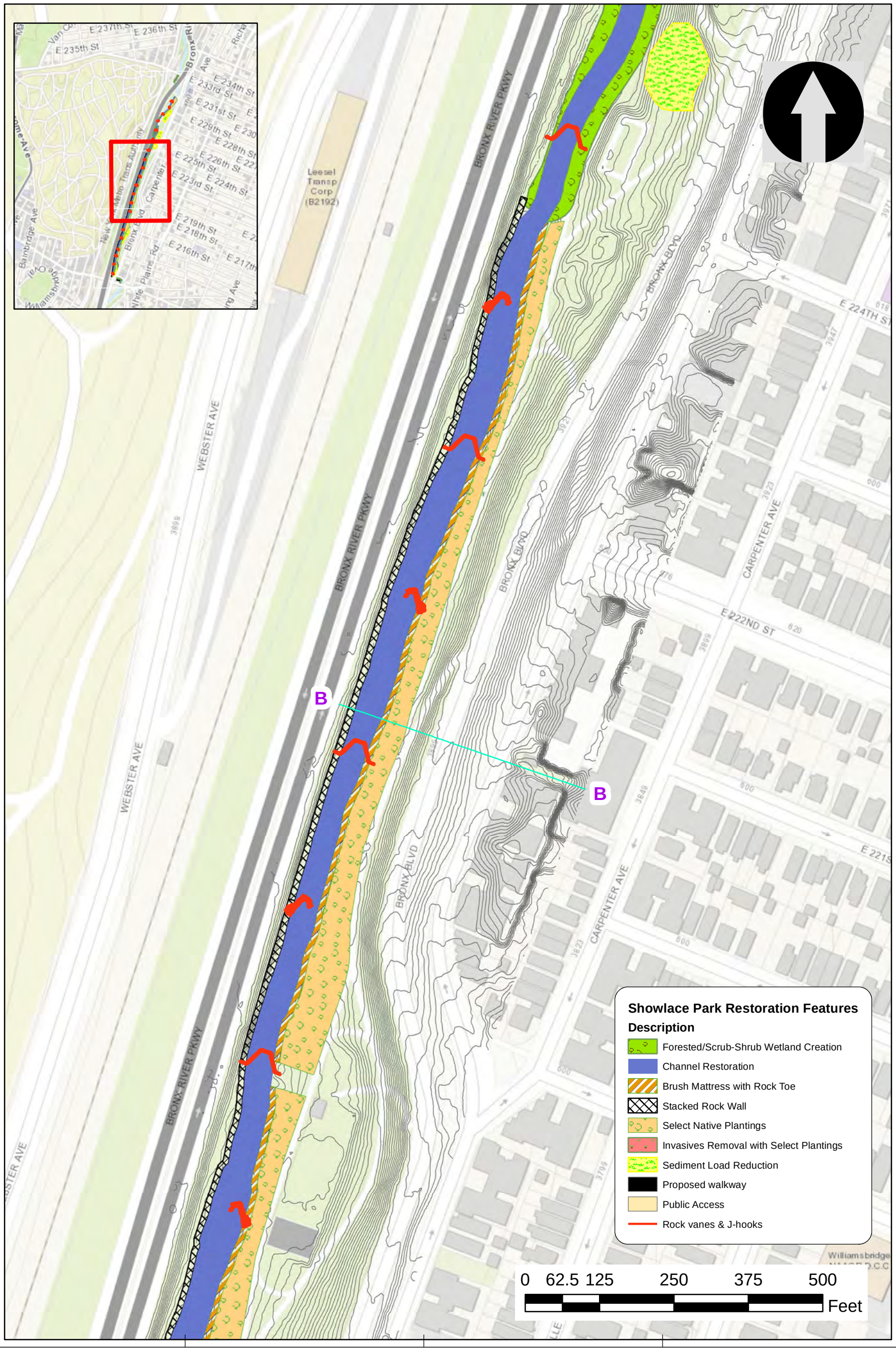
U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

US Army Cors of Engineers
New York District

L:\HRE_OverallFeasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Shoelace_Park\GIS\Alt_D_sep2019\HRE_Shoelace_Park_Sep19__Layout2.mxd

Map created 23 Sep 2019, e3enhgsw
Source: ESRI



Shoelace Park

Sheet 3 of 3

Shoelace Park
Ecosystem Restoration

Detailed Design for USACE Features

QUEENS NEW YORK

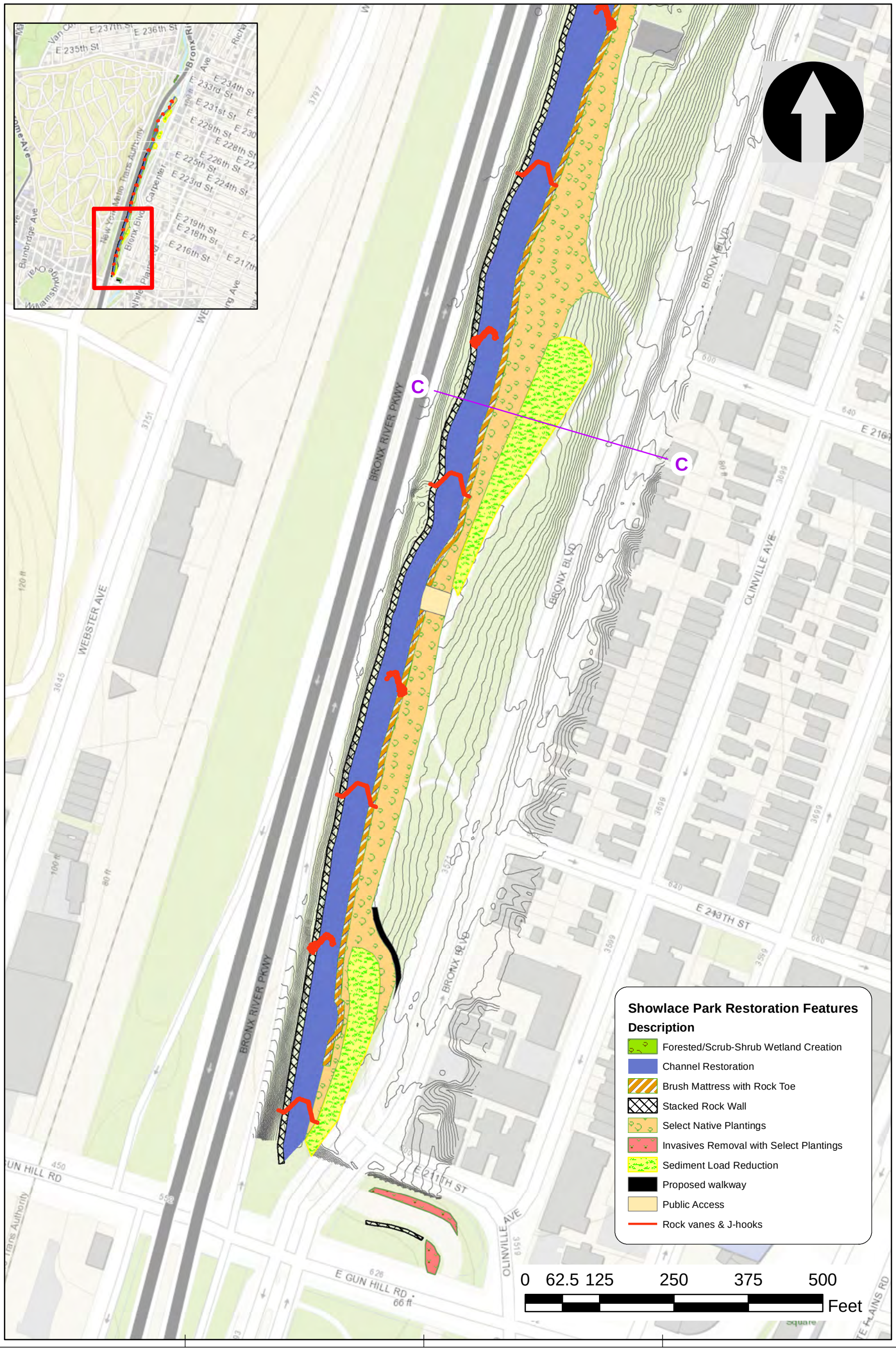
U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

US Army Corps of Engineers
New York District

L:\HRE_OverallFeasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Shoelace_Park\GIS\Alt_D_sep2019\HRE_Shoelace_Park_Sep19__Layout2.mxd

Map created 23 Sep 2019, e3enhgsw
Source: ESRI



Shoelace Park

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Shoelace_Park\GIS\Alt_D_sep2019\HRE_Shoelace_Park_Sep19__Layout2.mxd

Sheet 3 of 3

Shoelace Park
Ecosystem Restoration

Detailed Design for USACE Features

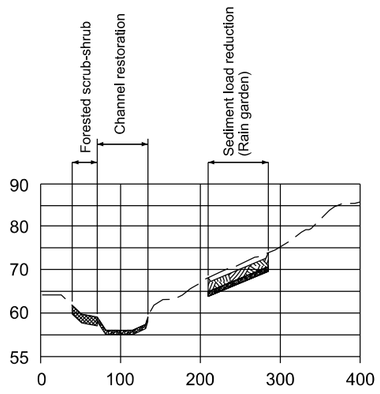
QUEENS NEW YORK

U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

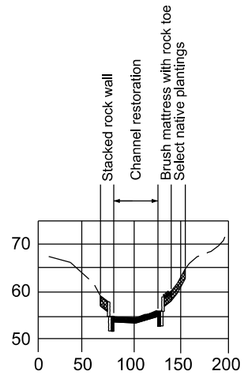
CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

US Army Corps of Engineers
New York District

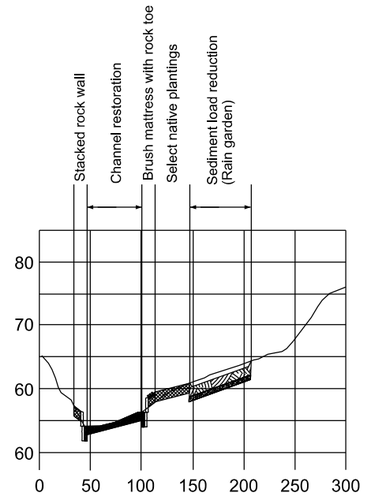
Map created 23 Sep 2019, e3enhgsw
Source: ESRI



X-Section AA



X-Section BB



X-Section CC

See grading plan for cross-section locations

Shoelace Park

US Army Corps
of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DWN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
PLOTTED BY:
SIZE: ANSI D
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
PLOT DATE: $DATE$

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-ENH

SHOELACE PARK
ECOSYSTEM RESTORATION

Cross-Sections

NEW YORK
BRONX

SHEET
REFERENCE
NUMBER

SHEET OF

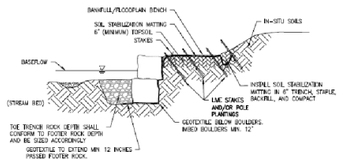
D

C

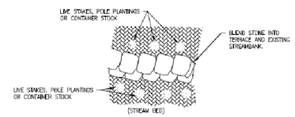
B

A

BOULDER TOE REVETMENT - SECTION VIEW



BOULDER TOE REVETMENT - PLAN VIEW

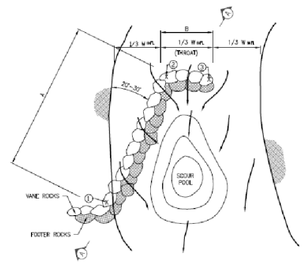


Boulder Toe Revetment Detail

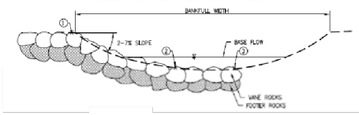
n.t.s.

Detail adapted from In-Stream Structures, Details and Construction Guidleines, prepared for the Philadelphia Water Department, September 2015

J-HOOK VANE - PLAN VIEW



J-HOOK VANE - SECTION VIEW A-A

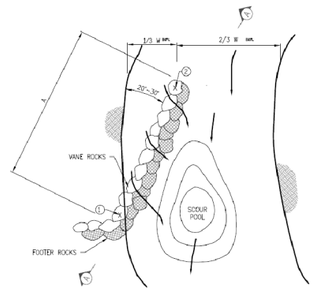


J-Hook Vane Detail

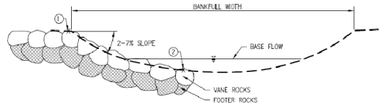
n.t.s.

Detail adapted from In-Stream Structures, Details and Construction Guidleines, prepared for the Philadelphia Water Department, September 2015

ROCK VANE - PLAN VIEW



ROCK VANE - SECTION VIEW A-A

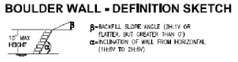


Rock Vane Detail

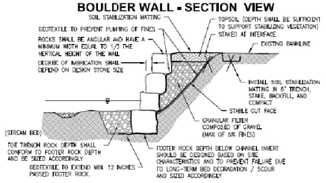
n.t.s.

Detail adapted from In-Stream Structures, Details and Construction Guidleines, prepared for the Philadelphia Water Department, September 2015

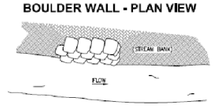
BOULDER WALL - DEFINITION SKETCH



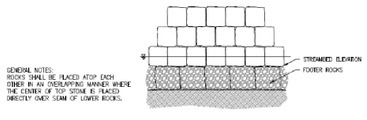
BOULDER WALL - SECTION VIEW



BOULDER WALL - PLAN VIEW



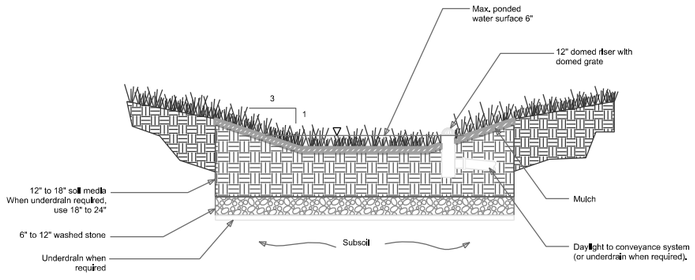
BOULDER WALL - ELEVATION VIEW



Boulder Wall Detail

n.t.s.

Detail adapted from In-Stream Structures, Details and Construction Guidleines, prepared for the Philadelphia Water Department, September 2015



Typical Bioswale - Profile

n.t.s.

Source: NY State Stormwater Manual January 2015

Shoelace Park

US Army Corps of Engineers New York District

MARK	DESCRIPTION	DATE	APPR.
MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW | DRN BY: GSW | CKD BY: GSW | SUBMITTED BY: GSW | DATE: | SOLICITATION NO.: | CONTRACT NO.: | FILE NAME: | PLOTTED BY: | PLOT DATE: SDATE$ | SIZE: ANSI D

U. S. ARMY ENGINEER DISTRICT NEW YORK http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH ECOSYSTEM RESTORATION TEAM CENAN-EN-H

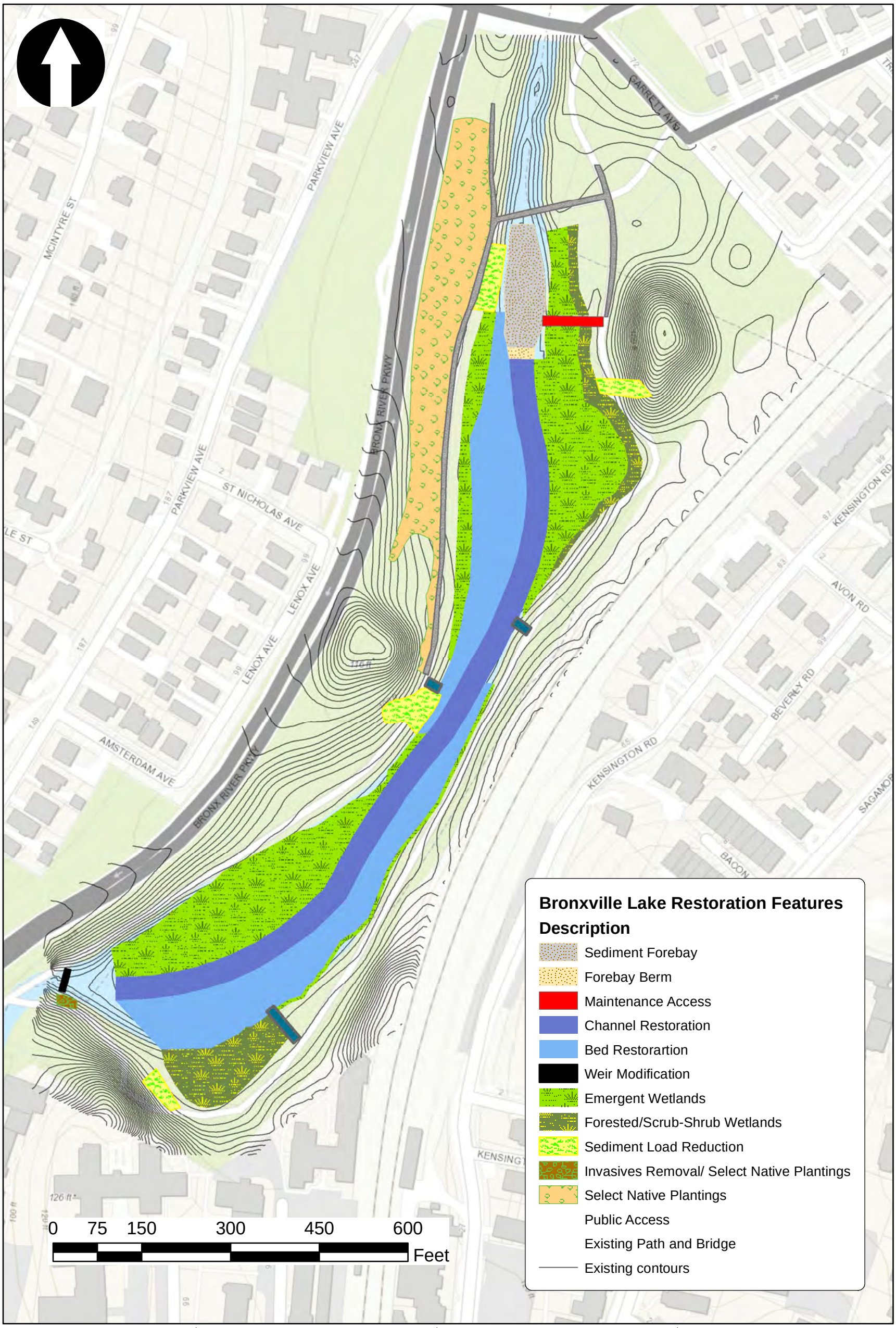
SHOELACE PARK ECOSYSTEM RESTORATION

Feature Details

BRONX NEW YORK

SHEET REFERENCE NUMBER

SHEET OF



BRONXVILLE LAKE

BRONXVILLE LAKE
STREAM & ECOSYSTEM RESTORATION

Detailed Design for USACE Features

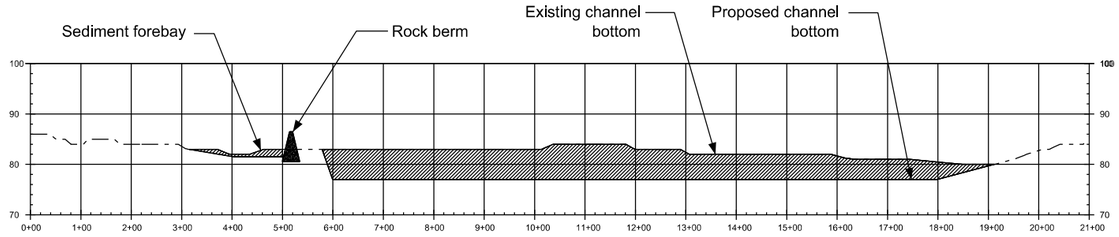
BRONXVILLE NEW YORK

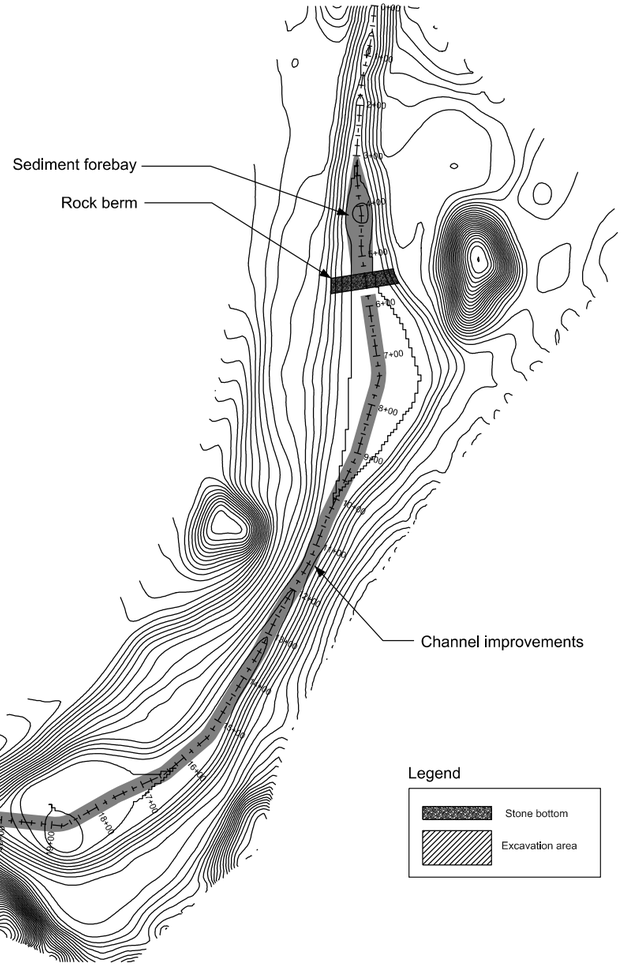
US Army Corps of Engineers New York District

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Bronxville_Lake\GIS\HRE_BVLake_08JUL19__Layout1.mxd

MAY 2009 NYD BORDER

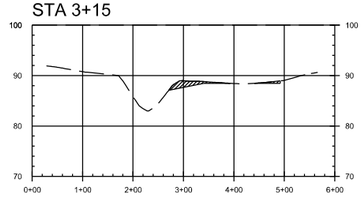
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Bronxville_Lake\Microstation\Bronx River details.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Bronxville_Lake\Microstation\Pen tables\BVL-Xsections.tbl



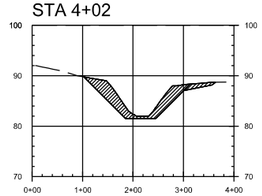


Plan view not to standard scale

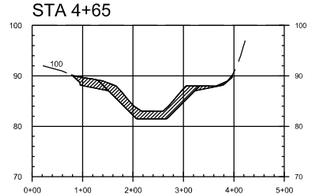
STA 3+15



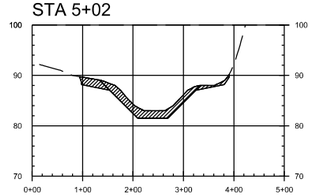
STA 4+02



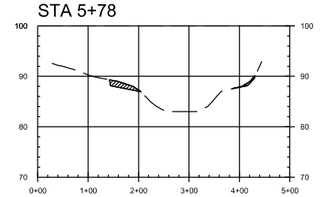
STA 4+65



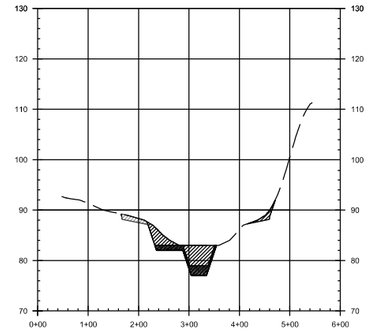
STA 5+02



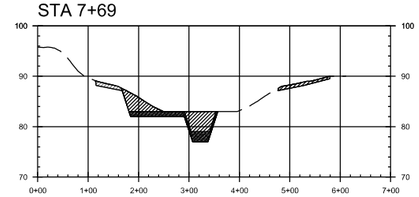
STA 5+78



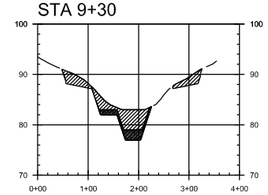
STA 6+02



STA 7+69

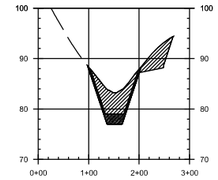


STA 9+30

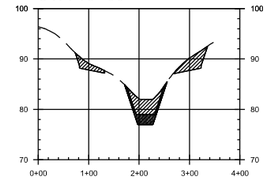


Cross-sections scale: 1V:10H

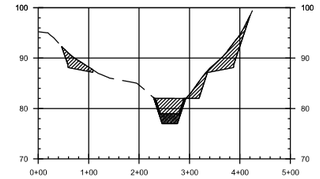
STA 11+95



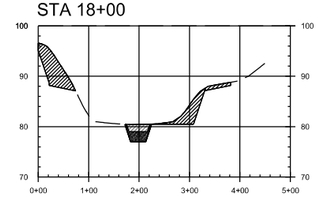
STA 13+69



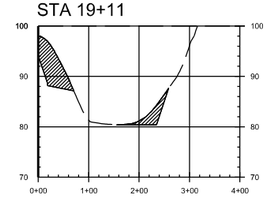
STA 15+72



STA 18+00



STA 19+11



WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

Bronxville Lake

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DRN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
PLOTTED BY:
PLOT DATE: 1/7/2020
SIZE: ANSI D

U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

BRONXVILLE LAKE
STREAM AND ECOSYSTEM RESTORATION

CROSS-SECTIONS

BRONXVILLE NEW YORK

SHEET REFERENCE NUMBER

SHEET OF

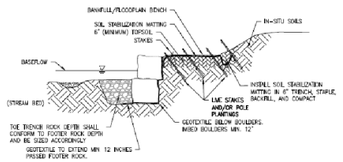
D

C

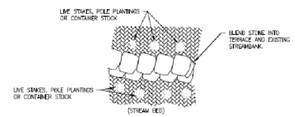
B

A

BOULDER TOE REVETMENT - SECTION VIEW



BOULDER TOE REVETMENT - PLAN VIEW

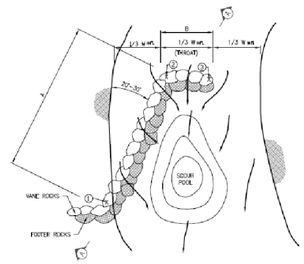


Boulder Toe Revetment Detail

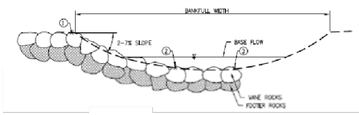
n.t.s.

Detail adapted from In-Stream Structures, Details and Construction Guidleines, prepared for the Philadelphia Water Department, September 2015

J-HOOK VANE - PLAN VIEW



J-HOOK VANE - SECTION VIEW A-A

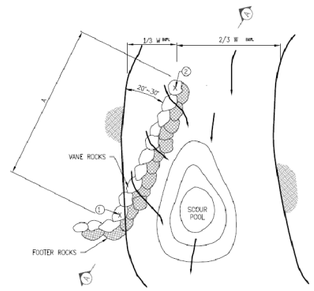


J-Hook Vane Detail

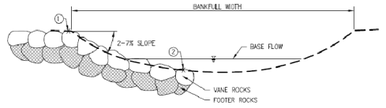
n.t.s.

Detail adapted from In-Stream Structures, Details and Construction Guidleines, prepared for the Philadelphia Water Department, September 2015

ROCK VANE - PLAN VIEW



ROCK VANE - SECTION VIEW A-A

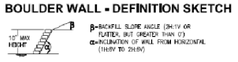


Rock Vane Detail

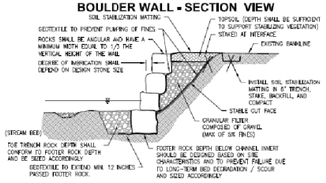
n.t.s.

Detail adapted from In-Stream Structures, Details and Construction Guidleines, prepared for the Philadelphia Water Department, September 2015

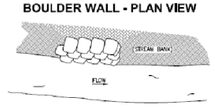
BOULDER WALL - DEFINITION SKETCH



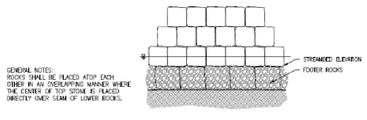
BOULDER WALL - SECTION VIEW



BOULDER WALL - PLAN VIEW



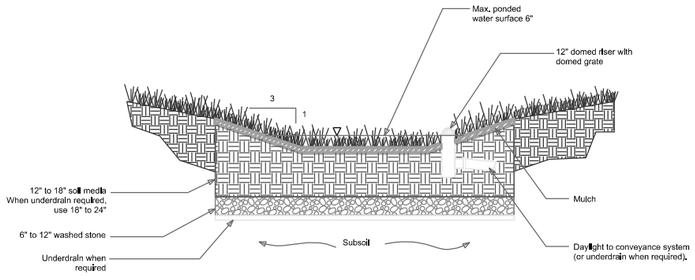
BOULDER WALL - ELEVATION VIEW



Boulder Wall Detail

n.t.s.

Detail adapted from In-Stream Structures, Details and Construction Guidleines, prepared for the Philadelphia Water Department, September 2015



Typical Bioswale - Profile

n.t.s.

Source: NY State Stormwater Manual January 2015

Shoelace Park

US Army Corps of Engineers New York District

MARK	DESCRIPTION	DATE	APPR.
MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW | DRN BY: GSW | CKD BY: GSW | SUBMITTED BY: GSW | DATE: | SOLICITATION NO.: | CONTRACT NO.: | FILE NAME: | PLOTTED BY: | PLOT DATE: SDATE$ | SIZE: ANSI D

U. S. ARMY ENGINEER DISTRICT NEW YORK http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH ECOSYSTEM RESTORATION TEAM CENAN-EN-H

SHOELACE PARK ECOSYSTEM RESTORATION

Feature Details

BRONX NEW YORK

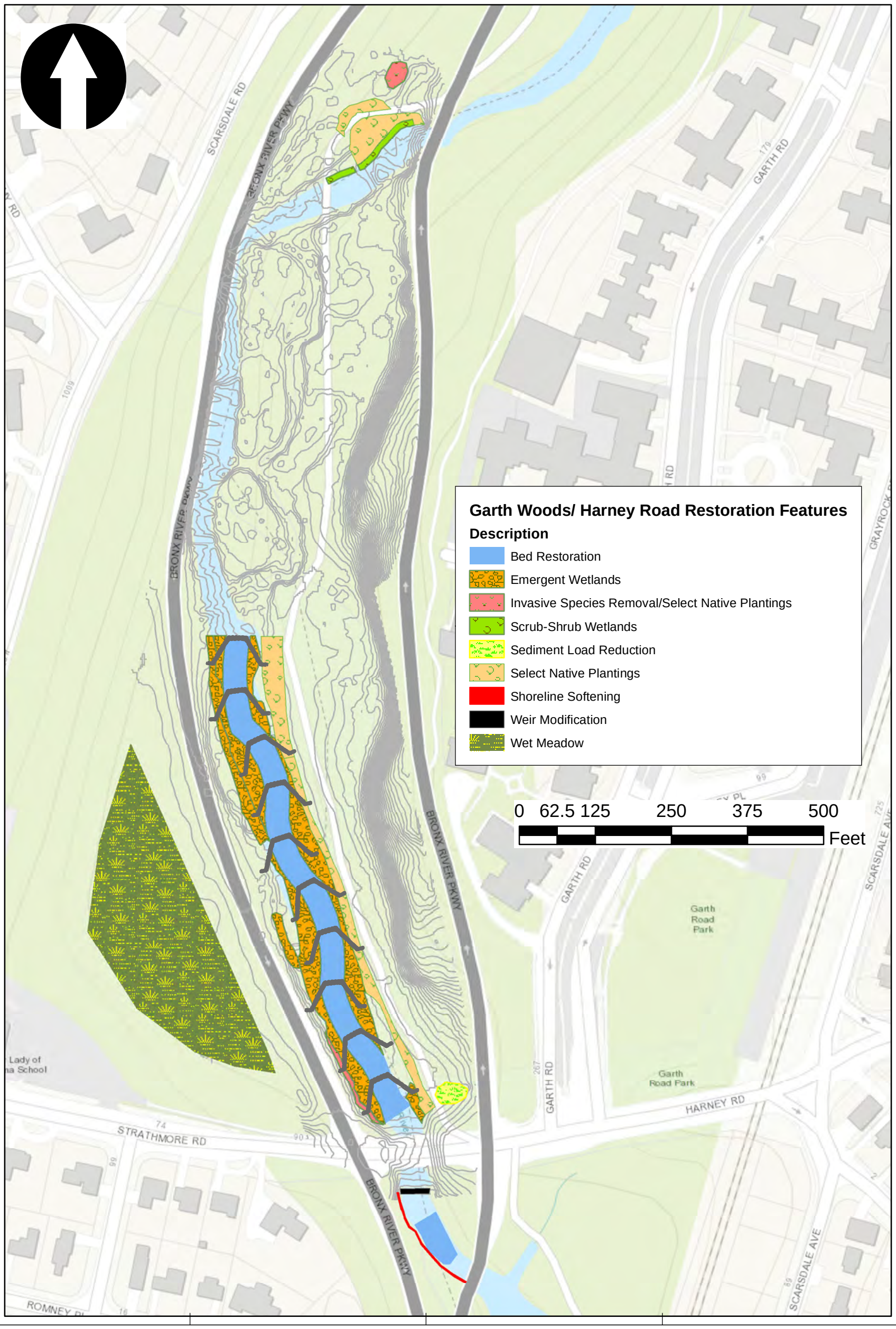
SHEET REFERENCE NUMBER

SHEET OF

Bronxville Lake Quantities					
Item				Qty	UOM
INVASIVE SPECIES REMOVAL W/ SELECT NATIVE PLANTINGS					
	Clearing & grubbing			40	CY
	Plantings				
		Sassafras		10	EA
			Sassafras albidium		
		Red oak		10	EA
			Quercus rubra		
		White oak		10	EA
			Quercus alba		
SELECT NATIVE PLANTING					
	Clearing & grubbing			1,700	CY
	Plantings				
		Sassafras		330	EA
			Sassafras albidium		
		Red oak		330	EA
			Quercus rubra		
		White oak		330	EA
			Quercus alba		
REALIGN CHANNEL					
	Hydraulic dredging			21,900	CY
SHORELINE EXCAVATION - Entire site					
	Excavation				
			Right bank	19,800	CY
			Left bank	8,300	CY
TOPSOIL - for all plantings					
	Topsoil (6" layer)			2,800	CY
EMERGENT WETLAND CREATION					
	Clearing & grubbing			400	CY
	Plantings				
		Cinnamon fern		1,130	EA
			Osmundastrum cinnamaeum		
		Sedge		4,510	EA
			Carex stricta		
		Arrow arum		4,510	EA
			Peltandra virginica		
		Bulrush		4,510	EA
			Scripus atrovirens		
		Common rush		4,510	EA
			Juncus effuses		
		Broad leafed cattail		2,010	EA
			Typha latifolio		
FORESTED SCRUB/SHRUB WETLAND CREATION					
	Clearing & grubbing			3,700	CY
	Trees				
		Arrowwood		364	EA
			Viburnum dentatum		
		Elderberry		364	EA
			Sambucus spp.		
		Buttonbush		364	EA
			Cephalanthus accidentalis		
		Serviceberry		364	EA
			Amalenchier spp.		
		Red osier dogwood		2,278	EA
			Cornus stolonifera		
		Willow		2,278	EA
			Salix (sp.)		
		Red maple		182	EA
			Acer rubrum		
		Sweet gum		182	EA
			Liquidambar styraciflua		
		Pin oak		182	EA
			Quercus palustris		
	Seed Mix				
		Wet meadow seed mix		100	LB

Cont'd

Item				Qty	UOM
BED RESTORATION					
	Stone for channel bottom				
			Angular stone	18,510	Tons
BIOSWALES					
			Total excavation	2,400	CY
			Soil medium	1,840	CY
			Mulch	540	CY
	Stone for underdrains				
			Bank run gravel	1,070	Tons
FOREBAY RESTORATION					
	Excavation (hydraulic)			2,500	CY



Garth Woods/ Harney Road

GARTH WOODS/ HARNEY ROAD
STREAM & ECOSYSTEM RESTORATION

Detailed Design for USACE Features

Scarsdale NEW YORK

U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

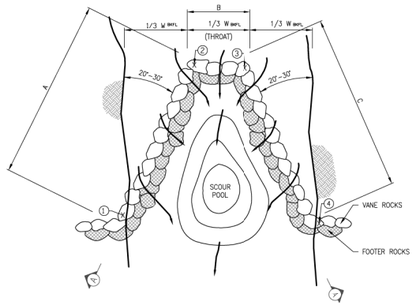
20 Aug 2019

US Army Cors
of Engineers
New York District

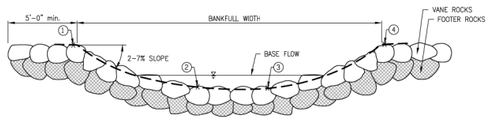
MAY 2009 NYD BORDER

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Garth_Woods_Harney_Rd\Microstation\Garth_design.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Bronx_Sites\Garth_Woods_Harney_Rd\Microstation\Garth.tbl

CROSS ROCK VANE - PLAN VIEW



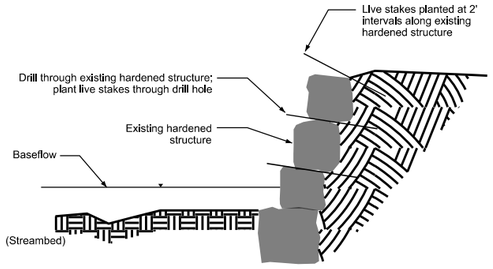
CROSS ROCK VANE - SECTION VIEW A-A



Rock Cross Vane Detail

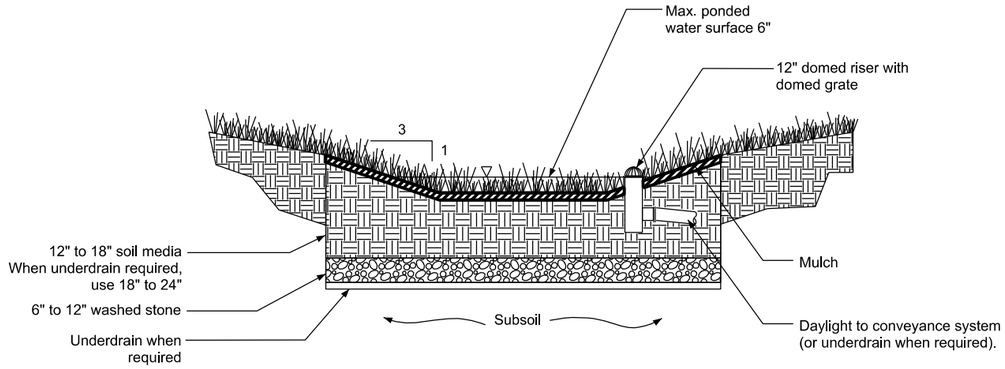
n.t.s.

Detail adapted from In-Stream Structures Details and Construction Guidelines, prepared for the Philadelphia Water Department, September 2015



Shoreline Softening Detail

n.t.s.



Typical Bioswale - Profile

n.t.s.

Source: NY State Stormwater Manual January 2015

INVASIVE SPECIES REMOVAL W/ SELECT NATIVE PLANTINGS		
Clearing & grubbing (9")	70	CY
Common excavation (9")	70	CY
Common fill (12")	110	CY
Topsoil (6")	1,380	CY
Plantings		
Sassafras	20	EA
Sassafras albidium		
Red oak	20	EA
Quercus rubra		
White oak	20	EA
Quercus alba		
SELECT NATIVE PLANTING		
Clearing & grubbing (9")	560	CY
Common excavation (9")	560	CY
Common fill (12")	900	CY
Topsoil (6")	450	CY
Plantings		
Sassafras	110	EA
Sassafras albidium		
Red oak	110	EA
Quercus rubra		
White oak	110	EA
Quercus alba		
EMERGENT WETLANDS		
Clear/grub (9" depth)	970	CY
Common excavation (33" depth)	3,550	CY
Top soil (6" depth)	780	CY
Plantings		
Cinnamon fern	1,530	EA
Osmundastrum cinnamaeum		
Sedge	6,090	EA
Carex stricta		
Arrow arum	6,090	EA
Peltandra virginica		
Bulrush	6,090	EA
Scripus atrovirens		
Common rush	6,090	EA
Juncus effuses		
Broad leafed cattail	2,710	EA
Typha latifolio		

EMERGENT WET MEADOW		
Clear/grub (9" depth)	2,030	CY
Common excavation (33" depth)	7,430	
Top soil (6" depth)	1,620	CY
New England Roadside Matrix Wet Meadow Seed Mix	40	LBS
FORESTED SCRUB/SHRUB WETLAND CREATION		
Trees		
Arrowwood	6	EA
Viburnum dentatum		
Elderberry	6	EA
Sambucus spp.		
Buttonbush	6	EA
Cephalanthus accidentalis		
Serviceberry	6	EA
Amalenchier spp.		
Red osier dogwood	36	EA
Cornus stolonifera		
Willow	36	EA
Salix (sp.)		
Red maple	3	EA
Acer rubrum		
Sweet gum	3	EA
Liquidambar styraciflua		
Pin oak	3	EA
Quercus palustris		
Seed Mix		
Wet meadow seed mix	10	LB
ROCK VANES		
Channel excavation for vanes		
In-stream excavation	1,800	CY
Bank excavation for tie-ins	400	CY
Rock for vanes	2,010	Tons
Rock for bank tie-ins	150	Tons

CHANNEL MODIFICATIONS/ IMPROVED STONE BOTTOM		
Channel excavation volume	2,640	CY
(Not including in footprints of rock vanes)		
Angular stone for channel bottom	5,890	Tons
(Not including in footprints of rock vanes)		
SHORELINE SOFTENING		
Drill through existing hardened structure	1,000	lf
Live willow stakes	580	EA
SEDIMENT LOAD REDUCTION		
Bioswales		
Total excavation	290	CY
Soil medium	240	CY
Mulch	70	CY
Stone for underdrains	70	CY
Bank run gravel	130	Tons
WEIR MODIFICATION		
Demolition	30	CY

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DWN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
PLOTTED BY:
PLOT DATE: 7/7/2020
SIZE: ANSI D

U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

GARTH HARNEY
STREAM & ECOSYSTEM RESTORATION

DETAIL SHEET

SCARSDALE NEW YORK

SHEET REFERENCE NUMBER

SHEET OF

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

Garth Harney

Garth-Harney Quantities					
Item				Qty	UOM
INVASIVE SPECIES REMOVAL W/ SELECT NATIVE PLANTINGS					
	Clearing & grubbing (9")			70	CY
	Common excavation (9")			70	CY
	Common fill (12")			110	CY
	Topsoil (6")			1,380	CY
	Plantings				
		Sassafras		20	EA
			Sassafras albidium		
		Red oak		20	EA
			Quercus rubra		
		White oak		20	EA
			Quercus alba		
SELECT NATIVE PLANTING					
	Clearing & grubbing (9")			560	CY
	Common excavation (9")			560	CY
	Common fill (12")			900	CY
	Topsoil (6")			450	CY
	Plantings				
		Sassafras		110	EA
			Sassafras albidium		
		Red oak		110	EA
			Quercus rubra		
		White oak		110	EA
			Quercus alba		
EMERGENT WETLANDS					
	Clear/grub (9" depth)			970	CY
	Common excavation (33" depth)			3,550	CY
	Top soil	(6" depth)		780	CY
	Plantings				
		Cinnamon fern		1,530	EA
			Osmundastrum cinnamaeum		
		Sedge		6,090	EA
			Carex stricta		
		Arrow arum		6,090	EA
			Peltandra virginica		
		Bulrush		6,090	EA
			Scripus atrovirens		
		Common rush		6,090	EA
			Juncus effuses		
		Broad leafed cattail		2,710	EA
			Typha latifolio		

Item				Qty	UOM
EMERGENT WET MEADOW					
	Clear/grub (9" depth)			2,030	CY
	Common excavation (33" depth)			7,430	
	Top soil	(6" depth)		1,620	CY
	New England Roadside Matrix Wet Meadow Seed Mi			40	LBS
FORESTED SCRUB/SHRUB WETLAND CREATION					
	Trees				
		Arrowwood		6	EA
			Viburnum dentatum		
		Elderberry		6	EA
			Sambucus spp.		
		Buttonbush		6	EA
			Cephalanthus accidentalis		
		Serviceberry		6	EA
			Amalenchier spp.		
		Red osier dogwood		36	EA
			Cornus stolonifera		
		Willow		36	EA
			Salix (sp.)		
		Red maple		3	EA
			Acer rubrum		
		Sweet gum		3	EA
			Liquidambar styraciflua		
		Pin oak		3	EA
			Quercus palustris		
	Seed Mix				
		Wet meadow seed mix		10	LB
ROCK VANES					
	Channel excavation for vanes				
		In-stream excavation		1,800	CY
		Bank excavation for tie-ins		400	CY
	Rock for vanes			2,010	Tons
	Rock for bank tie-ins			150	Tons
CHANNEL MODIFICATIONS/ IMPROVED STONE BOTTOM					
	Channel excavation volume			2,640	CY
		(Not including in footprints of rock vanes)			
	Angular stone for channel bottom			5,890	Tons
		(Not including in footprints of rock vanes)			
SHORELINE SOFTENING					
	Drill through existing hardened structure			1,000	lf
	Live willow stakes			580	EA

Item				Qty	UOM
SEDIMENT LOAD REDUCTION					
	Bioswales				
			Total excavation	290	CY
			Soil medium	240	CY
			Mulch	70	CY
	Stone for underdrains			70	CY
			Bank run gravel	130	Tons
STEPPED ROCK WALL					
	Rock			600	Tons
	Excavation for rock			300	CY
	Live willow cuttings			580	EA
	Geotextile			470	SY
WEIR MODIFICATION					
	Demolition			30	CY

L:\HRE_Overall\Feasibility_Detailed_Design\Detailed_Designs\Passaic Sites\Branch_Brook\HRE_BranchBrook_12AUG19__Layout1.mxd

Branch Brook Park

0 250 500 1,000 1,500 2,000
Feet

Branch Brook Park Restoration Features

Description

- Channel Deepening
- Emergent Wetlands
- Forested/Scrub-Shrub Wetlands
- Invasives Species Removal/ Select Native Plantings
- Select Native Plantings
- Stream Naturalization and Clearing

BRANCH BROOK PARK
STREAM & ECOSYSTEM RESTORATION

Detailed Design for USACE Features

NEWARK NEW JERSEY

U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

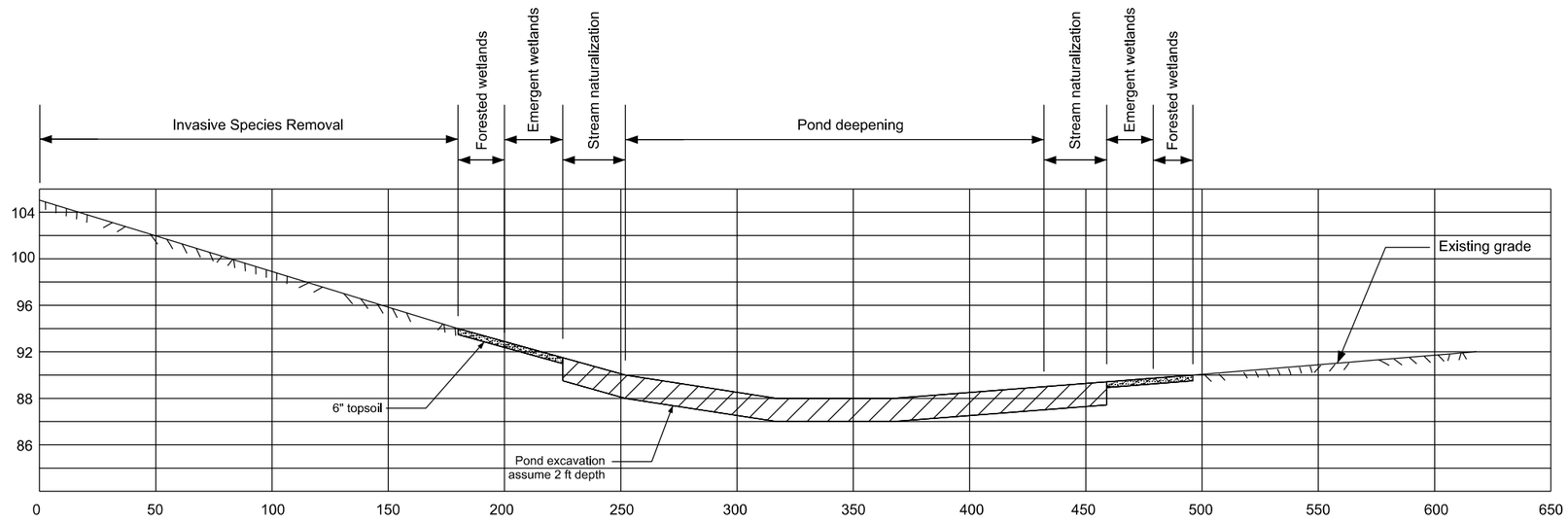
CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

20 Aug 2019

US Army Cors of Engineers
New York District

MAY 2009 NYD BORDER

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Passaic Sites\Branch_Brook\MicroStation\BranchBrookDetails.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Passaic Sites\Branch_Brook\MicroStation\Branch_Brook_details.tbl



Representative Pond Cross-Section

n.t.s.

Quantities

INVASIVE SPECIES REMOVAL W/ SELECT NATIVE PLANTINGS			
	Clearing & grubbing	10,780	CY
	Plantings		
	Sassafras	2,130	EA
	Sassafras albidium		
	Red oak	2,130	EA
	Quercus rubra		
	White oak	2,130	EA
	Quercus alba		
STREAM NATURALIZATION			
	Hydraulic dredging	3,170	CY
POND DEEPENING			
	Hydraulic dredging	55,020	CY
TOPSOIL - for all plantings			
	Topsoil (6" layer)	27,070	CY
EMERGENT WETLAND CREATION			

EMERGENT WETLAND CREATION			
	Clearing & grubbing	12,400	CY
	Plantings		
	Cinnamon fern	19,530	EA
	Osmundastrum cinnamaeum		
	Sedge	78,120	EA
	Carex stricta		
	Arrow arum	78,120	EA
	Peltandra virginica		
	Bulrush	78,120	EA
	Scripus atrovirens		
	Common rush	78,120	EA
	Juncus effuses		
	Broad leafed cattail	34,720	EA
	Typha latifolio		

FORESTED SCRUB/SHRUB WETLAND CREATION			
	Clearing & grubbing	10,650	CY
	Trees		
	Arrowwood	1291	EA
	Viburnum dentatum		
	Elderberry	1291	EA
	Sambucus spp.		
	Buttonbush	1291	EA
	Cephalanthus accidentalis		
	Serviceberry	1291	EA
	Amalenchier spp.		
	Red osier dogwood	8067	EA
	Cornus stolonifera		
	Willow	8067	EA
	Salix (sp.)		
	Red maple	645	EA
	Acer rubrum		
	Sweet gum	645	EA
	Liquidambar styraciflua		
	Pin oak	645	EA
	Quercus palustris		
	Seed Mix		
	Wet meadow seed mix	340	LB

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

Branch Brook Park

US Army Corps of Engineers
New York District

MARK | DESCRIPTION | DATE | APPR.

DESIGNED BY: GSW | DRN BY: GSW | CKD BY: GSW | SUBMITTED BY: GSW | DATE: | SOLICITATION NO.: | CONTRACT NO.: | FILE NAME: | PLOTTED BY: | PLOT DATE: 8/23/2019 | SIZE: ANSI D

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

BRANCH BROOK PARK
STREAM & ECOSYSTEM RESTORATION

DETAIL SHEET

NEWARK NEW JERSEY

SHEET REFERENCE NUMBER

SHEET OF

| Branch Brook Park Quantities | | |



Oak Island Yards

Oak Island Yards
NEWARK, NEW JERSEY

Planting Plan

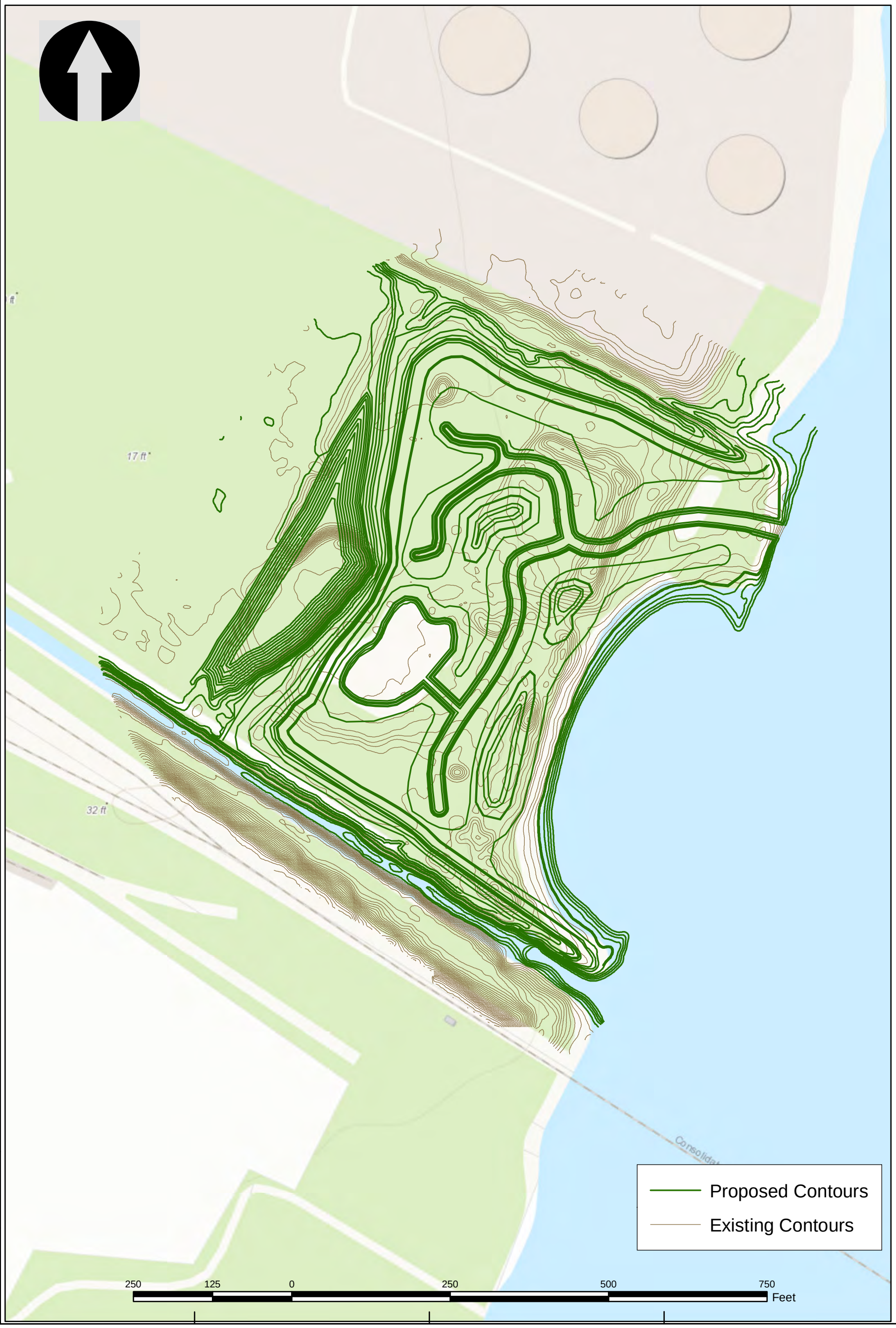
U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

US Army Corps of Engineers
New York District

Map created 11 Jan 2020, e3enhmjm

Oak Island Yards Quantities				
Item			**Qty**	**UOM**
Site Clearing and Grubbing			7.97	AC
Excavated Material			111,800	CY
Area to be graded			10.82	AC
Clean Fill			5	CY
Low Marsh			5.32	AC
	Plants		63,730	EA
High Marsh			0.85	AC
	Plants		10,190	EA
Scrub/Shrub			0.44	AC
	Plants		1,880	EA
Martime Forest			2.85	AC
	Plants		17,340	EA
	Trees		1,380.00	EA



Oak Island Yards

Oak Island Yards
NEWARK, NEW JERSEY

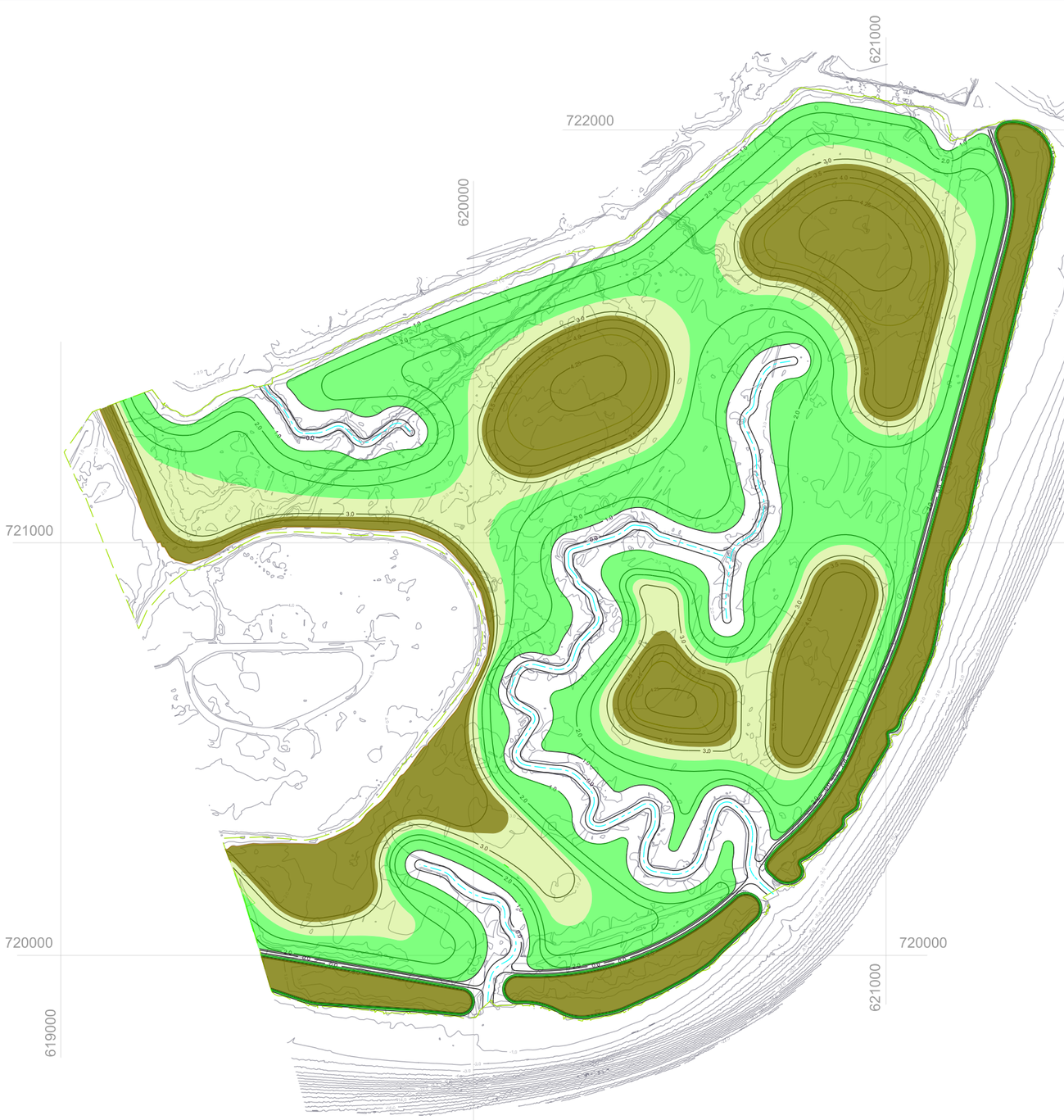
Grading Plan

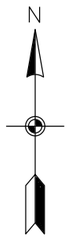
U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

US Army Cors
of Engineers
New York District

Map created 11 Jan 2020, e3enhmjm





Legend

- Low marsh: 26.5 acres
  Elev 1.0 ft to elev 2.75 ft
- High marsh: 11.7 acres
  Elev 2.75 ft to elev 3.25 ft
- Scrub shrub: 13.8 acres
  Elev 3.25 ft to elev 4.25 ft

1. Construction to begin in 2028 with 3 year duration. (Completion by 2031.)
2. Vegetation ranges based on tide data collected in 2008, projected to 2031 at the intermediate rate of sea level rise.

Not to standard scale

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Hackensack Sites\MetroMedia Marsh\Microstation\MetroMedia Final Feasibility_20200304.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Hackensack Sites\MetroMedia Marsh\Microstation\Pen tables\Metro_planting_plan.tbl

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

DESIGNED BY: GSW
DWN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
FILE NAME:
SIZE: ANSI D
PLOTTED BY:
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 3/4/2020

METROMEDIA TRACT
WETLANDS RESTORATION

PLANTING PLAN

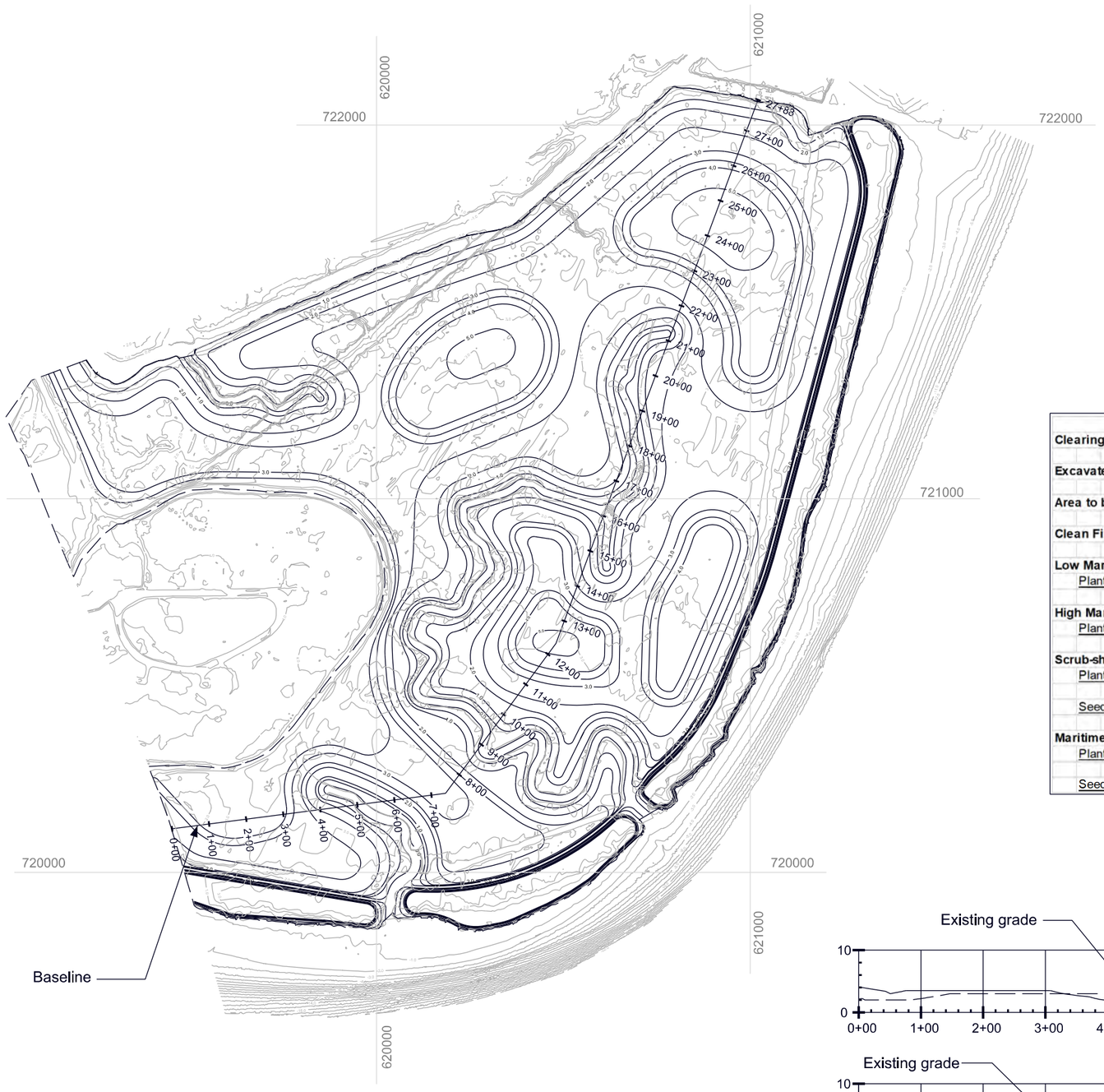
HACKENSACK MEADOWLANDS NEW JERSEY

SHEET REFERENCE NUMBER
L-001
SHEET 2 OF 2

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

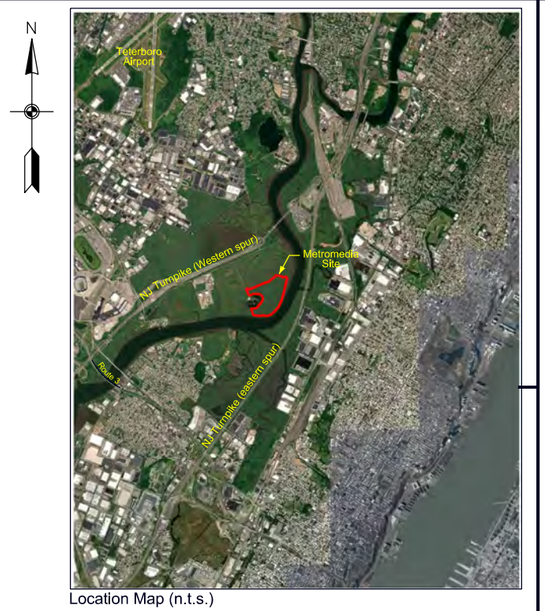
Metromedia Marsh



Not to standard scale

Quantities

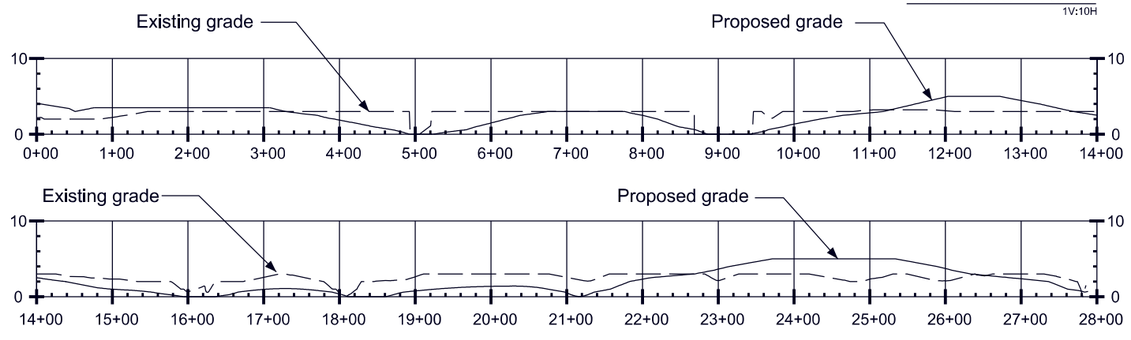
Item	Qty	UOM
Clearing & Grubbing	57.2	AC
Excavated Material	38,000	CY
Area to be Graded	67.3	AC
Clean Fill	41,000	**CY**
Low Marsh	26.5	AC
Plants	291,470	EA
High Marsh	11.7	AC
Plants	140,160	EA
Scrub-shrub	9.7	AC
Plants	18,590	EA
Seed	4.3	TON
Maritime Upland	4.1	AC
Plants	7,860	EA
Seed	1.8	TON



Location Map (n.t.s.)

Baseline Profile

1V:10H



US Army Corps of Engineers
New York District

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

DESIGNED BY: GSW
DWN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
FILE NAME:
SIZE: ANSI D
PLOTTED BY:
DATE:
SOLICITATION NO.:
CONTRACT NO.:
PLOT DATE: 11/15/2018

METROMEDIA TRACT
WETLANDS RESTORATION

GRADING PLAN

HACKENSACK MEADOWLANDS NEW JERSEY

SHEET REFERENCE NUMBER

SHEET 1 OF 2

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

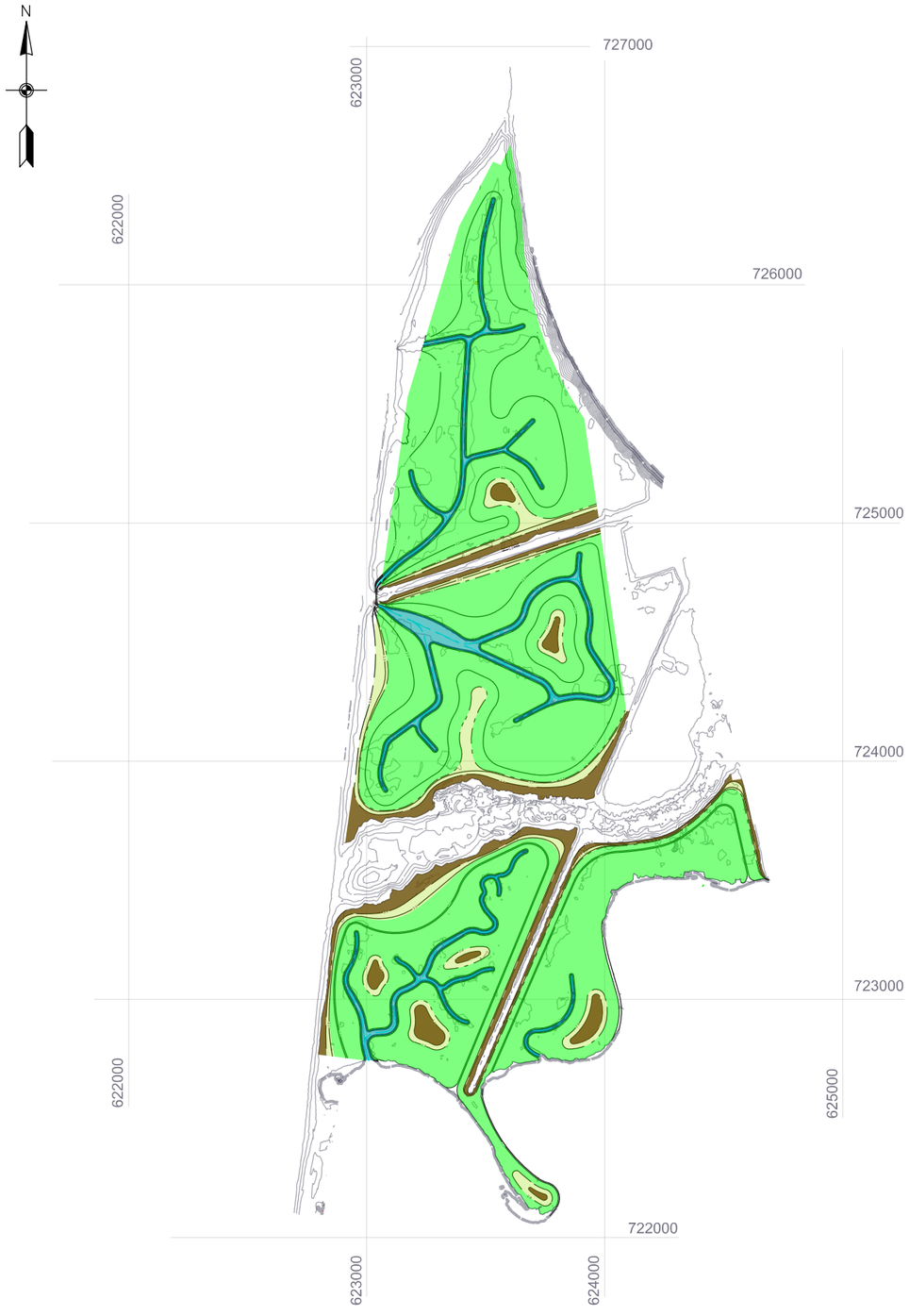
Metromedia Marsh

L:\HRE-Overall\Feasability_Detailed_Design\Detailed_Designs\Hackensack Sites\MetroMedia Marsh\Microstation\MetroMedia Final Feasibility.dgn
L:\HRE-Overall\Feasability_Detailed_Design\Detailed_Designs\Hackensack Sites\MetroMedia Marsh\Microstation\Pen tables\Metromedia plan view.tbl

Metromedia Quantities		
Item	Qty	UOM
Clearing & Grubbing	57.2	AC
Excavated Material	38,000	CY
Area to be Graded	67.3	AC
Clean Fill	41,000	**CY**
Low Marsh	26.5	AC
Plants	291,470	EA
High Marsh	11.7	AC
Plants	140,160	EA
Scrub-shrub	9.7	AC
Plants	18,590	EA
Seed	4.3	TON
Maritime Upland	4.1	AC
Plants	7,860	EA
Seed	1.8	TON

MAY 2009 NYD BORDER

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Hackensack Sites\Meadowlark_MarshMicroStation\Meadowlark_design.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Hackensack Sites\Meadowlark_MarshMicroStation\Pen Tables\Meadowlark planting plan.tbl



Legend

- Low marsh: 56.2 ac
  Elev. 1.4 ft to 2.9 ft
- High marsh: 6.5 ac
  Elev. 2.9 ft to 3.4 ft
- Scrub/upland: 5.3 ac
  Elev. 3.4 ft and above
- Channel: 4.6 ac



Location Map (n.t.s.)

QUANTITIES

Item	Qty	UOM
Area to be Graded	72.6	AC
Excavated Material	64,400	CY
Clearing and grubbing	53,600	CY
General excavation	10,800	CY
Clean Fill	**29,200**	**CY**
General fill	11,800	**CY**
Clean cap	12,500	**CY**
Low Marsh	56.2	AC
Plants	618,140	EA
High Marsh	6.5	AC
Plants	77,870	EA
Upland	5.3	AC
Plants	10,160	EA
Seed	2.4	TON
Box Culvert		
6 ft box culvert (assumed size)	50	LF
Wingwalls	2	EA
Fencing & Gates		
Construction Fence		
Fence	2,000	LF
Posts	250.0	
Security gate	1.0	EA
Silt Fence		
Fence	1,000	LF
Posts	170	
Herbivory Fence	62.7	AC
Fence	292,190	LF
Posts	27,590	EA
Mylar tape	1,241,460	LF
Turbidity Curtain	3,900.0	LF

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DRN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
SIZE: ANSI D
PLOTTED BY:
PLOT DATE: 10/8/2019

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

MEADOWLARK MARSH
WETLAND RESTORATION

PLANTING PLAN

HACKENSACK MEADOWLANDS NEW JERSEY

SHEET REFERENCE NUMBER

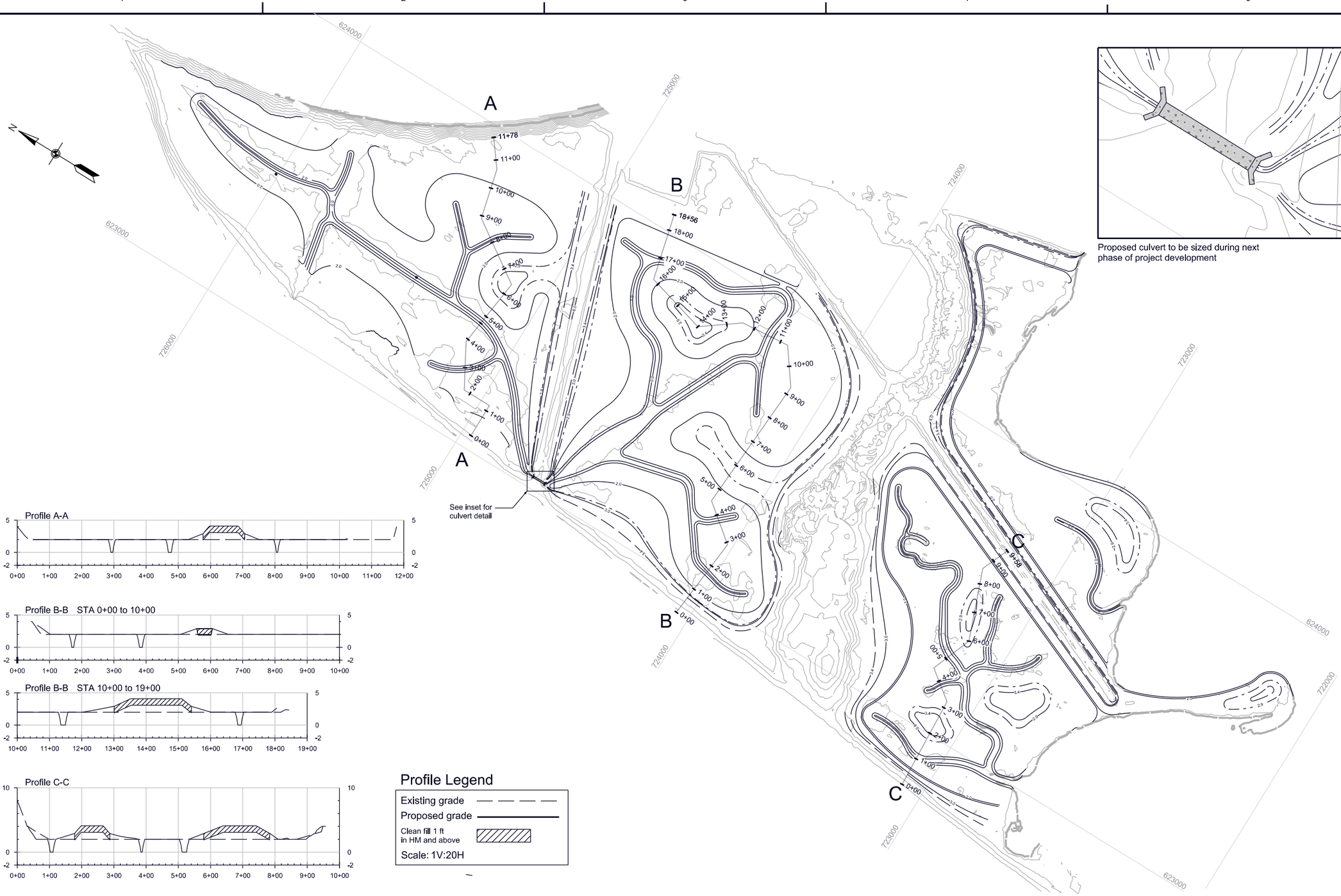
SHEET OF

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

MEADOWLARK MARSH

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Hackensack Sites\Meadowlark_Marsh\MicroStation\Meadowlark_design.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Hackensack Sites\Meadowlark_Marsh\MicroStation\Pen Tables\Meadowlark grading plan.tbl
MAY 2009 NYD BORDER



Proposed culvert to be sized during next phase of project development

Profile A-A

Profile B-B STA 0+00 to 10+00

Profile B-B STA 10+00 to 19+00

Profile C-C

Profile Legend

Existing grade

Proposed grade

Clean fill 1 ft in HM and above

Scale: 1V:20H

Drawing not to standard scale

Coordinate system is State Plane, New Jersey
Vertical datum: NAVD88

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

Meadowlark Marsh

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DRAWN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
PLOTTED BY:
PLOT DATE: 8/2/2019
SIZE: ANSI D

U.S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

MEADOWLARK MARSH
WETLAND RESTORATION

GRADING PLAN

HACKENSACK MEADOWLANDS — NEW JERSEY

SHEET REFERENCE NUMBER

SHEET OF

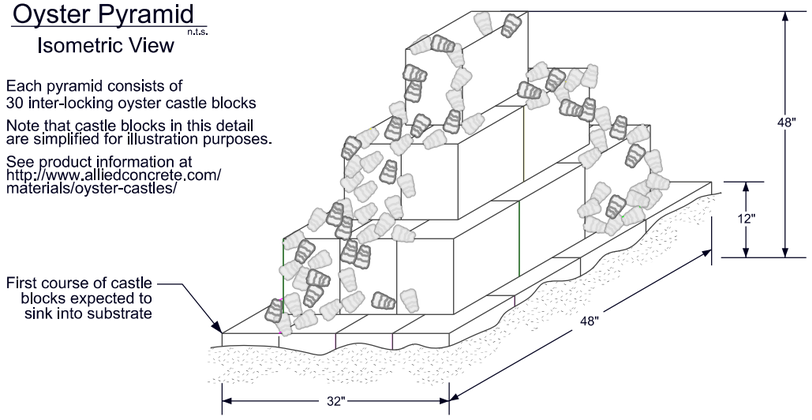
Meadowlark Quantities		
Item	Qty	UOM
Area to be Graded	72.6	AC
Excavated Material	64,400	CY
Clearing and grubbing	53,600	CY
General excavation	10,800	CY
Clean Fill	**29,200**	**CY**
General fill	11,800	**CY**
Clean cap	12,500	**CY**
Low Marsh	56.2	AC
Plants	618,140	EA
High Marsh	6.5	AC
Plants	77,870	EA
Upland	5.3	AC
Plants	10,160	EA
Seed	2.4	TON
Box Culvert		
6 ft box culvert (assumed size)	50	LF
Wingwalls	2	EA
Fencing & Gates		
Construction Fence		
Fence	2,000	LF
Posts	250.0	
Security gate	1.0	EA
Silt Fence		
Fence	1,000	LF
Posts	170	
Herbivory Fence	62.7	AC
Fence	292,190	LF
Posts	27,590	EA
Mylar tape	1,241,460	LF
Turbidity Curtain	3,900.0	LF

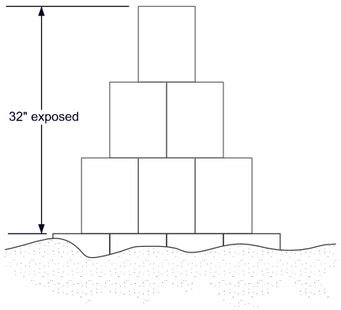
MAY 2009 NYD BORDER

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Oyster sites\MicroStation_all sites\HRE_oysters.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Oyster sites\MicroStation_all sites\Pen tables\Earle Plan View.tbl

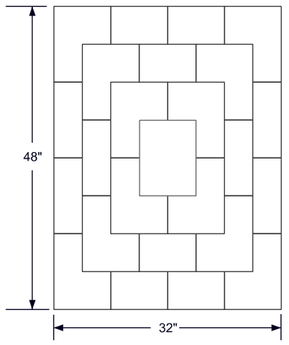
Oyster Pyramid
n.t.s.
Isometric View

1. Each pyramid consists of 30 inter-locking oyster castle blocks
2. Note that castle blocks in this detail are simplified for illustration purposes.
3. See product information at http://www.alliedconcrete.com/materials/oyster-castles/





Oyster Pyramid
n.t.s.
Elevation View



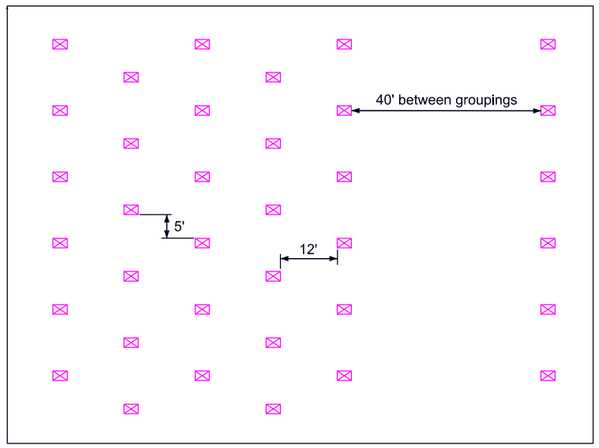
Oyster Pyramid
n.t.s.
Plan View



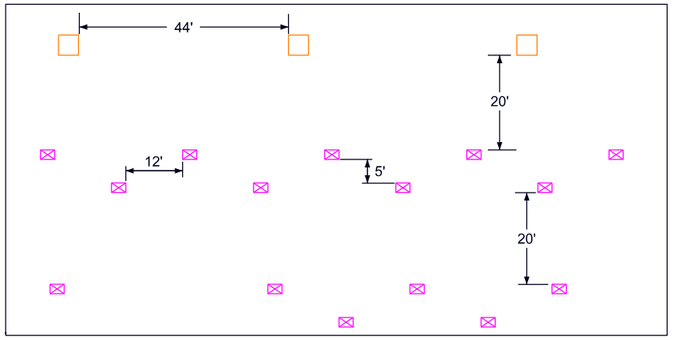
Location Map (n.t.s.)

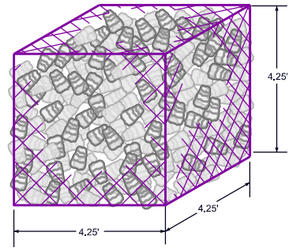
US Army Corps of Engineers
New York District

Area of Detail - 1



Area of Detail - 2





Oyster Gabion
n.t.s.

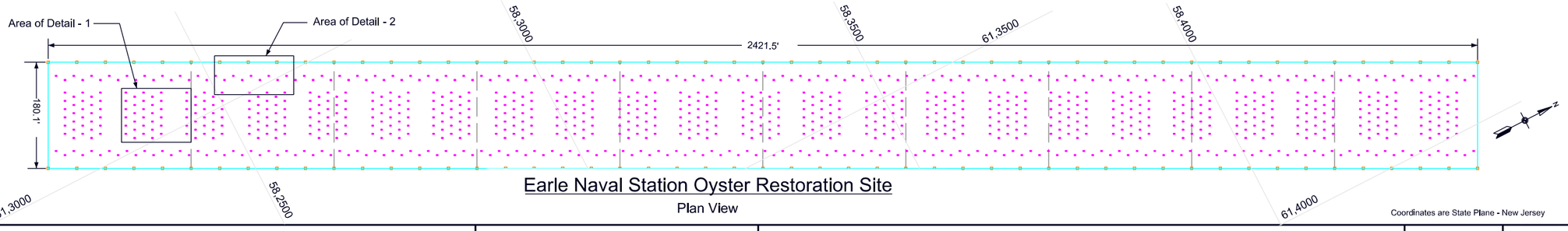
Quantities

Description	Qty	UOM
Area of oyster restoration	**10**	**AC**
Oyster gabions (4.25' x 4.25' x 4.25')	102	EA
Oyster Pyramids	1,010	EA
Oyster Castle Blocks		
30 castle blocks/pyramid	30,300	EA
Spat-on-shell		
Inside gabions	72	CY
Surface of pyramids	274	CY
Total	350	CY
Shell		
Inside gabions	150	CY

Assumptions

1. Gabions are 3/4 filled with shell / spat-on-shell
2. 1/3 contents of each gabion is spat-on-shell; 2/3 is plain shell
3. The surface area of each pyramid is covered with 3" thick spat-on-shell, or 0.3 cf per pyramid

Legend
- Oyster cage - 4.25' x 4.25' x 4.25'
- Oyster pyramid - footprint 48" x 32"
- Represents 1 acre



Earle Naval Station Oyster Restoration Site
Plan View

Coordinates are State Plane - New Jersey

DESIGNED BY: GSW	DATE:
DWN BY: GSW	CKD BY: GSW
SUBMITTED BY:	SOLICITATION NO.:
FILE NAME:	CONTRACT NO.:
SIZE: ANSI D	PLOTTED BY:
	PLOT DATE: 1/15/2019

U. S. ARMY ENGINEER DISTRICT NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

Earle Naval Station
Oyster Restoration
Plan View & Details
Middletown Township, New Jersey

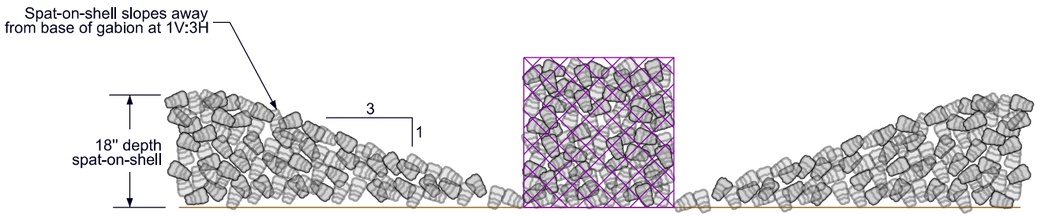
SHEET REFERENCE NUMBER
C-001
SHEET 1 OF 1

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

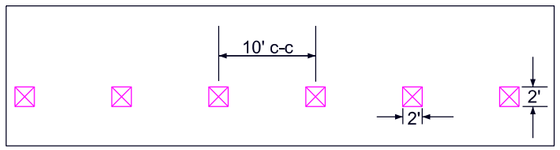
150 75 0 150 300
Scale: 1" = 150'

Earle Naval Weapons Station Quanitites			
Description		Qty	UOM
Area of oyster restoration		**10**	**AC**
Oyster gabions (4.25' x 4.25' x 4.25')		102	EA
Oyster Pyramids		1,010	EA
Oyster Castle Blocks			
	30 castle blocks/pyramid	30,300	EA
Spat-on-shell			
	Inside gabions	72	CY
	Surface of pyramids	274	CY
	Total	350	CY
Shell			
	Inside gabions	150	CY



Bush Terminal Gabion Detail
n.t.s.
Elevation View

Gabion Spacing
n.t.s.

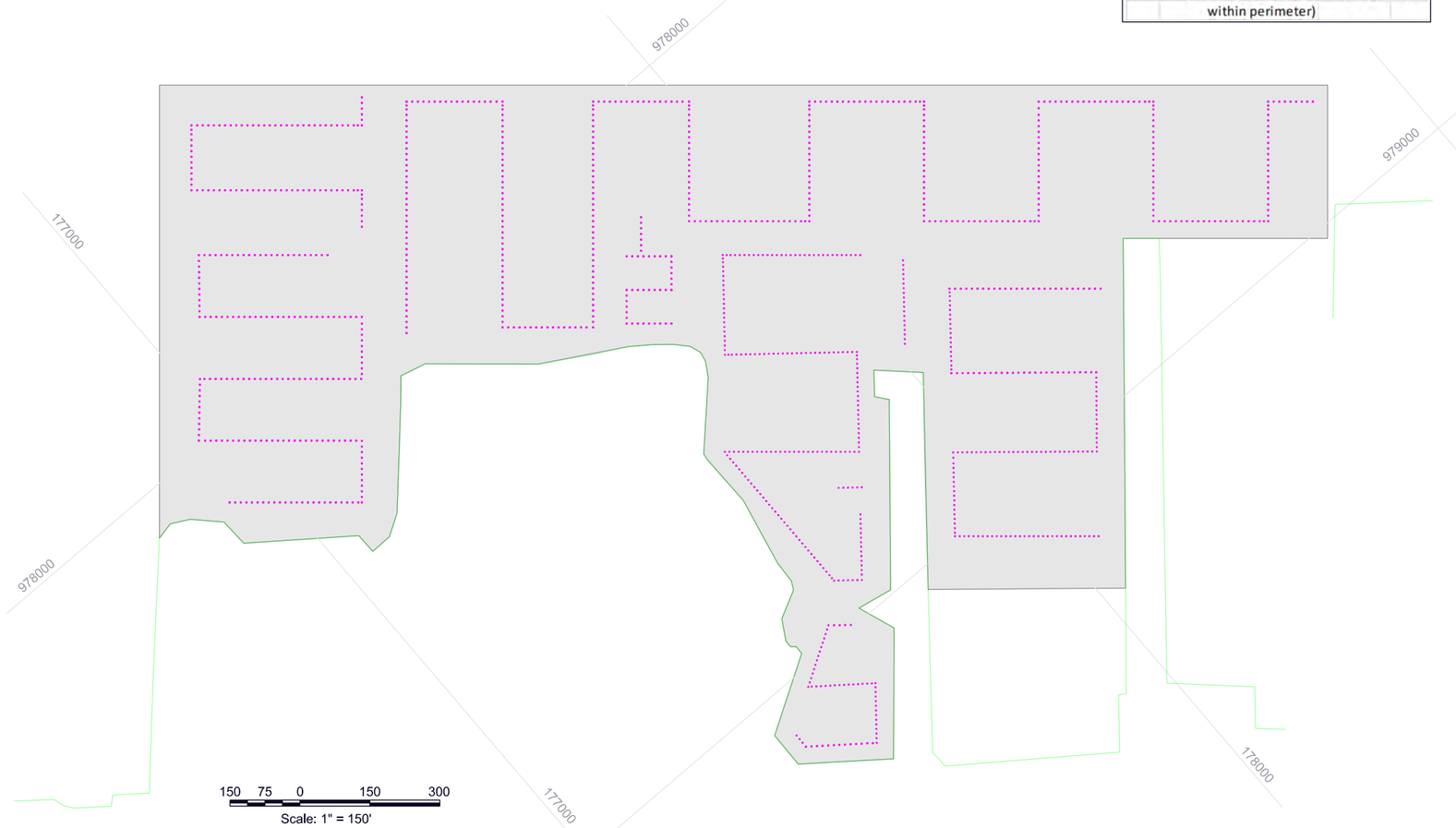


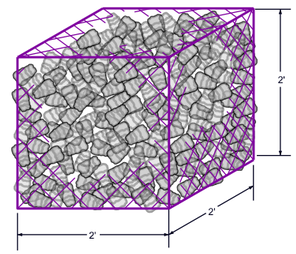
Quanitites

Description	Qty	UOM
Area of oyster restoration	**31.9**	**AC**
Oyster gabions (2' x 2')	1,100	EA
Spat-on-shell		
Within site perimeter	74,445	CY
Inside gabions	330	CY
Subtotal	74,775	CY
Total (Add 3% for loss)	**76,680**	CY
within perimeter)		



Location Map (n.t.s.)





Legend

Gabion (2' x 2' x 2')

Spat-on-shell, 18" thickness

US Army Corps of Engineers New York District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

DESIGNED BY: GSW
DWN BY: GSW
CKD BY:
SUBMITTED BY: GSW
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
SIZE: ANSI D
PLOTTED BY:
PLOT DATE: 12/6/2019

Bush Terminal
Oyster Restoration

Plan View & Details

Brooklyn, New York

SHEET REFERENCE NUMBER
C-001

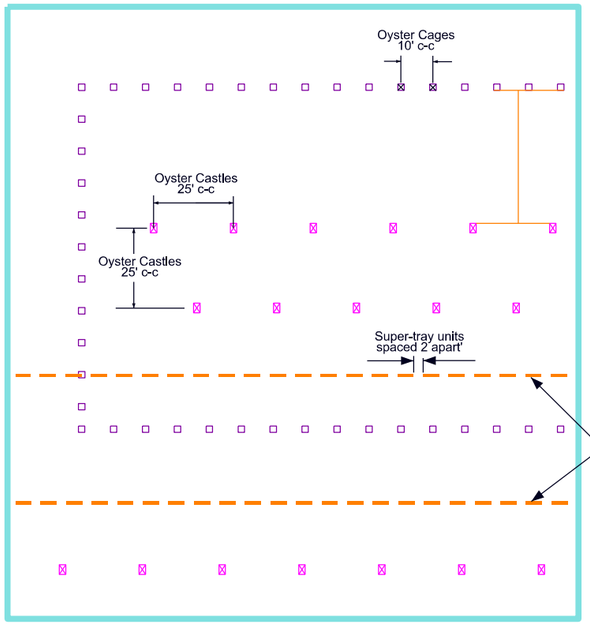
SHEET 1 OF 1

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

MAY 2009 NYD BORDER
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Oyster sites\MicroStation_all sites\HRE_oysters.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Oyster sites\MicroStation_all sites\Pen tables\Bush Terminal Plan View.tbl

Bush Terminal Quantities			
Item		Qty	UOM
Area of oyster restoration		**31.9**	**AC**
Oyster gabions (2' x 2')		1,100	EA
Spat-on-shell			
	Within site perimeter	74,445	CY
	Inside gabions	330	CY
	Subtotal	74,775	CY
	Total	**76,680**	CY



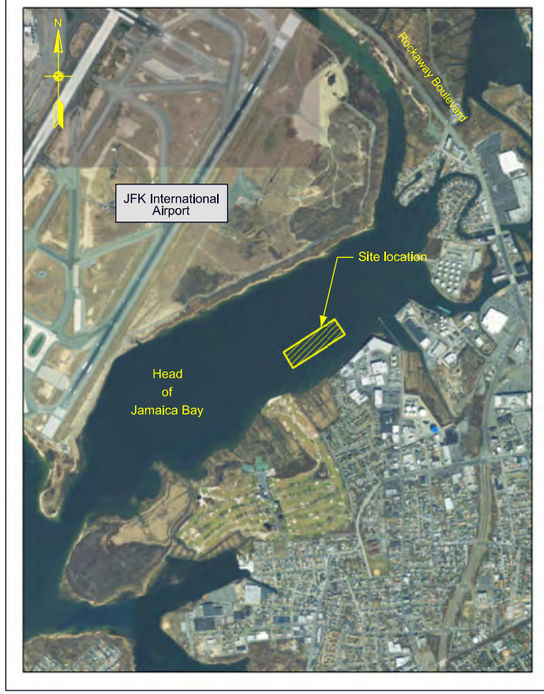
Inset (n.t.s.)

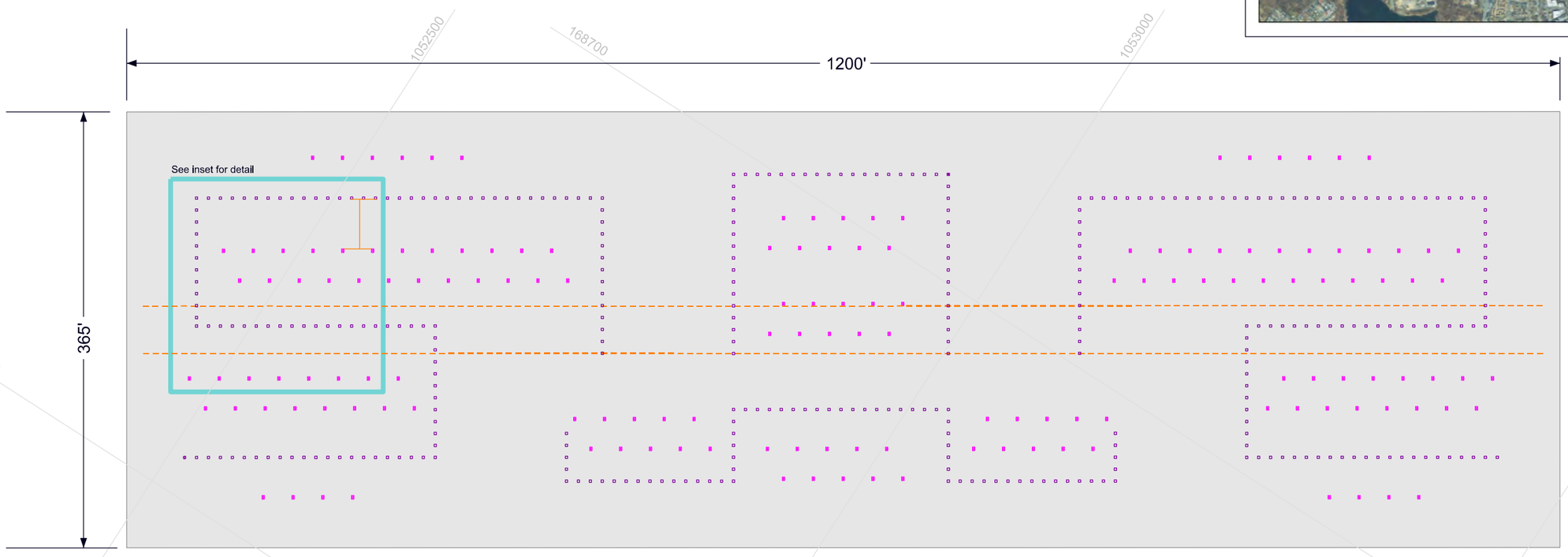
Legend

- Oyster cage (gabion)
- Oyster pyramid
- Spat-on-shell
- Hanging super-trays

Quantities

Description	Qty	UOM
Area of oyster restoration	**10.1**	**Ac**
Hanging super-trays	470	EA
Oyster pyramids (48" x 32" base)	150	
30 oyster castles per pyramid	**4,500**	EA
Oyster gabions (2' x 2')	340	EA
Shell		
Within site boundary	12,910	CY
Inside gabions	90	CY
Total	**13,000**	CY
Spat-on-shell		
Within site boundary	4,310	CY
Inside gabions	30	CY
On pyramids (assume 3 cf per)	20	CY
Inside hanging super-trays	30	CY
Total	**4,390**	CY
Porcelain	**8,610**	CY





US Army Corps
of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DWN BY: GSW
CKD BY:
SUBMITTED BY: GSW
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
SIZE: ANSI D
PLOTTED BY:
PLOT DATE: 1/9/2020

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

HEAD OF JAMAICA BAY
OYSTER RESTORATION

PLAN VIEW

JAMAICA BAY
NEW YORK

SHEET
REFERENCE
NUMBER
C-001

SHEET 1 OF 2

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

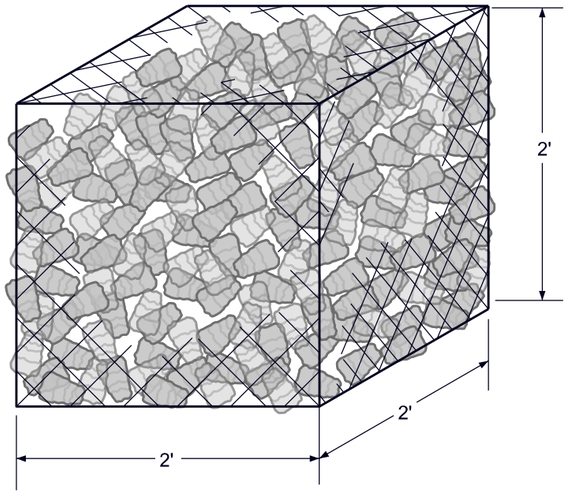
50 25 0 50 100FT
SCALE: 1"= 50'

MAY 2009 NYD BORDER

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Oyster sites\MicroStation_all sites\HRE_oysters.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Oyster sites\MicroStation_all sites\Pen tables\Head of JamBay Plan View.tbl

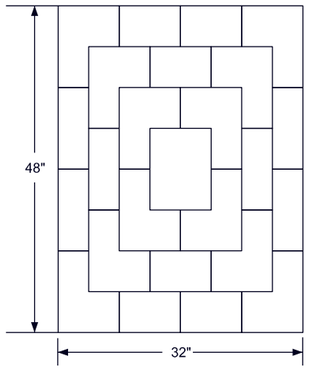
MAY 2009 NYD BORDER

L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Oyster sites\MicroStation_all sites\HRE_oysters.dgn
L:\HRE_Overall\Feasability_Detailed_Design\Detailed_Designs\Oyster sites\MicroStation_all sites\Pen tables\Oyster details.tbl

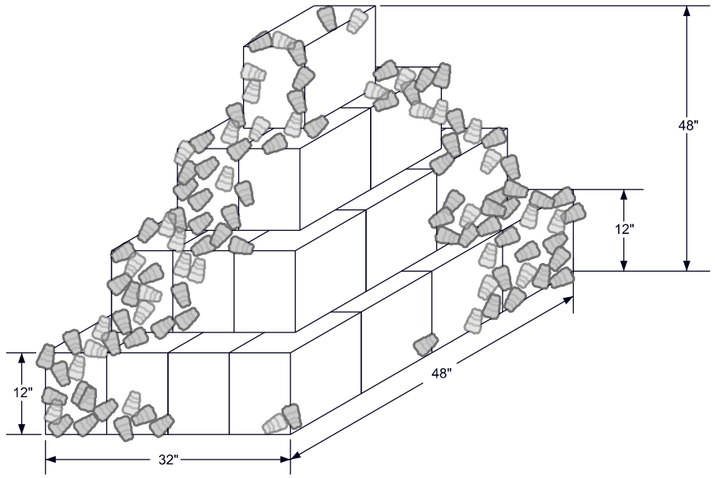


Oyster cage/ gabion
n.t.s.

1. 2' x 2' x 2' gabion filled with shell pre-seeded with spat
2. Gabions to be surrounded by 12" layer of spat-on-shell, sloped away from base of gabion at 1V:3H slope. (See elevation view of oyster pyramid.)

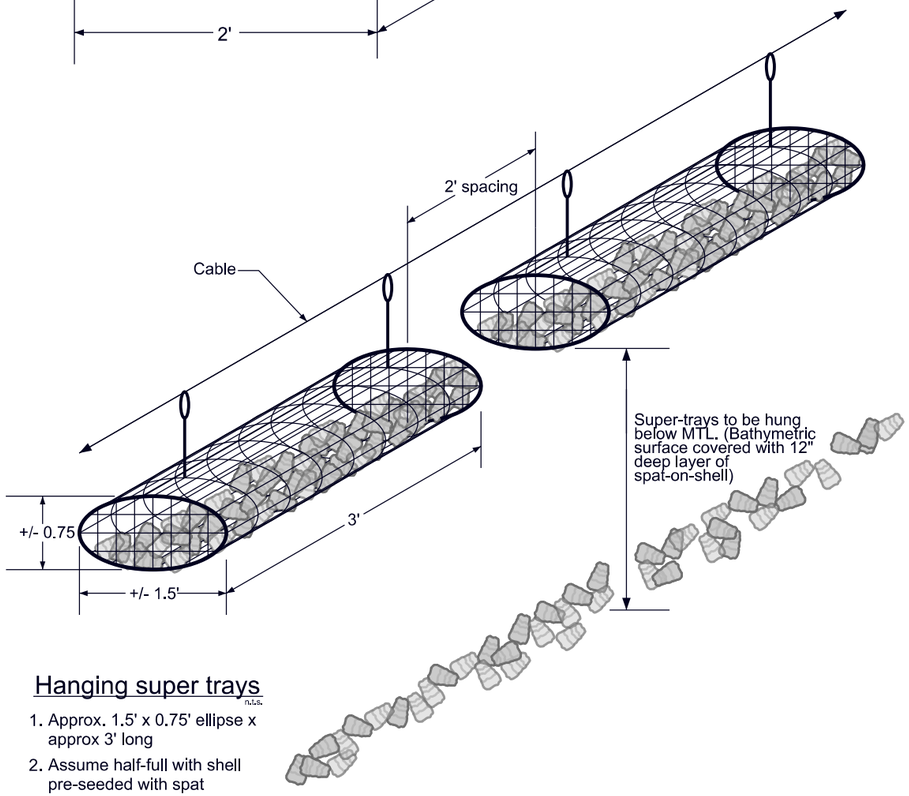


Oyster Pyramid
Plan View
n.t.s.



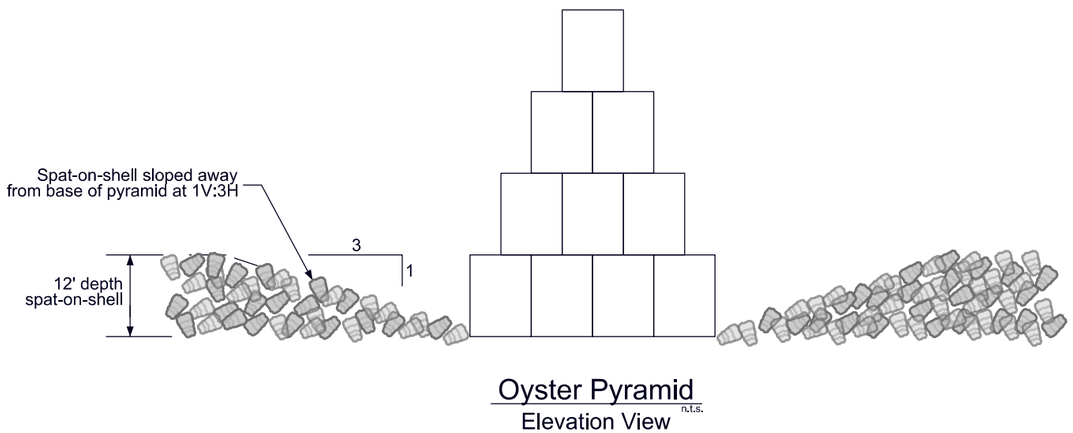
Oyster Pyramid
Isometric View
n.t.s.

1. Each pyramid consists of 30 inter-locking oyster castle blocks
2. Note that castle blocks in this detail are simplified for illustration purposes.
3. See product information at http://www.alliedconcrete.com/materials/oyster-castles/



Hanging super trays
n.t.s.

1. Approx. 1.5' x 0.75' ellipse x approx 3' long
2. Assume half-full with shell pre-seeded with spat
3. See product information at www.seapa.com.au



Oyster Pyramid
Elevation View
n.t.s.

US Army Corps of Engineers
New York District

MARK	DESCRIPTION	DATE	APPR.
MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: GSW
DWN BY: GSW
CKD BY: GSW
SUBMITTED BY: GSW
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NAME:
SIZE: ANSI D
PLOTTED BY:
PLOT DATE: 4/22/2019

U. S. ARMY ENGINEER DISTRICT
NEW YORK
http://www.nan.usace.army.mil

CIVIL RESOURCES BRANCH
ECOSYSTEM RESTORATION TEAM
CENAN-EN-H

HEAD OF JAMAICA BAY
OYSTER RESTORATION

DETAIL SHEET

NEW YORK

JAMAICA BAY

SHEET REFERENCE NUMBER

SHEET 2 OF 2

WARNING: THIS DOCUMENT MAY CONTAIN SENSITIVE SECURITY INFORMATION AND THEREFORE MUST BE TREATED AS A CONFIDENTIAL DOCUMENT. THE INFORMATION CONTAINED IN THIS DOCUMENT MUST BE MAINTAINED IN A CONFIDENTIAL MANNER TO PREVENT COMPROMISING HOMELAND SECURITY AS PROVIDED IN SECTION 214 OF THE HOMELAND SECURITY ACT OF 2002. NO PART OF THIS DOCUMENT SHALL BE REPRODUCED, RELEASED OR DISTRIBUTED WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE UNITED STATES ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT (USACE - NYD). UNAUTHORIZED REPRODUCTION, RELEASE OR DISTRIBUTION MAY RESULT IN CIVIL PENALTY OR OTHER ACTION BY USACE-NYD.

ALL DIMENSIONS/EXISTING CONDITIONS SHOWN SHALL BE CHECKED AND VERIFIED BY THE CONTRACTOR AT THE SITE. ANY DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE GOVERNMENT FOR CLARIFICATIONS. DRAWING SHALL NOT BE SCALED TO OBTAIN DIMENSIONS OR DISTANCES.

Head of Jamaica Bay Quanitites			
Description		Qty	UOM
Area of oyster restoration		**10.1**	**AC**
Hanging super-trays		470	EA
Oyster pyramids (48" x 32" base)		150	
	30 oyster castles per pyramid	**4,500**	EA
Oyster gabions (2' x 2')		340	EA
Shell			
	Within site boundary	12,910	CY
	Inside gabions	90	CY
	Total	**13,000**	CY
Spat-on-shell			
	Within site boundary	4,310	CY
	Inside gabions	30	CY
	On pyramids	20	CY
	Inside hanging super-trays	30	CY
	Total	**4,390**	CY
Porcelain		**8,610**	CY

Attachment C-2
HRE
Sea Level Change: Tables and Mapping

Table 1.

Hudson Raritan Estuary Ecosystem Restoration Project

8516945, Kings Point, NY

NOAA's 2006 Published Rate: 0.00771 feet/yr

All values are expressed in feet relative to LMSL

Year	USACE Low	USACE Int	USACE High
1992	0	0	0
1993	0.01	0.01	0.01
1994	0.02	0.02	0.02
1995	0.02	0.02	0.03
1996	0.03	0.03	0.04
1997	0.04	0.04	0.05
1998	0.05	0.05	0.06
1999	0.05	0.06	0.07
2000	0.06	0.07	0.09
2001	0.07	0.08	0.1
2002	0.08	0.09	0.11
2003	0.09	0.1	0.13
2004	0.09	0.11	0.15
2005	0.1	0.12	0.16
2006	0.11	0.13	0.18
2007	0.12	0.14	0.2
2008	0.12	0.15	0.22
2009	0.13	0.16	0.24
2010	0.14	0.17	0.26
2011	0.15	0.18	0.28
2012	0.15	0.19	0.3
2013	0.16	0.2	0.33
2014	0.17	0.21	0.35
2015	0.18	0.22	0.37
2016	0.19	0.24	0.4
2017	0.19	0.25	0.42
2018	0.2	0.26	0.45
2019	0.21	0.27	0.48
2020	0.22	0.29	0.51
2021	0.22	0.3	0.54
2022	0.23	0.31	0.56
2023	0.24	0.32	0.6
2024	0.25	0.34	0.63
2025	0.25	0.35	0.66
2026	0.26	0.37	0.69
2027	0.27	0.38	0.72
2028	0.28	0.39	0.76
2029	0.28	0.41	0.79
2030	0.29	0.42	0.83
2031	0.3	0.44	0.87
2032	0.31	0.45	0.9
2033	0.32	0.47	0.94
2034	0.32	0.48	0.98
2035	0.33	0.5	1.02
2036	0.34	0.51	1.06
2037	0.35	0.53	1.1
2038	0.36	0.54	1.14
2039	0.36	0.56	1.18
2040	0.37	0.57	1.22
2041	0.38	0.59	1.27
2042	0.39	0.61	1.31
2043	0.39	0.62	1.36
2044	0.4	0.64	1.4
2045	0.41	0.66	1.45
2046	0.42	0.68	1.5
2047	0.42	0.69	1.55
2048	0.43	0.71	1.59
2049	0.44	0.73	1.64
2050	0.45	0.75	1.69
2051	0.46	0.76	1.75
2052	0.46	0.78	1.8
2053	0.47	0.8	1.85
2054	0.48	0.82	1.9
2055	0.49	0.84	1.96
2056	0.49	0.86	2.01
2057	0.5	0.88	2.07
2058	0.51	0.9	2.12
2059	0.52	0.92	2.18
2060	0.52	0.94	2.24
2061	0.53	0.96	2.3
2062	0.54	0.98	2.36
2063	0.55	1	2.42
2064	0.56	1.02	2.48
2065	0.56	1.04	2.54
2066	0.57	1.06	2.6
2067	0.58	1.08	2.66
2068	0.59	1.1	2.73
2069	0.59	1.12	2.79
2070	0.6	1.14	2.86
2071	0.61	1.16	2.92
2072	0.62	1.19	2.99
2073	0.63	1.21	3.06
2074	0.63	1.23	3.13
2075	0.64	1.25	3.19
2076	0.65	1.27	3.26
2077	0.66	1.3	3.33
2078	0.66	1.32	3.41
2079	0.67	1.34	3.48
2080	0.68	1.37	3.55
2081	0.69	1.39	3.62
2082	0.69	1.41	3.7
2083	0.7	1.44	3.77
2084	0.71	1.46	3.85
2085	0.72	1.49	3.92
2086	0.73	1.51	4
2087	0.73	1.54	4.08
2088	0.74	1.56	4.16
2089	0.75	1.58	4.24
2090	0.76	1.61	4.32
2091	0.76	1.64	4.4
2092	0.77	1.66	4.48
2093	0.78	1.69	4.56
2094	0.79	1.71	4.64
2095	0.79	1.74	4.73
2096	0.8	1.76	4.81
2097	0.81	1.79	4.9
2098	0.82	1.82	4.98
2099	0.83	1.84	5.07
2100	0.83	1.87	5.16

Table 2.

Hudson Raritan Estuary Ecosystem Restoration Project

8531680, Sandy Hook, NJ

NOAA's 2006 Published Rate: 0.01280 feet/yr

All values are expressed in feet relative to LMSL

Year	USACE Low	USACE Int	USACE High
1992	0	0	0
1993	0.01	0.01	0.01
1994	0.03	0.03	0.03
1995	0.04	0.04	0.04
1996	0.05	0.05	0.06
1997	0.06	0.07	0.07
1998	0.08	0.08	0.09
1999	0.09	0.09	0.11
2000	0.1	0.11	0.13
2001	0.12	0.12	0.14
2002	0.13	0.14	0.17
2003	0.14	0.15	0.19
2004	0.15	0.17	0.21
2005	0.17	0.18	0.23
2006	0.18	0.2	0.25
2007	0.19	0.21	0.28
2008	0.21	0.23	0.3
2009	0.22	0.24	0.33
2010	0.23	0.26	0.35
2011	0.24	0.28	0.38
2012	0.26	0.29	0.4
2013	0.27	0.31	0.43
2014	0.28	0.33	0.46
2015	0.29	0.34	0.49
2016	0.31	0.36	0.52
2017	0.32	0.38	0.55
2018	0.33	0.39	0.58
2019	0.35	0.41	0.62
2020	0.36	0.43	0.65
2021	0.37	0.45	0.68
2022	0.38	0.46	0.72
2023	0.4	0.48	0.75
2024	0.41	0.5	0.79
2025	0.42	0.52	0.83
2026	0.44	0.54	0.86
2027	0.45	0.56	0.9
2028	0.46	0.58	0.94
2029	0.47	0.6	0.98
2030	0.49	0.62	1.02
2031	0.5	0.63	1.06
2032	0.51	0.65	1.11
2033	0.53	0.67	1.15
2034	0.54	0.69	1.19
2035	0.55	0.72	1.24
2036	0.56	0.74	1.28
2037	0.58	0.76	1.33
2038	0.59	0.78	1.37
2039	0.6	0.8	1.42
2040	0.61	0.82	1.47
2041	0.63	0.84	1.52
2042	0.64	0.86	1.57
2043	0.65	0.88	1.62
2044	0.67	0.91	1.67
2045	0.68	0.93	1.72
2046	0.69	0.95	1.77
2047	0.7	0.97	1.83
2048	0.72	1	1.88
2049	0.73	1.02	1.93
2050	0.74	1.04	1.99
2051	0.76	1.06	2.05
2052	0.77	1.09	2.1
2053	0.78	1.11	2.16
2054	0.79	1.14	2.22
2055	0.81	1.16	2.28
2056	0.82	1.18	2.34
2057	0.83	1.21	2.4
2058	0.84	1.23	2.46
2059	0.86	1.26	2.52
2060	0.87	1.28	2.58
2061	0.88	1.31	2.65
2062	0.9	1.33	2.71
2063	0.91	1.36	2.78
2064	0.92	1.38	2.84
2065	0.93	1.41	2.91
2066	0.95	1.43	2.98
2067	0.96	1.46	3.05
2068	0.97	1.49	3.11
2069	0.99	1.51	3.18
2070	1	1.54	3.25
2071	1.01	1.57	3.33
2072	1.02	1.59	3.4
2073	1.04	1.62	3.47
2074	1.05	1.65	3.54
2075	1.06	1.68	3.62
2076	1.08	1.7	3.69
2077	1.09	1.73	3.77
2078	1.1	1.76	3.84
2079	1.11	1.79	3.92
2080	1.13	1.82	4
2081	1.14	1.84	4.08
2082	1.15	1.87	4.16
2083	1.16	1.9	4.23
2084	1.18	1.93	4.32
2085	1.19	1.96	4.4
2086	1.2	1.99	4.48
2087	1.22	2.02	4.56
2088	1.23	2.05	4.64
2089	1.24	2.08	4.73
2090	1.25	2.11	4.81
2091	1.27	2.14	4.9
2092	1.28	2.17	4.99
2093	1.29	2.2	5.07
2094	1.31	2.23	5.16
2095	1.32	2.26	5.25
2096	1.33	2.29	5.34
2097	1.34	2.32	5.43
2098	1.36	2.36	5.52
2099	1.37	2.39	5.61
2100	1.38	2.42	5.71

Table 3.

Hudson Raritan Estuary Ecosystem Restoration Project

8518750, The Battery, NY

NOAA's 2006 Published Rate: 0.00909 feet/yr

All values are expressed in feet relative to LMSL

Year	USACE Low	USACE Int	USACE High
1992	0	0	0
1993	0.01	0.01	0.01
1994	0.02	0.02	0.02
1995	0.03	0.03	0.03
1996	0.04	0.04	0.04
1997	0.05	0.05	0.06
1998	0.06	0.06	0.07
1999	0.06	0.07	0.08
2000	0.07	0.08	0.1
2001	0.08	0.09	0.11
2002	0.09	0.1	0.13
2003	0.1	0.11	0.14
2004	0.11	0.12	0.16
2005	0.12	0.13	0.18
2006	0.13	0.14	0.2
2007	0.14	0.16	0.22
2008	0.14	0.17	0.24
2009	0.15	0.18	0.26
2010	0.16	0.19	0.28
2011	0.17	0.21	0.31
2012	0.18	0.22	0.33
2013	0.19	0.23	0.35
2014	0.2	0.24	0.38
2015	0.21	0.26	0.41
2016	0.22	0.27	0.43
2017	0.23	0.28	0.46
2018	0.24	0.3	0.49
2019	0.25	0.31	0.52
2020	0.25	0.32	0.55
2021	0.26	0.34	0.57
2022	0.27	0.35	0.61
2023	0.28	0.37	0.64
2024	0.29	0.38	0.67
2025	0.3	0.4	0.7
2026	0.31	0.41	0.74
2027	0.32	0.43	0.77
2028	0.33	0.44	0.81
2029	0.34	0.46	0.84
2030	0.35	0.47	0.88
2031	0.35	0.49	0.92
2032	0.36	0.51	0.96
2033	0.37	0.52	1
2034	0.38	0.54	1.04
2035	0.39	0.56	1.08
2036	0.4	0.57	1.12
2037	0.41	0.59	1.16
2038	0.42	0.61	1.2
2039	0.43	0.62	1.25
2040	0.44	0.64	1.29
2041	0.45	0.66	1.34
2042	0.45	0.68	1.38
2043	0.46	0.7	1.43
2044	0.47	0.71	1.48
2045	0.48	0.73	1.52
2046	0.49	0.75	1.57
2047	0.5	0.77	1.62
2048	0.51	0.79	1.67
2049	0.52	0.81	1.72
2050	0.53	0.83	1.77
2051	0.54	0.85	1.83
2052	0.55	0.87	1.88
2053	0.55	0.89	1.93
2054	0.56	0.91	1.99
2055	0.57	0.93	2.04
2056	0.58	0.95	2.1
2057	0.59	0.97	2.16
2058	0.6	0.99	2.22
2059	0.61	1.01	2.27
2060	0.62	1.03	2.33
2061	0.63	1.05	2.39
2062	0.64	1.07	2.45
2063	0.65	1.09	2.51
2064	0.65	1.12	2.58
2065	0.66	1.14	2.64
2066	0.67	1.16	2.7
2067	0.68	1.18	2.77
2068	0.69	1.2	2.83
2069	0.7	1.23	2.9
2070	0.71	1.25	2.96
2071	0.72	1.27	3.03
2072	0.73	1.3	3.1
2073	0.74	1.32	3.17
2074	0.75	1.34	3.24
2075	0.75	1.37	3.31
2076	0.76	1.39	3.38
2077	0.77	1.42	3.45
2078	0.78	1.44	3.52
2079	0.79	1.46	3.6
2080	0.8	1.49	3.67
2081	0.81	1.51	3.75
2082	0.82	1.54	3.82
2083	0.83	1.56	3.9
2084	0.84	1.59	3.97
2085	0.85	1.61	4.05
2086	0.85	1.64	4.13
2087	0.86	1.67	4.21
2088	0.87	1.69	4.29
2089	0.88	1.72	4.37
2090	0.89	1.75	4.45
2091	0.9	1.77	4.53
2092	0.91	1.8	4.62
2093	0.92	1.83	4.7
2094	0.93	1.85	4.78
2095	0.94	1.88	4.87
2096	0.95	1.91	4.96
2097	0.95	1.93	5.04
2098	0.96	1.96	5.13
2099	0.97	1.99	5.22
2100	0.98	2.02	5.31

HRE SEA LEVEL RISE IMPACT ANALYSIS MAPS

DEAD HORSE BAY

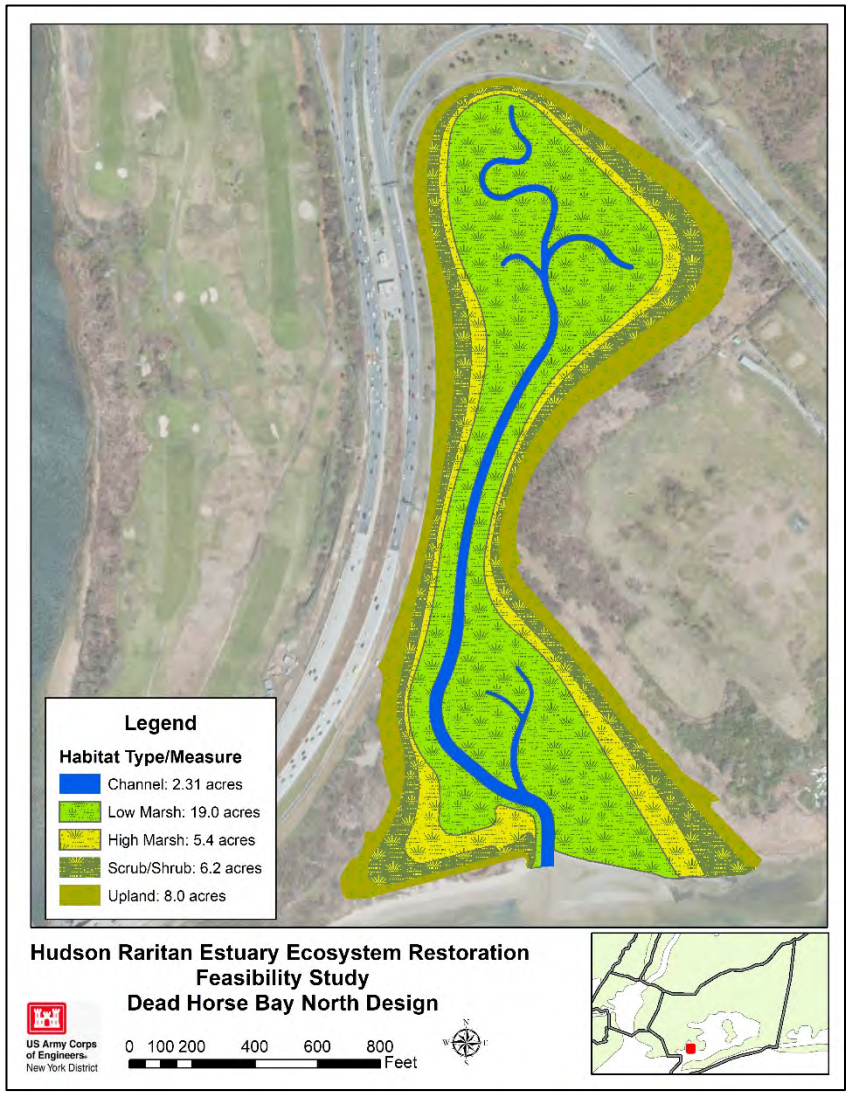


Figure 1. Dead Horse Bay Proposed Design

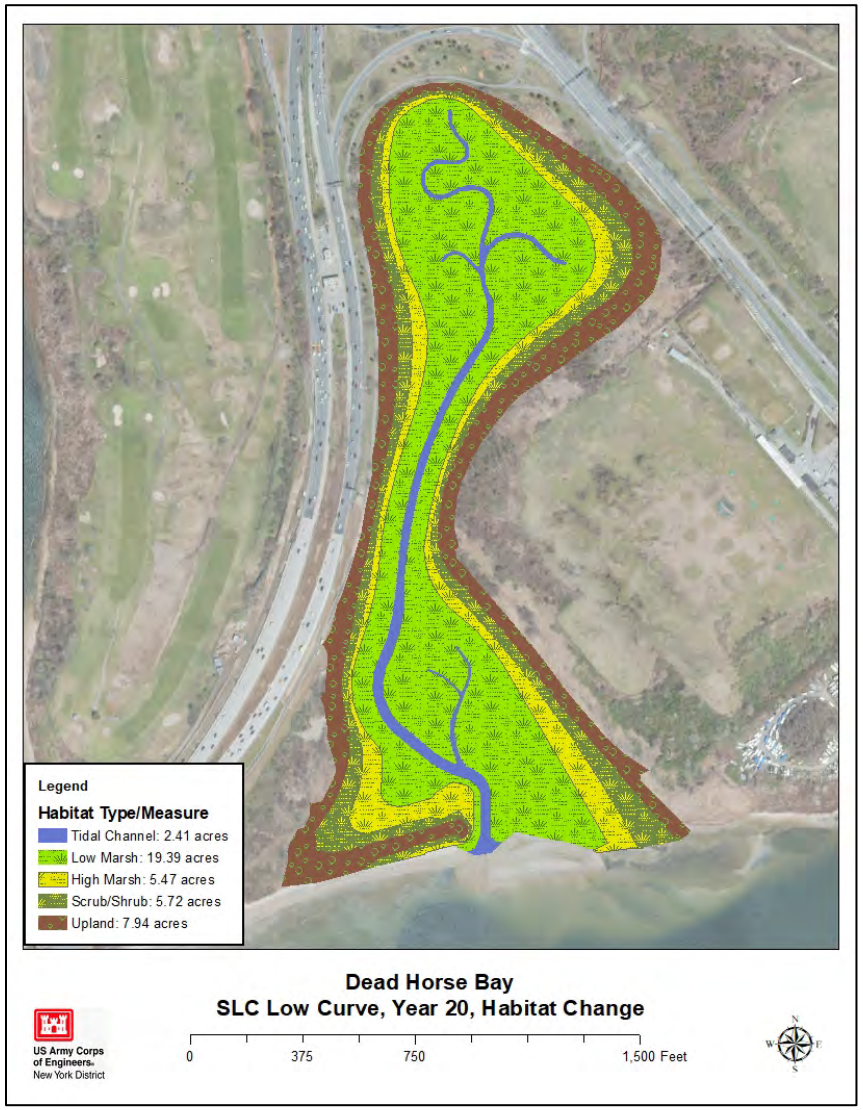


Figure 2. Dead Horse Bay, SLC Low Curve, Year 20

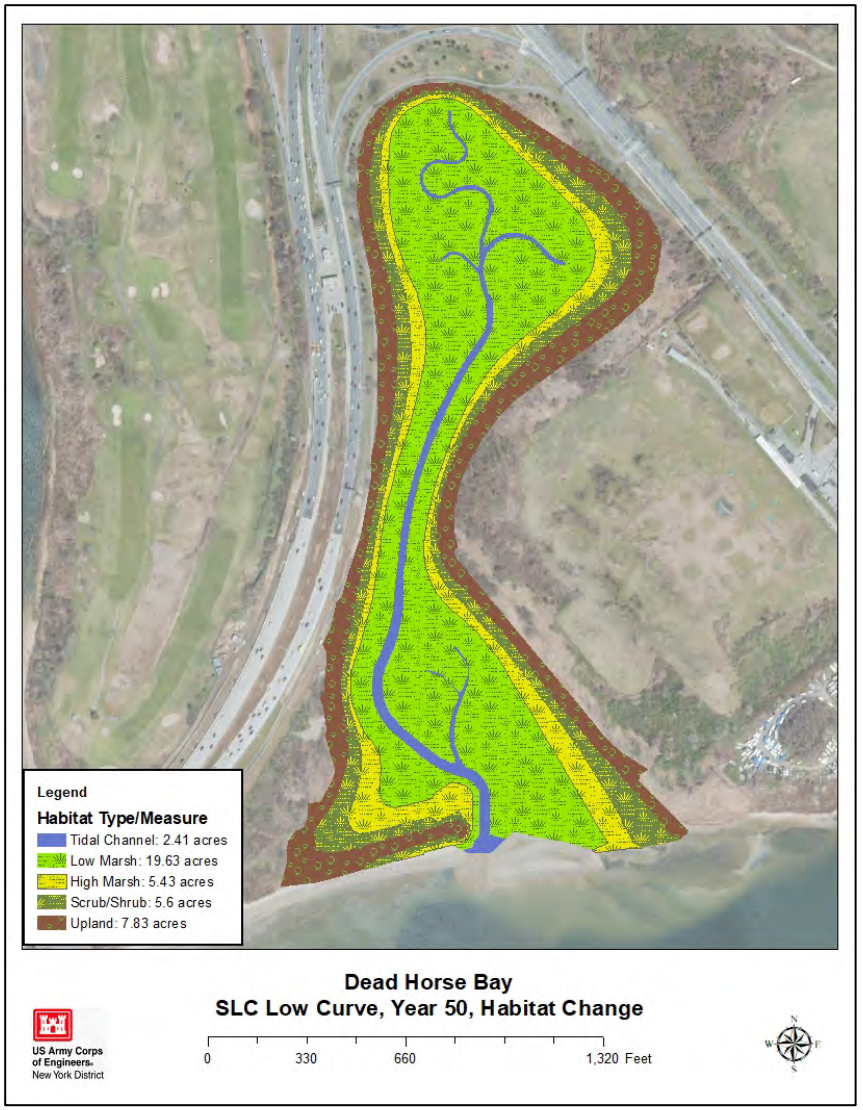


Figure 3. Dead Horse Bay, SLC Low Curve, Year 50



Figure 4. Dead Horse Bay, SLC Intermediate Curve, Year 20

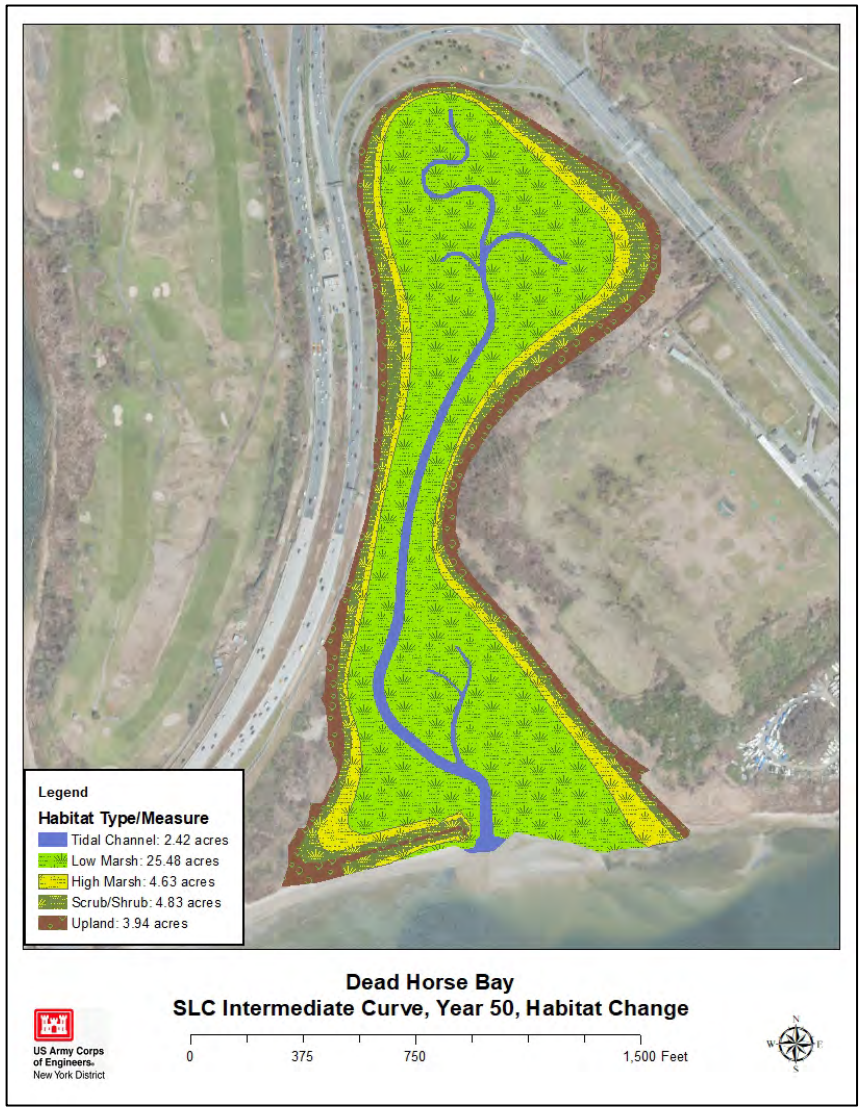


Figure 5. Dead Horse Bay, SLC Intermediate Curve, Year 50

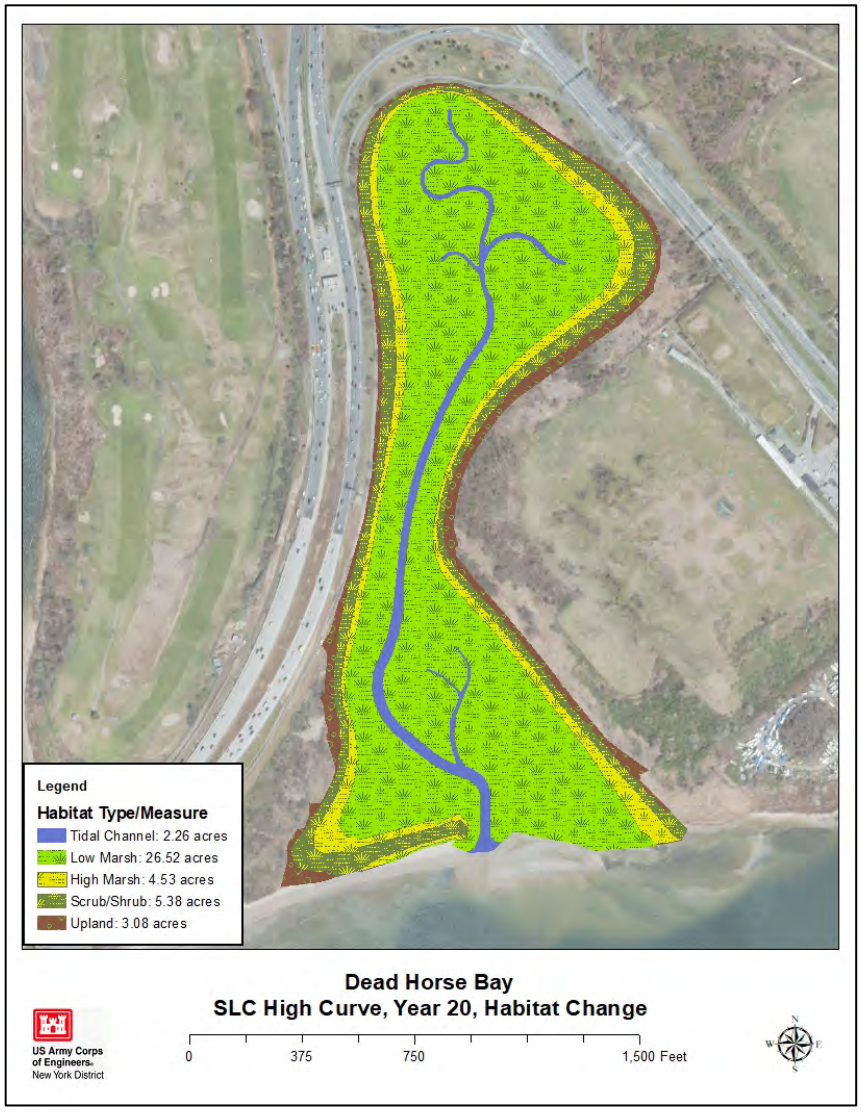


Figure 6. Dead Horse Bay, SLC High Curve, Year 20



Figure 7. Dead Horse Bay, SLC High Curve, Year 50

FRESH CREEK

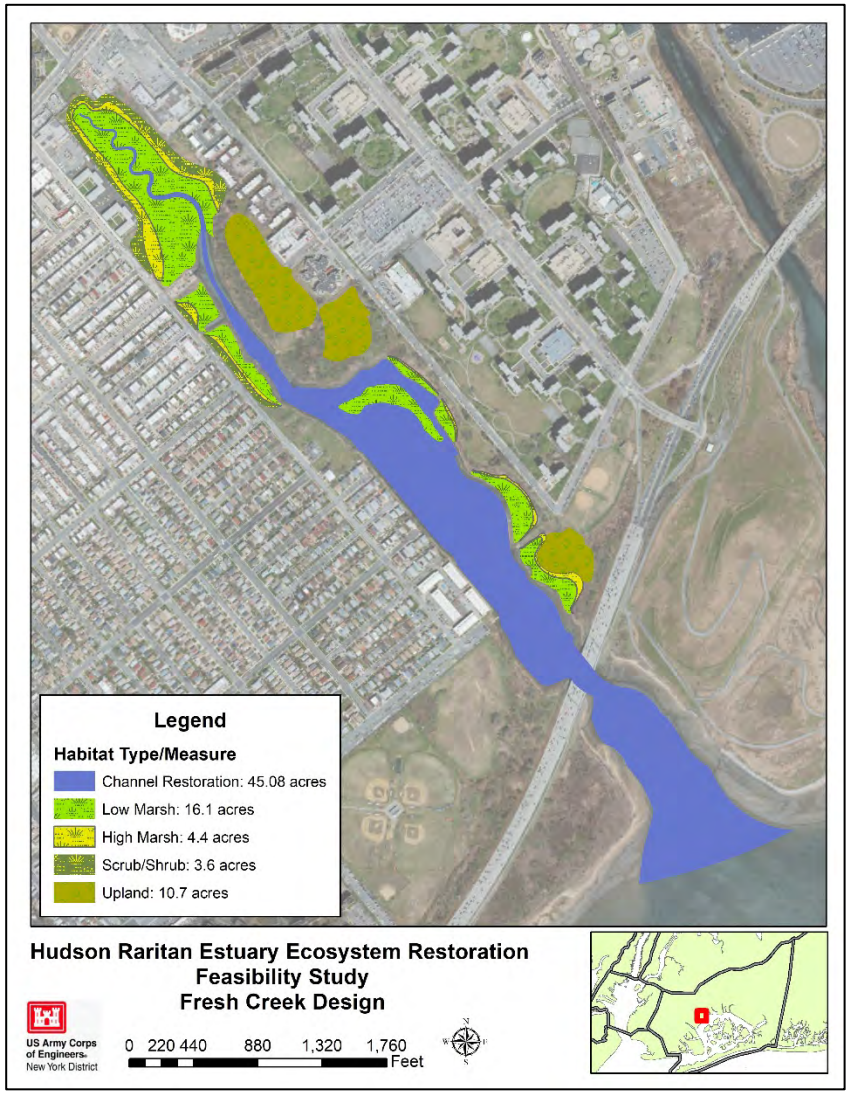


Figure 8. Fresh Creek Proposed Design

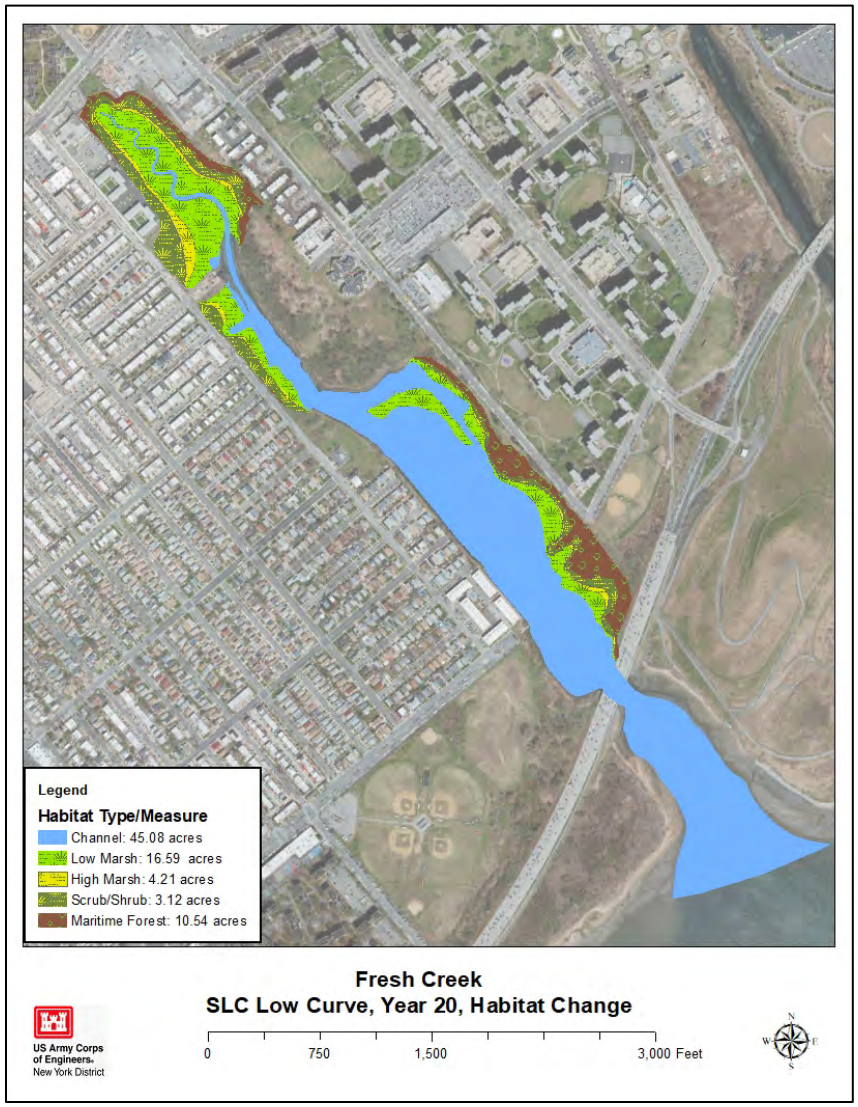


Figure 9. Fresh Creek, SLC Low Curve, Year 20

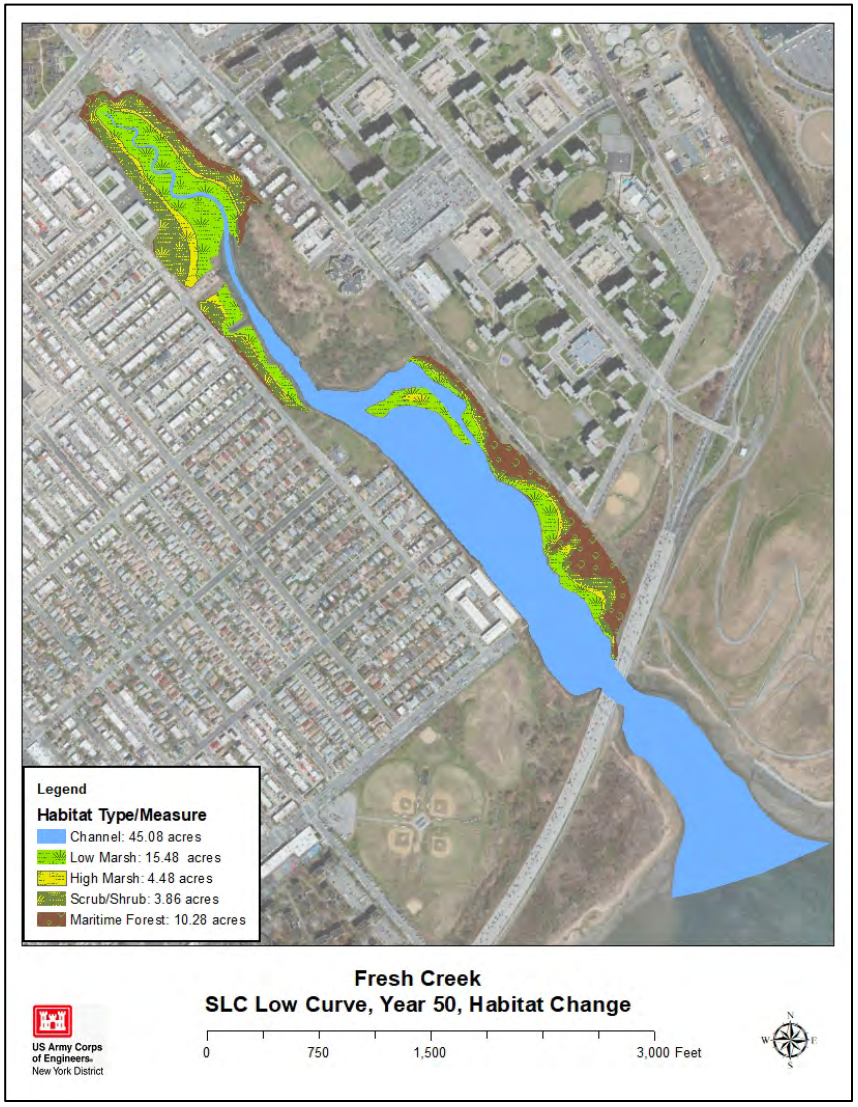


Figure 10. Fresh Creek, SLC Low Curve, Year 50

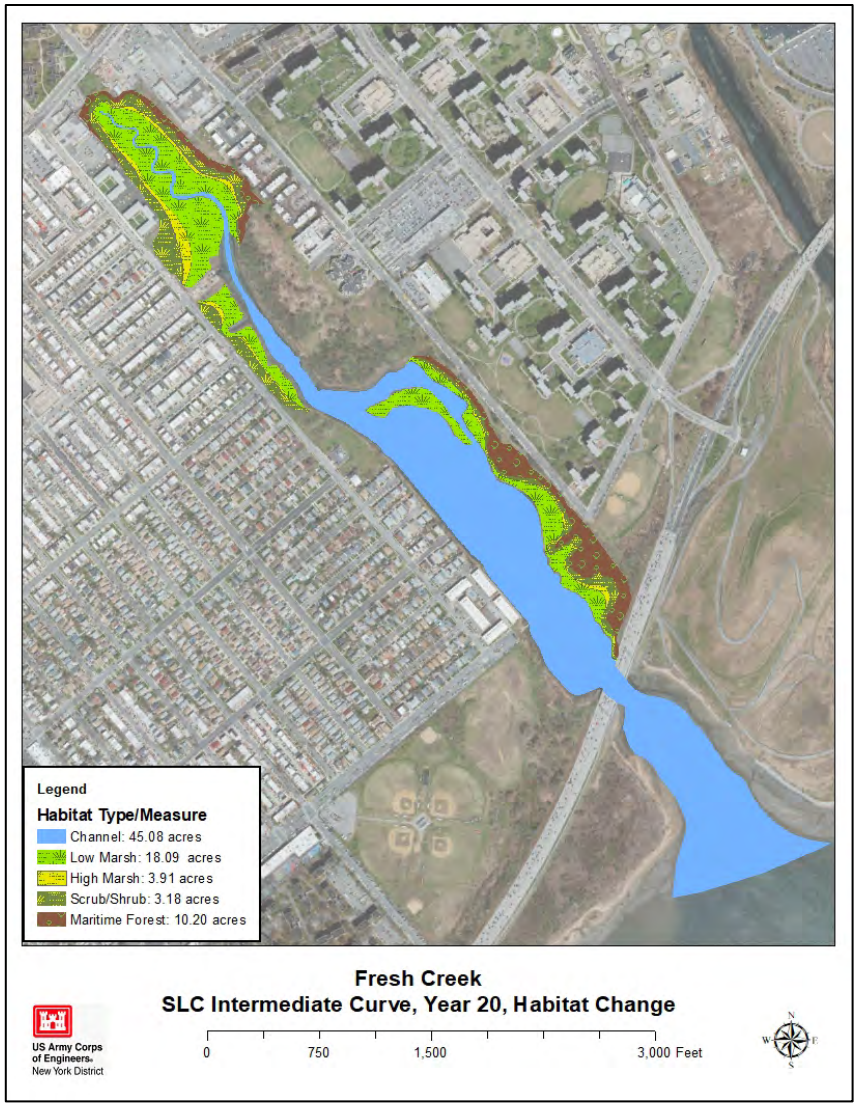


Figure 11. Fresh Creek, SLC Intermediate Curve, Year 20

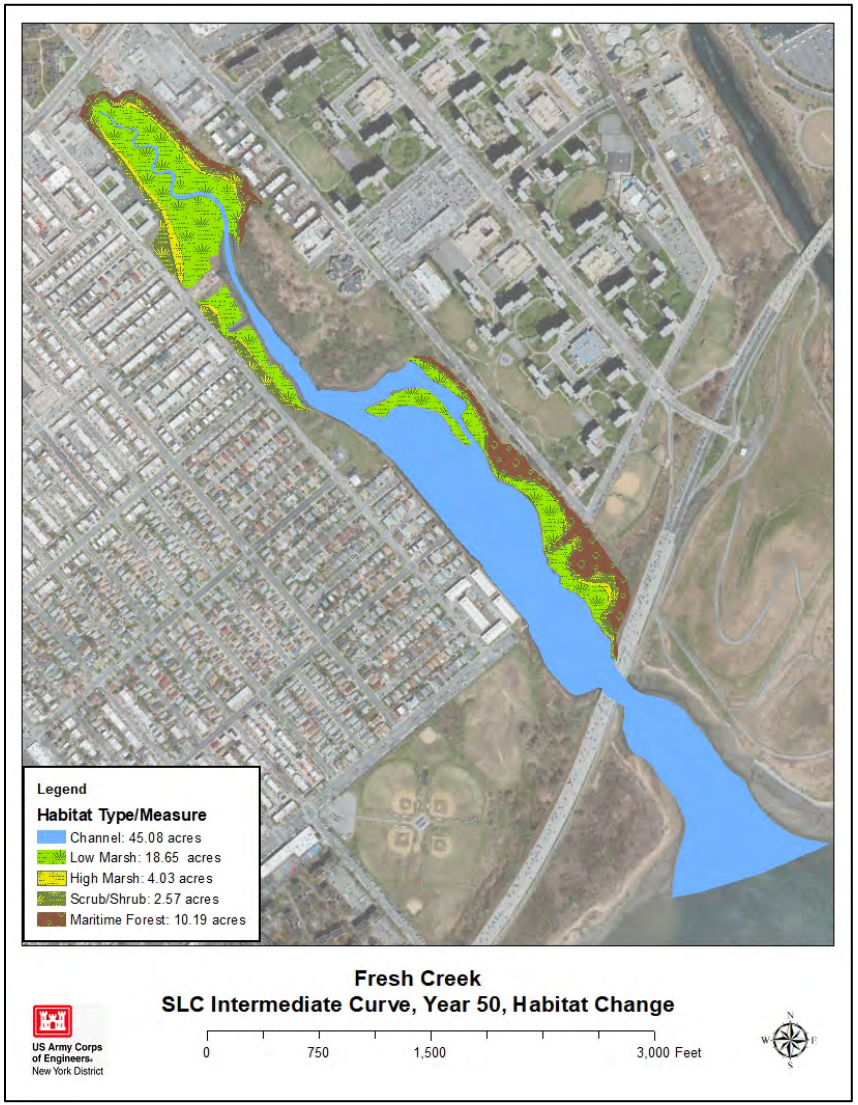


Figure 12. Fresh Creek, SLC Intermediate Curve, Year 50

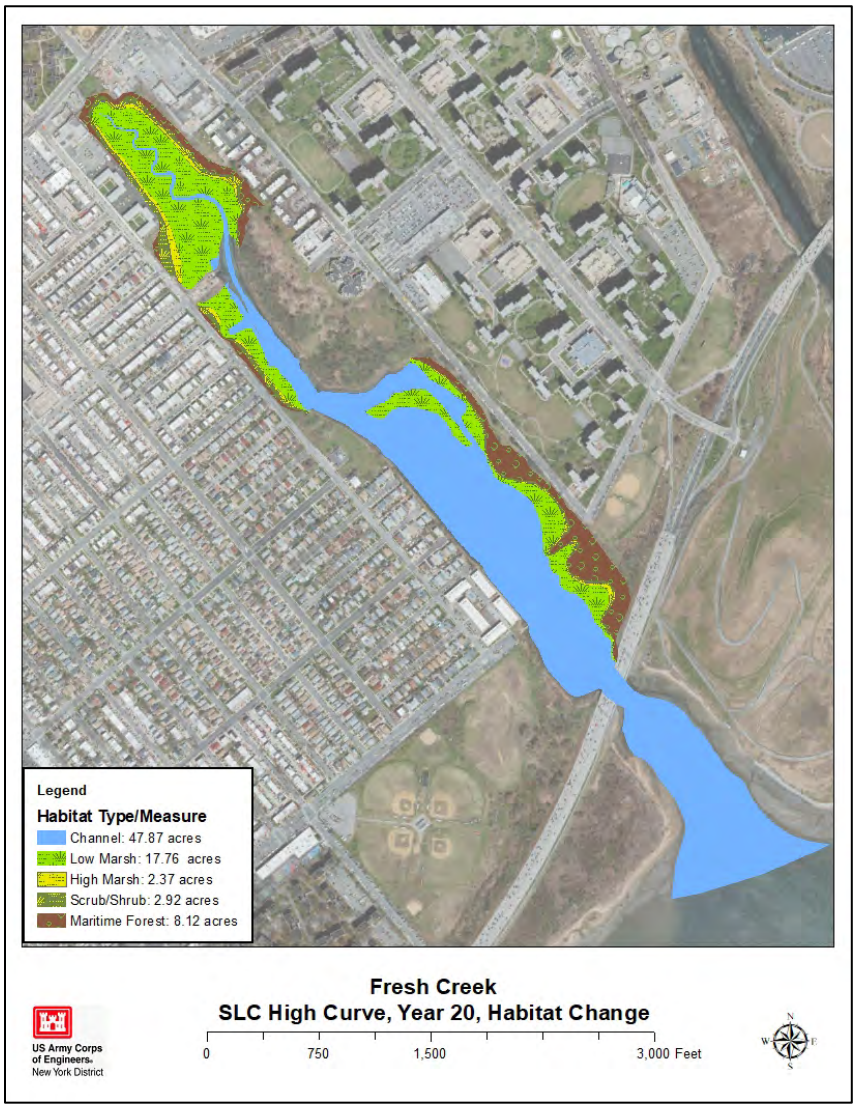


Figure 13. Fresh Creek, SLC High Curve, Year 20

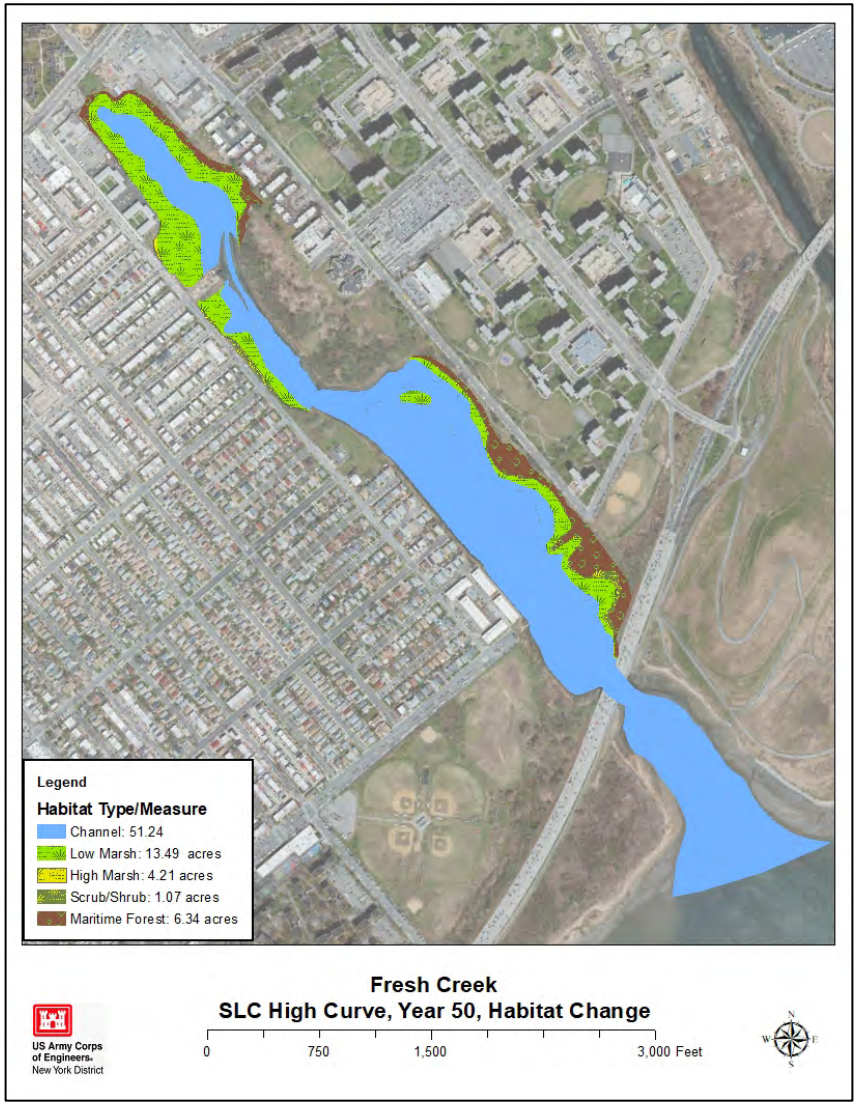


Figure 14. Fresh Creek, SLC High Curve, Year 50

DUCK POINT

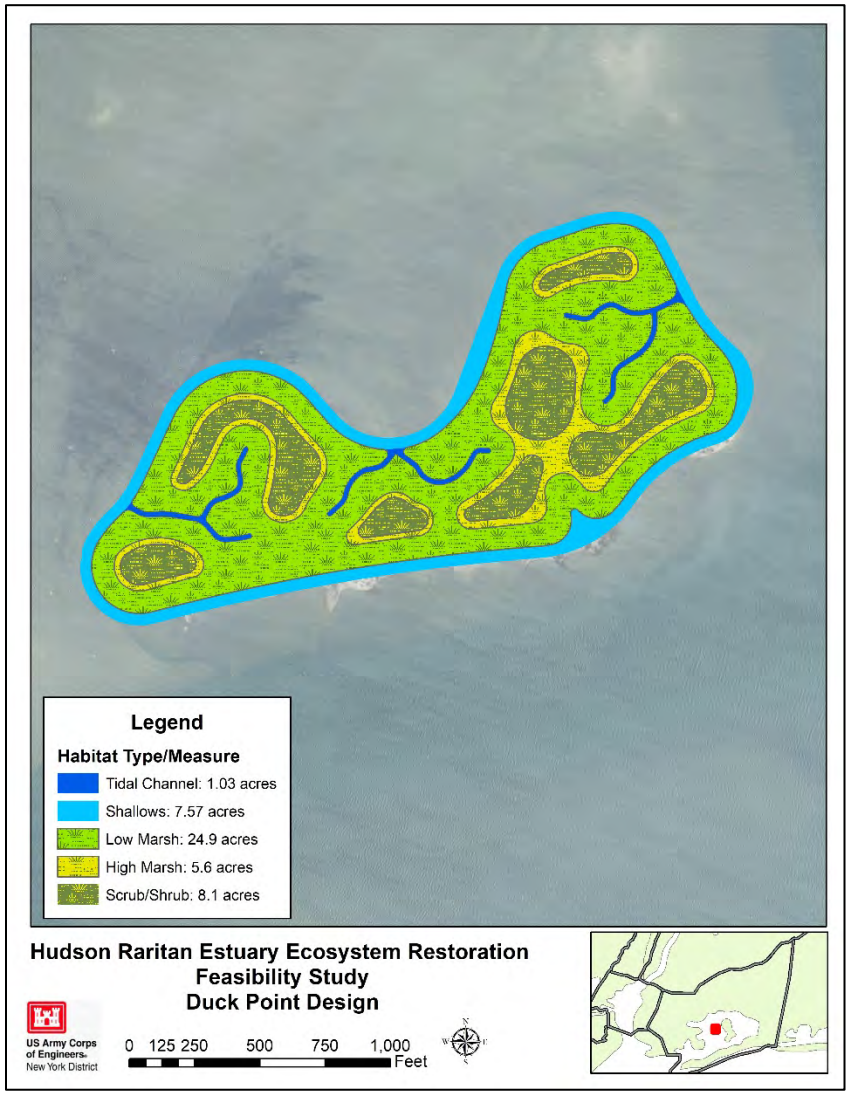


Figure 15. Duck Point Proposed Design



Figure 16. Duck Point, SLC Low Curve, Year 20



Figure 17. Duck Point, SLC Low Curve, Year 50

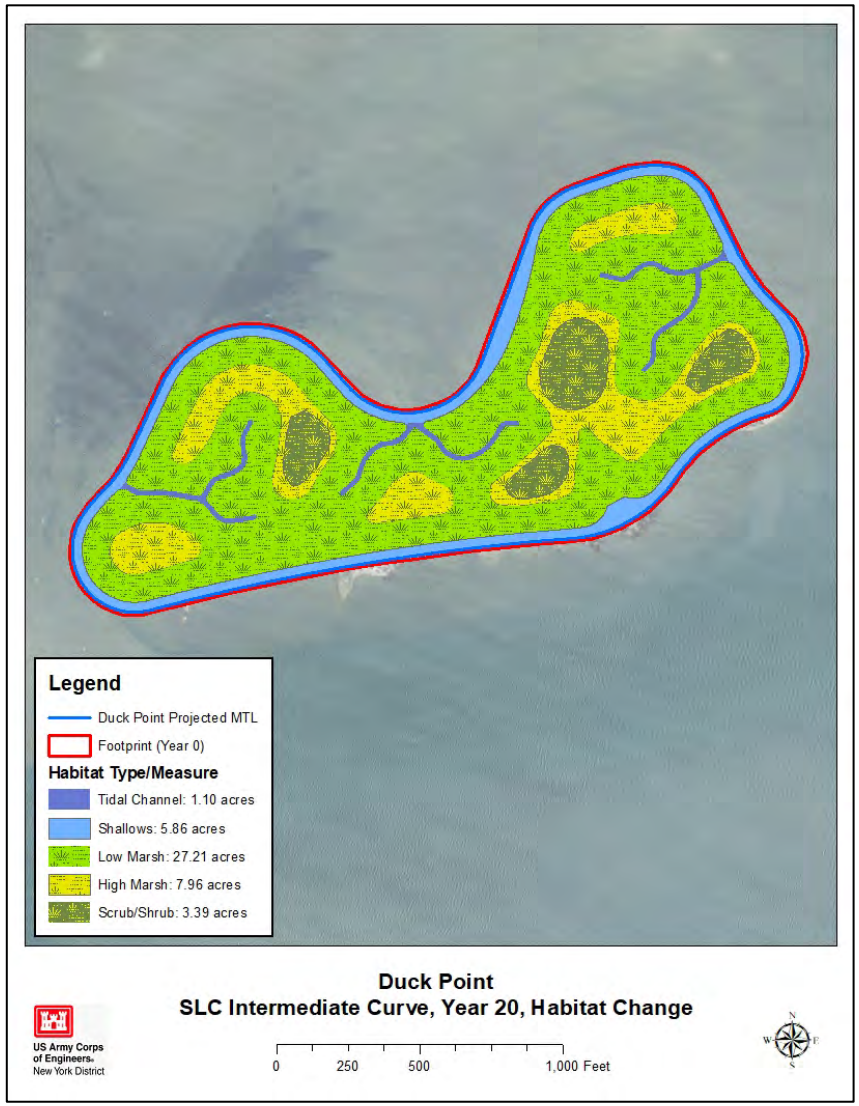


Figure 18. Duck Point, SLC Intermediate Curve, Year 20

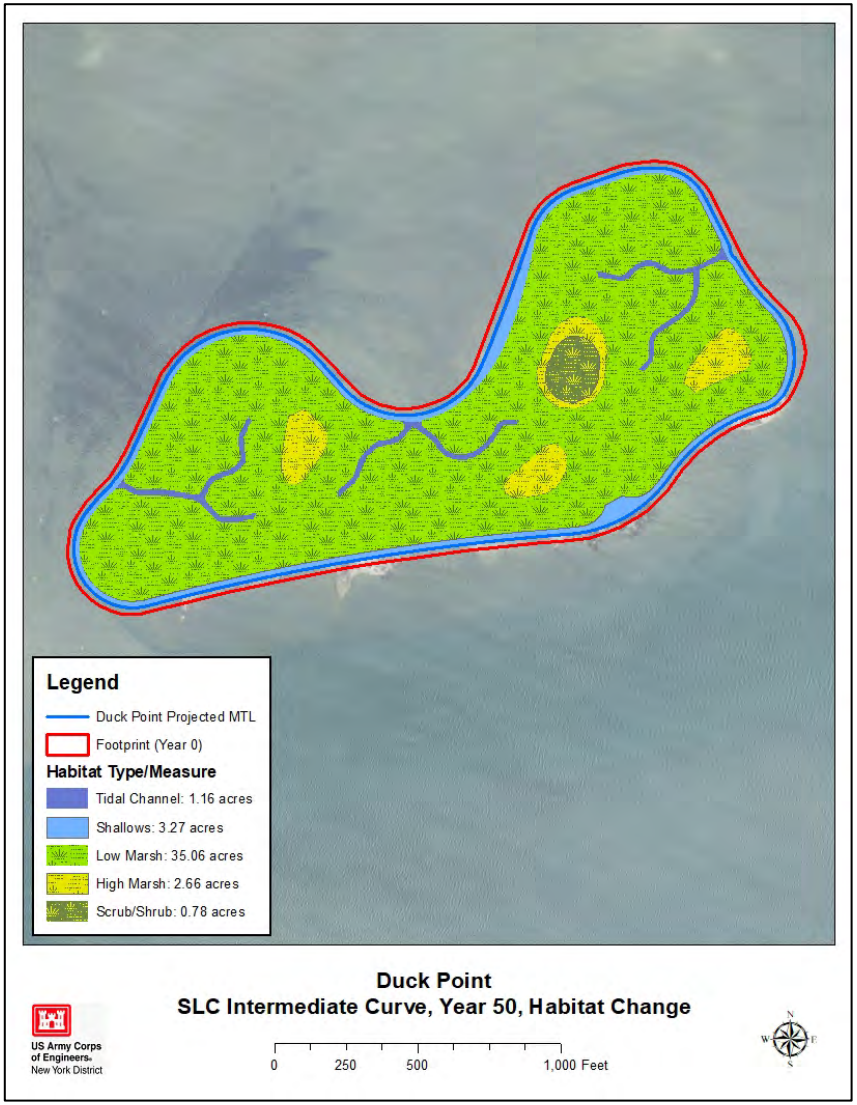


Figure 19. Duck Point, SLC Intermediate, Year 50

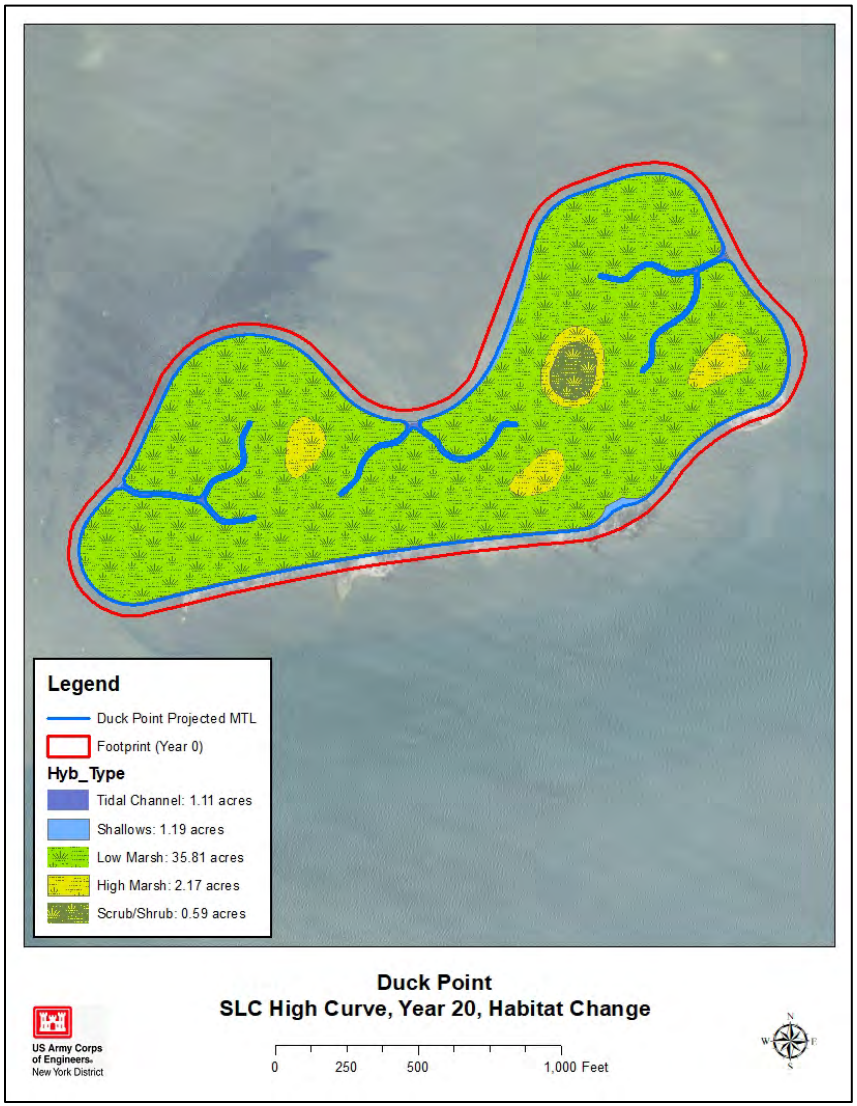


Figure 20. Duck Point, SLC High Curve, Year 20

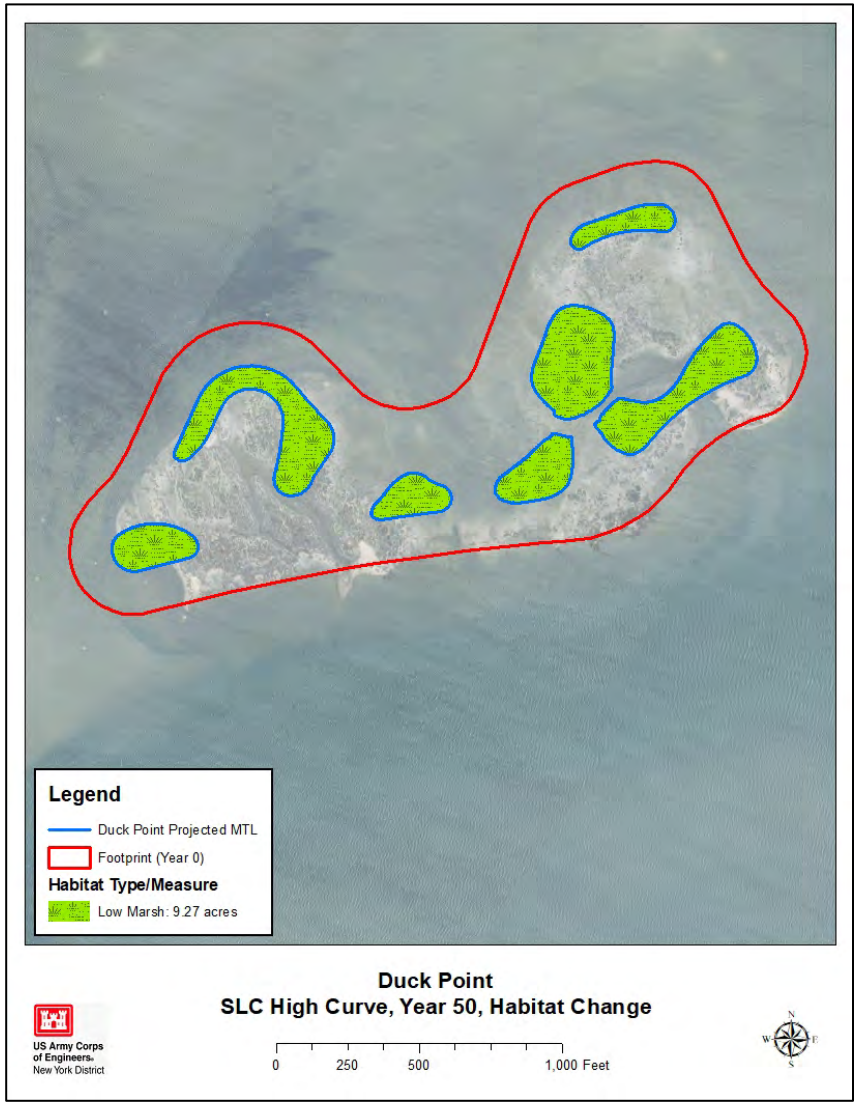


Figure 21. Duck Point, SLC High Curve, Year 50

STONY CREEK MARSH

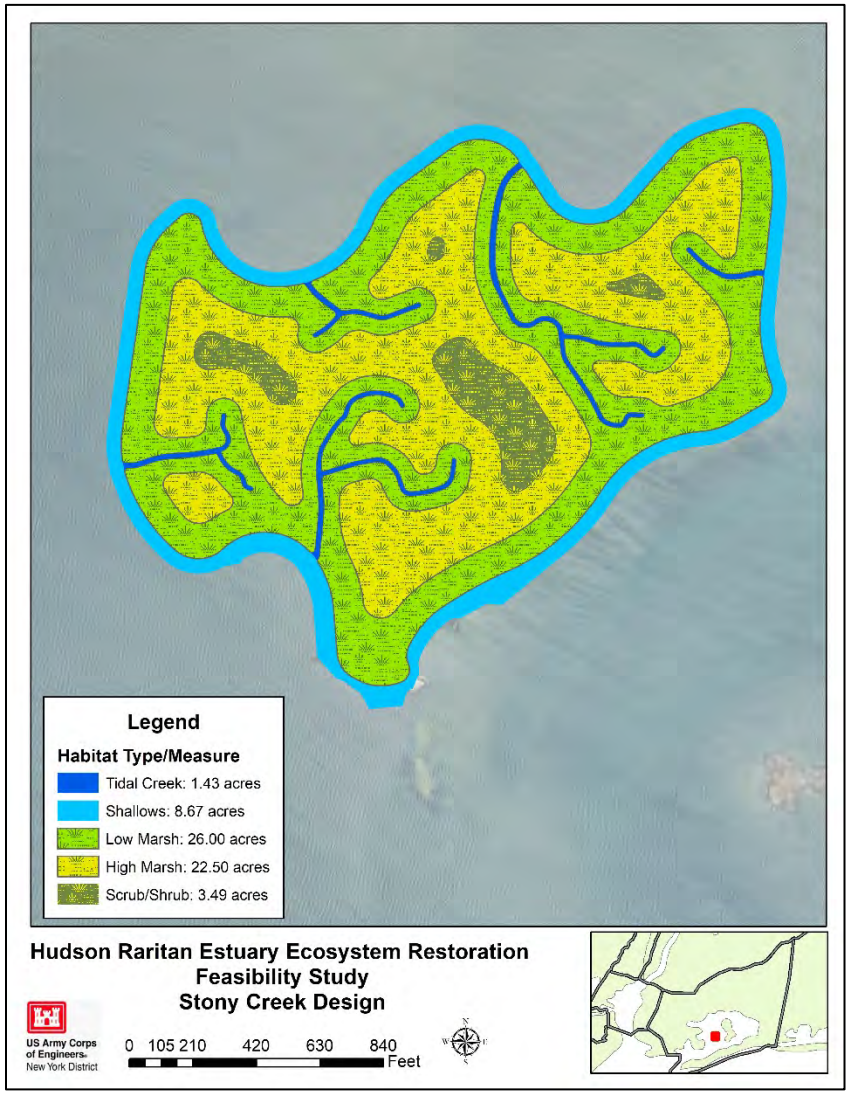


Figure 22. Stony Creek Proposed Design

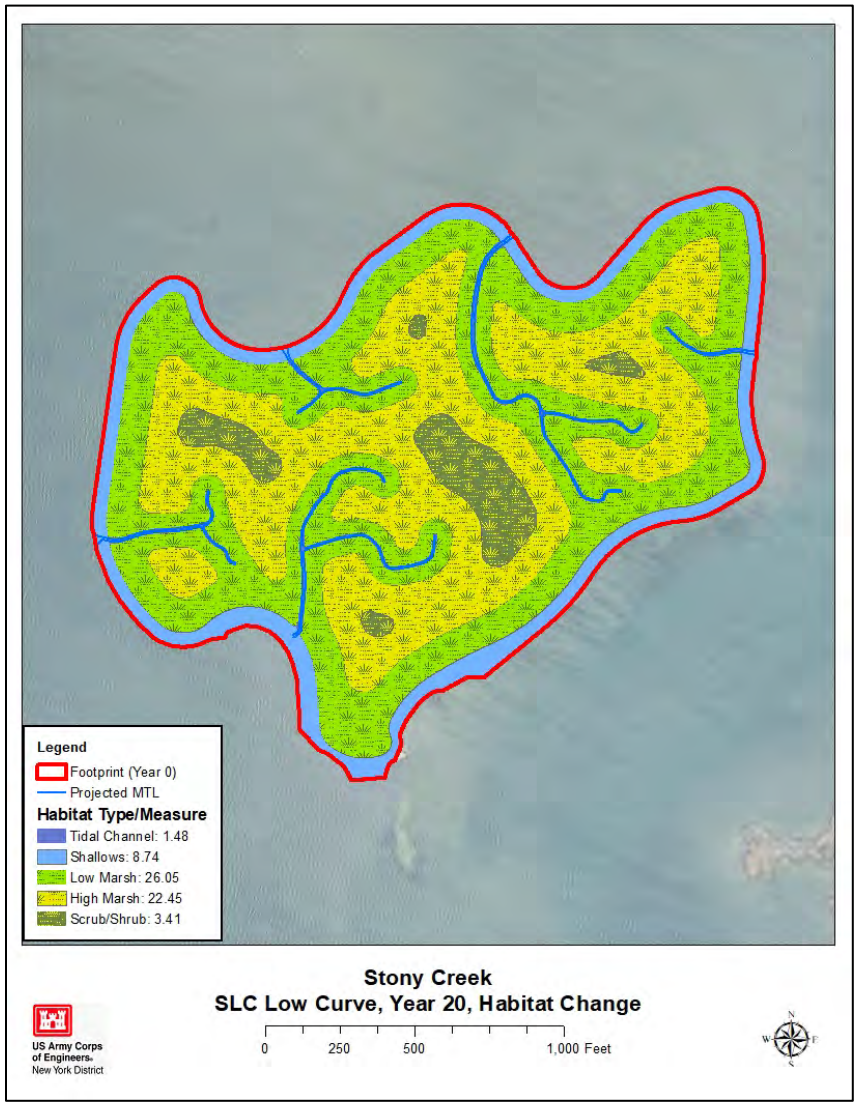


Figure 23. Stony Creek SLC Low Curve, Year 20

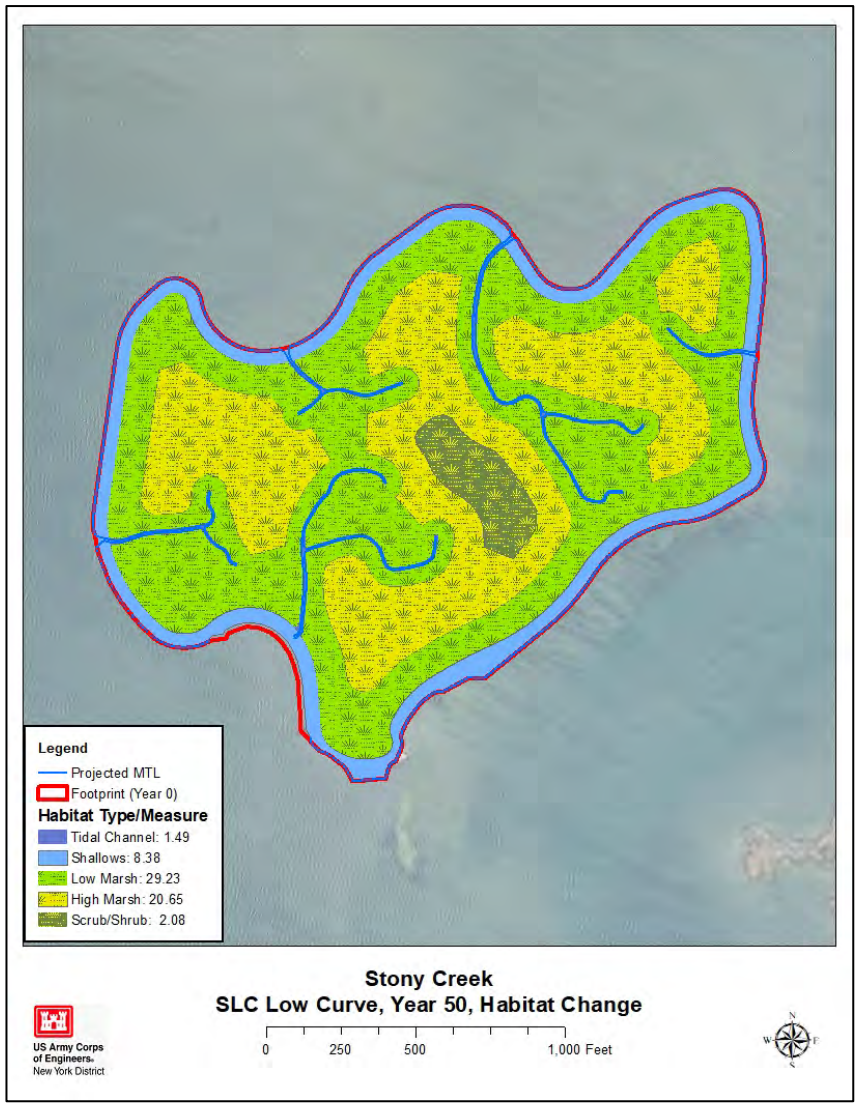


Figure 24. Stony Creek SLC Low Curve, Year 50

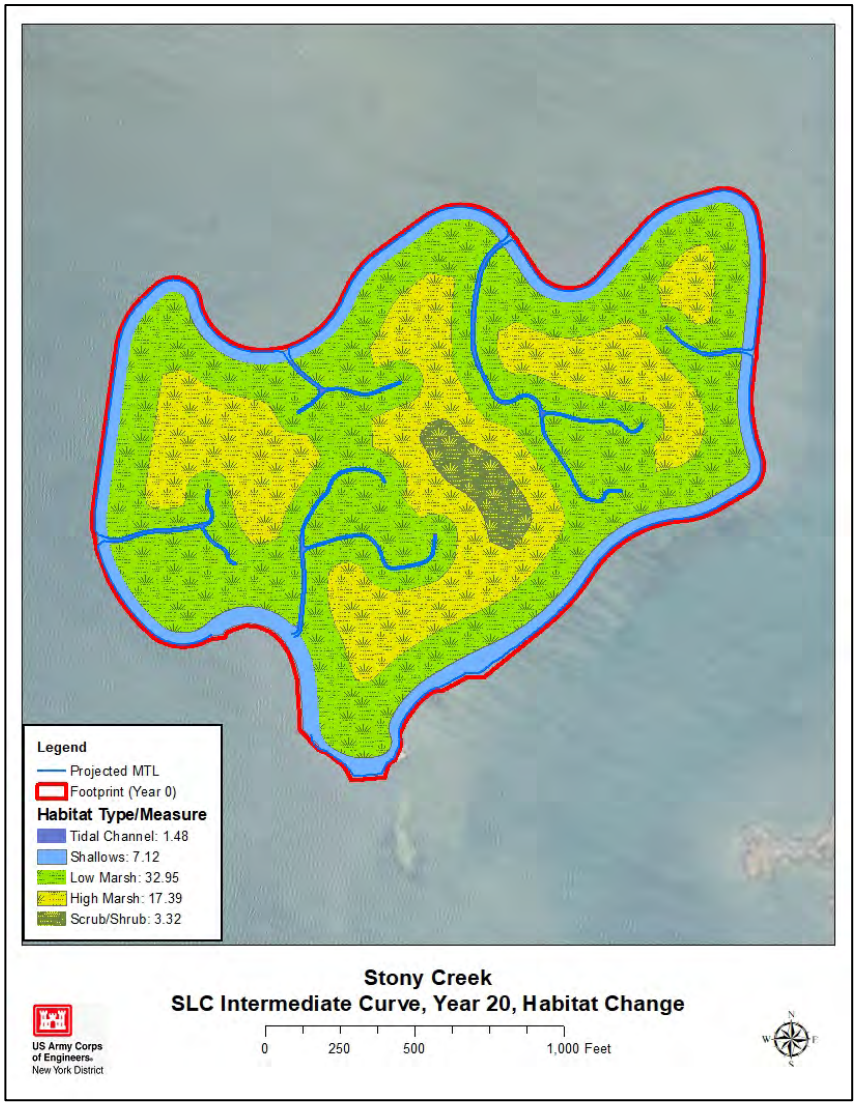


Figure 25. Stony Creek SLC Intermediate Curve, Year 20

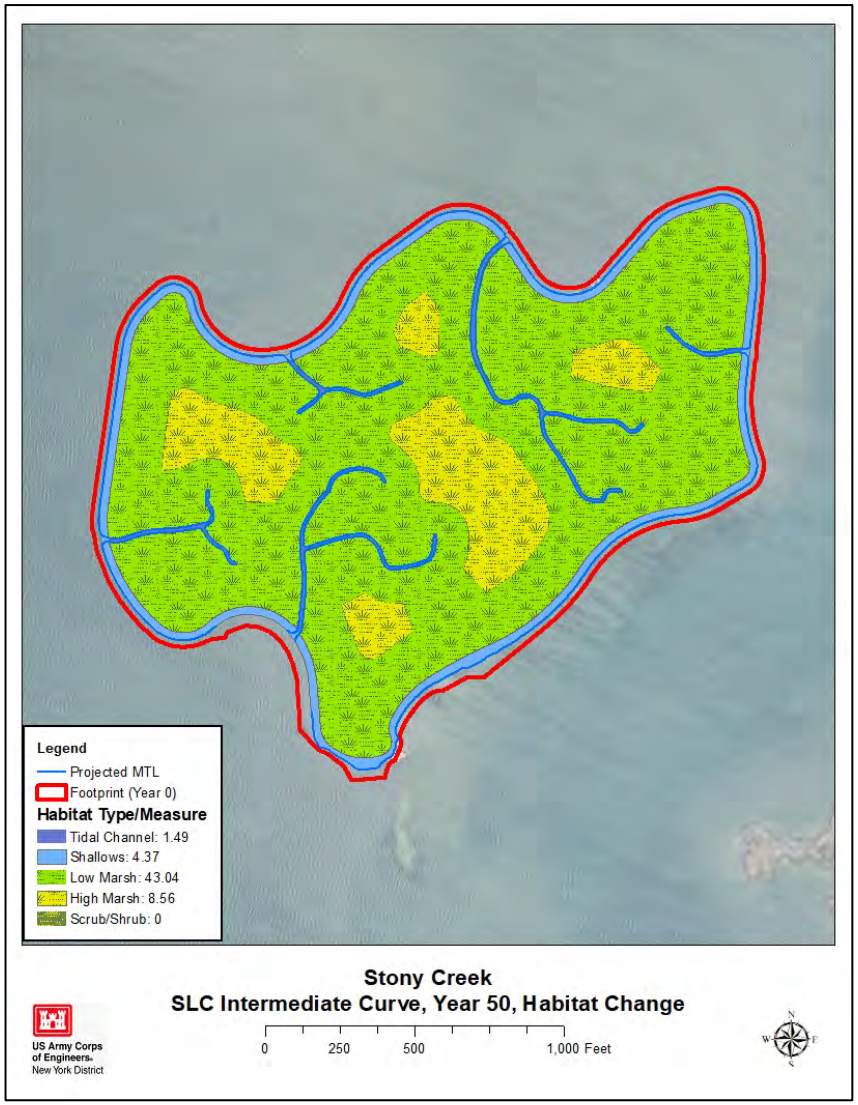


Figure 26. Stony Creek SLC Intermediate Curve, Year 50

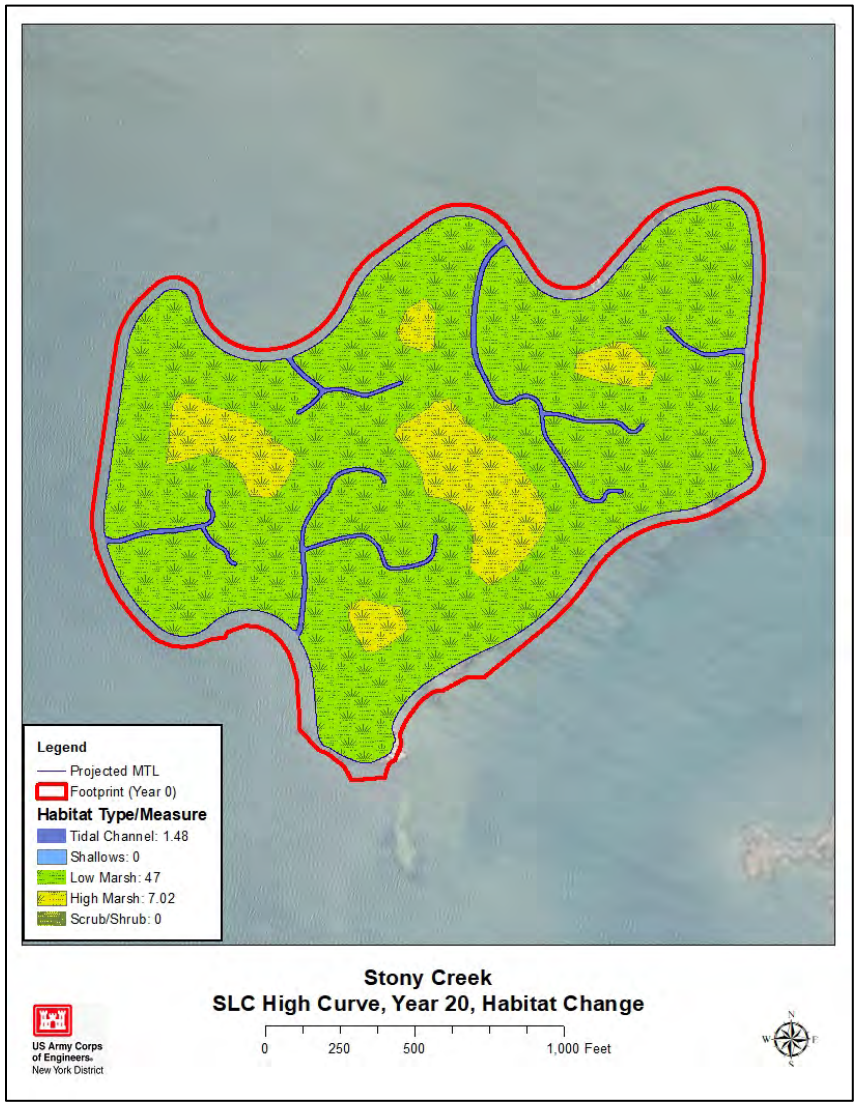


Figure 27. Stony Creek SLC High Curve, Year 20

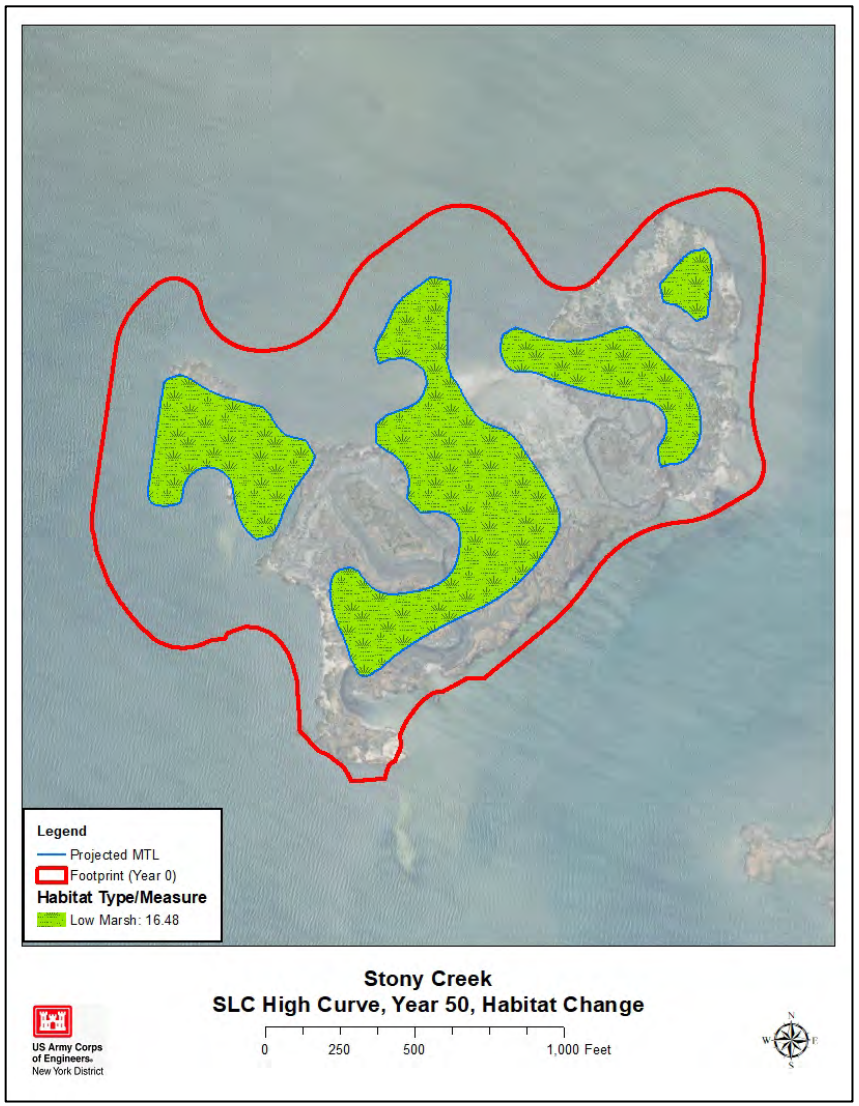


Figure 28. Stony Creek SLC High Curve, Year 20

PUMPKIN PATCH WEST

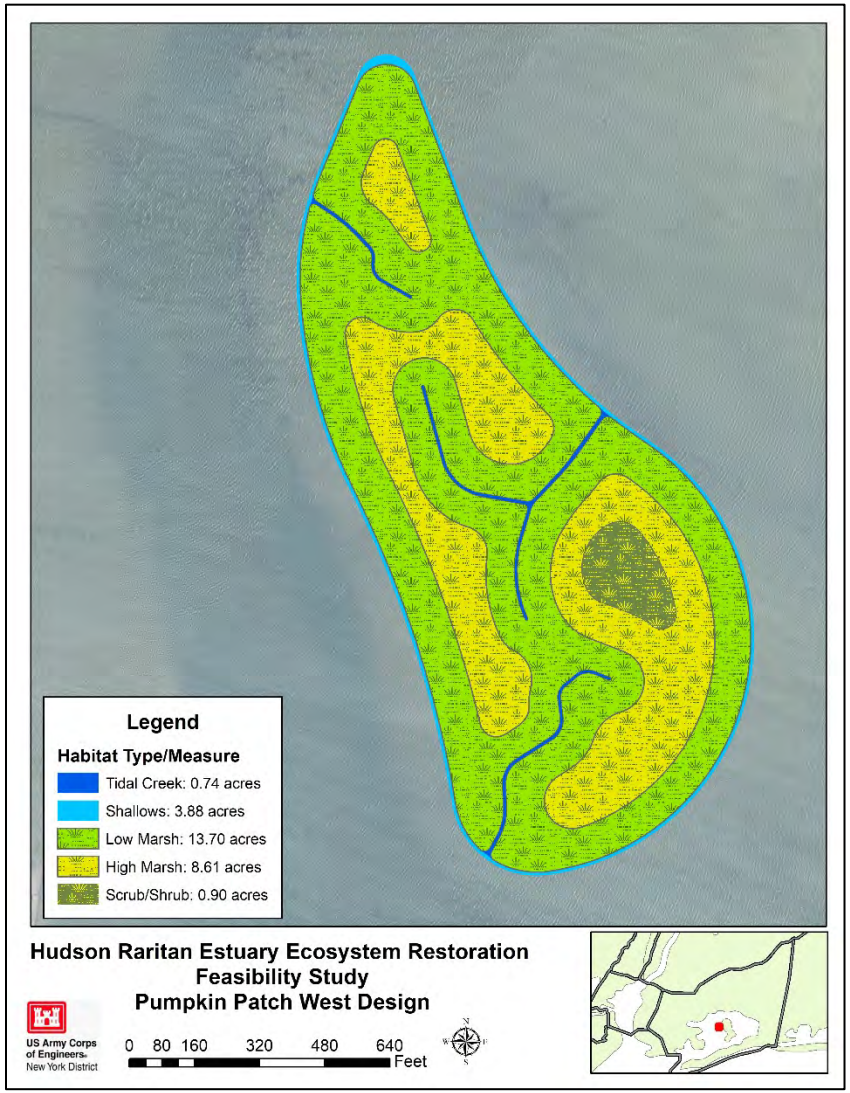


Figure 29. Pumpkin Patch West Proposed Design

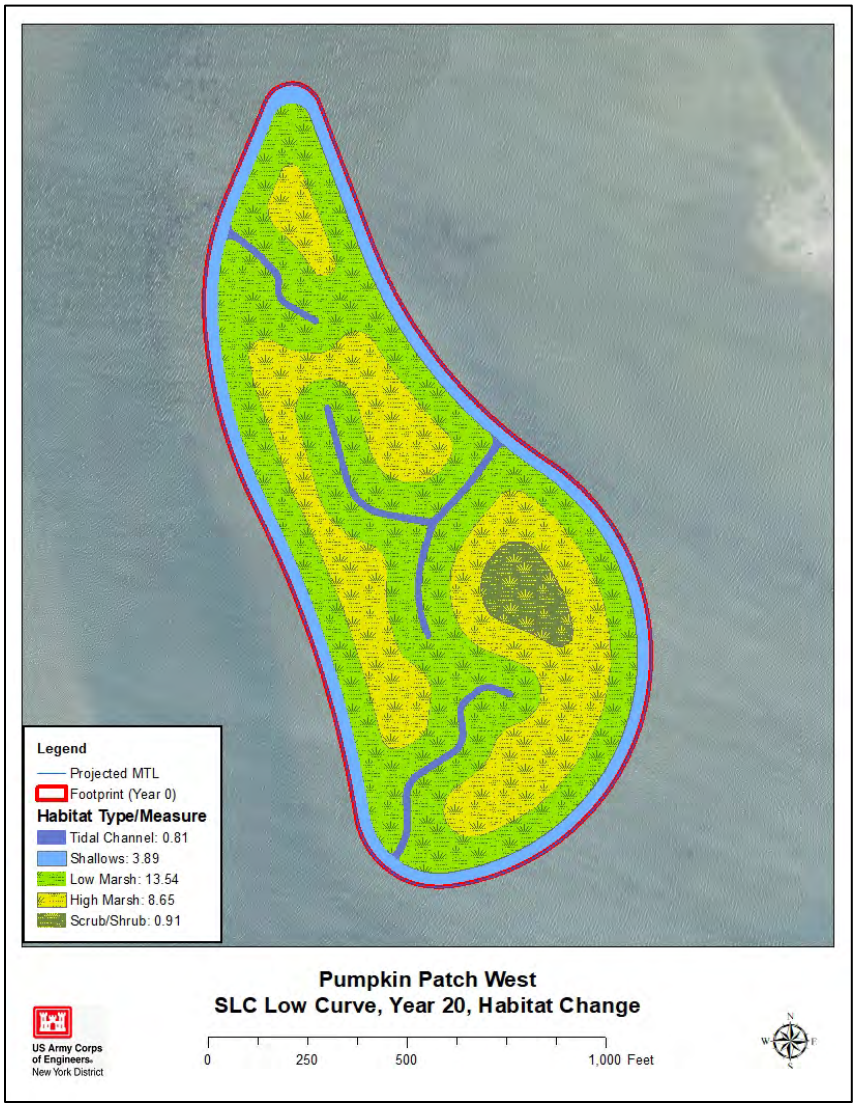


Figure 30. Pumpkin Patch West SLC Low Curve, Year 20

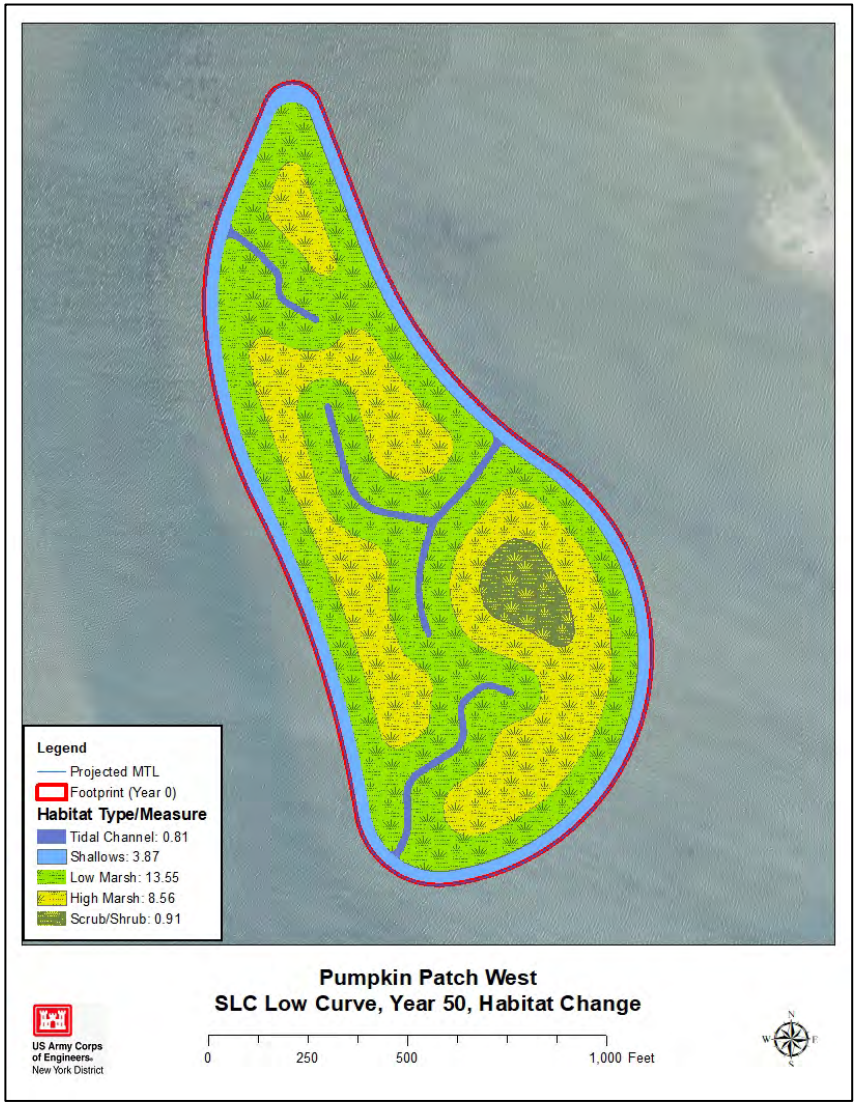


Figure 31. Pumpkin Patch West SLC Low Curve, Year 50

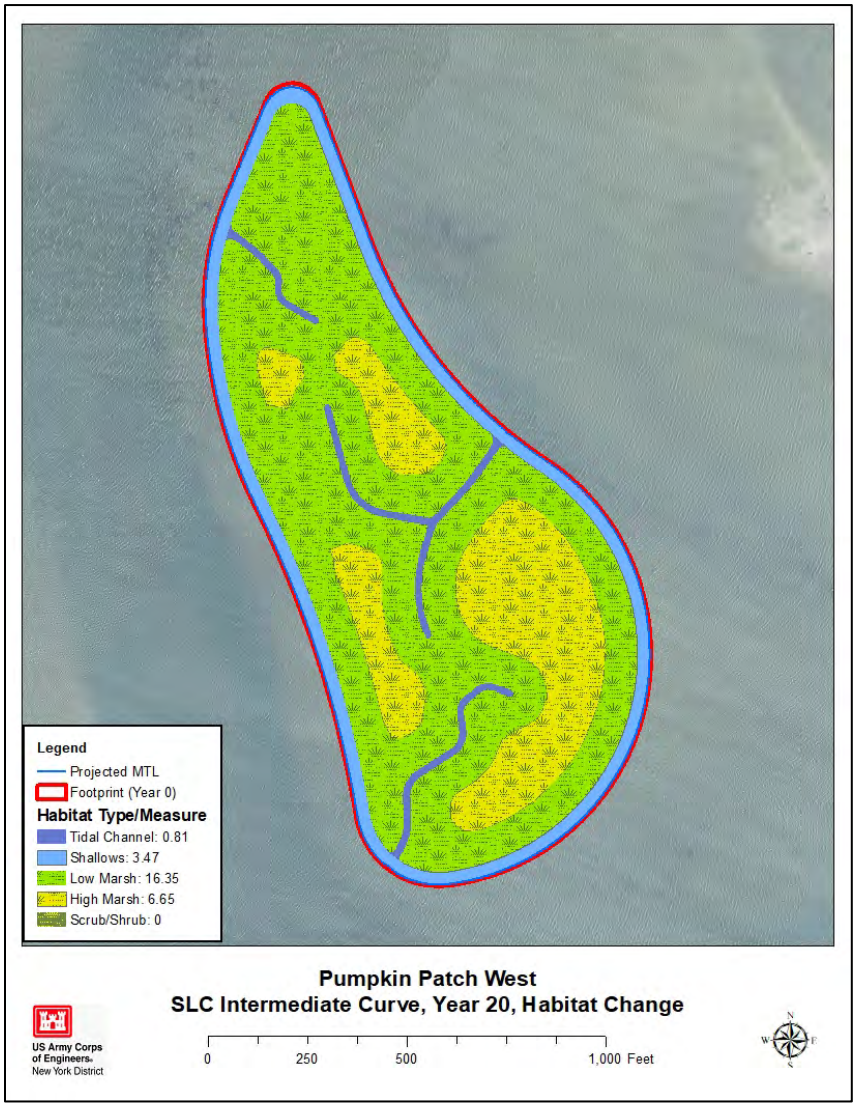


Figure 32. Pumpkin Patch West SLC Intermediate Curve, Year 20

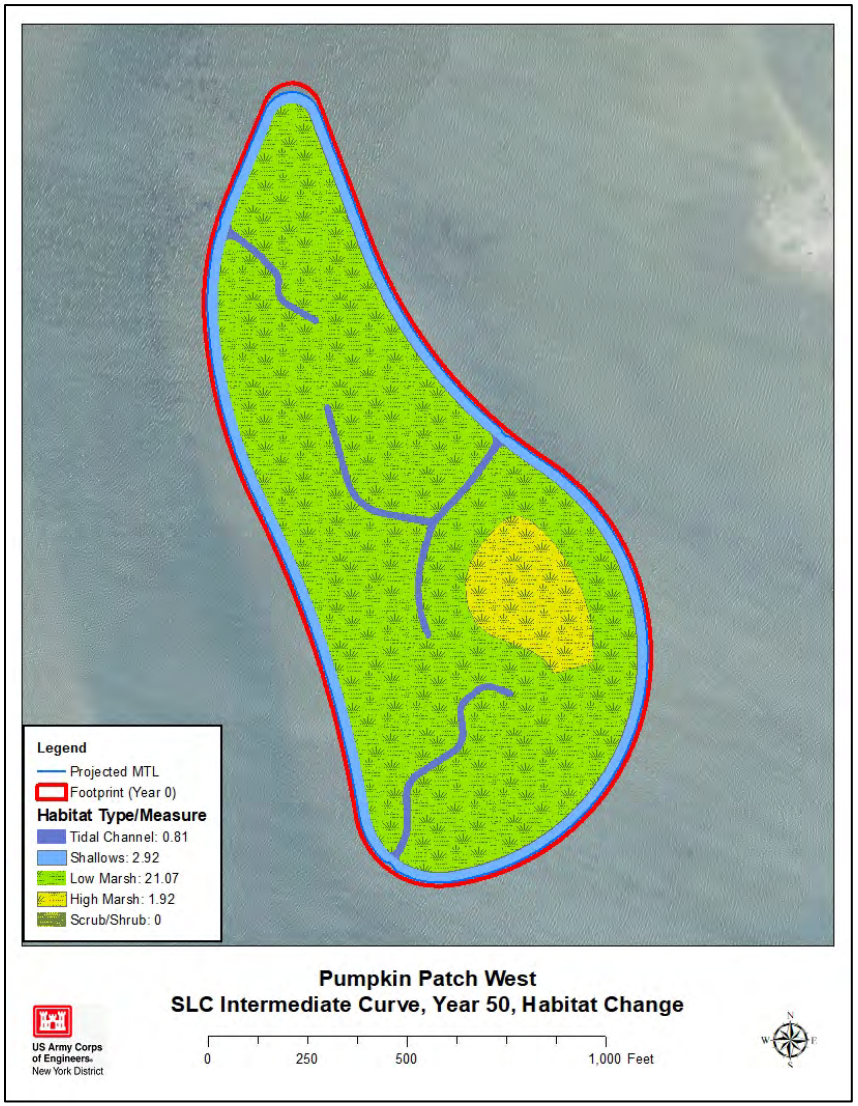


Figure 33. Pumpkin Patch West SLC Intermediate Curve, Year 50

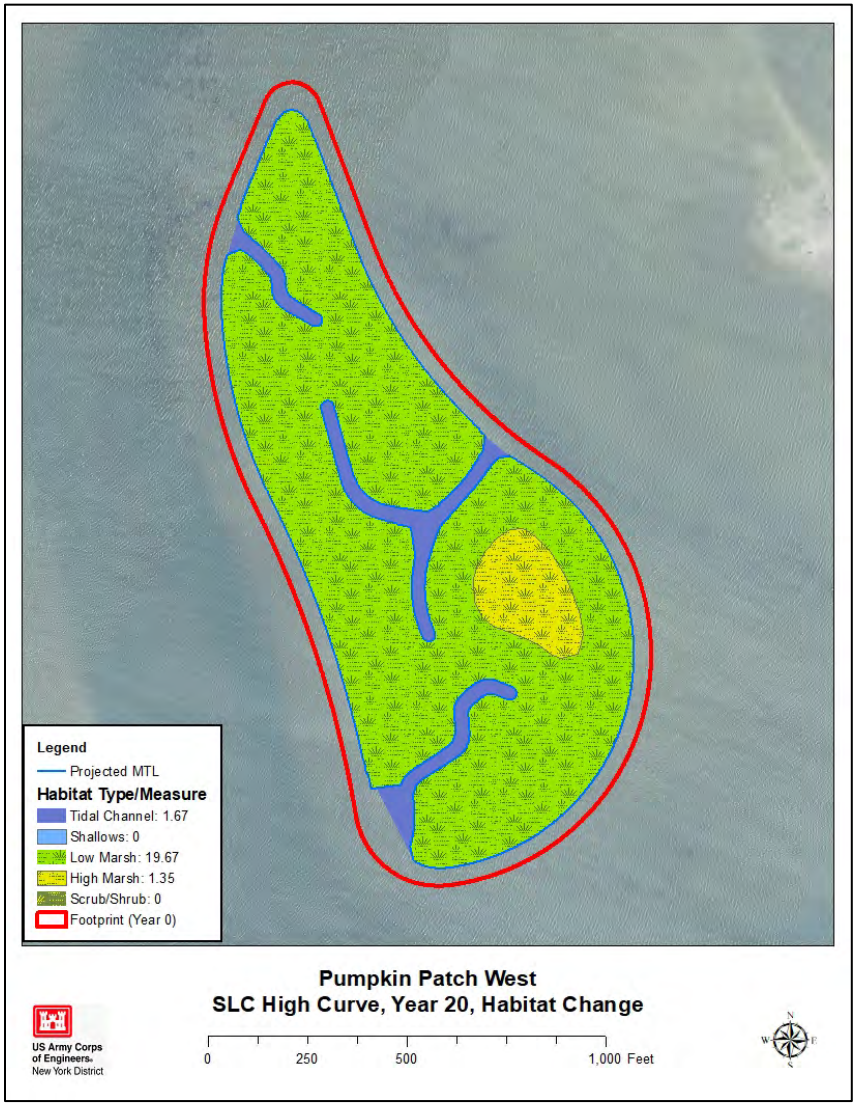


Figure 34. Pumpkin Patch West SLC High Curve, Year 20

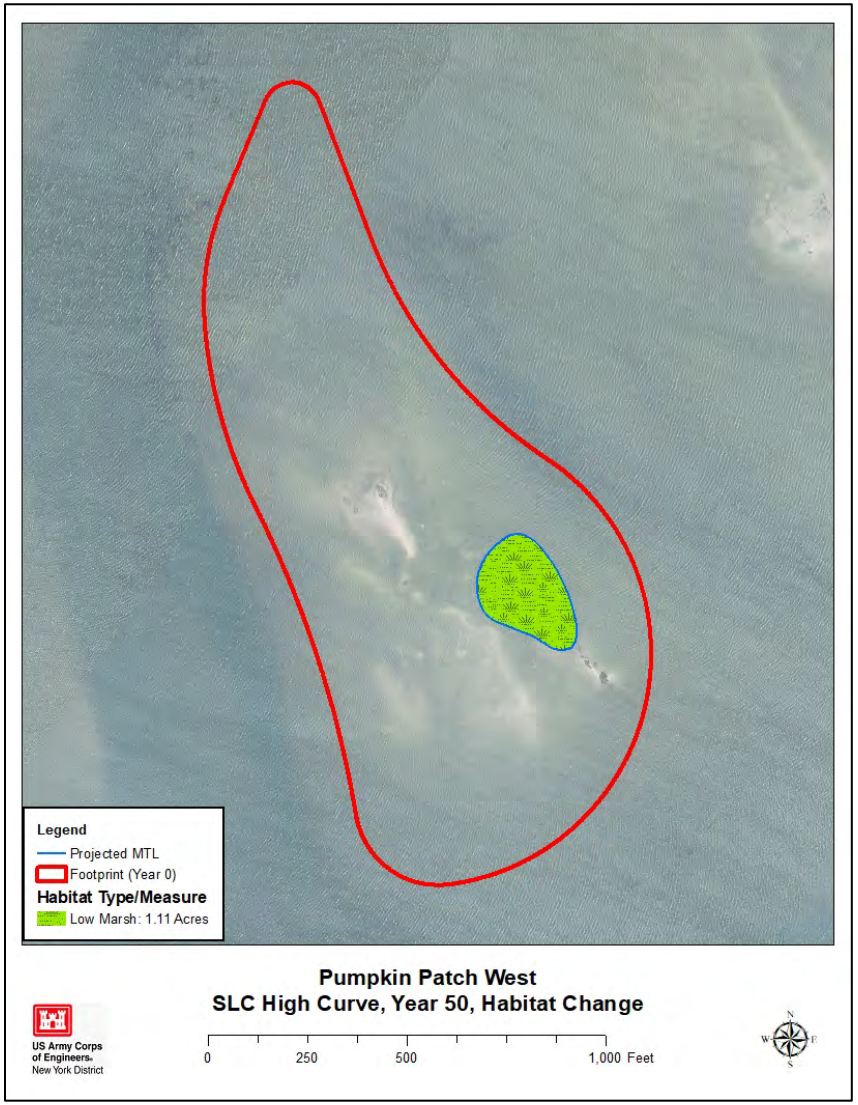


Figure 35. Pumpkin Patch West SLC High Curve, Year 50

PUMPKIN PATCH EAST

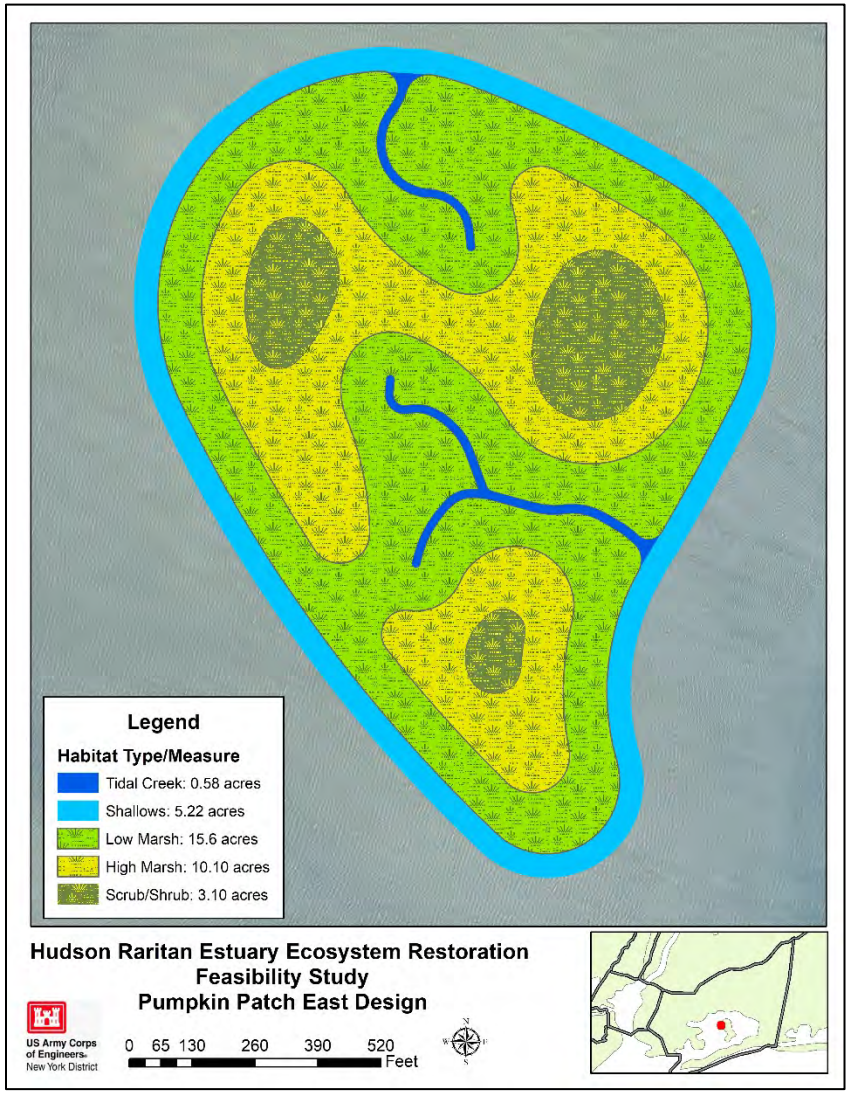


Figure 36. Pumpkin Patch East Proposed Design

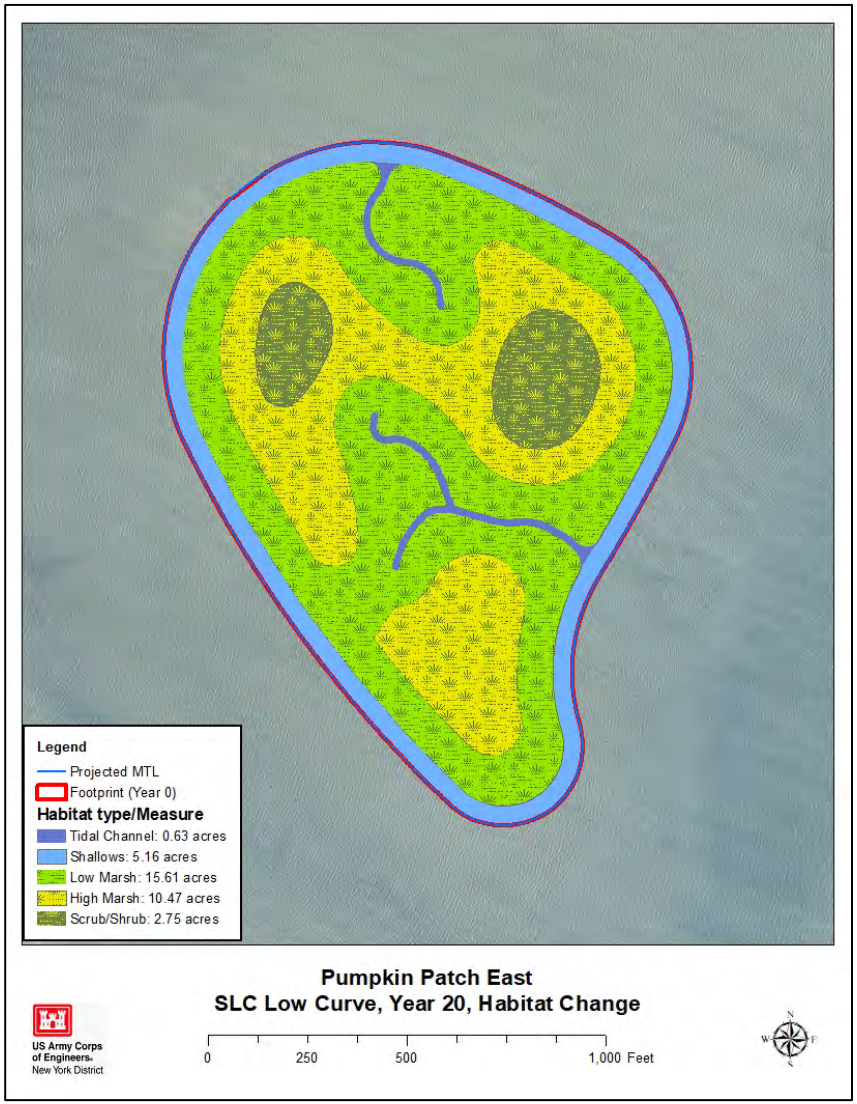


Figure 37. Pumpkin Patch East SLC Low Curve, Year 20

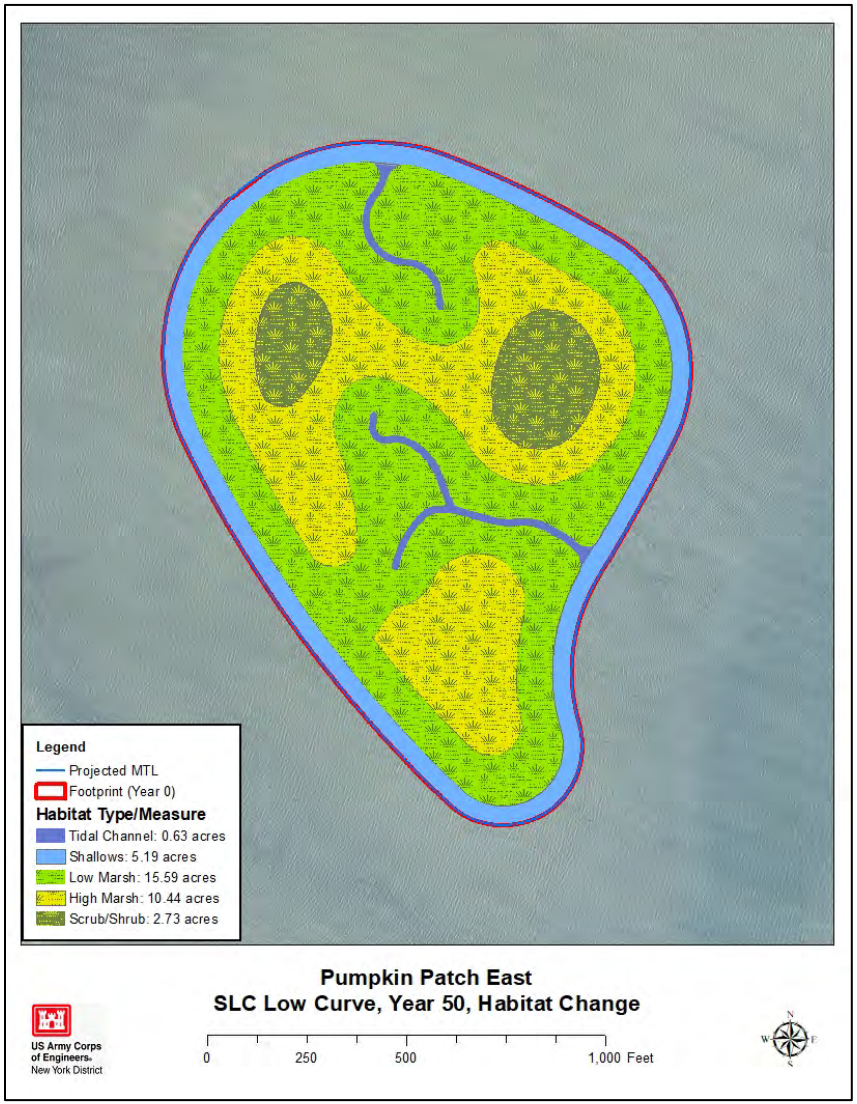


Figure 38. Pumpkin Patch East SLC Low Curve, Year 50



Figure 39. Pumpkin Patch East SLC Intermediate Curve, Year 20

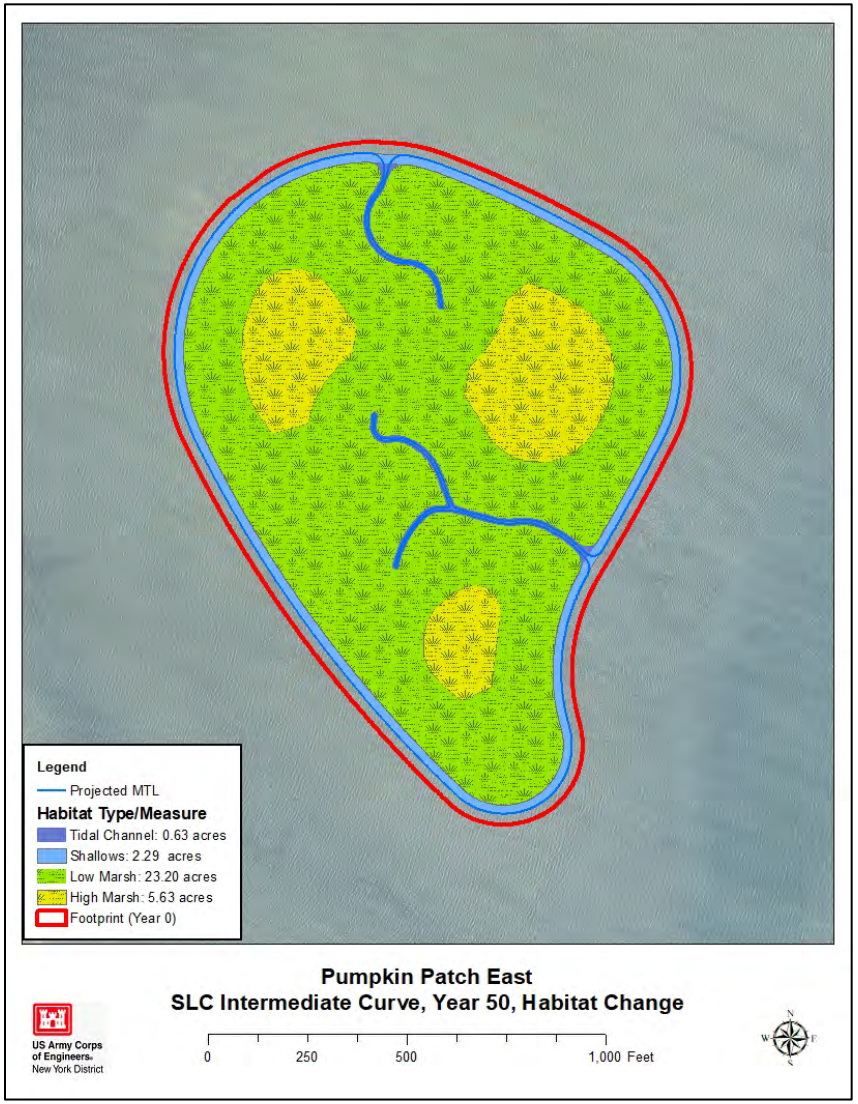


Figure 40. Pumpkin Patch East SLC Intermediate Curve, Year 50



Figure 41. Pumpkin Patch East SLC High Curve, Year 20

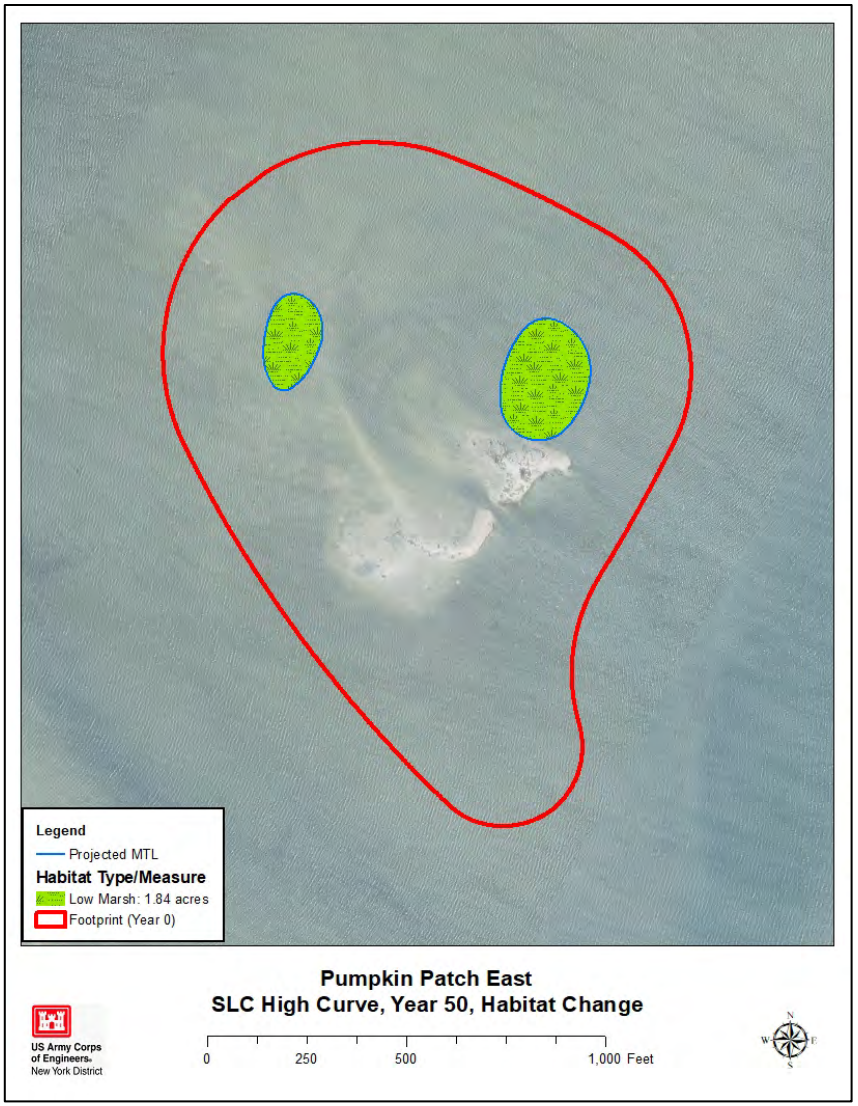


Figure 42. Pumpkin Patch East SLC High Curve, Year 50

ELDERS CENTER

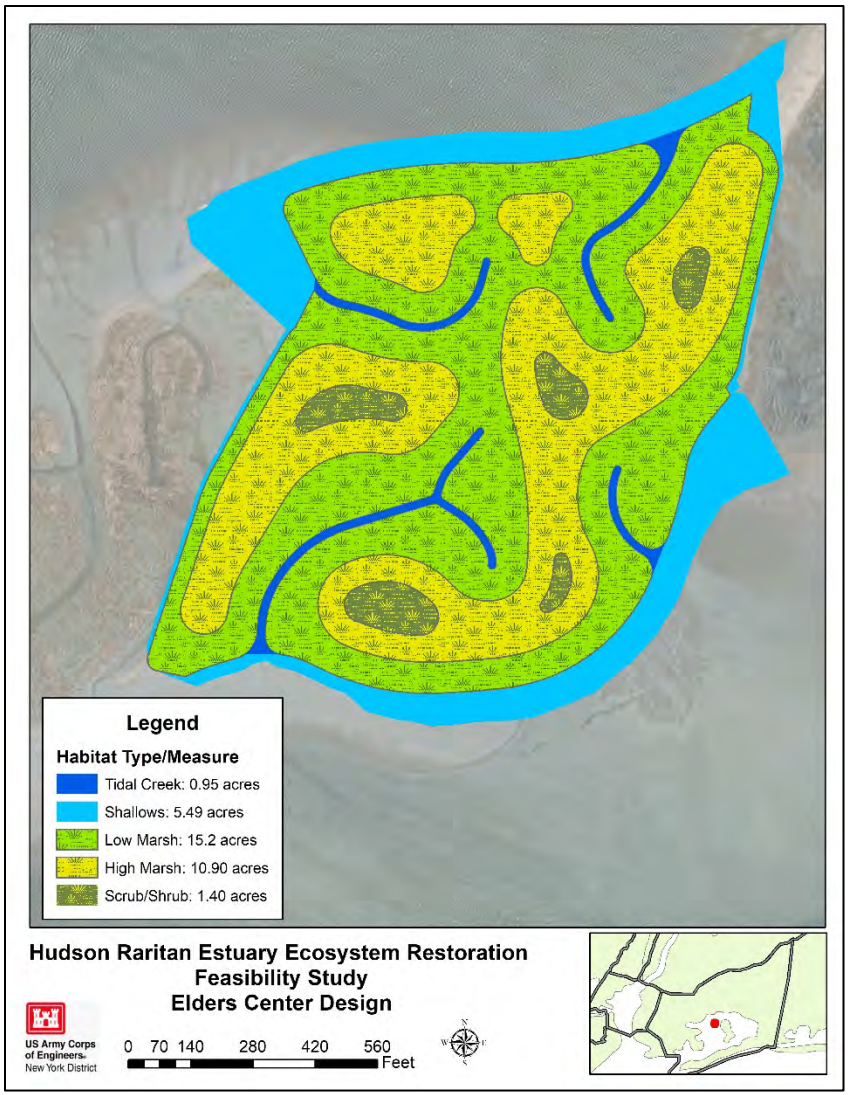


Figure 43. Elders Center Proposed Design

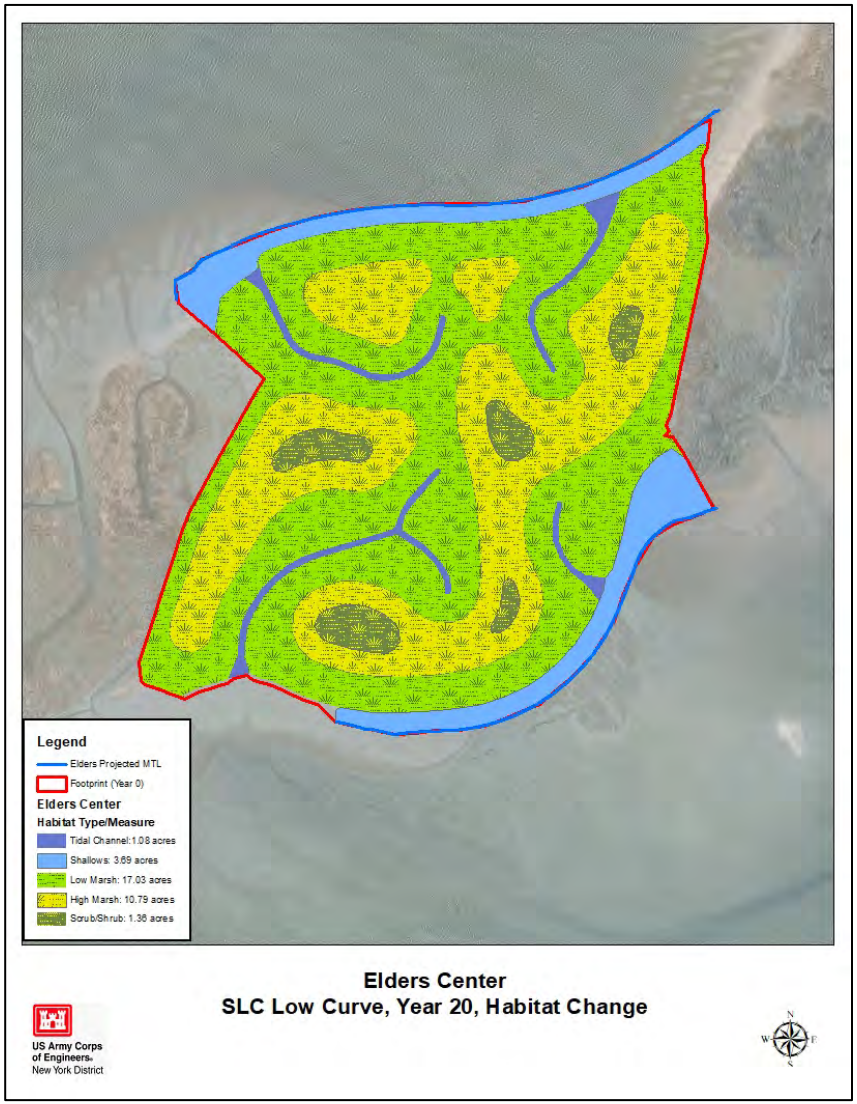


Figure 44. Elders Center SLC Low Curve, Year 20

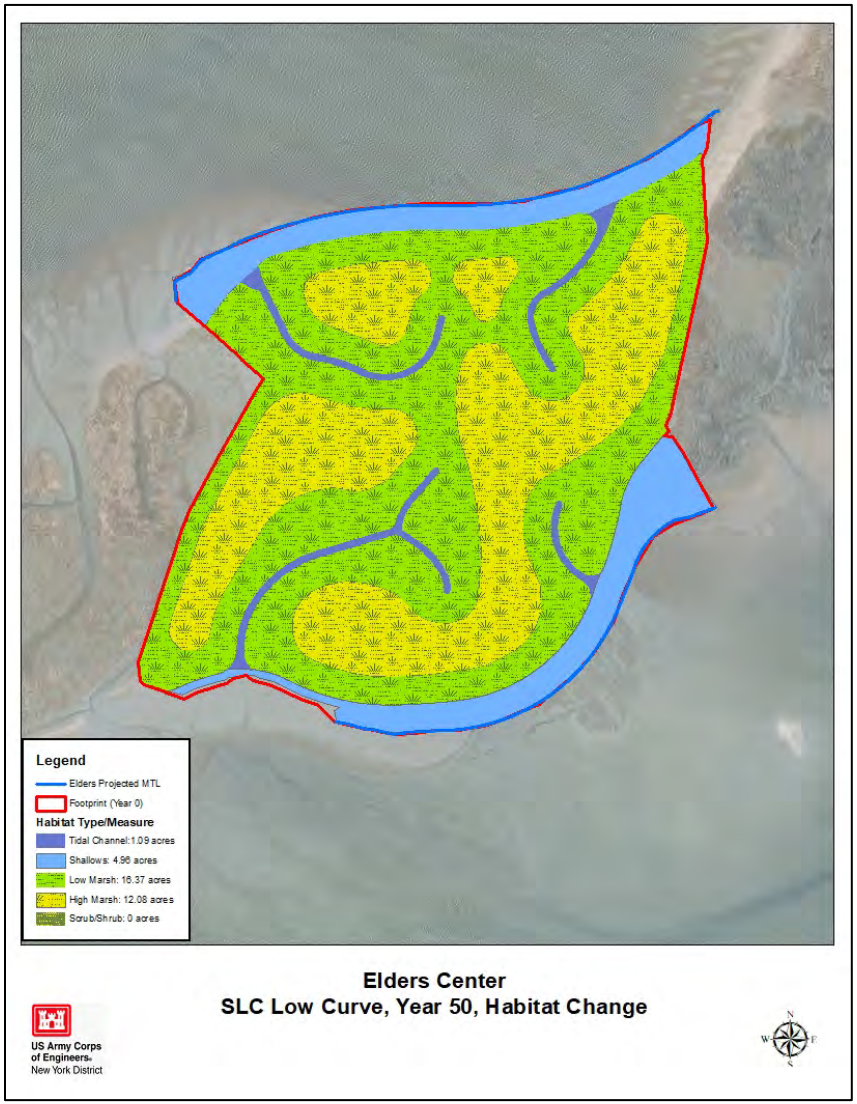


Figure 45. Elders Center SLC Low Curve, Year 50

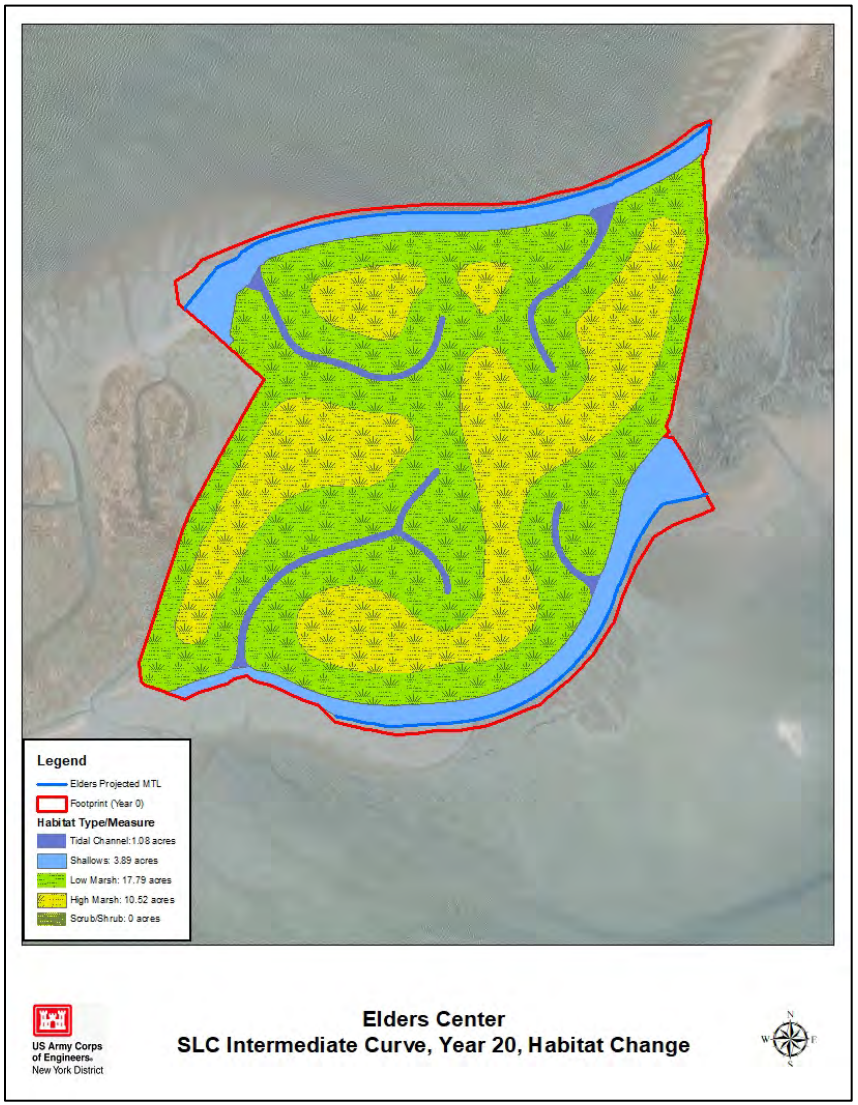


Figure 46. Elders Center SLC Intermediate Curve, Year 20

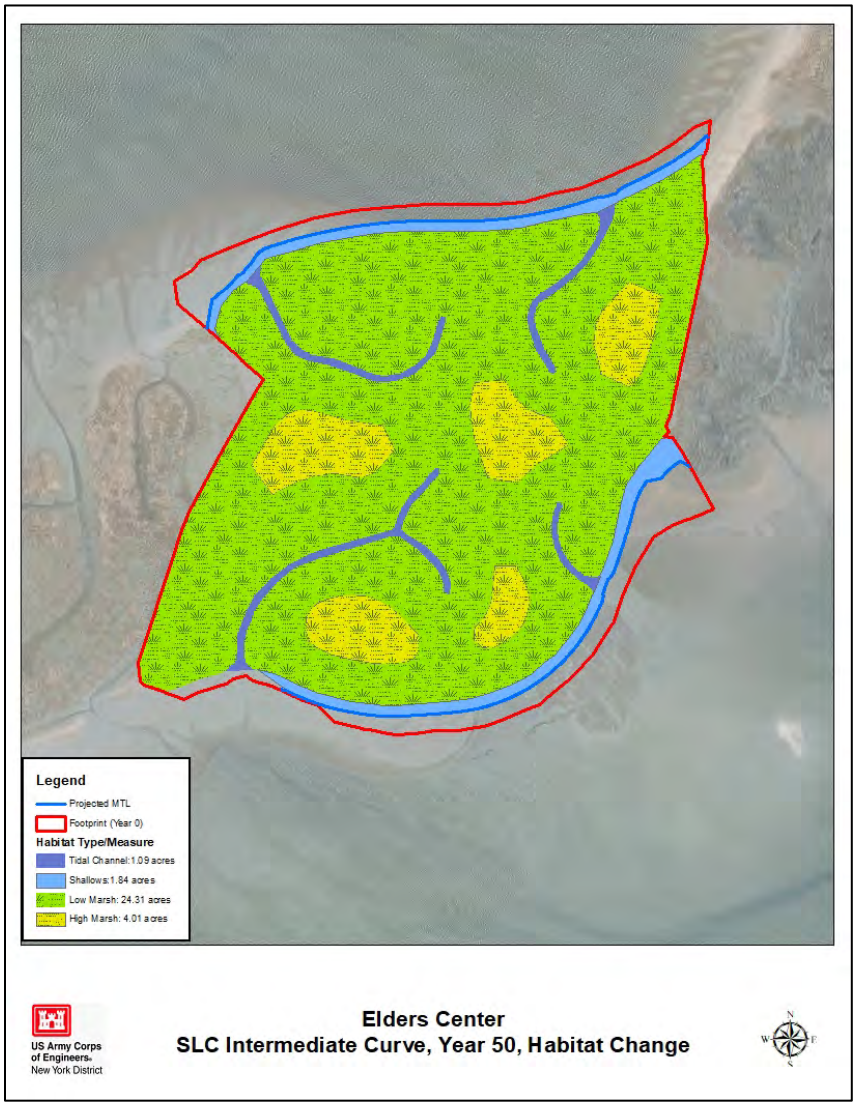


Figure 47. Elders Center SLC Intermediate Curve, Year 50

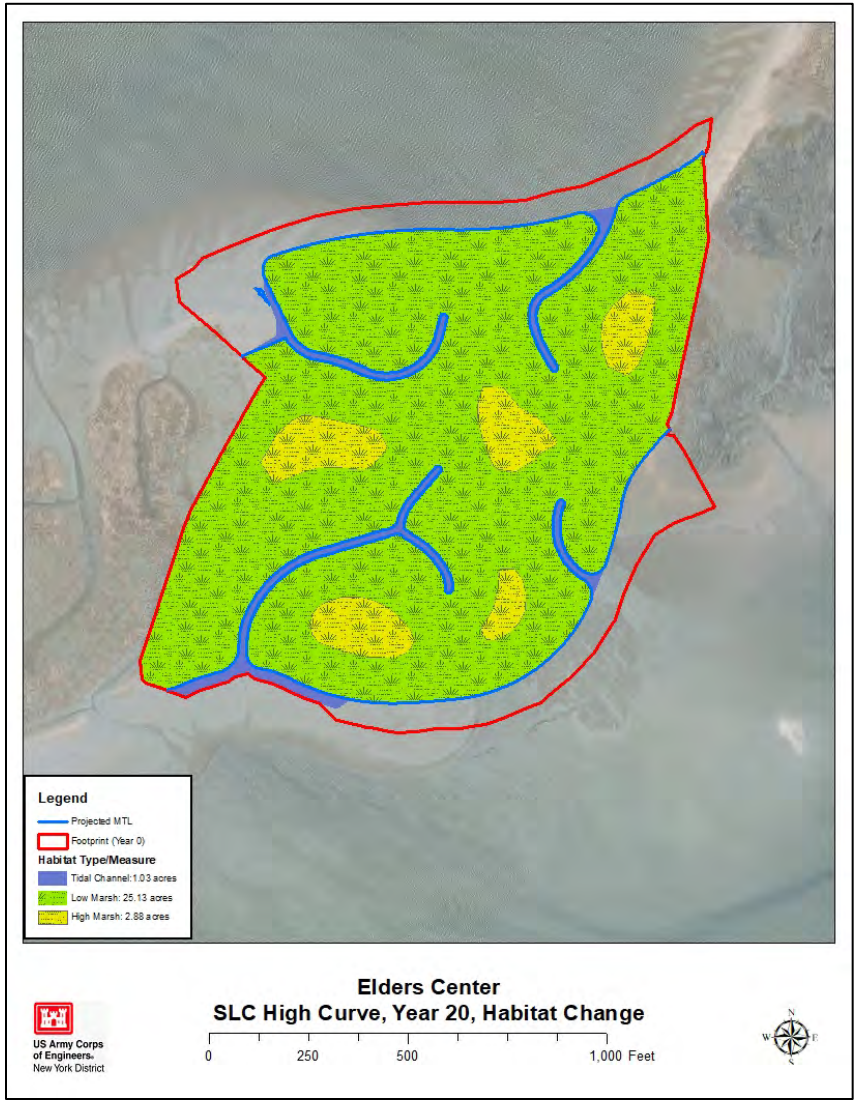


Figure 48. Elders Center SLC High Curve, Year 20

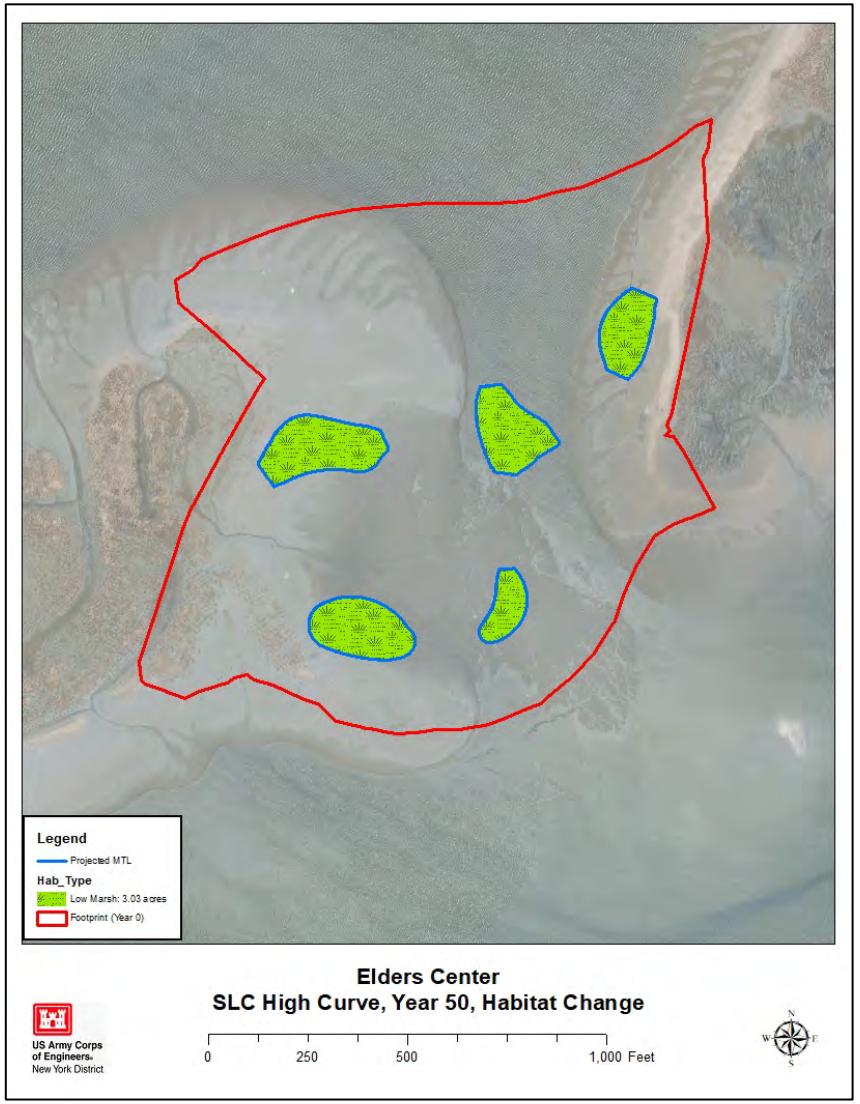


Figure 49. Elders Center SLC High Curve, Year 50

FLUSHING CREEK

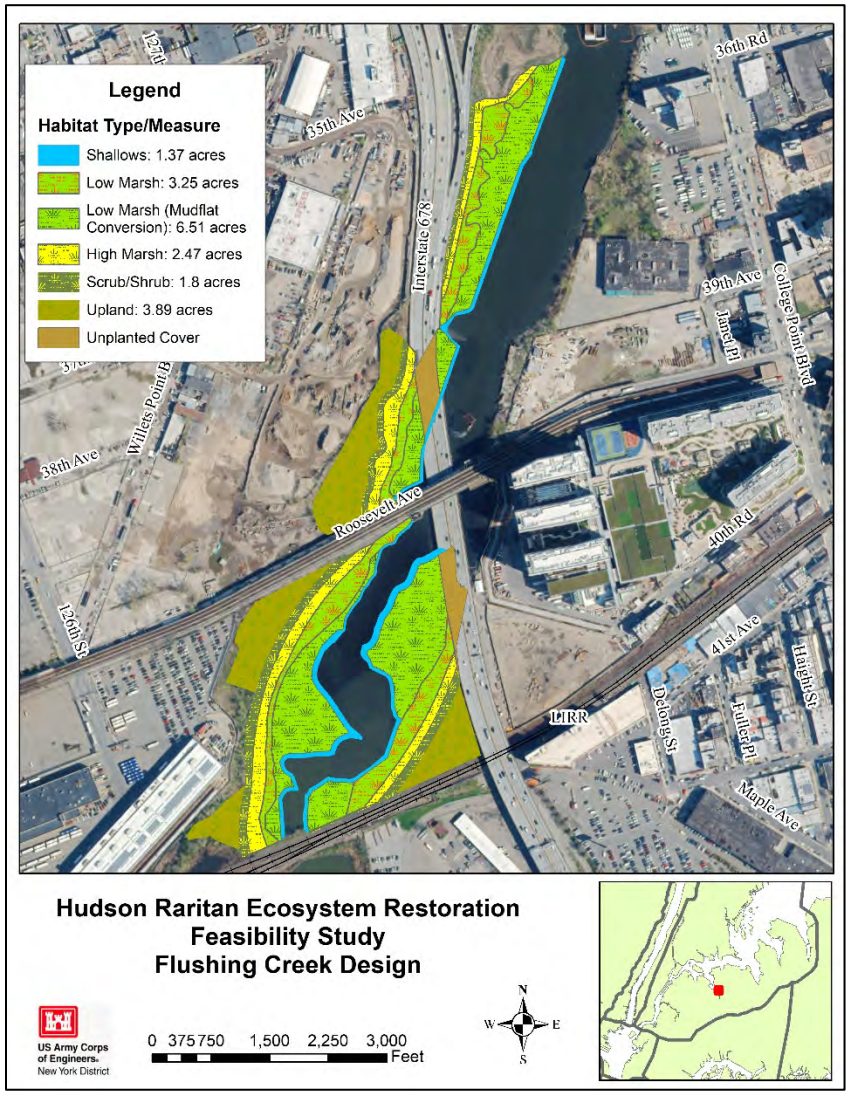


Figure 50. Flushing Creek Proposed Design

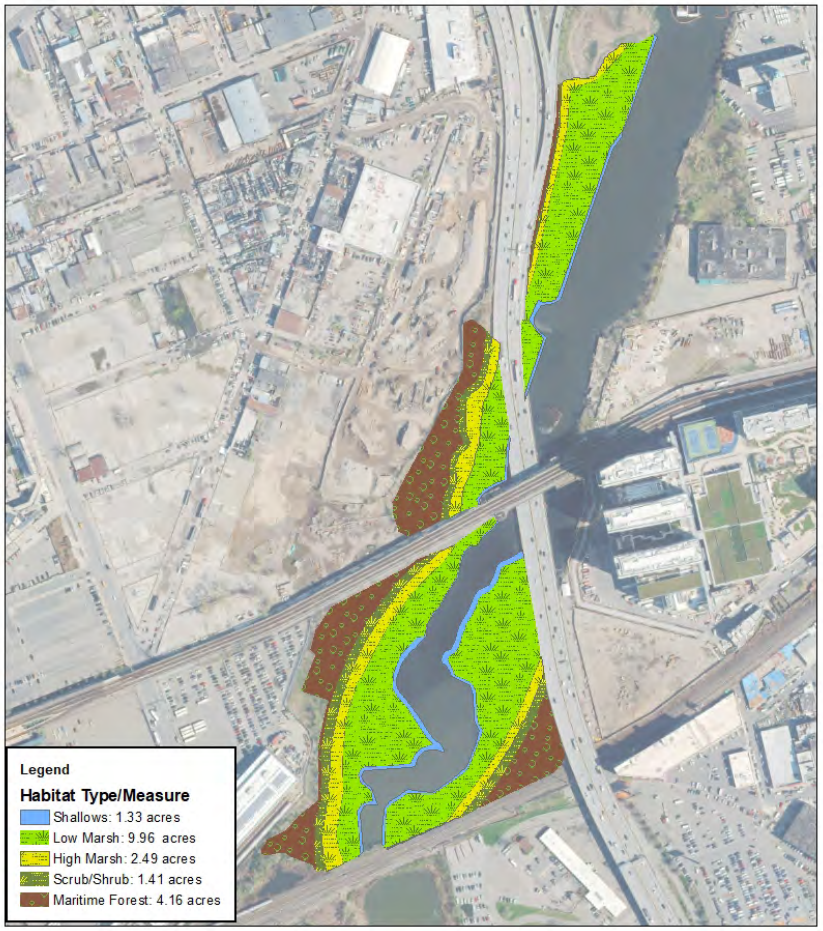


Figure 51. Flushing Creek SLC Low Curve, Year 20

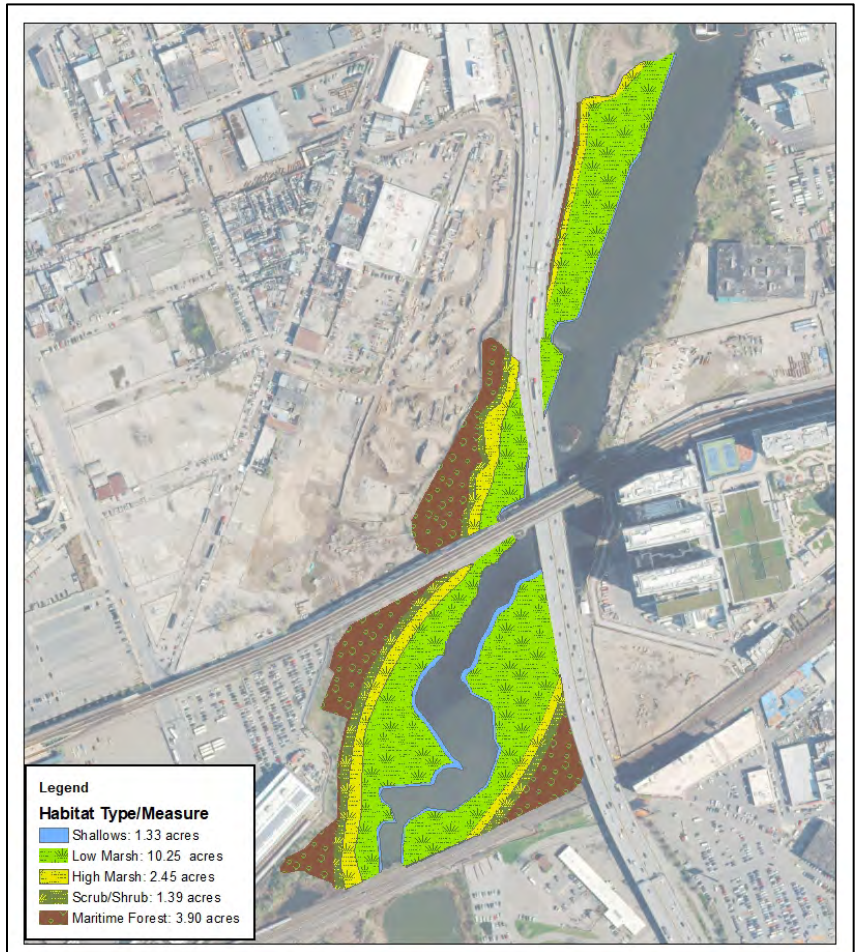


Figure 52. Flushing Creek SLC Low Curve, Year 50

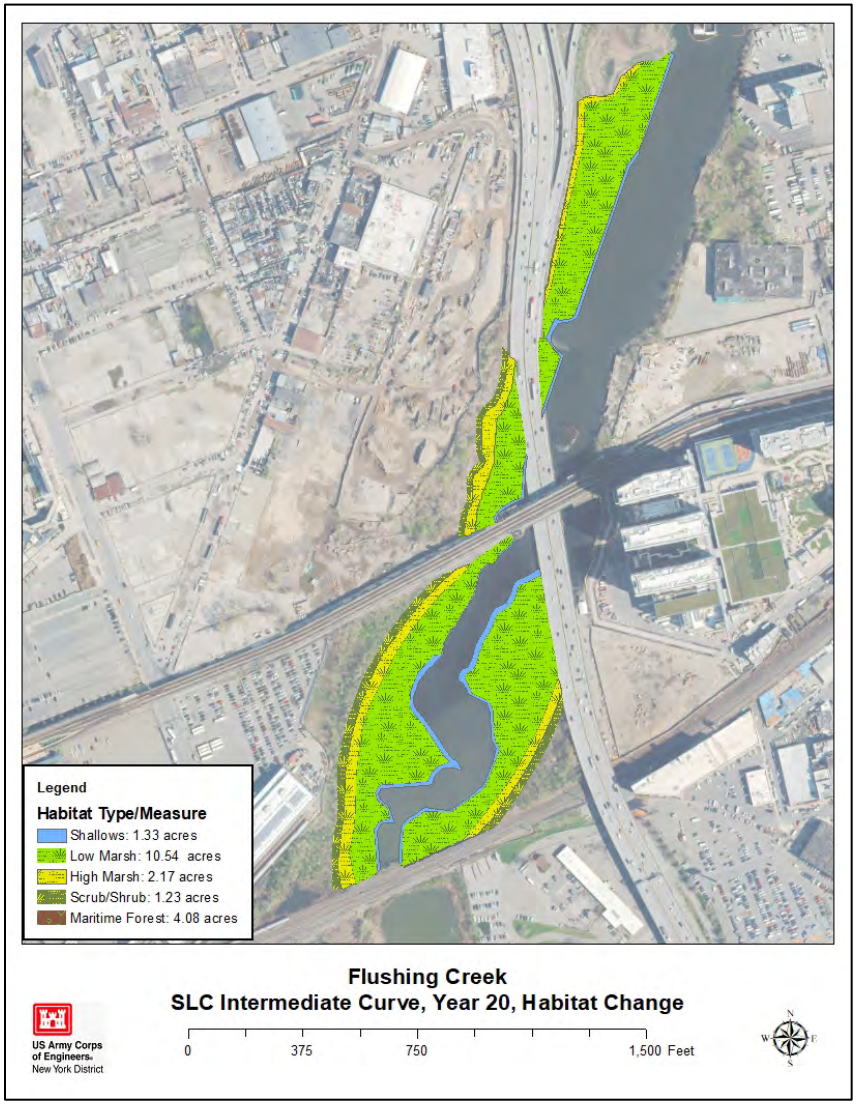


Figure 53. Flushing Creek SLC Intermediate Curve, Year 20

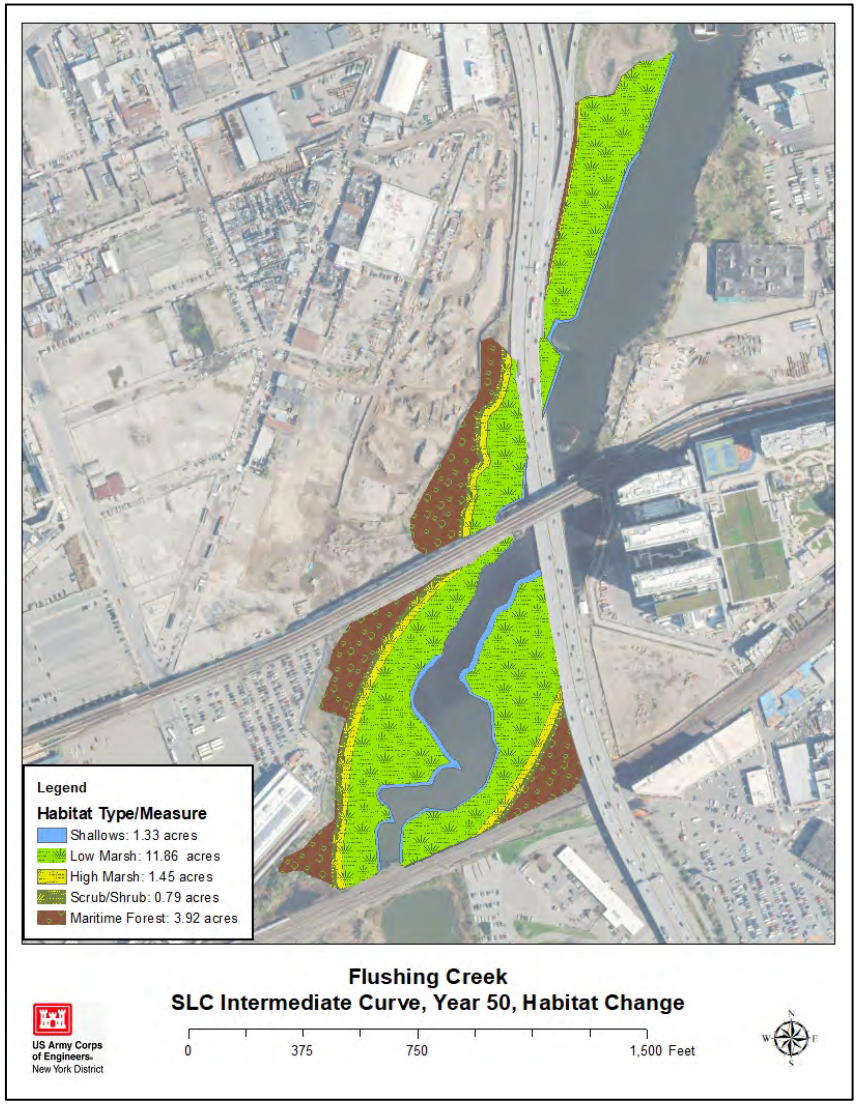


Figure 54. Flushing Creek SLC Intermediate Curve, Year 50

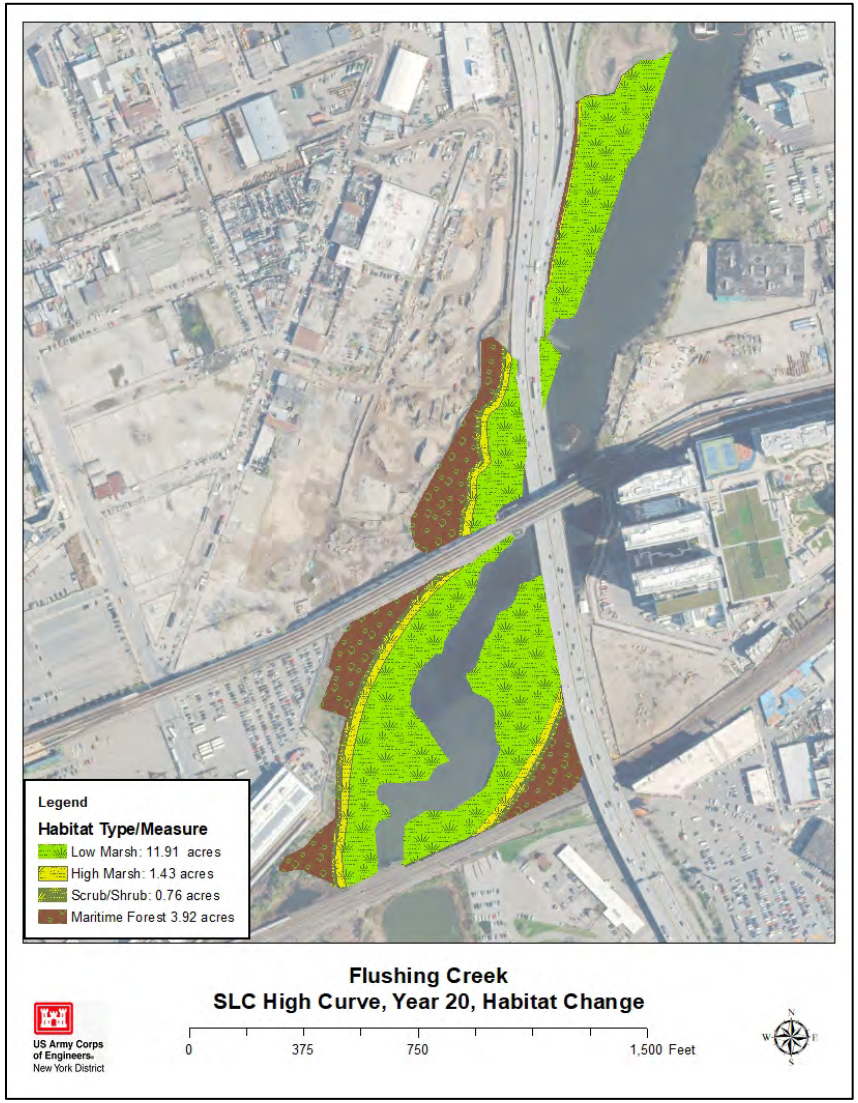


Figure 55. Flushing Creek SLC High Curve, Year 20

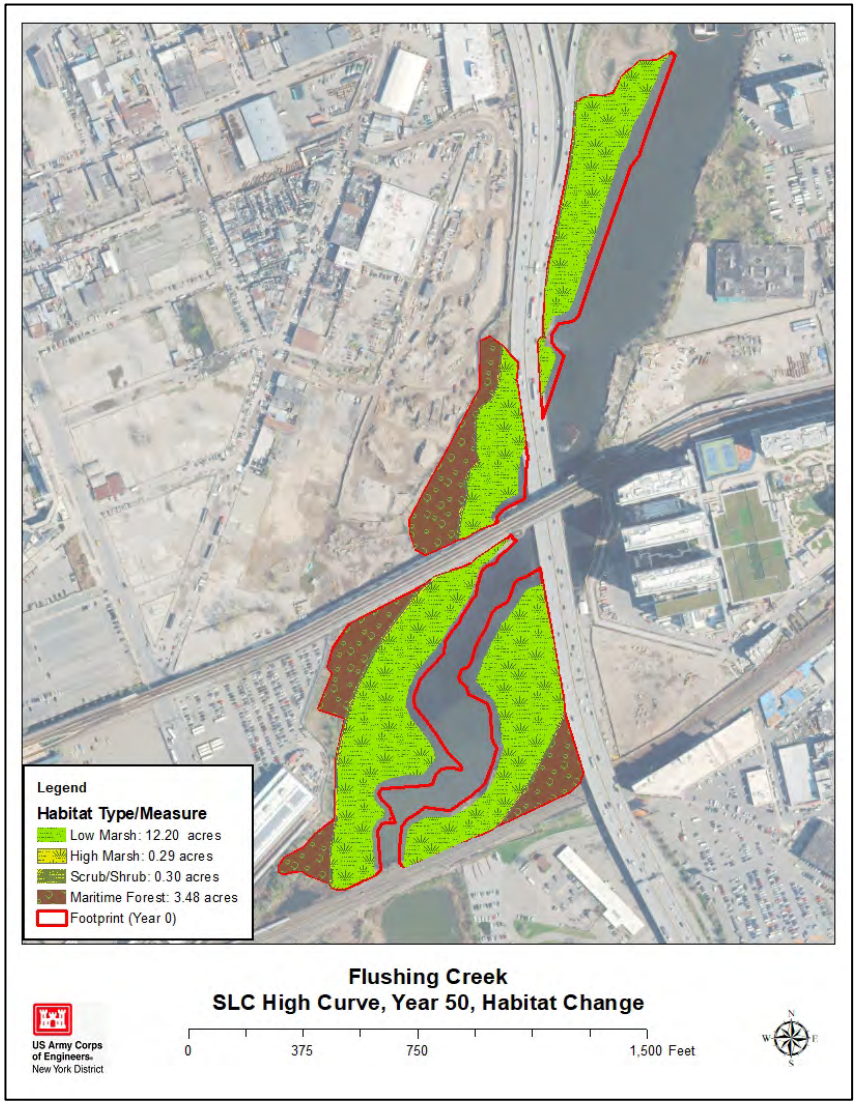


Figure 56. Flushing Creek SLC High Curve, Year 50

OAK ISLAND YARDS

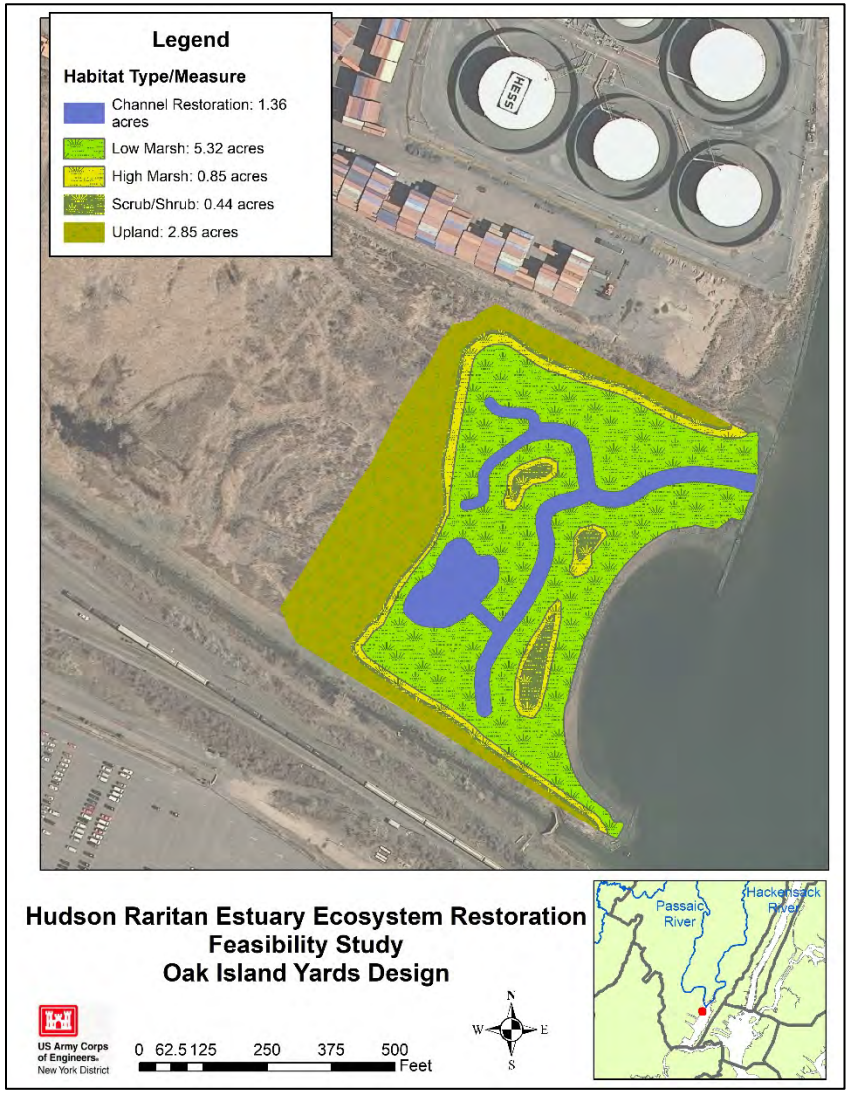


Figure 57. Oak Island Yards Proposed Design

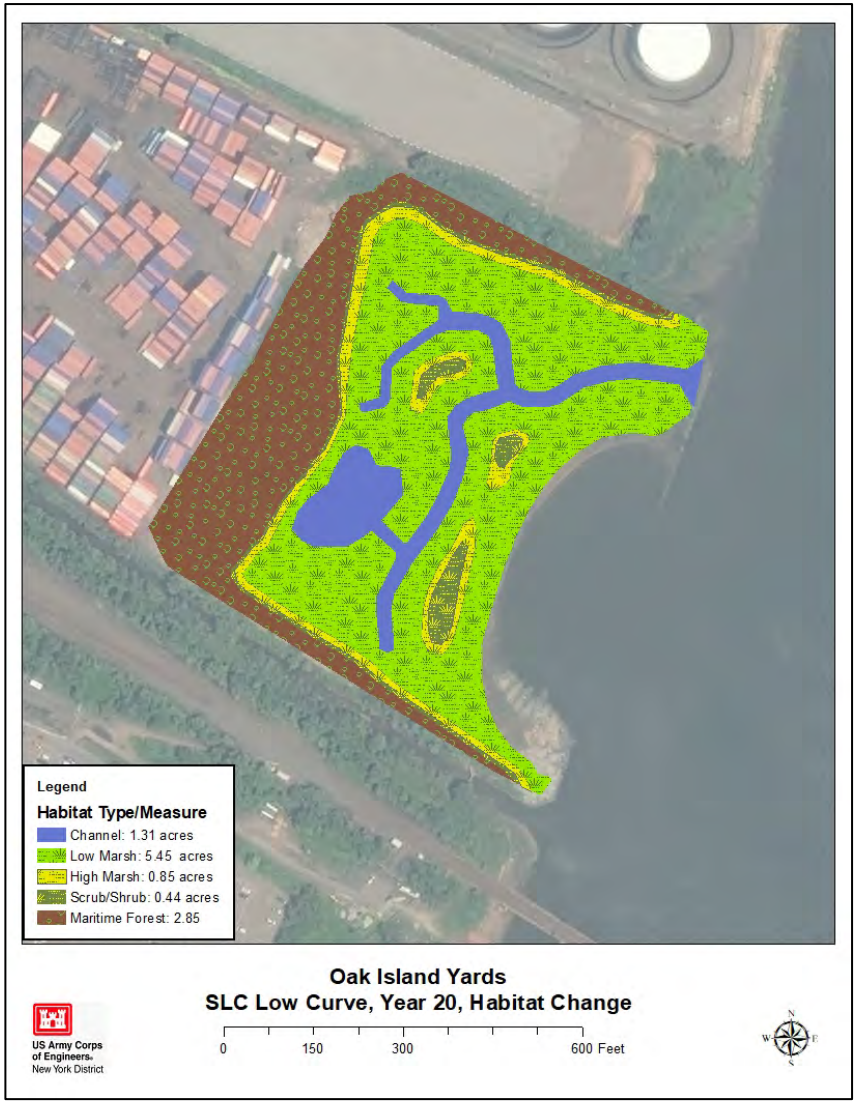


Figure 58. Oak Island Yards SLC Low Curve, Year 20

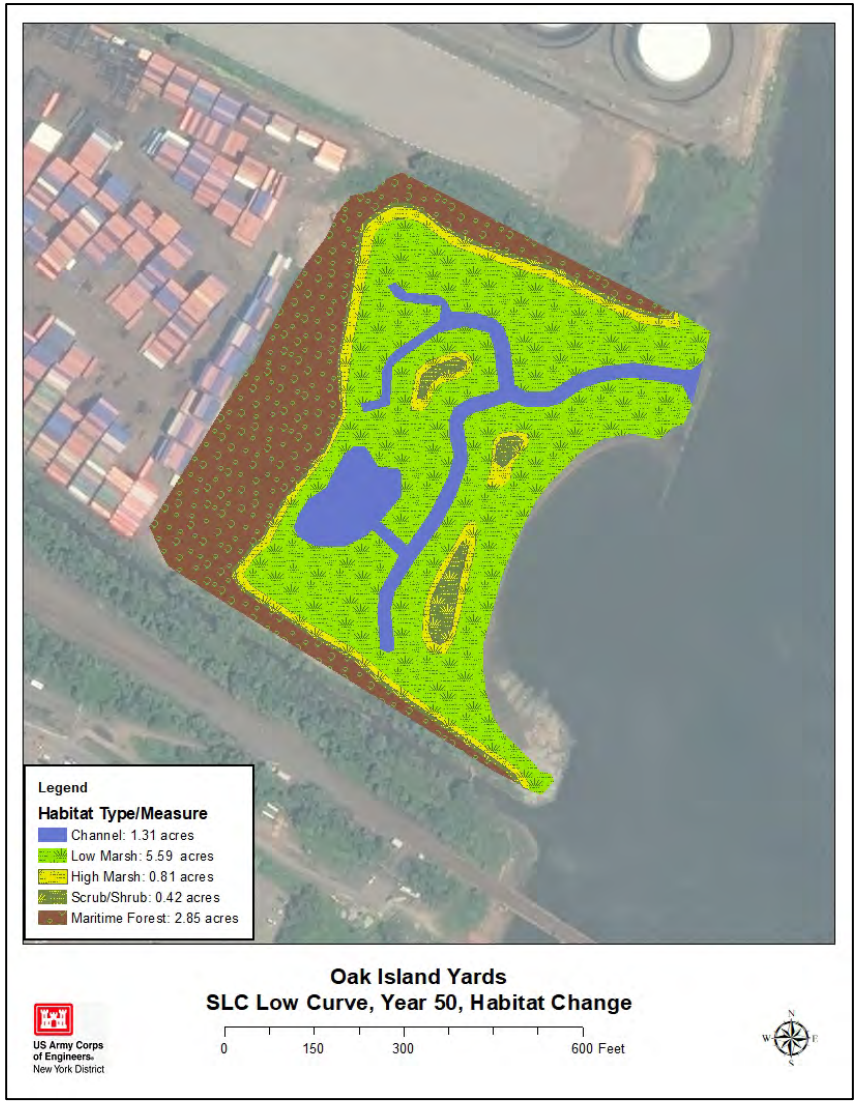


Figure 59. Oak Island Yards SLC Low Curve, Year 50

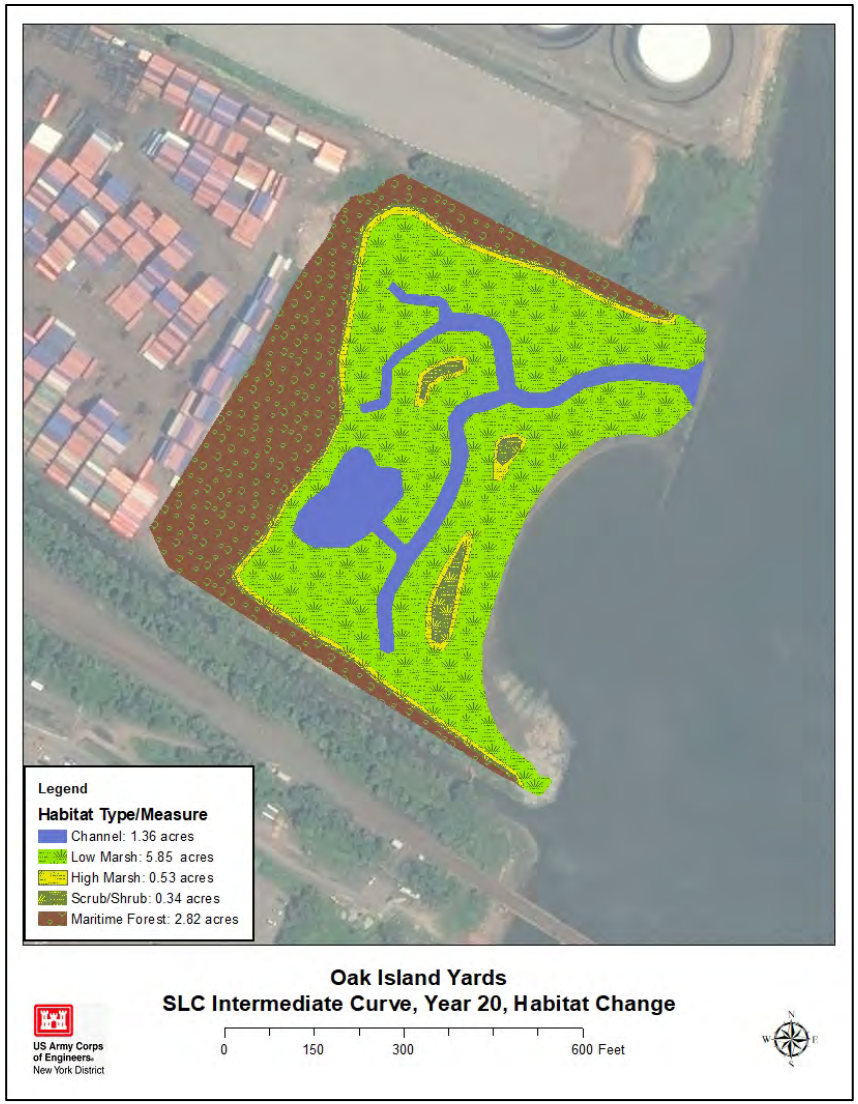


Figure 60. Oak Island Yards SLC Intermediate Curve, Year 20

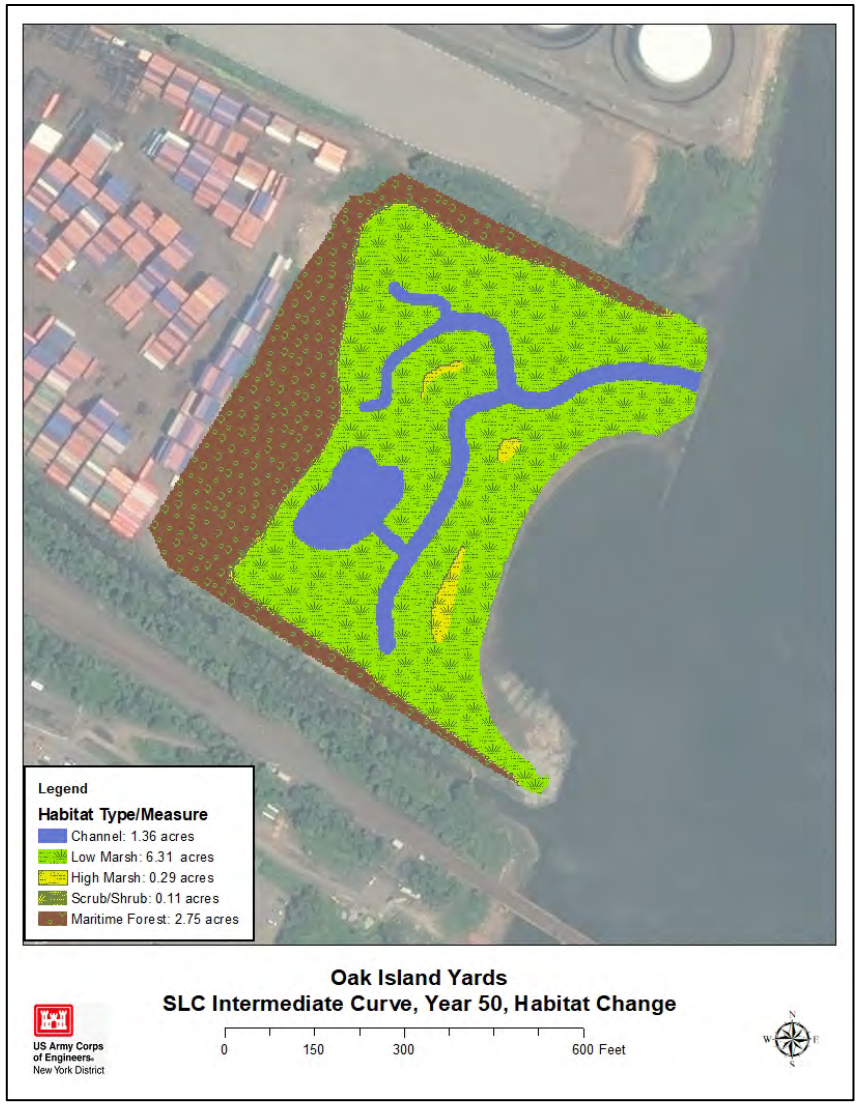


Figure 61. Oak Island Yards SLC Intermediate Curve, Year 50

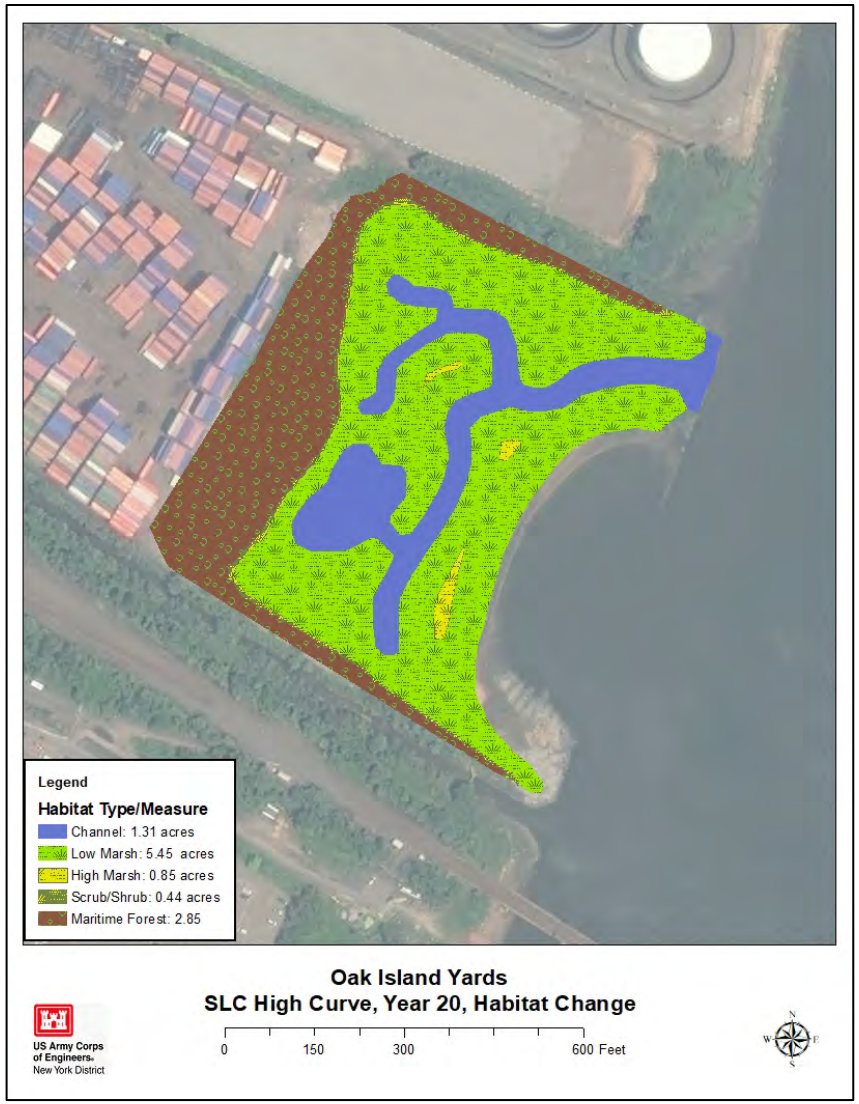


Figure 62. Oak Island Yards SLC High Curve, Year 20

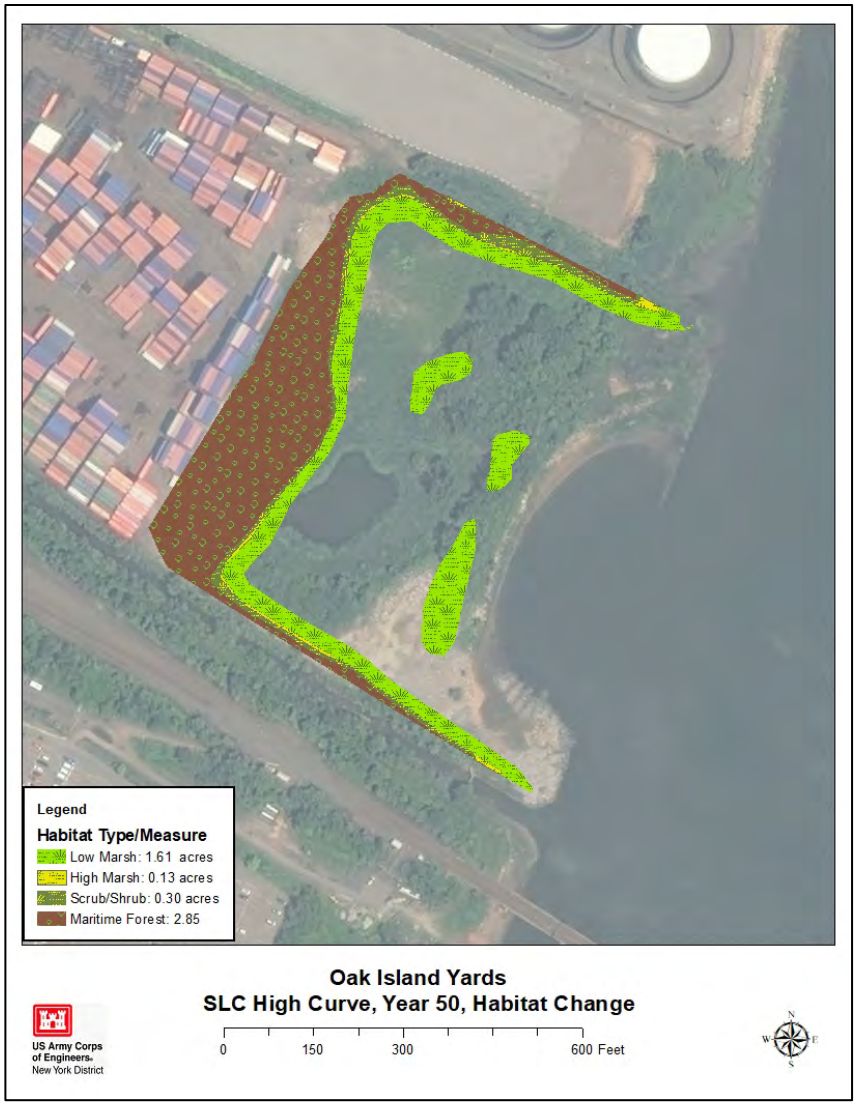


Figure 63. Oak Island Yards SLC High Curve, Year 50

METROMEDIA

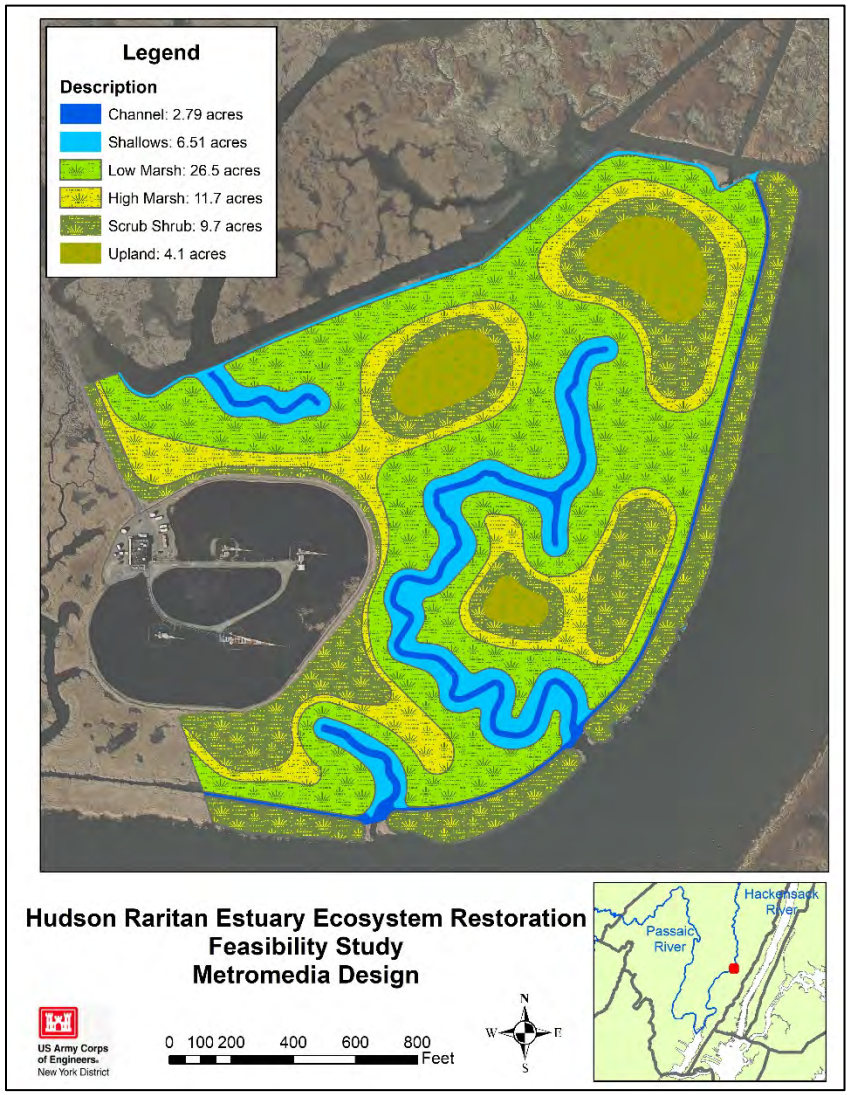


Figure 64. Metromedia Proposed Design

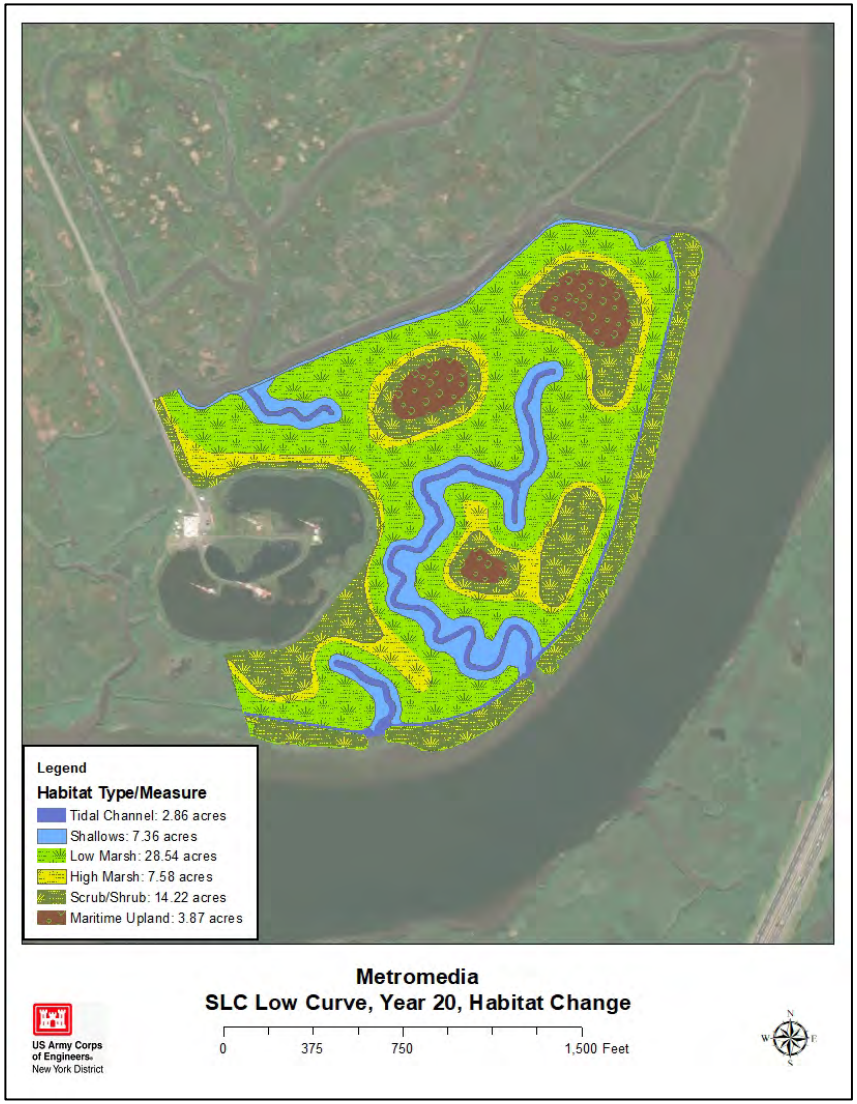


Figure 65. Metromedia SLC Low Curve, Year 20

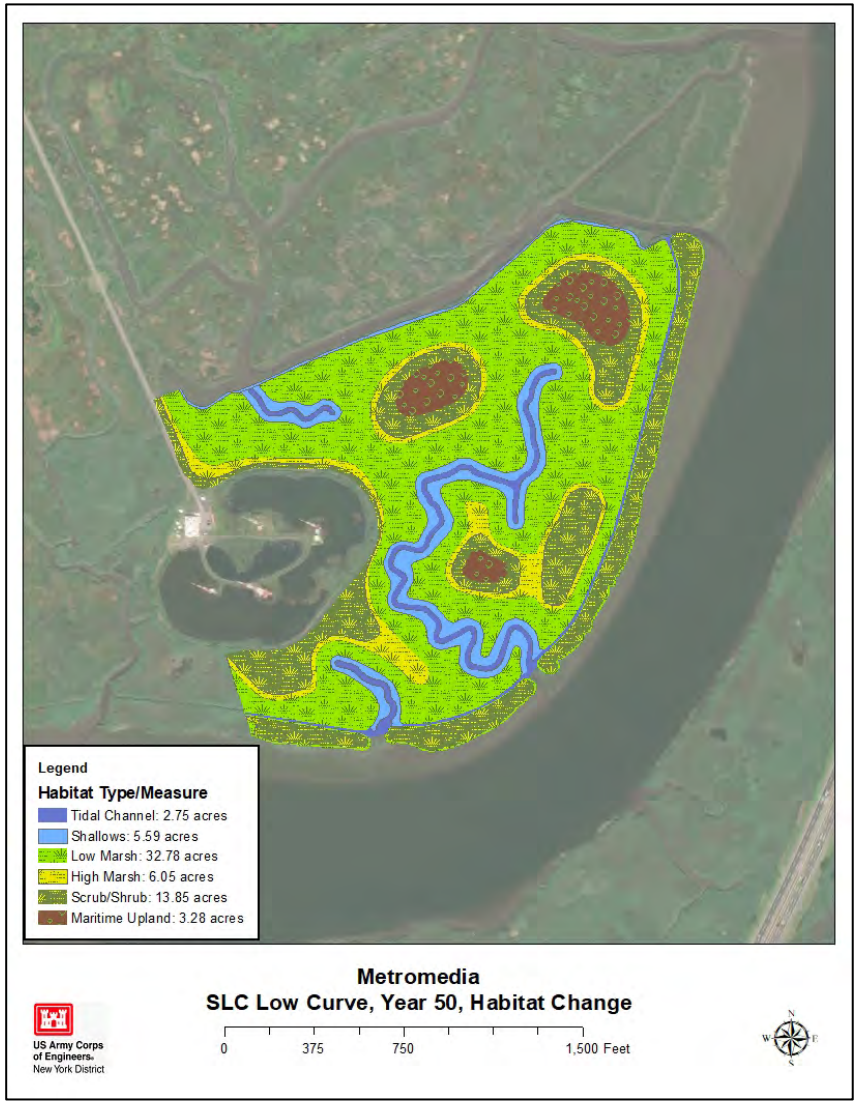


Figure 66. Metromedia SLC Low Curve, Year 50

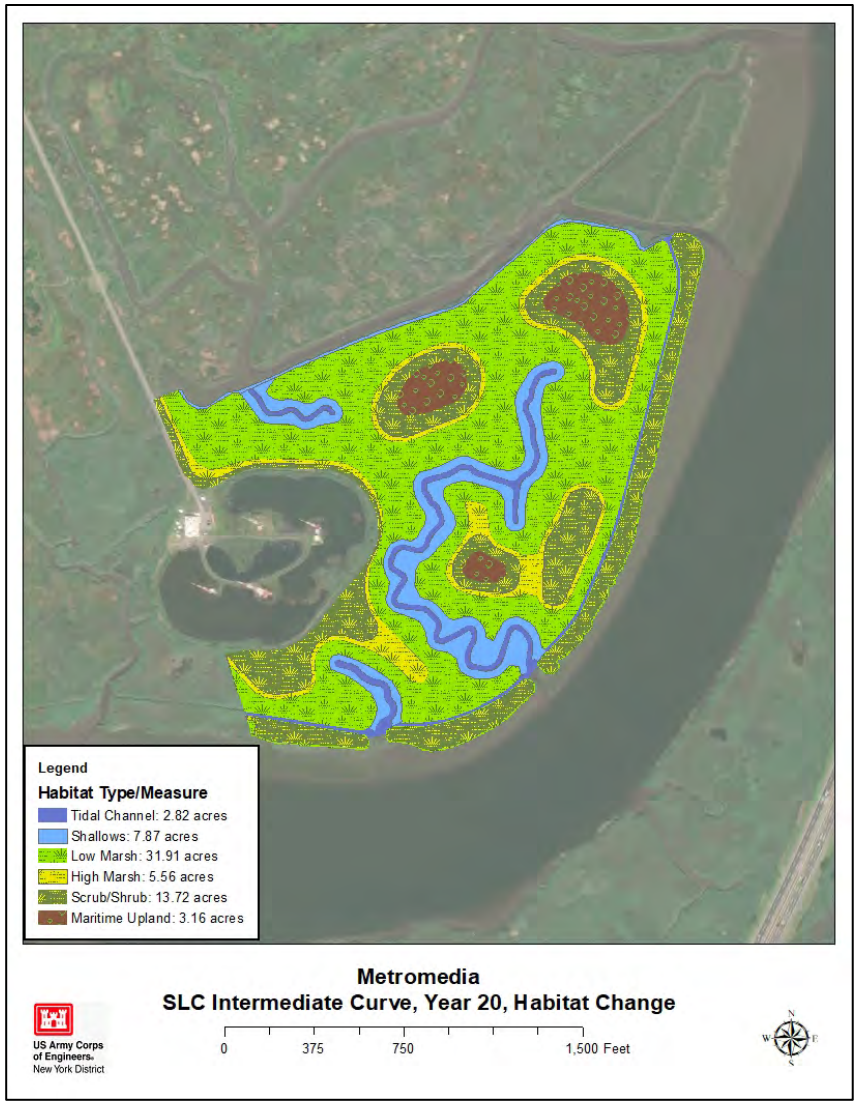


Figure 67. Metromedia SLC Intermediate Curve, Year 20

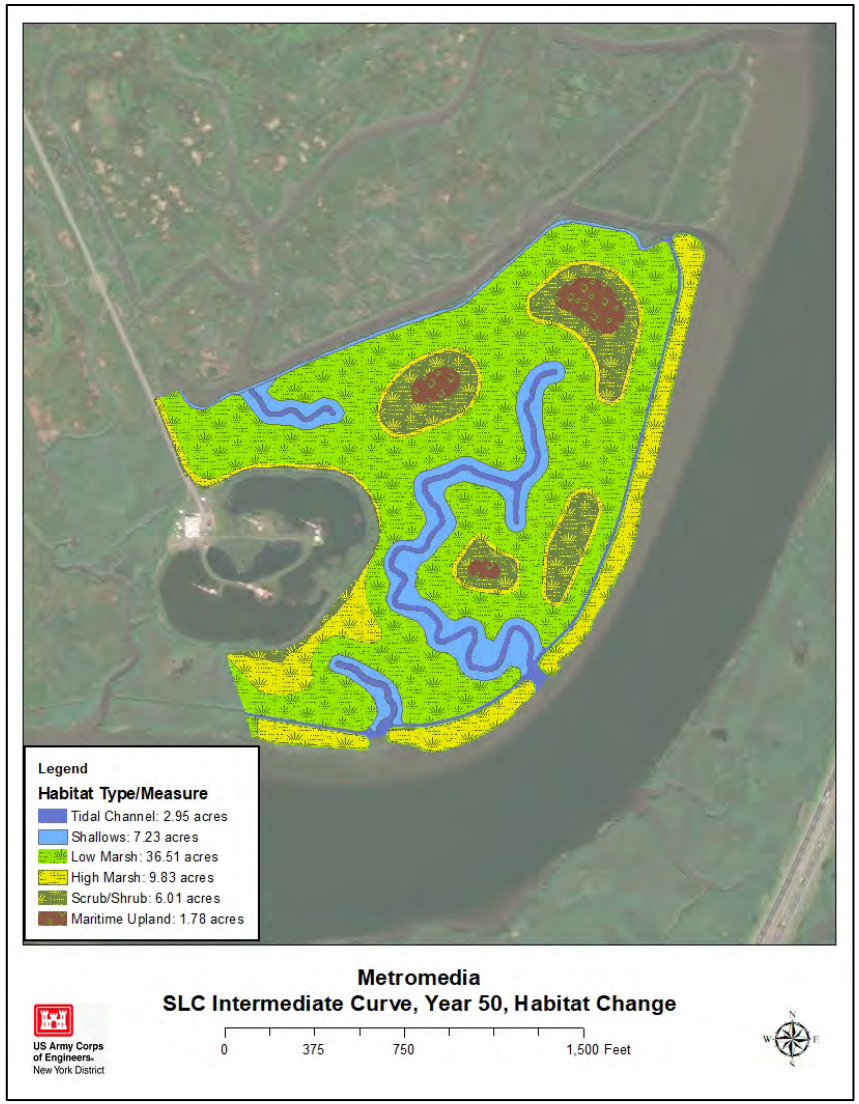


Figure 68. Metromedia SLC Intermediate Curve, Year 50

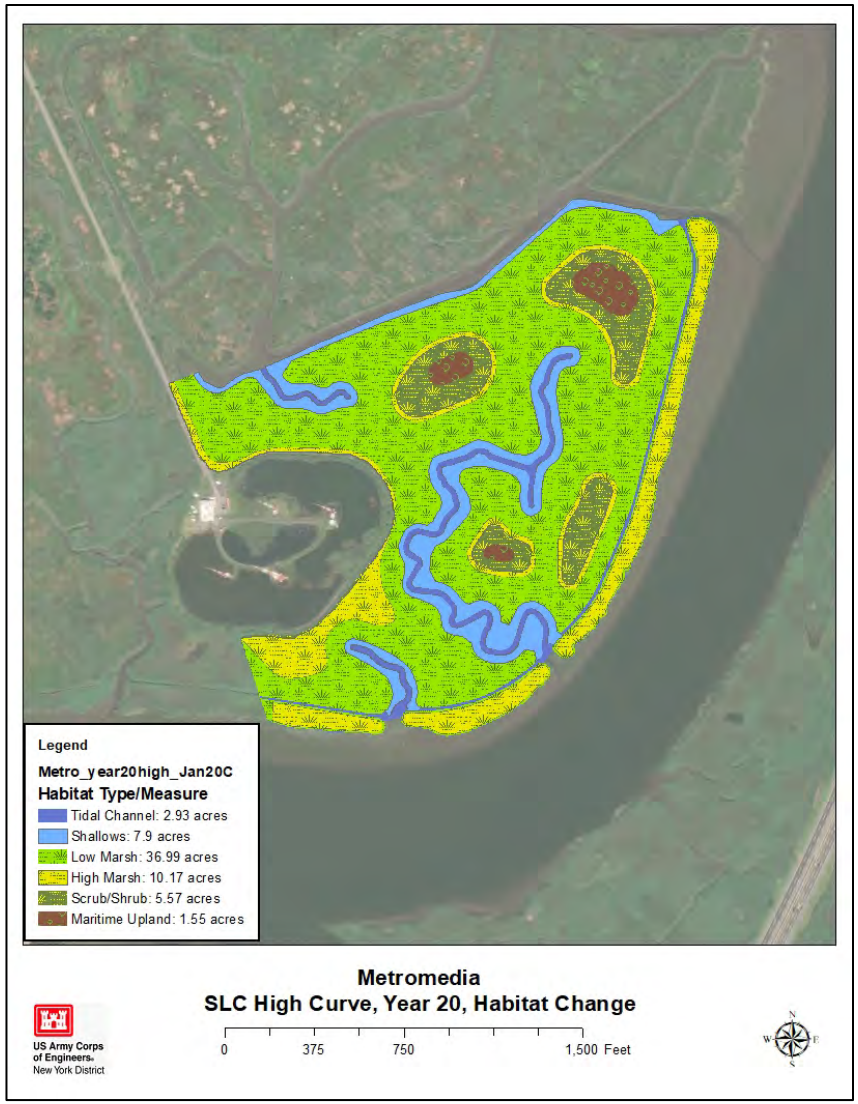


Figure 69. Metromedia SLC High Curve, Year 20

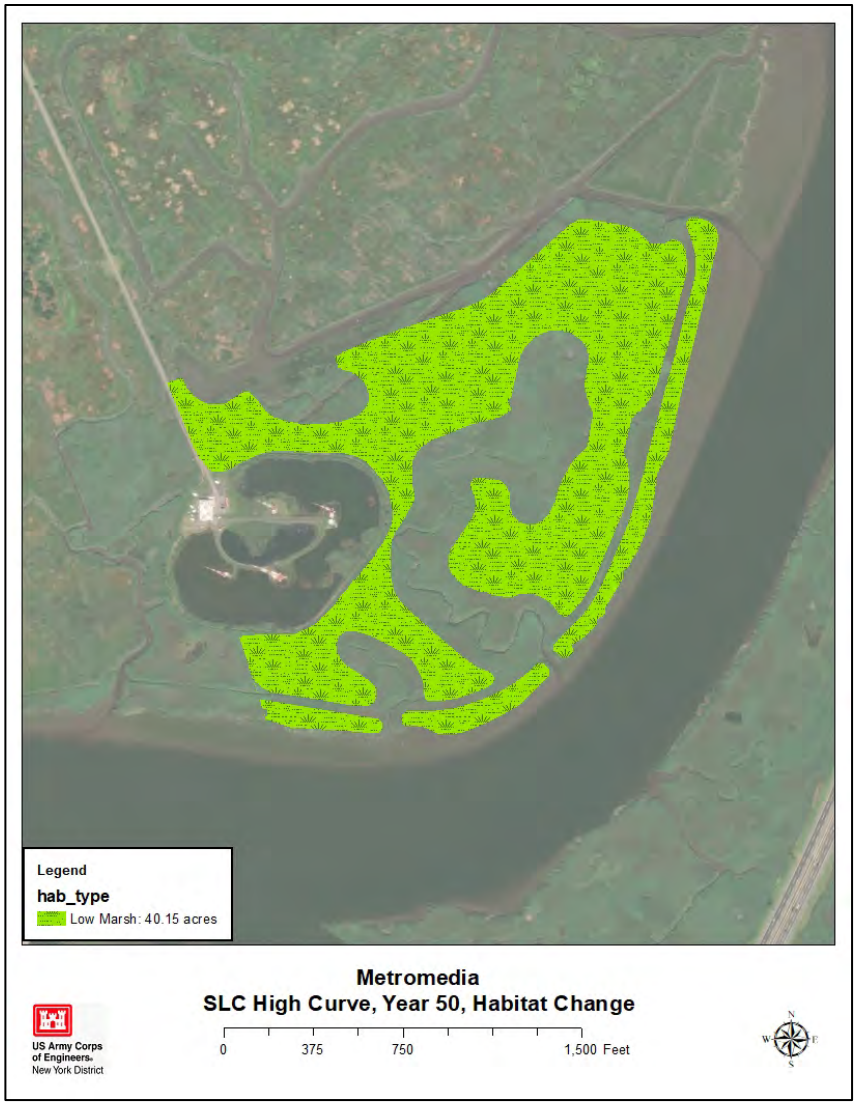


Figure 70. Metromedia SLC High Curve, Year 50

MEADOWLARK

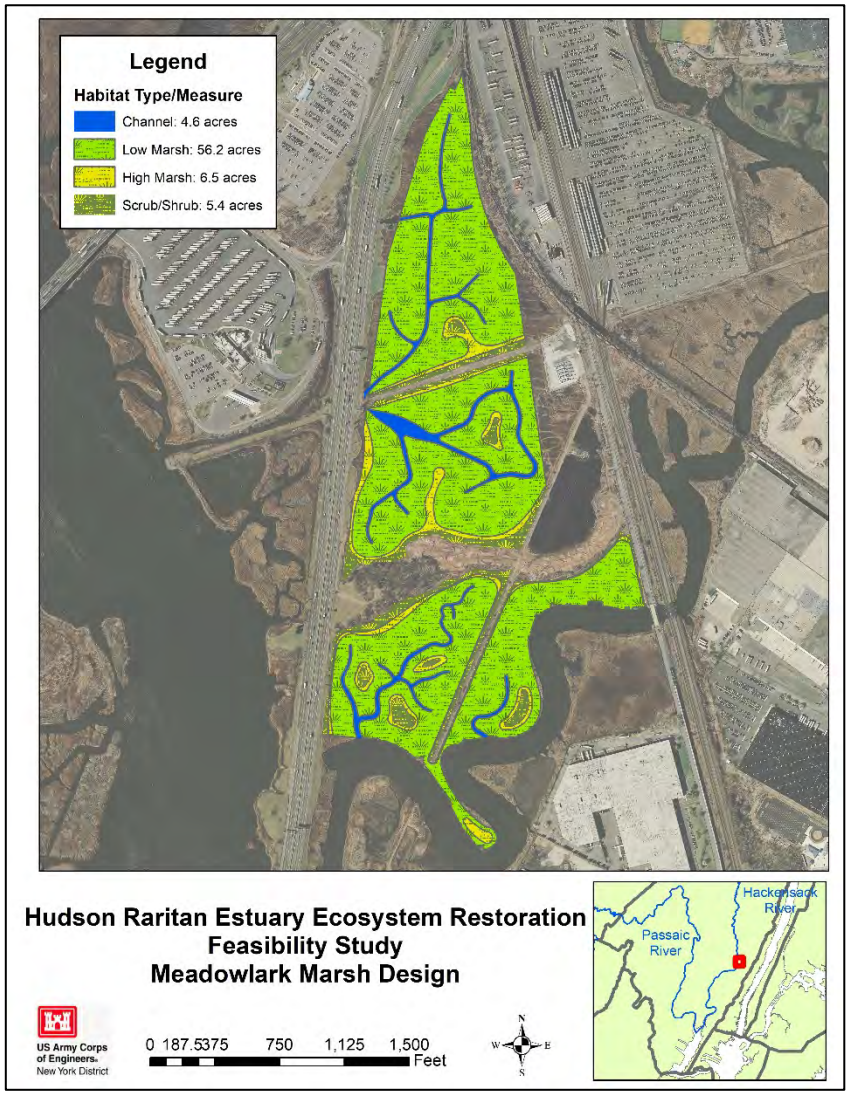


Figure 71. Meadowlark Proposed Design

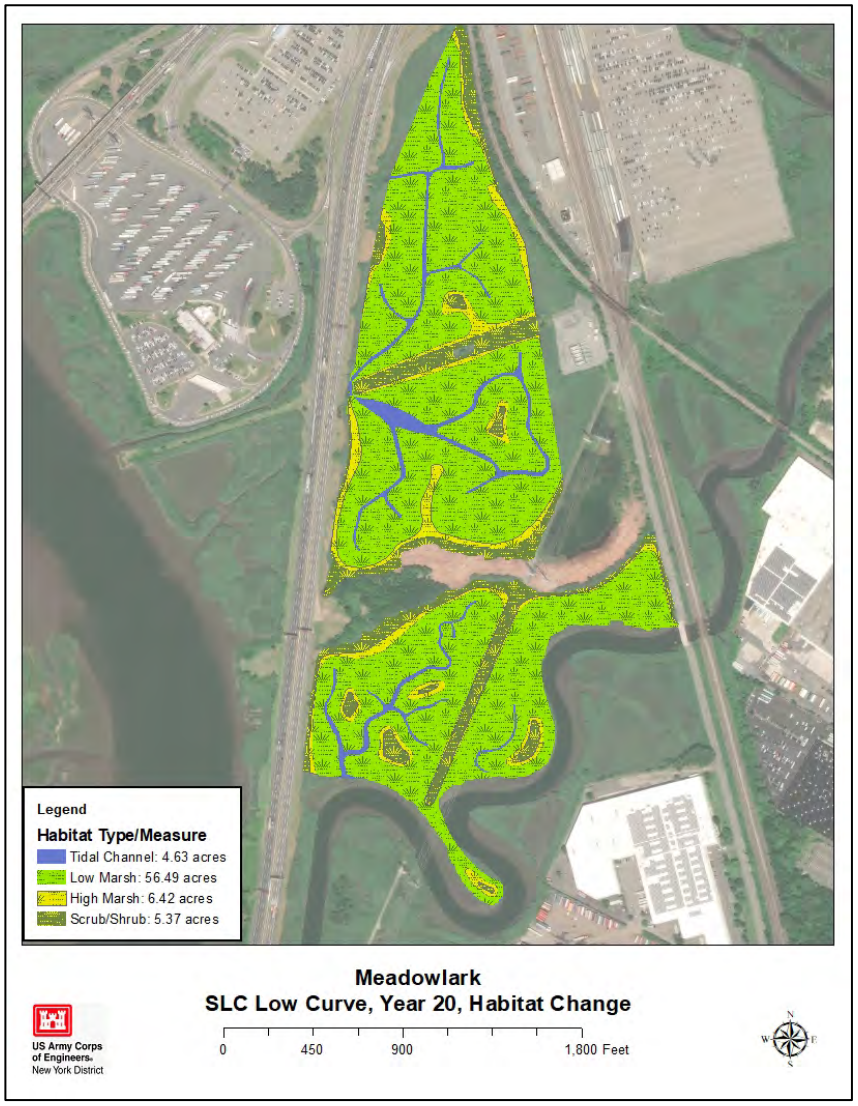


Figure 72. Meadowlark SLC Low Curve, Year 20

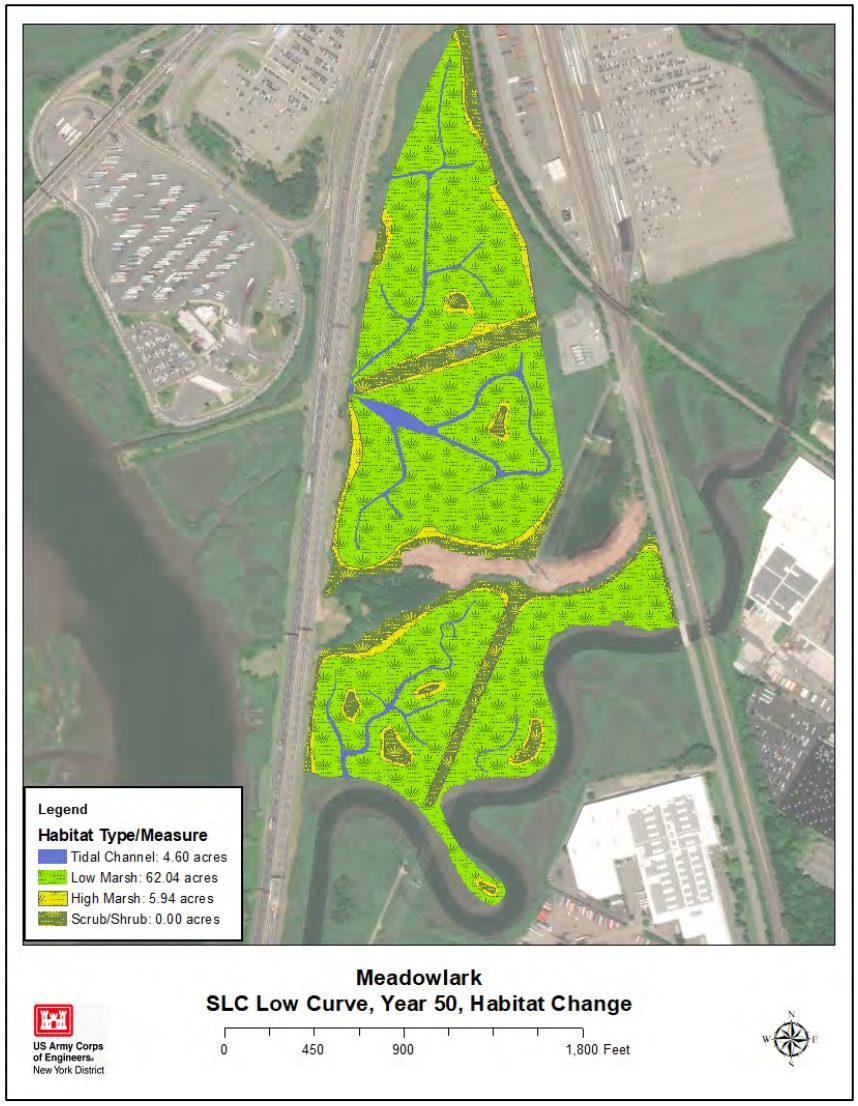


Figure 73. Meadowlark SLC Low Curve, Year 50

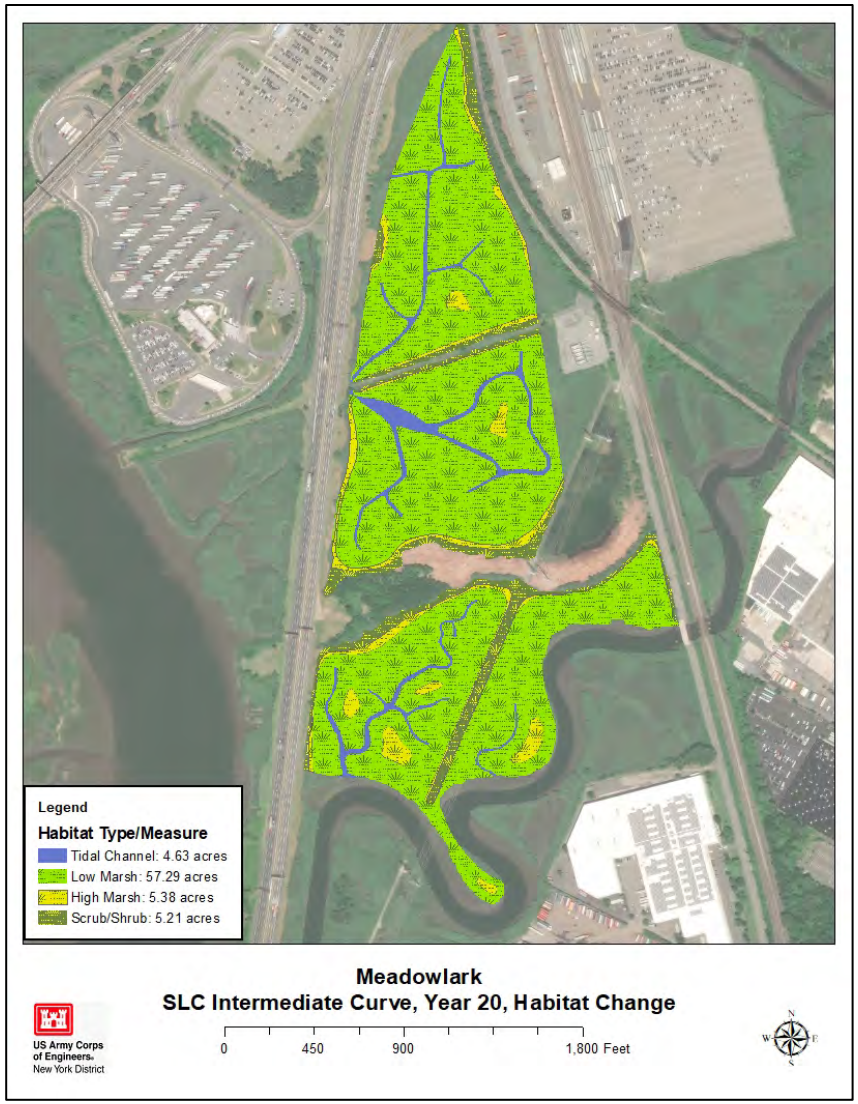


Figure 74. Meadowlark SLC Intermediate Curve, Year 20

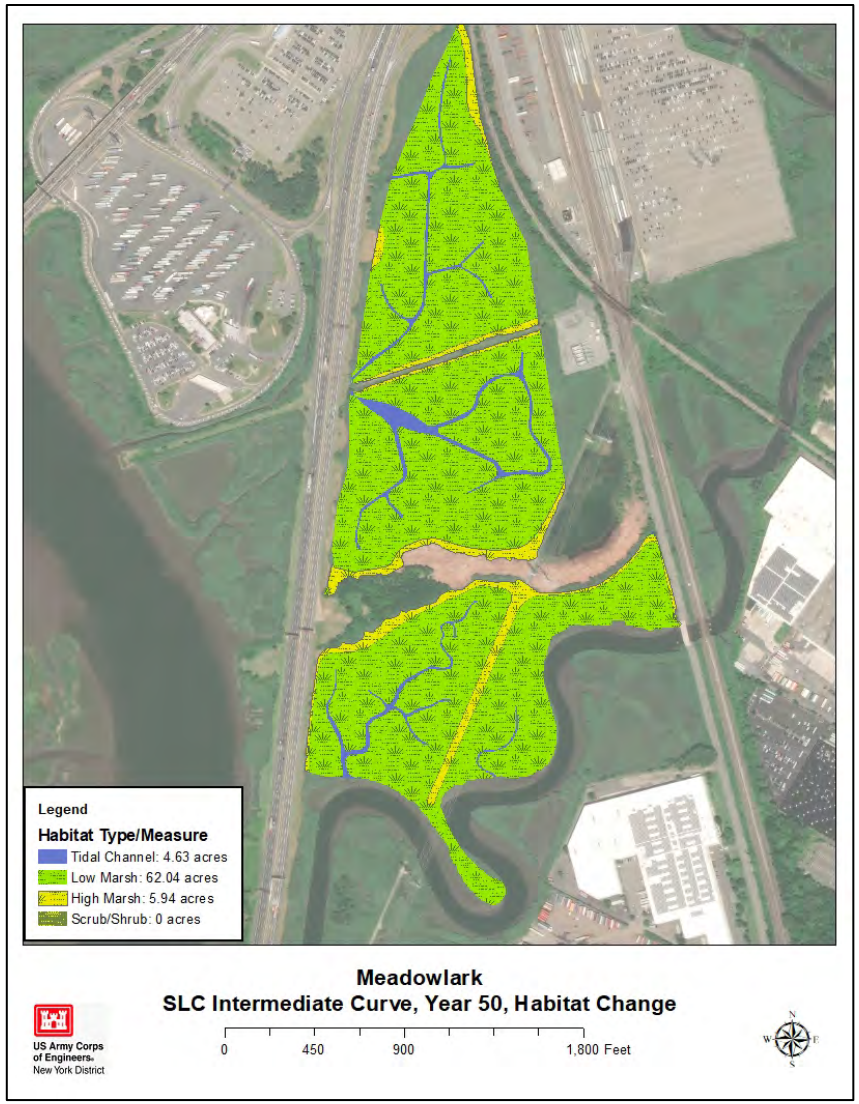


Figure 75. Meadowlark SLC Intermediate Curve, Year 50

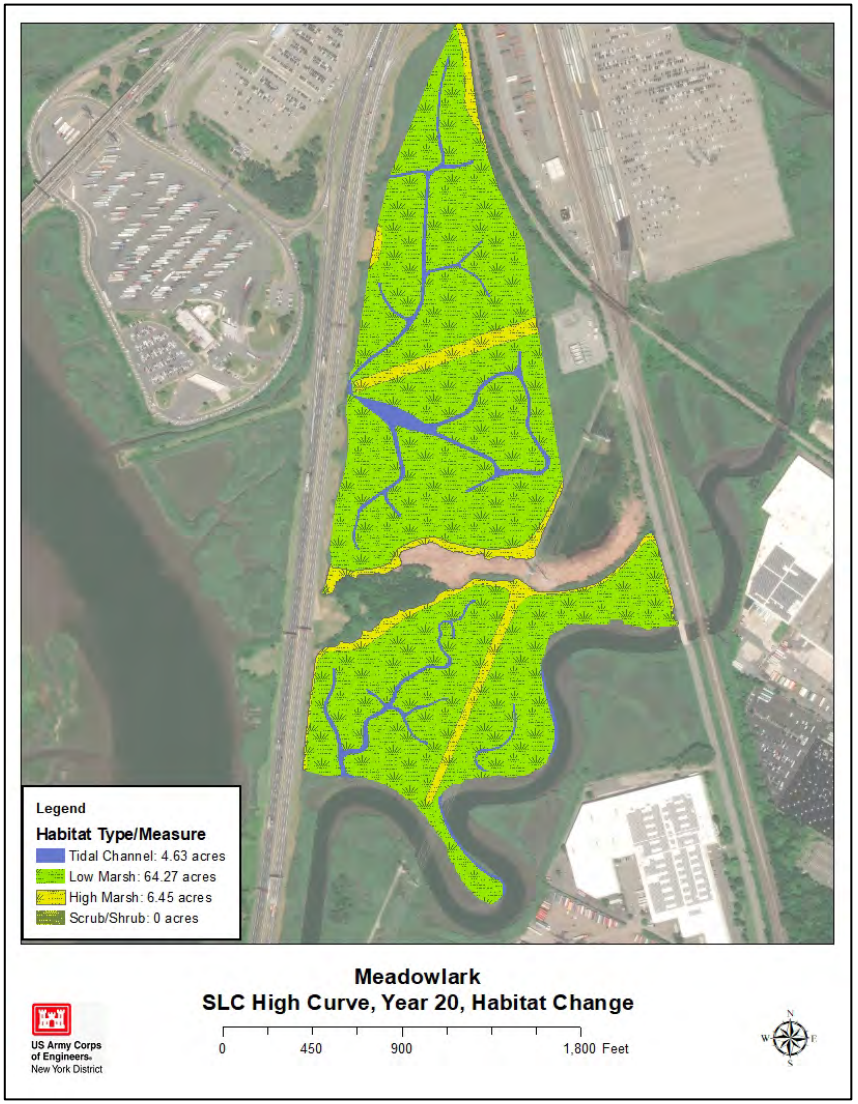


Figure 76. Meadowlark SLC High Curve, Year 20

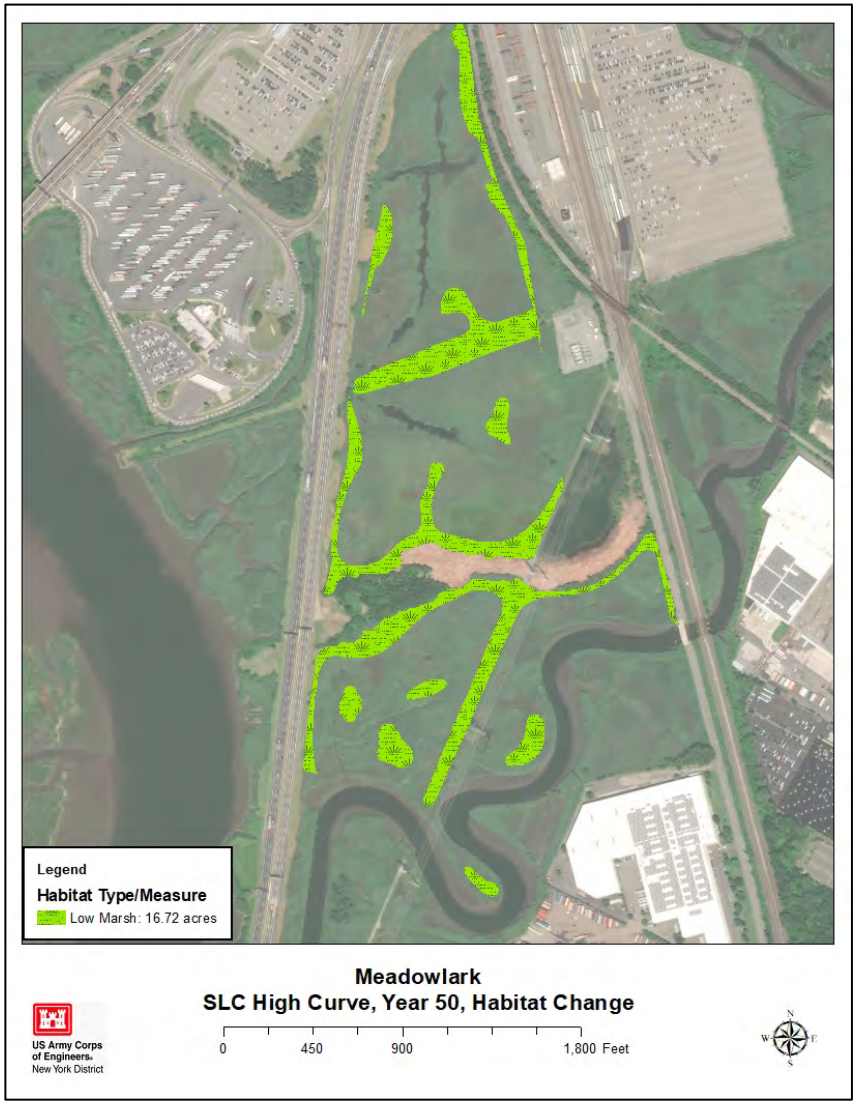


Figure 77. Meadowlark SLC High Curve, Year 50

Attachment C-3
HRE
Jamaica Bay Engineering Appendix

US ARMY CORPS
OF ENGINEERS
NEW YORK DISTRICT

HUDSON-RARITAN ESTUARY ECOSYSTEM RESTORATION

ENGINEERING APPENDIX – JAMAICA BAY

DRAFT FEASIBILITY REPORT



IN PARTNERSHIP WITH

NEW YORK CITY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
59-17 JUNCTION BOULEVARD, 10TH FLOOR
FLUSHING, NY 11373

January 2010

Hudson-Raritan Estuary Ecosystem Restoration Feasibility Study

Engineering Appendix

Draft Feasibility Report

New York District
U.S. Army Corps of Engineers

TABLE OF CONTENTS

TABLE OF CONTENTS II
LIST OF FIGURES V
LIST OF TABLES VII
1. INTRODUCTION 2
2. AUTHORIZATION 2
3. BACKGROUND 3
4. SITE CONTRAINTS AND RESTORATION GOALS 5
4.1 DEAD HORSE BAY 5
4.2 PAERDEGAT BASIN 6
4.3 FRESH CREEK 6
4.4 SPRING CREEK 7
4.5 HAWTREE POINT 7
4.6 BAYSWATER STATE PARK 7
4.7 DUBOS POINT 8
4.8 BRANT POINT 8
5. EXISTING CONDITIONS 9
5.1 TOPOGRAPHY/BATHYMETRY 9
5.2 GEOTECHNICAL INFORMATION 12
5.3 TIDAL CONDITIONS, SALINITY AND TEMPERATURE 15
5.4 STORM SURGES 19
5.6 SHORELINE CHANGE 24
5.6.1 Dead Horse Bay 26
5.6.2 Bayswater State Park 30
5.6.3 Dubos Point 31
5.6.4 Brant Point 33
5.7 SLOPE STABILITY ANALYSIS 34
5.7.1 Paerdegat Basin 35
5.7.2 Fresh Creek 35
5.7.3 Bayswater State Park 35
5.7.4 Dubos Point 36
5.7.5 Brant Point 36
5.5 WAVE ANALYSIS 36
5.5.1 Wind Generated Wave Analysis 36
5.5.1.1 Dead Horse Bay – North and South 38
5.5.1.2 Bayswater State Park 42
5.5.1.3 Dubos Point 46
5.5.1.4 Brant Point 48
5.5.2 Vessel Generated Wave Analysis 50
5.5.2.1 Bayswater State Park 52
5.5.2.2 Dubos Point 52
5.5.2.3 Brant Point 53
5.6 WATER QUALITY MODELING RESULTS 54

5.6.1 Paerdegat Basin 55
5.6.2 Fresh Creek 56
6. ANALYSIS AND DESIGN OF RESTORATION ALTERNATIVES 57
6.1 DESIGN CRITERIA AND ASSUMPTIONS 57
6.2 HABITAT RESTORATION FEATURES 58
6.3 SHORELINE STABILIZATION ALTERNATIVES IN INTERTIDAL AREAS 59
6.4 SPECIFIC FEATURES DESIGNED AT THE INDIVIDUAL SITES 68
6.4.1 Dead Horse Bay 69
6.4.1.1 Hydrodynamic Model Results 70
6.4.1.2 Inlet Stabilization Design 74
6.4.1.3 Shoreline Dune Structure Design 81
6.4.2 Paerdegat Basin 84
6.4.3 Fresh Creek 84
6.4.4 Bayswater State Park 85
6.4.4.1 Shoreline Protection Structures Analysis and Design 88
6.4.4.2 Training Structures Analysis and Design 90
6.4.5 Dubos Point 90
6.4.5.1 Shoreline Protection Structures Analysis and Design 92
6.4.5.2 Training Structures Analysis and Design 94
6.4.6 Brant Point 94
7. FUTURE WITH AND WITHOUT PROJECT CONDITIONS 99
7.1 DEAD HORSE BAY 101
7.2 BAYSWATER STATE PARK 103
7.3 DUBOS POINT 104
7.4 BRANT POINT 105
8. COST ESTIMATES AND CONSTRUCTION PROCEDURES OF CHOSEN ALTERNATIVES 108
8.1 COST ESTIMATE 108
8.2 CONSTRUCTION PROCEDURES 108
8.2.1 General 108
8.2.2 Site-Specific Descriptions 116
8.2.2.1 Dead Horse Bay 116
8.2.2.1 Paerdegat Basin 117
8.2.3 Fresh Creek 118
8.2.5 Hawtree Point 119
8.2.6 Bayswater State Park 119
8.2.7 Dubos Point 120
8.2.8 Brant Point 121
9. MONITORING 122
9.1 MONITORING PLAN 122
9.2 FIRST YEAR POST-CONSTRUCTION SITE ASSESSMENT 122
9.3 SALT MARSH ONE, THREE, FIVE AND TEN YEARS POST CONSTRUCTION 122
9.3.1 Topographic/Bathymetric Monitoring 123
9.3.2 Sinuosity Monitoring 123

9.3.3 Hydrology/hydraulics/hydrodynamics Monitoring 123
9.3.4 Geotechnical Monitoring 123
9.4 SHORELINE STABILIZATION STRUCTURES MONITORING..... 124
9.5 COASTAL DUNE AND MARINE FOREST AREAS ONE AND FIVE YEARS POST CONSTRUCTION 124
9.6 MONITORING COSTS 124
9.7 POTENTIAL CORRECTIVE ACTIONS 125
9.8 CONTINGENCY INSPECTIONS 126
9.9 REPORT PREPARATION 126
10. REFERENCES 126
APPENDIX A: EXISTING AND PROPOSED HABITIAT CONDITIONS 130
APPENDIX B: 130
SUMMARY OF TIDE GAGE JAMAICA BAY ECOSYSTEM RESTORATION PROJECT 130
FEASIBILITY STUDY. MARCH 2003 130
APPENDIX C: SHORELINE CHANGE ANALYSIS 130
APPENDIX D: ADDITIONAL RECOMMENDED SHORE PROTECTION FEATURES 130
APPENDIX E: WATER QUALITY MODELING RESULTS..... 130
APPENDIX F: MCACES COST ESTIMATE SUMMARIES 130
APPENDIX G: MCACES BACKUP DATA AND CALCULATIONS..... 130
APPENDIX H: SHORELINE SLOPE STABILITY ANALYSIS FIGURES 130

LIST OF FIGURES

Number	Title	Page
	Figure 3.1 – JBERP Restoration Sites	
	Figure 5.1 – JBERP Tide Gage Locations	
	Figure 5.2 Elevation of Low Marsh/High Marsh Breakline in Jamaica Bay (and surrounding Hudson-Raritan Estuary)	
	Figure 5.3 Storm Surge Output Stations in the vicinity of JBERP sites	
	Figure 5.4 Storm Surges in the vicinity of JBERP sites	
	Figure 5.5 Dead Horse Bay Shoreline – 1959	
	Figure 5.6 Dead Horse Bay Shoreline – 1966	
	Figure 5.7 Dead Horse Bay Shoreline – 1974	
	Figure 5.8 Dead Horse Bay Shoreline – 1996	
	Figure 5.9. Shoreline Change Rate (End-Point Averaging) Along the Dead Horse Bay North Site	
	Figure 5.10. Shoreline Change Rate (End-Point Averaging) Along the Dead Horse Bay South Site	
	Figure 5.11 Shoreline Change Rate (End-Point Averaging) Along the Bayswater State Park Site	
	Figure 5.12 Shoreline Change Rate (End-Point Averaging) Along the Dubos Point Site	
	Figure 5.13 Shoreline Change Rate (End-Point Averaging) Along the Brant Point Site	
	Figure 5.14 Wind Rose Plot of Resultant Wind Speed and Direction for JFK Wind Data (1984 to Present).	
	Figure 5.15 Fetch Directions for Dead Horse Bay	
	Figure 6.1 Modified Shields Diagram for Waves and Stability in Non-Breaking Waves	
	Figure 6.2 Permissible Duration of Wave Load and Grass	
	Figure 6.3. Example Bio-stabilization Methods	
	Figure 6.4. Examples of Breakwalls, Rafeets, Prisms, and Floating Panel	
	Figure 6.5. Transmission Coefficients for Floating Attenuators	
	Figure 6.6. Transmission Coefficients for Rubble Mound Structures.	
	Figure 6.7 Proposed Habitats for Dead Horse Bay North and South	
	Figure 6.8 Design Grading Plan – June 2003	
	Figure 6.9 Temporal Velocities - Design Grading Plan – June 2003	
	Figure 6.10 Temporal Velocities - Design Grading Plan – June 2003	
	Figure 6.11 Longshore Currents with Respect to Existing Grade at Dead Horse Bay – North Site	
	Figure 6.12. Plan View of the Jetties at the Dead Horse Bay – North Site.	
	Figure 6.13. Cross-section View of the Jetties at the Dead Horse Bay – North Site	
	Figure 6.14 Pre- and Post-storm Profiles for a Typical Section at Dead Horse Bay – South Site.	
	Figure 6.15. FEMA 540 feet^2 Storm Induced Erosion Volume Rule.	

Number	Title	Page

Figure 6.16 Plan View of the Geotubes and Dune at the Dead Horse Bay – South Site
Figure 6.17 Cross-section View of the Geotubes and Dune at Dead Horse Bay – South Site
Figure 6.18 2002 Aerial Image of Bayswater State Park.
Figure 6.19 Plan View of the Shore Protection Measures at Bayswater State Park.
Figure 6.20. Cross-section View of the Shore Protection Measures at Bayswater State Park
Figure 6.21 Plan View of the Shore Protection Measures at Dubos Point
Figure 6.22. Cross-section View of the Shore Protection Measures at Dubos Point.
Figure 6.23 Plan View of the Shore Protection Measures at Brant Point
Figure 6.24 Cross-section View of the Shore Protection Measures at Brant Point.
Figure 7.1 The 50-Year Erosion Shoreline Project on to the Existing Habitat Map at Dead Horse Bay South
Figure 7.2 The 50-Year Erosion Shoreline Project on to the Existing Habitat Map at Bayswater State Park
Figure 7.3 The 50-Year Erosion Shoreline Project on to the Existing Habitat Map at Dubos Point
Figure 7.4 The 50-Year Erosion Shoreline Project on to the Existing Habitat Map at Brant Point

LIST OF TABLES

Number	Title	Page
	Table 5.1 Tidal Datums for Water Level Recorders at or near Jamaica Bay Ecosystem Restoration Sites	
	Table 5.2 Salinity and Temperature Readings at JBERP sites	
	Table 5.3 Storm Surges in the vicinity of JBERP sites	
	Table 5.4 Dead Horse Bay Erosion Rates	
	Table 5.5 Bayswater State Park Erosion Rates	
	Table 5.6 Dubos Point Erosion Rates	
	Table 5.7 Brant Point Erosion Rates	
	Table 5.8 Extreme Wind Speeds	
	Table 5.9. Dead Horse Bay North - Wind Generated Wave Results.	
	Table 5.10. Dead Horse Bay South - Wind Generated Wave Results.	
	Table 5.11 Bayswater State Park Wind Generated Wave Results for the West-Northwest Reference Point	
	Table 5.12 Bayswater State Park Wind Generated Wave Results for the West-Northwest Reference Point	
	Table 5.13. Dubos Point - Wind Generated Wave Results.	
	Table 5.14 Brant Point - Wind Generated Wave Results.	
	Table 5.15 Vessel Characteristics.	
	Table 5.16. Vessel (Tugboat and Ship) Waves Generated at Bayswater State Park	
	Table 5.17. Vessel (Tugboat and Ship) Waves Generated at Dubos Point	
	Table 5.18. Vessel (Tugboat and Ship) Waves Generated at Brant Point	
	Table 6.1 Decision Matrix for Jamaica Bay Shoreline Stabilization Measures	
	Table 6.2. Explanation of Groups and Categories in Decision Matrix.	
	Table 6.3. Directional Averaged Wind Speeds for Dead Horse Bay North	
	Table 6.4. Dead Horse Bay North Hindcast Wave Results.	
	Table 6.5. Dead Horse Bay North Transformed Wave Results.	
	Table 6.6. Sediment Transport Potential for Dead Horse Bay – North Site.	
	Table 6.7. Inlet Parameters from ACES.	
	Table 7.1 Dead Horse Bay Existing, Proposed and Future Without Project Habitat Acres	
	Table 7.2 Bayswater State Park Existing, Proposed and Future Without Project Habitat Acres	
	Table 7.3 Dubos Point Existing, Proposed and Future Without Project Habitat Acres	
	Table 7.4 Brant Point Existing, Proposed and Future Without Project Habitat Acres	

Executive Summary

The New York District of the U.S. Army Corps of Engineers (USACE) has completed this Engineering Appendix to the Draft Integrated Feasibility Report/Environmental Assessment for the Jamaica Bay Ecosystem Restoration Project (JBERP). This report is written as supporting documentation to assess the need for restoring the existing degraded habitat, evaluate the environmental effects of the restoration activities, and determine a design plan that maximizes the environmental benefits while minimizing the economic costs for the eight project sites. Project sites include Dead Horse Bay, Paerdegat Basin, Fresh Creek, Hawtree Point, Spring Creek, Bayswater State Park, Dubos Point, and Brant Point.

The overall purpose of the project is to improve the environmental quality of Jamaica Bay by ameliorating the adverse impacts of past activities at the project sites. Field observations of the sites indicate that the ecology of the areas are degraded, due to past filling of tidal wetlands, poor water quality, and the predominance of invasive species. JBERP includes the restoration of over 161 acres of salt marsh, almost 80 acres of beach/dune habitat, and over 217 acres of upland around Jamaica Bay.

This project will include the excavation of fill from shoreline areas to restore tidal marshes. Some sites (Dead Horse Bay, Bayswater State Park, Dubos Point, Spring Creek) include the creation of tidal creeks to permit proper tidal inundation of newly created marshes, and to prevent the recolonization of invasive species. Most of the excavated materials will be reused onsite for landscaping of adjacent upland features, such as maritime forests and grasslands, which will protect the marshes and provide transitional zones to the surrounding uplands.

This project also includes two sites where water quality improvements are a major goal. These sites, Paerdegat Basin and Fresh Creek, are currently severely degraded due to past dredging activities and due to the combined sewage outfalls that empty into the basins. By partially filling these water bodies to more closely reflect pre-dredging tidal circulation, water quality is expected to improve. With improved water quality as well as the accompanying wetland and upland restorations at these sites, it is anticipated that the habitat functions will be enhanced.

Designs at some of the sites require the installation of stabilizing structures. Training structures will be built at the mouths of tidal creeks created at Dead Horse Bay, Dubos Point, and Bayswater State Park. These training structures will maintain the opening of the proposed tidal creeks. Toe stabilization is being recommended at Dubos Point to protect the existing wetland habitat. This site has dilapidated existing piles that are the remnants of the bulkhead used to create the peninsula. At the points on the shoreline where most of piles have failed, erosion is evident. At Brant Point, offshore rubble mound structures are integral to the recommended plan. Studies have shown that this shoreline has retreated at a rate of 3 feet/year since 1959 (USACE 2003e). A beached barge at this site showed the success of offshore structures in protecting the shoreline.

The project's non-federal sponsors are the New York City Department of Environmental Protection, the New York City Department of Parks and Recreation, and the National Park Service. The sponsors are fully supportive of measures to restore the degraded ecosystem of

Jamaica Bay. In addition, the New York State Department of Environmental Conservation, the U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, and the U.S. Environmental Protection Agency are aware of and support the project. Furthermore, the project compliments the goals and efforts of other state and local organizations, notably the New York/New Jersey Harbor Estuary Program, a National Estuary Program authorized by the USEPA, and the North American Waterfowl Management Plan, an international agreement signed in 1986 that seeks to increase waterfowl populations through increasing and restoring wetland habitat.

For further information, please contact:

Kerry Anne Donohue Couch, P.E.
Technical Manager
U.S. Army Corps of Engineers, New York District
Engineering Division, Engineering Management Branch
26 Federal Plaza
New York, NY 10278-0090
ATTN: CENAN-EN-M
PHONE: 917-790-8354
FAX: 212-264-6495
kerry.a.donohue@usace.army.mil
http://www.nan.usace.army.mil

JAMAICA BAY ECOSYSTEM RESTORATION PROJECT

ENGINEERING APPENDIX

DRAFT FEASIBILITY REPORT

1. INTRODUCTION

The JBERP Feasibility Study was conducted under the U.S. Army Corps of Engineers (USACE) as authorized by a resolution adopted by the Committee on Public Works and Transportation of the United States House of Representatives on August 1, 1990. This resolution states that the project will be conducted "to determine the feasibility of improvements for beach erosion control, hurricane protection and environmental improvements in Jamaica Bay…"

The New York District of the U.S. Army Corps of Engineers (USACE) has prepared a Draft Feasibility Report (FR) to begin addressing the environmental restorations in Jamaica Bay, New York under the Jamaica Bay Ecosystem Restoration Project (JBERP) authority. This FR has been prepared under the General Investigations program of the Corps. The New York City Department of Environmental Protection (NYCDEP) is the non-federal partner for this study. The FR includes an evaluation of the alternative plans, the selection of the plans that maximize environmental benefits while minimizing costs, and a presentation to the public of information on the potential benefits and impacts associated with the proposed project. This project scope is consistent with the USACE objective of National Ecosystem Restoration.

2. AUTHORIZATION

The Jamaica Bay Ecosystem Restoration Project Feasibility Study was conducted under the U.S. Army Corps of Engineers (USACE) General Investigations program. This Feasibility Study was authorized by a resolution adopted by the Committee on Public Works and Transportation of the United States House of Representatives on August 1, 1990, which states:

"Resolved by the Committee on Public Works and Transportation of the United States House of Representatives, that the Board of Engineers for Rivers and Harbors, is requested to review the report of the Chief of Engineers on the Atlantic Coast of New York City from East Rockaway Inlet and Jamaica Bay, New York published as House Document 215, Eighty-ninth Congress, First Session, and other pertinent reports, to determine whether modification of the recommendations contained therein are advisable at this time, to determine the feasibility of improvements for beach erosion control, hurricane protection and environmental improvements in Jamaica Bay including environmentally sensitive areas along Plumb Beach, Brooklyn, New York."

Under this study authorization, a reconnaissance report was completed in January 1994. The reconnaissance study concluded that there is Federal interest in addressing shore protection, storm damage reduction, and environmental restoration. On the basis of these findings, the Corps and the NYCDEP signed a Feasibility Cost Sharing Agreement on February 22, 1996, amended by a Schedule and Cost Change Request signed May 10 2000, specifically to investigate environmental improvements in Jamaica Bay.

The current Jamaica Bay Ecosystem Restoration Project is one step in the process of fulfilling this authority. The restoration of the bay is expected to be a long project that will be continued in the future. Numerous sites have been proposed for restoration within the bay. Eight sites are

being recommended for work at this time through JBERP. However, this does not preclude future studies and restoration work from being completed under this authority.

3. BACKGROUND

Jamaica Bay is a tidal waterway connected to the lower bay of New York Harbor by Rockaway Inlet. The bay is located 17 miles south and east of the Battery, New York City and is 8 miles long, 4 miles wide, and covers an area of approximately 26 square miles. Jamaica Bay spans the southern portions of Kings County and Queens County. Eight specific sites within this region are being considered by this project for restoration. These sites include Dead Horse Bay, Paerdegat Basin, Fresh Creek, Spring Creek, Hawtree Point, Bayswater State Park, Dubos Point, and Brant Point (Figure 3.1). These sites focus on the degraded perimeter areas, which were selected based upon an extensive site screening process discussed in the main report (JBERP Feasibility Report/Environmental Impact Assessment (FR/EIS)).

Lying within the Atlantic Coastal Plain geological province, Jamaica Bay consists of loose unconsolidated cretaceous to recent sediments resting on deeply buried crystalline rock floor. The loose sediments are associated with past glaciations periods that resulted in an outwash plain. This sandy plain merged into the historical tidal marshes and barrier island beaches. Over time, physical and biological processes molded the Jamaica Bay into a highly productive ecosystem.

In 1997, USACE finalized the “Jamaica Bay: Navigational Channels and Shoreline Environmental Surveys” report. This report identified 39 potential sites for restoration activities, as based on two previous reports prepared by NYCDEP (1995, Jamaica Bay Comprehensive Watershed Management Plan) and by NYSDEC (1993, Restoration of Natural Resources Through the Jamaica Bay Damages Account: Reconnaissance Phase Report). Out of these 39 sites, twelve were identified by USACE, NYCDEP, NYSDEC, NPS and interested local groups as the highest priority and the most important sites for potential ecological restoration. These twelve sites included the eight focused on in this report, as well as Gerritsen Creek, Spring Creek North (actually considered as a part of the overall Spring Creek site in the 1997 USACE report), Broad Channel, Jo Co Marsh, and Ruffle Bar (JABERRT 2002). See the main JBERP Feasibility report for the reasons for excluding the latter 4 sites in the conclusion of the study.

In April of 2000, NPS and the US Army Corps of Engineers entered into an Interagency Agreement to conduct assessments for the 12 sites. USACE and NPS, along with the City University of New York – Aquatic Research and Environmental Assessment Center at Brooklyn College, established the Jamaica Bay Ecosystem Research and Restoration Team (JABERRT) for Jamaica Bay. JABERRT completed an extensive literature search and conducted a detailed inventory and biogeochemical characterization of Jamaica Bay for the 2000 to 2001. Their final report was published in 2002. This report serves as the basis for identifying existing conditions and recommending restoration options at each of the JBERP sites.

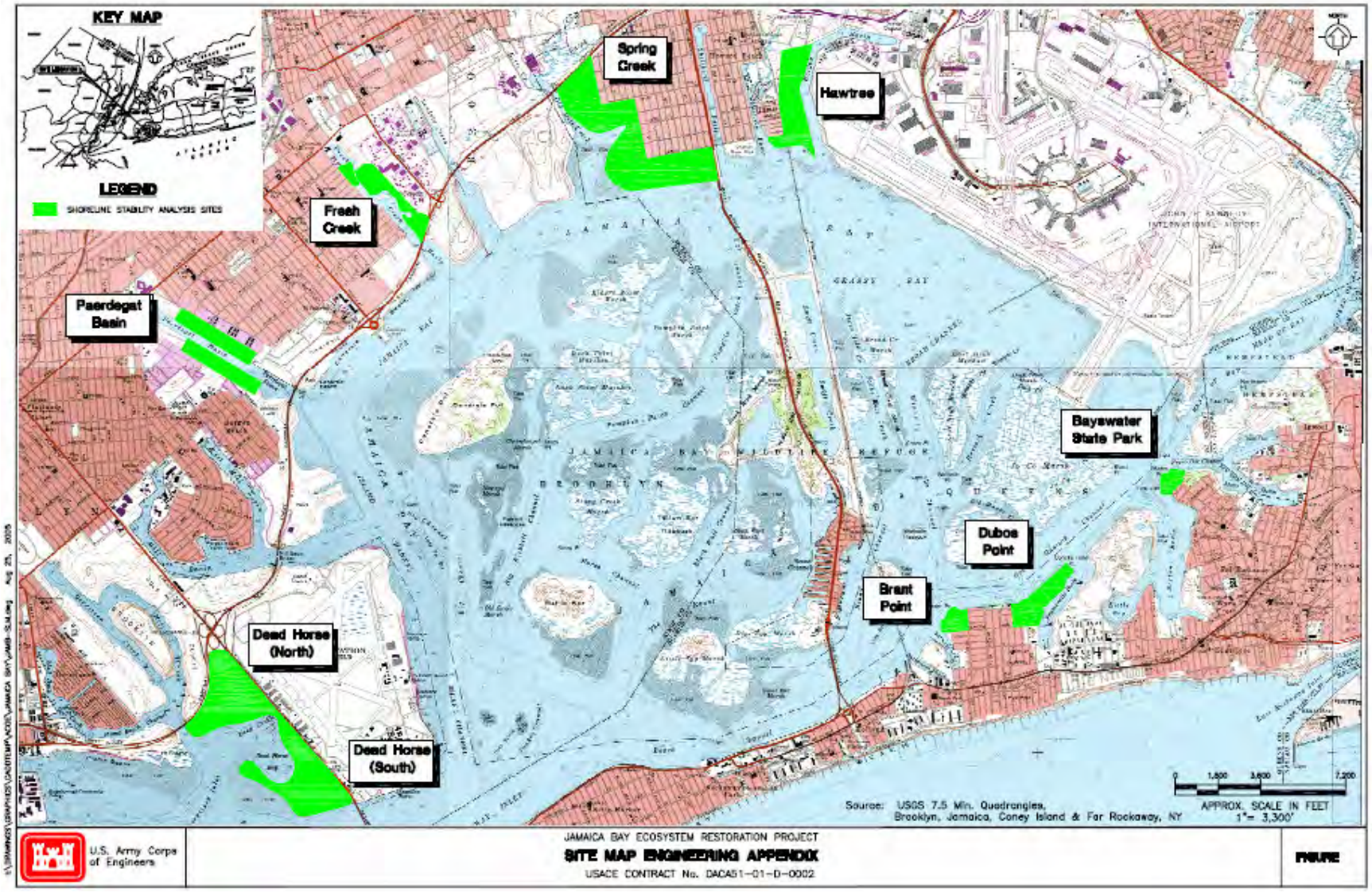


Figure 3.1 JBERP Restoration Sites

The *Existing Conditions, Future Without Project Conditions, Goals and Objectives Report* (USACE 2002a) includes a detailed report of all sites, including historic and existing conditions maps. The existing condition maps, which provide a detailed analysis of vegetative communities at each site, were compiled by the National Park Service as a part of the JABERRT (2002) study. Offshore habitat types such as shallow water, deep water, and mudflat areas, as well as areas beyond the original JABERRT boundaries, were mapped separately by USACE using aerial photos, topographic maps and other ancillary data. The acreages and maps shown for each site in this report are a compilation of the NPS and USACE efforts.

The overall plan includes the restoration of approximately 155 acres of wetland, including 68 acres of high marsh and 87 acres of low marsh. Seven acres of open water, including tidal creeks and a tidal pool, will also be created. JBERP will include the creation and preservation of over 79 acres of beach and dune habitats, and nearly 218 acres of native coastal upland habitats including forests, scrub shrub, and grasslands. With this project, approximately 437 acres of introduced invasives, including Japanese knotweed (*Polygonum cuspidatum*), mugwort (*Artemisia vulgaris*) and common reed (*Phragmites australis*) will be restored to native vegetation.

4. SITE CONTRAINTS AND RESTORATION GOALS

The *Conceptual Plan Report – Final* (USACE, 2003) laid out the site constraints and restoration goals for each of the eight sites. The existing habitat conditions for all sites can be found in Appendix A. The site constraints and restoration goals are summarized below.

4.1 Dead Horse Bay

In view of the land disturbance history and existing site conditions, site constraints for Dead Horse Bay include:

Presence of extensive areas of invasive plant species;
Moderate to long fetch with active shore zone;
Covering of the historic marsh with fills, including the solid waste landfill in the southern project area placed after 1948;
Erosion and exposure of the solid waste landfill;
Steep slopes on the southwest and southern shorelines;
Possible presence of rare, threatened or endangered (RTE) species;
Presence of contaminants that may need more detail to interpret the insignificance of specific restoration activities;

Restoration goals for Dead Horse Bay include:

Replacing monotypic stands of vegetation with diverse native plantings;
Restoring tidal marsh systems to offset both historical and future losses;
Stabilizing the solid waste landfill from erosive forces along the southwest and southern shores;

Creating upland habitat to blend restoration areas back into surrounding areas and buffer them from future impacts;
Creating dune habitat in the high-energy southern parcel;
Shoreline protection strategies to both address erosion and provide macroinvertebrate habitat;

4.2 Paerdegat Basin

In view of the land disturbance history and existing site conditions, site constraints for Paerdegat Basin include:

Presence of contaminated sediments which may need to be evaluated in further detail to determine the influence on the restoration actions;
Poor water quality;
Presence of extensive areas of invasive plants;
Presence of fill to the water edge with steep bank slopes;
Lack of smooth cordgrass in the upper reaches of the basin;
Possible presence of RTE species in the project area;
Poor tidal flushing of the basin;
The presence of the historic dredge placement on both sides of the basin that are assumed to be comprised of coastal sands that could be used for creating a dune grassland / oak complex;

Restoration goals for Paerdegat Basin include:

Replacing stands of invasive vegetation with diverse native plantings;
Restoring tidal marsh systems to offset both historical and future losses;
Enhancing upland habitat to blend restoration areas back into surrounding areas, to buffer the wetlands from future impacts, and to minimize faunal contaminant contact;
Basin bathymetry reconfiguration to promote optimal circulation;
The continued improvement of water quality after completion of the combined sewer overflow improvement at the head of the basin;

4.3 Fresh Creek

In view of the land disturbance history and existing site conditions, existing site constraints include:

Poor water quality at the head of Fresh Creek;
Poor benthic habitat;
Fills deposited on historic wetlands;
Presence of extensive areas of invasive plant species;
Presence of contaminated sediments which may need to be evaluated in further detail to determine the influence on the restoration actions;
Restoration of the remaining salt marshes of Fresh Creek;
Presence of a combined sewer outfall at the head of the basin;

Restoration goals include:

Restoring tidal marsh systems to serve as a filter for the CSO until the outfall can be improved or rerouted;
Replacing monotypic stands of vegetation with diverse native plantings;

Restoring tidal marsh to the maximum extent possible;
Enhancing existing marshes by filling in and revegetating ditches;
Creating upland habitat to blend restoration areas back into surrounding areas and buffer them from future impacts;
Improving benthic habitat through water quality and sediment improvement;
Basin bathymetry reconfiguration to promote optimal circulation;
Reuse the excavated fill to create onsite upland habitat;

4.4 Spring Creek

In view of the land disturbance history and site conditions, existing design constraints include:
Poor water quality, though not as severe as Paerdegat Basin or Fresh Creek;
Presence of contaminants which may require additional data and/or interpretation during the plans and specifications phase depending upon final restoration approach;
Presence of extensive areas of invasive plant species;
Presence of RTE species;
Coastal sands from the Flynn Causeway historically used to fill wetlands, which could be reused for dune restoration along the southern shoreline;

Restoration goals for Spring Creek include:
Replacing monotypic stands of vegetation with diverse native plantings;
Restoring tidal marsh systems to offset both historical and future losses;
Incorporate passive recreation activity components for the local community;
Establish dune complex habitat in the south of the project area;
Creating upland habitat to blend restoration areas back into surrounding areas and buffer them from future impacts;

4.5 Hawtree Point

In view of the land disturbance history and existing site conditions, site constraints include:
Presence of monotypic stands of invasive plant species;
Presence of contaminants;

Restoration goals include:
Replacing monotypic stands of vegetation with diverse native plantings;
Creating upland habitat to blend restoration areas back into surrounding areas, discourage reinfestation of invasive species, and protect wetlands from future impacts;

4.6 Bayswater State Park

In view of the land disturbance history and existing site conditions, site constraints include:
Presence of extensive areas of invasive plant species
Dilapidated seawall
Presence of contaminants which may require additional data and/or interpretation during the plans and specifications phase depending upon final restoration approach.

Restoration goals include:

Integrating proposed restoration areas with the existing native vegetation communities in particular the mature woodland

Address the failing bulkhead through the use of strategically placed shoreline erosion control structures to protect existing habitat from erosion loss and also to create macroinvertebrate habitat

Replacing common reed dominated areas with intertidal marsh and a tidal creek system

4.7 Dubos Point

In view of the land disturbance history and existing site conditions, site constraints include:

Presence of areas of invasive plant species;

High-energy shore zone along western and northern edges of the property;

Presence of contaminants, though further evaluation may be necessary for complete evaluation;

Presence of existing salt marsh which may be affected by restoration activities;

Mosquito infestation of adjacent properties due to pooling water;

Existing dilapidated coastal shore protection structures;

Dumped trash and debris;

Restoration goals include:

Address shore erosion through placement of environmentally sensitive structures;

Selectively remove invasive species monocultures and replace with diverse native vegetation;

Enhance circulation of tidal water throughout site to reduce mosquito populations;

4.8 Brant Point

In view of the land disturbance history and existing site conditions, site constraints include:

Extensive dumping of soil, trash and debris;

Presence of invasive plant species;

Continuing shore erosion;

Presence of contaminants may need further evaluation depending upon restoration action;

Establishment of upland habitat to utilize on-site fills and blend restoration areas back into surrounding areas;

Presence of a grounded barge offshore which has acted as an erosion control device and created high quality benthic habitat behind the structure;

Restoration goals include:

Address the chronic shoreline erosion to arrest the continual loss of land by considering the incorporation of structures that mimic the proven strategy of the grounded barge, which also enhance macroinvertebrate habitat

Stop the indiscriminate dumping on the parcel

Create salt marsh habitat after addressing shore erosion threat

Establish upland restoration that complements restored salt marsh areas

Restoring tidal marsh systems to offset both historical and future losses

Use excavated materials to create upland habitat zones

5. EXISTING CONDITIONS

The *Existing Conditions, Future Without Project Conditions, Goals and Objectives Report* (USACE 2002a) includes detailed existing conditions of all eight sites. Further investigations for existing conditions at the site are described in this section.

5.1 Topography/Bathymetry

To determine current site topography and bathymetry, the project site was surveyed in the spring of 2002. This work was accomplished by surveying multiple profile lines across the site at 100 to200-foot intervals. The distance between surveyed points along each profile was less than 20 feet. The landward portion of the survey was completed using land-based surveying procedures, while the portions of the land that remained inundated were completed via a hydrographic survey. The landward limit of the surveys for all sites was the project limits. The seaward limit for all surveys was 300 ft from the shoreline, or the navigation channel, which ever came first. All survey data was collected with enough accuracy to produce topographic mapping with one-foot contours for use by the USACE in further development of the site design.

The final elevations developed from the Spring 2002 survey are available upon request. The horizontal grid for the survey is presented in the Long Island New York State Plane North American Datum 1983 horizontal coordinate system, and the elevations are referenced to the North American Vertical Datum 1988 (NAVD88). More detailed surveys will be needed in the next phase of the study.

Dead Horse Bay Topography/Bathymetry

In the north portion of the site there is a steep sand beach with a drainage channel that meanders through the berm, emptying a standing pool of brackish water. The pool remains undrained at low tide. The beach slope varies from a 6% slope from the upland, towards the drainage channel inlet, and 3% in the vicinity of the inlet. The beach habitat forms roughly a twenty-five (25) foot strip along the shoreline at low tide. West of the inlet a scarp begins to form, which becomes as high as 10 ft. Gerritsen Creek inlet is to the west of the site. It has been stabilized by the abutments of the Belt Parkway Bridge. The standing pool extends north into the site 400 ft. The lowest elevation of the pool is 0.0 ft, while most grades are between 1.5 to 4 ft NAVD88. Proceeding inland, the next 400 ft area is relatively flat, with grades between 5 to7 ft NAVD88. The back portion of the site, 800 to1600 ft from the shoreline, is also relatively flat with grades 10 to 12 ft NAVD88. There is a mound in the middle of this area that reaches elevations in excess of 22 ft NAVD88.

In the south portion of the site a large mudflat is present offshore of the northwest shoreline, so that the –3.5 ft contour is over 400 ft offshore. However, the beach face remains fairly steep, with 2 to 6% slopes present. The steeper beach slopes are present in the south section of the

western facing shoreline. A 4 to 6 ft high scarp starting at 3 ft NAVD88 is a consistent feature of the topography, also steepest at the south section of the western facing shoreline. The interior section of Dead Horse – South is also fairly flat, with most grades ranging from 9 to 14 ft NAVD88.

Paerdegat Basin Topography/Bathymetry

Paerdegat Basin is a straight channel 7000 ft long, with a continuous width of approximately 300 at the first 300 ft and then it widens to 450 ft. The upstream portion of the basin is approximately –7 to –9 ft NAVD88, with very steep slopes (approaching 1V:1H) on each bank. The west bank reaches elevations between 12 to 15 ft NAVD88, while the east bank has elevations that exceed 28 ft NAVD88. Slowly the channel starts to deepen to –10 approximately 500 feet from the upstream end. The east bank is usually 5 to 6 ft NAVD88, with a maximum grade of 10 ft NAVD88. The west bank is steeper; jumping to 10 ft NAVD88 50 ft from the shoreline, and the maximum grade is 32 ft NAVD88. There is a marina close to the mouth of the basin. Just before the marina (1700 ft from the Belt Parkway Bridge), the depth of the channel reaches –18 ft NAVD88. In front of the marina the depth is 2 ft shallower at –16 ft NAVD, and the last 650 ft of the basin has an average maximum depth of -13 ft. The Belt Parkway Bridge spans the mouth of the basin, at 250 ft wide and 20 ft deep. Just seaward of the bridge a "sill feature" is present, which is –16 ft NAVD88 for approximately 200 ft of linear length of the basin. After the sill, the grade quickly drops to meet the navigation channel at depths greater than –30 ft NAVD88.

Fresh Creek Topography/Bathymetry

The upper 1300 ft of the creek has a maximum depth of –7 ft NAVD88, an average depth of -4 to -5 ft NAVD88, and average width of 300 ft. The banks are steep (close to 1V: 1H) and quickly rise to 15 ft NAVD88 on both sides of the creek.

The creek narrows to 130 ft width next 500 ft (downstream). The average depth is approximately -8 ft NAVD88, but the depth is very variable in this section of the creek. There is an existing low marsh on southwest bank of the creek, with elevation ranges between 1 to 4 ft NAVD88. The northwest bank is steep, with grades rising above 20 ft NAVD88 less than 220 ft from the shoreline.

A mid-creek island exists in the next downstream section of the creek (or 2200 ft upstream from the Belt Parkway). The island is 50 to150 ft wide, 800 ft long with most elevations between 2 to 3 ft NAVD88. The main channel of the creek becomes deeper in this section, with elevations dropping to –15 ft NAVD88. The remaining length of the creek out to the belt parkway has depths of approximately –10 to -13 ft NAVD88. On the bay side of the Belt Parkway Bridge depths rise to approximately –9 ft NAVD88 to form a "sill feature", before eventually dropping to over –30 ft NAVD88 when the creek bottom meets the navigation channel in the bay
.

Spring Creek Bay Topography/Bathymetry

The shoreline in the project area at Spring Creek is very sinuous, covering 7900 ft of shoreline fringe. On the south facing shoreline (directly on Jamaica Bay), the offshore slope is a mild 2%. The slope becomes steeper (3 to 4%) in the beach face portion of the profile, and maximum slope occurs between 2 to 5 ft NAVD where the slope exceeds 7.5 %. The interior portion of the site in this area reaches grades above 16 ft NAVD88. The average dune height is 8 to 10 ft NAVD88.

A mudflat exists off the southwest shoreline of the site, at the mouth of spring creek. The mudflat extends approximately 1500 ft into the creek, with elevations hovering at between 0.0 to –1.0 ft NAVD88. The shoreline slopes are highly variable traveling upstream, ranging from 2 to 20%. The upland elevations are highly variable, with the average grade approximately 4 ft NAVD88, and the maximum grade is 7 ft NAVD88. The most northern sections of the project shoreline have slightly steep shorelines between 5 to 20%, with similar average and maximum interior grades as the middle section.

Hawtree Topography/Bathymetry

The topography of this site is highly influenced by the debris and remnant structures that still exist on the site. The offshore slope between –2 to 2 ft NAVD88 varies from 4 to 40%, with the steeper slopes located close to the entrance to Bergen Basin. A berm feature is slightly visible, located between 1 to 2 ft NAVD. The upland portion of the site has most grades between 5 to 7 ft NAVD88, with the maximum grade being 8.5 ft NAVD88.

Bayswater State Park Topography/Bathymetry

The site has 1000 ft of shoreline facing west, with a sand spit growing south. The offshore slopes are extremely flat in the southern section near the sand spit, with elevations never exceeding –7 ft NAVD 700 ft offshore. Slopes between –4 to 0 ft NAVD88 range from 5 to 20%. A crumbling seawall exists parallel to the shoreline, approximately between –2 to 2 ft, although sections of the seawall top reach 5 ft NAVD88. The interior portion of this side of the site is flat, with grades ranging from 5 to 10 ft, maximum of 11 ft NAVD88.

As the shoreline bends from western facing to northern facing, the-20 ft deep navigation channel is offshore approximately 350 ft. There is an underwater bench feature at –6 ft NAVD for approximately 300 ft of shoreline, but for the most part there is a steady 2.5% slope

Dubos Point Topography/Bathymetry

The 2600 ft long Dubos Point peninsula parallels Decosta Ave, between 65th and 63rd Streets. The most eastern 1500 ft long section of the site is still connected the main barrier island mass. It has fairly flat beach slopes (between –2 to 2 ft NAVD) (3%) which quickly drop to 20%. The offshore slope is steepest between -10 to –20 ft NAVD88, where the slope is 25%. A 50 to 70 ft wide beach is present, and the topography rises to 7 ft NAVD88 80 ft inland from the waterline, with the maximum elevation at 9 ft NAVD88.

The peninsula itself protrudes into Jamaica Bay 1000 ft, and it has an average width of 50 ft. The topographic/bathymetric survey concentrated on the northwest shoreline of the peninsula, the location of the proposed restoration. The first 500 ft of the peninsula (south section) has slopes of approximately 6% between –2 to 2 NAVD88. Again, the offshore slope is 3% between 0 to –10 NAVD88, steepest (25%) between -10 to –20 ft NAVD88, and mildest (2.5%) between –20 to –30 ft NAVD88. The interior of the peninsula reaches 7.5 ft NAVD88 450 ft from the shoreline.

The northern tip of the peninsula is very flat, with interior elevations averaging 3.0 ft NAVD88, and the maximum elevation is 5 ft NAVD88. The beach slope is slightly steeper (2.6 to 6 %) between –2 to 2 ft NAVD88. The offshore slope is 5.5% between 0 to –10 NAVD88, very steep (50%) between -10 to –20 ft NAVD88, and 25% between –20 to –30 ft NAVD88.

Brant Point Topography/Bathymetry

Brant Point has a steep beach face, with slopes ranging from 40 to 50 % from –2 to 2 NAVD88. From 0 to –4 NAVD88 slopes range from 10 to 20%. The bathymetry from –4 to –20 NAVD88 is highly variable. The western end of the site has 50% slopes between –10 to –20 NAVD88, while the eastern end of the site has 3% slopes in those depths. There is an impounded pool of water just inland of the beach, which has depths of 0.0 ft NAVD88. The average elevation of the upland portion of the site is between 5 to 7 ft NAVD88. The maximum elevation is 14 ft NAVD88.

5.2 Geotechnical Information

The JBERP sites lie within the Southern Long Island watershed, contained within the Coastal Plain Physiographic region. Surficial deposits on Long Island are glacial in origin with morainal deposits to the north and outwash deposits to the south. The surficial deposits form the unconfined aquifer and local water-bearing deposits of lesser extent, including the Jameco aquifer. These systems are underlain by the Magothy and Lloyd aquifers, which are generally confined.

Dead Horse Bay Geotechnical Information

The soil in the area is characterized by medium, fine, well-sorted sand, with the median sand diameter of 0.226 to 0.312 mm for the 3 on-shore grab samples. The Natural Resources Conservation Service (NRCS) and the New York City Soil and Water Conservation District are in the process of developing an official soil survey book and maps for New York City and for GNRA. A draft soils survey of the GNRA obtained from NRCS shows that soils within the Dead Horse Bay site include Beaches, Bigapple Coarse sand, Bigapple-Blownout land complex, Fortress sand, Hooksan fine sand, Hooksan-Dune land complex, Ipswich mucky peat, Rikers gravelly coarse sand, Breeze loamy sand, Fishkill sandy loam, and Gravesend-Oldmill coarse sand. Most of these soils series describe disturbed areas that are filled with over 40 inches of various materials that have varying drainage qualities (NRCS 2004).

Paerdegat Basin Geotechnical Information

The soil here was medium-sorted sand, with the median sand diameter of 0.316 to 0.502 mm for the 7 on-shore grab samples. In a draft soil survey for New York City, NRCS has identified the soils of the Paerdegat Basin site as Bigapple-Fortress series complex, Bigapple-Verazano complex, and Inwood-Laguardia-Ebbetts complex. The Bigapple and Fortress series are soils consisting of sandy dredge material over 40 inches thick, which has been placed onto an area. The Verazano series consists of a thick human-transported loamy layer over sandy sediments. The Inwood, Laguardia, and Ebbetts series all consist of demolished construction material mixed with various soils to create fill material (NRCS 2004).

Fresh Creek Geotechnical Information

The soil here was poorly-sorted sandy-gravel, with the median diameter of 3.01 to 4.2 mm for the gravelly areas and 0.395 to 0.458 mm for the sandy grab samples. The deposition of historic fills has been irregular at this site. All samples showed significant amounts of gravel, sand and silt for all samples. Even the clay present in each sample ranged from 2 to 7%. In a draft soil survey for New York City, NRCS has identified the soils of the Fresh Creek site as Bigapple-Fortress series complex, Inwood-Laguardia-Ebbetts complex, Greatkills-Freshkills complex, Pavement and Buildings-Bigapple-Verazano complex, and Ipswich-Pawcatuck-Matunuck mucky peat. Both the Bigapple and Fortress series are soils consisting of sandy dredge material over 40 inches thick, which has been placed onto an area. The Inwood, Laguardia, and Ebbetts series all consist of demolished construction material mixed with various soils to create fill material. The Verazano series consists of a thick human-transported loamy layer over sandy sediments. Greatkills soils are a mixture of household garbage, construction debris and other discarded materials layered with natural soil fill. Freshkills soils are only household landfill capped with a thin layer of loamy soils. Ipswich, Pawcatuck, and Matunuck are all tidal marsh soils, differing in the thickness of the organic layer before reaching sand (NRCS 2004).

Spring Creek Bay Geotechnical Information

A draft soils survey of the GNRA obtained from NRCS shows that soils within the Spring Creek site include Beaches, Bigapple Coarse sand, Breeze loamy sand, Fortress sand, Gravesend – Oldmill complex, Hooksan fine sand, Hooksan-Dune land complex, Pawcatuck mucky peat, and Sandyhook mucky fine sandy loam. The majority of soils are the Gravesend – Old mill complex which includes household fill covered with a layer of sand. Bigapple, Breeze, and Fortress sands all describe disturbed areas that are filled with over 40 inches of various sandy materials that have varying drainage qualities. Hooksan and the Hooksan-Dune land Complex describe sandy areas. Pawcatuck is a poorly drained sandy soil with an organic surface layer (16 to 51 inches deep) that is inundated by saltwater at high tide. The Sandyhook series is similar to Pawcatuck, but with a thinner organic layer (less than 8 inches) with high concentrations of sulfur.

Hawtree Geotechnical Information

The soil here was poorly-sorted sand, with the median sand diameter of 0.308 to 0.376 mm for the 2 on-shore grab samples. A significant percentage of both gravel and silt were found in the 2 samples, suggesting that the historic placement of fill at this site was inconsistent. A draft soils

survey of the GNRA obtained from NRCS shows that soils within the Hawtree Point site include Beaches, Barren sand, Bigapple Coarse sand, Bigapple sandy loam, Pavement/ buildings, and Sandyhook mucky fine sandy loam. The Bigapple soil series and the Barren sand series both denote areas of dredge fill placement. The Pavement includes the basketball courts and buildings of the Charles Memorial Park. The Sandyhook series is a poorly drained soil with a thin organic layer, usually supporting intertidal wetlands. (NRCS 2004).

Bayswater State Park Geotechnical Information

The soil here was medium-sorted sand, with the median sand diameter of 0.285 to 0.451 mm for the 4 on-shore grab samples. In a draft soil survey for New York City, NRCS has identified the soils of Bayswater State Park as Bigapple – Fortress series complex. Both of these soil series denote sandy dredge material over 40 inches thick, which has been placed onto an area. The Bigapple series consists of very deep, well drained soils with rapid permeability (NRCS 2004). The Fortress series consists of very deep, moderately well drained soils with rapid permeability (NRCS 2004). An offshore geotechnical investigation off the west-facing shoreline revealed that the subsurface is primarily composed of poorly graded fine to medium sand with various amounts of silt (SP to SM) and a discontinuous layer of clay (CL and ML).

Dubos Point Geotechnical Information

The soil here was well-sorted sand, with the median sand diameter of 0.264 to 0.621 mm for the 3 on-shore grab samples. All 3 samples were very consistent, with less than 1% gravel and clay, and only 5 to 10% silt. A draft soils survey obtained from NRCS shows that soils within the Dubos Point site are Bigapple- Fortress complex. The Bigapple soils series includes areas covered by dredge spoils (NRCS 2004). The Fortress series also denotes a filled area, but composing of dredged, outwash, or eolian sands (NRCS 2004). The offshore subsurface is primarily composed of poorly graded fine to medium sand with trace amounts of silt. In summary, the offshore soils are sand (SP-SM) and Fat Clay (CH), with phi angles between 0 to 25 degrees.

Brant Point Geotechnical Information

The soil here was both poorly-sorted and well-sorted sand. The well-sorted sand sample had a median sand diameter of 0.276 mm, with less than 2% of gravel, silt or clay. The other 2 on-shore grab samples had 21-32% gravel, with median particle size diameters between 0.344 to 0.735 mm and 6 to 12% silt content. A draft soils survey of New York City obtained from NRCS shows that soils within and around the Brant Point site include Pavement and Buildings-Bigapple-Verazano complex. The Bigapple soil series denotes an area historically filled with sandy dredge material over 40 inches thick (NRCS 2004). The Verazano series also denotes an area historically filled, but this series includes areas filled with a loamy mantle over sandy sediments (NRCS 2004). An offshore geotechnical investigation done in May 2004 revealed that the subsurface is primarily composed of poorly graded fine to medium sand with varying amounts of silt. A discontinuous layer (approximately five feet in thickness) of elastic silt was encountered three feet below the mud line. In summary, sand (SP-SM) and fines (MH-OH) were

found in the vicinity of where shore protection structures area proposed. The phi angle was between 10 to 25 degrees.

5.3 Tidal Conditions, Salinity and Temperature

A field data collection program was undertaken during this study to determine the tidal datums in the open water areas adjacent to the proposed tidal restoration sites in the Jamaica Bay Ecosystem Restoration Project (JBERP). The tidal datums were calculated from local water level data that were monitored at each restoration site. The water level gages were taking measurements at the same time that biological benchmarking and topographical surveys were being done.

In Summary, the field effort involved continuous monitoring of the water level changes due to tides for a period of six weeks. The locations of the gages are shown in Figure 5.1. The gages were placed at these locations for the following reasons, in order of priority: proximity to a proposed restoration site and reference site, a low energy environment (protected from vessel wakes, wind generated waves and currents), low accessibility to potential vandals, and depth of water at low tide. Six of the gages were installed on 16 October 2001 and the remaining six were installed on 23 October 2001. All of the gages were installed from a boat, with the exception of one site (Dead Horse North – Interior). Data was retrieved from the gages on 31 October 2001 and 29 November 2001. The gages were removed on 29 November 2001. Every effort was made to satisfy the biologists and hydraulic engineer's request for location characteristics while ensuring the safety and optimal performance of the equipment. The biobenchmarks and tidal datums observed were used to develop the design criteria for the sites that had low and high marsh creation. Table 5.3 presents this information and Appendix B contains the entire *Summary of Water Level Data Report.*

Salinity is a critical parameter in determining the success of tidal wetland restoration. While intertidal vegetation in the northeast can exist in low saline conditions, usually the native species, especially spartina alternaflora, spartina patens and distichilis pacata are out competed by invasive species, especially phragmities australis. Phragmities australis cannot survive in high saline environments. Table 5.2 shows that the open water sampled at all sites are highly saline, with the highest saline measurements found at Dead Horse Bay and Brant Point, the sites closest to Rockaway Inlet and the Atlantic Ocean.

Included in table 5.2 are surface water temperatures measured at the site (JABERRT 2002). Most of the average temperatures at all the sites are nearly the same. It is interesting to observe how Paerdegat Basin, Fresh Creek and Spring Creek do not freeze. The reason for this could be the presence of the Sewage Treatment Plants and Combined Sewage Outfalls at the head of these waters. Ice formation does cause erosion and damaging effects to low marsh vegetation and shore protection structures.

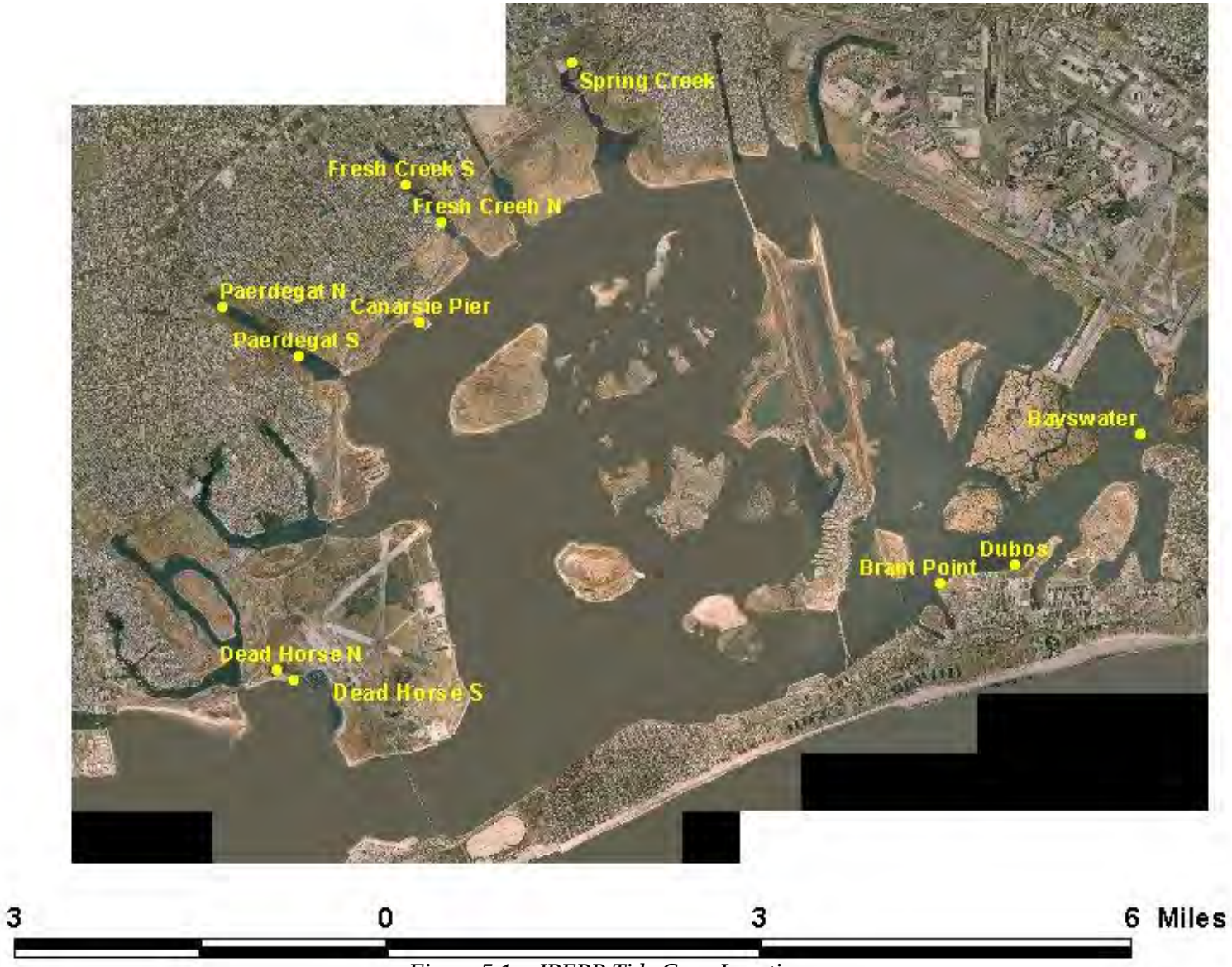


Figure 5.1 – JBERP Tide Gage Locations

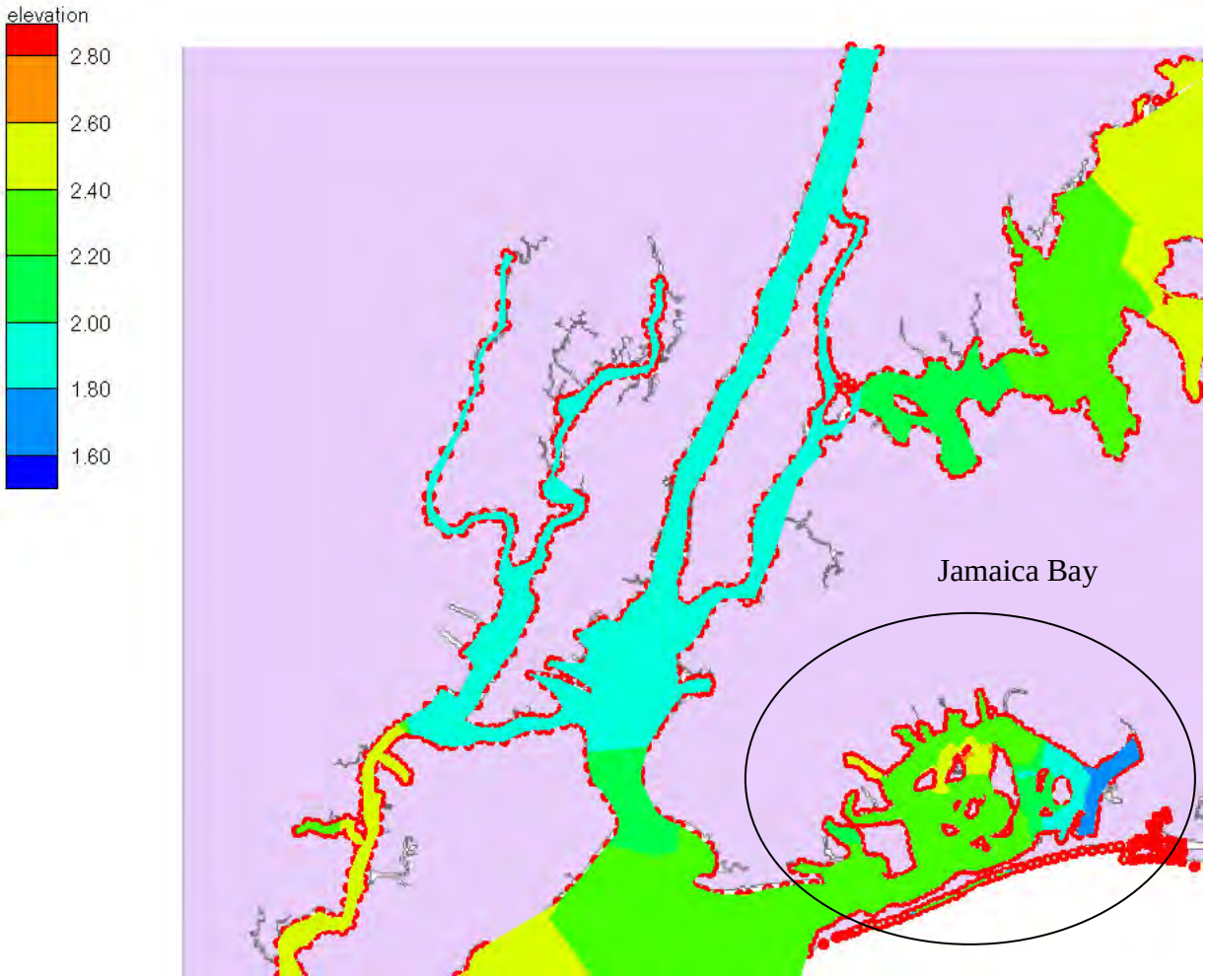
Site Name	Northing	Easting	Monitoring Period –2001 unless indicated	MLLW	MLW	MTL	MHW	MHHW	MHWS	Tide Range	Break Between Smooth Cordgrass and Salt Marsh Hay*	Lowest Common Reed Elevation*
Dead Horse North - Exterior	153039	1011012	16-Oct to 29-Nov		**-3.00**	**-0.50**	2.00	2.09	2.97	**5.00**	2.33	1.99
Dead Horse North - Interior	153465	1010234	23-Oct to 29-Nov				2.52	2.52	3.31	**n/a**	1.31	1.99
Paerdegat Basin North	168878	1007926	16-Oct to 29-Nov	-3.29	-3.20	-0.52	2.17	2.24	3.42	5.37	2.43	1.78
Paerdegat Basin South	166794	1011183	16-Oct to 29-Nov	-3.15	-3.07	-0.48	2.10	2.17	3.29	5.16	2.43	1.78
Canarsie Pier	168225	1016293	16-Oct to 29-Nov	-3.34	-3.27	-0.52	2.23	2.34	3.29	5.50	n/a	n/a
Fresh Creek North	174088	1015728	16-Oct to 29-Nov		-2.19	0.15	2.49	2.56	3.72	4.67	2.25	2.49
Fresh Creek South	172486	1017254	16-Oct to 29-Nov	-2.84	-2.75	-0.09	2.57	2.64	3.82	5.32	2.25	2.49
Spring Creek North	179310	1022852	23-Oct to 29-Nov		-2.29	-0.05	2.18	2.18	3.25	4.47	n/a	n/a
Hawtree			23-Oct to 29-Nov		**-3.12**	**-0.62**	1.88	1.93	3.17	**5.00**	2.25	3.14
Bayswater	163478	1046965	23-Oct to 29-Nov		-2.02	0.43	2.89	2.90	3.83	4.86	1.77	2.40
Dubos	157962	1041656	23-Oct to 29-Nov		-2.21	0.09	2.39	2.43	3.46	4.60	1.99	2.63
Brant Point	157148	1038492	23-Oct to 29-Nov		-2.77	-0.28	2.20	2.24	3.25	4.97	2.31	n/a

* from Jamaica Bay Ecosystem Restoration Project Conceptual Plan Report, USACE February 2003

Bold Datums indicate that the value was calculated based on the average tide range of 5.00 ft for this sampling period. The gage pressure sensors were not deep enough and did not read the lower water levels.

Table 5.1 Tidal Datums for Water Level Recorders at or near Jamaica Bay Ecosystem Restoration Sites

Figure 5.2 Elevation of Low Marsh/High Marsh Breakline in Jamaica Bay (and surrounding Hudson-Raritan Estuary)



	SALINITY (PPT)			TEMPERATURE (DEGREE F)		
	MIN	MAX	AVERAGE	MIN	MAX	AVERAGE
DEAD HORSE BAY	20	36	27.1	29.5	80	54.3
PAERDEGAT BASIN	17.7	30.5	25.7	33.8	79.9	56.3
FRESH CREEK	18.7	30	26.1	33	81.5	56.1
SPRING CREEK	19	31.3	25.9	32.7	78.1	55.9
HAWTREE POINT	14.3	30.1	25	32	85.8	56.7
BAYSWATER STATE PARK	20.2	28.9	25.8	29.7	77.7	56.1
DUBOS POINT	20.7	29.4	25.9	30	75.7	55
BRANT POINT	20.7	29.4	26	29.8	77.5	N/A

Table 5.2 Salinity and Temperature Readings at JBERP sites

5.4 Storm Surges

The storm surge model performed for this project was based on the analysis performed for the FIMP (Fire Island to Montauk Point) reformulation study (CENAN, 2005 draft). To develop stage-frequency relationships in Jamaica Bay, the ADCIRC (ADvanced CIRCulation) model (Luettich et al., 1992) and one-dimensional EST (Empirical Simulation Technique; Borgman et al., 2003) were employed. Storm stages at Sandy Hook for the 2, 25, 50, and 100-year return periods were selected from the draft stage-frequency results produced for the FIMP study (Borgman, 2003 draft). Stage for each return period was represented by its median value and estimates of its upper and lower statistical bounds.

Storm Surge Model Application

The primary purpose of the storm surge model was to develop a database of historical tropical and extratropical event hydrographs that have impacted the study domain. First, historical events were identified based on a minimum surge-only criteria (CENAN, 2005 draft). In all, 22 historical extratropical and 14 historical tropical events were selected for storm surge modeling. Each of the historic events was simulated in ADCIRC, over a computational domain spanning the northeastern Atlantic Ocean, using state-of-the-art input meteorological fields (CENAN, 2005 draft). Peak storm water level, representing astronomical tide plus wind-generated surge and barometric pressure effects, was extracted at Sandy Hook for each storm. These peak storm water levels were subsequently analyzed with EST methods to develop a stage-frequency relationship for this location.

Stage-Frequency Development

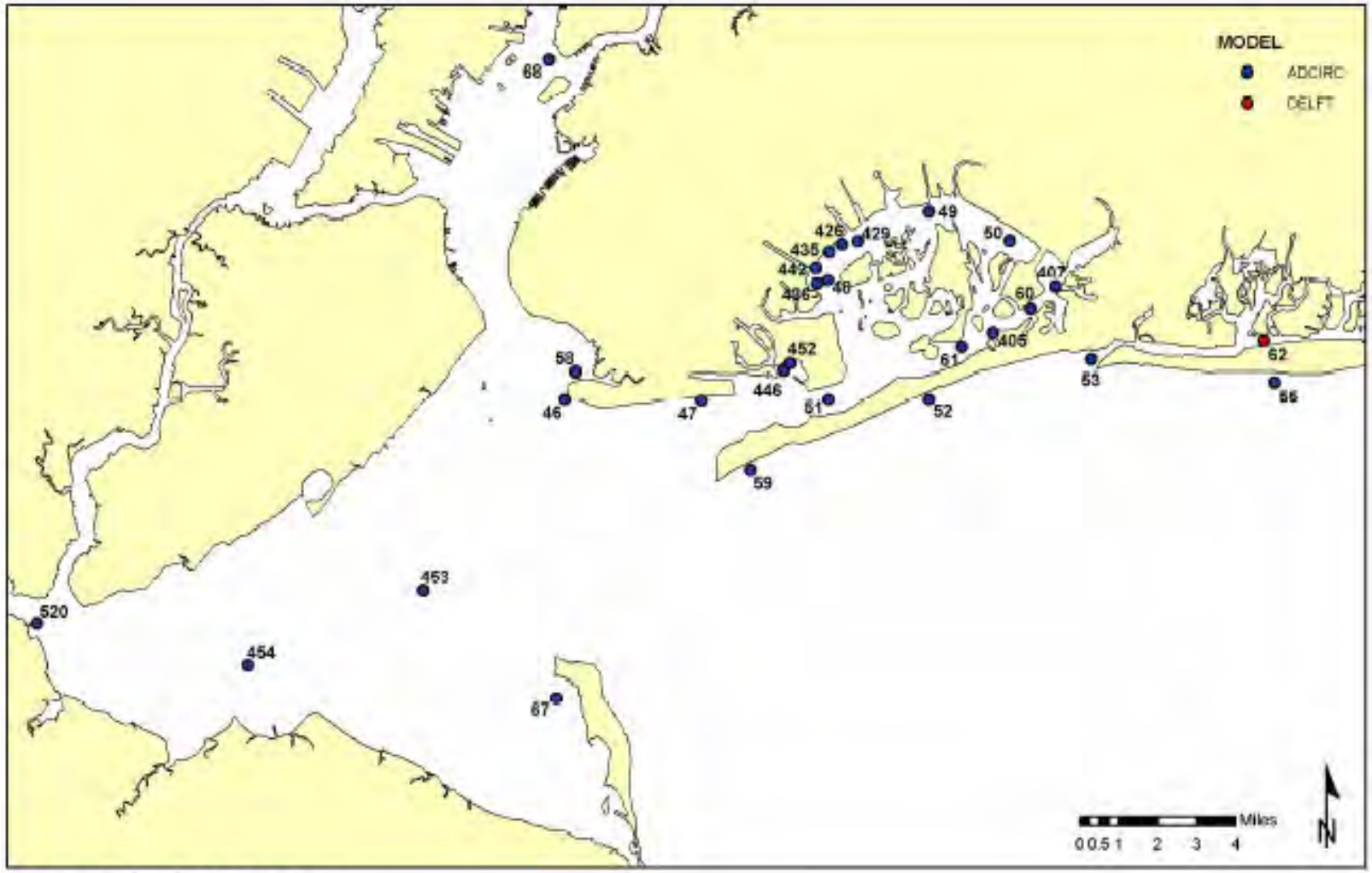
Draft one-dimensional EST methods developed for the FIMP study were employed to generate a stage-frequency relationship at Sandy Hook. The EST is a nonparametric approach which resamples from a single data set, here the simulated historical water levels at Sandy Hook. First, an empirical cumulative distribution function (EDF) is developed for the simulated historical water level set. This EDF is essentially an inversion of the stage-frequency relationship, stated in terms of probability rather than return period. The upper tail of the EDF, representing extreme events larger than those contained in the historical data set, is extrapolated using spline-fitting methods. The lower tail, representing storms smaller than those simulated with ADCIRC, was truncated based on the expected value for maximum annual astronomical tide. Once this EDF is constructed, it is randomly resampled 1000 times. The 1000 samples are then ranked to extract the 25th, 50th, and 75th percent exceedance intervals. The 50th percent exceedance interval represents the median stage while the 25th and 75th percent exceedance intervals represent the upper and lower statistical bounds. The resulting draft EST stage-frequency relationship at Sandy Hook was compared with that estimated from NOAA measured water levels. Over the interval of comparable overlap, namely the 10-yr to 75-yr return period interval, there is excellent agreement (CENAN, 2005 draft).

In summary, the sites on the south side of the bay and further from the Atlantic Ocean had the higher storm surges. For the annual event, Bayswater State Park had the highest stage at 5.51 ft, followed by Dubos (5.50 ft) and Hawtree (5.49 ft). For the 10-year event, Dubos had the highest elevation at 7.02 ft, followed by Bayswater State Park (7.01 ft) and Brant (7.0 ft). For the 100-year event, Bayswater State Park again had the highest stage at 8.61 ft, followed by Dubos (8.54 ft) and Hawtree (8.53). The range of storm surge stages for all frequencies usually did not vary more than 0.4 ft throughout the bay. The Dead Horse Bay storm surges consistently were the lowest calculated stages, at 5.22, 6.69, and 8.11 ft for the 1, 10 and 100-year events. It should be noted that the bathymetry used in the model for Jamaica Bay was obtained through National Oceanographic & Atmospheric Administration (NOAA) chart (12350), which has limited resolution for this application.

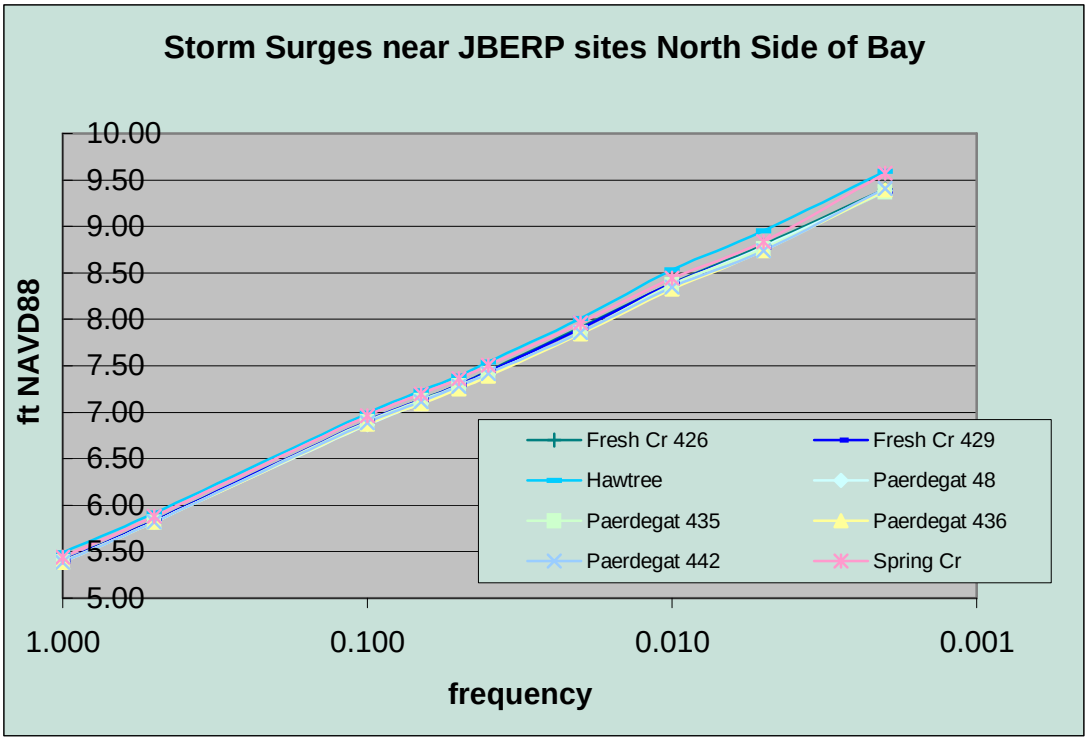
Table 5.3 Storm Surges in the vicinity of JBERP sites

			Storm Surge, Combined Tropical and Extratropical Storms (ft NAVD88)									
		Return Period (yr):	1	2	10	15	20	25	50	100	200	500
LOCATION DESCRIPTION	Station #	Nearest Site										
Island Channel (Jamaica Bay)	48	Paerdegat	5.38	5.82	6.87	7.10	7.27	7.41	7.86	8.37	8.78	9.38
Channel Bridge (Jamaica Bay)	49	Spring Cr	5.44	5.88	6.96	7.20	7.36	7.51	7.96	8.44	8.84	9.57
Grassy Bay (JFK airport)	50	Hawtree	5.49	5.92	6.99	7.23	7.39	7.54	8.01	8.53	8.95	9.59
Marine Parkway Bridge	51	Dead Horse	5.28	5.71	6.74	6.96	7.12	7.25	7.69	8.18	8.57	9.19
Grass Hassock Channel	60	Dubos	5.50	5.93	7.02	7.25	7.41	7.55	8.03	8.54	8.95	9.59
Jamaica Bay (kad 1)	405	Brant	5.48	5.91	7.00	7.23	7.40	7.54	7.98	8.49	8.88	9.58
Jamaica Bay (kad 3)	407	Bayswater	5.51	5.94	7.01	7.25	7.42	7.57	8.05	8.61	9.06	9.78
Jamaica Bay (kad 6a and 7a)	426	Fresh Cr	5.39	5.83	6.90	7.13	7.30	7.44	7.91	8.39	8.80	9.40
Jamaica Bay (kad 6b and 7b)	429	Fresh Cr	5.40	5.84	6.91	7.14	7.29	7.44	7.90	8.39	8.77	9.38
Jamaica Bay (kad 8)	435	Paerdegat	5.39	5.82	6.90	7.12	7.29	7.42	7.86	8.38	8.76	9.37
Jamaica Bay (kad 9a and 10a)	436	Paerdegat	5.38	5.82	6.87	7.10	7.25	7.39	7.84	8.32	8.74	9.40
Jamaica Bay (kad 9a and 10a)	442	Paerdegat	5.38	5.82	6.89	7.12	7.28	7.42	7.86	8.34	8.74	9.40
Jamaica Bay (kad 11)	446	Dead Horse	5.22	5.65	6.69	6.91	7.06	7.20	7.64	8.11	8.49	9.10
Jamaica Bay (kad 12)	452	Dead Horse	5.23	5.65	6.69	6.91	7.07	7.22	7.66	8.15	8.54	9.11

Figure 5.3 Storm Surge Output Stations in the vicinity of JBERP sites



Storm water level output stations.



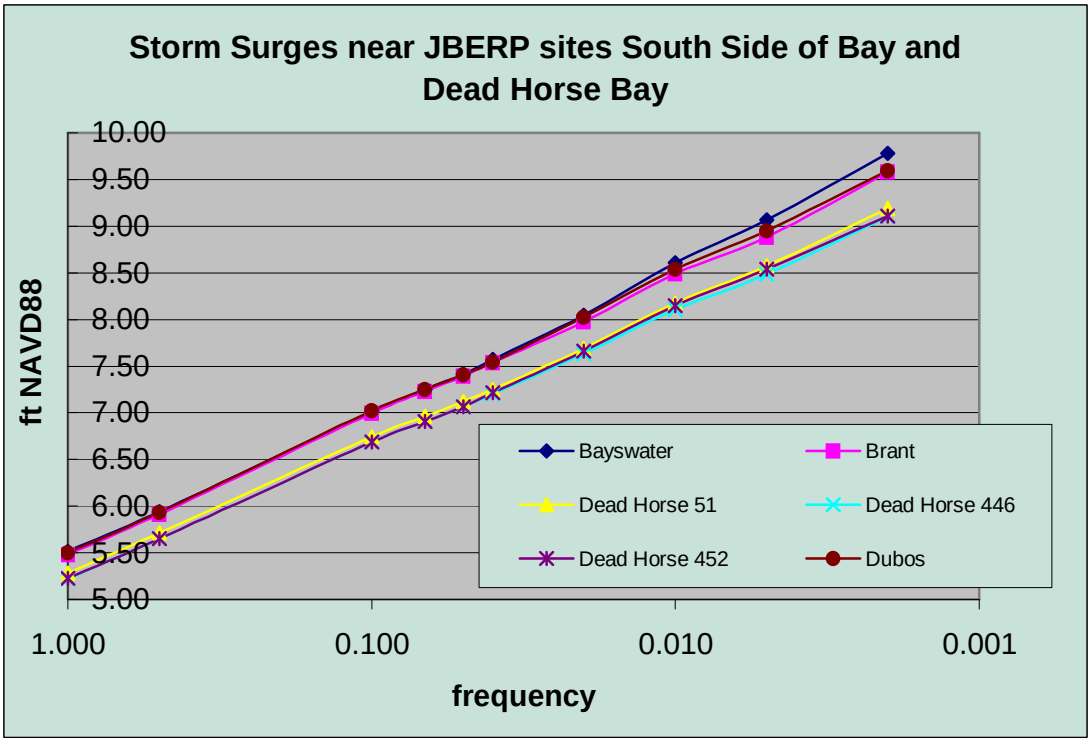


Figure 5.4 Storm Surges in the vicinity of JBERP sites

5.6 Shoreline Change

Shoreline change, mainly in the form of shoreline recession, is related to the dynamics of Jamaica Bay, such as winds, waves, tides, and current effects. Wave and current actions transports the sediment along the shoreline. Water levels, mainly due to tides and elevated water levels during storms, enhance these effects by increased destructive energy levels. Other geological and coastal developments also shape the present position of the shoreline. Soil type and grain size determines the natural angle of repose, the strength of the soil to resist erosion and its deposition/suspension characteristics. Interventions on natural dynamics due to erosion control measures (coastal structures, vegetation, and other) can decrease the recession rate locally while accelerating the rate on the adjacent shorelines. Depending on the availability of the sources in the system, a shoreline may experience both erosion and accretion due to the dynamic forces of the nature. Generally, gain of sediment in a system would translate in to shoreline accretion, whereas, loss of sediment would translate into a shoreline recession.

Dynamic shorelines exhibit both short- and long-term variations. Short-term variations can be attributed to seasonal differences in storm intensities, and localized differences in sediment type. Long-term variations (in the order of years) reflect cumulated effects. Short-term rates may be highly variable while long-term effects are averaged.

Historical shoreline change for four sites, Dead Horse Bay, Brant Point, Dubos Point, and Bayswater State Park, was studied for the period from 1959 to 1996. The objective of this analysis was to determine a qualitative estimate of the magnitude of shoreline change occurring at the four sites. The Paerdegat Basin, Fresh Creek and the northern portion of the Spring Creek site did not have visible shoreline changes, with the exception of when filling or excavation activities occurred. While the southern shorelines of Spring Creek and Hawtree have experienced minor erosion, the restoration goals at those sites did not involve shoreline stabilization, and most of the restoration activities concentrated on the upland habitats.

Methodology

Four ortho-rectified aerial images of each of the four sites were utilized for the shoreline change analysis, which were made available by the USACE. These images included 1959, 1966, 1974, and 1996 aerials spanning 37 years. The 1996 imagery was ortho-rectified by New York City Department of Environmental Protection. The imagery of 1959, 1966, and 1974 were ortho-rectified based on the imagery of 1996 using ArcView® GIS. In this process, four to eight ground control points were selected from each image to be rectified as well as from the imagery of 1996. The control points were selected from the visible features, both in the imagery of 1996 and the imagery to be rectified, such as streets and streams. The imagery of 1959, 1966, and 1974 were then aligned to the ortho-rectified imagery of 1996 by linking each control point on the imagery of 1959, 1966, and 1974 to the corresponding point on the imagery of 1996, thus ortho-rectifying each image. The approach used for the shoreline change analysis includes the interpretation of erosion/accretion reference features located and mapped on a series of ortho-rectified aerial images.

The first step in the historical shoreline change analysis of a site is to create an imaginary baseline common to all the digital ortho-photos from which all distances can be referenced. Therefore, a segmental baseline was created on landside roughly parallel to the shoreline for each of the four sites. The length of the baseline was sized to cover the delineated areas of interest. Transects were then drawn perpendicular to the baseline across the shoreline approximately every 100 feet.

Two reference features, "primary" and "secondary" line were initially used to assess the shoreline change for this study. These reference features and their limitations on the application to this project are defined as follows:

Water Line: The intersection of Bay water with beach/land was selected as one of the reference feature used to measure the shoreline change process. This feature is the easiest to map as compared to other features. However, the position of the primary line is entirely dependent on the time that the aerial photograph was taken. That is, comparison of two aerial photos taken at high and low tides could give the impression of erosion or accretion simply as the result of primary line position on a beach slope. This could potentially add up to significant errors in horizontal shoreline distance, as measured from the baseline. For example, an error could be as much as 40 to 60 feet in terms of shoreline location for a nearshore slope of 1V:20H and a 2 to 3 feet difference in tidal water elevation. Generally, aerial images do not include time stamps to determine the corresponding tide level at the time of photography. In some cases though, it is possible to assess whether the picture was taken during a high tide period or low tide period by comparing the aerial images with respect to shoreline features and field observations. This assessment was considered during the mapping of the primary line feature.

Vegetation Line: The secondary line was also utilized to check for changes in trends for confirmation of the primary line. The secondary line was mapped as a reference feature, which generally reflects the maximum reach of wave attack, or the vegetation line. This line was identified from the aerial photographs and digitized for analysis.

For Bayswater State Park, Dubos and Brant Point sites, the reference feature lines exhibited very similar trends for the periods considered, where shoreline recession is apparent (see Shoreline Change Analysis Report, USACE 2003). Since the vegetation line also corresponded to habitat maps, the vegetation line is discussed further in the shoreline change analysis, and it was used to determine erosion rates for future conditions at the site. Dead Horse Bay has only its vegetation line digitized. The remaining sites did not experience significant erosion, so the shoreline change analysis was not performed at those sites.

Appendix C (Shoreline Change Analysis) includes the images illustrating reference features for the Bayswater State Park, Dubos Point and Brant Point sites. The Shoreline Change Analysis figure for Deadhorse Bay follows in this analysis as an example of the methodology.

Shoreline Change Rate Analysis

Determination of a reliable shoreline change rate requires relatively long sampling intervals. By using long intervals, short-term variations due to episodic processes are smoothed. Since the

earliest aerial dates back 37 years, this analysis period has precedence over the other periods with relatively shorter time spans.

A number of analytical methods are available to determine shoreline change rates at a specific site. In most cases, these rates will be site specific, especially when there are significant variations in the shoreline position data. For this study, an end-point analysis was used in combination with the average of rates (AOR) method where applicable. End-point analysis takes the first and last points in the selected record and calculates the rate as its name implies. Results are highly dependent on the period chosen for the analysis. Therefore, variations giving rise to certain trends might be missed. The AOR method was implemented, in addition to end-point-analysis, to account for those trends with significantly longer periods (i.e. in the order of years).

When compared to 1996 photograph year, the 1959, 1966, and 1974 photographs allow for three relatively long analysis periods of 37, 30, and 22 years, respectively. These periods were used for end-point analysis, and averaged for the AOR analysis. Comparisons were made and site-specific rates were determined for all periods. The AOR methodology was employed where there are large variations in the rate data. These variations could be attributed to both natural phenomenon and/or mapping errors during the reference line process. This shoreline change process is outlined for the first site, Dead Horse Bay. All other sites (Bayswater State Park, Dubos Point and Brant Point) aerial photograph comparison analyses can be viewed in *Shoreline Stability Analysis Report for Jamaica Bay Ecosystem Restoration Project*, USACE, 2002

5.6.1 Dead Horse Bay

Dead Horse Bay has undergone extreme changes over the last 50 years (Figures 5.5 – 5.8). The northern portion of the site (Dead Horse North) has been influenced by the stabilization of Gerritsen Creek Inlet, and the construction of the Belt Parkway, the adjacent driving range, and the adjacent marina. The southern portion of the site lies behind a large mudflat. Dead Horse – South land mass was created by fill (clean and household trash) deposited there while Floyd Bennett Field was being constructed. Both portions of the site experience extremely different erosion and accretional patterns.

Overall, Dead Horse North accreted between 1959 – 1996 and between 1966-1996. It eroded -1.93 ft/yr between 1974-1996. The erosion was most severe in the shoreline west of the creek outlet. This area currently has 5 to7 ft high bluffs that have vertical faces that are most likely due to the longshore sediment transport influences of Gerritsen Creek inlet. No restoration is proposed in this section of the shoreline. The shoreline in front of the creek is highly variable, likely due to a large sediment supply coming from the bluffs, and the hydrodynamics of the creek outlet. Dead Horse South has variable erosion/deposition patterns because its shorelines face many directions (north-west ,west, southwest, and south) with many different physical characteristics and influences on the shorelines. Trends that describe all of these faces are nearly non-existent. The shorelines of greatest concern to this project are sections 4 and 5, which are the shorelines that are speckled with trash coming from the upland. Section 4 experienced erosion in all time periods, with an average of -5.17 ft/year. This shoreline faces Rockaway Inlet and is exposed to large waves (to be discussed in the next section). Section 5 experienced -1.04 ft/year from 1974 – 1996, but otherwise the shoreline has been relatively stable.

Figure 5.5 Dead Horse Bay Shoreline - 1959

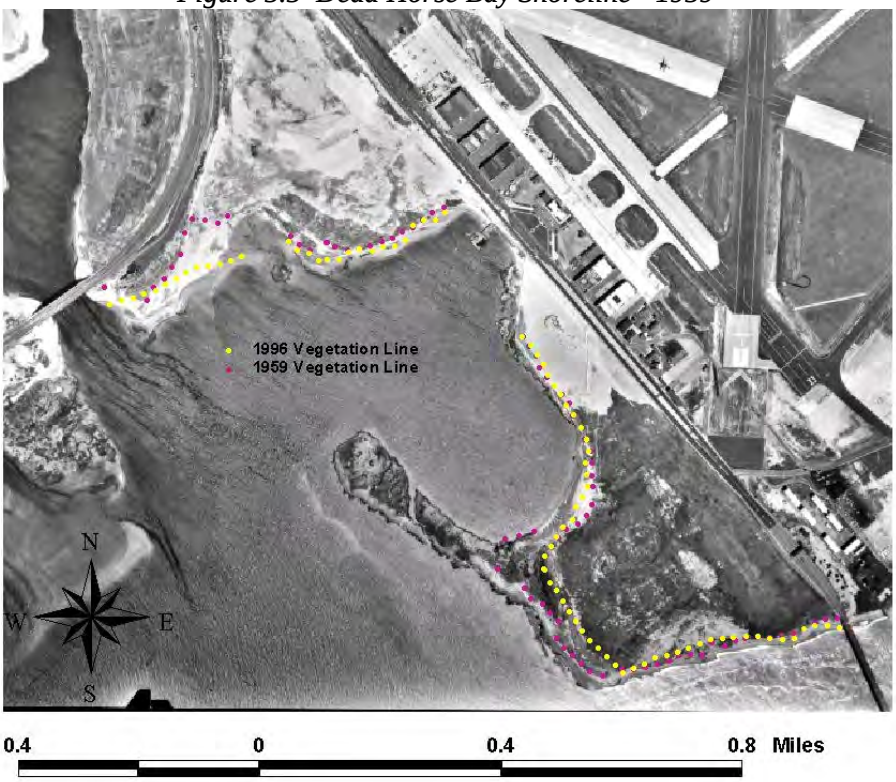


Figure 5.6 Dead Horse Bay Shoreline – 1966

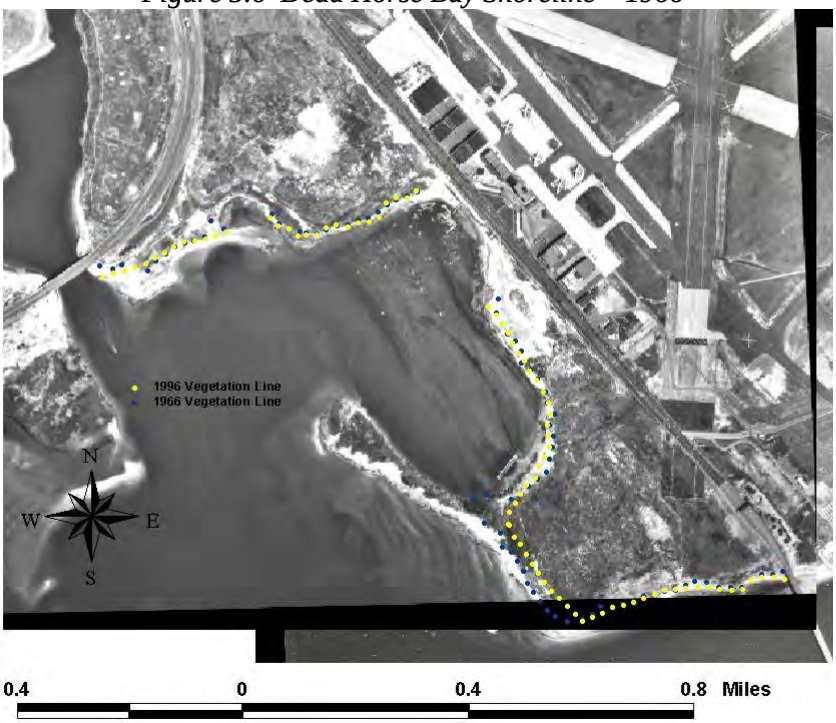


Figure 5.7 Dead Horse Bay Shoreline – 1974

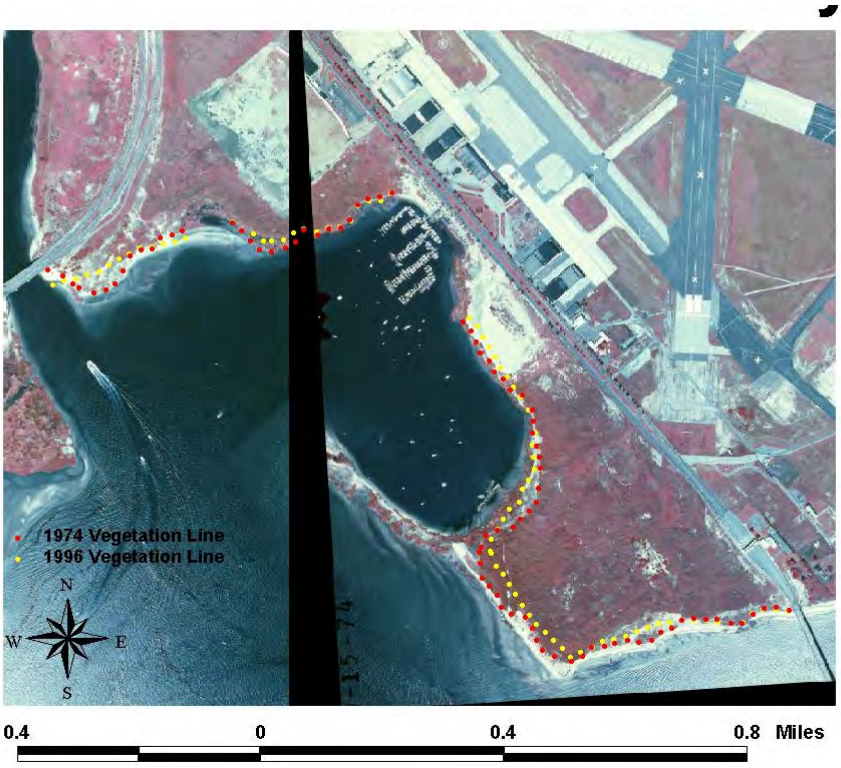


Figure 5.8 Dead Horse Bay Shoreline – 1996

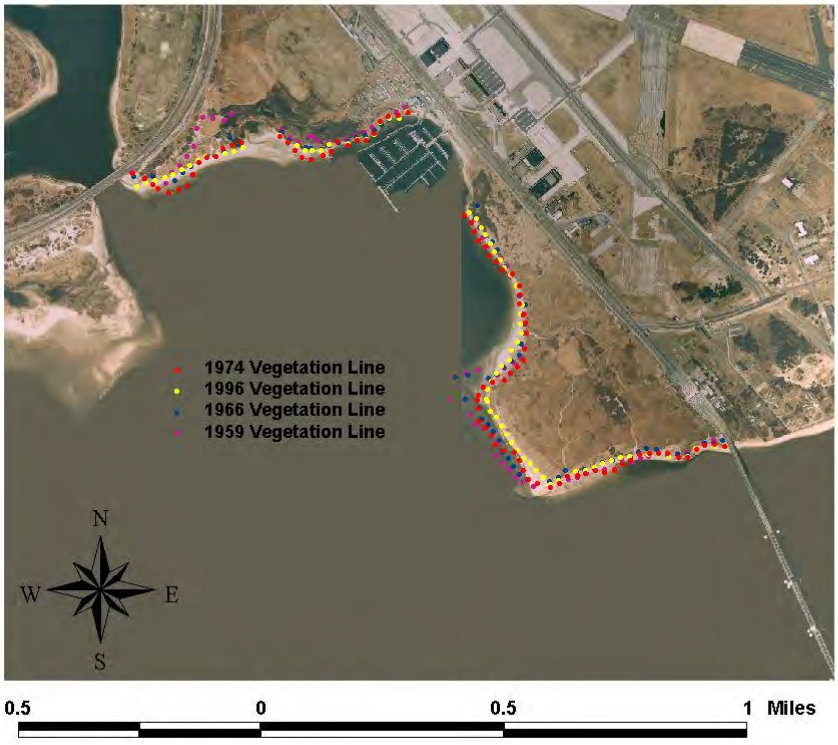


Table 5.4 Dead Horse Bay Erosion Rates

	Period	Dead Horse North Vegetation Line (feet/yr)				
		West of Creek Outlet Section 1 (Transect No. 1-13)	East of Creek Outlet Section 2 (Transect No. 14-17)	Transition (Transect No. 18)	Marina (Transect No. 19-29)	Combined Average (All Sections)
End-point Averaging	1959-1996	1.50	1.39	4.00	1.16	1.44
	1966-1996	0.33	0.79	0.77	0.32	0.41
	1974-1996	-3.02	-1.81	-4.64	-0.52	-1.93
AVERAGE (AOR)		-0.40	0.12	0.04	0.32	**-0.03**

	Period	Dead Horse South Vegetation Line (feet/yr)					
		Section 1 Faces Southwest (Transect No. 1-9)	Section 2 Faces West (Transect No. 10-15)	Section 3 Faces Northwest (Transect No. 16-23)	Section 4 Faces Southwest (Transect No. 24-35)	Section 5 Faces South (Transect No. 36-55)	Combined Average (All Sections)
End-point Averaging	1959-1996	-0.19	0.63	-1.99	-5.67	-0.23	-1.49
	1966-1996	0.68	0.64	-2.22	-4.54	0.80	-0.75
	1974-1996	-2.53	1.08	2.67	-5.32	-1.04	-1.48
AVERAGE (AOR)		-0.68	0.78	-0.51	-5.17	-0.16	**-1.24**

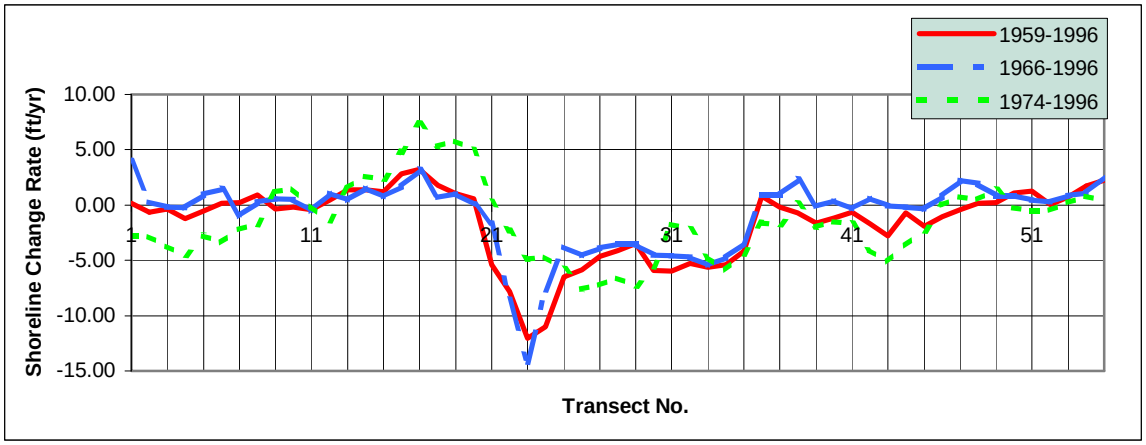


Figure 5.9. Shoreline Change Rate (End-Point Averaging) Along the Dead Horse Bay North Site.

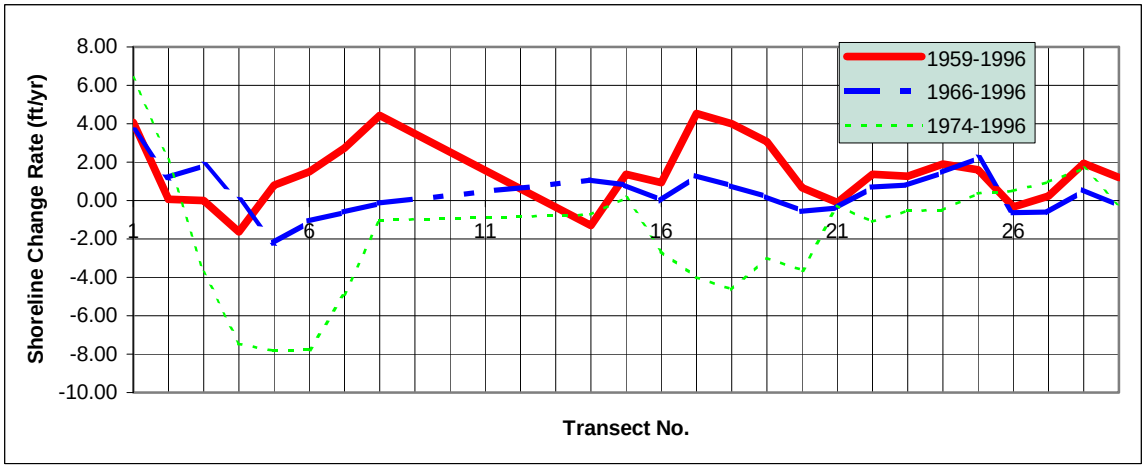


Figure 5.10. Shoreline Change Rate (End-Point Averaging) Along the Dead Horse Bay South Site

5.6.2 Bayswater State Park

Aerial images over the years revealed the existence of spit formations along the western and northern edges of the Bayswater State Park site. The existing wall at the northwest corner of the Bayswater State Park seems to have a nodal point effect where the sediment transport patterns alter direction to each side of this point. In the 1996 image, the easterly spit has assumed a new alignment, more towards the north. Potentially, construction of the JFK runway extension and/or dredging could have affected the sediment transport patterns around Bayswater State Park.

The Bayswater State Park site was divided into two sections. Section 1 includes Transects 1 through 13 on the western side of the park up to the existing wall at the northwest corner. Section 2 spans from the wall to the eastern side of the park, including Transects 14 through 38.

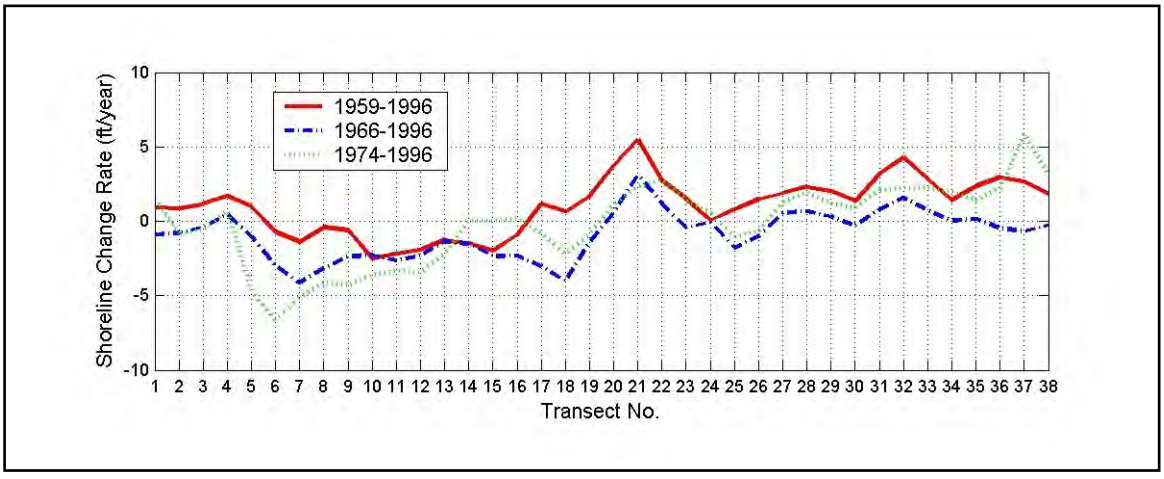
Table 5.5 summarizes the shoreline change rates, and Figure 5.11 shows the change in the rate along the shoreline for Bayswater State Park for the three periods. Section 1 and 2 shows differing rates for each end-point analysis. Section 1 has an average of -1.2 feet/year recession

rate for the vegetation line. Average advancement rates for Section 2 were determined 1.3 feet/year. The overall (AOR) averages of advancement rates were calculated as 0.0 feet/year, and 0.6 feet/year for the two reference features. These averages show that the northern shoreline of Bayswater State Park has advanced with contribution from the spit formations. Figure 5.11 also shows that the seawall on the northwest corner of the site seems to act as a nodal point where the erosional trend on the west changes to an accretional trend. This can also be seen visually in the aerial photography included in *Shoreline Stability Analysis Report for Jamaica Bay Ecosystem Restoration Project*, USACE, 2002. Unlike the Brant Point and Dubos Point Sites, shoreline change was accretionary for the period from 1959 to 1966. This period, therefore, helped to offset some of recession rates for the remaining periods. Consequently, it is reasonable to assume that as a whole the Bayswater State Park site has been on average dynamically stable since 1959.

Table 5.5. Average Shoreline Change Rates for Bayswater State Park

	Period	Vegetation Line (feet/yr)		
		Section 1 (Transect No. 1-13)	Section 2 (Transect No. 14-38)	Combined Average (Section 1-2)
End-point Averaging	1959-1996	-1.1	3.3	1.9
	1966-1996	-1.6	0.0	-0.5
	1974-1996	-0.9	0.8	0.3
AVERAGE (AOR)		-1.2	1.3	0.6

Figure 5.11. Shoreline Change Rates (End-Point Averaging) along the Bayswater State Park Site



5.6.3 Dubos Point

Once a tidal marsh, Dubos Point was partially surrounded with a bulkhead and filled to allow development along the shoreline in the first quarter of the 20th century (USACE, 2002). Over the years, this bulkhead altered the sediment transport pattern around the Dubos Point. Erosion along the west bulkhead of Dubos Point was noted as a result of the deformation of the structure. Some portion of the bulkhead still remains today and has a variable effect on the shoreline process around Dubos Point. Dredging activities were also noted around the filled area where the sediment transport patterns are expected to be impacted.

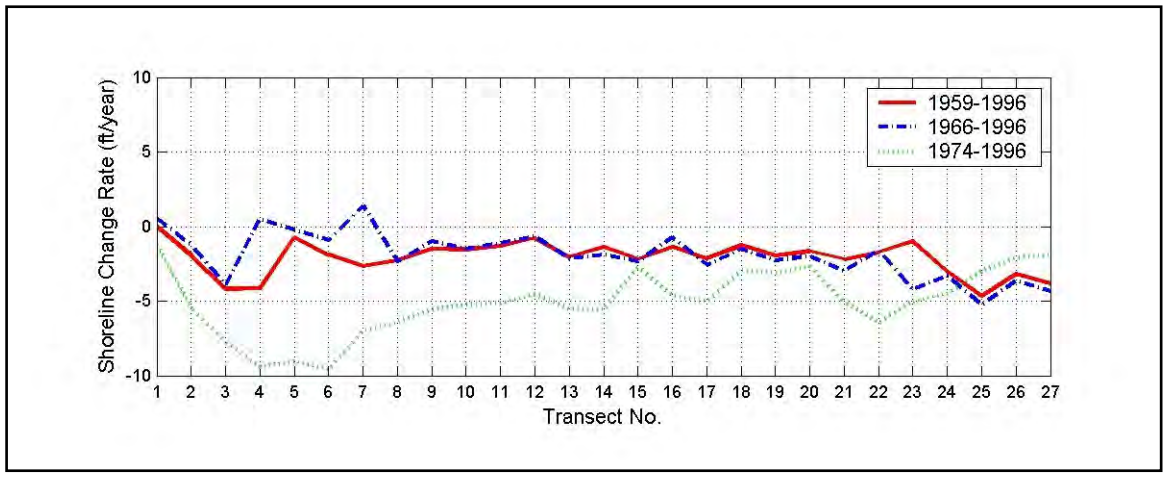
Dubos Point was analyzed in two sections, the natural shoreline composed of the large tidal flats and/or ditches along the beach (Section 1) and the bulkhead area (Section 2). Section 1 (Transects 1 through 7) also covers the area to the west of the Dubos Point. Section 2 includes the Transect lines from 8 through 27 for the remaining part of the Dubos Point shoreline.

Table 5.6 summarizes the shoreline change rates, and Figure 5.12 shows the change in the rate along the shoreline for the Dubos Point for the three periods. The shoreline recession rate is significantly higher for the period of 1974-1996 while significant accretion is noted in the 1966-1974 periods, similar to what was observed at Brant Point. Section 1 has an average of -3.4 feet/year recession rate at the vegetation line. The average recession rate for Section 2 was determined to be -2.9 feet/year. Similar to Brant Point, recession rates for the periods 1959-1996, and 1966-1996 were approximately less than half the rates for the period of 1974-1996. This is mainly due to an accretionary period of 1966-1974, which reduces the long-term average recession rates. The combined average of recession rate was calculated to be -3.0 feet/year. Consequently, it is reasonable to assume that the Dubos Point shoreline retreated at a rate of about -3.0 feet/year since 1959 based on the vegetation line reference feature.

Table 5.6. Average Shoreline Change Rates for Dubos Point.

	Period	Vegetation Line (feet/yr)		
		Section 1 (Transect No. 1-7)	Section 2 (Transect No. 8-27)	Combined Average (Section 1-2)
End-point	1959-1996	-2.2	-2.1	-2.1
	1966-1996	-0.9	-2.1	-1.9
	1974-1996	-7.1	-4.6	-5.1
AVERAGE (AOR)		-3.4	-2.9	-3.0

Figure 5.12. Shoreline Change Rates (End-Point Averaging) along the Dubos Point Site.



5.6.4 Brant Point

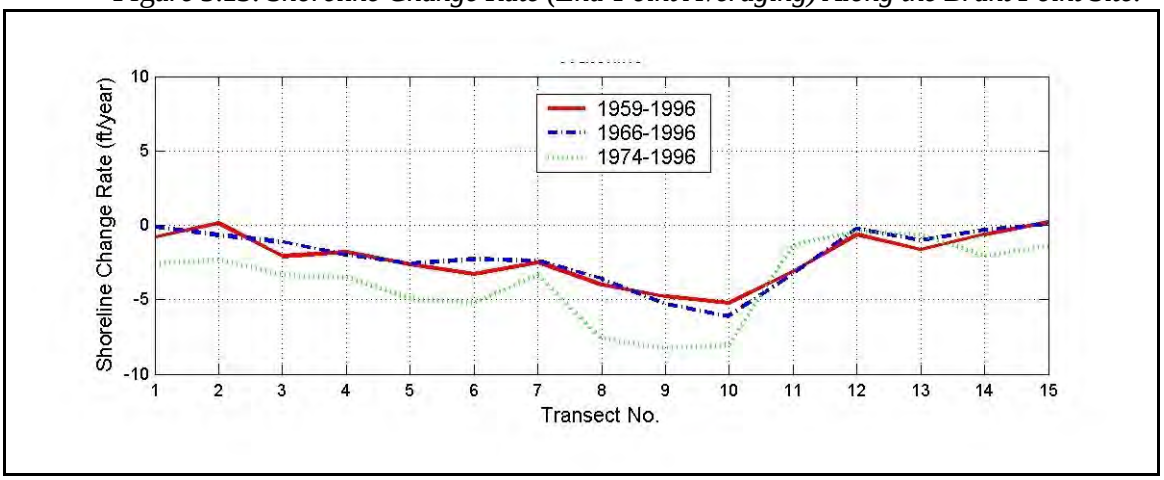
The Brant Point shoreline has exhibited long-term shoreline recession since the early 1900's (USACE, 2002). For the purposes of this report, Brant Point was divided into two sections due to northerly and northwesterly exposures to wave attack as well as the different shoreline characteristics. Section 1 span from Transect Line 1 through 9 on the west side, and Section 2 spans from Transect 10 through 14 on the north side of the Brant Point. Section 1 shoreline consists of natural material with deposits of shells, and exposed organic clay layers along the shoreline. Portions of the north face of the Brant Point (Section 2) shoreline consist of a riprap edge where the shoreline is locally armored with broken concrete slabs. This armoring protects the shoreline from wave attack; therefore, historical recession rates at the north side could be expected to be less than the west side of the shoreline. A tombolo, created by an abandoned barge founded along the west side (Section 1) of Brant Point, was not included into the rate calculations. This tombolo existed only on 1996 aerial.

Table 5.7 summarizes the shoreline change rates, and Figure 5.13 shows the change in the rate along the shoreline for the three periods. Section 1 and 2 shows differing rates for each end-point analysis corresponding to different wave exposures. Section 1 has an average of - 4.3 feet/year recession rate. The average recession rates for Section 2 were determined to be -2.4 feet/year. Recession rates for the periods 1959-1996, and 1966-1996 were approximately half the rates for the period of 1974-1996, especially for Section 1. This is mainly due to an accretionary period from 1966 to 1974, which reduces the long-term average recession rates. The combined average of recession rate was calculated as -2.6 feet/year. Consequently, it is reasonable to assume that the Brant Point shoreline has retreated at a rate of about -3.0 feet/year since 1959.

Table 5.7. Average Shoreline Change Rates for Brant Point

	Period	Vegetation Line (feet/yr)		
		Section 1 (Transect No. 1-9)	Section 2 (Transect No. 10-14)	Combined Average (Section 1-2)
End-point Averaging	1959-1996	-3.4	-2.3	-2.5
	1966-1996	-3.5	-2.3	-2.5
	1974-1996	-6.0	-2.7	-3.8
AVERAGE (AOR)		-4.3	-2.4	-3.0

Fig*ure 5.13. Shoreline Change Rate (End-Point Averaging) Along the Brant Point Site.*



5.7 Slope Stability Analysis

The overall slope stability was assessed for five of the sites: Paerdegat Basin, Fresh Creek, Brant Point, Dubos Point and Bayswater State Park. The goal of the analysis was to identify any areas within the sites where slopes may be unstable due to steep slopes, weak soil strata and/or exposure to high tidal velocities. For the purposes of this analysis the following data were analyzed:

- Historic and recent shoreline photographic documentation; (USACE 2002)
- Project survey topography and bathymetry data (Spring 2002);
- Velocity data developed by HydroQual, Inc. (USACE 2003)
- Geotechnical data (grain size distribution) from the HTRW testing results (USACE, 2003).

In general, there does not appear to be any areas of significant slope instability at any of the sites. Slopes are generally 1V:4H or shallower and average velocities are generally less than 1 foot per

second (fps), the maximum permissible near bottom channel velocities for fine sand (ASCE, 1995). A description of the findings at each site is presented in the following sections. The, figures showing the slopes along the shorelines of the five sites are included in Appendix H (Shoreline Slope Stability Analysis Figures).

5.7.1 Paerdegat Basin

The shoreline slope stability analysis for Paerdegat Basin showed generally stable slopes with most slopes shallower than 1V:4H. Average velocities for incoming tides ranged from 0.1 fps to 0.4 fps and average velocities for outgoing tides ranged from 0.1 fps to 0.4 fps. Geotechnical data indicates that the upper most 10 to 12 feet of material in the area consists of fine to coarse sands and general fill/debris (glass, paper brick, etc.), which is generally underlain by an older organic silty clay meadow mat strata.

The shoreline slope analysis identified a few isolated areas where the slopes were in the 1V:2H range. These areas should be investigated further in the field. The steeper slope areas were located mostly along the southern shoreline and near the entrance of the basin.

5.7.2 Fresh Creek

The shoreline slope stability analysis for Fresh Creek showed generally stable slopes with most slopes shallower than 1V:4H. Average velocities for incoming tides ranged from 0.6 fps to 1.1 fps and average velocities for outgoing tides ranged from 0.4 fps to 1.0 fps. Geotechnical data indicates that the upper most 5 to 26 feet of material in the area consists of fine to coarse sands and general fill/debris, which is generally underlain by an older organic silty clay meadow mat strata.

The shoreline slope analysis identified a few isolated areas where the slopes were in the 1V:2H range. These areas should be investigated further in the field. Like Paerdegat basin, the steeper slope areas were located mostly along the southern shoreline.

5.7.3 Bayswater State Park

The shoreline slope stability analysis for Bayswater State Park showed generally stable slopes with most slopes shallower than 1V:4H. Average velocities for incoming tides ranged from 0.1 fps to 0.3 fps and average velocities for outgoing tides ranged from 0.0 fps to 0.5 fps. Geotechnical data indicates that the upper most 5 to 12 feet of material in the area consists of fine to coarse sands and general fill/debris, which is generally underlain by an older organic silty clay meadow mat strata.

The shoreline slope analysis identified a few isolated areas where the slopes were in the 1V:2H to 1V:1H range. These areas should be investigated further in the field. The steeper slope areas were located mostly along the northern shoreline and seem to occur along the vegetated edge of the shoreline.

5.7.4 Dubos Point

The shoreline slope stability analysis for Dubos Point showed stable slopes with all slopes shallower than 1V:3H and most slopes shallower than 1V:4H. Average velocities for incoming tides ranged from 0.0 fps to 0.3 fps and average velocities for outgoing tides ranged from 0.0 fps to 0.4 fps. Geotechnical data indicates that the upper most 5 to 7 feet of material in the area consists of fine to coarse sands and general fill/debris, which is generally underlain by an older organic silty clay meadow mat strata.

No unstable slopes were identified at the Dubos Point site.

5.7.5 Brant Point

The shoreline slope stability analysis for Brant Point showed generally stable slopes with most slopes shallower than 1V:4H. Only one isolated area near the southern end of the shoreline showed a slope in the 1V:2H range. Average velocities for incoming tides ranged from 0.3 fps to 0.5 fps and average velocities for outgoing tides ranged from 0.3 fps to 0.8 fps. Geotechnical data indicates that the upper most 4 to 6 feet of material in the area consists of fine to coarse sands and general fill/debris, which is underlain by a 1 to 3 feet thick peat mat strata, which is in turn underlain by a gray fine to medium sand/clay layer.

No unstable slopes were identified at the Brant Point site.

5.5 Wave Analysis

Wave-induced effects are one of the primary factors affecting sediment transport processes in a coastal region. Waves generated by winds, as well as waves generated by the vessels traveling along the navigational channels, were considered for the sites under investigation. Vessel generated waves are of particular interest due to the potentially high volume of ship traffic passing by each site everyday.

5.5.1 Wind Generated Wave Analysis

Site-specific wave conditions (height, period, and direction) at Dead Horse Bay, Paerdegat Basin, Fresh Creek, Hawtree Point, Bayswater State Park, Dubos Point, and Brant Point were determined using local wind data and a series of analytical models. A detailed description of the procedures used to compute wave characteristics at each of the site is presented in this section.

Bathymetric information for the area was obtained through National Oceanographic & Atmospheric Administration (NOAA) chart (12350), and through survey transect data collected by this study in Spring 2002.

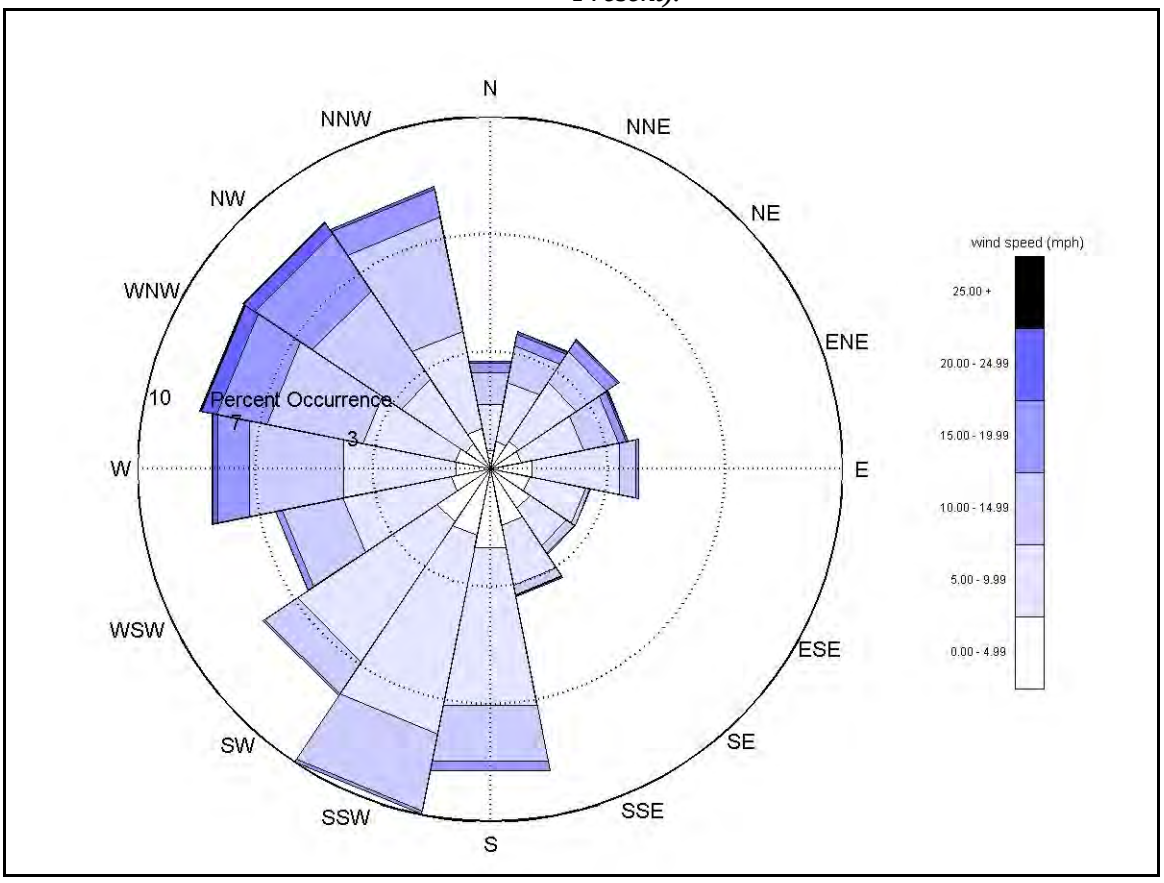
Winds blowing across Jamaica Bay generate waves that will impact the project sites. Due to the restricted nature of the Bay, the major factors affecting the magnitude and period of the waves

are the fetch length, average depth, wind speed, and wind duration. Sixteen possible wind directions were considered to determine the wind-generated waves for the analysis.

Local, historic wind data collected at JFK Airport (spanning from early 1980's to present) was obtained from the National Climatic Data Center (NCDC). Additional information utilized during the present study included an earlier study (USACE, 1981) that utilized the JFK airport data as well as the some general information provided in the Coastal Engineering Manual (CEM) (USACE 2002).

Overall wind conditions during the 18-year time period for JFK Airport are presented in Figure 5.14, which shows the distribution of wind speed (mph) data (illustrated using a wind rose plot). The color-coded sidebar indicates the magnitude of wind speed, the circular axis represents the direction of wind approach relative to North (North being 0 degrees), and the extending radial lines indicate percent occurrence within each magnitude and directional band. The most common direction of wind approach, as well as the approach direction of a significant portion of the winds, is from the southerly and northerly components of westerly directions.

Figure 5.14. Wind Rose Plot of Resultant Wind Speed and Direction for JFK Wind Data (1984 to Present).



To determine the extreme wave conditions for design considerations, it is necessary to associate extreme wind conditions with design return period(s). Table 5.8 summarizes the extreme wind

speeds determined for this study by considering the physically possible directions. The predominant wind directions match with the directions in the wind data collected.

The proper averaging time for design and planning considerations varies dramatically as a function of wind speed and fetch length (USACE, 2002). Based on the guidance provided in the CEM, 5-, 15- and 15-min averaging time intervals were utilized for 50-year, 20-year, and 10-year winds, respectively.

Table 5.8. Extreme Wind Speeds

Return Period	Wind Speed (mph)	Averaging time
50-year	75	5-min
20-year	59	15-min
10-year	52	15-min

The waves generated by the wind data summarized in Tables 5.9 through 5.18 were predicted using a computer model developed by the USACE. This computer model is part of the Automated Coastal Engineering System (ACES), published by the Coastal Engineering Research Center (USACE, 1992). The program, entitled Wind Speed Adjustment and Wave Growth, provides simplified estimates for wave growth over open-water and restricted fetches, such as Jamaica Bay, in both deep and shallow water. The ACES model addresses only wind-generated waves, and does not account for the effects of refraction, diffraction, and non-linear effects.

Wind data, along with the geometry and average water depth of the fetch, is required input to the ACES program. The fetch, or distance over which wind acts on the water, is restricted in Jamaica Bay, which in turn limits the wave generation. When all other factors are kept constant, longer fetches will generate larger waves. Therefore, each wind condition input into ACES takes into account the restricted geometry and all the fetch lengths when calculating the associated wave conditions. That is, a short fetch wind direction may generate larger waves if radially close to a longer fetch direction, other conditions being equal. Additionally, an iterative approach was used to obtain maximum fetch-limited wave conditions during the modeling process, when dealing with averaging schemes as well as the storm duration. Standard ACES output includes a spectral significant (modal) wave height (H_{mo}), peak period (T_p), and a mean wave direction (MWD) for each of the fetch bands.

Fetch directions and related information corresponding to the specific sites under investigation, as well as results of the wind-generated wave analysis for the all sites, are presented below.

5.5.1.1 Dead Horse Bay – North and South

The spectral significant wave height (H_{mo}), the peak period (T_p), and mean wave direction resulting from the ACES predictions for Dead Horse Bay – North and South are shown in Tables X and X (Dead horse Bay – North and South Wind Generated Wave Results). These results

correspond to two representative (reference) locations along the North and South shorelines. Figure 5.15 shows the fetch directions for wind wave generation. Three different sets of results are presented corresponding to design return periods of 50-year, 20-year and 10-year respectively. In general, for the Dead Horse Bay – North Site:

- The model predicts that the maximum waves will be generated when the winds are blowing from SW corresponding to longest fetch direction.
- The modal wave height was estimated to be 5.4 feet, 4.7 feet, and 4.3 feet for the 50-year, 20-year and 10-year wind speeds, respectively.
- Peak periods were 4.4 sec, 4.1 second and 3.9 second for the 50-year, 20-year and 10-year return-periods, respectively.
- Mean wave directions were estimated to be between 220 and 230 degrees (measured clockwise from true North) for northwesterly fetch directions.
- Southwesterly fetches will generate about 40% larger waves and longer periods than southeasterly fetches.

In general, for the Dead Horse Bay – South Site:

- The model predicts that the maximum waves will be generated when the winds are blowing from west-southwest (WSW) corresponding to longest fetch direction.
- The modal wave height was estimated to be 6.9 feet, 5.6 feet and 5.0 feet for the 50-year, 20-year and 10-year wind speeds, respectively.
- Peak periods were 5.5 sec, 4.7 sec, and 4.5 second for the 50-year, 20-year and 10-year return-periods, respectively.
- Mean wave directions were estimated to be between 245 and 250 degrees (measured clockwise from true North) for northeasterly fetch directions.
- Southwesterly fetches will generate about 100% larger waves and longer periods than southeasterly fetches.

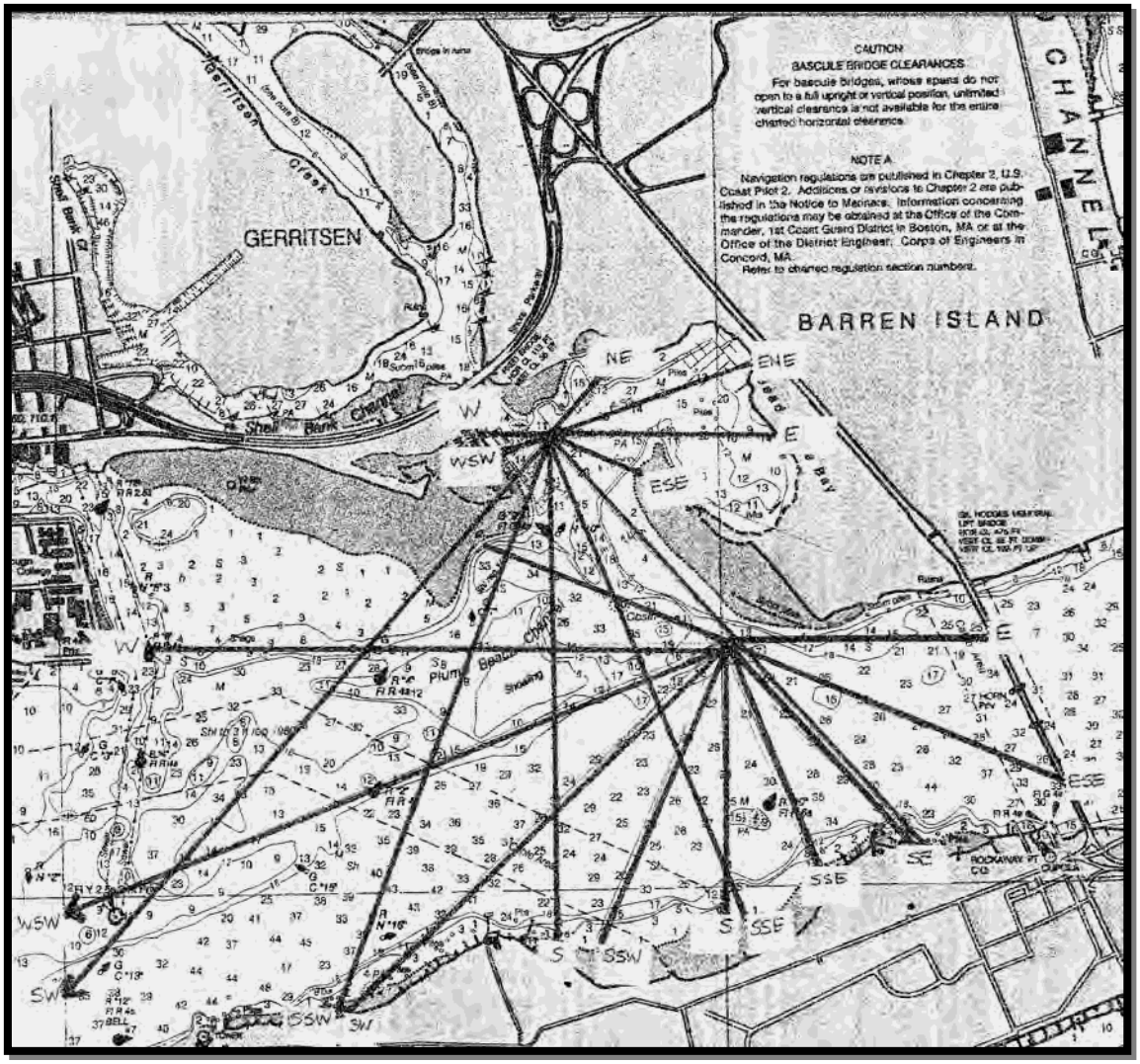
Table 5.9. Dead Horse Bay North - Wind Generated Wave Results.

Fetch		Fetch Length	Depth	Wave Characteristics								
				50-year			20-year			10-year		
				Height	Period	MWD	Height	Period	MWD	Height	Period	MWD
No.	Direction	(mi)	(feet)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)
1	N											
2	NNE											
3	NE	0.20	15	2.6	2.7	70	2.2	2.5	70	1.9	2.4	70
4	ENE	0.55	20	2.7	2.8	76	2.3	2.6	76	2.0	2.4	76
5	E	0.60	15	3.6	3.3	133	3.1	3.1	133	2.7	2.9	133
6	ESE	0.25	20	3.9	3.4	137	3.3	3.2	137	2.9	3.0	137
7	SE	1.40	10	3.5	3.3	140	3.0	3.1	140	2.6	2.9	140
8	SSE	1.30	15	5.2	4.2	216	4.5	3.9	216	4.0	3.7	216
9	S	1.25	15	5.4	4.4	220	4.7	4.1	220	4.2	3.8	220
10	SSW	1.50	15	5.4	4.4	222	4.7	4.1	222	4.3	3.9	222
11	SW	5.00	10	5.4	4.4	224	4.7	4.1	224	4.3	3.9	224
12	WSW	0.10	10	4.5	4.2	226	4.0	3.9	226	3.6	3.7	226
13	W	0.10	10	4.5	4.2	228	3.9	4.0	228	3.6	3.7	228
14	WNW											
15	NW											
16	NNW											

Table 5.10. Dead Horse Bay South- Wind Generated Wave Results.

Fetch		Fetch Length	Depth	Wave Characteristics								
				50-year			20-year			10-year		
				Height	Period	MWD	Height	Period	MWD	Height	Period	MWD
No.	Direction	(mi)	(feet)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)
1	N											
2	NNE											
3	NE											
4	ENE											
5	E	0.40	20	2.7	2.8	112	2.3	2.6	112	2.0	2.4	112
6	ESE	0.60	25	2.9	2.9	127	2.4	2.7	127	2.1	2.5	127
7	SE	0.70	30	3.0	2.9	135	2.5	2.7	135	2.2	2.6	135
8	SSE	0.60	30	3.2	3.0	178	2.6	2.8	178	2.3	2.7	178
9	S	0.80	30	4.5	4.0	241	3.5	3.6	241	3.0	3.3	241
10	SSW	0.95	25	6.4	4.8	244	5.1	4.3	244	4.4	4.0	244
11	SW	1.10	25	6.7	5.4	246	5.4	4.7	246	4.8	4.4	246
12	WSW	12.00	15	6.9	5.5	248	5.6	4.7	248	5.0	4.5	248
13	W	1.70	15	6.7	5.4	249	5.4	4.7	249	4.8	4.4	249
14	WNW	1.30	10	4.0	4.3	251	3.4	3.9	251	3.0	3.6	251
15	NW											
16	NNW											

Figure 5.15 Fetch Directions for Dead Horse Bay



5.5.1.2 Bayswater State Park

The spectral significant wave height (H_{mo}), the peak period (T_p), and mean wave direction resulting from the ACES predictions for Bayswater State Park are shown in Tables 5.11 and 5.12. These results correspond to two representative (reference) locations along the Bayswater State Park shoreline. The first reference point was located on the west/northwest side and the second reference point was located on the north face of the Bayswater shoreline. The north reference point is naturally more protected than the west/northwest reference point. Figure 5.16 shows the fetch directions for wind wave generation. Three different sets of results are presented corresponding to design return periods of 50-year, 20-year and 10-year respectively. In general, for the west/northwest reference location of Bayswater State Park:

- The model predicts that the maximum waves will be generated when the winds are blowing from NNW corresponding to longest fetch direction.
- The modal wave height was estimated to be 3.8 feet, 3.0 feet, and 2.6 feet for the 50-year, 20-year and 10-year wind speeds, respectively.
- Peak periods were 3.3 sec, 3.0 second and 2.8 second for the 50-year, 20-year and 10-year return-periods, respectively.
- Mean wave directions were estimated to be between 333 and 339 degrees (measured clockwise from true North) for northwesterly fetch directions.
- Northwesterly fetches will generate about 10% larger waves and shorter periods than northeasterly fetches.

In general, for the north reference location of Bayswater State Park:

- The model predicts that the maximum waves will be generated when the winds are blowing from north-northeast (NNE) corresponding to longest fetch direction.
- The modal wave height was estimated to be 3.3 feet, 2.6 feet and 2.2 feet for the 50-year, 20-year and 10-year wind speeds, respectively.
- Peak periods were 3.1 sec, 2.7 sec, and 2.6 second for the 50-year, 20-year and 10-year return-periods, respectively.
- Mean wave directions were estimated to be between 20 and 24 degrees (measured clockwise from true North) for northeasterly fetch directions.
- Northwesterly fetches will generate about 10% smaller waves and shorter periods than northeasterly fetches.

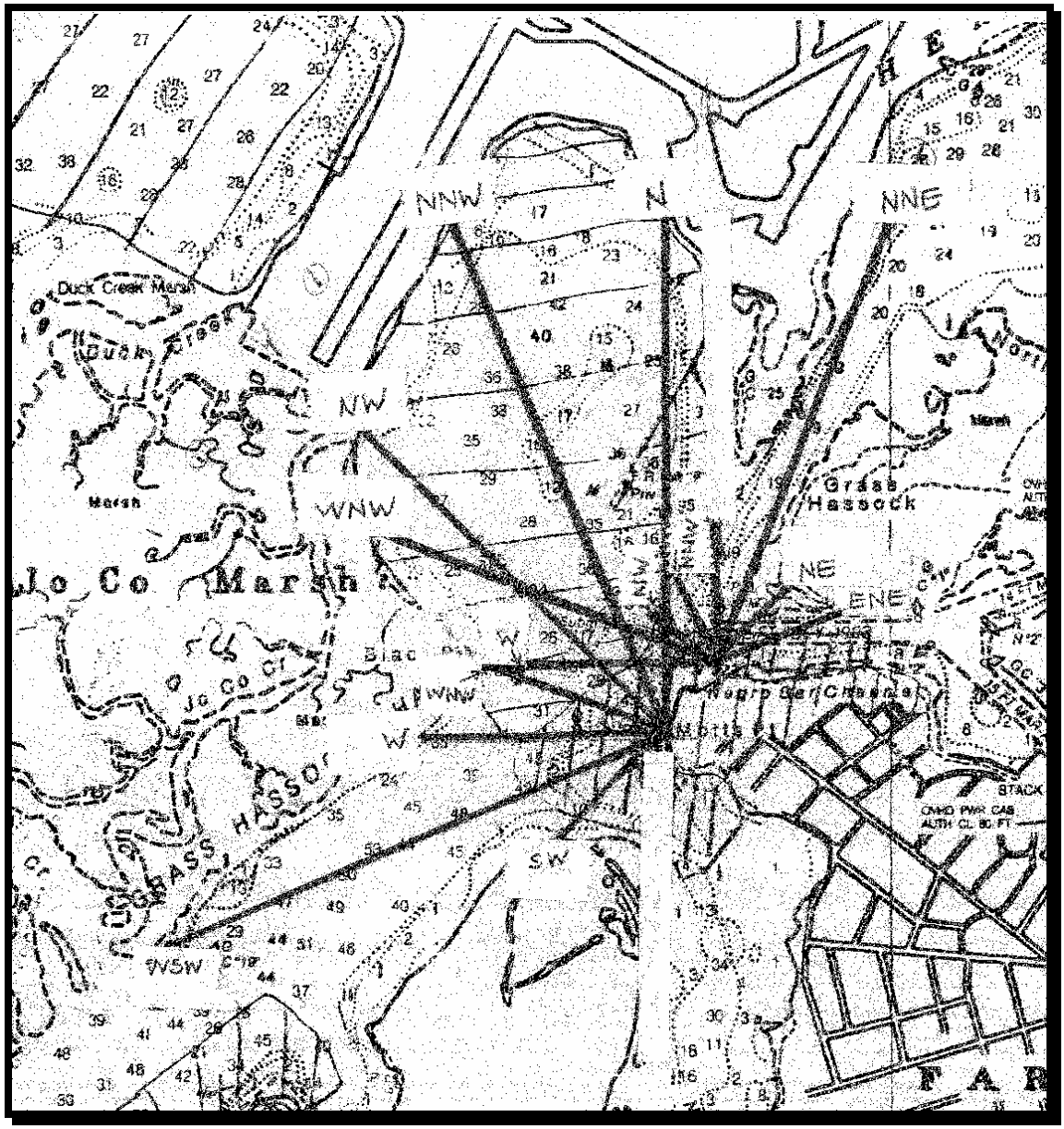
Table 5.11 Bayswater State Park Wind Generated Wave Results for the West-Northwest Reference Point

Fetch		Fetch Length	Depth	Wave Characteristics								
				50-year			20-year			10-year		
				Height	Period	MWD	Height	Period	MWD	Height	Period	MWD
No.	Direction	(mi)	(feet)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)
1	N	0.80	16	3.5	3.2	345	2.7	2.9	345	2.4	2.7	345
2	NNE											
3	NE											
4	ENE											
5	E											
6	ESE											
7	SE											
8	SSE											
9	S											
10	SSW	0.15	16	2.6	2.8	244	2.0	2.5	244	1.8	2.3	244
11	SW	0.22	16	3.2	3.1	246	2.5	2.7	246	2.2	2.6	246
12	WSW	0.90	42	3.6	3.3	249	2.8	2.9	249	2.5	2.7	249
13	W	0.40	34	3.4	3.2	251	2.6	2.8	251	2.3	2.7	251
14	WNW	0.30	26	3.1	3.0	321	2.4	2.7	321	2.1	2.6	321
15	NW	0.71	30	3.6	3.3	333	2.8	2.9	333	2.5	2.7	333
16	NNW	0.95	26	3.8	3.3	339	3.0	3.0	339	2.6	2.8	339

Table 5.12 Bayswater State Park Wind Generated Wave Results for the North Reference Point.

Fetch		Fetch Length	Depth	Wave Characteristics								
				50-year			20-year			10-year		
				Height	Period	MWD	Height	Period	MWD	Height	Period	MWD
No.	Direction	(mi)	(feet)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)
1	N	0.25	16	3.0	3.0	20	2.4	2.6	20	2.1	2.5	20
2	NNE	0.78	21	3.3	3.1	22	2.6	2.7	22	2.2	2.6	22
3	NE	0.16	16	3.0	2.9	24	2.3	2.6	24	2.1	2.5	24
4	ENE	0.23	16	2.4	2.7	27	1.9	2.4	27	1.6	2.2	27
5	E											
6	ESE											
7	SE											
8	SSE											
9	S											
10	SSW											
11	SW											
12	WSW											
13	W	0.39	34	2.9	2.9	287	2.3	2.6	287	2.0	2.4	287
14	WNW	0.62	26	3.0	2.9	290	2.3	2.6	290	2.0	2.5	290
15	NW	0.12	30	2.8	2.8	293	2.2	2.5	293	1.9	2.4	293
16	NNW	0.16	26	2.5	2.7	18	1.9	2.4	18	1.7	2.3	18

Figure 5.16 Fetch Directions for Bayswater State Park.



5.5.1.3 Dubos Point

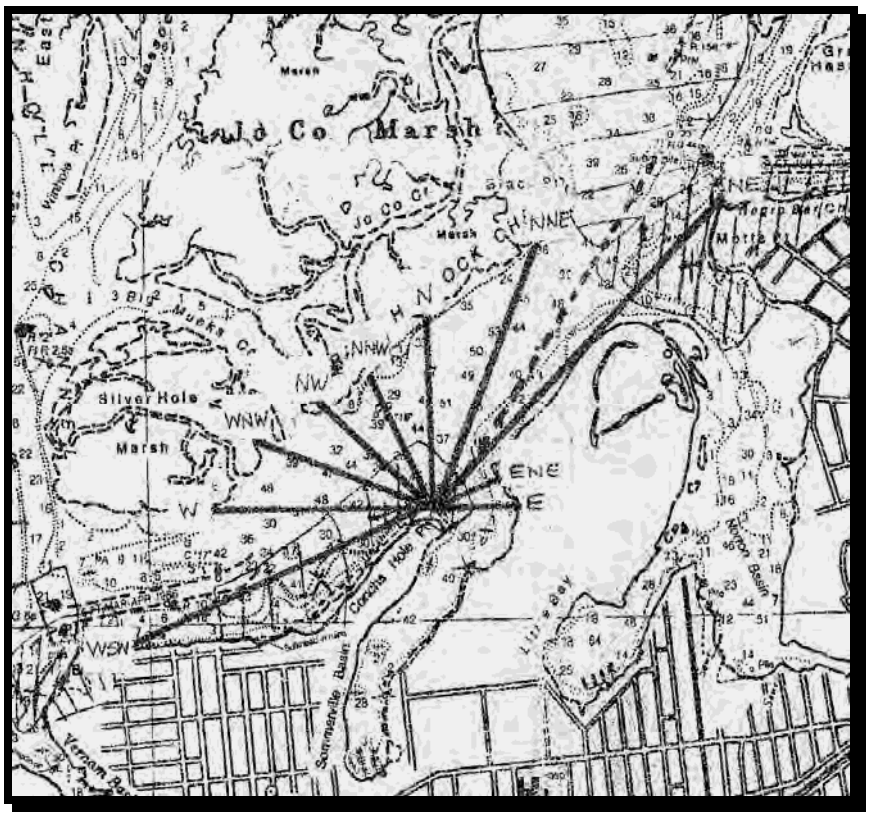
The spectral significant wave height (H_{mo}), the peak period (T_p), and mean wave direction resulting from the ACES predictions for Dubos Point are shown in Table 5.13. These results correspond to a representative (reference) location along the Dubos Point shoreline. Figure 5.17 shows the fetch directions for wind wave generation. Three different sets of results are presented corresponding to design return periods of 50-, 20-, and 10-year winds, respectively. In general, for the Dubos Point Site:

- The model predicts that the maximum waves will be generated when the winds are blowing from northeast (NE), and north-northeast (NNE) which corresponds to longest fetch direction.
- The modal wave height was estimated to be 3.6 feet, 2.8 feet and 2.5 feet for the 50-year, 20-year and 10-year wind speeds, respectively.
- Peak periods were 3.3 sec, 2.9 second and 2.8 second for the 50-year, 20-year and 10-year wind speeds, respectively.
- Mean wave directions were estimated to be between 40 and 45 degrees (measured clockwise from true North) for northeasterly fetch directions.
- Northwesterly fetches will generate about 20% smaller waves and shorter periods than northeasterly fetches

Table 5.13. Dubos Point Wind Generated Wave Results.

Fetch		Fetch Length	Depth	Wave Characteristics								
				50-year			20-year			10-year		
				Height	Period	MWD	Height	Period	MWD	Height	Period	MWD
No.	Direction	(mi)	(feet)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)
1	N	0.39	42	3.0	3.0	33	2.3	2.7	33	2.0	2.5	33
2	NNE	0.63	42	3.6	3.3	40	2.8	2.9	40	2.5	2.8	40
3	NE	0.95	16	3.6	3.2	42	2.8	2.9	42	2.5	2.7	42
4	ENE	0.16	16	3.3	3.1	45	2.6	2.8	45	2.3	2.6	45
5	E	0.24	16	2.6	2.8	48	2.0	2.5	48	1.8	2.4	48
6	ESE											
7	SE											
8	SSE											
9	S											
10	SSW											
11	SW											
12	WSW	0.62	34	3.0	3.0	255	2.4	2.6	255	2.1	2.5	255
13	W	0.47	36	3.0	2.9	255	2.3	2.6	255	2.0	2.5	255
14	WNW	0.53	42	2.9	2.9	289	2.3	2.6	289	2.0	2.4	289
15	NW	0.30	42	2.7	2.8	294	2.1	2.5	294	1.8	2.4	294
16	NNW	0.31	42	2.4	2.7	14	1.9	2.4	14	1.6	2.3	14

Figure 5.17 Fetch Directions for Dubos Point.



5.5.1.4 Brant Point

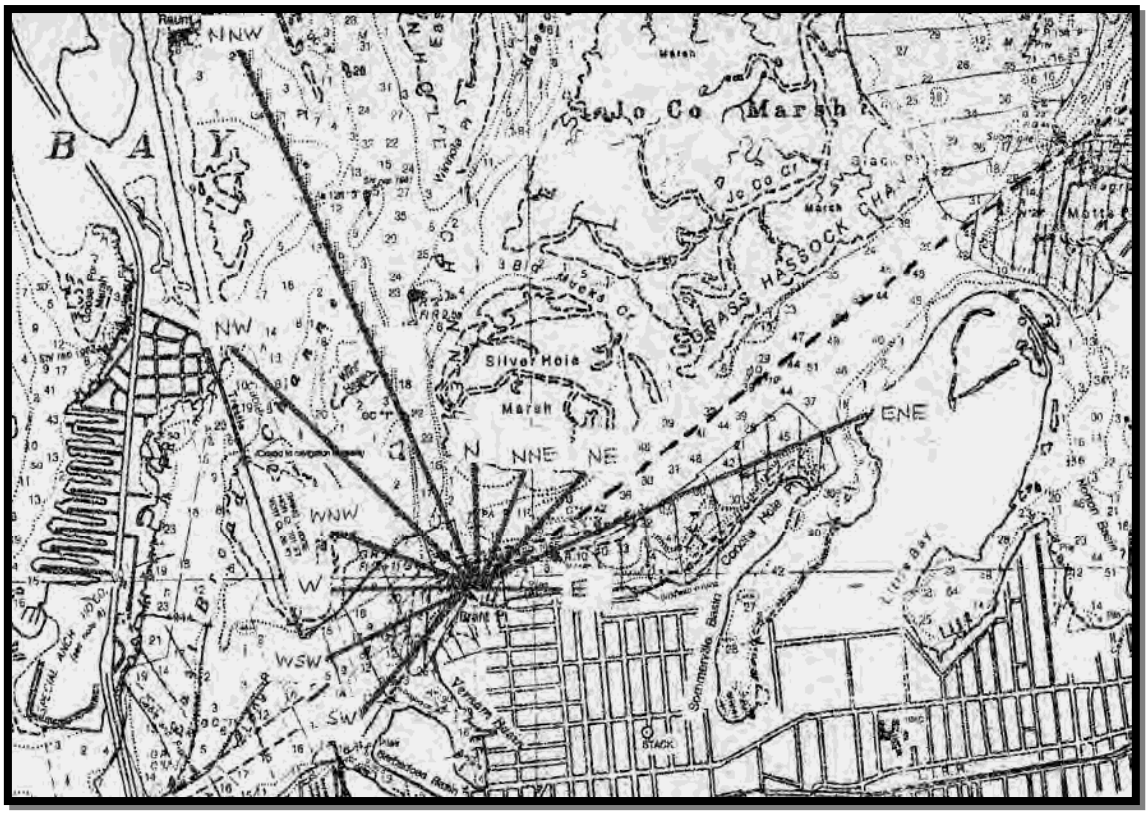
The spectral significant wave height (H_{mo}), the peak period (T_p), and mean wave direction resulting from the ACES predictions for Brant Point are shown in Table 5.14. These results correspond to a representative (reference) location along the Brant Point shoreline. Figure 5.18 shows the fetch directions for wind wave generation. Three different sets of results are presented corresponding to design return periods of 50-, 20-, and 10-year winds, respectively. In general, for the Brant Point Site:

- The model predicts that the maximum waves will be generated when the winds are blowing from east-northeast (ENE) corresponding to longest fetch direction.
- The modal wave height was estimated to be 3.9 feet, 3.0 feet and 2.7 feet for the 50-year, 20-year and 10-year wind speeds, respectively.
- Peak periods were 3.4 sec, 3.0 sec, and 2.8 second for the 50-year, 20-year and 10-year return-periods, respectively.
- Mean wave directions were estimated to be between 64 and 68 degrees (measured clockwise from true North) for northeasterly fetch directions.
- Northwesterly fetches will generate about 10% smaller waves and shorter periods than northeasterly fetches.

Table 5.14 Brant Point Wind Generated Wave Results

Fetch		Fetch Length	Depth	Wave Characteristics								
				50-year			20-year			10-year		
				Height	Period	MWD	Height	Period	MWD	Height	Period	MWD
No.	Direction	(mi)	(feet)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)	(feet)	(sec)	(deg N)
1	N	0.31	21	2.7	2.8	329	2.1	2.5	329	1.9	2.4	329
2	NNE	0.31	16	2.9	2.9	62	2.3	2.6	62	2.0	2.5	62
3	NE	0.39	16	3.7	3.4	65	2.9	3.0	65	2.4	2.8	65
4	ENE	1.90	26	4.1	3.6	67	3.2	3.2	67	2.7	2.9	67
5	E	0.10	16	3.6	3.4	69	2.8	3.0	69	2.4	2.8	69
6	ESE											
7	SE											
8	SSE											
9	S											
10	SSW											
11	SW	0.38	16	2.4	2.6	232	1.9	2.3	232	1.7	2.2	232
12	WSW	0.38	21	2.5	2.6	244	1.9	2.4	244	1.7	2.2	244
13	W	0.32	21	2.6	2.8	309	2.0	2.5	309	1.8	2.3	309
14	WNW	0.39	21	3.2	3.0	313	2.5	2.7	313	2.2	2.6	313
15	NW	0.79	21	3.5	3.3	333	2.7	2.9	333	2.3	2.7	333
16	NNW	1.40	21	3.7	3.4	336	2.9	3.0	336	2.4	2.8	336

Figure 5.18 Fetch Directions for Brant Point.



5.5.2 Vessel Generated Wave Analysis

Considering the proximity of the navigational channels, as well as the volume of the traffic in these channels, vessel generated waves have the potential to severely impact the following sites: Brant Point, Dubos Point, and Bayswater State Park.

The movement of a boat hull through water produces wave fronts that propagate from both the bow and stern pressure distribution, along the length of the hull. The magnitude of the wave depends on the vessel speed, the hull surface geometry, and the channel cross-sectional shape (if the channel is relatively shallow and/or narrow). The wave pattern consists of diverging and transverse waves (ENV Report 4, 1997). The strongest waves are the diverging waves, obliquely propagating from the vessel at an angle of 35°. A typical train of waves will rarely exceed ten.

Each site was analyzed separately and the results are summarized in this section. Specific vessel information was obtained from Arthur Kill Ship Wave Study (USACE, 2002). Table5.15 lists the assumptions made for the physical characteristics of the tugboat and barges used for this study. Shortest distance from the navigational channel to a reference point along the shoreline was measured for each site. This distance varied with vessel type due to water depth limitations on vessel draft. Vessel characteristics were obtained through the recorded logs of the Arthur Kill (2002) study. Tugboats were recorded with cruising speeds from 3 knots up to 11 knots. A range of 8 to 12 knot vessel speeds were tested for tugboats to conservatively estimate the wave heights, whereas a vessel speed of 8 knot was tested for the larger barges. It was assumed that the

larger ships did not generate waves larger than that of tugboats and/or barges, as stated in the Arthur Kill (2002) study. Methodology outlined by Sorenson (1997) were utilized and compared to determine the wave heights and periods.

Table 5.15 Vessel Characteristics.

Vessel Type	Tug	Barge
Vessel Length, feet (L_v)	72	320
Vessel Beam, feet (B)	30	80
Vessel Draft, feet (D)	13	14
Vessel Speed, kt (V)	8-12	8
Vessel Displacement, tons (W)	400	11,000
Distance from Sailing Line, feet (x)	Varies	Varies
Water Depth, feet (d)	Varies	Varies

5.5.2.1 Bayswater State Park

At Bayswater State Park, the largest wave generated in the channel was 1.7 feet with a 1.1 second period corresponding to vessel speed of 12 knots. Larger ships or barges did not generate bigger waves as compared to the waves generated by tugboats. Table 5.16 summarizes the results for Bayswater State Park for waves generated by both tugboats and barges.

Table 5.16. Vessel Waves Generated at Bayswater State Park.

Vessel Speed	Distance to reference point	Vessel Generated Wave		
		Height	Period	Direction
(knots)	(feet)	(feet)	(sec)	(deg)*
Tugboat				
8	200	0.6	0.7	65
10	200	1.1	0.9	
12	200	1.7	1.1	
Barge				
8	500	0.8	0.7	65

*Wave orthogonal direction with respect to shoreline orientation

Conclusions

In summary, the size range of the vessel-generated waves is smaller than the locally generated wind waves. The angle of wave incidence and the frequency of occurrence are also different from the locally generated waves. While the boat waves only represent very short duration events (in the order of minutes), they occur daily or perhaps many times in a day versus individual storm events of several hour duration, but with the return periods of ten or more years.

5.5.2.2 Dubos Point

The largest wave generated in the channel was 2.1 feet with a 1.0 second period corresponding to vessel speed of 12 knots. As in Brant Point case, larger ships or barges did not generate bigger waves as compared to the waves generated by tugboats. Table 5.17 summarizes the results for Dubos Point for waves generated by both tugboats and barges.

Table 5.17. Vessel Waves Generated at Dubos Point.

Vessel Speed	Distance to reference point	Vessel Generated Wave		
		Height	Period	Direction
(knots)	(feet)	(feet)	(sec)	(deg)*
Tugboat				
8	400	0.7	0.7	35
10	400	1.4	0.9	
12	400	2.1	1.0	
Barge				
8	600	0.9	0.7	35

* Wave orthogonal direction with respect to shoreline orientation

5.5.2.3 Brant Point

The largest wave generated in the channel was 2.1 feet with a 1.1 second period corresponding to vessel speed of 12 knots. Larger ships or barges did not generate bigger waves as compared to the waves generated by tugboats, mainly due to their limited cruising speed along the channel. Table 5.18 summarizes the results for waves generated by both tugboats and barges for Brant Point.

Table 5.18. Vessel (Tugboat and Ship) Waves Generated at Brant Point.

Vessel Speed	Distance to reference point	Vessel Generated Wave		
		Height	Period	Direction
(knots)	(feet)	(feet)	(sec)	(deg)*
Tugboat				
8	300	0.7	0.7	35
10	300	1.4	0.9	
12	300	2.1	1.1	
Barge				
8	300	0.5	0.7	35

* Wave orthogonal direction with respect to shoreline orientation

5.6 Water Quality Modeling Results

Jamaica Bay is a heavily impacted estuary located within the boundaries of New York City. Some areas of Jamaica Bay and the basins that are tributary to it experience hypoxic or anoxic conditions. These low dissolved oxygen levels can have a profound effect on the biota that live within the bay. Two of the sites in JBERP, Paerdegat Basin and Fresh Creek, have large Sewage Treatment Plants and Combined Sewage Outfalls at the head of the creeks. A hydrodynamic/water quality model of Paerdegat Basin and Fresh Creek were developed in this study to assess how planned bathymetric alterations will affect habitat in these areas.

Five and six different scenarios were proposed and analyzed for Paerdegat Basin and Fresh Creek, respectively. The scenarios involved recontouring the bathymetry of the basin and creek to see its effect on water quality. The results of these model scenarios can be found in the *Daft Water Quality Modeling for the Jamaica Bay Ecosystem Restoration Project,* USACE March 2003.

This modeling analysis consisted of developing models for Paerdegat Basin and Fresh Creek to evaluate up to six bathymetric alteration scenarios in each tributary and their effect on habitat. The New York City Department of Environmental Protection (NYCDEP) has facility upgrade plans to abate combined sewer overflows (CSOs) at the Paerdegat and Fresh Creek sewage treatment plants. These improvements were considered in determining the scenarios, A North Channel Model (NCM) was created within the existing Jamaica Bay Eutrophication Model (JEM) (NYC DEP, 2002) which included both Paerdegat Basin and Fresh Creek, as well as Hendrix Creek and Bergen Basin. The alternatives that were analyzed are listed below. The scenarios (five scenarios in Paerdegat Basin and six scenarios in Fresh Creek) included bathymetric changes and the incorporation of the CSO facility plans at both of the tributaries. These scenarios were as follows:

Paerdegat Basin Evaluation
(1) Existing conditions with the natural sill in place,
(2) Existing conditions with CSO improvements,
(3) Existing conditions without the natural sill in place and with CSO improvements,
(4) Upstream half of the basin filled to MLW and the downstream half left alone, without the sill and with CSO improvements,
(5) Upstream half of the basin filled to 4 ft below MLW and the downstream half left alone, without the sill and with CSO improvements.

Fresh Creek Evaluation
(1) Existing conditions with the natural sill in place,
(2) Existing conditions with CSO improvements,
(3) Existing conditions without the natural sill in place and with CSO improvements,
(4) Upstream half filled to MLW, lower half as is, without the sill and with CSO improvements,
(5) Upstream half as is, lower half filled to 4 ft below MLW or as is (which ever is less), without the sill and with CSO improvements,
(6) Upstream half as is, lower half hued to 8 ft below MLW or as is (which ever is less), without the sill and with CSO improvements.

Due to the distance between the two tributaries and to save computational time, modifications were made to both tributaries and run at the same time. All of the runs were based on 1988 meteorological, tidal, and loading conditions. Bathymetric conditions were based on the latest available data. To

summarize the results of the NCM scenarios a series of tables were developed, presenting model results from each scenario for current velocity, shear stress and dissolved oxygen (DO) along the center channel of both Paerdegat Basin and Fresh Creek. The results are for two critical DO months, July and August. These results can be found in USACE, March 2003 report. All tables referenced below can be found in Appendix E.

5.6.1 Paerdegat Basin

Table E-1 presents the maximum ebb and flood bottom current velocities computed for each scenario along the center channel of Paerdegat Basin during July and August. In general, this table shows that the bottom current velocities are very small, generally less than 5 cm/s. Also, the maximum flood tide velocity was greater than the maximum ebb tide velocity, except at the mouth and for scenarios that included filling portions of the basin. The various scenarios that were examined were designed to increase these velocities and induce greater flushing of the Basin. The facility plan had little impact on the velocities. Removing the sill at the mouth of the basin generally reduced the maximum velocities, especially at the head end where greater flushing is desired. Scenario 4 produced the highest velocities in the basin, but the lowest velocities at the head end. Scenarios 5 and 6 produced small changes in the velocities. These bathymetry and velocities changes had an effect on the bottom shear stress. The maximum computed bottom shear stresses during July and August in Paerdegat Basin are presented in Table E-2. A general rule of thumb is that at a shear stress of 1.0 dyne/cm2 results in the resuspension of the grained cohesive sediments. A medium size sand (0.5 rnm) would require a shear stress of approximately 2.5 dyne/cm2 before bed resuspension would occur. This table shows that under existing conditions, very little resuspension occurs, and this remains the case for most of the scenarios. The exception to this is scenario 4, which results in high shear stresses that would most likely result in a significant redistribution of bottom sediment. Table E-3 presents the average monthly shear stress. The values presented in this table indicate that on average most of Paerdegat Basin will remain depositional zones under the various conditions analyzed. There are possible exceptions kt a few segments under scenario 4 conditions, where the average shear stress is approximately 1.0 dyne/cm2 and would revent deposition. One of the more important parameters for determining habitat suitability is the dissolved oxygen concentration. Each of the scenarios developed were designed to improve DO levels in Paerdegat Basin. Table E-4 presents the model results for monthly average bottom water DO. The calibration scenario shows that the monthly average DO concentrations in Paerdegat Basin are quite low with concentrations less than 2.0 mg/L at the head end. Much of the basin is computed to have average DO concentrations less than 4.0 mg/L. Implementation of the Facility Plan improves DO conditions at the head end of the basin with diminishing improvement towards the mouth. Removing the sill at the mouth of the basin has minimal effect on the model results. Scenario 4 increases DO the upper portion of the basin significantly, but this scenario would most likely be eliminated from consideration due to the high shear stresses than develop. Scenario 5 also provides a significant DO improvement in Paerdegat Basin.

Table E-5 presents the minimum dissolved oxygen concentrations computed in Paerdegat Basin during July and August, respectively. The model results show, that despite the improvements in the average DO concentrations there may still be excursions into hypoxic conditions in the basin. Note that these results indicate very low concentrations at the mouth of the basin. It is very likely that these low concentrations at the mouth are due to conditions outside of Paerdegat Basin, so that improvements in Jamaica Bay itself are required before occasional low DO concentrations in the basin can be totally eliminated.

Table E-6 presents the monthly minimum of the daily average DO concentrations. This is accomplished by computing the daily average of the 24 hourly averages and taking the monthly minimum. The values in this table indicate that for scenarios 4 and 5 that the extreme low values shown in Table E-5 do not have a long duration. Further evidence for this is presented in Table E-7 which presents the percent of time that the DO concentration is computed to be greater than 3.0 mg/L. The 3.0 mg/L level is currently the proposed draft acute DO standard under consideration by the New York State Department of Environmental Conservation. While much of the basin is computed to have DO concentrations greater than 3.0 mg/L at or less than 50 percent of the time during July, in scenarios 4 and 5 that percentage increases to 75 percent or greater for most of the basin. The head end of the basin continues to have low DO levels for all of the scenarios. Based on the results of these modeling scenarios it appears that a hybrid version of scenarios 4 and 5 would result in the most improvement in Paerdegat Basin. In addition, some level of filling near the mouth of the basin may also improve water quality in the basin.

5.6.2 Fresh Creek

The maximum bottom layer flood and ebb velocities in Fresh Creek during July and August are presented in Table E-8. In general, the flood tide velocities are greater than then ebb tide velocities. Velocities are also on a whole smaller than those computed in Paerdegat Basin. Removal of the sill at the mouth of the creek does little to affect the velocities in the upper half of the creek and reduces the velocities at the mouth. Scenario 4 increases the velocities in the half of the creek except for the head. Scenarios 5 and 6 increase the maximum flood velocities to a small extent near the mouth, but the velocities are reduced in the upper half of the creek. The responses of the shear stresses to bathymetric alterations in Fresh Creek were similar to the responses in Paerdegat Basin (Table E-9). The shear stresses generally remained below 1.0 dyne/cm2 until the scenarios where portions of the creek were filled. When the creek was filled to ***MLW*** in the upper half (scenario 4), the shear stresses increased to as high as 4.1 dyne/cm2 during August. This shear stress would cause resuspension of material and bed loading of sandy material. Filling the lower portion of the creek in scenario 5 resulted in occasional shear stresses greater than 1.0 dyne/cm2. Table E-10 shows that the average shear stresses remain below 0.5 dyne/cm2 for all of the scenarios indicating
that the creek would remain a depositional area.

Table E-11 presents the monthly average DO concentration for July and August. The DO in Fresh Creek is computed be lowest at the head end and in the deeper portion near the mouth under calibration conditions. The facility plan results in improved DO along the entire creek with the largest improvements occurring in the upper portions. Removing the sill results in small changes in the average DO and the effect is slightly lower DO levels in most of the creek. Filling the upper portion of the creek results in higher DO concentrations in the upper half of the creek and slightly lower DO levels near the mouth of Fresh Creek. Filling the lower half of the creek has the opposite effect with improved DO near the mouth and slightly lower concentrations in portions of the upper end. The minimum DO concentrations, presented in Table E-12, are generally not as low as computed in Paerdegat Basin, although the head end is essentially anoxic in all of the scenarios. Each scenario generally results in higher minimum DO concentrations, but the DO levels do occasionally decline to hypoxic levels. Tables E-13 and E-14 present the minimum daily average DO and the percent of time
the DO concentration is computed to be greater than 3.0 mg/L, respectively. The tables show, that most of the improvement to the upper half of the creek is due to the implementation of CSO controls

and that filling the upper portion of the creek provides only a marginal improvement. The most effective scenario for increasing the DO concentration near the mouth is scenario 5. Under scenario 5 conditions Fresh Creek is computed to have a DO concentration greater than 3.0 mg/L greater than 90 percent of the time for most of the creek during July and August. The results indicate that some bathymetric alterations would improve the DO concentrations in Fresh Creek. In general, some level of filling near the mouth of the creek would improve DO levels and as a consequence aquatic habitat. Filling portions of Paerdegat Basin and Fresh Creek would mostly like result in bringing these tributaries closer to their historical depths and bring them back to a more natural state.

6. ANALYSIS AND DESIGN OF RESTORATION ALTERNATIVES

Alternatives at each site were developed based on site constraints, standard biological and physical parameters for salt marsh restoration, and other design guidelines developed during a series of planning/design team meetings. The basic alternative layouts were developed in accordance with the overall project goals of restoring the largest acreage of salt marsh possible, stabilizing the eroding and receding shorelines, and improving water quality without adversely affecting the existing wetlands. The basic, guiding ecological principals for salt marsh restoration were also used in the alternative designs.

Projects that involve creating or restoring wetlands are subject to a set of chemical, physical and biological design requirements. The first and foremost set of requirements is connected to the physiological limitations and environmental requirement for marsh vegetation establishment and growth, predominantly focusing on achieving the proper target elevations relative to the tide. Approximately three alternatives were created for each site. The evaluation of these alternatives can be found in the main report (USACE, 2005).

6.1 Design Criteria and Assumptions

The overall objective of the project is to restore the degraded ecology of the sites by restoring/creating wetland habitats and stabilizing the eroding and receding shorelines without adversely affecting the existing wetlands. General and site-specific design criteria for the project sites include the following:

1. The overall study area is defined as Jamaica Bay, a tidal waterway connected to the lower bay of New York Harbor by Rockaway Inlet. The bay is located 17 miles south and east of the Battery, New York City and is 8 miles long, 4 miles wide, and covers an area of approximately 26 square miles. Three of the eight specific project sites are located within Kings County (Brooklyn): Dead Horse Bay, Paerdegat Basin, Fresh Creek; four sites are located in Queens County (Queens) Hawtree Point, Bayswater State Park, Dubos Point, and Brant Point; and one site straddles the Brooklyn-Queens borough line: Spring Creek.
2. The project site plans shall maximize environmental benefits while minimizing the economic costs.
3. The project site plans shall decrease the predominance of and/or prevent the recolonization of invasive species.
4. The project site enhancement plans shall promote/improve tidal inundation, circulation, and flushing, where applicable (as it relates to a specific site).

5. Project site plans shall create uplands features to protect the existing and proposed wetlands, as well as provide transitional zones to the surrounding upland areas.
6. Where possible, project site plans shall include the reuse of excavated materials onsite.
7. To improve water quality at Paerdegat Basin and Fresh Creek, plans shall include the partial filling of the degraded water bodies to more closely reflect the historic tidal prism.
8. Designs shall provide for "equilibrium solutions," holding shoreline positions and not allowing for more erosion or accretion.
9. At Dead Horse Bay, Dubos Point, and Bayswater State Park, plans shall include training structures to minimize the sedimentation at the mouth of the inlet channel, as well as minimizing the downdrift effect of these structures.
10. For the shoreline stabilization measures at Dead Horse Bay – South, the Federal Emergency Management Agency's (FEMA) "540 rule" shall be considered in the design. The "540 rule" states that the minimum requirement for the cross-sectional area of the primary frontal dune, as measured perpendicular to the shoreline and above the 100-year stillwater flood elevation and seaward of the dune crest, is 540 square feet. This standard represents the minimal dune area to be considered effective in providing protection from a 100-year storm surge and associated wave action..

General and site-specific design assumptions for the project sites include the following (note cost estimation assumptions are included in Section 8):

1. The plans for Dead Horse Bay, Dubos Point, Brant Point, and Bayswater State Park include shoreline stability structures to protect the sites from wind- and vessel-generated waves as wave-induced effects are one of the primary factors affecting sediment transport processes.
2. Locations of the work site access roads (temporary) at the project sites were assumed to be the shortest straight-line access to construction areas. For Dubos Point where the use of a barge is not feasible, the design included a trapezoidal sand berm with a 12-foot wide crest to be constructed parallel to the shore along the entire northern shoreline. The berm footprint will be located from the shore out to the high tide elevation. As the Dubos Point site is experiencing beach erosion, the berm will not be removed at the end of site construction; instead it will be leveled out to a gentle slope in line with the suggested plan and left in place as beach renourishment.
3. The geotechnical data on which the Dead Horse Bay design was based is from the *Draft HTRW Sampling Program Report, Jamaica Bay Environmental Restoration Project* (USACE, 2002).
4. Observed water levels, currents, and topographic mapping (surveys, GIS, etc.) was used as a basis for the analysis, and cross-sections of the shoreline protection and training structures. Topographic mapping as cited throughout the report was dated April 2002.

6.2 Habitat Restoration Features

Creating/Restoring ecosystems involve creating/restoring habitats that have greater ecological values than the habitats that currently exist The proposed restoration plans for each site can be found in Appendix A. Final planting plans will be developed in the Plans and Specifications phase of the project and will include native species. Low marsh restoration sites are expected to be planted with predominantly smooth cordgrass (*Spartina alterniflora*). The high marsh will

include predominantly salt meadow hay (*S. patens*), but will also include marsh elder (*Iva frutescens*) and spike grass (*Distichlis spicata*).

Plantings for the upland habitats will include a variety of native species including, but not limited to the plants described below. Maritime shrub habitat typically includes marsh elder, groundsel (*Baccharis halimifolia*), northern bayberry (*Myrica pensylvanica*), switchgrass (*Panicum virgatum*), pasture rose (*Rosa carolina*), beach-plum (*Prunus maritima*), wild rose (*Rosa virginiana*), sand rose (*Rosa rugosa*), shining sumac (*Rhus copallinum*), highbush blueberry (*Vaccinium corymbosum*), American holly (*Ilex opaca*), shadbush (*Amelanchier canadensis*), and black cherry (*Prunus serotina*; Reschke 1990). The dominant grasses of the maritime grassland habitat include little bluestem (*Schizachyrium scoparium*), common hairgrass (*Deschampsia flexuosa*), and poverty grass (*Danthonia spicata*; Reschke 1990). Other typical grassland species include Pennsylvania sedge (*Carex pensylvanica)*, rush (*Juncus greenei*), Indian grass (*Sorghastrun nutans*), Atlantic golden aster (*Pityopsis falcata*), bushy rockrose (*Helianthermum dumosum*), hoary frostweed (*H. propinquum*), flattop goldenrod (*Euthamia graminifolia*), white-topped aster (*Aster paternus*), pussy's toes (*Antennaria plantaginifolia*), bitter milkwort (*Polygala polygama*), bayberry, shining sumac, northern dewberry (*Rubus flagellaris*; Reschke 1990).

Coastal dune habitats include beachgrass (*Ammophila breviligulata*), dusty miller (*Atrtemisia stelleriana*), beach pea (*Lathyrus japonicus*),sedge (*Carex silicea*), seaside goldenrod (*Solidago sempervirens*), and sand-rose (*Rosa rugosa*). Stabilized dunes include beach heather (*Hudsonia tomentosa*), bearberry (*Arctostaphylos uva-ursi*), cyperus (*Cyperus polystachyos* var. *macrostachyus*), beach pinweed (*Lechea maritime*), jointweed (*Polygonella articulate*), bayberry, and beach-plum (Reschke 1990).

Dominant maritime forest species include American holly, black oak (*Quercus velutina*), and beech (*Fagus grandifolia*; Reschke 1990). Other typical tree species found in this habitat include sassafras (*Sassafras albidium*) shadbush, post oak (*Quercus stellata*). Vines found in maritime forest include Virginia creeper (*Parthenocissus quinquefolia*), poison ivy (*Toxicodendron radicans*), greenbrier (*Smilax rotundifolia*), sawbrier (*S. glauca*), and grape (*Vitis* sp.). Understory shrubs include black huckleberry (*Gaylussacia baccata*) and highbush blueberry (Reschke 1990). Herbaceous species in this habitat include wild sarsaparilla (*Aralia nudicaulis*) starflower (*Smilacina stellata*) Canada mayflower (*Maianthemum canadense*; Reschke 1990).

6.3 Shoreline Stabilization Alternatives in Intertidal areas

Shoreline stabilization treatments in actively eroding intertidal marshes range considerably in cost, effectiveness, and longevity. Three of the JBERP sites (Bayswater State Park, Dubos and Brant Point) had proposed low marsh habitats in actively eroding shorelines. A design alternatives analysis was performed at these sites to determine suitable and cost effective shoreline stability measures that could be implemented at each of the sites. These 3 sites all involved stabilizing eroding shorelines in areas where low marsh habitat was desired, and in areas where minimization of bay bottom footprint was a requirement by the New York State Department of Environmental Conservation (NYS DEC) regulatory agency. All of the

alternatives were developed based on the site-specific needs determined in the *Conceptual Plan Report – Final* (USACE, November 2003).

For the shoreline stability analysis, each of the sites was divided into two distinct sections with unique shoreline processes occurring in each of the sections. The alternative analysis presented below follows this sectional breakdown. To aid in the evaluation of the different design alternatives, a project specific decision matrix was created to help determine the recommended shoreline stability measures for three of the sites: Bayswater State Park, Dubos Point, and. Brant Point. Following is a discussion on the types of shoreline stabilization measures considered for each site and the method of evaluation used in the decision matrix.

Stabilization Methods

The types of structures considered to stabilize the shorelines were classified in three main groups:

1. Rubble Mound Structures;
2. Panel Breakwalls and Floating Structures; and
3. Bioengineering Measures.

Rubble mound structures included detached offshore structures, shore attached Tee-groins, groins, and revetments. The panel breakwalls and floating structures included panels, prisms, and rafeets. The fixed structures within this group included caissons, sheetpile walls, and concrete sills. Bioengineering measures and beach fill were considered as additional control measures that could be implemented in conjunction with some of the structural measures discussed above. The beach fill alternative was not considered as a stand-alone solution for any of the sites because of the NYS DEC's desire to minimize bay bottom footprint. However, the combination of beach fill and other structures, especially rubble mound structures, has proven to be a good alternative to minimize any potential adverse effects of the structures.

The bioengineering measures were divided into two categories: inter-tidal and sub-tidal. The purpose of the division was to differentiate between the expected wave energy absorption capacity of the solution type. In general, a sub-tidal placement is expected to withstand higher wave/hydraulic energy environments than that of an inter-tidal placement.

In general, passive stabilization measures can fall into one of three categories, bio-stabilization, offshore wave attenuation methods, and shoreline rubble and beach structures. As mentioned above, bio-stabilization approaches can only perform within a limited range of wave agitation. An offshore attenuation system, as the name implies, does not fully eliminate the wave energy, but reduces it to some degree. Shoreline rubble and beach structures generally entail placing fill along the shoreline in the form of rubble masses or sand and gravel.

Depending on the intended function of the site, composite measures can be formulated that contain elements of more than one or even all of the measures described above. Following is a discussion of these alternative stabilization methods, including their limitations.

Bio-stabilization

Studies by Komar and Miller (1974) suggest that incipient motion of sediment (onset of erosion) in waves is similar to that for unidirectional flow. Maximum permissible near bottom channel velocities for fine sand are in the range of 1 fps; an extrapolated value for a vegetated bank is 3 fps (ASCE, 1995). Assuming wave action to be nearly a shallow water wave environment at the vegetated edge, then the maximum tolerable wave height to be resisted, unaided, by vegetation would be 1.8 feet in 3 feet of water. Bottom channel velocity can be given as:

$$U = (H/2)\sqrt{g/d}$$

Figure 6.1a shows sediment stability measurements in oscillating flow similar to what occurs in waves. The Shields parameter ψ is a non-dimensional shear stress value of 0.02 found to be the erosion threshold for waves. This is 33-percent less than for uniform flow conditions in the sediment size range of concern.

Figure 6.1b shows a comparison between stability calculations with orbital velocities from linear wave theory and the limiting Shields number mentioned above (Schiereck, 2001). The threshold can be given as:

$$\frac{a_b}{T^2 \Delta g} = 0.025\left(\frac{a_b}{d_{50}}\right) \longrightarrow d_{n50} = 2.15\frac{\hat{u}_b^{2.5}}{\sqrt{T}(\Delta g)^{1.5}}$$

in which a_b is the orbital stroke at the bottom and $\hat{u}_b$ the maximum velocity, where d_{n50} is assumed to equal $0.84d_{50}$. This implies that a wave height of less than 1 foot would be able to initiate the sand movement. Therefore, the target transmitted wave height allowed to reach the shoreline should be less than 1 foot.

Figure 6.1 Modified Shields Diagram for Waves and Stability in Non-Breaking Waves (Schiereck, 2001).

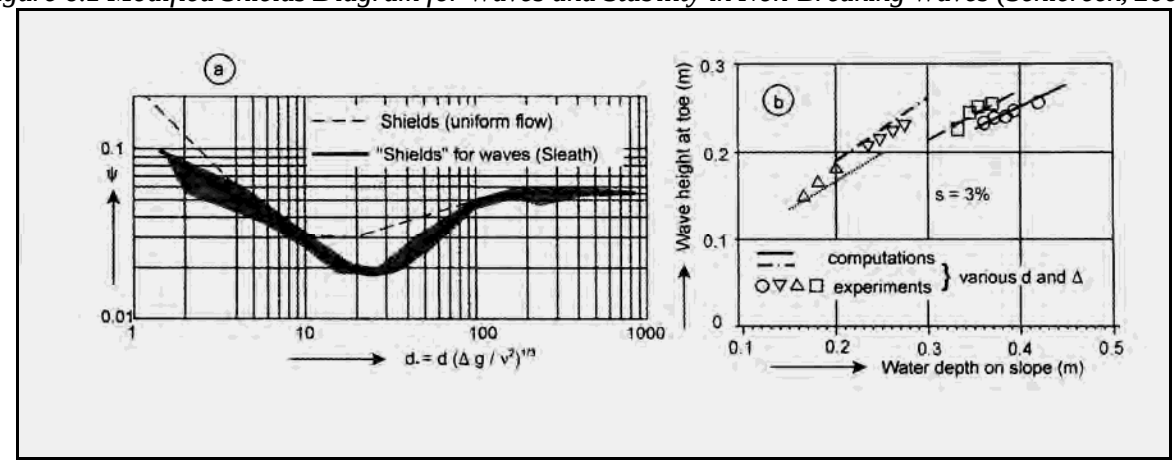
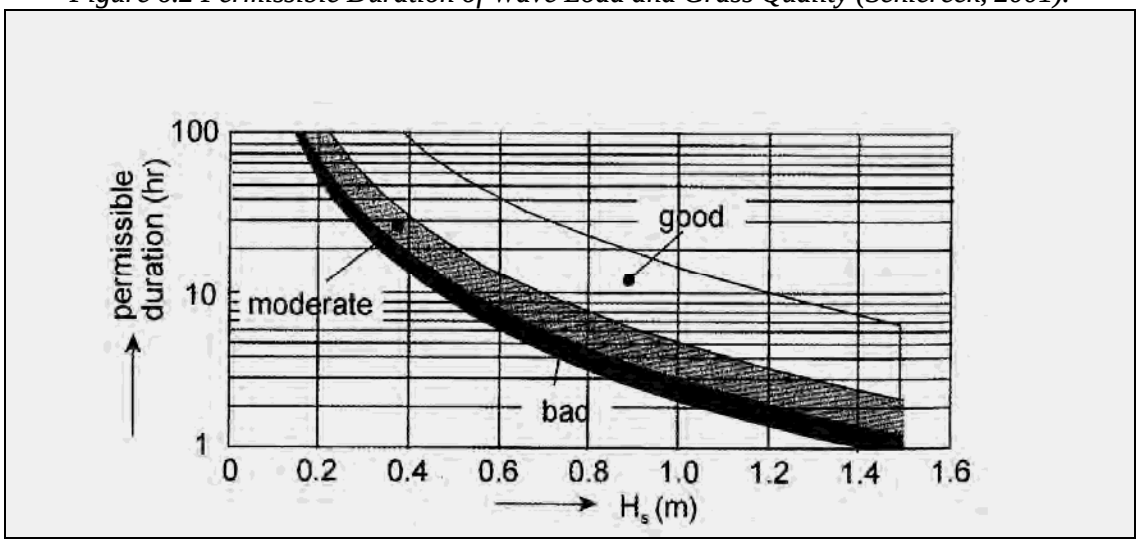


Figure 6.2 shows permissible duration and magnitude of wave load on a vegetated slope. Based on this figure and an assumed exposure time of 6 to 10 hours, a transmitted wave height of 1.5 to 2.0 feet could be tolerated for poor to moderate quality vegetation.

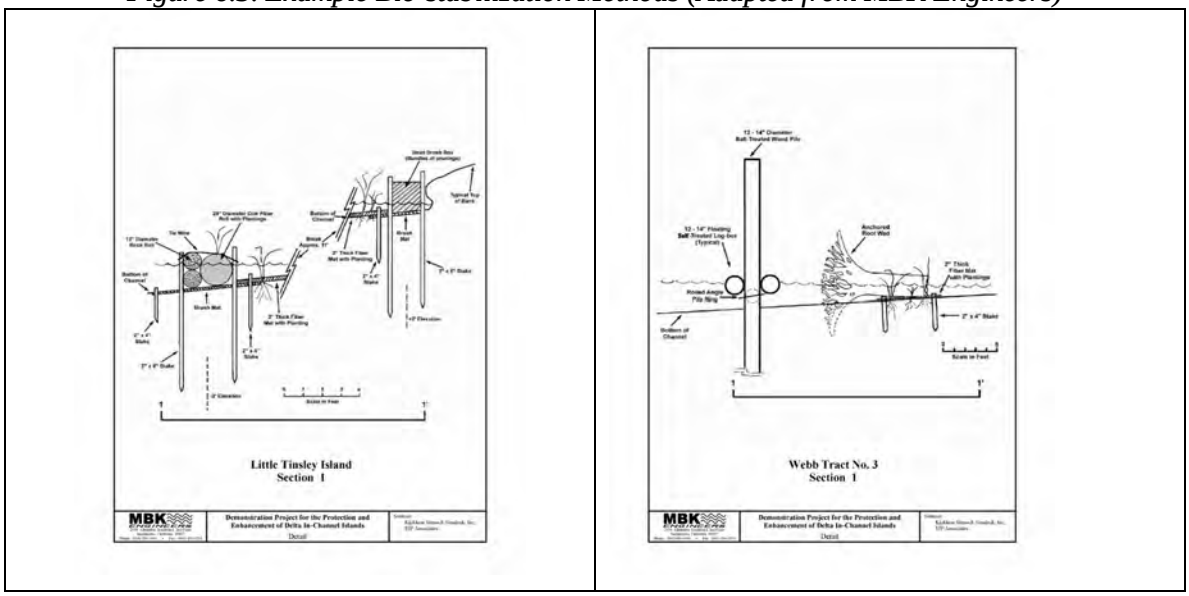
Figure 6.2 Permissible Duration of Wave Load and Grass Quality (Schiereck, 2001).



In general, erosion of vegetated soil or slopes should be expected when wave heights exceed 1.5 feet. Therefore, bio-stabilization will have limited use in an exposed coastal environment unless it is supplemented with other stabilization measures.

Examples of bio-stabilization methods are shown in Figure 6.3 (Example Bio-stabilization Methods). The installations are more robust than simple replanting of vegetation, and often include staking root wads and logs of coconut husks, which act as a nursery for plantings until their root structure can be established.

Figure 6.3. Example Bio-stabilization Methods (Adapted from MBK Engineers)



Offshore Wave Attenuation Devices

Fixed or floating wave fences can be created offshore from the eroding shorelines as a way of reducing the amount of energy reaching the beach. In general, such systems penetrate only a limited distance down into the water column so as to allow natural circulation of the water. Floating systems offer the advantages of being compliant with the changes in the water surface, so that high walls do not protrude out of the water during low tide settings. Unfortunately, they have the disadvantage of requiring continuous monitoring and regular maintenance because of the mechanical workings of the components.

Figure 6.4 shows examples of offshore attenuating systems. Conceivably, these could be configured of natural materials such as floating logs, provided comparable attenuation can be achieved. An indication of the scale of attenuator required is presented in Figure 6.5. Note that to achieve effective attenuation, the system, whether floating of fixed panels, must project down into the water column approximately 50% of the depth, or be nearly 50% of the wavelength in breadth. Therefore, individual floating logs will be of virtually no value unless water depths are very shallow (say <2 feet), and/or the wavelengths are extremely short.

Arrays of individual piles can also serve to dampen wave action, but again, the required breadth of the field of at least a half wave length to be effective, and hence requires significant water area to work.

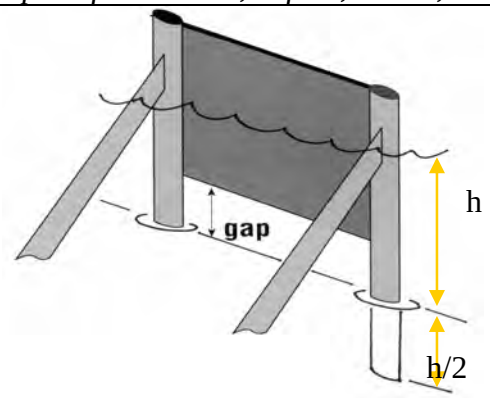
Rubble Shore Structures

Masses of material can be added along the shoreline, either as a way of blocking some wave action, or absorbing the wave action that has arrived. The geometric size of created mass is determined by the amount of wave attenuation required. As shown in Figure 6.6, a mound built just to the low water line (R_c=0) will transmit approximately 50% of the wave energy, while that same mound, at an elevated tide equal to roughly the wave height will transmit roughly 80% of the wave energy (CIRIA, 1991).

If beach fill is used as the absorber, then the size of the material needs to be scaled to the arriving wave energy level. Sand must be scaled to a wave climate of less than a foot to remain stable. Gravels can be introduced to potentially stabilize the beach up to approximately 3 feet of wave height (Allen and Fischenich, 2000). For larger waves, a system of wave damping by other means coupled with the resistance of the gravel can be used.

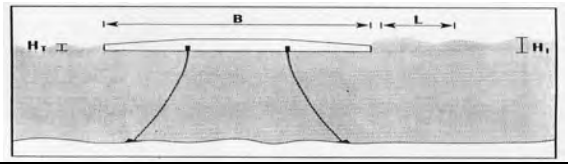
Figure 6.4. Examples of Breakwalls, Rafeets, Prisms, and Floating Panel.

Breakwalls



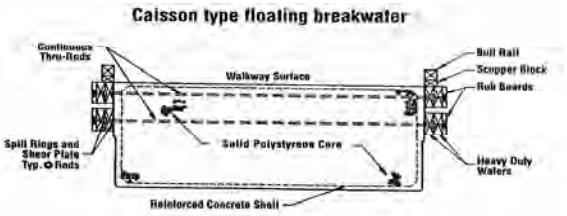
Rafeets





Prisms





Floating Panel



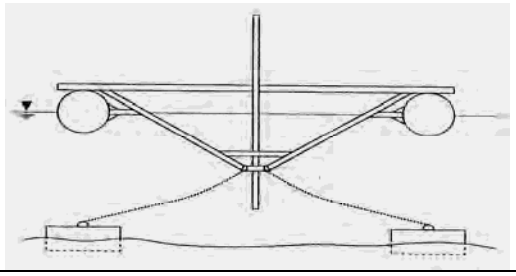


Figure 6.5. Transmission Coefficients for Floating Attenuators.

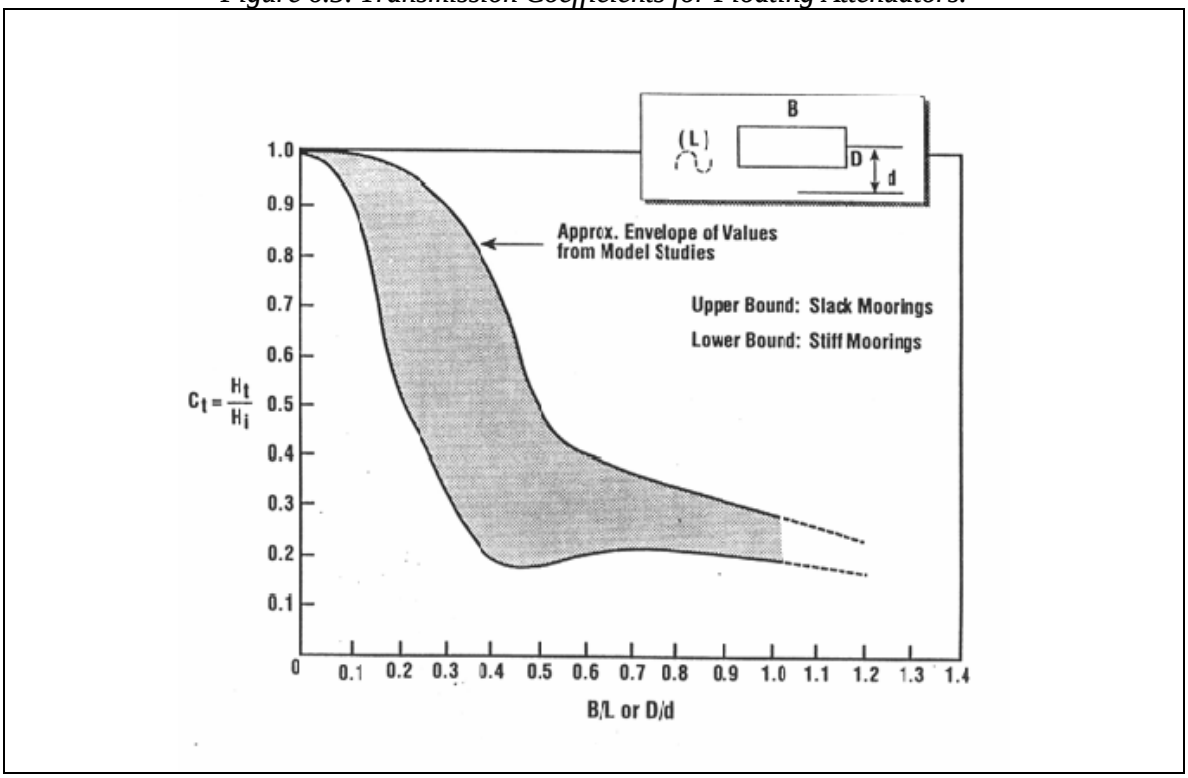
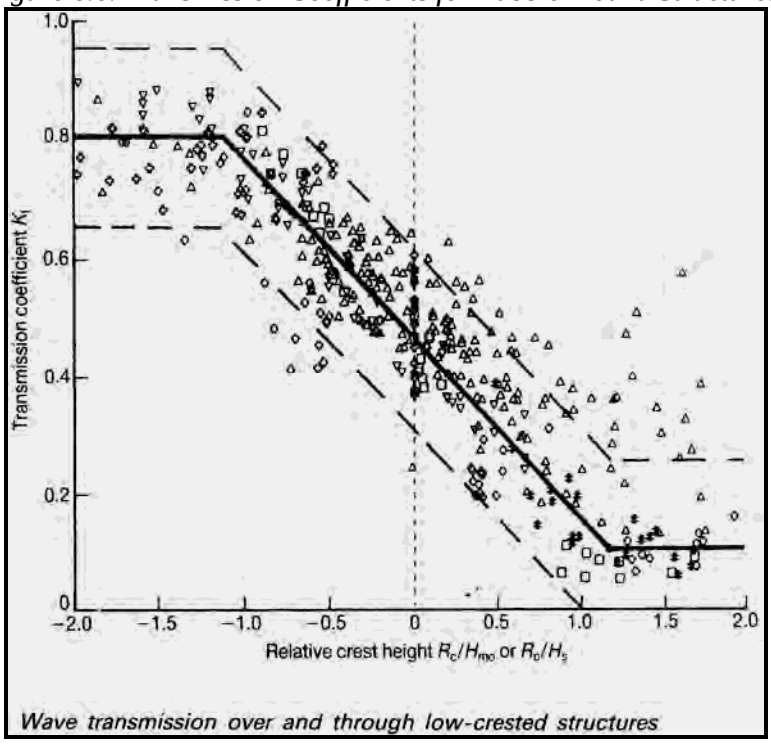


Figure 6.6. Transmission Coefficients for Rubble Mound Structures.



Composite Schemes

The various methods described above can be joined three-dimensionally to create shoreline protection schemes. The use of artificial headlands can create tombolos and pocket beaches. Sills can be used to create perched shorelines of sand or gravel fill to generally absorb (wave) runup action. Both can be used to reduce the energy levels reaching the shoreline to less than a 1.5-foot wave, allowing vegetation to be enhanced or re-established.

Decision Matrix

The project specific decision matrix is presented in Table 6.1, which incorporates all of the shoreline stabilization methods considered for three sites: Brant Point, Dubos Point, and Bayswater State Park. Within the decision matrix, each stabilization method was examined and ranked from 1 to 5 in a total of ten categories (A-J) which were grouped into four main groups as shown in Table 6.2.

A rank of 1 in a specific category indicates that the stabilization method does not perform well in this specific category, whereas a rank of 5 indicates that a stabilization method does perform well in this category. For instance, a stabilization method with a high implementation cost would have a low score (say, 1 or 2 depending on the relative magnitude of the cost) and a relatively low cost stabilization method would have a higher score (say, 4 or 5). Site-specific conditions were considered when ranking stabilization methods in the Site Suitability group; however, the costs, structural integrity, and environmental impact groups were viewed as more generalized non-site specific ranking groups.

Ranking category “A” is the relative cost of a stabilization method. The relative cost in comparison to the alternatives considered herein was applied as a multiplier for overall score calculation. Durability “B” and maintenance “C” were included in the structural integrity group. Durability consideration was governed by the ability of the structure to withstand the destructive energy within its design life of 50 years. Maintenance “C” was ranked by the level of maintenance required for a specific type of structure. Therefore, a low rank in this category means a high level of maintenance requirement and vice versa for a high rank.

The Environmental Impact group included factors “D” to “G”. A high rank was given to the methods that allowed for any new habitat creation as shown by factor “D”. Potential effects (both adverse and positive) to adjacent areas were considered in factor “E”. Aesthetics of a specific method from a public viewing perspective were ranked in factor “F”. The ability to permit the implementation of a method (permittability) of each alternative was ranked as “G” based on a perception of the regulatory climate and what methods have historically been accepted.

The sum of the Structural Integrity group rankings and the environmental impact group rankings (Sum SE) were used as a multiplier in calculation of the total score for each stabilization method.

Table 6.1 Decision Matrix for Jamaica Bay Shoreline Stabilization Measures

DECISION MATRIX										BRANT POINT										DUBOS POINT										BAYSWATER STATE PARK									
										SECTION 1					SECTION 2						SECTION 1					SECTION 2						SECTION 1					SECTION 2				
Stabilization Group	Stabilization Method	cost	Structural Integrity		Environmental Impacts				Sum SE	Site Suitability			SUM SSI	Score I	Site Suitability			SUM SSII	Score II	Selected Alternative	Site Suitability			SUM SSI	Score I	Site Suitability			SUM SSII	Score II	Selected Alternative	Site Suitability			SUM SSI	Score I	Site Suitability			SUM SSII	Score II	Selected Alternative
		A	B	C	D	E	F	G		H	I	J			H	I	J				H	I	J			H	I	J				H	I	J			H	I	J		
Rubble Mound	Offshore Detached	2	5	5	4	1	3	1	19	4	5	4	13	**494**	3	5	4	12	**456**	Alternative 1 (Section I)	3	4	4	11	**418**	2	3	3	8	**304**	Alternative 1 (Section I & II)	3	4	3	10	**380**	1	1	2	4	**152**	Alternative 1 (Section I & II)
	Groins-Shore Attached	2	5	5	3	1	3	1	18	2	3	3	8	**288**	1	1	2	4	**144**		2	4	3	9	**324**	1	1	2	4	**144**		4	2	2	8	**288**	4	4	2	10	**360**	
	Tee-Groins Shore Attached	2	5	5	4	1	3	1	19	4	5	4	13	**494**	3	5	4	12	**456**	Alternative 2 (Section I)	2	4	4	10	**380**	2	2	3	7	**266**		4	4	3	11	**418**	4	4	2	10	**380**	
	Revetment	3	4	4	3	2	2	2	17	1	1	2	4	**204**	5	4	3	12	**612**	Alternative 1 & 2 (Section II)	1	1	2	4	**204**	1	1	1	3	**153**		2	4	1	7	**357**	1	3	1	5	**255**	
Panel Breakwalls & Floating Structures	Panel Breakwalls	3	4	4	1	3	1	3	17	3	4	3	10	**480**	3	4	3	10	**480**		4	4	3	11	**561**	5	5	3	13	**663**	Alternative 3 (Section I & II)	2	3	2	7	**357**	2	2	1	5	**255**	Alternative 2 (Section I & II)
	Floating	3	3	1	2	4	4	4	18	3	3	2	8	**432**	3	3	2	8	**432**		1	3	2	6	**324**	1	2	2	5	**270**		1	1	1	3	**162**	1	1	1	3	**162**	
	Prisms	3	3	1	2	4	4	4	18	3	3	2	8	**432**	3	3	2	8	**432**		2	3	2	7	**378**	1	2	2	5	**270**		1	1	1	3	**162**	1	1	1	3	**162**	
	Rafts	3	3	1	2	4	4	4	18	3	3	2	8	**432**	3	3	2	8	**432**		1	3	2	6	**324**	1	2	2	5	**270**		1	1	1	3	**162**	1	1	1	3	**162**	
	Panel Breakwalls w/Pier	3	4	4	2	3	3	2	17	3	4	3	10	**540**	3	4	3	10	**540**	Alternative 3 (Section I & II)	4	4	3	11	**561**	5	5	3	13	**663**	Alternative 3 (Section I & II)	2	3	2	7	**357**	3	2	2	7	**357**	Alternative 3 (Section I & II)
	Caissons	2	5	5	1	2	3	2	18	3	4	1	8	**288**	3	4	1	8	**288**		1	1	1	3	**108**	4	4	4	12	**432**		1	2	1	4	**144**	1	1	1	3	**108**	
	Sheetpile Walls	2	5	5	1	2	2	3	18	1	1	1	3	**108**	1	2	1	4	**144**		1	1	3	5	**180**	5	5	4	14	**504**	Alternative 2 (Section I & II)	3	5	1	9	**324**	1	2	1	4	**144**	
	Concrete Sill	2	5	4	2	5	5	3	24	4	2	3	9	**432**	4	2	3	9	**432**		4	3	3	10	**480**	4	5	3	12	**576**	Alternative 2 (Section I & II)	1	2	4	7	**336**	2	1	1	4	**192**	
Bio-Engineering	Floating Log & Root Wad (Inter Tidal)	4	1	3	5	5	5	5	24	2	2	3	7	**672**	1	2	3	6	**576**	*	3	3	4	10	**960**	1	2	4	7	**672**	*	1	1	1	3	**288**	3	3	2	8	**768**	*
	Floating Log & Root Wad (Sub-Tidal)	3	2	1	5	5	5	5	23	2	2	3	7	**483**	1	2	3	6	**414**		3	3	4	10	**690**	1	2	4	7	**483**		1	1	1	3	**207**	2	2	2	6	**414**	
	Beach Fill ***	3	3	2	4	5	5	4	23	4	1	4	9	**621**	2	2	4	8	**552**	**	4	3	3	10	**690**	3	3	3	9	**621**	**	5	1	4	10	**690**	1	1	1	3	**207**	**

TABLE INTERPRETATION

Ranking Categories

A	Implementation costs?
B	Durability of the structure?
C	Required maintenance of the structure?
D	Creation of new habitat?
E	Affect on adjacent habitat?
F	Is the measure aesthetically pleasing?
G	Ability to be permitted (permitability)
H	Compatible with existing conditions?
I	Meets site design criteria?
J	Is environmental and recreational value added to the site?

Ranking Levels

1 Poor Performance
2 ↓
3 Adequate Performance
4 ↓
5 Excellent Performance

Scoring Computation

Score I = A * Sum SE * Sum SS I
Score II = A * Sum SE * Sum SS II

Where:

A = Cost Factor Ranking
Sum SE = B+C+D+E+F+G
Sum SS I = H+I+J (in Section I)
Sum SS II = H+I+J (In Section II)

Selected Alternatives

Alternative 1
Alternative 2
Alternative 3

Notes

* In combination with breakwalls and floating structures
** In combination with rubble mound structures
*** Beach Fill only used in conjunction with other stabilization methods

Table 6.2. Explanation of Groups and Categories in Decision Matrix.

Main Group	Category	Ranking Factor
COST	A	Implementation costs?
STRUCTURAL INTEGRITY	B	Durability of the structure?
	C	Required maintenance of the structure?
ENVIRONMENTAL IMPACT	D	Creation of new habitat?
	E	Affect on adjacent areas?
	F	Is the measure aesthetically pleasing?
	G	Ability to be permitted (permittability)
SITE SUITABILITY	H	Compatible with existing conditions?
	I	Meets site design criteria?
	J	Is environmental and recreational value added to the site?

The last group, site suitability, consists of the ranking factors that are directly related to each specific site and each specific section of a site under analysis. Factor "H", compatibility with existing conditions, represents the ranking for the stabilization methods compatibility with the existing environment in the area. For example, a method was ranked higher if a similar structure and/or feature already exists at the site. Functionality "I" of a specific method was ranked as compared to other methods to gage how well its' expected performance satisfies the design criteria of the site. The environmental value "J" of a specific stabilization method, including its' recreational value was also ranked. More naturalized types of structures, those that provide potential fish and/or benthic habitat, and those structures that would support recreational opportunities, such as fishing or beach use, would be given a higher rank. The sum of the rankings obtained from the Site Suitability group (Sum SS) was used as a multiplier to calculate the overall score for each stabilization method at a specific site.

Final scores for each of the shoreline stabilization methods for each particular section of each site were calculated by multiplying the cost factor "A" by the sum of structural integrity and environmental impact factors "B" to "G" (Sum SE), by the sum of the site suitability factors "H" to "J" for a specific section of a site (Sum SS I or Sum SS II), using the following equations:

- Final Score for Section I of a site = A * Sum SE * Sum SS I
- Final Score for Section II of a site = A * Sum SE * Sum SS II

The individual rankings and final scores for each of the shoreline stabilization methods for each site are shown in the Decision Matrix for Jamaica Bay Shoreline Structures (Table 6.1). The results obtained from this alternatives analysis were used in combination with past experience and engineering judgment to develop the site-specific alternatives for shoreline stabilization.

6.4 Specific Features designed at the individual sites

Wave criteria information was formulated for four sites: Dead Horse Bay, Brant Point, Dubos Point, and Bayswater State Park. The information suggests that a pure bio-stabilization solution

is not viable at any of the locations because the wave energy is too large on a daily basis. Floating type wave attenuators are also viewed as unlikely candidates because of the level of monitoring and maintenance required to ensure their functionality, as well as avoiding potential navigational issues if they should break away from their moorings.

The aesthetic factor was an important concern for the selection of the concept plans. Therefore, schemes which offered the lowest profile when seen from shore were preferred aesthetically. At the same time, impact on the existing benthos should be minimized, so the footprint of the protection needed to be minimized unless the installation could be viewed as an enhancement to the habitat. Finally, public access needed to be provided in some areas, which dictates the form, arrangement, and details of the protection measure.

All of the JBERP sites, with the exception of Spring Creek and Hawtree, needed additional analysis and design of select proposed plan characteristics The following sections discuss these site-specific design requirements and features.

6.4.1 Dead Horse Bay

Dead Horse Bay was investigated as two separate sites, Dead Horse Bay – North and Dead Horse Bay – South (Figure 6.7). For the Dead Horse Bay – North Site, a hydrodynamic analysis of the proposed channel network was performed. In addition, inlet stabilization for the site's main channel was designed. For the Dead Horse Bay – South Site, it was necessary for the design to include a dune structure to stabilize the shoreline and upland landfill.

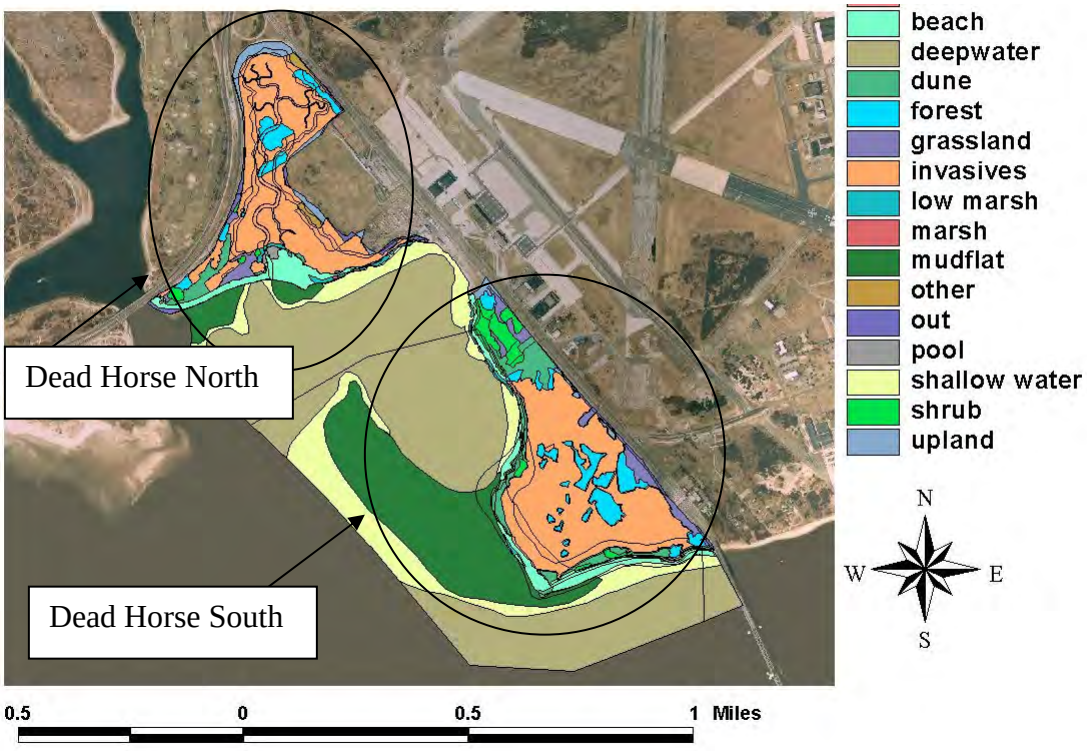
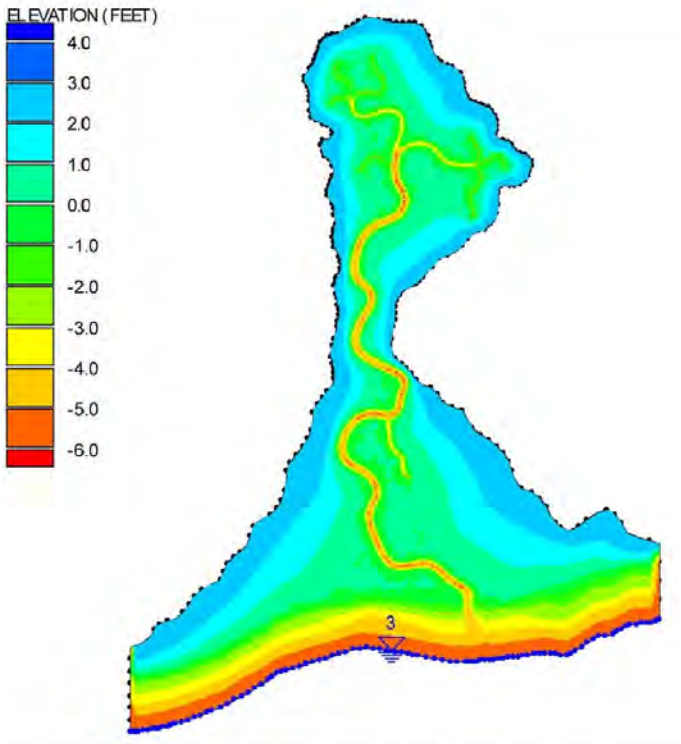


Figure 6.7 Proposed Habitats for Dead Horse Bay North and South

6.4.1.1 Hydrodynamic Model Results

Dead Horse Bay North Hydrodynamic Modeling Report - Jamaica Bay Ecosystem Restoration Project (USACE, 2003) presents the hydrodynamic analyses of the USACE's initial conceptual restoration design for the Dead Horse Bay – North Site as shown on Figures 6.7 and 6.8. The purpose of the hydrodynamic study was to determine the extent and duration of tidal inundation and draining across the site that would be expected to be achieved with the proposed conceptual design and to aid in evaluating the inlet stability.

Figure 6.8 Design Grading Plan – June 2003.



.

Tidal Data

Tidal fluctuations in Dead Horse Bay provides the "driving force" behind the flooding and draining of the restored marsh at the Dead Horse Bay – North Site. Therefore, the proper tidal signal must be established to ensure the validity of the hydrodynamic modeling of the restoration design. Tidal datums and vegetation zone elevations were calculated in this study. For the purposes of the hydrodynamic modeling, the tidal, bio-benchmark, and design zone data were reviewed to establish the proper tidal signal to evaluate the restoration design. It was concluded that the spring high tide water surface elevation (MHWS = 3.0 feet NAVD 88) and the mudflat elevation (MLW = -3.0 feet NAVD 88) were the appropriate maximum and minimum tidal water surface elevations to be used to generate the tidal signal at the Dead Horse bay Site. This tidal range represents the maximum and minimum tide elevations that will influence the restored marsh at the site.

Hydrodynamic Modeling

Hydrodynamic modeling was performed to simulate the tidal flooding and draining of the site. Simulations were run for both the existing conditions and for the initial proposed conceptual design (proposed conditions). The results of the modeling were then used to assess the effectiveness of the initial design in terms of inundation and draining efficiency, and to verify that the magnitude of the velocities in the proposed channels.

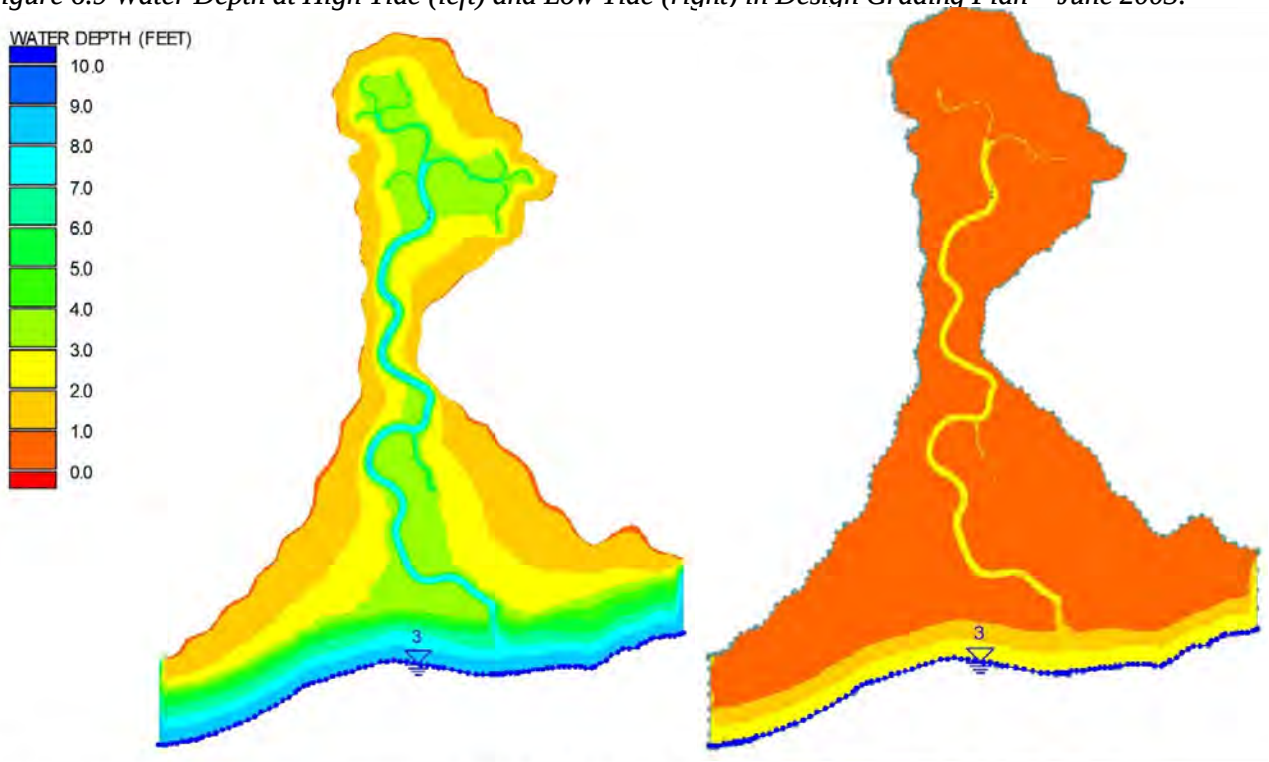
The computer simulations were performed using the USACE two-dimensional, depth-integrated finite element model, RMA-2, with a Surface Modeling System (SMS) user interface. RMA-2 computes water surface elevations and horizontal velocity components for subcritical, free-surface flow in two-dimensional flow fields. The RMA-2 model resolves the depth-integrated equations of fluid mass and momentum conservation. The model determines water level and velocities in the channels and on the marsh plain.

A digital terrain model surface was created with the site survey to replicate existing conditions. The existing condition consists primarily of upland with minor amounts of remnant marsh on the shoreline. For the RMA-2 modeling purposes, the upland area (area above spring high tide) was removed from the existing surface. The removal had no effect on the modeling results since ground surfaces with elevations above the spring high tide elevation will not be affected by normal tidal flows. Next, the digital terrain surface was generated for the proposed conditions using the conceptual restoration design for Dead Horse Bay from the Conceptual Report (USACE, 2003).

Modeling Results

Figures 6.9 show the water depth at high and low tides. The hydrodynamic analysis demonstrated that the proposed Dead Horse Bay – North Site allows for tidal inundation and drainage of both the low marsh and high marsh zones of the initial conceptual restoration design.

Figure 6.9 Water Depth at High Tide (left) and Low Tide (right) in Design Grading Plan – June 2003.



The velocities throughout the existing site during a tidal cycle are in the range of 0.0 to 0.24 feet per second (fps). Figures 6.9 shows a graphical summary of the maximum velocities over the site. The temporal velocity distribution for the incoming and outgoing tides at the point of maximum velocity is shown on Figure 6.10. The velocities throughout the site for proposed conditions during a tidal cycle are in the range of 0.0 to 0.76 fps. The maximum velocities occur in the main channel at mid tide, which serves as the primary drainage channel for the conceptual design.

Figure 6.9 Maximum Velocities and Temporal Velocity Locations - Design Grading Plan – June 2003.

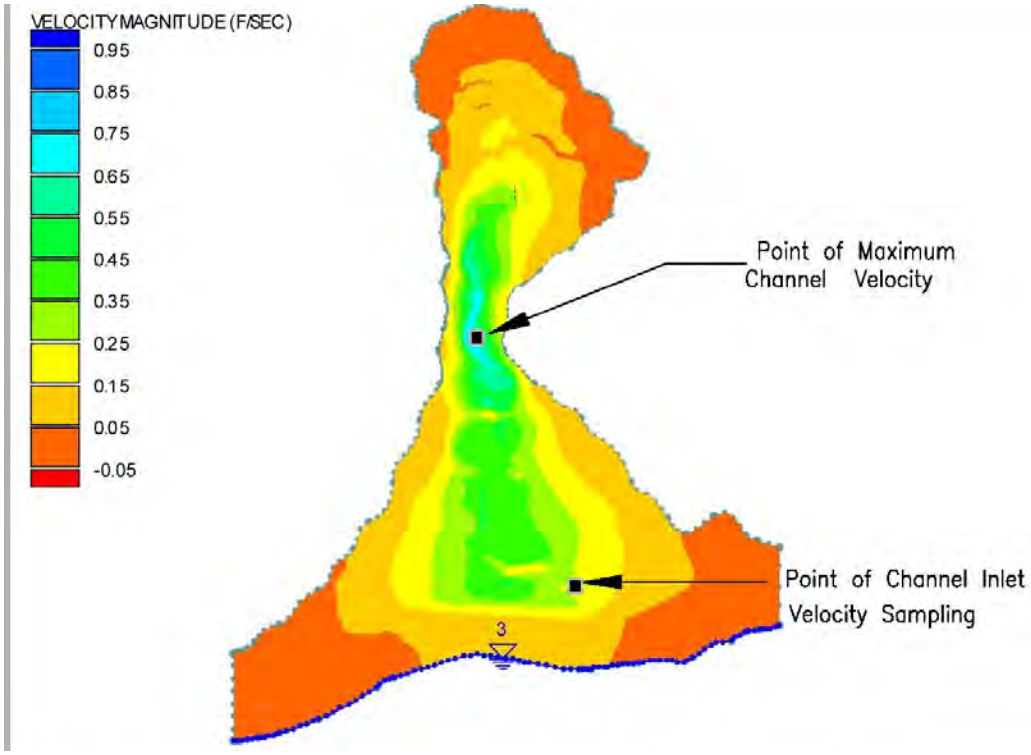
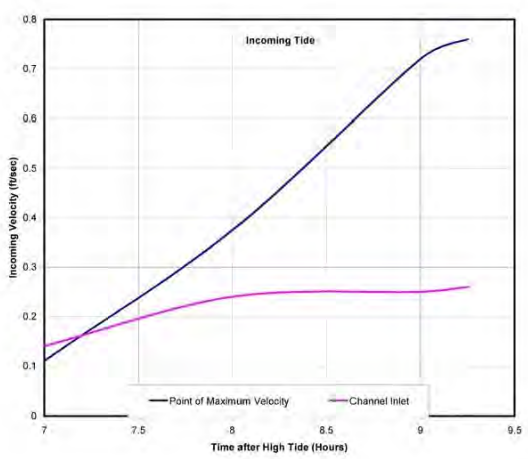
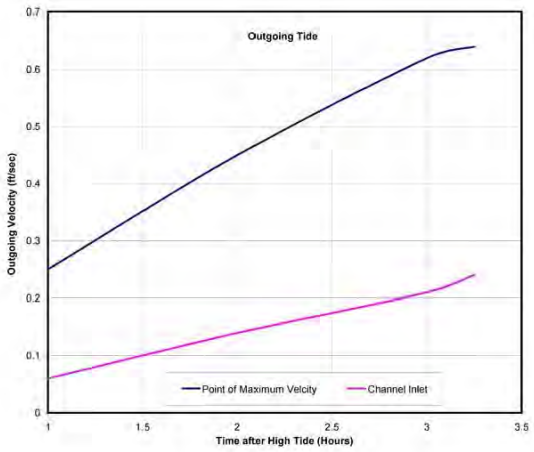


Figure 6.10 Temporal Velocities at Select Locations- Design Grading Plan – June 2003





Stability Analysis

The RMA-2 model predicts velocities within the Dead Horse Bay North Site, as discussed above. However, the RMA-2 model does not analyze stability or determine 'critical' velocities or shear stress. Therefore, the stability analysis requires a different methodology. Given the fact that RMA-2 provides velocities, it was decided to calculate the 'critical' velocity for the marsh channels to assess channel stability. The HEC-18 method was used for channel stability analysis. It should be noted that the stability analysis considered erosive stability only. The evaluation of littoral transport and coastal processes were considered next in this analysis.

To determine the size of the bed material in the proposed channels at the Dead Horse Bay North site, soil boring data was reviewed, site history was reviewed and site observations were made. Based on the known history of the site, it was anticipated that once the site is excavated down to marsh elevations that historical marsh plain soils will be encountered. Therefore, for the purposes of the stability analysis it was assumed that the bed material will be a sandy silty clay material with a particle size of approximately 0.05 mm.

Critical velocities were determined at two locations – one at the proposed channel inlet and the other at a point along the channel where the highest velocity was computed by the RMA-2 model. The critical velocity of the bed material at the two channel sections based on the sandy silty clay layer is 0.89 fps. Predicted flow velocities at the two channel locations computed by the RMA-2 model were less than the critical velocities at the corresponding channel locations. Therefore, it can be concluded that the channels for the proposed Dead Horse Bay – North design will be stable across the entire design tidal prism. Should tides with larger fluxes than the design tide occur at the site, it is anticipated that the velocities will not be significantly different than those predicted for the design tide.

The initial conceptual restoration for the Dead Horse Bay – North Site on which the hydrodynamic model was based was revised in the *Conceptual Plan Report – Final* (USACE, 2003). As shown in Figure 6.6, revisions included the straightening of the southern end of the channel and the addition of jetties at the mouth of the channel to prevent siltation due to longshore and sedimentation. However, as the tidal regime, tidal influence, and water elevations at the site will remain the same, the modified channel network will still allow for proper inundation and drainage of the site as the tide floods and ebbs. If the hydrodynamic analysis was rerun with the revised conceptual plan, the straightened southern end of the channel would yield slightly smaller channel velocities. Therefore, it can also be concluded that the channels for the revised Dead Horse Bay – North design are predicted to be stable when the flow velocities are at their maximum. Furthermore, an added benefit of the removal of the bend where velocities were shown to be high is a reduction in the potential for channel erosion in this area.

Refer to the *Dead Horse Bay North Hydrodynamic Modeling Report - Jamaica Bay Ecosystem Restoration Project* (USACE, 2003) for further information regarding the methods and specific data used in the inundation and stability analysis.

6.4.1.2 Inlet Stabilization Design

For the Dead Horse Bay – North Site, inlet stabilization design elements included: 1) local wave hindcasting and transformation, 2) longshore current generation, and 3) sediment transport potential determination.

Local, historic wind data collected at JFK Airport (spanning from early 1980's to present) was obtained from the National Climatic Data Center (NCDC). Directional, hourly average winds were derived from entire data set. Table 6.3 (Directional Averaged Wind Speeds for Dead Horse Bay North) below presents these wind speeds for the potential fetch directions. Waves generated by the wind data were predicted using a computer model (ACES) developed by the USACE. The program is entitled "Wind Speed Adjustment and Wave Growth," and provides simplified estimates for wave growth over open-water and restricted fetches, such as Jamaica Bay, in deep and shallow water. Standard ACES output includes a spectral significant (modal) wave height (H_{mo}), peak period (T_p), and a mean wave direction (MWD) for each of the fetch bands.

Table 6.3. Directional Averaged Wind Speeds for Dead Horse Bay North.

Fetch No	Directional		
	Angle		Average Wind Speed
1	0	N	9.2
2	22.5	NNE	9.1
3	45	NE	8.7
4	67.5	ENE	8.5
5	90	E	7.0
6	112.5	ESE	5.8
7	135	SE	5.8
8	157.5	SSE	6.0
9	180	S	7.6
10	202.5	SSW	7.9
11	225	SW	7.4
12	247.5	WSW	8.4
13	270	W	10.2
14	292.5	WNW	11.3
15	315	NW	11.9
16	337.5	NNW	10.1

Table 6.4 presents the results of wave hindcast along with the data used as an input. These hindcast waves are transformed to a nearshore location by using another module of ACES software, wave transformation by Snell's law. Table 6.5 presents these results. The last column in this table lists the wave crest angle relative to the shoreline orientation, which will dictate the direction of the sediment transport.

Table 6.4. Dead Horse Bay North Hindcast Wave Results.

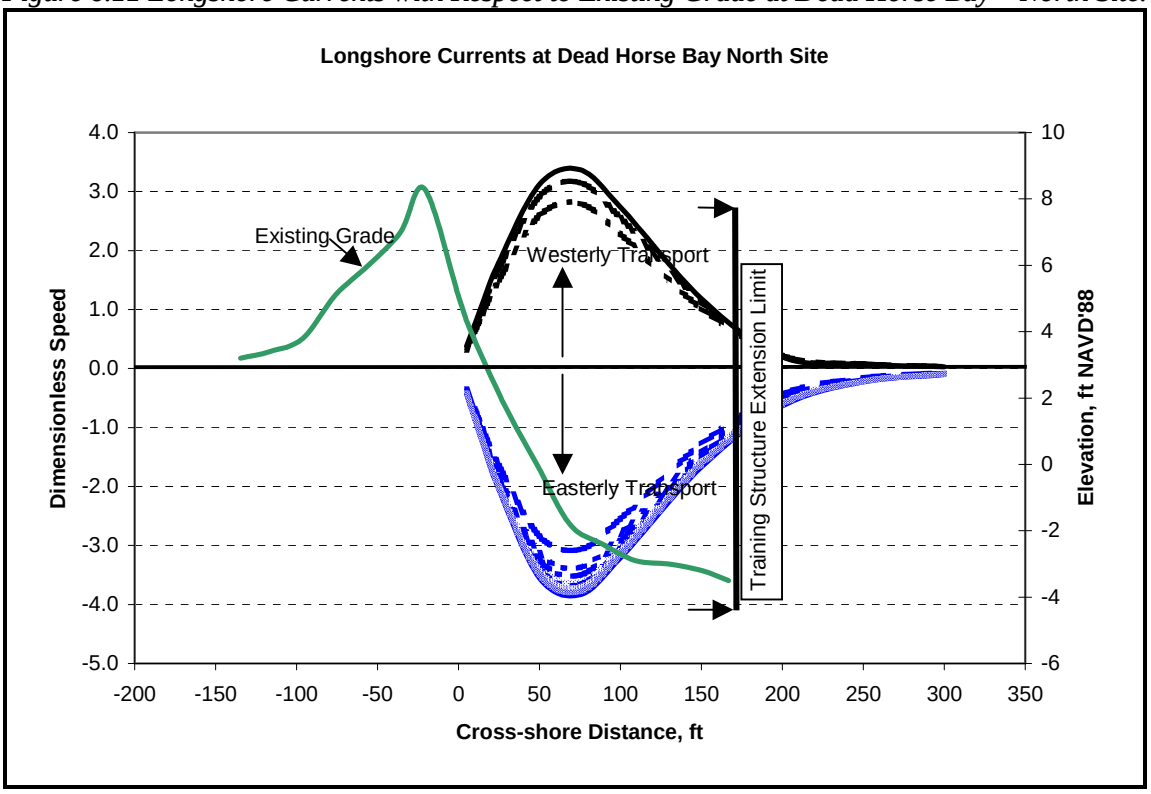
Fetch #	Directional		Fetch	Depth	Hindcast Wave		
	Angle	ID	(mi)	(feet)	Height (feet)	Period (sec)	MWD (deg N)
1	0	N					
2	22.5	NNE					
3	45	NE	0.20	15	0.3	1.0	70
4	67.5	ENE	0.55	20	0.3	1.1	76
5	90	E	0.60	15	0.4	1.2	133
6	112.5	ESE	0.25	20	0.3	1.1	137
7	135	SE	1.40	10	0.3	1.1	140
8	157.5	SSE	1.30	25	0.5	1.4	216
9	180	S	1.25	15	0.7	1.6	220
10	202.5	SSW	1.50	15	0.7	1.7	222
11	225	SW	5.00	10	0.7	1.6	225
12	247.5	WSW	0.10	10	0.7	1.7	226
13	270	W	0.10	10	0.9	1.8	228
14	292.5	WNW					
15	315	NW					
16	337.5	NNW					

Table 6.5. Dead Horse Bay North Transformed Wave Results.

Fetch No	Directional		Fetch	Depth	Transformed Wave (Snell's Law)				Crest Angle (degrees with respect to shoreline orientation*)
	Angle	ID	(mi)	(feet)	Height (feet)	Period (sec)	Refracted Angle	MWD (deg N)	
1	0	N							
2	22.5	NNE							
3	45	NE	0.20	15	0.29	1.0	10	70	10
4	67.5	ENE	0.55	20	0.29	1.1	16	76	16
5	90	E	0.60	15	0.27	1.2	65	133	73
6	112.5	ESE	0.25	20	0.24	1.1	71	137	77
7	135	SE	1.40	10	0.22	1.1	73	140	80
8	157.5	SSE	1.30	25	0.45	1.4	-21	216	-24
9	180	S	1.25	15	0.61	1.6	-15	220	-20
10	202.5	SSW	1.50	15	0.64	1.7	-14	222	-18
11	225	SW	5.00	10	0.59	1.6	-12	225	-15
12	247.5	WSW	0.10	10	0.66	1.7	-11	226	-14
13	270	W	0.10	10	0.82	1.8	-9	228	-12
14	292.5	WNW							
15	315	NW							
16	337.5	NNW							

Longshore sediment transport potential was computed along with the induced longshore current. The methodology outlined for the distribution of the longshore currents (depth integrated) by Longuet-Higgins (1970) and Basco (1982) was utilized. Figure 6.11 shows the longshore current profiles with respect to the existing grade for all possible fetches that will generate sediment transport. The direction of the currents was determined by the relative angle with respect to shoreline. Westerly current (or sediment transport) was assumed to have a positive direction, and easterly direction as negative.

Figure 6.11 Longshore Currents with Respect to Existing Grade at Dead Horse Bay – North Site.



Sediment transport potential was determined by the methodology outlined in the CEM (2002), namely the CERC formula:

$$Q_l = K\left(\frac{\rho\sqrt{g}}{16\kappa^{0.5}(\rho_s-\rho)(1-n)}\right)H_b^{2.5}\sin(2\alpha)$$

where K is an empirical coefficient, κ is breaker index, ρ is the specific density, H_b is the breaker height, and α is the crest angle.

Table 6.6 shows the sediment transport potential for each of the potential fetch directions from which it is generated. Total yearly transport was calculated for each direction and listed as Q_l. This yearly amount was then weighted by the percent occurrence of that specific direction to determine the actual rate, Q^*_l. Actual transport rate per direction were summed to determine the

westerly and easterly transport. Consequently, net potential transport rate was calculated as the difference between the easterly and westerly total volumes. The gross transport rate (independent of direction) is only 5% greater than the net transport rate. This provides a desirable outcome of not producing large transport perturbations in shoreline position or accumulating sediment in eddy or inlet areas. Easterly sediment transport is significantly larger than the westerly transport due to orientation of the shoreline with respect to incoming waves. That is, majority of the wave crest alignment with respect to the shoreline will generate an easterly transport. The current setting of the shoreline, as well as the sediment accumulation at the mouth of the existing inlet, supports this finding.

Table 6.6. Sediment Transport Potential for Dead Horse Bay – North Site.

Fetch No	Directional		Sediment Transport					
	Angle	ID	Q_l	% Occurrence	Q^*_l	Total Q^*_l	Direction of Transport (Towards)	NET TRANSPORT
1	0	N						
2	22.5	NNE						
3	45	NE	7,949	4.6%	362			
4	67.5	ENE	4,801	4.1%	198			
5	90	E	6,774	4.4%	300	1,087	>> WEST	
6	112.5	ESE	3,189	3.0%	96			
7	135	SE	4,349	3.0%	131			
8	157.5	SSE	23,936	3.8%	914			17,623
9	180	S	55,205	9.0%	4,974			
10	202.5	SSW	17,067	10.3%	1,758			
11	225	SW	46,552	8.0%	3,720	18,710	EAST <<	
12	247.5	WSW	602	6.4%	39			
13	270	W	87,913	8.3%	7,306			
14	292.5	WNW						
15	315	NW						
16	337.5	NNW						

Assuming that there are enough sand sources at Dead Horse Bay – North location, mainly from the sediment rich bluffs on the western two thirds of the shoreline, there is a potential of about 18,000 cubic yard of sediment transport towards east.

If not protected, the proposed inlet mouth expected to be filled due to the above potential sediment movement. Therefore, a shore-perpendicular structure is warranted to prevent the sediment accumulation at the mouth and therefore clogging the vital tidal exchange for the habitat upland. However, the location of this structure is critical to limit the impact on the downdrift side.

The physical characteristics of the training structures were determined to minimize the need for dredging at the mouth of the inlet. In the mean time, some bypassing is allowed for the minimization of the downdrift beaches. In addition to the analysis explained above, the “Inlet

Processes" module of the ACES software was further utilized for further analysis. The input and output values are presented in Table 6.7. This tool was utilized iteratively for sizing of the inlet.

The length of the training structures were determined to be 170 feet on the updrift side nominally to block 85% of longshore transport as shown in Figure 6.12. The length of the structure was reduced to 130 feet on the downdrift side due to limited reverse transport. That is, the net transport is predominantly from west to east. The average width and depth at the mouth was approximated as 60 feet, and 6 feet respectively, including the main channel in the middle. Stability parameter (P/M_{total}, where P is the tidal prism and M is annual littoral drift), was determined to be more than 20, corresponding to a rating of typical bar-bypassers as given by the CEM (2002). It is intended that some of the sediment is by-passed to limit the impact on the downdrift side. The inlet characteristics need to be optimized in the next phase of design through the use of sophisticated tools such as numerical and/or physical modeling.

A typical section of the training structures was determined by the ACES software as shown in Figure 6.13. Side slopes were kept at 1V:1.5H for minimum footprint. One layer of armor with about 3 feet thickness over a core layer has been recommended. Crest width was kept at a minimum of 4 feet at 5 feet elevation. Single layer armor consisted of about 2 tons rough angular stone. A minimum of 1-foot thick of bedding material overlaying a geotextile layer is provided as foundation.

Table 6.7. Inlet Parameters from ACES.

Bay Properties		
Surface area A_b	2.153e+006	

Channel Properties		
Average depth (d)	6.000	feet
Average width (b)	60.000	feet
Length (L)	150.000	feet

Tide Property		
Period (T)	12.420	
Range ($2a_o$)	5.390	feet

Energy Loss Coefficients	
Entrance k_{en}	0.100
Exit k_{ex}	1.000

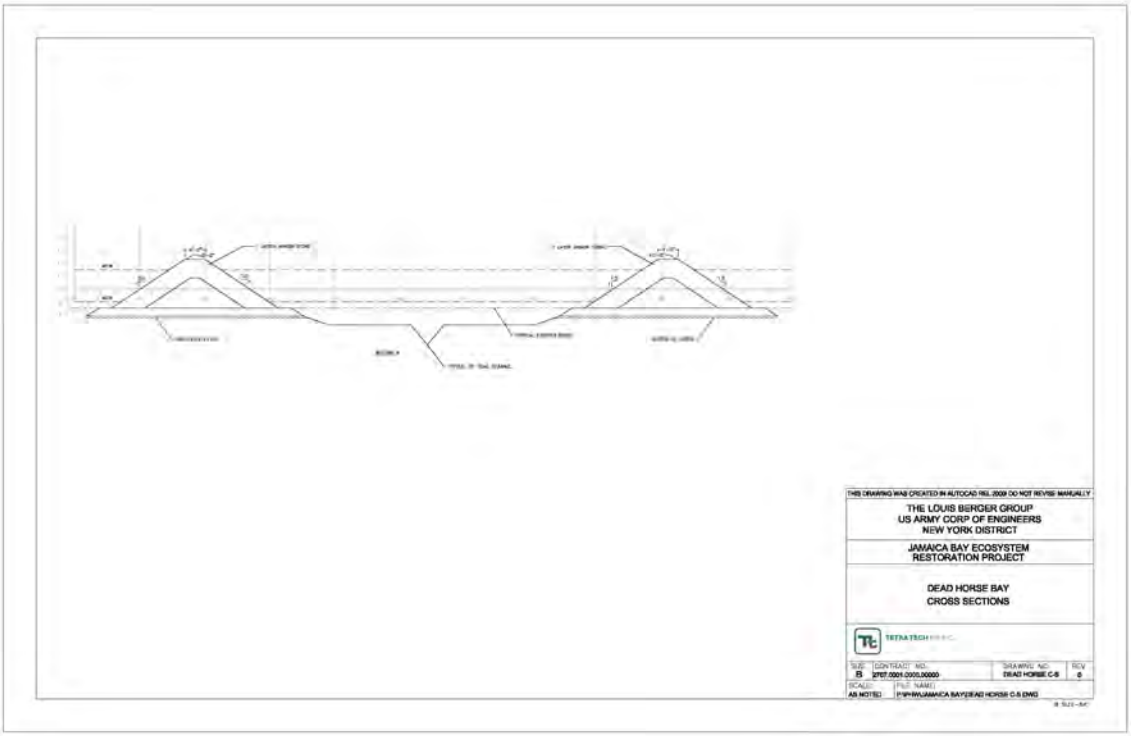
Other Parameters		
U'_{max}	0.500	
U'_{maf}	0.480	
Q_r	0.000	ft³/sec
$\frac{a_{b\,max}}{a_o}$	0.960	
$\frac{a_{b\,min}}{a_o}$	-0.560	

Channel Properties					
Cross sectional area A_c	360	ft²	Hydraulic radius (R)	5	feet
Max velocity V_m	1.49482	ft/sec	Max discharge Q_{max}	538.135	ft³/sec
Keulegan/King Parameters					
K	5.05102		K_1	71.1859	
K_2	0.0234652		F	1.325	
$\frac{a_b}{a_s}$	0.780		Max velocity V_m	0.660	ft/sec
ϵ	53.000				
Tidal Prism					
P	9.05163e+006	ft³	Travel time across bay	238.01	
Other Parameters					
U_{max}	1.13244	ft/sec	U_{maf}	1.08714	ft/sec
Bay tidal range	4.09639	feet	Q_{max}	407.678	ft³/sec
Q_{maf}	391.371	ft³/sec	Q'_r	0	

Figure 6.12. Plan View of the Jetties at the Dead Horse Bay – North Site.



Figure 6.13. Cross-section View of the Jetties at the Dead Horse Bay – North Site.



6.4.1.3 Shoreline Dune Structure Design

As summarized in Table 5.4 (Dead Horse Bay Erosion Rates), the southwest shoreline of the Dead Horse – South site experiences an average of 5.1 ft/yr from 1959 to 1996. This erosion is cutting into the bluffs in this location and exposing the landfill material that was dumped at the site approximately between 1930 –1950 (USAC 2003). A reinforced dune system has been conceptualized for the Dead Horse Bay – South Site to serve buffer zone for storm protection and containment of the landfill material. The shoreline stabilization system consists of buried geotubes, which compliment the restoration goal for the site of coastal dune and maritime forest enhancement and/or creation. Analysis of the system included a review of existing transects, grades, slopes, and qualitative comparison against the historical shoreline location. The location of the dune system and reinforced sections were identified.

The shoreline erosion analysis, as well as existing profile information and site visits, showed that Dead Horse Bay – South had experienced significant sediment loss. As determined in the wind wave analysis section, the site is exposed to high wave energy through the East Rockaway inlet, in addition to long term erosion of the shoreline. As seen from the existing profile survey shown in Figure 6.14, the beach face along the shoreline eroded up to the edge of the landfill creating a steep slope (“beach scarp”). Debris from the landfill is exposed all along the dune face at the site and has littered the beach along the entire shoreline of the site. As such, one of the restoration goals for this site is the creation of dune and beach habitat after the completion of the shoreline stabilization.

The EDUNE software was utilized for the sectional properties of the dune system. The EDUNE model predicts the time-dependent evolution of existing or design beach and dune profiles for specified storm surge and storm wave conditions. This model is based on the application of Dean's (1977) equilibrium beach profile theory. This theory assumes that a given beach profile will evolve toward a new equilibrium form and position in response to elevated water levels and increased breaking wave heights. The time-dependent profile response is obtained by solving the equation for conservation of sediment in finite-difference form, along with a simplified expression for cross-shore sediment transport rates. Input for the analysis included a typical survey profile, wave information (determined earlier for the site), as well as storm surge information.

Post-storm profiles were simulated at the end of the input storm. Figure 6.14 compares this post-storm profile to the pre-storm (existing) profile. After approximately 8 hours of continuous storm, erosion volume reaches to approximately 550 cubic feet per foot of the entire profile. This is similar to the erosion volume of 540 cubic feet per foot used for FEMA studies. Figure 6.15 shows the plot of the data for the FEMA rule corresponding to 100-year return period. Further investigation of the EDUNE simulation shows that the total shoreline retreat would be close to 130 feet, measured from the toe of the existing scarp for an unprotected shoreline.

The recommended location for a protective dune system is shown in Figure 6.16. The area being protected is only the exposed corner of the Dead Horse Bay – South location. The rest of the shoreline area gets flatter with almost no dune behind it, and sees lower wave energy due to the shoreline orientation; therefore, it does not require supplemental protection. The plan also aligns

well with the proposed conceptual restoration design, both in terms of the length and footprint area.

Figure 6.14 Pre- and Post-storm Profiles for a Typical Section at Dead Horse Bay – South Site.

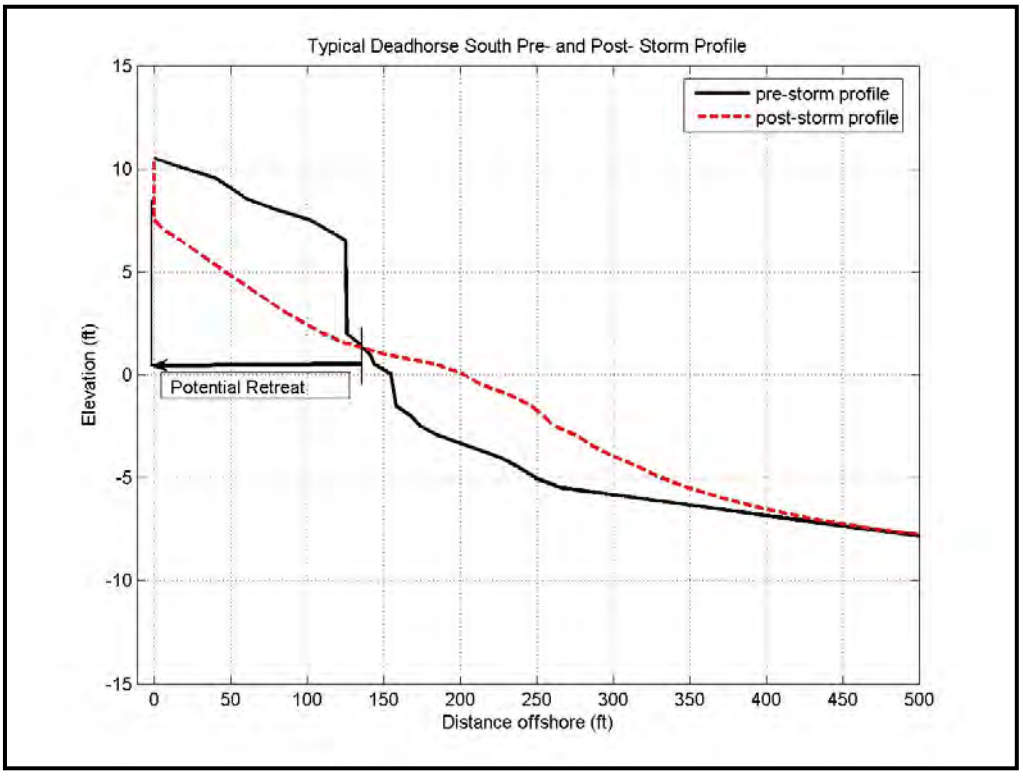


Figure 6.15. FEMA 540 feet^2 Storm Induced Erosion Volume Rule.

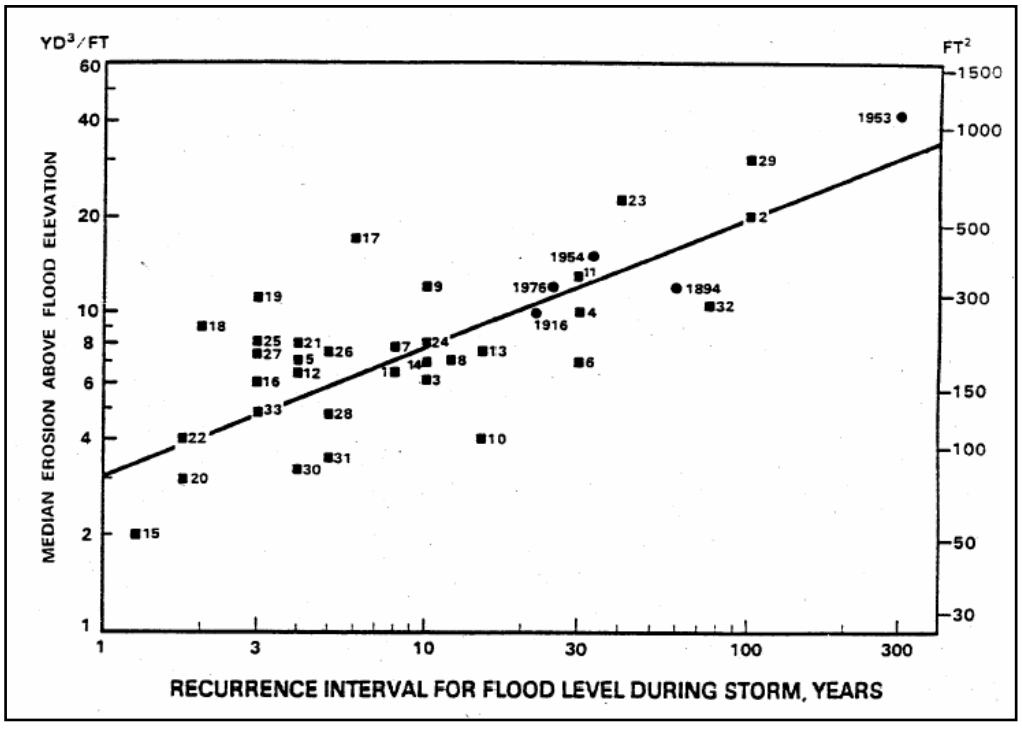


Figure 6.16 Plan View of the Geotubes and Dune at the Dead Horse Bay – South Site.

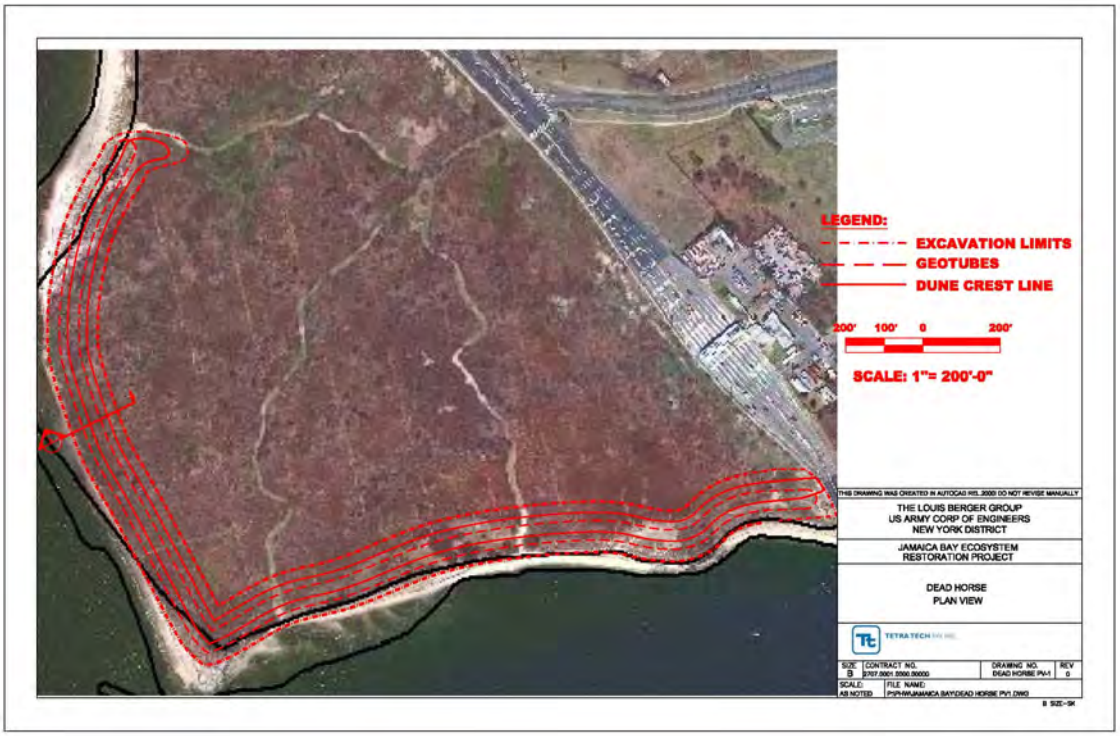
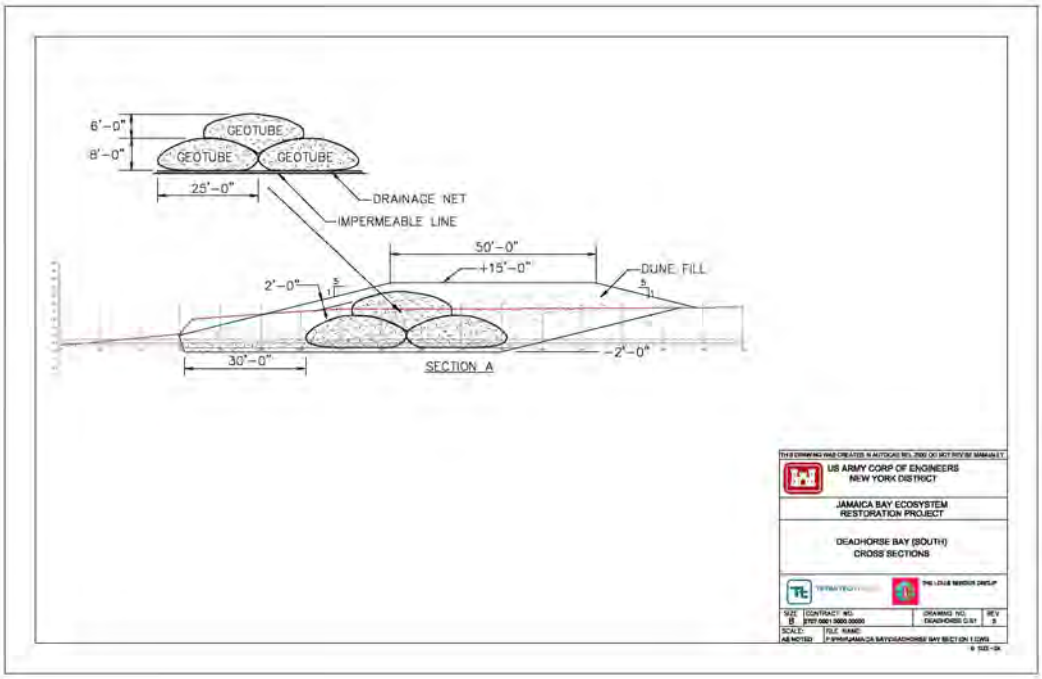


Figure 6.17 shows a typical cross-section for the reinforced dune fill. The setback of the dune fill is adjusted such a way that the landward most limit is about 130 feet, which is equivalent to the length of retreat expected after a storm, if left unprotected. The core volume of the fill, made up of three geotubes stacked in a pyramid shape, is about 500 cubic feet per foot, and remaining dune fill volume is about 1000 cubic feet per foot of the shoreline. At least 2-foot of cover around the Geotubes, including at the bottom, was provided for the protection of the textile from rupture due to the materials such as glass in the landfill. Another 2 feet of cover on top of the geotubes will provide for coastal dune substrate. Crest elevation is set to 15 feet to accommodate the geotubes core, which will have about 14 feet in height for a pyramid of three. This will limit the overtopping over the dune along with a runup value of about 10 feet. Crest width was set to 50 feet, and side slopes were set to 1V:5H, merging with the existing grade on both ends.

Figure 6.17 Cross-section View of the Geotubes and Dune at Dead Horse Bay – South Site.



6.4.2 Paerdegat Basin

Water Quality Improvement Features

The water quality modeling discussed in section 5.6 of this report indicated that the scenario that filled the basin up to MLW (or –2 ft NAVD88) not only showed the highest Dissolved Oxygen (DO) levels, but the scenario yielded the highest maximum velocities which aid circulation. However, the bottom shear stresses would likely be too high and the material would re-suspend and not remain at that depth. The scenario that fills the basin up to MLW would require a huge amount of material and cost which could make this option not feasible. In addition, the basin is used by recreational boaters, many of which need a larger draft than MLW. The proposed alternative to improve water quality in Paredegat Basin is shown in Appendix A. This alternative fills the basin up to –3.2 ft MLW (-1.2 ft NAVD88) at the head of the creek. The fill continues, tapering down to –8 ft MLW (-6 ft NAVD88) at the upstream side of the marina found towards the mouth of the creek. Not only will the fill improve circulation and DO levels, the fill will cap any contaminants that lie in the bottom of the creek which has settled out from years of CSO(s) discharging into the creek. The fill will be clean sand which offers an excellent medium for benthic habitats to re-colonize.

6.4.3 Fresh Creek

Water Quality Improvement Features

The water quality restoration features for Fresh Creek are very similar to Paredegat Basin because the water quality modeling results for Fresh Creek (discussed in section 5.6 of this report) are remarkably similar to the results rendered for Paredegat Basin. Again, the scenario

that filled the basin up to MLW (-2 ft NAVD88) showed the best DO and circulation results. However, the bathymetry at that contour would be unstable, as the bottom shear stresses would mobilize the sediment. The proposed alternative for Fresh Creek also involves filling the head of the basin to –3.2 MLW (-1.2 NAVD88). However, an intertidal marsh will be created in the upper 1200 ft of the creek, so that the channel, now approximately 300 f t wide and -6 ft MLW (-4 ft NAVD88), will be 10-20 ft wide and –3.2 ft MLW (-1.2 ft). The channel bottom will continue to be filled, tapering the depth uniformly from –3.2 ft MLW at the head of the creek to –4 ft MLW just downstream of an island found in the middle of the creek (approximately 3000 ft from the head of the creek). From the mid-creek island to the edge of the Jamaica Bay North Navigation Channel, the bottom will be filled from –4 ft MLW to –8 ft MLW, and then existing grades will be met at a 1:10 slope. Appendix A has the plan view and cross sections that describe the filling activities. Just like Paredegat Basin, not only will the fill improve DO and circulation, it will cap any contaminants currently existing on the bottom of the creek, and the clean sand will serve as an excellent medium for productive benthic communities.

6.4.4 Bayswater State Park

Contrary to the other sites, Bayswater State Park shows different shoreline change characteristics for each section analyzed (i.e. more along-shore rather than cross-shore sediment movement as indicated in the Shoreline Stability Report [USACE, 2002]). The existing concrete wall at the northwest tip of Bayswater State Park seems to be located at a nodal point where the sediment transport patterns alter direction on either each side of this point. Section 1 has experienced erosion over the years with contributions to the formation of the spits and Section 2 on the north face has experienced long-term accretion with continuous spit like formation. Seawall remnants have acted like a revetment over the years, preventing further erosion. When compared to the historical images (USACE, 2002), it appears that there is no more sediment in the system and that the spit formations have conceptually been diminishing in size and volume to maintain the existing shoreline, therefore requiring a closed sediment solution. Three potential shoreline stability alternatives for the Bayswater State Park site are described below.

Alternative 1

The Detached Offshore Breakwater Alternative for Bayswater State Park figure found in Appendix D (Additional Recommended Shore Protection Features) depicts the first alternative, a detached breakwater system on both sides of the Motts Point (nodal point). Three breakwaters at 150 feet in length with 75 feet between sections are suggested on each side of the nodal point. A relatively small size training structure is also recommended at the tip of the Motts Point, where an inlet is proposed to provide tidal flows to a proposed marsh (USACE, 2002). The gap across the inlet has been left wider to allow more wave and current action to prevent shoaling.

A typical cross sectional view of the breakwater is shown the “Typical Detached Offshore Breakwater Cross Section” figure found in Appendix D. The crest elevation of the structure is planned to be at +1 foot above the MHW elevation. To minimize the footprint of the structures, the side slopes were kept at 1V:1.5H. Appropriate sizing of the armor material would be in the range of 1 to 1.5 tons for median size rocks with one layer random placement method. These parameters could be refined more in the final design stage. The ratio of breakwater length over

the distance to the shoreline (l/y) was kept at 1.6 to 1.9 and the ratio of the gap over the breakwater length (b/l) was kept at 0.5.

Small-scale beach fill is also recommended, especially for the Section 1 area, to prevent any potential adverse downdrift effects for the adjacent properties. Two terminal groins, potentially a sheet pile wall attached with a public access pier, are recommended on both ends of Section 1. On the far eastern side of Section 2, a supplemental groin field with a beach fill is suggested as a potential future addition to prevent any erosion due to proposed breakwaters on the neighboring areas. While the present shoreline appears stable, a decrease in sediment supply may introduce erosion. This recommendation is mainly a precautionary measure. Configuring a beach fill with any breakwater alternative to allow some sediment leakage would help eliminate the need for the groin field.

Figure 6.18 2002 Aerial Image of Bayswater State Park.



A bioengineering solution is also a promising alternative for Section 2 with significantly reduced cost as compared to additional structures or beach nourishment. This alternative would also add to the environmental value of the site. The "Typical Bio-Engineering Solution Cross Section with Rolls and Box" figure in Appendix D shows a typical bioengineering solution cross-section, which could be built either in segments or continuously. The selection will depend on the level of protection required for Section 2.

Alternative 2

The "Tee-Groin Breakwater Alternative for Bayswater State Park" figure in Appendix D shows the second alternative, which involves a series of Tee-groins in both Sections 1 and 2. This alternative is structurally similar to that of a detached breakwater with the addition of the shore attachment (stem) structure. The elevation of this stem at a point along the longitudinal section can be adjusted to provide circulation for the pocket beach cells between the Tee-groins.

Five Tee-groins with two end groins at the two ends were recommended with this alternative. Direction and location of the Tee groins were adjusted to potentially reverse the sediment transport direction (Bodge, 1998). The length of each groin was designed to be 100 feet with gap spacing of 140 feet (Silvester and Hsu, 1993). A terminal groin at the west end was selected to be 40 feet long and with a spacing of 120 feet. The middle groin would extend landward and be shaped as an L-groin to act as a jetty at the proposed inlet of a channel system to convey tidal flows to a proposed marsh. A training structure opposite to the L-groin is also recommended to block any sediment movement in westerly directions.

A typical cross sectional view of the breakwater is shown in the "Typical Tee-Groin Breakwater Cross Section" figure in Appendix D. The crest elevation of the structure is proposed to be at the MHW elevation. To minimize the footprint of the structures, the side slopes were kept at 1V:1.5H. Appropriate sizing of the armor material would be in the range of 1 to 1.5 tons for median size rocks with one layer random placement method. The shore attachment structure has a variable elevation and starts above the MHW elevation on shore and mimics the existing beach slope to the breakwater structure at the MLW elevation. A cell structure for recreational purposes can also be considered with this solution such as at the Brant Point Site.

Small-scale beach fill is also recommended, especially for the Section 1 area, to prevent any potential adverse downdrift effects for the adjacent properties. It is recommended to design and fill these pocket beaches to an equilibrium shape. The existing spit-like formations extended to the south could potentially be mined as a source of sediment for redistribution along the shoreline. Future growth of the spit is expected to cease, and some retreat of the spit may actually occur.

Similar comments of Alternative 1 would be valid for this alternative for Section 2. No action alternative can also be considered as an alternative for Section 2. This can be decided based on the detailed design analysis at next stage of the design.

Alternative 3

The third alternative is the panel breakwall with an attached pier as shown in the "Panel Breakwall Breakwater Alternative for Bayswater State Park" figure in Appendix D. The panel breakwall will be installed to the seaward side of the pier with a total length of 1,350 feet with three walkways to provide public access from the park area. The breakwall is designed to protect the area that is exposed to more wave action on the west and northwest corner of Motts Point. The walkway in the middle is designed to have a sheet pile wall next to the proposed channel inlet. This is to prevent potential shoaling at the inlet mouth.

The "Typical Panel Breakwall Breakwater Cross Section with Pier Over It" figure in Appendix D shows the cross-section of the panel breakwall. The top elevation of the panel is proposed to be at 3 feet above the MHW elevation, and the bottom elevation is proposed to be 2 feet above the sea floor to allow circulation, and a small percentage of the wave energy. This opening will also provide a passage for the benthic community at the site. The width of the walkways and pier are designed to be 10 feet.

Concrete panels and piles can be used to construct the wall. It is also possible to utilize wood clad in vinyl as the construction material. The main selection criteria should be durability versus cost of the materials. Concrete would have a longer design life with potentially longer spans in between pilings as compared to wood panels. However, a wooden structure would cost less than the concrete panels and piling. Vinyl clad would significantly increase the durability and design life of pressure treated wood with increased cost. A public pier would increase recreational value to this alternative by means of providing fishing, and sightseeing opportunities for the public.

Bioengineering is also recommended with this alternative on the eastern half of the Section 2. Boxed fiber rolls that allow marsh plant growth could be utilized as the protective measure. This is mainly to protect the coastal dune with vegetation and tree lines along Section 2. The total length should be determined along with the proposed plan and local site conditions.

6.4.4.1 Shoreline Protection Structures Analysis and Design

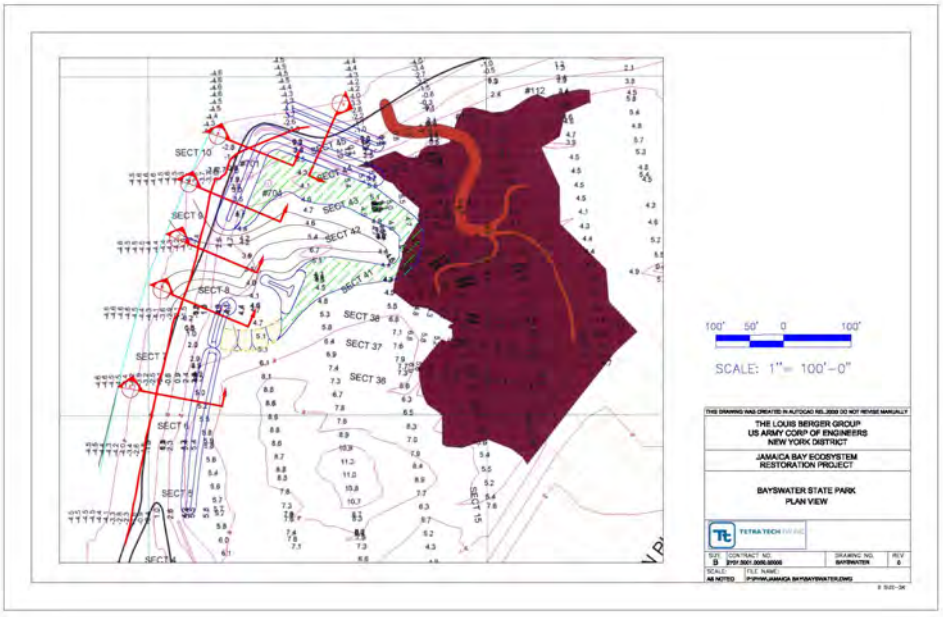
Following a series of discussions with the stakeholders, including the regulatory agencies, a modified version of the alternatives explained above was adopted for this site. The main driver for the modification was to further lower the footprint of the proposed alternative and keep all improvements located landward of MHW. However, the need for the shoreline protection scheme was not diminished.

The proposed alternative, as depicted in Figure 6.19 consisted of the rubble structures, somewhat similar to Alternative 2 above, with the inclusion of a lagoon at the northwest corner of the Bayswater State Park. The inlet structure, as proposed in the conceptual designs for this site, was kept in this alternative. Training structures on both sides of the inlet was proposed to prevent accumulation of the sediment at the entrance. The west side of the training structure was also used for the protection of the northwest corner of the park. The new version of the proposed alternative included: a lagoon, an entrance to the lagoon, a beach, and low marsh area for habitat. An inner rubble structure, wave absorber, had to be included across from the lagoon entrance to minimize the wave energy inside the lagoon. The shape and size of the inner structure was adjusted so that the wave will focus around it and be dissipated on the structure and the relatively

beach area around the structure. The southern section of the west shoreline of the park was proposed to be protected by a sand dune with a relatively small, buried-rubble core inside.

The rubble structures along the north and west side of the park is intended to hold the shoreline position as it exists today, and not necessarily promote erosion or accretion of the sediments on both sides of the park area.

Figure 6.19 Plan View of the Shore Protection Measures at Bayswater State Park.

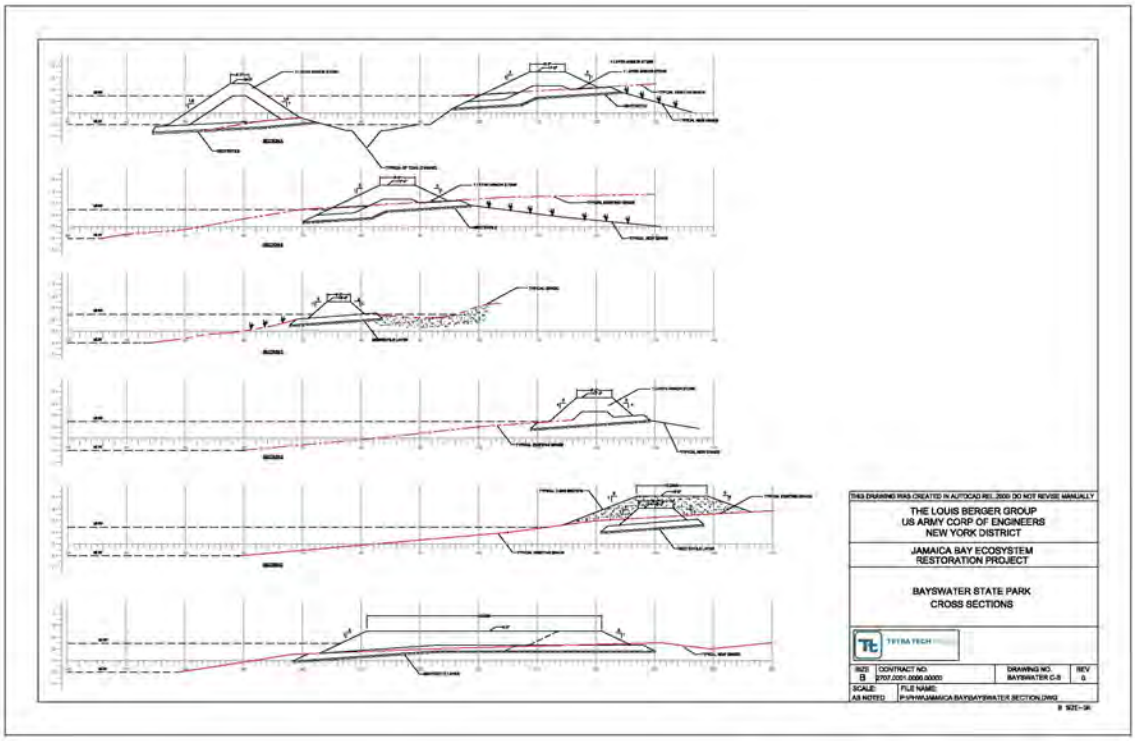


The rubble structures along the shoreline were sized with the help of the ACES software, created by the USACE. All dimensions were minimized, where possible, to limit the footprint area. The rubble mound structure is made up of one layer of rough angular stones with a median size of approximately 900 lbs. The side slopes were adjusted to be on 1V:2H for structural stability. The crest elevation was kept at +7 feet to tie in to the existing grade, as well as retain the views from the park. The crest width was kept at the minimum recommended level of 6 feet. A minimum 1-foot thick bedding layer atop a geotextile cover is recommended.

A similar sizing is suggested for the wave absorbing structure inside lagoon, with a crest elevation of 5 feet. The longitudinal section length was kept at about 40 feet, and a mild sloped sandy beach surrounds this structure.

Transition from the onshore breakwater to buried wall provided by a trapezoidal section with a crest width of 6 feet, and elevation of 6 feet. The crest width and elevation was 12 feet and 8 feet, respectively for the dune section over the buried wall. A minimum bedding layer of 1-foot is recommended in all sections. The side slopes of the dune fill were kept on 1V:5H for stability. The cross sectional views are presented in Figure 6.20.

Figure 6.20. Cross-section View of the Shore Protection Measures at Bayswater State Park.



6.4.4.2 Training Structures Analysis and Design

A training structure was placed on the east side of the long flank to keep the inlet from clogging. Side slopes were set to 1V:1.5H, with a crest elevation and width of 5 feet and 4 feet, respectively. The structure is oriented parallel to the inlet canal alignment as intended, and also perpendicular to the major fetch direction. This latter will enabled to lower the crest elevation as compared to opposite side. The landward side of the rubble structure is transitioned into the existing grade. Section A in Figure 6.20 shows a typical view of the inlet training structure.

6.4.5 Dubos Point

In the first quarter of the 20th century, the Dubos Point Site was partially bulkheaded and filled to allow development along the shoreline (USACE, 2002). While the development did not occur, some portion of the bulkhead still remains today.

Alternative 1

As determined in the Decision Matrix for Jamaica Bay Shoreline Structures (Table 6.1), a detached breakwater alternative scored highest for the Dubos Point Site. This option was applied to both regions of the site even though the Decision Matrix specifies it only for Section 1. For practical purposes it was decided that it would be better to span the entire length of the Dubos Point shoreline with the same type of structure.

Proposed ecological plans (USACE, 2002) entail sculpting and interior wetland from the upland forest area. To flush the wetland, a tidal connection must be artificially created. There are two

options for the location of the inlet to provide tidal waters to the proposed marsh. Although it is recommended to locate this inlet on the eastern shore of the peninsula, the plan view as shown in the "Detached Offshore Breakwater Alternative for Dubos Point" figure in Appendix D considers a possible entrance on the northwest side of Dubos Point. This location is bounded with a small training structure as well as a large opening between the breakwaters to prevent any potential shoaling.

A total of seven detached breakwaters were designed, two in Section 1, each 200 feet in length and spaced at 100 feet, and five in Section 2, each 250 feet in length and spaced at 150 feet. The last breakwater on the northeast corner was curved and extended to 300 feet in length to protect the tip of the Dubos Point. Distances from the shoreline to each breakwater decreased from a southwest to a northeast direction in Section 2, to allow salient formation for southern breakwaters and tombolo formation for northern breakwaters. This would provide additional protection to the point where the wave exposure is expected to be greater. The ratio of breakwater length over the distance to the shoreline (*l/y*) was kept at 1.4 to 2.8 and the ratio of the gap over the breakwater length (*b/l*) was kept at 0.6. Small-scale beach fill is also recommended (especially for the Section 1 area) to prevent any potential adverse downdrift effects to the adjacent properties.

A typical cross-section for the detached breakwater is provided in the "Typical Detached Offshore Breakwater Cross Section" figure in Appendix D. Note the presence of a distinct slope change on the bay side of the point. In the final design, this should be analyzed cautiously for two reasons: 1) the proximity of the rubble mound structure to top of slope may induce a slope failure and 2) the sudden change in slope near the rubble mound may cause breaking wave effects on the structure. If selected, the detached rubble mound breakwater design should be analyzed for both of these concerns.

The crest elevation of the rubble mound breakwater design structure should be kept at +1 foot above the MHW elevation with a side slope of 1V:1.5H. A single layer of armor rock of 1 to 1.5 tons of median size would be more suitable for this site.

Alternative 2

The "Sill Structure with Fill Alternative for Dubos Point" and "Typical Panel Breakwall Breakwater Cross Section with Pier Over It" figures in Appendix D present the plan view and cross-sectional views of the second alternative for Dubos Point, respectively. As shown in the Decision Matrix for Jamaica Bay Shoreline Structures (Table 6.1), panel breakwalls with a pier offers recreational opportunities and nearly zero structure footprint impacts. The total length of the structure is determined to be around 3,000 feet. A 2-foot opening between the panel and the bay bottom was designed to provide circulation and a passage for the native habitat. The total length of the pier (for recreational purposes) was kept only for the Section 1 area to reduce the total cost of this alternative. If preferred, it can be extended for the entire length of the panel breakwalls with increased cost. A walkway (potentially two) is also provided for public access. Public access to the pier would provide fishing for anglers as well as sightseeing for naturists and local people.

Bioengineering measures are recommended for this alternative to prevent potential erosion around and beyond the high water line, due to the fact that some wave action will be allowed from the opening underneath the panel breakwalls. Boxed fiber rolls that allow marsh plant growth could be utilized as the protective measure, as shown in the "Typical Bio-Engineering Solution Cross Section with Rolls and Box" figure in Appendix D.

Alternative 3

Alternative 3 is a submerged sill structure with fill placed behind the structure (see "Panel Breakwall Breakwater Alternative for Dubos Point" figure in Appendix D). This alternative is designed to encompass the entire Section 1 and Section 2 shoreline with a total length of 3,250 feet. It is located landward from the existing slope change to minimize the amount of fill. Submerged structures, in general, will decrease the transmitted wave energy to some extent. However, this may not be enough for shoreline stabilization purposes. Therefore, the clear distance from the edge of the slope change to sill structure would act as a natural berm to decrease wave energy.

A pre-cast concrete module or a low crested sheet pile wall (wood, concrete or vinyl) can be designed as the sill structure. Currently, the proposed plan includes a sheet pile wall, as shown in the "Typical Sill Structure Cross Section – Concrete Wall or Sheetpile Wall" figure in Appendix D, due to potential slope stability problems. The sheet pile wall could be driven to a depth that would adequately support the fill material if the existing slope outside the structure were to fail. Toe protection measures should also be taken to protect the toe of the new structure.

Material for the beach fill should be compatible or coarser grained then the existing beach material to decrease the amount of sediment transported along the shoreline. The fill is designed as a blanket cover, mimicking the existing topography up to the MHW elevation. Bioengineering measures are recommended at this level to stop further wave action and erosion beyond this point. Boxed roll hays can also be utilized with wooden stakes either continuously or discretely along the shoreline, as shown in the "Typical Bio-Engineering Solution Cross Section with Rolls and Box" figure in Appendix D.

The two ends of the sill structure should be closed to confine the beach fill. The total length of this structure would be about 3,250 feet. Allowance for dynamic movement of the beach alongshore should be provided, including the need for future nourishment. Training structures to avoid sedimentation of the channel inlet should also be provided.

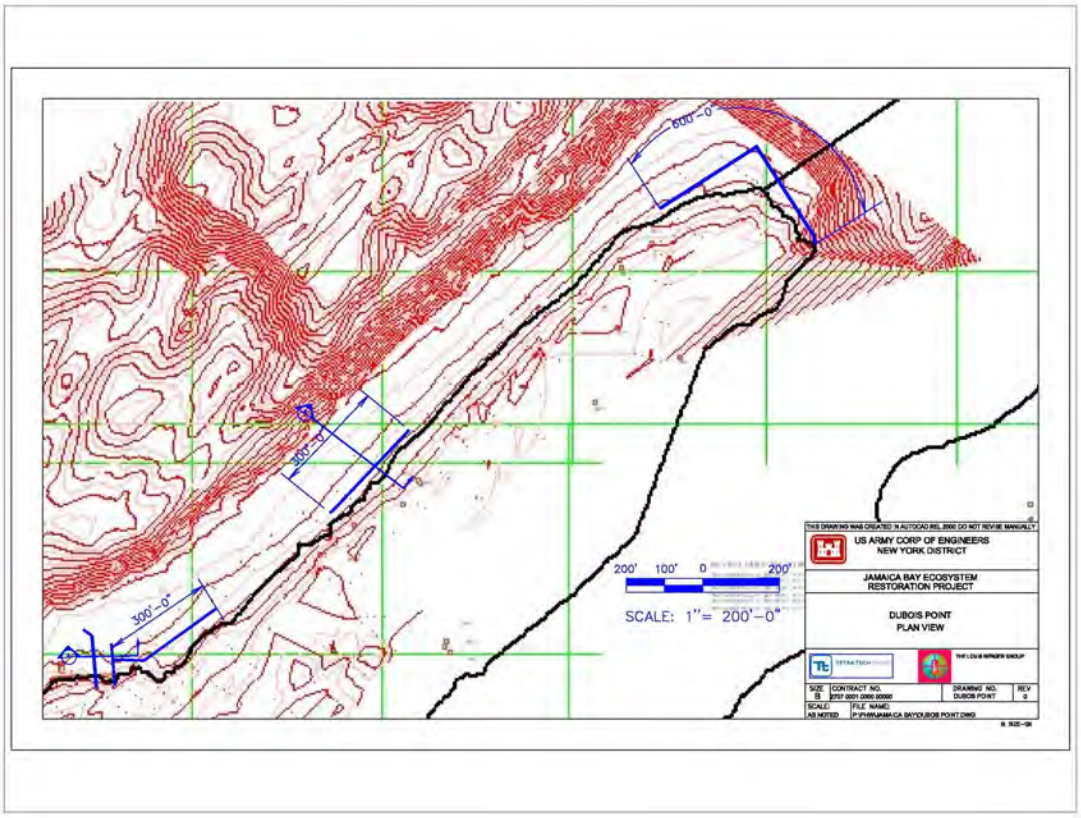
6.4.5.1 Shoreline Protection Structures Analysis and Design

The recommended alternative for Dubos Point has evolved since the evaluation of the alternatives, as outlined above, as well as from the *Conceptual Plan – Final* (USACE, 2003). The modifications to these alternatives were made after meeting with regulators, stakeholders of the site, as well as the USACE. The discussions lead to choosing a bare minimum measure to more or less stabilize the existing structures. The current recommended alternative for the shoreline protection is essentially a derivate of the Alternative 3.

A low crested sheetpile wall (made out of composite material) serves as the sill structure. The residual life for the existing wall seems to be poor based on the visual observations at the site. This is also evident from the fact that there is a pronounced sediment lost, or shoreline retreat. This erosion may lead to potential slope stability problems, and the shoreline may continue to erode if not modified. This instability may then jeopardize the restoration plan for the upland side. Therefore, to increase the survivability of the overall plan, it is recommended at a minimum to restore the existing bulkhead structure.

Figure 6.21 shows the limits of the recommended plan, coinciding with the section where the historical retreat was determined to be significant. The sheetpile is to be driven next to the old one, and to about same crest elevation, as it currently exists at +2 feet, slightly lower than the mean high water (MHW at 2.39 feet). Landward of the sill, a beach fill is recommended. Material for the beach fill should be compatible or coarser grained then the existing beach material to decrease the amount of sediment transported along the shoreline. The fill is designed as a blanket cover, mimicking the existing topography up to the MHW elevation on landward side. The sheet pile is to be driven to a depth that would adequately support the fill material and to eliminate the need for toe protection, if the existing slope outside the structure were to fail. The two ends of the sill structure should be returned to shore to confine the beach fill. The total length of this structure would be about 2,400 feet. Allowance for dynamic movement of the beach alongshore should be provided, however, using a cobble size material will minimize the need for future nourishment.

Figure 6.21 Plan View of the Shore Protection Measures at Dubos Point.

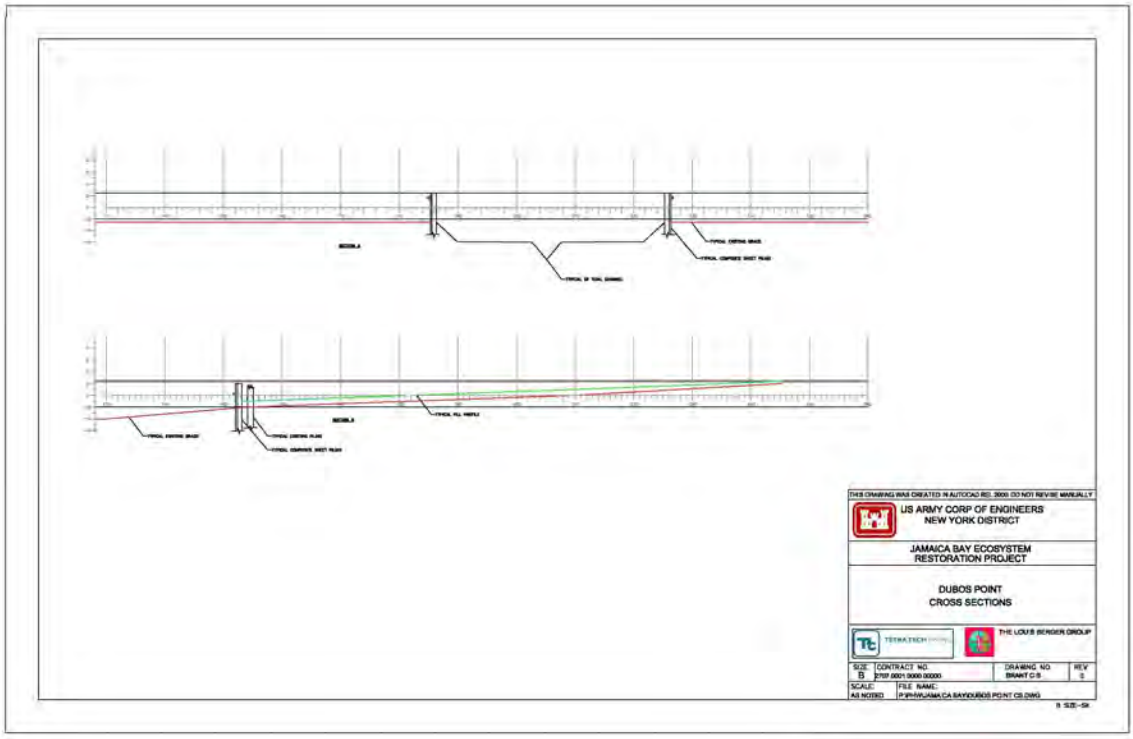


6.4.5.2 Training Structures Analysis and Design

The conceptual plan includes cutting a channel through the southwest corner of the Dubos Point. Training structures at the mouth of this channel are provided to avoid shoaling of the channel inlet. The recommended plan for the training structures is similar to the beach sill in order to keep the footprint to a minimum, and simplify construction. Using the same detail for the entire shore will also minimize the costs of system versus another may likely be overridden by the mobilization costs and logistics costs of setting up for more than one technique.

The top elevation of the training structure was set at 2.5 feet, slightly above the mean higher high water (MHHW at 2.43 feet) to account for the monthly variations in the water level. The training structure on the west side is extended beyond the MLW line, with a spur pointing towards northwest for further protection (from easterly sediment movement) of the inlet mouth. The total length of this structure was about 170 feet, including the spur at the end. East side structure was kept at 110 feet, with the assumption that the net movement is from west to east, based on the historical aerials where there is a formation of a pocket beach just to the west of the training structures. Figure 6.22 shows typical cross-sectional views of the site. It is recommended that using a numerical or physical modeling, or a detailed analytical analysis in the absence of modeling will optimize the structure locations and sizes.

Figure 6.22. Cross-section View of the Shore Protection Measures at Dubos Point.



6.4.6 Brant Point

Brant Point site was divided into two sections, due to the northerly and northwesterly exposures to wave attack, as well as the different shoreline characteristics. The Brant Point shoreline has exhibited long-term shoreline recession since the early 1900's. As indicated in the Shoreline Stability Analysis Report (USACE, 2002), the Section 1 shoreline consists of natural material with deposits of shells, and exposed clay layers along the shoreline. Portions of the north face of the Brant Point (Section 2) shoreline consist of an un-engineered riprapped edge where the shoreline is locally armored with broken concrete slabs. A tombolo has formed behind derelict-grounded barge along the west side (Section 1) of Brant Point. The geomorphology at this site provided insight into site conditions and coastal processes, which were used to guide the design alternative development.

The proposed restoration plan at Brant Point includes the creation of a tidal marsh, coastal meadow, and an upland forest (USACE, 2002). The proposed tidal marsh will cover a large area on the north side where construction rubble fill currently exists and an area behind the existing marsh on the west side of the site. An existing ditch on the northwest shoreline will provide the necessary tidal flows to support the proposed tidal marsh. Therefore, any potential shoreline stability alternative should include a measure to keep the existing inlet open. The north face (Section 2) requires a measure to protect the edge of the proposed tidal marsh.

The Decision Matrix for Jamaica Bay Shoreline Structures (Table 6.1) was developed based upon the site characterization. Rubble mound structures; offshore detached and Tee-groin solutions, as well as panel breakwalls (with and without walkways on top) were identified as the best potential alternatives for this site. A revetment on the north side also scored high.

Alternative 1

The "Detached Offshore Breakwater Alternative for Brant Point" figure in Appendix D shows the detached breakwater alternative with revetment on the north side and potentially at the north edge of the existing bulkhead on the northwest side. Three breakwaters are proposed, each 120 feet in length with 70 feet of spacing between them. Proximity of the breakwater to the shoreline is 70 feet on average. This distance should promote sand accretion in the form of tombolo formation. Creation of tombolos similar to the ones formed by the existing barge is desirable to create more habitat for marine life like horseshoe crabs. The ratio of breakwater length over the distance to the shoreline (l/y=1.7) as well as ratio of the gap over the breakwater length (b/l=0.6) dictates the formation of a tombolo, based on the guidance provided by Coastal Engineering Manual (2002), and ASCE Design Guidelines for Coastal Groins and Nearshore Breakwaters (1994).

Any accretional formation on the shoreline will solely depend on the amount of sand available in the dynamic region of the shoreline. Even though the existing tombolo provides some proof for the existence of the sand in the past, this may not be true with today's (or future) conditions at the site. It is recommended that some sort of beach fill with compatible or coarser sediment be placed in addition to the offshore breakwaters. The potential effect of these structures to the adjacent areas needs to be investigated further by analytical and/or numerical tools before implementation. However, it is unlikely that there will be an adverse effect, since a bulkhead

protects the southern boundary, and the northern boundary is already receded to a stable level. Any bypassing of nourishment sand would benefit neighboring beaches.

The detached breakwater alternative conceptual design also includes a gap between the existing barge and the first breakwater to allow some wave and current agitation where the existing drainage ditch discharges. This is mainly to prevent any potential sedimentation at the mouth of the ditch. Small size training structures could also be considered at each side of the ditch. The breakwaters are sited to be in a sub-tidal region to promote habitat creation both on and around the structure. The "Typical Detached Offshore Breakwater Cross-section" figure in Appendix D provides a typical cross-section. The crest elevation of the structure is planned to be at +1 foot above the MHW elevation. A wave transmission coefficient value of around 0.3 was targeted as to reduce waves sufficient to allow vegetation to then resist erosion. To minimize the footprint of the structures, the side slopes were kept at 1V:1.5H, which is relatively steep for these kinds of structures. Appropriate sizing of the armor material is projected in the range of 1 to 1.5 tons with one layer random placement method. These parameters could be refined more in the next design stage. Geotubes can also be used as an alternative material at this site.

A revetment type structure is recommended on the north face of the Brant Point site, similar to what exists at the site. This revetment should cover the dynamic area, which is mainly governed by the wave action. A smaller scale revetment is also recommended on the west edge of the site adjacent to the existing bulkhead.

Alternative 2

The "Tee-Groin Breakwater Alternative for Brant Point" and "Typical Tee-groin Breakwater Cross-section" figures in Appendix D present the Tee-groin alternative structure plan and cross-sectional view, respectively. This alternative has many similarities to the detached breakwaters except for a few important points. In this alternative, two Tee-groins with a terminal groin are proposed to be 100 feet and 60 feet in length with a 100 feet spacing between the groins. These structures are designed to be about 100 feet away from the shoreline based on the guidelines provided by Silvester and Hsu (1993). Similar to the previous alternative, revetments on both sides of the site are recommended.

Crest elevation of the main shore-parallel section was designed at the MHW elevation. Beach fill within the Tee-groin cells to create pocket beaches is strongly recommended for this alternative. Equilibrium profiles of these pocket beaches can be estimated by the available analytical and/or numerical tools to determine the amount and size of the fill required. Fill, in the form of compatible sediment, could reduce the potential downdrift effects.

Similar sized armor material as used for the detached breakwater alternative can be utilized for the Tee-groins and terminal groin. The shore connection (stem) can be made up of either sheet piling or rubble mound as the breakwater itself. Crest elevation of this section is kept at an elevation lower than that of the breakwater section to provide a template for the nourishment. The gap created by this section would provide both sediment bypass for the downdrift section and a clear passage for the native habitat. As an additional alternative, a cell like structure is suggested for public access to deep water. In this case both the stem and cell elevation should be

significantly higher than the MHW elevation to prevent wave splash and promote pedestrian safety.

Alternative 3

The "Panel Breakwall Breakwater Alternative for Brant Point" and "Typical Panel Breakwall Breakwater Cross Section with Pier Over It" figures in Appendix D present the plan and cross-sectional views of a third alternative: a panel breakwall in combination with a recreational pier. As shown in the cross-sectional view, the panel walls have about a 2-foot opening at the bottom to allow circulation. Sizing of these openings was determined so as to limit the wave energy on the shoreline, therefore, limiting the erosion. Detailed analytical theory is provided in Appendix I (Wave Transmission Analysis). This opening will also provide a passage for the marine life at the site. The panel wall spans from north of the existing barge to the end of the project limit on the northeast corner. The total length of the structure is designed to be approximately 750 feet. The pier over the panel walls extends to cover the entire panel wall length; however, the length of the pier can be reduced to lower the overall cost. Three walkways from the two ends of the pier and from the middle were planned as shown in the "Panel Breakwall Breakwater Alternative for Brant Point" figure in Appendix D The width of the walkways and pier are designed to be 10 feet.

Concrete panels and piles can be used to construct the wall. It may also be possible to utilize vinyl-clad material. The main criteria in selection of the material should be durability, cost, and structural suitability. Concrete would have a longer design life with potentially longer spans in between pilings as compared to wood panels. A wooden structure would have a lower first cost, but requires more maintenance and has a shorter design life. Public access to the pier could be provided through the walkways.

Shoreline Protection Structures Analysis and Design

The recommended alternative for Brant Point has evolved slightly since the evaluation of the alternatives as outlined above, as well as from the *Conceptual Plan – Final* (USACE, 2003). The modifications to these alternatives were made after meeting with regulators, stakeholders of the site, as well as the USACE. The shoreline protection was warranted at this site due to historical retreat and wave exposure, along with the need for a protection of the conceptual plans on the landward side. The current recommended alternative for the shoreline protection is essentially a slight derivation of the Alternative 1 above.

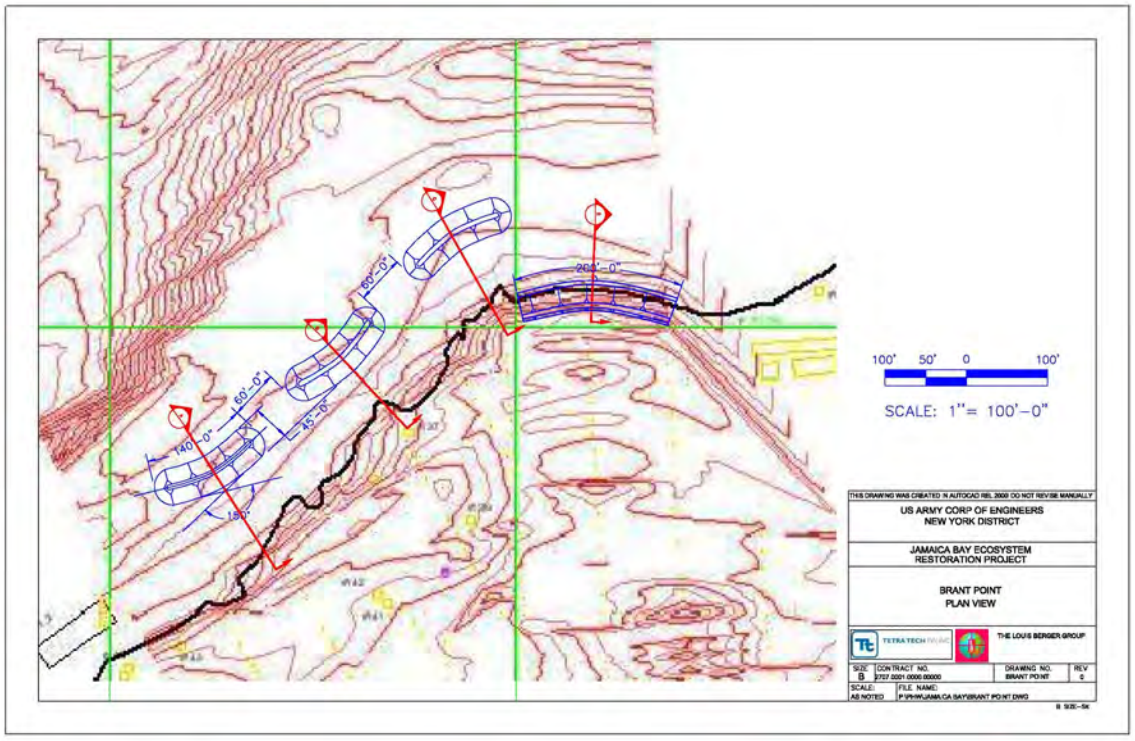
Figure 6.23 shows the recommended detached breakwater system with revetment on the north side. Three breakwaters are proposed, each 140 feet in length with 60 feet of spacing between them. Proximity of the breakwater to the shoreline is 75 feet on average. This distance should promote sand accretion in the form of tombolo formation, provided that there is enough sand in the system. The ratio of breakwater length over the distance to the shoreline (l/y=1.9) as well as ratio of the gap over the breakwater length (b/l=0.4) dictates the formation of a tombolo, based on the guidance provided by Coastal Engineering Manual (2002), and ASCE Design Guidelines for Coastal Groins and Nearshore Breakwaters (1994).

Alternative 1 recommended that some sort of beach fill with compatible or coarser sediment be placed in addition to the offshore breakwaters. However, this was not included in this recommended alternative due concerns of covering the natural habitat.

As a modification to the Alternative 1 above, the detached breakwaters were curved, or tuned, for potentially enhanced performance by aligning the structures with the predominant wave direction. An iterative method was used for the optimization of the overall curvature and shape of the detached breakwaters by considering predominant as well as all other wave approach directions. The tangents on each half wing of the breakwaters were determined to be 150°.

This recommended plan also includes a larger gap between the existing barge and the first breakwater to allow some wave and current agitation where the existing drainage ditch discharges. This is mainly to prevent any potential sedimentation at the mouth of the ditch.

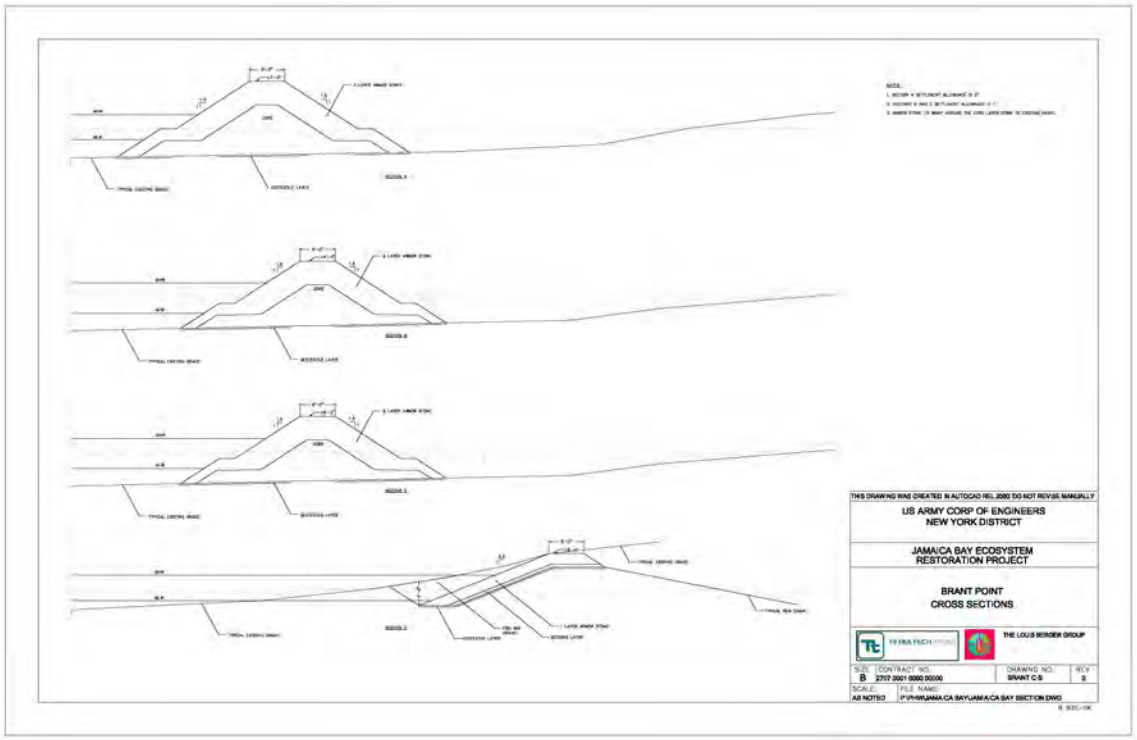
Figure 6.23 Plan View of the Shore Protection Measures at Brant Point.



The breakwaters are designed to be in a sub-tidal region to promote habitat creation both on and around the structure. Figure 6.24 provides typical cross-section views of the site. The crest elevation and width of the structure is planned to be at +7.5 foot, and 6 feet, respectively. A wave transmission coefficient value of around 0.3 limits the size of waves that can reach the shoreline. To minimize the footprint of the structures, the side slopes were kept at 1H:1.5V. The median size armor material was determined to be around 1250 lbs with two-layer random placement method atop the core. A 1-foot thick bedding layer was recommended atop a geotextile cover. Up to 2 feet of allowance for settlement of structures on the north side and 1 foot at the south side was included based on the available geotechnical information.

A revetment structure is recommended on the north face of the Brant Point site, similar to what exists at the site. This revetment covers the dynamic area, which is mainly governed by the wave action. A gravel fill was recommended for the toe protection. The recommend size of the fish mix fill material is between 2 and 8 inches in diameter to promote habitat creation within inter tidal zone. The footprint of the revetment may need further adjusting so as not to exceed the existing footprint of the rubble landfill. The potential effect of these structures to the adjacent areas needs to be investigated further by analytical and/or numerical tools before implementation.

Figure 6.24 Cross-section View of the Shore Protection Measures at Brant Point.



7. FUTURE WITH AND WITHOUT PROJECT CONDITIONS

The coastal habitats that currently exist on all the 8 sites in the JBERP study have and will experience ecosystem function degradation in a variety of forms. The topography and bathymetry of Jamaica Bay has been grossly altered in the last 200 years, which is discussed extensively in the *Jamaica Bay Ecosystem Restoration Project: Existing Conditions, Future Without Project Conditions, Goals and Objectives Report* (USACE, 2002). The future without project conditions at all the sites will involve further expansion of invasive species, possible water quality dedgredation if improvements are not made to the water treatment plants and CSO's that discharge into the bay. Development pressures, both upland (more impervious surfaces, earth moving actvities, rerouting of rainfall runoff, etc) and below MLW (modifications to the Belt Parkway and other roadway bridges, JFK Airport runway modifications, navigation channel maintenance activities, bulkheading, etc) are likely to cause further dedgradation to all 8

sites. These future with and without project impoacts, and their impact to existing and proposed coastal habitats are discussed in the main JBERP Feasiblity Report. The largest physical future impact at all 8 sitese that can be estimated would be erosion of the shoreline. Section 5.6 and 5.7 (Shoreline Change and Slope Stability Analysis) discuss the impact of erosion and slope stability. A review of the aerial photographs from 1959, 1966, 1974 and 1996 for all sites show that the shoreline at Paerdaget Basin, Fresh Creek, and the northern section of the Spring Creek site have been stable. The aerial photographs take into account all physical process that affect the shoreline, including erosion from water movement (waves, high velocities, etc) and from sea level rise for the last 4 decades. The aforementioned 3 sites appear to be able to adjust to erosional forces and/or sediment supply. This study assumes that for these three sites that the existing and future without project conditions shorelines will be similar. All future without project changes will be from changes in habitat only, quantified in the main report (USACE, 2005). The portion of the Spring Creek site that faces south and the Hawtree Point site may expierience erosion. However, only upland habitat improvements are planned in those locations, found +-150 ft inland from Jamaica Bay.

A comparison of the future (50 year projection) with and without project conditions at Dead Horse Bay, Bayswater State Park, Dubos Point and Brant Point follows. The average erosion/per section of shoreline, for each of these sites (Tables 5.4 – 5.7) are used throughout this analysis. The shoreline digitized in section 5.6 was the vegetation line. On the 1996 aerial photograph, this line matched existing habitats found along the shoreline – either the seaward limit of low marsh or the landward limit of beach habitat. This vegatation line deliniated on the 1996 aerial served as the baseline for this analysis. Thus it was assumed that future erosion would move the seaward limit the of low marsh first (or the habitat landward of the beach), and then impact the next habitats landward. The erosion rates calculated in section 5.6 have been multiplied by 50 to determine what the shoreline retreat would be in 50 years.

As erosion occurs, it will convert habitats from low marsh or coastal dune or scrub/shrub, to habitats that are typically found seaward of the vegetation line (beach, mudflat, shallow water, deep water, etc.). Equilibrium beach profile theory (Dean 1977) was applied to determine the future habitiat types of the areas that will erode in 50 years. This theory states that as shorelines erode, the shape and characteristics of the shoreline remain relatively the same. The average width of the existing beach, mudflat, and shallow water habitats were estimated. For the future without project conditions, the widths were multiplied by the linear length of shoreline to estimate the future acreages for these habitiat types. However, if the existing acreages for these habitats were more than the average width multiplied by the linear length of shoreline, the existing acreages were assumed for the future withot project conditions. For Dead Horse Bay and Bayswater State Park sites, while observing the series of historical photgraphs in the vicinity of the most erosive sections of their shoreline, it appears that the deep water has always been very far from the shoreline. For those 2 site the future upland habitat losses would turn into mudflat habitat instead of deep water. For Dubos and Brant Points, where deep water is close to shore, future upland habitat losses would turn into deep water (“water” habitat is the same as “deep water” habitat). The names of the habitat types in this analysis were taken from the vegetative mapping done and documented in the main report. This analysis had to be consistent with the vegetative mapping nomenclature so the habitat acre summaries could be used in

determining the cost effectiveness of the proposed plans. Refer to the main report for a description of the habitat types indicated in this analysis.

7.1 Dead Horse Bay

Dead Horse Bay – North

Besides the shoreline in the vicinity of the existing drainage inlet, the Dead Horse Bay North site does not experience erosion. Table 5.4 discussed in section 5.6 shows a maximum erosion rate of 0.4 ft/yr, and 2 sections are acreeting at rates as great as 3.2 ft/yr. (The average erosion/per section of shoreline is used throughout this analysis). Thus, the Dead Horse Bay North site future without project conditions with respect to erosion of the shoreline is also espected to be similar to existing conditions. The proposed projet and the future with project are also assumed to be the same.

Dead Horse Bay - South

Dead Horse Bay South site has experienced erosion, espeically on the southern most west facing shoreline, where rates are as high as 5.2 ft/yr (see Table 5.4). Figure 7.1 shows the existing habitats for Dead Horse Bay – South site. The blue lines Figure 7.1 show transects spaced 100 ft apart that are the length of the average yearly erosion, multiplied by 50 to represent the vegetation line (a.k.a. shoreline) in 50 years. The projected 50-year vegetation line is perpendicular to those transects. The specific erosion rates for each of the 5 sections of the shoreline were projected accordingly (see Table 5.4). Next, all habitats seaward of the 50-year projected vegetaion line were summed and compared to the acres of the existing habitat types. Shallow water and deep water habitat acres remained the same in the existing and future without project habitat summaries, as a constant width of these habitat types were not prominent features. The future beach acres was calculated by averaging the existing beach width (85 ft) and multiplying it by the linear length of the eroded shoreline (1400 ft). Only the mudflat habitat increased dramatically in the future without project condition. Table 7.1 shows the existing, future without project and proposed plan habitat acres.

The future with-project habitat acres were assumed to be the same as the current project habitat acres. The shore protection structure proposed at this site would maintain the location of the existing shoreline, so that the present and future with project habitats would be the same, as indicated in Table 7.1

Figure 7.1 The 50-Year Erosion Shoreline Project on to the Existing Habitat Map at Dead Horse Bay South

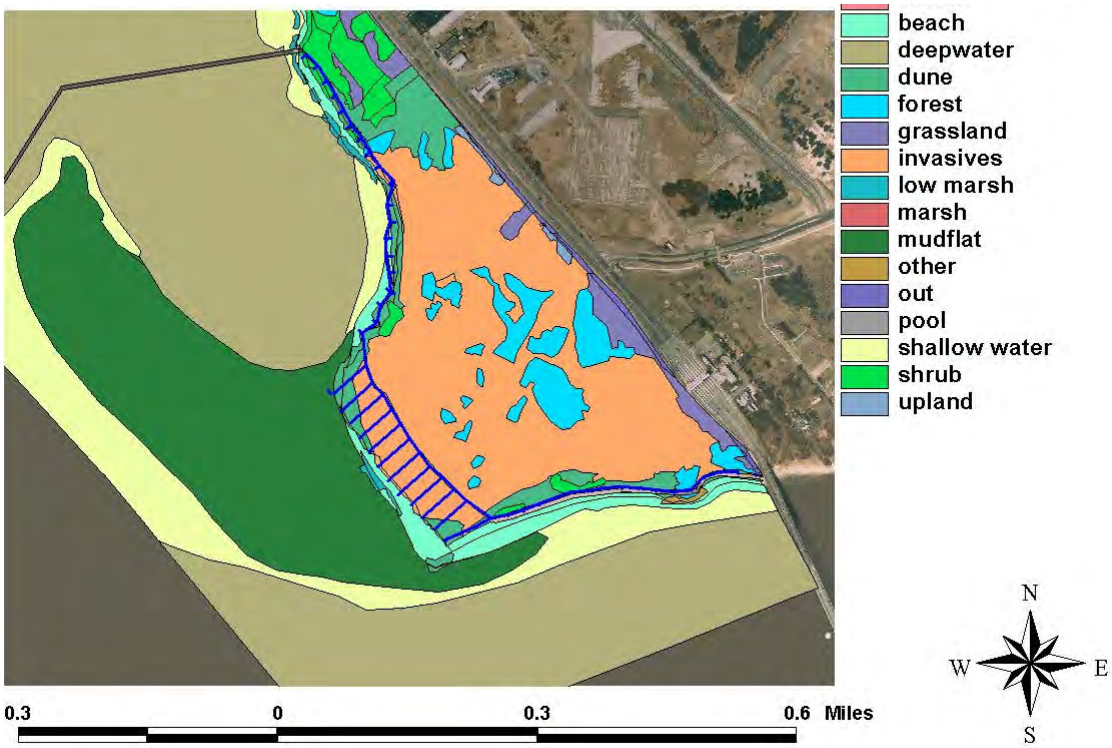


Table 7.1 Dead Horse Bay Existing, Proposed and Future Without Project Habitat Acres

	Existing Acres	Future without Project Acres	Present and Future Proposed Plan Acres
Beach	15.38	18.14	11.02
Channel	0.00	0.00	3.67
Deepwater	182.04	182.04	181.10
Dune	13.99	11.67	40.26
Forest	16.67	16.59	11.31
Grassland	6.96	6.96	6.77
High marsh	0.00	0.00	6.82
invasives	103.90	98.24	1.34
low marsh	2.62	1.65	32.39
MaritimeForest	0.00	0.00	48.51
marsh	0.05	0.05	0.00
mudflat	67.07	74.00	64.22
other	1.83	1.61	0.09
out	4.00	4.00	1.85
pool	0.56	0.56	0.02
shallow water	48.46	48.46	47.24
shrub	7.22	6.79	7.18
upland	5.85	5.85	13.64

7.2 Bayswater State Park

The section of the Bayswater State Park shoreline that faces west experiencees –1.2 ft/year of erosion (see table 5.5). The calculated wave height for that shoreline is 3.8 ft for the 50-year wind-generated wave (see table 5.11), which could be why a seawall was originally built on the shoreline. If the remnants of the seawall were removed, it is very likely that the shoreline would expierence erosion rates far greater than –1.2 ft/year. However, this analysis will only project the average erosion rate of –1.2 ft/year to determine without project shoreline in 50 years (Figure 7.2). The eroded habitats were assumed to be converted to mudflat, as deep water is over 400 ft from the existing eroding shoreline in most places. The average existing beach width was assumed to be 18 ft, and the length of the eroding shoreline is 1000 ft. The shallow water and deep water habitat acres remained the same for the existing conditions and the future without project conditions, as constant widths for these habitat types were not prominent features.

The section of the Bayswater State Park shoreline that faces north is accreting at a rate of 1.3 ft/yr. Thus, future habitat conversions due to erosion were not calculated in this stretch of the project. The future with-project habitat acres were assumed to be the same as the current project habitat acres. The shore protection structure proposed at this site would maintain the location of the existing shoreline, so that the present and future with project habitats would be the same, as indicated in Table 7.2

Figure 7.2 The 50-Year Erosion Shoreline Project on to the Existing Habitat Map at Bayswater tate Park

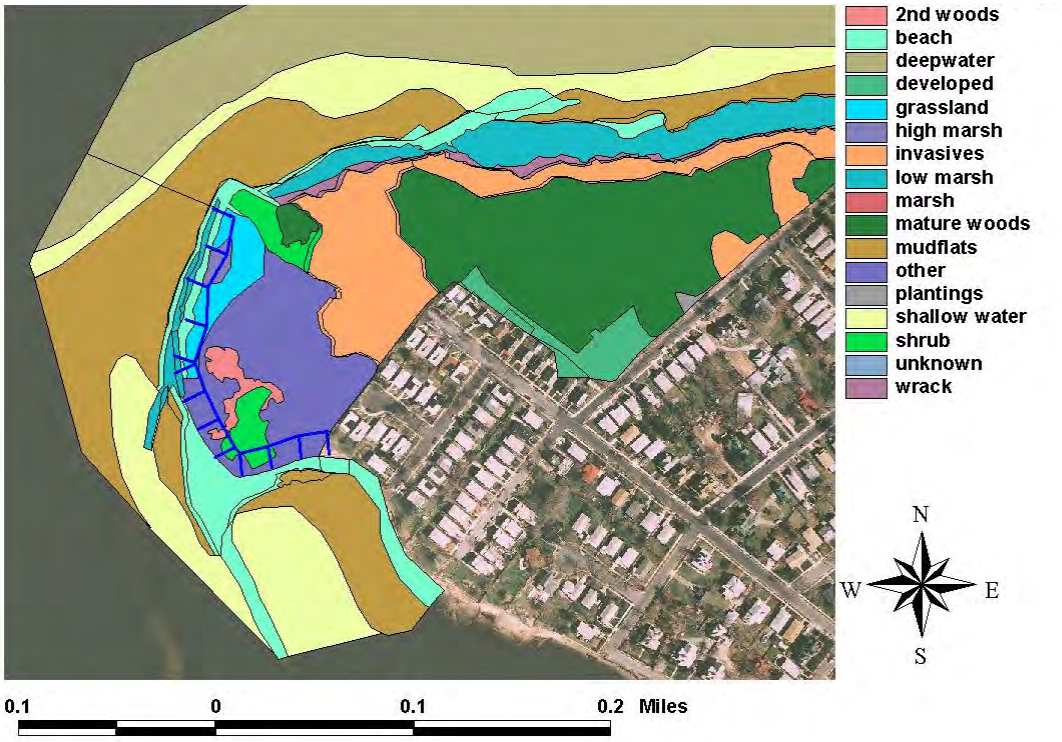


Table 7.2 Bayswater State Park Existing, Proposed and Future Without Project Habitat Acres

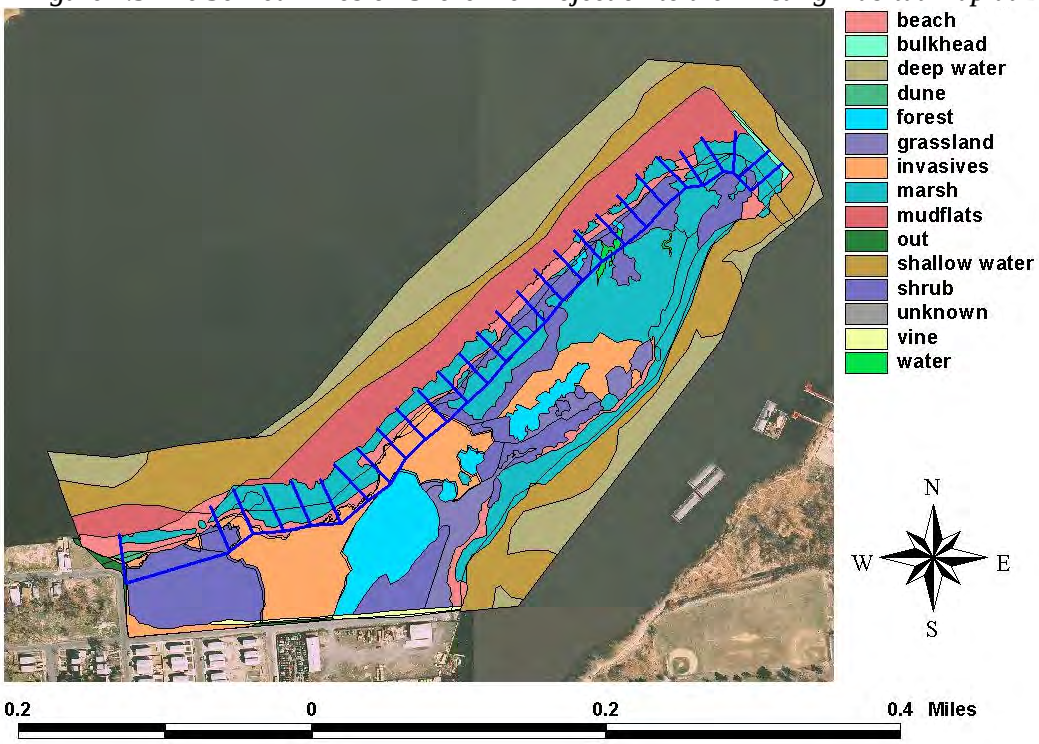
	Existing	Future w/o Project	Present and Future Proposed Plan Acres
2nd woods	0.64	0.62	0.40
Beach	3.18	3.59	2.75
Deepwater	15.78	15.78	15.78
Developed	1.18	1.18	1.18
Grassland	1.85	1.59	1.15
high marsh	0.14	0.05	0.35
Invasives	5.88	5.88	3.44
low marsh	5.50	5.10	5.20
Marsh	0.33	0.33	0.33
mature woods	8.56	8.56	8.55
Mudflats	13.39	14.42	13.30
Other	3.52	2.95	2.43
Plantings	0.21	0.21	0.21
shallow water	10.76	10.76	10.76
Shrub	0.82	0.71	0.64
Unknown	0.08	0.08	0.08
Wrack	0.87	0.87	0.77
No Label	0.16	0.16	2.10
Channel	0.00	0.00	0.21
Dune	0.00	0.00	1.50
lo marsh	0.00	0.00	2.03
training structure	0.00	0.00	0.16
Lowmarsh	0.00	0.00	0.47
open water	0.00	0.00	0.39
Structure	0.00	0.00	0.65

7.3 Dubos Point

For Dubos Point, the shoreline is eroding at an average rate of -3.4 ft/yr and –2.9 ft/yr for the two sections of the shoreline defined in the shoreline change analysis (see Table 5.6). Just like the Bayswater State Park site, the existing shore protection structures, while in a severe state of disrepair, is still mitigation the erosion rates. Since the deep water habitat is close to shore, it was assumed that deep water habitat would be gained at the expense of the upland habitat after 50 years of without project erosion. Assuming equilibrium beach profile theory, the average widths of 102 ft and 72 ft were assumed for mudflat and shallow water, respectively, for future without project conditions. The shoreline length is 3026 ft. The width of the existing beach was highly varialbe, so the existing beach acreage was assumed for the future without project condition. Table 7.3 summerizes the habitat types and acreages for existing and future without project conditions. The future with-project habitat acres were assumed to be the same as the current project habitat acres. The shore protection structure proposed at this site would maintain

the location of the existing shoreline, so that the present and future with project habitats would be the same, as indicated in Table 7.3.

Figure 7.3 The 50-Year Erosion Shoreline Project on to the Existing Habitat Map at Dubos Point



7.4 Brant Point

For Brant Point, the erosion rates were –4.3 ft/yr and –2.4 ft/yr for the two sections of the shoreline analyzed in section 5.4. Just like Dubos Point, deep water is close to shore, so the deep water habitat was gained at the expense of upland habitats for the 50 year without project projects. The beach, mudflat and shallow water habitat acreages remained the same for existing and future without project conditions. The future with-project habitat acres were assumed to be the same as the current project habitat acres. The shore protection structure proposed at this site would maintain the location of the existing shoreline, so that the present and future with project habitats would be the same, as indicated in Table 7.4.

Table 7.3 Dubos Point Existing, Proposed and Future Without Project Habitat Acres

	Existing	Future w/o Project	Present and Future Proposed Plan Acres
beach	2.77	0.64	2.71
bulkhead	0.13	0.13	0.13
channel			0.42
creek			0.32
deep water	8.56	24.96	8.56
dune	0.07	0.00	0.07
forest	3.09	3.02	4.94
grassland	1.66	1.66	1.53
hi marsh			0.84
invasives	5.98	4.95	1.53
lo marsh			3.35
marsh	10.54	6.01	10.22
mudflats	6.75	7.11	6.73
out	0.22	0.04	0.14
shallow water	11.42	4.98	11.42
shrub	8.05	5.82	6.76
unknown	0.00	0.00	0.00
vine	0.29	0.29	0.04
water	0.13	0.06	0.11

Figure 7.4 The 50-Year Erosion Shoreline Project on to the Existing Habitat Map at Brant Point

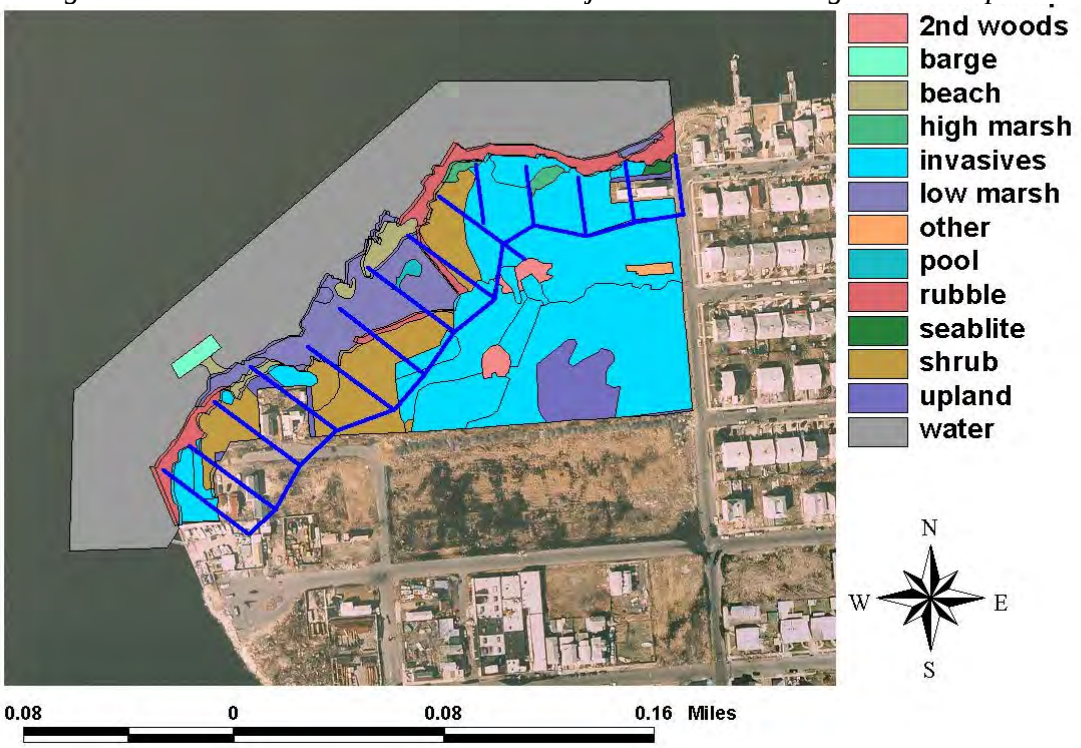


Table 7.4 Brant Point Existing, Proposed and Future Without Project Habitat Acres

	Existing	Future w/o Project	Present and Future Proposed Plan Acres
2nd woods	0.145	0.145	0.000
barge	0.076	0.076	0.076
beach	0.225	0.225	0.224
forest	0.000	0.000	2.443
high marsh	0.084	0.084	0.009
hi marsh	0.000	0.000	0.728
invasives	5.114	5.114	0.049
low marsh	1.124	1.124	2.974
meadow	0.000	0.000	2.471
other	0.042	0.042	0.000
pool	0.031	0.031	0.031
rubble	0.680	0.680	0.597
seablite	0.032	0.032	0.006
shrub	1.527	1.527	0.039
upland	0.566	0.566	0.000
water	5.778	5.778	5.778
(no label)	0.153	0.153	0.345

8. COST ESTIMATES AND CONSTRUCTION PROCEDURES OF CHOSEN ALTERNATIVES

8.1 Cost Estimate

Construction costs were estimated using the USACE's Micro Computer Aided Cost Estimating System (MCACES). The MCACES cost estimates were based on selected alternatives from the *Conceptual Plan Report – Final* (USACE, November 2003). The selected alternatives can be found in Appendix A. Acreages for project sites listed in the *Conceptual Plan Report - Final* (USACE, November 2003) were updated September 2004.

The costs are based on unit quantities (i.e. item, length, area or volume) for each construction item. Planning, Engineering, & Design was estimated at 20% of the total project construciton cost, while Construction Management was estimated at 8% of the total project construciton cost. Costs for Lands and Damages were also included

Costs were acquired from several sources: 1) RSMeans Heavy Cost Construction Data Index January 2004 (New York City cost index values were used and included insurance and tax markup on labor costs [35%] and locality cost markup [32.4% - materials and 28.4% on labor and equipment]); 2) MCACES project databases for equipment, adjusted from June 1999 rates to January 2004 rates using the ENR indexes, as well as the same city cost indexes used for the RSMeans costs; 3) MCACES project databases for labor, updated using Davis Bacon wage rates for January 2004 - General Decision number NY20030003; 4) cost estimate for a USACE-NYD New York City Project – Tidal Marsh Community Restoration Design for Gerritsen Creek Project; 5) Costs provided by a USACE Contractor "Environmental Concern;" and 6) Vendor quotes. Using the ENR indexes, an escalation to March 2005 was applied to the entire estimate, as well as a contingency markup of 20%. Fully-funded costs based on midpoints of construction for each site were calculated in separate excel spreadsheets using quarterly indexes from EM 1100-2-1304 30 Sep 2004 and EC11-2-181 28 Apr 05, for Accounts 06 & 10 and Accounts 01, 30, & 31, respectively. Midpoints of construction assumed for each project site as follows: Paerdegat 1/07; Bayswater State Park 6/07; Fresh Creek 1/08; Dubos 6/08; Spring Creek 1/09; Brant 6/09; Dead Horse 1/10; and Hawtree 6/10.

The MCACES include notes stating all assumptions made for each project. See Appendix F for the MCACES summary sheets and fully funded cost tables and Appendix G (MCACES Backup Data and Calculations) for all cost estimating backup calculations and notes. The costs for all the sites are summarized in Table 8.1

8.2 Construction Procedures

8.2.1 General

The general construction sequence for the restoration sites will be as follows:

1. Mobilization;
2. Installation of construction fence and staging features;
3. Vector pest control, if necessary;
4. Installation of soil erosion and sediment control features;
5. Installation of temporary work access road;
6. Site clearing, including removal of existing vegetation, where applicable;
7. Excavation and grading where applicable;
8. Installation of shoreline stabilization structures where applicable;;
9. Installation of herbivory fencing;
10. Planting and seeding;
11. Installation of site amenities; and
12. Demobilization.

General construction procedures for MCACES items such as mmobilization, demobilization and construction of temporary site access road are described below. Some items, such as soil erosion and sediment control features, have been grouped together to follow the general construction sequence. Construction procedures for site specific features, such as shoreline stabilization structures and hydraulically placed fill, are detailed in the site descriptions that following the general descriptions.

Mobilization and Ddemobilization: Mobilization of the site includes the establishment of the support facilities within the construction staging area, as well as the mobilization of the support facilities (i.e., office trailers, storage trailers, small tools, etc.) and heavy equipment for construction operations. Connecting electric power and telephone service to the trailers will also be completed under this item. Demobilization will include removal of the support facilities from the site, as well as the demobilization of the heavy equipment. This cost was estimated at 3 percent of the total construction cost.

Construction Fence and Staging Features: Temporary chain link fence will be erected around the site perimeters where necessary, as well as at the staging area for security. Temporary signs bearing project information will be posted.

Vector pest control: Vector pest control includes removal of rodents at the site prior to construction, as well as muskrat and mosquito control throughout the duration of the project.

Soil Erosion and Sediment Control: Soil erosion and sediment control devices include silt fence, sediment traps, straw bales, and anti-tracking pads. These will be furnished and installed at the commencement of site operations and maintained throughout the construction period. Devices will be installed per the approved soil erosion and sediment control plans and maintained accordingly.

Temporary Work Access Road: The number and lengths of temporary work access roads vary by site based on site geometry and conditions, but the general materials and installation are the same. Certain sites have individual access issues that are addressed with separate access features; these are described under the site-specific descriptions.

Work under the temporary work access road item includes constructing the access road(s) by leveling the road footprint, installing filter fabric for stabilization, and then placing and compacting 12-inch aggregate. Removal of the filter fabric and aggregate at the completion of the project is included, as well as either the restoration of the footprint area to existing conditions or establishment of the area as part of a new habitat(s) at the site.

Clearing Site: Clearing the site will involve the application of an herbicide to help in the eradication of the existing vegetation where necessary. The herbicide will be applied from the ground using spray equipment mounted on all terrain vehicles. After the herbicide has been applied and allowed to penetrate into the root zone for a minimum of 45 days, vegetation will be removed. Clearing the site will also include the felling, chipping, and stump removal of existing trees that are within excavation and grading zones and clearing any trash on the site.

Any debris from clearing operations, including vegetation or trash, will be removed from the site and disposed of at a licensed disposal or recycling facility in accordance with all federal, state, and city laws and regulations.

*Unclassified Excavation***:** The unclassified excavation item includes earthwork, both wet and dry, as well as grading for earthwork dry. It is important that the elevational gradient established from open water (i.e. tidal channels and Jamaica Bay) to low and high marsh, gradually transitions so that the wetland vegetation occupies a gentle slope of increasing elevation. In this way, at low tide, mudflat areas will be exposed along the edges of the interface of the low marsh and openwater; at high tide, the marsh areas will be flooded at varying depths, depending on elevations.

Wet excavation will occur in the creation of channels, and low and high marsh habitats, as well as for the installation of the shoreline stabilization structures, where elevations are lower and will be inundated by the tide. As the sites are along the shoreline of Jamaica Bay, it will be inefficient and costly to attempt to dewater the sites. Therefore, the wet excavation schedule will consider tidal cycles and all work will be performed “in the dry,” that is during periods of low tide. (Note that it may not be possible to perform excavation for some shoreline stabilization structures “in the dry” due to their locations actually in Jamaica Bay. Soil erosion and sediment control measures, such as localized floating turbidity barriers, may need to be employed in these instances.) Wet excavation will likely require the use of specialized equipment outfitted for work in wet soils, and/or the adapting of standard construction equipment and construction methods for work on soft soils. Equipment may include: hydraulic excavators outfitted with long reach booms; low ground pressure off-road hauling equipment; low ground pressure dozers; low ground pressure utility vehicles; and the use of crane mats to support excavators and assist them in moving across wet areas of the site. Dry excavation will occur in the coastal dune, scrub/shrub, and meadow, as well as maritime forest habitats.

In general, excavation and grading for the proposed features and habitats includes the removal of existing substrates to proposed grades. For wet areas, fine grading is done at the time of excavation as the substrates are saturated and it is not advantageous to pass back over these

areas. For dry areas, hydraulic excavators and dozers are used to first excavate the areas to approximate grades, and then dozers can go back over the areas to achieve final grades.

Over-excavation will be required in some habitat areas due to the necessity to place clean-sand fill or topsoil at depths ranging from 0.5 foot to 2 feet to provide for appropriate planting substrate. Fill requirements are discussed in detail under the applicable planting area items.

At this phase, it is assumed that the site's earthwork design is balanced and the all excavated materials will be used on site. Loading and on site hauling costs were included in all excavation items.

Planting - General: For all planting areas, before planting operations commence, planting zone elevations will be verified by the site engineer. Herbivory fence will be installed prior to planting. As with earthwork, the planting operations schedule will need to consider tidal cycles; all planting will need to be done "in the dry."

Maintenance of planting areas during construction and a one-year plant guarantee are built into the unit costs for the plants. Maintenance will include preventing the intrusion of weeds and other undesired vegetation, watering, and backfilling (by hand) settled areas for the duration of construction. The one-year plant guarantee will be conditional of at least 85 percent survival of the planted contract quantity. In addition, the overall planting item costs include the services of a restoration specialist to assist with the final determination of plant area elevations, selection of plant and seed species, and to be on-site during planting operations to ensure adherence to correct planting and seeding methods and make any modifications as conditions warrant.

Low Marsh Planting: Low marsh plants will be grass plugs/peat pots planted at 3-foot centers at a density of 4,840 plants per acre. At this phase, it is assumed that the species planted will be *Spartina alterniflora* (smooth cordgrass). Plant stock will be nursery-grown and all plant materials are included in the price for this item. The planting window for low marsh planting will be from April 15th to June 15th.

Prior to placement of the plugs/peat pots in the planting hole, a 6-month controlled release fertilizer will be placed in the bottom of the planting hole at the rate of 30 grams per plant. The plants will then be placed at the appropriate depth with the root system oriented downward. While the plant is in this position, the soil around the plant will be firmly tamped into place by hand.

Herbivory fencing is incorporated into the cost for low marsh planting. It includes the installation of four-foot high waterfowl barrier around the salt marsh areas to be planted, prior to planting, to discourage waterfowl from grazing on newly planted vegetation. The fencing will be placed to create maximum 50-foot-by-50-foot cells erected on wood posts at 10-foot spacing. Nylon twine will be strung across the tops of the cells from the perimeter stakes to the interior stakes with gaps no greater than 5 feet between strands. Reflective mylar tape will then be tied to the top of each stake, as well as along the top of the fence fabric and along the interior nylon twine. Costs also include a weekly inspection of the fence condition and any necessary repairs for the project duration.

Clean-sand fill is also built into the cost of low marsh planting. The clean sand will be placed atop finished grades to a depth of 6 inches over the entire low marsh planting area to provide for suitable planting substrate for the low marsh plants. The sand will be spread by a bulldozer or other acceptable grading equipment and methods, and then compacted by the movement of the spreading/grading equipment over the layer before a successive layer is constructed. Fill will be free from refuse, foreign materials, roots, hard soil, stiff clay, cobbles, and material deleterious to plant growth. The cost of trucking the material to the site is included in the unit price of the material.

High Marsh Planting: High marsh plants will include both grass plugs/peat pots and gallon-container shrubs. Plugs/peat pots will be planted at 2-foot centers at a density of 10,890 plants per acre. Gallon container shrubs will be planted at a density of 100 plants per acre. At this phase, it is assumed that the species planted will be *Spartina patens* (saltmeadow cordgrass) for plugs/peat pots and *Baccharis halimfolia* (groundsel bush), *Iva frutescens* (marsh elder), and *Myrica pensylvanica* (northern bayberry) for shrubs. Plants will be intermixed and planted in a staggered formation as directed by the restoration specialist. Plant stock will be nursery grown and all plant materials are included in the price for this item. Shrubs will be inoculated with mycorrhizae fungi either at the nursery or on site at the time of planting. The planting window for plugs/peat pots is from April 15th to June 15th; for shrubs, it is April 1st to May 30th.

For plugs/peat pots, prior to placement of the plant in the planting hole, a 6-month controlled release fertilizer will be placed in the bottom of the planting hole at the rate of 30 grams per plant. The plants will then be placed at the appropriate depth with the root system oriented downward. While the plant is in this position, the soil around the plant will be firmly tamped into place by hand.

For shrubs, plant pits will be dug approximately 4 inches wider than the stock size. Prior to placement of the plant in the planting hole, a 4-ounce scoop of 6-month controlled release fertilizer will be placed in the bottom of the planting hole. The shrubs will be planted 1 inch higher than grown in the nursery and the backfill soil will be placed around the rootmass to form a raised mound around the plant.

Clean sand fill is built in to the cost of high marsh planting. The clean sand will be placed atop finished grades to a depth of 6 inches over the entire high marsh planting area to provide for suitable planting substrate for the high marsh plants. The sand will be spread by a bulldozer or other acceptable grading equipment and methods, then compacted by the movement of the spreading/grading equipment over the layer before a successive layer is constructed. Fill will be free from refuse, foreign materials, roots, hard soil, stiff clay, cobbles, and material deleterious to plant growth. The cost of trucking the material to the site is included in the unit price of the material.

Coastal Dune Planting: Coastal dune plants will include both grass plugs and gallon-container shrubs. Plugs will be planted at 3-foot centers at a density of 4,840 plants per acre. Gallon container shrubs will be planted at 8-foot centers at a density of 680 plants per acre. At this phase, it is assumed that the species planted will be *Ammophila breviligulata* (American

beachgrass) for plugs and *Baccharis halimfolia* (groundsel bush), *Iva frutescens* (marsh elder), and *Myrica pensylvanica* (northern bayberry) for shrubs. Plants will be intermixed and planted in a staggered formation as directed by the restoration specialist. Plant stock will be nursery grown and all plant materials are included in the price for this item. Shrubs will be inoculated with mycorrhizae fungi either at the nursery or on-site at the time of planting. The planting window for plugs is from April 15th to June 15th; for shrubs, it is April 1st to May 30th.

For plugs, prior to placement of the plant in the planting hole, a 6-month controlled release fertilizer will be placed in the bottom of the planting hole at the rate of 30 grams per plant. The plants will then be placed at the appropriate depth with the root system oriented downward. While the plant is in this position, the soil around the plant will be firmly tamped into place by hand.

For shrubs, plant pits will be dug approximately 4 inches wider than the stock size. Prior to placement of the plant in the planting hole, a 4-ounce scoop of 6-month controlled release fertilizer will be placed in the bottom of the planting hole. The shrubs will be planted 1 inch higher than grown in the nursery and the backfill soil will be placed around the rootmass to form a raised mound around the plant.

Clean-sand fill is built in to the cost of coastal dune planting. The clean sand will be placed atop finished grades to a depth of 2 feet over the entire coastal dune planting area to provide for suitable planting substrate for the dune plants. The sand will be placed in successive horizontal layers not over 6 inches in depth extending across the entire area of fill. The sand will be spread by a bulldozer or other acceptable grading equipment and methods, then compacted by the movement of the spreading/grading equipment over the layer before a successive layer is constructed. Fill will be free from refuse, foreign materials, roots, hard soil, stiff clay, cobbles, and material deleterious to plant growth. The cost of trucking the material to the site is included in the unit price of the material.

Weeding and watering is incorporated into the cost of coastal dune planting. It includes watering and weeding the planting area post-planting, and as needed for the duration of construction.

Coastal Scrub/Shrub Planting: Coastal scrub/shrub plants will include grass plugs, forbs, 1- to 4-foot whip shrubs, and gallon-container shrubs. Plugs will be planted at 3-foot centers at a density of 4,840 plants per acre. Forbs will be planted at 30-foot centers at a density of 1,452 plants per acre. Whip and gallon container shrubs will be planted at 8-foot centers at a density of 680 plants per acre. At this phase, it is assumed that the species planted will be *Ammophila breviligulata* (American beachgrass) for plugs and *Baccharis halimfolia* (groundsel bush), *Iva frutescens* (marsh elder), and *Myrica pensylvanica* (northern bayberry) for shrubs. Forb and whip species will be decided upon in the next phase of the project. Plants will be intermixed and planted in a staggered formation as directed by the restoration specialist. Plant stock will be nursery-grown and all plant materials are included in the price for this item. Shrubs will be inoculated with mycorrhizae fungi either at the nursery or on-site at the time of planting. The planting window for plugs and forbs is from April 15th to June 15th; for shrubs, it is April 1st to May 30th.

For grass plugs and forbs, prior to placement of the plant in the planting hole, a 6-month controlled release fertilizer will be placed in the bottom of the planting hole at the rate of 30 grams per plant. The plants will then be placed at the appropriate depth with the root system oriented downward. While the plant is in this position, the soil around the plant will be firmly tamped into place by hand.

For shrubs (whips and containers), plant pits will be dug approximately 4 inches wider than the stock size. Prior to placement of the plant in the planting hole, a 4-ounce scoop of 6-month controlled release fertilizer will be placed in the bottom of the planting hole. The shrubs will be planted 1 inch higher than grown in the nursery and the backfill soil will be placed around the rootmass to form a raised mound around the plant.

Coastal scrub/shrub planting also includes seeding of the area with a warm season/grassland native seed mix. The method will be hydroseeding with fertilizer and straw mulch (wood cellulose fiber mulch may be substituted). Seed rate will be 10-15 pounds per acre of pure live seed; fertilizer will be a 6-month controlled release at 200 pounds per acre; and mulch will be 200 pounds (dry weight) per acre. The seeding window is from May 1st to May 31st.

Except for the Paerdegat Basin site, clean-sand fill is built in to the cost of coastal scrub/shrub planting. The clean sand will be placed atop finished grades to a depth of 1.5 feet over the entire scrub/shrub planting area to provide for suitable planting substrate for the scrub/shrub plants. The sand will be placed in successive horizontal layers not over 6 inches in depth extending across the entire area of fill. The sand will be spread by a bulldozer or other acceptable grading equipment and methods, then compacted by the movement of the spreading/grading equipment over the layer before a successive layer is constructed. Fill will be free from refuse, foreign materials, roots, hard soil, stiff clay, cobbles, and material deleterious to plant growth. The cost of trucking the material to the site is included in the unit price of the material.

Weeding and watering is incorporated into the cost of coastal scrub/shrub planting. It includes watering and weeding the planting area post-planting, and as needed for the duration of construction.

Coastal Meadow: Coastal meadow plants will include forbs and gallon-container shrubs. Forbs will be planted at 30-foot centers at a density of 1,452 plants per acre. Gallon container shrubs will be planted at 8-foot centers at a density of 680 plants per acre. At this phase, it is assumed that the species planted will be ***Baccharis halimfolia*** (groundsel bush), ***Iva frutescens*** (marsh elder), and ***Myrica pensylvanica*** (northern bayberry) for shrubs. The forb species will be decided upon in the next phase of the project. Plants will be intermixed and planted in a staggered formation as directed by the restoration specialist. Plant stock will be nursery-grown and all plant materials are included in the price for this item. Shrubs will be inoculated with mycorrhizae fungi either at the nursery or on-site at the time of planting. The planting window for forbs is from April 15th to June 15th; for shrubs, it is April 1st to May 30th.

For forbs, prior to placement of the plant in the planting hole, a 6-month controlled release fertilizer will be placed in the bottom of the planting hole at the rate of 30 grams per plant. The plants will then be placed at the appropriate depth with the root system oriented downward.

While the plant is in this position, the soil around the plant will be firmly tamped into place by hand.

For shrubs, plant pits will be dug approximately 4 inches wider than the stock size. Prior to placement of the plant in the planting hole, a 4-ounce scoop of 6-month controlled release fertilizer will be placed in the bottom of the planting hole. The shrubs will be planted 1 inch higher than grown in the nursery and the backfill soil will be placed around the rootmass to form a raised mound around the plant.

Coastal meadow planting also includes seeding of the area with a warm season/grassland native seed mix. The method will be hydroseeding with fertilizer and straw mulch (wood cellulose fiber mulch may be substituted). Seed rate will be 10-15 pounds per acre of pure live seed; fertilizer will be a 6-month controlled release at 200 pounds per acre; and mulch will be 200 pounds (dry weight) per acre. The seeding window is from May 1st to May 31st.

Except for the Paerdegat Basin site, clean-sand fill is built-in to the cost of coastal meadow planting. The clean sand will be placed atop finished grades to a depth of 2 feet over the entire coastal meadow planting area to provide for suitable planting substrate for the meadow plants. The sand will be placed in successive horizontal layers not over 6 inches in depth extending across the entire area of fill. The sand will be spread by a bulldozer or other acceptable grading equipment and methods, then compacted by the movement of the spreading/grading equipment over the layer before a successive layer is constructed. Fill will be free from refuse, foreign materials, roots, hard soil, stiff clay, cobbles, and material deleterious to plant growth. The cost of trucking the material to the site is included in the unit price of the material.

Weeding and watering is incorporated into the cost of coastal meadow planting. It includes watering and weeding the planting area post-planting, and as needed for the duration of construction.

Maritime Forest Planting: Maritime forest plants will include quart-container ferns/forbs, gallon-container shrubs, ball & burlap canopy trees, 1- to 4-foot whip canopy trees, 5- to 6-foot whip canopy trees, and gallon container understory trees. Ferns/forbs will be planted at 3-foot centers at a density of 4,840 plants per acre. All trees types will be planted at 10-foot centers at a density of 435 plants per acre. At this phase, it is assumed that the species planted will be ***Baccharis halimfolia*** (groundsel bush), ***Iva frutescens*** (marsh elder), and ***Myrica pensylvanica*** (northern bayberry) for shrubs. The forb and fern species will be decided upon in the next phase of the project. Plants will be intermixed and planted in a staggered formation as directed by the restoration specialist. Plant stock will be nursery-grown and all plant materials are included in the price for this item. Shrubs will be inoculated with mycorrhizae fungi either at the nursery or on-site at the time of planting. The planting window for ferns/forbs is from April 15th to June 15th; for shrubs and trees, it is April 1st to May 30th.

Plant pits will be dug approximately 4 inches wider than the stock size. Prior to placement of the plant in the planting hole, a 6-month controlled release fertilizer will be placed in the bottom of the planting hole (amount varies by plant type and will be determined by the restoration

specialist). The plants will be planted 1 inch higher than grown in the nursery and the backfill soil will be placed around the rootmass to form a raised mound around the plant.

Maritime forest planting also includes seeding of the area with a warm season/grassland native seed mix. The method will be hydroseeding with fertilizer and straw mulch (wood cellulose fiber mulch may be substituted). Seed rate will be 10-15 pounds per acre of pure live seed; fertilizer will be a 6-month controlled release at 200 pounds per acre; and mulch will be 200 pounds (dry weight) per acre. The seeding window is from May 1st to May 31st.

Topsoil is built-in to the cost of maritime forest planting. Topsoil will be placed atop finished grades to a depth of 6 inches over the entire maritime forest planting area to provide for suitable planting substrate for the forest plants. The topsoil will be spread by a bulldozer or another acceptable grading equipment. Then the topsoil will be compacted by the movement of the spreading/grading equipment over the layer before a successive layer is constructed. Topsoil will be free from refuse, foreign materials, roots, hard soil, stiff clay, cobbles, and material deleterious to plant growth. The cost of trucking the material to the site is included in the unit price of the material.

Weeding and watering is incorporated into the cost of maritime forest planting. It includes watering and weeding the planting area post-planting, and as needed for the duration of construction.

Site Amenities: Site amenities include perimeter boulders, concrete bollards, and permanent project information/interpretive signs. Boulders, approximately 1.5 feet in diameter, will be placed every 5 feet along the landside of a site's boundary to prevent vehicular traffic from entering the sites, negating the need for unaesthetic chain link fence. Removable 8-inch diameter steel pipe bollards will also be placed at entrances or ends of adjacent streets to further discourage vehicular traffic. The bollards will be concrete filled and painted, total of 8 feet long with 4 feet buried. Permanent project signs and interpretive signs describing the habitat functions and wildlife will be posted on steel rail posts.

8.2.2 Site-Specific Descriptions

8.2.2.1 Dead Horse Bay

The Dead Horse Bay Site includes both northern and southern portions. The restoration plan for the site includes low and high marsh, coastal dune, and maritime forest habitats, as well as shoreline stabilization in both portions. It is assumed that the site is clean and not contaminated. Project site size is 171 acres, of which 126 acres are habitat restoration areas.

Jetties: As described in Section 6.4.1.2, the shoreline stabilization measures at Dead Horse Bay – North include an inlet stabilization structure consisting of two parallel jetties extending into the Bay perpendicular to the shore that will prevent sediment accumulation at the mouth of the proposed tidal channel inlet (see Figure 6.12 - Plan View of the Jetties at the Dead Horse Bay – North Site).

Jetty construction will first require excavation of the structure footprint to match the elevations of the side slopes of the proposed tidal channel inlet (see Figure 6.13 - Cross-section View of the Jetties at the Dead Horse Bay – North Site). The cost of loading and hauling excavated materials on site is included in this item. A 200-pound tensile strength geotextile will be placed by hand over the footprint area. Bedding material, consisting of stone at diameters of 2 to 8 inches, will then be installed over the geotextile at a minimum 1-foot depth. The core of the jetty will then be constructed by installing 250- to 500-pound core stone atop the bedding layer, sized approximately 1 foot to 1.5 feet in diameter. Finally, 2700- to 4500-pound armor stones, sized approximately 2.5 to 3.5 feet in diameter, will be positioned atop the core stone. Delivery costs for all stone are included in this item.

Geotubes: As described in Section 6.4.1.3, the shoreline stabilization measures at Dead Horse Bay – South include a continuous reinforced dune system, with geotubes used as the core reinforcement (see Figure 6.16 - Plan View of the Geotubes and Dune at the Dead Horse Bay – South Site). The reinforced dune will provide a buffer zone for storm protection, as well as cover the exposed face of the existing exposed landfill, halting the dispersion of trash that is currently scattered across the beach.

The reinforced dune will be constructed by first excavating around the perimeter of the geotube location, pulling back the face of the exposed landfill and overexcavating at least 2 feet to protect the geotubes from rupture due to landfill debris (see Figure 6.17 – Cross-section View of the Geotubes and Dune at Dead Horse Bay – South Site). The base support for the geotubes includes clean sand placed at a 2-foot depth along the bottom of the footprint, followed by the installation of 200-pound tensile strength geotextile and then drainage net, a thicker geotextile designed for use with the geotubes consisting of a mesh set between two layers of filter fabric to promote drainage away from the bottom of the geotubes. Geotubes will be installed in 200-foot sections, with two sections placed per day. The geotube will be laid out over the sand/geotextile/drainage net base, and then 16-inch sleeves will be attached to openings at the tops of the geotubes. A hopper attached to a large crane will be fitted to each sleeve, and wet, clean sand will be pumped into the hopper until each geotube is filled. The cost of delivery of clean sand fill to the site is included in the unit price of the material.

As shown in the cross-section, three geotubes will be stacked in a pyramid shape. The geotubes will then be covered with a minimum of 2 feet of clean sand. The cost of the cover is included in the Coastal Dune Planting item as it is the planting substrate for coastal dune vegetation. The cost of pumps to bring water from the Bay to mix with the clean sand and an allowance for purchasing the hopper are included in this item.

The final MCACES project cost for the Dead Horse Bay Site, including contingency and escalation, is $51,943, 985.00.

8.2.2.1 Paerdegat Basin

The restoration design for the Paerdegat Basin Site includes low and high marsh, coastal meadow, and coastal scrub/shrub habitats, as well as recontouring of the existing basin. It is assumed the site is clean and not contaminated. The project site size is 80.2 acres.

Hydraulically Placed Fill: The reconfiguration of the basin bathymetry at the Paerdegat Basin site is a major portion of the restoration design cost. The hydraulically placed fill item includes placing clean, dredged materials to raise the basin grades and recontouring the basin bottom. This is intended to reduce water volume and promote optimal circulation by enhancing tidal exchange. Offshore dredged disposal fill will be delivered to the site by a work barge being pushed by a tugboat. The fill would be pumped from the barge onto the bottom of the basin, and then an excavator mounted on a separate work barge would grade the fill. Costs for obtaining and placing the fill, as well as the required vessels and crew, are included in this item. In addition, a workboat for crew transport to and from the barge is included.

There is a bridge located at the mouth of the basin with vertical clearance at 29 feet and horizontal clearance at 61 feet. Navigation charts show the depth to bottom underneath the bridge at 13 to 17 feet, so vessel passage under the bridge will need to coordinated with the tidal cycle.

The final MCACES project cost for Paerdegat Basin Site, including contingency and escalation, is $50,104,134.00.

8.2.3 Fresh Creek

The restoration design for the Fresh Creek Site includes low and high marsh, coastal scrub/shrub, and maritime forest habitats, as well as recontouring of the existing basin. It is assumed the site is clean and not contaminated. The project site size is 33.1 acres.

Hydraulically Placed Fill: Similar to Paerdegat Basin, the reconfiguration of the basin bathymetry at the Fresh Creek site is a major portion of the restoration design cost. The hydraulically placed fill item includes placing clean, dredged materials to raise the basin grades and recontouring the basin bottom. This is intended to reduce water volume and promote optimal circulation by enhancing tidal exchange. Offshore dredged disposal fill will be delivered to the site by a work barge being pushed by a tugboat. The fill would be pumped from the barge onto the bottom of the basin, and then an excavator mounted on a separate work barge would grade the fill. Costs for obtaining and placing the fill, as well as the required vessels and crew, are included in this item. In addition, a workboat for crew transport to and from the barge is included.

There is a bridge located at the mouth of the basin with vertical clearance at 21 feet and horizontal clearance at 43 feet. Navigation charts show the depth to bottom underneath the bridge at 9 to 11 feet, so vessel passage under the bridge will need to coordinated with the tidal cycle.

The final MCACES project cost for Fresh Creek Site, including contingency and escalation, is $26,180,143.00.

8.2.4 SPRING CREEK

The restoration design for the Spring Creek Site includes low and high marsh, coastal dune, and maritime forest habitats. It is assumed the site is clean and not contaminated. The project site size is 189.7 acres. The final MCACES project cost for Spring Creek Site, including contingency and escalation, is $57,153,407.

8.2.5 Hawtree Point

The restoration design for Hawtree Point Site includes high marsh and coastal scrub/shrub habitats. It is assumed the site is clean and not contaminated. The project site size is 1.8 acres. The final MCACES project cost for Hawtree Point Site, including contingency and escalation, is $614,065.

8.2.6 Bayswater State Park

The restoration plan for the Bayswater State Park Site includes low and high marsh, and coastal dune habitats, as well as shoreline stabilization. It is assumed that the site is clean and not contaminated. Project site size is 5.2 acres, of which 3.3 acres are habitat restoration areas.

As described in Section 6.4.4.1, the shoreline stabilization measures at Bayswater State Park include a training structure, several onshore breakwaters, and a buried rubble mound wall (see Figure X – Plan View of the Shore Protection Measures at Bayswater State Park). The training structure at the north end of the site will be set parallel to inlet of the proposed tidal channel, preventing accumulation of the sediment, as well as protect the northwest corner of the site. The onshore breakwaters and rubble wall along the north and west side of the site are intended to dissipate wave energies and hold the existing shoreline position.

Training Structure: Construction of the training structure will first require excavation of a portion of the structure footprint to obtain the required slopes and elevations (see Figure 6.20 – Cross-section View of the Shore Protection Measures at Bayswater State Park). The cost of loading and hauling excavated materials on site is included in this item. A 200-pound tensile strength geotextile will be sunk with sandbags and placed by hand over the footprint area. Bedding material, consisting of stone at diameters of 2 to 8 inches, will then be installed over the geotextile at a minimum 1-foot depth. The core of the structure will then be constructed by installing 250- to 500-pound core stone atop the bedding layer, sized approximately 1 foot to 1.5 feet in diameter. Finally, 2700- to 4500-pound armor stones, sized approximately 2.5 to 3.5 feet in diameter, will be positioned atop the core stone. Delivery costs for all stone are included in this item.

Onshore Breakwaters: Construction of the onshore breakwaters is similar to the training structure, except that the bedding layer is not needed. First, excavation of the structure footprint to obtain the required slopes and elevations will occur (see Figure 6.20 – Cross-section View of the Shore Protection Measures at Bayswater State Park). The cost of loading and hauling excavated materials on site is included in this item. A 200-pound tensile strength geotextile will be placed by hand over the footprint area. Core stone, sized at 1 foot to 1.5 feet in diameter and weighing 250 to 500 pounds, will be placed atop the geotextile. Finally, 2700- to 4500-pound

armor stones, sized approximately 2.5 to 3.5 feet in diameter, will be positioned atop the core stone. Delivery costs for all stone are included in this item.

Buried Rubble Mound Wall: Similar to both the training structure and onshore breakwaters, construction of the buried wall will first require excavation of a portion of the structure footprint to obtain the required slopes and elevations (see Figure 6.20 – Cross-section View of the Shore Protection Measures at Bayswater State Park). The cost of loading and hauling excavated materials on site is included in this item. A 200-pound tensile strength geotextile will then be placed by hand over the footprint area. Core stone, sized at 1 foot to 1.5 feet in diameter and weighing 250 to 500 pounds, will be placed atop the geotextile. Armor stones, sized approximately 2.5 to 3.5 feet in diameter and weighing 2700 to 4500 pounds, will be positioned atop the core stone. Finally, clean sand will be poured over the stone to create a dune with a crest elevation of 8 feet. Delivery costs for all stone are included in this item.

The final MCACES project cost for Bayswater State Park Site, including contingency and escalation, is $2,945,832.00.

8.2.7 Dubos Point

The restoration plan for the Dubos Point Site includes low and high marsh and maritime forest habitats, as well as shoreline stabilization. It is assumed that the site is clean and not contaminated. Project site size is 6.9 acres, of which 6.1 acres are habitat restoration areas.

Sheetpile Shore Protection and Training Structure: As described in Section 6.4.5.1 and 6.4.5.2, the shoreline stabilization measures at Dubos Point include the restoration of the existing bulkhead (see Figure 6.21 – Plan View of the Shore Protection Measures at Dubos Point). Due to the location of the restoration areas out into the Bay, it will be necessary to construct a sand access ways along the shoreline, as well as three separate walkouts to the proposed structure locations. Timber mats will be placed atop the sand access ways to provide stable surfaces for the heavy construction equipment.

The new sheet pile sections will be driven to a depth that would adequately support the fill material and eliminate the need for toe protection (see Figure 6.22 – Cross-section View of the Shore Protection Measures at Dubos Point). Using a vibratory driver/extractor attached to a crane, steel sheet piles will be driven on the waterfront side of the existing sections. After the piles are driven to approximately the same crest elevation as it currently exists at 2 feet (which is slightly lower than the mean high water elevation of 2.39 feet), timber swales will be attached to landside of the sheetpiles. After installation of the new sheetpile sections has been completed, the clean sand used to construct the walkouts will be removed and placed along the shoreline. This sand, along with the sand placed for the shoreline access way, will be graded to act as a blanket cover, mimicking the existing topography up to the MHW elevation on landward side for beach renourishment. Delivery costs for all materials are included in this item.

The training structure will be constructed similar to the toe protection structure, except they will be shore perpendicular, and they will be constructed in an area currently mid tide level or higher.

The final MCACES project cost for Dubos Point Site, including contingency and escalation, is $5,945,274.00.

8.2.8 Brant Point

The restoration plan for the Brant Point Site includes low and high marsh, coastal meadow, and maritime forest habitats, as well as shoreline stabilization. It is assumed that the site is clean and not contaminated. Project site size is 7.5 acres.

As described in Section 6.4.6, the shoreline stabilization measures at Brant Point include three offshore breakwaters and a revetment structure (see Figure 6.23 – Plan View of the Shore Protection Measures at Brant Point). The three breakwaters will be spaced 60 feet apart and be located an average of 75 feet from the shoreline. This distance is expected to promote sand accretion. In addition, the offshore breakwaters were curved for potentially enhanced performance by aligning the structures with the predominant wave direction. The revetment structure on the north face of the site, similar to what currently exists, protects the area from wave action.

Offshore Breakwaters: The proximity of the offshore breakwaters from the shoreline will necessitate the use of multiple vessels for material delivery and transport, as well as work platforms for equipment. Materials for the breakwater construction will be delivered to the site by a hopper barge being pushed by a tugboat. Equipment will be mounted on a separate work barge to carry out construction operations. Costs for material delivery to the site, as well as the required vessels and crew, are included in this item. In addition, a workboat for crew transport to and from the barges is included.

Construction of the offshore breakwaters will first require minor excavation of the structure footprint to obtain the level grades (see Figure 6.24 – Cross-section View of the Shore Protection Measures at Brant Point). The cost of loading and hauling excavated materials on site is included in this item. A 200-pound tensile strength geotextile will be will be sunk with sandbags and placed by hand over the footprint area. Core stone, sized at 1 foot to 1.5 feet in diameter and weighing 250 to 500 pounds, will be placed atop the geotextile. Finally, 2700- to 4500-pound armor stones, sized approximately 2.5 to 3.5 feet in diameter, will be positioned atop the core stone. Delivery costs for all stone are included in this item.

Revetment: Construction of the training structure will first require excavation of the structure footprint to obtain the required slopes and elevations (see Figure 6.24 – Cross-section View of the Shore Protection Measures at Brant Point). The cost of loading and hauling excavated materials on site is included in this item. A 200-pound tensile strength geotextile will be placed by hand over the footprint area. Core stone, sized at 1 foot to 1.5 feet in diameter and weighing 250 to 500 pounds, will be placed atop the geotextile, acting as a bedding layer. Armor stones, sized approximately 2.5 to 3.5 feet in diameter and weighing 2700 to 4500 pounds, will be positioned atop the core stone. A fix mix gravel, consisting of bedding stone between 2 and 4 inches in diameter will be placed for both toe protection and to promote fish and benthic habitat creation within inter tidal zone. Delivery costs for all stone are included in this item.

The final MCACES project cost for Brant Point, including contingency and escalation, is $5,095,140.00.

9. MONITORING

9.1 Monitoring Plan

Ecological Monitoring and Adaptive Management is included in the project plan. The ecological success of the restored habitats will be evaluated based on the following performance criteria:

- Successful establishment of each habitat type(tidal marsh: low marsh, high marsh, mudflat, tidal creek, estuarine subtidal; fresh water marsh: deep water pool, shallow water bench, shoreline fringe and riparian fringe; upland: maritime forest, maritime grass, martime scrub/shrub) relative to similar habitat types in the region
- Vegetation growth in the proper zones (e.g., hydric species in wet sites)
- Air quality parameters within permit constraints
- Water quality, general landscape, sinuosity and water depth similar to natural tidal creeks in the region.

The following monitoring plan discusses how the hydrology/hydraulics/hydrodynamics, topography/bathymetry, and geotechnical parameters of the site will be observed to understand their relationship to the project's performance as stated above. It is assumed that the compliance with submitted work plans (i.e., elevation checks) has been performed prior to and after planting. The monitoring plan presented below involves a first year post-construction site assessment and identification of performance criteria, methods, costs, and potential corrective actions for each of the created cover types.

9.2 First Year Post-Construction Site Assessment

All the restoration sites will need to be closely monitored during the first year after construction to ensure proper establishment of salt marsh vegetation, as well as upland habitats. Inspections would involve site checks by the project biologist and hydraulic/coastal engineer to allow the opportunity for identification and resolution of any gross problems (i.e., excessive erosion, invasive plants, tidal restrictions). Weekly post-construction inspection tours are recommended during the 2-month period following construction. Monthly inspections should follow for an additional 10-month period. The estimated costs for the first year post-construction site assessment program is $20,000 (Table 12).

9.3 Salt marsh One, Three, Five and Ten years Post Construction

There are several environmental factors that control the establishment, viability, and success of salt marsh habitat: salinity, hydrology, geomorphology, and soil texture and nutrients. These factors have been considered during the planning process, and will be revisited during the Plans and Specifications phase of the Project, to maximize the potential for salt marsh establishment. Existing productive tidal marshes close in size and proximity to the planned salt marshes will be used as a reference site during the monitoring phase.

9.3.1 Topographic/Bathymetric Monitoring

A topographic/bathymetric survey is planned one-year post construction for all sites. For each site, approximately ten (10) cross sections will be surveyed in the eight project areas , more or less depending on the size of the site. Three reference marshes will be defined throughout the bay, and ten (10) cross sections at these reference marshes will be surveyed simultaneously. The cross sections will be perpendicular to the tidal creek and the direction flow, and they will extend to the upland limit of high marsh on both sides of the creek where appropriate. For the sites/reference marshes where fringe marshes are proposed/exist, profile lines will be surveyed instead, perpendicular to the shoreline. Eight (8) spot elevations will be surveyed in each cross section/profile line to be used as biobenchmarks. This information will compare the project's design criteria and the project's performance criteria. Topographic/bathymetric monitoring is planned one, five and ten years after construction.

9.3.2 Sinuosity Monitoring

Sinuosity is a measure of the degree to which a channel deviates from a straight path and is calculated as the ratio of a channel's sinuous length to its straight length. Sinuosity sampling would occur at each reach of created channels at the restoration areas and reference areas. Sampling would occur during the year prior to construction and at post-construction years 1, 3, and 5. Sinuosity will be measured during low tide using a hand-held GPS instrument (accuracy +/- 3 ft). Sinuosity monitoring is planned one, three, five and ten years after construction. For the sites that do not have significant creek features, other plan view features will be measured, including drainage patterns, vegetation patterns, etc..

9.3.3 Hydrology/hydraulics/hydrodynamics Monitoring

The hydrology/hydraulics/hydrodynamics of the salt marsh is an integral part of the success of the tidal marsh habitat survival. Four (4) water level recorders will be placed in the project sites for a 3-month period, and four (4) water level recorders will be placed in the reference sites during the same time interval. The duration of flooding throughout the project and reference sites will be evaluated and compared with the established plant communities. Hydrology/hydraulics/hydrodynamics monitoring is planned one, five and ten years after construction.

9.3.4 Geotechnical Monitoring

Three (3) geotechnical samples will be taken at the project sites, and 3 (3) geotechnical samples will be taken at the reference sites. Particle size distribution of the substrate would be measured by collecting a 30-cm soil core, dividing it into a 0 to 10 cm portion and a 10 to 30 cm portion, drying, sieving, and weighing the sample for bulk density. Particle size distribution would be estimated. The ground surface at the location of the sample will be surveyed to determine if rebound/subsidence occurred as a result of removing large quantities of fill. Geotechnical monitoring is planned one, and five years after construction.

9.4 Shoreline Stabilization Structures Monitoring

Dead Horse Bay, Bayswater State Park, Dubos Point and Brant Point all have proposed shoreline stabilization structures. These structures will be inspected one, five and ten years after construction, for displacement of the structure material (stone, sheet pile, geotubes, etc.), settlement and general conditions different from post-placement conditions.

9.5 Coastal Dune and Marine Forest Areas One and Five years Post Construction

The success of the habitats planned for the coastal dune and marine forest coastal area are not as dependent on engineering considerations as the tidal and freshwater wetlands. Soil properties are variables that can have a considerable affect on the success of upland habitats. A reference upland area will be established. Three (3) soil sample 12 (30-cm) inches deep will be taken, and three (3) soil samples 12 (30-cm) inches deep will be taken in the 3 different habitat communities planned: maritime forest, maritime grass, martime scrub/shrub. Geotechnical monitoring is planned one, and five years after construction.

9.6 Monitoring Costs

Table 9.1 summarizes the estimated monitoring costs. The costs for the biological monitoring are not included in the summary.

Table 9.1 Estimated Cost for the Proposed Monitoring Plan: Engineering Components

	1year Post Construction	3 years Post Construction	5 years Post Construction	10 years Post Construction	Total
First Year Post-Construction Site Assessment	$160,000	$0	$0	$0	$160,000
Low/High Marsh, Mudflat, Tidal Creek, Estuarine Subtidal					
Topographic Survey	$ 132,000	N/A	$ 132,000	$ 132,000	$396,000
Sinuosity Assessment	$ 55,000	$ 55,000	$ 55,000	$ 55,000	$220,000
Geotechnical Assessment	$ 110,000	N/A	$ 110,000	N/A	$220,000
Hydrology Assessment	$ 132,000	N/A	$ 132,000	$ 132,000	$396,000
Subtotal	$ 429,000	$ 55,000	$ 429,000	$ 319,000	$1,232,000
Upland Areas					
Geotechnical Assessment	$33,000	N/A	$33,000	N/A	$66,000
Shore Protection Structures					
Condition Assessment	$20,000	N/A	$20,000	N/A	$40,000
Total	**$642,000**	**$55,000**	**$482,000**	**$319,000**	**$1,498,000**

9.7 Potential Corrective Actions

The District would review post-construction survey data and determine the need for corrective actions such as restocking previously planted areas, enhancing survival of planted vegetation, preventing *Phragmites* encroachment, and/or improvement of tidal flushing. Poor survival of planted stock (i.e., less than 50%) may require application of Osmocote® at 100 pounds (lbs.) of nitrogen/acre and 40 lbs. of phosphorus/acre as recommended by Broome et al. (1983), additional actions to improve tidal flushing, or additional protection from herbivores.

Encroachment of *Phragmites* into intertidal marsh would be monitored, and ameliorative actions would be taken as necessary. If *Phragmites* encroached upon more than 10% of a restoration site, the District would apply Rodeo® or a comparable herbicide recommended by the Middlesex County NRCS Office to the site. Prior to the application of any herbicides, the District would obtain approval of the landowner and appropriate state agencies.

In some areas, grazing by waterfowl and mammals can affect the success of marsh vegetation. Canada geese (*Branta canadensis*) and snow geese (*Chen hyperborean*) graze on emergent vegetation and can damage new plantings. Installations of fencing along the water's edge and shrub borders along the upland edge have been used to exclude geese and have been included

under the initial Project costs. However, additional waterfowl and mammal control may be necessary.

Extreme cases of erosion or inadequate flushing may require mechanical recontouring of channel shape and sinuosity, or changing the weir heights in the fresh water wetland. Lack of colonization by desired plant species adjacent to restored channels may warrant additional planting efforts and possibly even soil organic matter amendments to enhance structure for benthic macroinvertebrates. A combination of bank stabilization measures such as coconut fiber mats or rolls with soil amendments or plantings would serve to enhance ecosystem structure adjacent to the wetland channels.

If there is a significant difference in the vegetation variables the restoration area and the reference area at any monitoring year, and these difference are determined to be undesirable by the participating regulatory agencies, corrective action would be taken, and monitoring would continue on an annual basis until the criteria are met.

9.8 Contingency Inspections

The restoration area and the reference area would be inspected for damage in the event of severe storms or other destructive events. These visits should be conducted subsequent to such events to ensure that damage is documented and plans for repair and debris removal are made at the earliest possible opportunity.

9.9 Report Preparation

Data collected from the sampling events described above will be essential in determining whether the proposed project is meeting the restoration goals. A detailed report organizing and summarizing the field data would be prepared upon completion of each field inspection/survey. These reports would include copies of all completed field data forms, color photographs, and any other reports/data required by the state and federal permitting agencies. These reports would include a comparison between restored and reference area sites. In addition, to this analysis and where practical, the data will be presented graphically so restoration development can be easily compared and tracked over time.

The results of these reports can be presented at interagency meetings where recommendations for corrective actions can be discussed or to determine if the original performance criteria or Project goals should be reevaluated. The results can also be used to determine if additional monitoring may be required beyond the scope of the original plans or if other parameters should be monitored (e.g., salinity) to better evaluate the causes of failure if they occur.

10. REFERENCES

ACES, 1992. Automated Coastal Engineering System, software and Technical Reference, USCACE, September.

Allen, H.H., and Fischenich, C., 2000. “Coir geotextile roll and Wetland Plants for streambank erosion control” EMRRP technical notes collection (ERDC TN-EMRRP-SR-04).

Arthur Kill Ship Wave Study, 2002. Interim Draft Report prepared for The Port Authority of NY & NJ, Moffatt & Nichol Engineers, June.

ASCE 1994. Technical Engineering and Design Guides as Adapted From The US Army Corps of Engineers, No.6: Coastal Groins and Nearshore Breakwaters. ASCE Press, New York.

ASCE, 1995. Hydraulic design of flood control structures. ASCE Press, New York.

Basco, David R.,1982. Surf Zone Currents, Vol I state of Knowledge. Report no MR 82-7 (I). Coastal Engineering Research Center, Fort Belovoir, VA.

Bodge, Kevin R., 1998. Beach fill stabilization with tuned structures: Experience in the southeastern USA and Caribbean. Proceedings of the international conference organized by the Institution of Civil Engineers and held in London, UK, 19-20 March 1998.

Borgman, L. E., 2003. Background and Recommendations: Efficient Selection of Storm Surge Computer Runs to Enhance Empirical Simulation Analysis. Draft Report prepared for the US Army Corps of Engineers, New York District.

Borgman, L. E., Miller, M., Butler, L., and R. Reinhard, 1992. Empirical simulation of future hurricane storm histories as a tool in engineering and economic analysis. Proceedings, 5th International Conference on Civil Engineering in the Ocean, ASCE, November, College Station, TX.

CEM 2002, Coastal Engineering Manual, USACE, EM 1110-2-1100.

CIRIA, 1991. Manual on the use of rock in coastal and shoreline engineering. Construction Industry Research and Information Association. A.A. Balkema Publishers, VT.

Cox, Jack C. “Breakwater Attenuation Criteria and Specifications for Marina Basins”, Marina Design and Engineering Conference, International Marina Institute, 1987.

Dean, R.G. 1977, "Equilibrium Beach Profiles: U.S. Atlantic and Gulf Coasts," University of Delaware, Ocean Engineering Report No. 12.

Davis Bacon

ENV Report 4,1997. Interim Report For The Upper Mississippi River-Illinois Waterway System Navigation Study, USCAE.

New York City Department of Environmental Protection. *A Water Quality Model for Jamaica Bay: Calibration of The Jamaica Bay Eutrophication Model (JEM)*, 2000. prepared by HydroQual, Inc.

Komar, P.D., and Miller, M.C., 1974. "On the comparison between the threshold of sediment movement under waves and unidirectional currents with a discussion of the practical evaluation of the threshold," J. Sed. Pet., Vol.5, pp. 1093-1112.

Kriebel, David L, 1987. Edune Users Manual.

Kriebel, David L. and Chad A. Bollmann, "Wave Transmission Past Vertical Wave Barriers", International Conference Coastal Engineering, 1996.

Longuet-Higgins ,M.S., 1970. "Longshore currents generated by obliquely incident sea waves, Parts I and II." Journal of Geophysical Research. Vol 75. No.33, pp 6778-6801.

Luettich, R.A., Westerink, J.J., and N.W. Scheffner. 1992. ADCIRC: An Advanced Three-Dimensional Circulation Model for Shelves, Coasts, and Estuaries Report 1: Theory and Methodology of ADCIRC-2DDI and ADCIRC-3DL. Tech Rpt DRP-92-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg MS.

Reed Construction Data. *RSMeans Heavy Construction Cost Data 18th Annual Edition 2004*. RSMeans, Kingston, MA. 2003

Schiereck, Gerrit J., 2001. Introduction to bed, bank and shore protection. Delfeet University Press, Delfeet, Netherlands.

Silvester R., and Hsu, J.R.C., 1993. Coastal Stabilization, Innovative Concepts. PTR Prentice Hall Inc., Englewood Cliffs, New Jersey.

Sorensen, R.M., and Weggel, J.R, 1986. "Ship wave prediction for port and channel design," Proceedings of the Ports'86 Conference Oakland, CA.

Sorensen, R.M., and Weggel, J.R., 1984. "Development of ship wave design information," Proceedings of the 19th Conference on Coastal Engineering, Houston, TX.

USACE – Automated Coastal Engineering Software (ACES), 1992

USACE MCACES

USACE – New York. Liberty State Park Causeway, 1981. Liberty State Park Wind Analysis for Design Waves.

USACE – Coastal Engineering Manual (CEM) 2002

USACE, - New York District. *Jamaica Bay Ecosystem Restoration Project: Existing Conditions, Future Without Project Conditions, Goals and Objectives Report,* October.2002.

USACE – New York District. *Draft HTRW Sampling Program Report, Jamaica Bay Environmental Restoration Project*. 2002b. Compiled by AMEC Earth and Environmental, Inc for the New York District.

USACE – New York District. *Daft Water Quality Modeling for the Jamaica Bay Ecosystem Restoration Project*. March 2003. Compiled by Hydroqual, Inc.

USACE – New York District. *Dead Horse Bay North Hydrodynamic Modeling Report - Jamaica Bay Ecosystem Restoration Project*. June 2003. Compiled by The Louis Berger Group, Inc.

USACE – New York District. *Conceptual Plan Report - Final*. November 2003. Compiled by Barry A. Vittor & Associates, Inc. & Environmental Concern Inc.

USACE – New York District Draft *Shoreline Stability Analysis Report for Jamaica Bay Ecosystem Restoration Project*. December 2002 compiled by The Louis Berger Group and Foster Wheeler Environmental.

USACE – New York District. *Geotechnical Investigation Report - Jamaica Bay Ecosystem Restoration Project*. May 2004. Compiled by The Louis Berger Group, Inc.

USACE, New York District *FIMP – Existing Conditions Storm Surge Modeling and Stage-Frequency*. Draft Report, April 2005.

USACE – New York District. *Jamaica Bay Ecosystem Restoration Project Feasibility Study/EIS*. October 2005.

Wiegel, Richard L., Oceanographical Engineering, Prentice Hall, 1964.

APPENDIX A: EXISTING AND PROPOSED HABITIAT CONDITIONS

APPENDIX B:
SUMMARY OF TIDE GAGE JAMAICA BAY ECOSYSTEM RESTORATION PROJECT
FEASIBILITY STUDY. MARCH 2003

APPENDIX C: SHORELINE CHANGE ANALYSIS

APPENDIX D: ADDITIONAL RECOMMENDED SHORE PROTECTION FEATURES

APPENDIX E: WATER QUALITY MODELING RESULTS

APPENDIX F: MCACES COST ESTIMATE SUMMARIES

APPENDIX G: MCACES BACKUP DATA AND CALCULATIONS

APPENDIX H: SHORELINE SLOPE STABILITY ANALYSIS FIGURES

APPENDIX E: WATER QUALITY MODELING RESULTS

Table E-1. Maximum Ebb and Flood Current Velocities (cm/s) - Paerdegat Basin

	Scenarios											
July	1		2		3a		3b		4		5	
	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood
Head	-1.10	1.49	-0.17	1.42	-0.17	1.41	-0.17	1.42	-0.32	0.11	-0.17	1.40
	-0.76	2.22	-0.56	2.10	-0.56	2.08	-0.56	2.11	-1.07	0.25	-0.41	1.88
	-0.80	1.64	-0.81	1.62	-0.82	1.63	-0.81	1.63	-3.85	1.16	-0.53	1.13
	-1.14	2.47	-1.16	2.17	-1.15	1.98	-1.15	2.05	-5.74	2.33	-0.66	1.07
	-1.54	3.31	-1.58	3.00	-1.55	2.66	-1.57	2.83	-5.51	3.17	-0.85	1.17
	-1.67	3.75	-1.68	3.49	-1.69	3.04	-1.68	3.26	-5.36	4.01	-1.05	1.47
	-1.77	3.67	-1.72	3.42	-1.74	3.00	-1.72	3.20	-5.32	2.98	-1.18	1.65
	-1.75	3.30	-1.71	3.09	-1.71	2.74	-1.71	3.00	-0.89	1.18	-1.44	1.97
	-1.93	3.50	-1.88	3.21	-1.90	2.90	-1.88	3.16	-1.52	2.12	-1.58	1.84
	-1.89	3.57	-1.86	3.38	-2.12	3.47	-2.09	3.74	-2.43	3.16	-2.09	2.60
	-2.85	4.49	-2.84	4.47	-2.90	4.13	-2.86	4.64	-2.73	3.99	-2.71	3.86
	-2.85	3.29	-2.84	3.28	-2.65	2.76	-2.41	3.14	-2.81	3.89	-2.78	3.52
	-1.40	2.56	-1.38	2.56	-0.33	1.73	-1.62	2.72	-2.47	4.07	-2.25	3.49
Mouth	-2.41	2.38	-2.31	2.23	-2.34	2.28	-2.43	2.22	-2.50	2.56	-2.48	2.45
August	1		2		3a		3b		4		5	
	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood
Head	-0.24	1.31	-0.25	1.39	-0.25	1.39	-0.25	1.39	-0.11	0.23	-0.25	1.38
	-0.75	1.90	-0.78	2.17	-0.78	2.16	-0.78	2.17	-0.23	0.31	-0.61	1.86
	-0.94	1.51	-0.93	1.92	-0.92	1.93	-0.93	1.92	-0.62	0.81	-0.79	1.14
	-1.22	2.16	-1.23	1.62	-1.23	1.65	-1.24	1.68	-1.25	1.61	-1.00	1.18
	-1.50	2.92	-1.61	2.23	-1.61	2.15	-1.61	2.12	-1.81	2.15	-1.30	1.59
	-1.81	3.09	-1.97	2.35	-1.99	2.38	-1.98	2.31	-2.46	2.80	-1.64	2.00
	-1.88	3.05	-2.09	2.40	-2.09	2.47	-2.06	2.45	-1.87	2.13	-1.86	2.28
	-1.94	2.84	-2.07	2.21	-2.09	2.28	-2.07	2.27	-1.62	1.88	-2.20	2.73
	-2.13	3.24	-2.12	2.78	-2.02	2.59	-2.09	2.69	-2.30	2.62	-2.13	2.59
	-2.08	3.34	-1.96	3.01	-2.16	3.24	-2.19	3.29	-2.72	3.22	-2.48	2.81
	-3.28	4.44	-3.19	3.91	-2.99	4.21	-3.11	4.31	-2.75	3.72	-2.99	3.43
	-3.20	3.60	-3.19	3.59	-2.29	2.82	-2.51	3.09	-2.79	3.68	-2.83	3.30
	-1.94	2.81	-1.94	2.78	-1.19	1.77	-2.13	2.85	-2.82	3.91	-2.86	3.71
Mouth	-2.25	1.74	-2.28	1.86	-2.23	1.94	-2.34	1.88	-2.44	2.30	-2.56	2.14

Table E-2. Maximum Shear Stress (dyne/cm^2) - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Head	0.70	0.69	0.67	0.65	0.51	0.62
	1.06	1.16	1.10	1.16	2.56	0.92
	0.35	0.39	0.39	0.39	5.46	0.47
	0.37	0.33	0.25	0.27	5.21	0.49
	0.46	0.42	0.32	0.34	4.52	0.38
	0.49	0.46	0.35	0.37	4.33	0.56
	0.51	0.46	0.35	0.39	6.25	0.70
	0.55	0.38	0.31	0.34	3.95	0.81
	0.45	0.37	0.31	0.34	1.36	0.55
	0.56	0.52	0.39	0.40	0.61	0.42
	0.92	0.85	0.49	0.55	0.47	0.52
	1.10	0.76	0.36	0.73	0.69	0.57
	0.75	0.67	0.25	0.84	0.93	0.75
Mouth	0.57	0.58	0.56	0.55	0.57	0.55
August	1	2	3a	3b	4	5
Head	0.57	0.63	0.62	0.61	0.44	0.60
	0.85	1.05	1.10	1.07	1.63	0.78
	0.50	0.43	0.45	0.44	1.51	0.42
	0.29	0.25	0.26	0.26	1.90	0.49
	0.38	0.18	0.22	0.25	3.29	0.43
	0.37	0.26	0.31	0.34	4.82	0.65
	0.65	0.30	0.34	0.37	6.98	0.84
	0.46	0.37	0.34	0.38	4.57	1.06
	0.42	0.35	0.33	0.39	1.61	0.74
	0.54	0.43	0.42	0.49	0.76	0.47
	0.96	0.74	0.56	0.63	0.61	0.54
	1.16	1.00	0.45	0.84	0.89	0.71
	0.85	0.75	0.32	0.90	1.05	0.78
Mouth	0.56	0.53	0.50	0.50	0.49	0.50

Table E-3. Monthly Average Shear Stress (dyne/cm^2) - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Head	0.020	0.012	0.012	0.012	0.014	0.010
	0.041	0.027	0.027	0.028	0.066	0.022
	0.027	0.020	0.019	0.021	0.189	0.027
	0.024	0.020	0.019	0.021	0.268	0.039
	0.032	0.025	0.024	0.027	0.442	0.059
	0.045	0.035	0.033	0.036	0.656	0.085
	0.049	0.040	0.039	0.042	0.994	0.111
	0.047	0.040	0.039	0.043	0.660	0.134
	0.047	0.040	0.038	0.043	0.222	0.098
	0.061	0.052	0.045	0.050	0.092	0.073
	0.132	0.113	0.070	0.078	0.067	0.077
	0.139	0.120	0.047	0.098	0.094	0.092
	0.073	0.065	0.022	0.103	0.110	0.099
Mouth	0.086	0.086	0.076	0.098	0.098	0.097
August	1	2	3a	3b	4	5
Head	0.008	0.006	0.006	0.006	0.008	0.005
	0.023	0.020	0.021	0.021	0.043	0.016
	0.019	0.018	0.018	0.019	0.167	0.027
	0.018	0.017	0.017	0.018	0.263	0.043
	0.025	0.023	0.022	0.025	0.453	0.068
	0.035	0.034	0.033	0.036	0.678	0.100
	0.039	0.038	0.037	0.040	1.032	0.129
	0.041	0.040	0.039	0.043	0.717	0.161
	0.040	0.039	0.038	0.042	0.252	0.122
	0.051	0.050	0.044	0.049	0.097	0.083
	0.118	0.114	0.067	0.075	0.066	0.082
	0.138	0.135	0.047	0.101	0.088	0.096
	0.081	0.080	0.024	0.116	0.115	0.112
Mouth	0.079	0.081	0.069	0.097	0.092	0.093

Table E-4. Monthly Average DO (mg/L) - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Mouth	1.76	3.07	3.09	3.12	2.52	2.86
	2.24	3.27	3.33	3.33	4.32	3.24
	1.80	2.44	2.43	2.43	4.86	3.81
	1.93	2.43	2.36	2.40	4.89	3.90
	2.52	2.90	2.79	2.85	5.12	4.42
	3.13	3.44	3.32	3.40	5.12	4.46
	3.10	3.43	3.30	3.36	5.11	4.83
	2.89	3.08	2.91	3.01	5.11	4.74
	2.94	3.08	2.98	2.99	5.01	4.56
	3.58	3.57	3.18	3.34	3.93	3.45
	4.37	4.52	3.95	4.18	3.95	4.14
	4.83	4.99	4.47	4.71	4.28	4.64
	4.72	4.77	4.20	4.67	4.54	4.70
Head	4.77	4.81	4.79	4.81	4.71	4.74
August	1	2	3a	3b	4	5
Mouth	1.93	3.26	3.24	3.27	3.29	3.32
	2.64	3.75	3.77	3.75	4.82	3.78
	2.49	3.38	3.35	3.36	5.29	4.21
	2.67	3.42	3.36	3.39	5.34	4.45
	3.18	3.81	3.71	3.75	5.45	4.83
	3.50	3.99	3.90	3.93	5.47	5.01
	3.66	4.10	3.96	4.04	5.41	5.29
	3.54	3.91	3.78	3.84	5.43	5.29
	3.73	4.00	3.84	3.98	5.46	5.14
	4.02	4.13	3.81	3.93	4.62	4.34
	4.73	4.84	4.29	4.50	4.34	4.50
	5.09	5.16	4.53	4.83	4.49	4.78
	5.01	5.01	4.34	4.89	4.69	4.85
Head	4.84	4.85	4.79	4.85	4.76	4.81

Table E-5. Minimum DO (mg/L) - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Head	0.01	0.03	0.05	0.04	0.03	0.05
	0.05	0.30	0.26	0.25	0.51	0.24
	0.05	0.09	0.13	0.08	0.91	0.46
	0.14	0.25	0.13	0.18	0.84	0.38
	0.38	0.62	0.41	0.47	0.87	0.59
	0.83	0.90	0.94	1.18	1.14	0.24
	0.82	1.12	0.94	1.00	1.57	0.88
	0.76	0.71	0.41	0.62	0.90	0.54
	0.68	0.57	0.60	0.52	1.02	1.13
	1.29	1.12	1.20	1.08	1.19	0.72
	1.34	1.59	1.67	1.89	1.54	1.64
	1.17	1.49	2.21	1.99	1.53	1.89
	1.60	1.73	2.07	1.87	1.81	1.76
Mouth	2.71	2.75	2.63	2.71	2.71	2.57

August	1	2	3a	3b	4	5
Head	0.00	0.00	0.00	0.00	0.02	0.00
	0.00	0.00	0.01	0.01	1.35	0.00
	0.00	0.01	0.01	0.01	3.36	0.02
	0.01	0.12	0.10	0.11	3.79	0.02
	0.11	0.31	0.28	0.29	4.12	0.48
	0.28	0.48	0.45	0.47	4.11	1.20
	0.40	0.59	0.59	0.65	3.15	2.52
	0.28	0.42	0.43	0.42	3.30	1.68
	0.32	0.46	0.26	0.37	3.52	0.68
	0.69	0.75	0.64	0.76	0.90	0.48
	1.39	1.55	1.02	1.28	1.26	1.47
	1.41	1.86	0.85	1.93	1.14	1.66
	1.78	1.53	1.57	1.60	1.52	1.49
Mouth	2.22	2.29	2.18	2.19	2.16	2.20

Table E-6. Minimum Average Daily DO (mg/L) - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Head	0.90	1.88	1.29	1.88	0.35	0.52
	1.27	1.93	2.20	2.02	2.65	1.47
	0.54	0.95	0.94	0.90	3.45	1.99
	1.11	1.46	1.18	1.35	3.37	1.25
	1.54	1.90	2.04	1.81	3.91	1.89
	2.31	2.56	2.22	2.53	3.49	2.01
	2.21	2.41	2.24	2.28	3.79	3.60
	1.63	1.84	1.60	1.84	3.40	2.98
	1.80	1.73	1.76	1.59	3.33	3.28
	2.55	2.37	1.79	2.06	2.52	1.28
	3.22	3.35	2.72	2.95	2.79	2.89
	3.83	4.05	3.73	3.64	3.12	3.57
	3.50	3.59	3.38	3.79	3.67	3.77
Mouth	4.12	4.10	4.13	4.18	4.09	4.08

August	1	2	3a	3b	4	5
Head	0.32	1.12	1.11	1.12	0.13	0.97
	0.80	1.70	1.67	1.68	3.11	0.77
	0.35	1.02	0.64	0.79	4.30	1.54
	0.42	0.83	0.56	0.71	4.45	2.14
	1.07	1.54	1.38	1.45	4.57	2.52
	1.72	1.96	1.87	1.91	4.58	2.89
	1.89	2.20	2.09	2.16	4.54	3.71
	1.59	1.84	1.59	1.92	4.54	3.95
	1.66	2.03	2.00	2.13	4.61	3.27
	1.42	1.50	1.08	1.23	3.13	1.06
	3.48	3.47	1.98	2.60	2.42	2.73
	3.70	3.66	2.60	3.41	2.68	3.37
	3.70	3.67	2.64	3.55	3.25	3.43
Mouth	3.70	3.69	3.70	3.71	3.59	3.66

Table E-7. Percent of Time the DO Concentration is Greater than 3.0 mg/L - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Head	14.5	47.9	49.1	48.2	42.3	45.1
	25.2	54.8	56.5	56.7	85.1	56.9
	12.2	32.2	30.4	31.5	94.5	74.0
	15.3	29.6	26.9	27.7	96.0	76.2
	30.0	43.6	40.0	42.7	98.7	85.7
	52.8	63.5	59.3	62.0	97.3	83.8
	52.2	63.4	60.7	62.6	98.4	93.4
	42.3	47.8	41.6	45.4	97.3	89.5
	45.5	48.5	46.3	47.1	95.8	91.9
	62.9	61.5	50.6	55.7	75.1	62.9
	81.3	83.8	75.8	80.9	73.5	80.2
	88.7	91.3	93.9	93.4	84.0	91.1
	89.1	91.7	87.2	89.4	89.5	91.0
Mouth	99.2	99.7	99.5	99.6	99.3	99.5
August	1	2	3a	3b	4	5
Head	25.9	53.6	54.2	55.2	62.1	58.7
	42.7	64.7	64.3	63.8	91.9	67.0
	38.3	60.4	58.3	59.3	100.0	72.9
	42.3	59.9	58.3	58.9	100.0	79.3
	53.2	65.9	64.2	64.6	100.0	88.7
	60.7	69.7	67.2	68.5	100.0	92.9
	65.8	73.4	71.1	72.2	100.0	98.4
	63.1	67.5	65.2	66.8	100.0	98.9
	66.6	69.8	66.2	69.3	100.0	97.3
	70.6	71.5	63.9	67.0	86.7	79.3
	91.7	91.7	77.7	81.3	78.9	79.9
	97.6	97.6	86.6	92.6	82.7	90.3
	95.7	95.3	79.9	90.7	86.2	89.5
Mouth	96.9	97.3	96.4	96.9	94.6	95.3

Table E-8. Maximum Ebb and Flood Current Velocities (cm/s) - Fresh Creek

		Scenarios																					
July	1		2		3a		3b		4		5		6										
	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood									
Head	-0.18	0.37	-0.11	0.33	-0.11	0.34	-0.11	0.34	-0.08	0.11	-0.07	0.36	-0.08	0.33									
	-0.96	0.73	-0.47	0.75	-0.46	0.74	-0.46	0.74	-0.27	0.22	-0.32	0.53	-0.33	0.54									
	-0.88	0.82	-0.48	0.80	-0.47	0.80	-0.50	0.80	-0.68	1.20	-0.23	0.43	-0.27	0.47									
	-0.83	0.94	-0.57	0.92	-0.57	0.92	-0.58	0.92	-1.18	2.08	-0.28	0.50	-0.32	0.53									
	-0.82	1.00	-0.65	0.99	-0.65	0.98	-0.63	0.98	-1.32	2.26	-0.32	0.54	-0.36	0.57									
	-0.72	1.00	-0.67	0.99	-0.68	0.98	-0.68	0.97	-1.47	2.38	-0.34	0.55	-0.39	0.57									
	-1.02	1.39	-0.95	1.39	-0.96	1.49	-0.96	1.51	-1.29	1.84	-0.41	0.76	-0.53	0.83									
	-0.89	1.34	-0.89	1.18	-0.90	1.12	-0.80	1.12	-0.50	0.58	-0.62	1.04	-0.81	1.05									
	-1.82	3.10	-1.81	2.86	-1.84	2.53	-1.83	2.54	-0.97	1.17	-1.06	1.60	-1.64	2.35									
	-2.11	3.55	-2.08	3.33	-2.13	2.92	-2.12	2.92	-1.68	2.16	-1.30	2.13	-1.99	2.85									
	-1.66	2.61	-1.64	2.25	-1.64	2.19	-1.63	2.19	-1.74	2.19	-1.45	2.21	-1.83	2.35									
	-1.10	1.22	-1.10	1.14	-1.01	1.15	-1.00	1.16	-1.58	2.04	-1.18	2.49	-1.46	1.72									
	-1.87	2.96	-1.87	2.95	-1.58	2.49	-1.57	2.49	-1.81	2.96	-1.87	3.53	-2.03	3.18									
Mouth	-2.97	5.35	-2.98	5.35	-2.78	4.72	-2.76	4.72	-2.67	4.41	-2.65	4.52	-2.72	4.52									
August	1		2		3a		3b		4		5		6										
	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood									
Head	-0.19	0.48	-0.20	0.35	-0.20	0.34	-0.20	0.35	-0.13	0.23	-0.19	0.37	-0.19	0.36									
	-0.73	0.83	-0.74	0.80	-0.74	0.81	-0.74	0.81	-0.30	0.48	-0.53	0.71	-0.56	0.69									
	-0.59	0.72	-0.59	0.71	-0.60	0.71	-0.59	0.71	-0.51	0.85	-0.33	0.48	-0.34	0.48									
	-0.65	0.85	-0.65	0.84	-0.66	0.85	-0.65	0.85	-0.82	1.37	-0.36	0.58	-0.37	0.58									
	-0.72	0.93	-0.72	0.92	-0.72	0.93	-0.72	0.93	-0.93	1.51	-0.40	0.63	-0.41	0.63									
	-0.76	0.96	-0.75	0.95	-0.76	0.96	-0.76	0.96	-1.04	1.59	-0.43	0.66	-0.44	0.65									
	-1.42	1.81	-1.54	1.90	-1.56	1.93	-1.56	1.93	-1.02	1.32	-0.61	1.06	-0.88	1.33									
	-1.03	1.35	-1.08	1.27	-1.07	1.28	-1.06	1.28	-0.86	0.85	-1.08	1.49	-1.10	1.31									
	-1.92	3.13	-1.98	2.75	-1.98	2.50	-1.97	2.50	-1.31	1.47	-1.66	2.13	-1.91	2.18									
	-2.31	3.45	-2.36	3.12	-2.34	2.88	-2.37	2.89	-1.94	2.21	-1.98	2.81	-2.33	2.65									
	-1.82	2.31	-1.86	2.01	-1.84	2.06	-1.83	2.06	-1.92	2.07	-2.21	2.97	-2.10	2.38									
	-1.21	1.22	-1.21	1.17	-1.05	1.23	-1.03	1.24	-1.61	2.13	-2.39	3.35	-1.60	1.85									
	-2.35	3.45	-2.35	3.45	-1.82	2.74	-1.79	2.74	-1.87	2.96	-2.41	4.05	-2.34	3.52									
Mouth	-3.76	6.23	-3.66	6.24	-3.23	5.11	-3.21	5.08	-2.87	4.60	-3.00	4.86	-3.07	4.90									

Table E-9. Maximum Shear Stress (dyne/cm^2) - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	0.24	0.16	0.16	0.17	0.23	0.16	0.17
	0.85	0.42	0.47	0.60	1.10	0.46	0.53
	0.43	0.12	0.15	0.24	1.99	0.21	0.19
	0.15	0.08	0.07	0.12	2.19	0.14	0.12
	0.12	0.09	0.09	0.14	2.50	0.16	0.14
	0.13	0.11	0.11	0.18	2.58	0.16	0.16
	0.22	0.22	0.21	0.29	3.49	0.31	0.29
	0.26	0.25	0.25	0.25	1.55	0.40	0.24
	0.54	0.43	0.36	0.34	0.51	0.48	0.35
	0.70	0.55	0.44	0.45	0.50	0.82	0.53
	0.53	0.48	0.38	0.43	0.51	1.32	0.59
	0.54	0.44	0.28	0.36	0.47	1.61	0.46
	0.71	0.70	0.35	0.40	0.44	1.24	0.62
Mouth	1.77	1.77	0.81	0.79	0.59	0.95	0.91
August	1	2	3a	3b	4	5	6
Head	0.23	0.22	0.21	0.22	0.23	0.22	0.22
	0.54	0.20	0.20	0.25	0.78	0.26	0.26
	0.22	0.14	0.14	0.18	2.44	0.15	0.19
	0.17	0.10	0.10	0.16	2.87	0.15	0.16
	0.19	0.11	0.10	0.16	3.25	0.19	0.17
	0.16	0.12	0.11	0.17	3.35	0.21	0.19
	0.33	0.35	0.33	0.50	4.10	0.38	0.46
	0.25	0.25	0.24	0.28	1.80	0.51	0.32
	0.43	0.36	0.36	0.36	0.49	0.61	0.33
	0.47	0.39	0.40	0.39	0.50	1.05	0.41
	0.34	0.27	0.45	0.50	0.54	1.49	0.63
	0.60	0.48	0.39	0.49	0.54	1.91	0.64
	0.87	0.79	0.43	0.47	0.51	1.61	0.70
Mouth	2.16	2.17	0.84	0.84	0.64	1.12	1.05

Table E-10. Average Shear Stress (dyne/cm^2) - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	0.022	0.013	0.013	0.013	0.013	0.013	0.013
	0.044	0.028	0.028	0.036	0.066	0.036	0.037
	0.013	0.011	0.011	0.018	0.178	0.018	0.018
	0.010	0.009	0.010	0.015	0.199	0.016	0.016
	0.011	0.011	0.011	0.018	0.242	0.019	0.018
	0.012	0.012	0.012	0.020	0.267	0.021	0.020
	0.024	0.025	0.026	0.042	0.434	0.040	0.039
	0.026	0.024	0.025	0.032	0.240	0.073	0.036
	0.050	0.045	0.042	0.045	0.070	0.111	0.053
	0.067	0.060	0.059	0.062	0.064	0.178	0.079
	0.045	0.039	0.039	0.053	0.057	0.258	0.081
	0.050	0.045	0.028	0.044	0.054	0.286	0.068
	0.129	0.125	0.066	0.078	0.076	0.203	0.115
Mouth	0.283	0.282	0.160	0.159	0.136	0.188	0.183
August	1	2	3a	3b	4	5	6
Head	0.011	0.009	0.009	0.009	0.008	0.009	0.009
	0.026	0.023	0.023	0.030	0.063	0.030	0.031
	0.012	0.011	0.011	0.019	0.188	0.019	0.020
	0.011	0.011	0.011	0.018	0.207	0.018	0.018
	0.013	0.013	0.013	0.021	0.250	0.022	0.022
	0.014	0.014	0.014	0.024	0.277	0.025	0.024
	0.035	0.036	0.036	0.057	0.455	0.050	0.055
	0.027	0.027	0.027	0.036	0.264	0.085	0.042
	0.036	0.034	0.033	0.035	0.072	0.122	0.047
	0.053	0.051	0.050	0.053	0.060	0.199	0.078
	0.038	0.037	0.036	0.049	0.053	0.285	0.086
	0.046	0.045	0.026	0.042	0.048	0.319	0.074
	0.132	0.132	0.066	0.078	0.074	0.220	0.122
Mouth	0.289	0.289	0.161	0.160	0.134	0.191	0.187

Table E-11. Monthly Average DO (mg/L) - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	1.88	2.96	2.93	2.93	2.13	2.94	3.02
	2.96	4.13	4.10	4.09	3.94	4.05	4.18
	3.76	4.73	4.68	4.68	4.85	4.61	4.80
	4.01	4.86	4.81	4.80	4.94	4.66	4.89
	4.18	5.02	4.96	4.95	5.01	4.80	5.04
	4.27	5.04	4.97	4.95	5.02	4.85	5.05
	4.25	4.90	4.83	4.81	4.90	4.81	4.93
	3.44	3.81	3.70	3.67	4.76	4.74	4.26
	3.55	3.75	3.75	3.74	3.67	4.97	4.18
	3.75	3.91	3.96	3.95	3.76	5.12	4.31
	4.32	4.47	4.51	4.50	4.19	5.63	5.00
	5.17	5.25	5.01	5.01	4.71	5.74	5.29
	5.25	5.34	4.76	4.75	4.62	5.33	5.14
Mouth	5.05	5.11	4.99	4.98	4.89	5.10	5.02
August	1	2	3a	3b	4	5	6
Head	2.12	3.49	3.46	3.46	3.14	3.50	3.51
	3.45	4.66	4.62	4.62	4.79	4.70	4.69
	4.11	5.08	5.03	5.03	5.21	5.08	5.09
	4.37	5.19	5.15	5.15	5.27	5.17	5.21
	4.58	5.28	5.23	5.23	5.31	5.25	5.29
	4.70	5.31	5.27	5.27	5.34	5.30	5.34
	4.79	5.31	5.25	5.25	5.26	5.34	5.35
	3.87	4.26	4.12	4.12	5.24	5.28	4.61
	4.09	4.31	4.23	4.22	4.32	5.44	4.69
	4.23	4.38	4.31	4.31	4.29	5.50	4.76
	4.79	4.82	4.80	4.79	4.62	5.74	5.37
	5.35	5.38	5.16	5.15	4.91	5.79	5.53
	5.47	5.51	5.05	5.05	4.90	5.60	5.32
Mouth	5.27	5.29	5.08	5.08	4.97	5.23	5.15

Table E-12. Minimum DO (mg/L) - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	0.01	0.02	0.02	0.02	0.01	0.02	0.02
	0.14	0.59	0.40	0.40	0.23	0.40	0.59
	0.59	1.61	1.61	1.35	1.27	1.69	1.77
	0.85	1.31	1.32	1.30	1.65	0.65	1.41
	1.29	2.44	2.37	2.37	1.66	2.39	2.69
	0.45	1.60	1.53	1.52	1.86	2.04	1.91
	0.83	0.71	0.77	0.78	1.13	0.47	0.65
	0.51	0.92	0.85	0.87	1.07	1.31	0.80
	0.51	0.83	0.89	0.89	0.51	1.10	0.69
	0.51	0.66	0.70	0.70	0.52	1.17	0.60
	0.89	1.06	0.92	0.86	0.45	2.01	0.72
	2.39	2.78	1.89	1.84	1.69	2.94	1.88
	1.16	1.28	1.72	1.72	1.64	1.62	1.42
Mouth	1.85	2.06	2.39	2.40	2.24	2.36	2.23
August	1	2	3a	3b	4	5	6
Head	0.00	0.01	0.01	0.01	0.01	0.02	0.01
	0.07	0.97	0.95	0.97	1.85	1.16	1.09
	0.96	2.29	2.23	2.24	3.25	2.61	2.39
	1.45	2.65	2.55	2.54	2.73	2.87	2.82
	1.88	2.92	2.97	2.95	3.80	3.39	3.22
	2.17	3.13	2.73	3.08	3.80	3.39	3.29
	2.73	2.91	2.61	3.09	2.85	3.50	3.39
	0.31	0.46	0.35	0.35	2.60	1.63	0.35
	0.28	0.41	0.25	0.24	0.50	1.62	0.26
	0.38	0.48	0.30	0.29	0.25	1.32	0.44
	0.21	0.28	0.10	0.10	0.09	3.92	2.65
	1.80	1.75	1.79	1.80	1.27	4.20	1.76
	1.68	1.63	1.60	1.39	1.39	1.85	1.50
Mouth	2.61	2.63	2.49	2.49	2.21	2.56	2.40

Table E-13. Minimum Daily Average DO (mg/L) - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	0.94	0.52	0.54	0.54	0.23	0.33	0.45
	1.13	2.40	2.40	2.37	1.87	2.19	2.42
	2.36	3.56	3.57	3.51	3.49	3.43	3.66
	2.61	3.55	3.50	3.50	3.59	3.00	3.50
	2.82	3.95	3.86	3.84	3.73	3.12	3.76
	2.84	3.84	3.74	3.72	3.63	3.38	3.87
	2.34	3.31	3.25	3.25	3.46	2.99	3.06
	2.18	2.81	2.83	2.83	3.58	3.13	2.90
	2.10	2.57	2.65	2.66	2.32	3.63	2.70
	2.25	2.56	2.67	2.67	2.45	3.99	2.72
	2.77	2.95	3.00	3.01	2.25	4.73	3.24
	4.44	4.62	4.10	4.09	3.90	4.97	4.33
	4.03	4.18	3.94	3.93	3.91	4.21	4.19
Mouth	4.30	4.40	4.24	4.25	4.14	4.41	4.28
August	1	2	3a	3b	4	5	6
Head	0.04	0.27	0.20	0.21	0.09	0.43	0.21
	1.94	3.15	3.07	3.09	3.64	3.07	3.17
	2.63	3.56	3.53	3.53	4.23	3.73	3.66
	3.02	3.75	3.70	3.69	4.29	3.88	3.87
	3.15	3.83	3.81	3.80	4.33	4.02	3.97
	3.25	3.82	3.82	3.81	4.37	4.08	3.99
	3.50	3.93	3.91	3.90	4.37	4.20	4.10
	1.77	2.07	0.97	0.97	4.23	3.67	2.20
	0.84	0.99	0.84	0.87	1.56	4.21	2.06
	0.89	0.93	1.03	1.06	1.46	4.40	2.45
	2.79	1.99	1.90	1.79	2.01	4.81	4.07
	4.33	4.35	3.87	3.89	3.48	4.86	4.56
	4.24	4.22	3.72	3.72	3.67	4.20	4.12
Mouth	4.36	4.37	4.11	4.10	3.98	4.20	4.11

Table E-13. Minimum Daily Average DO (mg/L) - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	0.94	0.52	0.54	0.54	0.23	0.33	0.45
	1.13	2.40	2.40	2.37	1.87	2.19	2.42
	2.36	3.56	3.57	3.51	3.49	3.43	3.66
	2.61	3.55	3.50	3.50	3.59	3.00	3.50
	2.82	3.95	3.86	3.84	3.73	3.12	3.76
	2.84	3.84	3.74	3.72	3.63	3.38	3.87
	2.34	3.31	3.25	3.25	3.46	2.99	3.06
	2.18	2.81	2.83	2.83	3.58	3.13	2.90
	2.10	2.57	2.65	2.66	2.32	3.63	2.70
	2.25	2.56	2.67	2.67	2.45	3.99	2.72
	2.77	2.95	3.00	3.01	2.25	4.73	3.24
	4.44	4.62	4.10	4.09	3.90	4.97	4.33
	4.03	4.18	3.94	3.93	3.91	4.21	4.19
Mouth	4.30	4.40	4.24	4.25	4.14	4.41	4.28
August	1	2	3a	3b	4	5	6
Head	0.04	0.27	0.20	0.21	0.09	0.43	0.21
	1.94	3.15	3.07	3.09	3.64	3.07	3.17
	2.63	3.56	3.53	3.53	4.23	3.73	3.66
	3.02	3.75	3.70	3.69	4.29	3.88	3.87
	3.15	3.83	3.81	3.80	4.33	4.02	3.97
	3.25	3.82	3.82	3.81	4.37	4.08	3.99
	3.50	3.93	3.91	3.90	4.37	4.20	4.10
	1.77	2.07	0.97	0.97	4.23	3.67	2.20
	0.84	0.99	0.84	0.87	1.56	4.21	2.06
	0.89	0.93	1.03	1.06	1.46	4.40	2.45
	2.79	1.99	1.90	1.79	2.01	4.81	4.07
	4.33	4.35	3.87	3.89	3.48	4.86	4.56
	4.24	4.22	3.72	3.72	3.67	4.20	4.12
Mouth	4.36	4.37	4.11	4.10	3.98	4.20	4.11

Table E-14. Percent of Time the DO Concentration is Greater than 3.0 mg/L - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	17.0	53.6	52.2	52.2	32.4	52.0	54.9
	54.6	83.6	83.3	83.8	76.4	81.3	84.1
	76.9	94.8	95.0	95.0	96.8	95.2	96.0
	82.1	96.0	95.7	95.6	98.3	95.2	96.2
	85.3	98.3	98.4	98.5	98.7	96.5	98.3
	86.9	98.0	97.7	97.8	98.7	96.4	98.0
	85.2	95.2	95.6	95.6	98.1	93.3	95.3
	68.0	78.5	76.3	75.4	95.0	90.7	88.8
	63.1	67.0	68.0	68.0	64.7	89.5	74.7
	66.9	71.7	72.3	72.4	67.2	91.4	76.9
	77.1	80.8	84.7	84.4	78.6	99.6	91.4
	98.8	98.8	96.5	96.8	90.2	99.9	96.4
	93.7	94.6	90.0	89.5	86.1	95.8	94.3
Mouth	95.7	96.6	96.9	97.0	95.2	98.1	96.4

August	1	2	3a	3b	4	5	6
Head	30.5	65.2	64.3	64.4	57.6	64.0	65.1
	54.8	91.4	90.5	90.5	94.9	91.8	91.9
	74.6	98.9	97.7	98.3	100.0	99.1	99.1
	83.1	99.7	99.3	99.3	99.9	99.9	99.7
	88.3	99.9	99.9	99.9	100.0	100.0	100.0
	92.3	100.0	99.9	100.0	100.0	100.0	100.0
	96.8	99.9	99.7	100.0	99.1	100.0	100.0
	73.2	77.5	74.6	74.5	99.1	98.9	86.0
	75.0	77.2	76.2	76.1	77.0	98.8	83.9
	76.2	78.1	77.2	76.9	77.0	98.9	85.5
	89.5	89.0	89.3	89.3	85.9	100.0	99.3
	99.2	98.8	95.6	95.3	90.6	100.0	99.3
	98.7	98.7	93.3	93.6	90.2	99.3	96.9
Mouth	99.1	98.8	96.6	96.6	93.4	99.3	97.7

Shoreline Stability Report

TABLE OF CONTENTS

1.0 INTRODUCTION..... 1

2.0 AUTHORIZATION..... 1

3.0 BACKGROUND..... 1

4.0 SCOPE OF STUDY..... 2

5.0 DATA REVIEW AND EVALUATION..... 2

6.0 SHORELINE CHANGE ANALYSIS..... 3

Methodology..... 3
Shoreline Change Rate Analysis..... 4
Brant Point..... 5
Dubos Point..... 6
Bayswater Park..... 8

7.0 SLOPE STABILITY ANALYSIS..... 10

Paerdegat Basin..... 10
Fresh Creek..... 10
Bayswater State Park..... 11
Dubos Point..... 11
Brant Point..... 11

8.0 WIND WAVE AND VESSEL WAVE ANALYSIS..... 11

Wind Wave Analysis..... 12
Brant Point..... 14
Dubos Point..... 15
Bayswater Park..... 16
Vessel Wave Analysis..... 18
Brant Point..... 19
Dubos Point..... 20
Bayswater Park..... 21
Summary..... 21

9.0 SHORELINE STABILIZATION MEASURES..... 22

Bio-stabilization..... 22
Offshore Wave Attenuation Devices..... 23
Rubble Shore Structures..... 23
Composite systems..... 23
Discussion..... 25

10.0 REFERENCES..... 26

APPENDIX A..... 1

APPENDIX B..... 1

APPENDIX C 1

LIST OF FIGURES

Figure 1. Site Location Map

Figure 2. Shoreline change rates along the Brant Point site

Figure 3. Shoreline change rates along the Dubos Point site

Figure 4. Shoreline change rates along the Bayswater Park site

Figure 5. Wind rose plot of resultant wind speed and direction for JFK wind data (1984 to present)

Figure 6. Example bio-stabilization methods (adapted from MBK Engineers)

Figure 7. Example Breakwalls, Rafts, Prisms and Floating Panel

Figure 8. Transmission coefficients for floating attenuators

Figure 9. Transmission coefficients for rubble mound structures

LIST OF TABLES

Table 1. Average Shoreline change rates for Brant Point

Table 2. Average shoreline change rates for Dubos Point

Table 3. Average shoreline change rates for Bayswater Park

Table 4. Frequency (percent) distribution of JFK wind data (1984 to present)

Table 5. Extreme wind speeds

Table 6. Brant Point wind generated wave results

Table 7. Dubos Point wind generated wave results

Table 8. Bayswater Park wind generated wave results for west-northwest reference point

Table 9. Bayswater Park wind generated wave results for north reference point

Table 10. Vessel waves generated at Brant Point

Table 11. Vessel waves generated at Dubos Point

Table 12. Vessel waves generated at Bayswater Park

1.0 INTRODUCTION

Jamaica Bay, situated within the Boroughs of Brooklyn and Queens, New York City, is about 8 miles long, 4 miles wide, covers 26 square miles and opens into the Atlantic Ocean via Rockaway Inlet. Jamaica Bay opens to the Atlantic Ocean via Rockaway Inlet, which is about 17 miles by water southeast of the Battery. A Beach Erosion Control and Hurricane Protection project for the Atlantic Coast of New York City between East Rockaway Inlet and Rockaway Inlet and Jamaica Bay was authorized by the Flood Control Act (1965).

Over the past century, the Bay's fragile ecosystem has been degraded through human encroachment and increased urbanization. Combined Sewer Outfall (CSO) discharges have also exacerbated these effects. To investigate the feasibility of restoring portions of the ecosystem of Jamaica Bay, a number of environmental restoration measures are being evaluated. These measures include the need to: regrade shorelines, revegetate grasslands, create and/or restore additional estuarine, wetland and upland habitats, and improve circulation and flushing.

2.0 AUTHORIZATION

A reconnaissance study for Jamaica Bay, Marine Park and Plumb Beach, NY was authorized by a resolution of the Committee on Public Works and Transportation of the United States House of Representatives adopted 1 August 1990 to determine the feasibility of improvements for beach erosion control, hurricane protection and environmental improvements in Jamaica Bay, including environmentally sensitive areas along Plumb Beach. The reconnaissance study has resulted in the identification of a positive plan of improvement for ecosystem restoration.

3.0 BACKGROUND

A reconnaissance report was completed in January 1994. It recommended that a study be undertaken to investigate restoration of the Bay environment, including its wetland and aquatic habitats and the water quality that supports them. Initial reconnaissance study investigations indicated that a number of areas may be targeted for ecological restoration. The New York City Department of Environmental Protection (NYCDEP) is the Non-Federal sponsor. A Feasibility Cost Sharing Agreement (FCSA) was executed between the New York District of the United States Army Corps of Engineers (USACE) and the NYCDEP in February 1996 and the Environmental Restoration feasibility study efforts have been initiated and are ongoing. Twelve (12) restoration sites were selected in conjunction with input from environmental resource agencies, the Harbor Estuary Program (HEP) and the local sponsor. The study seeks to recommend restoration measures for each site, including designs for projects that may be implemented during the next phase, if warranted. The feasibility report is scheduled for completion in 2004. This Restoration feasibility study is also utilizing a hydrodynamic model of Jamaica Bay created by the NYCDEP as part of the formulation process in identifying environmental restoration efforts. This model study represents "in-kind" service contributions as part of the effort.

4.0 SCOPE OF STUDY

The tidal marshes of Jamaica Bay have historically experienced geomorphologic degradation resulting in shoreline recession and loss of wetlands, presumably caused in large part by increased navigation and land development. This Shoreline Stability Analysis Report prepared by Louis Berger, Inc. (Berger) for the New York District of the USACE looks at the shoreline stability of five (5) priority sites in Jamaica Bay, namely Paerdegat Basin, Fresh Creek, Brant Point, Dubos Point and Bayswater Park sites. Figure 1 shows the location of these sites within Jamaica Bay.

The shoreline stability analysis performed under this scope of work included the following components:

- Data Review and Evaluation
- Shoreline Change Analysis (Recession Analysis) for the Brant Point, Dubos and Bayswater Park sites
- Slope Stability Analysis for Paerdegat Basin, Fresh Creek, Brant Point, Dubos and Bayswater Park sites
- Wind Wave and Vessel Wave Analysis
- Identification of potential shoreline stabilization measures

In the remaining sections of this report each of the various components of the shoreline stability analysis will be discussed in detail.

5.0 DATA REVIEW AND EVALUATION

In order to evaluate the shoreline stability of the sites, land-based site inspections were performed in October 2002. No data was collected as part of this scope of work; however, the following data provided by the USACE was used as input for the analysis:

- Historic shoreline photographic documentation
- Survey topography/bathymetry (in the form of spot elevations and transects) and the NOAA Navigation Chart of Jamaica Bay
- Velocity data developed by HydroQual
- Arthur Kill Ship Wave Study, 2002
- Geotechnical data (grain size distribution) from the HTRW testing results

6.0 SHORELINE CHANGE ANALYSIS

Shoreline change, mainly in the form of shoreline recession, is related to the dynamics of Jamaica Bay, such as winds, waves, tides, and current effects. Wave and current action transports the sediment along the shoreline. Water levels, mainly due to tides and elevated water levels during storms, enhance these effects by increased destructive energy levels. Other geological and coastal developments also shape the present position of the shoreline. Soil type and grain size determines the natural angle of repose and strength of the soil to resist erosion. Interventions on natural dynamics due to erosion control measures (coastal structures, vegetation, and other) can decrease the recession rate locally while accelerating the rate on the adjacent shorelines. Depending on the availability of the sources in the system, a shoreline may experience both erosion and accretion due to the dynamic forces of the nature. Generally, gain of sediment in a system would translate in to shoreline accretion, whereas, loss of sediment would translate into a shoreline recession.

Dynamic shorelines exhibit both short- and long-term variations. Short-term variations can be attributed to seasonal differences in storm intensities, and localized differences in sediment type. Long-term variations (in the order of years) reflect cumulated effects. Short-term rates may be highly variable while long-term effects are averaged.

Historical shoreline change for the three sites, Brant Point, Dubos Point, and Bayswater Park, was studied for the period from 1959 to 1996. The objective of this analysis was to determine a qualitative estimate of the magnitude of shoreline change occurring at the three sites.

Methodology

Four ortho-rectified aerial images of each site were utilized for the shoreline change analysis, which were made available by the USACE. These images included 1959, 1966, 1974, and 1996 aerials spanning 37 years. The 1996 imagery was ortho-rectified by the USACE. The imagery of 1959, 1966 and 1974 were ortho-rectified by Berger based on the imagery of 1996 using ArcView GIS. In this process, four to eight ground control points were selected from each image to be rectified as well as from the imagery of 1996. The control points were selected from the visible features, both in the imagery of 1996 and the imagery to be rectified, such as streets and streams. The imagery of 1959, 1966 and 1974 were then aligned to the ortho-rectified imagery of 1996 by linking each control point on the imagery of 1959, 1966 and 1974 to the corresponding point on the imagery of 1996, thus ortho-rectifying each image. The approach used for the shoreline change analysis includes the interpretation of erosion/accretion reference features located and mapped on a series of ortho-rectified aerial images.

The first step in the historical shoreline change analysis of a site is to create an imaginary baseline common to all the digital ortho-photos from which all distances can be referenced. Therefore, a segmental baseline was created landward of waterline and roughly parallel to the shoreline for each of the three Jamaica Bay sites. The length of the baseline was sized to cover the delineated areas of interest. Transects were then drawn perpendicular to the baseline across the shoreline approximately every 100 ft.

Two reference features, waterline and vegetation line were used to assess the shoreline change for this study. These reference features and their limitations on the application to this project are defined as follows:

Water line: The intersection of Bay water with beach/land was selected as one of the reference feature used to measure the shoreline change process. This feature is the easiest to map as compared to other features. However, the position of the waterline is entirely dependent on the time that the aerial photograph was taken. That is, comparison of two aerial photos taken at high and low tides could give the impression of erosion or accretion simply as the result of water line position on a beach slope. This could potentially add up to significant errors in horizontal shoreline distance, as measured from the baseline. For example, an error could be as much as 40-60 ft in terms of shoreline location for a nearshore slope of 1:20 (horizontal:vertical) and a 2 to 3 ft difference in tidal water elevation. Generally, aerial images do not include time stamps to determine the corresponding tide level at the time of photography. In some cases though, it is possible to assess whether the picture was taken during a high tide period or low tide period by comparing the aerial images with respect to shoreline features and field observations. This assessment was considered during the mapping of the waterline feature. Other features such as a vegetation line were also utilized to check for changes in trends for confirmation.

Vegetation line: The stable vegetation line was mapped as a reference feature, which generally reflects the maximum reach of wave attack. The vegetation line was identified from the aerial photographs and digitized for analysis. However, discriminating the vegetation line is difficult, and best judgment had to be applied in early black and white pictures to locate the feature.

A third reference feature, high ground line, was used to help locate the baseline but was not used in shoreline change rate calculations. Appendix A includes the images illustrating all the refernce features.

Shoreline Change Rate Analysis

Determination of a reliable shoreline change rate requires relatively long sampling intervals. By using long intervals, short-term variations due to episodic processes are smoothed. Since the earliest aerial dates back 37 years, this analysis period has precedence over the other periods with relatively shorter time spans.

A number of analytical methods are available to determine shoreline change rates at a specific site. In most cases, these rates will be site specific, especially when there are significant variations in the shoreline position data.

For this study, an end-point analysis was used in combination with the average of rates (AOR) method where applicable. End-point analysis takes the first and last points in the selected record and calculates the rate as its name implies. Results are highly dependent on the period chosen for the analysis. Therefore, variations giving rise to certain trends might be missed. The AOR method was implemented, in addition to end-point-analysis, to account for those trends with significantly longer periods (i.e. in the order of years).

When compared to 1996 photograph year, the 1959 to 1996, 1966, and 1974 photographs allow for three relatively long analysis periods of 37, 30, and 22 years, respectively. The longest period of 37 years (1959 to 1996) was used for end-point analysis, and the others were included for the AOR analysis. Additional analysis was performed to gain a better understanding of the shoreline change rates on relatively shorter periods from 1959 to 1966, and 1966 to 1974; although, these periods were not included in the long-term shoreline change rate calculations.

Comparisons were made and site-specific rates were determined for all periods. The AOR methodology was employed where there are large variations in the rate data. These variations could be attributed to both natural phenomenon and/or mapping errors during the reference line process.

The following section presents the results for each of the three sites under investigation within the Jamaica Bay system. Appendix A includes the images for each site.

Brant Point

The Brant Point shoreline has exhibited long-term shoreline recession since the early 1900's (USACE, 2002). For the purposes of this report, Brant Point was divided into two sections due to northerly and northwesterly exposures to wave attack as well as the different shoreline characteristics. Section 1 spans from Transect Line 1 through 9 on the west side, and Section 2 spans from Transect 10 through 14 on the north side of the Brant point. Section 1 shoreline consists of natural material with deposits of shells, and exposed organic clay layers along the shoreline. Portions of the north face of the Brant Point (Section 2) shoreline consist of a ripraped edge where the shoreline is locally armored with broken concrete slabs. This armoring protects the shoreline from wave attack; therefore, historical recession rates at the north side could be expected to be less than the west side of the shoreline. A tombolo, created by an abandoned barge founded along the west side (Section 1) of Brant Point, was not included into the rate calculations. This tombolo existed only on 1996 aerial.

Table 1 summarizes the shoreline change rates, and Figure 2 shows the change in the rate along the shoreline for the three periods. These results are presented with two different reference features, waterline and vegetation line for the two sections. Both of the reference feature lines exhibit very similar trends for the periods considered, where shoreline recession is apparent. Section 1 and 2 shows differing rates for each end-point analysis corresponding to different wave exposures. Section 1 has an average of (-)3.1 ft/year recession rate at the waterline and (-)4.3 ft/year recession rate for vegetation line. The average recession rates for Section 2 were determined to be (-)1.6 ft/year and (-)2.4 ft/year for waterline and vegetation line, respectively. Recession rates for the periods 1959-1996, and 1966-1996 were approximately half the rates for the period of 1974-1996, especially for Section 1. This is mainly due to an accretionary period from 1966 to 1974, which reduces the long-term average recession rates. The combined average of recession rates was calculated as (-)2.6 ft/year, and (-)3.0 ft/year for two reference feature lines. Consequently, it is reasonable to assume based on combined waterline and vegetation line rates, that the Brant Point shoreline has retreated at a rate of about (-)3.0 ft/year since 1959.

Table 1. Average Shoreline change rates for Brant Point

	Average Water line (ft/yr)			Average Vegetation Line (ft/yr)		
Period	Section	Section	Combined	Section	Section	Combined
1959-1996	-2.4	-1.5	-2.2	-3.4	-2.3	-2.5
1966-1996	-2.2	-1.3	-2.0	-3.5	-2.3	-2.5
1974-1996	-4.6	-2.0	-3.7	-6.0	-2.7	-3.8
AVERAGE	-3.1	-1.6	-2.6	-4.3	-2.4	-3.0
1959-1966	-3.2	-2.3	-2.7	-3.2	-2.3	-2.6
1966-1974	4.3	0.7	2.4	3.3	-1.4	1.0

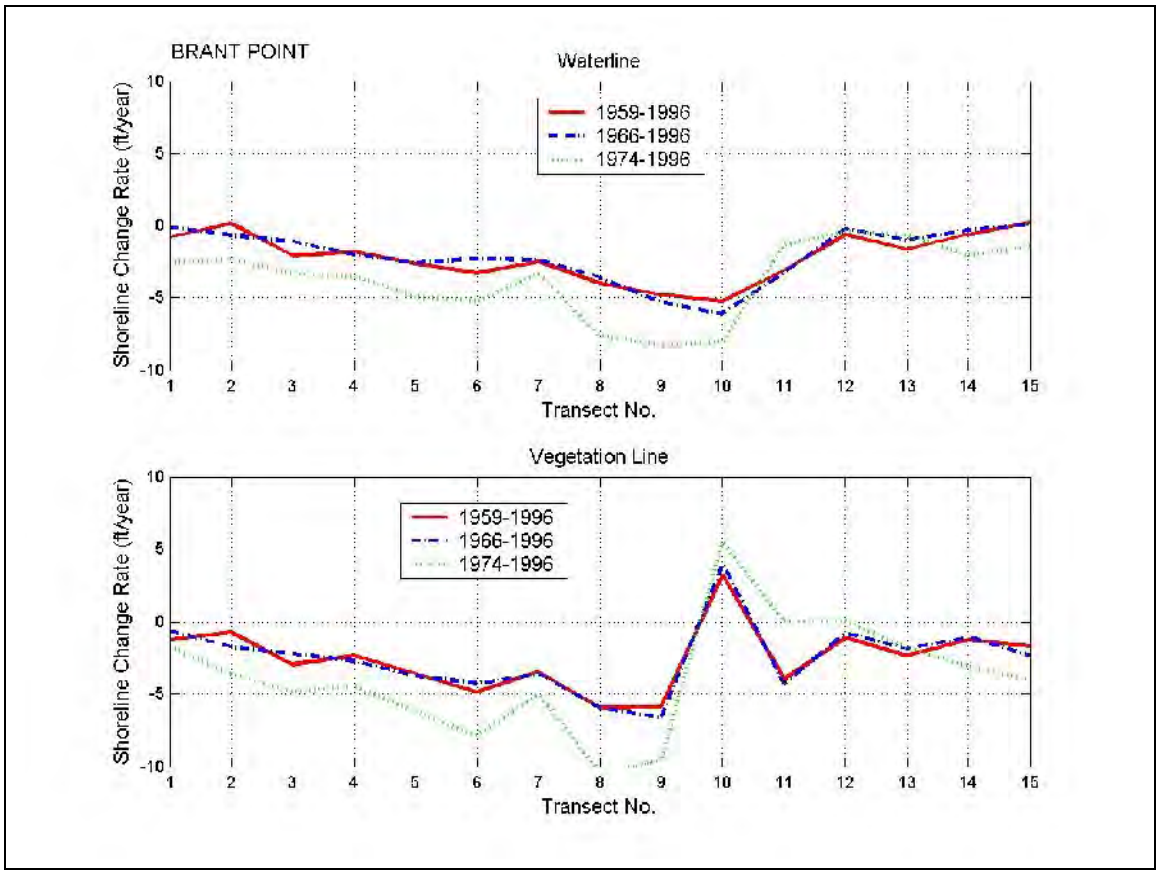


Figure 2. Shoreline change rates along the Brant Point site

Dubos Point

Once a tidal marsh, Dubos Point was partially bulkheaded and filled to allow development along the shoreline in the first quarter of the 20th century (USACE, 2002).

Over the years, this bulkhead altered the sediment transport pattern around the Dubos Point. Erosion along the west bulkhead of Conchs Hole Point was noted as a result of the deformation of the structure. Some portion of the bulkhead still remains today and has a variable effect on the shoreline process around Dubos Point. Dredging activities were also noted around the filled area where the sediment transport patterns are expected to be impacted.

Dubos Point was analyzed in two sections, the natural shoreline composed of the large tidal flats and/or ditches along the beach (Section 1) and the bulkhead area (Section 2). Section 1 (Transects 1 through 7) also covers the area to the west of the Dubos point. Section 2 includes the Transect lines from 8 through 27 for the remaining part of the Dubos Point shoreline.

The vegetation line was utilized as the primary erosion reference feature for this site, due to the fact that the existing bulkhead could bias the location of the waterline.

Table 2 summarizes the shoreline change rates, and Figure 3 shows the change in the rate along the shoreline for the Dubos Point for the three periods. The shoreline recession rate is significantly higher for the period of 1974-1996 while significant accretion is noted in the 1966-1974 periods, similar to what was observed at Brant Point. Section 1 has an average of (-)3.4 ft/year recession rate at the vegetation line. The average recession rate for Section 2 was determined to be (-)2.9 ft/year. Similar to Brant Point, recession rates for the periods 1959-1996, and 1966-1996 were approximately less than half the rates for the period of 1974-1996. This is mainly due to an accretionary period of 1966-1974, which reduces the long-term average recession rates. The combined average of recession rate was calculated to be (-)3.0 ft/year. Consequently, it is reasonable to assume that the Dubos Point shoreline retreated at a rate of about (-)3.0 ft/year since 1959 based on the vegetation line reference feature.

Table 2. Average shoreline change rates for Dubos Point

	Average Vegetation Line (ft/yr)		
Period	Section 1	Section 2	Combined Average
1959-1996	-2.2	-2.1	-2.1
1966-1996	-0.9	-2.1	-1.9
1974-1996	-7.1	-4.6	-5.1
AVERAGE	-3.4	-2.9	-3.0
1959-1966	-1.9	-7.6	-2.9
1966-1974	4.7	16.1	6.8

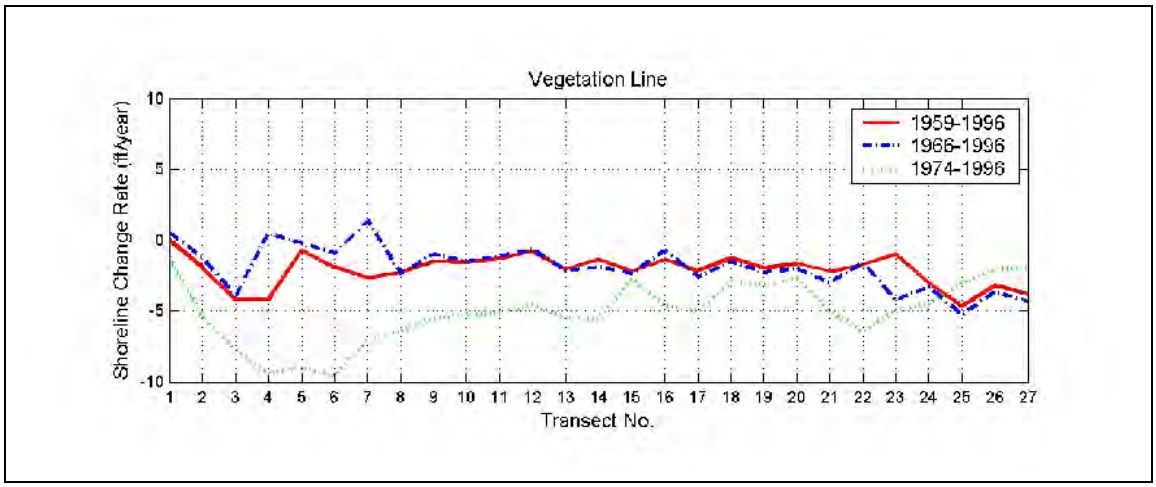


Figure 3. Shoreline change rates along the Dubos Point site

Bayswater Park

Aerial images over the years revealed the existence of spit formations along the western and northern edges of the Bayswater Park site. The existing wall at the northwest corner of the Bayswater Park seems to have a nodal point effect where the sediment transport patterns alter direction to each side of this point. In the 1996 image, the easterly spit has assumed a new alignment, more towards the north. Potentially, construction of the JFK runway extension and/or dredging could have affected the sediment transport patterns around Bayswater Park.

The Bayswater Park site was divided into two sections. Section 1 includes Transects 1 through 13 on the western side of the park up to the existing wall at the northwest corner. Section 2 spans from the wall to the eastern side of the park, including Transects 14 through 38.

Table 3 summarizes the shoreline change rates, and Figure 4 shows the change in the rate along the shoreline for Bayswater Park for the three periods. These results are presented for two different reference features, waterline and vegetation line for the two sections. Both of the feature lines exhibit very similar trends (when considering the average) for the all the periods considered. Section 1 and 2 shows differing rates for each end-point analysis. Section 1 has an average of (-)1.7 ft/year recession rate at the waterline and (-)1.2 ft/year recession rate for the vegetation line. Average advancement rates for Section 2 were determined as 0.7 ft/year and 1.3 ft/year for waterline and vegetation line, respectively. The overall (combined) averages of advancement rates were calculated as 0.0 ft/year, and 0.6 ft/year for the two reference features. These averages show that the northern shoreline of Bayswater Park has advanced with contribution from the spit formations. Figure 4 shows that the seawall on the northwest corner of the Park seems to act as a nodal point where the erosional trend on the west changes to an accretional trend. This can also be seen visually in the aerial photography included in Appendix A. Unlike Brant Point and Dubos Point sites, shoreline change was accretionary for the period from 1959 to 1966. This period, therefore, helped to offset some of recession rates for the

remaining periods. Consequently, it is reasonable to assume that as a whole the Bayswater Park site has been on average dynamically stable since 1959.

Table 3. Average shoreline change rates for Bayswater Park

	Water line Average (ft/yr)			Vegetation Line Average (ft/yr)		
Period	Section	Section	Combined	Section	Section	Combined
1959-1996	-0.4	1.7	1.0	-1.1	3.3	1.9
1966-1996	-1.8	-0.5	-0.9	-1.6	0.0	-0.5
1974-1996	-2.8	1.0	-0.2	-0.9	0.8	0.3
AVERAGE	-1.7	0.7	0.0	-1.2	1.3	0.6
1959-1966	5.7	10.8	9.2	1.2	17.5	12.5
1966-1974	0.9	-4.4	-2.8	-3.6	-2.3	-2.7

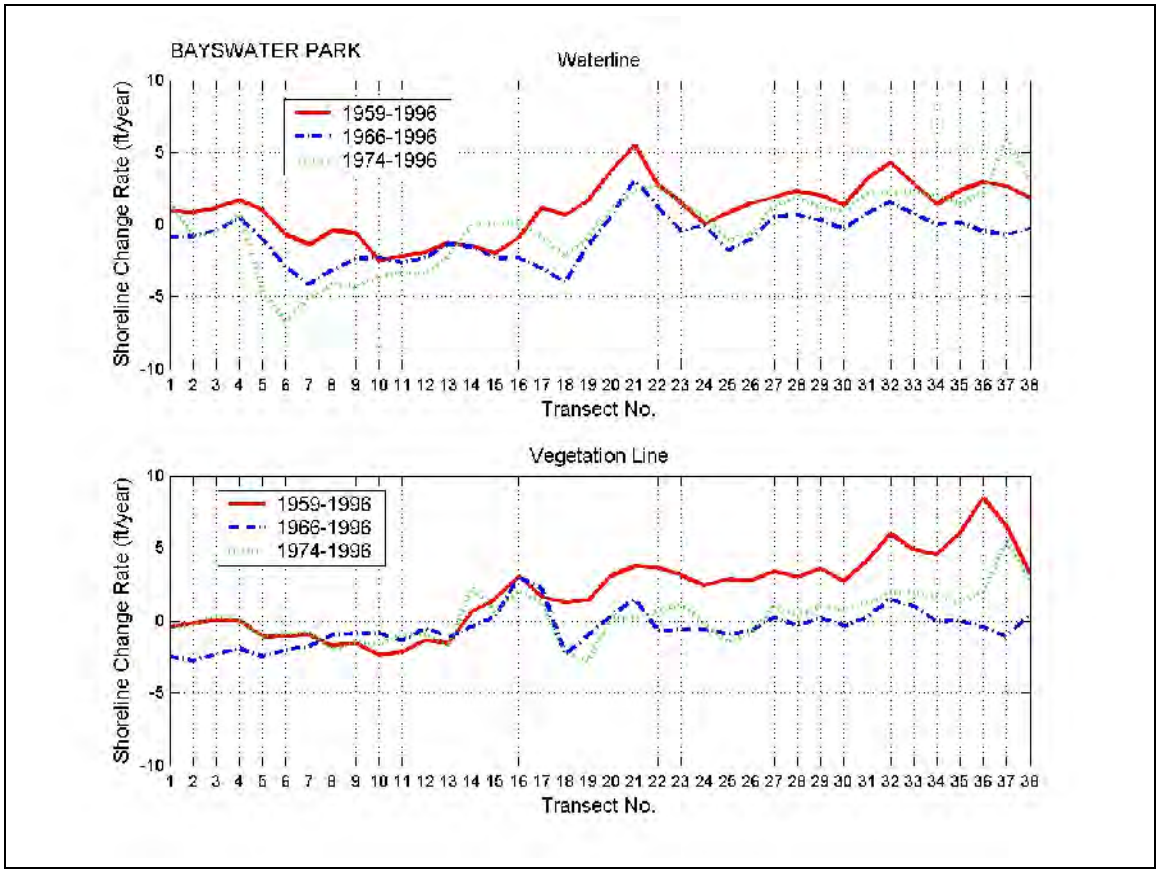


Figure 4. Shoreline change rates along the Bayswater Park site

7.0 SLOPE STABILITY ANALYSIS

The overall slope stability was assessed for all five of the Jamaica Bay priority sites, namely the Paerdegat Basin, Fresh Creek, Brant Point, Dubos Point and Bayswater Park sites. The goal of this analysis was to identify any areas within the sites where slopes may be unstable due to steep slopes, weak soil strata and/or exposure to high tidal velocities. For the purposes of this analysis the following data were analyzed:

- Historic and recent shoreline photographic documentation
- Survey topography and bathymetry data
- Velocity data developed by HydroQual
- Geotechnical data (grain size distribution) from the HTRW testing results

In general, there does not appear to be any areas of significant slope instability at any of the sites. Slopes are generally 4:1 (horizontal:vertical) or shallower and average velocities are generally less than 1 fps, the maximum permissible near bottom channel velocities for fine sand (ASCE, 1995). A description of the findings at each site is presented in the following sections. The velocity data provided by HydroQual and the shoreline slopes, as calculated based on the topography data provided by the USACE, are included in Appendix B.

Paerdegat Basin

The shoreline slope stability analysis for Paerdegat Basin showed generally stable slopes with most slopes shallower than 4:1 (horizontal:vertical). Average velocities for incoming tides ranged from 0.1 fps to 0.4 fps and average velocities for outgoing tides ranged from 0.1 fps to 0.4 fps. Geotechnical data indicates that the upper most 10 to 12 feet of material in the area consists of fine to coarse sands and general fill/debris (glass, paper brick, etc.), which is generaly underlain by an older organic silty clay meadow mat strata.

The shoreline slope analysis identified a few isolated areas where the slopes were in the 2:1 range. These areas should be investigated further in the field. The steeper slope areas were located mostly along the southern shoreline and near the entrance of the basin.

Fresh Creek

The shoreline slope stability analysis for Fresh Creek showed generally stable slopes with most slopes shallower than 4:1 (horizontal:vertical). Average velocities for incoming tides ranged from 0.6 fps to 1.1 fps and average velocities for outgoing tides ranged from 0.4 fps to 1.0 fps. Geotechnical data indicates that the upper most 5 to 26 feet of material in the area consists of fine to coarse sands and general fill/debris, which is generaly underlain by an older organic silty clay meadow mat strata.

The shoreline slope analysis identified a few isolated areas where the slopes were in the 2:1 range. These areas should be investigated further in the field. Like Paerdegat basin, the steeper slope areas were located mostly along the southern shoreline.

Bayswater State Park

The shoreline slope stability analysis for Bayswater State Park showed generally stable slopes with most slopes shallower than 4:1 (horizontal:vertical). Average velocities for incoming tides ranged from 0.1 fps to 0.3 fps and average velocities for outgoing tides ranged from 0.0 fps to 0.5 fps. Geotechnical data indicates that the upper most 5 to 12+ feet of material in the area consists of fine to coarse sands and general fill/debris, which is generaly underlain by an older organic silty clay meadow mat strata.

The shoreline slope analysis identified a few isolated areas where the slopes were in the 2:1 to 1:1 range. These areas should be investigated further in the field. The steeper slope areas were located mostly along the northern shoreline and seem to occur along the vegetated edge of the shoreline.

Dubos Point

The shoreline slope stability analysis for Dubos Point showed stable slopes with all slopes shallower than 3:1 and most slopes shallower than 4:1 (horizontal:vertical). Average velocities for incoming tides ranged from 0.0 fps to 0.3 fps and average velocities for outgoing tides ranged from 0.0 fps to 0.4 fps. Geotechnical data indicates that the upper most 5 to 7 feet of material in the area consists of fine to coarse sands and general fill/debris, which is generaly underlain by an older organic silty clay meadow mat strata.

No unstable slopes were identified at the Dubos Point site.

Brant Point

The shoreline slope stability analysis for Brant Point showed generally stable slopes with most slopes shallower than 4:1 (horizontal:vertical). Only one isolated area near the southern end of the shoreline showed a slope in the 2:1 range. Average velocities for incoming tides ranged from 0.3 fps to 0.5 fps and average velocities for outgoing tides ranged from 0.3 fps to 0.8 fps. Geotechnical data indicates that the upper most 4 to 6 feet of material in the area consists of fine to coarse sands and general fill/debris, which is underlain by a 1 to 3 feet thick peat mat strata, which is inturn underlain by a gray fine to medium sand/clay layer.

No unstable slopes were identified at the Brant Point site.

8.0 WIND WAVE AND VESSEL WAVE ANALYSIS

Wave-induced effects are one of the primary factors affecting sediment transport processes in a coastal region. Waves generated by winds as well as waves generated by

the vessels traveling along the navigational channels were considered for three the sites under investigation (Brant Point, Dubos Point, and Bayswater Park). Vessel generated waves are of particular interest due to the potentially high volume of ship traffic passing by each site everyday.

Wind Wave Analysis

Site-specific wave conditions (height, period, and direction) at Brant Point, Dubos Point, and Bayswater Park were determined using local wind data and a series of analytical models. A detailed description of the procedures used to compute wave characteristics at each of the site is presented in this section.

Bathymetric information for the area was obtained through National Oceanographic & Atmospheric Administration (NOAA) chart (12350), and through survey transect data provided by the USACE.

All possible wind directions were considered to determine the wind-generated waves for the analysis. Winds blowing across Jamaica Bay, mainly from northerly components, generate waves that will impact the areas of interest. Due to the restricted nature of the Bay, the major factors affecting the magnitude and period of the waves would be the fetch length, average depth, wind speed, and wind duration.

Local, historic wind data collected at JFK Airport (spanning from early 1980's to present) was obtained from the National Climatic Data Center. Additional information utilized during the present study included an earlier study (LSP, 1981) that utilized the JFK airport data as well as the some general information provided in the Coastal Engineering Manual (CEM, 2002).

Overall wind conditions during the 18 year time period for JFK Airport are presented in Figure 5, which shows the distribution of wind speed (mph) data (illustrated using a wind rose plot). The gray-scale sidebar indicates the magnitude of wind speed, the circular axis represents the direction of wind approach (coming from) relative to North (North being 0 degrees), and the extending radial lines indicate percent occurrence within each magnitude and directional band. The most common direction of wind approach, as well as the approach direction of a significant portion of the winds, is from the southerly and northerly components of westerly directions. Table 4 shows the frequency of each speed and directional bin. The numbers to the right and at the bottom represent the total frequency of occurrence for that specific directional bin and speed bin, respectively.

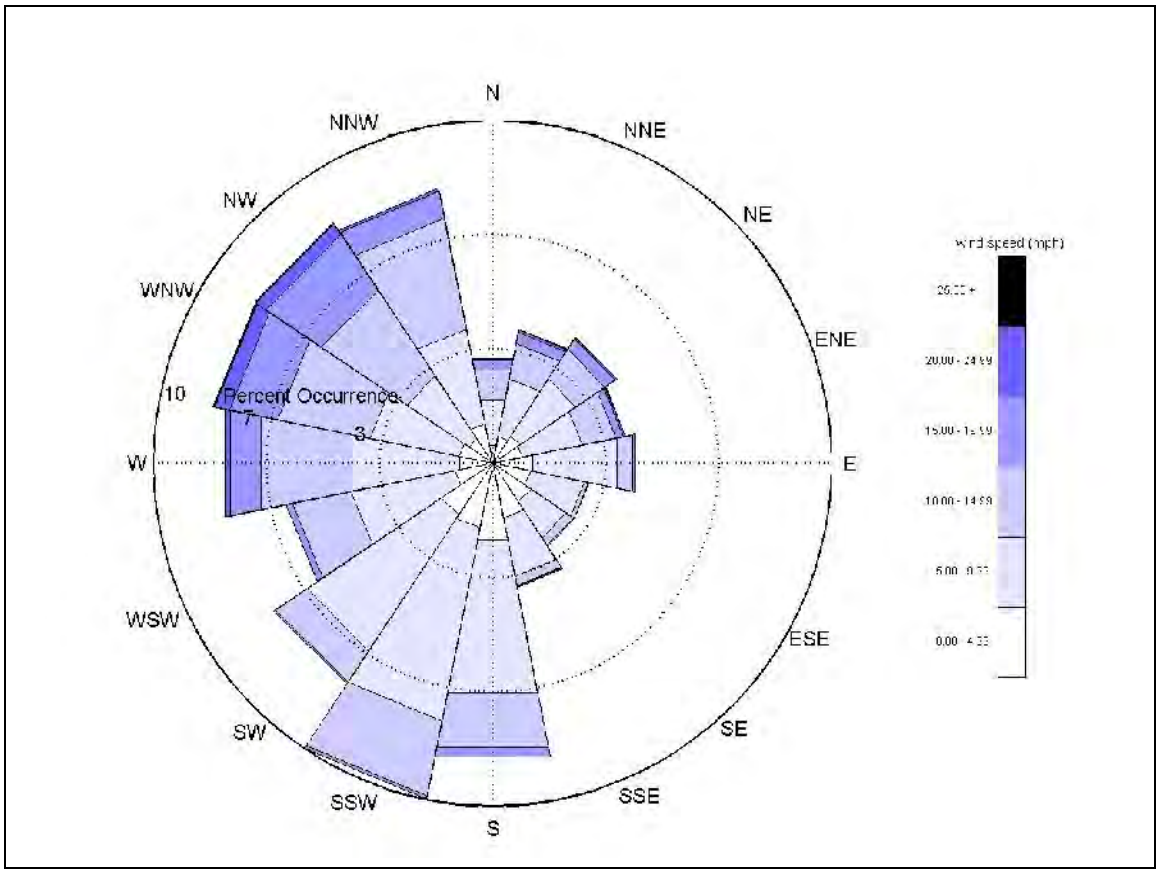


Figure 5. Wind rose plot of resultant wind speed and direction for JFK wind data (1984 to present).

Table 4. Frequency (percent) distribution of JFK wind data (1984 to present).

		Wind Speed (mph)						
		0-4.99	5-9.99	10-14.99	15-19.99	20-24.99	25+	TOTAL[1]
Direction	N	0.78	1.85	1.38	0.39	0.06	0.01	4.48
	NNE	0.77	1.82	0.86	0.44	0.10	0.01	4.00
	NE	0.96	1.90	1.15	0.28	0.09	0.00	4.37
	ENE	0.99	1.98	0.83	0.23	0.01	0.01	4.05
	E	1.25	2.44	0.38	0.06	0.01	0.00	4.14
	ESE	1.25	1.42	0.22	0.03	0.00	0.00	2.92
	SE	1.37	1.51	0.29	0.04	0.00	0.00	3.21
	SSE	1.82	2.40	0.62	0.13	0.03	0.00	5.00
	S	2.41	5.45	2.88	0.45	0.01	0.00	11.20
	SSW	1.73	5.70	1.70	0.09	0.00	0.00	9.21
	SW	1.35	4.04	1.79	0.09	0.04	0.00	7.31
	WSW	1.19	2.78	2.06	0.38	0.04	0.00	6.45
	W	1.00	2.99	3.04	1.50	0.33	0.07	8.94
	WNW	0.83	2.09	3.18	2.01	0.62	0.07	8.81
	NW	0.77	2.11	3.33	1.60	0.22	0.00	8.02
	NNW	0.94	1.67	1.93	0.42	0.06	0.00	5.03
	TOTAL[2]	19.41	42.14	25.63	8.12	1.64	0.19	

[1, 2] Total occurrences per direction and speed bin, respectively

To determine the extreme wave conditions for design considerations, it is necessary to associate extreme wind conditions with design return period(s). Table 5 summarizes the extreme wind speeds determined for this study, considering the all possible directions. The proper averaging time for design and planning considerations varies dramatically as a function of wind speed and fetch length (CEM, 2002). Based on the guidance provided in the CEM, 5-, 15- and 15-min averaging time intervals were utilized for 50-year, 20-year, and 10-year winds, respectively.

Table 5. Extreme wind speeds

Return Period	Wind Speed	Averaging time
50-year	75	5-min
20-year	59	15-min
10-year	52	15-min

The waves generated by the wind data (summarized in Tables 6, 7, 8 and 9) were predicted using a computer model developed by the USACE. This computer model is part of the Automated Coastal Engineering System (ACES), published by the Coastal Engineering Research Center (USACE, 1992). The program is entitled Wind Speed Adjustment and Wave Growth, and provides simplified estimates for wave growth over open-water and restricted fetches, such as Jamaica Bay, in deep and shallow water. The ACES model addresses only wind-generated waves, and does not account for the effects of refraction, diffraction, and non-linear effects. These wave transformations will be considered in the next phase.

Wind data along with the geometry and average water depth of the fetch is required input to the ACES program. The fetch, or distance over which wind acts on the water, is restricted in Jamaica Bay, which in return limits the wave generation. Longer fetches will generate larger waves with everything else kept constant. Fetch directions and related information corresponding to each site under investigation are provided in Tables 6, 7, 8 and 9. Each wind condition input into ACES takes into account the restricted geometry and all the fetch lengths when calculating the associated wave conditions. Additionally, an iterative approach was used to obtain maximum fetch-limited wave conditions during the modeling process, when dealing with averaging schemes as well as the storm duration. Standard ACES output includes a spectral significant (modal) wave height (H_{mo}), peak period (T_p), and a mean wave direction (MWD) for each of the fetch bands.

Results of the wind-generated wave analysis for the Brant Point, Dubos Point and Bayswater Park sites are presented in the following sections.

Brant Point

The spectral significant wave height (H_{mo}), the peak period (T_p), and mean wave direction resulting from the ACES predictions for Brant Point are shown in Table 6. These results correspond to a representative (reference) location along the Brant Point shoreline. Three

different sets of results are presented corresponding to design return periods of 50-, 20-, and 10-year winds, respectively. In general:

- The model predicts that the maximum waves will be generated when the winds are blowing from east-northeast (ENE) corresponding to longest fetch direction.
- The modal wave height was estimated to be 3.9 ft, 3.0 ft and 2.7 ft for the 50-year, 20-year and 10-year wind speeds, respectively.
- Peak periods were 3.4 sec, 3.0 sec, and 2.8 sec for the 50-year, 20-year and 10-year return-periods, respectively.
- Mean wave directions were estimated to be between 64 and 68 degrees (measured clockwise from true North) for northeasterly fetch directions.
- Northwesterly fetches will generate about 10% smaller waves and shorter periods than northeasterly fetches.

Table 6. Brant Point wind generated wave results

Fetch		Fetch Length	Depth*	Wave Characteristics								
				50-year wind			20-year wind			10-year wind		
				Height	Period	MWD	Height	Period	MWD	Height	Period	MWD
No.	Direction	(mi)	(ft)	(ft)	(sec)	(deg N)	(ft)	(sec)	(deg N)	(ft)	(sec)	(deg N)
1	N	0.31	21	2.7	2.8	329	2.1	2.5	329	1.9	2.4	329
2	NNE	0.31	16	2.9	2.9	62	2.3	2.6	62	2.0	2.5	62
3	NE	0.39	16	3.5	3.2	64	2.8	2.9	64	2.4	2.7	64
4	ENE	1.10	26	3.9	3.4	66	3.0	3.0	66	2.7	2.8	66
5	E	0.10	16	3.4	3.2	68	2.7	2.9	68	2.4	2.7	68
6	ESE											
7	SE											
8	SSE											
9	S											
10	SSW											
11	SW	0.38	16	2.4	2.6	232	1.9	2.3	232	1.7	2.2	232
12	WSW	0.38	21	2.5	2.6	244	1.9	2.4	244	1.7	2.2	244
13	W	0.32	21	2.6	2.8	309	2.0	2.5	309	1.8	2.3	309
14	WNW	0.39	21	3.2	3.0	313	2.5	2.7	313	2.2	2.6	313
15	NW	0.79	21	3.4	3.1	317	2.6	2.8	317	2.3	2.6	317
16	NNW	0.55	21	3.2	3.1	320	2.5	2.7	320	2.2	2.6	320

* assumed high tide

Dubos Point

The spectral significant wave height (H_{mo}), the peak period (T_p), and mean wave direction resulting from the ACES predictions for Dubos Point are shown in Table 7. These results correspond to a representative (reference) location along the Dubos Point shoreline.

Three different sets of results are presented corresponding to design return periods of 50-, 20-, and 10-year winds, respectively. In general:

- The model predicts that the maximum waves will be generated when the winds are blowing from northeast (NE) which corresponds to longest fetch direction.
- The modal wave height was estimated to be 3.6 ft, 2.8 ft and 2.5 ft for the 50-year, 20-year and 10-year wind speeds, respectively.
- Peak periods were 3.3 sec, 2.9 sec and 2.8 sec for the 50-year, 20-year and 10-year wind speeds, respectively.
- Mean wave directions were estimated to be between 40 and 45 degrees (measured clockwise from true North) for northeasterly fetch directions.
- Northwesterly fetches will generate about 20% smaller waves and shorter periods than northeasterly fetches.

Table 7. Dubos Point wind generated wave results

Fetch		Fetch Length	Depth *	Wave Characteristics								
				50-year wind			20-year wind			10-year wind		
				Height	Period	MWD	Height	Period	MWD	Height	Period	MWD
No.	Direction	(mi)	(ft)	(ft)	(sec)	(deg N)	(ft)	(sec)	(deg N)	(ft)	(sec)	(deg N)
1	N	0.39	42	3.0	3.0	33	2.3	2.7	33	2.0	2.5	33
2	NNE	0.63	42	3.6	3.3	40	2.8	2.9	40	2.5	2.8	40
3	NE	0.95	16	3.6	3.2	42	2.8	2.9	42	2.5	2.7	42
4	ENE	0.16	16	3.3	3.1	45	2.6	2.8	45	2.3	2.6	45
5	E	0.24	16	2.6	2.8	48	2.0	2.5	48	1.8	2.4	48
6	ESE											
7	SE											
8	SSE											
9	S											
10	SSW											
11	SW											
12	WSW	0.62	34	3.0	3.0	255	2.4	2.6	255	2.1	2.5	255
13	W	0.47	36	3.0	2.9	255	2.3	2.6	255	2.0	2.5	255
14	WNW	0.53	42	2.9	2.9	289	2.3	2.6	289	2.0	2.4	289
15	NW	0.30	42	2.7	2.8	294	2.1	2.5	294	1.8	2.4	294
16	NNW	0.31	42	2.4	2.7	14	1.9	2.4	14	1.6	2.3	14

* assumed high tide

Bayswater Park

The spectral significant wave height (H_{mo}), the peak period (T_p), and mean wave direction resulting from the ACES predictions for Bayswater Park are shown in Table 8 and 9.

These results correspond to two representative (reference) locations along the Bayswater Park shoreline. The first reference point was located on the west/northwest side and the second reference point was located on the north face of the Bayswater shoreline. The north reference point is naturally more protected than the west/northwest reference point. Three different sets of results are presented corresponding to design return periods of 50-year, 20-year and 10-year respectively. In general for the west/northwest reference location:

- The model predicts that the maximum waves will be generated when the winds are blowing from NNW corresponding to longest fetch direction.
- The modal wave height was estimated to be 3.8 ft, 3.0 ft, and 2.6 ft for the 50-year, 20-year and 10-year wind speeds, respectively.
- Peak periods were 3.3 sec, 3.0 sec and 2.8 sec for the 50-year, 20-year and 10-year return-periods, respectively.
- Mean wave directions were estimated to be between 333 and 339 degrees (measured clockwise from true North) for northwesterly fetch directions.
- Northwesterly fetches will generate about 10% larger waves and shorter periods than northeasterly fetches.

Table 8. Bayswater Park wind generated wave results for west-northwest reference point

Fetch		Fetch Length	Depth*	Wave Characteristics								
				50-year wind			20-year wind			10-year wind		
				Height	Period	MWD	Height	Period	MWD	Height	Period	MWD
No.	Direction	(mi)	(ft)	(ft)	(sec)	(deg N)	(ft)	(sec)	(deg N)	(ft)	(sec)	(deg N)
1	N	0.80	16	3.5	3.2	345	2.7	2.9	345	2.4	2.7	345
2	NNE	0.80	21	3.5	3.2	16	2.7	2.9	16	2.4	2.7	16
3	NE	0.15	16	3.1	3.0	20	2.4	2.7	20	2.1	2.5	20
4	ENE	0.20	16	2.4	2.7	25	1.9	2.4	25	1.7	2.3	25
5	E											
6	ESE											
7	SE											
8	SSE											
9	S											
10	SSW	0.15	16	2.6	2.8	244	2.0	2.5	244	1.8	2.3	244
11	SW	0.22	16	3.2	3.1	246	2.5	2.7	246	2.2	2.6	246
12	WSW	0.90	42	3.6	3.3	249	2.8	2.9	249	2.5	2.7	249
13	W	0.40	34	3.4	3.2	251	2.6	2.8	251	2.3	2.7	251
14	WNW	0.30	26	3.1	3.0	321	2.4	2.7	321	2.1	2.6	321
15	NW	0.71	30	3.6	3.3	333	2.8	2.9	333	2.5	2.7	333
16	NNW	0.95	26	3.8	3.3	339	3.0	3.0	339	2.6	2.8	339

* assumed high tide

For the north reference location

- The model predicts that the maximum waves will be generated when the winds are blowing from north-northeast (NNE) corresponding to longest fetch direction.
- The modal wave height was estimated to be 3.3 ft, 2.6 ft and 2.2 ft for the 50-year, 20-year and 10-year wind speeds, respectively.
- Peak periods were 3.1 sec, 2.7 sec, and 2.6 sec for the 50-year, 20-year and 10-year return-periods, respectively.
- Mean wave directions were estimated to be between 20 and 24 degrees (measured clockwise from true North) for northeasterly fetch directions.
- Northwesterly fetches will generate about 10% smaller waves and shorter periods than northeasterly fetches.

Table 9. Bayswater Park wind generated wave results for north reference point

Fetch		Fetch Length	Depth*	Wave Characteristics								
				50-year wind			20-year wind			10-year wind		
				Height	Period	MWD	Height	Period	MWD	Height	Period	MWD
No.	Direction	(mi)	(ft)	(ft)	(sec)	(deg N)	(ft)	(sec)	(deg N)	(ft)	(sec)	(deg N)
1	N	0.25	16	3.0	3.0	20	2.4	2.6	20	2.1	2.5	20
2	NNE	0.78	21	3.3	3.1	22	2.6	2.7	22	2.2	2.6	22
3	NE	0.16	16	3.0	2.9	24	2.3	2.6	24	2.1	2.5	24
4	ENE	0.23	16	2.4	2.7	27	1.9	2.4	27	1.6	2.2	27
5	E											
6	ESE											
7	SE											
8	SSE											
9	S											
10	SSW											
11	SW											
12	WSW											
13	W	0.39	34	2.9	2.9	287	2.3	2.6	287	2.0	2.4	287
14	WNW	0.62	26	3.0	2.9	290	2.3	2.6	290	2.0	2.5	290
15	NW	0.12	30	2.8	2.8	293	2.2	2.5	293	1.9	2.4	293
16	NNW	0.16	26	2.5	2.7	18	1.9	2.4	18	1.7	2.3	18

* assumed high tide

Vessel Wave Analysis

Considering the proximity of the navigational channels, as well as the volume of the traffic in these channels, vessel generated waves have the potential to severely impact the Dubos Point, Brant Point and Bayswater Park sites.

The movement of a boat hull through water produces waves fronts that propagate from both the bow and stern pressure distribution, along the length of the hull. The magnitude of the wave depends on the vessel speed, the hull surface geometry, and the channel cross-sectional shape (if the channel is relatively shallow and/or narrow). The wave pattern consists of diverging and transverse waves (ENV Report 4, 1997). The strongest waves are the diverging waves, obliquely propagating from the vessel at an angle of 35°. A typical train of waves will rarely exceed ten.

Each site was analyzed separately and the results are summarized in this section. Specific vessel information was obtained from Arthur Kill Ship Wave Study (2002). This information included the type of the vessel, volume of water displaced by the ship, speed, and draft (where available). Shortest distance from the navigational channel to a reference point along the shoreline was measured for each site. This distance varied with vessel type due to water depth limitations on ship draft. Vessel characteristics were obtained through the recorded logs of the Arthur Kill study (see Appendix C for a partial list). Tugboats were recorded with cruising speeds from 3 knots up to 11 knots. A range of 8 to 12 knot vessel speeds were tested for tug boats to conservatively estimate the wave heights. Whereas, a vessel speed of 8 knot was tested for the larger ships. However, as stated in the Arthur Kill study, large ships do not generate waves larger than that of tugboats and/or barges.

Methodology outlined by Sorenson and Weggel (1984, 1986) were utilized and compared to determine the wave heights and periods. Ship generated waves were then transformed to a reference depth of 5 ft by using linear wave theory (LWT), and Snell's law for shoaling and refraction. Direction of wave incidence at the reference depth is approximate and based on the diverging waves obliquely propagating from the vessel at an angle of 35°.

The results of the vessel wave analysis for each site are summarized in the following sections.

Brant Point

The largest wave generated (at reference depth of 5 ft) was 2.5 ft with a 3.1 sec period corresponding to vessel speed of 12 knots. As expected large ships did not generate the larger waves, mainly because of their cruising speed. Additionally, the size of the big ships was limited by the water depth of the navigational channels.

Table 10 summarizes the results for Brant Point for waves generated by both tugboats and ships.

Table 10. Vessel waves generated at Brant Point

Tug Boat					Tug Boat		
Vessel Speed (knots)	Distance to reference point (ft)	Vessel Generated Wave			Transformed Wave at 5 ft (LWT)		
		Height (ft) [Sorenson & Weggel]		Period (sec)	Height (ft)	Period (sec)	Direction* (deg)**
		1984	1986				
8	300	0.7	1.0	2.1	0.9	2.1	40 (130)
10	300	1.4	2.0	2.7	1.6	2.7	34 (124)
12	300	2.1	3.0	3.1	2.5	3.1	31 (121)
Ship					Ship		
8	300	0.4	0.8	2.1	0.7	2.1	40 (130)

* inbound -northeast- vessel route (outbound –southwest- vessel route)
** approximate angle between wave crest and shoreline

Dubos Point

The largest wave generated (at a reference depth of 5 ft) was 2.3 ft with a 3.2 sec period corresponding to vessel speed of 12 knots. As in Brant Point case, large ships did not generate the larger waves.

Table 11 below summarizes the results for Dubos Point for waves generated by both tugboats and ships.

Table 11. Vessel waves generated at Dubos Point.

Tug Boat					Tug Boat		
Vessel Speed (knots)	Distance to reference point (ft)	Vessel Generated Wave			Transformed Wave at 5 ft (LWT)		
		Height (ft) [Sorenson & Weggel]		Period (sec)	Height (ft)	Period (sec)	Direction* (deg)**
		1984	1986				
8	400	0.7	1.0	2.1	0.9	2.1	48 (138)
10	400	1.4	2.0	2.7	1.6	2.7	40 (130)
12	400	2.1	2.9	3.2	2.3	3.2	35 (125)
Ship					Ship		
8	600	0.2	0.3	2.1	0.2	2.1	48 (138)

* inbound -northeast- vessel route (outbound –southwest- vessel route)

** approximate angle between wave crest and shoreline

Bayswater Park

At Bayswater Park, the largest wave generated (at a reference depth of 5 ft) was 3.5 ft with a 3.2 sec period corresponding to vessel speed of 12 knots. Larger ships did not generate larger waves as in the previous two cases.

Table 12 below summarizes the results for Bayswater Park for waves generated by both tugboats and ships.

Table 12. Vessel waves generated at Bayswater Park.

Tug Boat					Tug Boat		
Vessel Speed (knots)	Distance to reference point (ft)	Vessel Generated Wave			Transformed Wave at 5 ft (LWT)		
		Height (ft)		Period (---)	Height (ft)	Period (sec)	Direction* (deg)**
		1984	1986				
8	200	0.8	1.2	2.1	1.1	2.1	21 (111)
10	200	1.6	2.3	2.7	2.1	2.7	20 (110)
12	200	2.5	3.8	3.2	3.5	3.2	18 (108)
Ship					Ship		
8	500	0.3	0.5	2.1	0.4	2.1	21 (111)

* inbound -northeast- vessel route (outbound –southwest- vessel route)
** approximate angle between wave crest and shoreline

Summary

The size range of the vessel generated waves is virtually the same as the locally generated wind waves. The only difference is related to the angle of wave incidence and the frequency of occurrence. While the boat waves only represent very short duration events (in the order of minutes), they occur daily or perhaps many times in a day versus individual storm events of several hour duration, but with the return periods of ten or more years.

Therefore, the recommended design criteria for operational purposes is a vessel wave environment of H= 2.5, 2.3, 3.5 ft and T= 3.1, 3.2, 3.2 for Brant Point, Dubos Point, and Bayswater Park sites, respectively. Note that, these values are significantly conservative values as compared to Arthur Kill Ship Wave Study (2002) measurements. The recommended storm wave design criteria of a H= 3.9, 3.6, 3.8 ft and T= 3.4, 3.3, 3.3 sec based on a 50-year event for Brant Point, Dubos Point, and Bayswater Park sites, respectively.

9.0 SHORELINE STABILIZATION MEASURES

Passive stabilization measures can fall into one of three categories, Bio-stabilization, Offshore wave attenuation methods, and shoreline rubble and beach structures. Generally bio-stabilization approaches can only perform within a limited range of wave agitation. An offshore attenuation system, as the name implies, does not fully eliminate the wave energy, but only reduces it in some measure. Shoreline rubble and beach structures generally entails placing fill along the shoreline in the form of rubble masses, or sand and gravel.

Depending on the intended function of the site, composite measures can be formulated that contain elements of more than one or even all of the measures just stated.

Bio-stabilization

Studies by Komar and Miller (1974) suggest that incipient motion of sediment (onset of erosion) in waves is similar to that for unidirectional flow. Maximum permissible near bottom channel velocities for fine sand are in the range of 1 fps, and an extrapolated value for a vegetated bank is 3 fps (ASCE, 1995). Assuming wave action to be nearly a shallow water wave environment at the vegetated edge, then the maximum tolerable wave height to be resisted, unaided, by vegetation would be 1.8 ft, in 3 ft of water.

$$U=(H/2)\sqrt{g/d}$$

In general, erosion of vegetated soil or slopes should be expected when wave heights exceed 1.5 ft. Therefore bio stabilization will have limited use in an exposed coastal environment unless it is supported with other measures.

Example bio stabilization methods are shown in Figure 6. The installations are more robust than simple replanting of vegetation, and often include staking of root wads and logs of coconut husks, which act as a nursery for plantings until their root structure can be established.

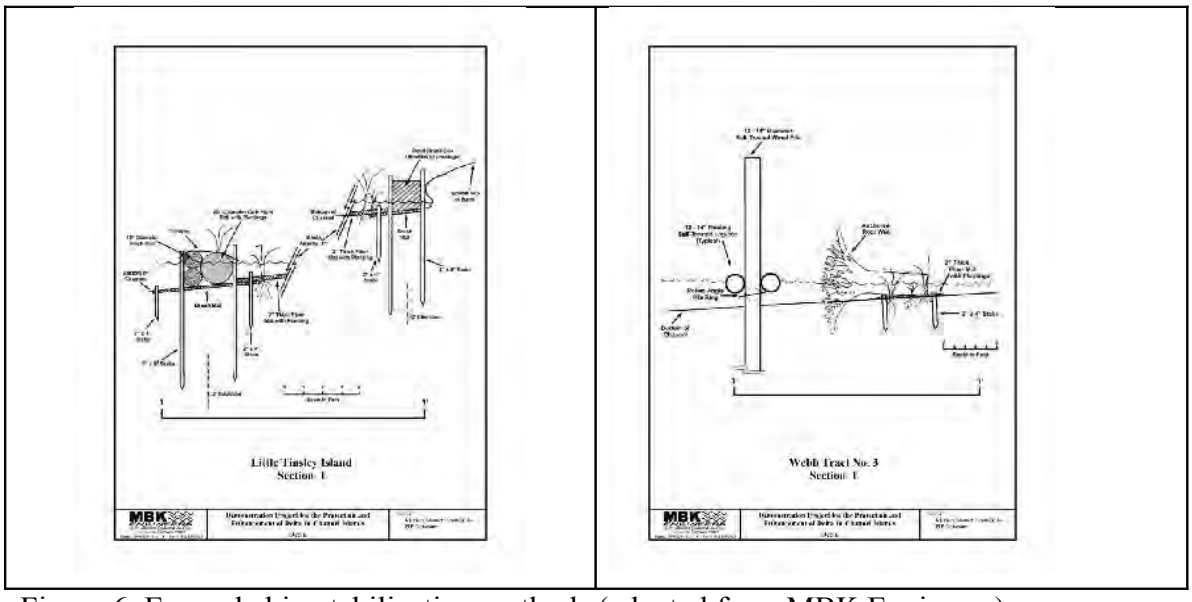


Figure 6. Example bio-stabilization methods (adapted from MBK Engineers)

Offshore Wave Attenuation Devices

Fixed or floating wave fences can be created offshore from the eroding shorelines as a way of reducing the amount of energy reaching the beach. In general, such systems penetrate only a limited distance down into the water column so as to allow natural circulation of the water. Floating systems offer the advantages of being compliant with the changes in the water surface, so that high walls do not protrude out of the water during low tide settings. Unfortunately, they have the disadvantage of also requiring continuous monitoring and regular maintenance because of the mechanical workings of the components.

Figure 7 shows examples of offshore attenuating systems. Conceivably, these could be configured of natural materials such as floating logs, provided comparable attenuation can be achieved. An indication of the scale of attenuator required is presented in Figure 8. Note that to achieve effective attenuation, the system, whether floating of fixed panels, must project down into the water column approximately 50% of the depth, or be nearly 50% of the wavelength in breadth. Therefore, individual floating logs will be of virtually no value unless water depths are very shallow (say <2 ft), and/or the wavelengths are extremely short.

Arrays of individual piles can also serve to dampen wave action, but again the required breadth of the field of at least a half wave length to be effective, and hence requires significant water area to work

Rubble Shore Structures

Masses of material can be added along the shoreline, either as a way of blocking some wave action, or absorbing the wave action that has arrived. The geometric size of created mass is determined by the amount of wave attenuation required. As shown in Figure 9, a mound built just to the low water line (R_c=0) will transmit approximately 50% of the wave energy, while that same mound, at an elevated tide equal to roughly the wave height will transmit roughly 80% of the wave energy (CIRIA, 1991).

If beach fill is used as the absorber, then the size of the material needs to be scaled to the arriving wave energy level. Sand must be scaled to a wave climate of less than a foot to remain stable. Gravels can be introduced to potentially stabilize the beach up to approximately 3 ft of wave height (Allen and Fischenich, 2000). For larger waves, a system of wave damping by other means coupled with the resistance of the gravel can be used.

Composite systems

The various methods can be joined three dimensionally to create shoreline protection schemes. The use of artificial headlands can create tombolos and pocket beaches. Sills can be used to create perched shorelines of sand or gravel fill to generally absorb (wave) runup action. Both can be used to reduce the energy levels reaching the shoreline to less than a 1.5 ft wave, allowing vegetation to be enhanced or re-established.

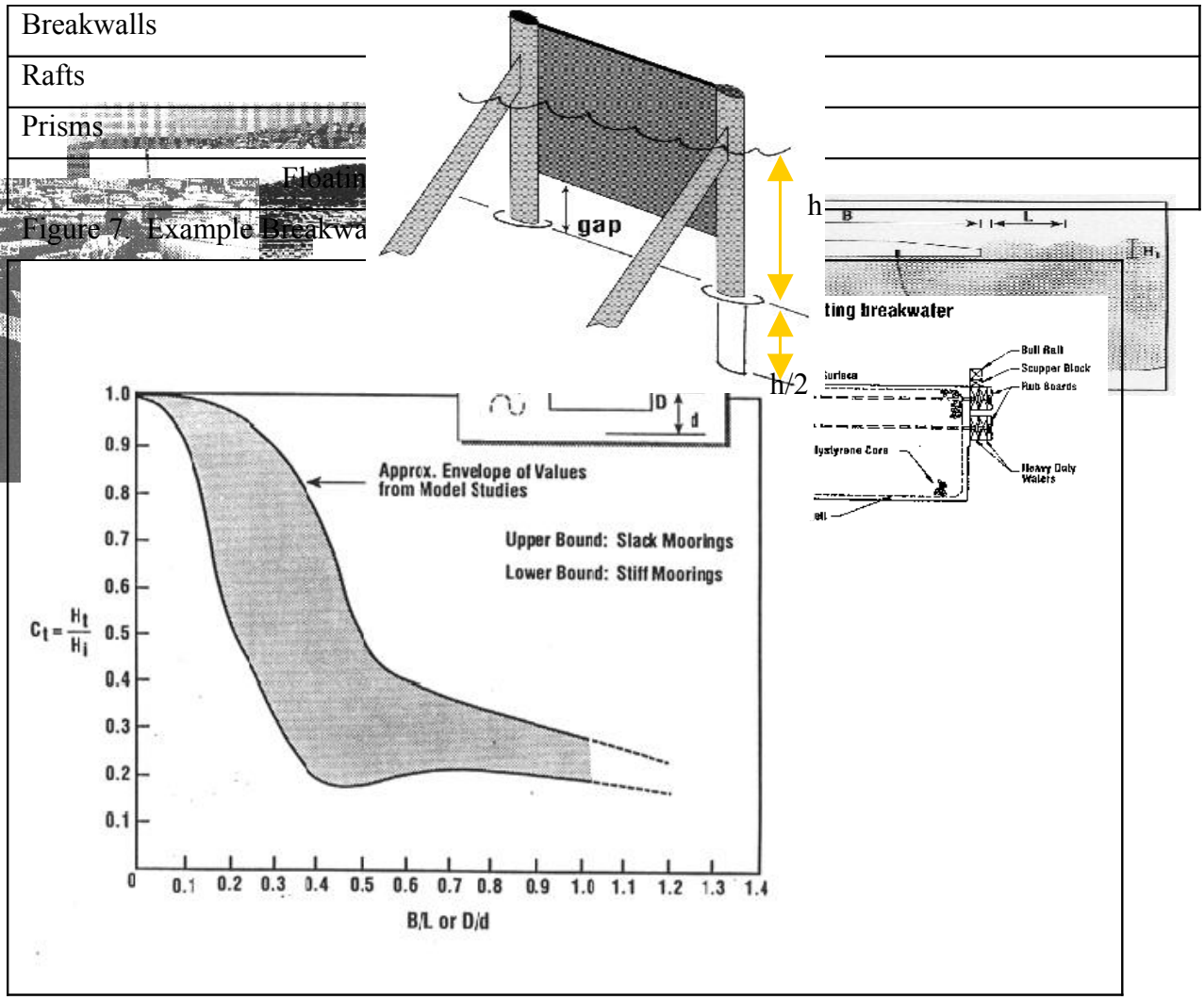


Figure 8. Transmission coefficients for floating attenuators

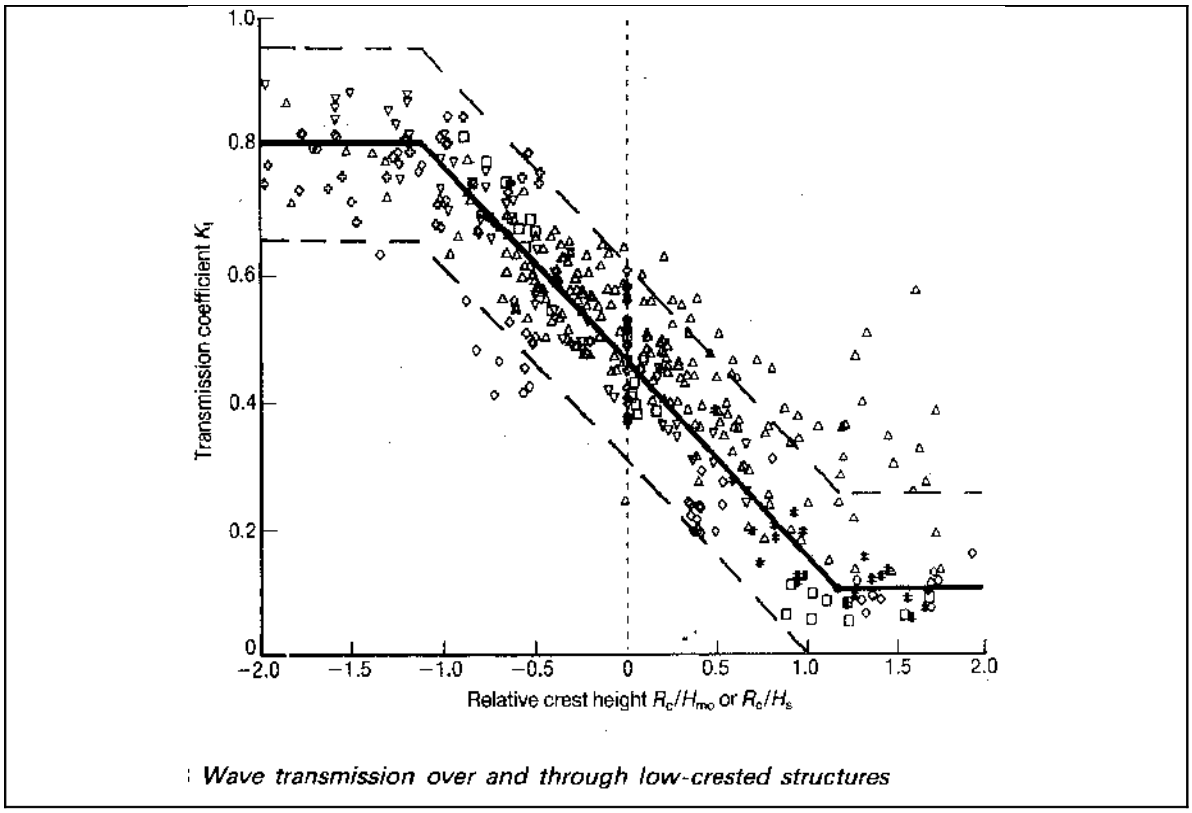


Figure 9. Transmission coefficients for rubble mound structures

Discussion

The wave criteria information formulated for the three sites (Brant Point, Dubos Point and Bayswater Park) suggests that a pure bio-stabilization solution is not viable at any of the locations because the wave energy is too large on a daily basis. Floating type wave attenuators are also viewed as unlikely candidates because of the level of monitoring and maintenance required to keep them performing and not become a navigational issue if they should breakaway from their moorings.

Because the sites are all intended as natural preserves, aesthetics has importance in the selection of the concept(s). Therefore, schemes which offer the lowest profile when seen from shore are preferred. At the same time, impact on the existing benthos should be minimized, so the footprint of the protection needs to be minimized unless the installation can be viewed as an enhancement to the habitat. Finally, public access needs to be provided in some areas, which dictate the form, arrangement, and details of the protection measure. In the next task, various schemes will be conformed to the specific criteria for each site.

10.0 REFERENCES

ACES, 1992. Automated Coastal Engineering System, software and Technical Reference, USCACE, September.

Allen, H.H., and Fischenich, C., 2000. "Coir geotextile roll and Wetland Plants for streambank erosion control" EMRRP technical notes collection (ERDC TN-EMRRP-SR-04).

Arthur Kill Ship Wave Study, 2002. Interim Draft Report prepared for The Port Authority of NY & NJ, Moffatt & Nichol Engineers, June.

ASCE, 1995. Hydraulic design of flood control structures. ASCE Press, New York.

CEM 2002, Coastal Engineering Manual, USACE, EM 1110-2-1100.

CIRIA, 1991. Manual on the use of rock in coastal and shoreline engineering. Construction Industry Research and Information Association. A.A. Balkema Publishers, VT.

ENV Report 4,1997. Interim Report For The Upper Mississippi River-Illinois Waterway System Navigation Study, USCAE.

HydroQual, Inc., 2002. Velocity Data table provided by the USACE via email.

Komar, P.D., and Miller, M.C., 1974. "On the comparison between the threshold of sediment movement under waves and unidirectional currents with a discussion of the practical evaluation of the threshold," J. Sed. Pet., Vol.5, pp. 1093-1112.

LSP, 1981. Liberty State Park Wind Analysis for Design Waves, USACE, by PRC Harris Inc.

Sorensen, R.M., and Weggel, J.R, 1986. "Ship wave prediction for port and channel design," Proceedings of the Ports'86 Conference Oakland, CA.

Sorensen, R.M., and Weggel, J.R., 1984. "Development of ship wave design information," Proceedings of the 19th Conference on Coastal Engineering, Houston, TX.

USACE, 2002. Jamaica Bay Ecosystem Restoration Project: Existing Conditions, Future Without Project Conditions, Goals and Objectives Report, October.

APPENDIX A

APPENDIX B

Hydroqual, Inc. 2002 Velocity Data provided by USACE.

VELOCITY DATA

Location	No.*	Segments [Col, Row]	Layer	Velocity [Incoming tides] (ft/sec)			Velocity [Outgoing tides] (ft/sec)			Direction ** (Degrees)
				Maximun	Minimum	Average	Maximum	Minimum	Average	
Fresh Creek	**3**	[20,30]	Top Layer	2.9	0.0	1.1	2.4	0.0	1.0	NE-61
			Bottom Layer	1.5	0.0	0.6	1.0	0.0	0.4	
			Average	2.0	0.0	0.9	1.6	0.0	0.7	
Paedergat Basin	**4**	[15,26]	Top Layer	1.0	0.0	0.4	1.4	0.0	0.4	NE-82
			Bottom Layer	0.4	0.0	0.1	0.3	0.0	0.1	
			Average	0.6	0.0	0.2	0.7	0.0	0.1	
Brant Point	**6**	[39,17]	Top Layer	1.6	0.0	0.7	1.6	0.0	0.8	NE-85
			Bottom Layer	0.8	0.0	0.3	0.7	0.0	0.3	
			Average	1.3	0.0	0.5	1.2	0.0	0.6	
Bays Water State Park	**7a**	[43,18]	Top Layer	1.4	0.0	0.3	1.5	0.0	0.5	NE-10
			Bottom Layer	0.4	0.0	0.1	0.2	0.0	0.0	
			Average	1.0	0.0	0.2	0.9	0.0	0.2	
	7b	[44,19]	Top Layer	1.1	0.0	0.3	1.5	0.0	0.4	NE-5
			Bottom Layer	0.4	0.0	0.1	0.2	0.0	0.1	
			Average	0.9	0.0	0.3	0.8	0.0	0.3	
Dubos Point	**8a**	[48,23]	Top Layer	1.6	0.0	0.3	1.6	0.0	0.4	NW-169
			Bottom Layer	0.4	0.0	0.1	0.4	0.0	0.1	
			Average	1.0	0.0	0.2	0.1	0.8	0.2	
	8b	[49,23]	Top Layer	0.8	0.0	0.2	0.8	0.0	0.2	NE-49
			Bottom Layer	0.0	0.2	0.0	0.2	0.0	0.0	
			Average	0.4	0.0	0.1	0.5	0.0	0.1	

NOTES:

* These are representative numbers for the segments or model cells.

**Direction: The values under the 'Direction' column represents the angle of the best fit line in a plot of the average velocities in the x-direction vs that in y direction. Angles are measured in degrees, anticlockwise from the positive x-axis where positive x-axis indicates the East and positive y-axis indicates North.

N- North, S-South, E-East, W-West, NW -Northwest, SW-Southwest, SE-Southeast, NE-Northeast

APPENDIX C

Partial Ship type and speed information from Arthur Kill Ship Wave Study (2002)

SHIP	TYPE	Speed (knots)
Brooklyn Service	Barge+Tug	6.7
Emma M. Roehrig	Barge+Tug	7.6
Matthew Tibbets	Barge+Tug	7.6
Dana L Moran	Barge+Tug	3.2
Emma M. Roehrig	Barge+Tug	6.9
Barabara Boushard	Barge+Tug	8.6
Emma M. Roehrig	Barge+Tug	5.3
Kristen Knutsen	Tanker	4.7
Stacey Morgan	Barge+Tug	8.1
Johanny Walker	Tug	9.2
Richmond	Barge+Tug	9.0
Barabara Boushard	Tug	10.4
Cheyene	Barge+Tug	10.3
Eagle Boston	Tanker	4
Nariva	Tanker	6.8

Water Quality Modeling Report

NYCDEP

City of New York
Department of Environmental Protection
New York, New York

DRAFT
WATER QUALITY MODELING FOR THE JAMAICA BAY ECOSYSTEM RESTORATION PROGRAM

Prepared by:
HydroQual, Inc.
One Lethbridge Plaza
Mahwah, NJ 07430

Under Subcontract to:
O'Brien and Gere Engineers
22 Saw Mill River Road
Hawthorne, New York 10532

March 2003
OBAG1312

CONTENTS

Section			Page
1	INTRODUCTION		1-1
2	THE MODELS		2-1
	2.1	INTRODUCTION	2-1
	2.2	MODEL INPUTS	2-4
		2.2.1 JEM	2-4
		2.2.1.1 Hydrodynamic Model	2-4
		2.2.1.2 Water Quality Model	2-15
		2.2.2 NCM	2-15
		2.2.2.1 Hydrodynamic Model	2-15
		2.2.2.2 Water Quality Model	2-25
3	JEM MODEL RESULTS		3-1
	3.1	SCENARIOS	3-1
	3.2	CALIBRATION	3-3
		3.2.1 Bathymetry	3-3
		3.2.2 Dissolved Oxygen	3-3
		3.2.3 Velocity and Shear Stress	3-3
		3.2.4 Salinity	3-7
	3.3	SCENARIO 1	3-7
		3.3.1 Bathymetry	3-7
		3.3.2 Dissolved Oxygen	3-15
		3.3.3 Velocity and Shear Stress	3-15
		3.3.4 Salinity	3-15
	3.4	SCENARIO 2	3-22
		3.4.1 Bathymetry	3-22
		3.4.2 Dissolved Oxygen	3-22
		3.4.3 Velocity and Shear Stress	3-22
		3.4.4 Salinity	3-22
	3.5	SCENARIO 3	3-29
		3.5.1 Bathymetry	3-29
		3.5.2 Dissolved Oxygen	3-29
		3.5.3 Velocity and Shear Stress	3-29
		3.5.4 Salinity	3-29
	3.6	SCENARIO 4	3-38
		3.6.1 Bathymetry	3-38
		3.6.2 Dissolved Oxygen	3-38
		3.6.3 Velocity and Shear Stress	3-38
		3.6.4 Salinity	3-38
	3.7	SCENARIO 5	3-38
		3.7.1 Bathymetry	3-38

CONTENTS (Continued)

Section			Page
3.7.2	Dissolved Oxygen		3-47
	3.7.3	Velocity and Shear Stress	3-47
	3.7.4	Salinity	3-47
3.8	SCENARIO 6		3-47
	3.8.1	Bathymetry	3-47
	3.8.2	Dissolved Oxygen	3-57
	3.8.3	Velocity and Shear Stress	3-57
	3.8.4	Salinity	3-57
3.9	JEM CONCLUSIONS		3-57
4	NCM RESULTS		4-1
4.1	SCENARIOS		4-1
4.2	SCENARIO 1		4-2
	4.2.1	Paerdegat Basin	4-2
	4.2.2	Fresh Creek	4-6
4.3	SCENARIO 2		4-6
	4.3.1	Paerdegat Basin	4-6
	4.3.2	Fresh Creek	4-11
4.4	SCENARIO 3		4-11
	4.4.1	Paerdegat Basin	4-18
	4.4.2	Fresh Creek	4-18
4.5	SCENARIO 4		4-28
	4.5.1	Paerdegat Basin	4-28
	4.5.2	Fresh Creek	4-32
4.6	SCENARIO 5		4-32
	4.6.1	Paerdegat Basin	4-32
	4.6.2	Fresh Creek	4-39
4.7	SCENARIO 6		4-39
4.8	TIDAL ELEVATION		4-47
4.9	MARSHES		4-47
5	NCM CONCLUSIONS		5-1
6	REFERENCES		6-1

APPENDIX A	WATER QUALITY MODEL KINETICS
APPENDIX B	RAINFALL RECORD
APPENDIX C	JEM BOUNDARY CONDITIONS
APPENDIX D	NCM BOUNDARY CONDITIONS
APPENDIX E	JEM RESULTS
APPENDIX F	NCM AVERAGE TIDE RESULTS
APPENDIX G	NCM INDIVIDUAL TIDE RESULTS
APPENDIX H	NCM RESULTS IN MARSH AREA

TABLES

Table		Page
E-1.	Maximum Ebb and Flood Current Velocities (cm/s) - Paerdegat Basin	ES-6
E-2.	Maximum Shear Stress (dyne/cm^2) - Paerdegat Basin	ES-7
E-3.	Monthly Average Shear Stress (dyne/cm^2) - Paerdegat Basin	ES-8
E-4.	Monthly Average DO (mg/L) - Paerdegat Basin	ES-9
E-5.	Minimum DO (mg/L) - Paerdegat Basin	ES-10
E-6.	Minimum Average Daily DO (mg/L) - Paerdegat Basin	ES-11
E-7.	Percent of Time the DO Concentration is Greater than 3.0 mg/L - Paerdegat Basin	ES-12
E-8.	Maximum Ebb and Flood Current Velocities (cm/s) - Fresh Creek	ES-13
E-9.	Maximum Shear Stress (dyne/cm^2) - Fresh Creek	ES-14
E-10.	Average Shear Stress (dyne/cm^2) - Fresh Creek	ES-15
E-11.	Monthly Average DO (mg/L) - Fresh Creek	ES-16
E-12.	Minimum DO (mg/L) - Fresh Creek	ES-17
E-13.	Minimum Daily Average DO (mg/L) - Fresh Creek	ES-18
E-14.	Percent of Time the DO Concentration is Greater than 3.0 mg/L - Fresh Creek	ES-19
2-1	State System Variables, Coupled Eutrophication/Chemical Equilibria Model	2-3
4-1.	NCM Tidal Ranges	4-48

FIGURES

Figures Page

1-1. Jamaica Bay Study Area 1-2
2-1. NCM Model Segmentation 2-2
2-2. JEM Model Segmentation 2-5
2-3. Principle Kinetic Interactions for Phosphorus and Nitrogen 2-6
2-4. Principle Kinetic Interactions for Silica and Organic Carbon 2-7
2-5. Principle Kinetic Interactions for Dissolved Oxygen 2-8
2-6. Sediment Flux Model 2-9
2-7. Sediment Model Interactions 2-10
2-8. JEM Tidal Boundary Conditions 2-11
2-9. JEM Temperature and Salinity Boundary Conditions 2-12
2-10. Example CSO Flows used in JEM 2-13
2-11. JEM Meteorological Forcings 2-14
2-12. JEM Loading Distribution 2-16
2-13. NCM Tidal Boundary Conditions 2-17
2-14. NCM Temperature and Salinity Boundary Conditions 2-19
2-15. CSO Flows Assigned in NCM 2-20
2-16. Storm Sewer Flows Assigned in NCM 2-21
2-17. WPCP Flows Assigned in NCM 2-22
2-18. Rainfall Record 2-23
2-19. NCM Meteorological Inputs 2-24
2-20. NCM DO Boundary Conditions 2-26
3-1. Tidal Conditions for Two Periods in July 3-2
3-2. JEM Bathymetry - Calibration Conditions 3-4
3-3. JEM Bottom DO - Hour 11 - Calibration 3-5
3-4. JEM Bottom DO - Hour 16 - Calibration 3-6
3-5. JEM Current Velocity and Shear Stress - Hour 1 - Calibration 3-8
3-6. JEM Current Velocity and Shear Stress - Hour 19 - Calibration 3-9
3-7. JEM Bottom Salinity - Hour 4 - Calibration 3-10
3-8. JEM Bottom Salinity - Hour 11 - Calibration 3-11
3-9. JEM Bottom Salinity - Hour 16 - Calibration 3-12
3-10. JEM Bottom Salinity - Hour 23 - Calibration 3-13
3-11. JEM Bathymetry - Scenario 1 3-14
3-12. JEM Bottom DO - Hour 11 - Scenario 1 3-16
3-13. JEM Bottom DO - Hour 16 - Scenario 1 3-17
3-14. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 1 3-18
3-15. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 1 3-19
3-16. JEM Bottom Salinity - Hour 4 - Scenario 1 3-20
3-17. JEM Bottom Salinity - Hour 11 - Scenario 1 3-21
3-18. JEM Bathymetry - Scenario 2 3-23
3-19. JEM Bottom DO - Hour 11 - Scenario 2 3-24
3-20. JEM Bottom DO - Hour 16 - Scenario 2 3-25
3-21. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 2 3-26
3-22. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 2 3-27

FIGURES (Continued)

Figures Page

3-23. JEM Bottom Salinity - Hour 4 - Scenario 2 3-28
3-24. JEM Bottom Salinity - Hour 11 - Scenario 2 3-30
3-25. JEM Bathymetry - Scenario 3 3-31
3-26. JEM Bottom DO - Hour 11 - Scenario 3 3-32
3-27. JEM Bottom DO - Hour 16 - Scenario 3 3-33
3-28. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 3 3-34
3-29. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 3 3-35
3-30. JEM Bottom Salinity - Hour 4 - Scenario 3 3-36
3-31. JEM Bottom Salinity - Hour 11 - Scenario 3 3-37
3-32. JEM Bathymetry - Scenario 4 3-39
3-33. JEM Bottom DO - Hour 11 - Scenario 4 3-40
3-34. JEM Bottom DO - Hour 16 - Scenario 4 3-41
3-35. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 4 3-42
3-36. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 4 3-43
3-37. JEM Bottom Salinity - Hour 4 - Scenario 4 3-44
3-38. JEM Bottom Salinity - Hour 11 - Scenario 4 3-45
3-39. JEM Bathymetry - Scenario 5 3-46
3-40. JEM Bottom DO - Hour 11 - Scenario 5 3-48
3-41. JEM Bottom DO - Hour 16 - Scenario 5 3-49
3-42. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 5 3-50
3-43. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 5 3-51
3-44. JEM Bottom Salinity - Hour 4 - Scenario 5 3-52
3-45. JEM Bottom Salinity - Hour 11 - Scenario 5 3-53
3-46. JEM Bottom Salinity - Hour 16 - Scenario 5 3-54
3-47. JEM Bottom Salinity - Hour 23 - Scenario 5 3-55
3-48. JEM Bathymetry - Scenario 6 3-56
3-49. JEM Bottom DO - Hour 11 - Scenario 6 3-58
3-50. JEM Bottom DO - Hour 16 - Scenario 6 3-59
3-51. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 6 3-60
3-52. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 6 3-61
3-53. JEM Bottom Salinity - Hour 4 - Scenario 6 3-62
3-54. JEM Bottom Salinity - Hour 11 - Scenario 6 3-63
3-55. JEM Bottom Salinity - Hour 16 - Scenario 6 3-64
3-56. JEM Bottom Salinity - Hour 23 - Scenario 6 3-65
4-1. Spring Tides Chosen for NCM Results 4-3
4-2. NCM Bathymetry - Existing Conditions 4-4
4-3. Transect of Paerdegat Basin - Hour 1 - Existing Conditions 4-5
4-4. Transect of Paerdegat Basin - Hour 8 - Existing Conditions 4-7
4-5. Transect of Fresh Creek - Hour 1 - Existing Conditions 4-8
4-6. Transect of Fresh Creek - Hour 8 - Existing Conditions 4-9
4-7. Transect of Fresh Creek - Hour 12 - Existing Conditions 4-10
4-8. NCM Bathymetry - Scenario 2 4-12
4-9. Transect of Paerdegat Basin - Hour 1 - Scenario 2 4-13

FIGURES (Continued)

Figures Page

4-10. Transect of Paerdegat Basin - Hour 8 - Scenario 2 4-14
4-11. Transect of Fresh Creek - Hour 1 - Scenario 2 4-15
4-12. Transect of Fresh Creek - Hour 8 - Scenario 2 4-16
4-13. Transect of Fresh Creek - Hour 12 - Scenario 2 4-17
4-14. NCM Bathymetry - Scenario 3a 4-19
4-15. NCM Bathymetry - Scenario 3b 4-20
4-16. Transect of Paerdegat Basin - Hour 1 - Scenario 3a 4-21
4-17. Transect of Paerdegat Basin - Hour 8 - Scenario 3a 4-22
4-18. Transect of Paerdegat Basin - Hour 1 - Scenario 3b 4-23
4-19. Transect of Paerdegat Basin - Hour 8 - Scenario 3b 4-24
4-20. Transect of Fresh Creek - Hour 1 - Scenario 3 4-25
4-21. Transect of Fresh Creek - Hour 8 - Scenario 3 4-26
4-22. Transect of Fresh Creek - Hour 12 - Scenario 3 4-27
4-23. NCM Bathymetry - Scenario 4 4-29
4-24. Transect of Paerdegat Basin - Hour 1 - Scenario 4 4-30
4-25. Transect of Paerdegat Basin - Hour 8 - Scenario 4 4-31
4-26. Transect of Fresh Creek - Hour 1 - Scenario 4 4-33
4-27. Transect of Fresh Creek - Hour 8 - Scenario 4 4-34
4-28. Transect of Fresh Creek - Hour 12 - Scenario 4 4-35
4-29. NCM Bathymetry - Scenario 5 4-36
4-30. Transect of Paerdegat Basin - Hour 1 - Scenario 5 4-37
4-31. Transect of Paerdegat Basin - Hour 8 - Scenario 5 4-38
4-32. Transect of Fresh Creek - Hour 1 - Scenario 5 4-40
4-33. Transect of Fresh Creek - Hour 8 - Scenario 5 4-41
4-34. Transect of Fresh Creek - Hour 12 - Scenario 5 4-42
4-35. NCM Bathymetry - Scenario 6 4-43
4-36. Transect of Fresh Creek - Hour 1 - Scenario 6 4-44
4-37. Transect of Fresh Creek - Hour 8 - Scenario 6 4-45
4-38. Transect of Fresh Creek - Hour 12 - Scenario 6 4-46
4-39. Tidal Elevations in the Marsh Areas for Existing Conditions 4-49
4-40. Elevation Differences in the Marsh Area Between the Existing Conditions and Scenario 4-50
4-41. Shear Stresses in the Marshes for Existing Conditions 4-52
4-42. Shear Stresses in the Marshes for Scenario 2 Conditions 4-53
4-43. Shear Stresses in the Marshes for Scenario 3a Conditions 4-54
4-44. Shear Stresses in the Marshes for Scenario 3b Conditions 4-55
4-45. Shear Stresses in the Marshes for Scenario 4 Conditions 4-56
4-46. Shear Stresses in the Marshes for Scenario 5 Conditions 4-57
4-47. Shear Stresses in the Marshes for Scenario 6 Conditions 4-58

EXECUTIVE SUMMARY

This modeling analysis consisted of two components. The first was to evaluate six bathymetric alteration scenarios in Jamaica Bay using the pre-existing Jamaica Bay Eutrophication Model (JEM) and determine the impact on habitat. The second was to develop models for Paerdegat Basin and Fresh Creek to evaluate, in conjunction with Facility Planning efforts being conducted by the New York City Department of Environmental Protection (NYCDEP) to abate combined sewer overflows (CSOs), up to six bathymetric alteration scenarios in each tributary and their effect on habitat. The second task led to the development of the North Channel Model (NCM) which included both Paerdegat Basin and Fresh Creek, as well as Hendrix Creek and Bergen Basin. The alternatives that were analyzed are listed below.

Six scenarios were evaluated using JEM. These scenarios were based on 1995-96 meteorological, tidal, and loading conditions. Only bathymetric changes were made. The scenarios include the following: (1) Remove the runway extention to a depth of 30 ft below mean low water (MLW), (2) Fill Grassy Bay to 15 ft below MLW, with the runway extention removed to a depth of 15 ft below MLW, (3) Remove the center 1000 ft of the runway extention to a depth of 30 ft below MLW, (4) Fill Grassy Bay to 15 ft below MLW and remove the center 1000 ft of the runway extension to 15 ft below MLW, (5) Remove the center 1000 ft of the runway extension to a depth of 30 ft below MLW and dredge the North Channel and Beach Channel to a depth of 30 ft below MLW, and (6) Fill Grassy Bay to 15 ft below MLW and remove the center 1000 ft of the runway to 15 ft below MLW, and dredge the North Channel and Beach Channel to a depth of 30 ft below MLW.

All of the scenarios improved water quality conditions in Grassy Bay. Most of the scenarios resulted in a decrease in DO levels east of the runway extension. None of the scenarios created conditions to change Grassy Bay from a depositional zone to a non-depositional zone. Overall, scenario 2 (removal of the runway to 15 ft below MLW and filling Grassy Bay to 15 ft below MLW) resulted in the largest DO improvement during the two tidal cycles analyzed. The computed improvements due to bathymetric changes in scenario 1 were nearly as large as scenario 2. Results from the scenarios where only the center of the runway was removed improved conditions in Grassy Bay only slightly less than removing the entire runway extension. Dredging the North Channel and Beach Channel reduced the velocities in these channels. As a consequence, lower current velocities and smaller shear stresses were computed in Grassy Bay. Since higher shear stresses result in higher vertical mixing it is likely that the reduced shear stresses resulting from dredging reduced the vertical mixing, thereby adversely affecting the dissolved oxygen.

NCM was run to evaluate five scenarios in Paerdegat Basin and six scenarios in Fresh Creek. The scenarios included bathymetric changes and the incorporation of the CSO facility plans at both of the tributaries. These scenarios were as follows:

Paerdegat Basin Evaluation

(1) Existing conditions with the natural sill in place,
(2) Existing conditions with CSO improvements,
(3) Existing conditions without the natural sill in place and with CSO improvements,
(4) Upstream half of the basin filled to MLW and the downstream half left alone, without the sill and with CSO improvements,
(5) Upstream half of the basin filled to 4 ft below MLW and the downstream half left alone, without the sill and with CSO improvements.

Fresh Creek Evaluation

(1) Existing conditions with the natural sill in place,
(2) Existing conditions with CSO improvements,
(3) Existing conditions without the natural sill in place and with CSO improvements,
(4) Upstream half filled to MLW, lower half as is, without the sill and with CSO improvements,
(5) Upstream half as is, lower half filled to 4 ft below MLW or as is (which ever is less), without the sill and with CSO improvements,
(6) Upstream half as is, lower half filled to 8 ft below MLW or as is (which ever is less), without the sill and with CSO improvements.

Due to the distance between the two tributaries and to save computational time, modifications were made to both tributaries and run at the same time. All of the runs were based on 1988 meteorological, tidal, and loading conditions. Bathymetric conditions were based on the latest available data.

To summarize the results of the NCM scenarios a series of tables have been developed presenting model results from each scenario for current velocity, shear stress and dissolved oxygen (DO) along the center channel of both Paerdegat Basin and Fresh Creek. The results are for two critical DO months, July and August.

Paerdegat Basin

Table E-1 presents the maximum ebb and flood bottom current velocities computed for each scenario along the center channel of Paerdegat Basin during July and August. In general, this table shows that the bottom current velocities are very small, generally less than 5 cm/s. Also, the maximum flood tide was greater than the maximum ebb tide, except at the mouth and for scenarios that included filling portions of the basin. The various scenarios that were examined were designed to increase these velocities and induce greater flushing of the Basin. The facility plan had little impact on the velocities. Removing the sill at the mouth of the basin generally reduced the maximum velocities, especially at the head end where greater flushing is desired. Scenario 4 produced the highest velocities in the basin, but the lowest velocities at the head end. Scenarios 5 and 6 produced small changes in the velocities.

These bathymetry and velocities changes had an effect on the bottom shear stress. The maximum computed bottom shear stresses during July and August in Paerdegat Basin are presented in Table E-2. A general rule of thumb is that at a shear stress of 1.0 dyne/cm^2 results in the resuspension of fine grained cohesive sediments. A medium size sand (0.5 mm) would require a shear stress of approximately 2.5 dyne/cm^2 before bed resuspension would occur. This table shows that under existing conditions, very little resuspension occurs, and this remains the case for most of the scenarios. The exception to this is scenario 4, which results in high shear stresses that would most likely result in a significant redistribution of bottom sediment. Table E-3 presents the average monthly shear stress. The values presented in this table indicate that on average most of Paerdegat Basin will remain depositional zones under the various conditions analyzed. There are possible exceptions in a few segments under scenario 4 conditions, where the average shear stress is approximately 1.0 dyne/cm^2 and would prevent deposition.

One of the more important parameters for determining habitat suitability is the dissolved oxygen concentration. Each of the scenarios developed were designed to improve DO levels in Paerdegat Basin. Table E-4 presents the model results for monthly average bottom water DO. The calibration scenario shows that the monthly average DO concentrations in Paerdegat Basin are quite low with concentrations less than 2.0 mg/L at the head end. Much of the basin is computed to have average DO concentrations less than 4.0 mg/L. Implementation of the Facility Plan improves DO conditions at the head end of the basin with diminishing improvement towards the mouth. Removing the sill at the mouth of the basin has minimal effect on the model results. Scenario 4 increases DO the upper portion of the basin significantly, but this scenario would most likely be eliminated from consideration due to the high shear stresses than develop. Scenario 5 also provides a significant DO improvement in Paerdegat Basin.

Table E-5 presents the minimum dissolved oxygen concentrations computed in Paerdegat Basin during July and August, respectively. The model results show, that despite the improvements in the average DO concentrations there may still be excursions into hypoxic conditions in the basin. Note that these results indicate very low concentrations at the mouth of the basin. It is very likely that these low concentrations at the mouth are due to conditions outside of Paerdegat Basin, so that improvements in Jamaica Bay itself are required before occasional low DO concentrations in the basin can be totally eliminated.

Table E-6 presents the monthly minimum of the daily average DO concentrations. This is accomplished by computing the daily average of the 24 hourly averages and taking the monthly minimum. The values in this table indicate that for scenarios 4 and 5 that the extreme low values shown in Table E-5 do not have a long duration. Further evidence for this is presented in Table E-7 which presents the percent of time that the DO concentration is computed to be greater than 3.0 mg/L. The 3.0 mg/L level is currently the proposed draft acute DO standard under consideration by the New York State Department of Environmental Conservation. While much of the basin is computed to have DO concentrations greater than 3.0 mg/L at or less than 50 percent of the time during July, in scenraios 4 and 5 that percentage increases to 75 percent or greater for most of the basin. The head end of the basin continues to have low DO levels for all of the scenarios.

Based on the results of these modeling scenarios it appears that a hybrid version of scenarios 4 and 5 would result in the most improvement in Paerdegat Basin. In addition, some level of filling near the mouth of the basin may also improve water quality in the basin.

Fresh Creek

The maximum bottom layer flood and ebb velocities in Fresh Creek during July and August are presented in Table E-8. In general, the flood tide velocities are greater than then ebb tide velocities. Velocities are also on a whole smaller than those computed in Paerdegat Basin. Removal of the sill at the mouth of the creek does little to affect the velocities in the upper half of the creek and reduces the velocities at the mouth. Scenario 4 increases the velocities in the half of the creek except for the head. Scenarios 5 and 6 increase the maximum flood velocities to a small extent near the mouth, but the velocities are reduced in the upper half of the creek.

The responses of the shear stresss to bathymetric alterations in Fresh Creek were similar to the responses in Paerdegat Basin (Table E-9). The shear stresses generally remained below 1.0 dyne/cm^2 until the scenarios where portions of the creek were filled. When the creek was filled to MLW in the upper half (scenario 4), the shear stresses increased to as high as 4.1 dyne/cm^2 during August. This

shear stress would cause resuspension of material and bed loading of sandy material. Filling the lower portion of the creek in scenario 5 resulted in occasional shear stresses greater than 1.0 dyne/cm^2. Table E-10 shows that the average shear stresses remain below 0.5 dyne/cm^2 for all of the scenarios indicating that the creek would remain a depositional area.

Table E-11 presents the monthly average DO concentration for July and August. The DO in Fresh Creek is computed be lowest at the head end and in the deeper portion near the mouth under calibration conditions. The facility plan results in improved DO along the entire creek with the largest improvements occuring in the upper portions. Removing the sill results in small changes in the average DO and the effect is slightly lower DO levels in most of the creek. Filling the upper portion of the creek results in higher DO concentrations in the upper half of the creek and slightly lower DO levels near the mouth of Fresh Creek. Filling the lower half of the creek has the opposite effect with improved DO near the mouth and slightly lower concentrations in portions of the upper end.

The minimum DO concentrations, presented in Table E-12, are generally not as low as computed in Paerdegat Basin, although the head end is essentially anoxic in all of the scenarios. Each scenario generally results in higher minimum DO concentrations, but the DO levels do occasionally decline to hypoxic levels. Tables E-13 and E-14 present the minimum daily average DO and the percent of time the DO concentration is computed to be greater than 3.0 mg/L, respectively. The tables show, that most of the improvement to the upper half of the creek is due to the implementation of CSO controls and that filling the upper portion of the creek provides only a marginal improvement. The most effective scenario for increasing the DO concentration near the mouth is scenario 5. Under scenario 5 conditions Fresh Creek is computed to have a DO concentration greater than 3.0 mg/L greater than 90 percent of the time for most of the creek during July and August.

The results indicate that some bathymetric alterations would improve the DO concentrations in Fresh Creek. In general, some level of filling near the mouth of the creek would improve DO levels and as a consequence aquatic habitat. Filling portions of Paerdegat Basin and Fresh Creek would mostly like result in bringing these tributaries closer to their historical depths and bring them back to a more natural state.

Table E-1. Maximum Ebb and Flood Current Velocities (cm/s) - Paerdegat Basin

	Scenarios											
July	1		2		3a		3b		4		5	
	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood
Head	-1.10	1.49	-0.17	1.42	-0.17	1.41	-0.17	1.42	-0.32	0.11	-0.17	1.40
	-0.76	2.22	-0.56	2.10	-0.56	2.08	-0.56	2.11	-1.07	0.25	-0.41	1.88
	-0.80	1.64	-0.81	1.62	-0.82	1.63	-0.81	1.63	-3.85	1.16	-0.53	1.13
	-1.14	2.47	-1.16	2.17	-1.15	1.98	-1.15	2.05	-5.74	2.33	-0.66	1.07
	-1.34	3.31	-1.58	3.00	-1.55	2.66	-1.57	2.83	-5.51	3.17	-0.85	1.17
	-1.67	3.75	-1.68	3.49	-1.69	3.04	-1.68	3.26	-5.36	4.01	-1.05	1.47
	-1.77	3.67	-1.72	3.42	-1.74	3.00	-1.72	3.20	-3.32	2.98	-1.18	1.65
	-1.75	3.30	-1.71	3.09	-1.71	2.74	-1.71	3.00	-0.89	1.18	-1.44	1.97
	-1.93	3.50	-1.88	3.21	-1.90	2.90	-1.88	3.16	-1.52	2.12	-1.58	1.84
	-1.89	3.57	-1.88	3.38	-2.12	3.47	-2.09	3.74	-2.43	3.16	-2.09	2.60
	-2.85	4.49	-2.84	4.47	-2.90	4.13	-2.86	4.64	-2.73	3.99	-2.71	3.86
	-2.85	3.29	-2.84	3.28	-2.05	2.76	-2.41	3.14	-2.81	3.89	-2.78	3.52
	-1.40	2.56	-1.38	2.56	-0.33	1.73	-1.62	2.72	-2.47	4.07	-2.25	3.49
Mouth	-2.41	2.38	-2.31	2.23	-2.34	2.28	-2.43	2.22	-2.50	2.56	-2.48	2.45

August	1		2		3a		3b		4		5	
	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood
Head	-0.24	1.31	-0.25	1.39	-0.25	1.39	-0.25	1.39	-0.11	0.23	-0.25	1.38
	-0.75	1.90	-0.78	2.17	-0.78	2.16	-0.78	2.17	-0.23	0.31	-0.61	1.86
	-0.94	1.51	-0.93	1.92	-0.92	1.93	-0.93	1.92	-0.62	0.81	-0.79	1.14
	-1.22	2.16	-1.23	1.62	-1.23	1.65	-1.24	1.68	-1.25	1.61	-1.00	1.18
	-1.50	2.92	-1.61	2.23	-1.61	2.15	-1.61	2.12	-1.81	2.15	-1.30	1.59
	-1.81	3.09	-1.97	2.35	-1.99	2.38	-1.98	2.31	-2.46	2.80	-1.64	2.00
	-1.88	3.05	-2.09	2.40	-2.09	2.47	-2.06	2.45	-1.87	2.13	-1.86	2.28
	-1.94	2.84	-2.07	2.21	-2.09	2.28	-2.07	2.27	-1.62	1.88	-2.20	2.73
	-2.13	3.24	-2.12	2.78	-2.02	2.59	-2.09	2.69	-2.30	2.62	-2.13	2.59
	-2.08	3.34	-1.96	3.01	-2.16	3.24	-2.19	3.29	-2.72	3.22	-2.48	2.81
	-3.28	4.44	-3.19	3.91	-2.99	4.21	-3.11	4.31	-2.75	3.72	-2.99	3.43
	-3.20	3.60	-3.19	3.59	-2.29	2.82	-2.51	3.09	-2.79	3.68	-2.83	3.30
	-1.94	2.81	-1.94	2.78	-1.19	1.77	-2.13	2.85	-2.82	3.91	-2.86	3.71
Mouth	-2.25	1.74	-2.28	1.86	-2.23	1.94	-2.34	1.88	-2.44	2.30	-2.56	2.14

Table E-2. Maximum Shear Stress (dyne/cm^2) - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Head	0.70	0.69	0.67	0.65	0.51	0.62
	1.06	1.16	1.10	1.16	2.56	0.92
	0.35	0.39	0.39	0.39	5.46	0.47
	0.37	0.33	0.25	0.27	5.21	0.49
	0.46	0.42	0.32	0.34	4.52	0.38
	0.49	0.46	0.35	0.37	4.33	0.56
	0.51	0.46	0.35	0.39	6.25	0.70
	0.55	0.38	0.31	0.34	3.95	0.81
	0.45	0.37	0.31	0.34	1.36	0.55
	0.56	0.52	0.39	0.40	0.61	0.42
	0.92	0.85	0.49	0.55	0.47	0.52
	1.10	0.76	0.36	0.73	0.69	0.57
	0.73	0.67	0.25	0.84	0.93	0.75
Mouth	0.57	0.58	0.55	0.55	0.57	0.55

August	1	2	3a	3b	4	5
Head	0.57	0.63	0.62	0.61	0.44	0.60
	0.85	1.05	1.10	1.07	1.63	0.78
	0.30	0.43	0.45	0.44	1.51	0.42
	0.29	0.25	0.26	0.26	1.90	0.49
	0.38	0.18	0.22	0.25	3.29	0.43
	0.37	0.26	0.31	0.34	4.82	0.65
	0.65	0.30	0.34	0.37	6.98	0.84
	0.46	0.37	0.34	0.38	4.57	1.06
	0.42	0.35	0.33	0.39	1.61	0.74
	0.54	0.43	0.42	0.49	0.76	0.47
	0.96	0.74	0.56	0.63	0.61	0.54
	1.16	1.00	0.45	0.84	0.89	0.71
	0.85	0.75	0.32	0.90	1.03	0.78
Mouth	0.56	0.53	0.50	0.50	0.49	0.50

Table E-3. Monthly Average Shear Stress (dyne/cm^2) - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Head	0.020	0.012	0.012	0.012	0.014	0.010
	0.041	0.027	0.027	0.028	0.066	0.022
	0.027	0.020	0.019	0.021	0.189	0.027
	0.024	0.020	0.019	0.021	0.268	0.039
	0.032	0.025	0.024	0.027	0.442	0.059
	0.045	0.035	0.033	0.036	0.656	0.085
	0.049	0.040	0.039	0.042	0.994	0.111
	0.047	0.040	0.039	0.043	0.660	0.134
	0.047	0.040	0.038	0.043	0.222	0.098
	0.061	0.052	0.045	0.050	0.092	0.073
	0.132	0.113	0.070	0.078	0.067	0.077
	0.139	0.120	0.047	0.098	0.094	0.092
	0.073	0.065	0.022	0.103	0.110	0.099
Mouth	0.086	0.086	0.076	0.098	0.098	0.097

August	1	2	3a	3b	4	5
Head	0.008	0.006	0.006	0.006	0.008	0.005
	0.023	0.020	0.021	0.021	0.043	0.016
	0.019	0.018	0.018	0.019	0.167	0.027
	0.018	0.017	0.017	0.018	0.263	0.043
	0.025	0.023	0.022	0.025	0.453	0.068
	0.035	0.034	0.033	0.036	0.678	0.100
	0.039	0.038	0.037	0.040	1.032	0.129
	0.041	0.040	0.039	0.043	0.717	0.161
	0.040	0.039	0.038	0.042	0.252	0.122
	0.051	0.050	0.044	0.049	0.097	0.083
	0.118	0.114	0.067	0.075	0.066	0.082
	0.138	0.135	0.047	0.101	0.088	0.096
	0.081	0.080	0.024	0.116	0.115	0.112
Mouth	0.079	0.081	0.069	0.097	0.092	0.093

Table E-4. Monthly Average DO (mg/L) - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Mouth	1.76	3.07	3.09	3.12	2.52	2.86
	2.24	3.27	3.33	3.33	4.32	3.24
	1.80	2.44	2.43	2.43	4.86	3.81
	1.93	2.43	2.36	2.40	4.89	3.90
	2.52	2.90	2.79	2.85	5.12	4.42
	3.13	3.44	3.32	3.40	5.12	4.46
	3.10	3.43	3.30	3.36	5.11	4.83
	2.89	3.08	2.91	3.01	5.11	4.74
	2.94	3.08	2.98	2.99	5.01	4.56
	3.58	3.57	3.18	3.34	3.93	3.45
	4.37	4.52	3.95	4.18	3.93	4.14
	4.83	4.99	4.47	4.71	4.28	4.64
	4.72	4.77	4.20	4.67	4.54	4.70
Head	4.77	4.81	4.79	4.81	4.71	4.74

August	1	2	3a	3b	4	5
Mouth	1.93	3.26	3.24	3.27	3.29	3.32
	2.64	3.75	3.77	3.75	4.82	3.78
	2.49	3.38	3.35	3.36	5.29	4.21
	2.67	3.42	3.36	3.39	5.34	4.45
	3.18	3.81	3.71	3.75	5.45	4.83
	3.50	3.99	3.90	3.93	5.47	5.01
	3.66	4.10	3.96	4.04	5.41	5.29
	3.54	3.91	3.78	3.84	5.43	5.29
	3.73	4.00	3.84	3.98	5.46	5.14
	4.02	4.13	3.81	3.93	4.62	4.34
	4.73	4.84	4.29	4.50	4.34	4.50
	5.09	5.16	4.53	4.83	4.49	4.78
	5.01	5.01	4.34	4.89	4.69	4.85
Head	4.84	4.85	4.79	4.85	4.76	4.81

Table E-5. Minimum DO (mg/L) - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Head	0.01	0.03	0.05	0.04	0.03	0.05
	0.05	0.30	0.26	0.25	0.51	0.24
	0.05	0.09	0.13	0.08	0.91	0.46
	0.14	0.25	0.13	0.18	0.84	0.38
	0.38	0.62	0.41	0.47	0.87	0.59
	0.83	0.90	0.94	1.18	1.14	0.24
	0.82	1.12	0.94	1.00	1.57	0.88
	0.76	0.71	0.41	0.62	0.90	0.54
	0.68	0.57	0.60	0.52	1.02	1.13
	1.29	1.12	1.20	1.08	1.19	0.72
	1.34	1.59	1.67	1.89	1.54	1.64
	1.17	1.49	2.21	1.99	1.53	1.89
	1.60	1.73	2.07	1.87	1.81	1.76
Mouth	2.71	2.75	2.63	2.71	2.71	2.57

August	1	2	3a	3b	4	5
Head	0.00	0.00	0.00	0.00	0.02	0.00
	0.00	0.00	0.01	0.01	1.55	0.00
	0.00	0.01	0.01	0.01	3.36	0.02
	0.01	0.12	0.10	0.11	3.79	0.02
	0.11	0.31	0.28	0.29	4.12	0.48
	0.28	0.48	0.45	0.47	4.11	1.20
	0.40	0.59	0.59	0.65	3.15	2.52
	0.28	0.42	0.43	0.42	3.30	1.68
	0.32	0.46	0.26	0.37	3.52	0.68
	0.69	0.75	0.64	0.76	0.90	0.48
	1.39	1.55	1.02	1.28	1.26	1.47
	1.41	1.86	0.85	1.93	1.14	1.66
	1.78	1.53	1.57	1.60	1.52	1.49
Mouth	2.22	2.29	2.18	2.19	2.16	2.20

Table E-6. Minimum Average Daily DO (mg/L) - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Head	0.90	1.88	1.29	1.88	0.35	0.52
	1.27	1.93	2.20	2.02	2.65	1.47
	0.54	0.95	0.94	0.90	3.45	1.99
	1.11	1.46	1.18	1.35	3.37	1.25
	1.54	1.90	2.04	1.81	3.91	1.89
	2.31	2.56	2.22	2.53	3.49	2.01
	2.21	2.41	2.24	2.28	3.79	3.60
	1.63	1.84	1.60	1.84	3.40	2.98
	1.80	1.73	1.76	1.59	3.33	3.28
	2.55	2.37	1.79	2.06	2.52	1.28
	3.22	3.35	2.72	2.95	2.79	2.89
	3.83	4.05	3.73	3.64	3.12	3.57
	3.50	3.59	3.38	3.79	3.67	3.77
Mouth	4.12	4.10	4.13	4.18	4.09	4.08

August	1	2	3a	3b	4	5
Head	0.32	1.12	1.11	1.12	0.13	0.97
	0.80	1.70	1.67	1.68	3.11	0.77
	0.35	1.02	0.64	0.79	4.30	1.54
	0.42	0.83	0.56	0.71	4.45	2.14
	1.07	1.54	1.38	1.45	4.57	2.52
	1.72	1.96	1.87	1.91	4.58	2.89
	1.89	2.20	2.09	2.16	4.54	3.71
	1.59	1.84	1.59	1.92	4.54	3.95
	1.66	2.03	2.00	2.13	4.61	3.27
	1.42	1.50	1.08	1.23	3.13	1.06
	3.48	3.47	1.98	2.60	2.42	2.73
	3.70	3.66	2.60	3.41	2.68	3.37
	3.70	3.67	2.64	3.55	3.25	3.43
Mouth	3.70	3.69	3.70	3.71	3.59	3.66

Table E-7. Percent of Time the DO Concentration is Greater than 3.0 mg/L - Paerdegat Basin

	Scenarios					
July	1	2	3a	3b	4	5
Head	14.5	47.9	49.1	48.2	42.3	45.1
	25.2	54.8	56.5	56.7	85.1	56.9
	12.2	32.2	30.4	31.5	94.3	74.0
	15.3	29.6	26.9	27.7	96.0	76.2
	30.0	43.6	40.0	42.7	98.7	85.7
	52.8	63.5	59.5	62.0	97.3	83.8
	52.2	63.4	60.7	62.6	98.4	93.4
	42.3	47.8	41.6	45.4	97.3	89.5
	45.5	48.5	46.3	47.1	95.8	91.9
	62.9	61.5	50.6	55.7	75.1	62.9
	81.3	83.8	75.8	80.9	73.5	80.2
	88.7	91.3	93.9	93.4	84.0	91.1
	89.1	91.7	87.2	89.4	89.5	91.0
Mouth	99.2	99.7	99.5	99.6	99.3	99.5

August	1	2	3a	3b	4	5
Head	25.9	53.6	54.2	55.2	62.1	58.7
	42.7	64.7	64.3	63.8	91.9	67.0
	38.3	60.4	58.3	59.3	100.0	72.9
	42.3	59.9	58.3	58.9	100.0	79.3
	53.2	65.9	64.2	64.6	100.0	88.7
	60.7	69.7	67.2	68.5	100.0	92.9
	65.8	73.4	71.1	72.2	100.0	98.4
	63.1	67.5	65.2	66.8	100.0	98.9
	66.6	69.8	66.2	69.3	100.0	97.3
	70.6	71.5	63.9	67.0	86.7	79.3
	91.7	91.7	77.7	81.3	78.9	79.9
	97.6	97.6	86.6	92.6	82.7	90.3
	95.7	95.3	79.9	90.7	86.2	89.5
Mouth	96.9	97.3	96.4	96.9	94.6	95.3

Table E-8. Maximum Ebb and Flood Current Velocities (cm/s) - Fresh Creek

	Scenarios													
July	1		2		3a		3b		4		5		6	
	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood
Head	-0.18	0.37	-0.11	0.33	-0.11	0.34	-0.11	0.34	-0.08	0.11	-0.07	0.36	-0.08	0.33
	-0.96	0.73	-0.47	0.75	-0.46	0.74	-0.46	0.74	-0.27	0.22	-0.32	0.53	-0.33	0.54
	-0.88	0.82	-0.48	0.80	-0.47	0.80	-0.50	0.80	-0.68	1.20	-0.23	0.43	-0.27	0.47
	-0.83	0.94	-0.57	0.92	-0.57	0.92	-0.58	0.92	-1.18	2.08	-0.28	0.50	-0.32	0.53
	-0.82	1.00	-0.65	0.99	-0.65	0.98	-0.65	0.98	-1.32	2.26	-0.32	0.54	-0.36	0.57
	-0.72	1.00	-0.67	0.99	-0.68	0.98	-0.68	0.97	-1.47	2.38	-0.34	0.55	-0.39	0.57
	-1.02	1.39	-0.95	1.39	-0.96	1.49	-0.96	1.51	-1.29	1.84	-0.41	0.76	-0.53	0.83
	-0.89	1.34	-0.89	1.18	-0.90	1.12	-0.89	1.12	-0.50	0.58	-0.62	1.04	-0.81	1.05
	-1.82	3.10	-1.81	2.86	-1.84	2.53	-1.83	2.54	-0.97	1.17	-1.06	1.60	-1.64	2.35
	-2.11	3.53	-2.08	3.33	-2.13	2.92	-2.12	2.92	-1.68	2.16	-1.30	2.13	-1.99	2.85
	-1.66	2.61	-1.64	2.25	-1.64	2.19	-1.63	2.19	-1.74	2.19	-1.45	2.21	-1.83	2.35
	-1.10	1.22	-1.10	1.14	-1.01	1.15	-1.00	1.16	-1.58	2.04	-1.78	2.49	-1.46	1.72
	-1.87	2.96	-1.87	2.95	-1.58	2.49	-1.57	2.49	-1.81	2.96	-1.87	3.53	-2.03	3.18
Mouth	-2.97	5.35	-2.98	5.35	-2.78	4.72	-2.76	4.72	-2.67	4.41	-2.65	4.52	-2.72	4.52

August	1		2		3a		3b		4		5		6	
	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood
Head	-0.19	0.48	-0.20	0.35	-0.20	0.34	-0.20	0.35	-0.13	0.23	-0.19	0.37	-0.19	0.36
	-0.73	0.83	-0.74	0.80	-0.74	0.81	-0.74	0.81	-0.30	0.48	-0.53	0.71	-0.56	0.69
	-0.59	0.72	-0.59	0.71	-0.60	0.71	-0.59	0.71	-0.51	0.85	-0.33	0.48	-0.34	0.48
	-0.65	0.85	-0.65	0.84	-0.66	0.85	-0.65	0.85	-0.82	1.37	-0.36	0.58	-0.37	0.58
	-0.72	0.93	-0.72	0.92	-0.72	0.93	-0.72	0.93	-0.93	1.51	-0.40	0.63	-0.41	0.63
	-0.76	0.96	-0.75	0.95	-0.76	0.96	-0.76	0.96	-1.04	1.59	-0.43	0.66	-0.44	0.65
	-1.42	1.81	-1.54	1.90	-1.56	1.93	-1.56	1.93	-1.02	1.32	-0.61	1.06	-0.88	1.33
	-1.03	1.35	-1.08	1.27	-1.07	1.28	-1.06	1.28	-0.86	0.85	-1.08	1.49	-1.10	1.31
	-1.92	3.13	-1.98	2.75	-1.98	2.50	-1.97	2.50	-1.31	1.47	-1.66	2.13	-1.91	2.18
	-2.31	3.45	-2.36	3.12	-2.38	2.88	-2.37	2.89	-1.94	2.21	-1.98	2.81	-2.33	2.65
	-1.82	2.31	-1.86	2.01	-1.84	2.06	-1.83	2.06	-1.92	2.07	-2.21	2.97	-2.10	2.38
	-1.21	1.22	-1.21	1.17	-1.05	1.23	-1.03	1.24	-1.61	2.13	-2.39	3.35	-1.60	1.85
	-2.35	3.45	-2.35	3.45	-1.82	2.74	-1.79	2.74	-1.87	2.96	-2.41	4.05	-2.34	3.52
Mouth	-3.76	6.23	-3.66	6.24	-3.23	5.11	-3.21	5.08	-2.87	4.60	-3.00	4.86	-3.07	4.90

Table E-9. Maximum Shear Stress (dyne/cm^2) - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	0.24	0.16	0.16	0.17	0.23	0.16	0.17
	0.85	0.42	0.47	0.60	1.10	0.46	0.53
	0.43	0.12	0.15	0.24	1.99	0.21	0.19
	0.15	0.08	0.07	0.12	2.19	0.14	0.12
	0.12	0.09	0.09	0.14	2.50	0.16	0.14
	0.13	0.11	0.11	0.18	2.58	0.16	0.18
	0.22	0.22	0.21	0.29	3.49	0.31	0.29
	0.26	0.25	0.25	0.25	1.55	0.40	0.24
	0.54	0.43	0.36	0.34	0.51	0.48	0.35
	0.70	0.55	0.44	0.45	0.50	0.82	0.53
	0.53	0.48	0.38	0.43	0.51	1.32	0.59
	0.54	0.44	0.28	0.36	0.47	1.61	0.46
	0.71	0.70	0.35	0.40	0.44	1.24	0.62
Mouth	1.77	1.77	0.81	0.79	0.59	0.95	0.91

August	1	2	3a	3b	4	5	6
Head	0.23	0.22	0.21	0.22	0.23	0.22	0.22
	0.54	0.20	0.20	0.25	0.78	0.26	0.26
	0.22	0.14	0.14	0.18	2.44	0.15	0.19
	0.17	0.10	0.10	0.16	2.87	0.15	0.16
	0.19	0.11	0.10	0.16	3.25	0.19	0.17
	0.16	0.12	0.11	0.17	3.35	0.21	0.19
	0.33	0.35	0.33	0.50	4.10	0.38	0.46
	0.25	0.25	0.24	0.28	1.80	0.51	0.32
	0.43	0.36	0.36	0.36	0.49	0.61	0.33
	0.47	0.39	0.40	0.39	0.50	1.05	0.41
	0.34	0.27	0.45	0.50	0.54	1.49	0.63
	0.60	0.48	0.39	0.49	0.54	1.91	0.64
	0.87	0.79	0.43	0.47	0.51	1.61	0.70
Mouth	2.16	2.17	0.84	0.84	0.64	1.12	1.05

Table E-10. Average Shear Stress (dyne/cm^2) - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	0.022	0.013	0.013	0.013	0.013	0.013	0.013
	0.044	0.028	0.028	0.036	0.066	0.036	0.037
	0.013	0.011	0.011	0.018	0.178	0.018	0.018
	0.010	0.009	0.010	0.015	0.199	0.016	0.016
	0.011	0.011	0.011	0.018	0.242	0.019	0.018
	0.012	0.012	0.012	0.020	0.267	0.021	0.020
	0.024	0.025	0.026	0.042	0.434	0.040	0.039
	0.026	0.024	0.025	0.032	0.240	0.073	0.036
	0.050	0.045	0.042	0.045	0.070	0.111	0.053
	0.067	0.060	0.059	0.062	0.064	0.178	0.079
	0.043	0.039	0.039	0.053	0.057	0.258	0.081
	0.050	0.045	0.028	0.044	0.054	0.286	0.068
	0.129	0.125	0.066	0.078	0.076	0.203	0.115
Mouth	0.283	0.282	0.160	0.159	0.136	0.188	0.183

August	1	2	3a	3b	4	5	6
Head	0.011	0.009	0.009	0.009	0.008	0.009	0.009
	0.026	0.023	0.023	0.030	0.063	0.030	0.031
	0.012	0.011	0.011	0.019	0.188	0.019	0.020
	0.011	0.011	0.011	0.018	0.207	0.018	0.018
	0.013	0.013	0.013	0.021	0.250	0.022	0.022
	0.014	0.014	0.014	0.024	0.277	0.025	0.024
	0.035	0.036	0.036	0.057	0.455	0.050	0.055
	0.027	0.027	0.027	0.036	0.264	0.085	0.042
	0.036	0.034	0.033	0.035	0.072	0.122	0.047
	0.053	0.051	0.050	0.053	0.060	0.199	0.078
	0.038	0.037	0.036	0.049	0.053	0.285	0.086
	0.046	0.045	0.026	0.042	0.048	0.319	0.074
	0.132	0.132	0.066	0.078	0.074	0.220	0.122
Mouth	0.289	0.289	0.161	0.160	0.134	0.191	0.187

Table E-11. Monthly Average DO (mg/L) - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	1.88	2.96	2.93	2.93	2.13	2.94	3.02
	2.96	4.13	4.10	4.09	3.94	4.05	4.18
	3.76	4.73	4.68	4.68	4.85	4.61	4.80
	4.01	4.86	4.81	4.80	4.94	4.66	4.89
	4.18	5.02	4.96	4.95	5.01	4.80	5.04
	4.27	5.04	4.97	4.95	5.02	4.85	5.05
	4.25	4.90	4.83	4.81	4.90	4.81	4.93
	3.44	3.81	3.70	3.67	4.76	4.74	4.26
	3.55	3.75	3.75	3.74	3.67	4.97	4.18
	3.75	3.91	3.96	3.95	3.76	5.12	4.31
	4.32	4.47	4.51	4.50	4.19	5.63	5.00
	5.17	5.25	5.01	5.01	4.71	5.74	5.29
	5.25	5.34	4.76	4.75	4.62	5.33	5.14
Mouth	5.05	5.11	4.99	4.98	4.89	5.10	5.02

August	1	2	3a	3b	4	5	6
Head	2.12	3.49	3.46	3.46	3.14	3.50	3.51
	3.45	4.66	4.62	4.62	4.79	4.70	4.69
	4.11	5.08	5.03	5.03	5.21	5.08	5.09
	4.37	5.19	5.15	5.15	5.27	5.17	5.21
	4.58	5.28	5.23	5.23	5.31	5.25	5.29
	4.70	5.31	5.27	5.27	5.34	5.30	5.34
	4.79	5.31	5.25	5.25	5.26	5.34	5.35
	3.87	4.26	4.12	4.12	5.24	5.28	4.61
	4.09	4.31	4.23	4.22	4.32	5.44	4.69
	4.23	4.38	4.31	4.31	4.29	5.50	4.76
	4.79	4.82	4.80	4.79	4.62	5.74	5.37
	5.35	5.38	5.16	5.15	4.91	5.79	5.53
	5.47	5.51	5.05	5.05	4.90	5.60	5.32
Mouth	5.27	5.29	5.08	5.08	4.97	5.23	5.15

Table E-12. Minimum DO (mg/L) - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	0.01	0.02	0.02	0.02	0.01	0.02	0.02
	0.14	0.59	0.40	0.40	0.23	0.40	0.59
	0.59	1.61	1.61	1.35	1.27	1.69	1.77
	0.85	1.31	1.32	1.30	1.65	0.65	1.41
	1.29	2.44	2.37	2.37	1.66	2.39	2.69
	0.45	1.60	1.53	1.52	1.86	2.04	1.91
	0.83	0.71	0.77	0.78	1.13	0.47	0.63
	0.51	0.92	0.85	0.87	1.07	1.31	0.80
	0.51	0.83	0.89	0.89	0.51	1.10	0.69
	0.51	0.66	0.70	0.70	0.52	1.17	0.60
	0.89	1.06	0.92	0.86	0.45	2.01	0.72
	2.39	2.78	1.89	1.84	1.69	2.94	1.88
	1.16	1.28	1.72	1.72	1.64	1.62	1.42
Mouth	1.85	2.06	2.39	2.40	2.24	2.36	2.23

August	1	2	3a	3b	4	5	6
Head	0.00	0.01	0.01	0.01	0.01	0.02	0.01
	0.07	0.97	0.95	0.97	1.85	1.16	1.09
	0.96	2.29	2.23	2.24	3.25	2.61	2.39
	1.45	2.65	2.55	2.54	2.73	2.87	2.82
	1.88	2.92	2.97	2.95	3.80	3.39	3.22
	2.17	3.13	2.73	3.08	3.80	3.39	3.29
	2.73	2.91	2.61	3.09	2.85	3.50	3.39
	0.31	0.46	0.35	0.35	2.60	1.63	0.35
	0.28	0.41	0.25	0.24	0.50	1.62	0.26
	0.38	0.48	0.30	0.29	0.25	1.32	0.44
	0.21	0.28	0.10	0.10	0.09	3.92	2.65
	1.80	1.75	1.79	1.80	1.27	4.20	1.76
	1.68	1.63	1.60	1.39	1.39	1.85	1.50
Mouth	2.61	2.63	2.49	2.49	2.21	2.56	2.40

Table E-13. Minimum Daily Average DO (mg/L) - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	0.94	0.52	0.54	0.54	0.23	0.33	0.45
	1.13	2.40	2.40	2.37	1.87	2.19	2.42
	2.36	3.56	3.57	3.51	3.49	3.43	3.66
	2.61	3.55	3.50	3.50	3.59	3.00	3.50
	2.82	3.95	3.86	3.84	3.73	3.12	3.76
	2.84	3.84	3.74	3.72	3.63	3.38	3.87
	2.34	3.31	3.25	3.25	3.46	2.99	3.06
	2.18	2.81	2.83	2.83	3.58	3.13	2.90
	2.10	2.57	2.65	2.66	2.32	3.63	2.70
	2.25	2.56	2.67	2.67	2.45	3.99	2.72
	2.77	2.95	3.00	3.01	2.25	4.73	3.24
	4.44	4.62	4.10	4.09	3.90	4.97	4.33
	4.03	4.18	3.94	3.93	3.91	4.21	4.19
Mouth	4.30	4.40	4.24	4.25	4.14	4.41	4.28

August	1	2	3a	3b	4	5	6
Head	0.04	0.27	0.20	0.21	0.09	0.43	0.21
	1.94	3.15	3.07	3.09	3.64	3.07	3.17
	2.63	3.56	3.53	3.53	4.23	3.73	3.66
	3.02	3.75	3.70	3.69	4.29	3.88	3.87
	3.15	3.83	3.81	3.80	4.33	4.02	3.97
	3.25	3.82	3.82	3.81	4.37	4.08	3.99
	3.50	3.93	3.91	3.90	4.37	4.20	4.10
	1.77	2.07	0.97	0.97	4.23	3.67	2.20
	0.84	0.99	0.84	0.87	1.56	4.21	2.06
	0.89	0.93	1.03	1.06	1.46	4.40	2.45
	2.79	1.99	1.90	1.79	2.01	4.81	4.07
	4.33	4.35	3.87	3.89	3.48	4.86	4.56
	4.24	4.22	3.72	3.72	3.67	4.20	4.12
Mouth	4.36	4.37	4.11	4.10	3.98	4.20	4.11

Table E-14. Percent of Time the DO Concentration is Greater than 3.0 mg/L - Fresh Creek

	Scenarios						
July	1	2	3a	3b	4	5	6
Head	17.0	53.6	52.2	52.2	32.4	52.0	54.9
	54.6	83.6	83.3	83.8	76.4	81.3	84.1
	76.9	94.8	95.0	95.0	96.8	95.2	96.0
	82.1	96.0	95.7	95.6	98.3	95.2	96.2
	85.3	98.3	98.4	98.5	98.7	96.5	98.3
	86.9	98.0	97.7	97.8	98.7	96.4	98.0
	85.2	95.2	95.6	95.6	98.1	93.3	95.3
	68.0	78.5	76.3	75.4	95.0	90.7	88.8
	63.1	67.0	68.0	68.0	64.7	89.5	74.7
	66.9	71.7	72.3	72.4	67.2	91.4	76.9
	77.1	80.8	84.7	84.4	78.6	99.6	91.4
	98.8	98.8	96.5	96.8	90.2	99.9	96.4
	93.7	94.6	90.0	89.5	86.1	95.8	94.3
Mouth	95.7	96.6	96.9	97.0	95.2	98.1	96.4

August	1	2	3a	3b	4	5	6
Head	30.5	65.2	64.3	64.4	57.6	64.0	65.1
	54.8	91.4	90.5	90.5	94.9	91.8	91.9
	74.6	98.9	97.7	98.3	100.0	99.1	99.1
	83.1	99.7	99.3	99.3	99.9	99.9	99.7
	88.3	99.9	99.9	99.9	100.0	100.0	100.0
	92.3	100.0	99.9	100.0	100.0	100.0	100.0
	96.8	99.9	99.7	100.0	99.1	100.0	100.0
	73.2	77.5	74.6	74.5	99.1	98.9	86.0
	75.0	77.2	76.2	76.1	77.0	98.8	83.9
	76.2	78.1	77.2	76.9	77.0	98.9	85.5
	89.5	89.0	89.3	89.3	85.9	100.0	99.3
	99.2	98.8	95.6	95.3	90.6	100.0	99.3
	98.7	98.7	93.3	93.6	90.2	99.3	96.9
Mouth	99.1	98.8	96.6	96.6	93.4	99.3	97.7

SECTION 1

INTRODUCTION

Jamaica Bay is a heavily impacted estuary located within the boundaries of New York City (Figure 1-1). Some areas of Jamaica Bay and the basins that are tributary to it experience hypoxic or anoxic conditions. These low dissolved oxygen levels can have a profound effect on the biota that live within the bay. The U.S. Army Corps of Engineers (USACOE) is currently planning habitat restoration projects within Jamaica Bay as part of the Jamaica Bay Ecosystem Restoration Project (JABERP) to improve wildlife habitat in the area. The restoration projects involve recontouring of upland, and marsh areas as well as possible bathymetric changes. The habitat restoration efforts also include planting salt marsh and upland vegetation. The projects include eight sites around Jamaica Bay including (in clockwise order from Dead Horse Bay) Dead Horse Bay, Paerdegat Basin, Fresh Creek, Spring Creek, the area between Hawtree and Bergen Basins, Bayswater State Park, Dubos Point, and Brant Point. Of these areas, two locations include bathymetric changes. These locations are Paerdegat Basin and Fresh Creek. The U.S. Army Corps of Engineers has requested that, as part of a cost sharing agreement, the New York City Department of Environmental Protection (NYCDEP) provide funding to develop a hydrodynamic/water quality model of Paerdegat Basin and Fresh Creek to assess how planned bathymetric alterations will affect habitat in these areas. The NYCDEP agreed to fund the modeling effort as in-kind services to the USACOE. HydroQual was contracted to provide these services.

The USACOE developed five different scenarios to be analyzed for Paerdegat Basin and six different scenarios to be analyzed for Fresh Creek. The results of these model scenarios will be presented in this report. In addition to these model runs, the USACOE requested six additional scenarios to be analyzed using the pre-existing Jamaica Bay Eutrophication Model (JEM). These scenarios also involve bathemetric changes to the bay and the assessment of how these changes might effect habitat in the bay. The results of these modeling analyses will also be presented in this report.

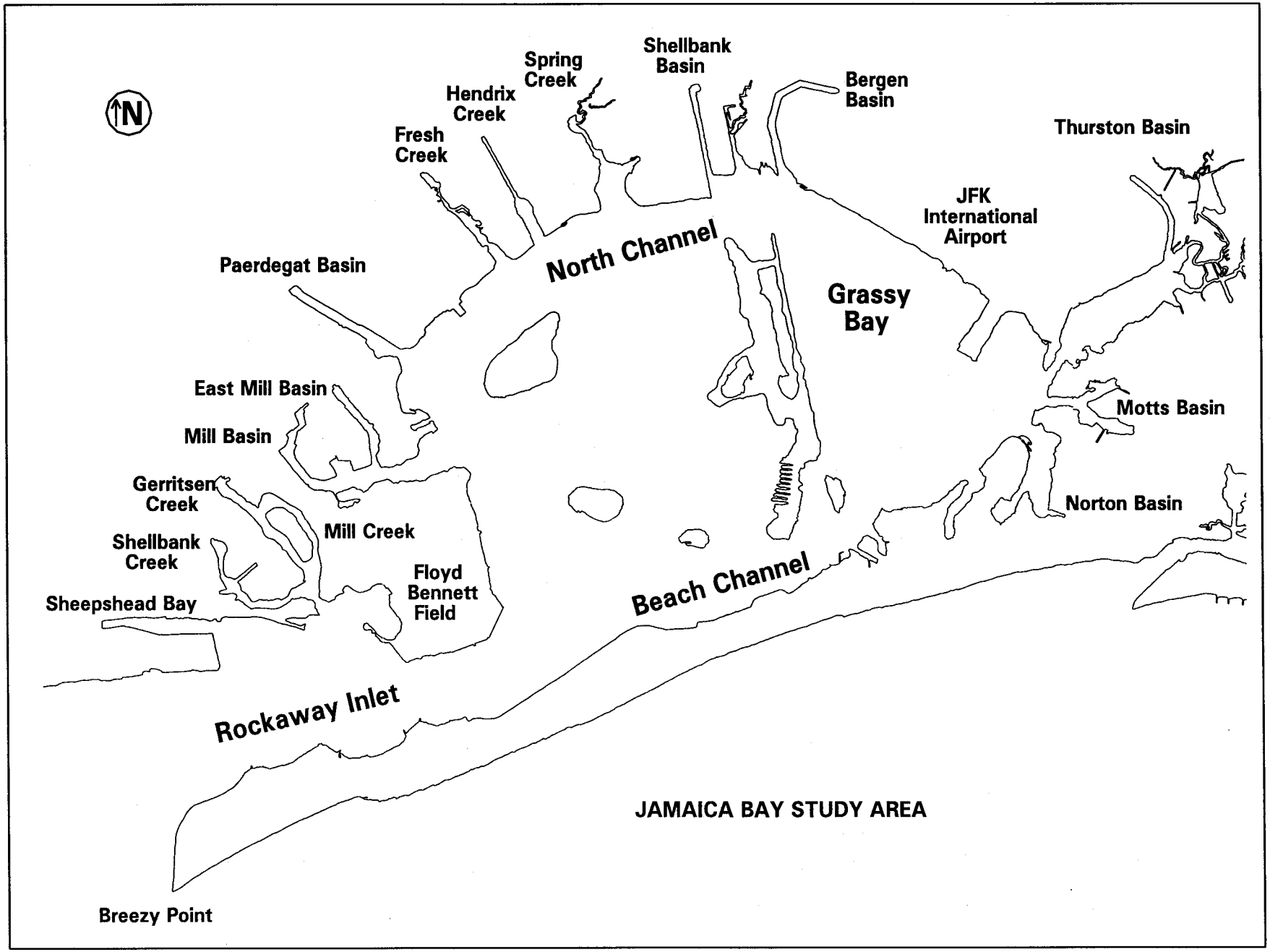


Figure 1-1. Jamaica Bay Study Area

SECTION 2

THE MODELS

2.1 INTRODUCTION

Two models were used for this project, the North Channel Model (NCM), and the Jamaica Bay Eutrophication Model (JEM). Both models are time-variable, three-dimensional, coupled hydrodynamic/water quality/sediment nutrient flux models. The models use the Estuarine Coastal and Ocean Model (semi-implicit) (ECOMsi) as the hydrodynamic model, and Row Column Advanced Ecosystems Modeling Program (RCA) for the water quality model. ECOMsi has the ability to compute when a water cell dries due to changes in tidal elevation. ECOMsi provides information on tidal elevations, flow, dispersion, salinity and temperature to RCA. RCA contains the water quality kinetics for the water quality constituents of concern and can be modified depending on what processes are important in a particular water body. RCA also includes a sediment nutrient flux model that allows the water quality model to track organic material that settles to the sediment and compute nutrient fluxes into or out of the sediment, thereby completing the mass balance around the system. NCM and JEM are described more thoroughly below.

NCM includes 26 state-variables that are listed in Table 2-1. These state-variables include the full complement of variables used for eutrophication modeling plus total and fecal coliform. The model was designed for use in several projects. These projects include JABERP, the Fresh Creek CSO Facility Plan, and the Use and Standards Attainment (USA) Project. The latter two projects are being performed for the NYCDEP. This design was developed, so that consistent results would be developed for each project. This lead to the incorporation of Hendrix Creek and Spring Creek into the model even though the USACOE was not specifically interested in modeling these creeks. The segmentation used in the model is presented in Figure 2-1. An attempt was made to develop a fine grid while also keeping the model run time less than one day for a year long run. The model has 42 surface segments in Paerdegat Basin plus an additional six segments added to represent a proposed marsh wetland area. Fresh Creek is represented by 29 surface segments. The entire model domain has 10 vertical layers. NCM was calibrated to data collected in 1988. NCM was used to assess the changes in velocity, bottom shear stress, salinity, and DO in Paerdegat Basin and Fresh Creek due to changes specified in several modeling scenarios.

JEM was developed in the mid-1990s and has similar kinetics to NCM. JEM does not include total and fecal coliform state-variables, but does include suspension feeder bivalves to account for the

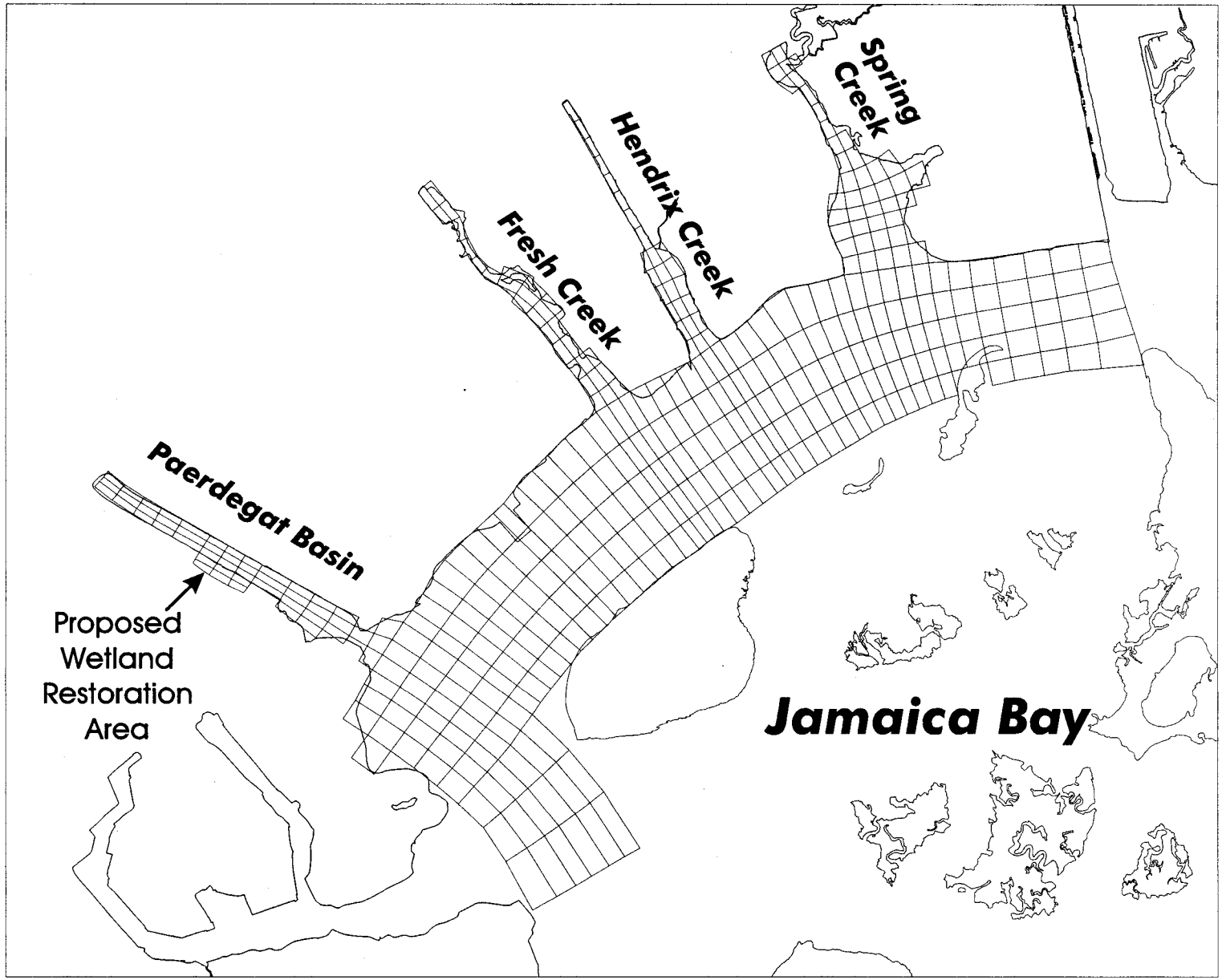


Figure 2-1. NCM Model Segmentation

Table 2-1

State System Variables, Coupled Eutrophication/Chemical Equilibria Model

1. Salinity (Sal)
2. Phytoplankton carbon - winter diatoms (P_{C1})
3. Phytoplankton carbon - summer assemblage (P_{C2})
4. Refractory particulate organic phosphorus (RPOP)
5. Labile particulate organic phosphorus (LPOP)
6. Refractory dissolved organic phosphorus (RDOP)
7. Labile dissolved organic phosphorus (LDOP)
8. Dissolved inorganic phosphorus (DIP)
9. Refractory particulate organic nitrogen (RPON)
10. Labile particulate organic nitrogen (LPON)
11. Refractory dissolved organic nitrogen (RDON)
12. Labile dissolved organic nitrogen (LDON)
13. Ammonia nitrogen (NH_3-N)
14. Nitrate + nitrate nitrogen (NO_2-N + NO_3-N)
15. Biogenic silica (BSi)
16. Available silica (Si)
17. Refractory particulate organic carbon (RPOC)
18. Labile particulate orgnaic carbon (LPOC)
19. Refractory dissolved organic carbon (RDOC)
20. Labile dissolved organic carbon (LDOC)
21. Reactive dissolved organic carbon (ReDOC)
22. Algal exudate dissolved organic carbon (ExDOC)
23. Dissolved oxygen equivalents (O_2^*)
24. Dissolved oxygen (DO)
25. Total coliform
26. Fecal coliform

filtering effects that these organisms have on particulate matter in the water column. JEM was developed to analyze the eutrophic conditions that occur within Jamaica Bay with less emphasis on the tributaries that surround the bay. For this reason the segmentation within the creeks was very coarse. Only eight surface segments were included for Paerdegat Basin and five surface segments for Fresh Creek. In Jamaica Bay itself the segement size is 1,000 ft by 1,000 ft. The model segmentation for JEM is presented in Figure 2-2. The model was calibrated to data collected in 1988 and from July 1995 to July 1996. JEM was used for two purposes in this project. The first was to provide boundary conditions for NCM. The second was to analyze six scenarios for bathymetric changes in the bay.

The model kineics for JEM have been described in HydroQual (2002) and will not be repeated here. Appendix A contains the model kinetic equations for each system and the associated model constants used in these equations.

Figures 2-3 through 2-5 present general schematics of how the state-variables in the models interact in both models. In general, organic matter is split into four "pools" comprising combinations of particulate, dissolved, refractory and labile material. Refractory matter reacts more slowly than labile material. The carbon group contains an additonal state-variable called reactive dissolved organic carbon. The reactive carbon reacts more quickly than labile carbon. Each of the figures presented show how phytoplankon, inorganic matter, and organic matter interact and how this material is recycled through the water column or settles to the sediment. Figures 2-6 and 2-7 present how the sediment interacts with the water column and the kinetics of the sediment model.

2.2 MODEL INPUTS

2.2.1 JEM

2.2.1.1 Hydrodynamic Model

The hydrodynamic model requires several inputs. These inputs include boundary tidal elevations, salinity and temperature boundary conditions, fresh water flows, and meteorological forcings such as air temperature, relative humidity, barometric pressure, solar radiation, and wind speed and direction. The model also requires a few constants to be assigned for bottom roughness, wetting and drying, and mixing. Figures 2-8 through 2-11 present the inputs used for the hydrodynamic model. The figures include tide elevation, boundary condition temperature and salinity, a sample of CSO overflow temporal patterns, and the meteorological inputs. A more thorough discussion of the model inputs is presented in HydroQual (2002).

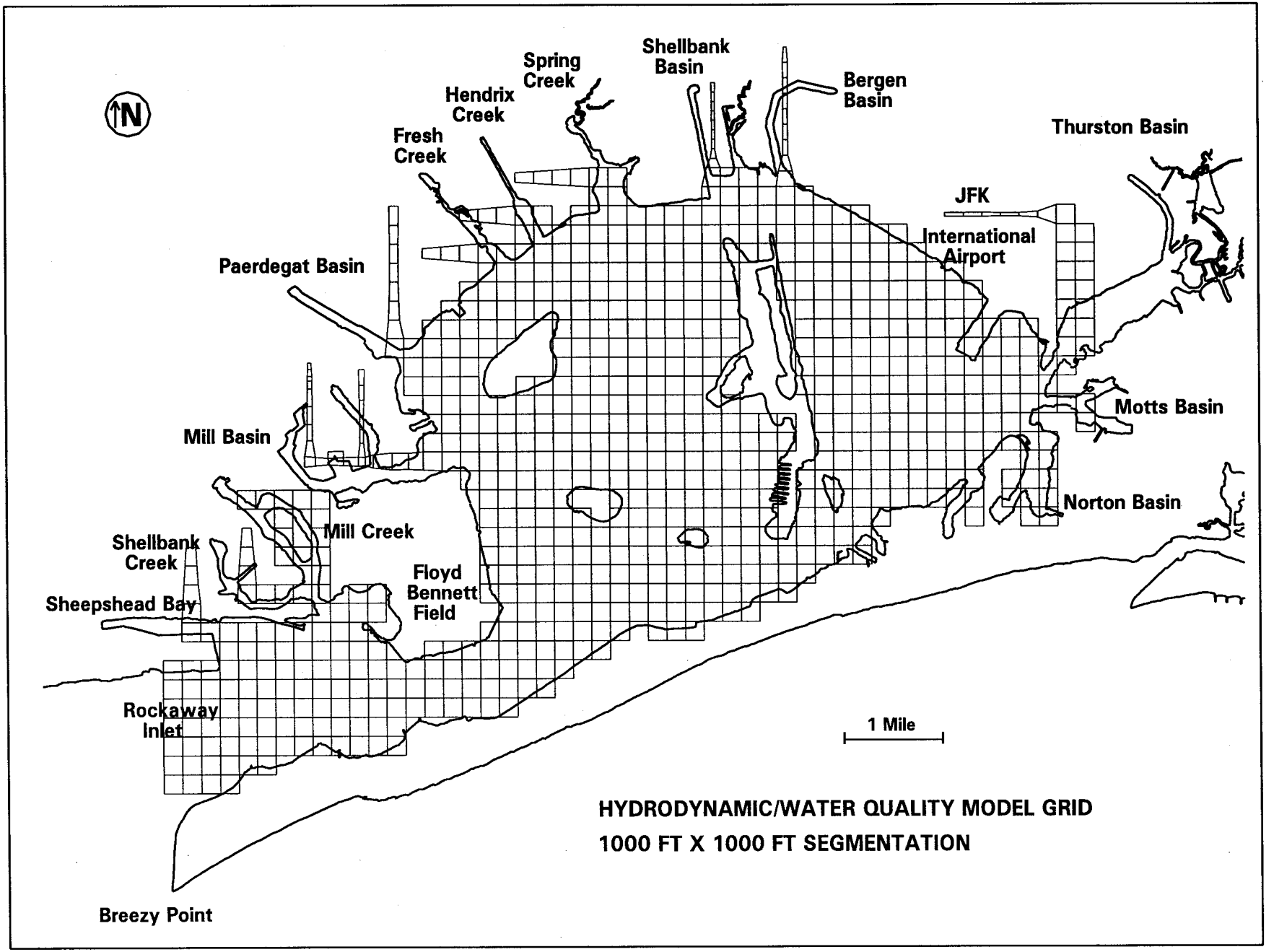
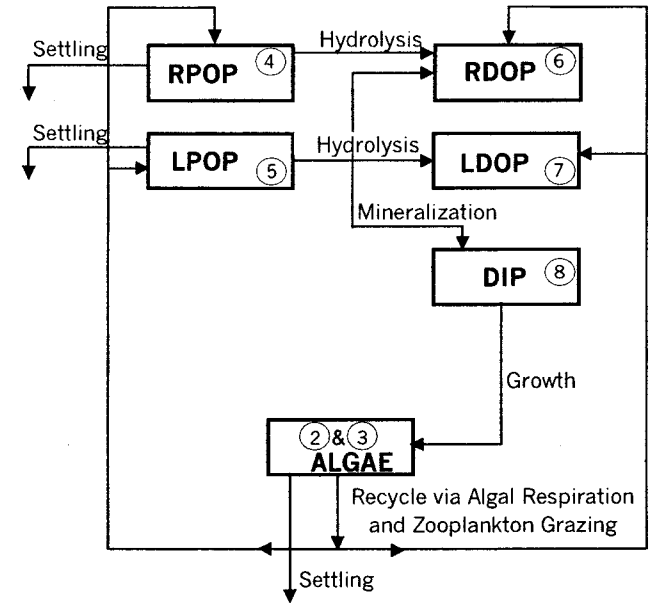
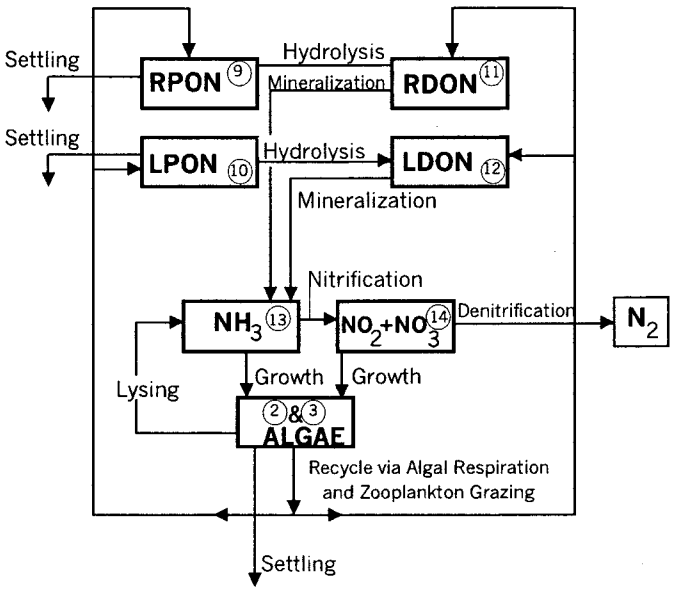


Figure 2-2. JEM Model Segmentation



PHOSPHORUS KINETICS

RPOP = Refractory Particulate Organic Phosphorus
LPOP = Labile Particulate Organic Phosphorus
RDOP = Refractory Dissolved Organic Phosphorus
LDOP = Labile Dissolved Organic Phosphorus
DIP = Dissolved Inorganic Phosphorus

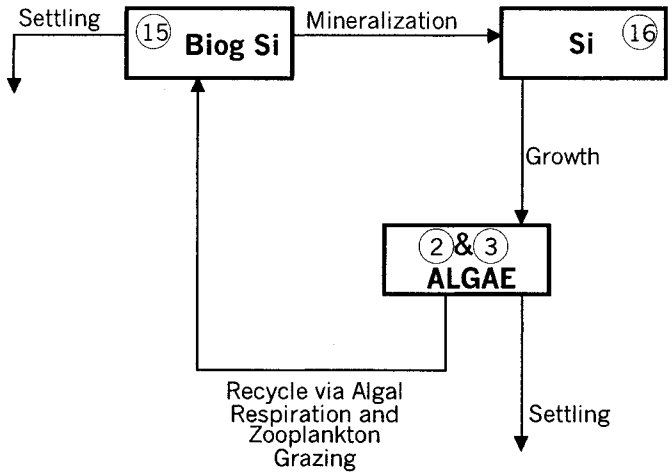


NITROGEN KINETICS

15 = System Number

RPON = Refractory Particulate Organic Nitrogen
LPON = Labile Particulate Organic Nitrogen
RDON = Refractory Dissolved Organic Nitrogen
LDON = Labile Dissolved Organic Nitrogen
NH_3 = Ammonia Nitrogen
NO_2+NO_3 = Nitrite + Nitrate Nitrogen

Figure 2-3. Principle Kinetic Interactions for Phosphorus and Nitrogen

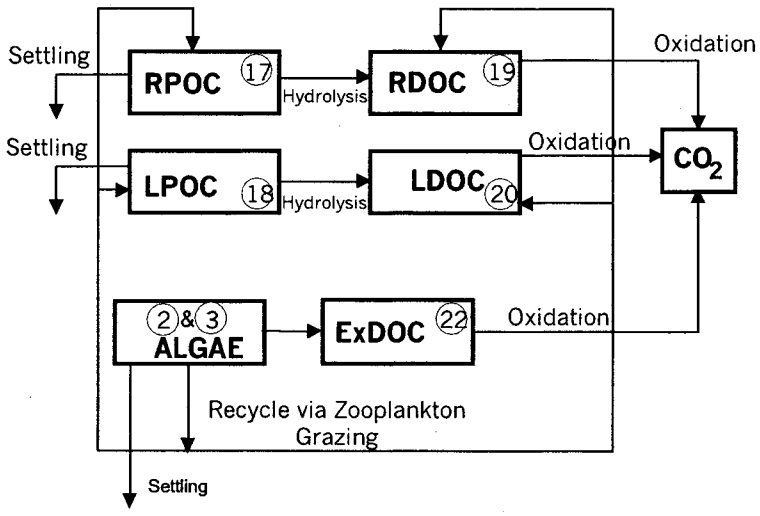


SILICA KINETICS

(20) System Number

Biog Si = Biogenic Silica

Si = Inorganic Silica



CARBON KINETICS

(5) = System Number

RPOC = Refractory Particulate Organic Carbon

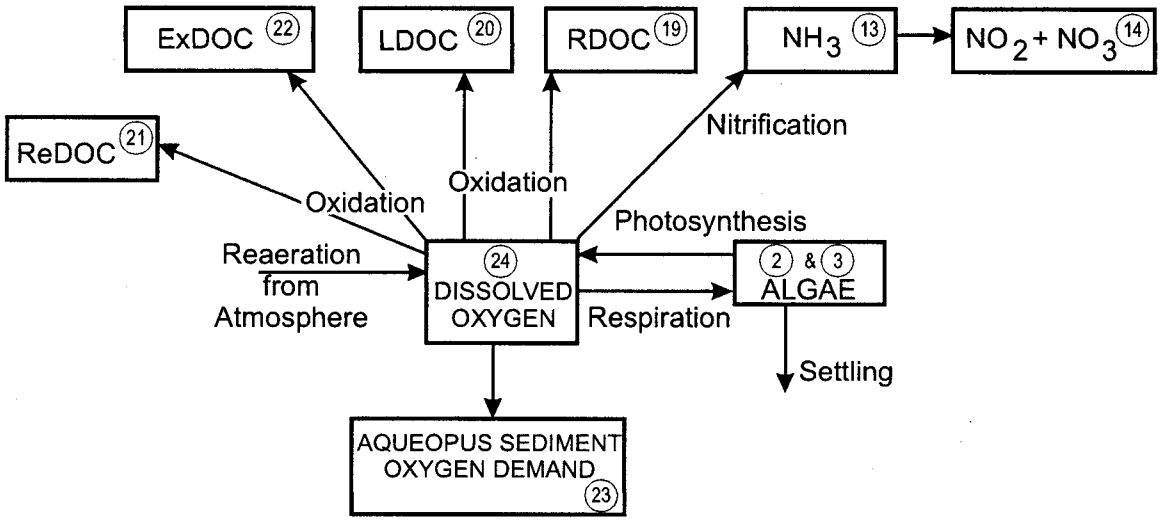
LPOC = Labile Particulate Organic Carbon

RDOC = Refractory Dissolved Organic Carbon

LDOC = Labile Dissolved Organic Carbon

ExDOC = Algal Exudate Dissolved Organic Carbon

Figure 2-4. Principle Kinetic Interactions for Silica and Organic Carbon



DISSOLVED OXYGEN

(14) System Number

LDOC = Labile Dissolved Organic Carbon
RDOC = Refractory Dissolved Organic Carbon
NH_3 = Ammonia
$NO_2 = NO_3$ = Nitrite + Nitrate
ReDOC = Reactive Dissolved Organic Carbon

Figure 2-5. Principle Kinetic Interactions for Dissolved Oxygen

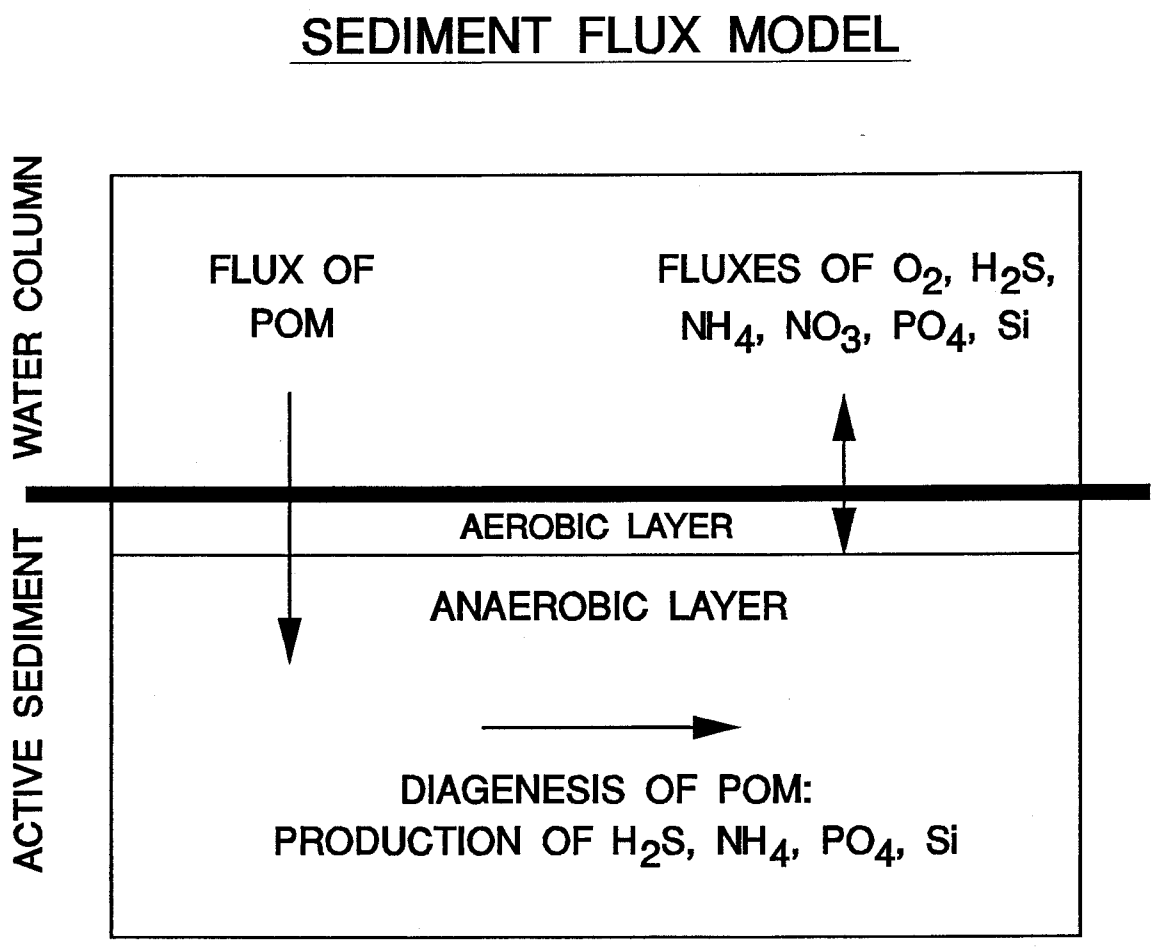


Figure 2-6. Sediment Flux Model

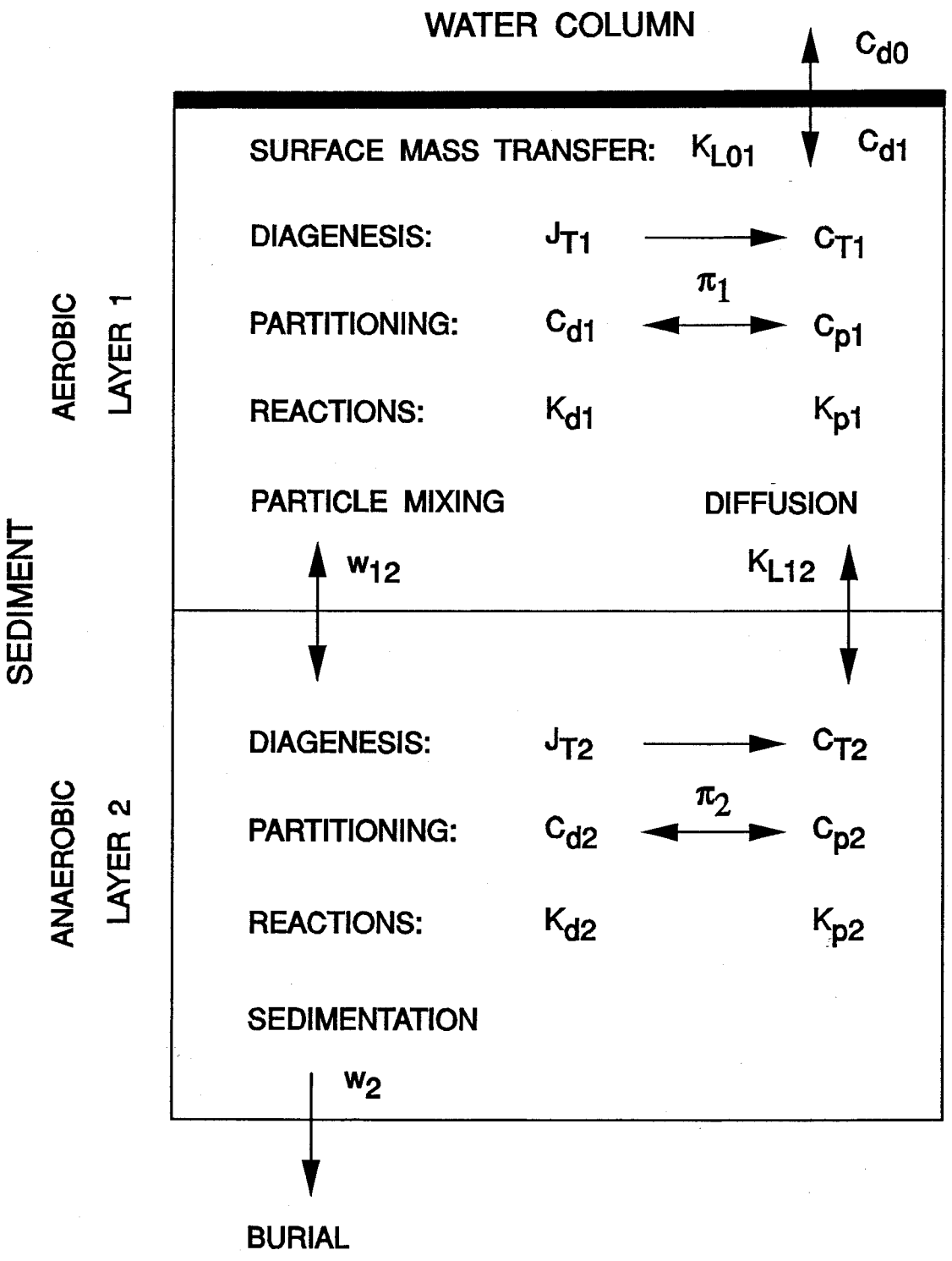


Figure 2-7. Sediment Model Interactions

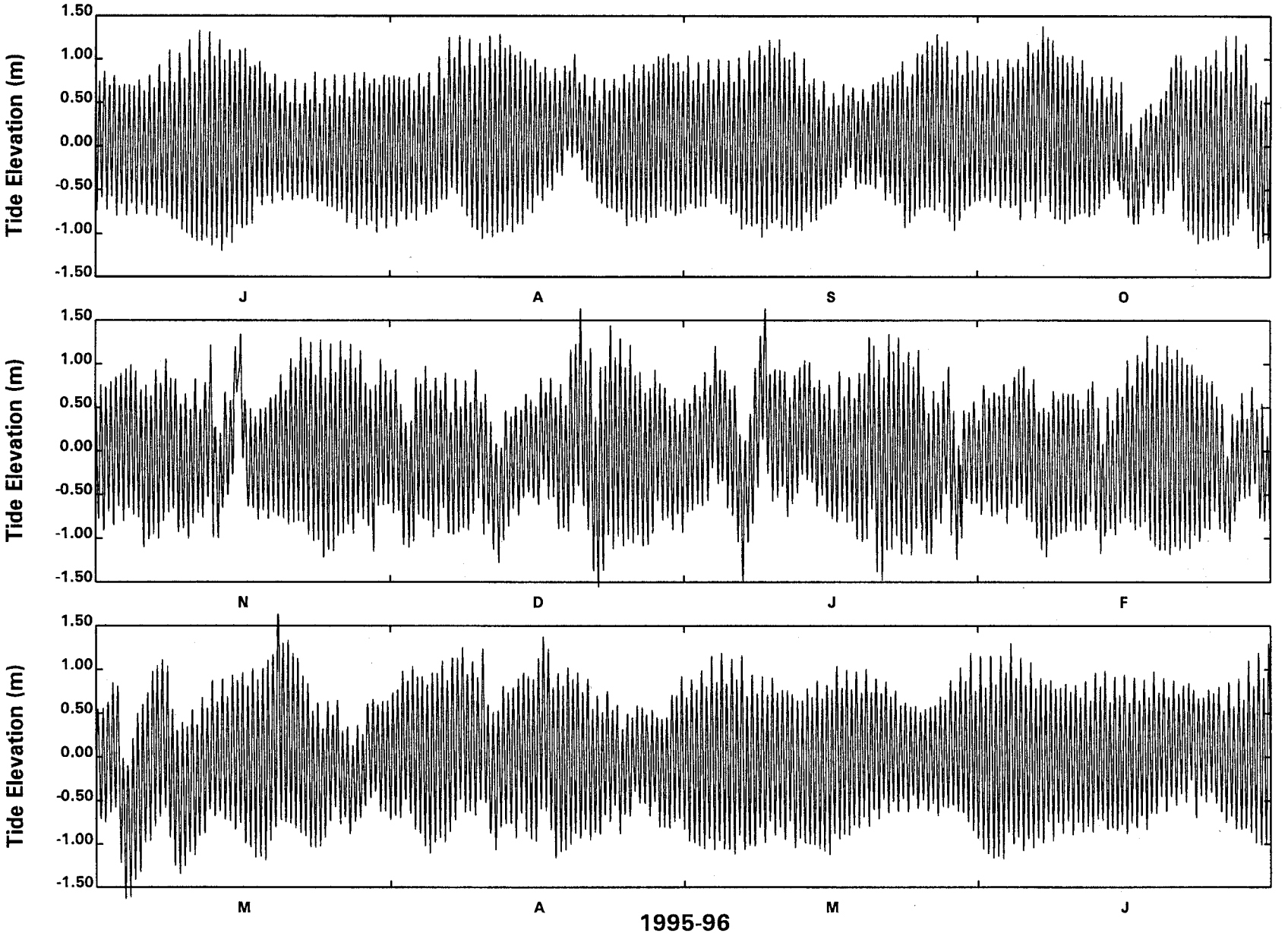


Figure 2-8. JEM Tidal Boundary Conditions

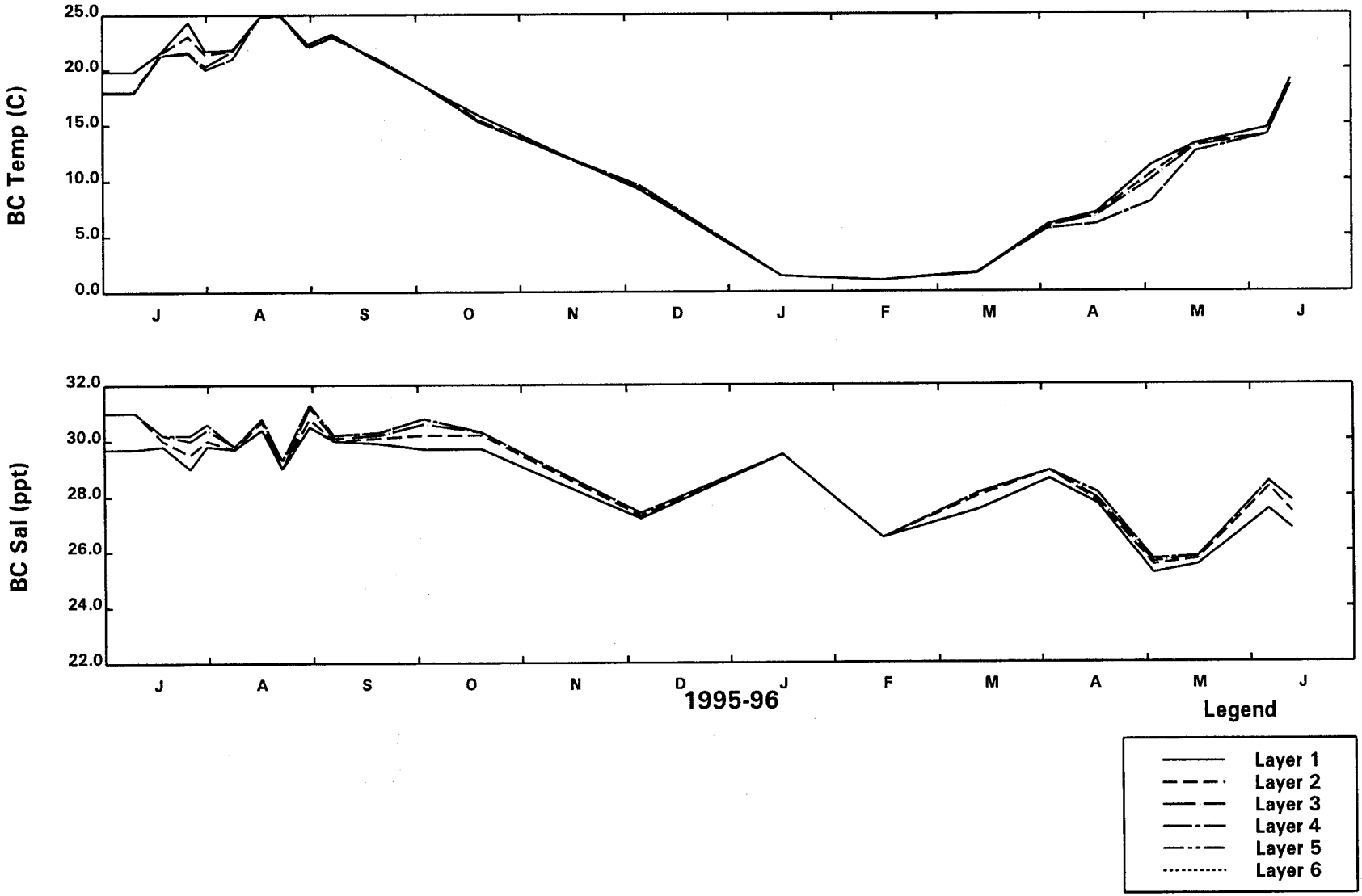


Figure 2-9. JEM Temperature and Salinity Boundary Conditions

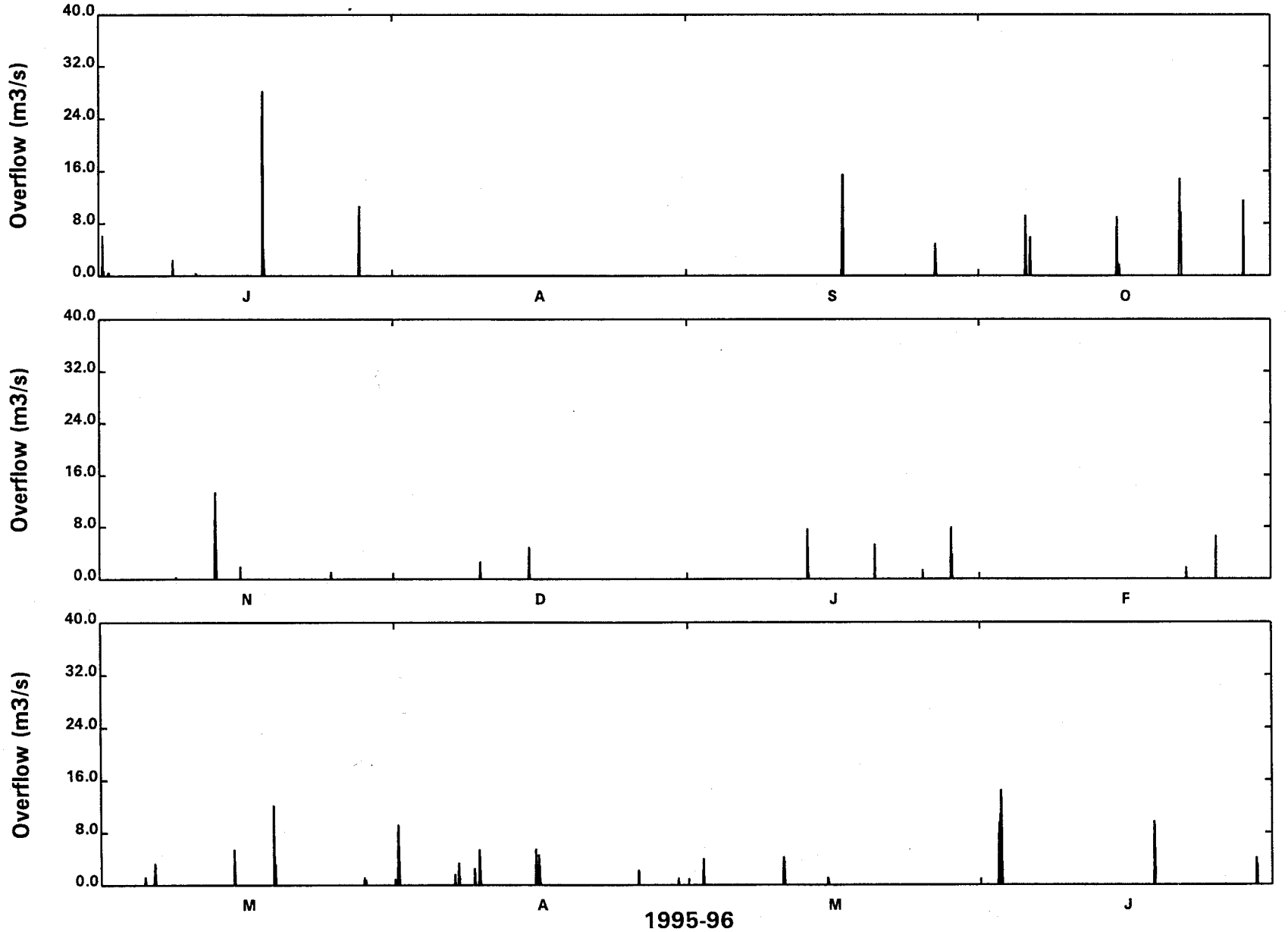


Figure 2-10. Example CSO Flows used in JEM

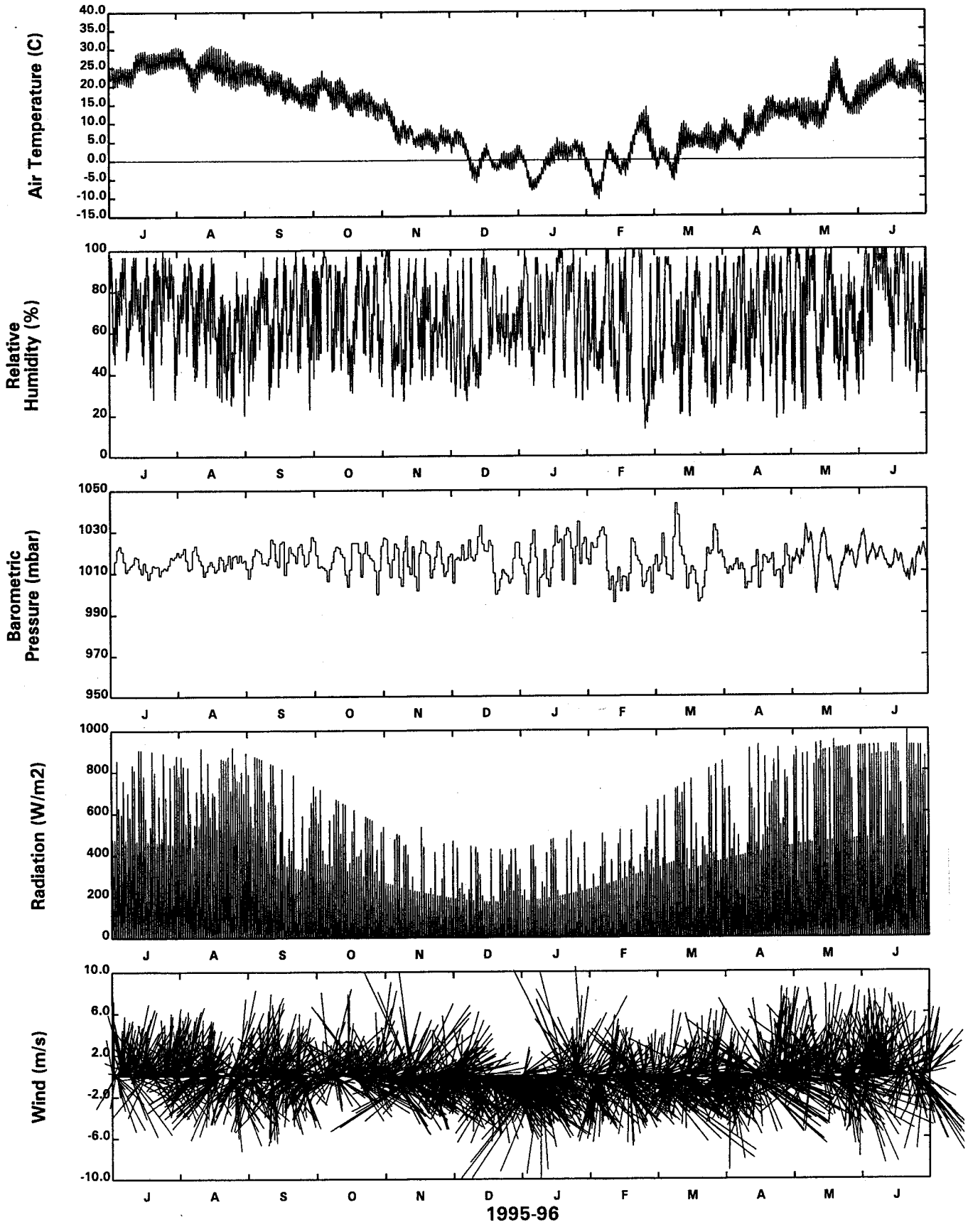


Figure 2-11. JEM Meteorological Forcings

One issue that should specifically be addressed is the model constants. One of the constants assigned in the hydrodynamic model is the bottom roughness. In this model, the constant that is assigned is z_0, which is the bottom roughness in meters. The value assigned within JEM is 0.003 m. Another constant is the minimum depth of water allowed in a segment at which point it is considered "dry." The value for this constant used in JEM is 0.15 m.

2.2.1.2 Water Quality Model

The water quality model all requires several forms of input. The inputs consist of hydrodynamic forcings, loads, boundary conditions, and parameters and constants. The hydrodynamic model provides the hydrodynamic forcings, which include tidal elevation, flow, dispersion, temperature and salinity. The loads included the WPCPs, CSOs, storm sewers, landfills and atmospheric deposition. A thorough description of the development and magnitude of the loads is presented in HydroQual (2002). Figure 2-12 presents a distribution of the loads by source into the bay. The boundary conditions were derived from a combination of concentrations from SWEM (System-wide Eutrophication Model of the NY Bight) and internal concentrations by means of "reflective boundaries." SWEM was run without any loads into Jamaica Bay to develop background boundary conditions. Then a constant was chosen to assign how much material that left Jamaica Bay during ebb tide would return during flood tide. The sum of the SWEM results and the material returning during the flood tide determined the model boundary conditions. The base boundary conditions are presented C. The model constants and parameters are presented in Appendix A. A more thorough description of all the model inputs is presented in HydroQual (2002).

2.2.2 NCM

2.2.2.1 Hydrodynamic Model

The hydrodynamic model requires several inputs to complete a model run. These inputs include tidal elevation boundary conditions, temperature and salinity boundary conditions, flow inputs, and meteorological inputs, along with a few constants and parameters. This sub-section provides a presentation of the inputs to the hydrodynamic model.

NCM has two open boundaries, the eastern boundary, which is just west of Shellbank Basin, and the western boundary, which is near the mouth of Mill Basin. Figure 2-13 presents the tidal elevations used at the eastern and western boundaries of the model. These boundary conditions were obtained from the Jamaica Bay Eutrophication Model (JEM) from the 1988 simulation. The maximum tidal range is on the order of 3.0 meters, but the more common range is on the order of 1.5 to 2.0

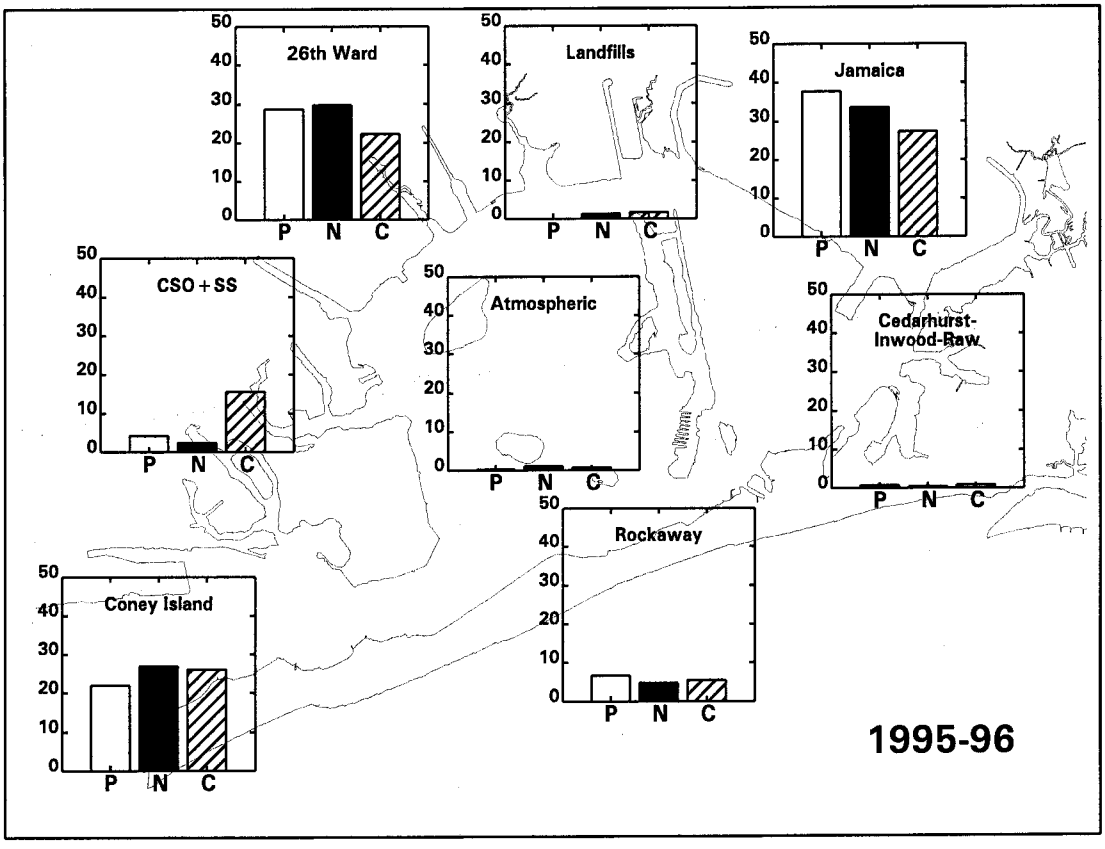


Figure 2-12. JEM Loading Distribution

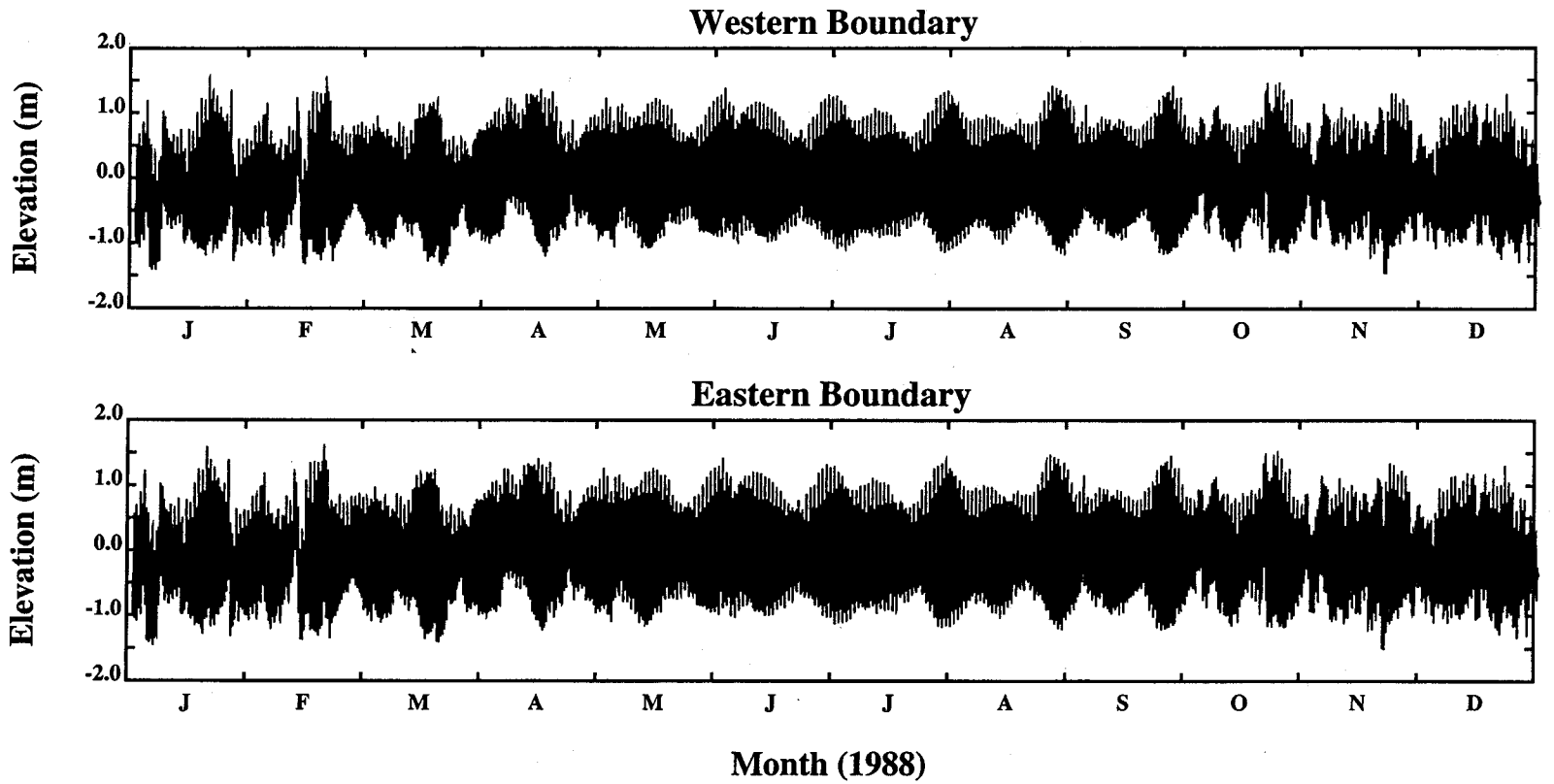


Figure 2-13. NCM Tidal Boundary Conditions

meters. Since these boundaries are very close to one another they are very similar to each other, with only small differences in timing and elevation.

Figure 2-14 presents the temperature and salinity boundary conditions. These boundary conditions were also obtained from JEM, but were slightly altered. During some storm events the difference in salinity between the eastern and western boundaries would occasionally exceed 2.0 ppt. On these occasions the model would become unstable. To correct this, the eastern boundary salinity was adjusted until there was only a 2.0 ppt difference between the two boundary conditions. The two sets of boundary conditions are quite similar, as was the case for the tidal elevations. The differences can be seen in the temperature in the slightly more stratified surface and bottom temperatures at the eastern boundary. The eastern boundary also tends to have lower salinity than the western boundary.

The hydrodynamic model requires flow input from natural and man-made sources. There are no riverine sources incorporated into this model. The only sources of flow included in the model are from combined sewer over flows (CSOs), storm sewers, and waste water treatment plants. NCM includes the input from six CSOs. Three of the CSOs are located at the head end of Paerdegat Basin, while the other three creeks (Fresh, Hendrix and Spring) each have one CSO at the head end. Figure 2-15 presents the flows assigned to the CSOs. Paerdegat Basin has the largest CSO volume followed by Fresh Creek. Spring Creek requires larger storms before overflows occur, so there are fewer CSOs. Hendrix Creek has the smallest volume of overflow in 1988. The storm sewer flows are presented in Figure 2-16. Only Paerdegat Basin and Fresh Creek have storms sewers. Figure 2-17 presents the flow from the 26th Ward Water Pollution Control Plant (WPCP). The flows for the CSOs (except for Paerdegat Basin) and the WPCP were developed by O'Brien and Gere Engineers using SWMM. The storm sewer flows and the CSO flow for Paerdegat Basin were developed by HydroQual using RAINMAN (rainfall runoff model). The rainfall record used as input to SWMM is presented in Figure 2-18. A table of the rainfall record is presented in Appendix B.

The last set of time series inputs required by the model is the meteorological inputs. These inputs include air temperature, relative humidity, barometric pressure, shortwave (solar) radiation, and wind speed and direction. The inputs used for 1988 are presented in Figure 2-19. These inputs are the same used for the JEM model and the data were originally obtained from New York City's Central Park and the JFK International Airport.

The remaining pieces of information required by the hydrodynamic model are the constants. An important constant is z_0, a roughness parameter. The usual range of z_0 is 0.001 to 0.003 m. Due to the relatively shallow water depths of the tributaries, the requirement for high spatial resolution of the model domain, which required a large number of model segments in the creeks (which in turn resulted in small segment sizes), and the large volumes of CSO that occurred during some of the

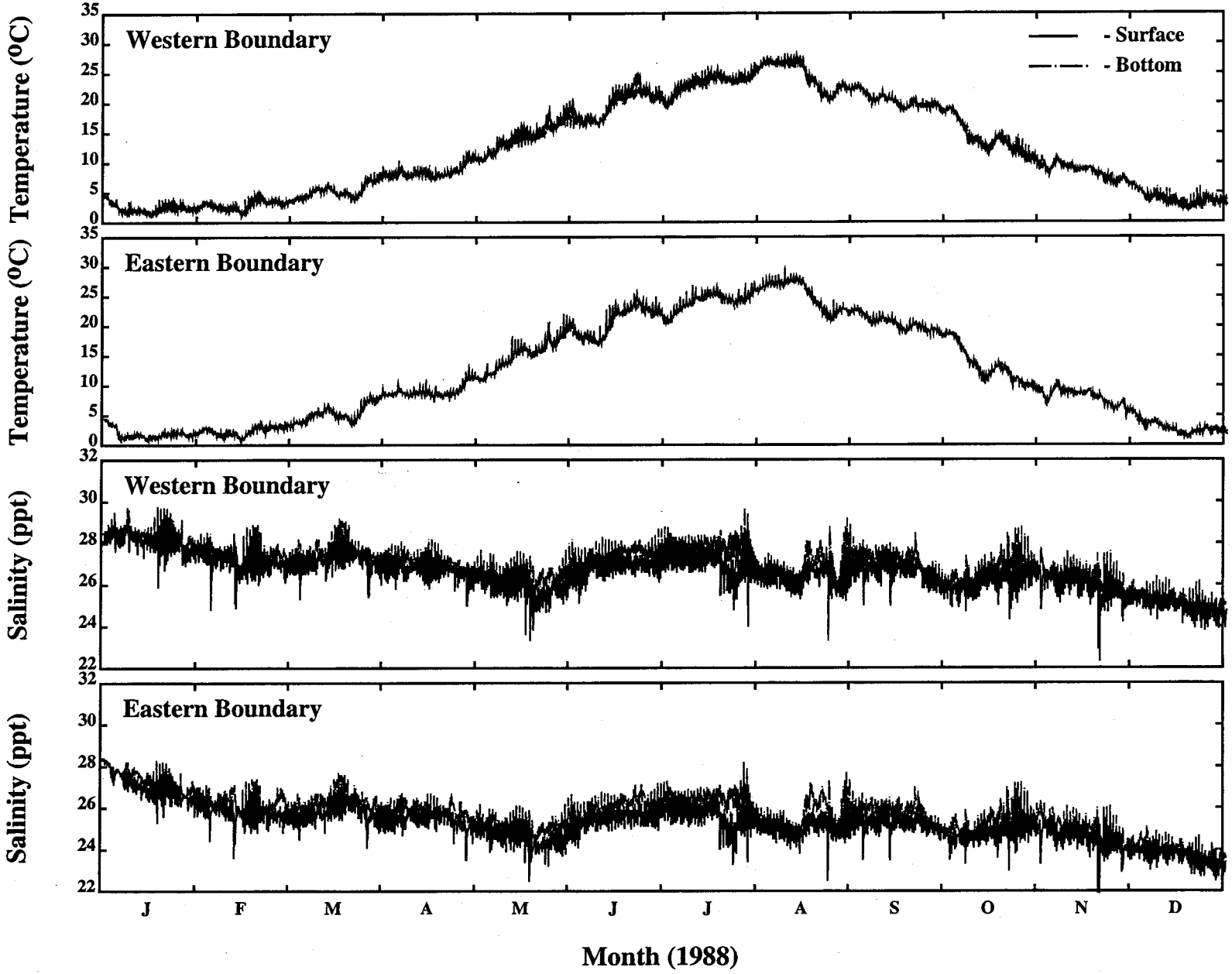


Figure 2-14. NCM Temperature and Salinity Boundary Conditions

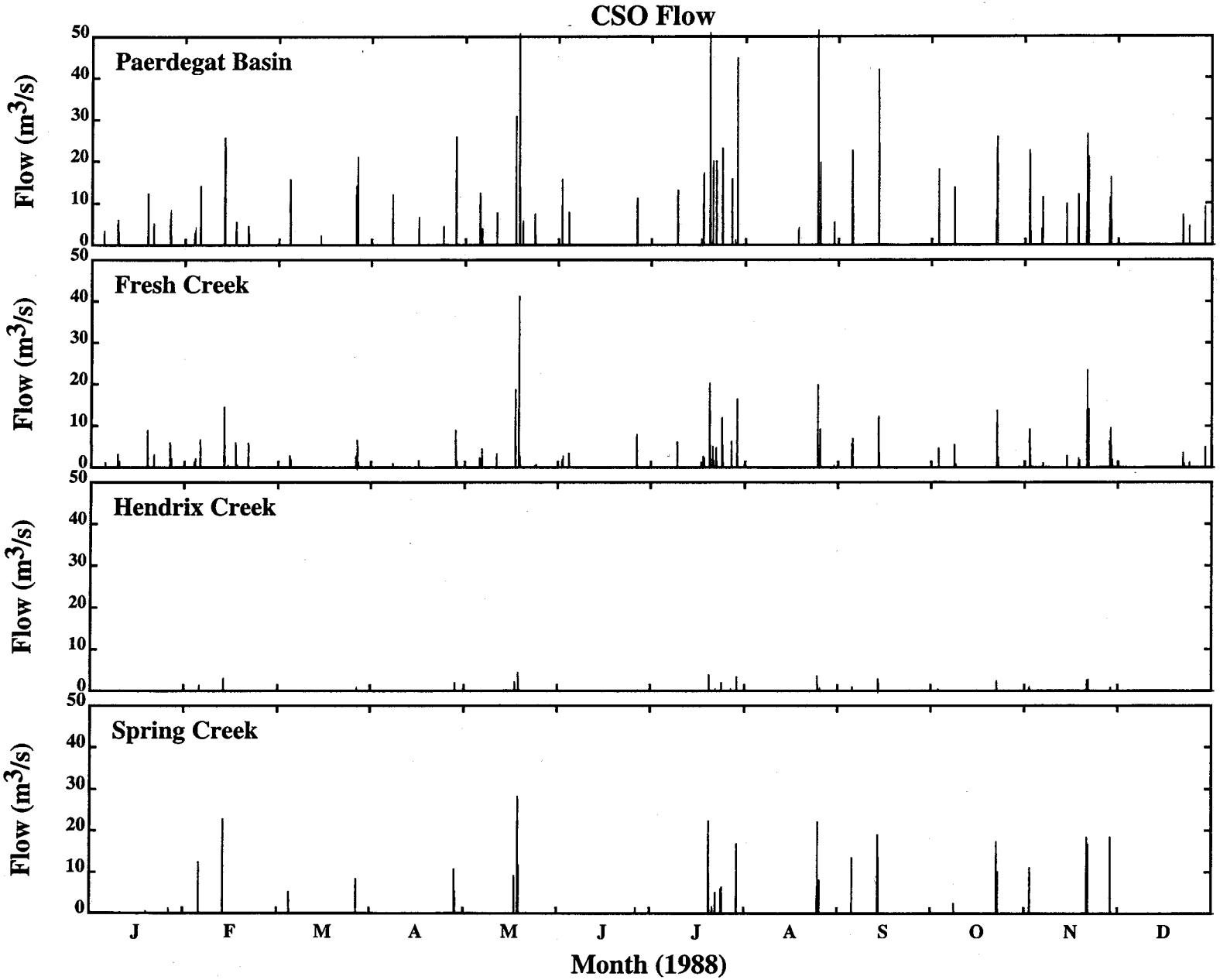


Figure 2-15. CSO Flows Assigned in NCM

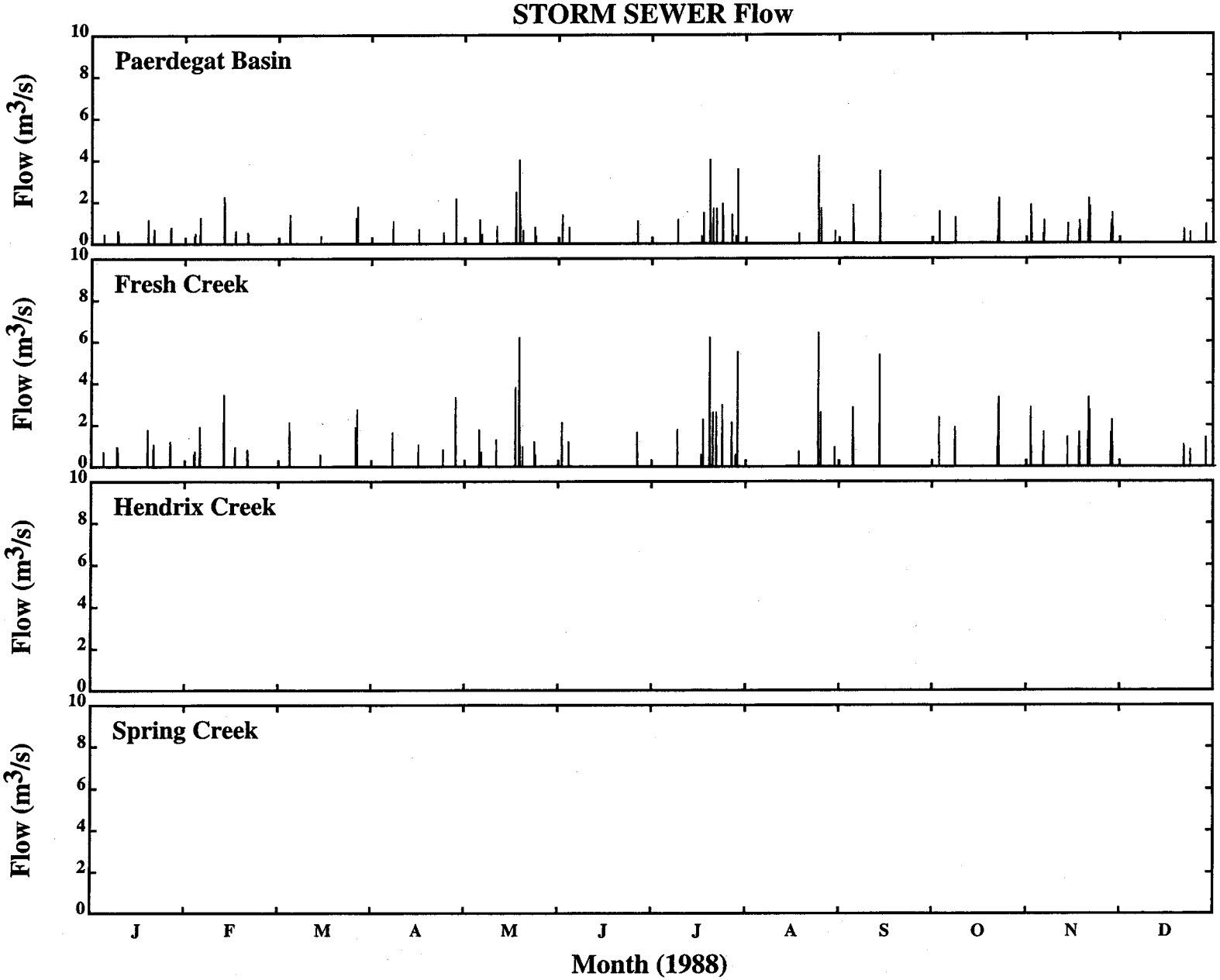


Figure 2-16. Storm Sewer Flows Assigned in NCM

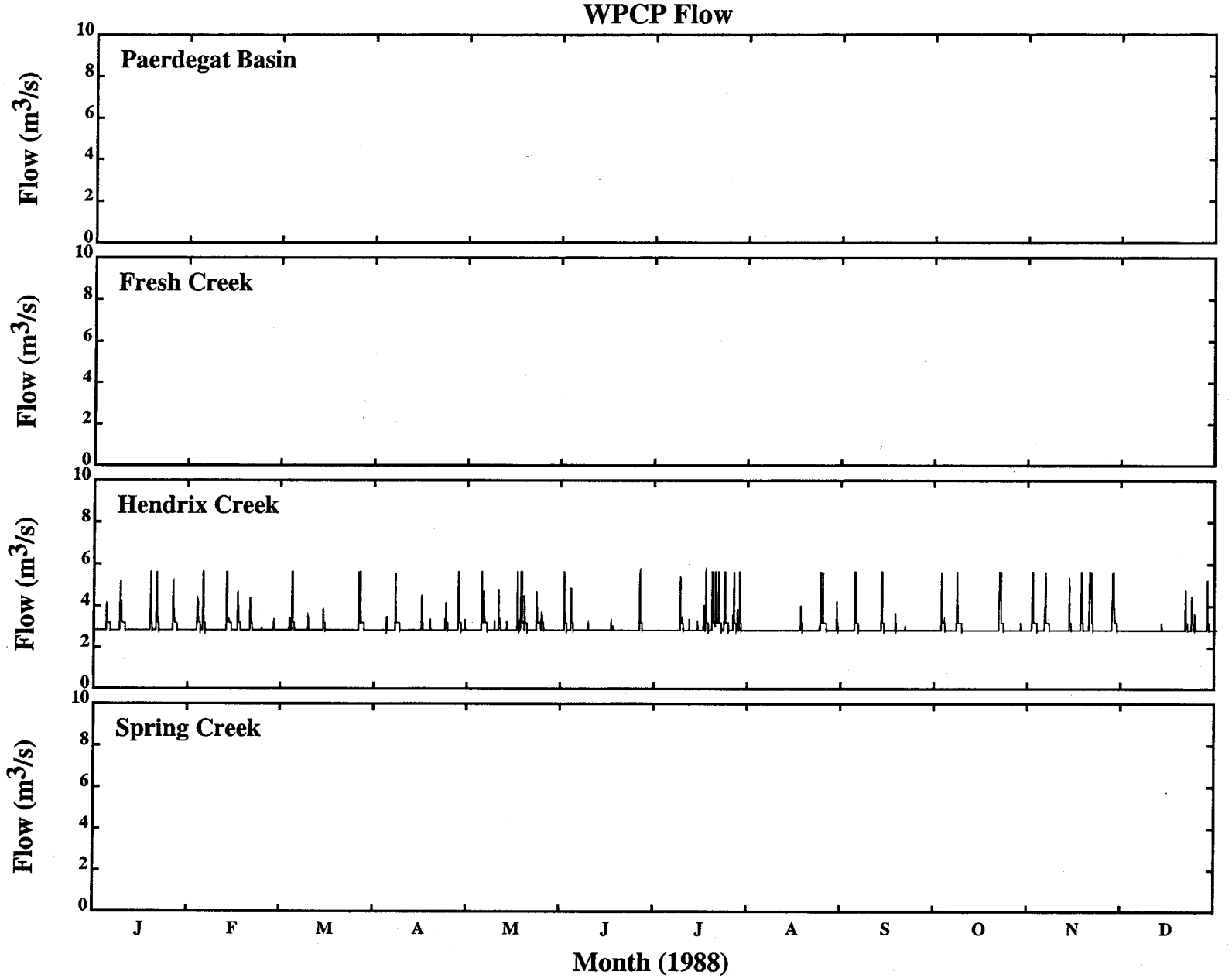


Figure 2-17. WPCP Flows Assigned in NCM

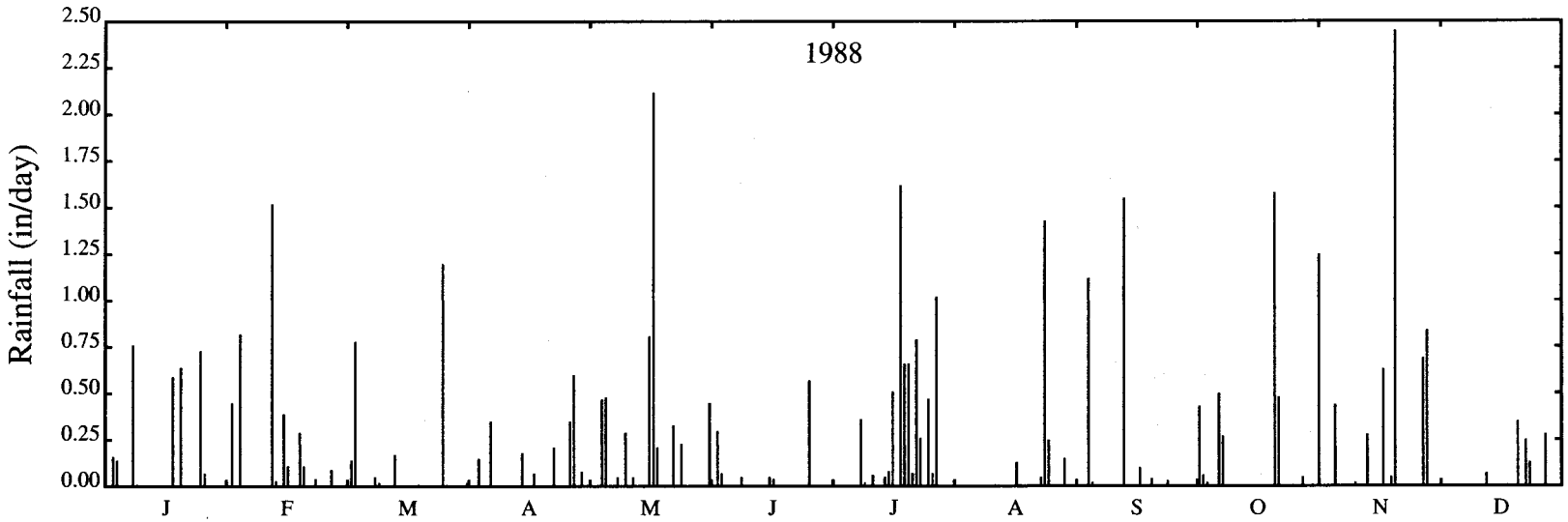


Figure 2-18. Rainfall Record

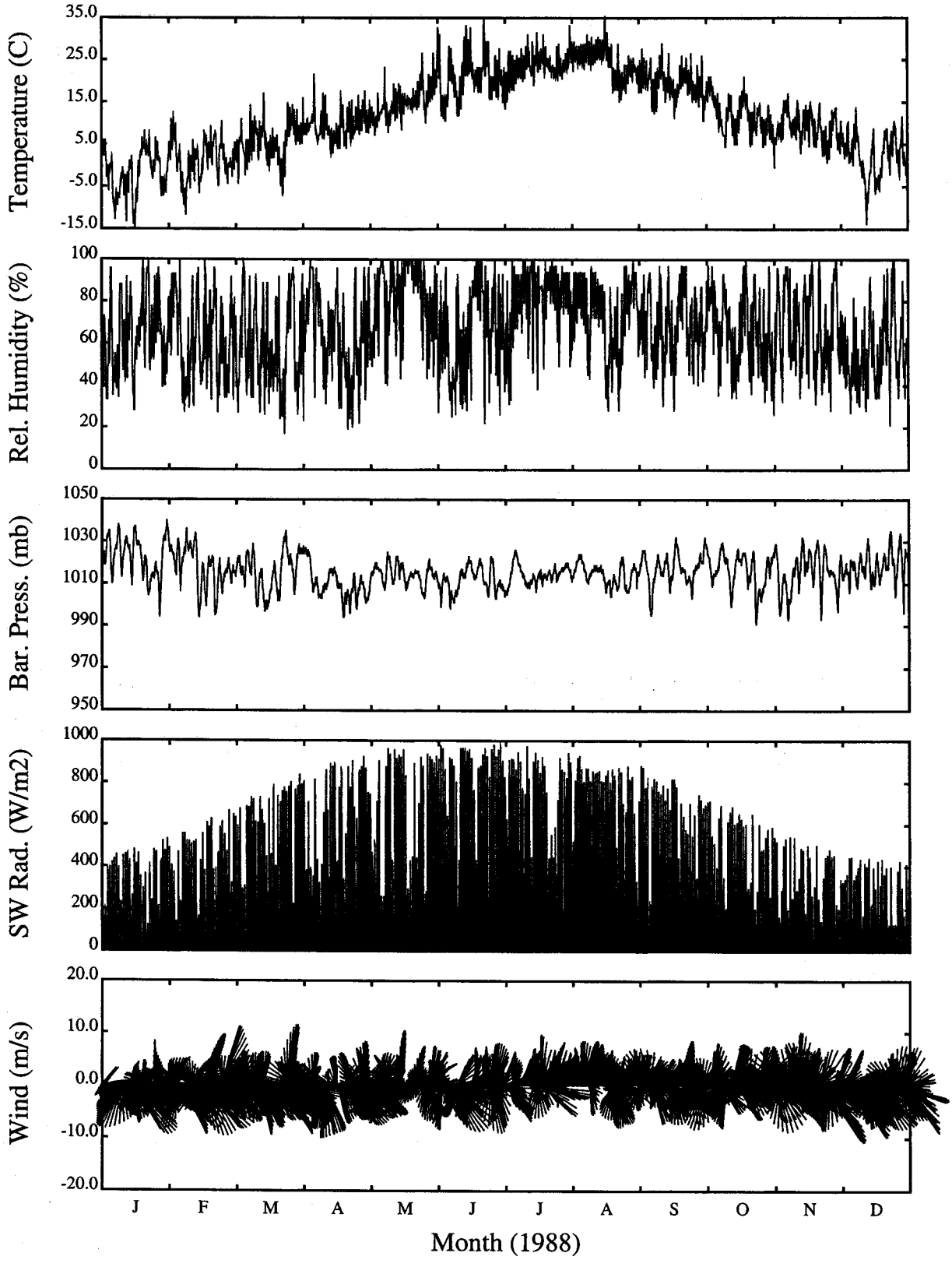


Figure 2-19. NCM Meteorological Inputs

larger rain events, the model would not remain stable using a z_0 within this range (0.001-0.003 m) and a computational time step that would allow a reasonable run time to complete an annual simulation. In order to run the model for the full year and remain stable a z_0 of 0.05 m was used. The model was calibrated to this value. The result was enormously high shear stresses during some storm events. To avoid these erroneous results, the model was run using a z_0 of 0.003 m for a shorter period to analyze the critical period of interest to the USACE presented in this report. In other words, while the model could not be run for the full year using a more commonly accepted value for z_0, the model was able to be run for the critical conditions chosen. The end result for this critical period was that the model computed slightly lower DO levels but more reasonable shear stresses.

2.2.2.2 Water Quality Model

The water quality model also requires several inputs in order to complete a simulation. These inputs include hydrodynamic forcings (from the hydrodynamic model), constants and parameters, time variable functions, boundary conditions, and loadings. The hydrodynamic forcings from the model include temperature, salinity, elevation, flows and dispersion. A listing of the constants and parameters is presented in Appendix A. The time variable functions include solar radiation, wind, and length of daylight. The solar radiation is necessary for the phytoplankton growth kinetics and the wind is required to calculate the reaeration rate. Both of these functions were presented in the previous section. The length of daylight simply indicates the fraction of the day that sunlight is present to fuel phytoplankton growth. Boundary conditions and loads will be presented in the following sections.

Boundary Conditions

Boundary conditions are required for each of the 26 systems in the model. These boundary conditions were assigned on an hourly basis and were obtained from JEM and the Jamaica Bay Coliform Model (JCM). Modifications were made to the dissolved oxygen boundary conditions to more appropriately represent the available data. In general, this meant decreasing the DO concentration in the bottom layers during the summer. The boundary conditions were assigned at six standard levels (depths = 0, 2, 4, 6, 8, and 12 meters) and then interpolated to the appropriate sigma levels at the actual boundaries of the model. For most of the model systems, the differences between the concentrations assigned at the six levels are relatively small. Figures presenting most of the assigned boundary conditions for the surface and bottom levels for the eastern and western boundaries are presented in Appendix D. The boundary conditions for DO are presented below.

Figure 2-20 presents the surface and bottom assigned DO boundary concentrations for the western and eastern boundaries. At both boundaries the DO concentrations remain above 9.0 mg/L

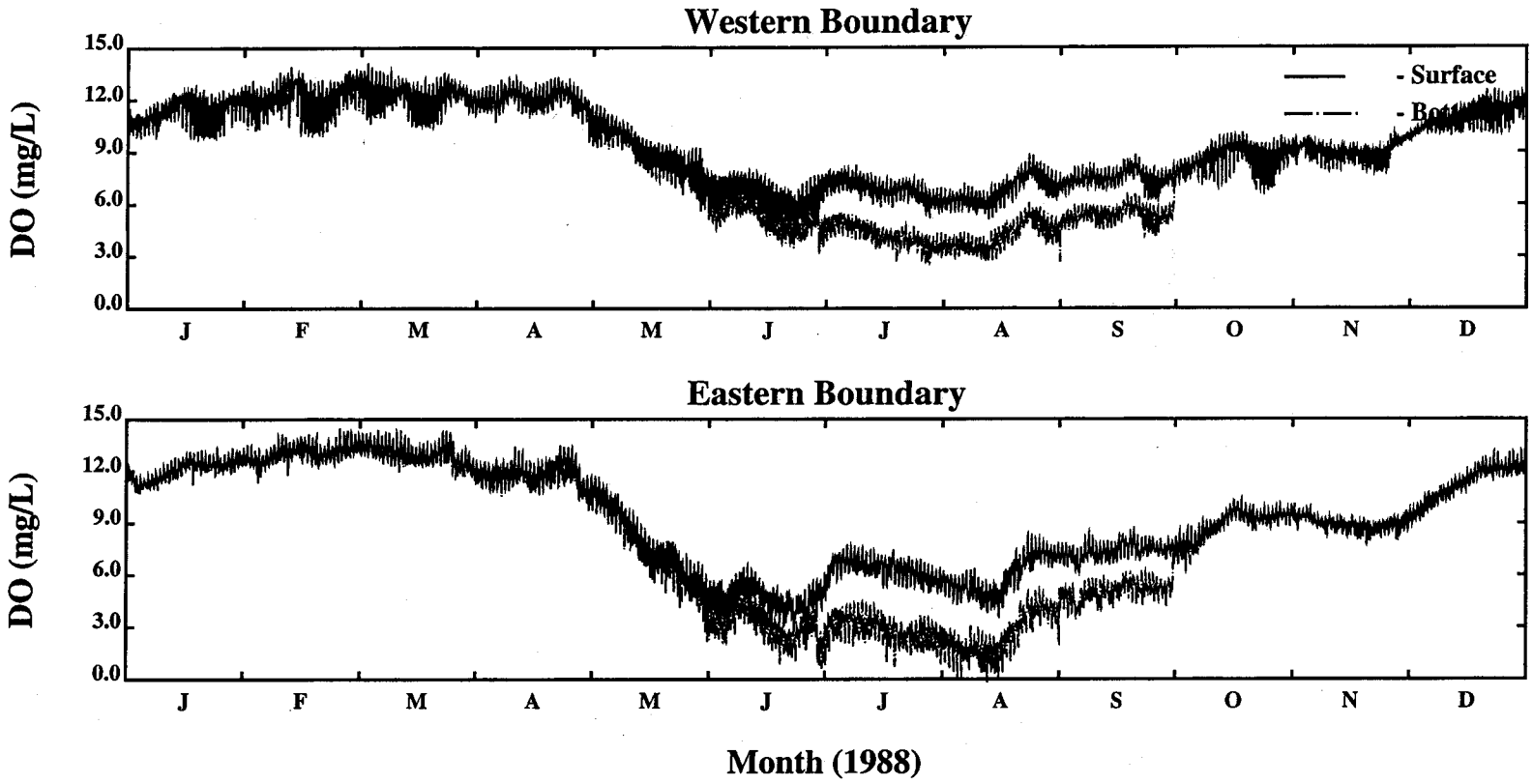


Figure 2-20. NCM DO Boundary Conditions

from January until near the end of April. During late-April and May the DO concentrations decline rapidly, with the eastern boundary conditions declining to a lower level. During June, boundary conditions become stratified and remain this way until the end of September. Well mixed DO boundary conditions are assigned from October through the end of December. On the western side of the model the boundary conditions decline to below 5.0 mg/L which is the DO standard for that portion of the bay. On the eastern side, DO concentrations are even lower with levels approaching anoxic conditions. These boundary conditions are important because they influence the DO concentrations that are computed in the creeks.

Loads

The model load inputs are separated into several components. The components include riverine, atmospheric, non-point sources, and point sources. There were no riverine sources included in the model. The atmospheric sources include wet-fall and dry-fall. While dry-fall occurs all the time and wet-fall occurs only when there is precipitation, the atmospheric loads were simplified due to their relatively small contribution to the overall loading. The concentrations assigned to the various constituents for wet-fall and dry-fall are presented in Table 2-2. These concentrations were based on data collected during the Jamaica Bay Eutrophication Study and literature values. The atmospheric loading was assigned on a monthly basis and varied according to the rainfall that occurred during each month. The atmospheric loads are presented in Table 2-3.

Table 2-2. Wet Deposition Concentrations and Areal Dry Deposition Rates used to Estimate Atmospheric Loadings

Constituent	Wet Fall (mg/L)	Dry Fall (mg/m^2-yr)
LDOP	9.0	0.0
DIP	11.0	0.0
LPON	107.0	33.7
LDON	422.0	0.0
NH_4	145.0	0.0
$NO_2 + NO_3$	354.0	246.7
LDOC	1300.0	0.0

Non-point sources included the Fountain Avenue and Pennsylvania Avenue Landfill. These sources were relatively small, although in some cases they are larger than the atmospheric loads. Without specific knowledge as to how these loads change with time, they were assigned with a constant rate. Portions of the load are assigned to Fresh Creek, Hendrix Creek, Spring Creek and Jamaica Bay. The total landfill load is displayed in Table 2-4. The organic loads were divided evenly between refractory and labile fractions. These loads are the same as those used in JEM.

Table 2-3. Monthly/Annual Atmospheric Loads

Month	LDOP	DIP	LPON	LDON	NH_4	NO_2+NO_3	LDOC
				(kg/d)			
January	0.2	0.2	3.1	9.2	3.1	13.4	28.2
February	0.3	0.3	3.8	12.1	4.1	15.8	37.1
March	0.1	0.2	2.6	7.0	2.4	11.6	21.5
April	0.1	0.2	2.3	6.1	2.1	10.8	18.7
May	0.3	0.4	4.5	14.9	5.1	18.2	45.8
June	0.1	0.1	2.0	4.6	1.6	9.6	14.2
July	0.4	0.5	5.7	19.6	6.7	22.1	60.3
August	0.1	0.2	2.3	5.9	2.0	10.7	18.1
September	0.2	0.2	3.0	8.6	3.0	12.9	26.5
October	0.2	0.3	3.3	9.9	3.4	14.0	30.4
November	0.4	0.5	5.9	20.1	6.9	22.6	62.0
December	0.1	0.1	1.6	3.2	1.1	8.4	9.8
Annual	0.2	0.3	3.3	9.8	3.4	14.0	30.3

Table 2-4. Daily Landfill Loads

Constituent	Load (kg/d)
DON	38.6
NH_4	140.7
NO_2 + NO_3	4.4
DOC	288.8

The CSO loads were developed in several different ways depending on the constituent. However, all of the loads were computed using flows from the SWMM model with the exception of Paerdegat Basin which used RAINMAN output. The phosphorus, nitrogen, and silica loads were based on the constant concentrations listed in Table 2-5. These concentrations were multiplied by the CSO flow computed by SWMM. Different concentrations were assigned to each of the CSOs based on data collected as part of the Jamaica Bay Eutrophication Study. These are the same concentrations that were used in JEM. The loads that were developed from these concentrations are presented in Table 2-6.

Table 2-5. CSO and Storm Sewer Nutrient Concentrations (mg/L)

Constituent	Paerdegat Basin	Fresh Creek	Hendrix Creek	Spring Creek	Storm Sewer
LPOP	0.21	0.28	0.25	0.37	0.11
LDOP	0.23	0.20	0.20	0.08	0.05
DIP	0.34	0.25	0.33	0.25	0.11
LPON	1.47	1.87	1.74	1.82	0.60
LDON	1.10	0.62	0.35	0.41	–
NH_4	1.59	1.98	2.44	2.23	0.27
$NO_2 + NO_3$	0.23	0.32	0.82	0.75	0.51
DSi	1.53	1.79	4.00	2.49	1.45

Table 2-6. CSO and Storm Sewer Annual Nutrient Loading

	Paerdegat Basin	Paerdegat Basin	Fresh Creek	Fresh Creek	Hendrix Creek	Spring Sewer
Constituent	CSO	SS	CSO	SS	CSO	CSO
			(kg/d)			
LPOP	5.52	0.28	2.89	0.43	0.22	2.78
LDOP	6.05	0.13	2.07	0.19	0.17	0.60
DIP	8.94	0.28	2.58	0.43	0.29	1.88
LPON	38.65	1.51	19.32	2.33	1.51	13.66
LDON	28.92	–	6.40	–	0.30	3.08
NH_4	41.81	0.68	20.45	1.05	2.12	9.23
$NO_2 + NO_3$	6.05	1.28	3.31	1.98	0.71	5.70
DSi	40.23	3.65	18.49	5.62	3.48	18.69
Avg. Flow (MGD)	6.94	0.66	2.74	1.03	0.23	1.99

Average daily flows (total annual overflow volume/366.) have been added to the table for comparison purposes.

The carbon loads were estimated by a different manner than the nutrient loads. First, O'Brien and Gere ran SWMM with a conservative tracer assigning one concentration to the sanitary flow and another to the stormwater flow. Based on the concentrations of the tracer computed at each CSO by SWMM, HydroQual computed the fraction of stormwater and the fraction of sanitary flow being discharged at each location. The carbon loads were then developed in an attempt to reproduce a BOD versus overflow curve developed by O'Brien and Gere based on composite data collected at the Fresh Creek CSO. This curve is defined by Equation 2-1. Since NCM does not include BOD as one of its state-variables, concentrations were assigned to each of the carbon state-variables for both the sanitary flow and the stormwater flow in an attempt to reproduce the BOD curve. By adjusting the concentrations assigned for the stormwater and sanitary flow into the various carbon reactivity classes, a reasonable reproduction of the BOD versus overflow curve was developed for Fresh Creek. O'Brien and Gere requested that this curve be used for all of the CSOs in the model. The carbon concentrations and loads are presented in Tables 2-7 and 2-8, respectively.

$$\text{BOD}\,(\text{mg}/\text{L}) = 152.494 - 37.89 \times \ln(\text{overflow volume in MG}) \qquad (2\text{-}1)$$

Table 2-7. Sanitary and Stormwater Carbon Concentrations

Constituent	Sanitary	Stormwater
	(mg/L)	
RPOC	20.	3.0
LPOC	70.	7.0
RDOC	5.	1.0
LDOC	10.	1.0
ReDOC	100.	0.5
Effective BOD	245.	4.8

Table 2-8. CSO and Storm Sewer Annual Carbon Loading

Constituent	Paerdegat Basin CSO	Paerdegat Basin SS	Fresh Creek CSO	Fresh Creek SS	Hendrix Creek CSO	Spring Creek CSO
			(kg/d)			
RPOC	149.52	7.54	67.97	11.63	3.83	65.65
LPOC	451.11	17.60	209.3	27.14	10.61	212.42
RDOC	42.54	2.51	19.03	3.88	1.15	17.65
LDOC	64.44	2.64	29.91	4.67	1.52	30.35
ReDOC	448.51	1.26	221.73	1.94	7.60	256.33
Effective BOD	1171.5	12.3	571.8	19.0	21.5	644.8

The storm sewer concentrations and loads have been included in the CSO tables presented above (Table 2-5 - Table 2-8). The loads were developed using output from RAINMAN and constant concentrations. These concentrations were estimated from data collected during the Jamaica Bay Eutrophication Study. The nutrient concentrations are the same as those used for JEM. The carbon concentrations were modified during the process of fitting the Fresh Creek CSO BOD curve.

The final set of loads is the effluent from the 26th Ward WPCP that discharges into Hendrix Creek. Loads were estimated using the flow estimates from SWMM and constant concentrations. The base flow was set at 65 MGD for the WPCP, but with the contribution of the stormwater flow the annual average flow was 67.8 MGD. The loads were based on 1988 concentrations. Table 2-9 presents the concentrations and loads from the 26th Ward WPCP. A base flow of 71 MGD was used for the scenarios run with CSO improvements. This flow represents the estimated year 2045 flows.

Table 2-9. WPCP Concentrations and Loads

Constituent	Concentration (mg/L)	Load (kg/d)
RPOP	0.09	23.1
LPOP	009	23.1
RDOP	0.09	23.1
LDOP	0.09	23.1
DIP	0.60	154
RPON	1.20	308
LPON	1.20	308
RDON	1.20	308
LDON	1.20	308
NH_4	7.40	1,900
$NO_2 + NO_3$	0.76	195
Dsi	630	1,620
RPOC	4.0	1,025
LPOC	4.0	1,025
RDOC	6.0	1,540
LDOC	6.0	1,540
DO	6.0	1,540
T. Coli (org/100 ml)	20.0	–
F. Coli (org/100 ml)	4.0	–
Effective BOD	9.2	2,365

SECTION 3

JEM MODEL RESULTS

3.1 SCENARIOS

Six scenarios were evaluated using JEM. These scenarios were based on 1995-96 meteorological, tidal, and loading conditions. Only bathymetric changes were made. The scenarios include the following: (1) Remove the runway extention to a depth of 30 ft below mean low water (MLW), (2) Fill Grassy Bay to 15 ft below MLW, with the runway extention removed to a depth of 15 ft below MLW, (3) Remove the center 1000 ft of the runway extention to a depth of 30 ft below MLW, (4) Fill Grassy Bay to 15 ft below MLW and remove the center 1000 ft of the runway extension to 15 ft below MLW, (5) Remove the center 1000 ft of the runway extension to a depth of 30 ft below MLW and dredge the North Channel and Beach Channel to a depth of 30 ft below MLW, and (6) Fill Grassy Bay to 15 ft below MLW and remove the center 1000 ft of the runway to 15 ft below MLW, and dredge the North Channel and Beach Channel to a depth of 30 ft below MLW. These scenario numbers will be used in the section heading to follow. Each scenario provides information on how to improve flushing in the back end of the bay to improve water quality and, in conjunction improve habitat.

Results of these six scenarios will be presented as well as results from the calibration to determine the effect of the bathymetric changes on conditions within Jamaica Bay. The model results that will be presented include current velocity, bottom shear stress, salinity and dissolved oxygen. The two spring tide conditions that occurred in July 1995 have been chosen for presentation purposes. The periods chosen occurred during period of low DO in Jamaica Bay. The tidal cycles chosen are presented in Figure 3-1. The shaded regions in the top panel are shown in more detail in the bottom two panels. Results were calculated on an hourly average basis for both spring tides (and an average of the two spring tides). While all of the figures will be available in Appendix E, only some of the figures will be presented in this section for comparative purposes. The hours are labeled 1 through 24, with 1 through 12 representing the first tidal cycle and 13 through 24 representing the second tidal cycle. Both tidal cycles start at approximately the same time in the tidal cycle, mean tide during flood tide (based on conditions in Grassy Bay). The first tidal cycle has a greater tide range and occurs during more saline conditions. The second tidal cycle occurs during conditions of lower DO and fresher conditions.

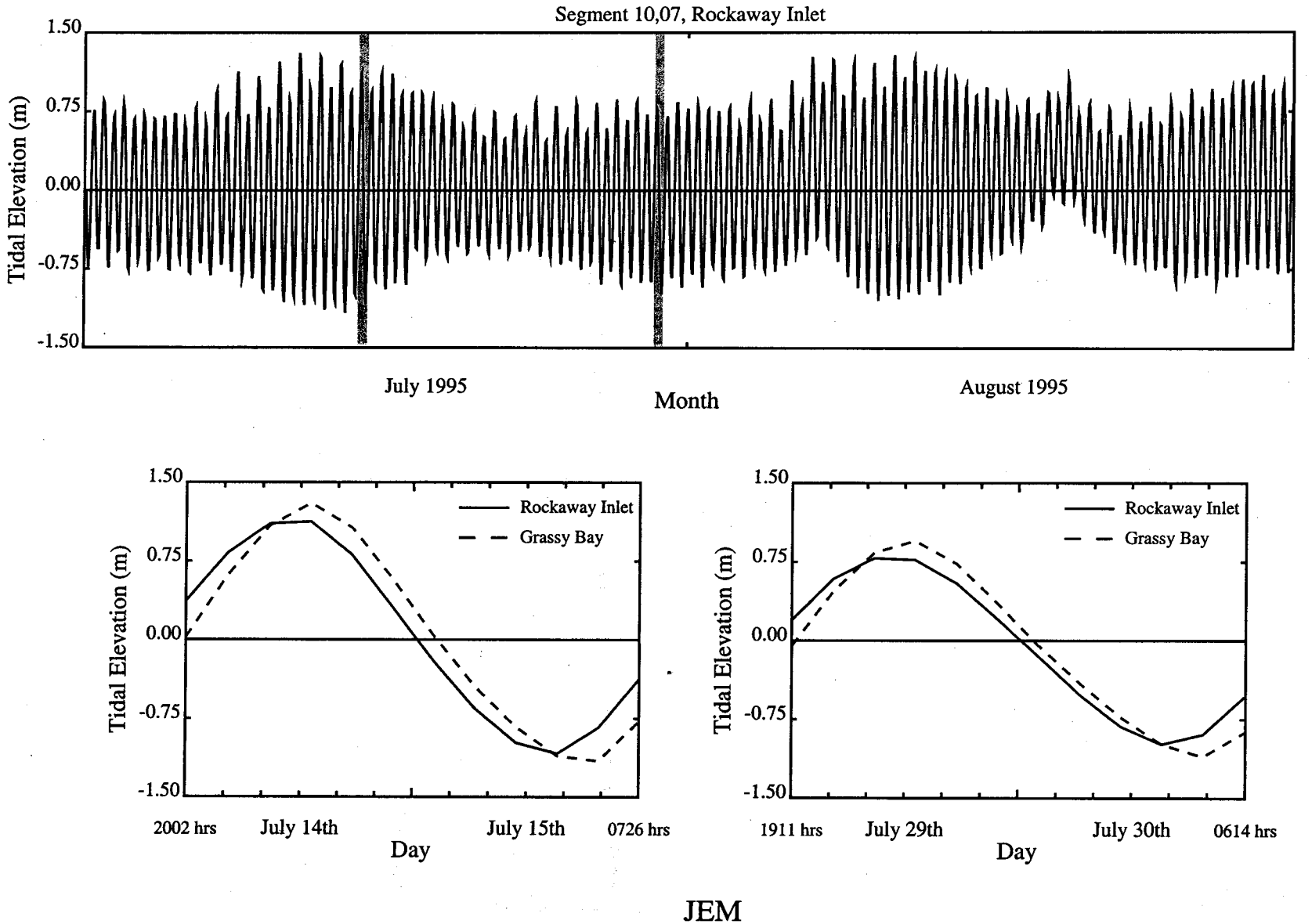


Figure 3-1. Tidal Conditions for Two Periods in July

3.2 CALIBRATION

3.2.1 Bathymetry

The bathymetry for the calibration conditions is presented in Figure 3-2. The segmentation is shown in model space so all of the segments, including the tributaries, are shown as being equal in size. The depths are shown with respect to mean tide, which is the datum that was chosen for the model. The colors indicate 1.5 m increments with blue representing a water depth of 0.0 to 1.5 m and red indicating a depth of greater than 10.5 m. Figure 3-2 shows that under the calibration conditions, the deeper waters are located along the outside of the bay in the Rockaway Inlet, the North Channel, Beach Channel and Grassy Bay. The central portion of the bay is shallower and is were most of the marshland is located. Also note the two white squares in the eastern portion of the bay. These represent the runway extension from the JFK Airport.

3.2.2 Dissolved Oxygen

One hour out of each of the two chosen tidal cycles has been chosen to present comparisons between the calibration or "existing conditions" and the various scenarios. These hours are hour 11 in the first tidal cycle (near low tide) and hour 16 in the second tidal cycle (near high tide). Figure 3-3 presents hour 11 conditions. Most of the bottom water in the bay has a DO concentration greater than 5.25 mg/L. However, in Grassy Bay and many of the tributaries, lower DO concentrations are computed by the model. In the area east of the runway, the DO is greater than 4.5 mg/L.

During hour 16 (Figure 3-4), the DO levels are quite low in Grassy Bay, generally less than 2.25 mg/L. On the eastern side of the runway, there are areas with computed DO concentrations less than 3.0 mg/L. The remainder of the bay generally has DO concentrations greater than 5.25 mg/L based on model results.

3.2.3 Velocity and Shear Stress

Figures presenting velocity vectors and shear stress have been developed for each of the 24 hours for each of the scenarios. To present comparisons between the scenarios, two hours have been chosen. These include hour 1, which is mean tide during flood tide, and hour 19, which is mean tide during ebb tide. The colors on these figures represent the shear stress (tau) on a scale of 0.0 (blue) to 2.0 dyne/cm^2 (red). The arrows represent bottom current vectors and are compared to the 1.0 m/s velocity arrow located in the upper right corner of the figures.

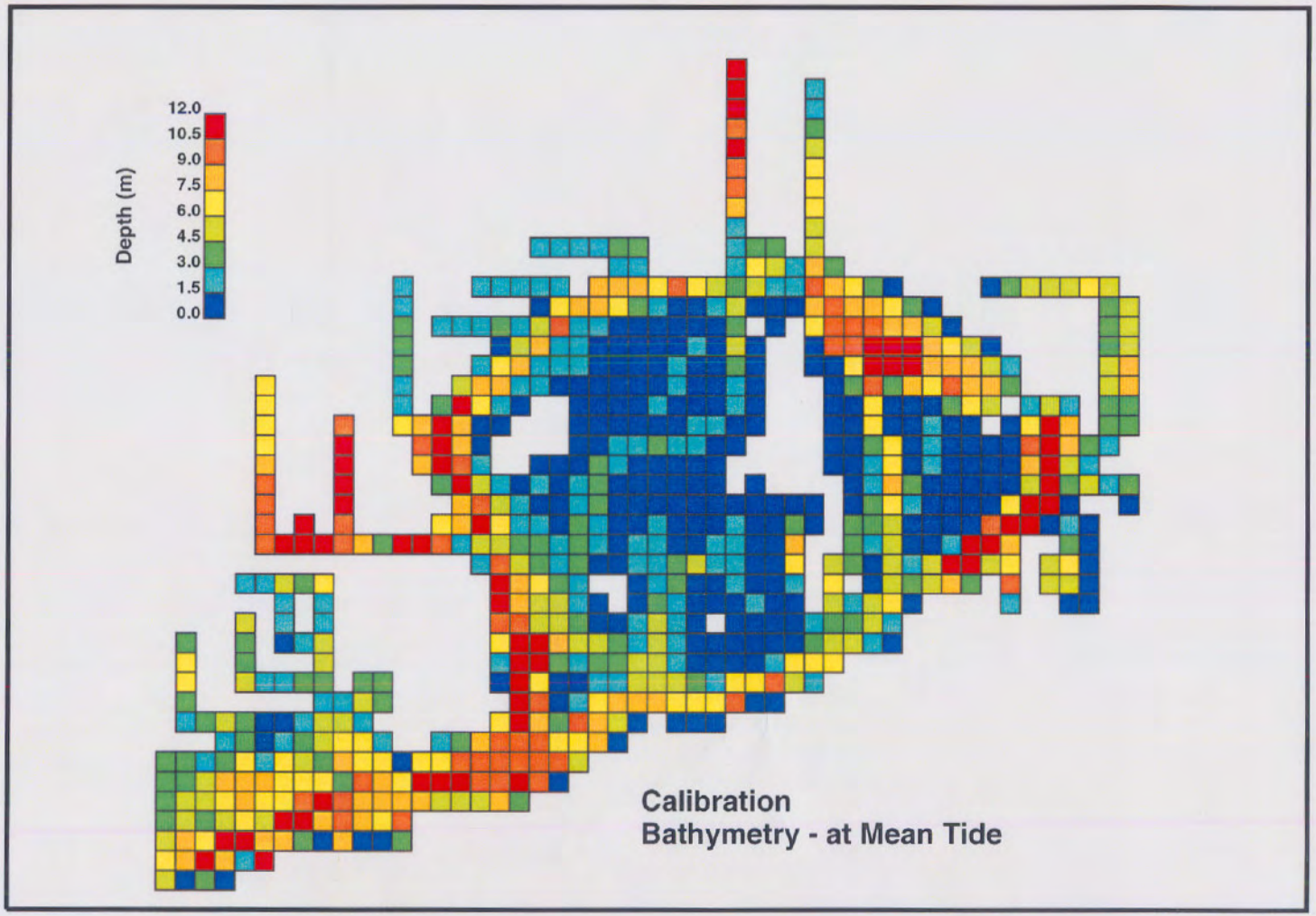


Figure 3-2. JEM Bathymetry - Calibration Conditions

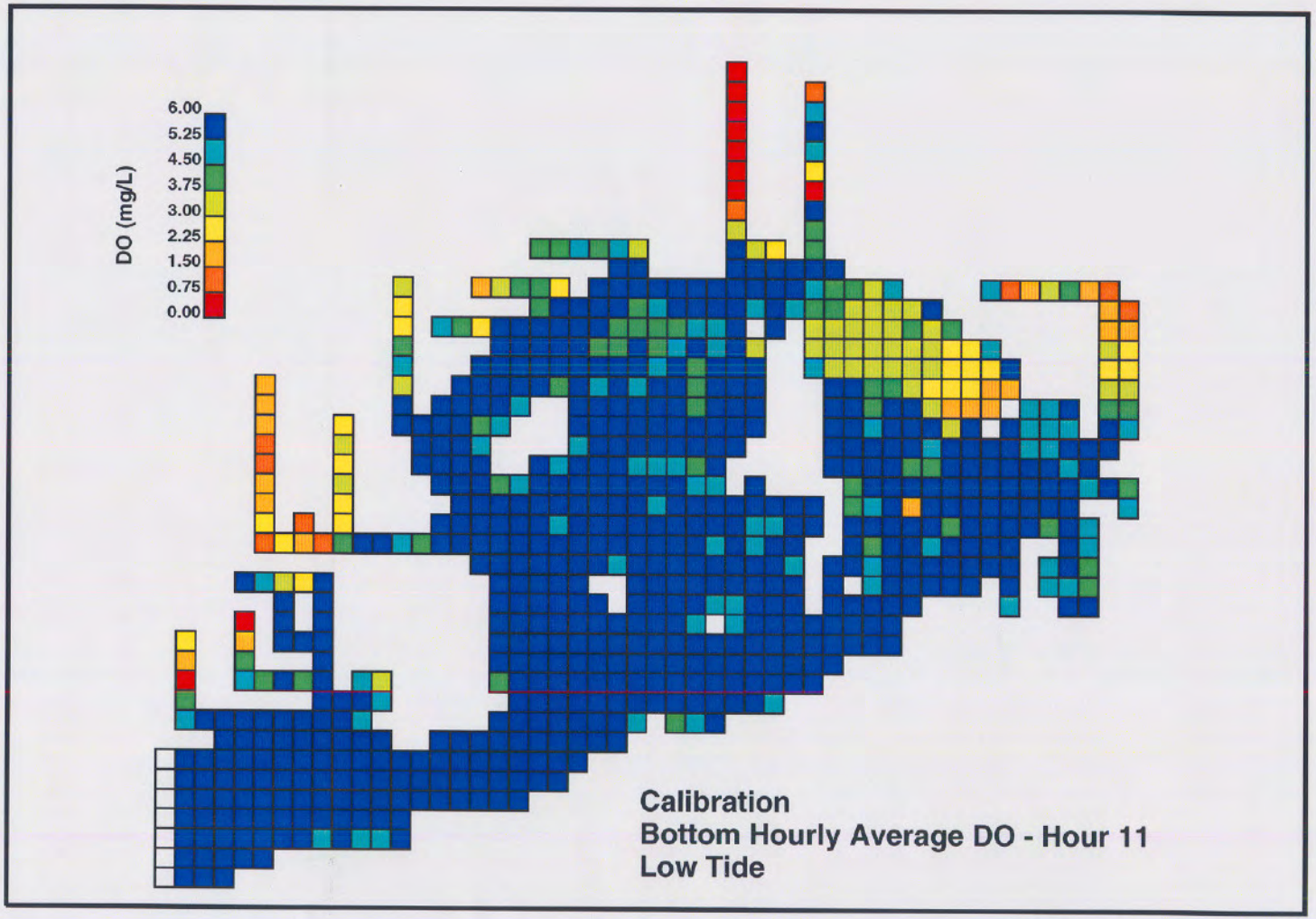


Figure 3-3. JEM Bottom DO - Hour 11 - Calibration

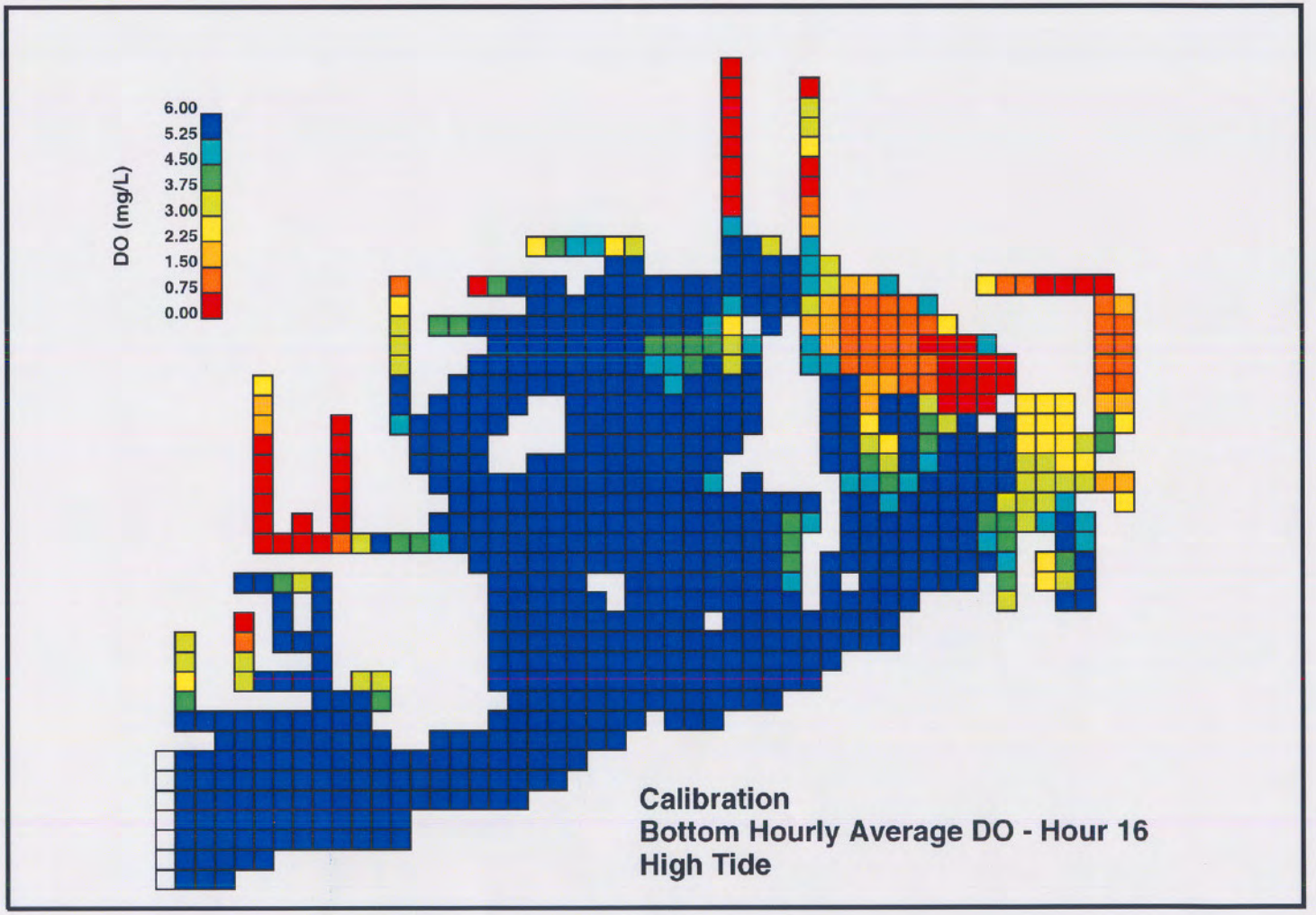


Figure 3-4. JEM Bottom DO - Hour 16 - Calibration

Figure 3-5 presents the hour 1 results for the calibration conditions. A large area of the bay is experiencing shear stresses greater than 1.0 dyne/cm^2, which would indicate a non-depositional zone during this period. The higher shear stresses subside in the back end of the bay. Low shear stresses are computed in Grassy Bay, the tributaries, and in some of the marsh areas indicating areas where deposition may occur during this period.

Hour 19 results are presented in Figure 3-6. This ebb tide occurs during a less energetic tidal cycle (smaller tidal range) than hour 1. A smaller area of the bay is in the greater than 1.75 dyne/cm^2 range. The high shear stresses are observed in the deep outer channels and the Rockaway Inlet where the higher velocities are found.

3.2.4 Salinity

The salinity in Jamaica Bay can be used to show water movement in the bay. The salinity is also important because it will determine what organisms can survive in the various areas of the bay. In general, Jamaica Bay is fresher in the back end of the bay, in Grassy Bay, and more saline with proximity to the Rockway Inlet and the Atlantic Ocean. The salinity figures to follow have a range of 27.0 ppt (blue) to 31.0 ppt (red) and show the bottom water concentrations. Four hours will be shown for the calibration (4, 11, 16, and 23) during high tide and low tide, and two hours will be shown (4 and 11) for the remaining scenarios unless noticeable differences can be observed between the various scenarios.

Figure 3-7 presents the salinity results for high tide (hour 4) under the calibration conditions. Saline water has penetrated through the Rockaway Inlet and into the western portion of the bay. The freshest area of the bay is Grassy Bay. During hour 11 (Figure 3-8), the more saline water has retreated from the Rockway Inlet and the area with a salinity less than 28.0 ppt has greatly expanded. During hour 16, high tide, much more of the bay has a salinity concentration less than 27.5 ppt and the Rockway Inlet has a salinity between 29.5 and 30 ppt as shown in Figure 3-9. Figure 3-10 (hour 23) shows more of the bay with a salinity of less than 27.5 ppt.

3.3 SCENARIO 1

3.3.1 Bathymetry

Scenario 1 involves the removal of the JFK Airport runway extension to a depth of 30 ft MLW. While the runway extension would never be removed, it could be possible to replace the extension with one that would allow flow to pass beneath it. Figure 3-11 shows the modified bathymetry. In the area

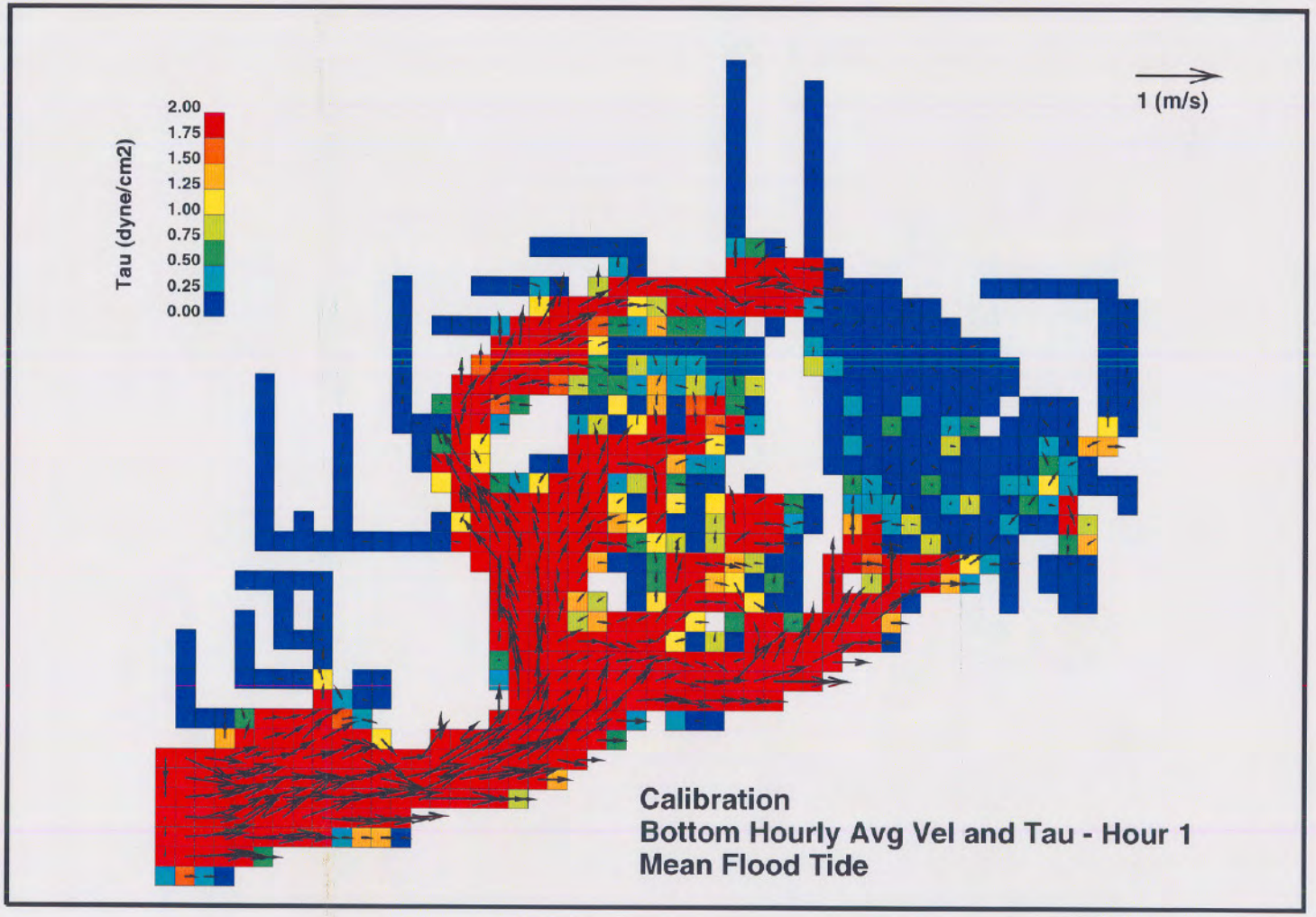


Figure 3-5. JEM Current Velocity and Shear Stress - Hour 1 - Calibration

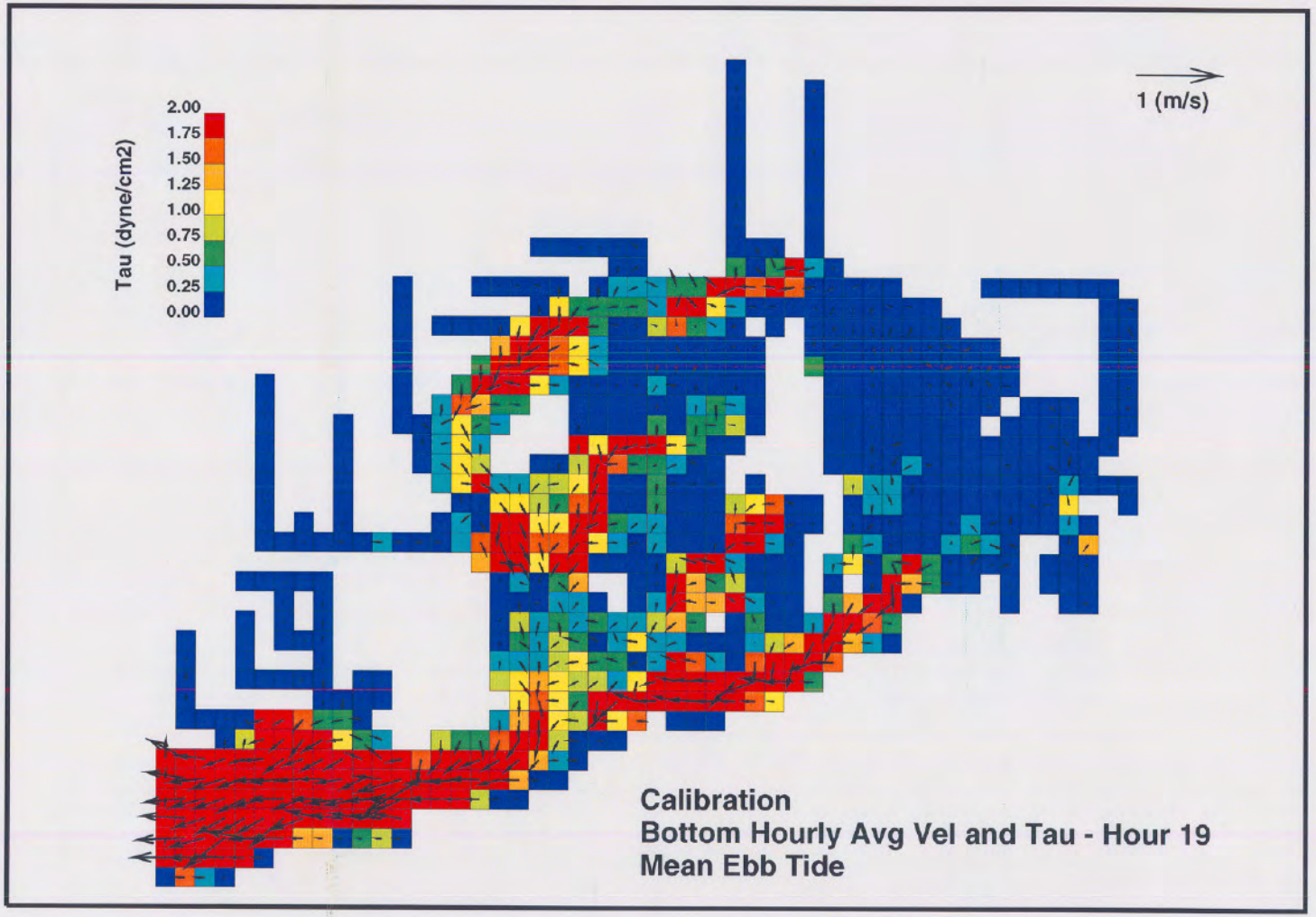


Figure 3-6. JEM Current Velocity and Shear Stress - Hour 19 - Calibration

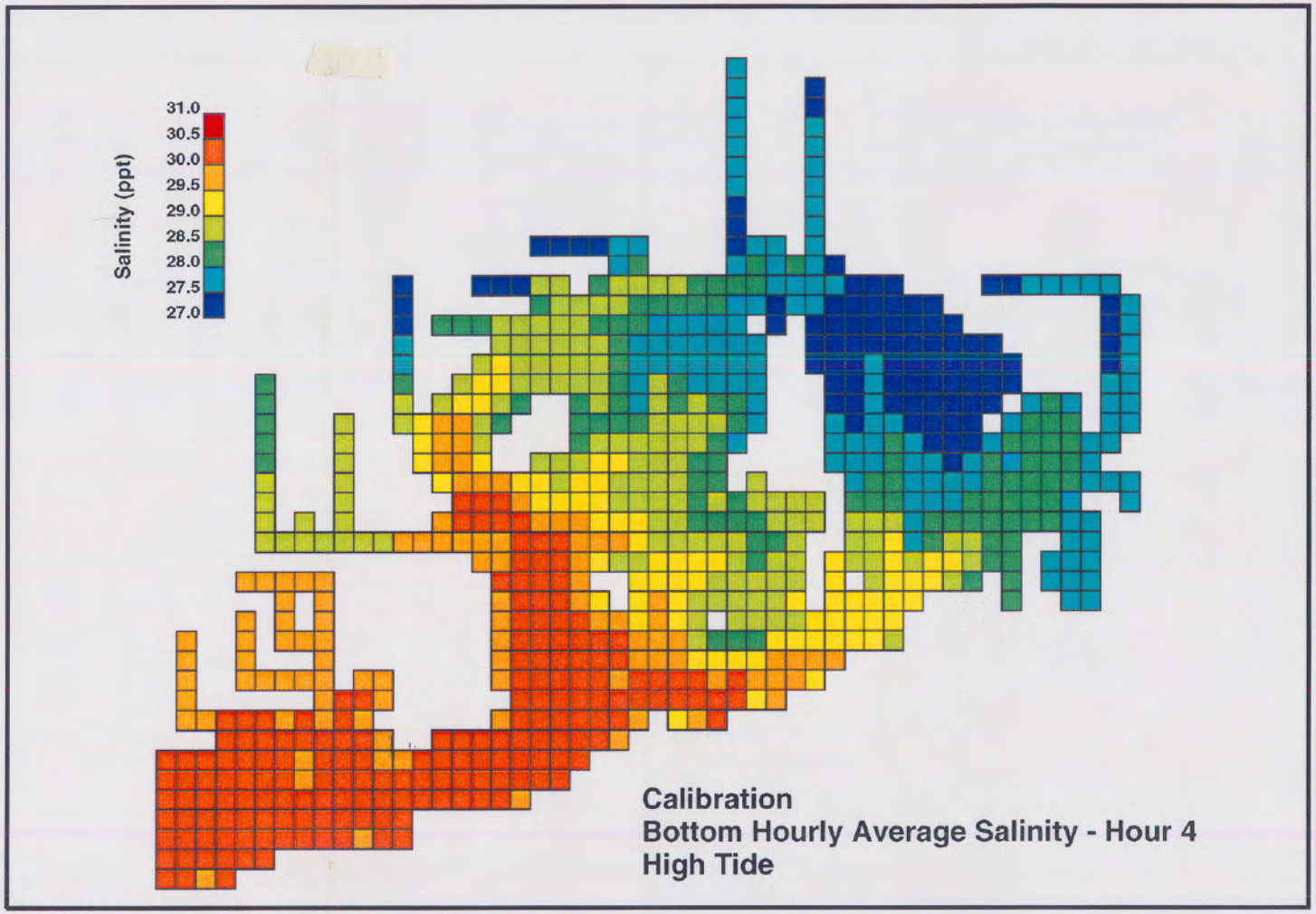


Figure 3-7. JEM Bottom Salinity - Hour 4 - Calibration

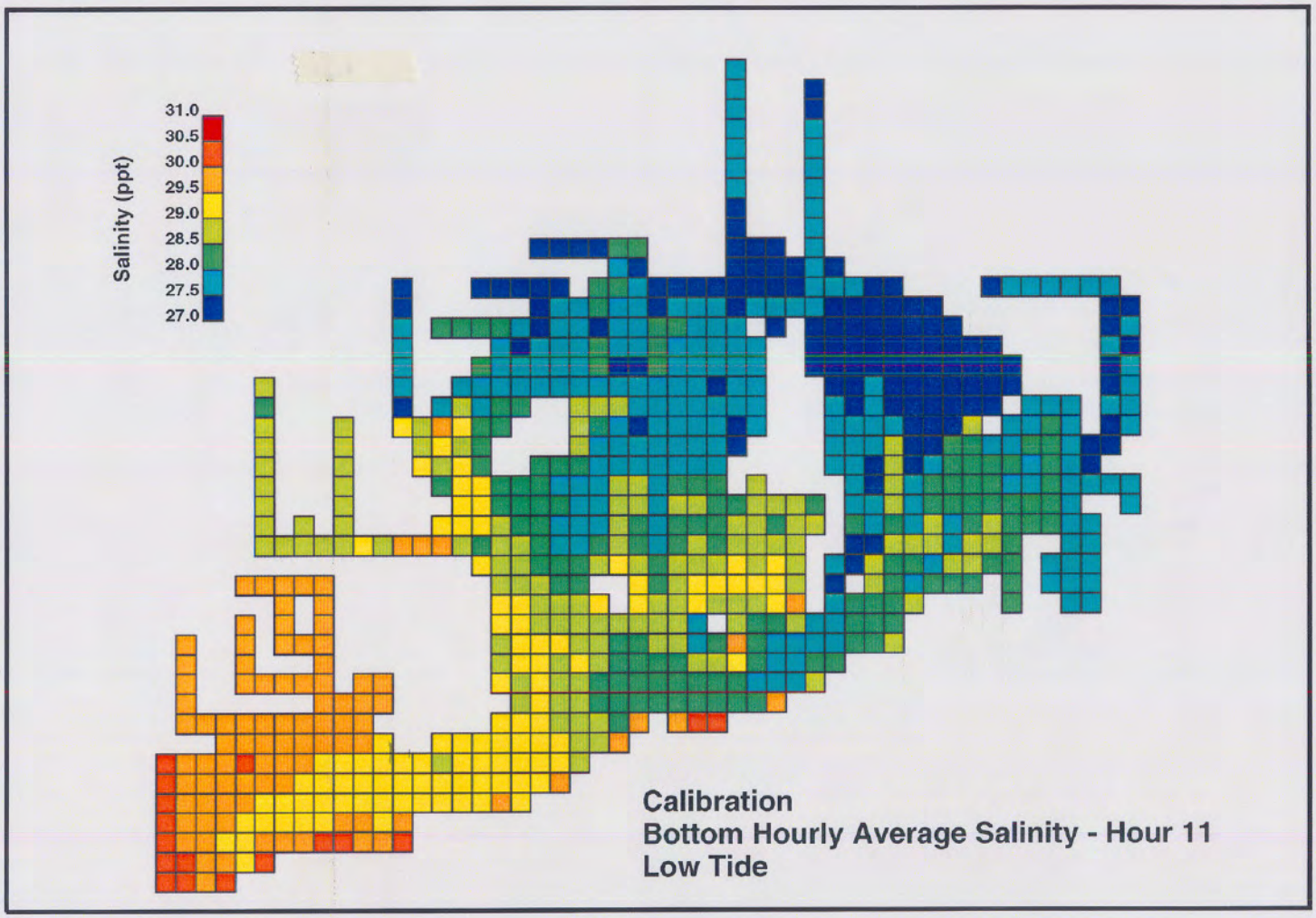


Figure 3-8. JEM Bottom Salinity - Hour 11 - Calibration

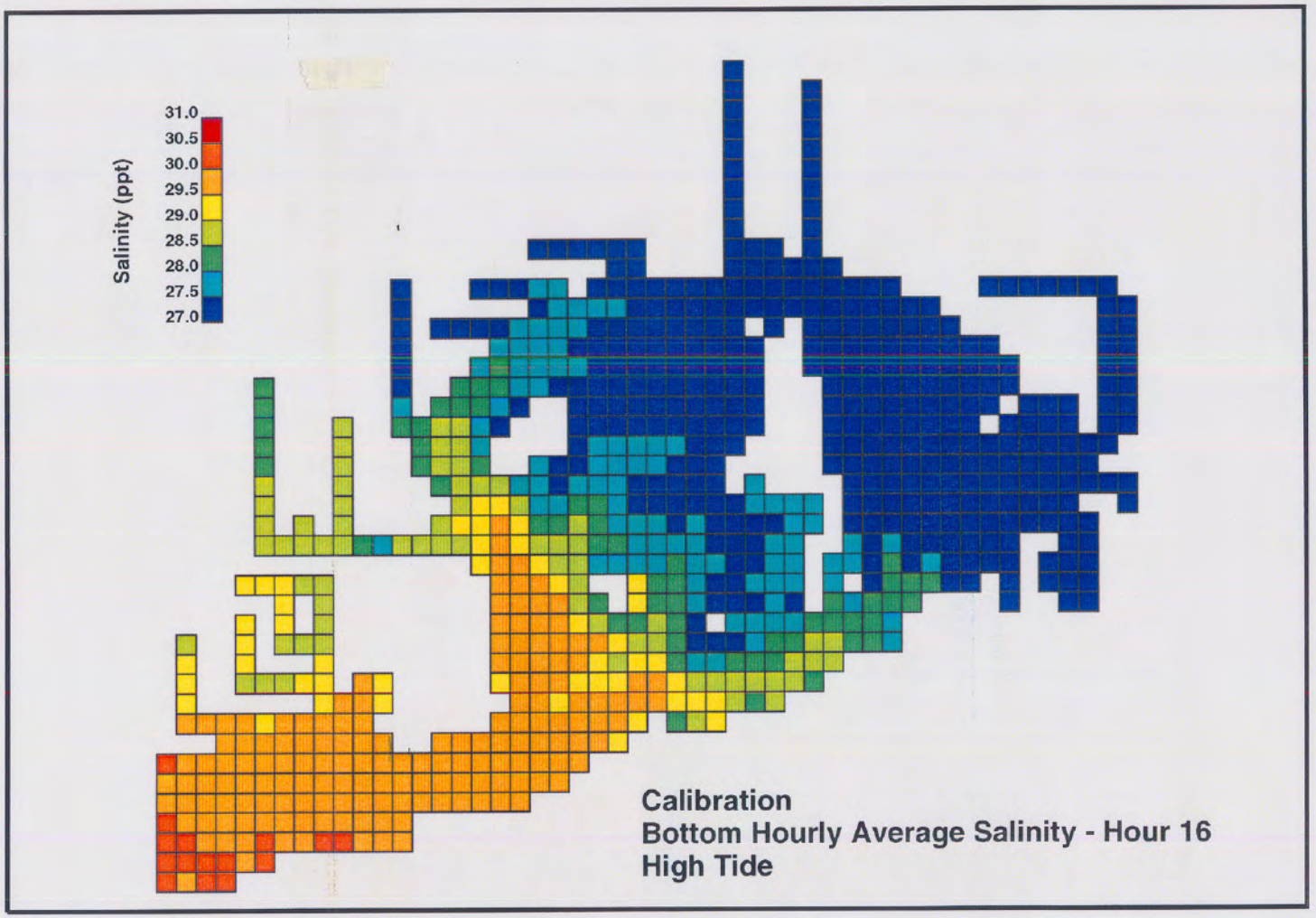


Figure 3-9. JEM Bottom Salinity - Hour 16 - Calibration

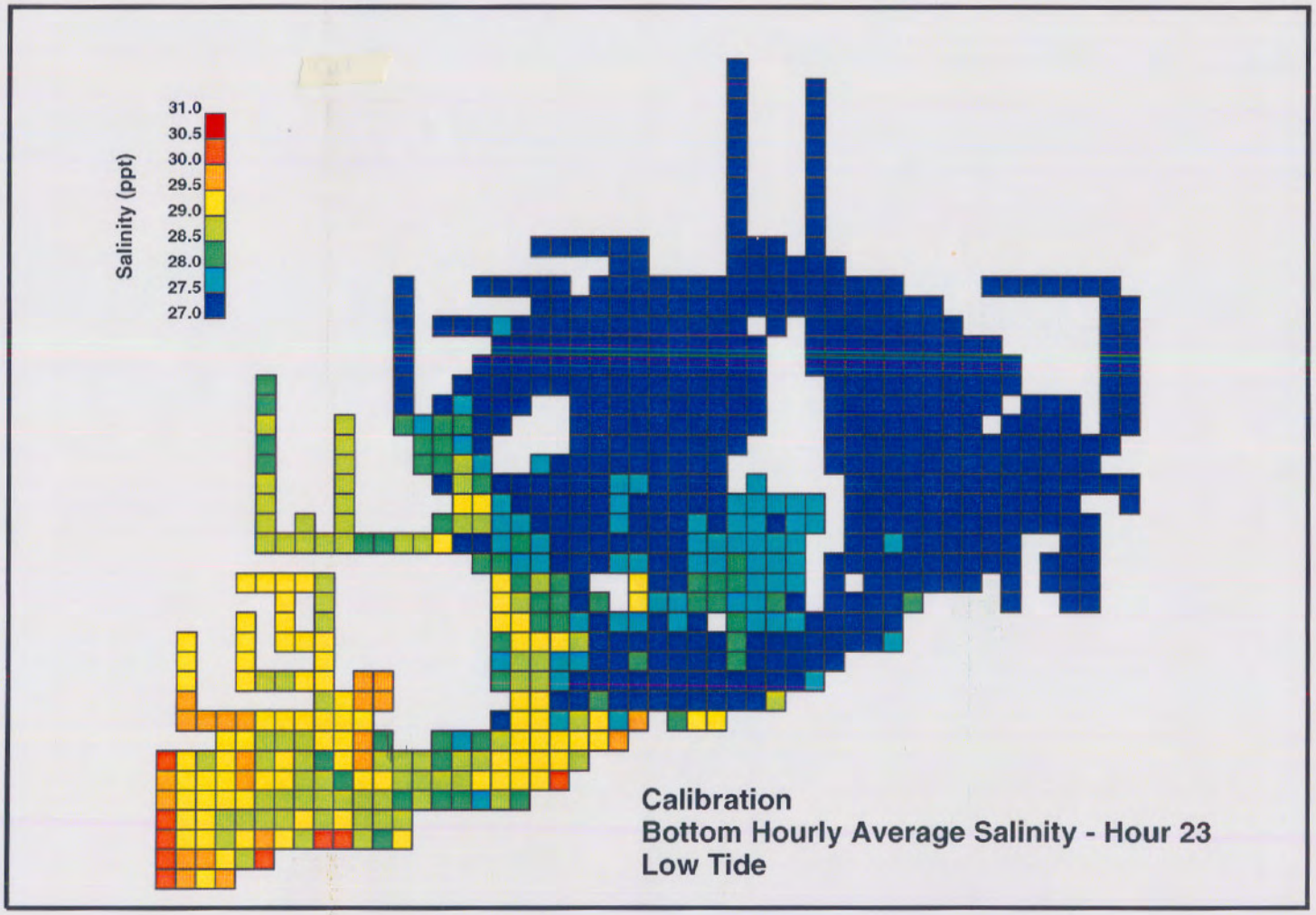


Figure 3-10. JEM Bottom Salinity - Hour 23 - Calibration

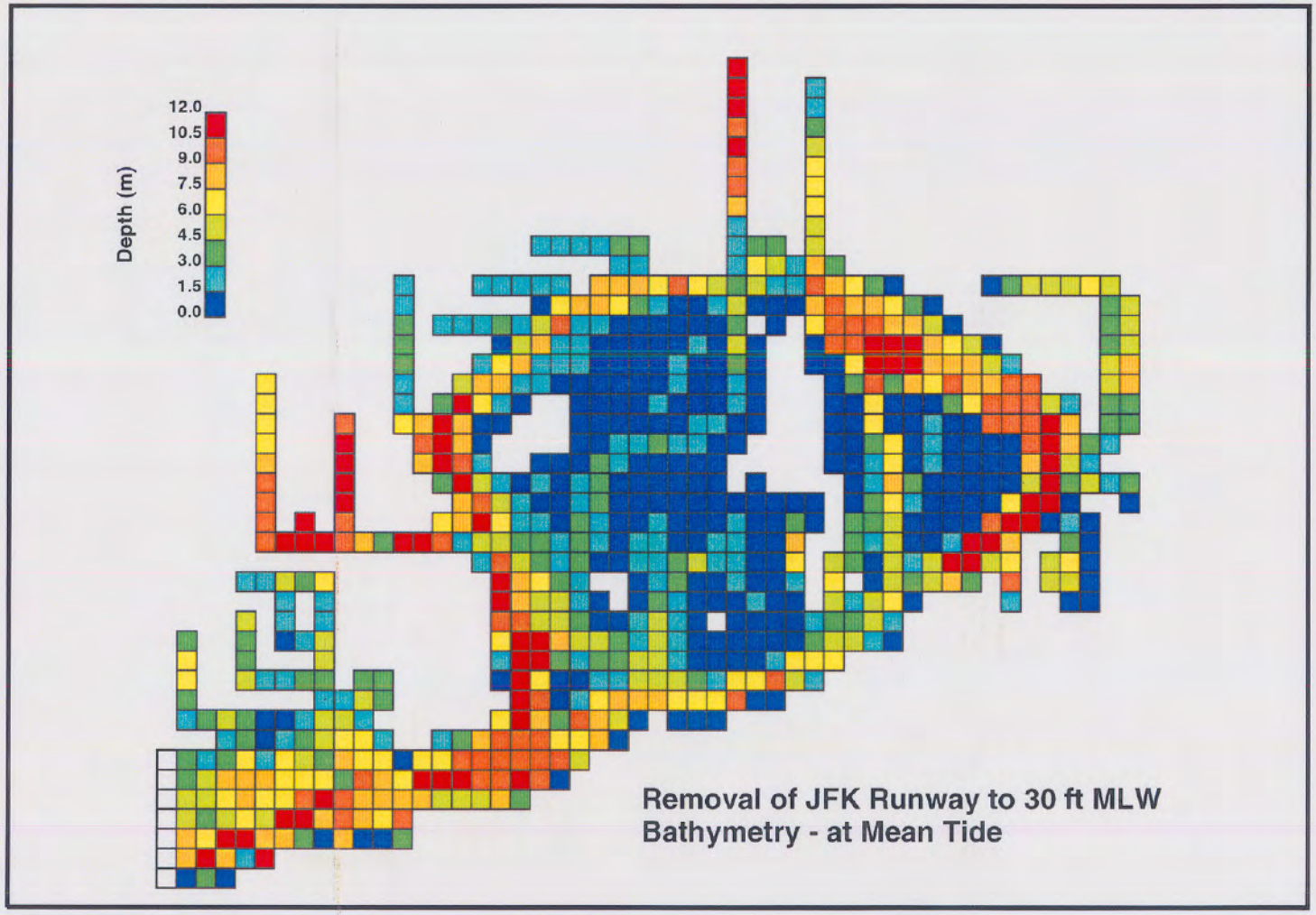


Figure 3-11. JEM Bathymetry - Scenario 1

where the runway extension was located several segments have been assigned a depth of 30 ft below MLW. (Note: the model bathymetry is based on mean tide, not MLW).

3.3.2 Dissolved Oxygen

When the runway is removed, there is improvement in the dissolved oxygen in Grassy Bay during hour 11. Figure 3-12 shows that the DO in Grassy Bay ranges from 3.75 to 5.25 mg/L during this hour. There is a small area east of the former runway location where the DO concentration decreases. This is probably due to the ability of the lower quality Grassy Bay water to flow into this region. Hour 16 also shows improvement in Grassy Bay although the DO concentration in the bay is computed to be between 0.75 and 3.0 mg/L (Figure 3-13). The water quality east of the former runway location deteriorate with DO concentrations declining to between 1.5 and 3.0 mg/L.

3.3.3 Velocity and Shear Stress

Removing the runway extension does little to affect the velocities in the western portion of the bay during hour 1(Figure 3-14). Some small differences can be observed in the eastern portion of the bay. On the southeastern side of Broad Channel there is an increased velocity northward into Grassy Bay. In the area near the mouth of Norton Basin, some of the velocity vectors have decreased and changed direction. Rather than pointing in the general vicinity of the runway the currents have changed direction and are headed toward Beach Channel. These changes in water currents result in the computed changes in dissolved oxygen.

During hour 19 and ebb tide, presented in Figure 3-15, small changes in the current velocity are observed in the eastern portion of the bay. In the North Channel, small increases in the shear stress are computed between Bergen and Shellbank Basins. Additional increases in the shear stress are computed in Grassy Bay, as indicated by the light blue cells. There are also small changes in the velocities near the southeastern portion of Broad Channel.

3.3.4 Salinity

Not surprisingly, based on the results of the DO and the velocity, the water in Grassy Bay becomes more saline, due to more flushing from the removal of the runway extension. Figures 3-16 and 3-17 show that more saline water is reaching the back end of the bay. Figure 3-16 shows slightly more penetration of saline water through the North Channel, while east of the runway extension, the salinity has declined.

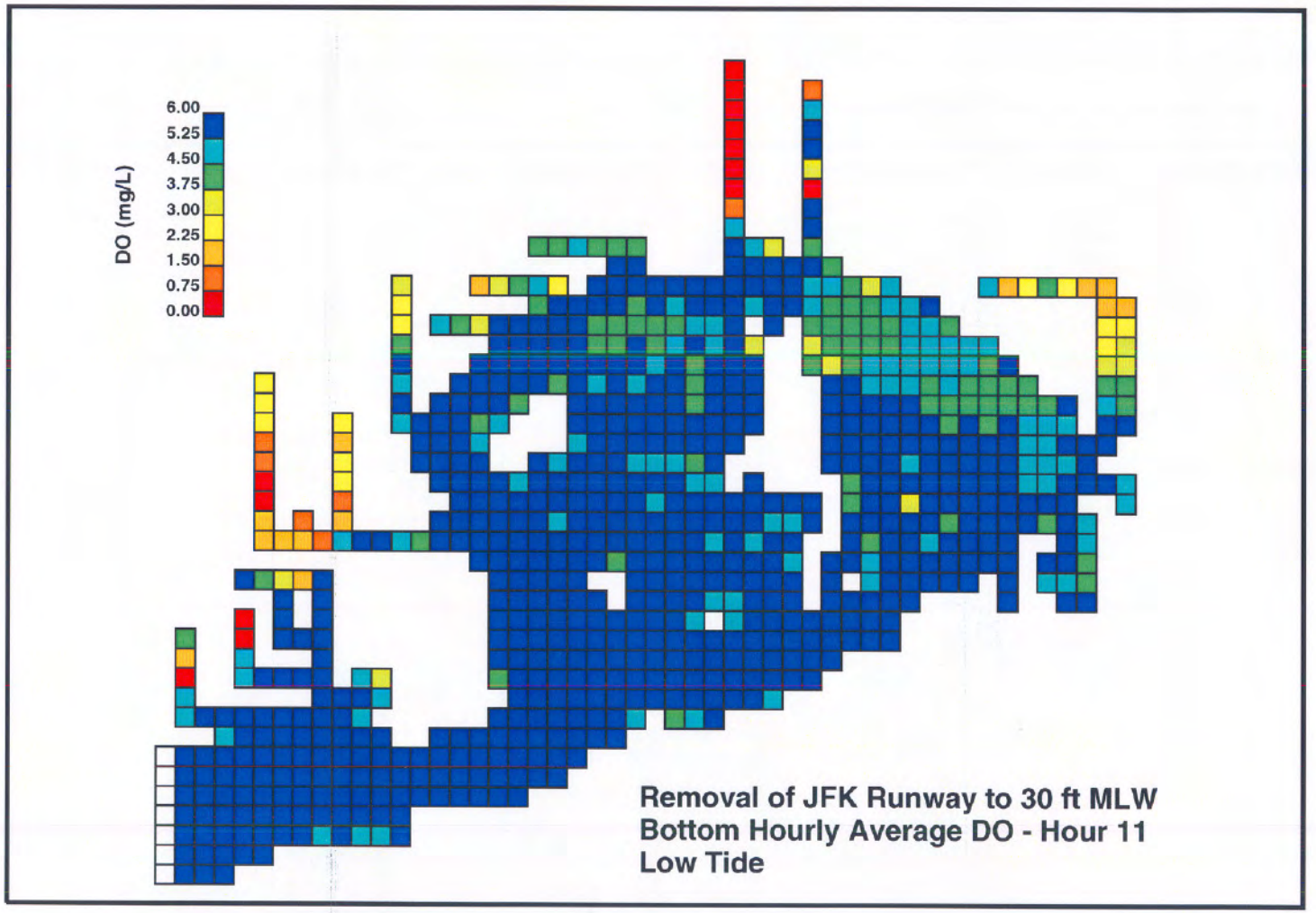


Figure 3-12. JEM Bottom DO - Hour 11 - Scenario 1

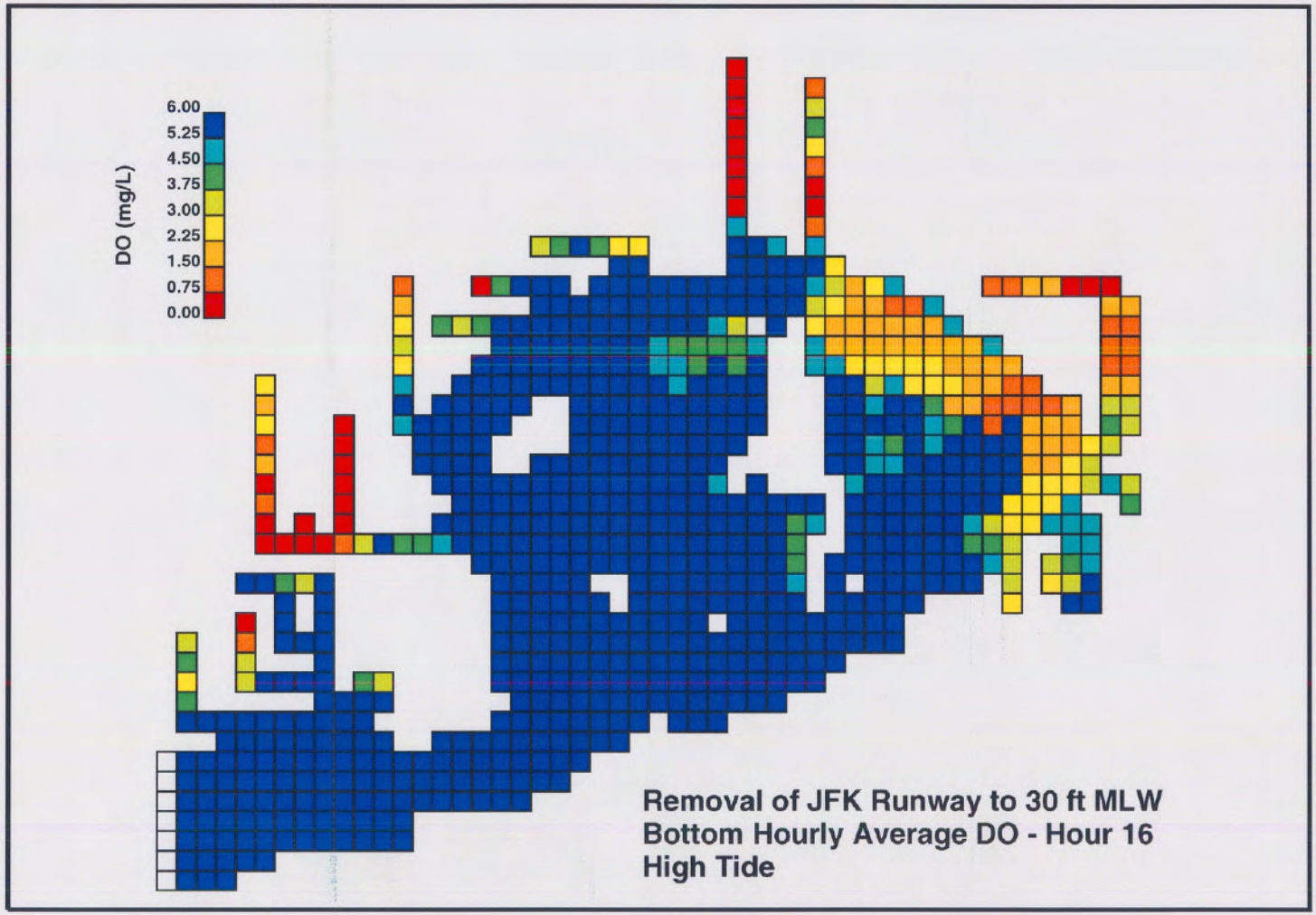


Figure 3-13. JEM Bottom DO - Hour 16 - Scenario 1

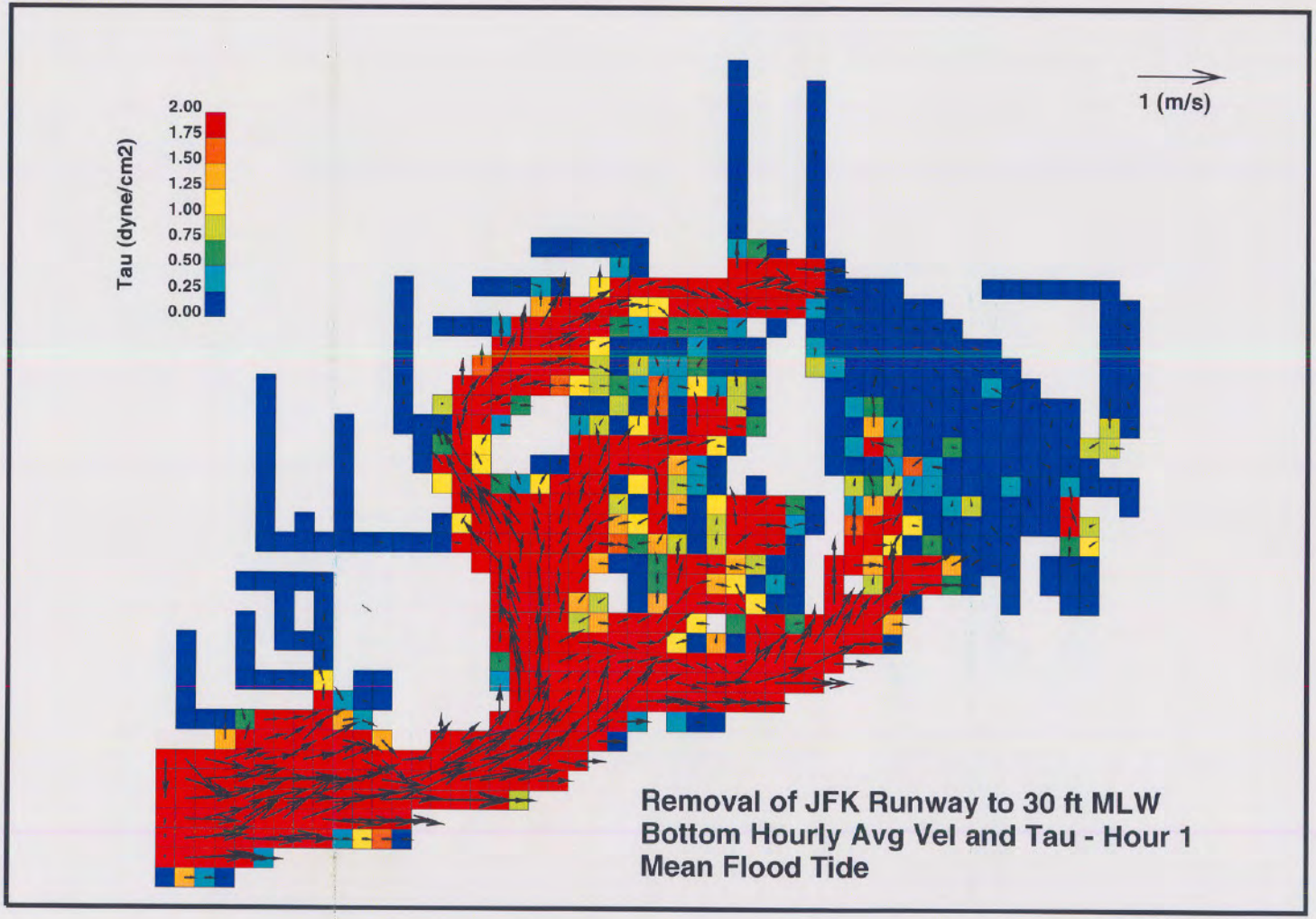


Figure 3-14. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 1

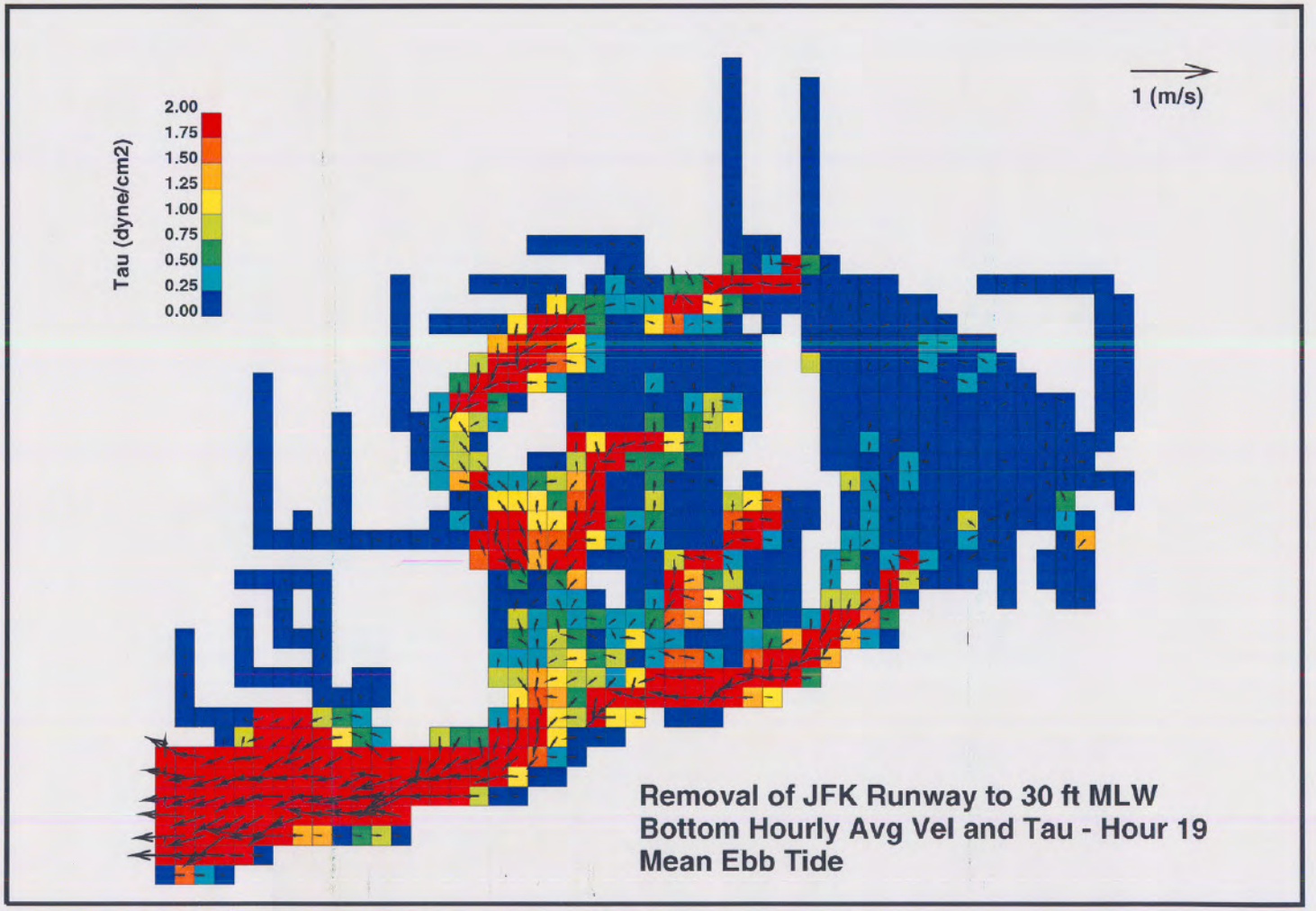


Figure 3-15. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 1

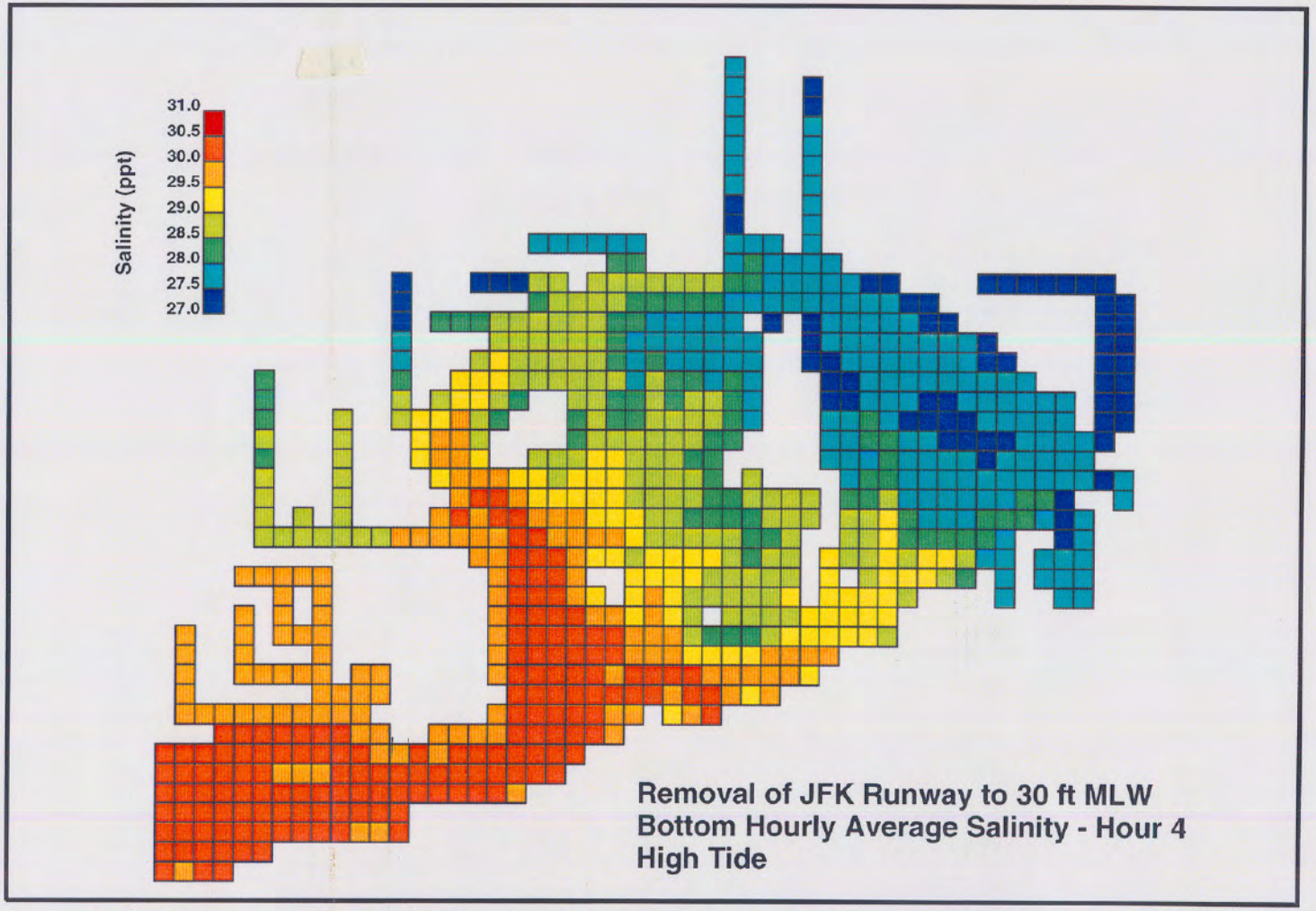


Figure 3-16. JEM Bottom Salinity - Hour 4 - Scenario 1

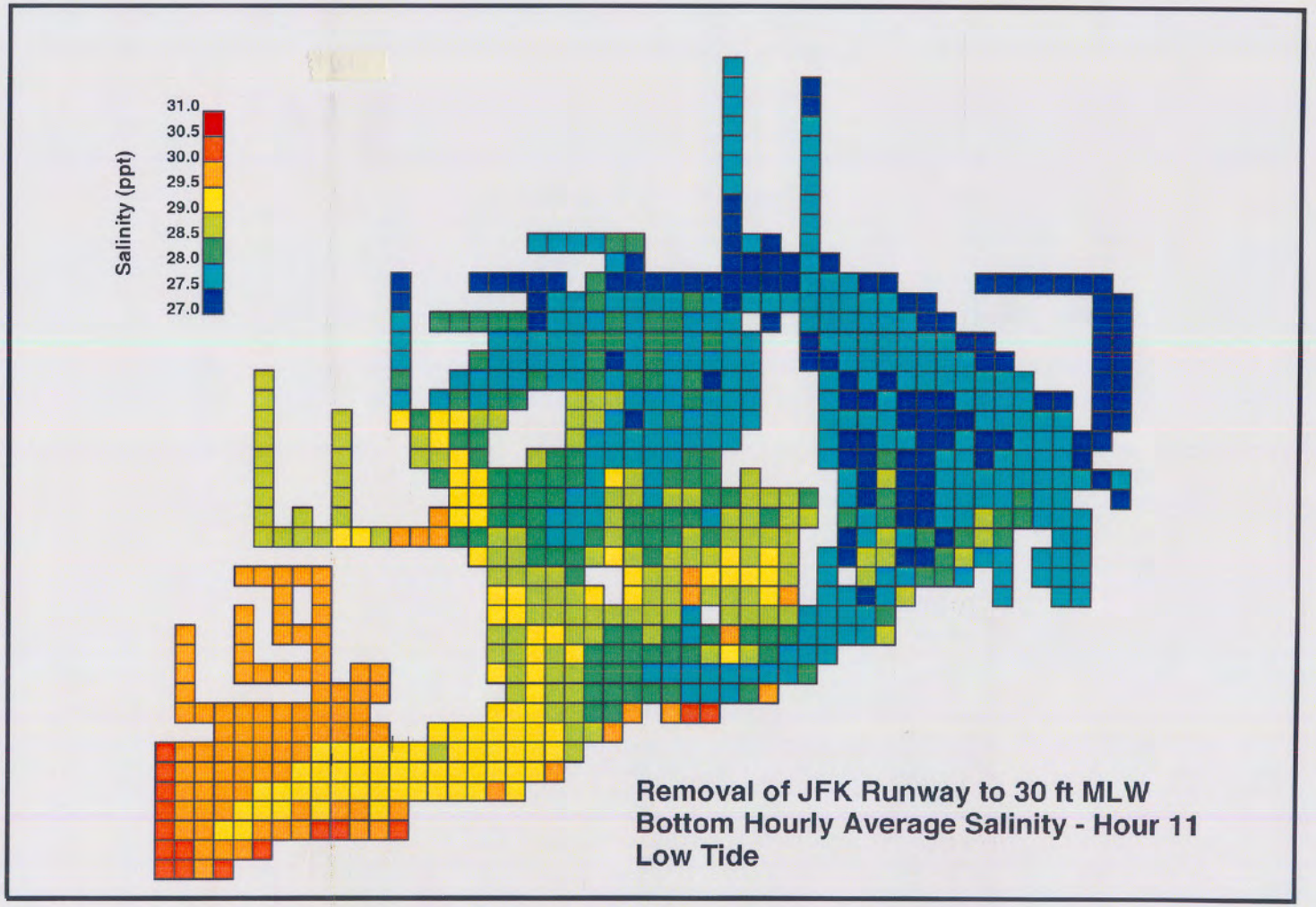


Figure 3-17. JEM Bottom Salinity - Hour 11 - Scenario 1

3.4 SCENARIO 2

3.4.1 Bathymetry

In scenario 2, the JFK Airport runway extension is removed to a depth of 15 ft MLW and Grassy Bay is filled to a depth of 15 ft MLW. Figure 3-18 presents the model bathymetry for this scenario. The segements in Grassy Bay are filled to the same level.

3.4.2 Dissolved Oxygen

The combination of filling Grassy Bay and removing the runway has a more positive effect on the dissolved oxygen than removing the runway alone. As shown in Figure 3-19, hour 11 conditions indicate improved DO levels in Grassy Bay, compared to scenario 1. The western portion of the bay shows more improvement than occurred for scenario 1 conditions. Also, the area to the east of the former runway location is not as adversely affected in scenario 2 as was the case for scenario 1. Hour 16 also shows more improvement in the DO concentrations in scenario 2 than in scenario 1. Figure 3-20 shows that the lowest DO concentrations computed for calibration conditions have been eliminated. The DO in Grassy Bay is computed to be between 1.5 mg/L and 3.75 mg/L. The area to the east of the runway is adversly affected when compared to existing conditions, but not to the extent of scenario 1.

3.4.3 Velocity and Shear Stress

As in the previous scenario, only small differences are observed between the calibration conditions and scenario 2 conditions. During hour 1, velocities along the eastern end of Broad Channel increase in the direction of Grassy Bay, as shown in Figure 3-21. In Grassy Bay itself, the velocities do not increase enough to markedly change the shear stress, but the velocities do increase and are more organized in the direction away from the North Channel. The shear stresses near the area of Norton Basin generally decline. Figure 3-22 shows that during hour 19, the current vectors are slightly larger and more organized in Grassy Bay than under calibration conditions.

3.4.4 Salinity

Figure 3-23 shows the salinity results for hour 4 in scenario 2. Again, Grassy Bay is more saline than during calibration conditions. The difference between scenario 1 and scenario 2 results is that in scenario 2 there is less penetration of saline waters through the North Channel and more penetration of saline waters through Beach Channel. Small differences in salinity are observed between hour 11 in

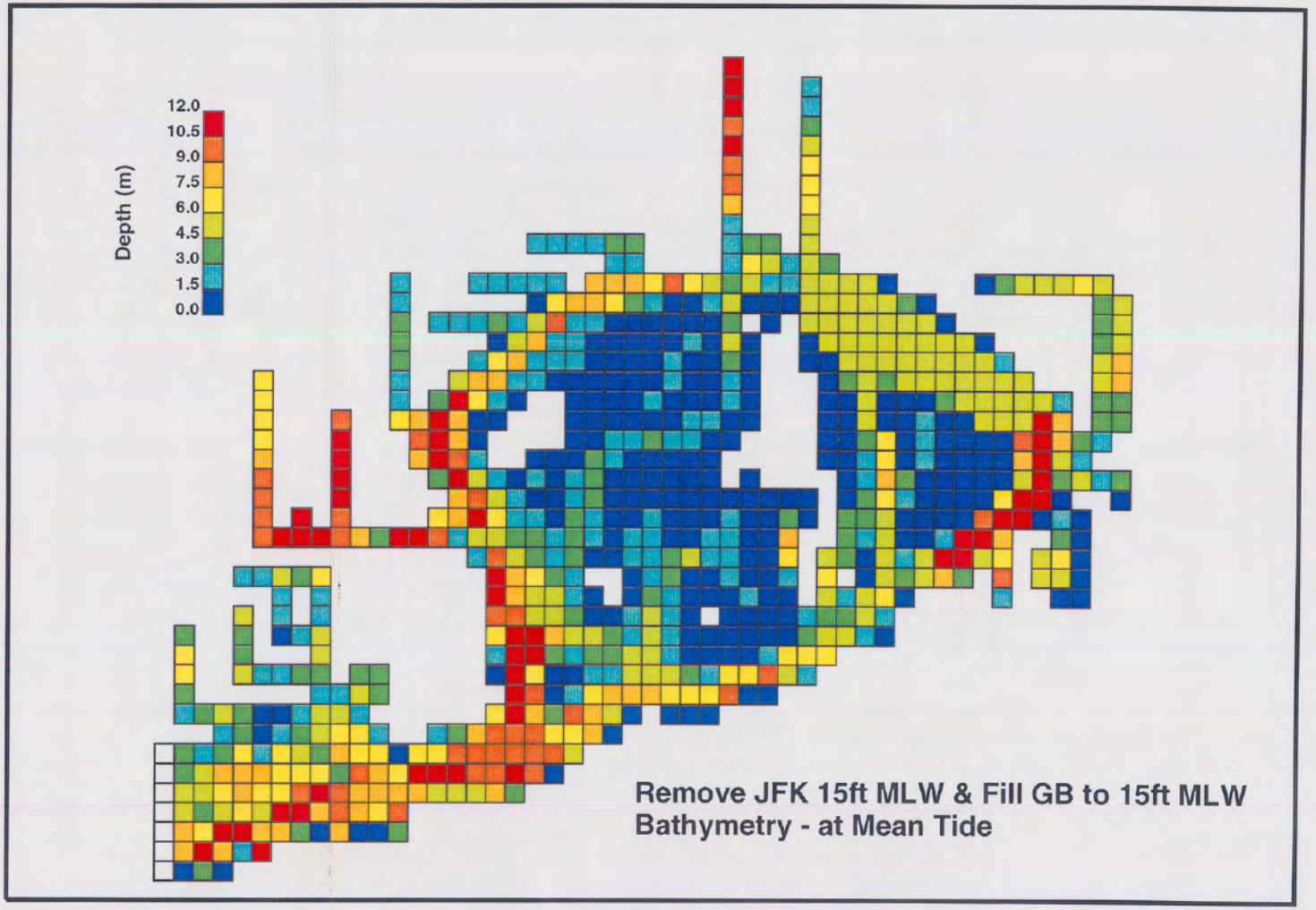


Figure 3-18. JEM Bathymetry - Scenario 2

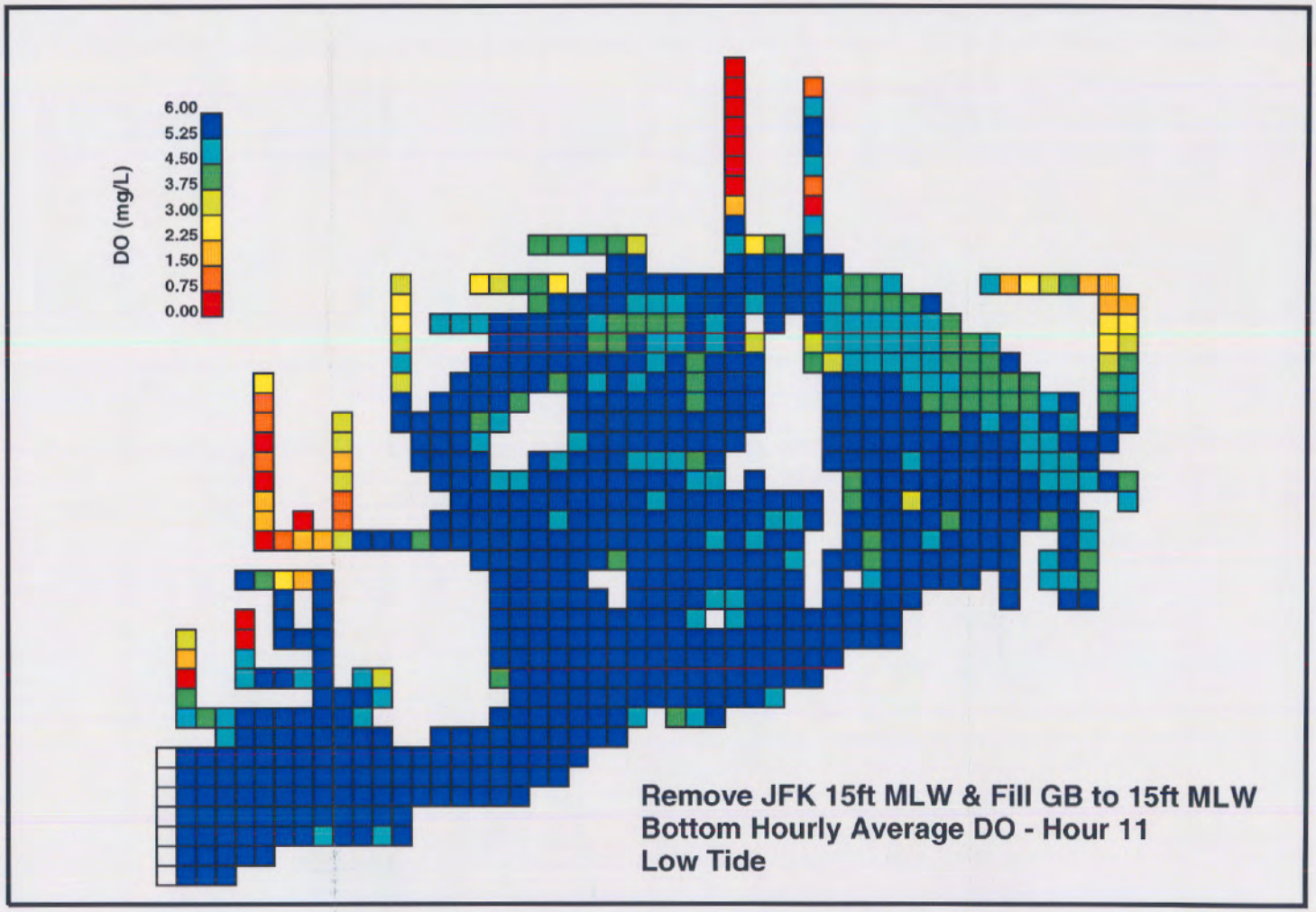


Figure 3-19. JEM Bottom DO - Hour 11 - Scenario 2

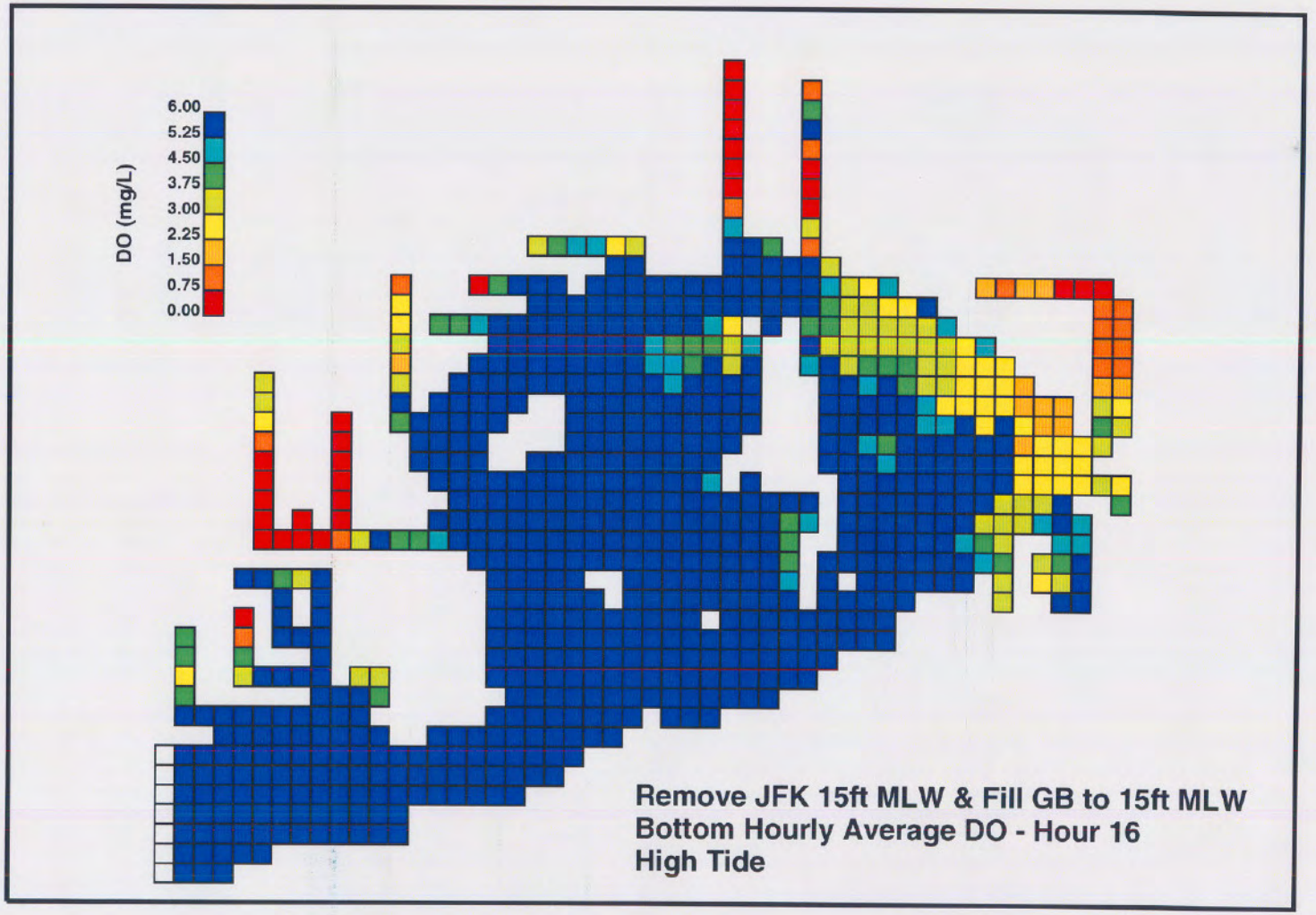


Figure 3-20. JEM Bottom DO - Hour 16 - Scenario 2

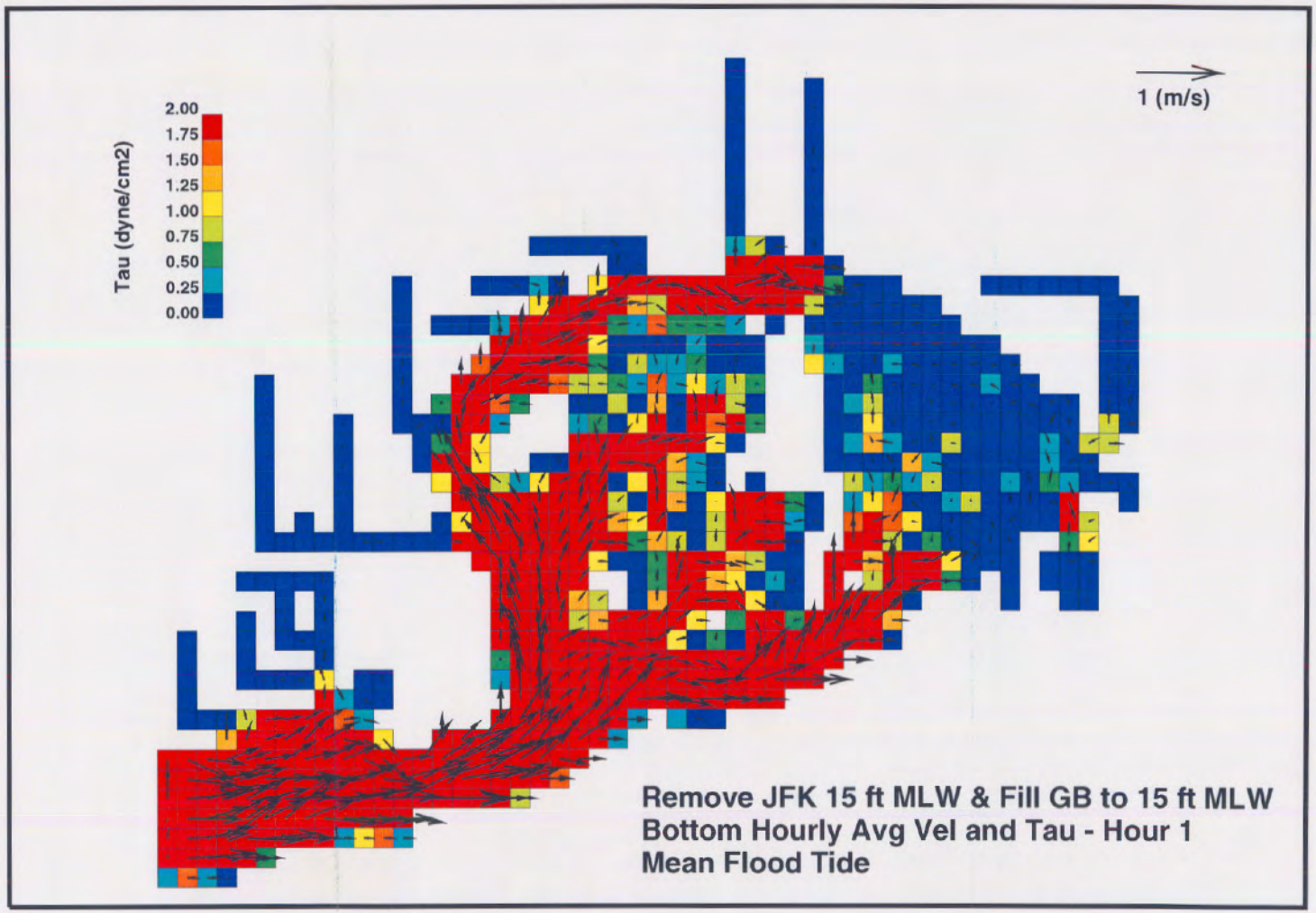


Figure 3-21. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 2

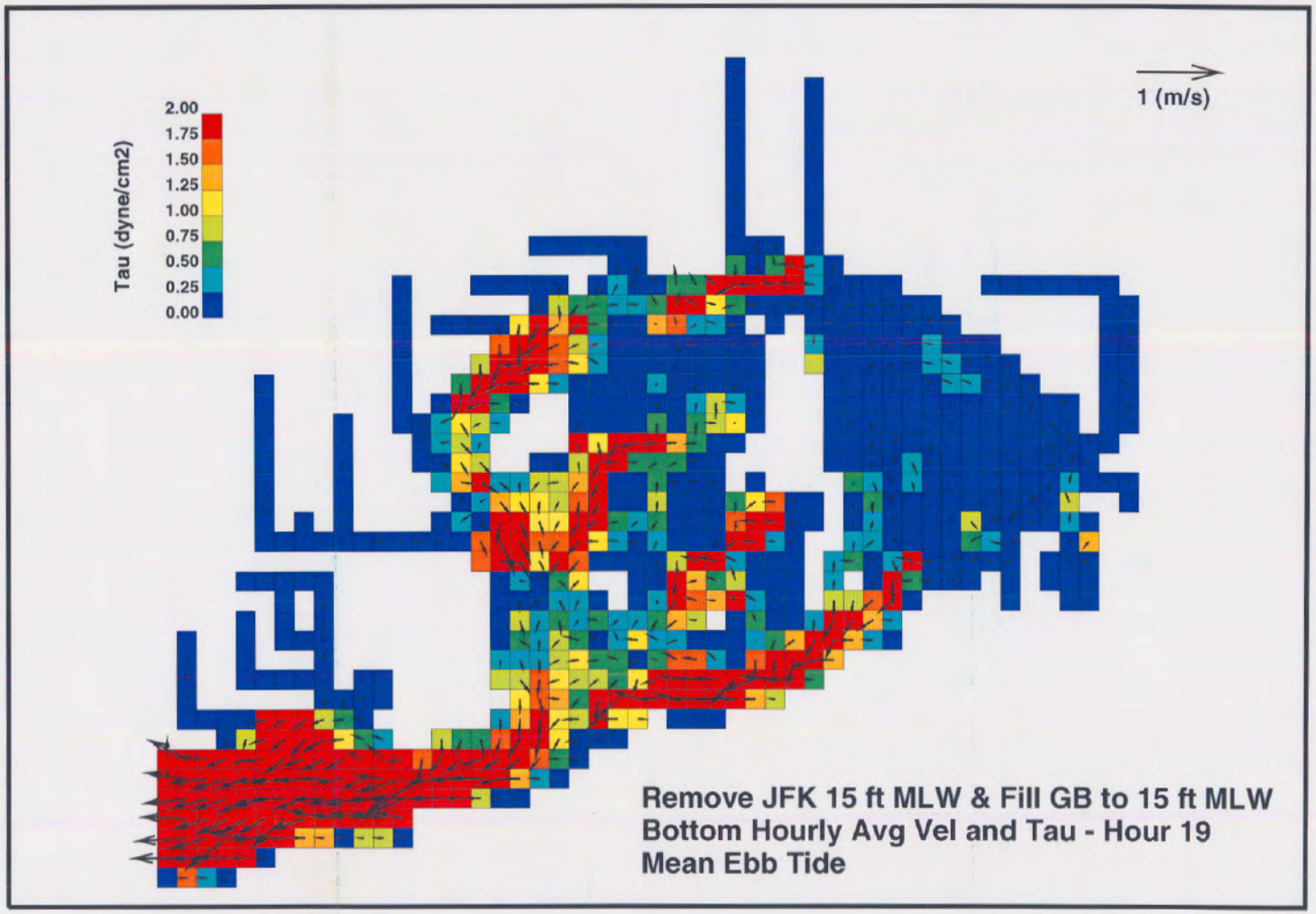


Figure 3-22. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 2

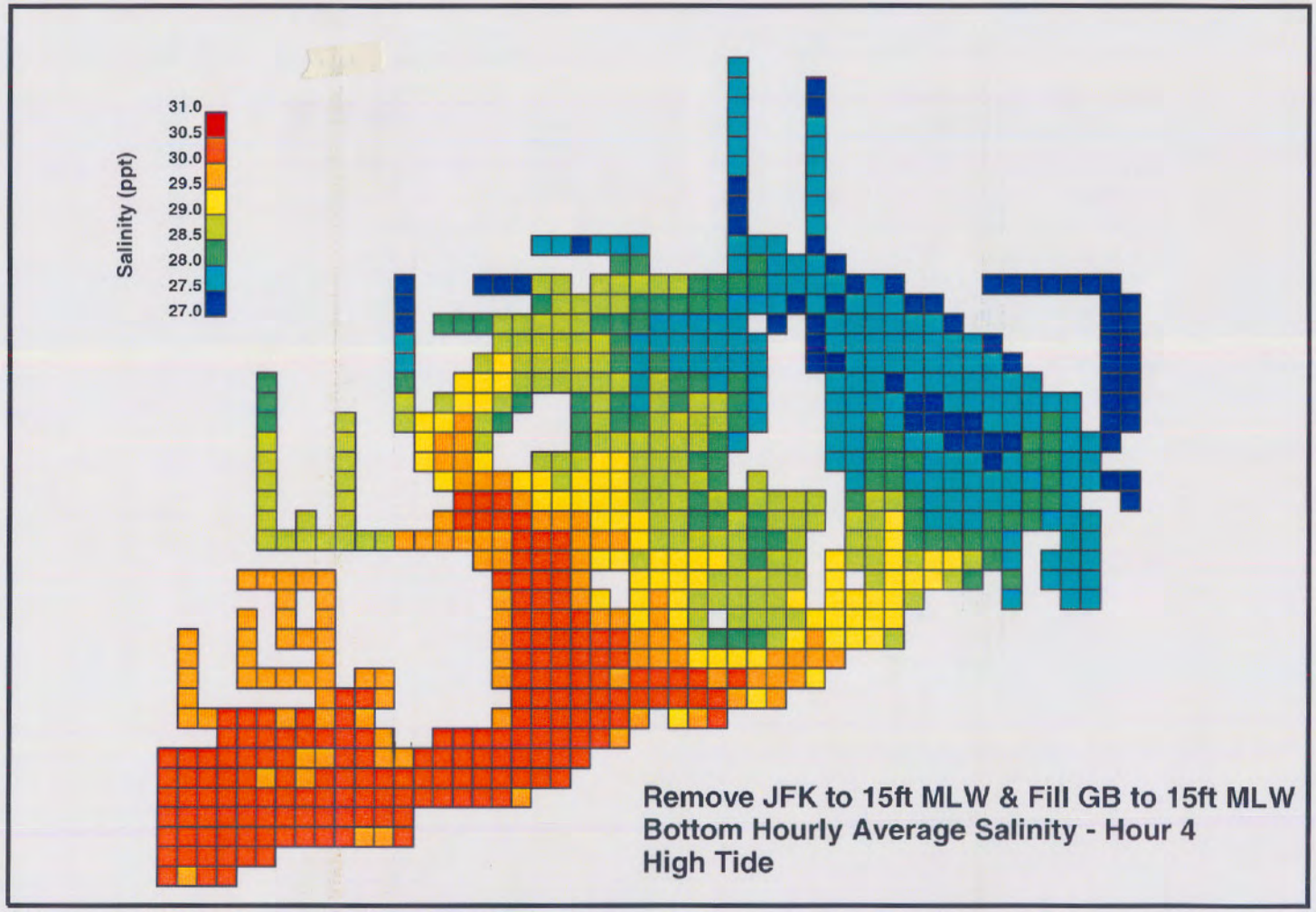


Figure 3-23. JEM Bottom Salinity - Hour 4 - Scenario 2

scenarios 1 and 2 (Figure 3-24). In general, Grassy Bay is more saline in scenario 2 than during calibration conditions.

3.5 SCENARIO 3

3.5.1 Bathymetry

Scenario 3 is very similar to scenario 1. The difference between the two is that only the center of the runway extension is removed in scenario 3 as opposed to the entire runway extension in scenario 1. The model segmentation in this area is 1000 ft by 1000 ft, so effectively a 1000 ft section of the runway was removed. In the current state of the model development, smaller sections of the runway cannot be removed. Figure 3-25 presents the bathymetry used for this scenario.

3.5.2 Dissolved Oxygen

The results of scenario 3 are very similar to those of scenario 1. During hour 11, the model computes slightly greater improvements in eastern Grassy Bay than for scenario 1 (Figure 3-26). The results in western Grassy Bay are approximately the same between the two runs. The area to the east of the runway is more detrimentally affected than during scenario 1. The model DO results for hour 16 (Figure 3-27) are very similar between scenario 3 and 1. Water quality conditions appear slightly worse for scenario 3 where only the center portion of the runway is removed.

3.5.3 Velocity and Shear Stress

Figures 3-28 and 3-29 present the velocity and shear stress results for hours 1 and 19, respectively, for scenario 3. These figures show that there is not very much difference between the results of scenario 1 and scenario 3. This indicates that the removal of just the center of the runway may be almost as effective as removing the entire runway extension in improving water quality, at least during some portions of the year.

3.5.4 Salinity

As shown in Figure 3-30, the differences in salinity between hour 4 in scenario 1 and hour 4 in scenario 3 are very small. Larger differences are computed in the back end of the bay during hour 11(Figure 3-31) between the two scenarios, but the differences are still minor.

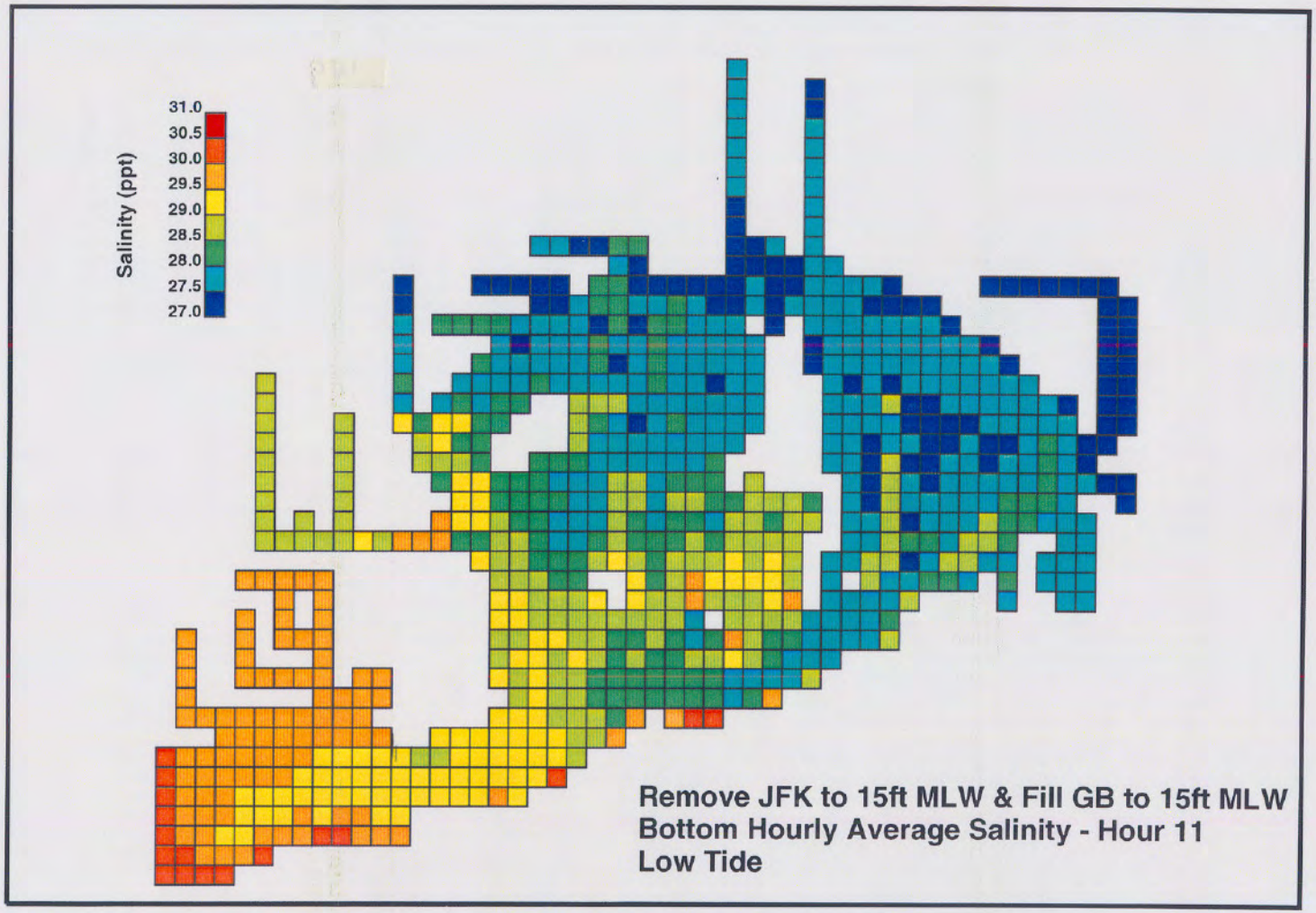


Figure 3-24. JEM Bottom Salinity - Hour 11 - Scenario 2

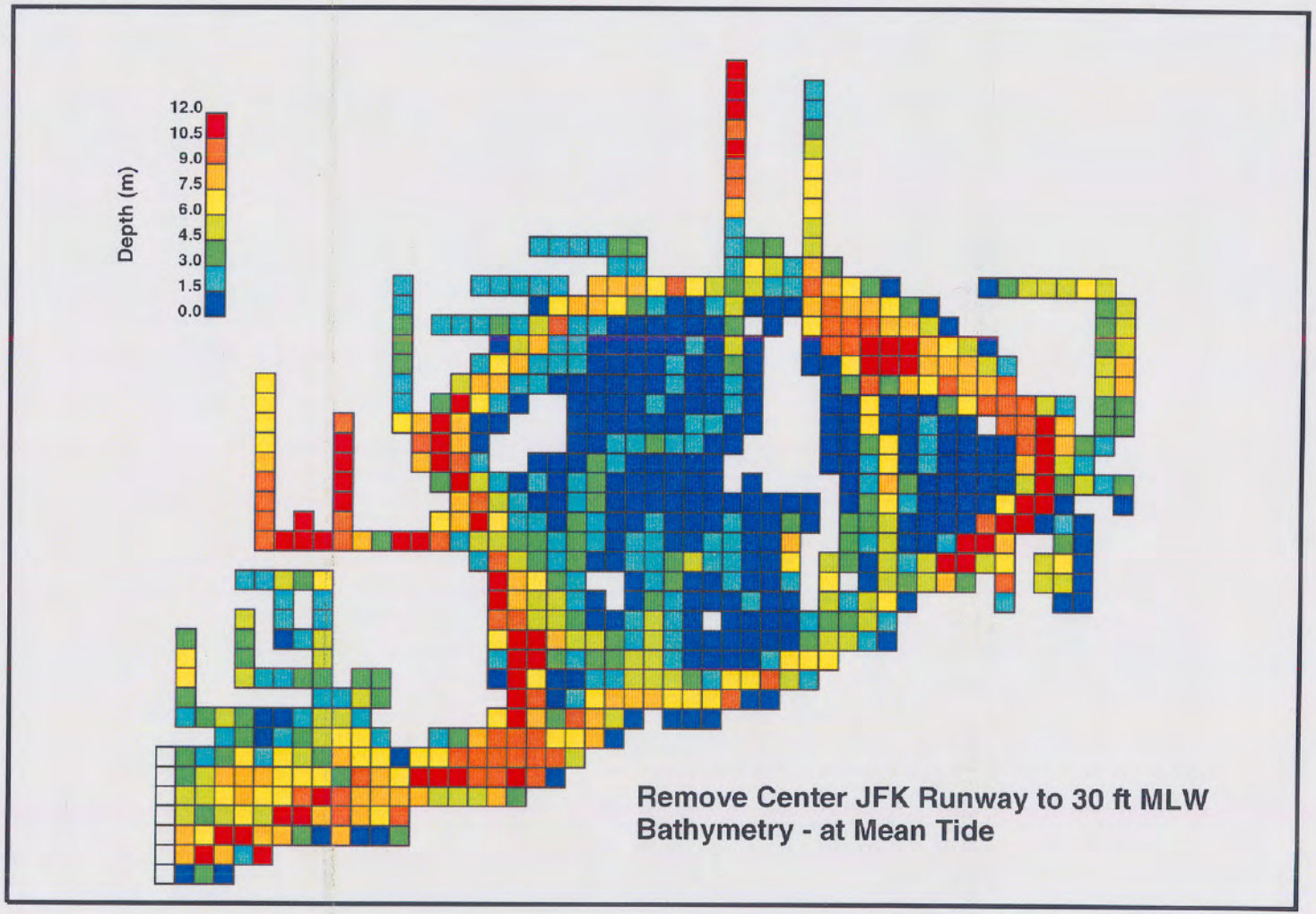


Figure 3-25. JEM Bathymetry - Scenario 3

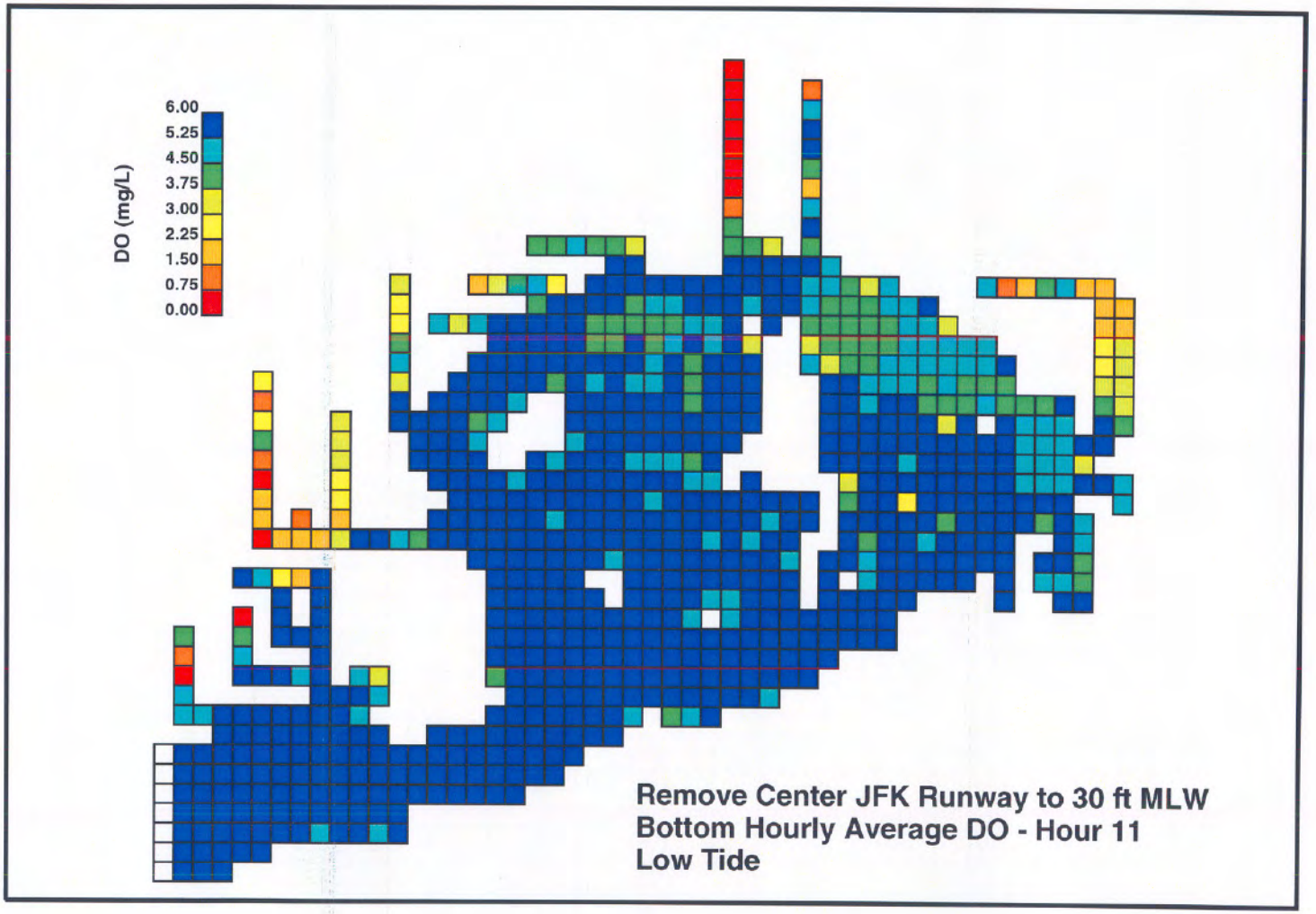


Figure 3-26. JEM Bottom DO - Hour 11 - Scenario 3

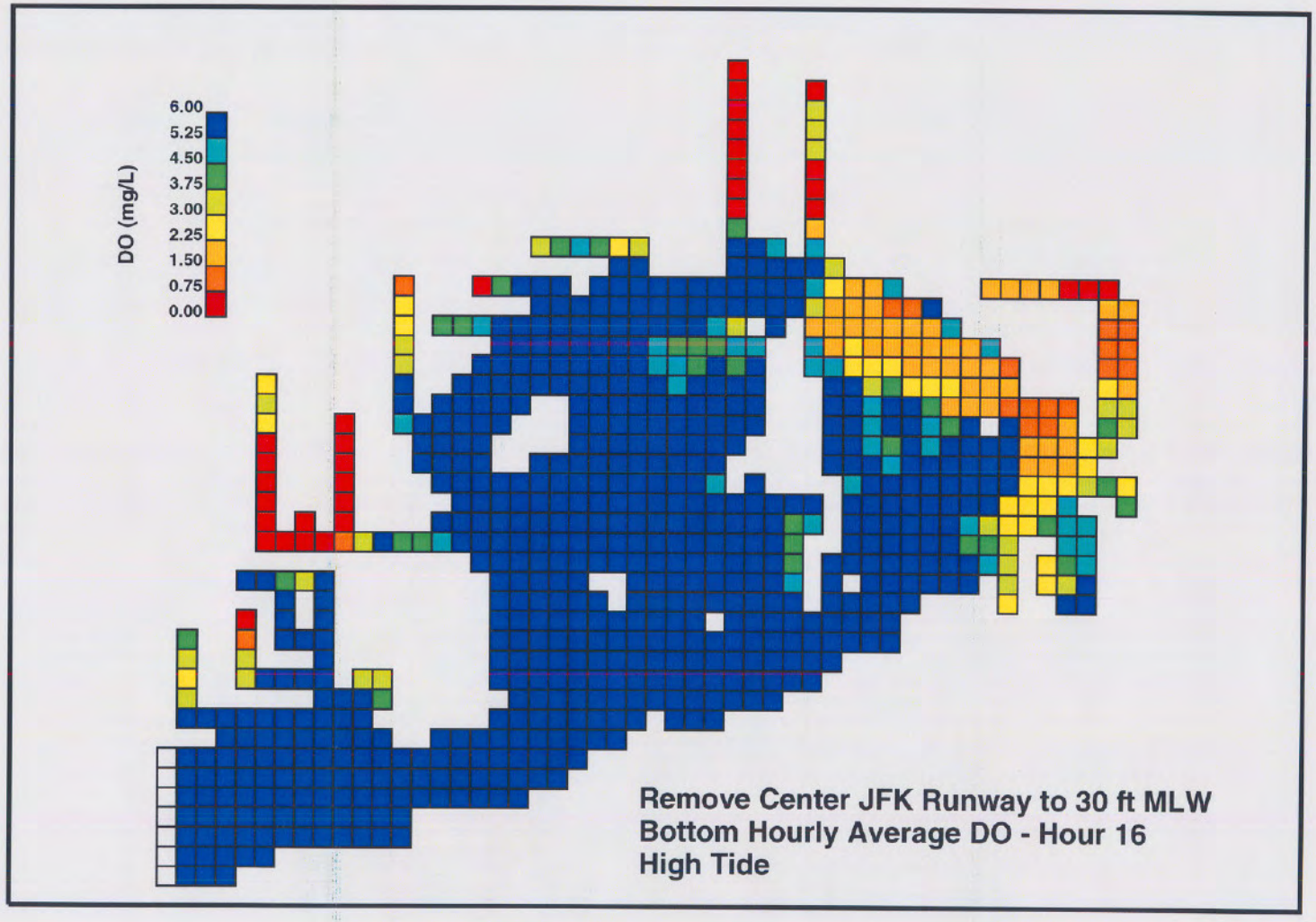


Figure 3-27. JEM Bottom DO - Hour 16 - Scenario 3

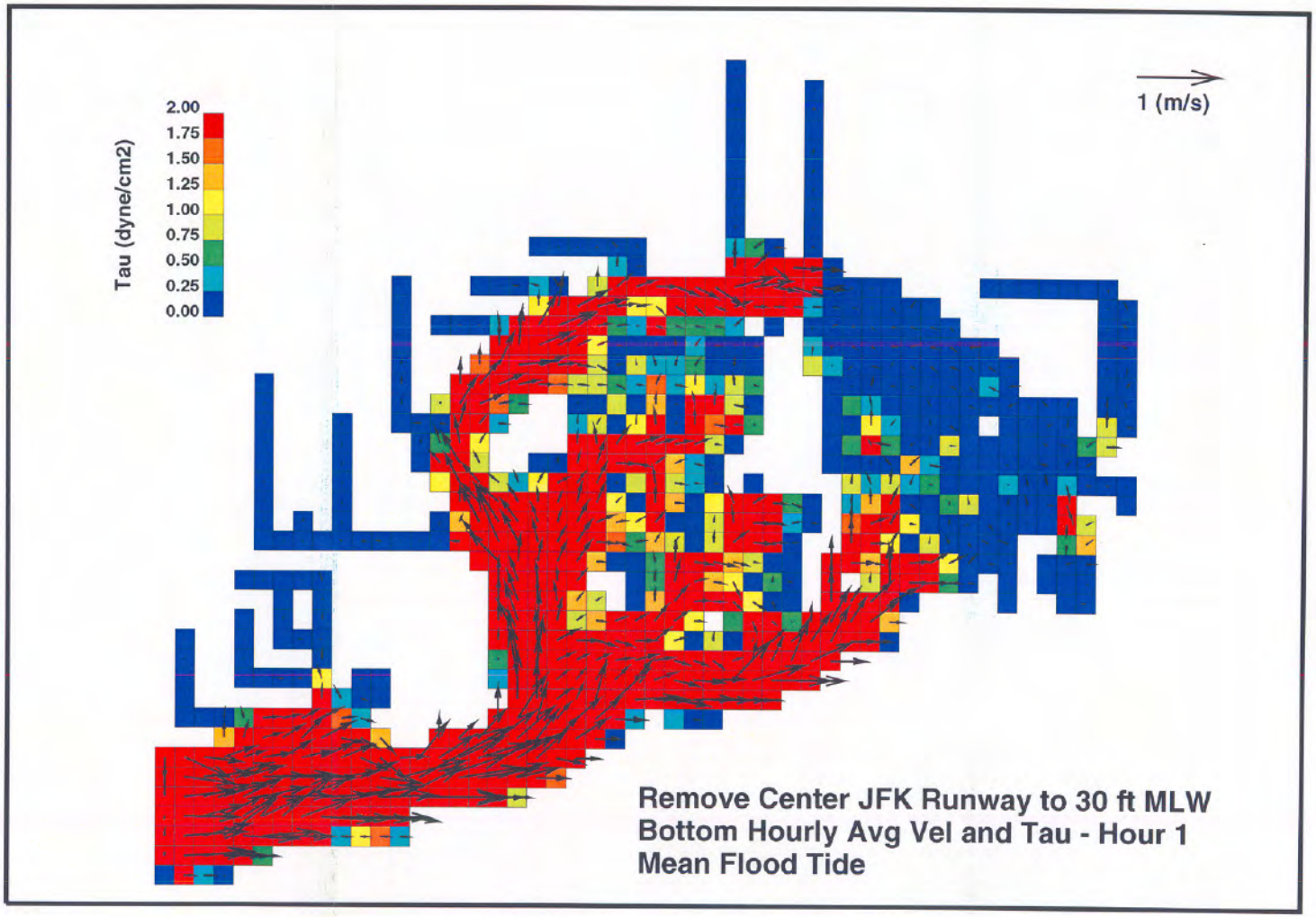


Figure 3-28. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 3

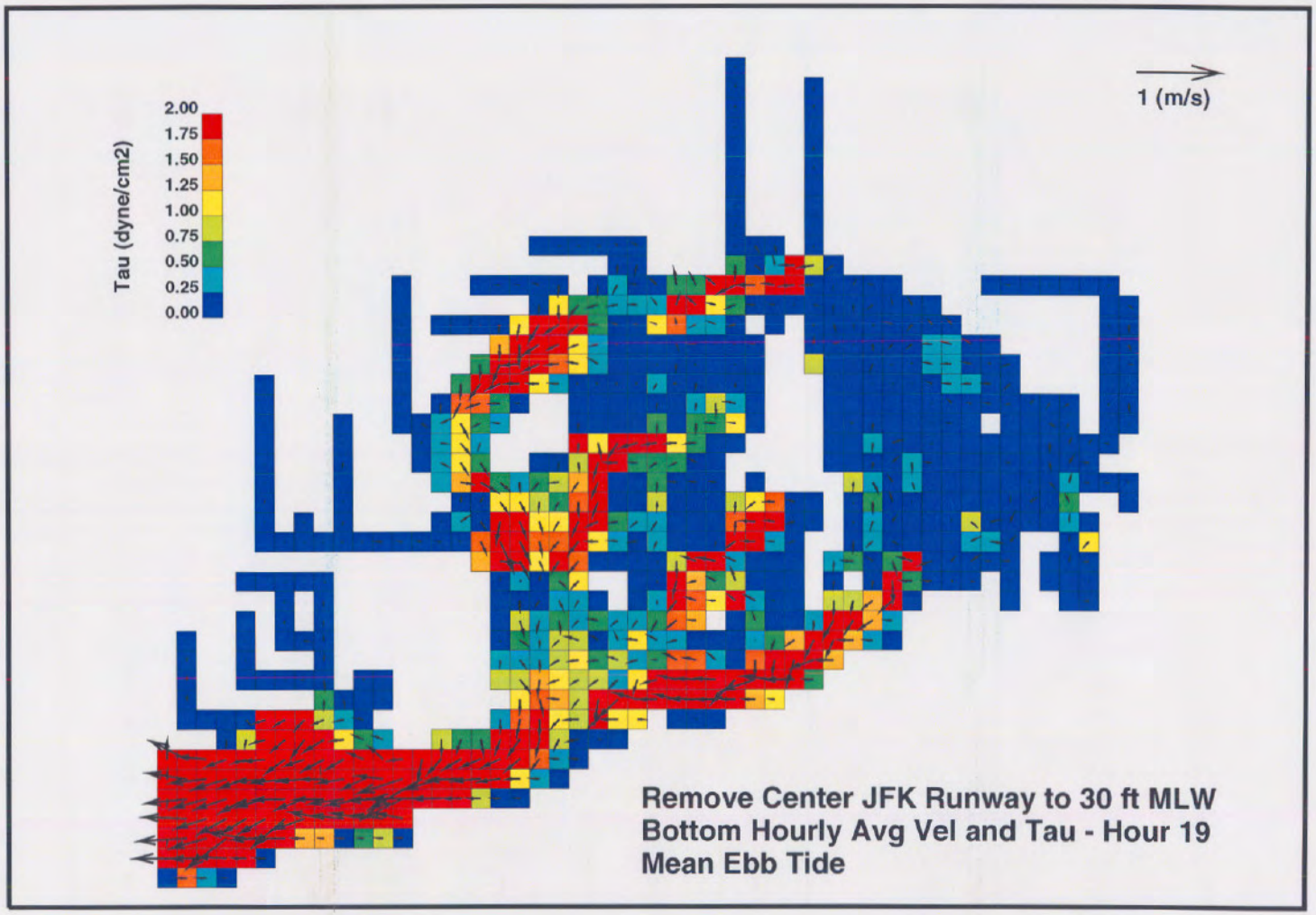


Figure 3-29. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 3

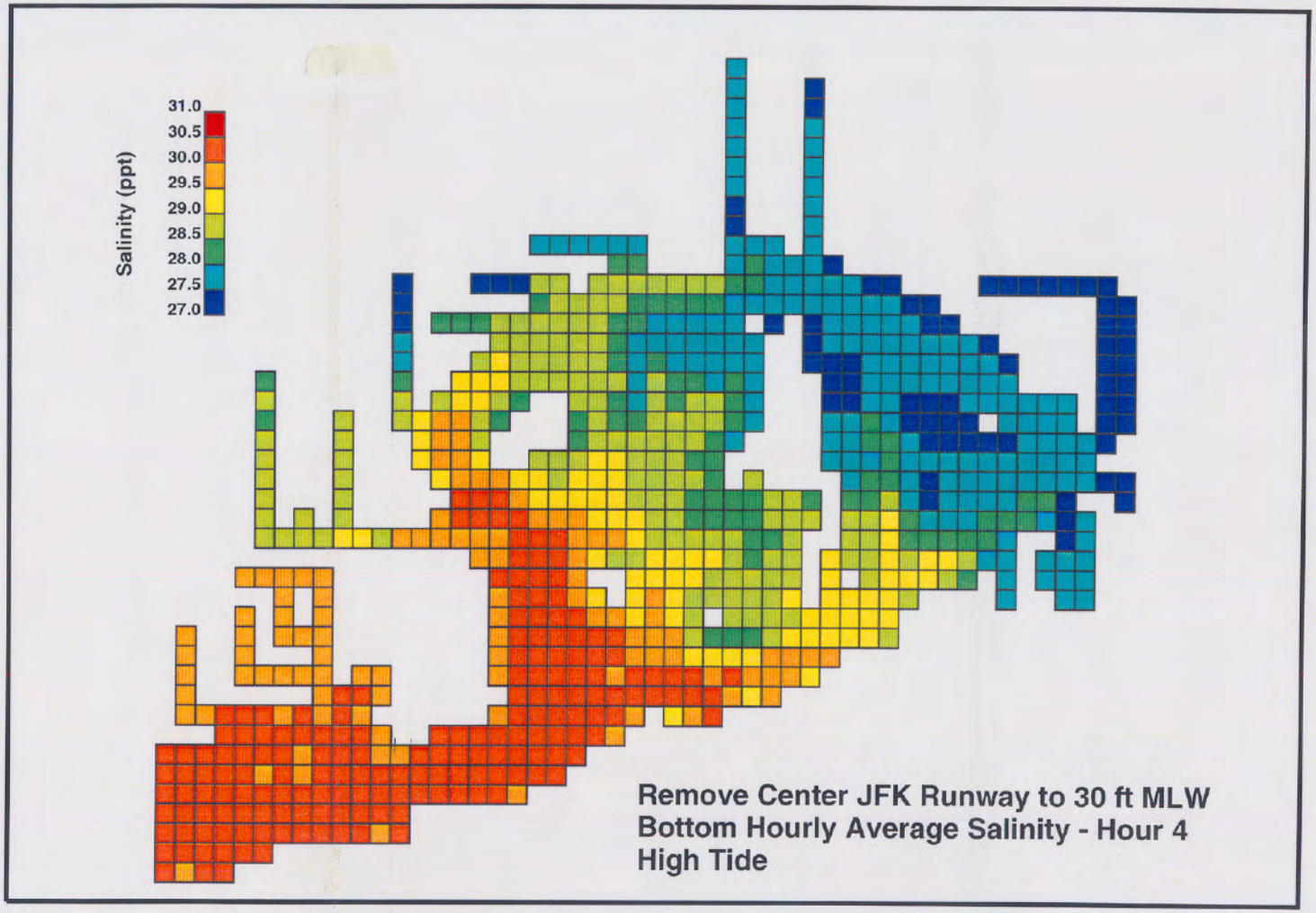


Figure 3-30. JEM Bottom Salinity - Hour 4 - Scenario 3

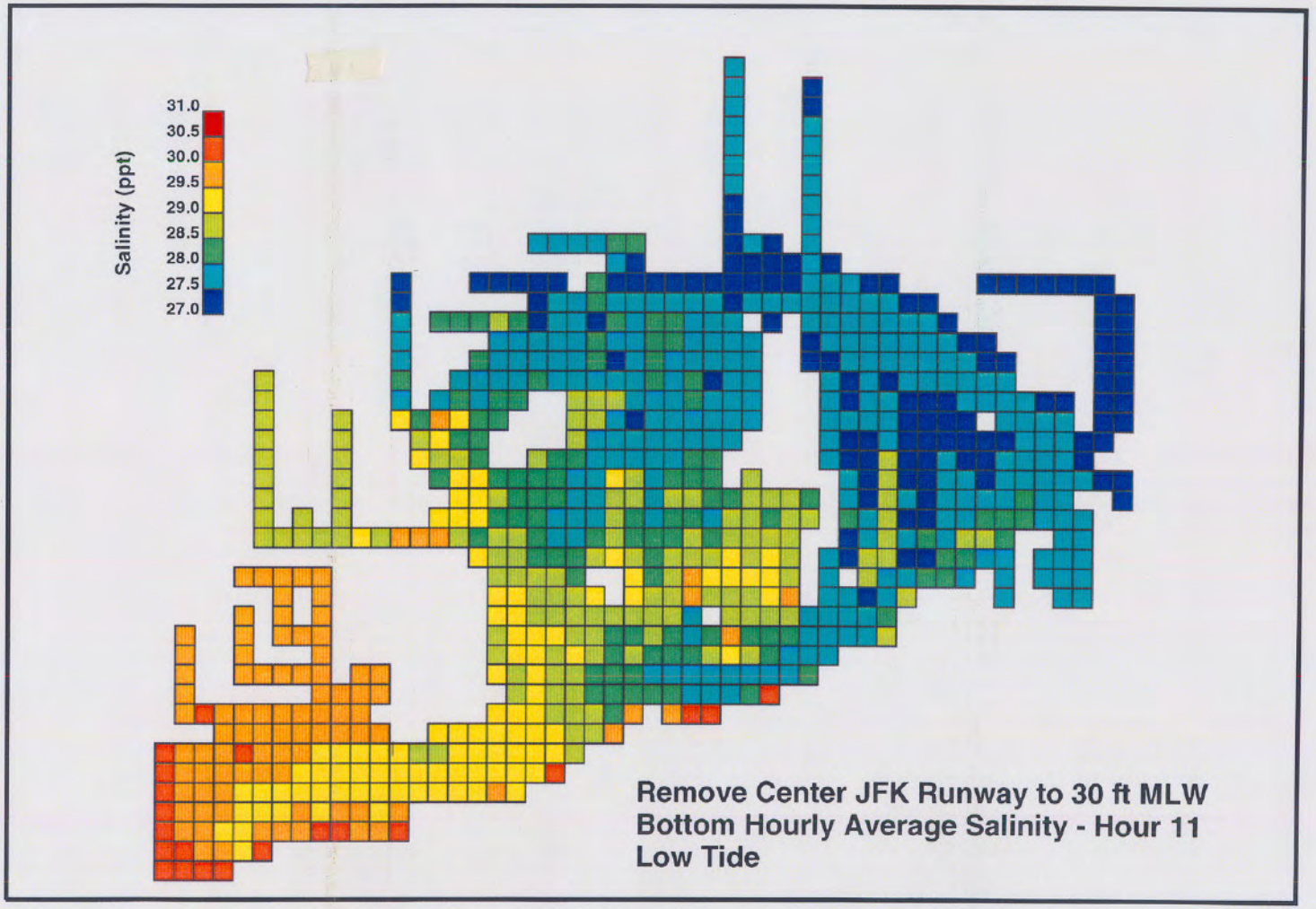


Figure 3-31. JEM Bottom Salinity - Hour 11 - Scenario 3

3.6 SCENARIO 4

3.6.1 Bathymetry

Scenario 4 is very similar to scenario 2. The difference between the two is that only the center of the runway extension is removed in scenario 4 as opposed to scenario 2 where the entire runway extension is removed. Figure 3-32 presents the bathymetry used for scenario 4.

3.6.2 Dissolved Oxygen

As shown in Figure 3-33, removing only the center of the runway in scenario 4 results in similar water quality to scenario 2. The differences in hour 11 in scenario 4 from scenario 2 are that the improvements in western Grassy Bay are not as great, there is a greater improvement in eastern Grassy Bay, and more of a detriment to water quality east of the runway. The results during high tide (hour 16) are pretty similar between scenario 2 and scenario 4 (Figure 3-34). Conditions on both sides of the runway may be slightly worse in scenario 4.

3.6.3 Velocity and Shear Stress

The results of hours 1 and 19 for velocity and shear stress are presented in Figure 3-35 and 3-36, respectively. These figures indicate that there is not a great difference between removing the entire runway extension, as in scenario 2, and removing only the center of the runway. Hour 19 does indicate a small decrease in the shear stress in Grassy Bay when compared to scenario 2. Both scenarios are enough to increase the current velocities in Grassy Bay and improve the water quality.

3.6.4 Salinity

Similar results are computed for salinity in scenarios 2 and 4 during hour 4 (Figure 3-37) and hour 11 (Figure 3-38).

3.7 SCENARIO 5

3.7.1 Bathymetry

In scenario 5, the center of the runway extension is removed to a depth of 30 ft below MLW and the North Channel and Beach Channel are dredged to a minimum depth of 30 ft below MLW. The bathymetry for scenario 5 is presented in Figure 3-39.

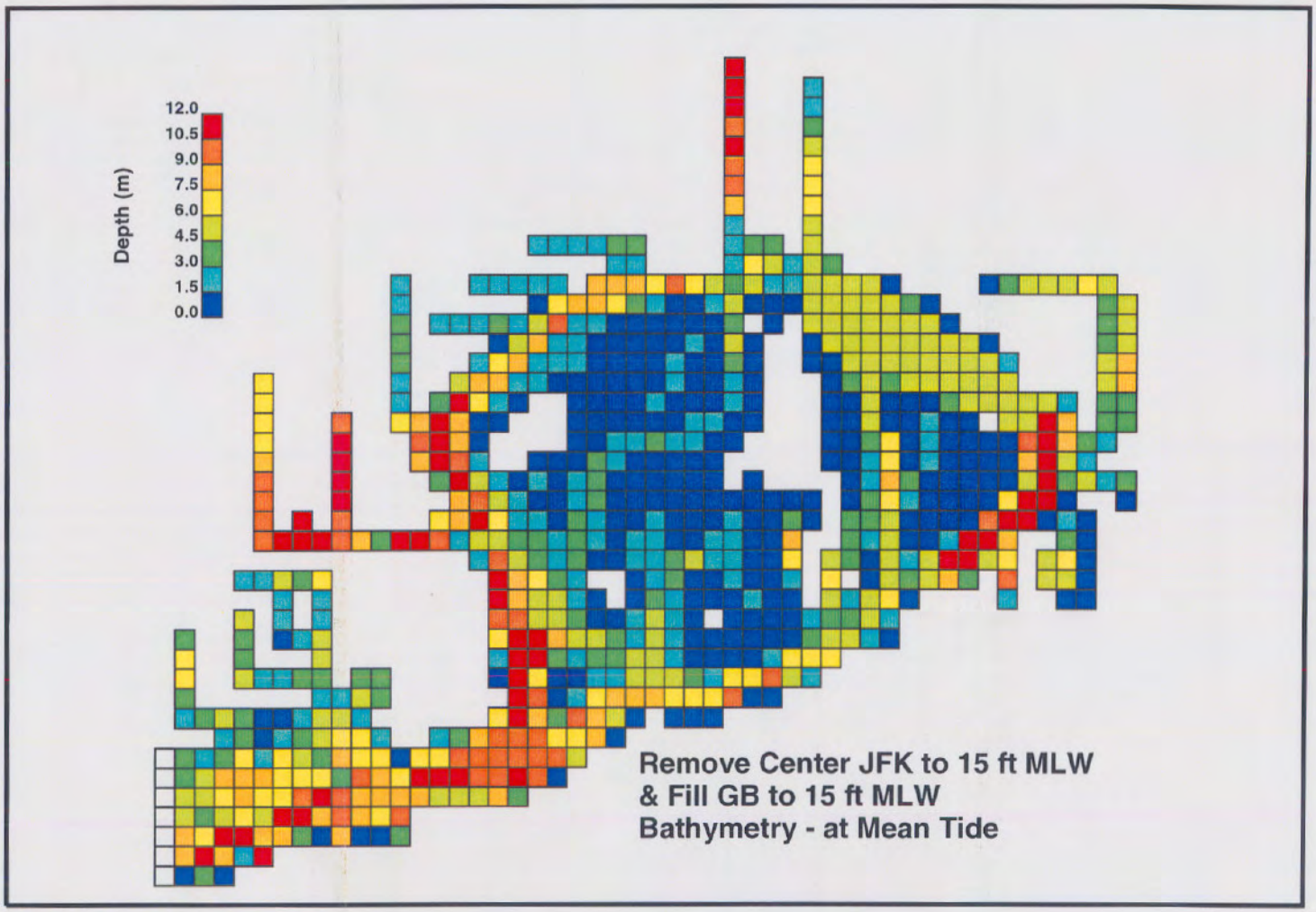


Figure 3-32. JEM Bathymetry - Scenario 4

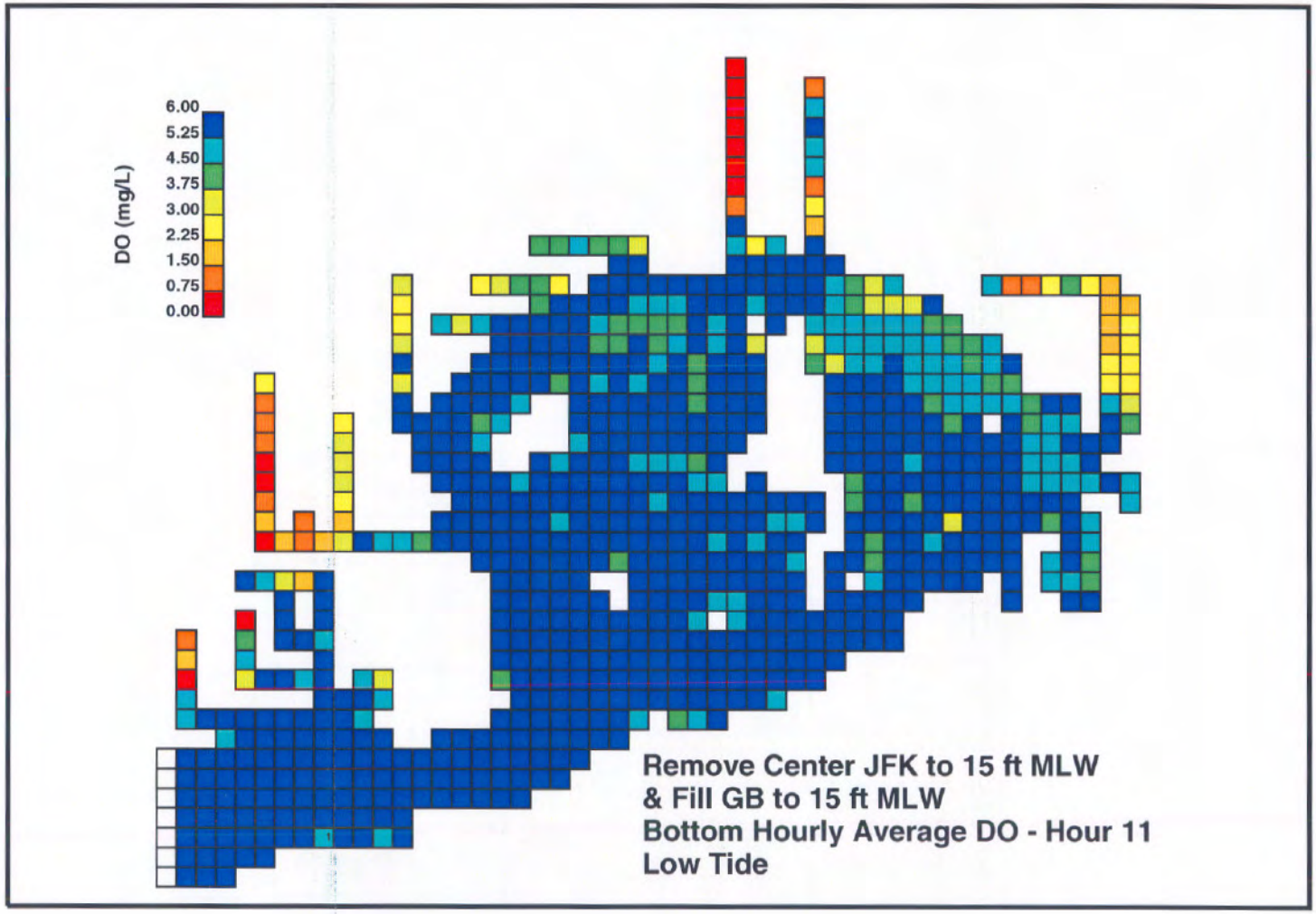


Figure 3-33. JEM Bottom DO - Hour 11 - Scenario 4

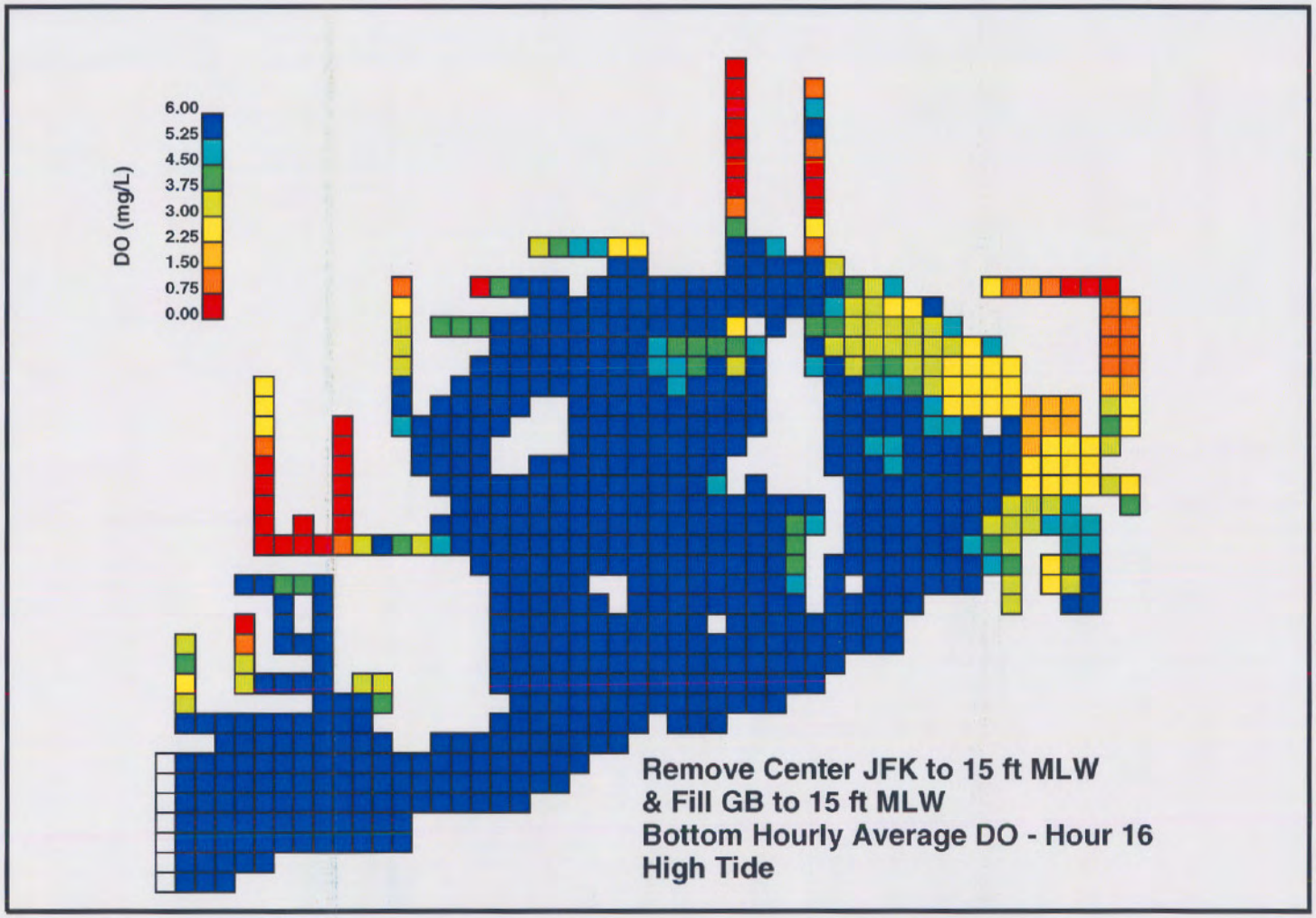


Figure 3-34. JEM Bottom DO - Hour 16 - Scenario 4

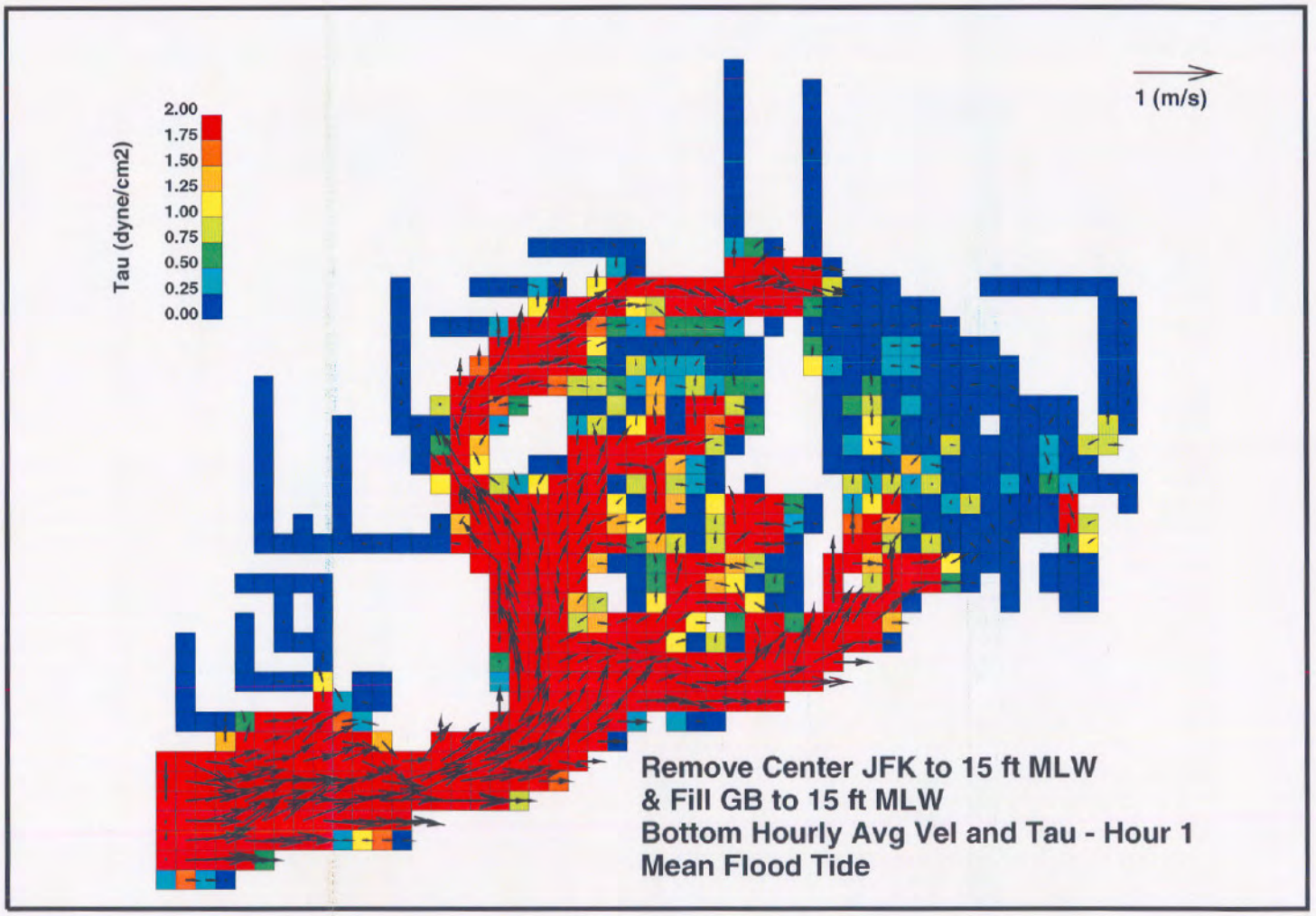


Figure 3-35. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 4

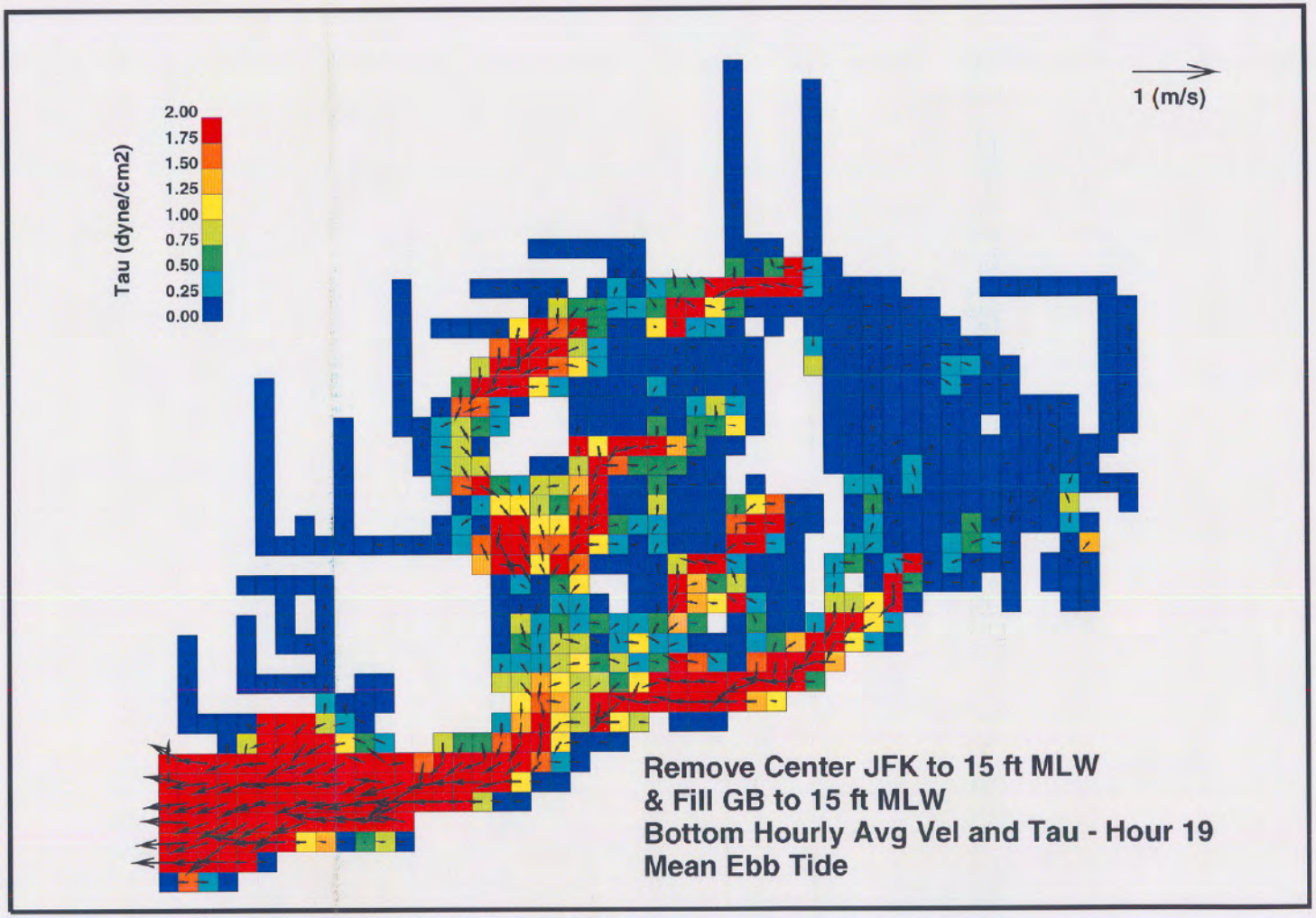


Figure 3-36. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 4

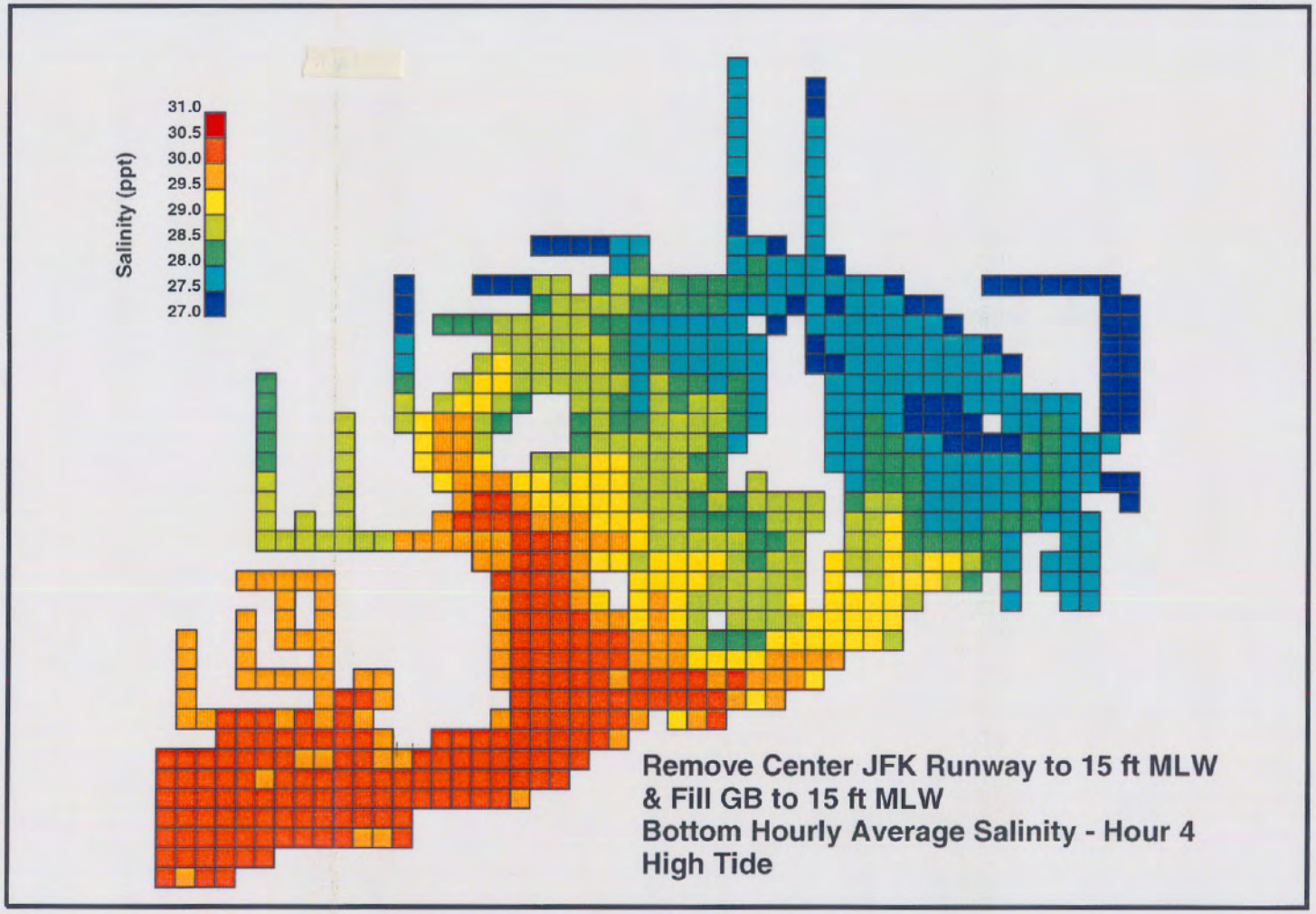


Figure 3-37. JEM Bottom Salinity - Hour 4 - Scenario 4

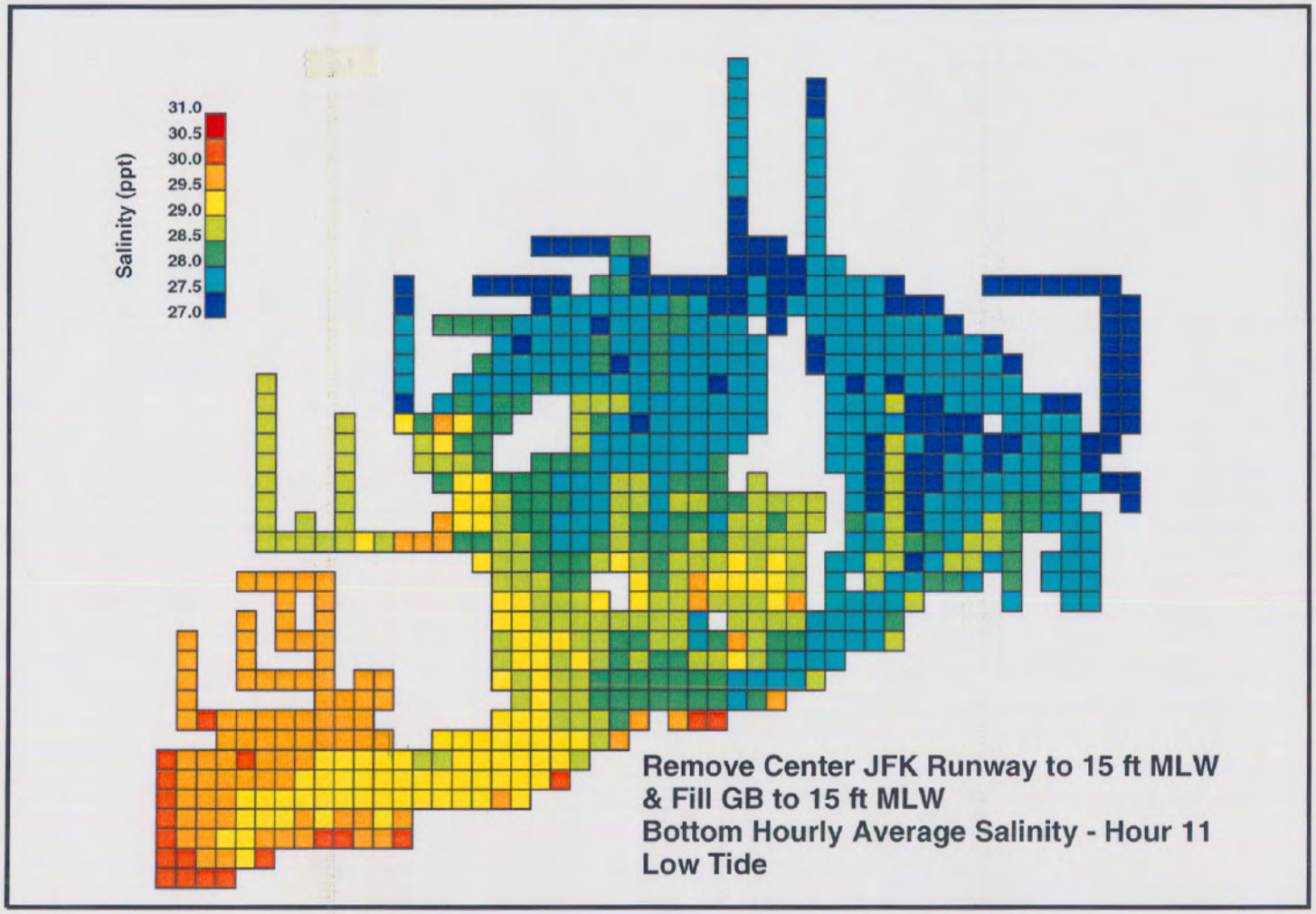


Figure 3-38. JEM Bottom Salinity - Hour 11 - Scenario 4

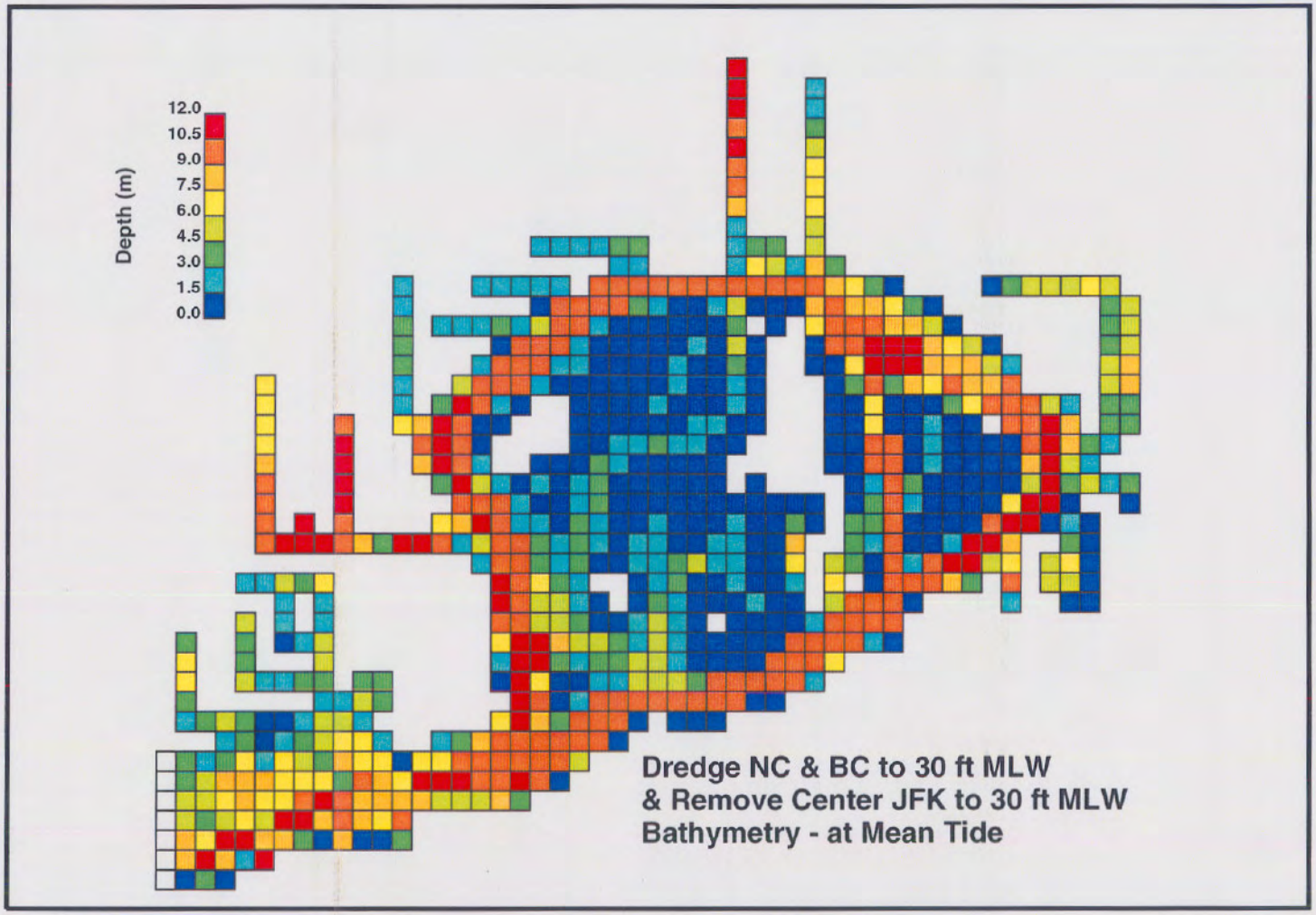


Figure 3-39. JEM Bathymetry - Scenario 5

3.7.2 Dissolved Oxygen

While scenario 5 DO conditions are better than calibration conditions, dredging the North Channel and Beach Channel does less to improve water quality in Grassy Bay than removing the center of the runway alone. Most of Grassy Bay is computed by the model to have DO concentrations less than 4.5 mg/L during hour 11 as shown in Figure 3-40. The model computes DO less than 5.25 mg/L further into the North Channel under this scenario than under calibration conditions. Figure 3-41, which presents hour 16, also shows that low DO water reaches further west into the North Channel when the channel is dredged. Lower DO water is also shown to reach closer to Beach Channel.

3.7.3 Velocity and Shear Stress

The reduction in the improvement in DO as compared to previous scenarios can be traced back to the changes in the velocities due to dredging the North Channel and Beach Channel. Figure 3-42 presents the results of scenario 5 during hour 1 for the velocity and shear stress. Dredging the channels resulted in reduced velocities in the North Channel and Beach Channel. It does appear, however, that slightly higher velocites are computed on the eastern side of Broad Channel. The velocities in Grassy Bay remain very small. The results during hour 19, shown in Figure 3-43, are similar to those of hour 1. The velocities in the North Channel and Beach Channel have decreased dramatically.

3.7.4 Salinity

Dredging the North Channel and Beach Channel makes a dramatic difference in terms of salinity. The area in Grassy Bay that had a salinity of 27.0 to 27.5 ppt during hour 4 of the calibration condition had a salinity of 28.0 to 28.5 ppt during hour 4 of scenario 5 (Figure 3-44). Large changes in salinity are also observed during hour 11 (Figure 3-45). Differences can also be observed in Figures 3-46 and 3-47 for hours 16 and 23. During these hours the salinity in the back end of the bay increases to above 27.5 ppt. The increases in salinity indicate that more seawater is reaching the back of the bay. This does not, however, translate into improved DO conditions in Grassy Bay.

3.8 SCENARIO 6

3.8.1 Bathymetry

The final scenario bathymetry is presented in Figure 3-48. In scenario 6, the center of the runway extension is removed to 15 ft below MLW, the North Channel and Beach Channel are dredged to a depth of 30 ft below MLW and Grassy Bay is filled to a depth of 15 ft below MLW.

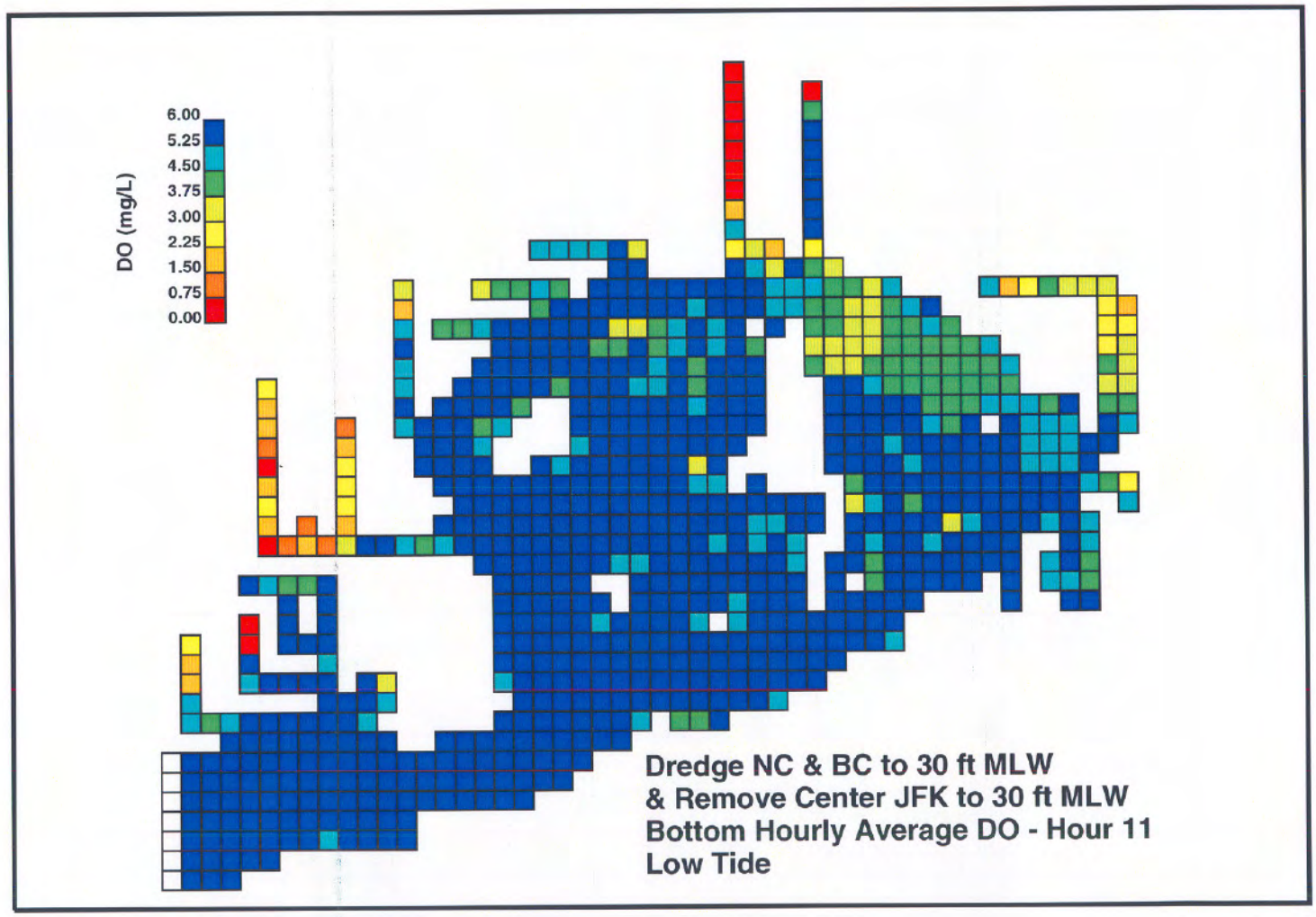


Figure 3-40. JEM Bottom DO - Hour 11 - Scenario 5

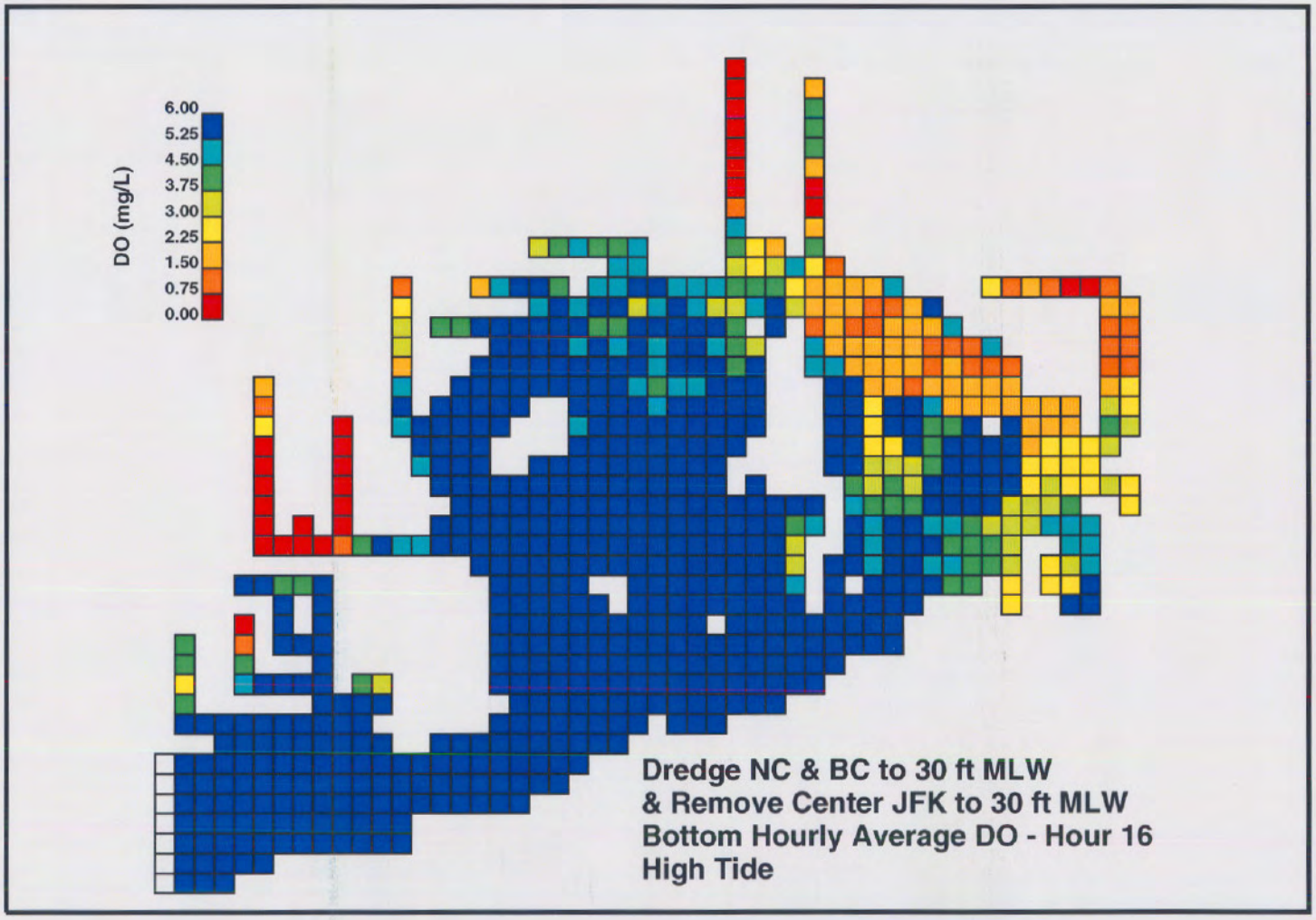


Figure 3-41. JEM Bottom DO - Hour 16 - Scenario 5

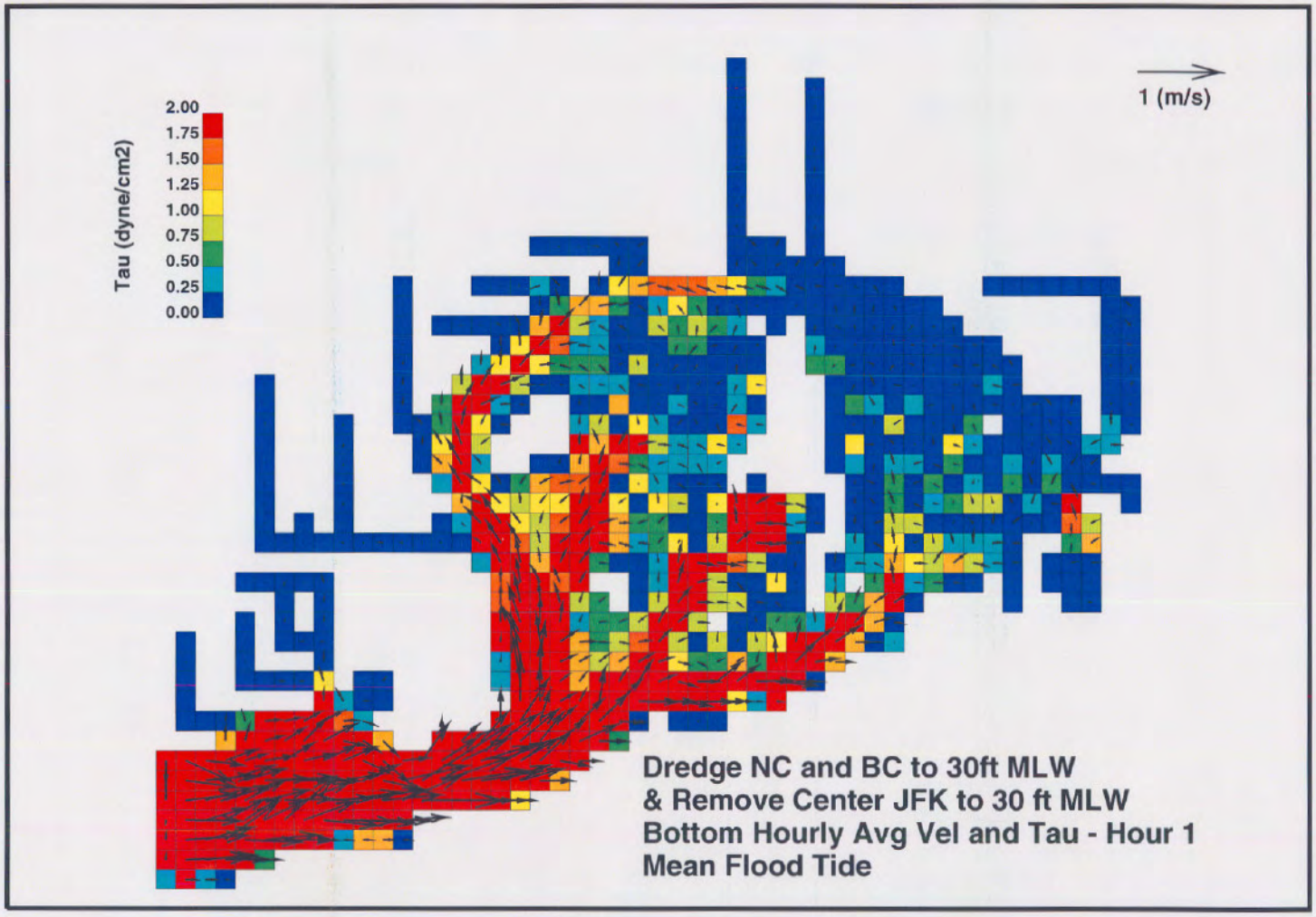


Figure 3-42. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 5

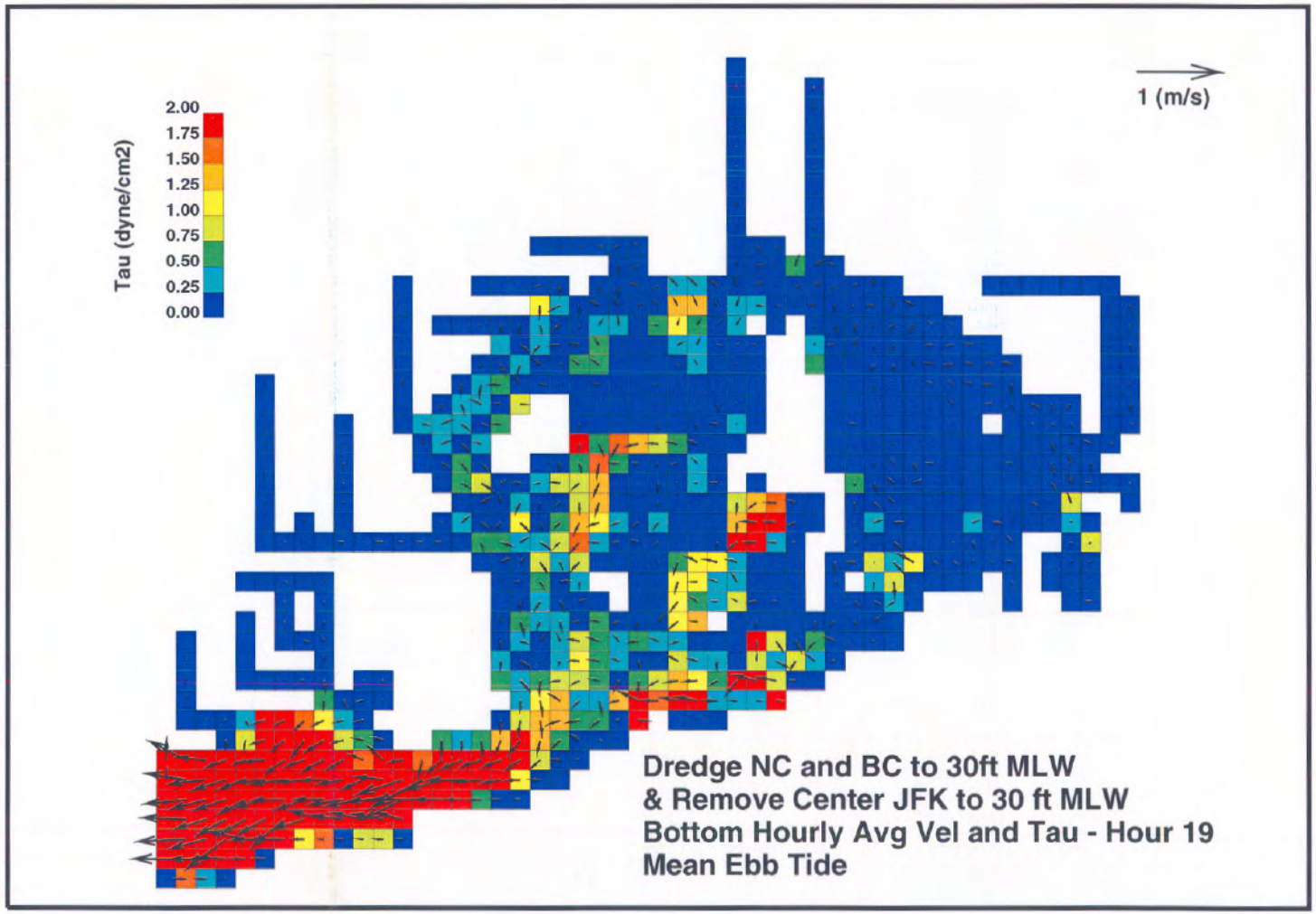


Figure 3-43. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 5

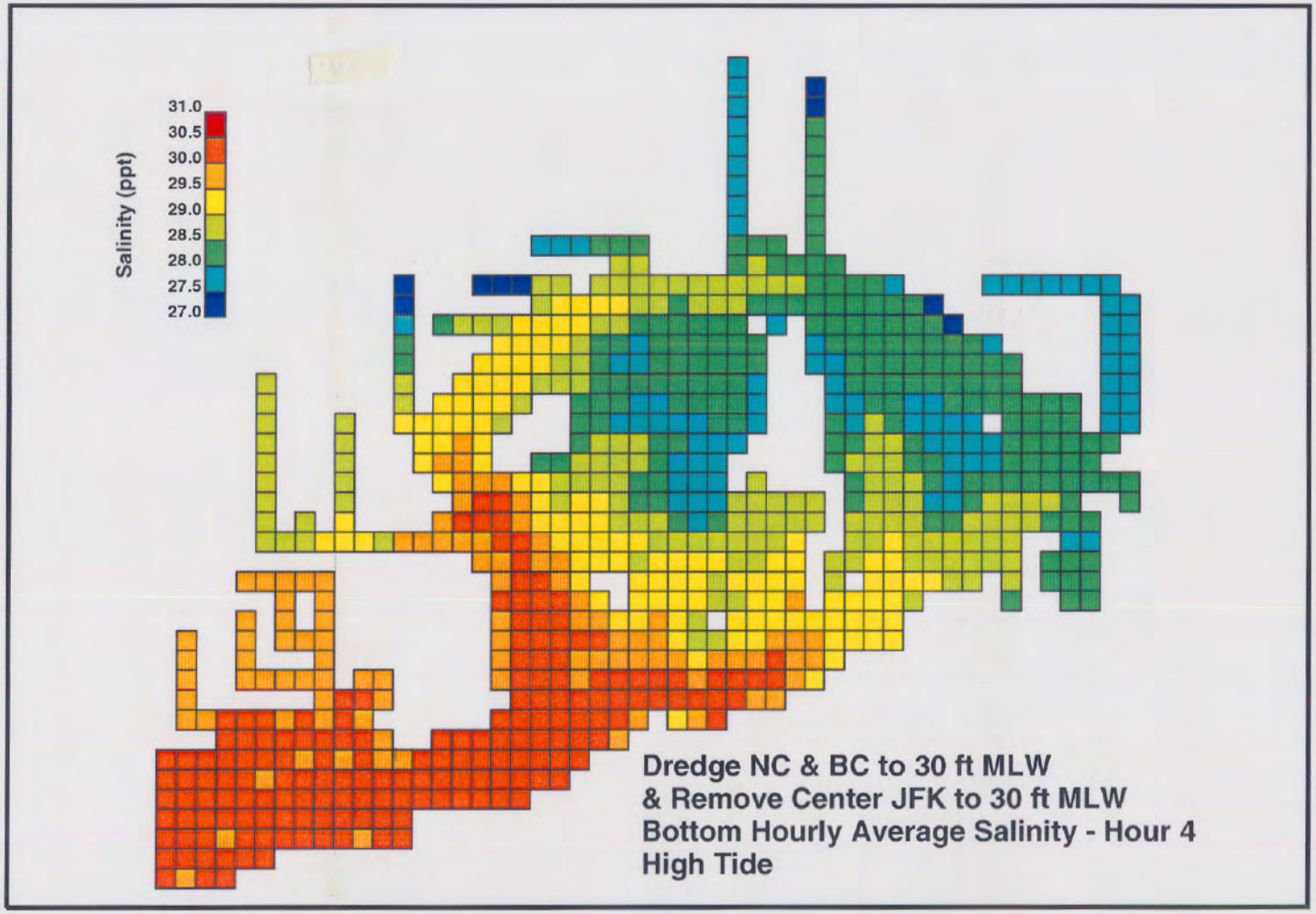


Figure 3-44. JEM Bottom Salinity - Hour 4 - Scenario 5

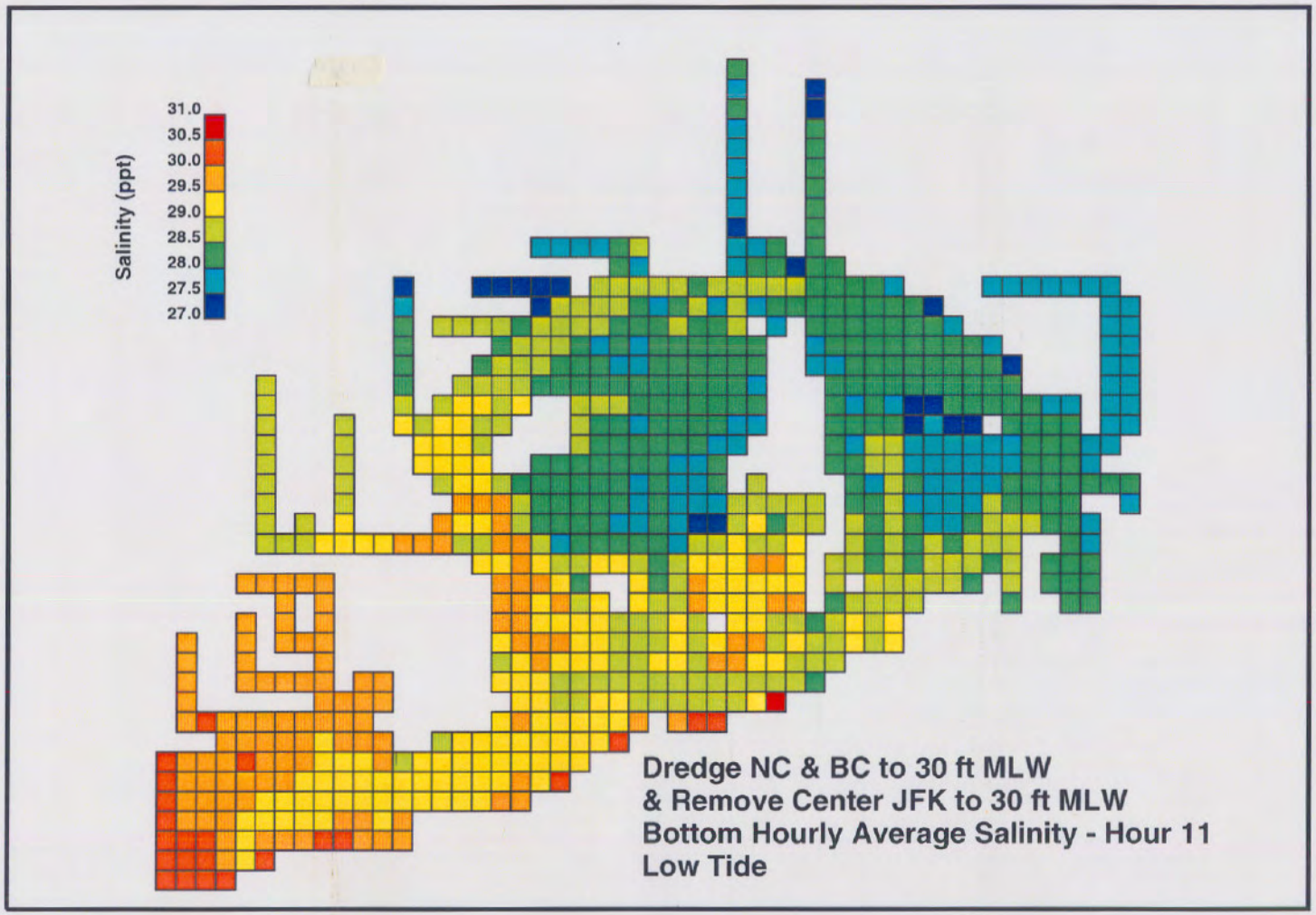


Figure 3-45. JEM Bottom Salinity - Hour 11 - Scenario 5

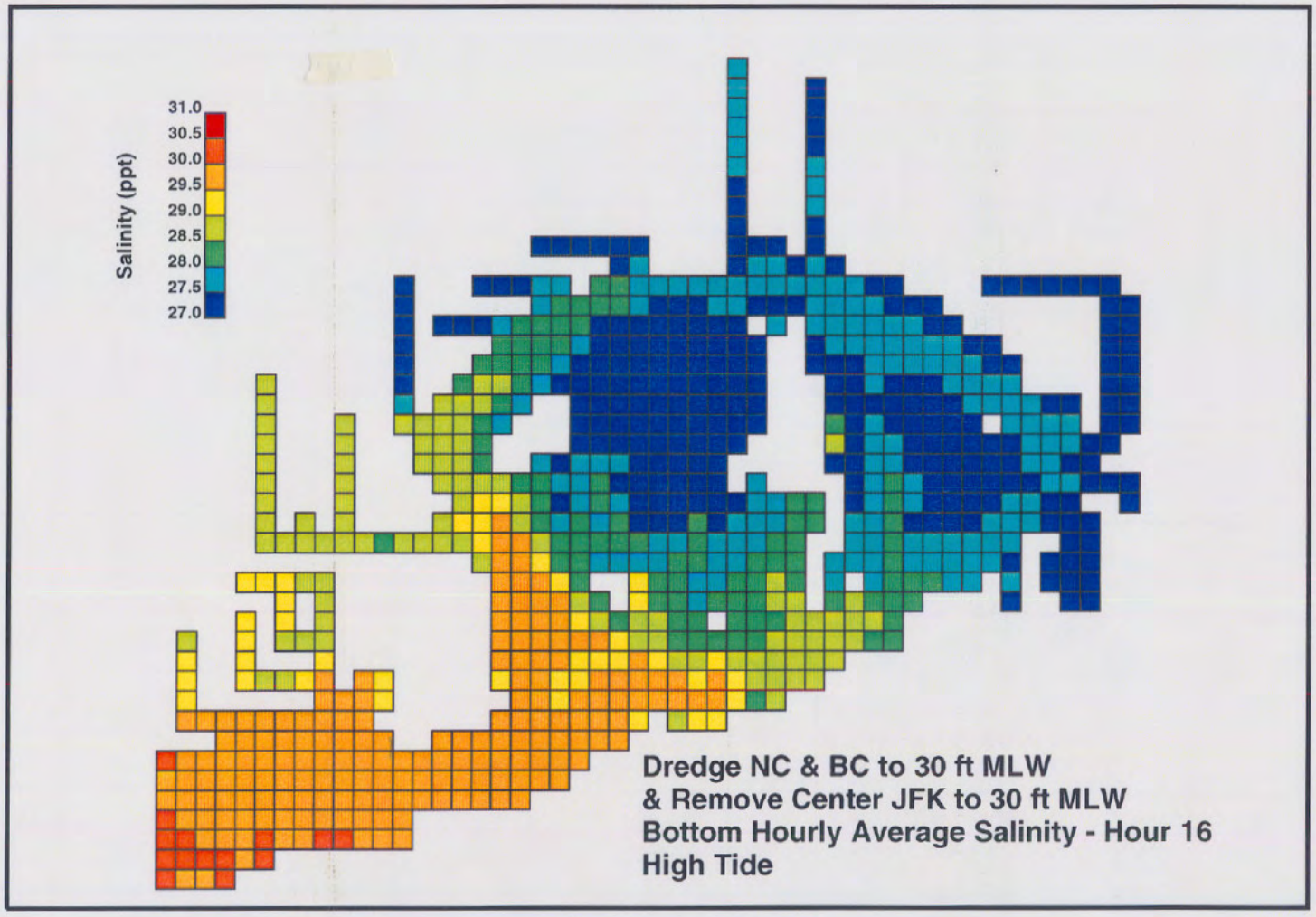


Figure 3-46. JEM Bottom Salinity - Hour 16 - Scenario 5

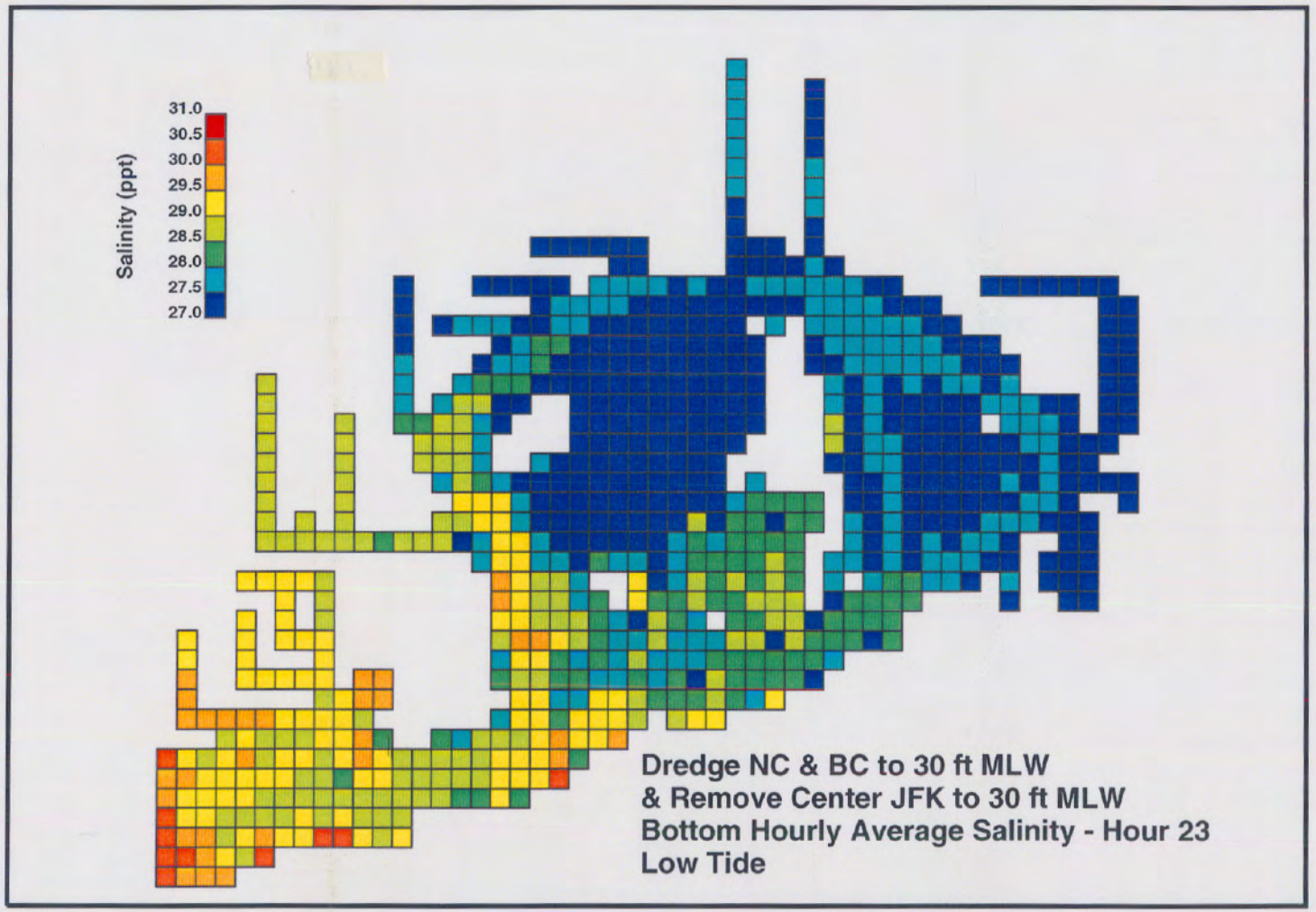


Figure 3-47. JEM Bottom Salinity - Hour 23 - Scenario 5

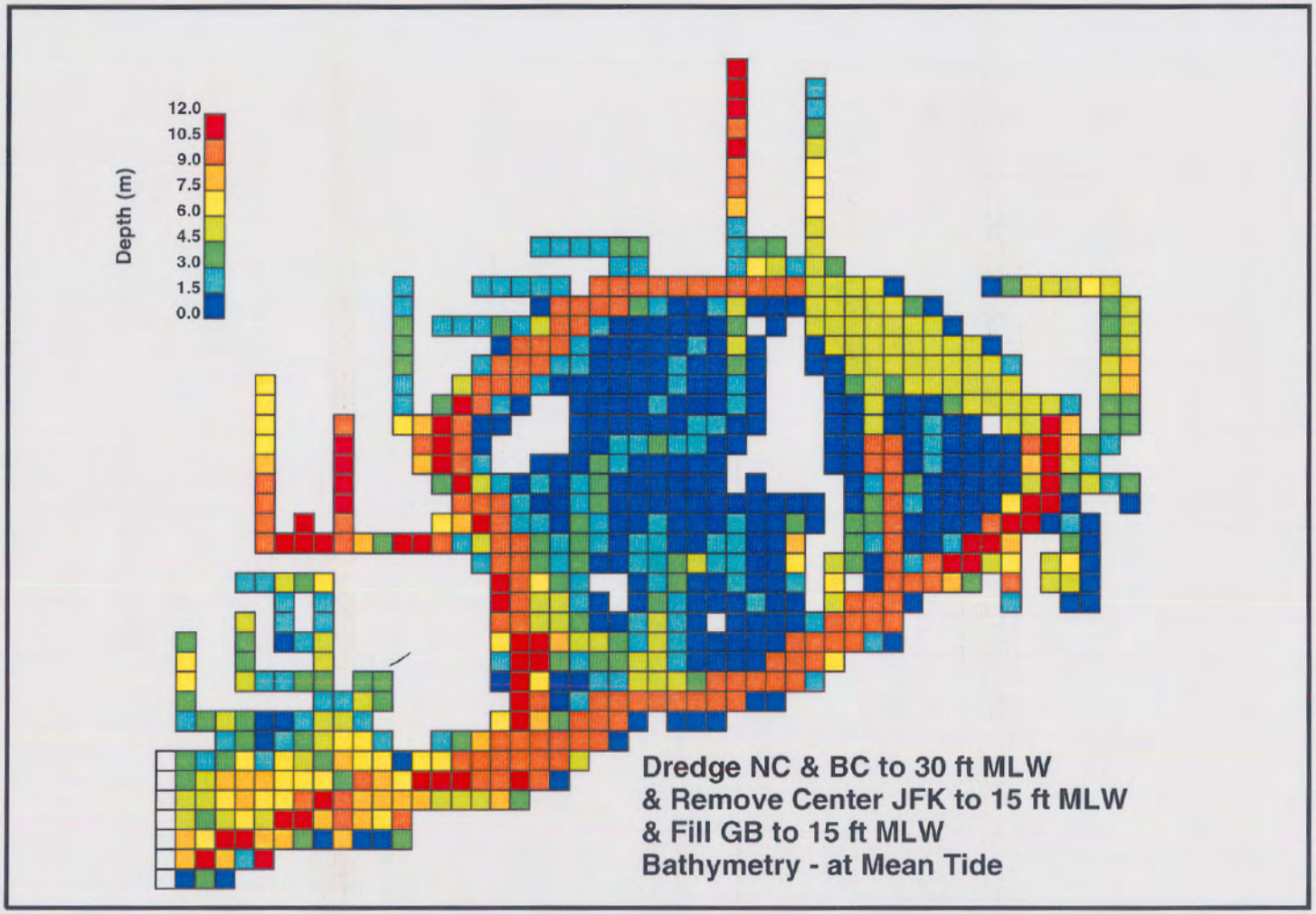


Figure 3-48. JEM Bathymetry - Scenario 6

3.8.2 Dissolved Oxygen

Scenario 6 results in the smallest improvement in DO in Grassy Bay, and causes a decrease in the dissolved oxygen concentration in the North Channel. Figures 3-49 and 3-50 present the computed dissolved oxygen results for scenario 6 during hours 11 and 16, respectively.

3.8.3 Velocity and Shear Stress

The shear stresses and velocities resulting from the bathymetric changes incorporated into this scenario are presented in Figure 3-51 for hour 1. The results are similar to scenario 5 with reduced velocities in the North Channel and Beach Channel. There are differences between these two runs, but both result in less water quality improvement than similar runs that do not include dredging the channels. The results in Figure 3-52 for hour 19 indicate a similar conclusion.

3.8.4 Salinity

Scenario 6 produces similar salinity results to scenario 5. Figures 3-53 and 3-54 for hours 4 and 11, respectively, show higher salinity in the back end of the bay than calibration conditions. Hours 16 and 23 (Figures 3-55 and 3-56) show that the higher salinity does not penetrate as far back into Grassy Bay when compared to scenario 5.

3.9 JEM CONCLUSIONS

All of the scenarios improved water quality conditions in Grassy Bay. Most of the scenarios resulted in a decrease in DO levels east of the runway extension. None of the scenarios created conditions to change Grassy Bay from a depositional zone to a non-depositional zone. Overall, scenario 2 (removal of the runway to 15 ft below MLW and filling Grassy Bay to 15 ft below MLW) resulted in the largest DO improvement during the two tidal cycles analyzed. The computed improvements due to bathymetric changes in scenario 1 were nearly as large as scenario 2. Results from the scenarios where only the center of the runway was removed improved conditions in Grassy Bay only slightly less than removing the entire runway extension. Dredging the North Channel and Beach Channel reduced the velocities in these channels. As a consequence, lower current velocities and smaller shear stresses were computed in Grassy Bay. Since higher shear stresses result in higher vertical mixing it is likely that the reduced shear stresses resulting from dredging reduced the vertical mixing, thereby adversely affecting the dissolved oxygen.

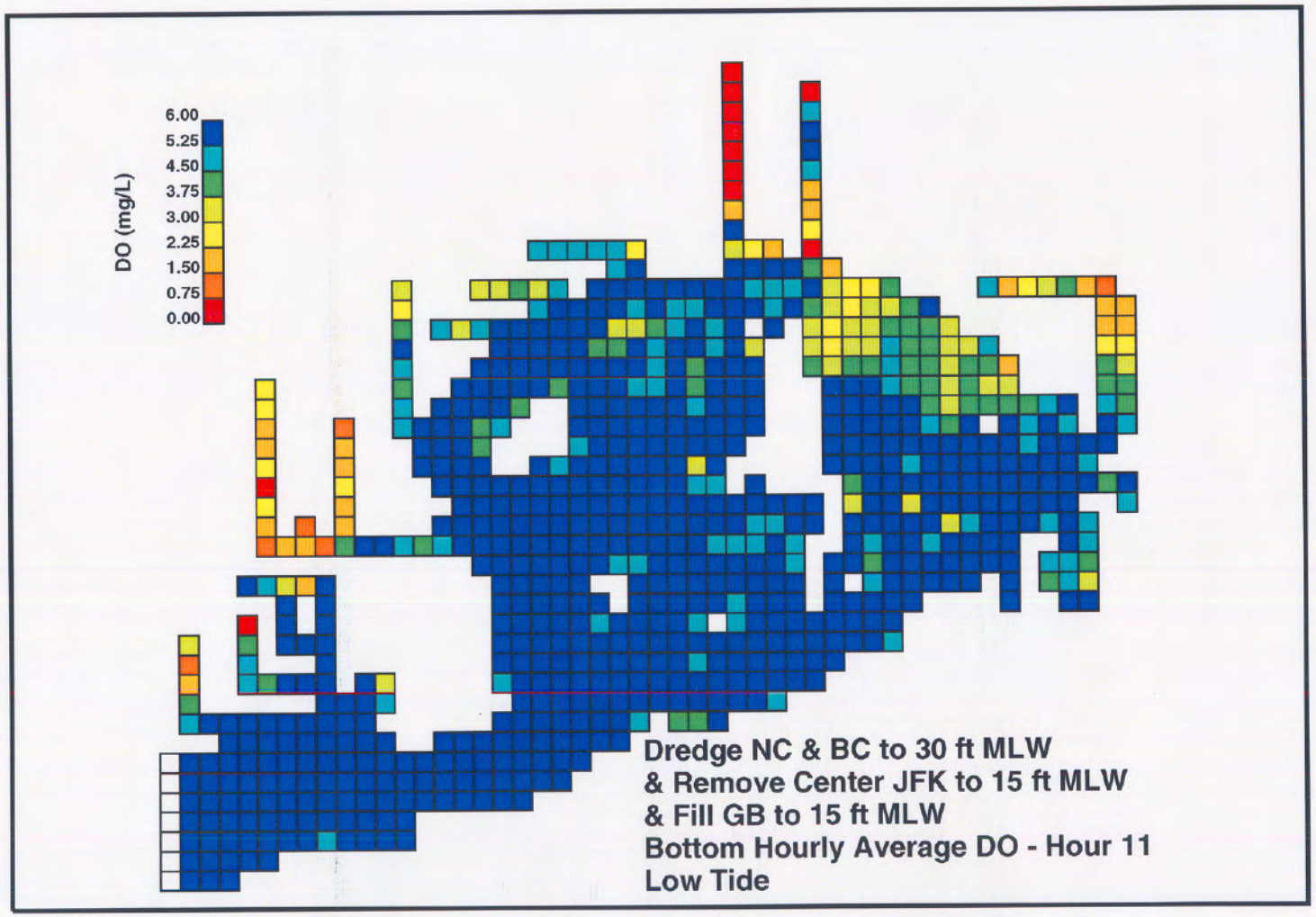


Figure 3-49. JEM Bottom DO - Hour 11 - Scenario 6

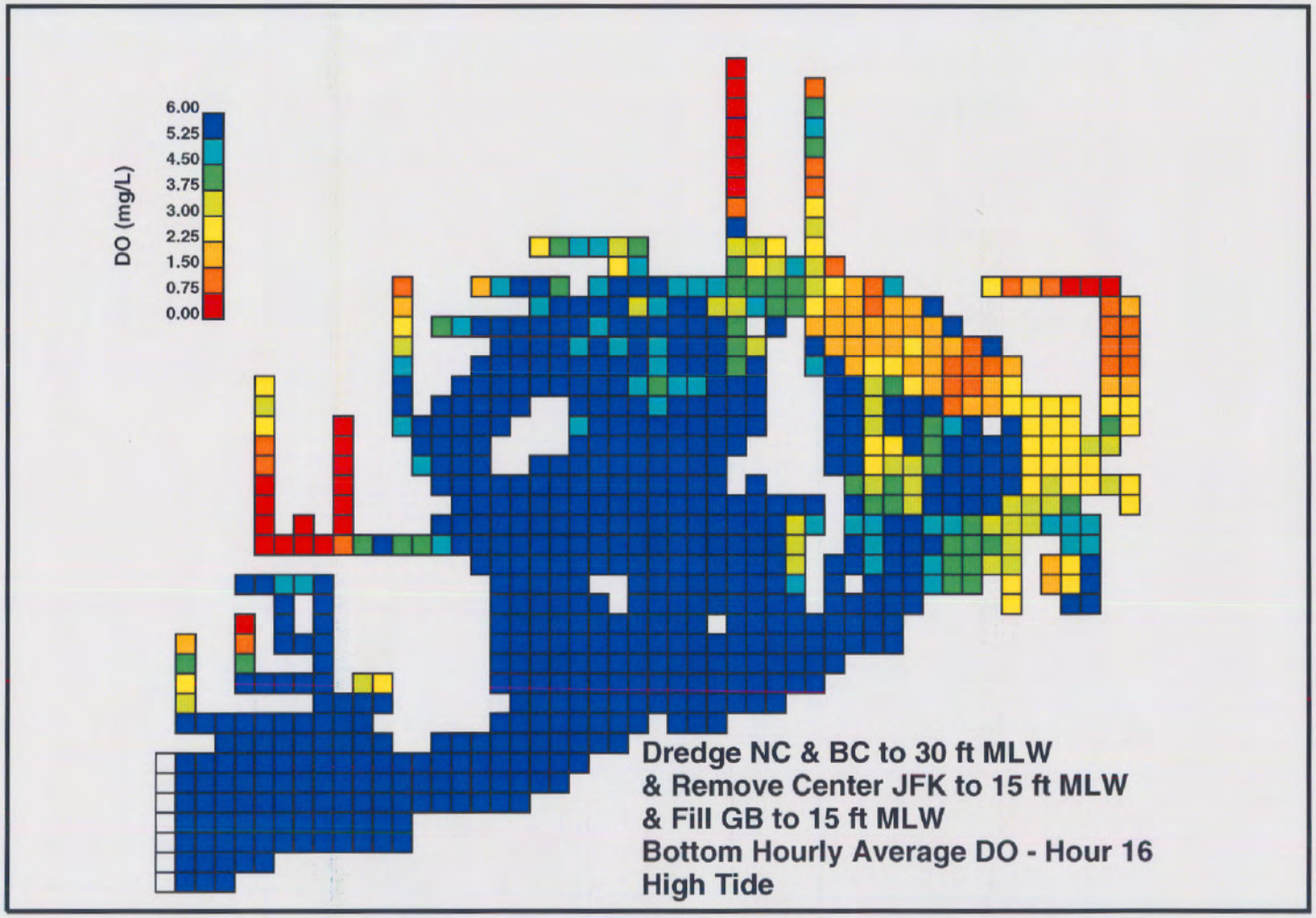


Figure 3-50. JEM Bottom DO - Hour 16 - Scenario 6

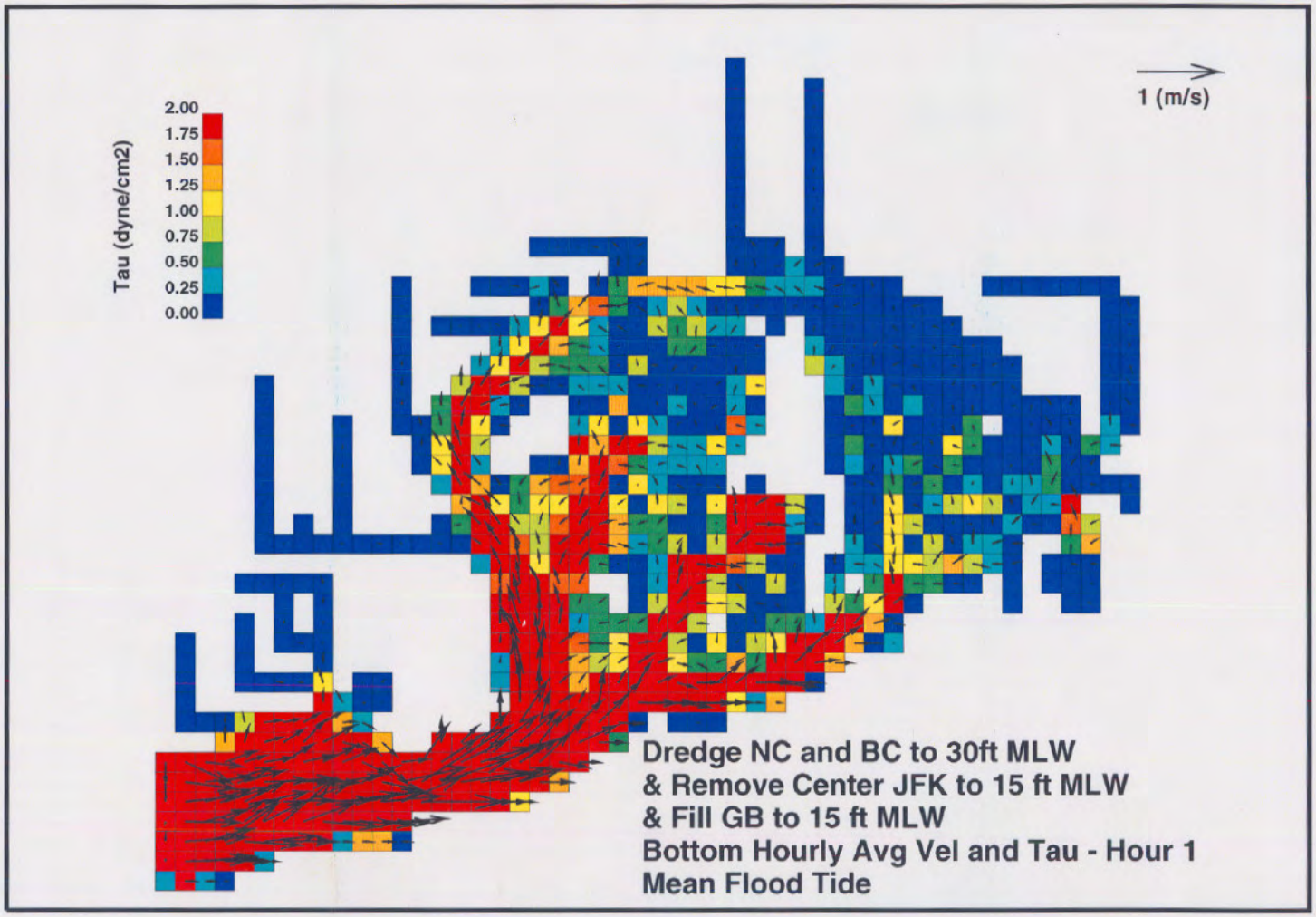


Figure 3-51. JEM Current Velocity and Shear Stress - Hour 1 - Scenario 6

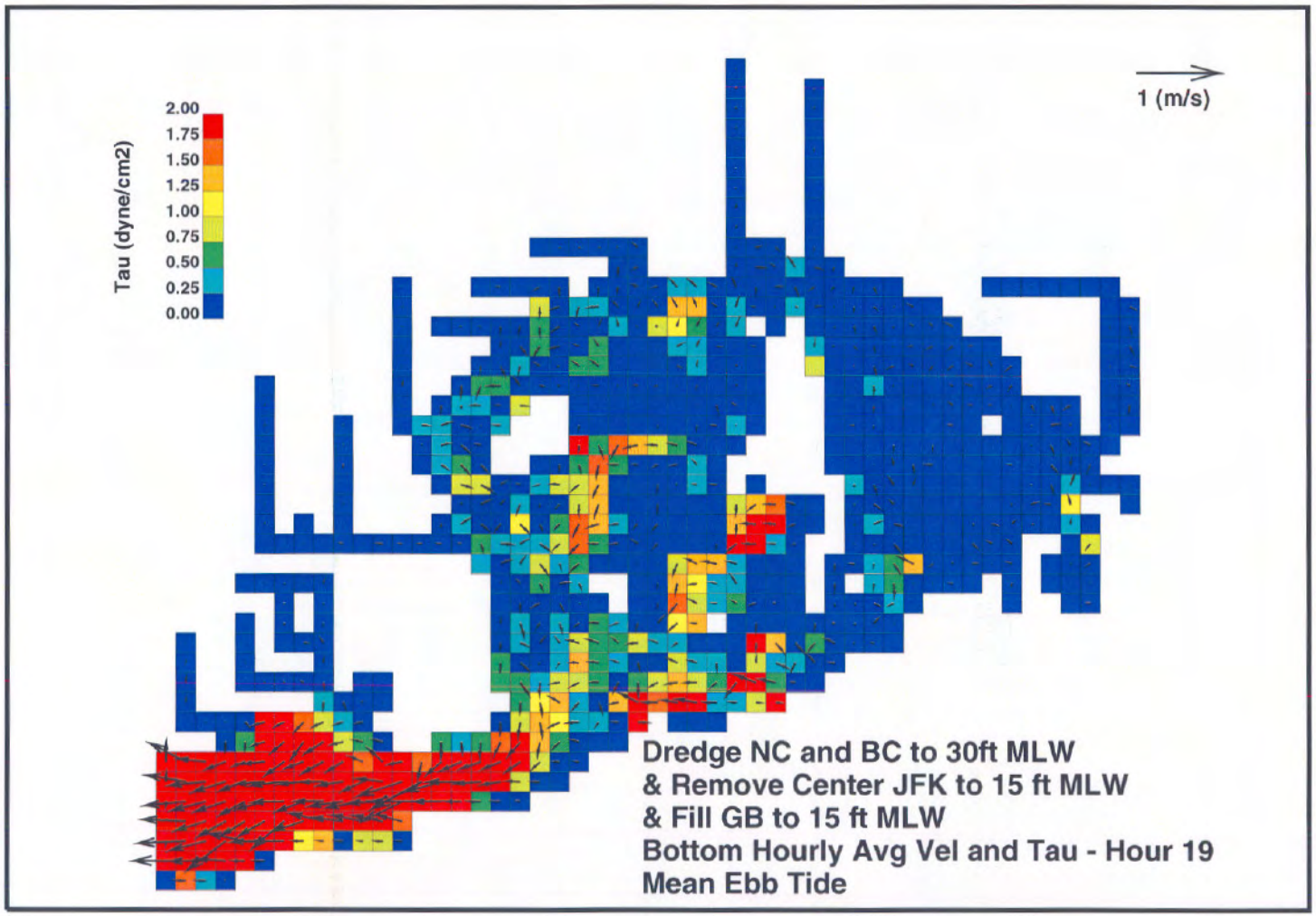


Figure 3-52. JEM Current Velocity and Shear Stress - Hour 19 - Scenario 6

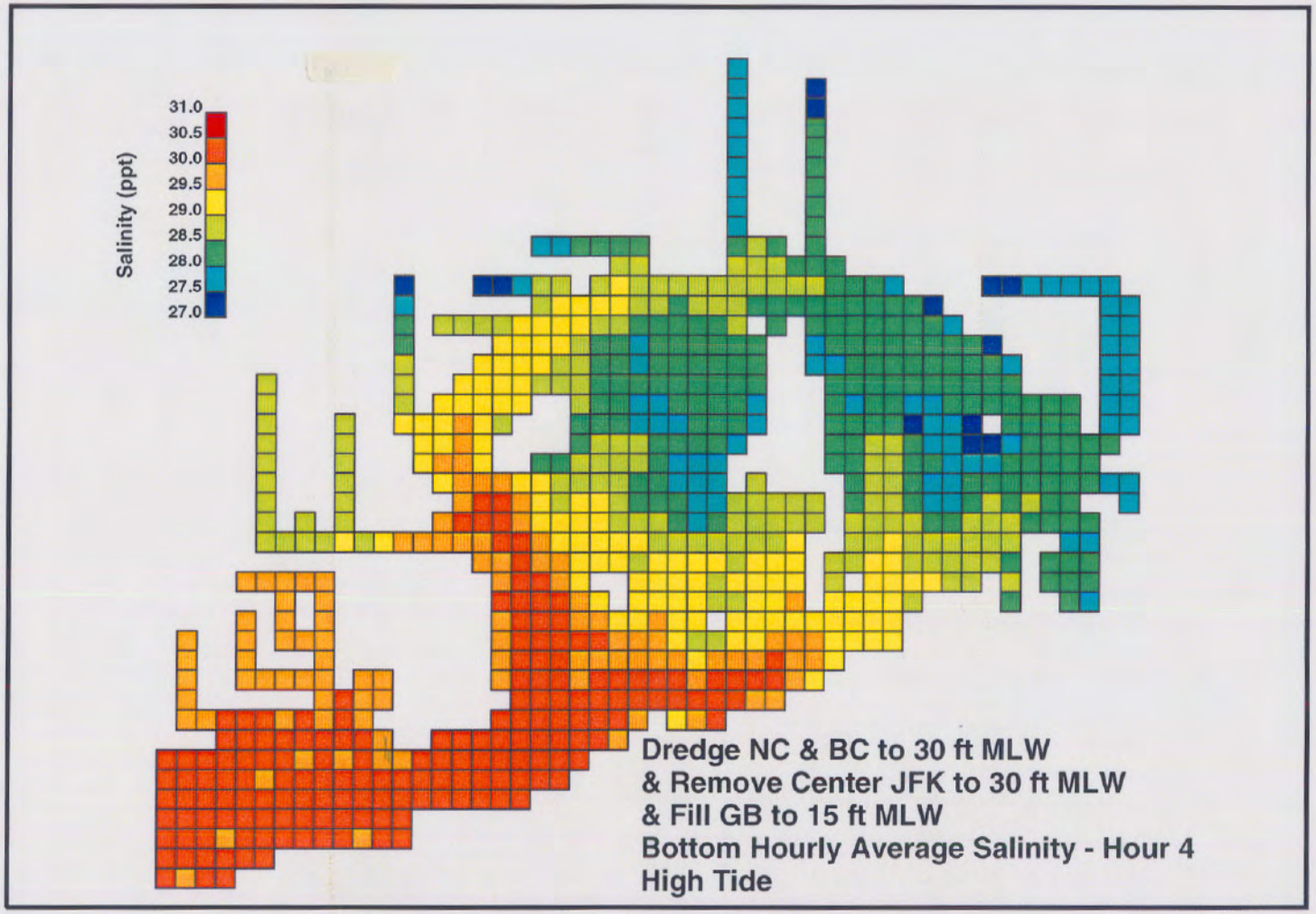


Figure 3-53. JEM Bottom Salinity - Hour 4 - Scenario 6

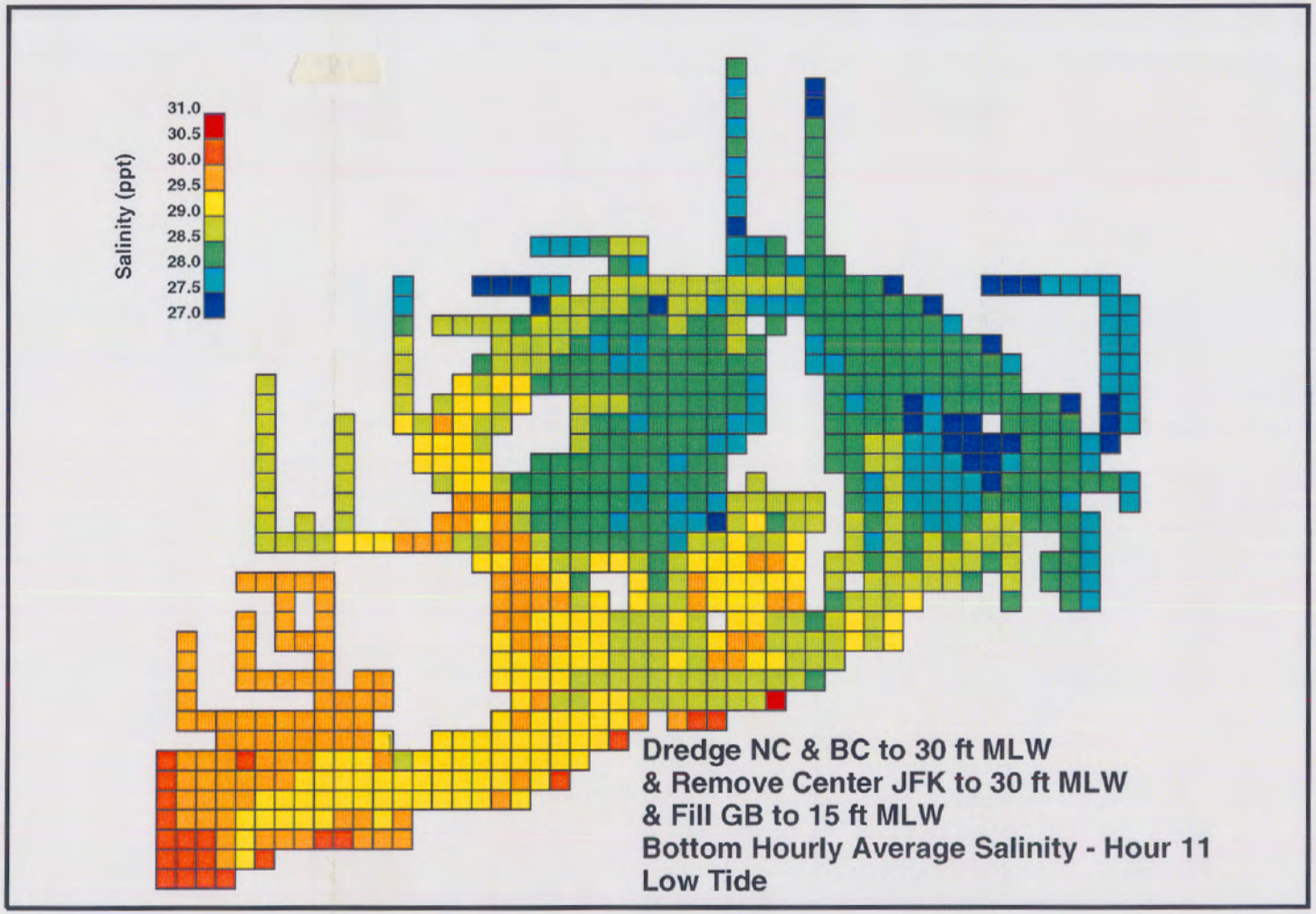


Figure 3-54. JEM Bottom Salinity - Hour 11 - Scenario 6

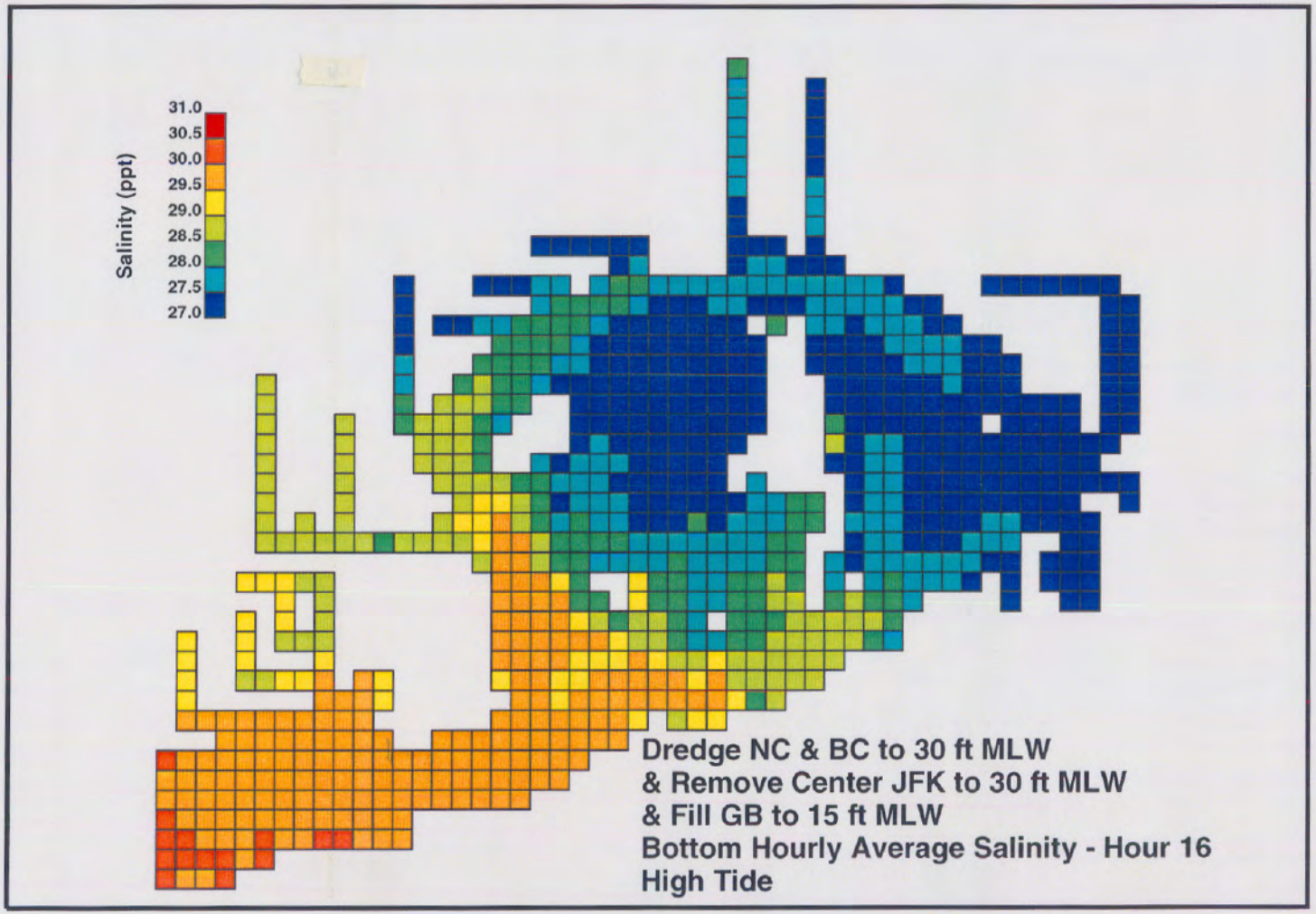


Figure 3-55. JEM Bottom Salinity - Hour 16 - Scenario 6

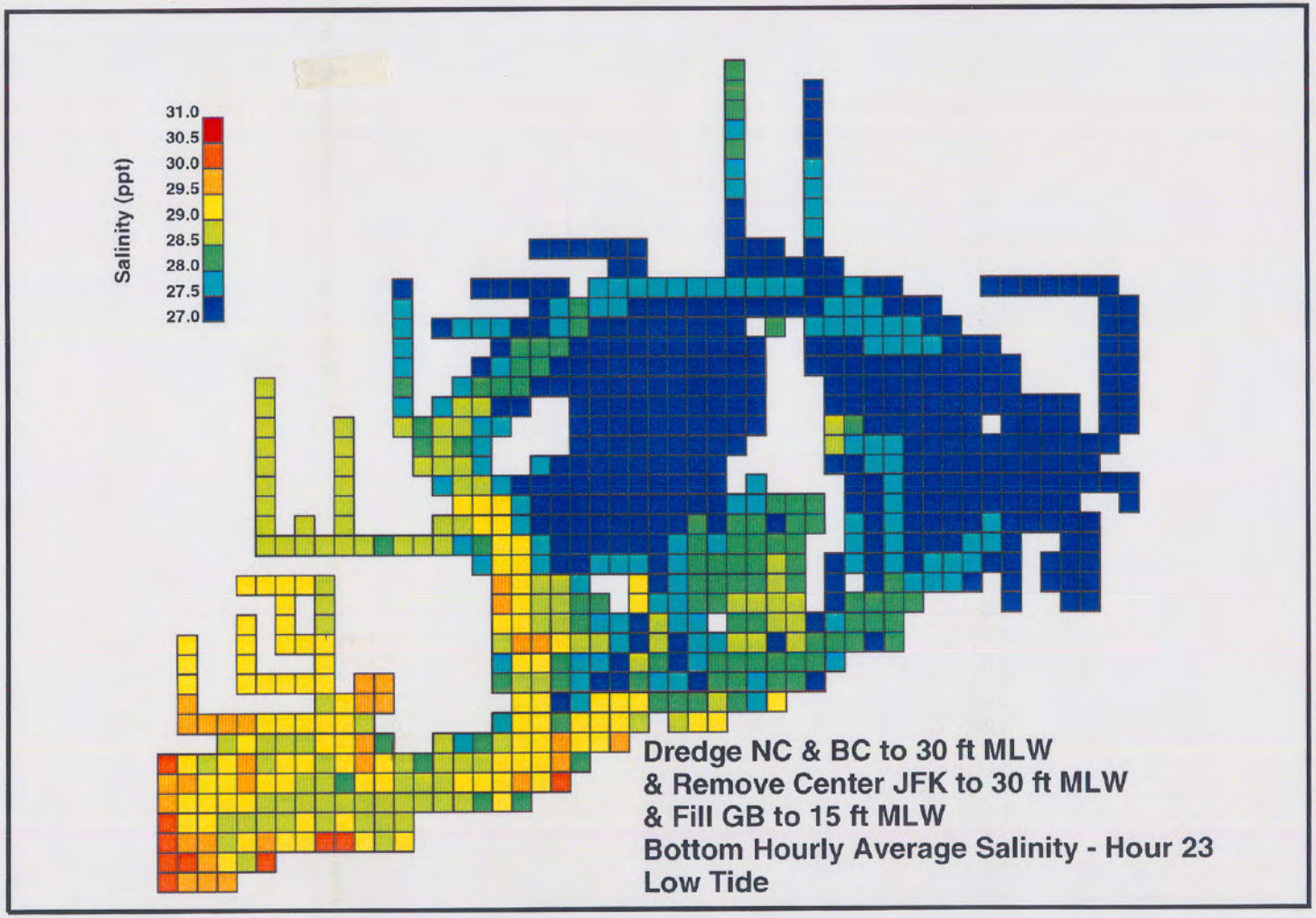


Figure 3-56. JEM Bottom Salinity - Hour 23 - Scenario 6

SECTION 4

NCM RESULTS

4.1 SCENARIOS

NCM was run to evaluate five scenarios in Paerdegat Basin and six scenarios in Fresh Creek. The scenarios included bathymetric changes and the incorporation of the CSO facility plans at both of the tributaries. These scenarios were as follows:

Paerdegat Basin Evaluation

(1) Existing conditions with the natural sill in place,
(2) Existing conditions with CSO improvements,
(3) Existing conditions without the natural sill in place and with CSO improvements,
(4) Upstream half of the basin filled to MLW and the downstream half left alone, without the sill and with CSO improvements,
(5) Upstream half of the basin filled to 4 ft below MLW and the downstream half left alone, without the sill and with CSO improvements.

Fresh Creek Evaluation

(1) Existing conditions with the natural sill in place,
(2) Existing conditions with CSO improvements,
(3) Existing conditions without the natural sill in place and with CSO improvements,
(4) Upstream half filled to MLW, lower half as is, without the sill and with CSO improvements,
(5) Upstream half as is, lower half filled to 4 ft below MLW or as is (which ever is less), without the sill and with CSO improvements,
(6) Upstream half as is, lower half filled to 8 ft below MLW or as is (which ever is less), without the sill and with CSO improvements.

Due to the distance between the two tributaries and to save computational time, modifications were made to both tributaries and run at the same time. All of the runs were based on 1988 meteorological, tidal, and loading conditions. Bathymetric conditions were based on the latest available data. The more specific conditions of each of the scenarios will be described in the following sections.

The results from these scenarios will be presented as a series of transect plots along the center channel of Paerdegat Basin and Fresh Creek. Results were calculated for the average of every hour, for 12 hours, of two spring tides during the summer, occurring on July 30th and August 12th, shown in Figure 4-1. One to three of the hours will be presented for each scenario to show the differences between the runs. The full series of averaged tidal figures will be shown in Appendix F. The results of the individual spring tides are presented in Appendix G. The results to follow, and shown in the appendices, include surface and bottom dissolved oxygen (DO), salinity, and velocity, as well as the bottom shear stress. The bathymetry of both transects will also be presented to help explain the differences between the model runs. A plan view for DO will also be presented. The tidal elevations and the differences in the tidal elevations due to the bathymetric changes will also be presented.

4.2 SCENARIO 1

Scenario 1 is the existing or baseline condition, and will be used to compare against the other scenarios. Figure 4-2 presents the bathymetry used for this model run. The North Channel is apparent in the model domain characterized by the red, orange and yellow colors. In the southern portion of the domain, the model is bordered by shallow areas, generally less than 3.0 m deep. The creeks are generally 0.0 to 4.5 m deep with a few deeper areas in Paerdegat Basin.

4.2.1 Paerdegat Basin

Figure 4-3 presents results in Paerdegat Basin for the first hour of the averaged spring tidal cycles chosen. This hour represents the period of greatest DO stratification during this tidal cycle and some of the highest computed shear stresses. At this time, the tide is approximately mean tide and flooding. During this period most of the basin is stratified with regard to DO and the bottom DO reaches concentrations as low as 1.0 mg/L. The surface DO concentration is above 5.0 mg/L for most of the basin except near the head end where the DO concentration approaches 4.0 mg/L. Near the mouth, the basin is well mixed and both the top and bottom DO are near 5.0 mg/L. The salinity is well mixed in the basin and ranges from approximately 24.5 ppt at the head end to almost 26 ppt at the mouth.

The surface and bottom velocity is presented in the third panel of Figure 4-3. The surface velocities are higher than the bottom velocities except at the head end, and both generally decrease toward the head end. During this portion of the tidal cycle, the velocities remain below 15 cm/s. The bottom velocities are enough to create a bottom shear stress of approximately 0.50 dynes/cm^2, which should not cause sediment resuspension. Generally, a shear stress of approximately 1.0 dynes/cm^2 is required to begin resuspending fine-grained cohesive sediments. The higher velocities and shear stresses are computed at the mouth of Paerdegat Basin where the natural still occurs.

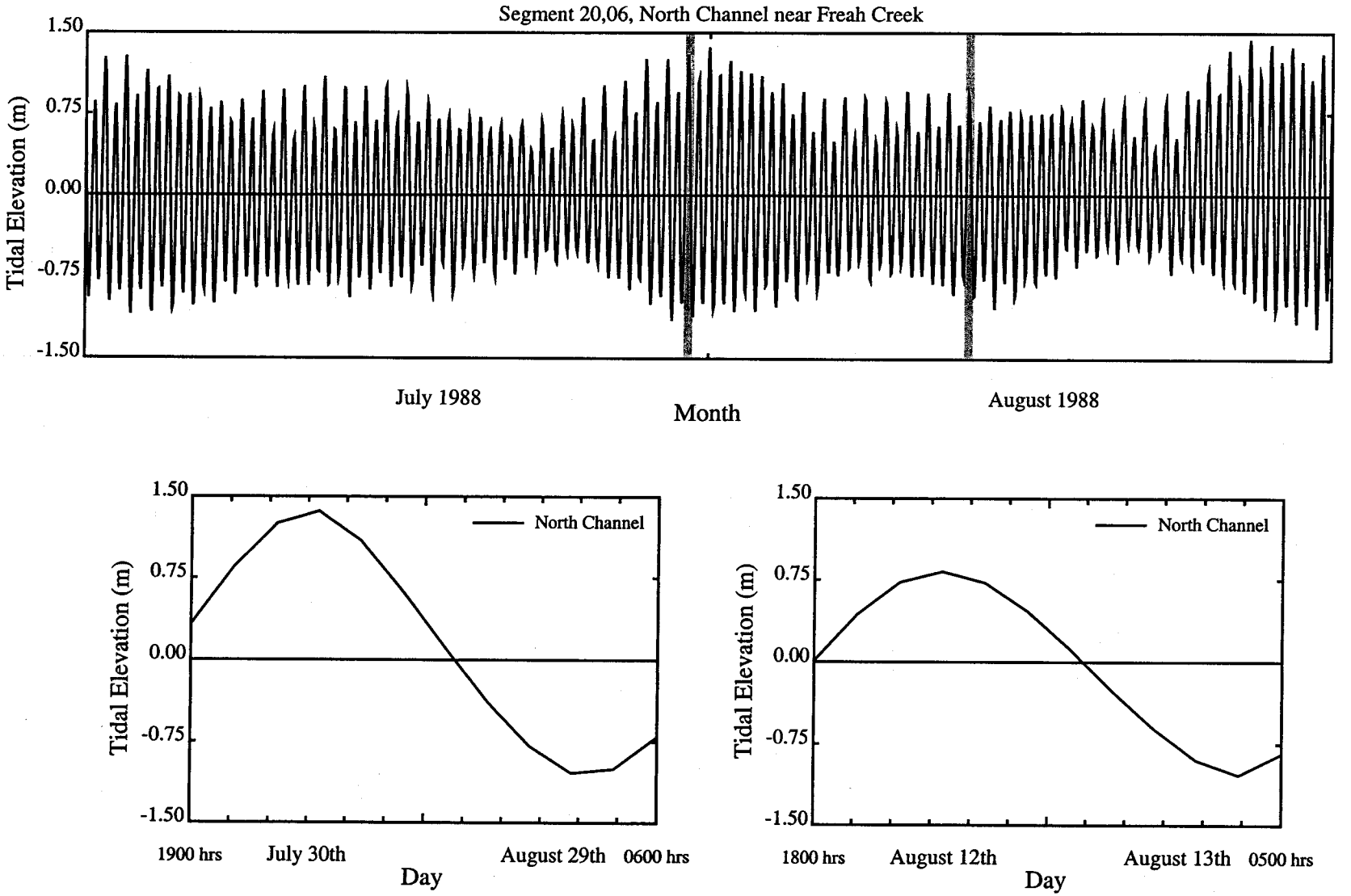


Figure 4-1. Spring Tides Chosen for NCM Results

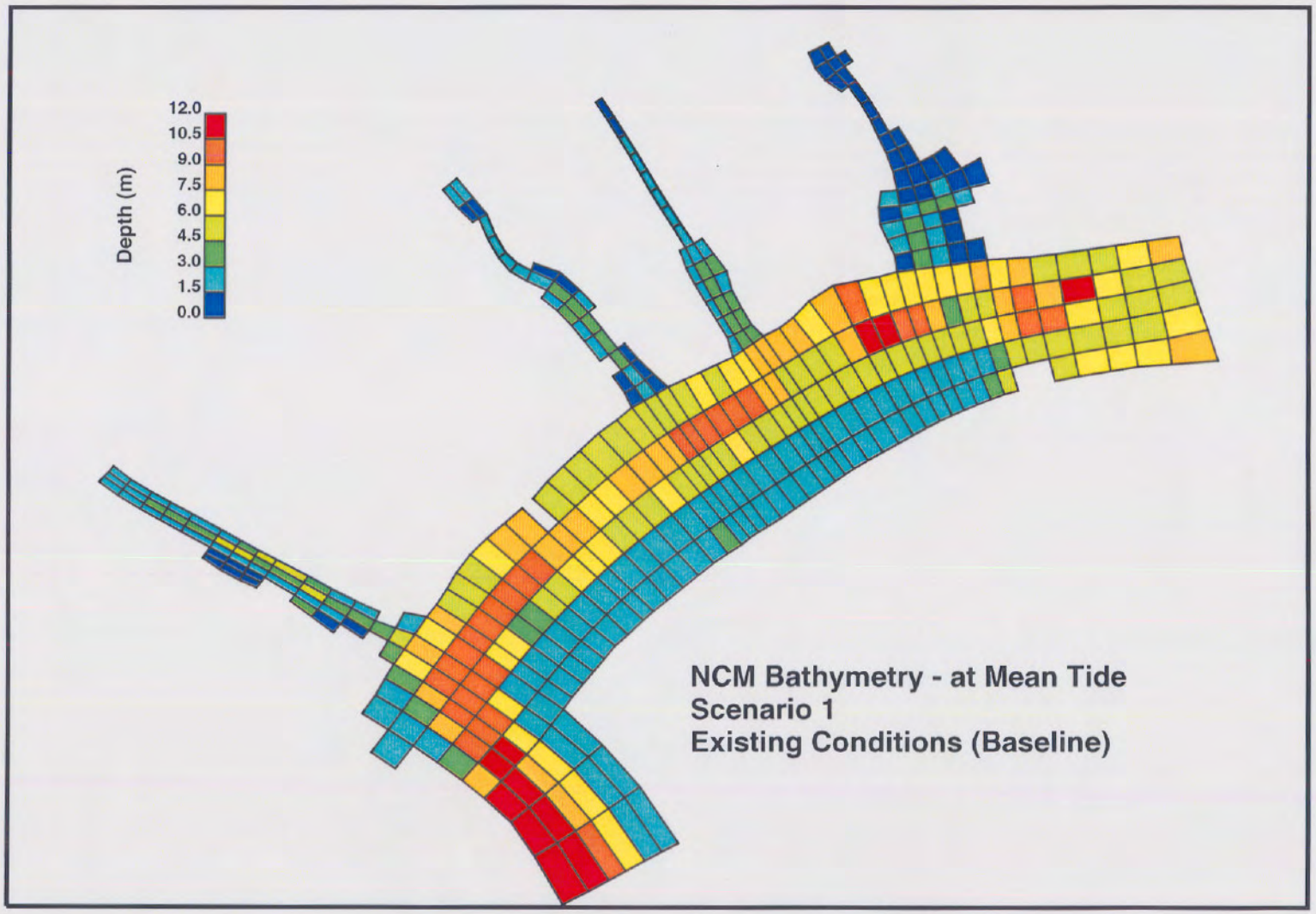


Figure 4-2. NCM Bathymetry - Existing Conditions

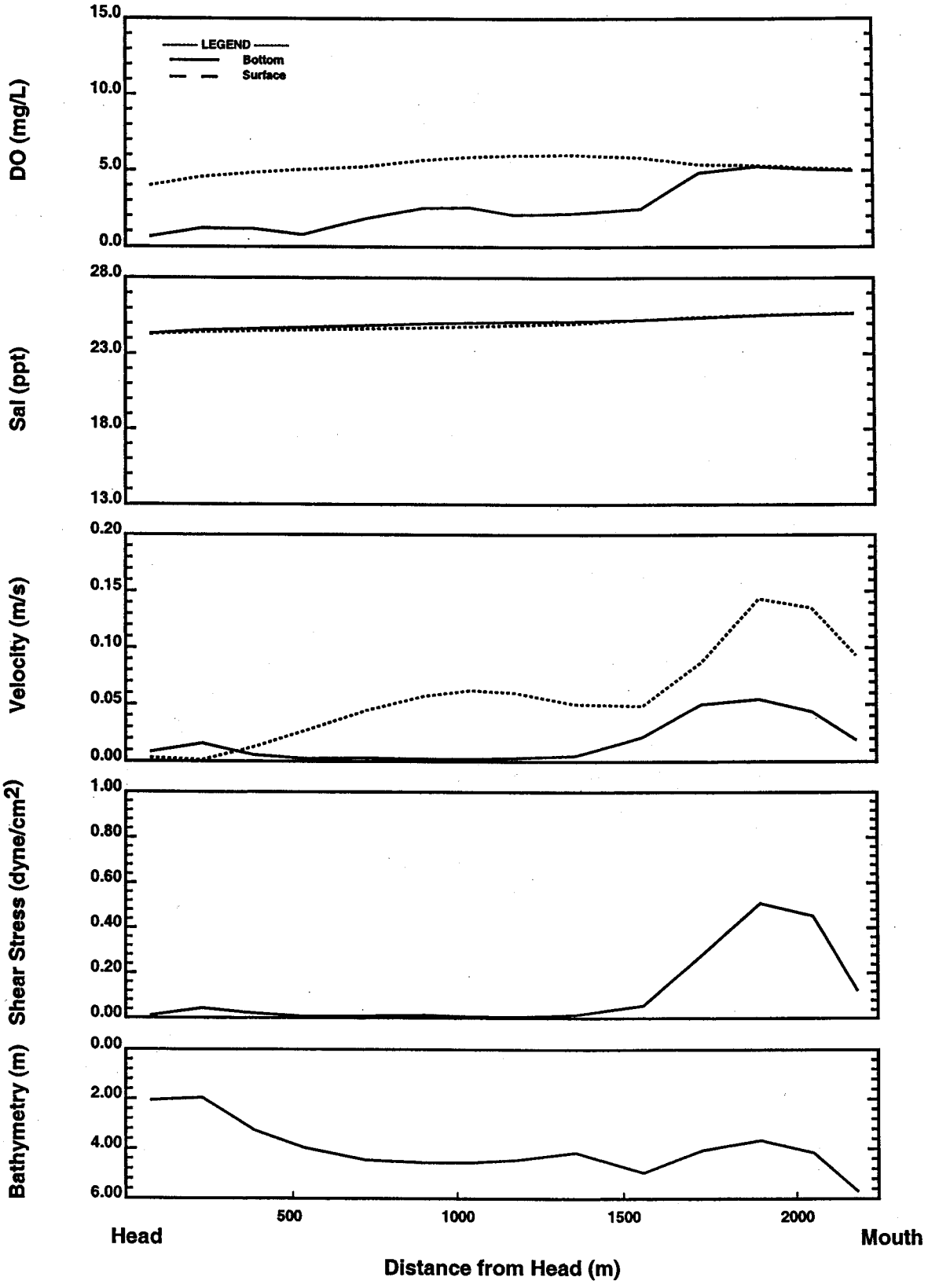


Figure 4-3. Transect of Paerdegat Basin - Hour 1 - Existing Conditions

Figure 4-4 presents hour 8 of the tidal cycle chosen. At this point in the tidal cycle, the tide is ebbing and just below mean tide level. The DO concentrations in the basin are more well mixed, and high shear stresses are calculated. The bottom water DO concentrations have increased while the surface DO concentrations have declined from the hour 1 concentrations. The salinity during hour 8 is slightly more stratified than hour 1. The surface velocities during hour eight are generally higher across the length of the basin. The bottom velocities are higher during hour 8 than hour 1 in the middle of the basin, but these velocities cause only slightly higher bottom shear stresses along this section of the basin. The bottom velocity at the mouth of the basin is lower during hour 8 than hour 1.

4.2.2 Fresh Creek

Existing conditions in Fresh Creek are presented in Figure 4-5 for hour 1. The dissolved oxygen computed by the model is the lowest at the head end and in the deeper section of the creek between 1,000 and 1,500 m from the head end. The salinity is similar to Paerdegat Basin with a concentration of 24 ppt at the head end and 26 ppt near the mouth. The bottom current velocities are low, with the highest velocities at the mouth. The surface velocities are highest at the mouth and where the creek becomes shallower. The highest velocity during this hour is approximately 10 cm/s.

During hour 8, the surface DO has declined from hour 1 levels across the entire length of the creek (Figure 4-6). The bottom DO concentration at the head end is computed to be less than 2.0 mg/l in the bottom water at this time. The DO stratification that was apparent in the deeper scetion near the mouth has diminished. The velocities at this time have increased across the creek with maximum current velocities reaching 16 cm/s. The maximum shear stress is computed at the mouth.

Figure 4-7 presents the results for surface and bottom DO, salinity and current velocity, as well as bottom shear stress for Fresh Creek during hour 12 of the tidal cycle. As compared to hour 8, the DO concentrations are similar, and the velocities have increased across the length of the creek except for a small portion of the deeper section. The bottom shear stress has increased dramatically at the mouth of the creek to greater than 1.0 dyne/cm^2.

4.3 SCENARIO 2

4.3.1 Paerdegat Basin

Scenario 2 is the same as scenario 1 except that the CSO facility plans are implemented at Paerdegat Basin and Fresh Creek. In Paerdegat Basin, the facility plan includes a 30 MG CSO storage tank with an additional 20 MG of in-line storage. The Coney Island Water Pollution Control Plant

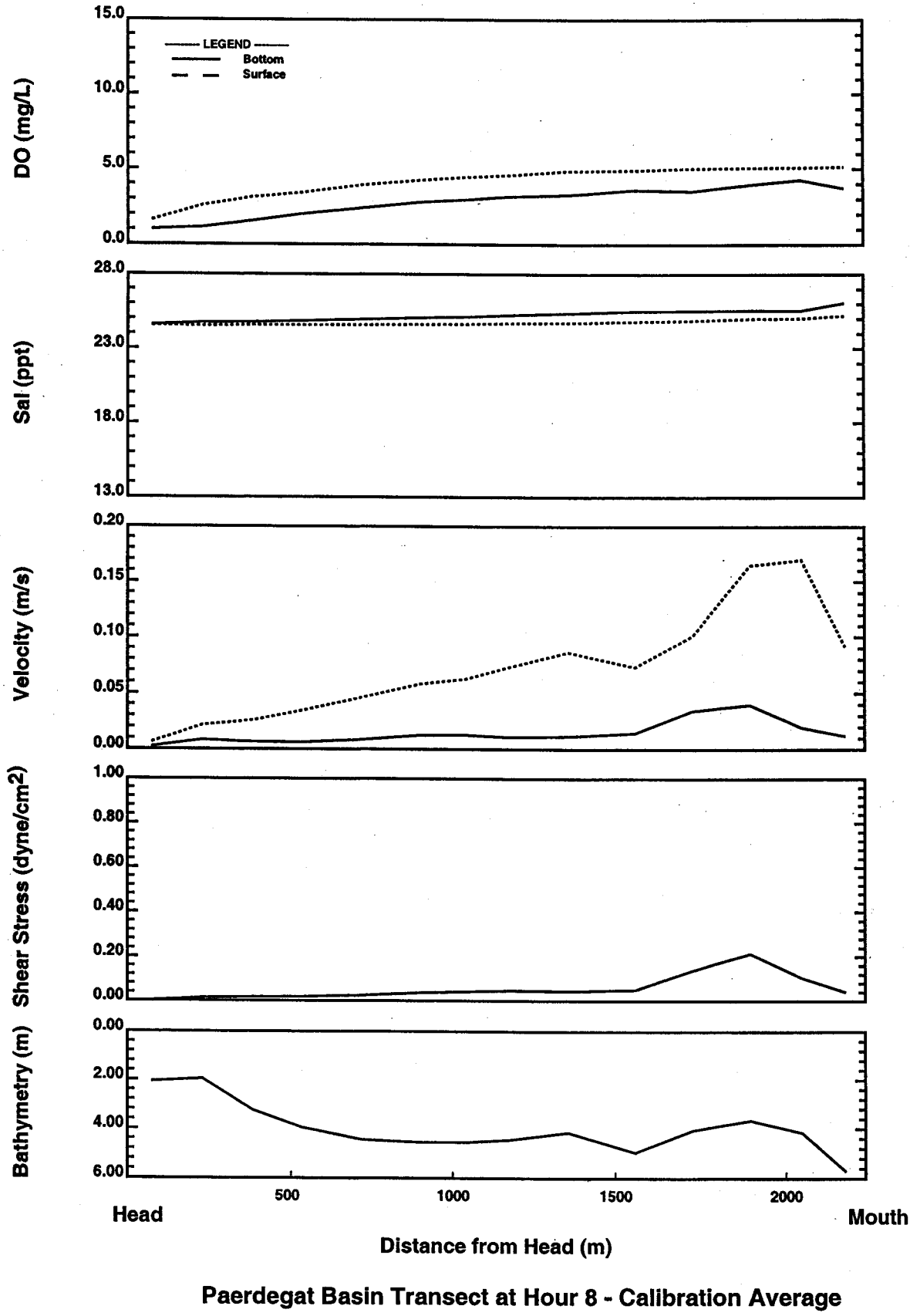


Figure 4-4. Transect of Paerdegat Basin - Hour 8 - Existing Conditions

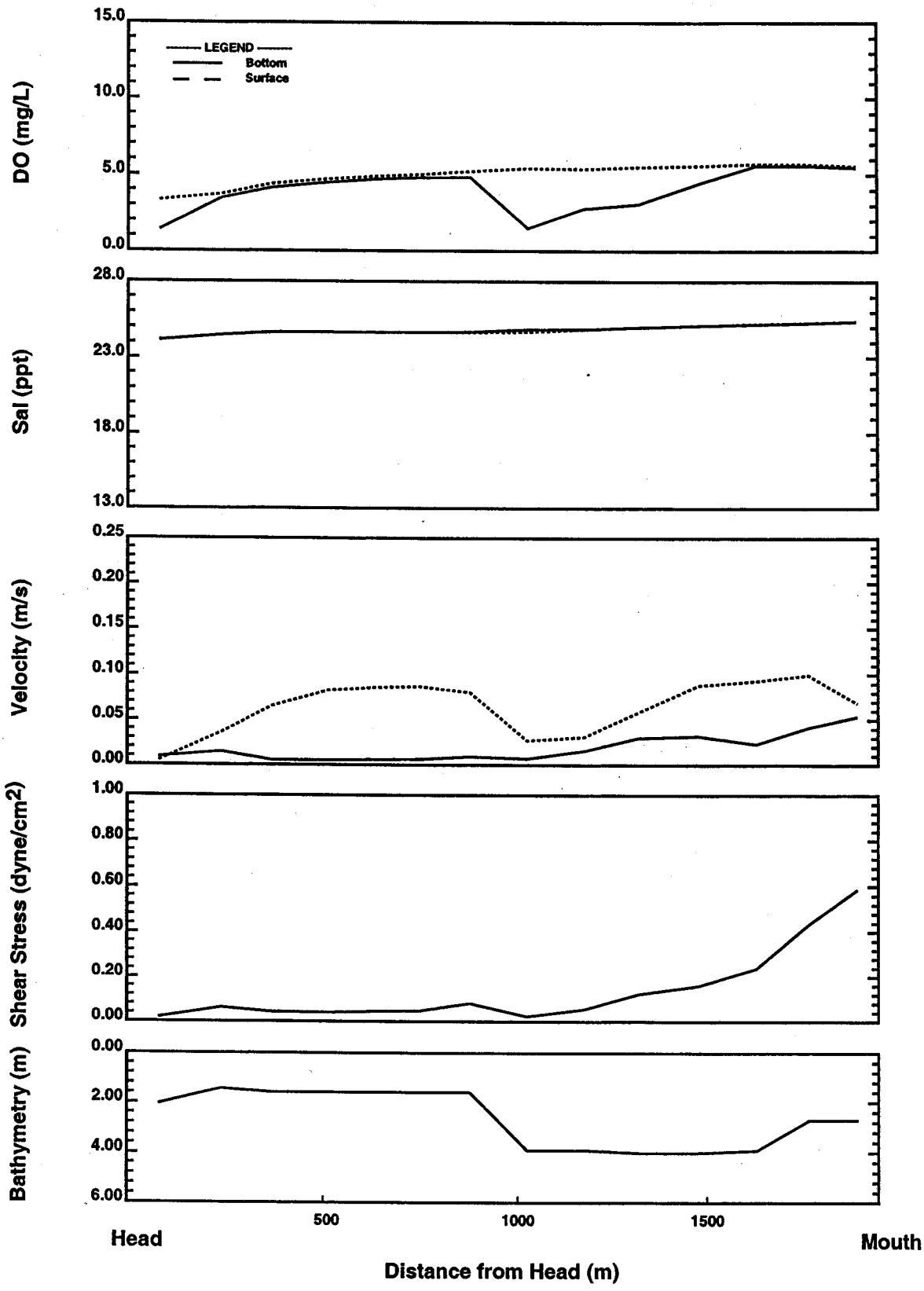


Figure 4-5. Transect of Fresh Creek - Hour 1 - Existing Conditions

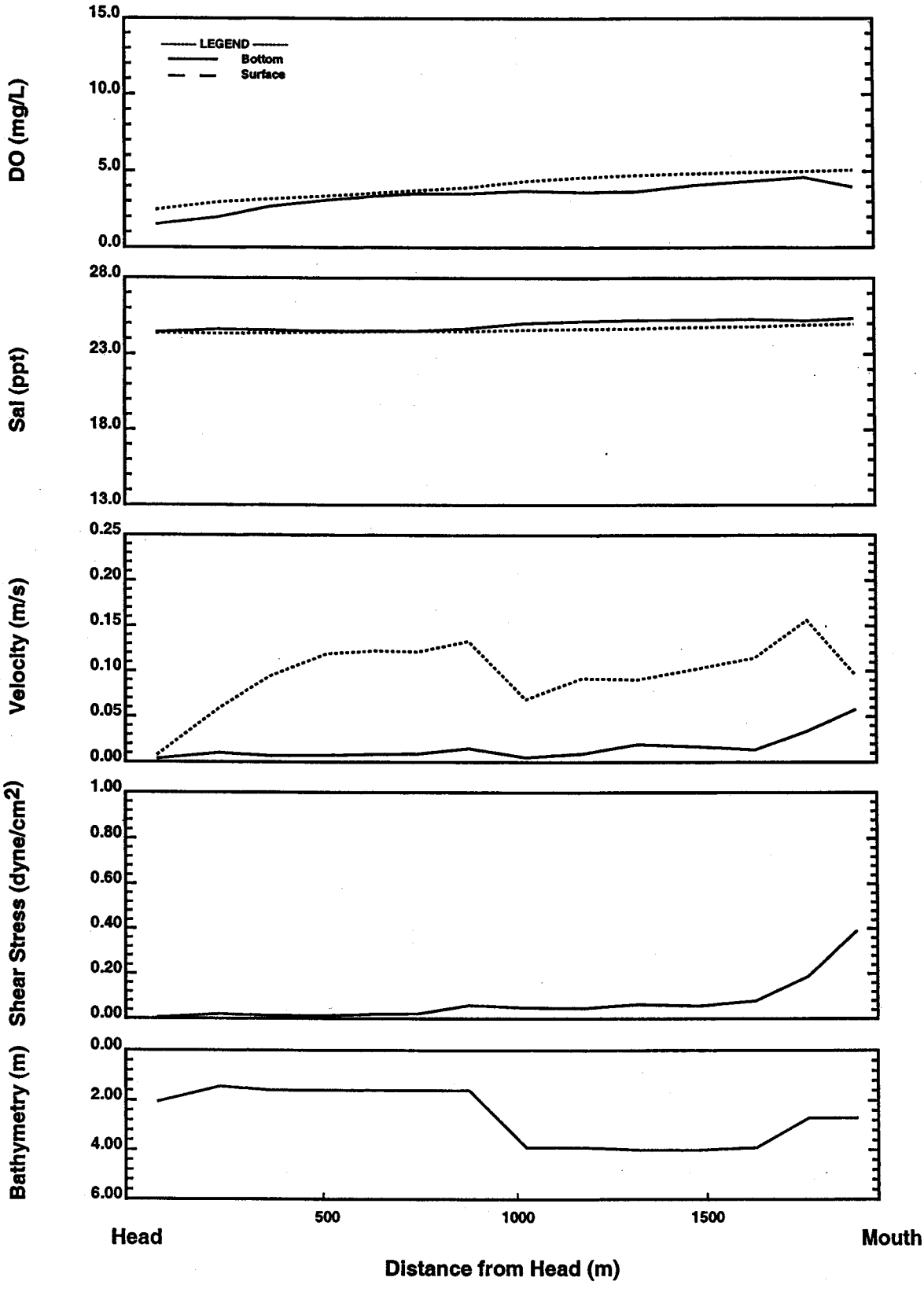


Figure 4-6. Transect of Fresh Creek - Hour 8 - Existing Conditions

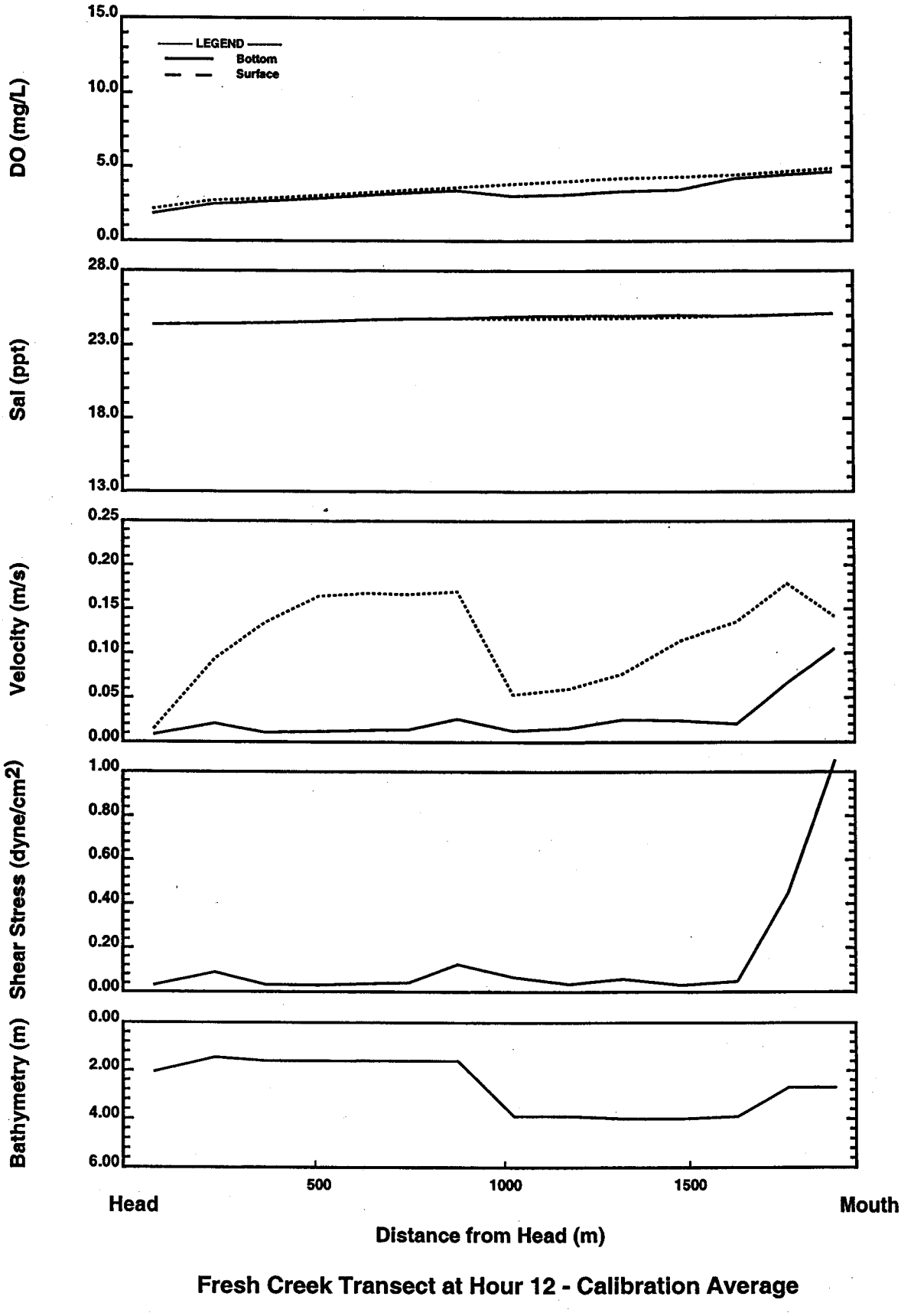


Figure 4-7. Transect of Fresh Creek - Hour 12 - Existing Conditions

(WPCP) is operated at two-times design dry-weather flow (2xDDWF) during rainfall events instead of 1.5xDDWF under existing conditions. The Fresh Creek CSO Facility Plan was not completed at the time of this analysis, so the most likely candidate at the time was chosen. The plan includes a 5 MG storage facility, cleaning of the sewer system, 2xDDWF at the 26th Ward WPCP plus an additional 50 MGD pumping capacity at the plant. For completeness sake, Figure 4-8 presents the bathymetry used for scenario 2, but it is the same as scenario 1.

Figures 4-9 and 4-10 present the surface and bottom DO, salinity, and velocities, as well as the bottom shear stress for hours 1 and 8. Since there were no bathymetric changes, the velocities and shear stresses remain the same. The salinities are also practically identical. However, the DO in Paerdegat Basin has improved due to the capture of some of the CSO overflow. The DO at the head end of the basin increases by 0.5 to 1.0 mg/L. The improvement diminishes with distance from the head end. While the DO improves as a result of the implementation of the CSO facility plan, there is still more room for improvement. During hour 8, shown in Figure 4-10, there is an improvement in DO of approximately 1.5 mg/L at the head end.

4.3.2 Fresh Creek

Figure 4-11 presents the results of the addition of the CSO facility plan in Fresh Creek. As in the case of Paerdegat Basin, no bathymetric changes were made so the velocity and shear stress remain the same. The DO increases along the length of the creek with the largest changes occurring at the head end. The DO increases from approximately 1.5 mg/L at the bottom, during existing conditions, to approximately 2.25 mg/L for this scenario. The DO concentration is computed to be greater than 2.5 mg/L across most of the length of the creek. Figure 4-12 shows that during hour 8, the facility plan contributed to an increase of approximately 1.5 mg/L in DO at the head end of the creek.

Figure 4-13 shows similar results for hour 12 with the DO concentration increasing by more than 1.0 mg/L at the head end with smaller improvements occurring as the distance from the head end increases. These improvements result in the DO concentration to remain above 3.0 mg/L for the entire length of the creek.

4.4 SCENARIO 3

Scenario 3 involves removing the sills at the entrances to Paerdegat Basin and Fresh Creek in an attempt to induce more flushing in the tributaries to reduce the detention time. In theory, this would allow more oxygenated water to flow in and result in less oxygen demanding material to settle in the basins. The CSO facility plans are also incorporated in this scenario. During the course of reviewing

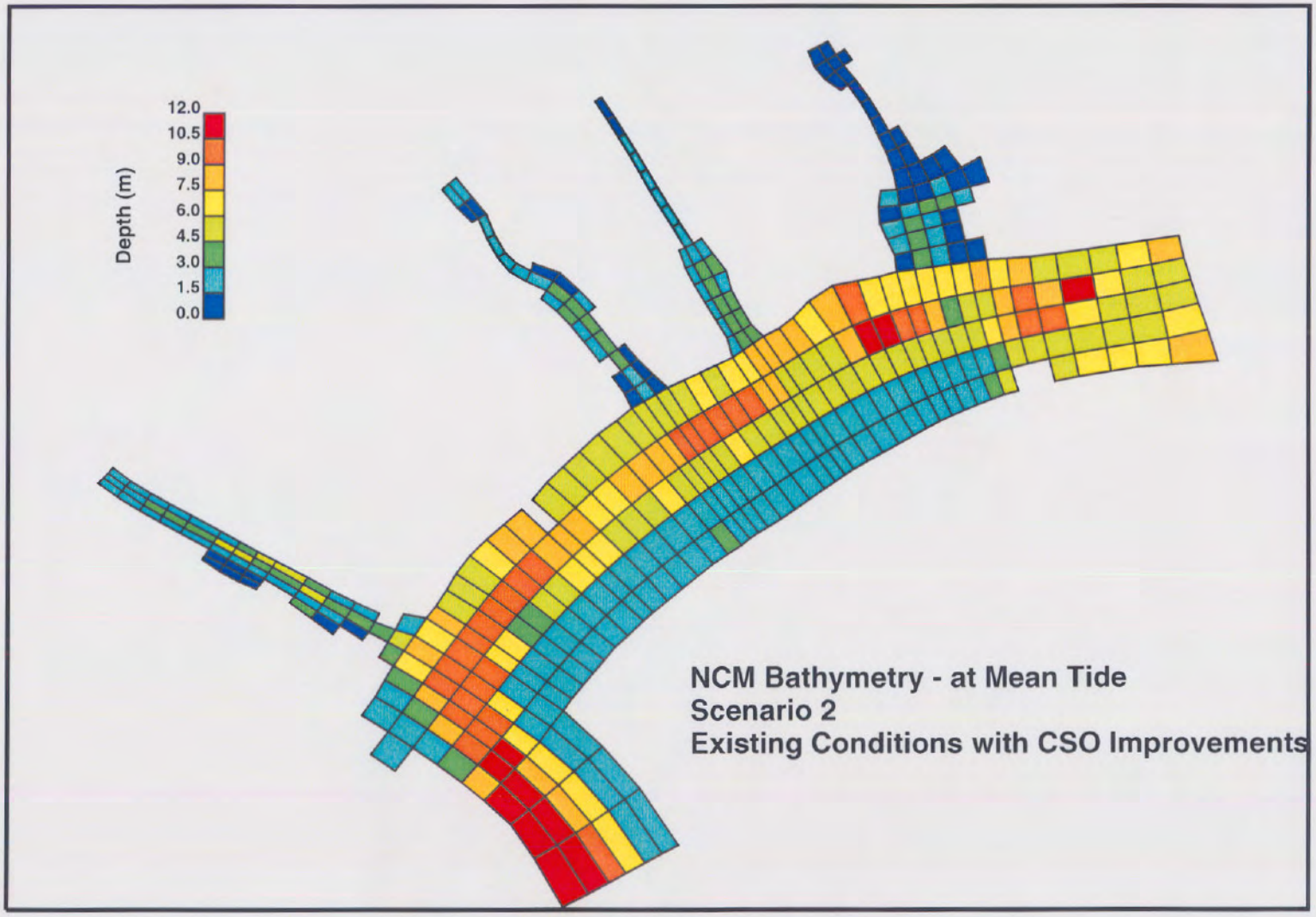


Figure 4-8. NCM Bathymetry - Scenario 2

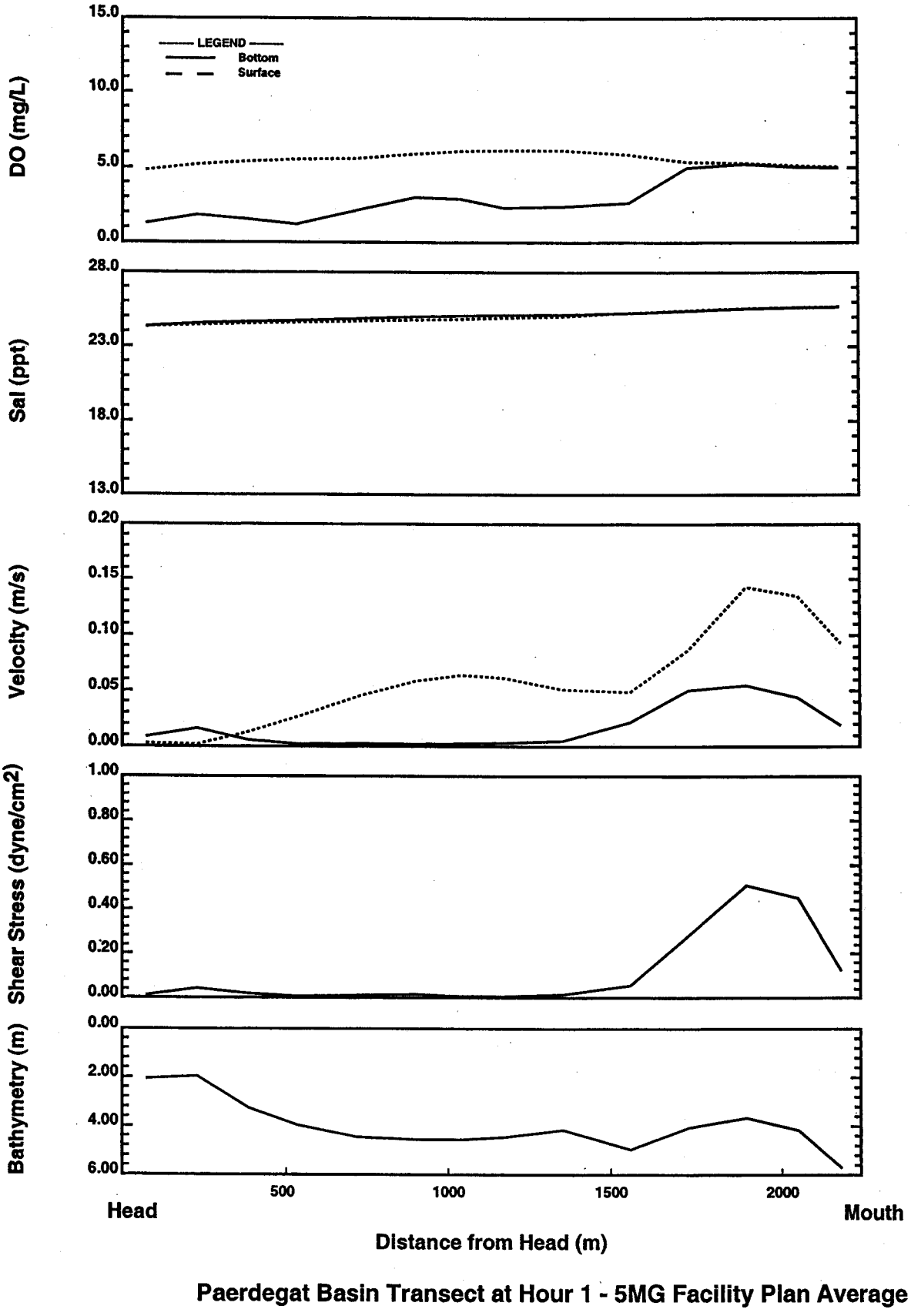


Figure 4-9. Transect of Paerdegat Basin - Hour 1 - Scenario 2

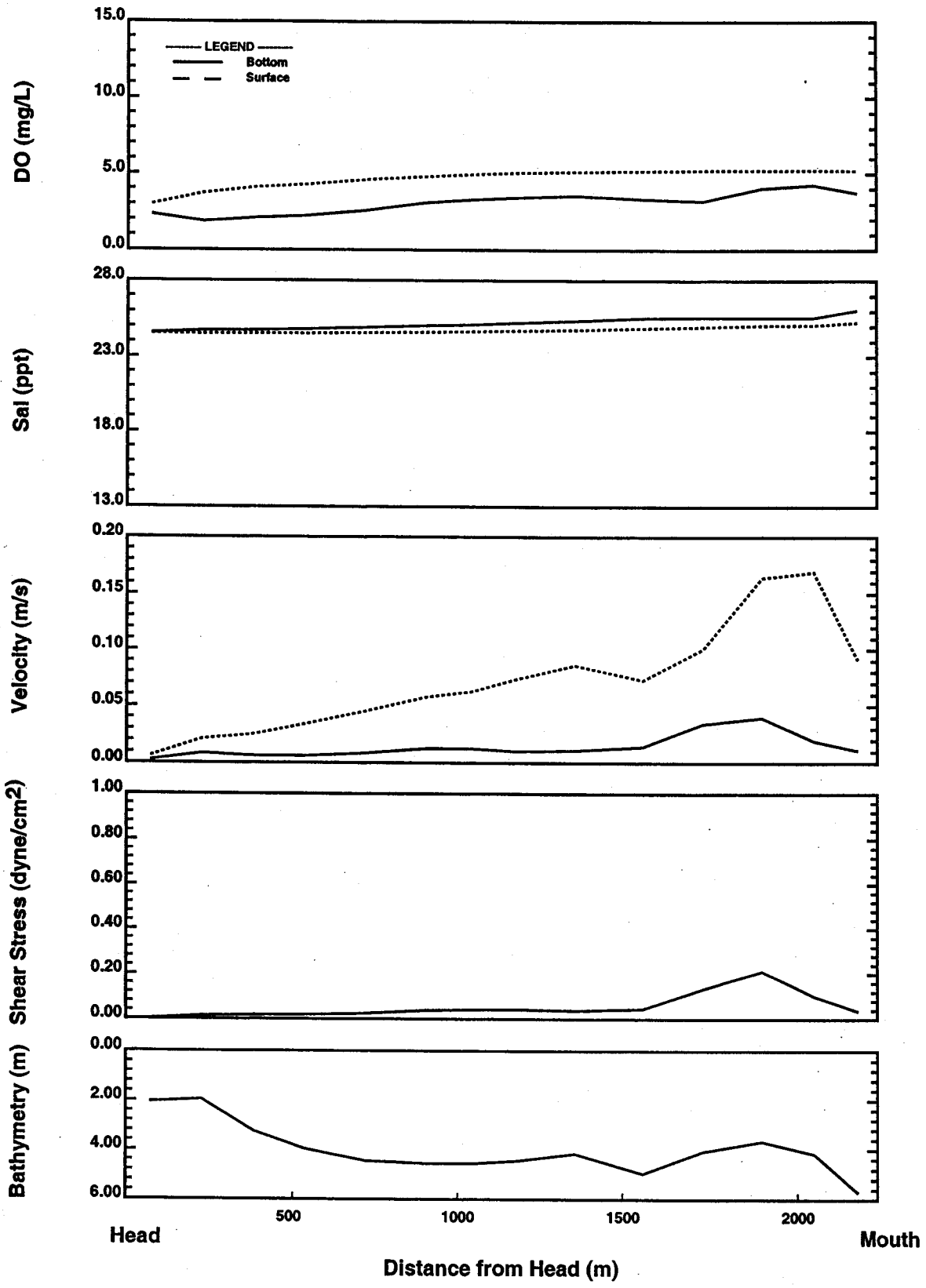


Figure 4-10. Transect of Paerdegat Basin - Hour 8 - Scenario 2

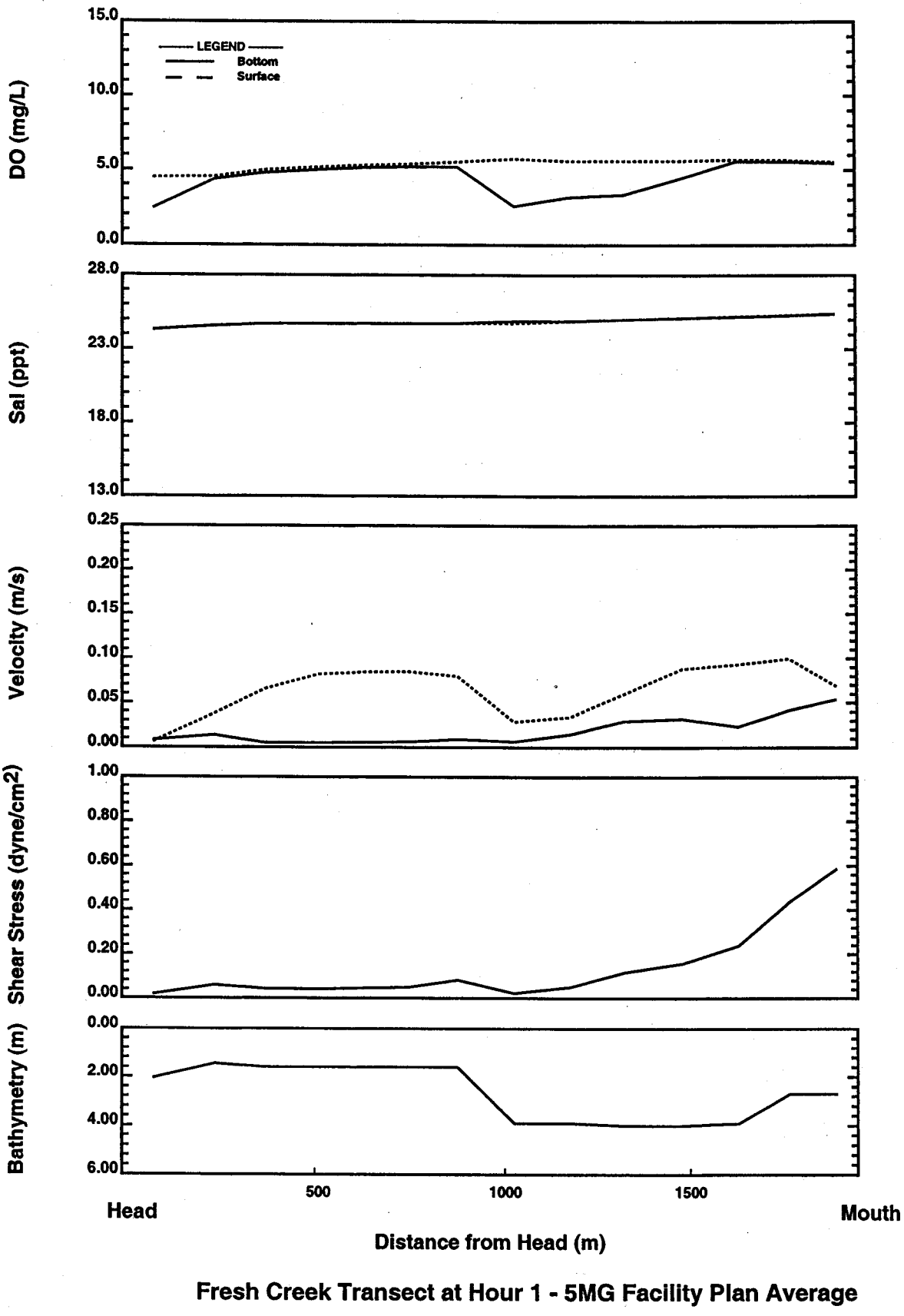


Figure 4-11. Transect of Fresh Creek - Hour 1 - Scenario 2

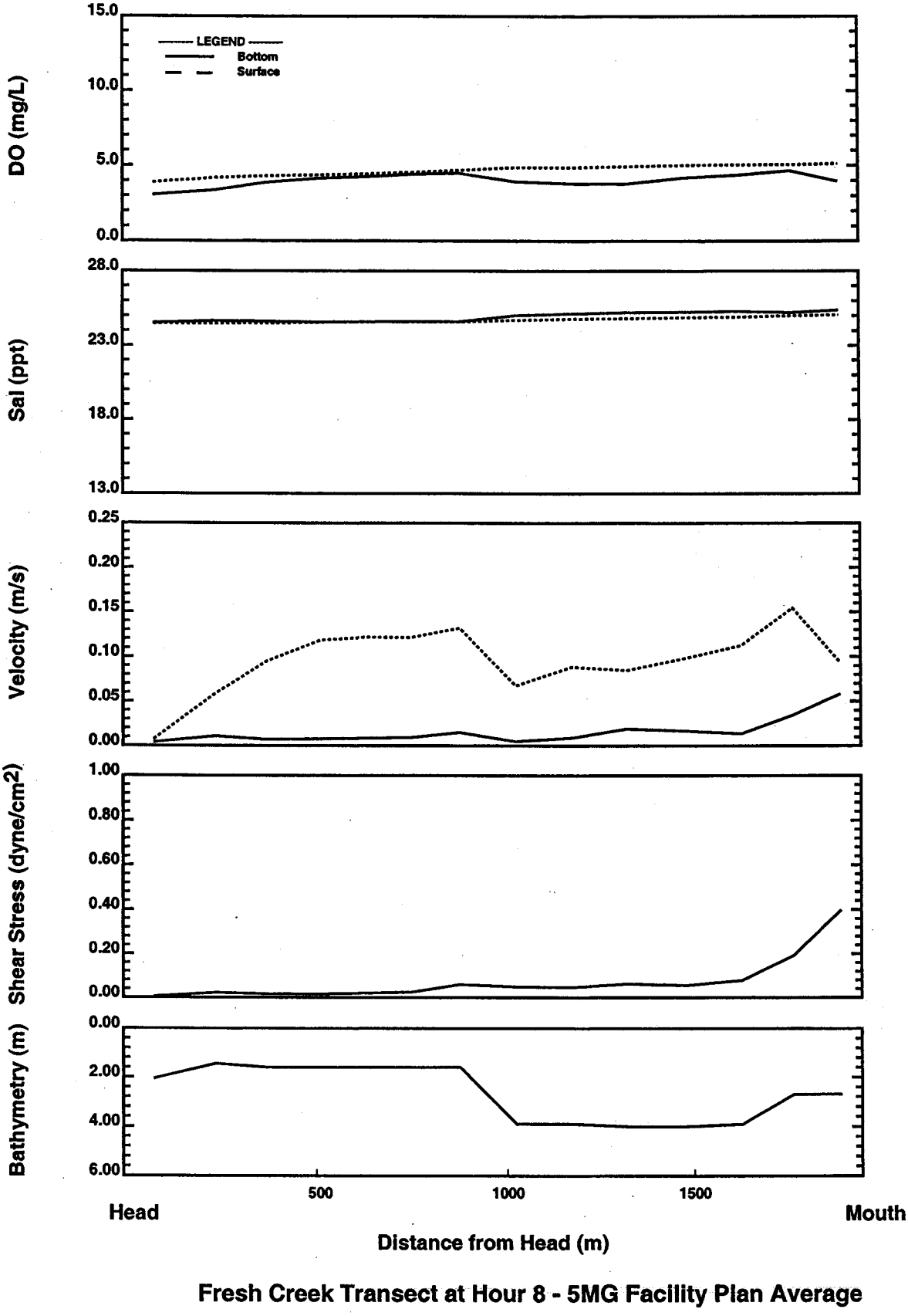


Figure 4-12. Transect of Fresh Creek - Hour 8 - Scenario 2

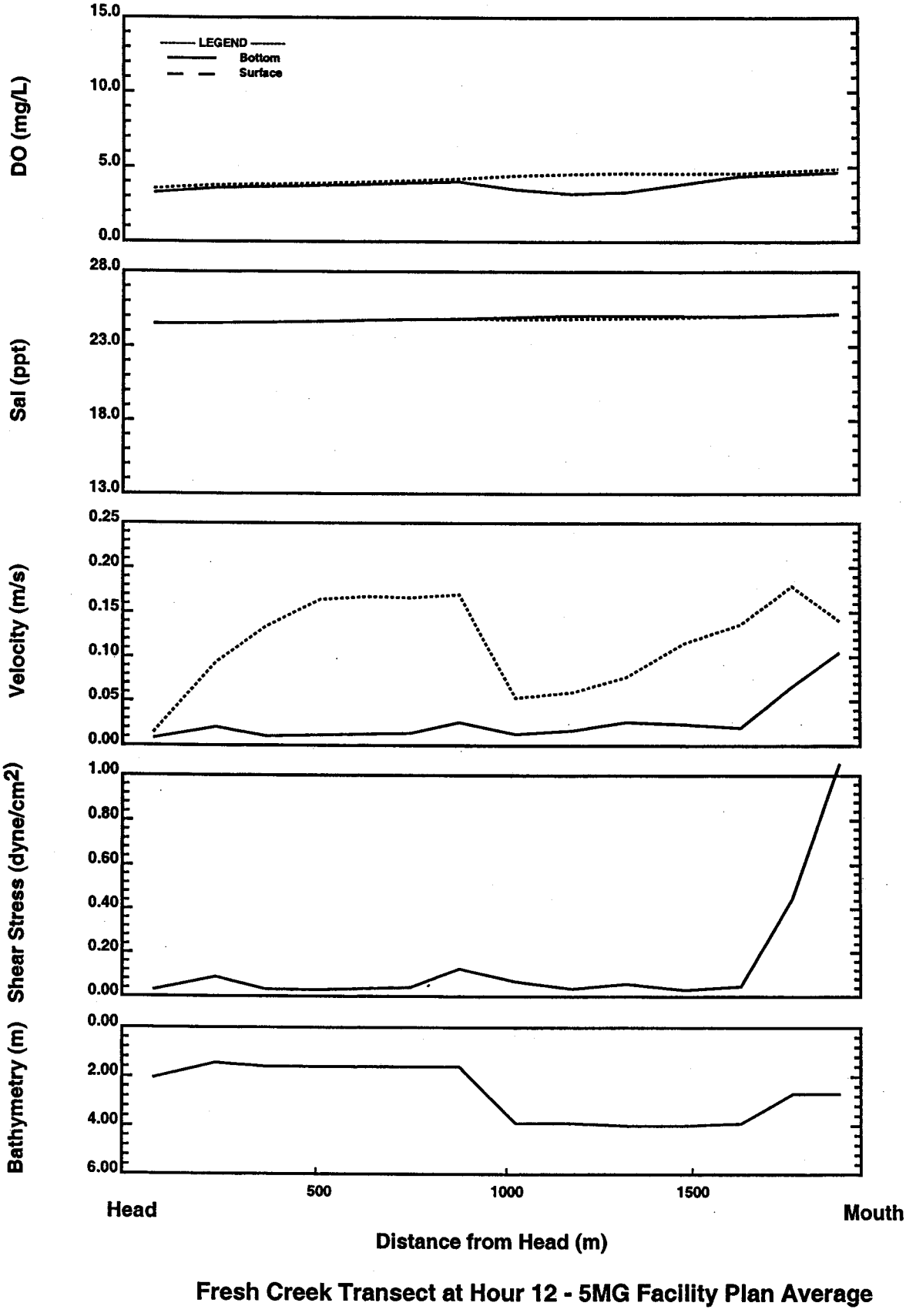


Figure 4-13. Transect of Fresh Creek - Hour 12 - Scenario 2

the current work that is being undertaken at each tributary, it was discovered that there is a sludge force main that extends under Paerdegat Basin that could preclude dredging in that location. This being the situation, two cases were run for this scenario. One case ignored the force main (Scenario 3a) and the other accounted for the force main and did not include dredging in that location (Scenario 3b). Figures 4-14 and 4-15 present the bathymetry used for scenarios 3a and 3b, respectively. The figures show the modifications to the mouths of the tributaries when compared to the baseline (Figure 4-2).

4.4.1 Paerdegat Basin

Figure 4-16 presents the model results for scenario 3a during hour 1 in Paerdegat Basin. The bathymetry change due to the removal of the sill is shown in the bottom panel. During hour 1 the velocity at the mouth of Paerdegat Basin is reduced, and the upstream velocities are relatively unchanged. As a result of the current velocity changes, the DO in the upstream portion of the basin remains unchanged, and the area of DO stratification expands further toward the mouth of the basin. During hour 8 (Figure 4-17), the lower current velocities near the mouth of the basin contribute to slightly lower bottom DO concentrations in the lower half of the basin.

Without dredging the basin directly above the force main, the length of the basin that shows DO stratification is reduced when compared the removing the sill completely during hour 1 (Figure 4-18). During hour 8 (Figure 4-19), the velocties are higher in the undredged area resulting in higher bottom DO levels when compared to scenario 3a. While neither sill removal scenario produced the hoped for results, the removal of the sill was kept in the remaining runs as outlined in the project scope. The bathymetric conditions without the dredging in the area of the force main were used in the remaining runs because it was considered the more realistic of the two scenarios.

4.4.2 Fresh Creek

The removal of the sill in Fresh Creek appears to have no positive effect on Fresh Creek during hour 1 of the tidal cycle (Figure 4-20). The DO concentration in the region between 1,000 and 1,500 m from the head end decreases, as the current velocity at the mouth and the deeper region of the creek is decreased. The DO in Fresh Creek is also adversely affected during hour 8 (Figure 4-21). The area near where the mouth was dredged shows a decrease in the DO concentration. Figure 4-22 shows there is slight increase in the velocity resulting in a slight increase in the bottom DO in the deeper section of the creek and a large decrease in the shear stress during hour 12.

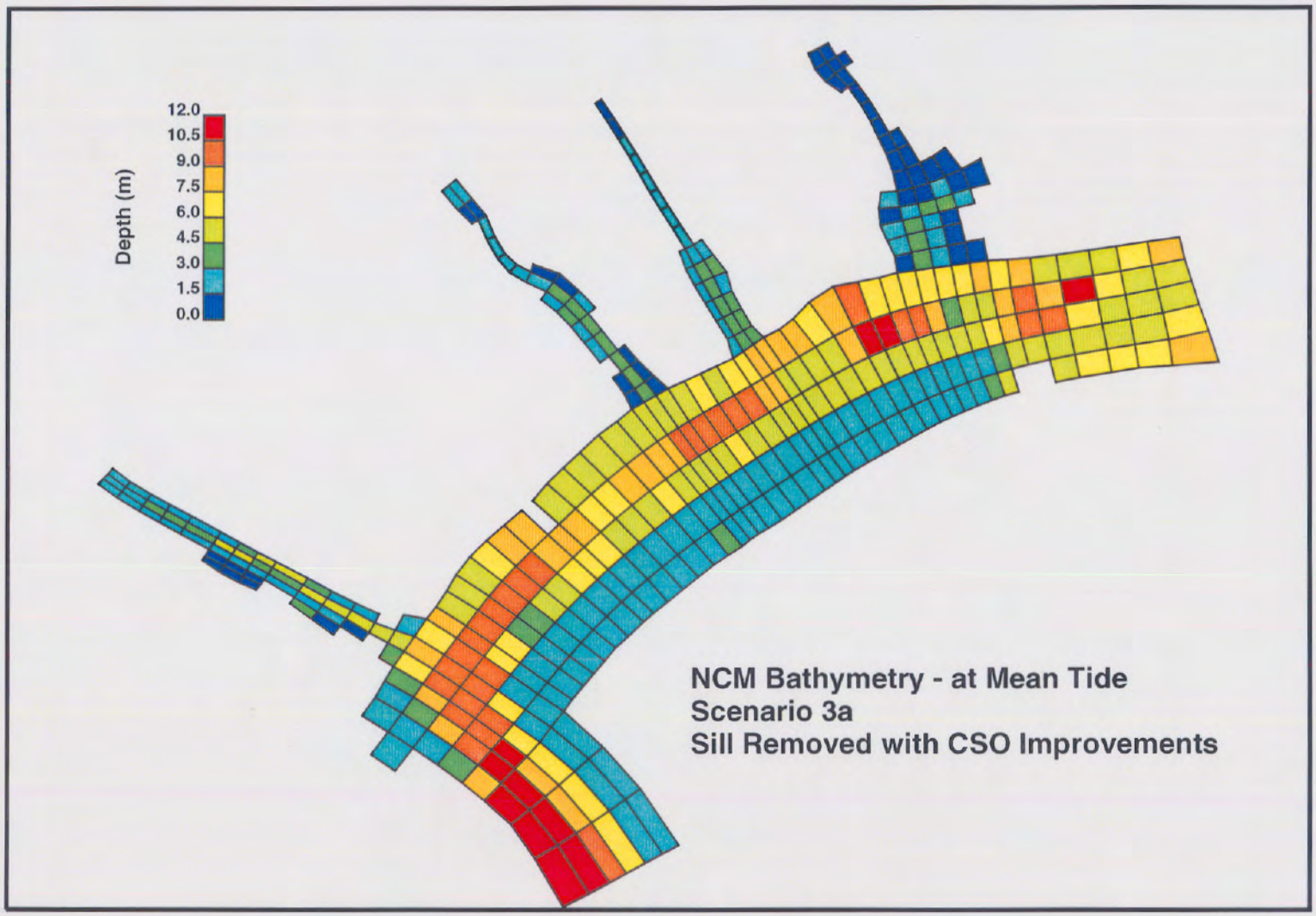


Figure 4-14. NCM Bathymetry - Scenario 3a

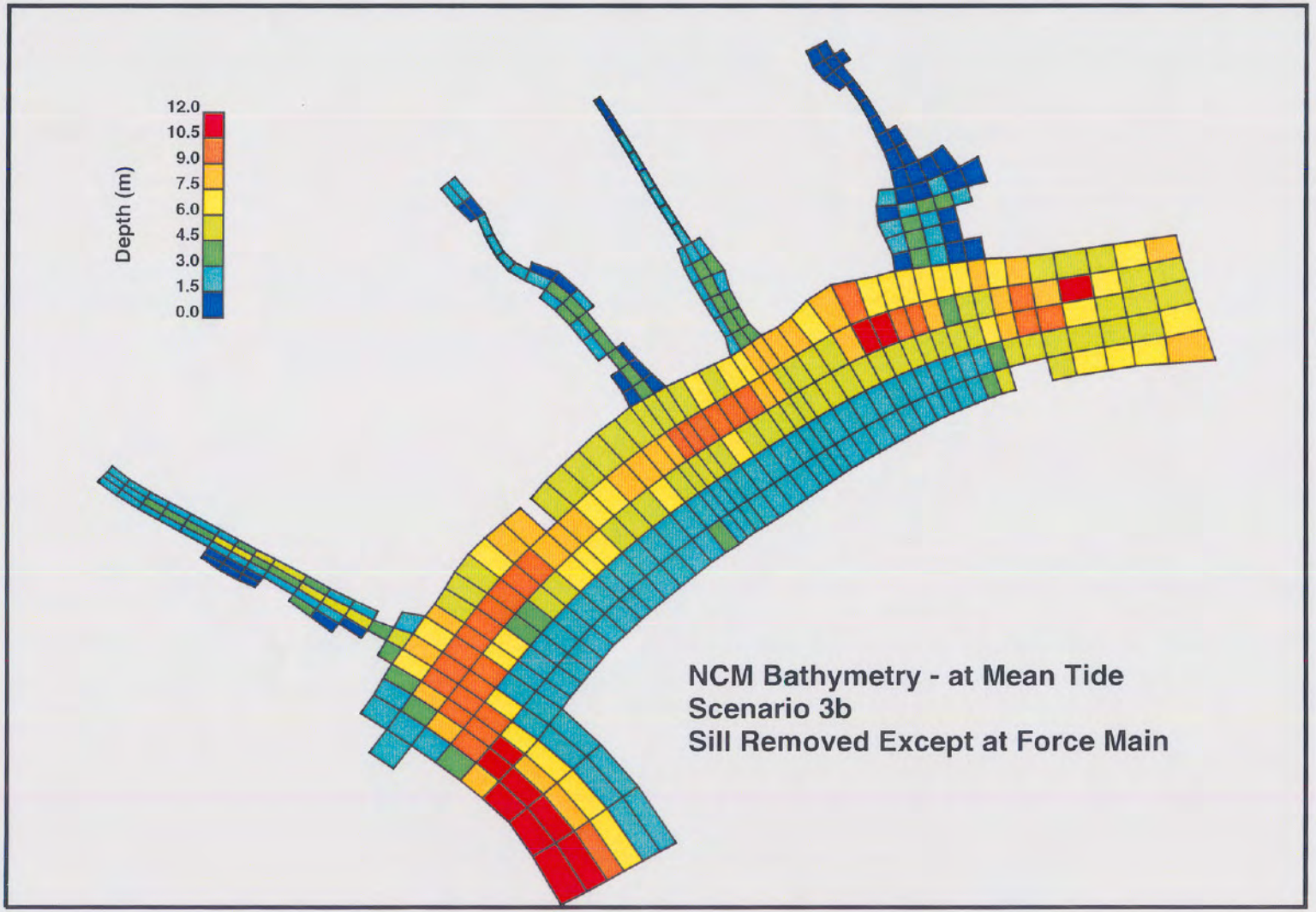


Figure 4-15. NCM Bathymetry - Scenario 3b

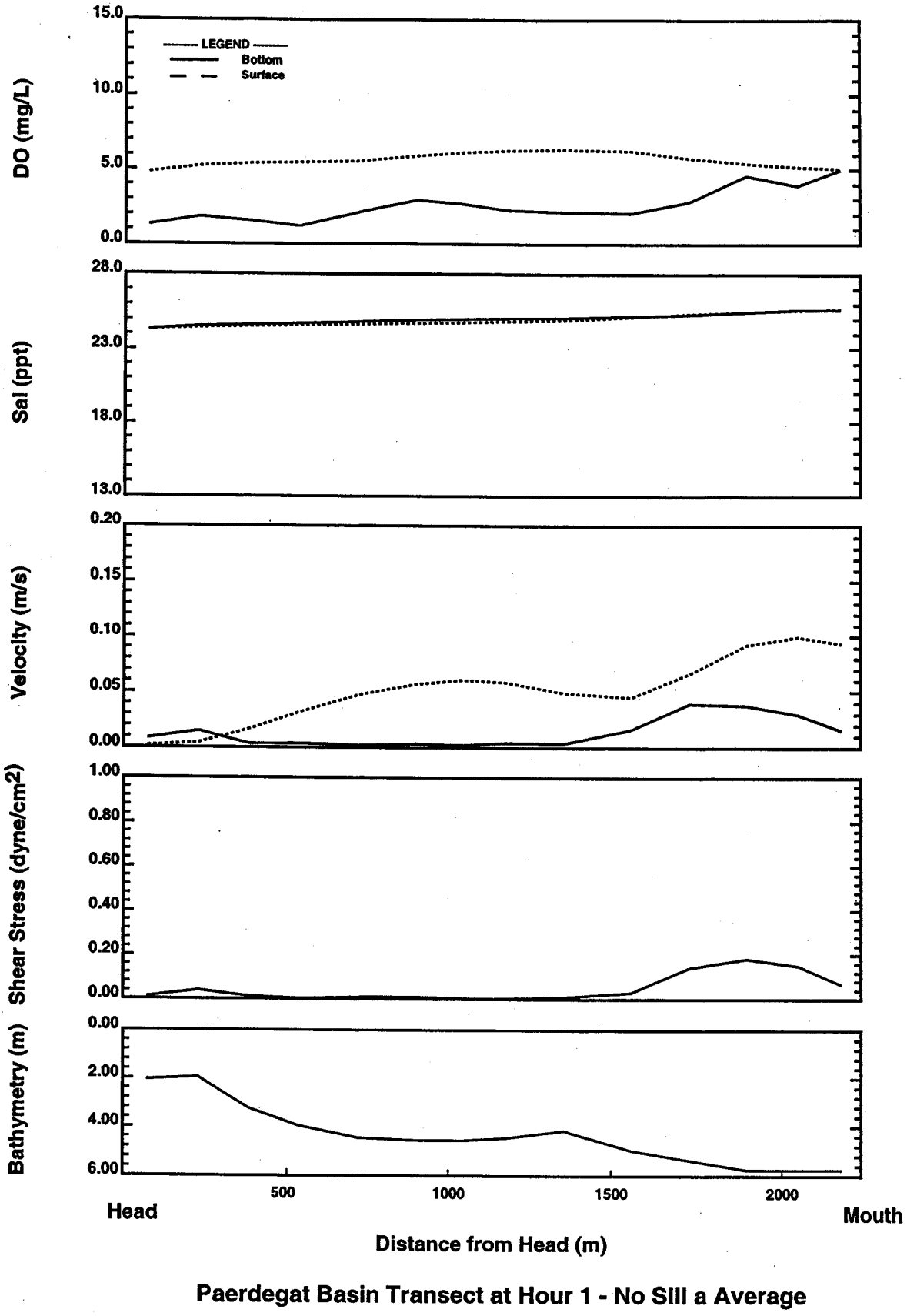


Figure 4-16. Transect of Paerdegat Basin - Hour 1 - Scenario 3a

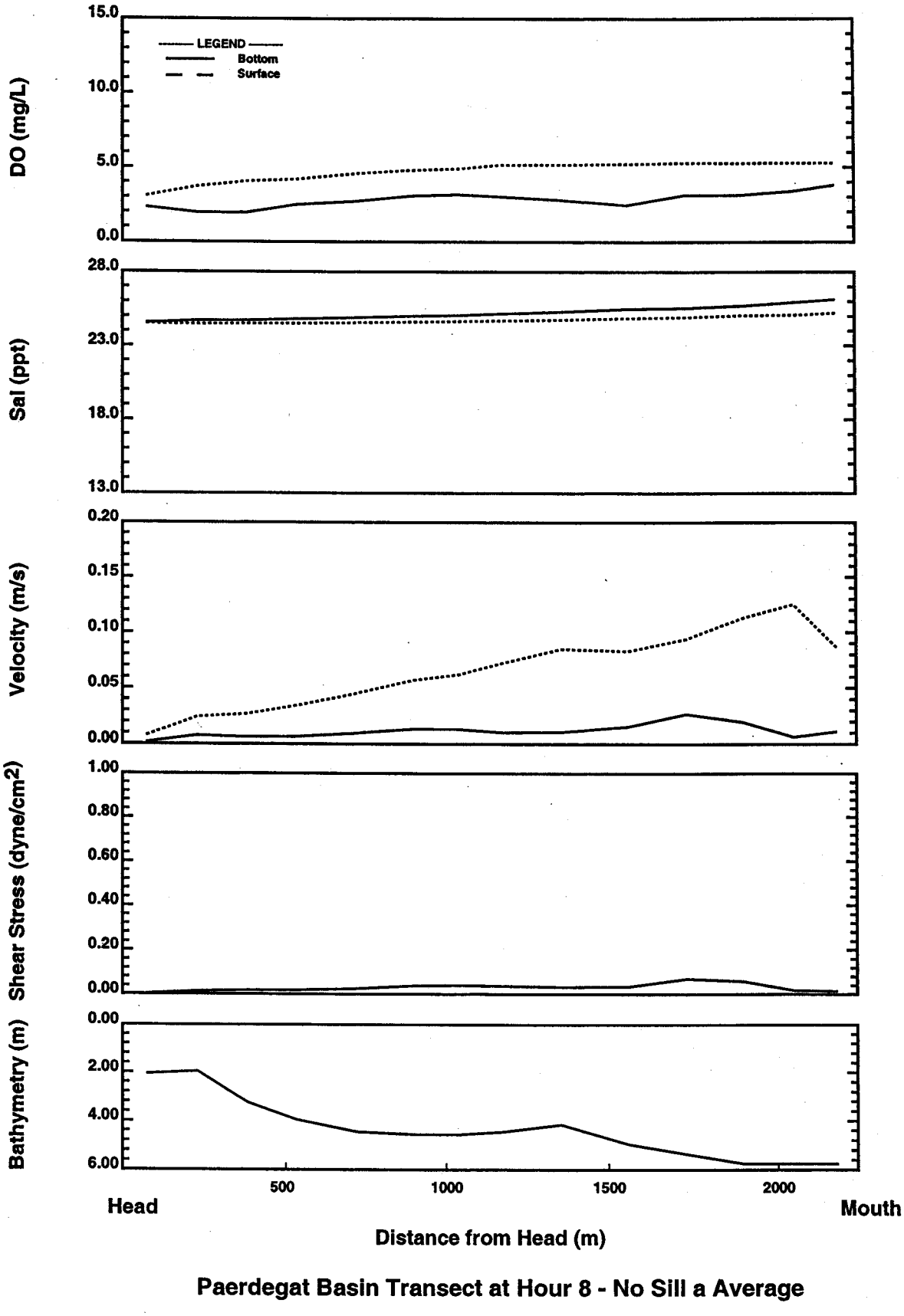


Figure 4-17. Transect of Paerdegat Basin - Hour 8 - Scenario 3a

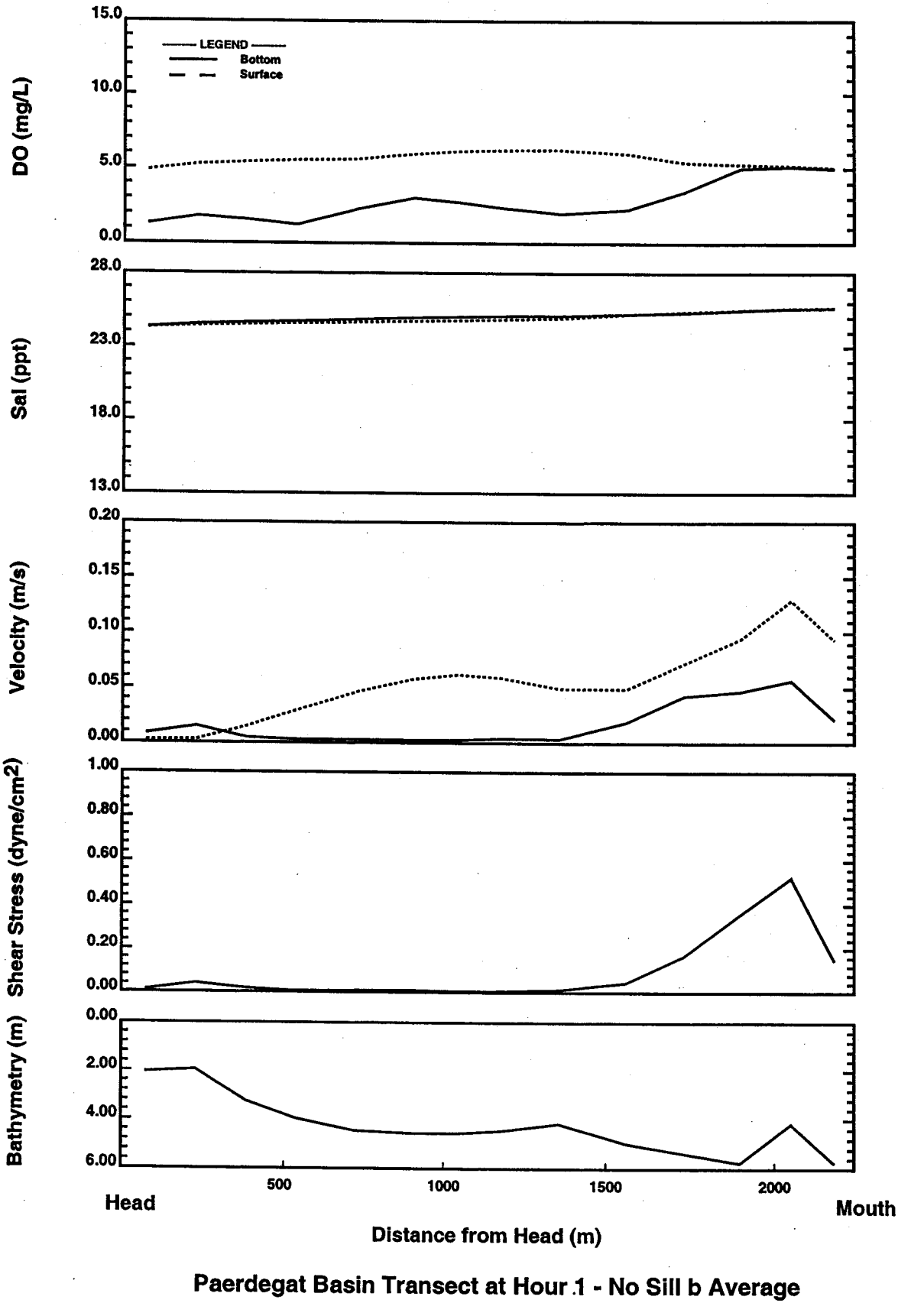


Figure 4-18. Transect of Paerdegat Basin - Hour 1 - Scenario 3b

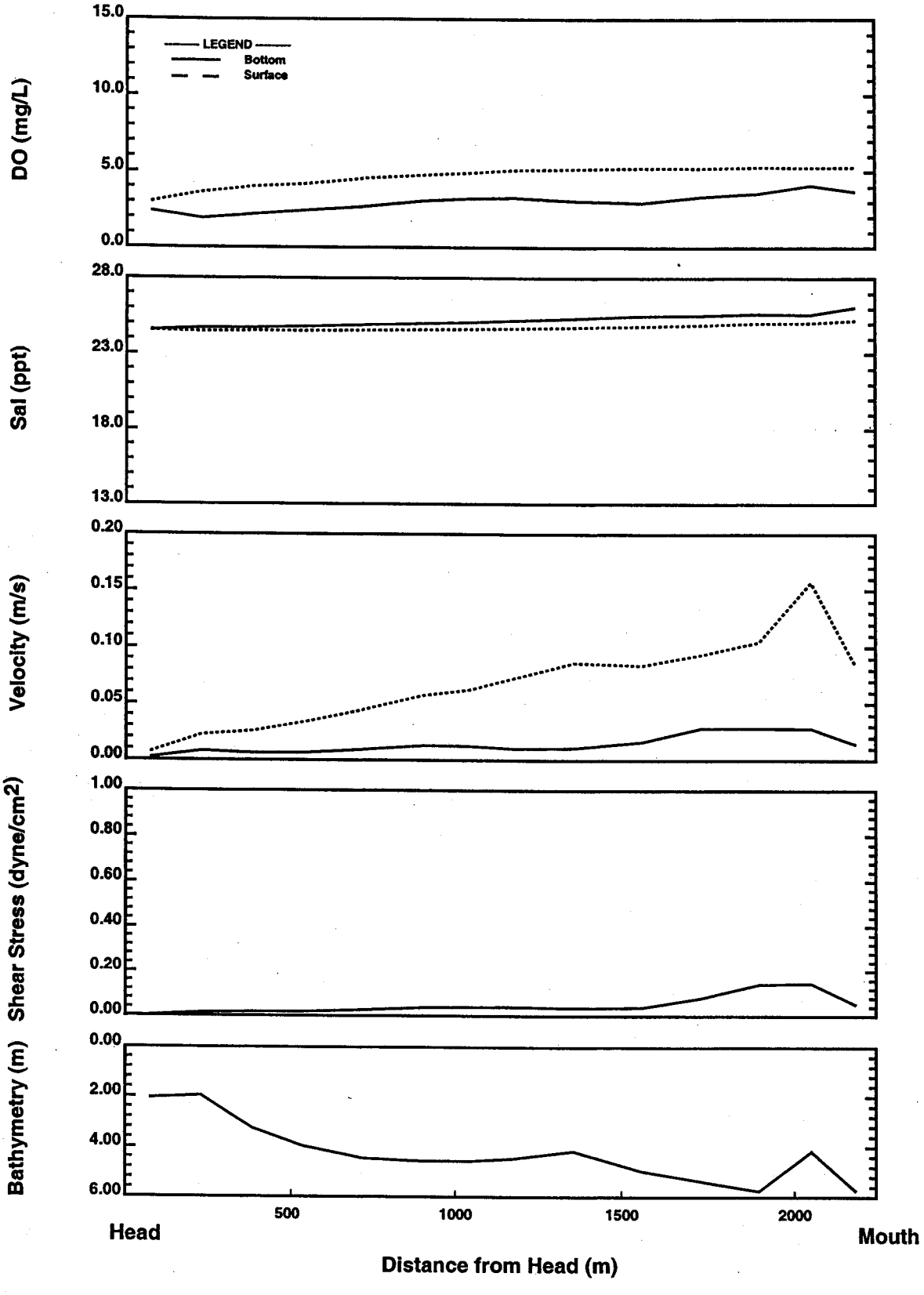


Figure 4-19. Transect of Paerdegat Basin - Hour 8 - Scenario 3b

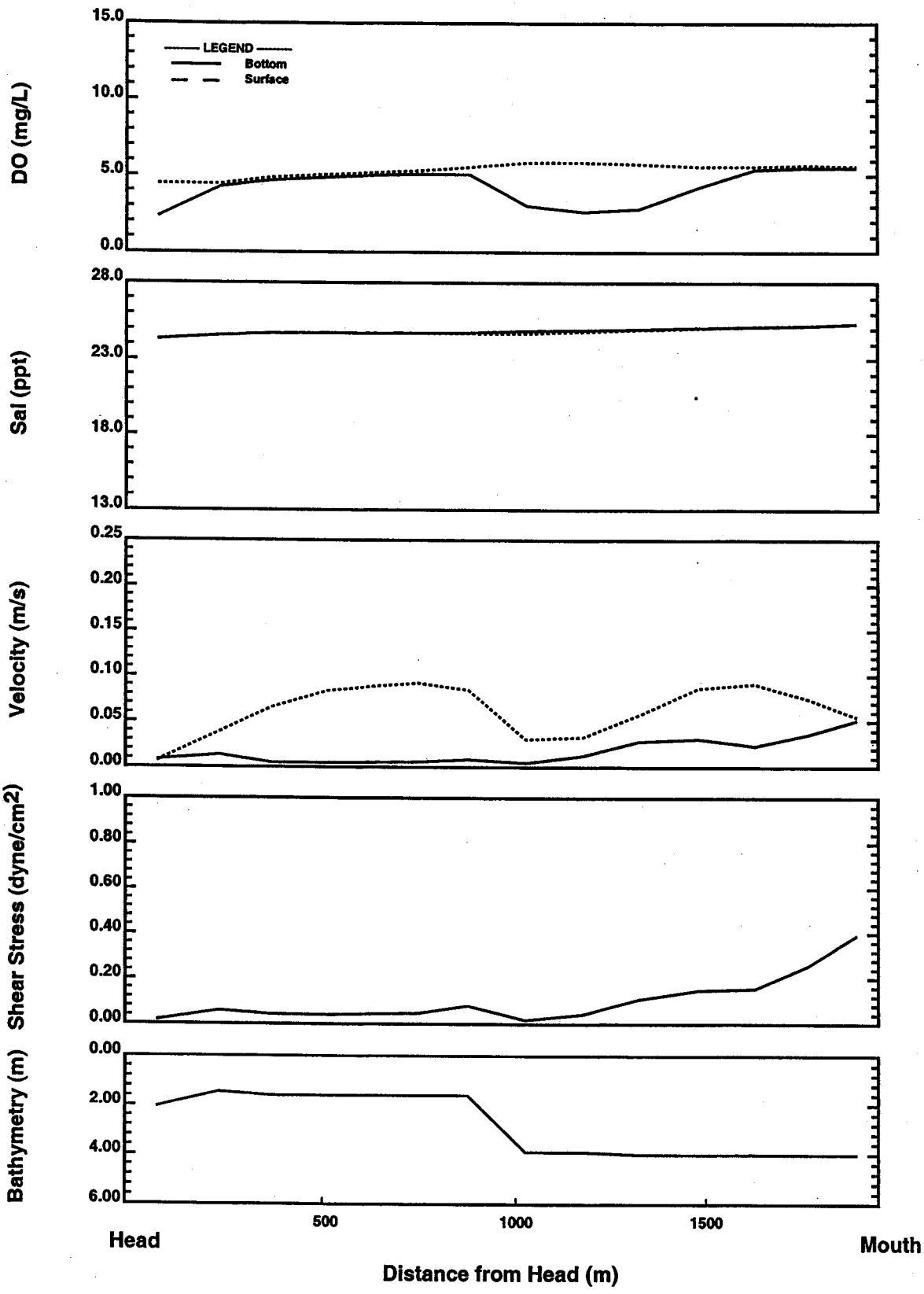


Figure 4-20. Transect of Fresh Creek - Hour 1 - Scenario 3

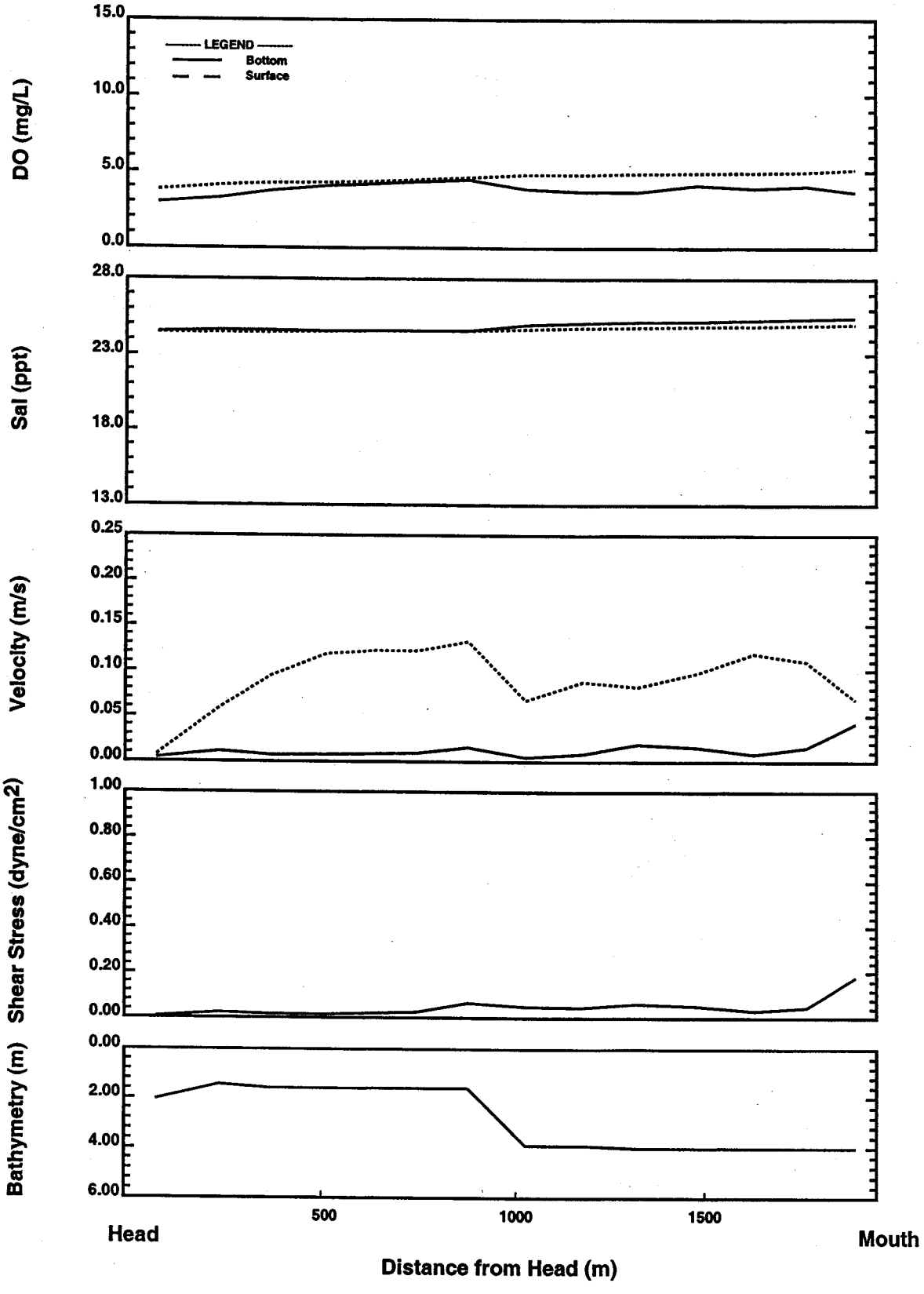


Figure 4-21. Transect of Fresh Creek - Hour 8 - Scenario 3

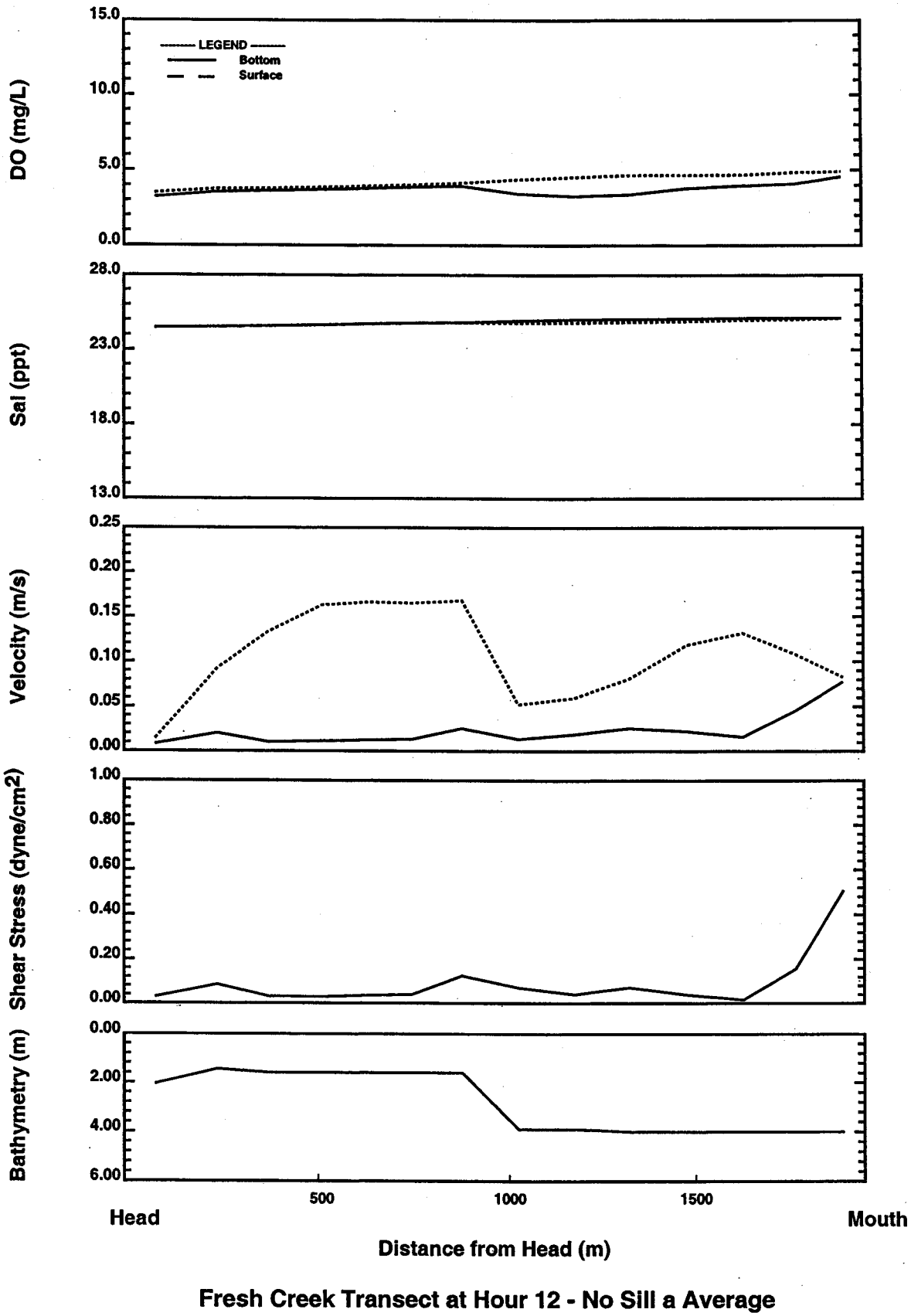


Figure 4-22. Transect of Fresh Creek - Hour 12 - Scenario 3

4.5 SCENARIO 4

In scenario 4, the upstream half of both tributaries were filled to MLW. The head ends of the tributaries were not filled to allow the discharge of CSO. The area from the middle of the basin to about 1,500 m from the head and was sloped gradually, so the result of filling the basin did not create an under water wall. Based on the results of scenario 3, the area over the force main was not dredged in Paerdegat Basin for scenario 4 and the scenarios that follow. Figure 4-23 presents the bathymetry used for scenario 4.

4.5.1 Paerdegat Basin

Filling the upstream half of Paerdegat Basin to MLW has a profound affect on the dissolved oxygen during hour 1 (Figure 4-24). All of the DO stratification that occurred in the area that was filled has been eliminated, and the DO concentration in this reach is greater than 4.0 mg/L. Some low DO concentrations are still computed at the head end (which was not filled) and near the mouth.

The salinity in Paerdegat Basin for hour 1 of the chosen tidal cycle changed slightly as a result of the bathymetric changes. The salinity at the head end of Paerdegat Basin declined by approximately one ppt. This is primarily due to the fact that the bottom of the basin is now elevated to level with lower salinity water.

The velocities and shear stress changed dramatically due to the bathymetric changes. The velocity and shear stress increased the most at the downstream end of the filled area. The surface velocity increased from 6 cm/s to 17 cm/s and the bottom velocity increased to 6 cm/s. This resulted in a bottom shear stress of greater than 1.0 dyne/cm^2, the point where sediment resuspension will occur.

Figure 4-25 shows that during hour 8 the DO has increased to above 3.0 mg/L for the entire reach of Paerdegat Basin. The velocities are also higher along the upper portion of the basin resulting in a shear stress of greater than 1.0 dyne/cm^2 in parts of the basin. Velocities near the mouth of the basin have been reduced from scenario 3b conditions.

Filling the upper half of Paerdegat Basin to MLW has a positive effect on the dissolved oxygen. The current velocities in the basin are increased, thereby improving the flushing of the basin and reducing, if not eliminating, the stratification in the basin. However, the MLW depth may be too shallow and could cause resuspension of sediment and sand causing unintentioned bathymetric changes

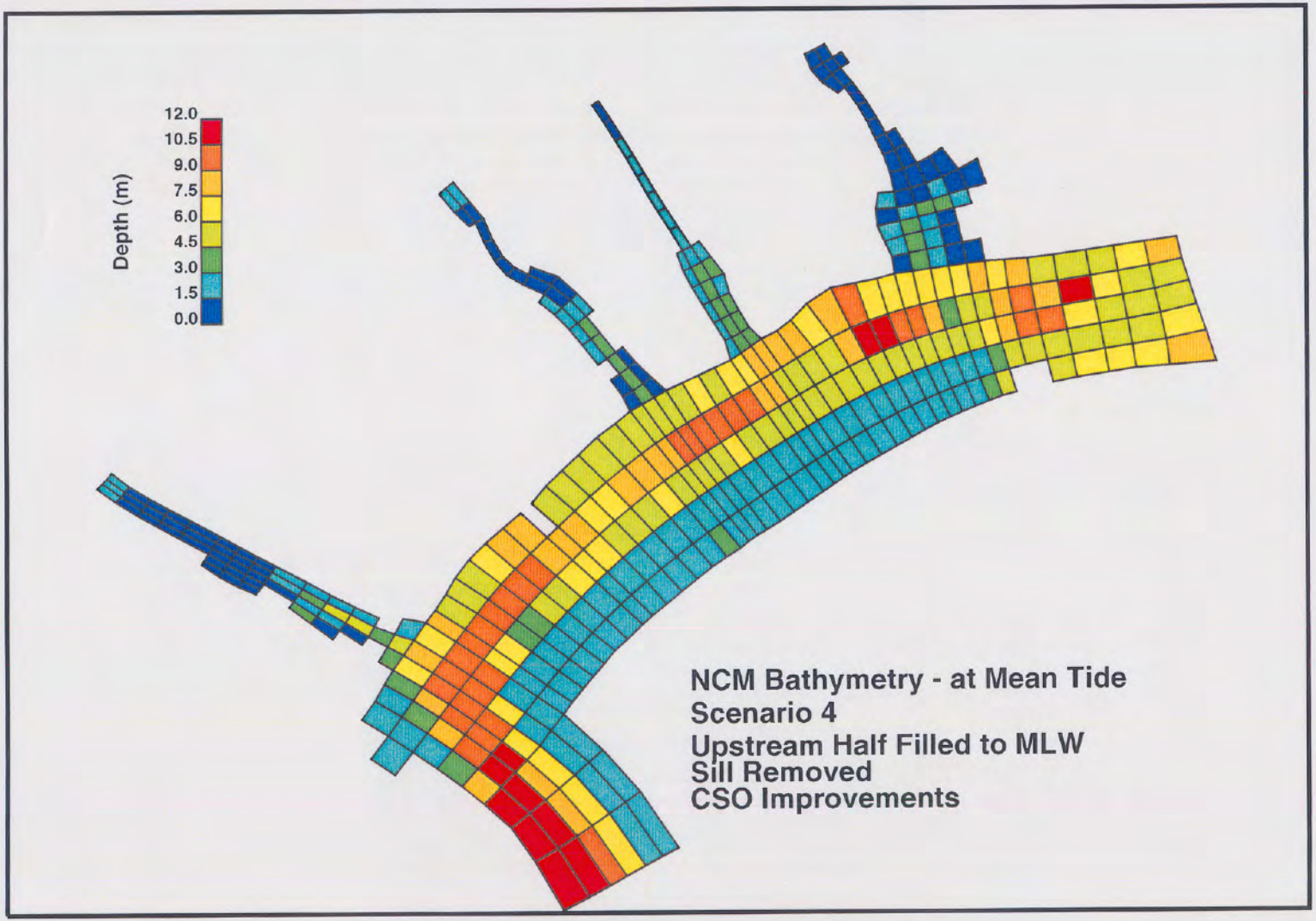


Figure 4-23. NCM Bathymetry - Scenario 4

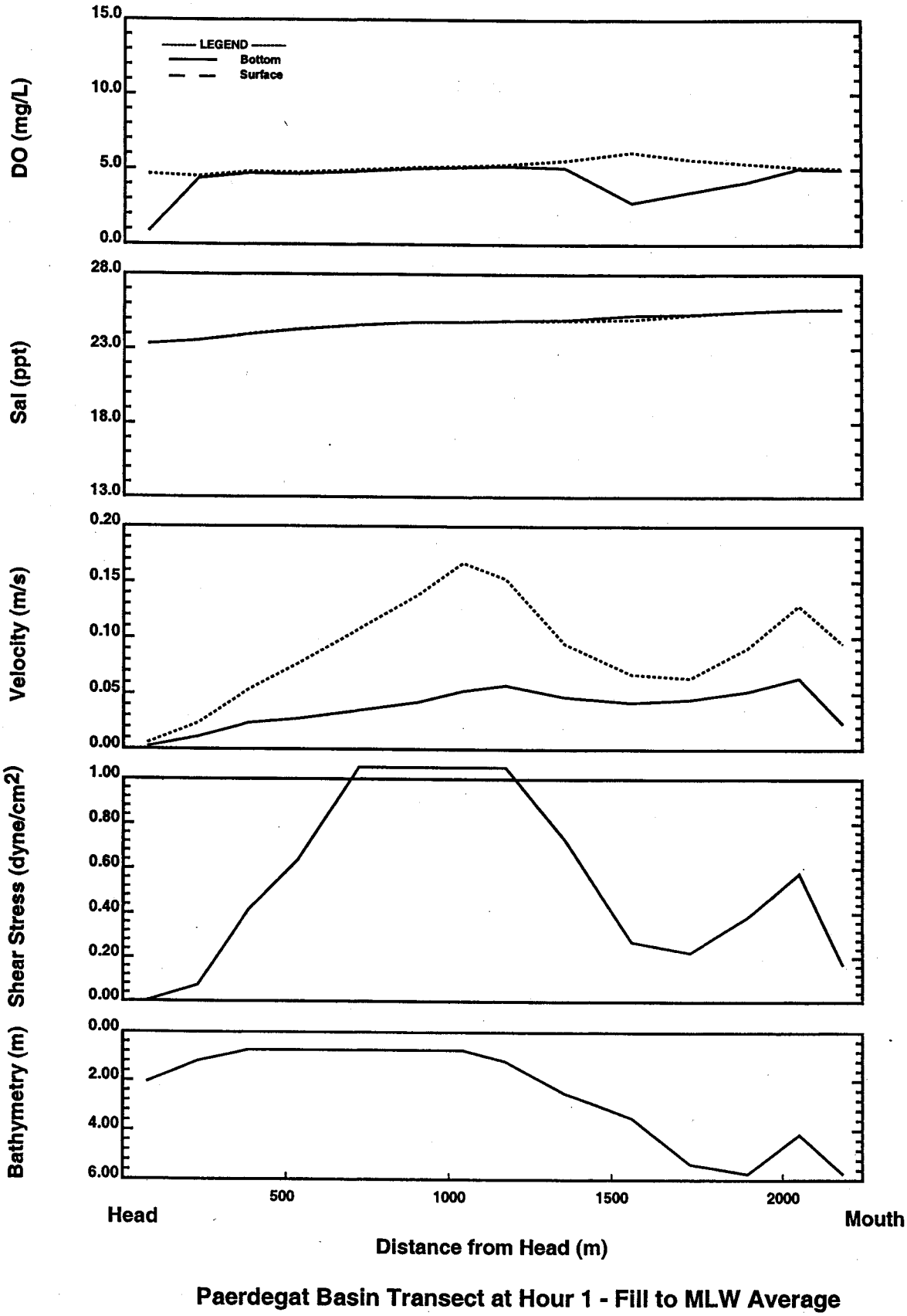


Figure 4-24. Transect of Paerdegat Basin - Hour 1 - Scenario 4

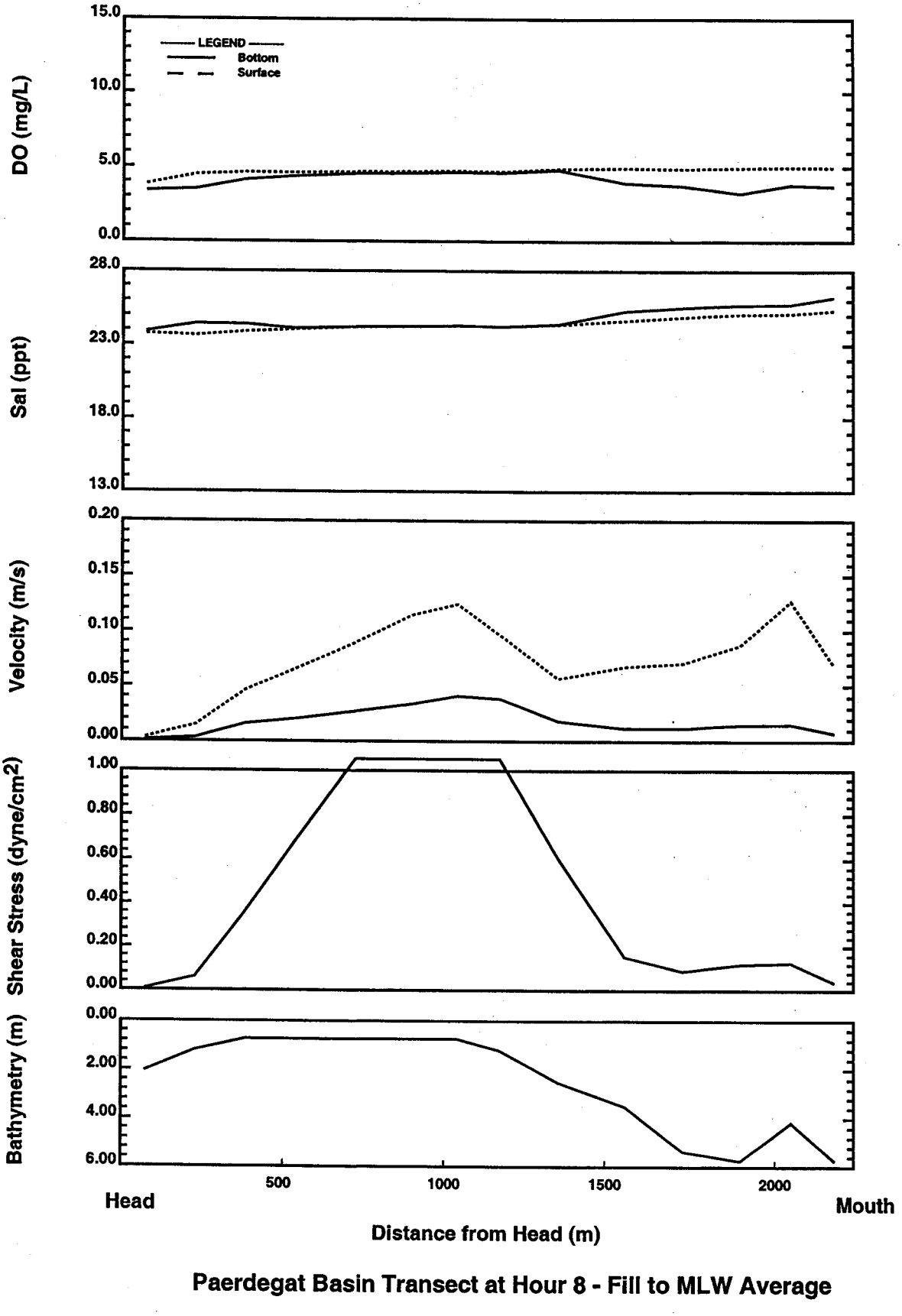


Figure 4-25. Transect of Paerdegat Basin - Hour 8 - Scenario 4

in Paerdegat Basin. Also, if the head end of the basin is not filled it may turn into a settling basin for CSO solids that would drive down the DO concentration at the head end.

4.5.2 Fresh Creek

Filling the upper half of Fresh Creek to MLW without filling the head end results in lower DO concentrations at the head end during hour 1 (Figure 4-26). The deeper section of the creek shows some improvement in the area of gradual slope added between the filled section and the unfilled section. The salinity in the head end of Fresh Creek decreases by nearly 1.0 ppt as was the case in Paerdegat Basin. The current velocities in the area that was filled shows a marked increase. As a consequence of the increased velocities, the bottom shear stress increases to greater than 1.0 dyne/cm^2.

During hour 8, the DO concentration is very similar between the MLW run and the sill removal run (Figure 4-27). Filling in the upper half of the creek leads to lower salinity, lower surface velocities, higher bottom velocities and higher shear stress in the area of the creek that was filled. Figure 4-28 shows that during hour 12 filling the upper end of Fresh Creek to MLW has a detrimental effect on the DO near the mouth of Fresh Creek. The velocities and shear stresses are greatly reduced. Overall, filling the upper half of Fresh Creek to MLW does not have a positive effect on habitat in the creek.

4.6 SCENARIO 5

Figure 4-29 presents the bathymetry used for scenario 5. In scenario 5, the upstream half of Paerdegat Basin was filled to 4 ft below MLW, and the lower half of Fresh Creek was filled to 4 ft below MLW. This creates an almost uniform depth in Fresh Creek.

4.6.1 Paerdegat Basin

Figure 4-30 presents the results of scenario 5 for hour 1 in Paerdegat Basin. Filling the upper half of the basin to 4 ft below MLW has nearly the same benefit to DO as scenario 4. The upper 500 m of the basin has DO concentrations 0.5 to 1.0 mg/L lower than scenario 4, but the bottom water at the very head end of the basin has improved DO because it can flush more easily with the rest of the basin. The velocities in the basin increase, when compared to the calibration condition, but the shear stresses do not reach a level that would cause resuspension. Velocities in the area where filling occurs are half those of the previous scenario where the basin was filled to MLW.

The model computations during hour 8 fall between the no sill and fill to MLW conditions. As shown in Figure 4-31, there is an improvement in the DO concentration over the no sill condition. The

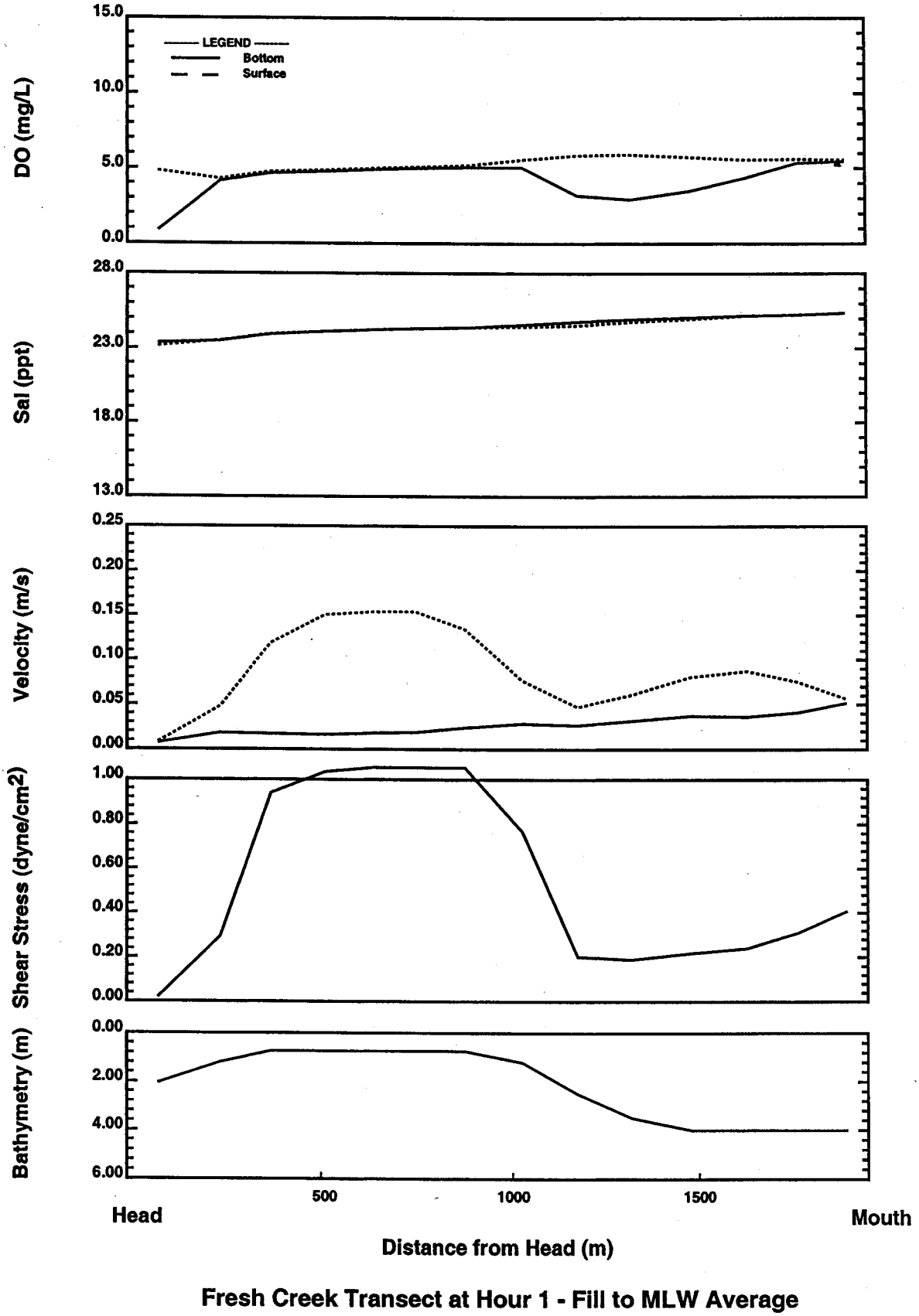
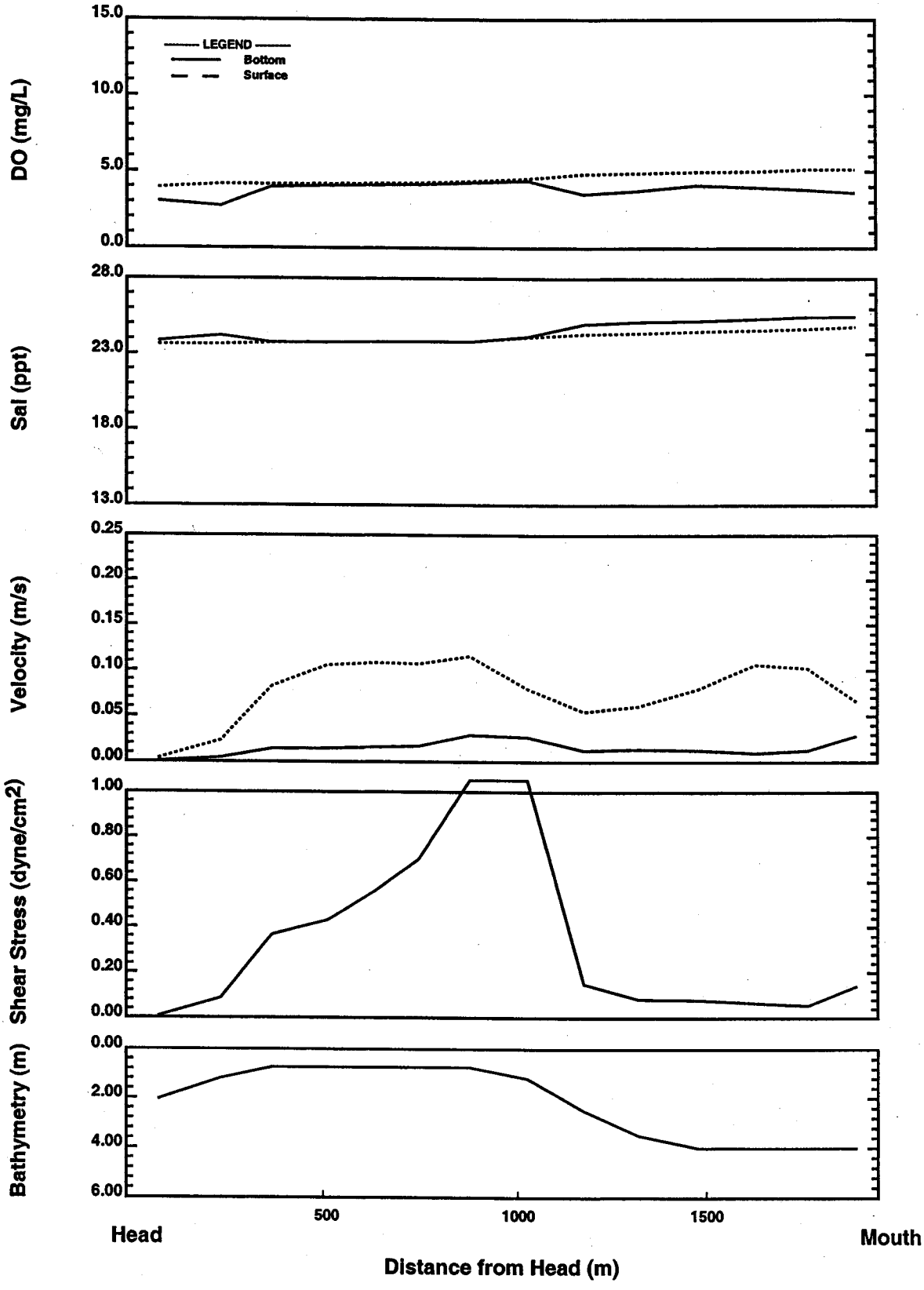


Figure 4-26. Transect of Fresh Creek - Hour 1 - Scenario 4



Fresh Creek Transect at Hour 8 - Fill to MLW Average

Figure 4-27. Transect of Fresh Creek - Hour 8 - Scenario 4

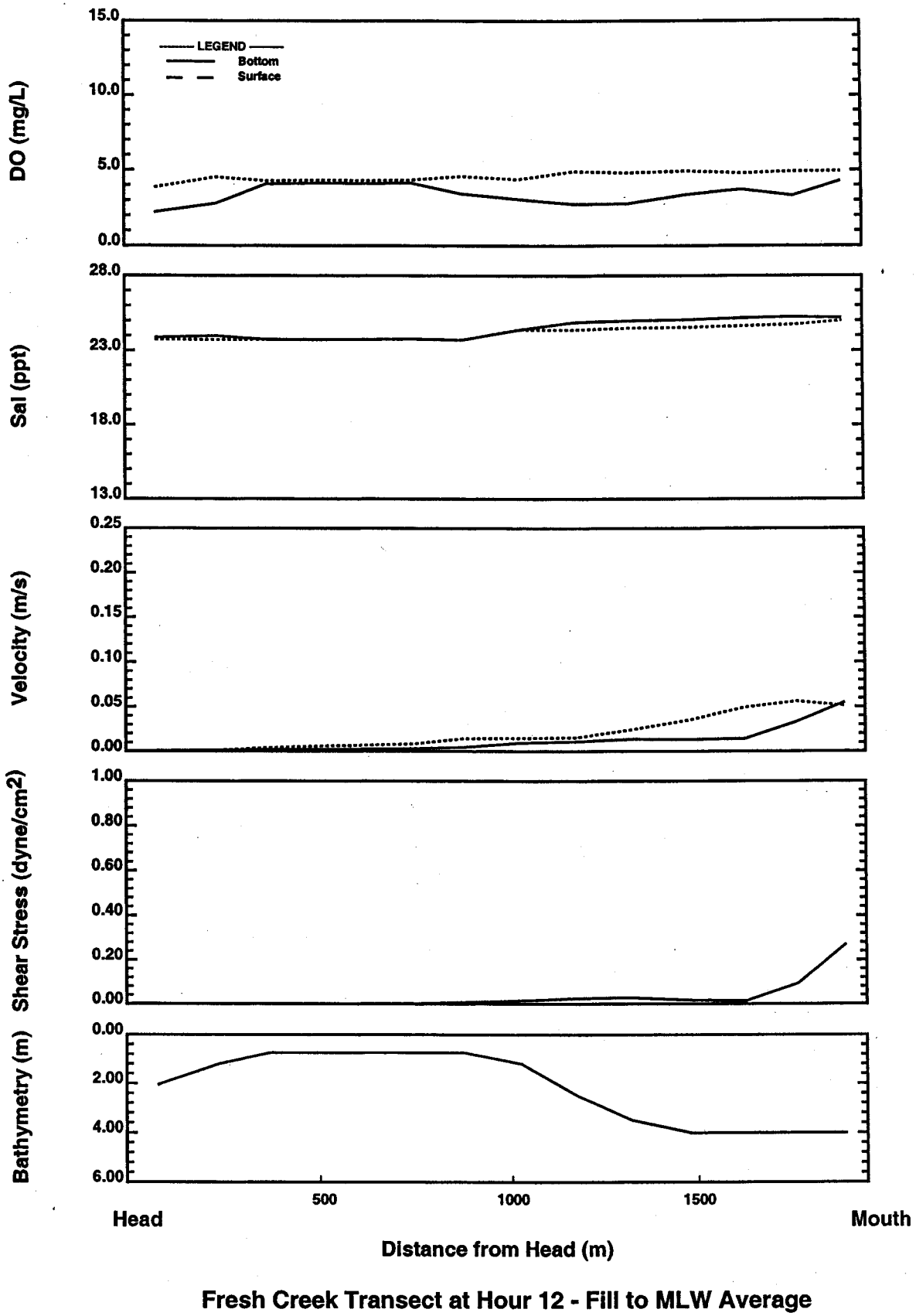


Figure 4-28. Transect of Fresh Creek - Hour 12 - Scenario 4

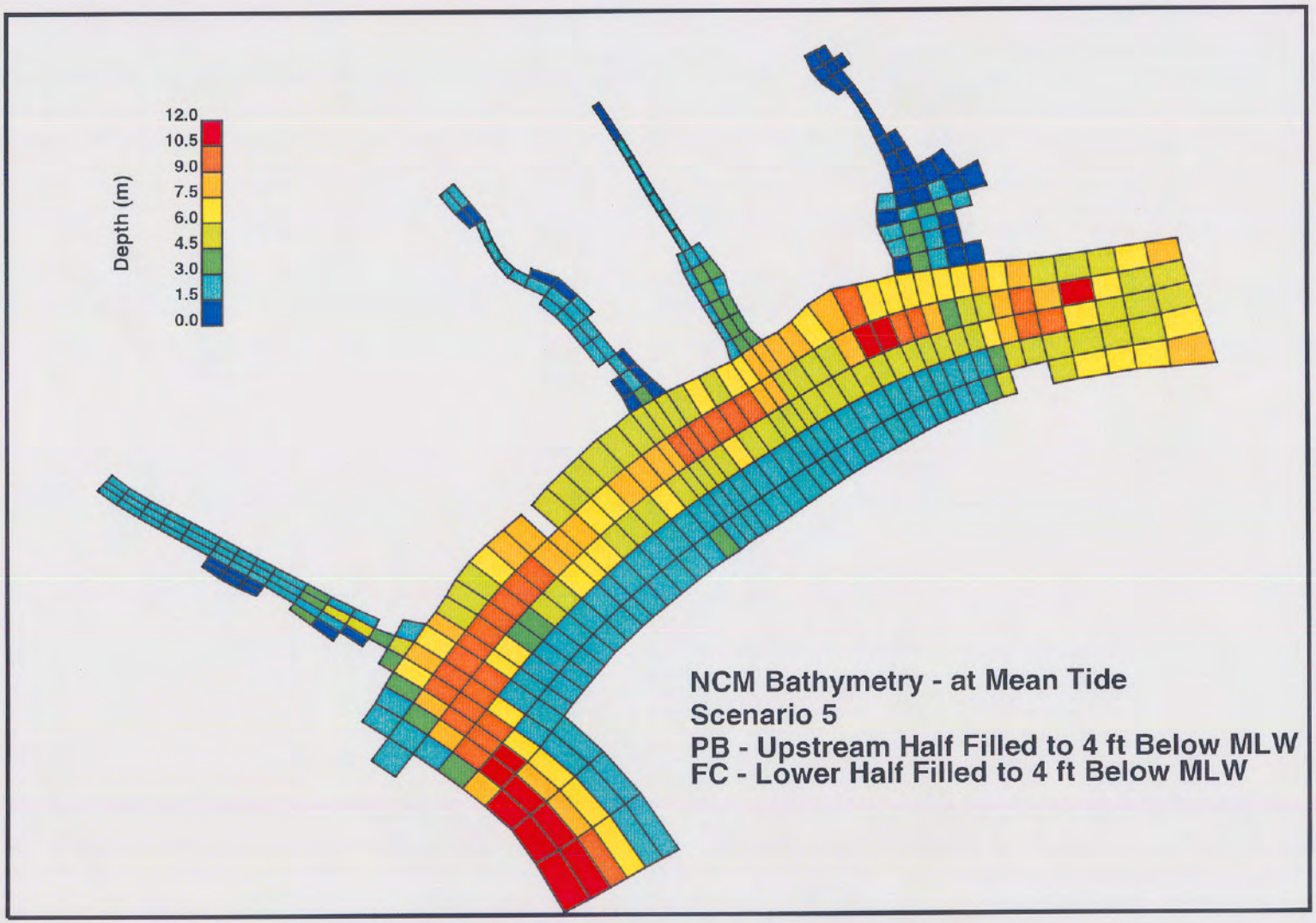


Figure 4-29. NCM Bathymetry - Scenario 5

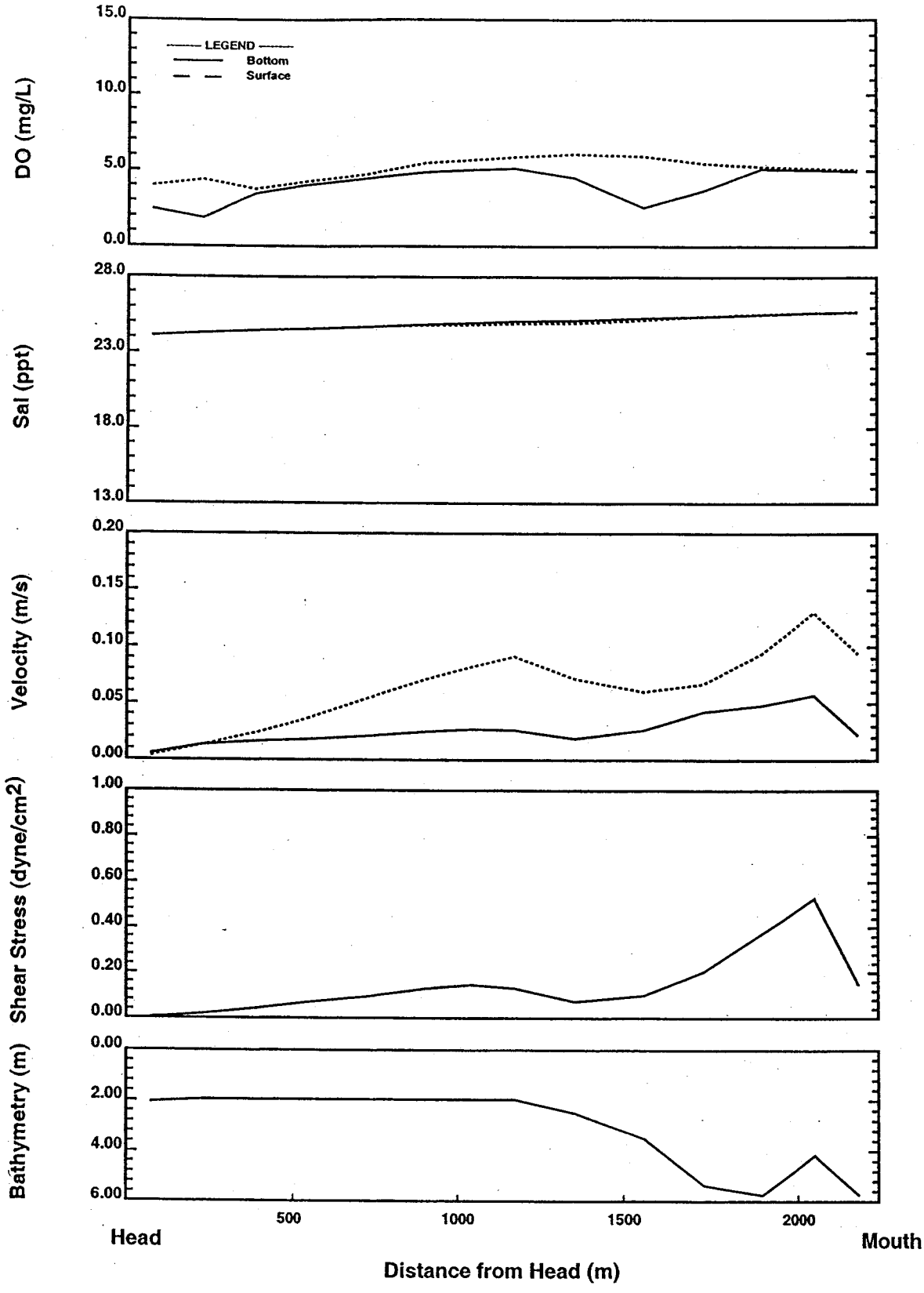


Figure 4-30. Transect of Paerdegat Basin - Hour 1 - Scenario 5

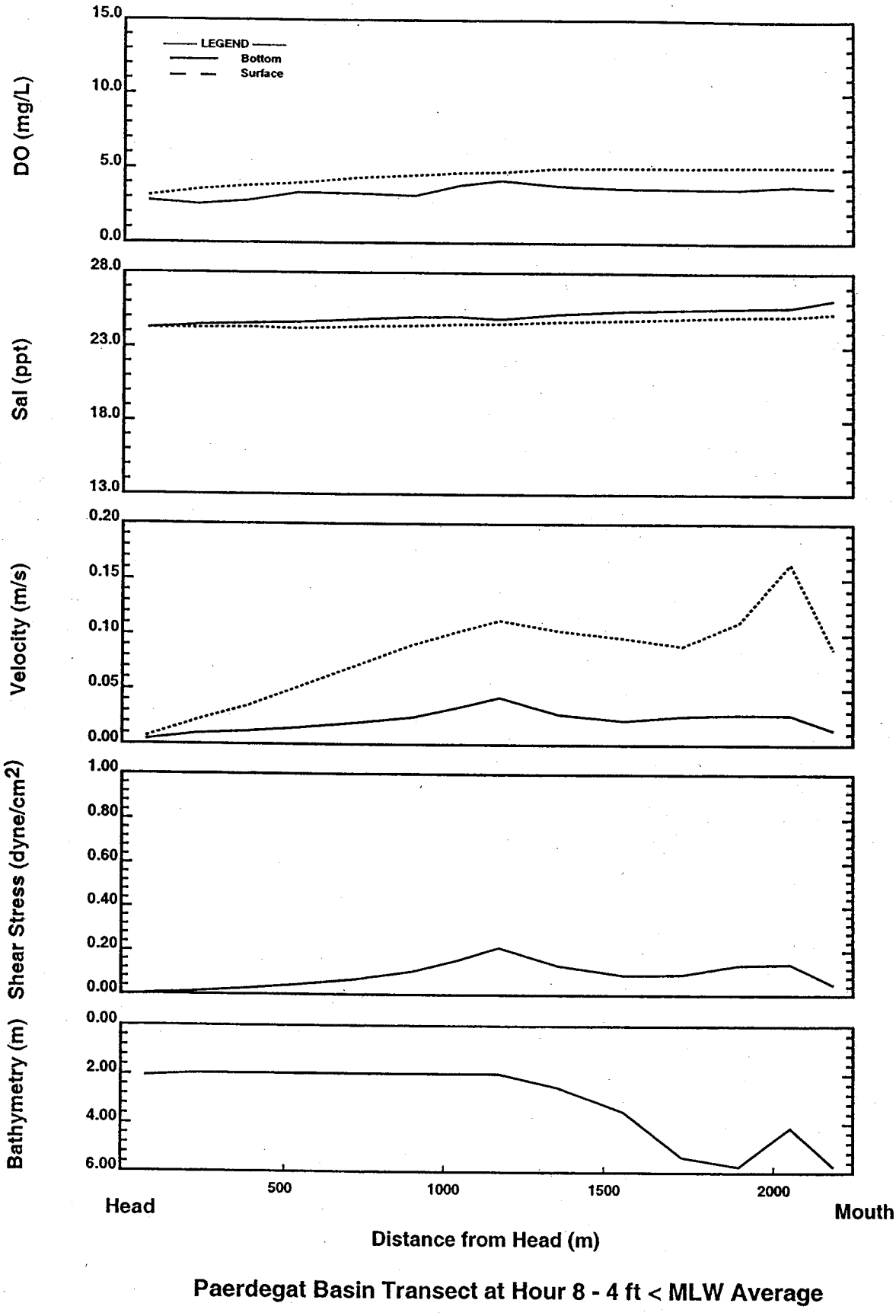


Figure 4-31. Transect of Paerdegat Basin - Hour 8 - Scenario 5

velocities during this hour are low enough so that the shear stresses remain under the level that would cause resuspension.

4.6.2 Fresh Creek

Figure 4-32 presents the model results for surface and bottom DO, salinity and velocity, as well as bottom shear stress during hour 1 in Fresh Creek. Recontouring the lower end of the creek eliminates the DO stratification that occurred in that area. The only area where low DO concentrations are still computed is the head end. It is very likely that if the head end of the creek were filled to the same level as the rest of the upper portion of the creek that the DO level would improve there as well. The bathymetric modifications cause only a small change in salinity. The current velocities in the lower end of the creek increase. This results in shears stresses that approach 1.0 dyne/cm^2.

During hour 8 (Figure 4-33), the DO concentration is higher near the mouth, but more stratified near the head end when compared with the no sill conditions. The current velocities in the lower half of the creek have increased and the shear stress in the lower half of the creek has increased as well. The results for hour 12 (Figure 4-34) show an improvement in the lower end of the creek with increased current velocities and shear stresses near the mouth.

4.7 SCENARIO 6

For scenario 6, the lower half of Fresh Creek was filled to 8 ft below MLW. Since there was no complimentary scenario for Paerdegat Basin it was assigned scenario 3b conditions. The bathymetry used for scenario 6 is shown in Figure 4-35. No results for Paerdegat Basin will be shown.

Figure 4-36 presents the results for Fresh Creek during hour 1. When compared to the "No Sill" scenario (3b), the model predicts improved DO levels in the middle of the creek. The model also predicts marginally higher current velocities and shear stresses in the lower half of the creek, lower velocities in the upper portion of the creek. The improvements in DO are not as great as in scenario 5. During hour 8, the DO improves in the middle section of the creek, but the model computes some DO stratification to occur (Figure 4-37). As shown in Figure 4-38, the model predicts more well mixed DO conditions during hour 12. For this scenario the shear stress does not reach 1.0 dynes/cm^2 during this tidal cycle.

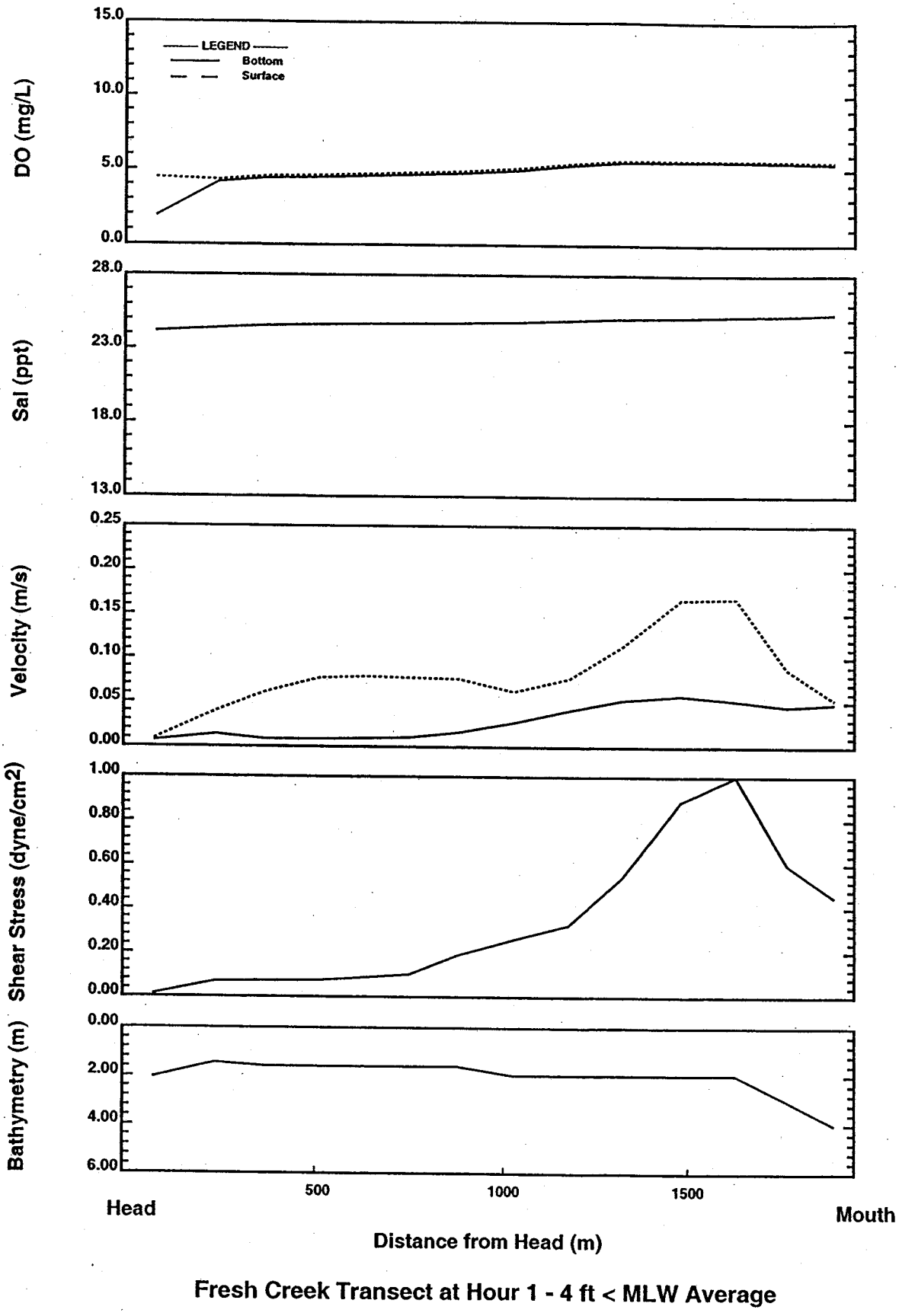


Figure 4-32. Transect of Fresh Creek - Hour 1 - Scenario 5

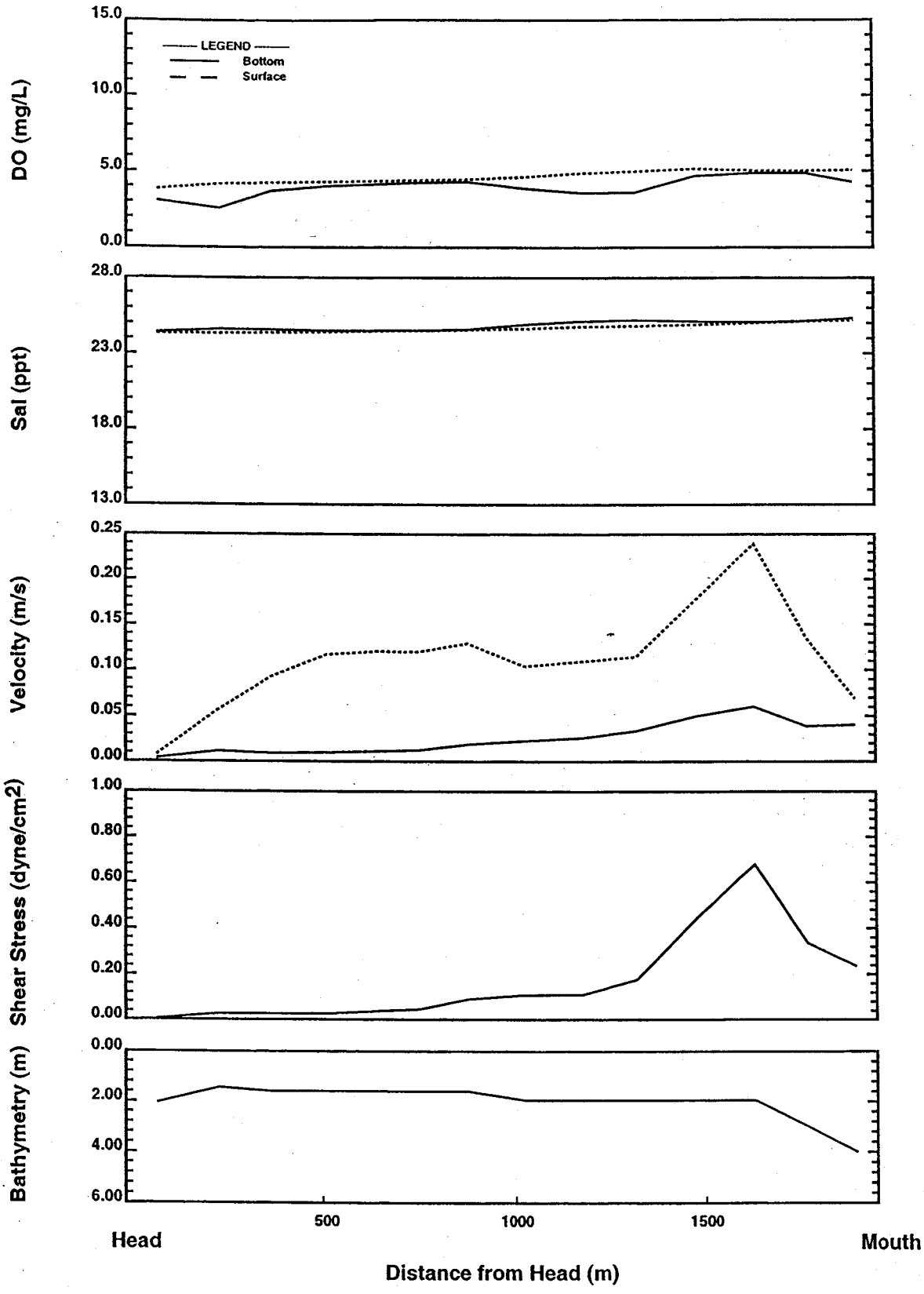


Figure 4-33. Transect of Fresh Creek - Hour 8 - Scenario 5

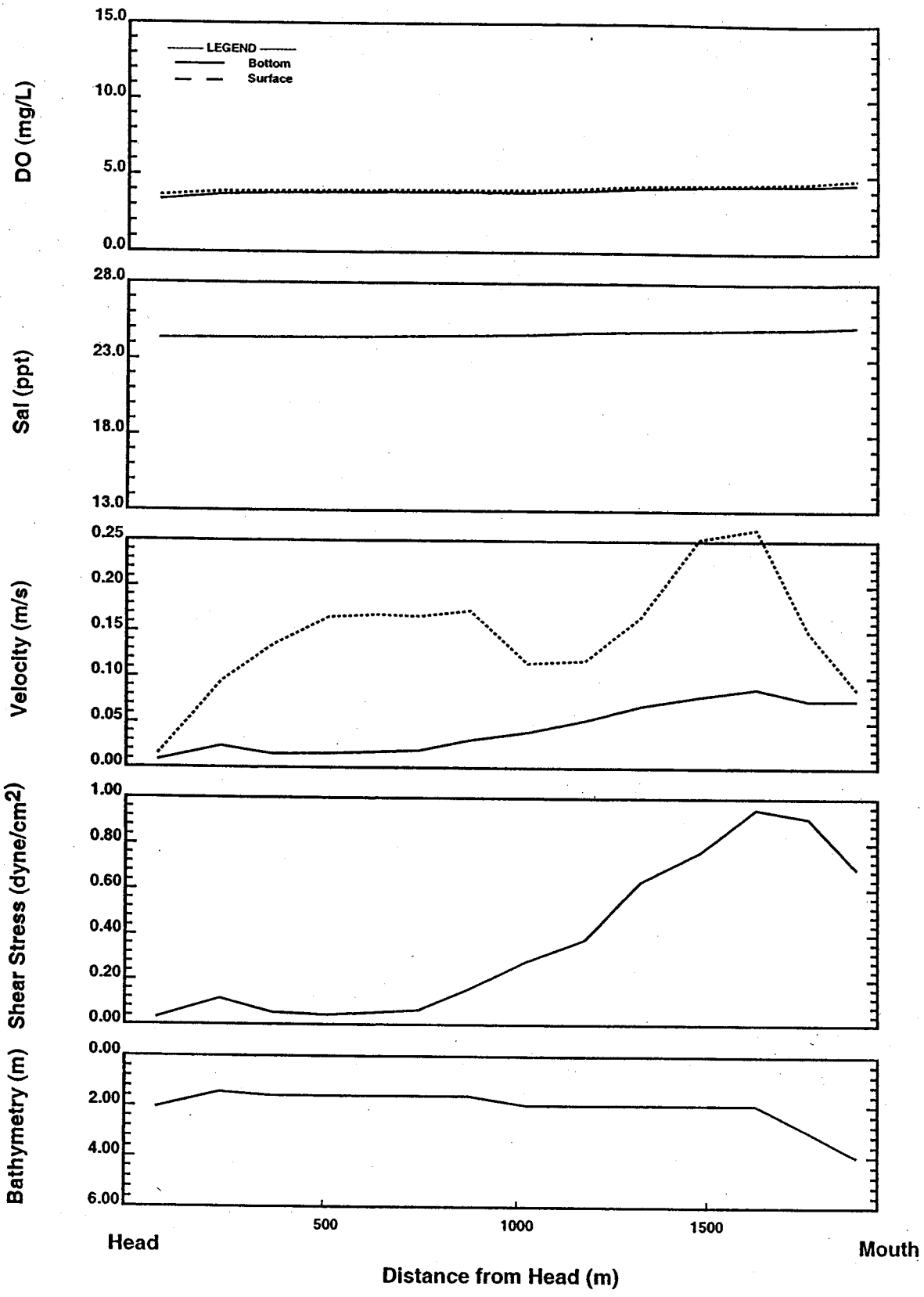


Figure 4-34. Transect of Fresh Creek - Hour 12 - Scenario 5

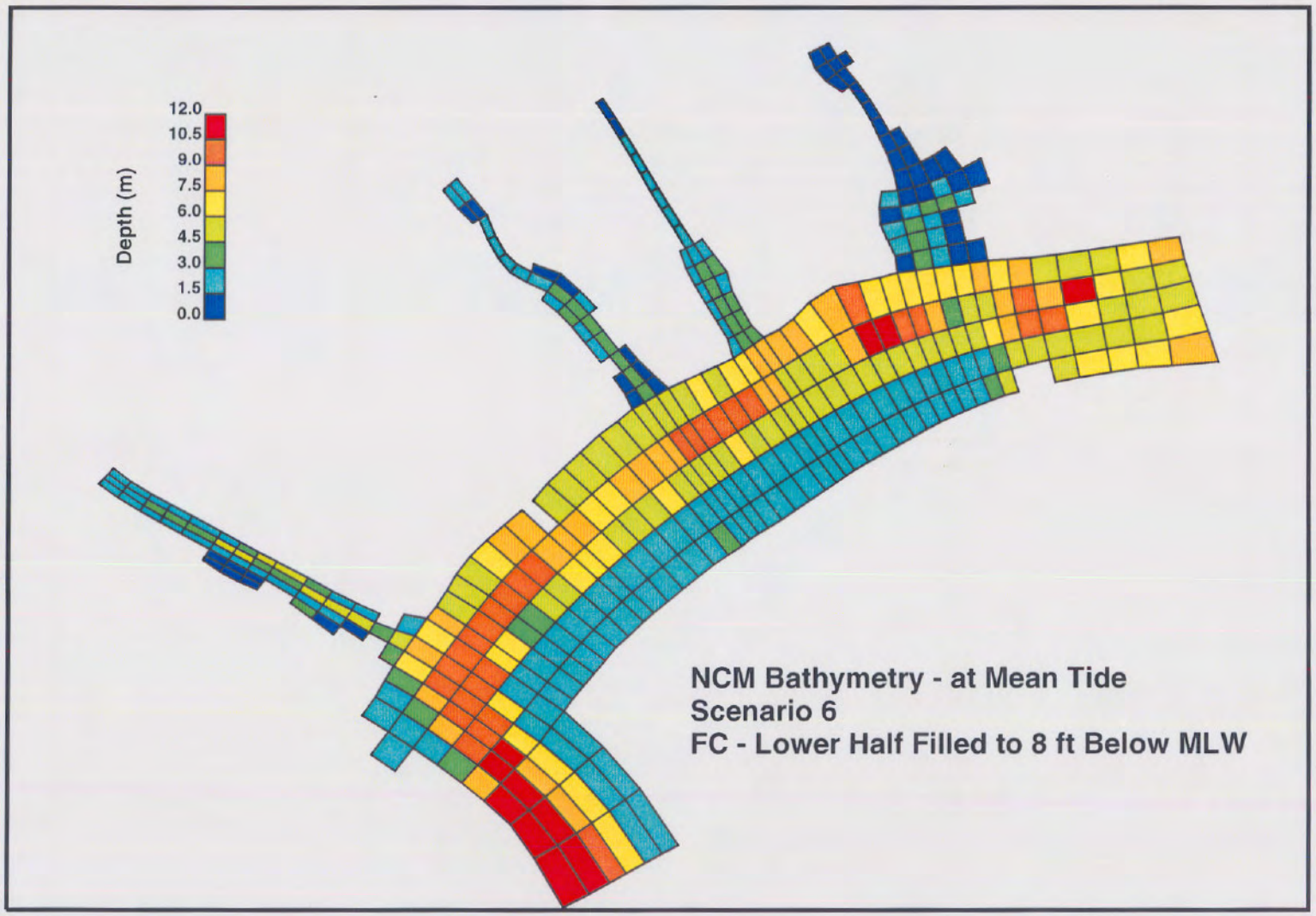


Figure 4-35. NCM Bathymetry - Scenario 6

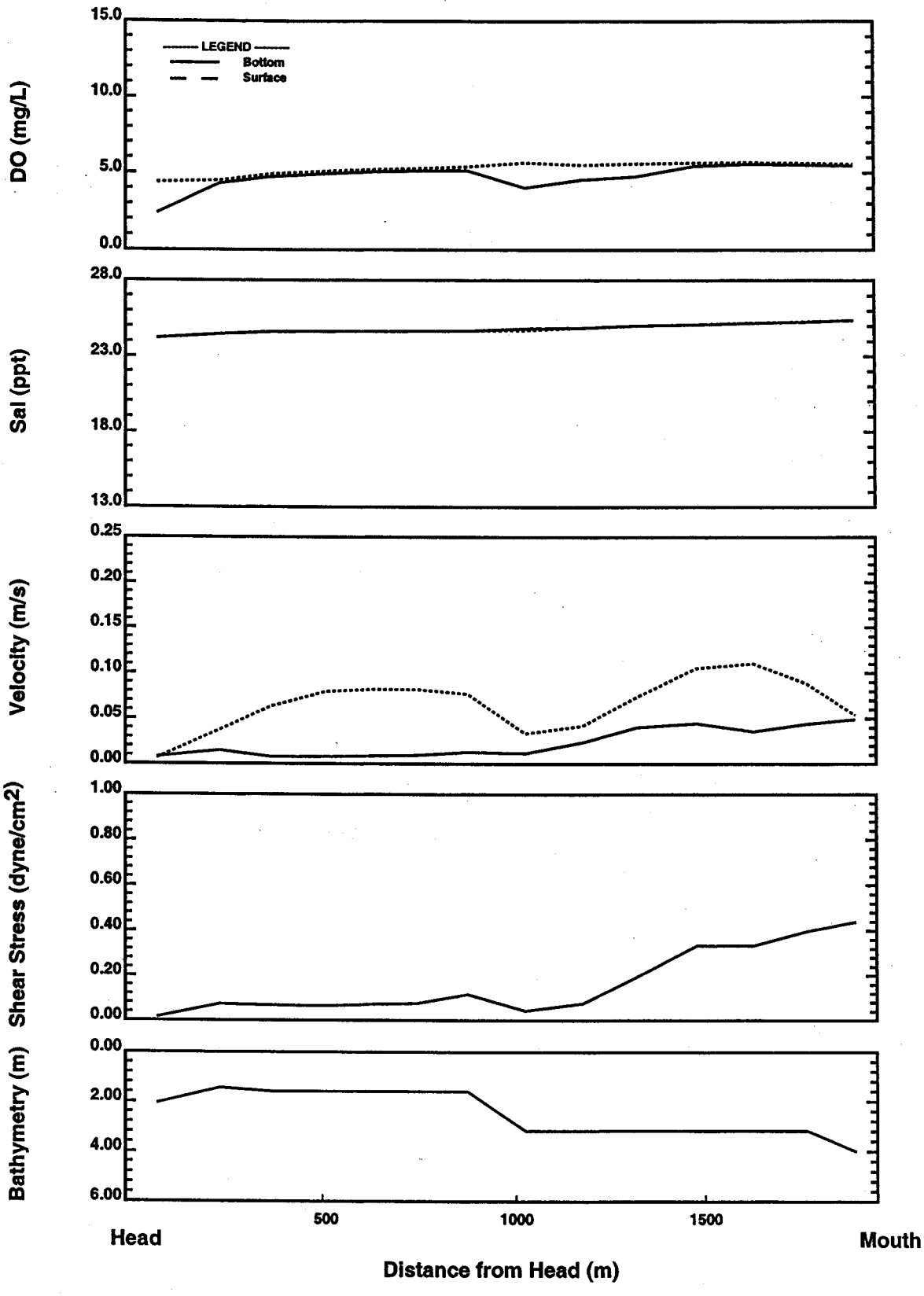


Figure 4-36. Transect of Fresh Creek - Hour 1 - Scenario 6

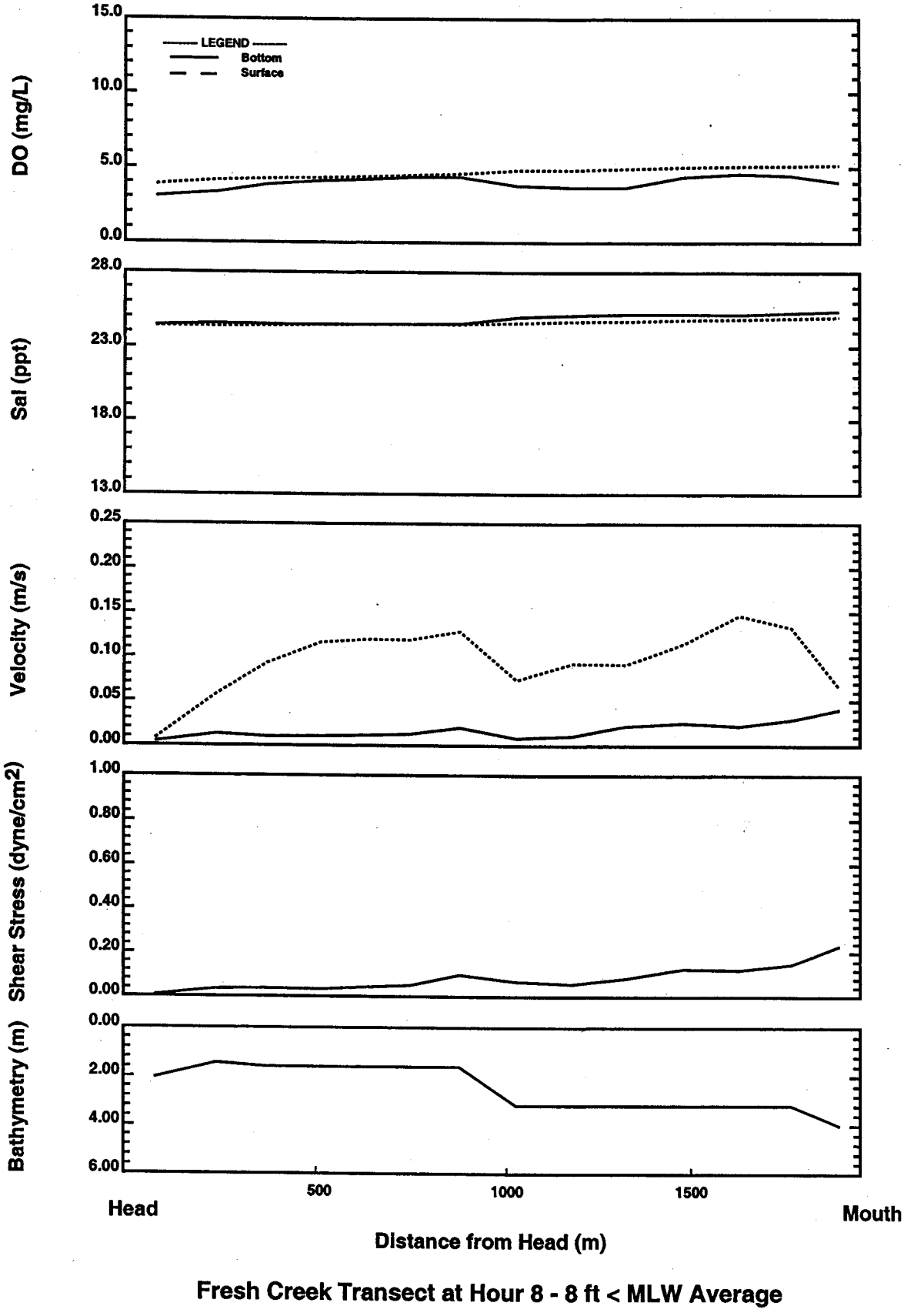


Figure 4-37. Transect of Fresh Creek - Hour 8 - Scenario 6

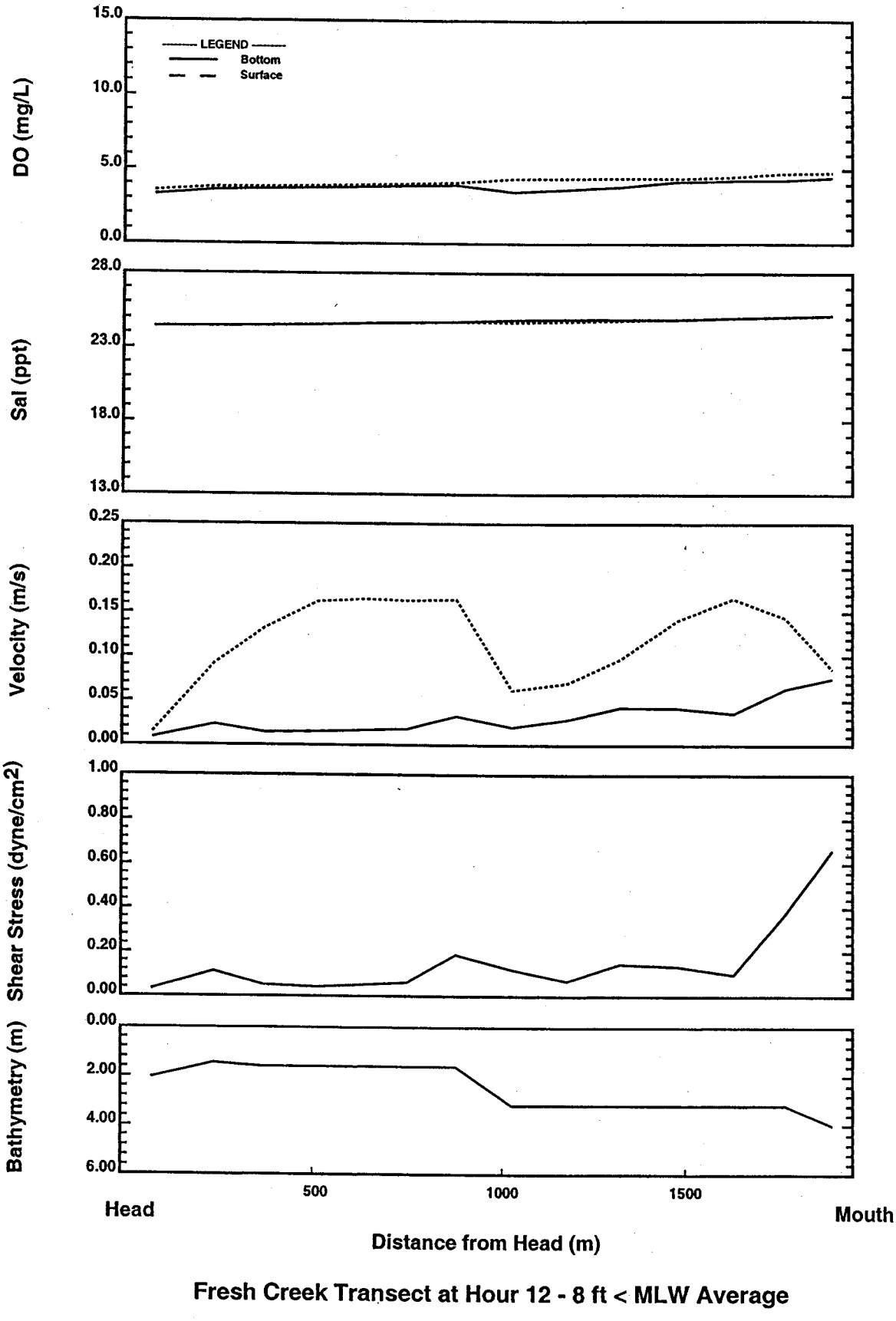


Figure 4-38. Transect of Fresh Creek - Hour 12 - Scenario 6

4.8 TIDAL ELEVATION

Table 4-1 presents the model results for the maximum range of the tide during each month of 1988 (calibration conditions) for the head, middle and mouth of Paerdegat Basin and Fresh Creek. Table 4-1 also includes the maximum and minimum tide elevations based on mean tide. The model results are not only "pure tide", but the results also include the low frequency (meteorological) components of the tide. This means the results can deviate from what might be expected from tidal harmonics alone due to strong weather patterns. During 1988, the more extreme tidal ranges occurred in January, February and November when the difference between the extreme high tide and the extreme low tide was slightly less than 3.0 meters. The extreme high tide occurred in February and the extreme low tide occurred in November. In general, the difference between the high tide at the mouth, and the high tide at the head end was less than 2.0 cm. Fresh Creek during July was the only exception. Low tide showed more variation. (Fresh Creek?)

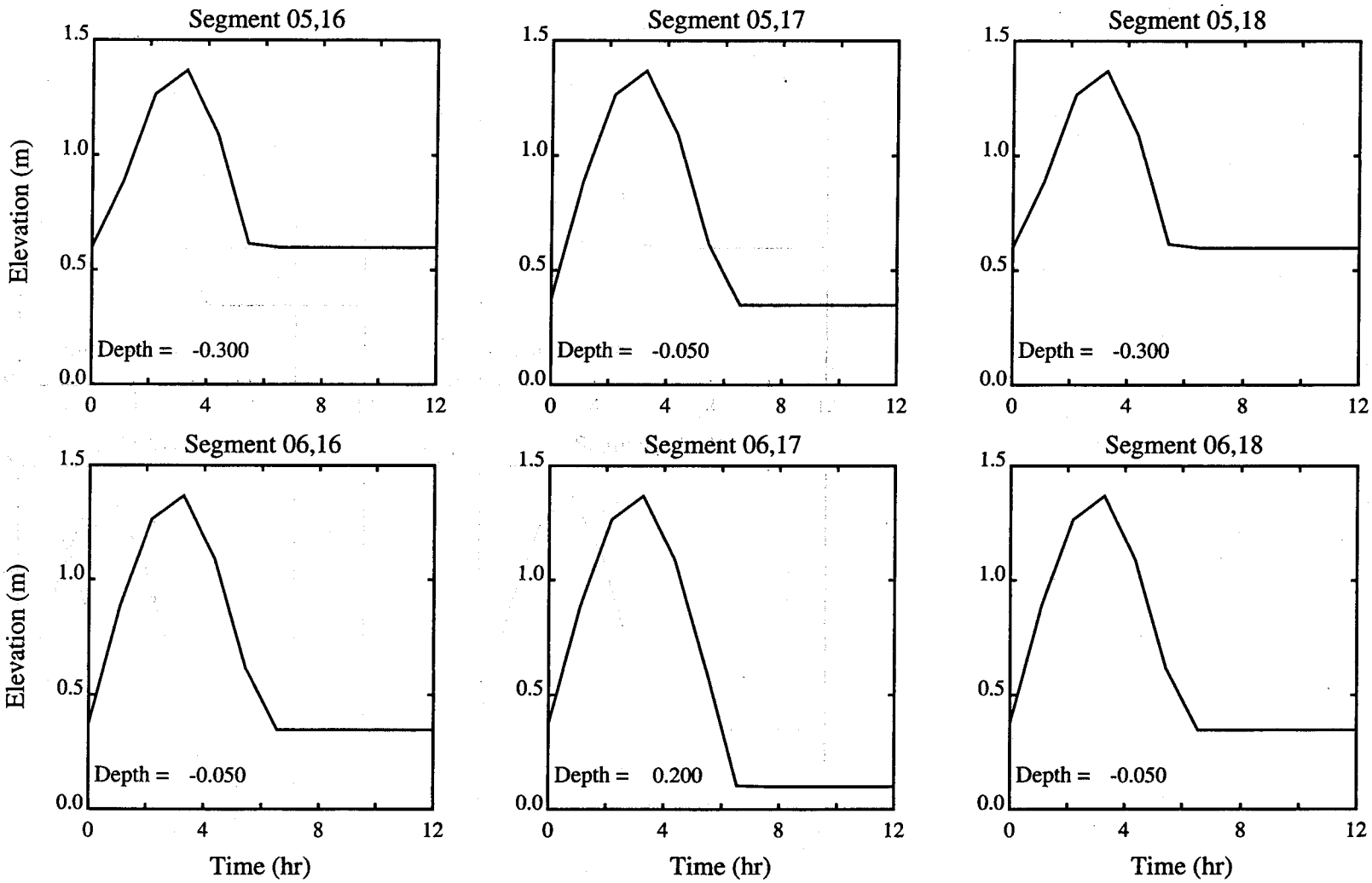
4.9 MARSHES

One concern the USACOE has involving the planting of marsh grass is planting at the proper elevation, so that the marshes are not too wet or too dry to support marsh growth. This section analyzes the potential changes in water elevations due to bathymetric changes. The proposed marsh area in Paerdegat Basin is represented in this model by six segments of various elevations. In this model, mean tide level is the zero datum. Segment elevations are specified as positive if they are below mean tide and negative if they are dry during mean tide. However, for water elevations the convention is reversed. The depths assigned to the marsh segments range from -0.3 m to 0.2 m. While the model simulates the wetting and drying of the marshes, in reality the segment is never fully dry. There is always a minimum amount of water in the segment as specified in the input. In this case the minimum depth of water in the segment is 0.3 m. When the water reaches this depth, the model shuts off communication with the cells next to it. When the tide comes in and the water elevation rises, communication is re-established. Figure 4-39 presents the tidal elevations for the two tidal cycles chosen under existing conditions. During the periods when the elevation does not change, the segment is dry. Figure 4-40 also shows the elevation difference between the calibration and scenario 4. This figure shows that the difference in elevation between the two scenarios is less than 2.0 cm. Appendix H presents comparisons between the calibration and the remaining segments and scenarios. In each case, the changes in the elevation are less than 2.0 cm.

A second concern for the USACOE with regard to the marshes is the susceptibility of the marshes to erosion. While this model is not a sediment transport model it can be used to estimate shear stress. Also, the model is not a fine scale model so that small-scale areas could have higher shear

Table 4-1. NCM Tidal Ranges

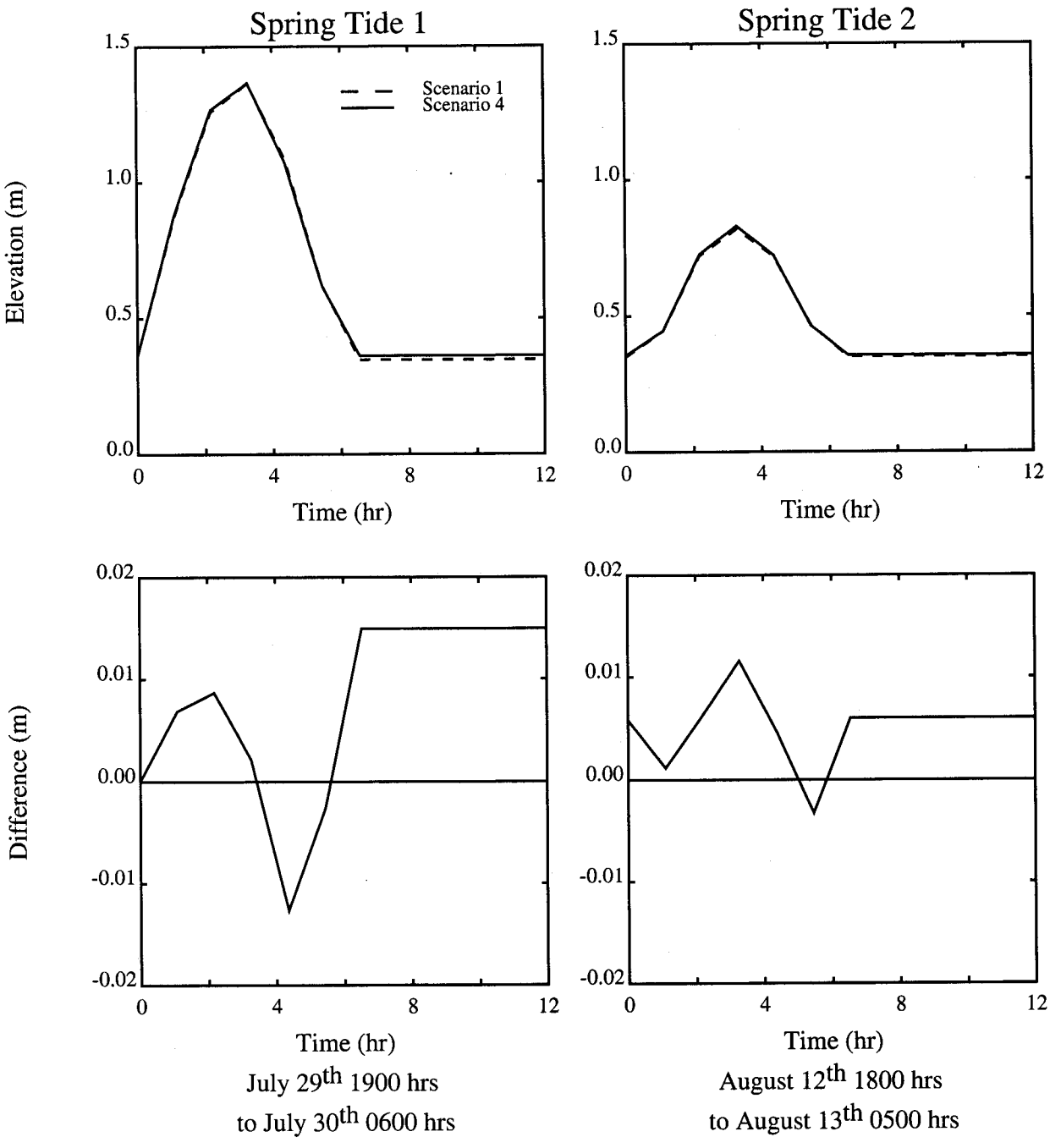
	Paerdegat Basin									Fresh Creek								
Location	Head (08,23)			Mid (08,17)			Mouth (08,10)			Head (25,23)			Mid (25,16)			Mouth (25,10)		
	Depth = 2.06 m			Depth = 4.56 m			Depth = 5.71 m			Depth = 2.06 m			Depth = 3.90 m			Depth = 2.70 m		
Month	Range	Max.	Min.	Range	Max.	Min.	Range	Max.	Min.	Range	Max.	Min.	Range	Max.	Min.	Range	Max.	Min
Jan	2.987	1.546	-1.441	2.984	1.547	-1.437	2.978	1.549	-1.429	2.706	1.558	-1.148	2.999	1.558	-1.441	3.000	1.559	-1.441
Feb	2.941	1.599	-1.342	2.930	1.595	-1.335	2.900	1.576	-1.324	2.758	1.609	-1.149	2.955	1.610	-1.345	2.950	1.606	-1.344
March	2.546	1.200	-1.346	2.538	1.200	-1.338	2.523	1.199	-1.324	2.366	1.216	-1.150	2.574	1.213	-1.361	2.567	1.209	-1.358
April	2.543	1.381	-1.162	2.539	1.377	-1.162	2.528	1.366	-1.162	2.539	1.391	-1.148	2.564	1.387	-1.177	2.557	1.381	-1.176
May	2.301	1.226	-1.075	2.301	1.226	-1.075	2.299	1.229	-1.070	2.328	1.233	-1.095	2.332	1.235	-1.097	2.333	1.237	-1.096
June	2.355	1.365	-0.990	2.348	1.362	-0.986	2.329	1.354	-0.975	2.383	1.376	-1.007	2.378	1.371	-1.007	2.365	1.365	-1.000
July	2.395	1.298	-1.097	2.386	1.293	-1.093	2.365	1.280	-1.085	2.413	1.324	-1.089	2.414	1.307	-1.107	2.392	1.288	-1.104
August	2.567	1.435	-1.132	2.559	1.433	-1.126	2.543	1.425	-1.118	2.595	1.447	-1.148	2.608	1.445	-1.163	2.590	1.443	-1.147
Sept	2.572	1.373	-1.199	2.573	1.374	-1.199	2.577	1.383	-1.194	2.538	1.391	-1.147	2.601	1.393	-1.208	2.608	1.397	-1.211
Octr	2.649	1.483	-1.166	2.635	1.483	-1.152	2.607	1.476	-1.131	2.648	1.500	-1.148	2.692	1.497	-1.195	2.658	1.490	-1.168
Nov	2.862	1.369	-1.493	2.855	1.366	-1.489	2.835	1.354	-1.481	2.539	1.392	-1.147	2.880	1.383	-1.497	2.870	1.373	-1.497
Dec	2.551	1.237	-1.314	2.545	1.236	-1.309	2.533	1.233	-1.300	2.407	1.257	-1.150	2.573	1.252	-1.321	2.563	1.247	-1.316



Scenario 1 - Baseline, Spring Tide, July 29th 1900 hrs to July 30th 0600 hrs

Tidal Elevation at the Marshy Segments of Paerdegat Basin

Figure 4-39. Tidal Elevations in the Marsh Areas for Existing Conditions



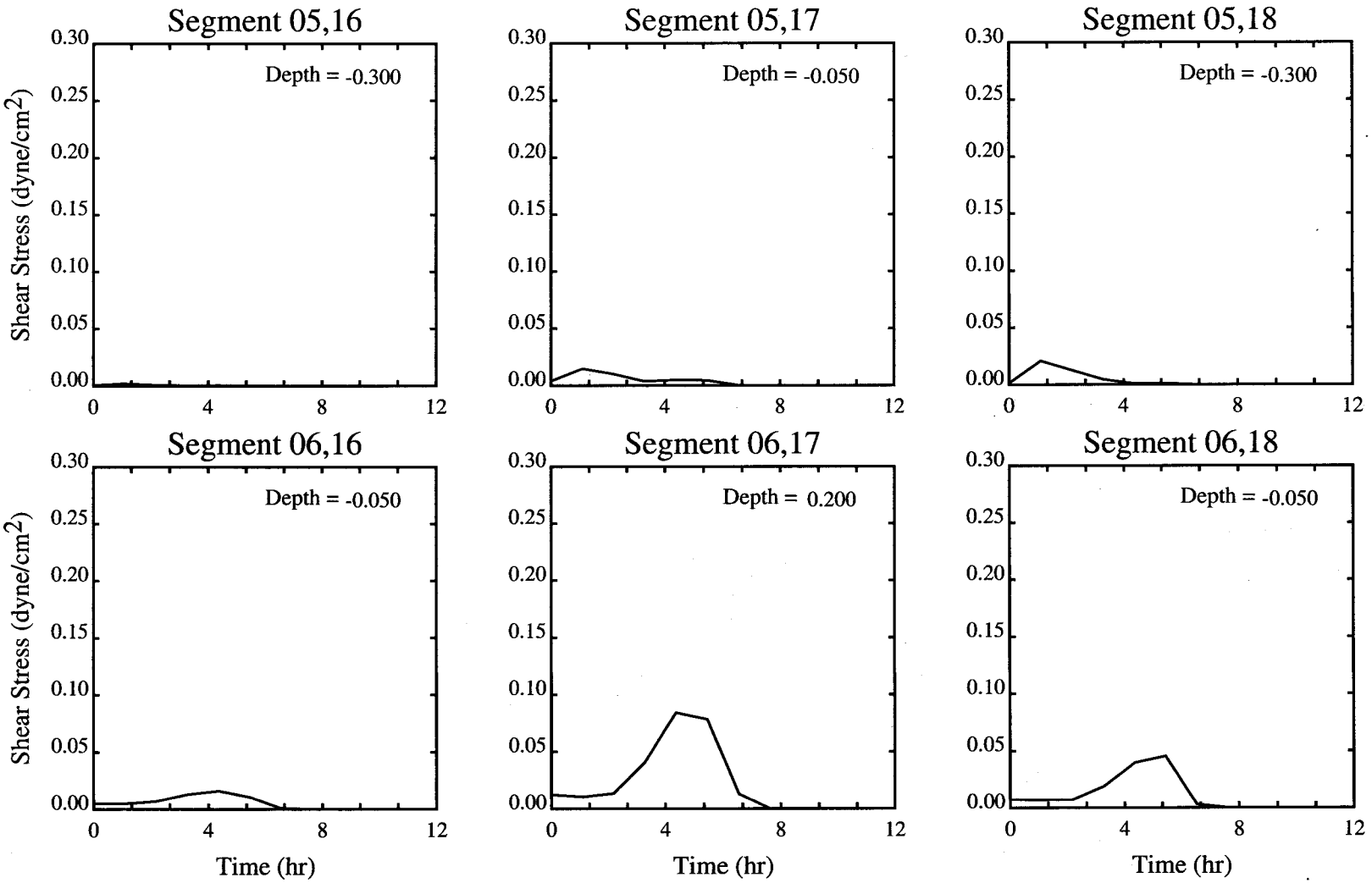
Segment: 06, 16

Elevation Diferences in Marshes in Paerdegat with Scenario 4 and 1

Figure 4-40. Elevation Differences in the Marsh Area Between the Existing Conditions and Scenario

stresses than computed by the model. Finally, this analysis was done for a period without a significant CSO overflow event. It is possible that higher velocities and shear stresses could occur during one of these events. Despite these issues, the shear stresses were calculated in the marsh area of Paerdegat Basin.

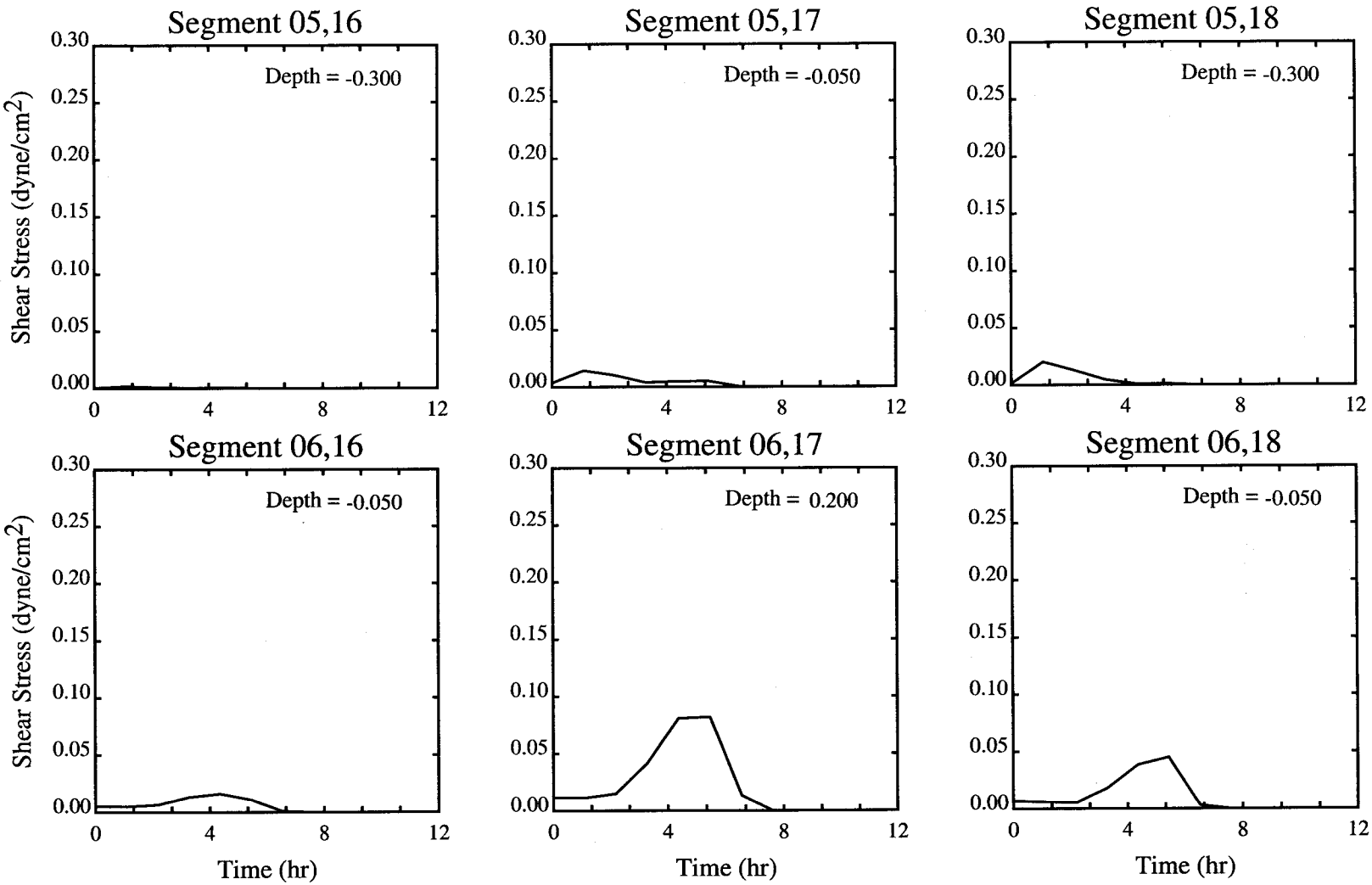
Figures 4-41 through 4-47 show the computed shear stresses for each of the marsh segments and each of the scenarios during the tidal cycle beginning July 29th (the tidal cycle with the largest elevation range). These figures show that when using a z_0 of 0.003 the shear stresses were less than half of 1.0 dyne/cm^2. The highest shear stresses occur during the scenario where the upper half of the basin is filled to MLW, as shown in Figure 4-45. These shear stresses remain below the level that would cause resuspension.



Scenario 1 - Baseline, Spring Tide, Day - July 29th 1900 hrs to July 30th 0600 hrs

Shear Stress (for Z_o = 0.003 run) at the Marshy Segments of Paerdegat Basin

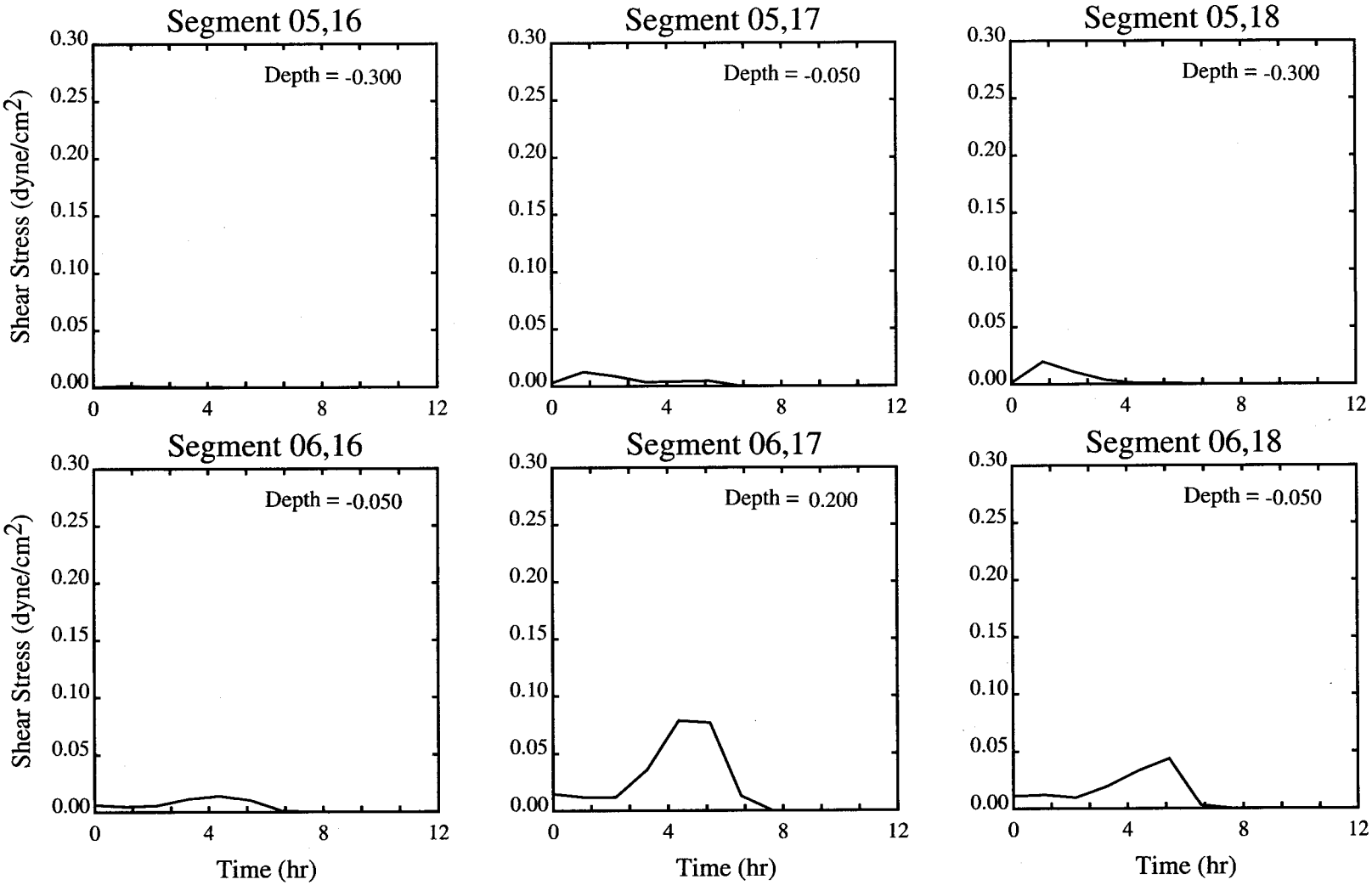
Figure 4-41. Shear Stresses in the Marshes for Existing Conditions



Scenario 2, Spring Tide, Day - July 29th 1900 hrs to July 30th 0600 hrs

Shear Stress (for Z_o = 0.003 run) at the Marshy Segments of Paerdegat Basin

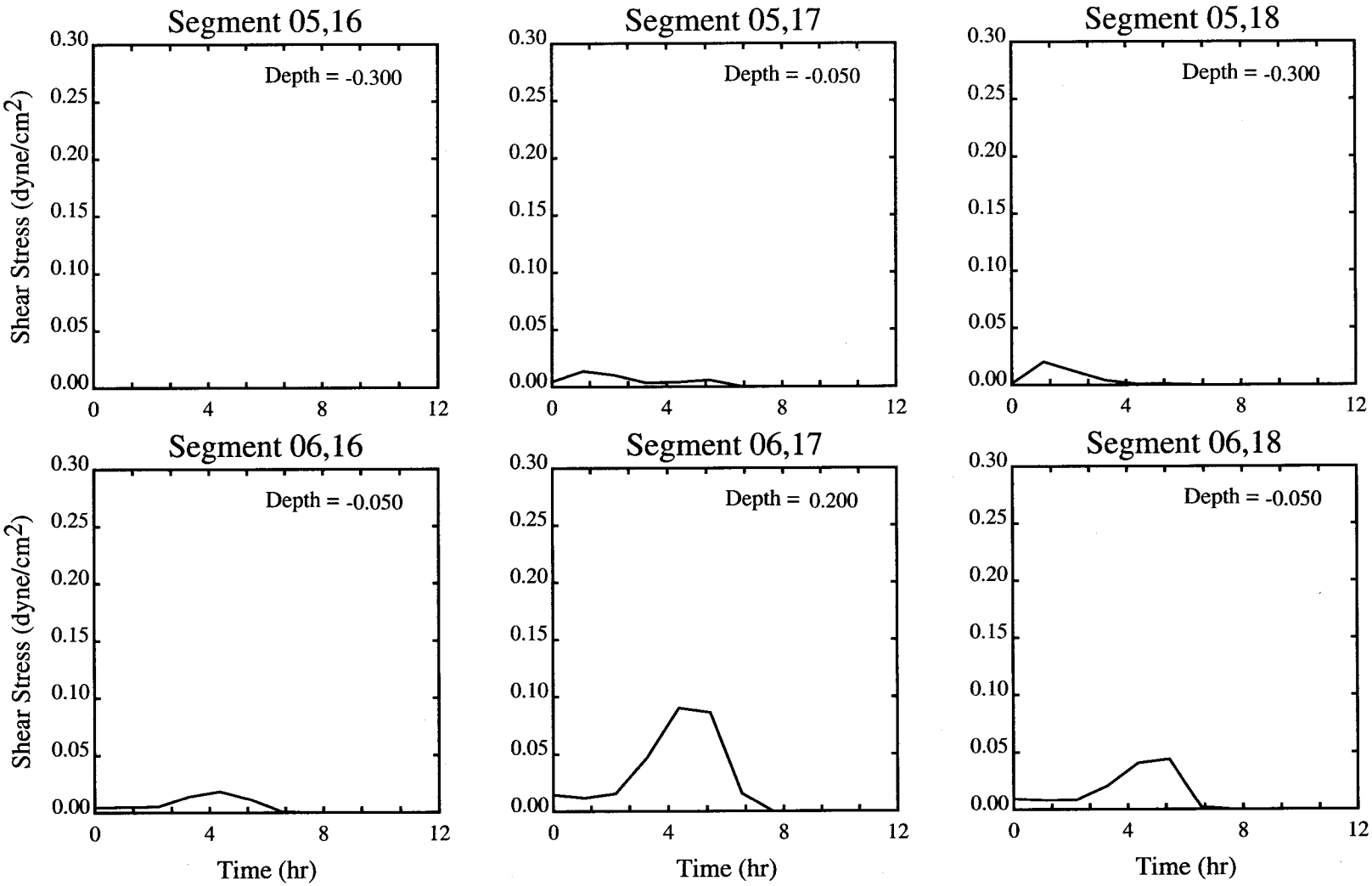
Figure 4-42. Shear Stresses in the Marshes for Scenario 2 Conditions



Scenario 3a, Spring Tide, Day - July 29th 1900 hrs to July 30th 0600 hrs

Shear Stress (for Z_o = 0.003 run) at the Marshy Segments of Paerdegat Basin

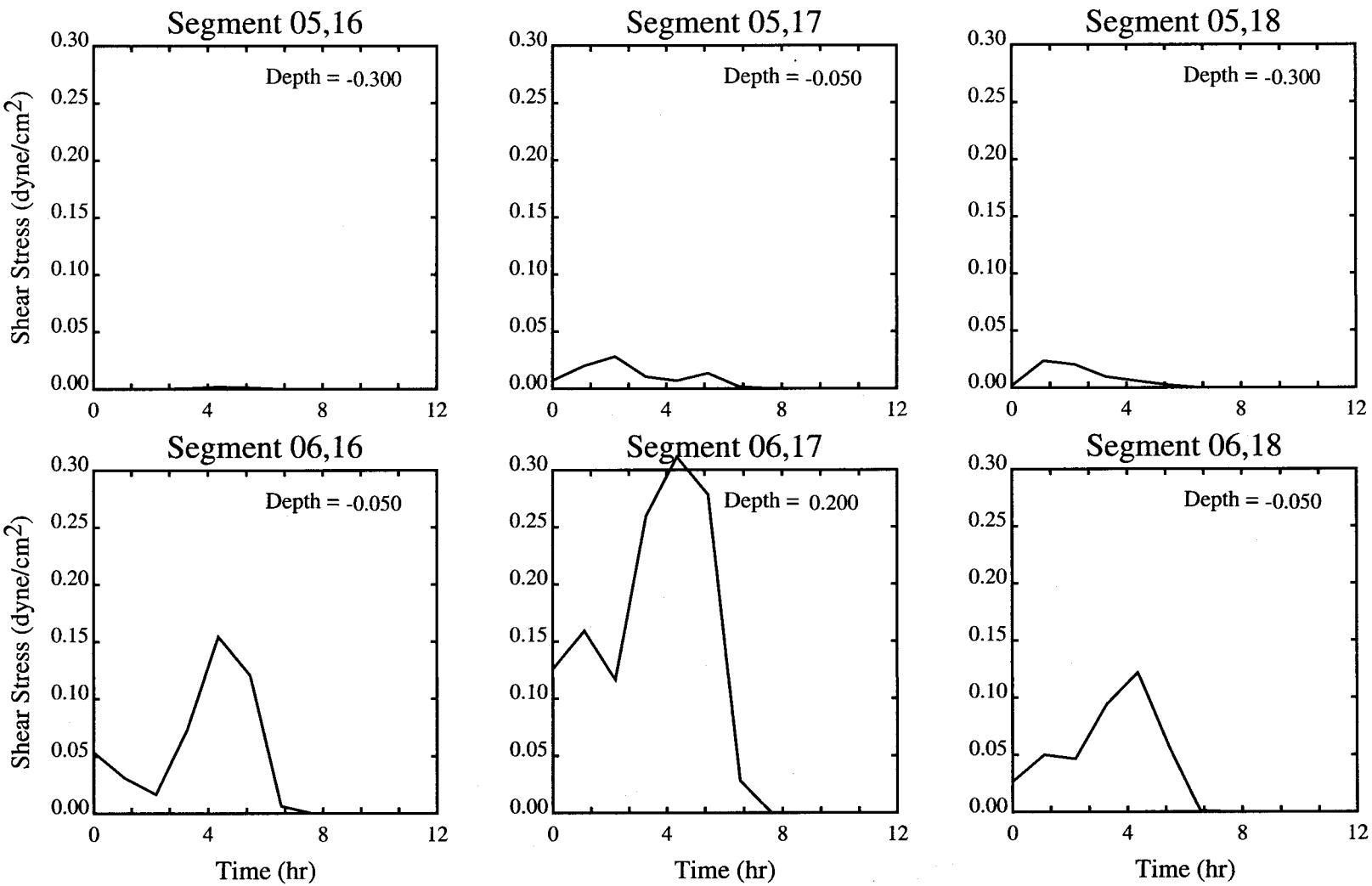
Figure 4-43. Shear Stresses in the Marshes for Scenario 3a Conditions



Scenario 3b, Spring Tide, Day - July 29th 1900 hrs to July 30th 0600 hrs

Shear Stress (for Z_o = 0.003 run) at the Marshy Segments of Paerdegat Basin

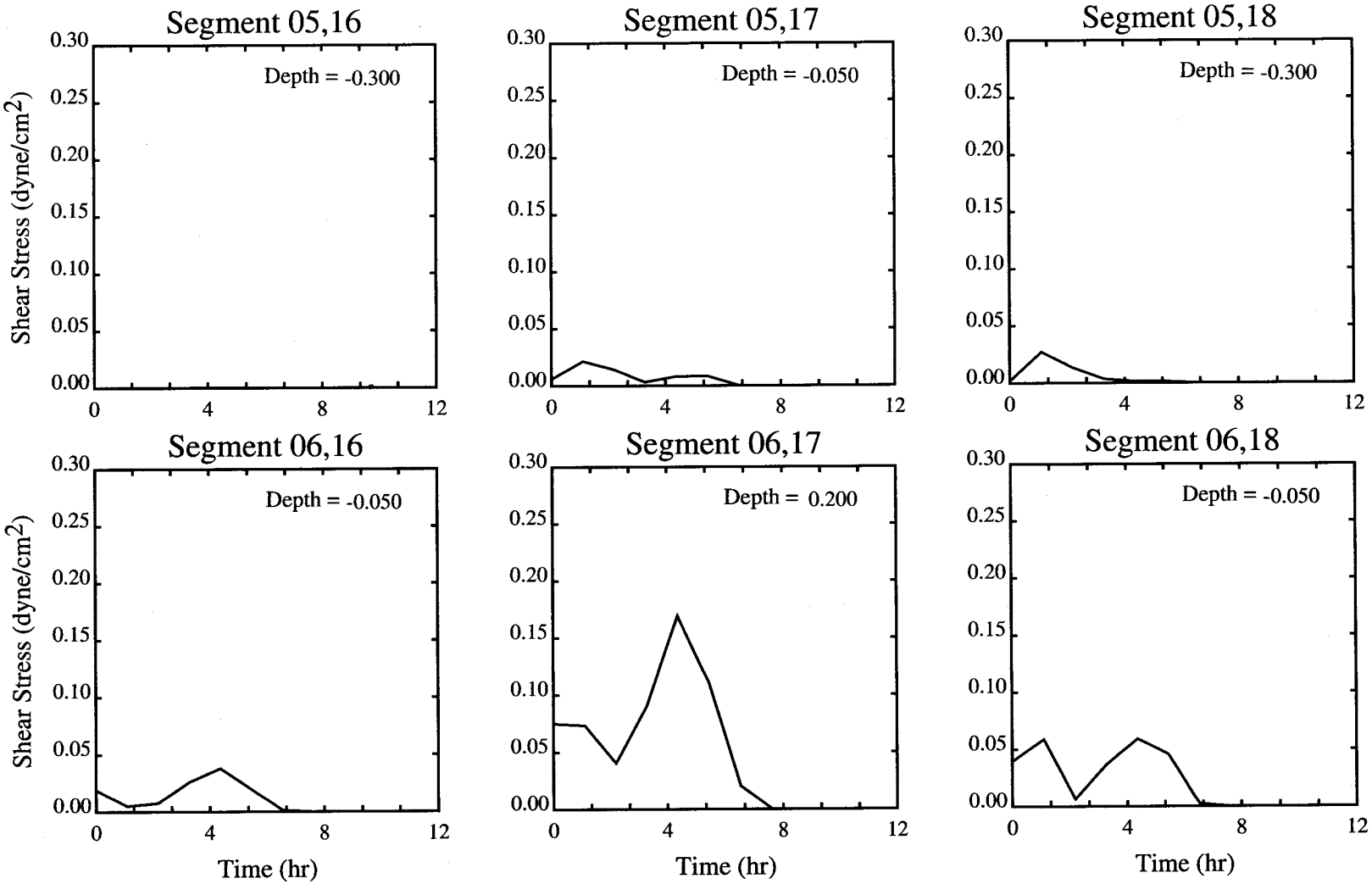
Figure 4-44. Shear Stresses in the Marshes for Scenario 3b Conditions



Scenario 4, Spring Tide, Day - July 29th 1900 hrs to July 30th 0600 hrs

Shear Stress (for Z_o = 0.003 run) at the Marshy Segments of Paerdegat Basin

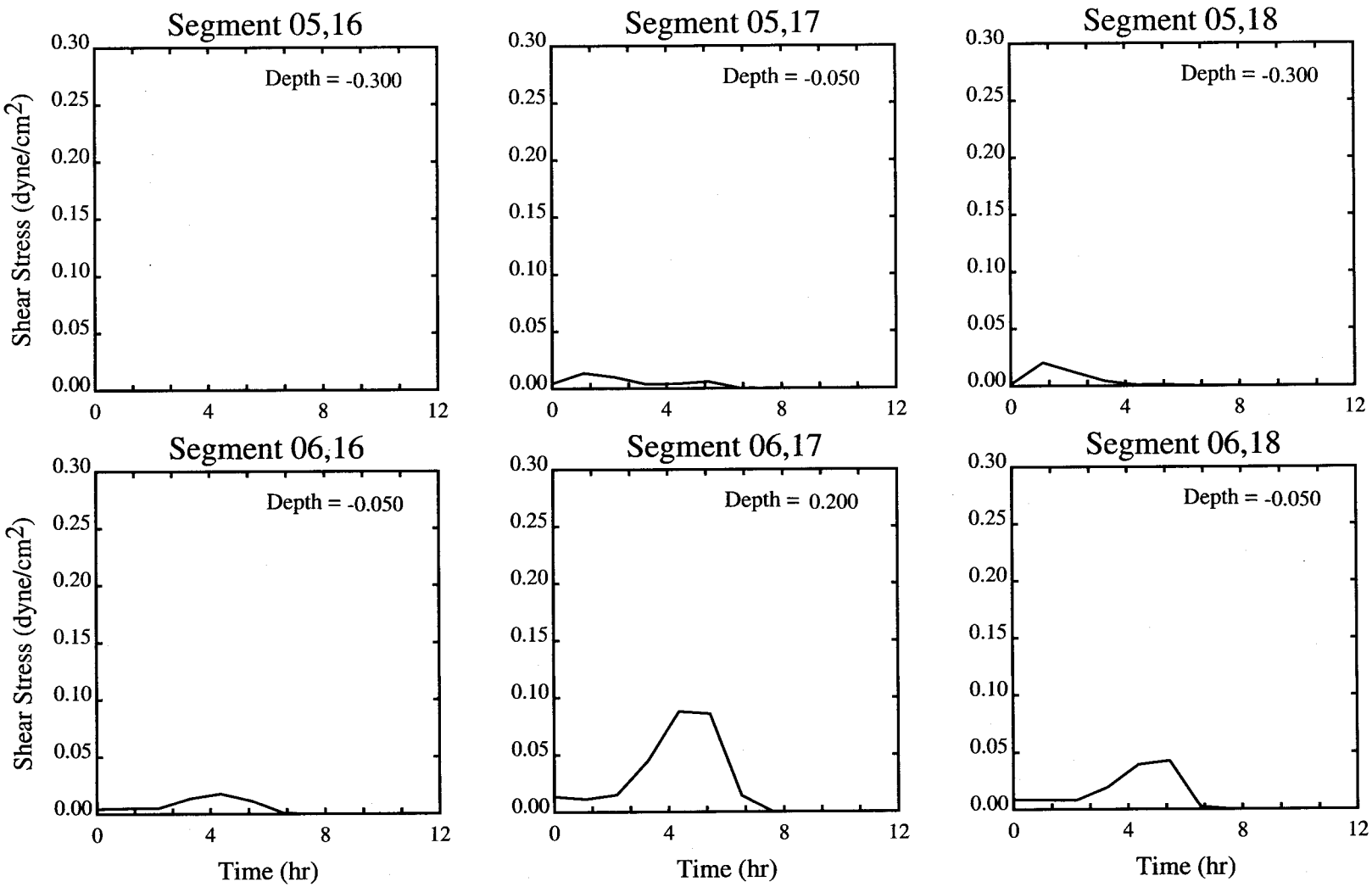
Figure 4-45. Shear Stresses in the Marshes for Scenario 4 Conditions



Scenario 5, Spring Tide, Day - July 29th 1900 hrs to July 30th 0600 hrs

Shear Stress (for Z_o = 0.003 run) at the Marshy Segments of Paerdegat Basin

Figure 4-46. Shear Stresses in the Marshes for Scenario 5 Conditions



Scenario 6, Spring Tide, Day - July 29th 1900 hrs to July 30th 0600 hrs

Shear Stress (for Z_o = 0.003 run) at the Marshy Segments of Paerdegat Basin

Figure 4-47. Shear Stresses in the Marshes for Scenario 6 Conditions

SECTION 5

NCM CONCLUSIONS

Based on the analyses of the scenarios outlined for Fresh Creek and Paerdegat Basin, it appears that both tributaries would benefit from some form of bathymetric recontouring. In general, the model did not respond well to areas with deep "holes" or "dips." The model also computed high shear stresses at shallow depths and areas with rapid depth changes. Based on the results of the scenarios, modifying the bathymetry to a depth of 3-4 ft below mean low water at the head end with a gradual increase in depth toward the mouth would provide the greatest benefit to the tributaries. Care should be taken to avoid dips in the recontoured bottom. The shallower depths increase the current velocities and increase the mixing in the tributaries and consequently increase the minimum DO concentrations in the tributaries. This model does not compute sediment transport, so it is not clear how quickly the bathymetry might change due to settling and erosion over time. While the CSO facility plans remove most of the CSO overflow, overflow events would still occur discharging solids into the tributaries. Sills near the mouths of the tributaries would continue to develop and required occassional dredging.

Bathymetric changes should cause minimal changes to tidal elevations. The planting of the marsh grasses can be based on the current knowledge of the tidal elevations in the tributaries. The shear stresses computed in the marshes were very small, so erosion should not occur. The model cannot be used to predict how quickly the marshes will fill and whether or not bank erosion will occur if the marshes are planted on a steep slope. In the case of Paerdegat Basin, the model cannot predict the possible erosion due to boat wakes or wind waves.

SECTION 6

REFERENCES

HydroQual, Inc. 2002. A water quality model for Jamaica Bay: Calibration of the Jamaica Bay Eutrophication Model (JEM). Prepared for the New York City Department of Environmental Protection.

US Army Corps
of Engineers®

JAMAICA BAY ECOSYSTEM RESTORATION PROJECT
NEW YORK, NEW YORK
FEASIBILITY STUDY
Project Cost and Schedule Risk Analysis Report

Prepared for:

U.S. Army Corps of Engineers,
New York District

Prepared by:

U.S. Army Corps of Engineers
Cost Engineering Directory of Expertise, Walla Walla

March 23, 2010

TABLE OF CONTENTS

EXECUTIVE SUMMARY ES-1

1. PURPOSE 1

2. BACKGROUND 1

3. REPORT SCOPE 2

3.1 Project Scope 2
3.2 USACE Risk Analysis Process 2

4. METHODOLOGY/PROCESS 3

4.1 Identify and Assess Risk Factors 4
4.2 Quantify Risk Factor Impacts 5
4.3 Analyze Cost Estimate Contingency 6

5. PROJECT ASSUMPTIONS 6

6. RISK ANALYSIS RESULTS 7

6.1 Risk Register 7
6.2 Cost Risk Analysis - Cost Contingency Results 8
6.3 Schedule Risk Analysis – Project Duration Contingency Results……..8

7. MITIGATION RECOMMENDATIONS 9

APPENDIX

APPENDIX A includes

Detailed Risk Analysis

- Risk Register Summary
- Sensitivity Charts
- Project Cost Presentation
- Project Confidence Curves

EXECUTIVE SUMMARY

Under the auspices of the U.S. Army Corps of Engineers (USACE), New York District, this report presents a recommendation for the total project cost and schedule contingencies for the Jamaica Bay Ecosystem Restoration Feasibility Study. In compliance with Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008, a formal risk analysis study was conducted for the development of contingency on the total project cost. The purpose of this risk analysis study was to establish project contingencies by identifying and measuring the cost and schedule impact of project uncertainties with respect to the estimated total project cost (at price level).

Specific to the Jamaica Bay project, the most likely project cost is estimated at approximately $158 Million. Based on the results of the analysis, the Cost Engineering Directory of Expertise for Civil Works (Walla Walla District) recommends a contingency value of $63.5 Million, or 40%.

The Project Delivery Team (PDT) conducted a brainstorming session to identify the risks associated with the project. Walla Walla Cost Dx performed risk analysis using the *Monte Carlo* technique, producing the aforementioned contingencies and identifying key risk drivers.

The following table ES-1 portrays the development of contingencies for the project. The contingency is based on an 80% confidence level, as per USACE Civil Works guidance.

Table ES-1. Contingency Development Summary

Contingency on Baseline Estimate	80% Confidence Project Cost
Baseline Estimate Cost (Most Likely) ->	**$158,045,950**
Baseline Estimate Cost Contingency Amount ->	$44,215,485
Baseline Estimate Construction Cost (80% Confidence) ->	**$202,261,435**

Contingency on Schedule	80% Confidence Project Schedule
Project Schedule Duration (Most Likely) ->	**182.3 Months**
Schedule Contingency Duration ->	122.4 Months
Project Schedule Duration (80% Confidence) ->	**304.7 Months**
Project Schedule Contingency Amount (80% Confidence) ->	**$19,320,466**

Project Contingency	80% Confidence Project Cost
Project Contingency Amount (80% Confidence) ->	**$63,535,952**
Project Contingency Percentage (80% Confidence) ->	**40%**

Project Cost (80% Confidence) ->	**$221,581,901**

KEY FINDINGS/OBSERVATIONS RECOMMENDATIONS

The key cost risk drivers identified through sensitivity analysis are Risks PR-6 (Market Conditions/Bidding Climate), PPM-4 (Local Agency/Regulator Issues), and GE-4 (Design Development Stage Incomplete or Preliminary), which together contribute over 80 percent of the statistical cost variance.

The key schedule risk drivers identified through sensitivity analysis are Risks CON-1 (FAA Involvement), CON-3 (Regulatory/Operational Work Windows), PPM-5 (Priorities Change on Existing Program), PPM-1 (Project Competing With Other Projects), and PR-4 (Political Factors Change at Local, State, or Federal Level), which together contribute over 63 percent of the statistical schedule variance.

Recommendations, as detailed within the main report, include the implementation of contingencies, further iterative study of risks throughout the project life-cycle, potential mitigation throughout the PED phase, and proactive monitoring and control of risks identified in this study.

Table ES-2. Contingency Analysis Table

Most Likely Cost Estimate	**$158,045,950**	
Confidence Level	**Value**	**Contingency**
0%	**$127,935,815**	**-19.05%**
5%	**$166,626,075**	**5.43%**
10%	**$174,142,095**	**10.18%**
15%	**$179,295,375**	**13.45%**
20%	**$183,498,464**	**16.10%**
25%	**$187,292,638**	**18.51%**
30%	**$190,555,166**	**20.57%**
35%	**$193,544,566**	**22.46%**
40%	**$196,380,246**	**24.26%**
45%	**$199,078,909**	**25.96%**
50%	**$201,882,154**	**27.74%**
55%	**$204,688,036**	**29.51%**
60%	**$207,720,767**	**31.43%**
65%	**$210,659,795**	**33.29%**
70%	**$214,173,154**	**35.51%**
75%	**$217,662,577**	**37.72%**
80%	**$221,581,901**	**40.20%**
85%	**$225,824,967**	**42.89%**
90%	**$231,189,330**	**46.28%**
95%	**$239,071,123**	**51.27%**
100%	**$281,077,470**	**77.85%**

Risk is comprised of cost and schedule risk elements. This analysis considers schedule elements in terms of uncaptured escalation and significant “Hotel” costs. The following tables tabulate the results of the risk analysis currently identified as 40%.

Figure ES-1. Cumulative Frequency Chart (Cost)

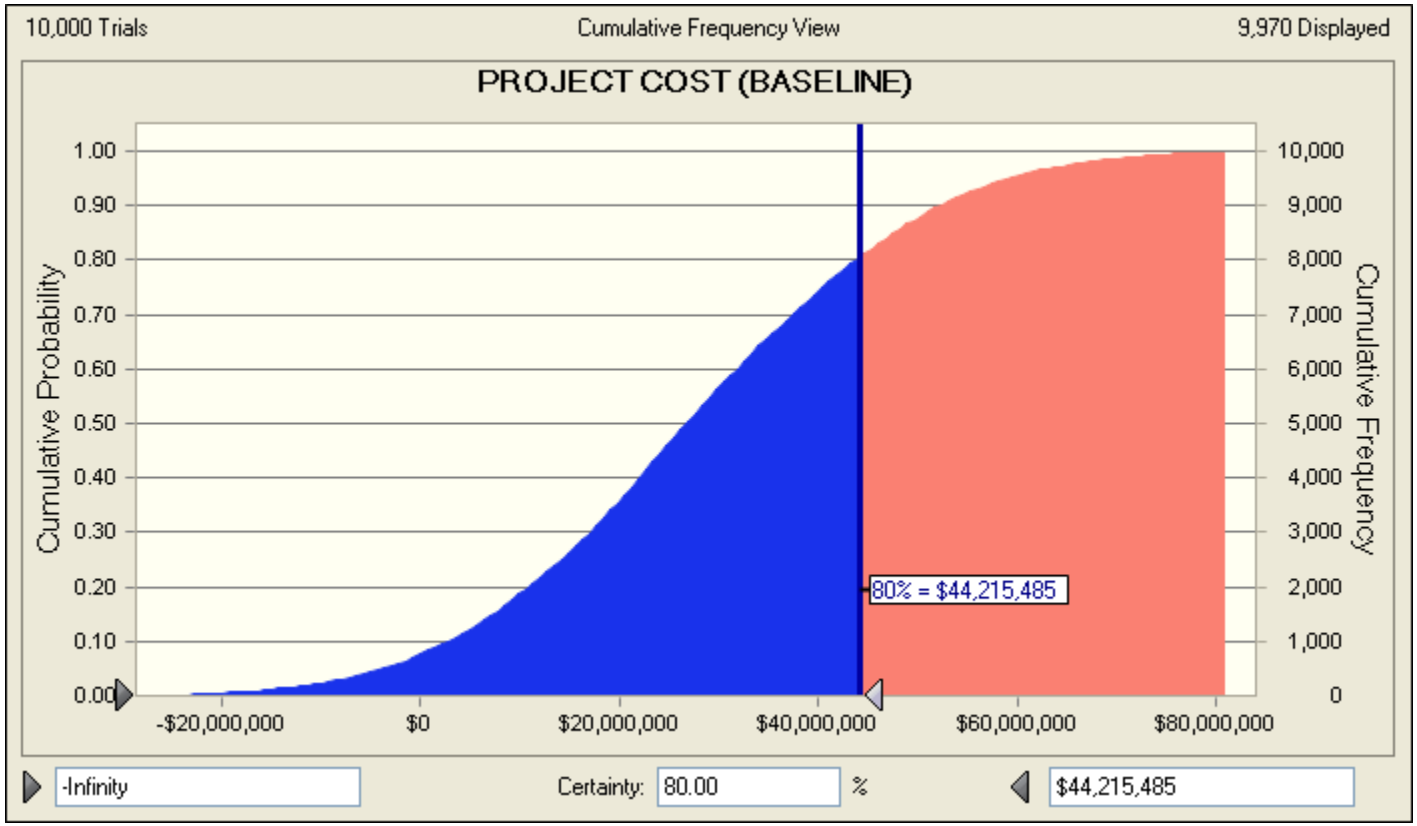


Figure ES-2. Sensitivity Chart (Cost)

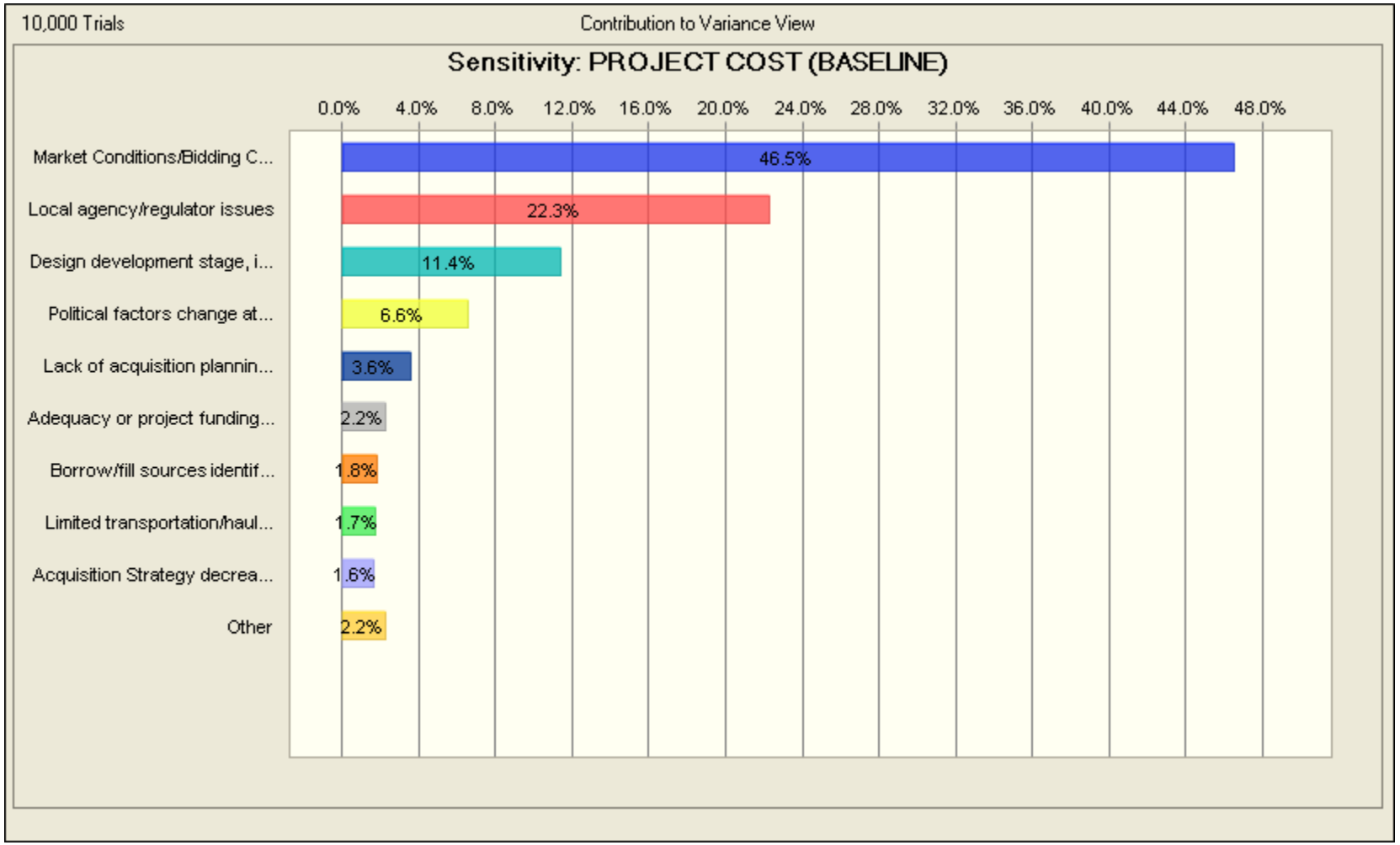


Figure ES-3. Cumulative Frequency Chart (Schedule)

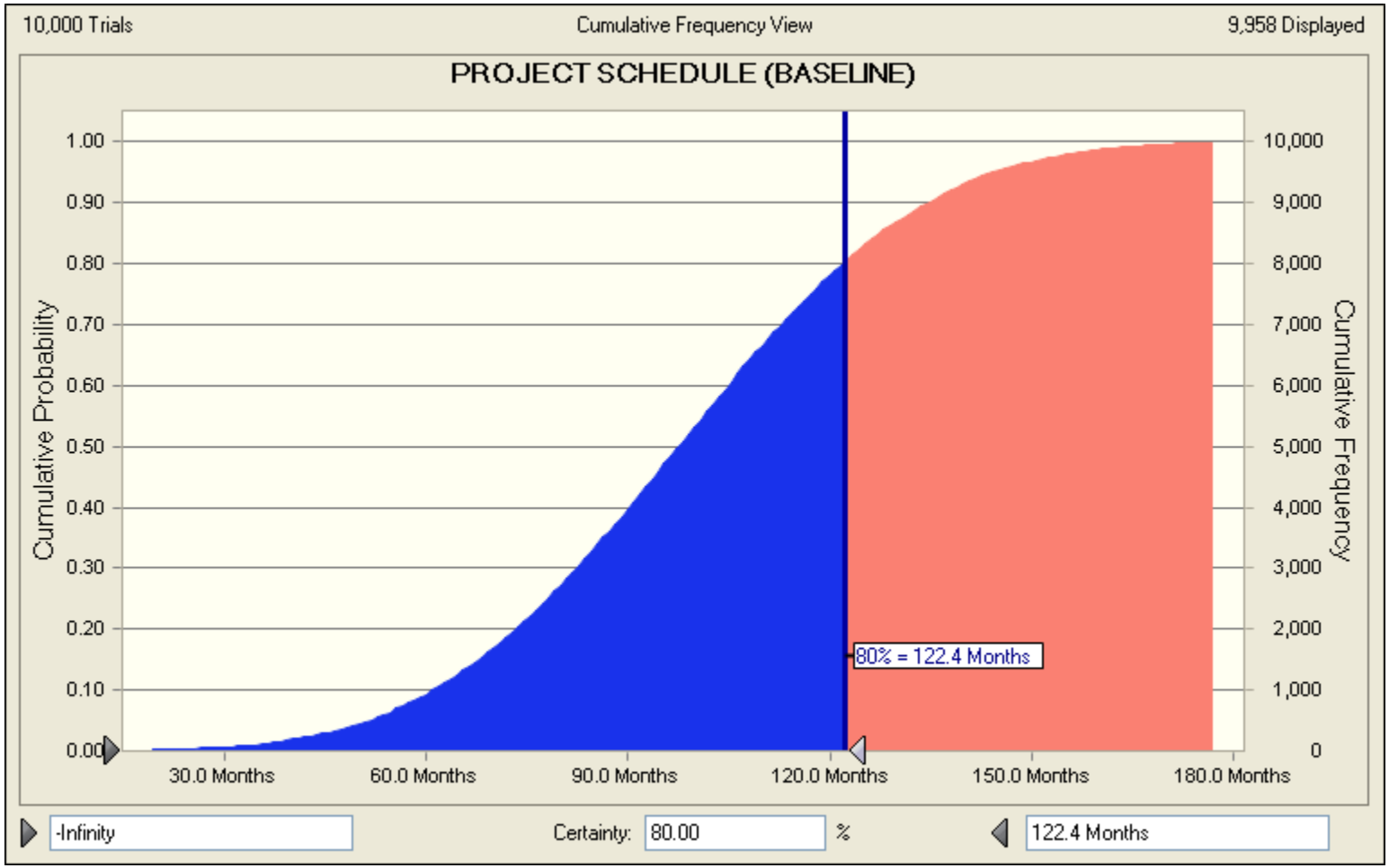
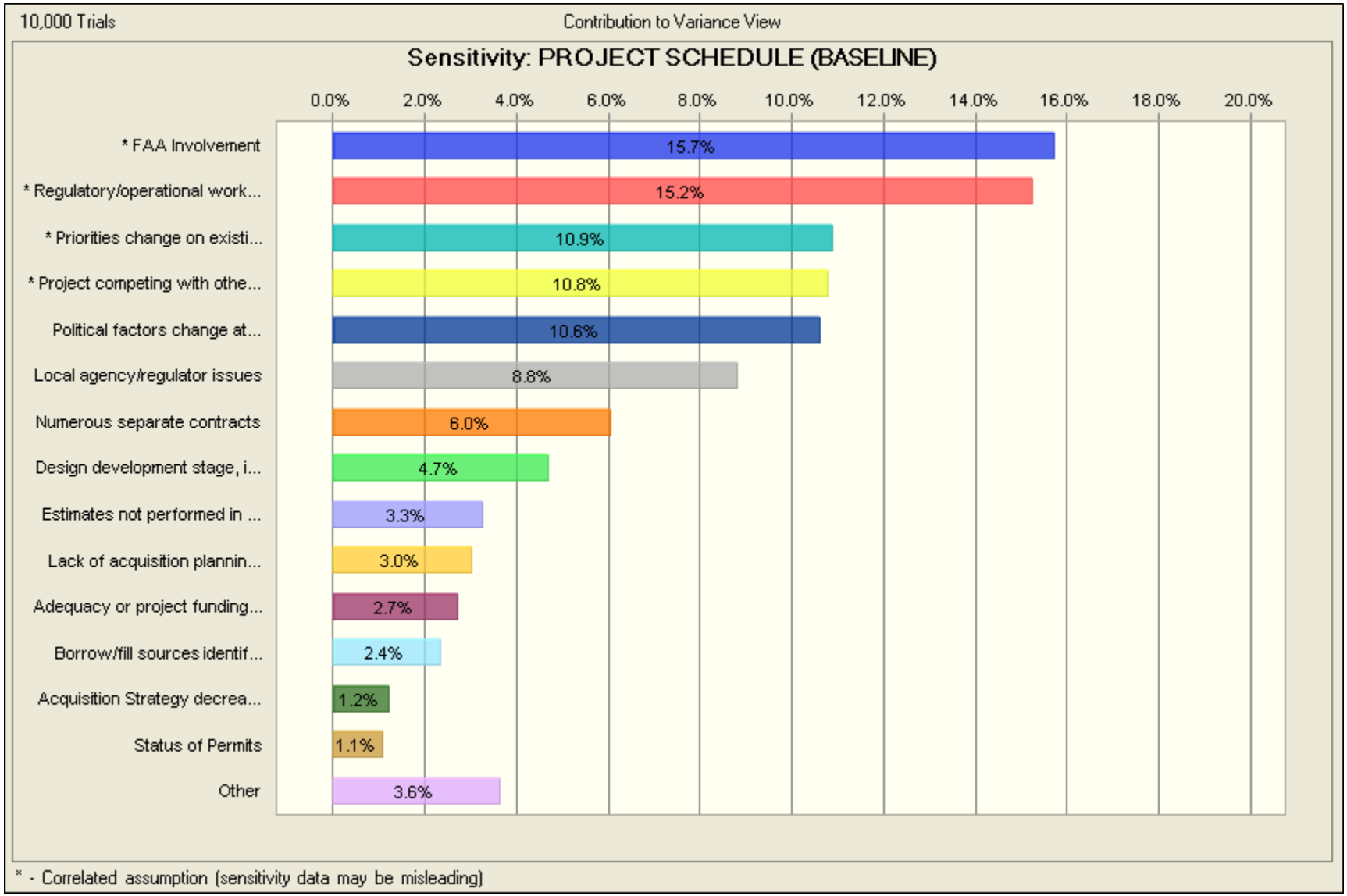


Figure ES-4. Sensitivity Chart (Schedule)



1. PURPOSE

This Risk Analysis is based on Jamaica Bay Ecosystem Restoration Feasibility Study. The purpose for a cost and schedule risk analysis (CSRA) is to briefly present discussion of the studied elements related to cost and schedule with an outcome contingency calculation at the recommended confidence level for both cost and schedule that are measured in terms of dollars. The most common and recommended contingency has been established at 80% confidence (P80).

2. BACKGROUND

Jamaica Bay is a tidal waterway connected to the lower bay of New York Harbor by Rockaway Inlet. The bay is located 17 miles south and east of the Battery, New York City and is 8 miles long, 4 miles wide, and covers an area of approximately 26 square miles. Jamaica Bay spans the southern portions of Kings County and Queens County. Eight specific sites within this region are being considered by this project for restoration. These sites include Dead Horse Bay, Paerdegat Basin, Fresh Creek, Spring Creek, Hawtree Point, Bayswater State Park, Dubos Point, and Brant Point. These sites focus on the degraded perimeter areas, which were selected based upon an extensive site screening process discussed in the main report (JBERP Feasibility Report/Environmental Impact Assessment (FR/EIS)).

Lying within the Atlantic Coastal Plain geological province, Jamaica Bay consists of loose unconsolidated cretaceous to recent sediments resting on deeply buried crystalline rock floor. The loose sediments are associated with past glaciations periods that resulted in an outwash plain. This sandy plain merged into the historical tidal marshes and barrier island beaches. Over time, physical and biological processes molded the Jamaica Bay into a highly productive ecosystem.

In 1997, USACE finalized the “Jamaica Bay: Navigational Channels and Shoreline Environmental Surveys” report. This report identified 39 potential sites for restoration activities, as based on two previous reports prepared by NYCDEP (1995, Jamaica Bay Comprehensive Watershed Management Plan) and by NYSDEC (1993, Restoration of Natural Resources Through the Jamaica Bay Damages Account: Reconnaissance Phase Report). Out of these 39 sites, twelve were identified by USACE, NYCDEP, NYSDEC, NPS and interested local groups as the highest priority and the most important sites for potential ecological restoration. These twelve sites included the eight focused on in the feasibility.

In April of 2000, NPS and the US Army Corps of Engineers entered into an Interagency Agreement to conduct assessments for the 12 sites. USACE and NPS, along with the City University of New York – Aquatic Research and Environmental Assessment Center at Brooklyn College, established the Jamaica Bay Ecosystem Research and Restoration Team (JABERRT) for Jamaica Bay. JABERRT completed an extensive literature search and conducted a detailed inventory and biogeochemical characterization of Jamaica Bay for the 2000 to 2001. Their final report was published

in 2002. This report serves as the basis for identifying existing conditions and recommending restoration options at each of the JBERP sites.

The overall plan includes the restoration of approximately 155 acres of wetland, including 68 acres of high marsh and 87 acres of low marsh. Seven acres of open water, including tidal creeks and a tidal pool, will also be created. JBERP will include the creation and preservation of over 79 acres of beach and dune habitats, and nearly 218 acres of native coastal upland habitats including forests, scrub shrub, and grasslands. With this project, approximately 437 acres of introduced invasives, including Japanese knotweed (*Polygonum cuspidatum*), mugwort (*Artemisia vulgaris*) and common reed (*Phragmites australis*) will be restored to native vegetation.

3. REPORT SCOPE

The scope of the risk analysis report is to calculate and present the cost and schedule contingencies at the 80 percent confidence level using the risk analysis processes, as mandated by U.S. Army Corps of Engineers (USACE) Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works. The report presents the contingency results for cost risks for all project features. The study and presentation does not include consideration for life cycle costs.

3.1 Project Scope

The scope of this study addresses the identification of problems, needs, opportunities and potential solutions that are viable from an economic, environmental, and engineering viewpoint.

3.2 USACE Risk Analysis Process

The risk analysis process follows the USACE Headquarters requirements as well as the guidance provided by the Cost Engineering Directory of Expertise for Civil Works (Cost Dx). The risk analysis process reflected within the risk analysis report uses probabilistic cost and schedule risk analysis methods within the framework of the Crystal Ball software. The risk analysis results are intended to serve several functions – one being the establishment of reasonable contingencies reflective of an 80 percent confidence level to successfully accomplish the project work within that established contingency amount. Furthermore, the scope of the report includes the identification and communication of important steps, logic, key assumptions, limitations, and decisions to help ensure that risk analysis results can be appropriately interpreted.

Risk analysis results are also intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as provide tools to support decision making and risk management as the project progresses through planning and implementation. To fully recognize its benefits, cost and schedule

risk analyses should be considered as an ongoing process conducted concurrent to, and iteratively with, other important project processes such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting, and scheduling.

In addition to broadly defined risk analysis standards and recommended practices, the risk analysis is performed to meet the requirements and recommendations of the following documents and sources:

- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Dx.
- Memorandum from Major General Don T. Riley (US Army Director of Civil Works), dated July 3, 2007.

- Engineering and Construction Bulletin issued by James C. Dalton, P.E. (Chief, Engineering and Construction, Directorate of Civil Works), dated September 10, 2007.

- Engineering Regulation ER 1110-2-1150 dated August 31, 1999.
- Engineering Regulation ER 1110-2-1302 dated September 15, 2008.
- Engineering Technical Letter 1110-2-573 dated September 30, 2008.

4. METHODOLOGY/PROCESS

The Cost Dx provided a senior civil cost engineer to perform the quantitative risk analysis. The Cost Dx cost engineer facilitated an initial risk identification meeting via teleconference with the New York District PDT on July 15, 2009. The initial risk identification meeting also included qualitative analysis to produce a risk register that served as the framework for the risk analysis. Following multiple iterations of revision and refinement of the baseline estimate during an ongoing ATR review process, the Cost Dx conducted quantitative analyses for cost and schedule risks. The cost and schedule risk models were completed and results reported on December 23, 2009. The final versions were completed on January 19, 2010.

The risk analysis process for this study is intended to determine the probability of various cost outcomes and quantify the required contingency needed in the cost estimate to achieve any desired level of cost confidence.

In simple terms, contingency is an amount added to an estimate to allow for items, conditions or events for which the occurrence or impact is uncertain and that experience suggests will likely result in additional costs being incurred or additional time being required. The amount of contingency included in project control plans depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans. The risk of overrun is expressed, in a probabilistic context, using confidence levels.

The Cost Dx guidance for cost and schedule risk analysis generally focuses on the 80-percent level of confidence (P80) for cost contingency calculation. It should be noted that use of P80 as a decision criteria is a risk averse approach (whereas the use of P50 would be a risk neutral approach, and use of levels less than 50 percent would be risk seeking). Thus, a P80 confidence level results in greater contingency as compared to a P50 confidence level. The selection of contingency at a particular confidence level is ultimately the decision and responsibility of the project's District and/or Division management.

The risk analysis process uses *Monte Carlo* techniques to determine probabilities and contingency. The *Monte Carlo* techniques are facilitated computationally by a commercially available risk analysis software package (Crystal Ball) that is an add-in to Microsoft Excel. Cost estimates are packaged into an Excel format and used directly for cost risk analysis purposes. The level of detail recreated in the Excel-format schedule is sufficient for risk analysis purposes that reflect the established risk register, but generally less than that of the native format.

The primary steps, in functional terms, of the risk analysis process are described in the following subsections. Risk analysis results are provided in section 6.

4.1 Identify and Assess Risk Factors

Identifying the risk factors via the PDT is considered a qualitative process that results in establishing a risk register that serves as the document for the quantitative study using the Crystal Ball risk software. Risk factors are events and conditions that may influence or drive uncertainty in project performance. They may be inherent characteristics or conditions of the project or external influences, events, or conditions such as weather or economic conditions. Risk factors may have either favorable or unfavorable impacts on project cost and schedule.

Checklists or historical databases of common risk factors are sometimes used to facilitate risk factor identification. However, key risk factors are often unique to a project and not readily derivable from historical information. Therefore, input from the entire PDT is obtained using creative processes such as brainstorming or other facilitated risk assessment meetings. In practice, a combination of professional judgment from the PDT and empirical data from similar projects is desirable and is considered.

Formal PDT meetings are held for the purposes of identifying and assessing risk factors. The meetings should include capable and qualified representatives from multiple project team disciplines and functions, for example:

- Project/Program managers
- Contracting/acquisition
- Real Estate
- Relocations
- Environmental
- Civil and Coastal Design

- Cost and schedule engineers
- Construction
- Key Sponsors

The initial formal meetings should focus primarily on risk factor identification using brainstorming techniques, but also include some facilitated discussions based on risk factors common to projects of similar scope and geographic location. Subsequent meetings should focus primarily on risk factor assessment and quantification.

Additionally, numerous conference calls and informal meetings are conducted throughout the risk analysis process on an as-needed basis to further facilitate risk factor identification, market analysis, and risk assessment.

4.2 Quantify Risk Factor Impacts

The quantitative impacts of risk factors on project plans are analyzed using a combination of professional judgment, empirical data, and analytical techniques. Risk factor impacts are quantified using probability distributions (density functions), because risk factors are entered into the Crystal Ball software in the form of probability density functions.

Similar to the identification and assessment process, risk factor quantification involves multiple project team disciplines and functions. However, the quantification process relies more extensively on collaboration between cost engineering, designers, and risk analysis team members with lesser inputs from other functions and disciplines.

The following is an example of the PDT quantifying risk factor impacts by using an iterative, consensus-building approach to estimate the elements of each risk factor:

- Maximum possible value for the risk factor.
- Minimum possible value for the risk factor.
- Most likely value (the statistical mode), if applicable.
- Nature of the probability density function used to approximate risk factor uncertainty.

- Mathematical correlations between risk factors.
- Affected cost estimate and schedule elements.

The resulting product from the PDT discussions is captured within a risk register as presented in section 6 for both cost and schedule risk concerns. Note that the risk register records the PDT's risk concerns, discussions related to those concerns, and potential impacts to the current cost and schedule estimates. The concerns and discussions are meant to support the team's decisions related to event likelihood, impact, and the resulting risk levels for each risk event.

4.3 Analyze Cost Estimate and Schedule Contingency

Contingency is analyzed using the Crystal Ball software, an add-in to the Microsoft Excel format of the cost estimate and schedule. *Monte Carlo* simulations are performed by applying the risk factors (quantified as probability density functions) to the appropriate estimated cost and schedule elements identified by the PDT. Contingencies are calculated by applying only the moderate and high level risks identified for each option (i.e., low-level risks are typically not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies as the project and risks evolve).

For the cost estimate, the contingency is calculated as the difference between the P80 cost forecast and the baseline cost estimate. Each option-specific contingency is then allocated on a civil works feature level based on the dollar-weighted relative risk of each feature as quantified by *Monte Carlo* simulation. Standard deviation is used as the feature-specific measure of risk for contingency allocation purposes. This approach results in a relatively larger portion of all the project feature cost contingency being allocated to features with relatively higher estimated cost uncertainty.

5. PROJECT ASSUMPTIONS

The following data sources and assumptions were used in quantifying the costs associated with the with- and without-project conditions at Jamaica Bay.

a. The MII MCACES (Micro-Computer Aided Cost Estimating Software) file “Jamaica Bay Ecosystem with comments 10-20-09” was the basis for the cost and schedule risk analyses.

b. The cost comparisons and risk analyses performed and reflected within this report are based on design scope and estimates that are at the feasibility level.

c. The schedule was analyzed for impact to the project cost in terms of both uncaptured escalation (variance from OMB factors and the local market) and “Hotel” costs (unavoidable fixed contract costs and/or languishing federal administration costs incurred throughout delay).

d. Per the CWCCIS Historical State Adjustment Factors in EM 1110-2-1304, State Adjustment Factor for New York is 1.15, adding approximately 0.27% differential between the local market and OMB inflation factors for future construction. For the P80 schedule, this comprises approximately 7% of the total contingency due to inflation.

e. Per the data in the estimate, the HOOH amount for the Contract Cost comprises approximately 8% of the Project Cost at Baseline. Thus, the assumed “Hotel” rate for this project is 8%. For the P80 schedule, this comprises approximately 12% of the total contingency due to the accrual of residual fixed costs associated with delay.

f. The Cost Dx guidance generally focuses on the eighty-percent level of confidence (P80) for cost contingency calculation. For this risk analysis, the eighty-percent level of confidence (P80) was used. It should be noted that the use of P80 as a decision criteria is a moderately risk averse approach, generally resulting in higher cost contingencies. However, the P80 level of confidence also assumes a small degree of risk that the recommended contingencies may be inadequate to capture actual project costs.

g. Only high and moderate risk level impacts, as identified in the risk register, were considered for the purposes of calculating cost contingency. Low level risk impacts should be maintained in project management documentation, and reviewed at each project milestone to determine if they should be placed on the risk "watch list" for further monitoring and evaluation.

6. RISK ANALYSIS RESULTS

The following table summarizes the results of the risk analysis currently identified as a 40% contingency amount based on 80% confidence level. The complete list of tables and figures are included within Appendix A.

Table 1. Contingency Development Summary

Contingency on Baseline Estimate	80% Confidence Project Cost
Baseline Estimate Cost (Most Likely) ->	**$158,045,950**
Baseline Estimate Cost Contingency Amount ->	$44,215,485
Baseline Estimate Construction Cost (80% Confidence) ->	**$202,261,435**

Contingency on Schedule	80% Confidence Project Schedule
Project Schedule Duration (Most Likely) ->	**182.3 Months**
Schedule Contingency Duration ->	122.4 Months
Project Schedule Duration (80% Confidence) ->	**304.7 Months**
Project Schedule Contingency Amount (80% Confidence) ->	**$19,320,466**

Project Contingency	80% Confidence Project Cost
Project Contingency Amount (80% Confidence) ->	**$63,535,952**
Project Contingency Percentage (80% Confidence) ->	**40%**

Project Cost (80% Confidence) ->	**$221,581,901**

6.1 Risk Register

A risk register is a tool commonly used in project planning and risk analysis. The actual risk register is provided in Appendix A. The complete risk register includes low level risks, as well as additional information regarding the nature and impacts of each risk.

It is important to note that a risk register can be an effective tool for managing identified risks throughout the project life cycle. As such, it is generally recommended that risk registers be updated as the designs, cost estimates, and schedule are further refined, especially on large projects with extended schedules. Recommended uses of the risk register going forward include:

- Documenting risk mitigation strategies being pursued in response to the identified risks and their assessment in terms of probability and impact.
- Providing project sponsors, stakeholders, and leadership/management with a documented framework from which risk status can be reported in the context of project controls.

- Communicating risk management issues.
- Providing a mechanism for eliciting feedback and project control input.
- Identifying risk transfer, elimination, or mitigation actions required for implementation of risk management plans.

6.2 Cost Risk Analysis – Project Cost Contingency Results

Table 2 provides the construction cost contingencies calculated for the P80 confidence level and rounded to the nearest thousand. The construction cost contingencies for the P50 and P100 confidence levels are also provided for illustrative purposes only.

Contingency was quantified as approximately $63.5 Million at the P80 confidence level (40% of the baseline cost estimate). For comparison, the cost contingency at the P50 and P100 confidence levels was quantified as 28% and 78% of the baseline cost estimate, respectively.

Table 2. Project Cost Contingency Summary

Risk Analysis Forecast	Baseline Estimate ($K)	Total Contingency[1] ($K)	Total Contingency (%)
50% Confidence Level			
Project Cost	$158,046	$43,836	27.7%
80% Confidence Level			
Project Cost	$158,046	$63,536	40.2%
100% Confidence Level			
Project Cost	$158,046	$123,032	77.9%

Note: 1) These figures combine uncertainty in the baseline cost estimates and schedule.
2) A P100 confidence level is an abstract concept for illustration only, as the nature of risk and uncertainty (specifically the presence of "unknown unknowns") makes 100% confidence a theoretical impossibility.

6.3 Schedule Risk Analysis – Total Project Duration Contingency Results

Table 3 provides the schedule duration contingencies calculated for the P80 confidence level. The schedule duration contingencies for the P50 and P100 confidence levels are also provided for illustrative purposes.

Schedule duration contingency was quantified as 122 months based on the P80 level of confidence. These contingencies were used to calculate the projected uncaptured escalation and "Hotel" cost impact of project delays that are included in the Tables 1 and 2 presentation of total cost contingency. The schedule contingencies were calculated by applying the high level schedule risks identified in the risk register for each option to the durations of critical path and near critical path tasks.

The schedule was not resource loaded and contained open-ended tasks and non-zero lags (gaps in the logic between tasks) that limit the overall utility of the schedule risk analysis. These issues should be considered as limitations in the utility of the schedule contingency data presented. Schedule contingency impacts presented in this analysis are based on calculation of uncaptured escalation and projected "Hotel" costs. Resource impacts related to potential schedule delays could not be evaluated.

See Appendix A for detailed tables and charts.

Table 3. Schedule Duration Contingency Summary

Risk Analysis Forecast	Baseline Schedule Duration (months)	Contingency[1] (months)	Contingency (%)
50% Confidence Level			
Total Project Duration	182	98	53.7%
80% Confidence Level			
Total Project Duration	182	122	67.1%
100% Confidence Level			
Total Project Duration	182	203	111.2%

Note: 1) The schedule was not resource loaded and contained open-ended tasks and non-zero lags (gaps in the logic between tasks) that limit the overall utility of the schedule risk analysis. These issues should be considered as limitations in the utility of the schedule contingency data presented in Table 3.
2) A P100 confidence level is an abstract concept for illustration only, as the nature of risk and uncertainty (specifically the presence of "unknown unknowns") makes 100% confidence a theoretical impossibility.

7. MITIGATION RECOMMENDATIONS

Risk Management is an all-encompassing, iterative, and life-cycle process of project management. The Project Management Institute's (PMI) *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, *4th edition*, states that "project risk management includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project." Risk identification and analysis are processes within the knowledge area of risk management. Its outputs pertinent to this effort include the risk register, risk quantification (risk analysis model), contingency report, and the sensitivity analysis.

The intended use of these outputs is implementation by the project leadership with respect to risk responses (such as mitigation) and risk monitoring and control. In short, the effectiveness of the project risk management effort requires that the proactive management of risks not conclude with the study completed in this report.

This section provides a list of recommendations for continued management of the risks identified and analyzed in this study. Whereas the developed contingency, itself, is a response to the potential for these risks, these risks warrant consideration of other potential responses and proactive monitoring and control. Note that this list is not all-inclusive.

1. Key Cost Risk Drivers: The key cost risk drivers identified through sensitivity analysis are Risks PR-6 (Market Conditions/Bidding Climate), PPM-4 (Local Agency/Regulator Issues), and GE-4 (Design Development Stage Incomplete or Preliminary), which together contribute over 80 percent of the statistical cost variance. Another notable cost risk driver is Risk PR-4 (Political Factors Change at Local, State, or Federal Level), which contributes 7 percent to the statistical cost variance.

a) Market Conditions/Bidding Climate: With respect to Market Conditions/Bidding Climate (Risk PR-6), Cost Dx recommends continuous monitoring of the price fluctuations and behaviors in the regional industry in the PDT's ongoing market research. Project leadership should craft the acquisition strategy with respect to the market trends to minimize the impact of industry contraction or saturation and to maximize competition. Ultimately, this is an external risk, and its impacts must be communicated to management. An amount for this should also be included and protected within the contingency and/or management reserve as a fallback.

b) Local Agency/Regulator Issues: With respect to Local Agency/Regulator Issues (Risk PPM-4), Cost Dx recommends that project leadership proactively collaborate and communicate to project sponsors, stakeholders, and regulating agencies regarding configuration management for this project. Project leadership should also proactively communicate with management and enlist support in reaching consensus on key issues as they relate to project scope. The PDT rated this risk as "critical" during qualitative analysis, and the quantitative analysis now supports that conclusion. Therefore, it is critical that project leadership also communicate the potential impacts of this issue to management and project stakeholders.

c) Design Development Stage Incomplete or Preliminary: With respect to Design Development Stage Incomplete or Preliminary (Risk GE-4), Cost Dx recommends that project leadership attempt to capture and finalize the scope of the project to the maximum extent possible. It is imperative to identify all features of work and probable methodologies prior to project authorization, continuing to refine scoping details during the Pre-Construction Engineering and Design (PED Phase).

d) Political Factors Change at Local, State, or Federal Level: With respect to Political Factors Change at Local, State, or Federal Level (Risk PR-4), Cost Dx recommends that project leadership actively monitor the political climate and its potential effects on the project. Project leadership should also communicate this risk and its impact to management. Ultimately, this is an external risk, and an amount for this should be included and protected within the contingency and/or management reserve as a fallback.

2. Key Schedule Risk Drivers: The key schedule risk drivers identified through sensitivity analysis are Risks CON-1 (FAA Involvement), CON-3 (Regulatory/Operational Work Windows), PPM-5 (Priorities Change on Existing Program), PPM-1 (Project Competing With Other Projects), and PR-4 (Political Factors Change at Local, State, or Federal Level), which together contribute over 63 percent of the statistical schedule variance.

a) FAA Involvement: With respect FAA Involvement (Risk CON-1), Cost Dx recommends that project leadership proactively coordinate with the FAA and the Port Authority for JFK International Airport, communicating the impacts of this risk to the project schedule.

b) Regulatory/Operational Work Windows: With respect to the Regulatory/Operational Work Windows (Risk CON-3), Cost Dx recommends proactive project management with respect to acquisition planning and strategy. Contract sequencing plans should enable maximum utility of designated construction windows.

c) Priorities Change on Existing Program: With respect to Priorities Change on Existing Program (Risk PPM-5), Cost Dx recommends proactive project management with respect to the schedule and the timeline for budget approval and disbursement of project funds. Changes to the anticipated timeline with respect to schedule should be controlled and reported to management for expeditious schedule recovery efforts.

d) Project Competing With Other Projects: With respect to Project Competing with Other Projects (Risk PPM-1), Cost Dx recommends communicating the impacts of this risk to management.

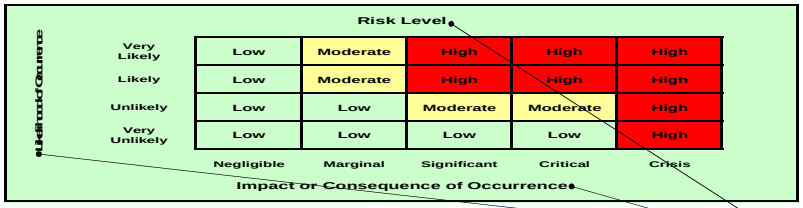
e) Political Factors Change at Local, State, or Federal Level: With respect to Political Factors Change at Local, State, or Federal Level (Risk PR-4), Cost Dx recommends that project leadership actively monitor the political climate and its potential effects on the project. Project leadership should also communicate this risk and its impact to management. Ultimately, this is an external risk, and an amount and duration for this should be included and protected within the contingency and/or management reserve.

3. Risk Management: Cost Dx recommends use of the outputs created during the risk analysis effort as tools in future risk management processes. The risk register should be updated at each major project milestone. The results of the sensitivity analysis may also be used for response planning strategy and development. These tools should be used in conjunction with regular risk review meetings, as discusses in section 6.1.

4. Risk Analysis Updates: Project leadership should review risk items identified in the original risk register and add others, as required, throughout the project life-cycle. Risks should be reviewed for status and reevaluation (using qualitative measure, at a minimum) and placed on risk management watch lists if any risk's likelihood or impact significantly increases. Project leadership should also be mindful of the potential for secondary (new risks created specifically by the response to an original risk) and residual risks (risks that remain and have unintended impact following response).

APPENDIX A

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - PDT Risk Register



Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component	
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)					
Contract Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)																
	PROJECT & PROGRAM MGMT															
PPM-1	Project competing with other projects	The PDT has identified that many other projects competing for resources and funding within the District and Region.	This risk could have an impact on overall project costs and could lead to significant delays to the overall project schedule.	Likely	Marginal	Moderate		Likely	Critical	High		Uniform		Project Manager	Project Schedule	
PPM-2	No control over staff priorities	The PDT identified that since there are many other projects competing for resources, there is a risk that there could be limited control over staff priorities.	The PDT assumed that this risk is fairly unlikely and would have minimal impact, as if priority was placed on this project, there would be control over staff.	Unlikely	Marginal	Low		Unlikely	Marginal	Low		Uniform		Project Manager	Project Schedule	
PPM-3	Internal red tape causes delays in getting decisions	The PDT identified that there is great concern that delays in obtaining approval on decisions has been and will continue to be experienced, such as new regulations and requirements as it pertains to decision documents process and reviews.	Additional red tape and regulation on obtaining approval on decision documents could negatively impact both the cost and schedule.	Very Likely	Significant	High		Very Likely	Significant	High		Triangular		Project Manager	Project Cost & Schedule	
PPM-4	Local agency/regulator issues	Several different entities (including the State as well as other local agencies and municipalities) have different conceptions of what the requirements for Jamaica Bay ought to be.	Not obtaining complete agreement or acceptance by local regulators and/or stakeholders could significantly impact the overall project cost and schedule.	Very Likely	Critical	High		Very Likely	Critical	High		Uniform		Project Manager	Project Cost & Schedule	
PPM-5	Priorities change on existing program	The PDT identified that, as in Risk PPM-4 above, there is the potential for priorities and features to change on the existing plan and project.	A change of priorities on the existing program could negatively impact both the cost and schedule.	Unlikely	Significant	Moderate		Unlikely	Significant	Moderate		Yes-No/Uniform		Project Manager	Project Cost & Schedule	
	CONTRACT ACQUISITION RISKS															
CA-1	Lack of acquisition planning support/involvement	At this time, the PDT has not had the involvement of contracting regarding the acquisition planning. There is potential for some of the work to be set aside for small business and/or be procured by negotiation rather than competitive bid.	The ultimate acquisition plan could impact both the cost and schedule.	Likely	Marginal	Moderate		Likely	Marginal	Moderate		Triangular		Contracting	Contract Cost & Schedule	
CA-2	Numerous separate contracts	There are currently contemplated to be 8 or more separate contracts.	The number of contracts could present risks to both cost and schedule in terms of the acquisition strategy, the fixed costs associated with letting multiple contracts, as well as contract phasing and sequencing issues.	Very Likely	Significant*	High*		Very Likely	Significant*	High*		Triangular		Contracting	Contract Cost & Schedule	***This item was upgraded during the Cost Risk Study at Request of PDT***
CA-3	Acquisition Strategy decreasing competition	The PDT expressed concern that, based on historical experience, the ultimate acquisition strategy, particularly for the dredging contracts, may actually limit the competition.	Limited bidding competition would affect both cost and schedule.	Very Likely	Marginal	Moderate		Very Likely	Marginal	Moderate		Uniform		Contracting	Contract Cost & Schedule	
	TECHNICAL RISKS															
GE-4	Design development stage, incomplete or preliminary	Whereas the PDT is confident in the products developed to date, they acknowledge that due to the phase of the project cycle, decisions are being made on preliminary data. The consensus was that there will be uncertainty with the assumptions made for scope until the project is further into PED.	The uncertainty with the design could impact the project cost and schedule.	Very Likely	Significant	High		Very Likely	Marginal	Moderate		Triangular		Technical Lead	Contract Cost & Schedule	
GE-5	Incomplete studies	The PDT expressed concern that due to the phase of the project, many of the project assumptions are based on incomplete studies and investigations.	The uncertainty with the status of studies and investigations may impact the project cost and schedule.	Unlikely	Significant	Moderate		Unlikely	Significant	Moderate		Triangular		Technical Lead	Contract Cost & Schedule	
GE-6	Surveys late/surveys in question	The PDT expressed that, based on historical experience, critical surveys and or reports could be completed later than anticipated.	History suggests that some delay in obtaining the surveys would not impact the overall projects cost or schedule (particularly of this magnitude) to a significant degree.	Likely	Negligible	Low		Likely	Negligible	Low		Triangular		Technical Lead	Contract Cost & Schedule	
GE-7	Borrow/fill sources identified/secured	There is concern regarding the timing and availability of borrow and fill sources, as there is a great deal of Federal work occurring at the entrance channel.	The timeframe for utilizing the identified borrow and fill sources may impact costs and could significantly impact the overall project schedule.	Likely	Marginal	Moderate		Likely	Critical	High		Triangular		Technical Lead	Contract Schedule	
GE-8	Hazardous waste concerns	Whereas there is little concern regarding the presence of hazardous waste, there is concern regarding the presence of contaminated waste. Projects include excavation at former landfill sites, some of which have hazardous metal residue in low levels.	The presence of contaminated material in substantial quantities could significantly impact the project costs, and could also impact the schedule to a lesser degree.	Likely	Significant	High		Likely	Marginal	Moderate		Uniform		Technical Lead	Contract Cost	
	LANDS AND DAMAGES RISKS															
LR-1	Status of real estate/easement acquisition	The issue of status of the real estate/easement acquisition is of concern to the PDT. Although Federal and/or local governments predominantly own the land in the project area, there is some question as to whether there might be delays in the approval of the plan.	Delays in execution of the real estate plan could negatively impact the schedule.	Unlikely	Marginal	Low		Unlikely	Significant	Moderate		Yes-No/Uniform		Real Estate	Project Schedule	

	REGULATORY AND ENVIRONMENTAL RISKS														
RE-1	Conforming to the State implementation plan for air quality	The region has stringent requirements for air quality issues. However, the current plan takes the State implementation plan requirements into consideration.	The consensus of the PDT was that the current project mitigates or avoids effects to air quality such that it most likely will not impact the project cost or schedule.	Likely	Negligible	Low		Likely	Negligible	Low		Triangular		Environmental	Project Cost
RE-2	Project in an area of high sensitivity for cultural artifacts	The project sites are in areas where there is some concern for the presence of cultural artifacts. However, experience and current information suggests that this is not likely to impact the cost and schedule.	The consensus of the PDT was that cultural resources most likely will not impact the project cost or schedule.	Very Unlikely	Significant	Low		Very Unlikely	Significant	Low		Yes-No/Uniform		Environmental	Project Cost & Schedule
RE-3	Status of Permits	The project is in a Coastal Zone, and portions of the project are within National or State Parks and or Scenic byways. There is also concern regarding the requirements and scrutiny of reviewing agencies (such as NPS), as well as changes in environmental guidance or regulations during the project duration. Thus, the status of several permits is in question.	The effects of the project's location impacting parks and involving other agencies/entities could impact the overall project cost and schedule.	Very Likely	Marginal	Moderate		Very Likely	Marginal	Moderate		Yes-No/Uniform		Project Manager	Project Cost & Schedule
	CONSTRUCTION RISKS														
CON-1	FAA Involvement	The project will involve and impact JFK International Airport. Thus, the involvement of the FAA is a concern.	FAA involvement and scrutiny will likely not impact the cost, but may pose a threat to the schedule.	Likely	Negligible	Low		Likely	Marginal	Moderate		Triangular		Project Manager	Project Schedule
CON-2	Limited transportation/haul routes	There is a constraint of limited transportation access throughout the project sites due to restrictions on bridges and waterways.	Limited accessibility could increase project costs.	Likely	Marginal	Moderate		Likely	Negligible	Low		Triangular		Technical Lead	Contract Cost
CON-3	Regulatory/operational work windows	There are environmental windows for dredging operations for fish concerns, and there are seasonal windows for planting times for the land-based work.	Environmental windows and constraints could impact the cost and schedule.	Likely	Marginal	Moderate		Likely	Marginal	Moderate		Triangular		Environmental	Contract Cost & Schedule
	SPRING CREEK RISKS														
SC-1	Timely delivery of critical GFE	There is potential that the Corps will have Plant material that Corps will have to grow plant material for the National Park Service (NPS) on 2 out of the 8 contracts.	Depending on the cooperation and requirements of NPS, the timely delivery of plant material could be an issue that significantly impacts cost and somewhat affects the overall schedule.	Likely	Significant	High		Likely	Marginal	Moderate		Yes-No/Uniform		Project Manager	Project Cost
	DEAD HORSE BAY RISKS														
DH-1	Timely delivery of critical GFE	There is potential that the Corps will have Plant material that Corps will have to grow plant material for the National Park Service (NPS) on 2 out of the 8 contracts.	Depending on the cooperation and requirements of NPS, the timely delivery of plant material could be an issue that significantly impacts cost and somewhat affects the overall schedule.	Likely	Significant	High		Likely	Marginal	Moderate		Yes-No/Uniform		Project Manager	Project Cost
	PAERDEGAT BASIN RISKS														
PB-1	Estimates not performed in CEDEP	Estimates were prepared in CEDEP and/or MII for all contracts except for Product developed by others. There some question as to the reliability of the quantity development for that estimate, as the source of sand may be coming from a maintenance dredge contract, and this contract will have a line item for hydraulically placed fill.	The current estimate assumes that the borrow source is 10 miles away. The cost and schedule could be impacted significantly if the borrow location is closer or farther away.	Likely	Marginal	Moderate		Likely	Significant	High		Triangular		Cost Engineering	Contract Cost & Schedule
	Programmatic Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)														
PR-1	Adequacy or project funding (incremental)	The PDT expressed concern that incremental funding may not be received in the outlays currently anticipated and planned.	Not receiving incremental funds on a timely basis or in the outlays anticipated could impact cost and could significantly impact the schedule.	Very Likely	Marginal	Moderate		Very Likely	Significant	High		Uniform		Project Manager	Project Schedule
PR-2	Obtaining authorization on a timely basis	The PDT has concern that the project may not be approved in the program year anticipated.	Not obtaining authorization according to the current schedule could significantly impact cost and schedule.	Very Likely	Significant	High		Very Likely	Critical	High		Yes-No/Uniform		Project Manager	Project Cost & Schedule
PR-3	Local communities pose objections	There is concern that local communities could pose some objection. However, the PDT contemplates minimal impact from local objections.	The PDT assumed that this risk is unlikely and would carry little impact if it did occur.	Unlikely	Negligible	Low		Unlikely	Negligible	Low		Yes-No/Uniform		Project Manager	Project Cost & Schedule
PR-4	Political factors change at local, state or federal level	There was some concern that political factors could change at the local, state, and or federal level regarding the scope of this project.	Change in the political factors and climate could affect the project cost and schedule.	Very Likely	Marginal	Moderate		Very Likely	Marginal	Moderate		Yes-No/Uniform		Project Manager	Project Cost & Schedule
PR-5	Stakeholders request late changes	One of the primary stakeholders is NPS, and experience indicates that they may request changes during project formulation and execution.	The PDT contemplated minimal likelihood and impact from changes requested after authorization.	Unlikely	Negligible	Low		Unlikely	Negligible	Low		Yes-No/Uniform		Project Manager	Project Cost & Schedule
PR-6	Acts of God	The project site is susceptible to the effects of hurricanes (nor'easter).	The occurrence of nor'easters that could impact the production in these project areas is so infrequent, that the PDT assumes that this will most likely not be an issue for this project.	Very Unlikely	Significant	Low		Very Unlikely	Significant	Low		Yes-No/Uniform			Project Cost & Schedule
PR-7	Market Conditions/Bidding Climate	Since the project is large, contains multiple contracts, and is to occur over an extended period of time, there is inherent risk of impact to costs (whether positive or negative) due to the fluctuation in market conditions for commodities and the industry bidding climate.	Fluctuations in the market conditions for commodities or the industry bidding climate could have a significant impact on project costs.	Likely	Significant	High		Likely	Negligible	Low		Triangular		Cost Engineering	Contract Cost

*Likelihood, Impact, and Risk Level to be verified through market research and analysis (conducted by cost engineer).

1. Risk/Opportunity identified with reference to the Risk Identification Checklist and through deliberation and study of the PDT.
2. Discussions and Concerns elaborates on Risk/Opportunity Events and includes any assumptions or findings (should contain information pertinent to eventual study and analysis of event's impact to project).
3. Likelihood is a measure of the probability of the event occurring -- **Very Unlikely**, **Unlikely**, **Moderately Likely**, **Likely**, **Very Likely.** The likelihood of the event will be the same for both Cost and Schedule, regardless of impact.
4. Impact is a measure of the event's effect on project objectives with relation to scope, cost, and/or schedule -- **Negligible**, **Marginal**, **Significant**, **Critical**, or **Crisis.** Impacts on Project Cost may vary in severity from impacts on Project Schedule.
5. Risk Level is the resultant of Likelihood and Impact**Low**, **Moderate**, or **High**. Refer to the matrix located at top of page.
6. Variance Distribution refers to the behavior of the individual risk item with respect to its potential effects on Project Cost and Schedule. For example, an item with clearly defined parameters and a solid most likely scenario would probably follow a triangular or normal distribution. A risk item for which the PDT has little data or probability of modeling with respect to effects on cost or schedule (i.e. "anyone's guess") would probably follow a uniform or discrete uniform distribution.
7. The responsibility or POC is the entity responsible as the Subject Matter Expert (SME) for action, monitoring, or information on the PDT for the identified risk or opportunity.
8. Correlation recognizes those risk events that may be related to one another. Care should be given to ensure the risks are handled correctly without a "double counting."
9. Affected Project Component identifies the specific item of the project to which the risk directly or strongly correlates.
10. Project Implications identifies whether or not the risk item affects project cost, project schedule, or both. The PDT is responsible for conducting studies for both Project Cost and for Project Schedule.
11. Results of the risk identification process are studied and further developed by the Cost Engineer, then analyzed through the Monte Carlo Analysis Method for Cost (Contingency) and Schedule (Escalation) Growth.

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost & Schedule Risk Analysis

Contingency on Base Estimate	80% Confidence Project Cost
Total Construction Cost (Most Likely) ->	$158,045,950
Construction Cost Contingency Amount ->	$44,215,485
Total Construction Cost (80% Confidence) ->	$202,261,435

Contingency on Schedule	80% Confidence Project Schedule
Total Project Schedule Duration (Most Likely) ->	182.3 Months
Schedule Contingency Duration ->	122.4 Months
Total Project Schedule Duration (80% Confidence) ->	304.7 Months
Project Schedule Contingency Amount (80% Confidence) ->	$19,320,466

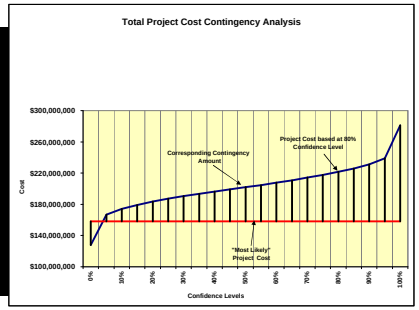
Total Project Contingency	80% Confidence Project Cost
Total Project Contingency Amount (80% Confidence) ->	$63,535,952
Total Project Contingency Percentage (80% Confidence) ->	40%

Total Project Cost (80% Confidence) ->	$221,581,901

- TOTAL PROJECT CONTINGENCY DEVELOPMENT -

Contingency Analysis

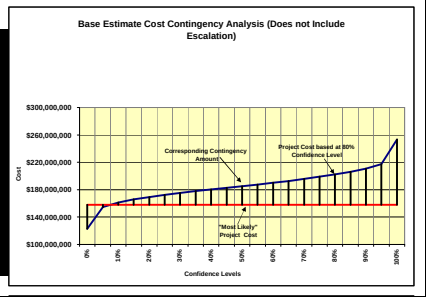
Most Likely Cost Estimate	$158,045,950	
Confidence Level	**Value**	**Contingency**
0%	$127,935,815	-19.05%
5%	$166,626,075	5.43%
10%	$174,142,095	10.18%
15%	$179,295,375	13.45%
20%	$183,498,464	16.10%
25%	$187,292,638	18.51%
30%	$190,555,166	20.57%
35%	$193,544,566	22.46%
40%	$196,380,246	24.26%
45%	$199,078,909	25.96%
50%	$201,882,154	27.74%
55%	$204,688,036	29.51%
60%	$207,720,767	31.43%
65%	$210,659,795	33.29%
70%	$214,173,154	35.51%
75%	$217,662,577	37.72%
80%	$221,581,901	40.20%
85%	$225,824,967	42.89%
90%	$231,189,330	46.28%
95%	$239,071,123	51.27%
100%	$281,077,470	77.85%

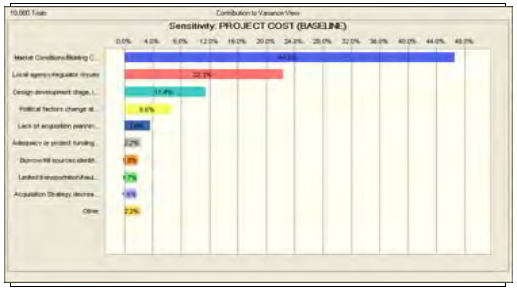


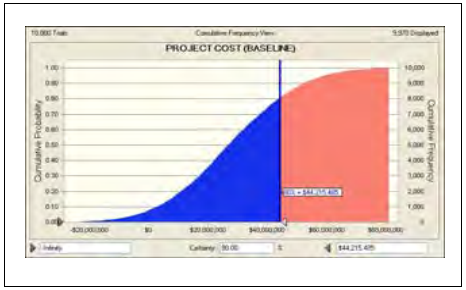
- BASE CONTINGENCY DEVELOPMENT -

Contingency Analysis

Most Likely Cost Estimate	$158,045,950	
Confidence Level	**Value**	**Contingency**
0%	$122,955,330	-22.18%
5%	$154,673,358	-2.13%
10%	$161,217,446	2.01%
15%	$165,663,479	4.82%
20%	$169,294,872	7.12%
25%	$172,575,571	9.19%
30%	$175,393,644	10.98%
35%	$177,967,458	12.60%
40%	$180,387,570	14.14%
45%	$182,710,493	15.61%
50%	$185,124,730	17.13%
55%	$187,545,037	18.66%
60%	$190,177,298	20.33%
65%	$192,738,221	21.95%
70%	$195,859,927	23.89%
75%	$198,833,139	25.81%
80%	$202,261,435	27.98%
85%	$205,942,060	30.31%
90%	$210,535,704	33.21%
95%	$217,384,613	37.55%
100%	$253,327,364	60.29%



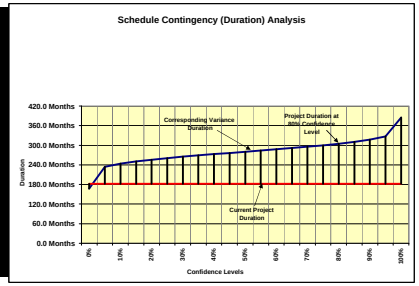




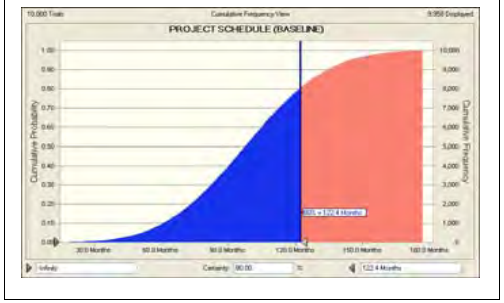
- SCHEDULE CONTINGENCY (DURATION) DEVELOPMENT -

Contingency Analysis

Most Likely Schedule	182.3 Months	
Confidence Level	**Value**	**Contingency**
0%	167.6 Months	-8.07%
5%	234.4 Months	28.59%
10%	243.7 Months	33.67%
15%	250.4 Months	37.37%
20%	255.9 Months	40.36%
25%	260.8 Months	43.04%
30%	265.0 Months	45.37%
35%	269.0 Months	47.54%
40%	272.9 Months	49.71%
45%	276.5 Months	51.68%
50%	280.2 Months	53.71%
55%	283.9 Months	55.73%
60%	287.7 Months	57.82%
65%	291.3 Months	59.80%
70%	295.5 Months	62.11%
75%	300.0 Months	64.54%
80%	**304.7 Months**	**67.11%**
85%	310.0 Months	70.05%
90%	317.4 Months	74.08%
95%	327.2 Months	79.48%
100%	385.0 Months	111.18%



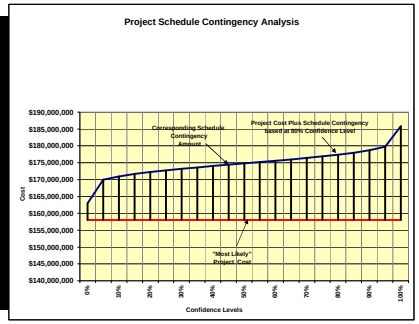


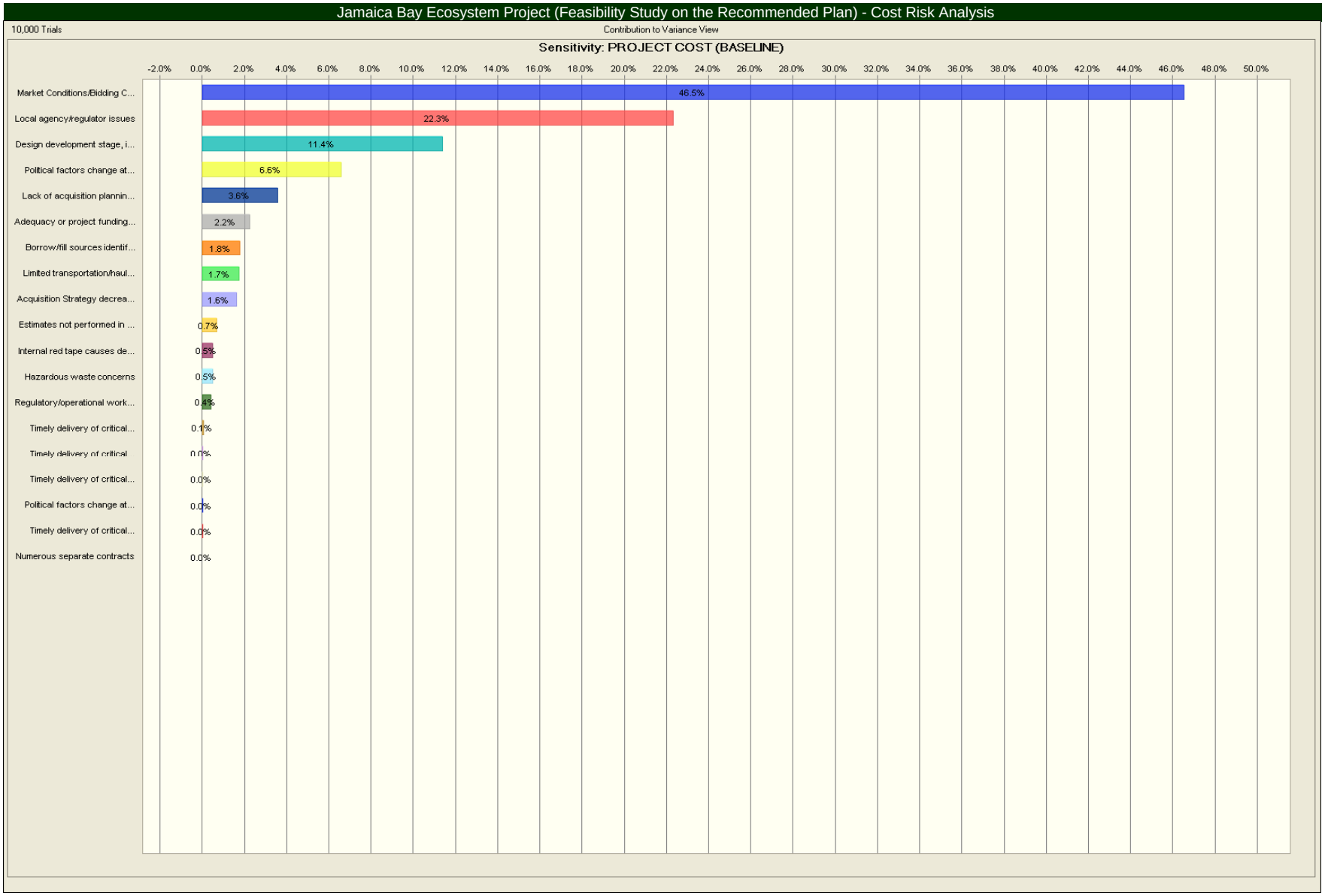


- SCHEDULE CONTINGENCY (AMOUNT) DEVELOPMENT -

Contingency Analysis

Most Likely Cost Estimate	$158,045,950	
Confidence Level	**Value**	**Contingency**
0%	$4,940,484	3.13%
5%	$11,952,717	7.56%
10%	$12,924,649	8.18%
15%	$13,631,896	8.63%
20%	$14,203,592	8.99%
25%	$14,717,068	9.31%
30%	$15,161,522	9.59%
35%	$15,577,108	9.86%
40%	$15,992,676	10.12%
45%	$16,368,416	10.36%
50%	$16,757,424	10.60%
55%	$17,143,000	10.85%
60%	$17,543,469	11.10%
65%	$17,921,573	11.34%
70%	$18,363,228	11.62%
75%	$18,829,438	11.91%
80%	**$19,320,466**	**12.22%**
85%	$19,882,907	12.58%
90%	$20,653,626	13.07%
95%	$21,686,510	13.72%
100%	$27,750,105	17.56%



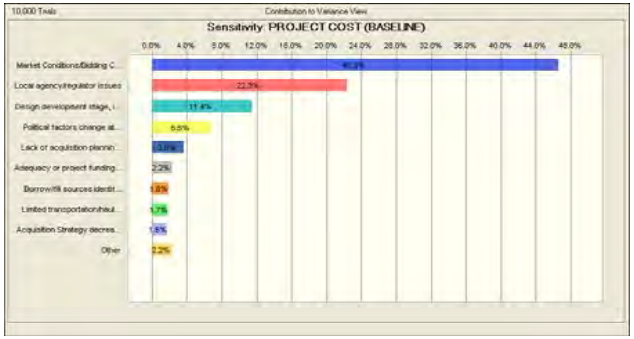

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis
10,000 Trials
Contribution to Variance View
Sensitivity: PROJECT COST (BASELINE)
-2.0% 0.0% 2.0% 4.0% 6.0% 8.0% 10.0% 12.0% 14.0% 16.0% 18.0% 20.0% 22.0% 24.0% 26.0% 28.0% 30.0% 32.0% 34.0% 36.0% 38.0% 40.0% 42.0% 44.0% 46.0% 48.0% 50.0%
Market Conditions/Bidding C... 46.5%
Local agency/regulator issues 22.3%
Design development stage, i... 11.4%
Political factors change at... 6.6%
Lack of acquisition plannin... 3.6%
Adequacy or project funding... 2.2%
Borrow/fill sources identif... 1.8%
Limited transportation/haul... 1.7%
Acquisition Strategy decrea... 1.6%
Estimates not performed in ... 0.7%
Internal red tape causes de... 0.5%
Hazardous waste concerns 0.5%
Regulatory/operational work... 0.4%
Timely delivery of critical... 0.1%
Timely delivery of critical 0.0%
Timely delivery of critical... 0.0%
Political factors change at... 0.0%
Timely delivery of critical... 0.0%
Numerous separate contracts 0.0%

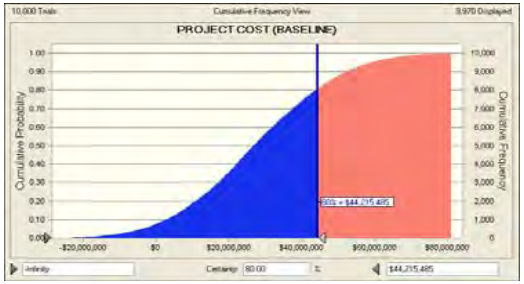
Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis Model

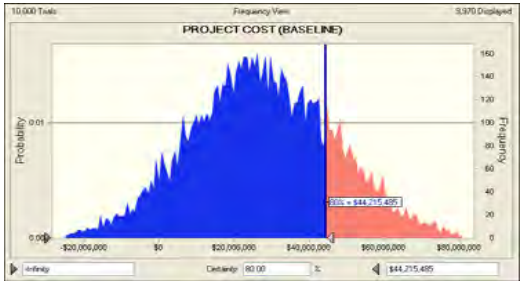
Risk No.	Risk/Opportunity Event	Project Cost: Likelihood*	Project Cost: Impact*	Project Cost: Risk Level*	Variance Distribution	Correlation to Other(s)	Crystal Ball Simulation Expected Values ($$): Low	Most Likely	High		Crystal Ball Simulation Expected Values (%s): Low	Most Likely	High	
Internal Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)														
PROJECT & PROGRAM MGMT														
PPM-1	Project competing with other projects	Likely	Marginal	Moderate						*Removed from Cost Risk Study - This item is captured by the Schedule Analysis*				
PPM-3	Internal red tape causes delays in getting decisions	Very Likely	Significant	High	Triangular		$0	$0	$6,617,508		0.00%	0.00%	4.19%	
PPM-4	Local agency/regulator issues	Very Likely	Critical	High	Uniform		($15,804,595)	$0	$15,804,595		-10.00%	0.00%	10.00%	
PPM-5	Priorities change on existing program	Unlikely	Significant	Moderate						*Removed from Cost Risk Study - This item is captured by the Schedule Analysis*				
CONTRACT ACQUISITION RISKS														
CA-1	Lack of acquisition planning support/involvement	Likely	Marginal	Moderate	Triangular		($7,785,112)	$0	$10,938,484		-4.93%	0.00%	6.92%	
CA-2	Numerous separate contracts	Very Likely	Significant*	High*	Triangular		($1,294,339)	$0	$16,165,855	*This item was upgraded during the Cost Risk Study at Request of PDT*	-0.82%	0.00%	10.23%	
CA-3	Acquisition Strategy decreasing competition	Very Likely	Marginal	Moderate	Uniform		$0	$0	$8,300,000		0.00%	0.00%	5.25%	
TECHNICAL RISKS														
GE-4	Design development stage, incomplete or preliminary	Very Likely	Significant	High	Triangular		($15,804,595)	$0	$15,804,595		-10.00%	0.00%	10.00%	
GE-5	Incomplete studies	Unlikely	Significant	Moderate						*Removed from Cost Risk Study - This item is captured by Risk GE-4*				
GE-7	Borrow/fill sources identified/secured	Likely	Marginal	Moderate	Triangular		($1,336,121)	$0	$7,361,699		-0.85%	0.00%	4.66%	
GE-8	Hazardous waste concerns	Likely	Significant	High	Uniform		($1,966,987)	$0	$5,279,808		-1.24%	0.00%	3.34%	
REGULATORY AND ENVIRONMENTAL RISKS														
RE-3	Status of Permits	Very Likely	Marginal	Moderate						*Removed from Cost Risk Study - This item is captured by the Schedule Analysis*				
CONSTRUCTION RISKS														
CON-2	Limited transportation/haul routes	Likely	Marginal	Moderate	Triangular		($3,858,321)	$0	$8,133,758		-2.44%	0.00%	5.15%	
CON-3	Regulatory/operational work windows	Likely	Marginal	Moderate	Triangular		$0	$0	$5,279,808		0.00%	0.00%	3.34%	
SPRING CREEK RISKS														
SC-1	Timely delivery of critical GFE (Spring Creek)	Likely	Significant	High	Yes-No/Uniform		($393,029)	$0	$982,572		-0.25%	0.00%	0.62%	0 0
DEAD HORSE BAY RISKS														
DH-1	Timely delivery of critical GFE (Dead Horse)	Likely	Significant	High	Yes-No/Uniform		($460,637)	$0	$460,637		-0.29%	0.00%	0.29%	0 0
PAERDEGAT BASIN RISKS														
PB-1	Estimates not performed in CEDEP	Likely	Marginal	Moderate	Triangular		($2,593,697)	$0	$4,322,828		-1.64%	0.00%	2.74%	
Programmatic Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)														
PR-1	Adequacy or project funding (incremental)	Very Likely	Marginal	Moderate	Uniform		$0	$0	$12,198,703		0.00%	0.00%	7.72%	
PR-2	Obtaining authorization on a timely basis	Very Likely	Significant	High						*Removed from Cost Risk Study - This item is captured by the Schedule Analysis*				
PR-4	Political factors change at local, state or federal level	Very Likely	Marginal	Moderate	Yes-No/Uniform		($7,902,297)	$0	$15,804,595		-5.00%	0.00%	10.00%	0 0
PR-6	Market Conditions/Bidding Climate	Likely	Significant	High	Triangular		($23,355,336)	$0	$38,925,561		-14.78%	0.00%	24.63%	
								$0		*Not Part of Study - Placeholder for Project Summation Purposes Only*				

Percentages are calculated as the variance from the assumption value to facilitate iteration of the model should the cost values change throughout the project phases. Uniform distribution percentages reflect variation from the total project cost.

PROJECT COST (BASELINE)	Percentile	Baseline TPC	Contingency Amoun	Baseline w/ Contingency	Contingency %
	0%	$158,045,950	($35,050,619)	$122,995,330	-22.18%
	5%	$158,045,950	($3,372,591)	$154,673,358	-2.13%
	10%	$158,045,950	$3,171,496	$161,217,446	2.01%
	15%	$158,045,950	$7,617,530	$165,663,479	4.82%
	20%	$158,045,950	$11,248,923	$169,294,872	7.12%
	25%	$158,045,950	$14,529,621	$172,575,571	9.19%
	30%	$158,045,950	$17,347,694	$175,393,644	10.98%
	35%	$158,045,950	$19,921,508	$177,967,458	12.60%
	40%	$158,045,950	$22,341,621	$180,387,570	14.14%
	45%	$158,045,950	$24,664,543	$182,710,493	15.61%
	50%	$158,045,950	$27,078,781	$185,124,730	17.13%
	55%	$158,045,950	$29,499,087	$187,545,037	18.66%
	60%	$158,045,950	$32,131,349	$190,177,298	20.33%
	65%	$158,045,950	$34,692,272	$192,738,221	21.95%
	70%	$158,045,950	$37,763,977	$195,809,927	23.89%
	75%	$158,045,950	$40,787,189	$198,833,139	25.81%
	80%	$158,045,950	$44,215,485	$202,261,435	27.98%
	85%	$158,045,950	$47,896,110	$205,942,060	30.31%
	90%	$158,045,950	$52,489,754	$210,535,704	33.21%
	95%	$158,045,950	$59,338,663	$217,384,613	37.55%
	100%	$158,045,950	$95,281,415	$253,327,364	60.29%







Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High	
PPM-1	Project competing with other projects				***Removed from Cost Risk Study - This item is captured by the Schedule Analysis and Risk PPM-5***

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-3	Internal red tape causes delays in getting decisions	$0	$0	$6,617,508

Notes: This item captures the risk that internal red tape causes delays in obtaining decisions that will ultimately cause a variance from the current working estimate for the project.

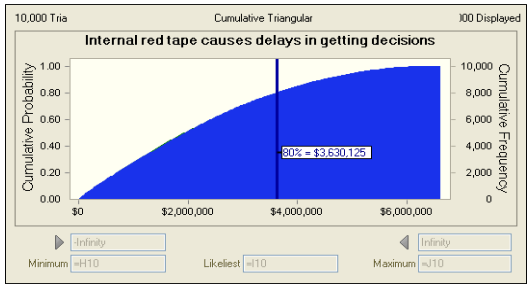
Likely Likely assumes no change from the baseline estimate.

Low Low assumes no change from the baseline estimate.

High High assumes that additional review is required, adding the cost of additional reviews, as well as prolonging the project such that the PDT incurs more cost in their time spent on the project. The worst case assumes that this adds a cumulative average delay of 4 months to each project feature, and 2 months review time to each project feature.

	PED	Const.	Total		
Bayswater State Park	*200*	*480*	*680*	*22.4 Months*	
Brant Point	*120*	*270*	*390*	*12.8 Months*	
Dead Horse Bay	*200*	*480*	*680*	*22.4 Months*	
Dubos Point	*120*	*270*	*390*	*12.8 Months*	
Fresh Creek	*180*	*270*	*450*	*14.8 Months*	
Hawtree Point	*120*	*270*	*390*	*12.8 Months*	
Paerdegat Basin	*208*	*480*	*688*	*22.6 Months*	
Spring Creek	*480*	*480*	*960*	*31.6 Months*	

4 Month Cumulative Interruption	***Feature Cost***	***Duration***	***Monthly Burn***	***PM Costs (0.5%)***	***Design Cost %***	***Design Costs***	***Contracting (0.5%)***	***S&A %***	***S&A Costs***	***Review Costs (0.5%)***	***Total***
Bayswater State Park	*$2,551,671*	*22.4 Months*	*$114,150*	*$2,283*	*13.95%*	*$63,694*	*$2,283*	*5.58%*	*$25,478*	*$1,141*	*$94,880*
Brant Point	*$4,465,996*	*12.8 Months*	*$348,348*	*$6,967*	*13.61%*	*$189,603*	*$6,967*	*5.44%*	*$75,841*	*$3,483*	*$282,862*
Dead Horse Bay	*$38,887,812*	*22.4 Months*	*$1,739,658*	*$34,793*	*16.28%*	*$1,132,634*	*$34,793*	*6.51%*	*$453,054*	*$17,397*	*$1,672,671*
Dubos Point	*$4,628,245*	*12.8 Months*	*$361,003*	*$7,220*	*15.60%*	*$225,298*	*$7,220*	*6.24%*	*$90,119*	*$3,610*	*$333,468*
Fresh Creek	*$23,935,168*	*14.8 Months*	*$1,618,017*	*$32,360*	*13.34%*	*$863,196*	*$32,360*	*5.33%*	*$345,278*	*$16,180*	*$1,289,375*
Hawtree Point	*$591,081*	*12.8 Months*	*$46,104*	*$922*	*12.06%*	*$22,246*	*$922*	*4.83%*	*$8,898*	*$461*	*$33,449*
Paerdegat Basin	*$45,233,133*	*22.6 Months*	*$1,999,988*	*$40,000*	*13.51%*	*$1,081,118*	*$40,000*	*5.41%*	*$432,447*	*$20,000*	*$1,613,564*
Spring Creek	*$37,752,844*	*31.6 Months*	*$1,196,293*	*$23,926*	*18.47%*	*$883,875*	*$23,926*	*7.39%*	*$353,550*	*$11,963*	*$1,297,239*
Subtotals	***$158,045,950***	***182.3 Months***	***$7,423,561***	***$148,471***		***$4,461,664***	***$148,471***		***$1,784,666***	***$74,236***	***$6,617,508***



Assumption: **Internal red tape causes delays in getting decisions**

Percentile	Assumption values
0%	$304
10%	$330,459
20%	$707,572
30%	$1,103,176
40%	$1,522,965
50%	$1,967,490
60%	$2,437,075
70%	$2,959,764
80%	$3,630,125
90%	$4,493,459
100%	$6,593,358

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

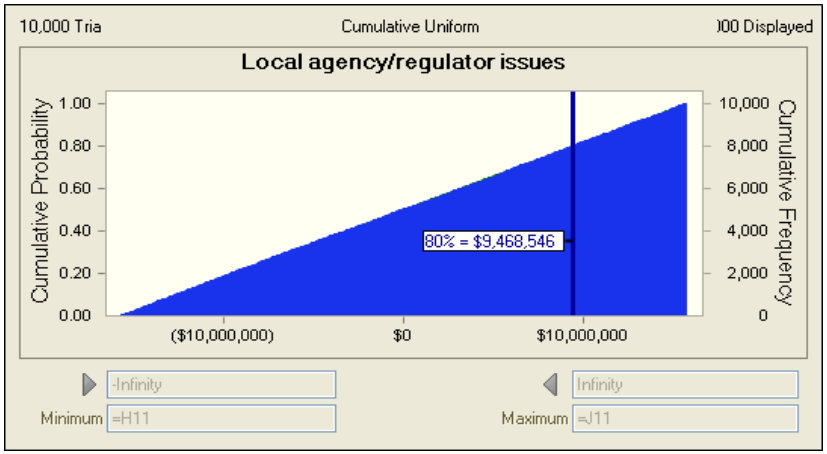
Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-4	Local agency/regulator issues	($15,804,595)	$0	$15,804,595

Notes: This item captures the risk that local agency/regulator issues will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes that input from local agencies and regulators eliminates up to 10% of the current scope from the project.

High High assumes that input from local agencies and regulators adds up to 10% additional scope (per the current regulation limits on scope configuration and modification post authorization) to the current project feature configurations and scopes.



Assumption: **Local agency/regulator issues**

Percentile	Assumption values
0%	($15,801,059)
10%	($12,692,231)
20%	($9,641,192)
30%	($6,485,945)
40%	($3,187,583)
50%	($48,233)
60%	$3,272,432
70%	$6,386,173
80%	$9,468,546
90%	$12,660,430
100%	$15,802,337

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High	
PPM-5	Priorities change on existing program				***Removed from Cost Risk Study - This item is captured by the Schedule Analysis***

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

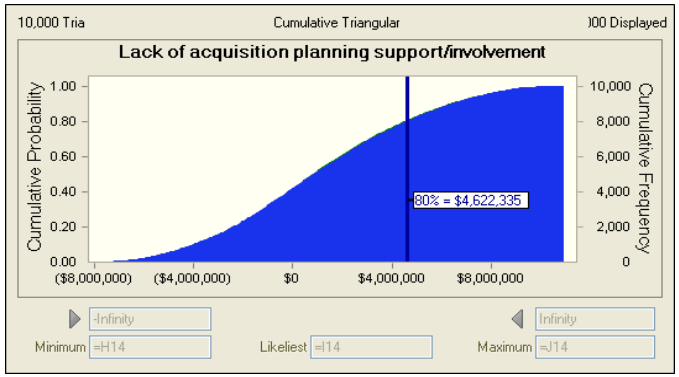
Risk Refer No.	Risk Event	Low	Most Likely	High
CA-1	Lack of acquisition planning support/involvement	($7,785,112)	$0	$10,938,484

Notes: This item captures the risk that lack of acquisition planning support/involvement will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes more favorable bidding and ultimate prices based on the contracting strategies actually employed. Assume the best case is 5% savings per feature.

High High assumes that all projects that can go to small businesses ($30 Million is the current bonding capacity for small business), adding up to 25% additional cost to each contract that goes to small business.



	CWE Contract Cost	***Best Case (-5%)***	***Worst Case (Small Business Adds 25%)***
Bayswater State Park	*$2,542,967*	$2,415,819	$3,178,709
Brant Point	*$4,420,602*	$4,199,572	$5,525,753
Dead Horse Bay	*$38,753,330*	$36,815,664	*$38,887,812*
Dubos Point	*$4,608,256*	$4,377,843	$5,760,319
Fresh Creek	*$23,657,339*	$22,474,472	$29,571,674
Hawtree Point	*$584,386*	$555,167	$730,482
Paerdegat Basin	*$43,516,016*	$41,340,215	*$45,233,133*
Spring Creek	*$37,619,346*	$35,738,379	*$37,752,844*
Subtotals	***$155,702,242***	***$147,917,130***	***$166,640,726***
Difference		**($7,785,112)**	**$10,938,484**

Assumption: **Lack of acquisition planning support/involvement**

Percentile	Assumption values
0%	($7,722,879)
10%	($3,991,009)
20%	($2,372,986)
30%	($1,207,248)
40%	($156,159)
50%	$886,347
60%	$1,978,410
70%	$3,168,162
80%	$4,622,335
90%	$6,474,617
100%	$10,809,262

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

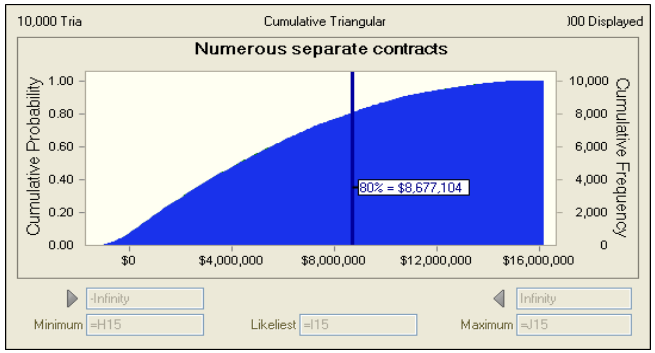
Risk Refer No.	Risk Event	Low	Most Likely	High
CA-2	Numerous separate contracts	($1,294,339)	$0	$16,165,855

Notes: This item captures the risk that having numerous separable contracts will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes that Bayswater State Park, Dubos Point, Brant Point, and Hawtree Point are bundled into one contract, eliminating 25% of the associated mobilization and demobilization costs, as well as saving up to 10% in the estimated total cost due to efficiencies.

High High assumes that Dead Horse Bay, Fresh Creek, Paedegat Basin, and Spring Creek are parceled into 3 separate contracts each to make them suitable for small businesses, adding additional mobilization and demobilizations (that add 25% to the total mob/demob costs), and adding up to 10% to each associated contract price due to loss of efficiency.



Assumption: **Numerous separate contracts**

Percentile	Assumption values
0%	($1,242,618)
10%	$272,725
20%	$1,184,487
30%	$2,156,819
40%	$3,165,773
50%	$4,335,066
60%	$5,573,414
70%	$6,947,765
80%	$8,677,104
90%	$10,692,072
100%	$15,950,106

Best Case	***CWE***	***Mob/Demob Costs***	***Mob/Demob Costs (25% Savings)***	***Efficiency Savings***	***New Contract Cost***
Bayswater State Park	*$2,542,967*	*$111,186*	*$83,390*	*$243,178*	*$2,271,992*
Brant Point	*$4,420,602*	*$184,306*	*$138,230*	*$423,630*	*$3,950,896*
Dubos Point	*$4,608,256*	*$205,878*	*$154,409*	*$440,238*	*$4,116,548*
Hawtree Point	*$584,386*	*$23,415*	*$17,561*	*$56,097*	*$522,435*
Subtotals	***$12,156,211***	***$524,785***	***$393,589***	***$1,163,143***	***$10,861,872***
Difference					***($1,294,339)***

Worst Case	***CWE***	***Mob/Demob Costs***	***Additional Mob/Demobs Cost (25%)***	**Efficiency Loss**	***New Contract Cost***
Dead Horse Bay	*$38,753,330*	*$920,299*	*$230,075*	*$3,783,303*	*$42,766,708*
Fresh Creek	*$23,657,339*	*$4,684,169*	*$1,171,042*	*$1,897,317*	*$26,725,698*
Paerdegat Basin	*$43,516,016*	*$5,581,601*	*$1,395,400*	*$3,793,441*	*$48,704,857*
Spring Creek	*$37,619,346*	*$888,942*	*$222,236*	*$3,673,040*	*$41,514,622*
Subtotals	***$143,546,031***	***$12,075,012***	***$3,018,753***	***$13,147,102***	***$159,711,886***
Difference					***$16,165,855***

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

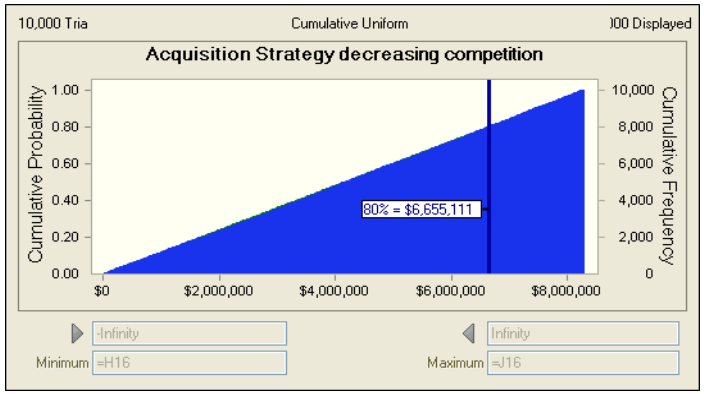
Risk Refer No.	Risk Event	Low	Most Likely	High
CA-3	Acquisition Strategy decreasing competition	$0	$0	$8,300,000

Notes: This item captures the risk that the acquisition strategy may actually decrease competition and will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes no change from the baseline estimate.

High High assumes that the eventual acquisition strategy actually decreases competition among bidders, as it make the award of said contracts less desirable for the market. Worst case assumes that this adds up to $10/CY additional costs on the projects requiring hydraulic fill (Fresh Creek and Paerdegat Basin).



Project Features	***Additional Cost***	***Estimated CY of Hydraulic Fill***	***Increased Cost Per CY***
Fresh Creek	$3,500,000	$350,000	$10.00
Paerdegat Basin	$4,800,000	$480,000	$10.00
Subtotals	***$8,300,000***		

Assumption: **Acquisition Strategy decreasing competition**

Percentile	Assumption values
0%	$1,057
10%	$835,866
20%	$1,715,624
30%	$2,555,527
40%	$3,376,537
50%	$4,160,650
60%	$5,006,032
70%	$5,840,259
80%	$6,655,111
90%	$7,441,565
100%	$8,299,828

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High
GE-4	Design development stage, incomplete or preliminary	($15,804,595)	$0	$15,804,595

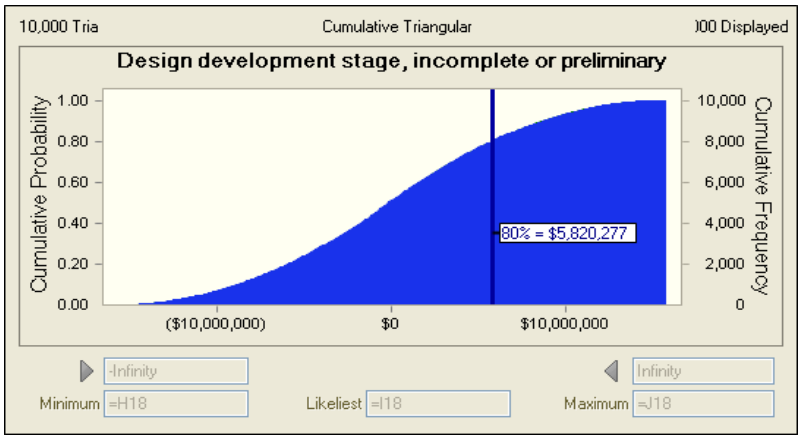
Notes:

This item captures the risk that the preliminary nature of the design development will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes that the CWE will vary by up to 10% by reducing currently contemplated scope, quantities, or methodology.

High High assumes that the CWE will vary by up to 10% by increasing currently contemplated scope, quantities, or methodology.



Assumption: **Design development stage, incomplete or preliminary**

Percentile	Assumption values
0%	($15,627,274)
10%	($8,825,053)
20%	($5,936,700)
30%	($3,647,123)
40%	($1,719,510)
50%	($97,400)
60%	$1,630,177
70%	$3,537,857
80%	$5,820,277
90%	$8,835,073
100%	$15,690,402

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High	
GE-5	Incomplete studies				***Removed from Cost Risk Study - This item is captured by Risk GE-4***

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High
GE-7	Borrow/fill sources identified/secured	($1,336,121)	$0	$7,361,699

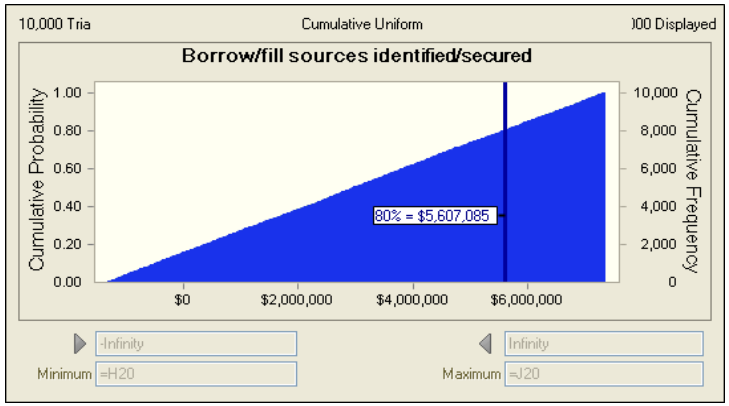
Notes:

This item captures the risk that not having the borrow/fill sources identified and secured will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes up to 25% savings due to efficiencies from the currently estimated dry and wet haul costs for each feature.

High High assumes a worst case of an average 10 mile round trip haul (Project Unit Cost of $14.51 per LCY) for all dry and wet haul for unclassified excavation for all features receiving borrow fill (Fresh Creek and Paerdegat Basin).



Project Features	*Unclassified Excavation*	*10 Mile Round Trip Cost*	*Potential Savings*
Fresh Creek	*$531,744*	*$1,182,523*	*$398,808*
Paerdegat Basin	*$4,812,740*	*$11,523,660*	*$3,609,555*
Subtotals	***$5,344,484***	***$12,706,183***	***$4,008,363***
Difference		***$7,361,699***	***($1,336,121)***

Assumption: **Borrow/fill sources identified/secured**

Percentile	Assumption values
0%	($1,335,452)
10%	($484,706)
20%	$384,186
30%	$1,255,278
40%	$2,156,334
50%	$2,975,268
60%	$3,844,660
70%	$4,690,378
80%	$5,607,085
90%	$6,488,882
100%	$7,360,964

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

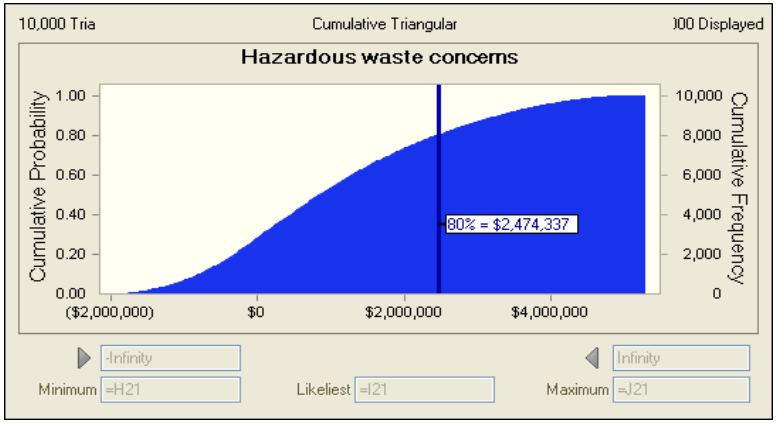
Risk Refer No.	Risk Event	Low	Most Likely	High
GE-8	Hazardous waste concerns	($1,966,987)	$0	$5,279,808

Notes: This item captures the risk that hazardous waste issues will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes there is less contaminated material than contemplated, creating increased productivity (102% in the MII file).

High High assumes more contaminated material than currently contemplated, creating decreased productivity of up to 5% in the MII file. Further study indicated that it is not very likely that the discovery of hazardous material will slow the production of these projects and because the material will stay within the confines of the property. No material will be trucked off-site. This is based on current and historical projects.



Assumption: **Hazardous waste concerns**

Percentile	Assumption values
0%	($1,909,597)
10%	($779,054)
20%	($302,276)
30%	$76,782
40%	$462,149
50%	$856,486
60%	$1,297,228
70%	$1,823,885
80%	$2,474,337
90%	$3,325,626
100%	$5,228,272

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High	
RE-3	Status of Permits				***Removed from Cost Risk Study - This item is captured by the Schedule Analysis***

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

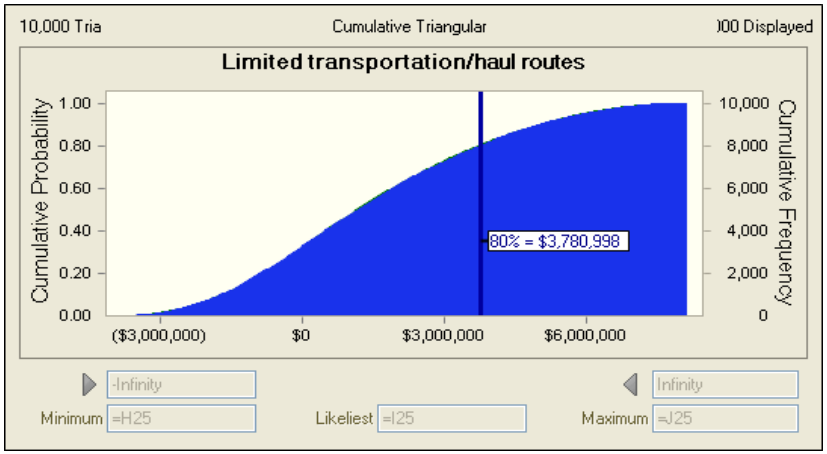
Risk Refer No.	Risk Event	Low	Most Likely	High
CON-2	Limited transportation/haul routes	($3,858,321)	$0	$8,133,758

Notes: This item captures the risk that the project areas having limited transportation and haul routes available will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes that the ultimate project cost will be improved over those currently contemplated, increasing productivity by up to 4% in the MII file.

High High assumes that the ultimate project cost will be improved over those currently contemplated, decreasing productivity by up to 7.5% in the MII file.



Assumption: **Limited transportation/haul routes**

Percentile	Assumption values
0%	($3,833,285)
10%	($1,707,593)
20%	($879,953)
30%	($159,019)
40%	$492,378
50%	$1,196,100
60%	$1,932,884
70%	$2,791,006
80%	$3,780,998
90%	$5,023,320
100%	$8,097,012

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

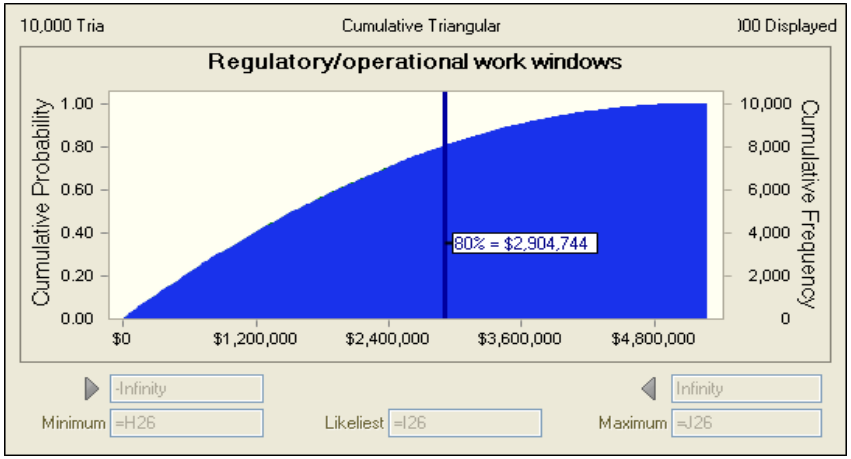
Risk Refer No.	Risk Event	Low	Most Likely	High
CON-3	Regulatory/operational work windows	$0	$0	$5,279,808

Notes: This item captures the risk that regulatory and operational work window constraints will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes no change from the baseline estimate.

High High assumes that the ultimate project cost will be improved over those currently contemplated, decreasing productivity by up to 5% in the MII file.



Assumption: **Regulatory/operational work windows**

Percentile	Assumption values
0%	$119
10%	$273,382
20%	$560,695
30%	$867,454
40%	$1,198,856
50%	$1,554,175
60%	$1,959,562
70%	$2,402,039
80%	$2,904,744
90%	$3,572,702
100%	$5,231,267

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

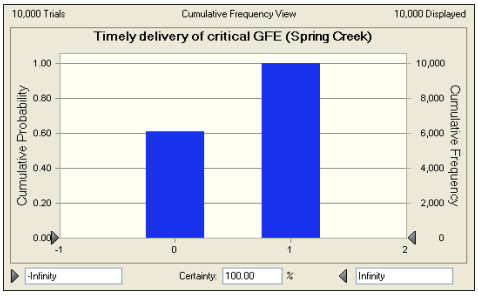
Risk Refer No.	Risk Event	Low	Most Likely	High
SC-1	Timely delivery of critical GFE	($393,029)	$0	$982,572

Notes: This item captures the risk that not receiving plant material for Spring Creek on a timely basis will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

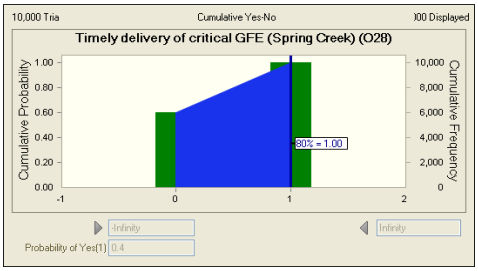
Low Low assumes that the conditions and the delivery of the Government furnished plants, trees, and shrubs for Spring Creek will actually be 10% cheaper than currently estimated.

High High assumes that issues with the conditions and delivery of the Government furnished plants, trees, and shrubs will increase the cost of the items by up to 25%.



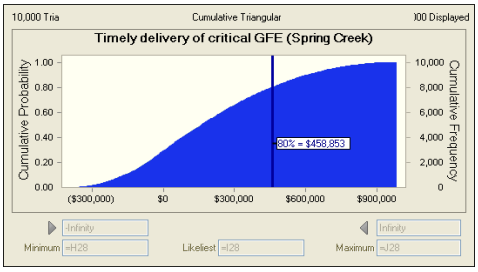
Forecast: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	1
80%	1
90%	1
100%	1



Assumption: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	1
80%	1
90%	1
100%	1



Assumption: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	($390,414)
10%	($162,045)
20%	($64,921)
30%	$8,187
40%	$80,428
50%	$161,852
60%	$246,839
70%	$342,607
80%	$458,853
90%	$609,875
100%	$968,933

Spring Creek Sub-Features	***Current Cost***	***Worst Case Cost (25% Higher)***	***Best Case Cost (10% Lower)***
Low Marsh Plants	*$553,698*	*$692,123*	*$498,329*
High Marsh Plants	*$284,524*	*$355,655*	*$256,072*
High Marsh Shrubs	*$20,712*	*$25,891*	*$18,641*
Coast Dune Plants	*368,475.68*	*$460,595*	*$331,628*
Coastal Dune Shrubs	*86,075.78*	*$107,595*	*$77,468*
Maritime Forest Plants	*$193,160*	*$241,450*	*$173,844*
Maritime Forest Shrubs	*$44,931*	*$56,039*	*$40,348*
Maritime Forest Trees	*$2,025,317*	*$2,531,646*	*$1,822,785*
Maritime Forest Seeding	*$353,493*	*$441,866*	*$318,143*
Subtotals	***$3,930,287***	***$4,912,858***	***$3,537,258***
Difference		***$982,572***	***($393,029)***

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High
DH-1	Timely delivery of critical GFE	($460,637)	$0	$460,637

Notes: This item captures the risk that not receiving plant material for Dead Horse Bay on a timely basis will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

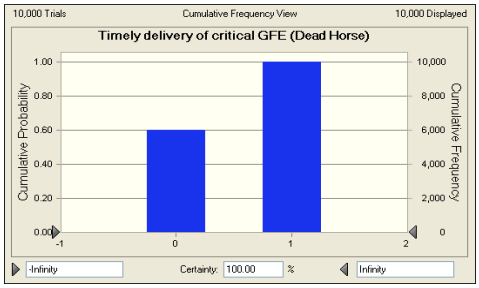
Low

Low assumes that the conditions and the delivery of the Government furnished plants, trees, and shrubs for Dead Horse Bay will actually be 10% cheaper than currently estimated.

High

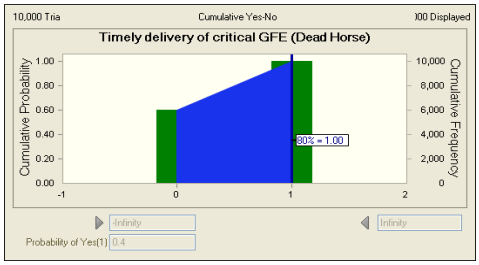
High assumes that issues with the conditions and delivery of the Government furnished plants, trees, and shrubs will increase the cost of the items by up to 10%. Upon further study, as long as the planting industry is given fair notice, availability of plants will not be an issue. Any problem that did arise would not likely cause the costs to vary by more than 10%.

Dead Horse Bay Sub-Features	*Current Cost*	*Worst Case Cost (10% Higher)*	*Best Case Cost (10% Lower)*
Low Marsh Plants	*$353,959*	*$389,355*	*$318,563*
High Marsh Plants	*$194,175*	*$213,593*	*$174,758*
High Marsh Shrubs	*$14,223*	*$15,645*	*$12,801*
Coast Dune Plants	*110,684.37*	*$121,753*	*$99,616*
Coastal Dune Shrubs	*2,145.16*	*$2,360*	*$1,931*
Maritime Forest Plants	*$264,726*	*$291,199*	*$238,253*
Maritime Forest Shrubs	*$61,528*	*$67,681*	*$55,376*
Maritime Forest Trees	*$3,120,479*	*$3,432,527*	*$2,808,431*
Maritime Forest Seeding	*$484,453*	*$532,899*	*$436,008*
Subtotals	***$4,606,373***	***$5,067,010***	***$4,145,736***
Difference		***$460,637***	***($460,637)***



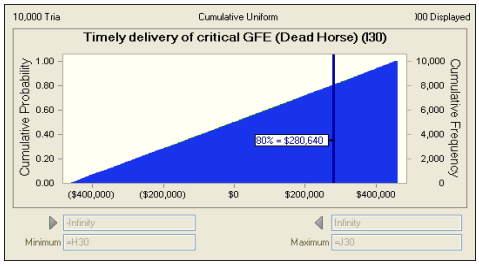
Forecast: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	1
70%	1
80%	1
90%	1
100%	1



Assumption: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	1
70%	1
80%	1
90%	1
100%	1



Assumption: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	($460,532)
10%	($368,812)
20%	($277,949)
30%	($179,632)
40%	($88,958)
50%	$6,370
60%	$98,747
70%	$189,596
80%	$280,640
90%	$370,299
100%	$460,545

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

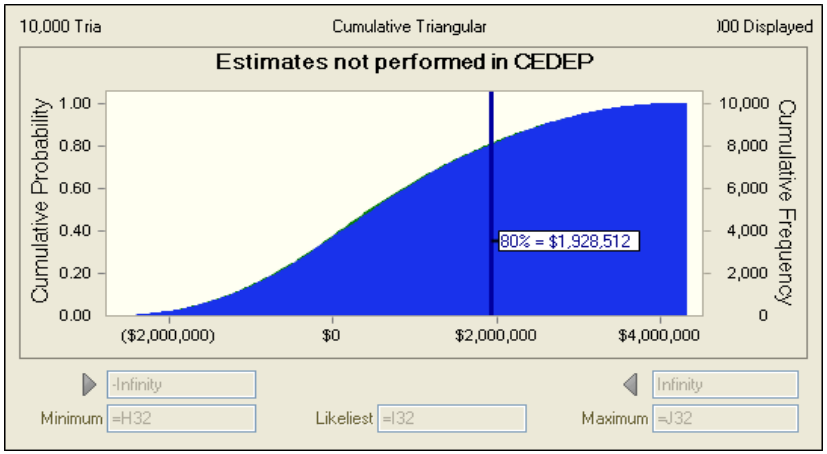
Risk Refer No.	Risk Event	Low	Most Likely	High
PB-1	Estimates not performed in CEDEP	($2,593,697)	$0	$4,322,828

Notes: This item captures the risk that not having estimates performed in CEDEP for Paerdegat Basin will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes that the hydraulically placed fill cost will improve by up to 15% by not being estimated using CEDEP.

High High assumes that the hydraulically place fill cost will increase by up to 25% by not being estimated using CEDEP.



Assumption: **Estimates not performed in CEDEP**

Percentile	Assumption values
0%	($2,561,738)
10%	($1,218,995)
20%	($667,092)
30%	($249,958)
40%	$125,001
50%	$512,417
60%	$915,223
70%	$1,352,784
80%	$1,928,512
90%	$2,607,876
100%	$4,278,016

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High
PR-1	Adequacy or project funding (incremental)	$0	$0	$12,198,703

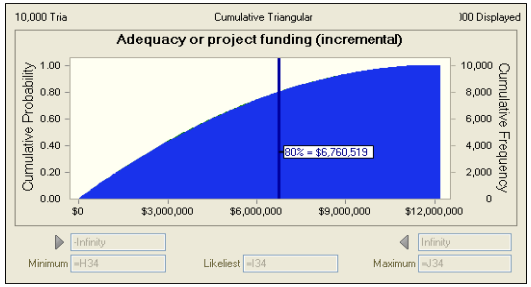
Notes: This item captures the risk that challenges with receiving adequate or timely funding increments will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes no variance due to incremental funding issues.

High High assumes that in the fifteen years of construction, there are delays in obtaining funding in at least 5 fiscal year changeovers, each creating up to 24 months of cumulative delay. Assume prorated equipment standby, prorated monthly burn rate for ongoing PED, S&A, PM, and other miscellaneous fixed costs, potential suspension/termination and reprocurement costs, plus an increase of 5% for inefficiencies and overtime for accelerated work.

24 Month Cumulative Interruption	*Feature Cost*	*Duration*	*Monthly Burn*	*Interpolated Delay*	*PM Costs (0.5%)*	*Design Cost %*	*Design Costs*	*Contracting (0.5%)*	*S&A %*	*S&A Costs*	*Equip. Cost*	*Equip. Standby*	*Termination/Re-Procurement Costs*	*Total*
Bayswater State Park	*$2,551,671*	*22.4 Months*	*$114,150*	*3.5 Months*	*$2,013*	*13.95%*	*$56,152*	*$2,013*	*5.58%*	*$22,461*	*$330,545*	*$33,894*	*$37,062*	*$153,595*
Brant Point	*$4,465,996*	*12.8 Months*	*$348,348*	*2.0 Months*	*$3,523*	*13.61%*	*$95,867*	*$3,523*	*5.44%*	*$38,347*	*$715,072*	*$73,323*	*$61,435*	*$276,017*
Dead Horse Bay	*$38,887,812*	*22.4 Months*	*$1,739,658*	*3.5 Months*	*$30,673*	*16.28%*	*$998,520*	*$30,673*	*6.51%*	*$399,408*	*$4,553,266*	*$466,889*	*$306,766*	*$2,232,929*
Dubos Point	*$4,628,245*	*12.8 Months*	*$361,003*	*2.0 Months*	*$3,651*	*15.60%*	*$113,915*	*$3,651*	*6.24%*	*$45,566*	*$331,990*	*$34,042*	*$68,626*	*$269,450*
Fresh Creek	*$23,935,168*	*14.8 Months*	*$1,618,017*	*2.3 Months*	*$18,879*	*13.34%*	*$503,593*	*$18,879*	*5.33%*	*$201,437*	*$4,366,683*	*$447,757*	*$1,561,390*	*$2,751,935*
Hawtree Point	*$591,081*	*12.8 Months*	*$46,104*	*2.0 Months*	*$466*	*12.06%*	*$11,248*	*$466*	*4.83%*	*$4,499*	*$51,335*	*$5,264*	*$7,805*	*$29,748*
Paerdegat Basin	*$45,233,133*	*22.6 Months*	*$1,999,988*	*3.6 Months*	*$35,678*	*13.51%*	*$964,316*	*$35,678*	*5.41%*	*$385,726*	*$8,129,195*	*$833,562*	*$1,860,534*	*$4,115,494*
Spring Creek	*$37,752,844*	*31.6 Months*	*$1,196,293*	*5.0 Months*	*$29,778*	*18.47%*	*$1,100,069*	*$29,778*	*7.39%*	*$440,028*	*$4,618,392*	*$473,567*	*$296,314*	*$2,369,534*
Subtotals	***$158,045,950***	***182.3 Months***	***$7,423,561***	***24.0 Months***	***$124,661***		***$3,843,679***	***$124,661***		***$1,537,472***	***$23,096,479***	***$2,368,297***	***$4,199,932***	***$12,198,703***



Assumption: **Adequacy or project funding (incremental)**

Percentile	Assumption values
0%	$712
10%	$634,659
20%	$1,305,395
30%	$2,036,273
40%	$2,780,305
50%	$3,634,324
60%	$4,532,725
70%	$5,580,428
80%	$6,760,519
90%	$8,396,896
100%	$12,001,033

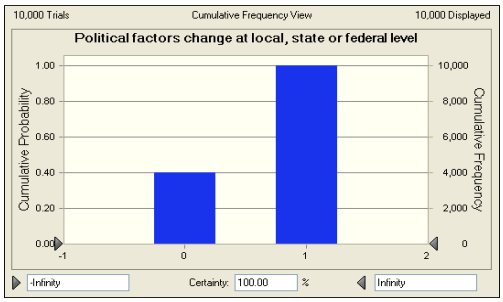
Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High	
PR-2	Obtaining authorization on a timely basis				***Removed from Cost Risk Study - This item is captured by the Schedule Analysis***

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

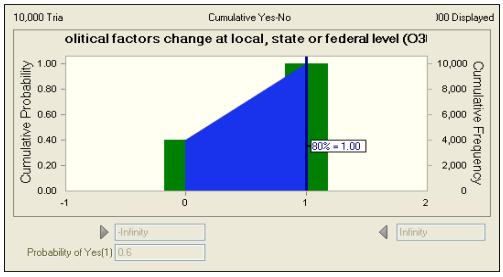
Risk Refer No.	Risk Event	Low	Most Likely	High
PR-4	Political factors change at local, state or federal level	($7,902,297)	$0	$15,804,595

Notes: This item captures the risk that political factors will cause a variance from the current working estimate for the project.
Likely Likely assumes no change from the baseline estimate.
Low Low assumes that scope is reduced by up to 5% due to changes in political factors.
High High assumes that scope is increased by up to 10% due to changes in political factors.



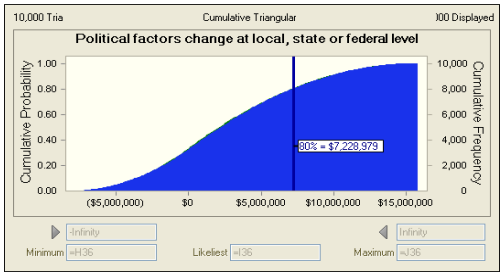
Forecast: **Political factors change at local, state or federal level**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	1
50%	1
60%	1
70%	1
80%	1
90%	1
100%	1



Assumption: **Political factors change at local, state or federal level**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	1
50%	1
60%	1
70%	1
80%	1
90%	1
100%	1



Assumption: **Political factors change at local, state or federal level**

Percentile	Assumption values
0%	($7,732,603)
10%	($3,608,169)
20%	($1,700,219)
30%	($273,326)
40%	$970,228
50%	$2,274,499
60%	$3,689,166
70%	$5,259,926
80%	$7,228,979
90%	$9,774,486
100%	$15,659,149

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost Risk Analysis

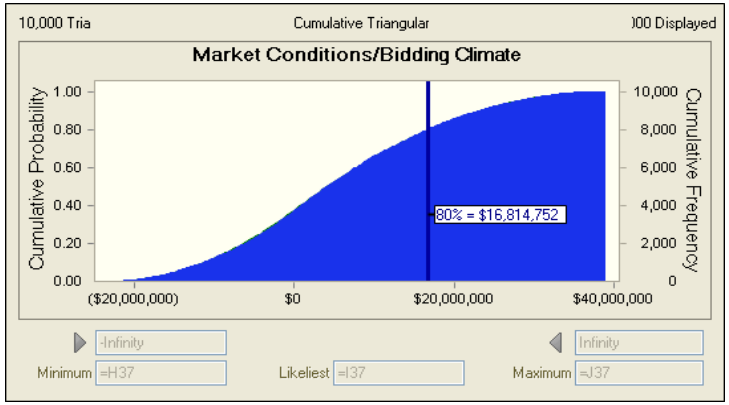
Risk Refer No.	Risk Event	Low	Most Likely	High
PR-6	Market Conditions/Bidding Climate	($23,355,336)	$0	$38,925,561

Notes: This item captures the risk that market conditions and bidding climate will cause a variance from the current working estimate for the project.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes up to 15% savings on contract costs due to fluctuations and market conditions.

High High assumes up to 25% increase on contract costs due to fluctuations and market conditions.

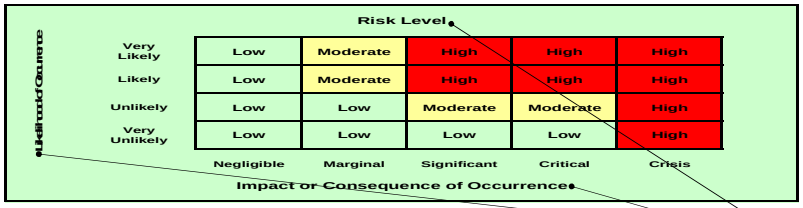


Assumption: **Market Conditions/Bidding Climate**

Percentile	Assumption values
0%	($23,073,961)
10%	($11,259,220)
20%	($6,026,260)
30%	($2,250,349)
40%	$1,007,800
50%	$4,265,983
60%	$7,857,593
70%	$11,991,399
80%	$16,814,752
90%	$23,471,595
100%	$38,411,579

Project Features	***Contract Costs***	***Best Case***	***Worst Case***
Bayswater State Park	*$2,542,967*	$2,161,522	$3,178,709
Brant Point	*$4,420,602*	$3,757,512	$5,525,753
Dead Horse Bay	*$38,753,330*	$32,940,331	$48,441,663
Dubos Point	*$4,608,256*	$3,917,017	$5,760,319
Fresh Creek	*$23,657,339*	$20,108,738	$29,571,674
Hawtree Point	*$584,386*	$496,728	$730,482
Paerdegat Basin	*$43,516,016*	$36,988,613	$54,395,020
Spring Creek	*$37,619,346*	$31,976,444	$47,024,183
Subtotals	***$155,702,242***	***$132,346,906***	***$194,627,803***
Difference		**($23,355,336)**	**$38,925,561**

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - PDT Risk Register



Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
Contract Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)															
	PROJECT & PROGRAM MGMT														
PPM-1	Project competing with other projects	The PDT has identified that many other projects competing for resources and funding within the District and Region.	This risk could have an impact on overall project costs and could lead to significant delays to the overall project schedule.	Likely	Marginal	Moderate		Likely	Critical	High		Uniform		Project Manager	Project Schedule
PPM-2	No control over staff priorities	The PDT identified that since there are many other projects competing for resources, there is a risk that there could be limited control over staff priorities.	The PDT assumed that this risk is fairly unlikely and would have minimal impact, as if priority was placed on this project, there would be control over staff.	Unlikely	Marginal	Low		Unlikely	Marginal	Low		Uniform		Project Manager	Project Schedule
PPM-3	Internal red tape causes delays in getting decisions	The PDT identified that there is great concern that delays in obtaining approval on decisions has been and will continue to be experienced, such as new regulations and requirements as it pertains to decision documents process and reviews.	Additional red tape and regulation on obtaining approval on decision documents could negatively impact both the cost and schedule.	Very Likely	Significant	High		Very Likely	Significant	High		Triangular		Project Manager	Project Cost & Schedule
PPM-4	Local agency/regulator issues	Several different entities (including the State as well as other local agencies and municipalities) have different conceptions of what the requirements for Jamaica Bay ought to be.	Not obtaining complete agreement or acceptance by local regulators and/or stakeholders could significantly impact the overall project cost and schedule.	Very Likely	Critical	High		Very Likely	Critical	High		Uniform		Project Manager	Project Cost & Schedule
PPM-5	Priorities change on existing program	The PDT identified that, as in Risk PPM-4 above, there is the potential for priorities and features to change on the existing plan and project.	A change of priorities on the existing program could negatively impact both the cost and schedule.	Unlikely	Significant	Moderate		Unlikely	Significant	Moderate		Yes-No/Uniform		Project Manager	Project Cost & Schedule
	CONTRACT ACQUISITION RISKS														
CA-1	Lack of acquisition planning support/involvement	At this time, the PDT has not had the involvement of contracting regarding the acquisition planning. There is potential for some of the work to be set aside for small business and/or be procured by negotiation rather than competitive bid.	The ultimate acquisition plan could impact both the cost and schedule.	Likely	Marginal	Moderate		Likely	Marginal	Moderate		Triangular		Contracting	Contract Cost & Schedule
CA-2	Numerous separate contracts	There are currently contemplated to be 8 or more separate contracts.	The number of contracts could present risks to both cost and schedule in terms of the acquisition strategy, the fixed costs associated with letting multiple contracts, as well as contract phasing and sequencing issues.	Very Likely	Marginal	Moderate		Very Likely	Marginal	Moderate		Triangular		Contracting	Contract Cost & Schedule
CA-3	Acquisition Strategy decreasing competition	The PDT expressed concern that, based on historical experience, the ultimate acquisition strategy, particularly for the dredging contracts, may actually limit the competition.	Limited bidding competition would affect both cost and schedule.	Very Likely	Marginal	Moderate		Very Likely	Marginal	Moderate		Uniform		Contracting	Contract Cost & Schedule
	TECHNICAL RISKS														
GE-4	Design development stage, incomplete or preliminary	Whereas the PDT is confident in the products developed to date, they acknowledge that due to the phase of the project cycle, decisions are being made on preliminary data. The consensus was that there will be uncertainty with the assumptions made for scope until the project is further into PED.	The uncertainty with the design could impact the project cost and schedule.	Very Likely	Significant	High		Very Likely	Marginal	Moderate		Triangular		Technical Lead	Contract Cost & Schedule
GE-5	Incomplete studies	The PDT expressed concern that due to the phase of the project, many of the project assumptions are based on incomplete studies and investigations.	The uncertainty with the status of studies and investigations may impact the project cost and schedule.	Unlikely	Significant	Moderate		Unlikely	Significant	Moderate		Triangular		Technical Lead	Contract Cost & Schedule
GE-6	Surveys late/surveys in question	The PDT expressed that, based on historical experience, critical surveys and or reports could be completed later than anticipated.	History suggests that some delay in obtaining the surveys would not impact the overall projects cost or schedule (particularly of this magnitude) to a significant degree.	Likely	Negligible	Low		Likely	Negligible	Low		Triangular		Technical Lead	Contract Cost & Schedule
GE-7	Borrow/fill sources identified/secured	There is concern regarding the timing and availability of borrow and fill sources, as there is a great deal of Federal work occurring at the entrance channel.	The timeframe for utilizing the identified borrow and fill sources may impact costs and could significantly impact the overall project schedule.	Likely	Marginal	Moderate		Likely	Critical	High		Triangular		Technical Lead	Contract Schedule
GE-8	Hazardous waste concerns	Whereas there is little concern regarding the presence of hazardous waste, there is concern regarding the presence of contaminated waste. Projects include excavation at former landfill sites, some of which have hazardous metal residue in low levels.	The presence of contaminated material in substantial quantities could significantly impact the project costs, and could also impact the schedule to a lesser degree.	Likely	Significant	High		Likely	Marginal	Moderate		Uniform		Technical Lead	Contract Cost
	LANDS AND DAMAGES RISKS														
LR-1	Status of real estate/easement acquisition	The issue of status of the real estate/easement acquisition is of concern to the PDT. Although Federal and/or local governments predominantly own the land in the project area, there is some question as to whether there might be delays in the approval of the plan.	Delays in execution of the real estate plan could negatively impact the schedule.	Unlikely	Marginal	Low		Unlikely	Significant	Moderate		Yes-No/Uniform		Real Estate	Project Schedule

	REGULATORY AND ENVIRONMENTAL RISKS														
RE-1	Conforming to the State implementation plan for air quality	The region has stringent requirements for air quality issues. However, the current plan takes the State implementation plan requirements into consideration.	The consensus of the PDT was that the current project mitigates or avoids effects to air quality such that it most likely will not impact the project cost or schedule.	Likely	Negligible	Low		Likely	Negligible	Low		Triangular		Environmental	Project Cost
RE-2	Project in an area of high sensitivity for cultural artifacts	The project sites are in areas where there is some concern for the presence of cultural artifacts. However, experience and current information suggests that this is not likely to impact the cost and schedule.	The consensus of the PDT was that cultural resources most likely will not impact the project cost or schedule.	Very Unlikely	Significant	Low		Very Unlikely	Significant	Low		Yes-No/Uniform		Environmental	Project Cost & Schedule
RE-3	Status of Permits	The project is in a Coastal Zone, and portions of the project are within National or State Parks and or Scenic byways. There is also concern regarding the requirements and scrutiny of reviewing agencies (such as NPS), as well as changes in environmental guidance or regulations during the project duration. Thus, the status of several permits is in question.	The effects of the project's location impacting parks and involving other agencies/entities could impact the overall project cost and schedule.	Very Likely	Marginal	Moderate		Very Likely	Marginal	Moderate		Yes-No/Uniform		Project Manager	Project Cost & Schedule
	CONSTRUCTION RISKS														
CON-1	FAA Involvement	The project will involve and impact JFK International Airport. Thus, the involvement of the FAA is a concern.	FAA involvement and scrutiny will likely not impact the cost, but may pose a threat to the schedule.	Likely	Negligible	Low		Likely	Marginal	Moderate		Triangular		Project Manager	Project Schedule
CON-2	Limited transportation/haul routes	There is a constraint of limited transportation access throughout the project sites due to restrictions on bridges and waterways.	Limited accessibility could increase project costs.	Likely	Marginal	Moderate		Likely	Negligible	Low		Triangular		Technical Lead	Contract Cost
CON-3	Regulatory/operational work windows	There are environmental windows for dredging operations for fish concerns, and there are seasonal windows for planting times for the land-based work.	Environmental windows and constraints could impact the cost and schedule.	Likely	Marginal	Moderate		Likely	Marginal	Moderate		Triangular		Environmental	Contract Cost & Schedule
	SPRING CREEK RISKS														
SC-1	Timely delivery of critical GFE	There is potential that the Corps will have Plant material that Corps will have to grow plant material for the National Park Service (NPS) on 2 out of the 8 contracts.	Depending on the cooperation and requirements of NPS, the timely delivery of plant material could be an issue that significantly impacts cost and somewhat affects the overall schedule.	Likely	Significant	High		Likely	Marginal	Moderate		Yes-No/Uniform		Project Manager	Project Cost
	DEAD HORSE BAY RISKS														
DH-1	Timely delivery of critical GFE	There is potential that the Corps will have Plant material that Corps will have to grow plant material for the National Park Service (NPS) on 2 out of the 8 contracts.	Depending on the cooperation and requirements of NPS, the timely delivery of plant material could be an issue that significantly impacts cost and somewhat affects the overall schedule.	Likely	Significant	High		Likely	Marginal	Moderate		Yes-No/Uniform		Project Manager	Project Cost
	PAERDEGAT BASIN RISKS														
PB-1	Estimates not performed in CEDEP	Estimates were prepared in CEDEP and/or MII for all contracts except for Product developed by others. There some question as to the reliability of the quantity development for that estimate, as the source of sand may be coming from a maintenance dredge contract, and this contract will have a line item for hydraulically placed fill.	The current estimate assumes that the borrow source is 10 miles away. The cost and schedule could be impacted significantly if the borrow location is closer or farther away.	Likely	Marginal	Moderate		Likely	Significant	High		Triangular		Cost Engineering	Contract Cost & Schedule
	Programmatic Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)														
PR-1	Adequacy or project funding (incremental)	The PDT expressed concern that incremental funding may not be received in the outlays currently anticipated and planned.	Not receiving incremental funds on a timely basis or in the outlays anticipated could impact cost and could significantly impact the schedule.	Very Likely	Marginal	Moderate		Very Likely	Significant	High		Uniform		Project Manager	Project Schedule
PR-2	Obtaining authorization on a timely basis	The PDT has concern that the project may not be approved in the program year anticipated.	Not obtaining authorization according to the current schedule could significantly impact cost and schedule.	Very Likely	Significant	High		Very Likely	Critical	High		Yes-No/Uniform		Project Manager	Project Cost & Schedule
PR-3	Local communities pose objections	There is concern that local communities could pose some objection. However, the PDT contemplates minimal impact from local objections.	The PDT assumed that this risk is unlikely and would carry little impact if it did occur.	Unlikely	Negligible	Low		Unlikely	Negligible	Low		Yes-No/Uniform		Project Manager	Project Cost & Schedule
PR-4	Political factors change at local, state or federal level	There was some concern that political factors could change at the local, state, and or federal level regarding the scope of this project.	Change in the political factors and climate could affect the project cost and schedule.	Very Likely	Marginal	Moderate		Very Likely	Marginal	Moderate		Yes-No/Uniform		Project Manager	Project Cost & Schedule
PR-5	Stakeholders request late changes	One of the primary stakeholders is NPS, and experience indicates that they may request changes during project formulation and execution.	The PDT contemplated minimal likelihood and impact from changes requested after authorization.	Unlikely	Negligible	Low		Unlikely	Negligible	Low		Yes-No/Uniform		Project Manager	Project Cost & Schedule
PR-6	Acts of God	The project site is susceptible to the effects of hurricanes (nor'easter).	The occurrence of nor'easters that could impact the production in these project areas is so infrequent, that the PDT assumes that this will most likely not be an issue for this project.	Very Unlikely	Significant	Low		Very Unlikely	Significant	Low		Yes-No/Uniform			Project Cost & Schedule
PR-7	Market Conditions/Bidding Climate	Since the project is large, contains multiple contracts, and is to occur over an extended period of time, there is inherent risk of impact to costs (whether positive or negative) due to the fluctuation in market conditions for commodities and the industry bidding climate.	Fluctuations in the market conditions for commodities or the industry bidding climate could have a significant impact on project costs.	Likely	Significant	High		Likely	Negligible	Low		Triangular		Cost Engineering	Contract Cost

*Likelihood, Impact, and Risk Level to be verified through market research and analysis (conducted by cost engineer).

1. Risk/Opportunity identified with reference to the Risk Identification Checklist and through deliberation and study of the PDT.
2. Discussions and Concerns elaborates on Risk/Opportunity Events and includes any assumptions or findings (should contain information pertinent to eventual study and analysis of event's impact to project).
3. Likelihood is a measure of the probability of the event occurring -- **Very Unlikely**, **Unlikely**, **Moderately Likely**, **Likely**, **Very Likely.** The likelihood of the event will be the same for both Cost and Schedule, regardless of impact.
4. Impact is a measure of the event's effect on project objectives with relation to scope, cost, and/or schedule -- **Negligible**, **Marginal**, **Significant**, **Critical**, or **Crisis.** Impacts on Project Cost may vary in severity from impacts on Project Schedule.
5. Risk Level is the resultant of Likelihood and Impact**Low**, **Moderate**, or **High**. Refer to the matrix located at top of page.
6. Variance Distribution refers to the behavior of the individual risk item with respect to its potential effects on Project Cost and Schedule. For example, an item with clearly defined parameters and a solid most likely scenario would probably follow a triangular or normal distribution. A risk item for which the PDT has little data or probability of modeling with respect to effects on cost or schedule (i.e. "anyone's guess") would probably follow a uniform or discrete uniform distribution.
7. The responsibility or POC is the entity responsible as the Subject Matter Expert (SME) for action, monitoring, or information on the PDT for the identified risk or opportunity.
8. Correlation recognizes those risk events that may be related to one another. Care should be given to ensure the risks are handled correctly without a "double counting."
9. Affected Project Component identifies the specific item of the project to which the risk directly or strongly correlates.
10. Project Implications identifies whether or not the risk item affects project cost, project schedule, or both. The PDT is responsible for conducting studies for both Project Cost and for Project Schedule.
11. Results of the risk identification process are studied and further developed by the Cost Engineer, then analyzed through the Monte Carlo Analysis Method for Cost (Contingency) and Schedule (Escalation) Growth.

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Cost & Schedule Risk Analysis

Contingency on Base Estimate	80% Confidence Project Cost
Total Construction Cost (Most Likely) ->	$158,045,950
Construction Cost Contingency Amount ->	$44,215,485
Total Construction Cost (80% Confidence) ->	$202,261,435

Contingency on Schedule	80% Confidence Project Schedule
Total Project Schedule Duration (Most Likely) ->	182.3 Months
Schedule Contingency Duration ->	122.4 Months
Total Project Schedule Duration (80% Confidence) ->	304.7 Months
Project Schedule Contingency Amount (80% Confidence) ->	$19,320,466

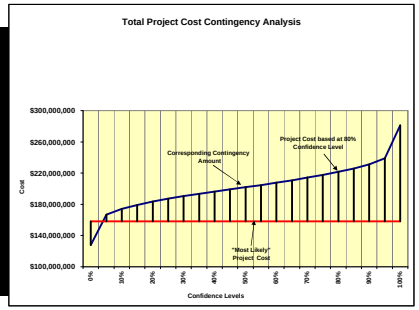
Total Project Contingency	80% Confidence Project Cost
Total Project Contingency Amount (80% Confidence) ->	$63,535,952
Total Project Contingency Percentage (80% Confidence) ->	40%

Total Project Cost (80% Confidence) ->	$221,581,901

- TOTAL PROJECT CONTINGENCY DEVELOPMENT -

Contingency Analysis

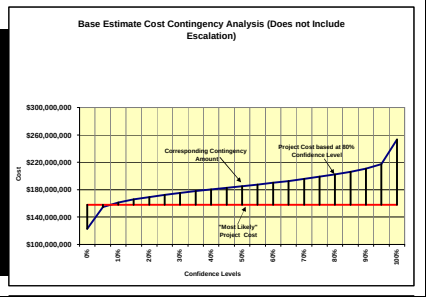
Most Likely Cost Estimate	$158,045,950	
Confidence Level	**Value**	**Contingency**
0%	$127,935,815	-19.05%
5%	$166,626,075	5.43%
10%	$174,142,095	10.18%
15%	$179,295,375	13.45%
20%	$183,498,464	16.10%
25%	$187,292,638	18.51%
30%	$190,555,166	20.57%
35%	$193,544,566	22.46%
40%	$196,380,246	24.26%
45%	$199,078,909	25.96%
50%	$201,882,154	27.74%
55%	$204,688,036	29.51%
60%	$207,720,767	31.43%
65%	$210,659,795	33.29%
70%	$214,173,154	35.51%
75%	$217,662,577	37.72%
80%	$221,581,901	40.20%
85%	$225,824,967	42.89%
90%	$231,189,330	46.28%
95%	$239,071,123	51.27%
100%	$281,077,470	77.85%

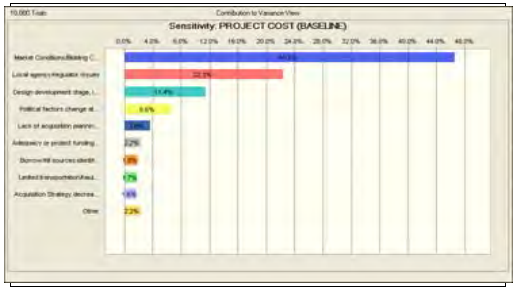


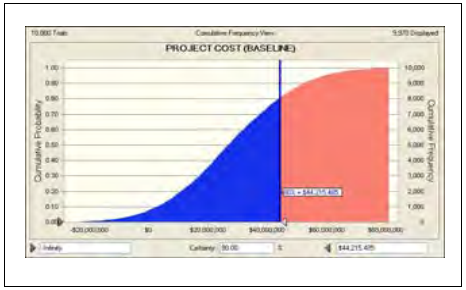
- BASE CONTINGENCY DEVELOPMENT -

Contingency Analysis

Most Likely Cost Estimate	$158,045,950	
Confidence Level	**Value**	**Contingency**
0%	$122,955,330	-22.18%
5%	$154,673,358	-2.13%
10%	$161,217,446	2.01%
15%	$165,663,479	4.82%
20%	$169,294,872	7.12%
25%	$172,575,571	9.19%
30%	$175,393,644	10.98%
35%	$177,967,458	12.60%
40%	$180,387,570	14.14%
45%	$182,710,493	15.61%
50%	$185,124,730	17.13%
55%	$187,545,037	18.66%
60%	$190,177,298	20.33%
65%	$192,738,221	21.95%
70%	$195,859,927	23.89%
75%	$198,833,139	25.81%
80%	$202,261,435	27.98%
85%	$205,942,060	30.31%
90%	$210,535,704	33.21%
95%	$217,384,613	37.55%
100%	$253,327,364	60.29%





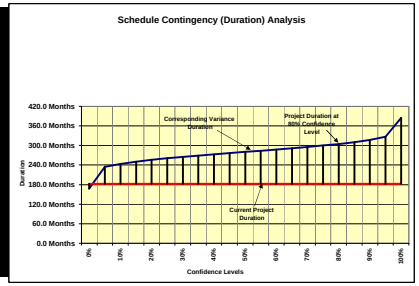


- SCHEDULE CONTINGENCY (DURATION) DEVELOPMENT -

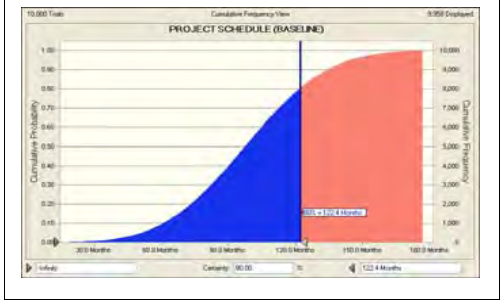
Contingency Analysis

Most Likely Schedule	182.3 Months

Confidence Level	Value	Contingency
0%	167.6 Months	-8.07%
5%	234.4 Months	28.59%
10%	243.7 Months	33.67%
15%	250.4 Months	37.37%
20%	255.9 Months	40.36%
25%	260.8 Months	43.04%
30%	265.0 Months	45.37%
35%	269.0 Months	47.54%
40%	272.9 Months	49.71%
45%	276.5 Months	51.68%
50%	280.2 Months	53.71%
55%	283.9 Months	55.73%
60%	287.7 Months	57.82%
65%	291.3 Months	59.80%
70%	295.5 Months	62.11%
75%	300.0 Months	64.54%
80%	304.7 Months	67.11%
85%	310.0 Months	70.05%
90%	317.4 Months	74.08%
95%	327.2 Months	79.48%
100%	385.0 Months	111.18%





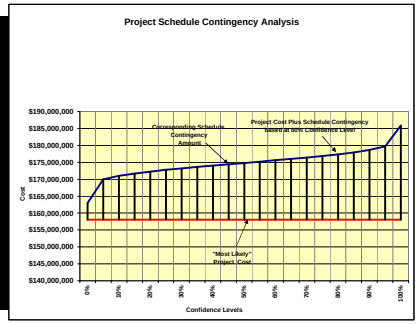


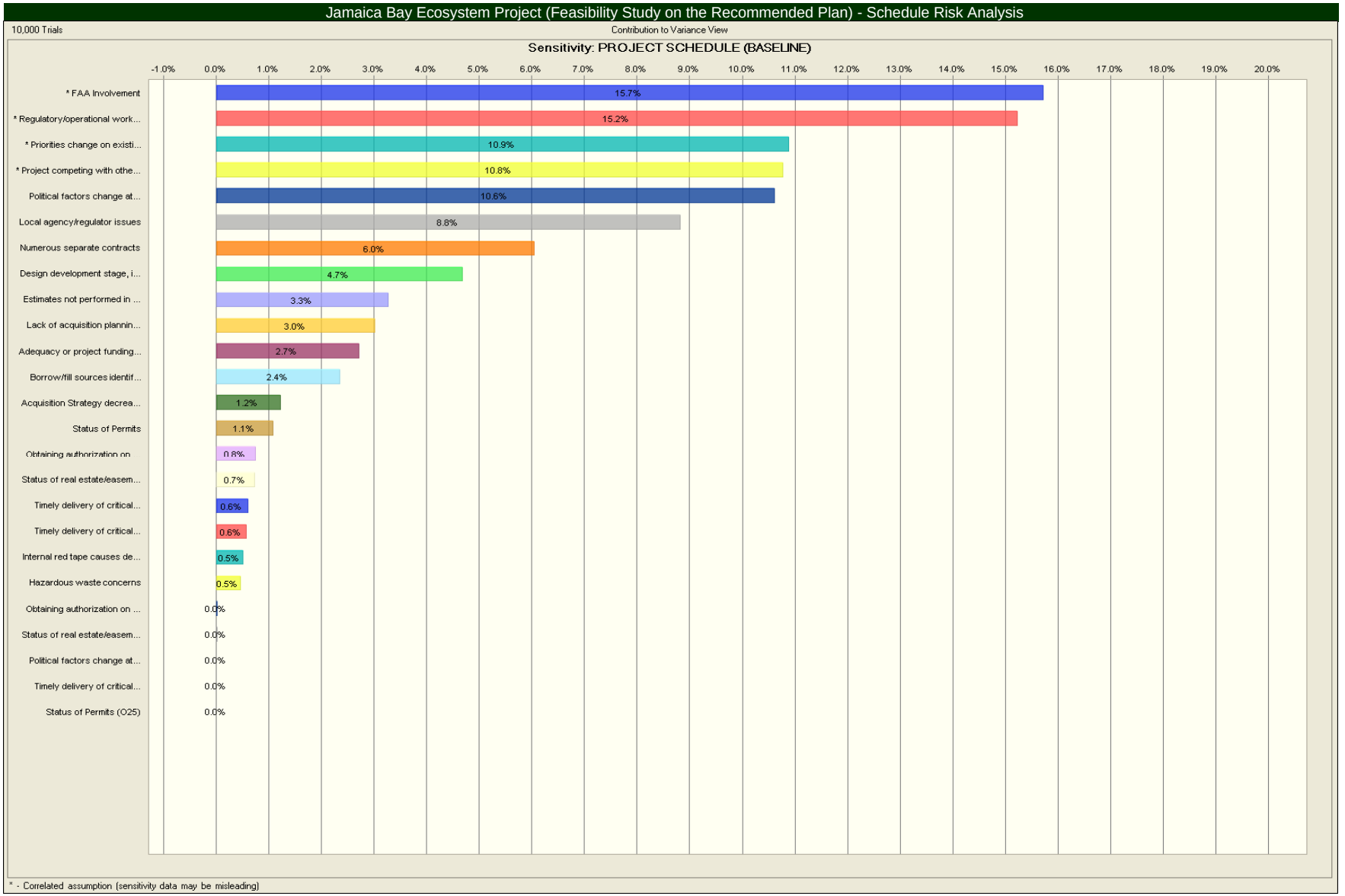
- SCHEDULE CONTINGENCY (AMOUNT) DEVELOPMENT -

Contingency Analysis

Most Likely Cost Estimate	$158,045,950

Confidence Level	Value	Contingency
0%	$4,940,484	3.13%
5%	$11,952,717	7.56%
10%	$12,924,649	8.18%
15%	$13,631,896	8.63%
20%	$14,203,592	8.99%
25%	$14,717,068	9.31%
30%	$15,161,522	9.59%
35%	$15,577,108	9.86%
40%	$15,992,676	10.12%
45%	$16,368,416	10.36%
50%	$16,757,424	10.60%
55%	$17,143,000	10.85%
60%	$17,543,469	11.10%
65%	$17,921,573	11.34%
70%	$18,363,228	11.62%
75%	$18,829,438	11.91%
80%	$19,320,466	12.22%
85%	$19,882,907	12.58%
90%	$20,653,626	13.07%
95%	$21,686,510	13.72%
100%	$27,750,105	17.56%



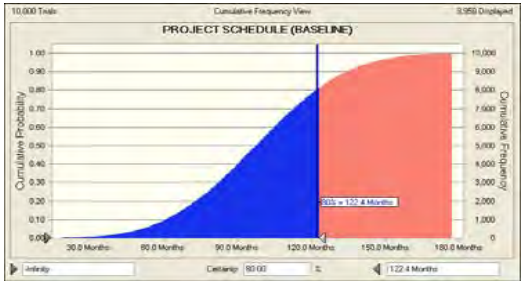

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis
10,000 Trials
Contribution to Variance View
Sensitivity: PROJECT SCHEDULE (BASELINE)
-1.0% 0.0% 1.0% 2.0% 3.0% 4.0% 5.0% 6.0% 7.0% 8.0% 9.0% 10.0% 11.0% 12.0% 13.0% 14.0% 15.0% 16.0% 17.0% 18.0% 19.0% 20.0%
* FAA Involvement 15.7%
* Regulatory/operational work... 15.2%
* Priorities change on existi... 10.9%
* Project competing with othe... 10.8%
Political factors change at... 10.6%
Local agency/regulator issues 8.8%
Numerous separate contracts 6.0%
Design development stage, i... 4.7%
Estimates not performed in ... 3.3%
Lack of acquisition plannin... 3.0%
Adequacy or project funding... 2.7%
Borrow/fill sources identif... 2.4%
Acquisition Strategy decrea... 1.2%
Status of Permits 1.1%
Obtaining authorization on 0.8%
Status of real estate/easem... 0.7%
Timely delivery of critical... 0.6%
Timely delivery of critical... 0.6%
Internal red tape causes de... 0.5%
Hazardous waste concerns 0.5%
Obtaining authorization on ... 0.0%
Status of real estate/easem... 0.0%
Political factors change at... 0.0%
Timely delivery of critical... 0.0%
Status of Permits (O25) 0.0%
* - Correlated assumption (sensitivity data may be misleading)

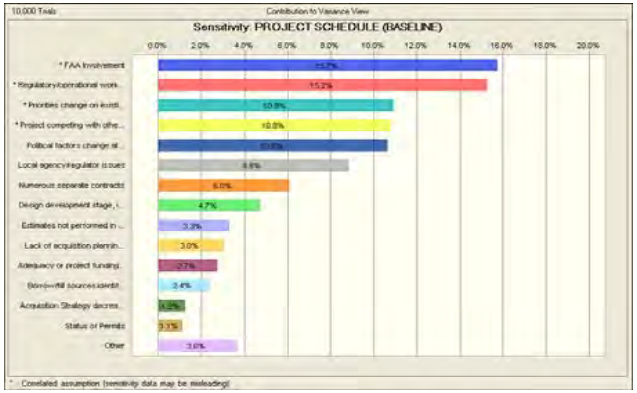
Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis Model

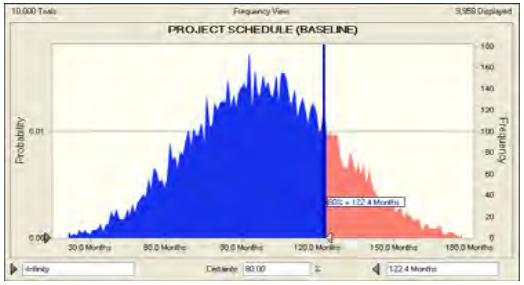
Risk No.	Risk/Opportunity Event	Project Schedule: Likelihood*	Impact*	Risk Level*	Variance Distribution	Correlation to Other(s)	Crystal Ball Simulation Expected Values (mos.): Low	Most Likely	High		Crystal Ball Simulation Expected Values (%s): Low	Most Likely	High	
Internal Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)														
PROJECT & PROGRAM MGMT														
PPM-1	Project competing with other projects	Likely	Critical	High	Uniform		0.0 Months	0.0 Months	24.0 Months		0.00%	0.00%	13.16%	
PPM-3	Internal red tape causes delays in getting decisions	Very Likely	Significant	High	Triangular		-3.0 Months	0.0 Months	9.0 Months		-1.65%	0.00%	4.94%	
PPM-4	Local agency/regulator issues	Very Likely	Critical	High	Uniform		-9.0 Months	0.0 Months	24.0 Months		-4.94%	0.00%	13.16%	
PPM-5	Priorities change on existing program	Unlikely	Significant	Moderate	Yes-No/Uniform		0.0 Months	0.0 Months	24.0 Months		0.00%	0.00%	13.16%	0 0
CONTRACT ACQUISITION RISKS														
CA-1	Lack of acquisition planning support/involvement	Likely	Marginal	Moderate	Triangular		-9.0 Months	0.0 Months	18.0 Months		-4.94%	0.00%	9.87%	
CA-2	Numerous separate contracts	Very Likely	Marginal	Moderate	Triangular		-12.0 Months	0.0 Months	24.0 Months		-6.58%	0.00%	13.16%	
CA-3	Acquisition Strategy decreasing competition	Very Likely	Marginal	Moderate	Uniform		-3.0 Months	0.0 Months	9.0 Months		-1.65%	0.00%	4.94%	
TECHNICAL RISKS														
GE-4	Design development stage, incomplete or preliminary	Very Likely	Marginal	Moderate	Triangular		-9.0 Months	0.0 Months	24.0 Months		-4.94%	0.00%	13.16%	
GE-5	Incomplete studies	Unlikely	Significant	Moderate						*Removed from Cost Risk Study - This item is captured by Risk GE-4*				
GE-7	Borrow/fill sources identified/secured	Likely	Critical	High	Triangular		-6.0 Months	0.0 Months	9.0 Months		-3.29%	0.00%	4.94%	
GE-8	Hazardous waste concerns	Likely	Marginal	Moderate	Uniform		-3.0 Months	0.0 Months	9.0 Months		-1.65%	0.00%	4.94%	
LANDS AND DAMAGES RISKS														
LR-1	Status of real estate/easement acquisition	Unlikely	Significant	Moderate	Yes-No/Uniform		0.0 Months	0.0 Months	12.0 Months		0.00%	0.00%	6.58%	0 $0
REGULATORY AND ENVIRONMENTAL RISKS														
RE-3	Status of Permits	Very Likely	Marginal	Moderate	Yes-No/Uniform		0.0 Months	0.0 Months	12.0 Months		0.00%	0.00%	6.58%	0 0
CONSTRUCTION RISKS														
CON-1	FAA Involvement	Likely	Marginal	Moderate	Triangular		-6.0 Months	0.0 Months	18.0 Months		-3.29%	0.00%	9.87%	
CON-3	Regulatory/operational work windows	Likely	Marginal	Moderate	Triangular		-6.0 Months	0.0 Months	18.0 Months		-3.29%	0.00%	9.87%	
SPRING CREEK RISKS														
SC-1	Timely delivery of critical GFE (Spring Creek)	Likely	Marginal	Moderate	Yes-No/Uniform		-3.0 Months	0.0 Months	9.0 Months		-1.65%	0.00%	4.94%	0 0
DEAD HORSE BAY RISKS														
DH-1	Timely delivery of critical GFE (Dead Horse Bay)	Likely	Marginal	Moderate	Yes-No/Uniform		-3.0 Months	0.0 Months	9.0 Months		-1.65%	0.00%	4.94%	0 0
PAERDEGAT BASIN RISKS														
PB-1	Estimates not performed in CEDEP	Likely	Significant	High	Triangular		-12.0 Months	0.0 Months	18.0 Months		-6.58%	0.00%	9.87%	
Programmatic Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)														
PR-1	Adequacy or project funding (incremental)	Very Likely	Significant	High	Uniform		0.0 Months	0.0 Months	24.0 Months		0.00%	0.00%	13.16%	
PR-2	Obtaining authorization on a timely basis	Very Likely	Critical	High	Yes-No/Uniform		0.0 Months	0.0 Months	12.0 Months		0.00%	0.00%	6.58%	0 0
PR-4	Political factors change at local, state or federal level	Very Likely	Marginal	Moderate	Yes-No/Uniform		-12.0 Months	0.0 Months	24.0 Months		-6.58%	0.00%	13.16%	0 0
								0.0 Months		*Not Part of Study - Placeholder for Project Summation Purposes Only*				

Percentages are calculated as the variance from the assumption value to facilitate iteration of the model should the cost values change throughout the project phases. Uniform distribution percentages reflect variation from the total project cost.

	Percentile	Baseline Schedule Duration	Contingency	Baseline w/ Contingency	Contingency %
PROJECT SCHEDULE (BASELINE)	0%	182.3 Months	**-14.7 Months**	**167.6 Months**	**-8.07%**
	5%	182.3 Months	**52.1 Months**	**234.4 Months**	**28.59%**
	10%	182.3 Months	**61.4 Months**	**243.7 Months**	**33.67%**
	15%	182.3 Months	**68.1 Months**	**250.4 Months**	**37.37%**
	20%	182.3 Months	**73.6 Months**	**255.9 Months**	**40.36%**
	25%	182.3 Months	**78.5 Months**	**260.8 Months**	**43.04%**
	30%	182.3 Months	**82.7 Months**	**265.0 Months**	**45.37%**
	35%	182.3 Months	**86.7 Months**	**269.0 Months**	**47.54%**
	40%	182.3 Months	**90.6 Months**	**272.9 Months**	**49.71%**
	45%	182.3 Months	**94.2 Months**	**276.5 Months**	**51.68%**
	50%	182.3 Months	**97.9 Months**	**280.2 Months**	**53.71%**
	55%	182.3 Months	**101.6 Months**	**283.9 Months**	**55.73%**
	60%	182.3 Months	**105.4 Months**	**287.7 Months**	**57.82%**
	65%	182.3 Months	**109.0 Months**	**291.3 Months**	**59.80%**
	70%	182.3 Months	**113.2 Months**	**295.5 Months**	**62.11%**
	75%	182.3 Months	**117.7 Months**	**300.0 Months**	**64.54%**
	80%	182.3 Months	**122.4 Months**	**304.7 Months**	**67.11%**
	85%	182.3 Months	**127.7 Months**	**310.0 Months**	**70.05%**
	90%	182.3 Months	**135.1 Months**	**317.4 Months**	**74.08%**
	95%	182.3 Months	**144.9 Months**	**327.2 Months**	**79.48%**
	100%	182.3 Months	**202.7 Months**	**385.0 Months**	**111.18%**







Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis Model	
Estimated Total Project Cost (Price Level)	**$158,045,950**
Max. Anticipated Annual Amount	**$10,408,634**
Enter Current OMB Escalation Rate	**1.80%**
Enter Current Project Location Escalation Rate	**2.07%**
Enter Assumed Hotel Rate	**8.00%**

	Date	Escalation Delta Amount	Hotel Amount	Total Schedule Contingency
Enter Current Project Start	1-Dec-08			
Enter Baseline Project Completion	7-Feb-24	$6,483,867.56		$6,483,867.56
Project Completion at 0% Confidence	16-Nov-22	$5,960,690.52	($1,020,206.05)	$4,940,484.47
Project Completion at 5% Confidence	10-Jun-28	$8,337,701.70	$3,615,014.96	$11,952,716.67
Project Completion at 10% Confidence	19-Mar-29	$8,667,167.94	$4,257,480.95	$12,924,648.89
Project Completion at 15% Confidence	10-Oct-29	$8,906,911.05	$4,724,984.97	$13,631,896.02
Project Completion at 20% Confidence	25-Mar-30	$9,100,704.86	$5,102,886.91	$14,203,591.77
Project Completion at 25% Confidence	21-Aug-30	$9,274,763.33	$5,442,304.54	$14,717,067.87
Project Completion at 30% Confidence	28-Dec-30	$9,425,424.75	$5,736,097.43	$15,161,522.18
Project Completion at 35% Confidence	27-Apr-31	$9,566,300.28	$6,010,807.62	$15,577,107.90
Project Completion at 40% Confidence	26-Aug-31	$9,707,169.67	$6,285,505.84	$15,992,675.51
Project Completion at 45% Confidence	13-Dec-31	$9,834,538.34	$6,533,877.39	$16,368,415.72
Project Completion at 50% Confidence	3-Apr-32	$9,966,404.60	$6,791,019.34	$16,757,423.94
Project Completion at 55% Confidence	24-Jul-32	$10,097,107.37	$7,045,892.43	$17,142,999.80
Project Completion at 60% Confidence	17-Nov-32	$10,232,858.58	$7,310,610.11	$17,543,468.70
Project Completion at 65% Confidence	7-Mar-33	$10,361,028.75	$7,560,544.58	$17,921,573.33
Project Completion at 70% Confidence	13-Jul-33	$10,510,740.99	$7,852,486.56	$18,363,227.55
Project Completion at 75% Confidence	25-Nov-33	$10,668,777.25	$8,160,660.53	$18,829,437.78
Project Completion at 80% Confidence	16-Apr-34	$10,835,226.45	$8,485,239.92	$19,320,466.37
Project Completion at 85% Confidence	27-Sep-34	$11,025,883.05	$8,857,024.23	$19,882,907.28
Project Completion at 90% Confidence	8-May-35	$11,287,141.88	$9,366,484.37	$20,653,626.25
Project Completion at 95% Confidence	2-Mar-36	$11,637,269.54	$10,049,240.55	$21,686,510.10
Project Completion at 100% Confidence	25-Dec-40	$13,692,711.12	$14,057,394.19	$27,750,105.31

Entry Required
Do Not Overwrite
Summary Data -- Do Not Overwrite

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

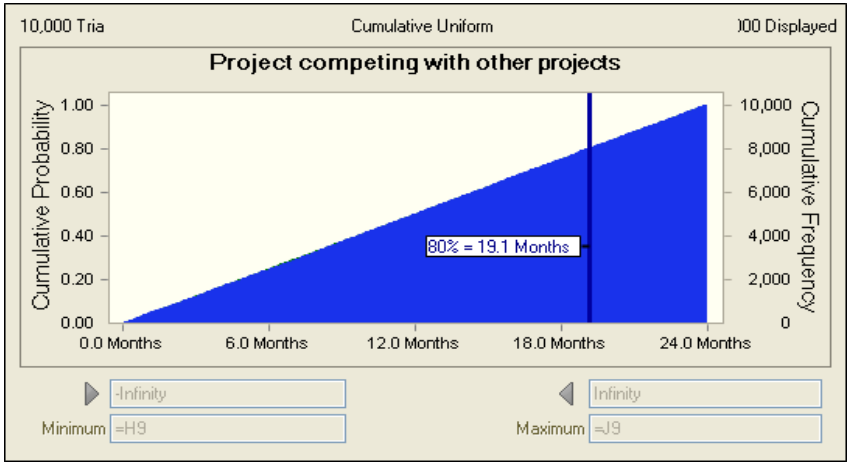
Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-1	Project competing with other projects	0.0 Months	0.0 Months	24.0 Months

Notes: This item captures the risk that competing for resources and priority with other projects will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes no change from the baseline schedule.

High High assumes that the project does not obtain the resources and priority above other projects, causing up to 24 months of delay on the overall project schedule.



Assumption: **Project competing with other projects**

Percentile	Assumption values
0%	0.0 Months
10%	2.5 Months
20%	4.8 Months
30%	7.3 Months
40%	9.6 Months
50%	12.0 Months
60%	14.4 Months
70%	16.7 Months
80%	19.1 Months
90%	21.6 Months
100%	24.0 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

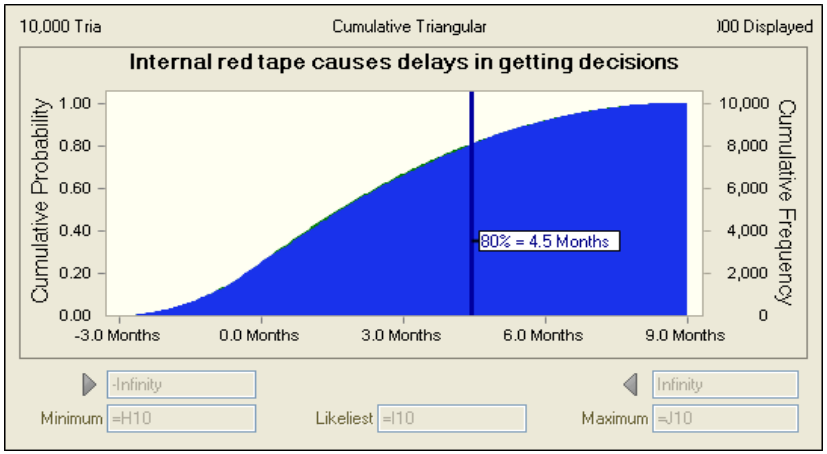
Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-3	Internal red tape causes delays in getting decisions	-3.0 Months	0.0 Months	9.0 Months

Notes: This item captures the risk that internal red tape causes delays in obtaining decisions that will ultimately cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes that internal red tape issues hinder the project implementation less than anticipated, saving up to 3 months on the overall project schedule.

High High assumes that internal red tape does cause delays in obtaining decisions, causing up to 9 months of delay on the overall project schedule.



Assumption: **Internal red tape causes delays in getting decisions**

Percentile	Assumption values
0%	'-3.0 Months
10%	'-1.1 Months
20%	'-0.3 Months
30%	0.3 Months
40%	1.0 Months
50%	1.7 Months
60%	2.5 Months
70%	3.4 Months
80%	4.5 Months
90%	5.8 Months
100%	8.9 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

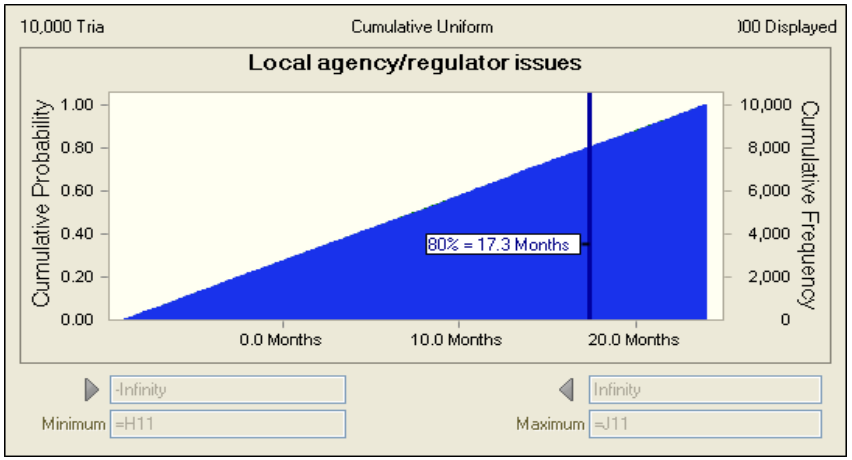
Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-4	Local agency/regulator issues	-9.0 Months	0.0 Months	24.0 Months

Notes: This item captures the risk that local agency/regulator issues will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes that local agency and regulator issues impact the implementation schedule less than anticipated, saving up to 9 months on the overall project schedule.

High High assumes that local agency/regulator issues do present significant challenges, causing up to 24 months of delay on the overall project schedule.



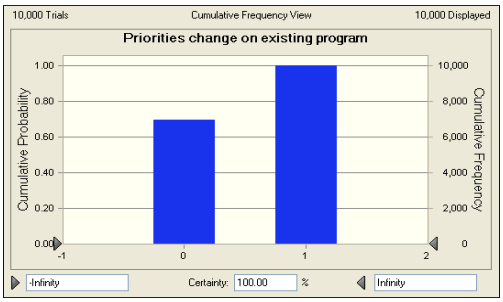
Assumption: **Local agency/regulator issues**

Percentile	Assumption values
0%	'-9.0 Months
10%	'-5.7 Months
20%	'-2.5 Months
30%	0.9 Months
40%	4.2 Months
50%	7.6 Months
60%	10.8 Months
70%	13.9 Months
80%	17.3 Months
90%	20.8 Months
100%	24.0 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

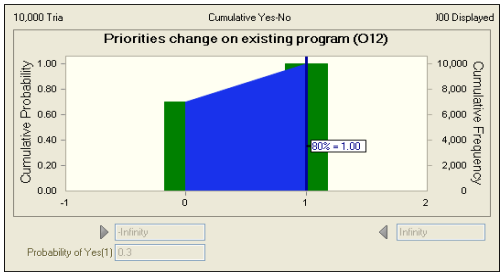
Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-5	Priorities change on existing program	0.0 Months	0.0 Months	24.0 Months

Notes: This item captures the risk that priorities may change on the existing program will cause a variance from the baseline schedule for the project.
Likely Likely assumes no change from the baseline schedule.
Low Low assumes no change from the baseline schedule.
High High assumes that priorities change on the existing program, causing up to 24 months of delay on the overall project schedule.



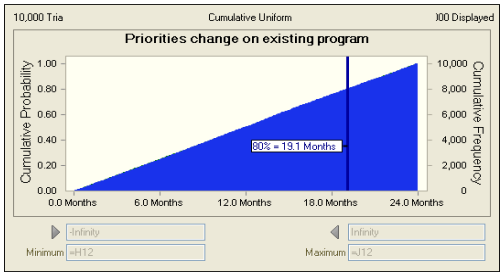
Forecast: **Priorities change on existing program**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	1
80%	1
90%	1
100%	1



Assumption: **Priorities change on existing program**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	1
80%	1
90%	1
100%	1



Assumption: **Priorities change on existing program**

Percentile	Assumption values
0%	0.0 Months
10%	2.5 Months
20%	4.9 Months
30%	7.3 Months
40%	9.6 Months
50%	12.0 Months
60%	14.2 Months
70%	16.7 Months
80%	19.1 Months
90%	21.7 Months
100%	24.0 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

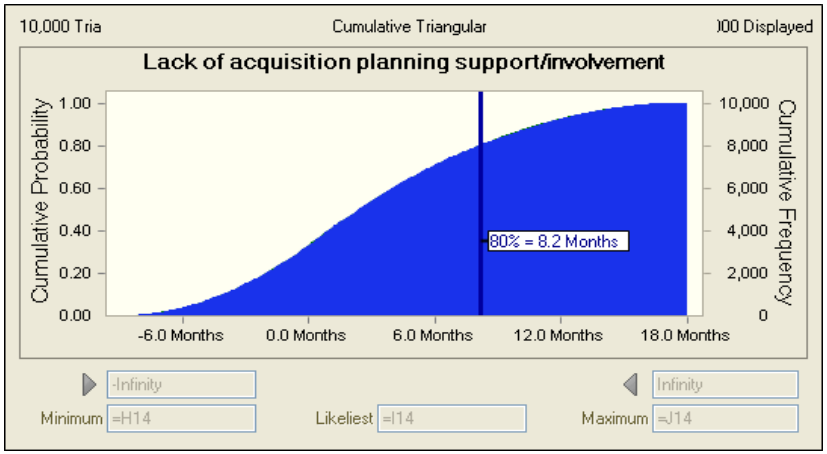
Risk Refer No.	Risk Event	Low	Most Likely	High
CA-1	Lack of acquisition planning support/involvement	-9.0 Months	0.0 Months	18.0 Months

Notes: This item captures the risk that lack of acquisition planning support/involvement will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes that the lack of acquisition planning and support actually present an opportunity to develop more favorable contracting situations than anticipated, saving up to

High High assumes that the lack of acquisition planning and support presents issues for the delivery of contracts, causing up to 18 months of delay on the overall project schedule.



Assumption: **Lack of acquisition planning support/involvement**

Percentile	Assumption values
0%	'-8.8 Months
10%	'-4.1 Months
20%	'-2.0 Months
30%	'-0.4 Months
40%	1.0 Months
50%	2.4 Months
60%	4.0 Months
70%	5.9 Months
80%	8.2 Months
90%	11.1 Months
100%	17.7 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

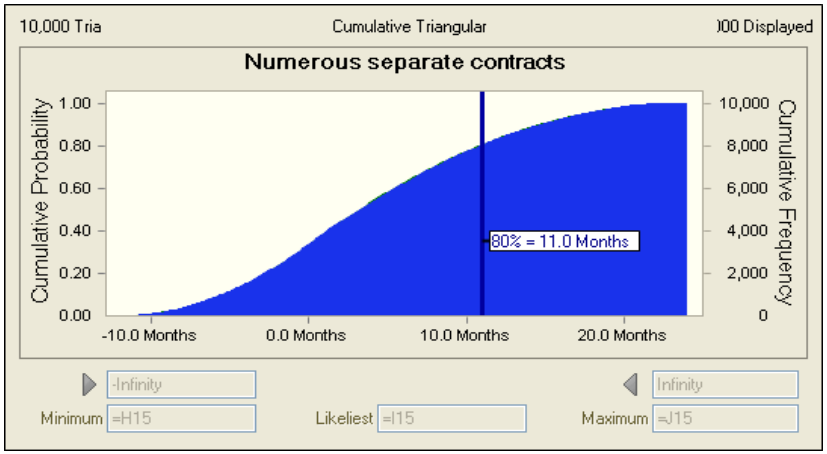
Risk Refer No.	Risk Event	Low	Most Likely	High
CA-2	Numerous separate contracts	-12.0 Months	0.0 Months	24.0 Months

Notes: This item captures the risk that having numerous separable contracts will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes fewer contracts are utilized than anticipated, saving up to 12 months on the overall project schedule.

High High assumes that up to a dozen additional contracts are used, requiring at a minimum 60 days each for pre-award activities, causing up to 24 months of delay on the overall project schedule.



Assumption: **Numerous separate contracts**

Percentile	Assumption values
0%	'-11.8 Months
10%	'-5.5 Months
20%	'-2.7 Months
30%	'-0.6 Months
40%	1.2 Months
50%	3.3 Months
60%	5.6 Months
70%	8.1 Months
80%	11.0 Months
90%	14.8 Months
100%	23.6 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

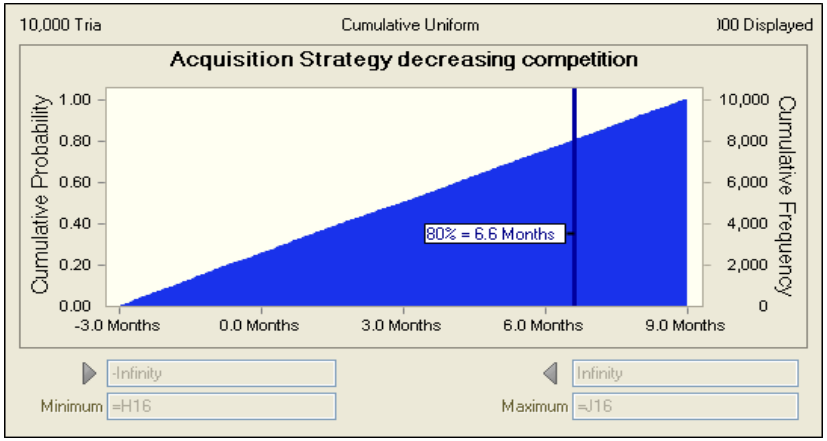
Risk Refer No.	Risk Event	Low	Most Likely	High
CA-3	Acquisition Strategy decreasing competition	-3.0 Months	0.0 Months	9.0 Months

Notes: This item captures the risk that the acquisition strategy may actually decrease competition and will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes that the acquisition strategy does not decrease competition nor has an impact the implementation schedule less than anticipated, saving up to 3 months on the overall project schedule.

High High assumes that the acquisition strategy does limit competition, causing up to 9 months of delay on the overall project schedule.



Assumption: **Acquisition Strategy decreasing competition**

Percentile	Assumption values
0%	'-3.0 Months
10%	'-1.8 Months
20%	'-0.7 Months
30%	0.5 Months
40%	1.7 Months
50%	3.0 Months
60%	4.2 Months
70%	5.4 Months
80%	6.6 Months
90%	7.8 Months
100%	9.0 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High
GE-4	Design development stage, incomplete or preliminary	-9.0 Months	0.0 Months	24.0 Months

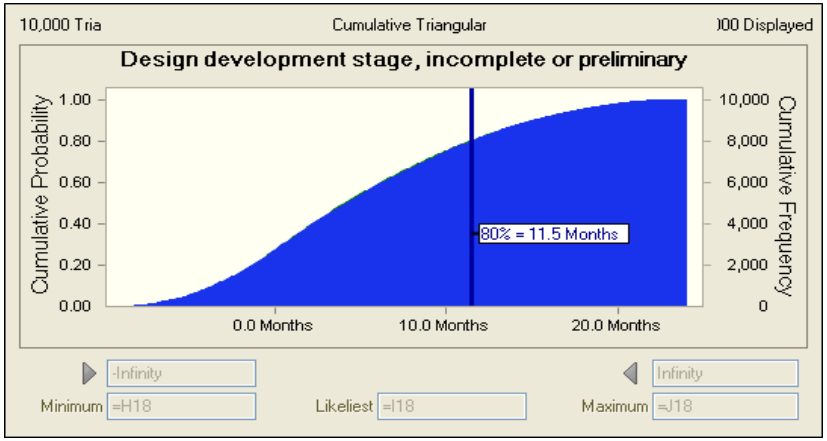
Notes:

This item captures the risk that the preliminary nature of the design development will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes that the preliminary nature of the design may actually introduce opportunity for improvement to the implementation schedule, saving up to 9 months on the overall

High High assumes that the preliminary nature of the design may lead to additional scope for the schedule, causing up to 24 months of delay on the overall project schedule.



Assumption: **Design development stage, incomplete or preliminary**

Percentile	Assumption values
0%	'-9.0 Months
10%	'-3.5 Months
20%	'-1.3 Months
30%	0.5 Months
40%	2.2 Months
50%	4.3 Months
60%	6.3 Months
70%	8.8 Months
80%	11.5 Months
90%	15.1 Months
100%	23.4 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High	
GE-5	Incomplete studies				***Removed from Cost Risk Study - This item is captured by Risk GE-4***

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

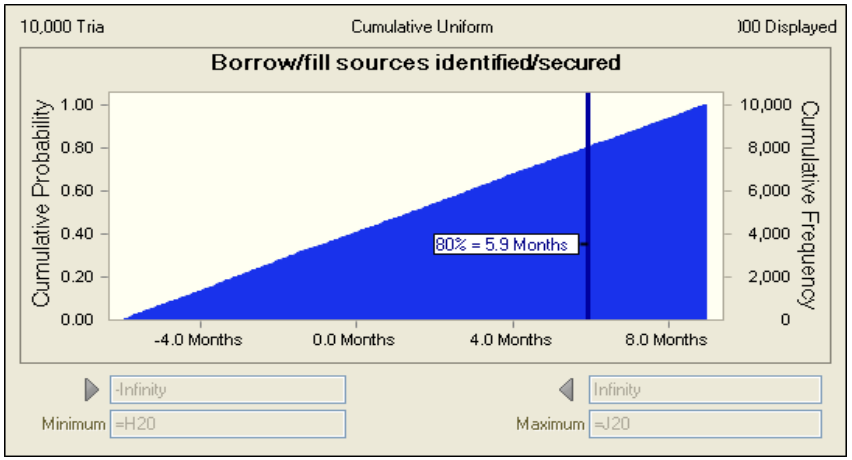
Risk Refer No.	Risk Event	Low	Most Likely	High
GE-7	Borrow/fill sources identified/secured	-6.0 Months	0.0 Months	9.0 Months

Notes: This item captures the risk that not having the borrow/fill sources identified and secured will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes that more favorable conditions for borrow and fill sources are identified than anticipated, saving up to 6 months on the overall project schedule.

High High assumes that less favorable borrow and fill site scenarios occur, causing up to 9 months of delay on the overall project schedule.



Assumption: **Borrow/fill sources identified/secured**

Percentile	Assumption values
0%	'-6.0 Months
10%	'-4.5 Months
20%	'-3.1 Months
30%	'-1.7 Months
40%	'-0.1 Months
50%	1.4 Months
60%	2.9 Months
70%	4.4 Months
80%	5.9 Months
90%	7.5 Months
100%	9.0 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

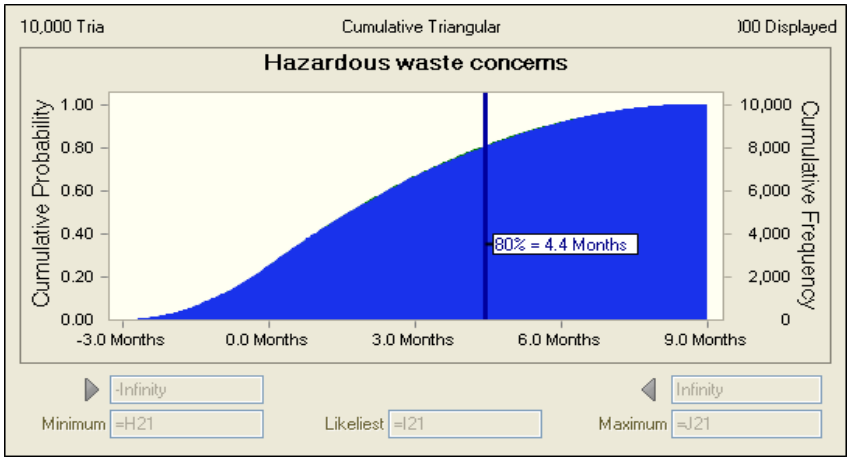
Risk Refer No.	Risk Event	Low	Most Likely	High
GE-8	Hazardous waste concerns	-3.0 Months	0.0 Months	9.0 Months

Notes: This item captures the risk that hazardous waste issues will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes that hazardous waste concerns impact the implementation schedule less than anticipated, saving up to 3 months on the overall project schedule.

High High assumes that hazardous waste concerns become significant issues for efficiency, causing up to 9 months of delay on the overall project schedule.



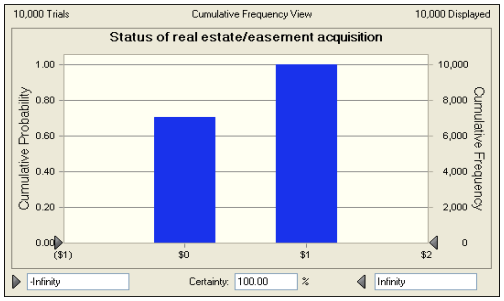
Assumption: **Hazardous waste concerns**

Percentile	Assumption values
0%	'-2.9 Months
10%	'-1.1 Months
20%	'-0.3 Months
30%	0.3 Months
40%	1.0 Months
50%	1.7 Months
60%	2.5 Months
70%	3.4 Months
80%	4.4 Months
90%	5.8 Months
100%	8.8 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

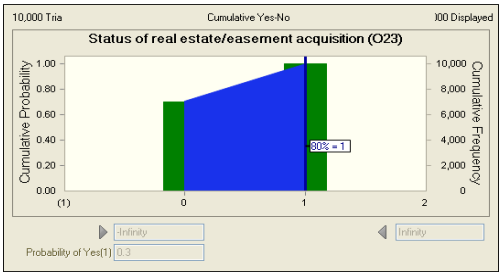
Risk Refer No.	Risk Event	Low	Most Likely	High
LR-1	Status of real estate/easement acquisitior	0.0 Months	0.0 Months	12.0 Months

Notes: This item captures the risk that not obtaining the real estate or easements in a timely manner will cause a variance from the baseline schedule for the project.
Likely Likely assumes no change from the baseline schedule.
Low Low assumes no change from the baseline schedule.
High High assumes that not obtaining the real estate and easements in a timely manner could cause up to 12 months of delay on the overall project schedule.



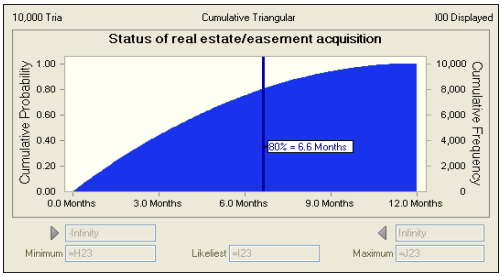
Forecast: **Status of real estate/easement acquisition**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	0
80%	1
90%	1
100%	1



Assumption: **Status of real estate/easement acquisition**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	0
80%	1
90%	1
100%	1



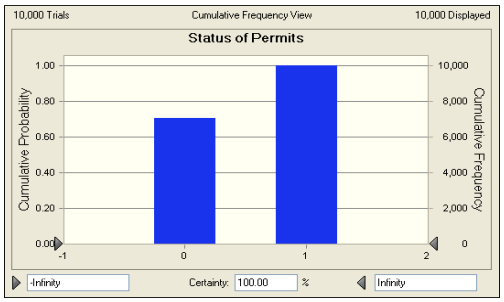
Assumption: **Status of real estate/easement acquisition**

Percentile	Assumption values
0%	0.0 Months
10%	0.6 Months
20%	1.3 Months
30%	2.0 Months
40%	2.7 Months
50%	3.5 Months
60%	4.4 Months
70%	5.5 Months
80%	6.6 Months
90%	8.2 Months
100%	12.0 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

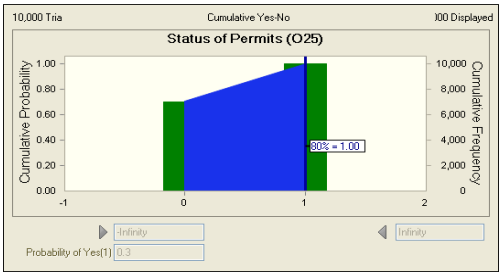
Risk Refer No.	Risk Event	Low	Most Likely	High
RE-3	Status of Permits	0.0 Months	0.0 Months	12.0 Months

Notes: This item captures the risk that not obtaining permits on a timely basis will cause a variance from the baseline schedule for the project.
Likely Likely assumes no change from the baseline schedule.
Low Low assumes no change from the baseline schedule.
High High assumes that there are significant challenges in obtaining permits, delaying the overall project schedule by up to 12 months.



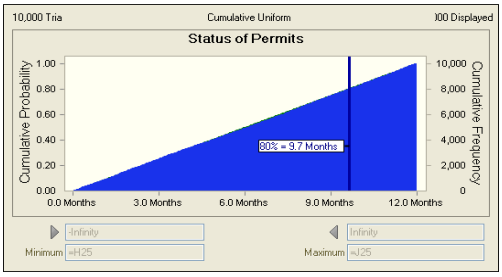
Forecast: **Status of Permits**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	0
80%	1
90%	1
100%	1



Assumption: **Status of Permits**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	0
80%	1
90%	1
100%	1



Assumption: **Status of Permits**

Percentile	Assumption values
0%	0.0 Months
10%	1.2 Months
20%	2.4 Months
30%	3.6 Months
40%	4.9 Months
50%	6.1 Months
60%	7.3 Months
70%	8.5 Months
80%	9.7 Months
90%	10.9 Months
100%	12.0 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

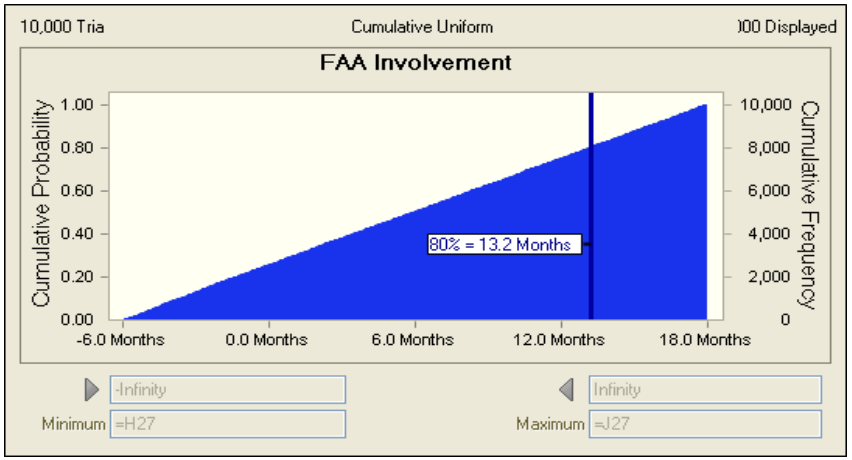
Risk Refer No.	Risk Event	Low	Most Likely	High
CON-1	FAA Involvement	-6.0 Months	0.0 Months	18.0 Months

Notes: This item captures the risk that the project areas having limited transportation and haul routes available will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes that issues in coordinating with the FAA impact the implementation schedule less than anticipated, saving up to 6 months on the overall project schedule.

High High assumes that there are significant challenges in coordinating with the FAA, causing up to 18 months of delay on the overall project schedule.



Assumption: **FAA Involvement**

Percentile	Assumption values
0%	'-6.0 Months
10%	'-3.7 Months
20%	'-1.4 Months
30%	1.1 Months
40%	3.5 Months
50%	5.9 Months
60%	8.3 Months
70%	10.7 Months
80%	13.2 Months
90%	15.6 Months
100%	18.0 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

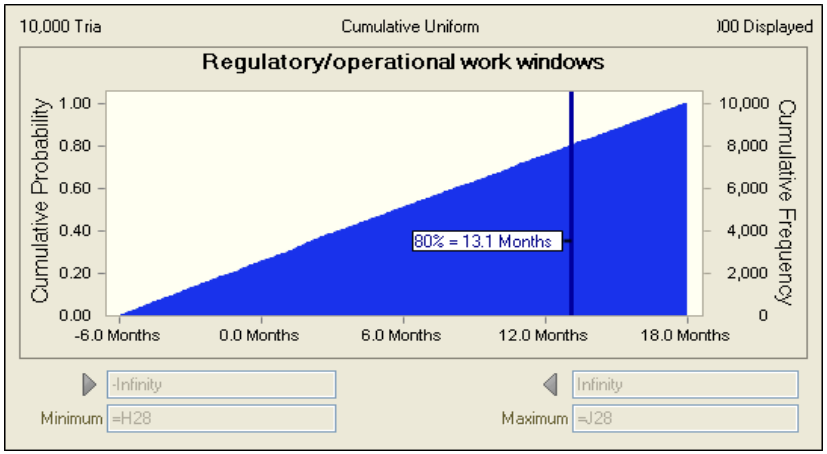
Risk Refer No.	Risk Event	Low	Most Likely	High
CON-3	Regulatory/operational work windows	-6.0 Months	0.0 Months	18.0 Months

Notes: This item captures the risk that regulatory and operational work window constraints will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes that regulatory or operational work window constraints are not as restrictive as anticipated, saving up to 6 months on the overall project schedule.

High High assumes that regulatory and operational work window constraints do present significant challenges for efficiency, causing up to 18 months of delay on the overall project schedule.



Assumption: **Regulatory/operational work windows**

Percentile	Assumption values
0%	'-6.0 Months
10%	'-3.7 Months
20%	'-1.3 Months
30%	1.1 Months
40%	3.3 Months
50%	5.8 Months
60%	8.2 Months
70%	10.7 Months
80%	13.1 Months
90%	15.6 Months
100%	18.0 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

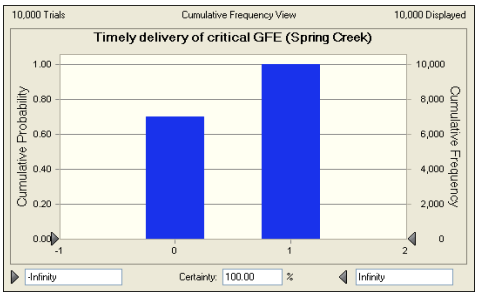
Risk Refer No.	Risk Event	Low	Most Likely	High
SC-1	Timely delivery of critical GFE	-3.0 Months	0.0 Months	9.0 Months

Notes: This item captures the risk that not receiving plant material for Spring Creek on a timely basis will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

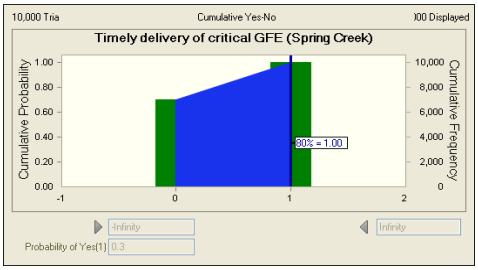
Low Low assumes that Government furnished plant material for Spring Creek is supplied in a timely manner, saving up to 3 months on the overall project schedule.

High High assumes that there are significant delays associated with the Government furnished plant material for Spring Creek, causing up to 9 months of delay on the overall project schedule.



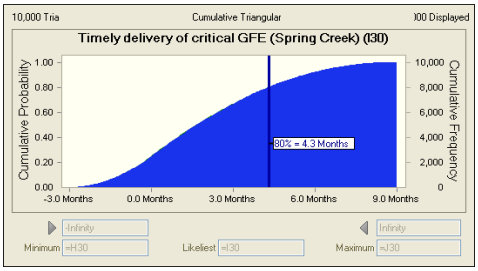
Forecast: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	1
80%	1
90%	1
100%	1



Assumption: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	1
80%	1
90%	1
100%	1



Assumption: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	'-2.9 Months
10%	'-1.1 Months
20%	'-0.3 Months
30%	0.3 Months
40%	1.0 Months
50%	1.7 Months
60%	2.5 Months
70%	3.3 Months
80%	4.3 Months
90%	5.7 Months
100%	8.9 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

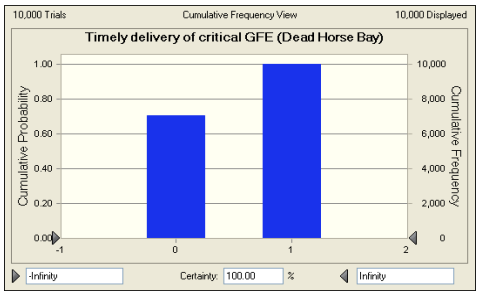
Risk Refer No.	Risk Event	Low	Most Likely	High
DH-1	Timely delivery of critical GFE	-3.0 Months	0.0 Months	9.0 Months

Notes: This item captures the opportunity that not receiving plant material for Dead Horse Bay on a timely basis will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

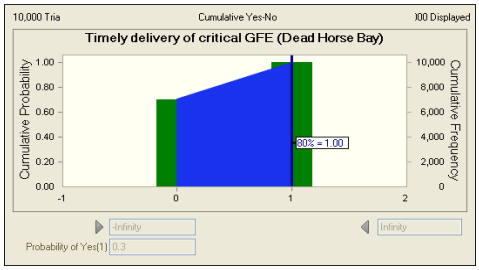
Low Low assumes that Government furnished plant material for Dead Horse Bay is supplied in a timely manner, saving up to 3 months on the overall project schedule.

High High assumes that there are significant delays associated with the Government furnished plant material for Dead Horse Bay, causing up to 9 months of delay on the overall project schedule.



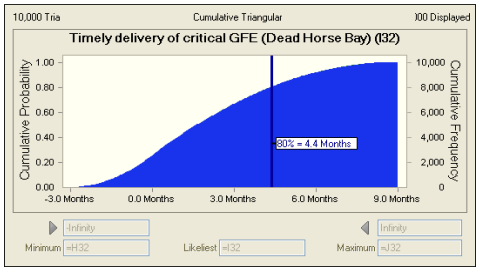
Forecast: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	0
80%	1
90%	1
100%	1



Assumption: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	0
80%	1
90%	1
100%	1



Assumption: **Timely delivery of critical GFE**

Percentile	Assumption values
0%	'-3.0 Months
10%	'-1.1 Months
20%	'-0.3 Months
30%	0.3 Months
40%	0.9 Months
50%	1.6 Months
60%	2.5 Months
70%	3.3 Months
80%	4.4 Months
90%	5.7 Months
100%	8.8 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

Risk Refer No.	Risk Event	Low	Most Likely	High
PB-1	Estimates not performed in CEDEP	-12.0 Months	0.0 Months	18.0 Months

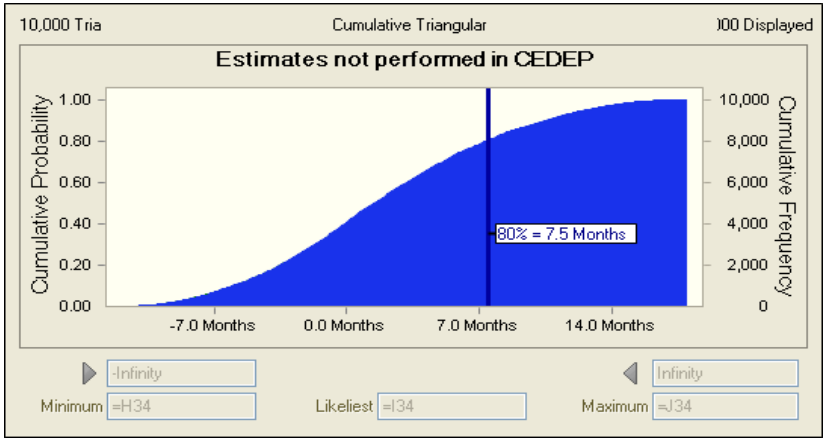
Notes: This item captures the risk that not having estimates performed in CEDEP for Paerdegat Basin will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low

Low assumes that performing the estimates in CEDEP could actually present opportunity for increased effective work time, saving up to 12 months on the overall project schedule.

High High assumes that using CEDEP to perform the dredging estimates could reveal incorrect assumptions regarding effective work time, causing up to 18 months of delay on the overall project schedule.



Assumption: **Estimates not performed in CEDEP**

Percentile	Assumption values
0%	'-11.8 Months
10%	'-6.0 Months
20%	'-3.5 Months
30%	'-1.7 Months
40%	'-0.1 Months
50%	1.5 Months
60%	3.2 Months
70%	5.1 Months
80%	7.5 Months
90%	10.6 Months
100%	17.8 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

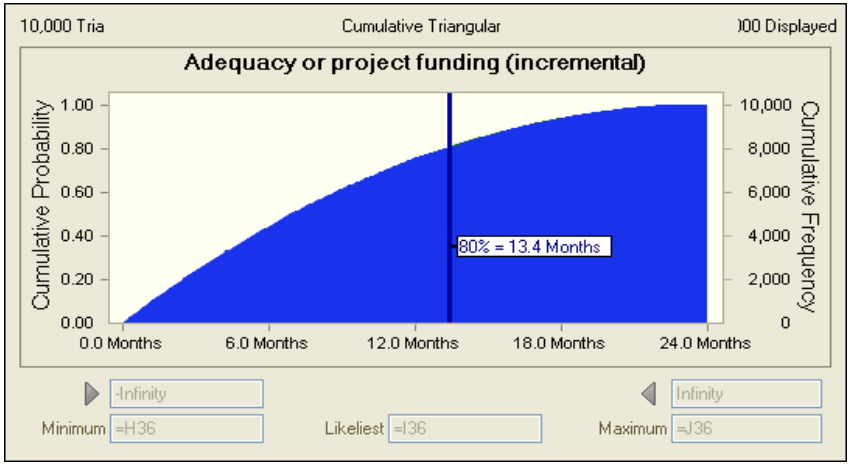
Risk Refer No.	Risk Event	Low	Most Likely	High
PR-1	Adequacy or project funding (incremental)	0.0 Months	0.0 Months	24.0 Months

Notes: This item captures the risk that challenges with receiving adequate or timely funding increments will cause a variance from the baseline schedule for the project.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes no change from the baseline schedule.

High High assumes that incremental funding issues do present significant challenges, causing up to 24 months of delay on the overall project schedule.



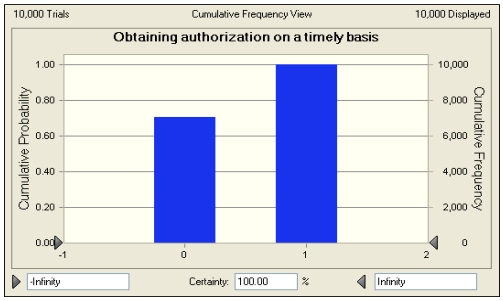
Assumption: **Adequacy or project funding (incremental)**

Percentile	Assumption values
0%	0.0 Months
10%	1.2 Months
20%	2.5 Months
30%	3.9 Months
40%	5.4 Months
50%	7.0 Months
60%	8.7 Months
70%	10.8 Months
80%	13.4 Months
90%	16.5 Months
100%	23.9 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

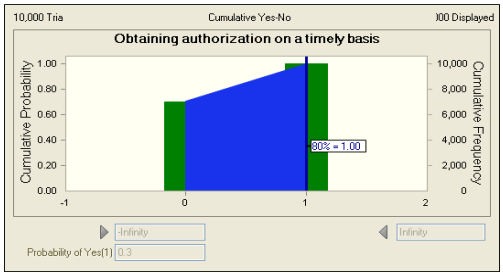
Risk Refer No.	Risk Event	Low	Most Likely	High
PR-2	Obtaining authorization on a timely basis	0.0 Months	0.0 Months	12.0 Months

Notes: This item captures the risk that not obtaining authorization on a timely basis will cause a variance from the baseline schedule for the project.
Likely Likely assumes no change from the baseline schedule.
Low Low assumes no change from the baseline schedule.
High High assumes that the project is not authorized on a timely basis, causing up to 12 months of delay on the overall project schedule.



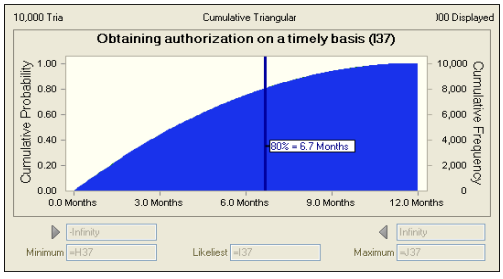
Forecast: **Obtaining authorization on a timely basis**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	0
80%	1
90%	1
100%	1



Assumption: **Obtaining authorization on a timely basis**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	0
80%	1
90%	1
100%	1



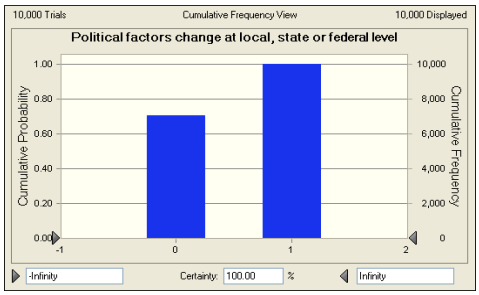
Assumption: **Obtaining authorization on a timely basis**

Percentile	Assumption values
0%	0.0 Months
10%	0.7 Months
20%	1.3 Months
30%	2.0 Months
40%	2.7 Months
50%	3.5 Months
60%	4.4 Months
70%	5.4 Months
80%	6.7 Months
90%	8.2 Months
100%	11.8 Months

Jamaica Bay Ecosystem Project (Feasibility Study on the Recommended Plan) - Schedule Risk Analysis

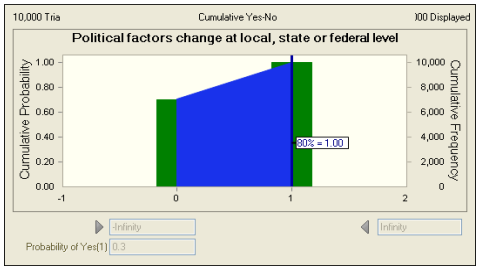
Risk Refer No.	Risk Event	Low	Most Likely	High
PR-4	Political factors change at local, state or federal level	-12.0 Months	0.0 Months	24.0 Months

Notes: This item captures the risk that political factors will cause a variance from the baseline schedule for the project.
Likely Likely assumes no change from the baseline schedule.
Low Low assumes that political factors impact the implementation schedule less than anticipated, saving up to 12 months on the overall project schedule.
High High assumes that political factors do present significant challenges, causing up to 24 months of delay on the overall project schedule.



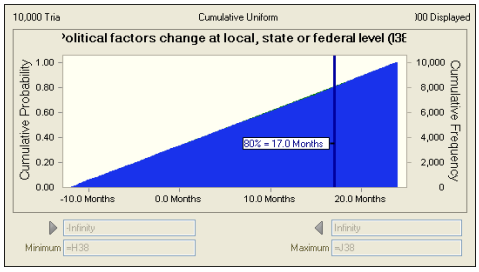
Forecast: **Political factors change at local, state or federal level**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	0
80%	1
90%	1
100%	1



Assumption: **Political factors change at local, state or federal level**

Percentile	Assumption values
0%	0
10%	0
20%	0
30%	0
40%	0
50%	0
60%	0
70%	0
80%	1
90%	1
100%	1



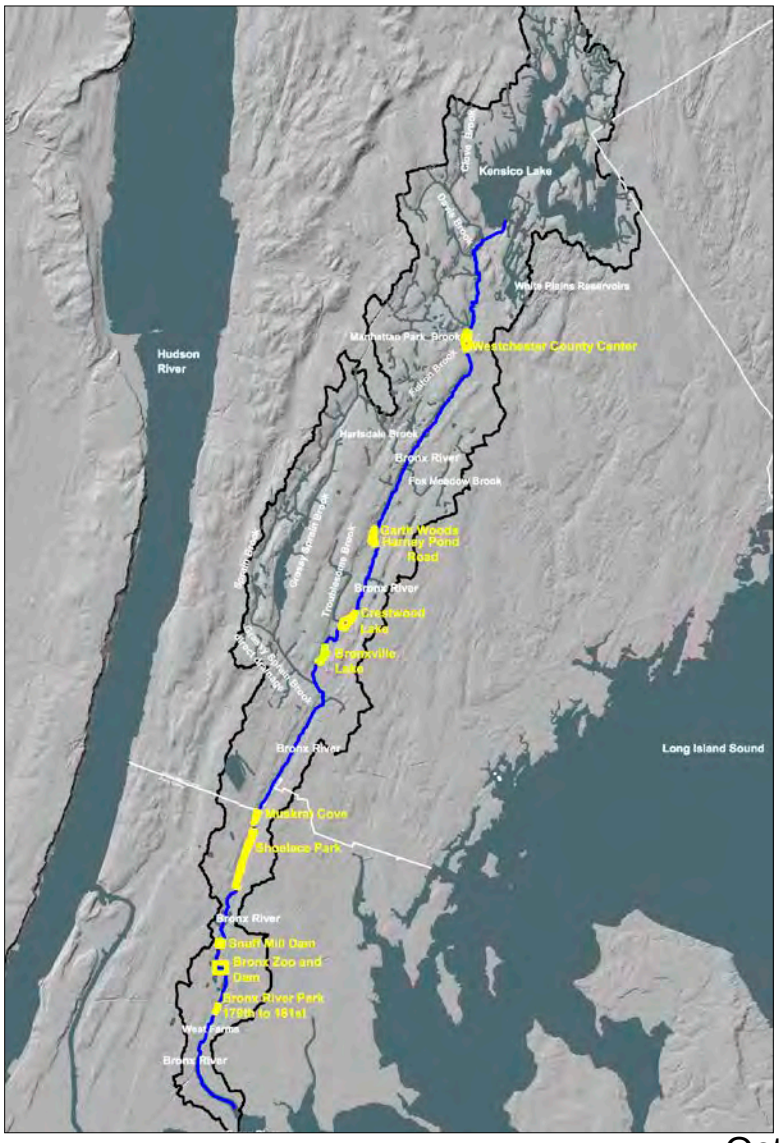
Assumption: **Political factors change at local, state or federal level**

Percentile	Assumption values
0%	'-12.0 Months
10%	'-8.5 Months
20%	'-4.8 Months
30%	'-1.3 Months
40%	2.5 Months
50%	6.1 Months
60%	9.8 Months
70%	13.5 Months
80%	17.0 Months
90%	20.4 Months
100%	24.0 Months

Attachment C-4
HRE
Bronx River: Geotechnical and Geological Report

Department Of The Army
New York District Corps of
Engineers
Jacob K. Javits Federal Building
26 Federal Plaza
New York, NY 10278-0090

Contract #W912DS-12-D-0002, Task Order #0019
Bronx River Ecosystem Restoration Feasibility Study: Geotechnical and geological report



October 24, 2014

e4sciences | Earthworks, LLC
27 Glen Road, North Entrance
Sandy Hook, Connecticut 06482
P.O. Box 178, Newtown, CT 06470
(203) 270-8100, Fax (203) 364-0480
www.e4sciences.com

All interpretations are opinions based on inferences from available geological data in literature. We cannot, and do not, guarantee the accuracy or correctness of any interpretation. We shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretations made by any of our officers, agents or employees.

Executive Summary

The United States Army Corps of Engineers (USACE-NAN) is planning to restore ecosystems within the Bronx River in Westchester and Bronx Counties in New York State.

The USACE-NAN assigned e4sciences (e4) to evaluate four sites in Westchester County and five sites in Bronx County. This report is a desktop study of the geology and the geotechnical properties of the rocks and sediments in the Bronx River valley, and particularly at the nine sites of interest. e4 mapped the geology from literature and field observations, topography using LiDAR, and soils from EPW and literature.

The Bronx River is approximate 23 miles long. It flows from Kensico Lake in the north to Hunts Point in the East River. The river is underlain by Cambrian-Ordovician and Proterozoic bedrock. The bedrock is folded and faulted. e4 determined that the river passes mostly along the Cambrian-Ordovician Inwood Marble in Westchester and the Bronx. The Inwood Marble is a softer layer that lies above the folded and faulted underlying Fordham Gneiss. The Bronx River valley is one of five roughly north-northeast/south-southwest troughs in Westchester County below the Kensico Dam in the north.

Just south of Bronxville Lake, the river follows the Inwood Marble and passes east to run for three miles along Cameron's Line, an Ordovician thrust fault just south of Bronxville.

In the Bronx, just north of the Bronx Botanical Garden, a Pleistocene fault forces the river to cross Cameron's line. The river crosses the Cambrian-Ordovician Hartland Formation to enter the East River at Hunts Point.

The Quaternary sediments in the northern Bronx River valley range from 0ft to 100ft. In southern Bronx river valley sediments are generally less than 10ft.

Rivers show three scales of meanders: (a) low-frequency long-wavelength meanders, (b) mid-frequency mid-wavelength meanders, and (c) high-frequency short-wavelength meanders. The six low-frequency long-wavelength meanders approximately 15,000ft in wavelength have an amplitude less than 500ft. Engineers most commonly measure the mid-frequency mid-wavelength meanders. In the Bronx River, these meanders show a relatively consistent wavelength of 1000ft and an amplitude less than 200ft. The high-frequency short-wavelength meanders track the variation of the thalweg. The short wavelengths in the Bronx River are 600ft and their amplitudes are less than 60ft.

For the most part, geological structure controls the Bronx River trajectory. The trajectory of the river has been altered by construction. The river is confined within its valley by man-made fill for Bronx River Parkway and for the Metro North Railroad. Bridge abutments obstruct the natural river processes in several areas.

The river ecosystem is choked at multiple locations by sand deposits produced from sand and salt treatment of roads for de-icing. From these deposits, a significant amount of salt dissolves into the river. The effect of the salt and the sand on the river has been negative, and these effects must be considered in the restoration design.

Table of Contents

Disclaimer....ii
Executive Summary....iii
Table of Contents....iv
List of Figures....iv
List of Tables....iv
List of Plates....v
1.0 Introduction....1
2.0 Bronx River Basin....3
3.0 Westchester County sites....7
3.1 Westchester County Center....7
3.2 Garth Woods and Harney Road....9
3.3 Crestwood Lake....11
3.4 Bronxville Lake....12
4.0 Bronx County sites....15
4.1 Muskrat Cove....17
4.2 Shoelace Park....18
4.3 Snuff Mill dam....19
4.4 Bronx Zoo and dam....20
4.5 Bronx River Park....21
5.0 Conclusions....24
Appendix I:....28
Appendix II:....31

List of Figures

Figure 1. Location map of the Bronx River....2
Figure 2. Shaded relief map of Bronx River Basin....1
Figure 3. Bedrock stratigraphy of the Bronx River basin....2
Figure 4. Geological cross sections north and south of the Bronx Botanical Gardens....3
Figure 5. Surficial geological map of the Bronx River Basin.....4
Figure 6. 1892 and 1938 USGS topographic maps showing in Westchester County Center....5
Figure 7. 1891 and 2013 USGS topographic maps showing Williams Bridge....6
Figure 8. Bedrock stratigraphy of the Bronx River basin....13
Figure 9. Bedrock geological map of the Bronx River basin.....14
Figure 10. 1891 and 2013 USGS topographic maps....15
Figure 11. 1891 and 2013 USGS topographic maps....16
Figure 12. Bedrock geological map of the Bronx River basin....22
Figure 13. Bedrock geological map of the Bronx River basin....23
Figure 14. 1891 and 2013 USGS topographic maps showing the Snuff Mill dam....24
Figure 15. 1891 and 2013 USGS topographic maps showing the Bronx Park....25

List of Tables

Table 1. List of sites from north to south (upstream – downstream).....1
Table 2. Summary of geomorphology Bronx River Valley....3
Table 3. Sub-watersheds in the Bronx River Basin....3
Table 4. Area of Bronx River Basin upstream from each site....4
Table 5. Range of elevations for the Bronx River Basin....4
Table 6. Bronx River valley characteristics for each site.....4
Table 7. General stratigraphy of the Bronx River north of Mosholu Parkway.....5
Table 8. General stratigraphy of the Bronx River south of Mosholu Parkway.....5

Table 9. Manmade structures across the Bronx River at or near the sites. 6
Table 10. Manmade confining structures along the Bronx River 7
Table 11. Summary of Bronx River attributes at Westchester County Center site. 7
Table 12. General stratigraphy of Westchester County Center site 8
Table 13. Summary of Bronx River attributes at Garth Woods and Harney Road site. 9
Table 14. General stratigraphy of Westchester County Center site 10
Table 15. Summary of Bronx River attributes at Crestwood Lake site. 11
Table 16. General stratigraphy of Crestwood Lake site 11
Table 17. Summary of Bronx River attributes at Bronxville Lake site. 12
Table 18. General stratigraphy of Bronxville Lake site 12
Table 19. Summary of Bronx River attributes at Muskrat Cove site. 17
Table 20. General stratigraphy of Westchester County Center site 17
Table 21. Summary of Bronx River attributes at Shoelace Park site. 18
Table 22. General stratigraphy of Shoelace Park site. 18
Table 23. Summary of Bronx River attributes Snuff Mill dam site. 19
Table 24. General stratigraphy of Snuff Mill dam site. 19
Table 25. Summary of Bronx River attributes Bronx Zoo and dam site. 20
Table 26. General stratigraphy of Bronx Zoo and dam site 20
Table 27. Summary of Bronx River attributes of the Bronx Park site. 21
Table 28. General stratigraphy of Bronx Zoo and dam site. 21

List of Plates

Plate 1. Location map
Plate 2. Bronx river basin bedrock and structural geology map
Plate 3. Westchester county topography and bedrock geology map

1.0 Introduction

The Bronx River Ecosystem Restoration Feasibility Study (Project) includes the planning, design, and alternatives for various opportunities within the Bronx River Basin. The Bronx River Basin occupies 55.1 square miles in Westchester and Bronx River Counties, New York, from 23 miles from headwaters at Davis Brook near the Kensico Reservoir, Valhalla, to the confluence with the East River. The Bronx River is highly developed with both residential and commercial facilities. The present scope of work has a total of nine sites in Westchester and Bronx Counties.

This report contains Task 3a Geotechnical Literature Survey. Task 3a is designed to determine the geological controls and characterize soils in the affected areas within each restoration site. Based on the available data, the Geotechnical and Geological report would include a discussion of geology, soil parameters, soil analysis, and dredged material characteristics. Public and private sources, including the Natural Resources Conservation Service, were contacted in order to determine the availability of existing subsurface data. Existing boring logs and reports are attached to the Geotechnical/ Geological report. Significant information such as the soil/rock type and depth are noted.

The activities stated above were done in accordance with the following references:

- ER 1110-2-1150 Engineering and Design of Civil Works Projects
- EM 1110-1-1804 Geotechnical Investigations

Assumptions at the current stage are that the existing soil information is sufficient for the development of the conceptual plan and no additional soil borings, soil sampling or testing were obtained. Risks associated with these assumptions have been documented in the Risk Register. Additional geotechnical investigation would be included in the future phase.

e4 conducted a literature search and compiled references on the geology and geotechnical aspects of the Bronx River basin and the nine sites. The results of the literature search are in Appendix I. e4 supplemented these literature data with observations at each site. e4 measured the location of bedrock exposures at the site.

This report first discusses the geology of the entire Bronx River Basin. Then the geology of the individual sites is presented from upstream to downstream. Thus the Westchester County sites are presented before the Bronx river sites. This presentation order is designed to follow the sediment and debris sources downstream. The downstream deposits of course influence flooding upstream.

Table 1. List of sites from north to south (upstream – downstream).

	Site	County
1	Westchester County Center	Westchester
2	Garth Woods and Harney Road	Westchester
3	Crestwood Lake	Westchester
4	Bronxville Lake	Westchester
5	Muskrat Cove	Bronx
6	Shoelace Park	Bronx
7	Snuff Mills Dam	Bronx
8	Bronx Zoo and dam	Bronx
9	Bronx River Park	Bronx

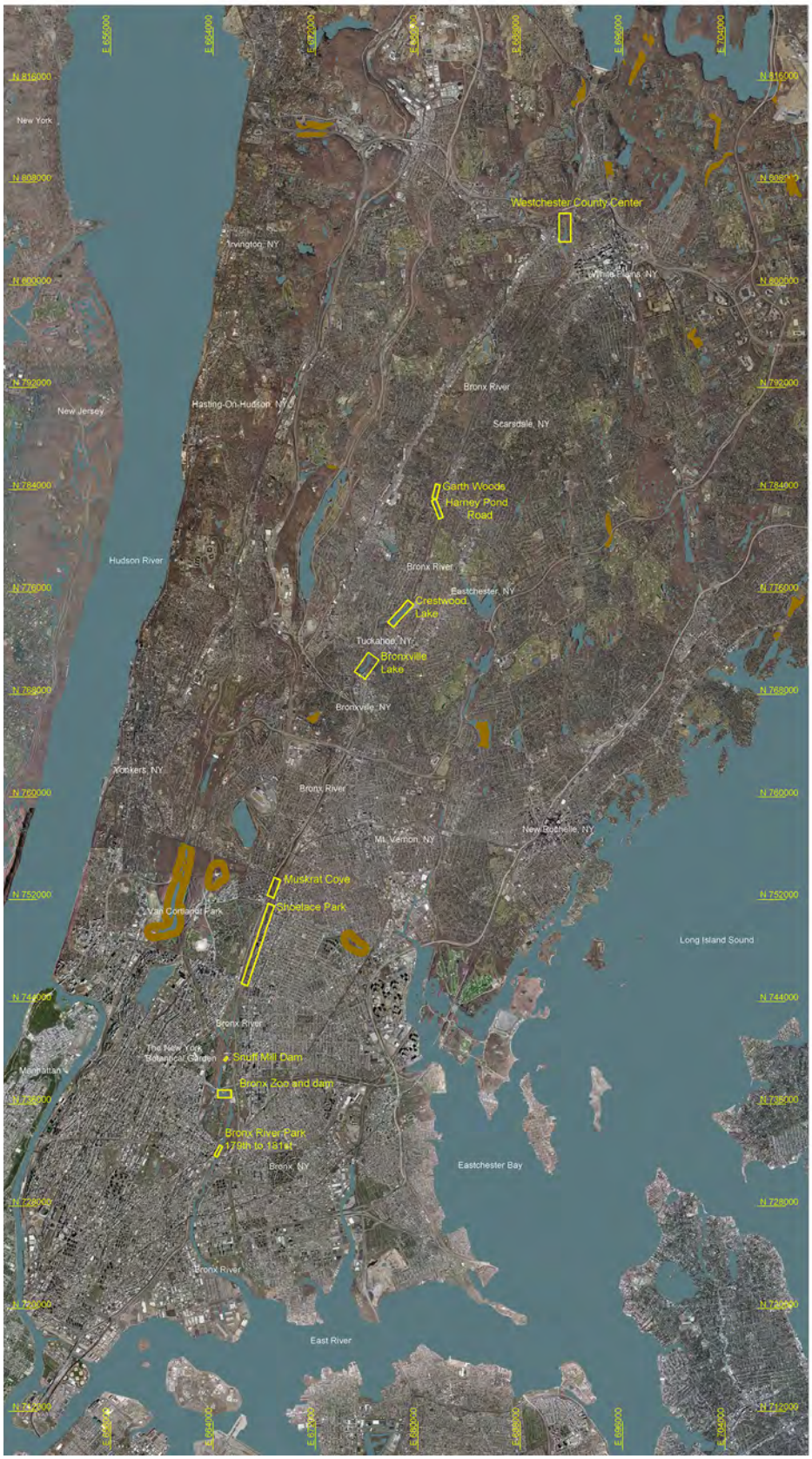


Figure 1. Location map of the Bronx River.

2.0 Bronx River Basin

The Bronx River Basin occupies 55.1 square miles in Westchester and Bronx River Counties, New York (Figure 2). The River is approximately 23 miles long. It flows from Kensico Lake (Reservoir) in the north to Hunts Point in the East River. At the same time, it is strongly controlled by the bedrock. The present areas of investigation include a total of nine sites in Westchester and Bronx Counties.

Figure 2 shows the topography is dominated by several NNE-SSW trending valleys and their associated ridges. Table 2 list general characteristics of the Bronx River. The river flows 15 miles through Westchester County and 8 miles through the Bronx. Westchester County hosts 65% of the river's length and 85% of the river's watershed. Table 3 lists 19 sub-watersheds that make up the Bronx river basin. 12 of these are tributary watersheds that comprise 62% of the Bronx River Basin. Table 4 shows the drainage areas upstream of the investigation sites.

Table 2. Summary of geomorphology Bronx River Valley

	Bronx river basin ranges
River length total	~23 miles
River length total Westchester County	~15 miles
River length total Bronx County	~8 miles
Total basin area	56.3 sq miles
Total basin area in NY	55.1 sq miles
Total basin area in Westchester County	47.1 sq miles
Bronx River valley area	21.3 sq miles
Tributary area	35.0 sq miles
Range of elevations	<0 to 270ft
Slopes	2 to 155 ft/mile
Low-flow channel width	20 to 250
Present-day width of river flood plain	50 to 620ft
Pre-railroad width of river flood plain	70 to 3,000ft
Roadway bridge crossings	66
Zoo tram bridges	2
Railroad bridges	6
Pedestrian bridges	~10
Dams	8

Table 3. Sub-watersheds in the Bronx River Basin

	Sub-watershed	Type	County	Drainage area sq miles
1	Kensico Reservoir	Tributary	Westchester	12.42
2	Clove Brook	Tributary	Westchester	1.32
3	Davis Brook	Tributary	Westchester	2.14
4	Upper Bronx River Basin	Bronx River valley	Westchester	5.02
5	White Plains Reservoirs	Tributary	Westchester	0.90
6	Manhattan Park Brook	Tributary	Westchester	3.31
7	Fulton Brook	Tributary	Westchester	0.98
8	Hartsdale Brook	Tributary	Westchester	1.21
9	Fox Meadow Brook	Tributary	Westchester	1.45
10	Middle Bronx River Basin	Bronx River valley	Westchester	5.08
11	Troublesome brook	Tributary	Westchester	2.69
12	Sprain Brook	Tributary	Westchester	3.91
13	Grassy Sprain Brook	Tributary	Westchester	2.66
14	Grassy Sprain Brook direct drainage	Tributary	Westchester	1.97
15	Lower Bronx River Basin	Bronx River valley	Westchester	3.26
16	Parkland	Bronx River valley	Bronx	3.58
17	Bronx Gardens/Zoo	Bronx River valley	Bronx	1.30
18	West Farms	Bronx River valley	Bronx	1.53
19	Estuary	Bronx River valley	Bronx	1.58

Table 4. Area of Bronx River Basin upstream from each site.

Site	Drainage area upstream of site	Additional drainage area to site
	sq miles	sq miles
Westchester County Center	18.18	4.44
Garth Woods and Harney Road	26.69	
Crestwood Lake	31.07	2.69
Bronxville Lake	34.63	
Muskrat Cove	48.33	
Shoelace Park	49.73	1.58
Snuff Mill Dam (Stone Mill)	52.15	
Bronx Zoo and Dam	52.57	
Bronx River Park	53.26	

The Kenisco Dam was built across the Bronx River. Kenisco Lake flows in the Bronx River. Elevation of the Bronx River below Kensico Lake is +270 feet. The e Bronx River flows into the East River at sea level. At that point the river bed is below sea level. Table 5 shows the ranges of elevations and average slopes for all the sites. Table 5 shows the approximate widths of the low-flow river and flood plain for each site. The river valleys are relatively narrow.

Table 5. Range of elevations for the Bronx River Basin

Site	Range of river elevations		Site river length	Average slope
	Up stream	Down stream		
	ft	ft	ft	ft/mile
Westchester County Center	177	174	2,620	6.0
Garth Woods and Harney Road	125	109	1,988	42.5
Crestwood Lake	98	94	2,442	4.3
Bronxville Lake	91	83	4,165	10.1
Muskrat Cove	58	56	1,350	7.8
Shoelace Park	51	48	6,757	2.3
Snuff Mill Dam (Stone Mill)	48	38	344	153.7
Bronx Zoo and Dam	29	21	1,256	33.6
Bronx River Park	16	9	905	40.8

Table 6. Bronx River valley characteristics for each site. Note that the pooled area of Harney Road reach is listed separately from Garth Woods reach.

	Low-flow channel widths		Estimated present-day flood plain width		Estimated pre-railroad flood plain width		Island dimension (visible in 2014)	
	Min	Max	Min	Max	Min	Max	length	width
	ft	ft	ft	ft	ft	ft	ft	ft
Westchester County Center	18	50	140	460	800	3,000	220[a]	135
Garth Woods	25	95	200	265	380	410	325[b]	130
Harney Road	50	95	100	260	250	620	30[c]	8
Crestwood Lake	82	250	280	620	500	1,400	80[d]	640
Bronxville Lake	90	250	180	300	410	580	440	50
Muskrat Cove	60	85	150	210	400	575	n.a	n.a
Shoelace Park	50	90	90	400	400	850	n.a	n.a
Snuff Mill Dam	50	30	50	50	70	50	70	
Bronx Zoo and Dam	50	130	350	390	430	750+	140	65
Bronx River Park	30	50	50	60	550	650	n.a	n.a

a. Tree covered island in braided reach
b. High-flow island formed when apparent abandoned stream is full.
c. Gravel and cobble bar south of weir.
d. Largest of four sediment islands as of July 2014.

Figure 3 shows the geology map overlain on the topography modified from the NYS digital geological map. Figure 4 shows the geological cross sections and correlation key from Baskerville 1992 USGS geological map of the Bronx. NYS digital geological map is based on the compiled 1971 and does not reflect Merguerian's and Baskerville's recognition of Cameron's Line thrust fault and the Hartland formation. The map has been updated to include the modern interpretation.

The main bedrock types in the river basin consist of the Cambrian-Ordovician Inwood Marble, Hartland formation schist and gneiss, and the Proterozoic Fordham Gneiss and Yonkers Gneiss.

Tables 7 and 8 summarize the stratigraphy of the Bronx River north of the Mosholu Parkway and south of the Mosholu Parkway, respectively.

Table 7. General stratigraphy of the Bronx River north of Mosholu Parkway.

Age	Description
Holocene	Modern river sediments
Holocene	Fill and man-made structures
Holocene	Thin soils
Holocene	Fluvial sediments
Pleistocene	Pleistocene glacial lake clays and silts
Pleistocene	Pleistocene glacial outwash deposits
Pleistocene	Pleistocene glacial moraine tills
Cambrian-Ordovician	Inwood Marble
Cambrian-Ordovician	Hartland Formation
Proterozoic	Yonkers Gneiss
Proterozoic	Fordham Gneiss

Table 8. General stratigraphy of the Bronx River south of Mosholu Parkway.

Age	Description
Holocene	Modern river sediments
Holocene	Fill and Man-made structures
Holocene	Thin soils
Holocene	Fluvial sediments
Pleistocene	Pleistocene glacial boulders
Cambrian-Ordovician	Hartland Group

The Bronx River is underlain by Cambrian-Ordovician and Proterozoic metamorphic bedrock. The bedrock is folded and faulted. e4 determined that the river valley mostly along the Cambrian-Ordovician Inwood Marble in Westchester and the Bronx. The Inwood Marble is generally a softer unit that lies above the folded and faulted underlying Fordham Gneiss. The Bronx River valley is one of five roughly north-northeast to south-southwest troughs in Westchester County below the Kensico Dam in the north.

From Kenisco Dam the Bronx River flows southwest and then south following a valley underlain by the Inwood Marble. At the Westchester County Center site the Bronx River meets the Fulton Brook flowing northeast down the same Inwood Marble Valley. In the vicinity of the Westchester County Center site the Bronx River crosses a major east-west fault and flows south-southeast across the Yonkers Gneiss into the Fordham Gneiss.

From there the Bronx River turns and flows south-southwest along a valley underlain by the Fordham Gneiss. At Garth Woods the river flows south-southeast into a valley underlain by the Inwood Marble. The River stays in the Inwood Marble past Crestwood Lake and Bronxville Lake. Just south of Bronxville Lake, the river follows a south-southeast turn/fold in the Inwood Marble that turns south-southwest again into a valley along the western side of Cameron's line, a

major Ordovician thrust fault. After about 1.5 miles the river follows the Fordham Gneiss. At Muskrat Cove in the Bronx the river passes back into the Inwood Marble for two miles along Cameron's Line. At Gun Hill Road the river meanders across Cameron's Line and back.

Near the Mosholu Parkway just north of the Botanical Gardens, a Pleistocene Mosholu fault forces the river to cross Cameron's line (Kemp, 1897; Merguerian and Sanders, 1996a; Wheeler, 2006). The river flows across the major structural divide and structural fabric and rocks of gneiss and schist of the Cambrian-Ordovician Hartland Formation to enter the East River at Hunts Point.

The Bronx River basin is in the New England Upland physiographic province of the Appalachian Highlands region. As such Pleistocene glaciers have carved down and removed most older soils and sediments. Bedrock is exposed in areas throughout the basin. Sediment is relatively thin and ranges from 0ft to ~80ft thick.

Figure 5 shows the distribution of the relatively thin surficial sediments. Sediment is Pleistocene till of sand and gravel, outwash sands, and glacial lake silts and sands overlain by Holocene fluvial deposits. Sediment is predominantly Pleistocene tills and outwash deposits. The thickest deposits, including glacial till and outwash sands and gravel, occur just north of the Mosholu Parkway and in the Westchester County Center area.

The Bronx River valley north of the Mosholu Parkway is a U-shaped glacial carved valley. The Bronx River Valley south of the Mosholu Parkway is a V-shaped stream carved valley without Pleistocene sediments beyond boulders (Kemp, 1897; Merguerian and Sanders, 1996a).

For the most part, geological structure controls the Bronx River trajectory. The river is further confined within its valley by man-made fill for Bronx River Parkway and for the Metro North Railroad. Bridge abutments obstruct the river processes in several areas.

Table 10 lists manmade structures that cross the Bronx River and restrict, dam, or otherwise modify flow. Figure 11 lists manmade structures that confine river and reduce the width of the flood plain. The original Bronx River valley/flood plain prior to the construction of the railroad and parkway was relatively narrow. Widths ranged from 70 to 3,000ft (Tables 2 and 6). The widest area, 3,000ft, is at the confluences of the tributaries at Westchester County Center site where a fault intersects the valleys. Addition of fill and the construction of the railway and parkway further constricted the narrow valleys.

Table 9. Manmade structures across the Bronx River at or near the sites.

	Dams/weirs	RR bridge	Road bridge crossings	Pedestrian bridges	Other
Westchester County Center	0	0	3	1	2 pipe crossings
Garth Woods	0	0	1	1	0
Harney Road	1	0	2	0	0
Crestwood Lake	1	0	1	0	0
Bronxville Lake	1	0	1	1	0
Muskrat Cove	0	1	2	0	0
Shoelace Park	0	0	5	0	0
Snuff Mill Dam	1	0	0	0	0
Bronx Zoo and Dam	1[a]	0	2	0	0
Bronx River Park	1[b]	1	1	0	0

a. Double dam
b. Dam upstream of site

Table 10. Manmade confining structures along the Bronx River

Site reaches	Manmade constraint on west bank	Manmade constraint on east bank
Westchester County Center N reach	north-bound parkway	railroad
Westchester County Center mid reach	south-bound parkway	north-bound parkway
Westchester County Center S reach	north-bound parkway	railroad
Garth Woods reach	south-bound parkway	north-bound parkway
Harney Road reach	south-bound parkway	north-bound parkway
Crestwood Lake	parkway	railroad
Bronxville Lake	parkway	railroad
Muskrat Cove N reach	parkway	railroad
Muskrat Cove S reach	railroad	parkway
Shoelace Park	parkway and railroad	
Snuff Mill Dam	none	none
Bronx Zoo and Dam	none	none
Bronx River Park	buildings	buildings

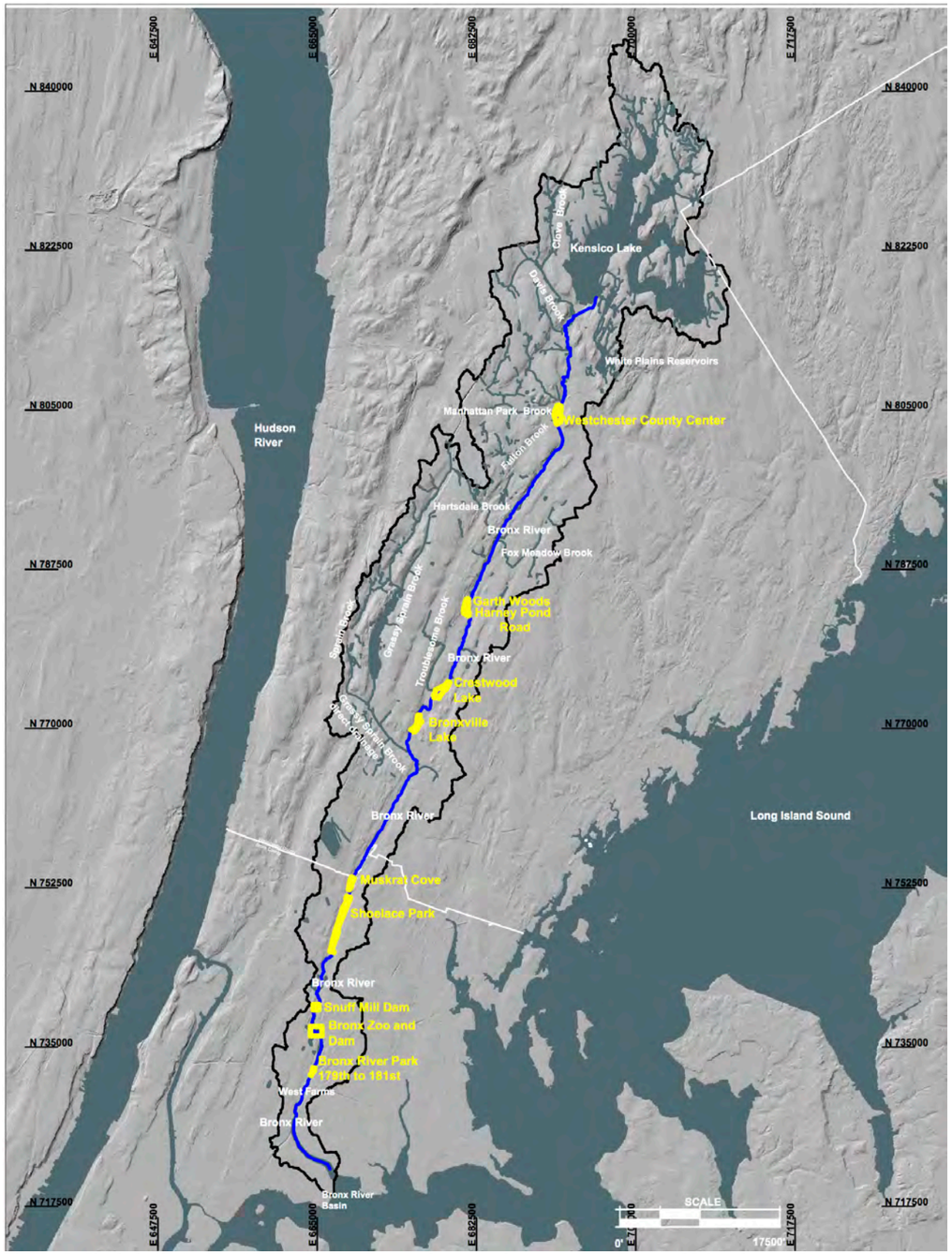
The river ecosystem is choked in multiple places by sand deposits produced from sand and salt treatment of roads for de-icing. From these deposits, a significant amount of salt dissolves into the river. Sediment islands have formed in most of the ponded reaches. The effect of the salt and the sand on the river has been negative, and these effects must be considered in the restoration design.

Figure 6 shows the Westchester County Center Site area in 1892 and 1938 topographic maps. The 1892 map shows a less restricted river valley. The Fulton Brook tributary meets the Manhattan Park Brook Tributary before flowing into the Bronx River. The 1938 map shows that the design of the Bronx River Parkway pins the tributaries to pass beneath bridges and flow into the Bronx River separately. The south and north bound parkway roads confines the lateral movement of the river. The general 1938 geometry is similar to that of today.

Figures 7 shows the 1891 and 2013 topographic maps of an area that extends from north of Muskrat Cove to just south of Shoelace Park. The 1891 map shows the river meanders through this stretch. The 2013 map shows the river channel is constrained to be relatively straight. The railroad and Bronx River Parkway occupy approximately a third of the valley.

In the 1891 map, one set of meanders has wavelengths ranging from 800 to 2,700ft and amplitudes from 200 to 450ft. A set of higher-frequency meanders wavelengths ranging from 250 to 550ft and amplitudes around 70 to 80ft. With a narrower valley the meanders in the present day have smaller amplitudes and wavelengths.

Rivers show three scales of meanders: (a) low-frequency long-wavelength meanders, (b) mid-frequency mid-wavelength meanders, and (c) high-frequency short-wavelength meanders. The six low-frequency long-wavelength meanders approximately 15,000ft in wavelength have amplitudes less than 500ft. Engineers most commonly measure the mid-frequency mid-wavelength meanders. In the Bronx River, these meanders show a relatively consistent wavelength of 1000ft and an amplitude less than 200ft. The high-frequency short-wavelength meanders track the variation of the thalweg. The short wavelengths in the Bronx River are 600ft and their amplitudes are less than 60ft.



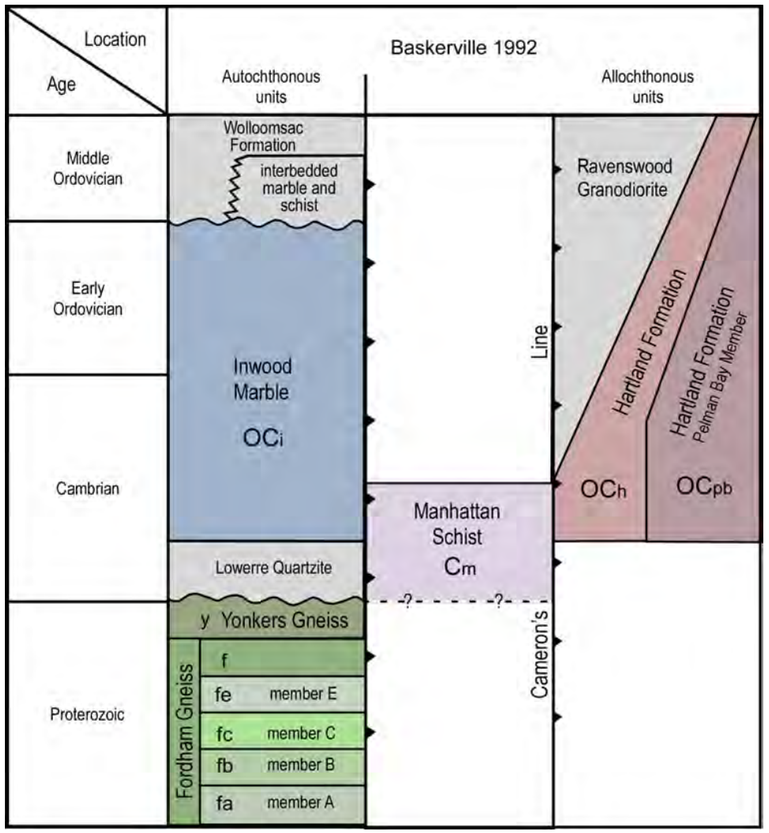
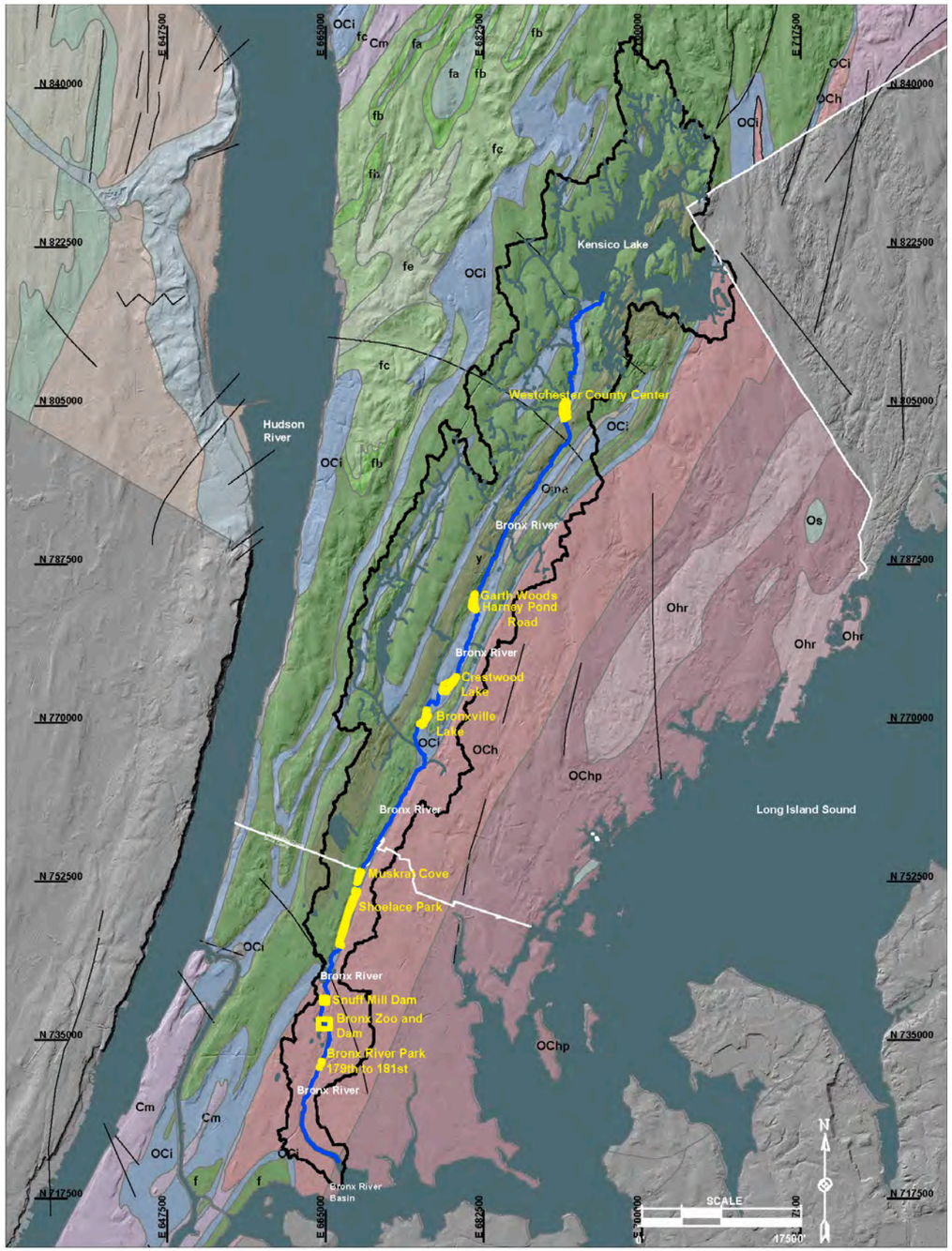


Figure 2. Shaded relief map of Bronx River Basin and surrounding areas in Bronx and Westchester Counties. The tributaries of the Bronx River are marked in gray blue.



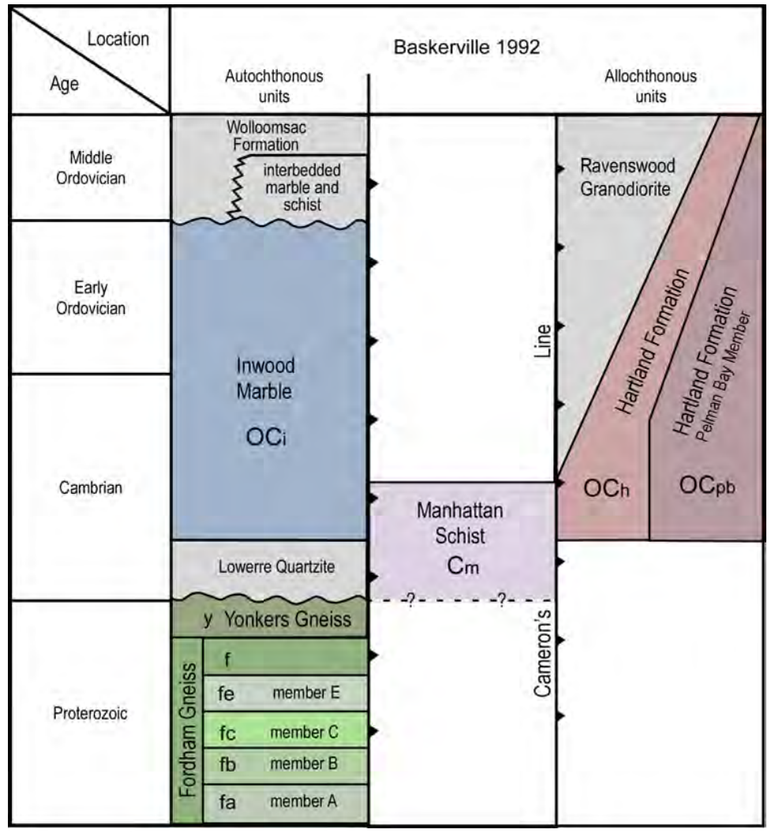
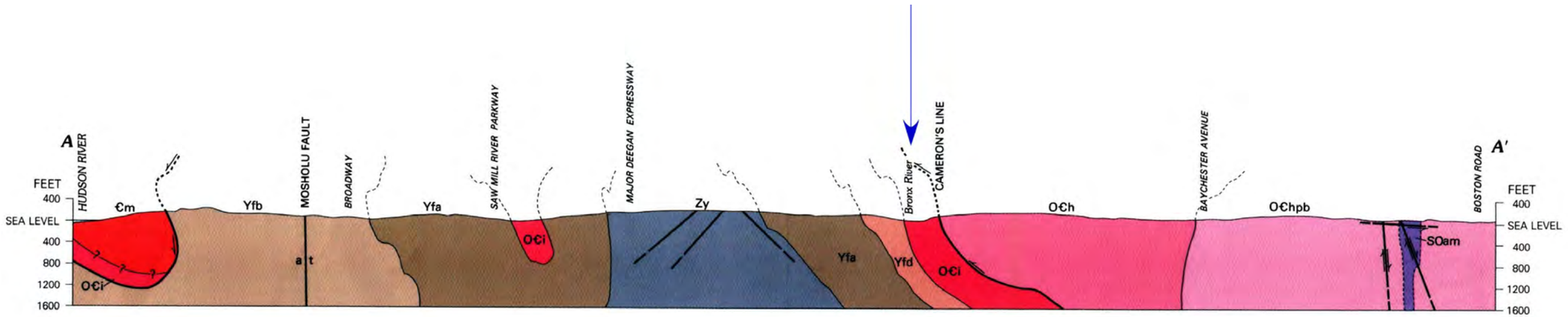
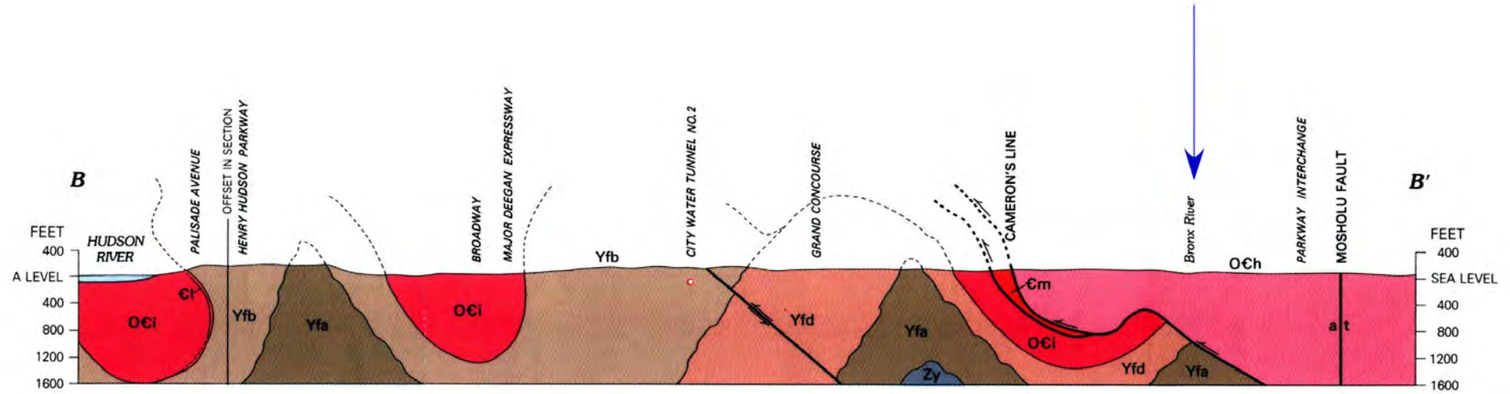


Figure 3. Bedrock stratigraphy of the Bronx River basin and key to bedrock geology. Gray indicates formations not shown on map. The tributaries of the Bronx River are marked in gray blue.





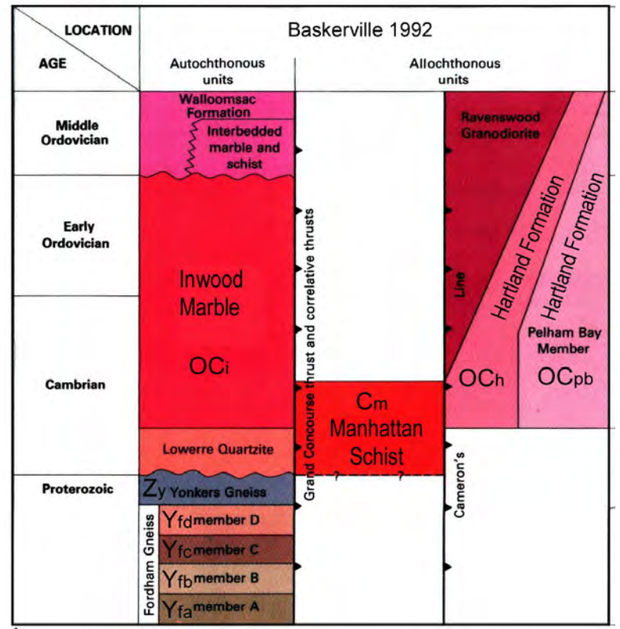
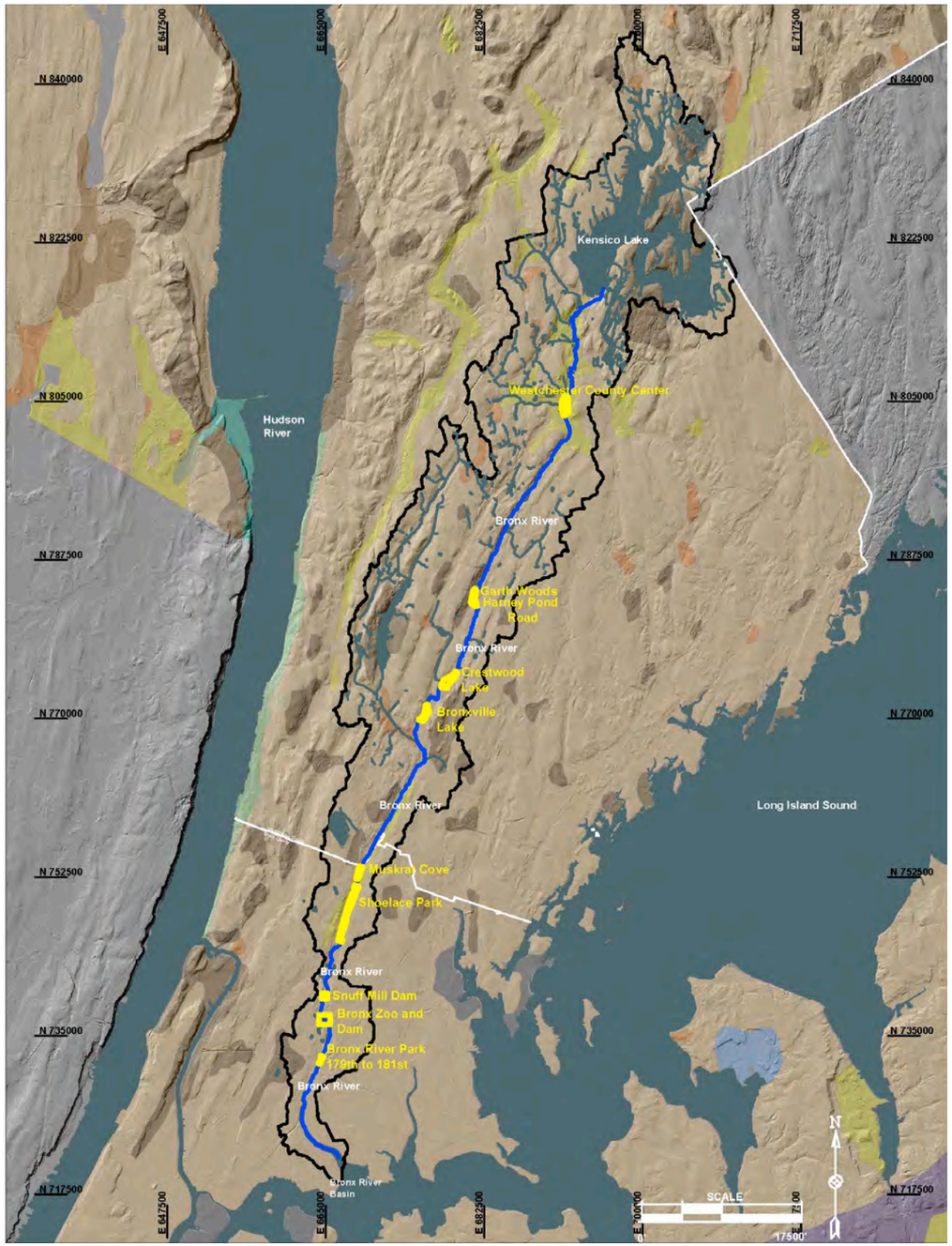


Figure 4. Geological cross sections north and south of the Bronx Botanical Gardens from Baskerville (1992). Blue arrows indicate location of Bronx River. North of the gardens the river follows a valley underlain by the Inwood marble and in parts the Fordham Gneiss. South of the gardens the river crosses Cameron's line and is underlain by the Hartland formation. Note the colors in the cross section are different than the color maps in the other figures.



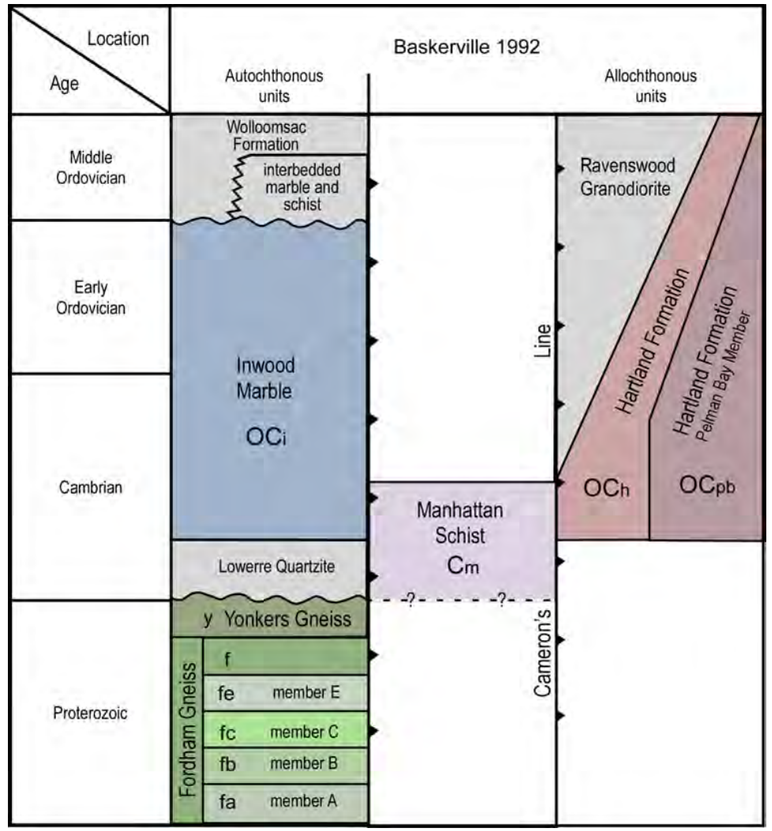


Figure 5. Surficial geological map of the Bronx River Basin. The tributaries of the Bronx River are marked in gray blue.

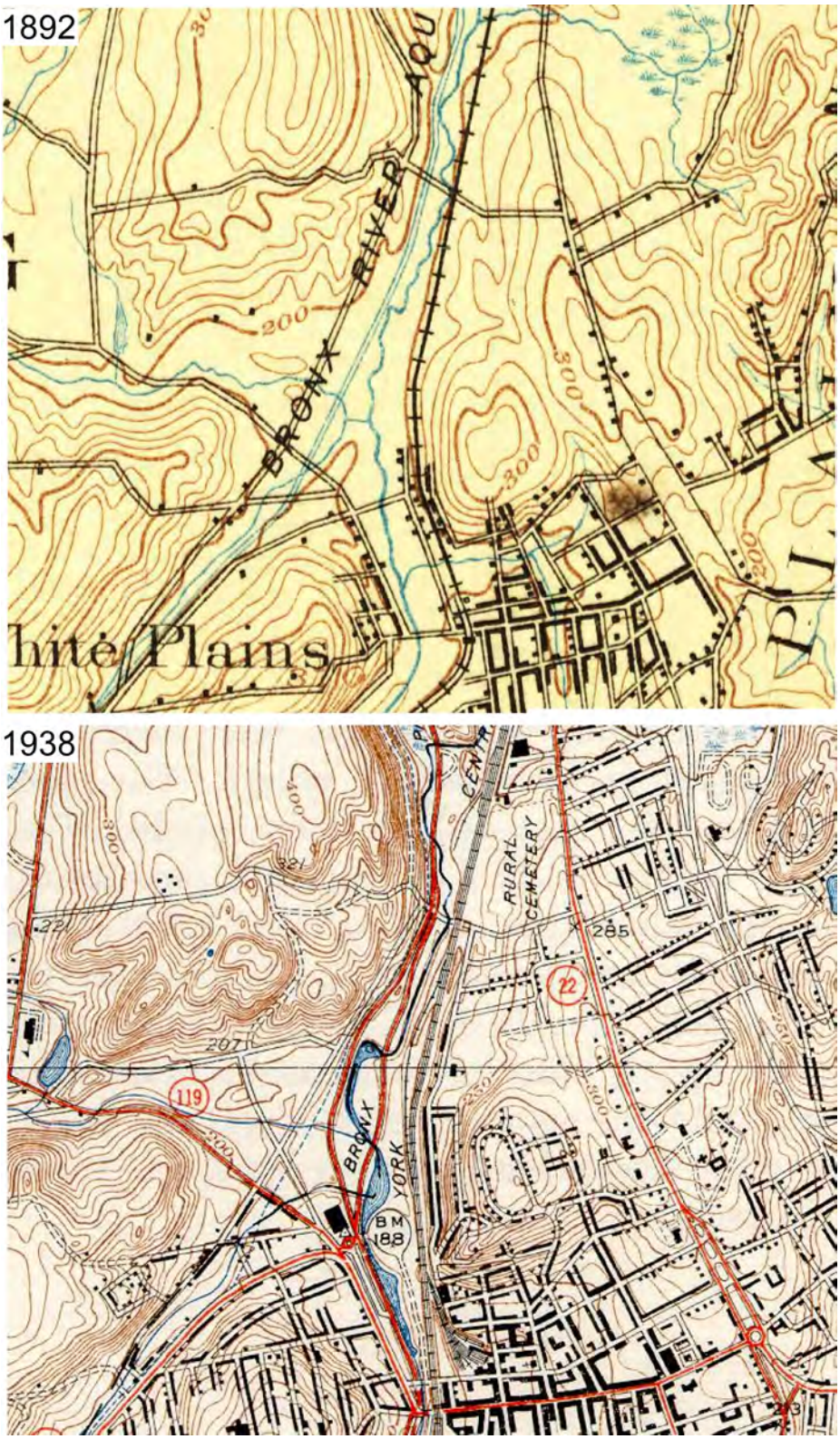


Figure 6. 1892 and 1938 USGS topographic maps showing the Bronx River in Westchester County Center area. The 1892 map shows the Manhattan Park Brook joining the Fulton Brook before flowing into the Bronx River. Meanders occur throughout. The 1938 map shows the two tributaries flowing separately under the Bronx River Parkway and into the Bronx River.

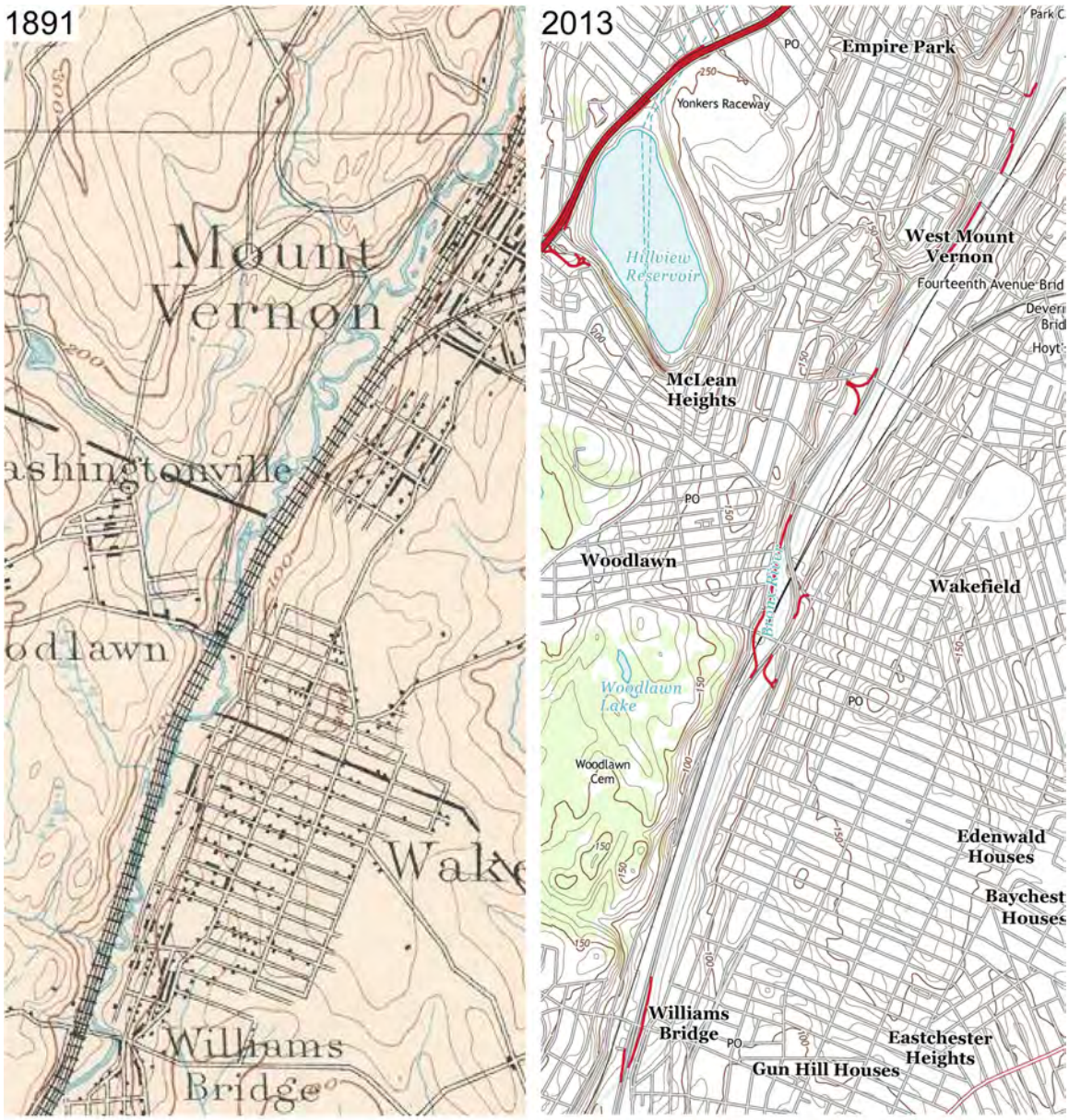


Figure 7. 1891 and 2013 USGS topographic maps showing the Bronx River from Williams Bridge in the Bronx to Mt Vernon in Westchester County. The area shown includes Muskrat Cove and Shoelace Park. The 1891 map shows the Bronx River meanders the length shown in the image. The 2013 map shows few bends in the river. The Bronx River Parkway has narrowed the river valley.

3.0 Westchester County sites

Figures 8 and 9 shows the bedrock geology of the northern and southern Bronx River Basin in Westchester County. The four sites in Westchester County are discussed in the following.

3.1 Westchester County Center

The Westchester County site sits in a valley at the confluence of the Bronx River and two tributaries, the Manhattan Park Brook and the Fulton Brook (Figure 6). The 1891 USGS topographic quadrangle shows the two tributaries joining before reaching the Bronx River. The 1938 USGS topographic quadrangle shows the present-day configuration after the construction of the Bronx River parkway.

Table 11 list stream attributes at this site.

Table 11. Summary of Bronx River attributes at Westchester County Center site.

	Bronx River Basin values
River length at site	2,620ft
Watershed upstream of site	18.18 sq miles
Tributary watershed: Manhattan Park Brook	3.31 sq miles
Tributary watershed: Fulton Brook	0.98 sq miles
Elevations of river	177 to 174ft
Average slope	6.0ft/mile
Low-flow channel width	18 to 50ft
Present-day width of river flood plain	140-460ft
Pre-railroad width of river flood plain	800-3,000ft
Roadway bridge crossings	4 across Bronx 3 across the tributaries
Railroad bridges	0
Pedestrian bridges	1
Dams	0
Other obstructions	Partially buried pipeline across river and tributary

Manhattan Park Brook joins the Bronx River just before the river flows east under the north-bound Bronx River Parkway bridge midway through the area. Little and Biedenham (2007) identify this as the “Westchester County Center tributary” and identified it as the tributary contributing the most sediment to the Bronx River.

South of the Manhattan Park Brook the Fulton Brook flows under the north-bound Bronx River Parkway and joins the Bronx River. Between the south and northbound Parkway the Fulton Brook has two sharp meanders and exhibits extensive bank erosion.

The southern portion of the site where the river is east of the north-bound Bronx River Parkway is braided. The 1938 topographic map and 2000 map indicate this historically had been a ponded part of the river. The present-day river braids. A treed silt island that is accreting upstream dominates the site. Wood and other debris have accumulated on the upstream side of the island. The debris then will collect silt and will eventually become vegetated. This island is helping to remove debris and silt from the river.

This site lies in the “fluvial” reach 5a of Little and Biedenham (2007). They conducted grain size analyses on a sample from Manhattan Park Brook (sample Bed 4), two samples in the Bronx River (samples Bed 5 and 6) and two samples from the bank (bank 1 and 2). Bed 5 and Bank 1 are upstream of the Manhattan Park Brook and Bed 6 and Bank 2 are downstream. The bedforms where the samples were collected were not identified.

Table 12 lists the general stratigraphy of the site. Bedrock from north to south includes Inwood Marble, Fordham Gneiss, and Yonkers Gneiss (Figure 8). A major east-west fault is just south of the site.

Table 12. General stratigraphy of Westchester County Center site

Age	Description
Holocene	Modern river sediments: sands, gravels, cobbles
Holocene	Modern river sediments: silt, organic muds
Holocene	Fill and pathway/lawn
Holocene	Fill and parkway
Holocene	Fill and railroad
Holocene	Thin soils
Holocene	Pond/lake clays
Holocene	Fluvial sediments
Pleistocene	Pleistocene glacial outwash sands and gravels
Pleistocene	Pleistocene glacial tills of sand and gravel
Cambrian-Ordovician	Inwood Marble (calcitic and dolomitic)
Proterozoic	Yonkers Gneiss
Proterozoic	Fordham Gneiss

The surficial geology map (Figure 5) indicates this area has one of the thickest sequences of sediments in the Bronx River Valley. Sediments appear to be up to 80 or 90 feet thick. Pleistocene outwash sands and gravels dominate the composition. Near surface there are fluvial sands and silts. A gray clayey silt Pond or lake deposit is exposed a few feet beneath the surface on the banks of the Fulton Brook and The Bronx River between the Parkway roads.

Modern river sediments include silt, organic mud, sand, gravel and cobbles.

3.2 Garth Woods and Harney Road

North of Garth Woods the Bronx River flows south-southwest along a valley underlain by the Fordham Gneiss (Figure 9). At Garth Woods and Harney Road the river turns south-southeast into a valley underlain by the Inwood Marble.

Table 13 lists attributes of the river valley at this site.

Table 13. Summary of Bronx River attributes at Garth Woods and Harney Road site.

	Bronx River Basin values
River length at site	2,620ft
Watershed upstream of site	26.69 sq miles
Elevations of river	125 to 109ft
Average slope	26.7ft/mile
Low-flow channel width Garth Woods	25 to 95ft
Low-flow channel width Harney Road	50 to 95ft
Present-day width of river flood plain Garth Woods	200-265ft
Present-day width of river flood plain Harney Road	100-260ft
Pre-railroad width of river flood plain Garth Woods	380-410ft
Pre-railroad width of river flood plain Harney Road	250-600ft
Roadway bridge crossings	3
Railroad bridges	0
Pedestrian bridges Garth Woods	1
Dams	0
Other obstructions	Partially buried pipeline across river and tributary

The Garth Woods reach of the site lies in the "throughput" reach 9 of Little and Biedenham (2007). They collected Sample Bank 3 in the northern part of the site. They noted extensive bank erosion. Coarse sands, gravels, cobbles, and small boulders occur through this reach. The River is eroding the wall support of the south-bound Bronx River Parkway.

A streambed that flows during high flow periods is preserved in the woods. Old aerial photographs and the topographic maps indicate that it is unlikely that this streambed is the major channel. This channel is dominated by sand and gravel bed forms. Banks are deeply eroded undercutting tree roots. The e4 team visited the site after high flow following a major rain in July 2014. The bedforms in the apparently abandoned channel were fresh and only marked with raccoon and turtle tracks.

The southern part of this reach and the northern part of Harney Road reach has thick (>4ft) deposits of organic silt. In the pool channel the sediment appeared not to have been greatly disturbed by the high flow event prior to the e4 team visit. Fish nest depressions were still intact and only had thin sparse layers of plant debris. The channel is full with sand and gravel. Organic silt bars occur in the northern half of the reach.

The Harney Road site lies in the "pool" reach 10 of Little and Biedenham (2007). They collected their Sample Bed 11 from this reach. They indicate that the sediment depths are deeper than their 4ft probe. e4 confirmed this in the organic silt in the north.

A sediment island that existed in 2006 (Figure 17 in Little and Biedenham 2007) is now planted with cattails and willows.

The gravels and cobbles fill the channel floor south of the weir south of Harney Road Bridge. A mid channel bar of cobbles occurs in this area.

Table 14 summarizes the stratigraphy in this area. Garth Woods lies over the Fordham Gneiss. (Figure 9). The river in Harney Road reach crosses from the Fordham Gneiss to the Inwood Marble. e4 mapped an outcrop exposure of the Inwood Marble on the eastern slope of Harney Road reach. The foliation and fold axes are sub-parallel to the valley.

Table 14. General stratigraphy of Westchester County Center site

Age	Description
Holocene	Modern river sediments: sands, gravels, cobbles, boulders
Holocene	Modern river sediments: silt, organic muds
Holocene	Fill and pathway/lawn
Holocene	Fill and parkway
Holocene	Thin soils
Holocene	Older fluvial sediments
Pleistocene	Pleistocene glacial outwash sands and gravels
Pleistocene	Pleistocene glacial tills of sand and gravel
Cambrian-Ordovician	Inwood Marble (calcitic and dolomitic)
Proterozoic	Fordham Gneiss

Figure 10 shows the 1891 and 2013 topographic maps of the area. The 2013 map shows that the Bronx River runs between the south-bound and north-bound parkway roads. In 1891 the river valley at the south end at Harney Road has been narrowed by the parkway. The river valley at the north end of Garth Woods is approximately the same as it was in 1891 because the parkway was not built that slope.

3.3 Crestwood Lake

Crestwood Lake lies at the confluence of Bronx River and Troublesome Brook (Figure 11). Note that on many modern maps Crestwood Lake is the name for the lake upstream on Troublesome Brook. The original name for that lake was Troublesome Lake.

Table 15 summarizes the attributes of the Bronx River valley at this Crestwood Lake denoted by the USACE. The lake is dammed and has several sediment islands. The largest of which has become vegetated.

Table 15. Summary of Bronx River attributes at Crestwood Lake site.

	Bronx River Basin values
River length at site	1,988ft
Watershed upstream of site	26.7 sq miles
Tributary watershed: Troublesome Brook	2.7 sq miles
Elevations of river	98 to 94ft
Average slope	4.3ft/mile
Low-flow channel width	82 to 250ft
Present-day width of river flood plain	280-620ft
Pre-railroad width of river flood plain	500-1,400ft
Roadway bridge crossings	1
Railroad bridges	0
Pedestrian bridges	0
Dams	1
Islands	Up to 4 sediment islands

Crestwood Lake is “pool reach 10” of Little and Biedenham (2007). They indicate that the Crestwood Lake appears to have some of the largest accumulation of sediments in the Bronx River pools with sediments probed to be deeper than 4ft. They indicate fine gravel and sand in the upstream portion of the lake; and sand, silt and organic material in the downstream portion of the lake.

Table 16 summarizes the basic stratigraphy at this site. Figure 9 shows that the Inwood Marble underlies the entire stretch. The Inwood Marble outcrops just to the south of this site along Yonkers Avenue in Tuckahoe (e4sciences|Earthworks, 2010). The foliation and fold axes sub-parallel Yonkers Avenue. Southwest of this area the Bronx River meander appear to follow folds in the marble. Sediment other than the modern lake sediments are expected to be thin (<10ftin the river valley.

Table 16. General stratigraphy of Crestwood Lake site

Age	Description
Holocene	Modern river sediments: sands, fine gravels
Holocene	Modern river sediments: silt, organic muds
Holocene	Fill and parkway
Holocene	Fill and dam
Holocene	Fill and railroad
Holocene	Thin soils
Pleistocene	Thin Pleistocene glacial outwash sands and gravels
Cambrian-Ordovician	Inwood Marble (calcitic and dolomitic)

Figure 11 shows the 1891 and 2013 topographic maps of Crestwood Lake and Bronxville Lake. Both lakes existed in 1891. Crestwood Lake is bound by the parkway on the west and the railroad along the east.

3.4 Bronxville Lake

Bronxville Lake lies in the same valley as Crestwood Lake just south of the Yonkers Avenue. Table 17 summarizes the attributes of the river valley at this site. This dammed lake has a couple of sediment islands only visible at low water. They are not vegetated at this time.

Table 17. Summary of Bronx River attributes at Bronxville Lake site.

	Bronx River Basin values
River length at site	4,165ft
Watershed upstream of site	34.6 sq miles
Elevations of river	91 to 83ft
Average slope	10.1ft/mile
Low-flow channel width	90 to 250ft
Present-day width of river flood plain	180-300ft
Pre-railroad width of river flood plain	410-580ft
Roadway bridge crossings	1
Railroad bridges	0
Pedestrian bridges	1
Dams	1
Islands	Up to 2 sediment islands- non-vegetated

Bronxville Lake is the "pool reach 14" of Little and Biedenham (2007). Their probing indicated sediments are greater than 4ft thick. They observed sand, silt, and organic material.

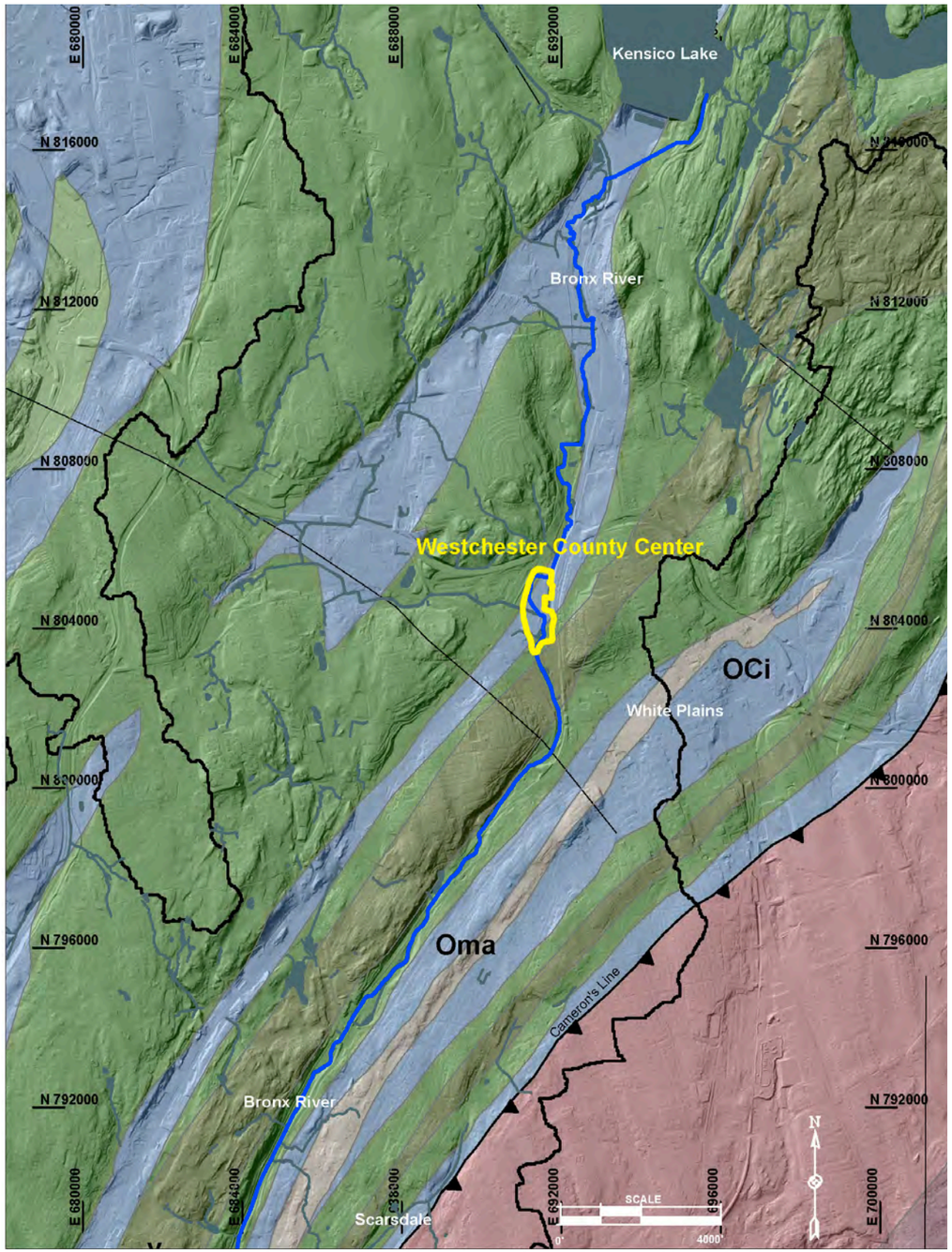
Table 18 summarizes the basic stratigraphy at this site. Figure 9 shows that the Inwood Marble underlies the entire stretch. e4 mapped the locations of 7 exposures of the Inwood Marble around the lake. Just north of Bronxville Lake Bronx River turns to the east to Yonkers Avenue. The river appears be following folds in the marble. The Inwood Marble outcrops along Yonkers Avenue in Tuckahoe (e4sciences|Earthworks, 2010). The foliation and fold axes sub-parallel Yonkers Avenue. Sediment other than the modern lake sediments are expected to be thin (<10ft in the river valley).

Table 18. General stratigraphy of Bronxville Lake site

Age	Description
Holocene	Modern river sediments: sands, fine gravels
Holocene	Modern river sediments: silt, organic muds
Holocene	Fill and parkway
Holocene	Fill and dam
Holocene	Fill and railroad
Holocene	Thin soils
Pleistocene	Thin Pleistocene glacial outwash sands and gravels
Cambrian-Ordovician	Inwood Marble (calcitic and dolomitic)

At Yonkers Avenue to the northeast the river is confined by bedrock that is supported by walls. The Bronxville Lake is confined in part by shallow bedrock, the parkway to the west and the railroad to the east.

Figure 11 shows the 1891 and 2013 topographic maps of Crestwood Lake and Bronxville Lake. Both lakes existed in 1891.



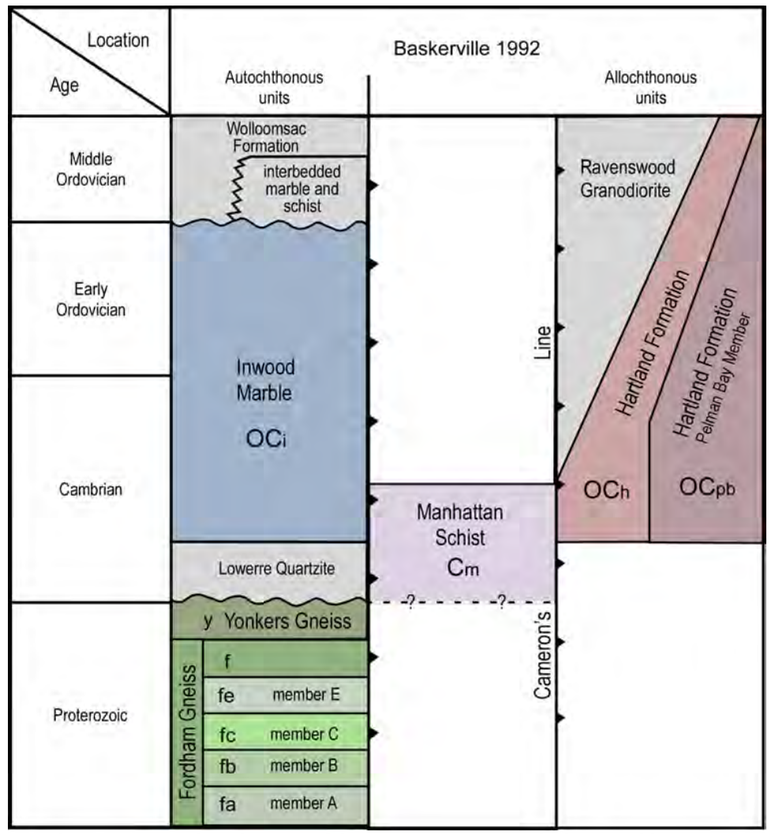
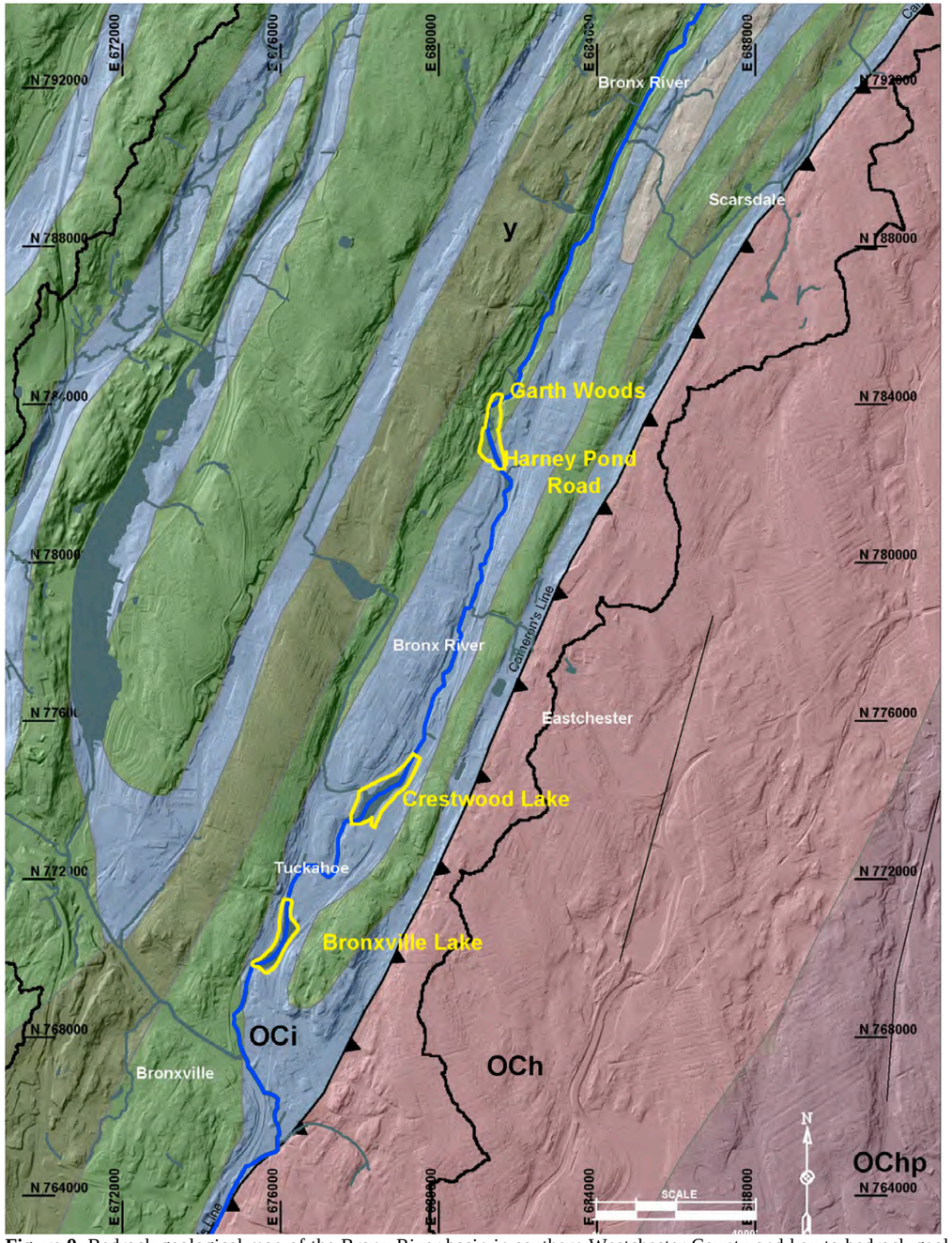


Figure 8. Bedrock stratigraphy of the Bronx River basin in Westchester County and key to bedrock geology. Gray indicates formations not shown on map. The tributaries of the Bronx River are marked in gray blue.



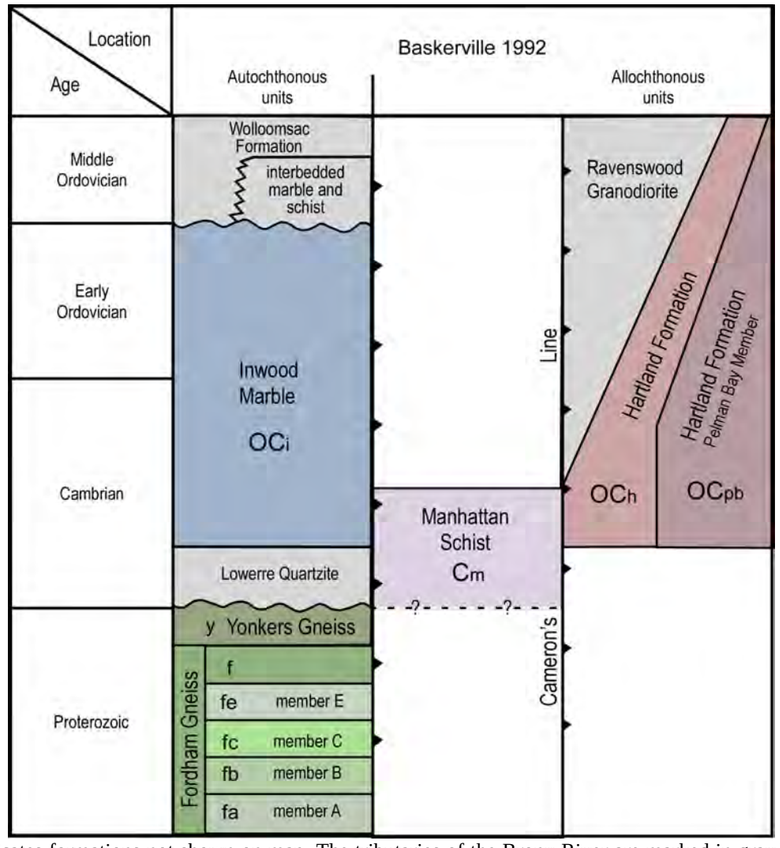


Figure 9. Bedrock geological map of the Bronx River basin in southern Westchester County and key to bedrock geology. Gray indicates formations not shown on map. The tributaries of the Bronx River are marked in gray blue. The tributaries of the Bronx River are marked in gray blue.

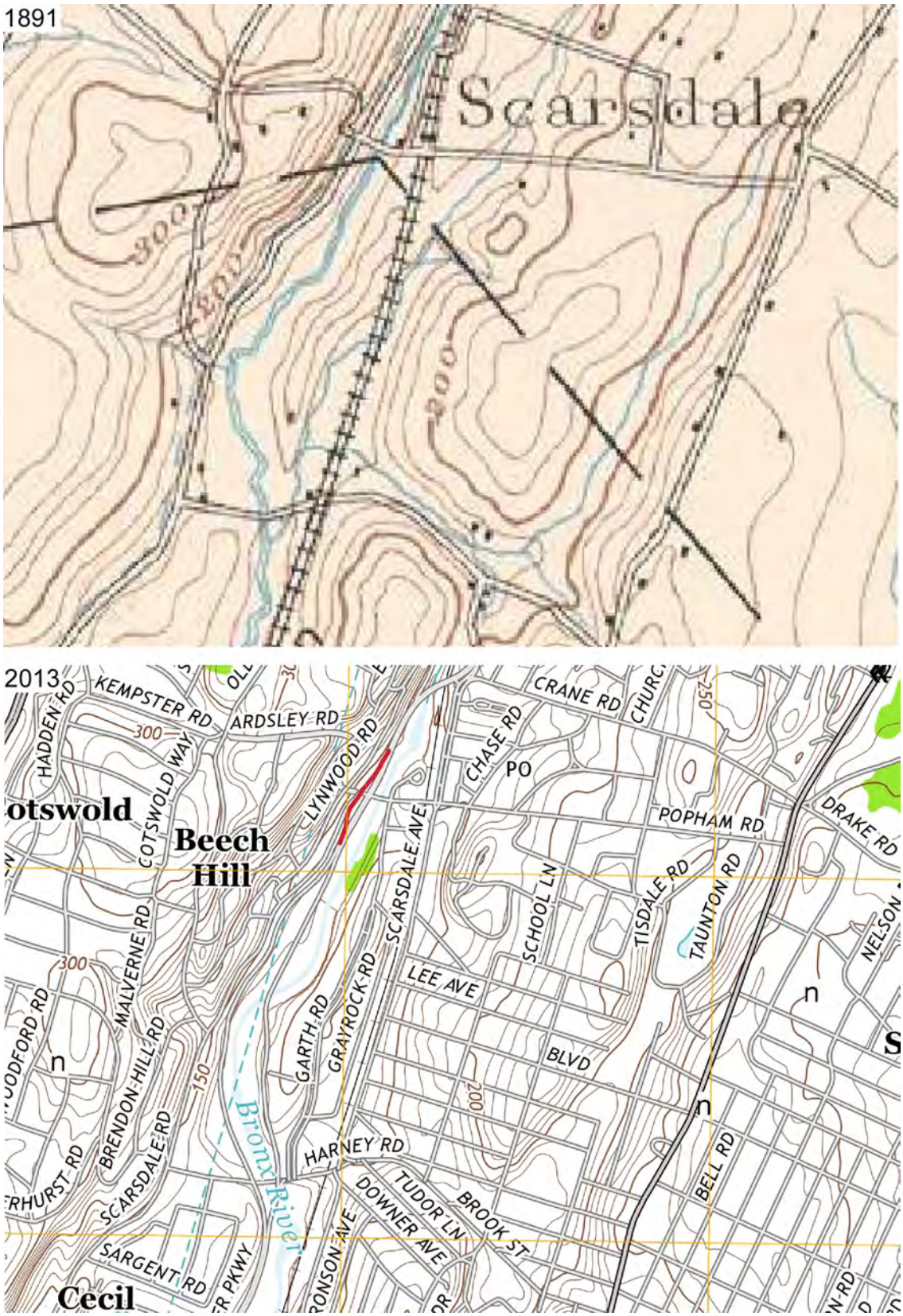


Figure 10. 1891 and 2013 USGS topographic maps showing the Harney Road and Garth Woods Area in Westchester County.

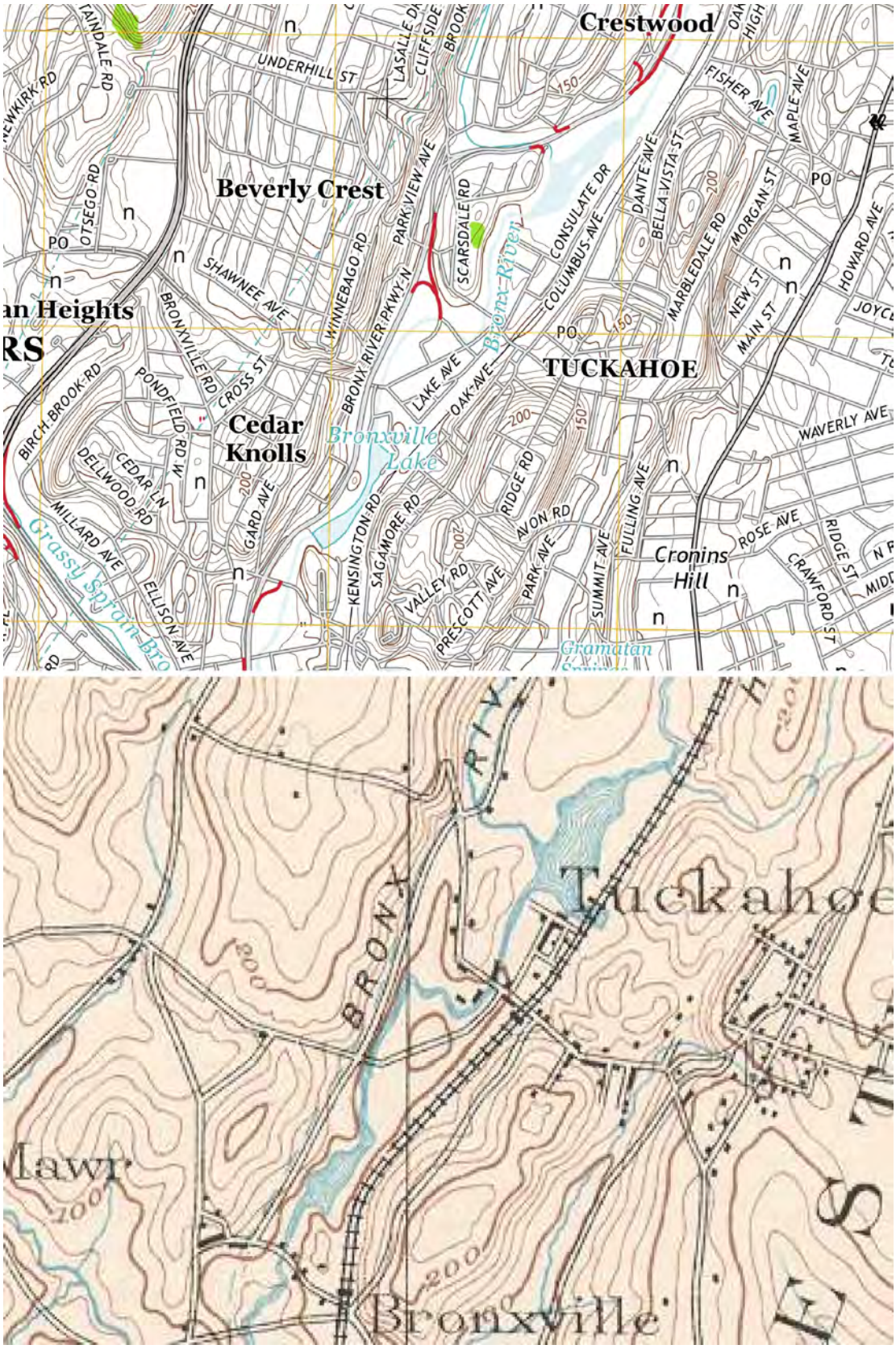


Figure 11. 1891 and 2013 USGS topographic maps showing the Crestwood Lake and Bronxville Lake area in Westchester County. The river is the boundary between Yonkers to the west and Tuckahoe to the east.

4.0 Bronx County sites

Figures 12 and 13 show bedrock geology of the northern and southern Bronx River in Westchester County. The four sites in Bronx County are discussed in the following.

4.1 Muskrat Cove

Muskrat Cove lies along a narrow valley bounded by Cameron's Line thrust on the east (Figure 12). Table 19 list stream attributes at this site.

Table 19. Summary of Bronx River attributes at Muskrat Cove site.

	Bronx River Basin values
River length at site	1,350ft
Watershed upstream of site	48.33 sq miles
Elevations of river	58 to 56ft
Average slope	7.8ft/mile
Low-flow channel width	60 to 85ft
Present-day width of river flood plain	150-210ft
Pre-railroad width of river flood plain	400-575ft
Roadway bridge crossings	2
Railroad bridges	1
Pedestrian bridges	0
Dams	0

Table 20 summarizes the general stratigraphy at this site. The river is underlain by the Fordham Gneiss except at the southernmost end of the site where the river flows back over the Inwood Marble.

Table 20. General stratigraphy of Westchester County Center site

Age	Description
Holocene	Modern river sediments: sands, gravels, cobbles
Holocene	Modern river sediments: silt, organic muds
Holocene	Fill and parkway
Holocene	Fill and railroad
Holocene	Thin soils
Holocene	Deeper fluvial sediments
Pleistocene	Pleistocene glacial outwash sands and gravels
Pleistocene	Pleistocene glacial tills of sand and gravel
Cambrian-Ordovician	Inwood Marble (calcitic and dolomitic)
Proterozoic	Fordham Gneiss

Figures 7 shows the 1891 and 2013 topographic maps of an area that extends from north of Muskrat Cove to just south of Shoelace Park. The 1891 map shows river meanders through this stretch. The 2013 map shows the river channel is constrained to be relatively straight. The railroad and Bronx River Parkway occupy approximately a third of the valley.

4.2 Shoelace Park

Shoelace Park is in the same narrow valley of Muskrat Cove (Figure 12). The valley is bound by Cameron's Line thrust on the east.

Table 21. Summary of Bronx River attributes at Shoelace Park site.

	Bronx River Basin values
River length at site	6757ft
Watershed upstream of site	49.73 sq miles
Additional watershed above downstream end	1.58 sq miles
Elevations of river	51 to 48ft
Average slope	2.3ft/mile
Low-flow channel width	50 to 90ft
Present-day width of river flood plain	90-400ft
Pre-railroad width of river flood plain	400-850ft
Roadway bridge crossings	5
Railroad bridges	0
Pedestrian bridges	0
Dams	0

Table 22 summarizes the general stratigraphy at this site. The river is underlain by the Inwood Marble just east of the contact with the Fordham Gneiss. The east side of the valley is bounded by Cameron's Line.

Table 22. General stratigraphy of Shoelace Park site.

Age	Description
Holocene	Modern river sediments: sands, gravels, cobbles
Holocene	Modern river sediments: silt, organic muds
Holocene	Fill and pathway/lawn
Holocene	Fill and parkway
Holocene	Fill and railroad
Holocene	Thin soils
Holocene	Deeper fluvial sediments
Pleistocene	Pleistocene glacial outwash sands and gravels
Pleistocene	Pleistocene glacial tills of sand and gravel
Cambrian-Ordovician	Inwood Marble (calcitic and dolomitic)
Proterozoic	Fordham Gneiss

This site is "alluvial reach 17" of Little and Biedenham (2007). Their Sample Bed 14 and Bed 15 were collected at the south and north end of the site, respectively. Samples were collected, however the bedforms from which they were collected were not identified. 55% of Sample Bed 15 is coarser than coarse sand. Only 5% of Sample Bed 14 is coarser than coarse sand.

Figure 7 shows the 1891 and 2013 topographic maps of an area that extend from north of Muskrat Cove to just south of Shoelace Park. The 1891 map shows river meanders through this stretch. The 2013 map shows the river channel is constrained to be relatively straight. The railroad and Bronx River Parkway occupy approximately a third of the valley.

4.3 Snuff Mill dam

Snuff Mill dam lies below Mosholu Fault and is surrounded by exposed Hartland Formation (Figure 13). Table 23 summarizes the river attributes at this site.

Table 23. Summary of Bronx River attributes Snuff Mill dam site.

	Bronx River Basin values
River length at site	344ft
Watershed upstream of site	52.15 sq miles
Elevations of river	48 to 38ft
Average slope	153ft/mile
Low-flow channel width	50 to 30ft
Present-day width of river flood plain	50-50ft
Pre-railroad width of river flood plain	50-70ft
Roadway bridge crossings	0
Railroad bridges	1
Pedestrian bridges	0
Dams	0

Table 24 summarizes the general stratigraphy at this site. The river flows over gneiss and schist of the Hartland Formation. There is generally no Pleistocene sediment, and older stream sediment is sparse. Most sediment is what has accumulated upstream of the dam. e4 mapped rock outcrops at this site.

Table 24. General stratigraphy of Snuff Mill dam site.

Age	Description
Holocene	Modern river sediments: ponded sands, silt, organic muds
Holocene	Fill and Dam
Holocene	Thin soils
Pleistocene	Pleistocene glacial boulders
Cambrian-Ordovician	Hartland Group

Figure 14 shows the 1891 and 2013 topographic maps of area from north of Snuff Mill dam to south of the Bronx Zoo and dam. Rock slopes confine the narrow valley. The 1891 and 2003 maps show that there has been little change to the width by man.

4.4 Bronx Zoo and dam

The Bronx Zoo and dam site lie in an area where the Bronx River flows eastward then southward between rock islands (Figure 14). Table 25 summarizes the river attributes at this site.

Table 25. Summary of Bronx River attributes Bronx Zoo and dam site.

	Bronx River Basin values
River length at site	1,256ft
Watershed upstream of site	52.57 sq miles
Elevations of river	29 to 21ft
Average slope	33.6ft/mile
Low-flow channel width	350 to 390ft
Present-day width of river flood plain	350 to 390ft
Pre-railroad width of river flood plain	430-750+
Roadway bridge crossings	1
Railroad bridges	0
Pedestrian bridges	0
Dams	1 double dam

Table 26 summarizes the general stratigraphy at this site. The river flows over gneiss and schist of the Hartland Formation (Figure 13). There is generally no Pleistocene sediment, and older stream sediment is sparse. Most sediment is what has accumulated upstream of the dam. e4 mapped rock outcrops at this site.

Table 26. General stratigraphy of Bronx Zoo and dam site

Age	Description	
Holocene	Modern river sediments	Ponded sands, Silt, organic muds
Holocene	Thin soils	
Pleistocene	Pleistocene glacial sediments	boulders
Cambrian-Ordovician	Hartland Formation	

Figure 14 shows the 1891 and 2013 topographic maps of area from north of Snuff Mill dam to south of the Bronx Zoo and dam. The river width has not changed. The islands are not indicated in the 1891 map.

4.5 Bronx River Park

The Bronx River at the Bronx River Park site is confined between buildings that line the shoreline (Figure 15). The southernmost dam on the Bronx River is immediately upstream from the site. Table 27 summarizes the river attributes at this site.

Table 27. Summary of Bronx River attributes of the Bronx Park site.

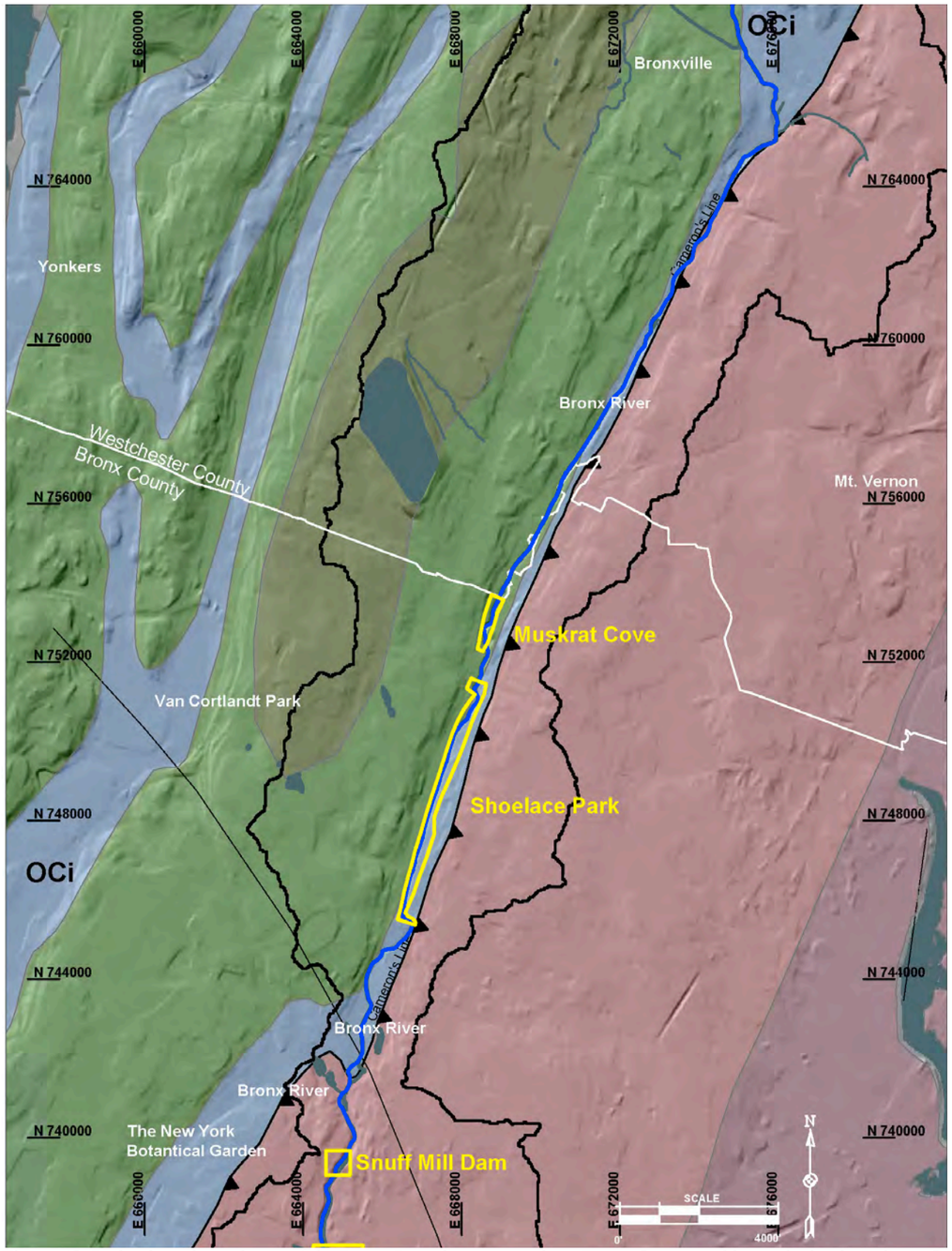
	Bronx River Basin values
River length at site	905ft
Watershed upstream of site	53.26 sq miles
Elevations of river	16 to 9ft
Average slope	40.8ft/mile
Low-flow channel width	30 to 50ft
Present-day width of river flood plain	50-60ft
Pre-railroad width of river flood plain	550-650ft
Roadway bridge crossings	1
Railroad bridges	1
Pedestrian bridges	0
Dams	1 north of site

Table 28 summarizes the general stratigraphy at this site. The river flows over gneiss and schist of the Hartland Formation (Figure 13). There is generally no Pleistocene sediment, and older stream sediment is sparse. Most sediment is what has accumulated upstream of the dam. e4 mapped rock outcrops at this site.

Table 28. General stratigraphy of Bronx Zoo and dam site.

Age	Description	
Holocene	Modern river sediments	Ponded sands, Silt, organic muds
Holocene	Thin soils	
Pleistocene	Pleistocene glacial sediments	boulders
Cambrian-Ordovician	Hartland Formation	

Figure 14 shows the 1891 and 2013 topographic maps of area from north of Bronx Park site area. Buildings confine the eastern shore. This area was already built up by 1891. A meander existed south of the area in 1891, and it has been eliminated.



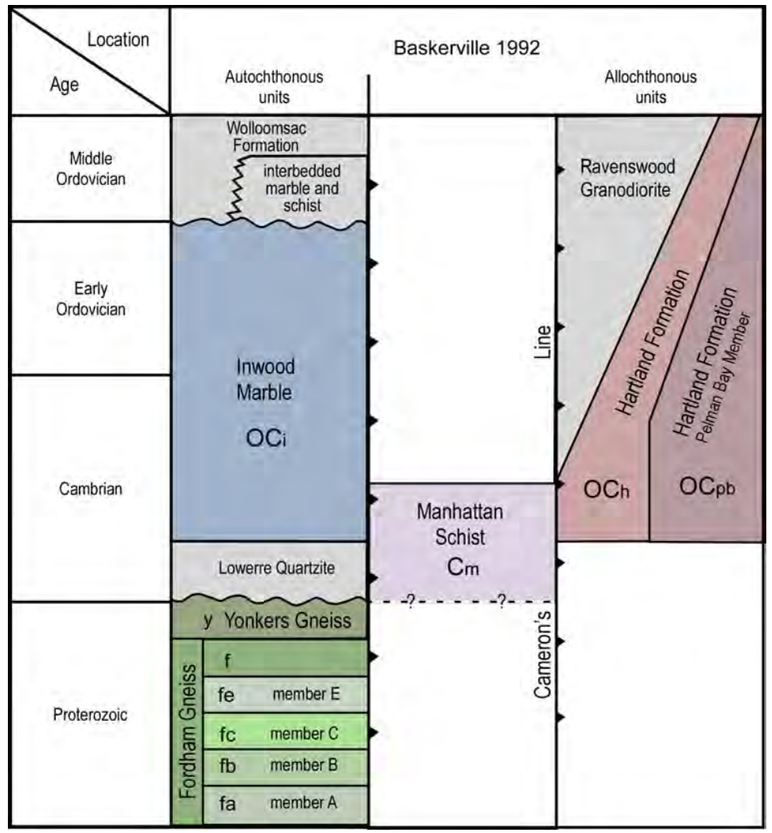
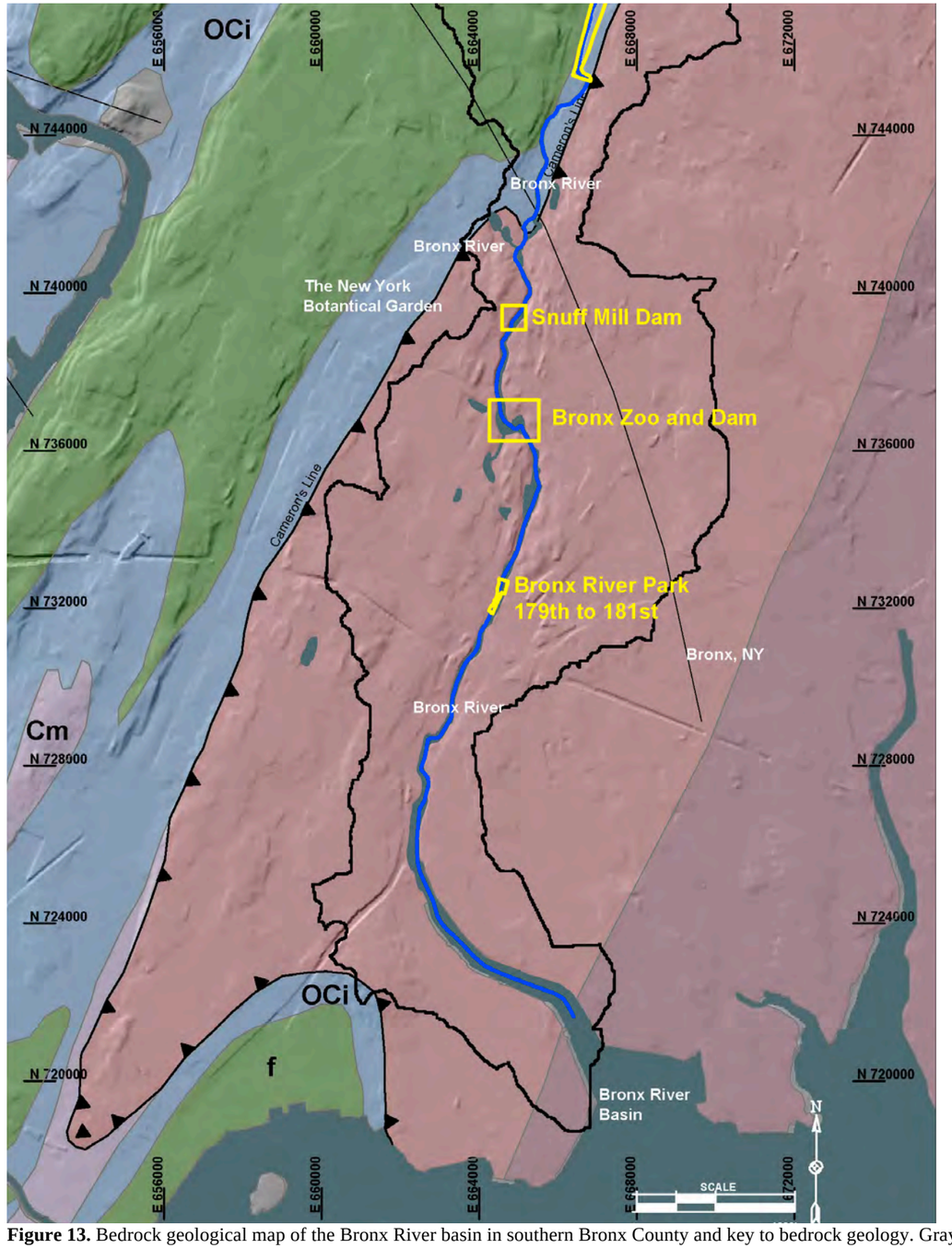


Figure 12. Bedrock geological map of the Bronx River basin in northern Bronx County and key to bedrock geology. Gray indicates formations not shown on map. The tributaries of the Bronx River are marked in gray blue.



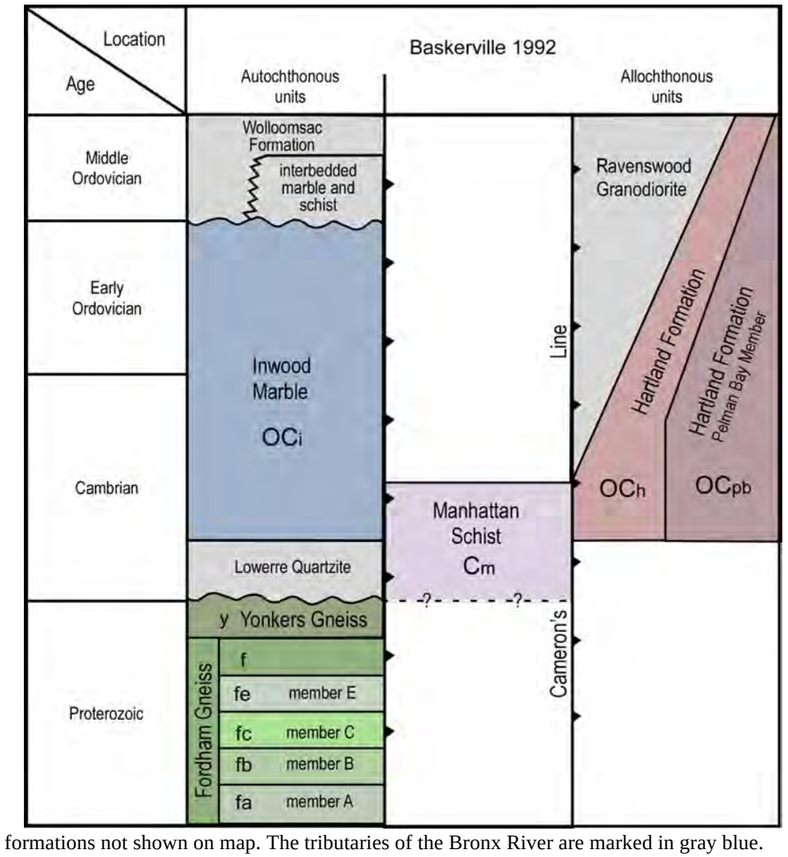


Figure 13. Bedrock geological map of the Bronx River basin in southern Bronx County and key to bedrock geology. Gray indicates formations not shown on map. The tributaries of the Bronx River are marked in gray blue.

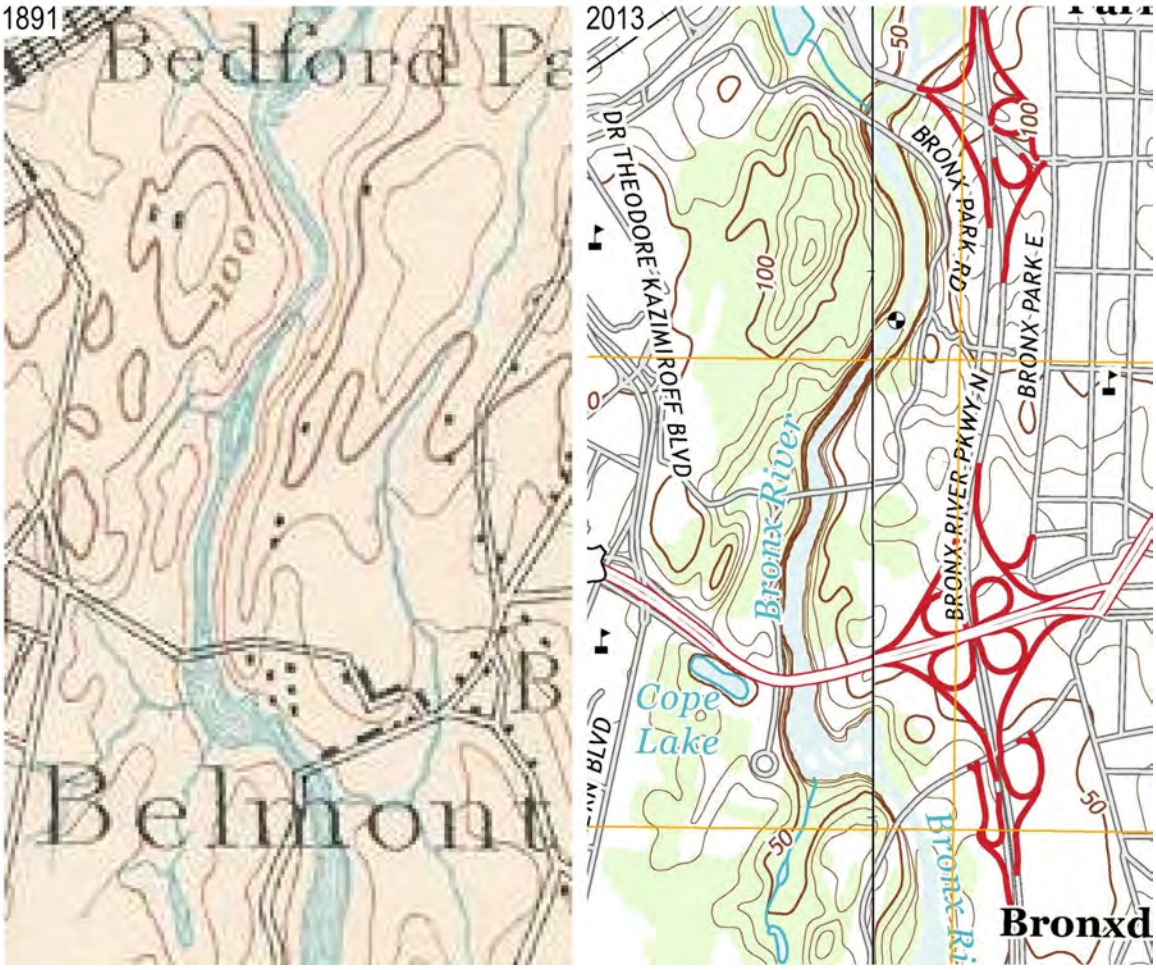


Figure 14. 1891 and 2013 USGS topographic maps showing the Snuff Mill dam and Bronx Zoo and dam area in Bronx County.

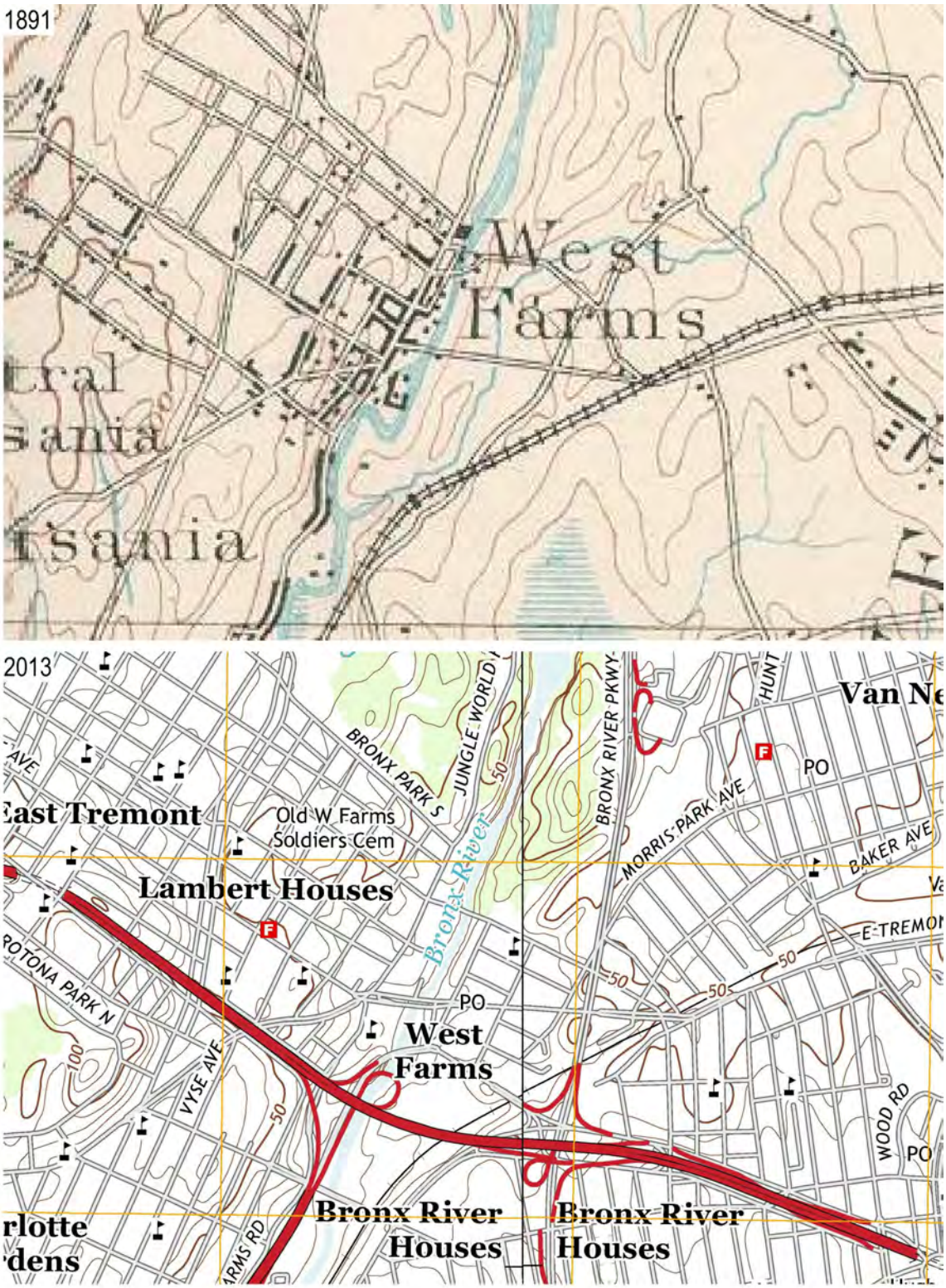


Figure 15. 1891 and 2013 USGS topographic maps showing the Bronx Park area in Bronx County.

5.0 Conclusions

The United States Army Corps of Engineers (USACE-NAN) is planning to restore ecosystems within the Bronx River in Westchester and Bronx Counties in New York State.

The USACE-NAN assigned e4sciences (e4) to evaluate four sites in Westchester County and five sites in Bronx County. This report is a desktop study of the geology and the geotechnical properties of the rocks and sediments in the Bronx River valley, and particularly at the nine sites of interest. e4 mapped the geology from literature and field observations, topography using LiDAR, and soils from EPW and literature.

1. The Bronx River is approximately 23 miles long. It flows from Kensico Lake in the north to Hunts Point in the East River.

2. The river is underlain by Ordovician bedrock. The Ordovician is folded and faulted. e4 determined that the river passes mostly along the Ordovician Inwood Marble in Westchester and the Bronx.

3. The Inwood Marble is a softer folded rock unit more readily eroded that lies above the folded and faulted underlying Fordham Gneiss.

4. The Bronx River valley is one of five roughly north-northeast/south-southwest troughs in Westchester County below the Kensico Dam in the north.

5. Just south of Bronxville Lake, the river follows the Inwood Marble and passes east to run for three miles along Cameron's Line, an Ordovician thrust fault just south of Bronxville.

6. In the Bronx, just north of the Botanical Gardens, a Pleistocene fault forces the river to cross Cameron's line.

7. The river crosses the Cambrian-Ordovician Hartland Formation to enter the East River at Hunts Point.

8. The Quaternary sediments in the Bronx River valley range from 0 to ~80ft thick. They are mostly Pleistocene till and outwash sands and gravels.

9. Rivers show three scales of meanders: (a) low-frequency long-wavelength meanders, (b) mid-frequency mid-wavelength meanders, and (c) high-frequency short-wavelength meanders.

10. The six low-frequency long-wavelength meanders approximately 15,000ft in wavelength and have an amplitude less than 500ft.

11. Engineers most commonly measure the mid-frequency mid-wavelength meanders. In the Bronx River, these meanders show a relatively consistent wavelength of 1000ft and an amplitude less than 200ft.

12. The high-frequency short-wavelength meanders track the variation of the thalweg. The short wavelengths in the Bronx River are 600ft and their amplitudes are less than 60ft.

13. For the most part, geological structure controls the Bronx River trajectory.

14. The river is further confined within its valley by man-made fill for Bronx River Parkway and for the Metro North Railroad. Bridge abutments obstruct the natural river processes in several areas.

15. The river ecosystem is choked in multiple places by sand deposits produced from sand and salt treatment of roads for de-icing.

16. From these deposits, a significant amount of salt dissolves the river.

17. The effect of the salt and the sand on the river has been negative, and these effects must be considered in the restoration design.

Appendix I:
References

References

Asselstine and I.G. Grossman, 1955, The groundwater resources of Westchester County, New York. Part 1, Record of wells and test holes.

Baskerville, C. A., 1982a, The foundation geology of New York City, in Legget, R. F., ed., Geology under cities: Geological Society of America Reviews in Engineering Geology, v. 5, p. 95-117.

Baskerville, C. A., 1992, Bedrock and engineering geologic maps of Bronx County and parts of New York and Queens counties, New York: U. S. Geological Survey Miscellaneous Investigations Series Map I-2003 (scale 1:24,000).

Baskerville, C. A., and R. H. Fakundiny. 2003. Engineering Geology of New York City: Continuing Value of Geologic Data. In *Earth Science in the City: A Reader*. Special Publication Series 56, edited by G. Heinken, R. Fakundiny, and J. Sutter, pp. 43-59. American Geophysical Union, Washington, D.C.

e4sciences|Earthworks, 2010, Report of Yonkers Avenue rehabilitation, Tucjahoe, NY, Geotechnical and Hydraulic concerns.

Kemp, J. F., 1897, The glacial (sic) or postglacial diversion of the Bronx River from its old channel: New York Academy of Sciences Transactions, v. 16 (1896), p. 18-24, map.

Little, C.D., D.S. Biedenham, 2007, Geomorphic Assessment and Sediment Impact Assessment for Bronx River, Final Report, New York, U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.

Merguerian, Charles; and Sanders, J. E., 1996a, Diversion of the Bronx River in New York City - evidence for postglacial surface faulting?, p. 131-145 in Hanson, G. N., chm., Geology of Long Island and metropolitan New York, 20 April 1996, State University of New York at Stony Brook, NY, Long Island Geologists Program with Abstracts, 177 p.

Merguerian, Charles, 1983a, Tectonic significance of Cameron's Line in the vicinity of the Hodges Complex--an imbricate thrust model for western Connecticut: American Journal of Science, v. 283, pp. 341-368.

Merguerian, Charles; and Baskerville, C. A., 1987, The geology of Manhattan Island and the Bronx, New York City, New York, p. 137-140 in Roy, D. C., ed., Northeastern Section of the Geological Society of America, Centennial Field guide, v. 5, 481 p.

Merguerian, Charles; and Sanders, J. E., 1991, Trip 16: Geology of Manhattan and the Bronx, 21 April 1991: New York Academy of Sciences Section of Geological Sciences Trips on the Rocks Guidebook, 141 p.

Merguerian, Charles; and Sanders, J. E., 1993a, Trip 26, Cameron's Line and The Bronx parks, 08 May 1993 (revision of Trip 21, 24 November 1991): New York Academy of Sciences Section of Geological Sciences Trips on the Rocks Guidebook, 126 p.

Merguerian, Charles; and Charles A. Baskerville, 1987, Geology of Manhattan Island and the Bronx, New York City, New York, Geological Society of America Centennial Field Guide-Northeastern Section.

Sanderson, Eric W., Kim Fisher, Mario Giampieri, and Fiona McKibben, 2014, An analysis of the historical streams and wetlands between the Harlem and Hudson Rivers and the Bronx River, New York City, with recommendations for restoration.

USACE, NYC DEP Westchester Government, 2010, Bronx River Basin, New York, Ecosystem Restoration Study, Volume I.

USACE, NYC DEP Westchester Government, 2010, Bronx River Basin, New York, Ecosystem Restoration Study, Volume II.

USDA and Cornell Soil Survey of Putman and Westchester Counties, New York.

USDA and NRCS Soil Survey of Bronx River Watershed, Bronx, New York.

Wheeler, R.L., 2006, Quaternary tectonic faulting in the Eastern United States, Engineering Geology, v82, pp.165-186.

Topographic maps

USGS, 2013, Central Park NY-NJ 7.5 minute topographic quadrangle map
USGS 1947, Central Park NY-NJ 7.5 minute topographic quadrangle map
USGS, 2013, Flushing NY 7.5 minute topographic quadrangle map
USGS, 1947, Flushing NY 7.5 minute topographic quadrangle map
USGS, 1891, Harlem NY-NJ 15 minute topographic quadrangle map
USGS, 1897, Harlem NY-NJ 15 minute topographic quadrangle map
USGS, 1901, Harlem NY-NJ 15 minute topographic quadrangle map
USGS, 2013, Mount Vernon, NY 7.5 minute topographic quadrangle map
USGS, 1947, Mount Vernon, NY 7.5 minute topographic quadrangle map
USGS, 1892, Tarrytown, NY-NJ 15 minute topographic quadrangle map
USGS, 1902, Tarrytown, NY-NJ 15 minute topographic quadrangle map
USGS, 2013, White Plains, NY 7.5 minute topographic quadrangle map
USGS, 1947, White Plains, NY 7.5 minute topographic quadrangle map
USGS, 1938, White Plains, NY 7.5 minute topographic quadrangle map
USGS, 1932, White Plains, NY 7.5 minute topographic quadrangle map

Westchester County GIS data

http://giswww.westchestergov.com/wcgis/Lidar.htm
http://giswww.westchestergov.com/wcgis/DataWarehouse.htm
http://giswww.westchestergov.com/wcgis/Data.htm

NY State Geology Map GIS data

http://www.nysm.nysed.gov/gis/

Bronx Geology Map GIS data

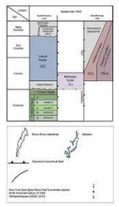
http://data.geocomm.com/catalog/US/61061/816/index.html
http://3dparks.wr.usgs.gov/nyc/highlands/manhattan.htm
http://dukelabs.com/Publications/PubsPdf/CMCAB1987_DNAG_GeolManhattanBronx.pdf

Appendix II:
11x17 Versions of Plates

Sciences | Earthworks, LLC

Plate 1: Geological maps



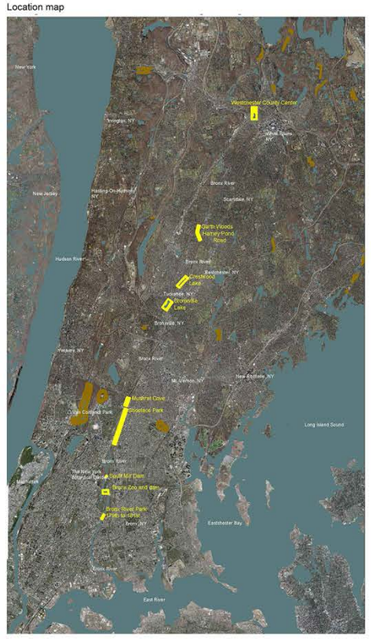


Drawn By: Scott Bright

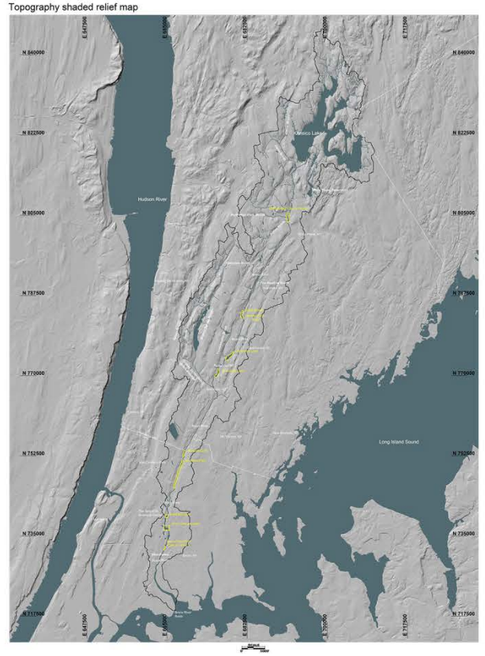
Approved By:

Date: September 12, 2014

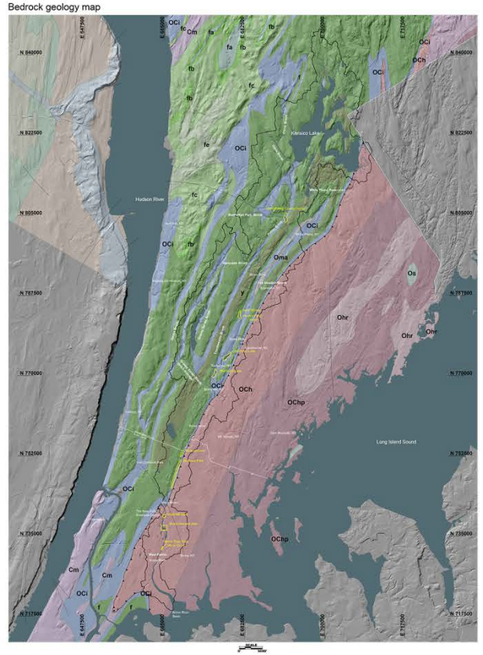
Location map



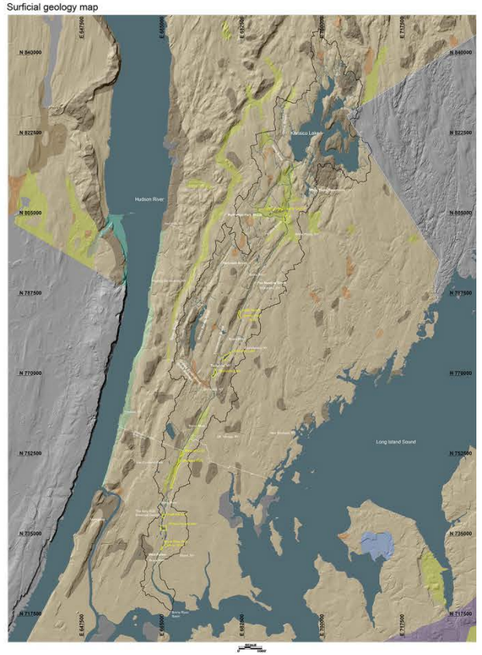
Topography shaded relief map



Bedrock geology map



Surficial geology map

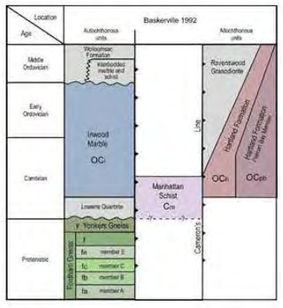


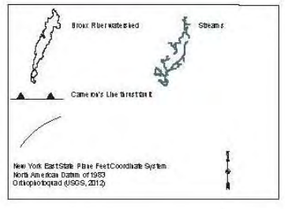
esciences | Earthworks, LLC

Plate 2: North Westchester county bedrock geology map

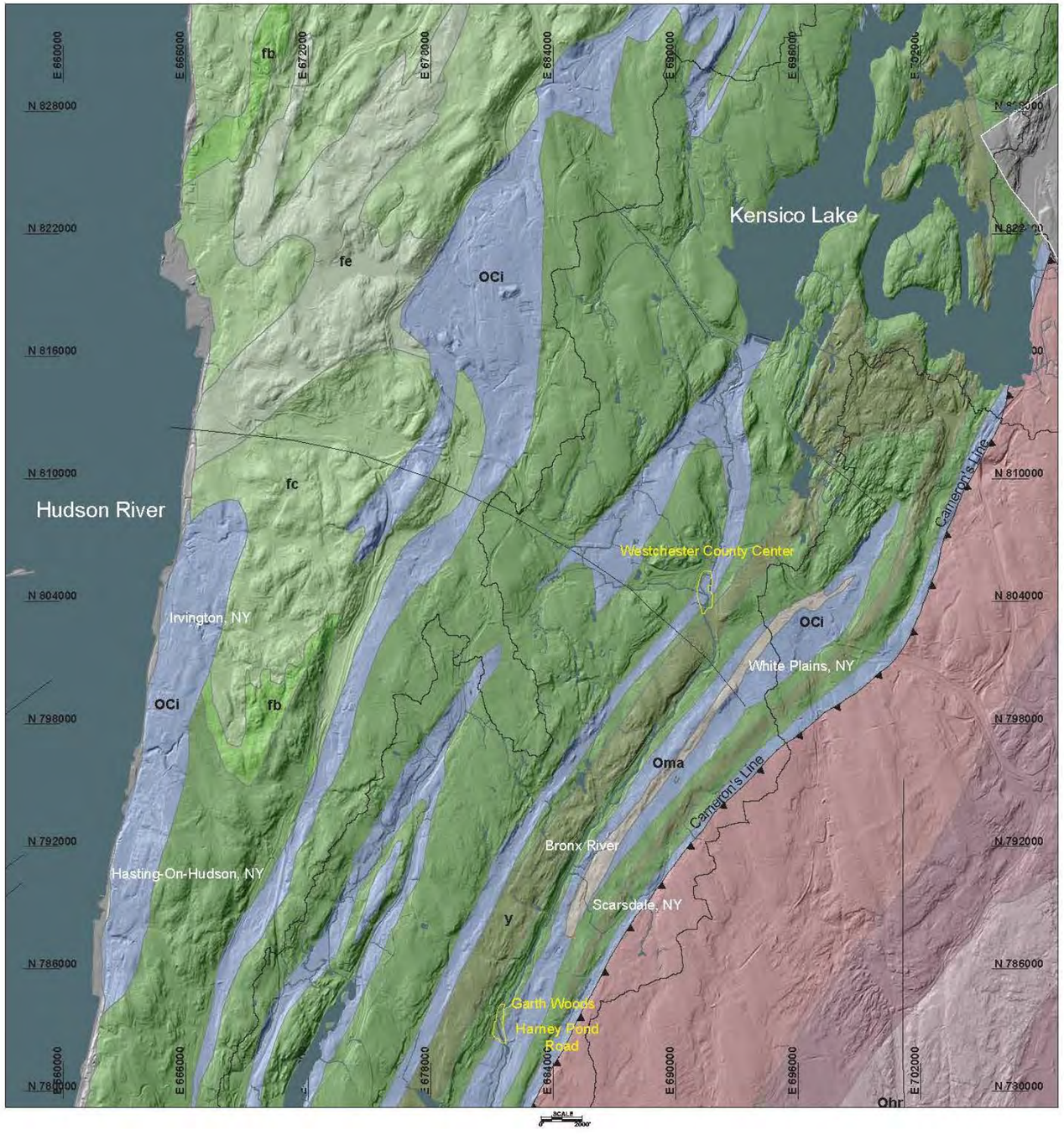
Contract # W912DS-12-D-002, Task Order TO 0019;
Bronx River Ecosystem Restoration Feasibility Study, Geological study







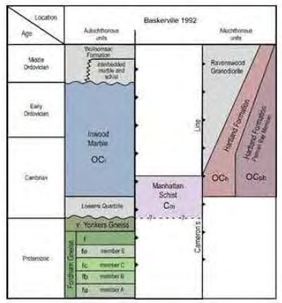
Drawn By: Brett Boyle
Approved By:
Date: September 12, 2014

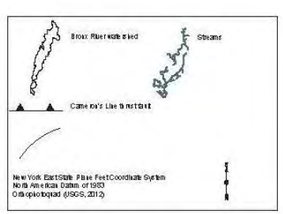


edsciences | Earthworks, LLC

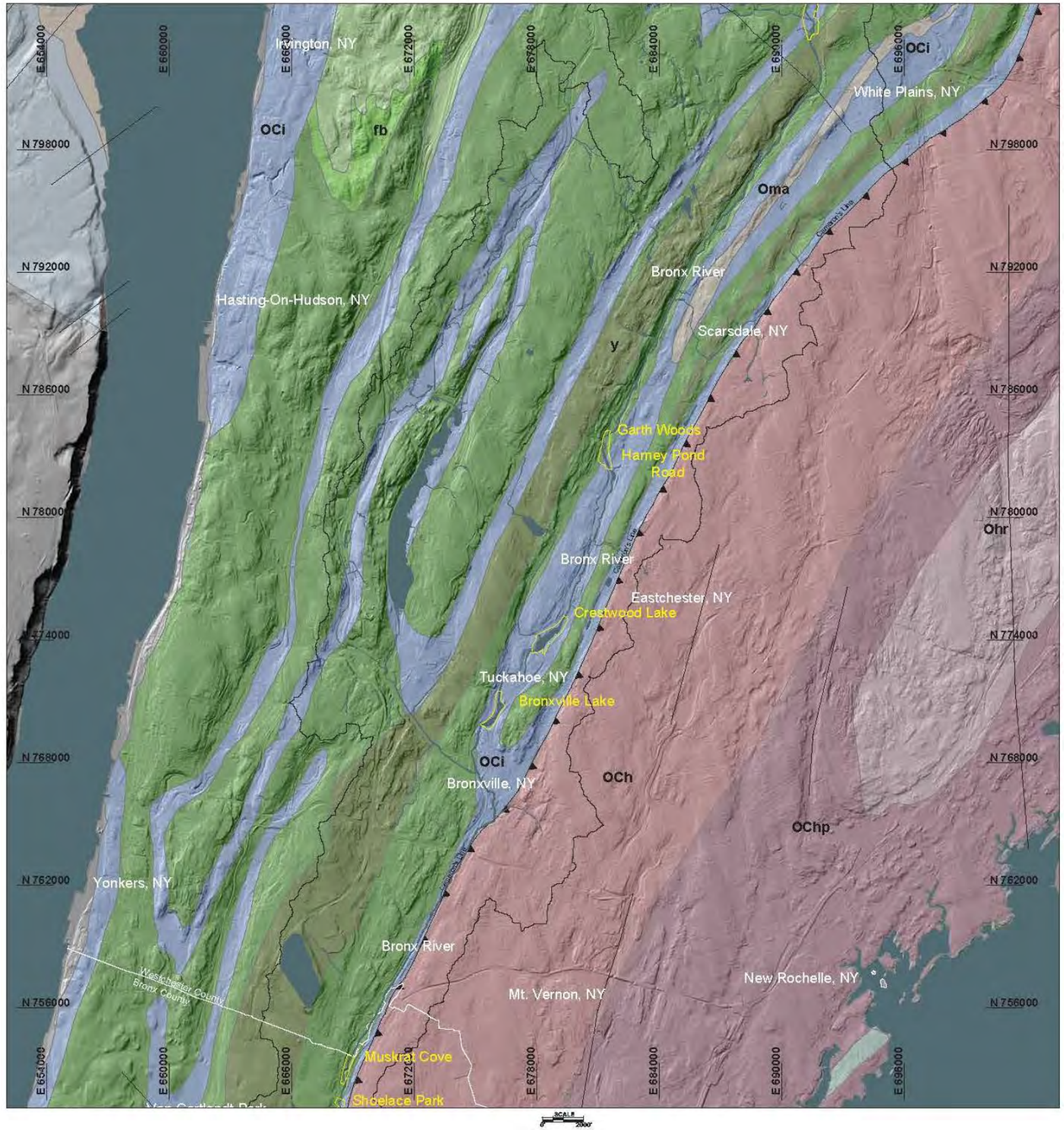
Plate 3: South Westchester county bedrock geology map







Drawn By: Brickett Boyd
Approved By:
Date: September 12, 2014



Attachment C-5
HRE
Bronx River Geomorphic Assessment and SIAM Modeling

Geomorphic Assessment and Sediment Impact Assessment for Bronx River, New York



Final Report

by

Charles D. Little, Jr., P.E., and David S. Biedenharn, PhD., P.E.

U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS

March 2007

Geomorphic Assessment and Sediment Impact Assessment for Bronx River, New York

Final Report

By

Charles D. Little, Jr., P.E., and David S. Biedenharn, PhD., P.E.

U.S. Army Engineer Research and Development Center
Coastal and Hydraulics Laboratory
3909 Halls Ferry Road
Vicksburg, Mississippi 39180

March 2007

PREFACE

This report discusses work performed during fiscal year 2006 by the Coastal and Hydraulics Laboratory (CHL) of the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. The work was requested and sponsored by the U.S. Army Corps of Engineers New York District.

The report was prepared under the direct supervision of Mr. James R. Leech, Chief of River Engineering Branch, and under the general supervision of Mr. Thomas W. Richardson, Director of CHL. The report was prepared by Charles D. Little, Jr., P.E., and David S. Biedenharn, PhD., P.E., both of River Engineering Branch, CHL.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC and Col. Richard B Jenkins was Commander.

TABLE OF CONTENTS

PREFACE…… iii
LIST OF FIGURES…….……... vi
LIST OF TABLES……..…….. vii

1. INTRODUCTION ……..……..…….. 1

2. OBJECTIVES……..……...…….. 1

3. DESCRIPTION OF STUDY AREA……..…….. 2
   3.1 Location……..…….2
   3.2 Basin Description……..……. 3
   3.3 Stream Characteristics…….……... 3

4. ANALYSIS AND RESULTS……...4
   4.1 Baseline Geomorphic Assessment……..4
      4.1.1 Data Gathering…….4
      4.1.2 Field Investigation……... 5
      4.1.3 Comparative Channel Surveys……..... 5
      4.1.4 Sediment Sources…….6
      4.1.5 Bed Material Samples……..16
      4.1.6 Sediment Transport Characteristics…….. 18
      4.1.7 Geomorphic Reaches…….…… 21
      4.1.8 Geomorphic Summary…… 29
   4.2 Sediment Impact Assessment (SIAM Model)…… 30
      4.2.1 SIAM Model Description…… 30
      4.2.2 SIAM Input Data……. 30
         4.2.2.1 Bed Material……. 30
         4.2.2.2 Discharge Duration…….. 31
         4.2.2.3 Sediment Properties……. 32
         4.2.2.4 Sediment Sources……. 33
         4.2.2.5 Hydraulics……..... 35
      4.2.3 SIAM Computations……... 35
      4.2.4 SIAM Results…….. 36
         4.2.4.1 Local Balance Discussion……..... 36
         4.2.4.2 Wash Load Discussion……. 39
         4.2.4.3 Bed Material Supply Discussion…….. 40
         4.2.4.4 Conversion of Local Balance to Average Annual Deposition Depth…….. 41

5. CONCLUSIONS AND RECOMMENDATIONS……. 42
   5.1 Sediment Sources …… 42
   5.2 Sediment Deposition in Pools …… 42
   5.3 SIAM Results ……. 43

5.4 Specific Questions from Westchester County, NYC ……. 43
Department of Parks/Recreation, and USAED, New York
5.5 Recommendations …….. 45

6. REFERENCES……. 46

LIST OF FIGURES

Figure 1. Bronx River study area location …….. 3
Figure 2. Comparative cross section site 1 …….. 5
Figure 3. Comparative cross section site 2 …….. 6
Figure 4. Comparative cross section site 3 …….. 6
Figure 5. Bank material sample locations …….. 7
Figure 6. Bank material gradations …….. 8
Figure 7. Stream bank erosion near Westchester County Center …….. 9
Figure 8. Stream bank erosion at Scout Field near Bronxville …….. 9
Figure 9. Upper bank slope erosion near Garth Woods …….. 10
Figure 10. Sediment source from Westchester County Center tributary …….. 11
Figure 11. Minor bank erosion on Troublesome Brook …….. 12
Figure 12. Sprain Brook tributary near confluence with Bronx River ……. 12
Figure 13. Typical gully erosion under Bronx River Parkway overpass …….. 13
Figure 14. Roadway surface erosion along Bronx River Parkway …….. 14
Figure 15. Potential source of coarse sediment is railroad embankment …….. 15
immediately adjacent to channel (Hartsdale Station) ……..
Figure 16. Sediment deposition in pool at Harney Road …….. 16
Figure 17. Bed material sample locations …….. 17
Figure 18. Bed material gradations (Bed1 through Bed8) …….. 18
Figure 19. Bed material gradations (Bed9 through Bed17) …….. 18
Figure 19. Location of geomorphic reaches 1 through 4 …….. 16
Figure 20. Typical through-put reach…….. 19
Figure 21. Typical alluvial reach……..…….. 20
Figure 22. Typical pool reach…….. 20
Figure 23. Location of geomorphic reaches 1 through 4 …….. 21
Figure 24. Location of geomorphic reaches 5a through 6 …….. 22
Figure 25. Location of geomorphic reaches 7a through 9…….. 23
Figure 26. Location of geomorphic reaches 10 through 12 …….. 24
Figure 27. Location of geomorphic reaches 13a through 15 …….. 25
Figure 28. Location of geomorphic reaches 16a and 16b..…….. 26
Figure 29. Location of geomorphic reach 17…….. 27
Figure 30. Location of geomorphic reaches 18 through 20..…….. 28
Figure 31. Location of geomorphic reaches 21 and 22 ……. 29
Figure 32. SIAM bed material gradations …….. 31

LIST OF TABLES

Table 1. Data sources and acquisitions ……. 4
Table 2. SIAM flow duration input (from Bronxville gage)…….. 31
Table 3. Wash load threshold diameters for SIAM reaches…….. 32
Table 4. SIAM input for bank erosion sediment source…….. 33
Table 5. SIAM input for watershed sediment source…….. 34
Table 6. SIAM results for Local Balance in tons/year……..36
Table 7. SIAM results for Wash Load in tons/year…….. 39
Table 8. SIAM results for Bed Material Supply in tons/year……..…. 40
Table 9. Estimated average annual deposition depths from Local Balance…….. 41

1. INTRODUCTION

The U.S. Army Corps of Engineers, New York District (NAN) is the lead Federal agency in a cooperative study with the Westchester County Department of Planning and the New York City Department of Environmental Protection addressing ecosystem restoration in the Bronx River Basin, Westchester and Bronx Counties, New York. The study area covers approximately 56 square miles and approximately 23 miles of river channel from Kensico Reservoir near North White Plains, NY, to the confluence of the Bronx River with the East River. Intense urbanization and development have led to degradation of the environment within the study area. Direct impacts on the ecological resources within the study area include loss of wetland acreage, destruction of aquatic and riparian habitat, increased sedimentation, increases in nutrient and other pollutant loading, and stream bank erosion. Indirect impacts of urbanization include increased run-off, reduced groundwater recharge, and increased stream temperatures. In addition, low head dams along the river system serve as impediments to fish passage. As a result of these impacts, fish and wildlife habitat as well as water quality have been degraded within the study area.

Watershed problems associated with sedimentation and channel instability often require a system-wide analysis to adequately identify the causes and effects of the problems and to formulate potential solutions. In order to assess the overall stability and sedimentation trends of the Bronx River study area, the U.S. Army Engineer Research and Development Center Coastal and Hydraulics Laboratory (ERDC-CHL) conducted a geomorphic assessment and sediment impact assessment for the watershed. The geomorphic assessment defines past and present channel and watershed dynamics, identifies sources and characteristics of sediments derived from the basin, and determines the stability of the channel system. Field investigations were conducted in May and July 2006 to document watershed conditions and collect bed and bank material samples to support the geomorphic assessment. The sediment impact assessment of the Bronx River was conducted using the Sediment Impact Analysis Methods (SIAM) model developed through a joint effort between ERDC and the Corps of Engineers Hydrologic Engineering Center (HEC). SIAM is a reach-averaged sediment transport computational tool incorporated into the HEC-RAS modeling system that provides a means of determining sediment continuity within a system and assessing the sediment impacts of potential rehabilitation and restoration measures.

2. OBJECTIVES

The objectives of this study were to a) conduct a geomorphic assessment of the Bronx River watershed in the area from Kensico Reservoir in Westchester County to Dam 1 near 174th Street in the Bronx, and b) conduct a sediment assessment of the Bronx River using the SIAM model. The portion of the Bronx River downstream of Dam 1 is in the tidal zone of the East River and was not included in the assessment. The geomorphic assessment includes data gathering, a detailed field investigation, sediment sampling and analysis, and channel stability classification. The products of the geomorphic assessment

are a reach by reach evaluation of existing conditions of the Bronx River, identification of significant sediment sources and characteristics, and evaluation of channel stability for each reach. The sediment assessment includes developing a SIAM model from existing HEC-RAS models provided by NAN. Sediment sources input to the model were estimated from available data and observations from the geomorphic assessment. The SIAM model was used to determine sediment continuity for each geomorphic reach for existing conditions. The impacts of bank stabilization and control of other watershed sediments were also estimated in additional SIAM computations and compared to existing condition results. The products of the sediment impact assessment include identification of reaches prone to excessive sediment deposition and/or erosion, a rough estimate of sediment magnitudes, and an estimate of the potential impact of sediment control on sedimentation trends in the reaches.

An additional objective of this report is to address specific questions and concerns regarding sedimentation impacts on the Bronx River that have been raised by Westchester County, NYC Department of Parks/Recreation, and NAN. The items to be addressed are:

- What and where are the sources of sediment?
- What are the characteristics of the sediment?
- Where are the primary areas of erosion and deposition within the river system? Are some impoundments filling more rapidly than others?
- What are the rates of deposition?
- How does land use within the watershed affect sediment?
- Which tributaries are the primary sediment producers?
- Can re-suspension of sediment deposits within the impoundments be a sediment source?
- Is sediment concentration correlated with seasonal conditions or stream flow?
- How will potential physical modifications to the channel system and sediment sources impact sediment movement within the system?

3. DESCRIPTION OF STUDY AREA

3.1 Location. The study area is located in central and southern Westchester County and central Bronx County in New York. The upper limit of the study is Kensico Reservoir near North White Plains, and the lower limit of the study is Dam 1 near 174th Street in the Bronx. The basin runs in a general northeast to southwest direction and traverses through the highly developed area of greater New York City including the villages of White Plains, Scarsdale, Tuckahoe and Bronxville. The location of the study area is shown in Figure 1.

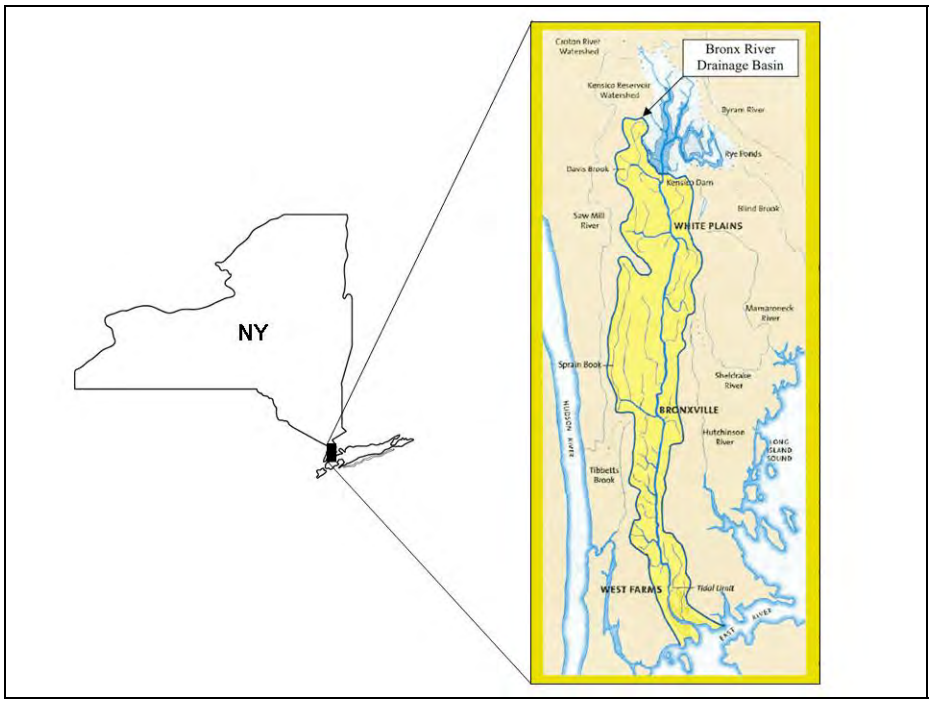


Figure 1. Bronx River study area location.

3.2 Basin Description. The Bronx River basin within the study limits is a highly built up urban area within the greater New York City metropolitan area. The drainage area of the study area encompasses approximately 56 square miles, through which the Bronx River traverses approximately 23 miles. The basin shape is relatively narrow and elongated, with widths ranging from approximately 4 miles in the Ardsley/White Plains area to approximately 1.5 miles in the vicinity of Shoelace Park. Elevation relief over the study area is approximately 360 feet, ranging from approximately 370 feet near Kensico Dam to approximately 10 feet near Dam 1. Land use is primarily high density commercial and residential throughout most of the study area, with industrial areas located in the lower portion of the area in the Bronx. The Bronx River Parkway and the Metro North Railroad both generally parallel the river throughout Westchester County and a portion of Bronx County. The Bronx River Parkway in Westchester County and the Bronx Park in Bronx County basically form a continual "greenway" along the river, and the flood plain as a result is not very built up. A series of low head dams along the river form small impoundments or lakes, with the largest pools located near Tuckahoe and Bronxville in Crestwood Lake and Bronxville Lake, respectively.

3.3 Stream Characteristics. The Bronx River in the study area can be basically characterized as a low sinuosity, single thread channel. Some stream channelization was conducted as part of the Bronx River Parkway construction in the early 1900s. Bank heights range from 3 to 6 feet, and channel widths in natural reaches vary from 10 to 40 feet and approach 150 to 200 feet in impoundment areas above the low head dams located along the system. Channel slope ranges from approximately 5 to 25 feet per mile in natural reaches, with flatter slopes found in impounded reaches. Major tributaries to the Bronx River included Davis Brook, an unnamed stream near White Plains (hereafter

referred to as Westchester County Center tributary), Troublesome Brook, and Sprain Brook. Bed material ranges from sands and gravels in the milder sloped reaches to small/medium cobbles in the steep reaches. Stream flow is perennial, with an average base flow of approximately 10 to 20 cubic feet per second. A USGS stream gage was operational at Bronxville from 1944 to 1989, and daily discharge records indicate a maximum flow for that period of 1610 cubic feet per second. According to the FEMA Flood Insurance Study (FIS) for New York, the 10-year frequency discharge at the gage is 1,875 cubic feet per second (FEMA, 2001). Flow characteristic is generally flashy, with most events transpiring with 24 hours.

4. ANALYSIS AND RESULTS

The analysis procedure consisted of two related phases: a) the geomorphic (or baseline) assessment of the Bronx River watershed and b) the sediment impact assessment for the Bronx River using the SIAM model. Results from the geomorphic assessment were used, along with data collected during the field investigations, as input data for the SIAM model.

4.1 Baseline Geomorphic Assessment. The baseline geomorphic assessment consisted of data gathering, field investigations, and data analysis. The baseline geomorphic assessment was conducted primarily to determine the existing sources and characteristics of sediment within the project area and to assess the overall stability of the stream/watershed in the project area. The baseline geomorphic assessment also provides the foundation for the more quantitative SIAM analysis.

4.1.1 Data Gathering. A comprehensive data gathering effort was conducted to compile a historical database. The use of historical data enables the identification of trends and provides useful information about past changes within the watershed. The type of data to be gathered includes but is not limited to hydrologic and hydraulic data, sediment data, aerial photography, channel surveys, mapping, and geologic data. Data sources collected include aerial photography, GIS data and mapping, channel surveys and HEC-RAS geometry from NAN, daily discharge data from the USGS, and bed material pebble counts and reach assessments from NYC Department of Parks and Recreation. A summary of data utilized in the study is given in Table 1.

Table 1. Data sources and acquisitions.

Data Source	Data Acquired
USACED, New York	DRGs and DOQQs of study area, 1970's FEMA HEC-2 model (Bronx County), 2005 FEMA preliminary HEC-RAS model, 1970's FIS report peak flows, GIS data for subbasins in Bronx and Westchester counties
U.S. Geological Survey	Daily discharge data for Bronx River at Bronxville, 1944-1989

NYC Dept. of Parks/Rec (Marit Larson)	Channel reach types and pebble count data for Bronx River in Bronx County

4.1.2 Field Investigations. Field reconnaissance of the Bronx River watershed was conducted during May and July 2006. The purpose of the field investigations was to develop an overall assessment of the morphology of the study area and to collect necessary sediment samples. The study area was walked on foot as much as possible to provide comprehensive documentation of existing conditions; however, many reaches were inaccessible and could only be documented at bridges. The field investigation involved documenting the status of existing channels and structures, location of problem areas, identification of type and extent of bed and bank erosion processes, sediment source and sink areas, and significant morphological features. Sediment data was collected from the bed and banks and gradations developed in the laboratory.

4.1.3 Comparative Channel Surveys. Channel surveys were obtained from the New York District in HEC-RAS format. This data was obtained from HEC-2 and HEC-RAS models used in FEMA flood insurance studies for the Bronx River. The HEC-2 model was developed in the mid-1970s and covers the portion of the Bronx River in Bronx County. The HEC-RAS model is a preliminary model developed from 2005 GIS data and covers the river in Westchester County. Bridge locations were used as common landmarks to identify the location of comparative cross sections from the two surveys in the area between 241st Street and Mt. Vernon Avenue where the 2 surveys overlapped. The comparative cross section plots are shown in Figures 2 through 4. Although insufficient detail exists to provide a reliable comparison, the cross sections do indicate that there have been no significant systematic changes in channel depth or width for the time period 1970s to the present.

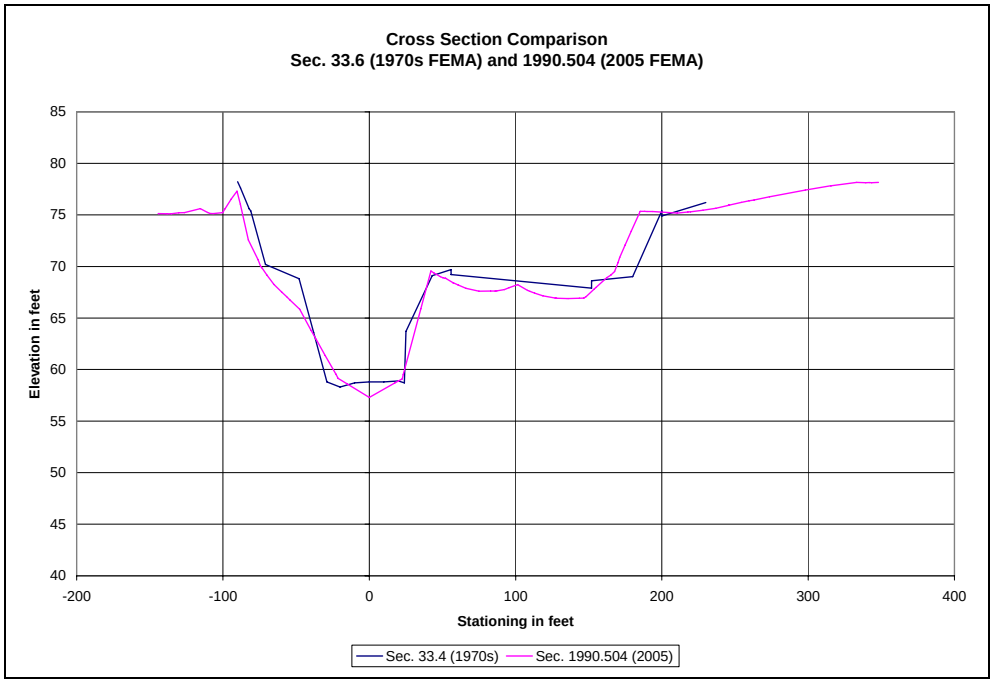


Figure 2. Comparative cross section site 1.

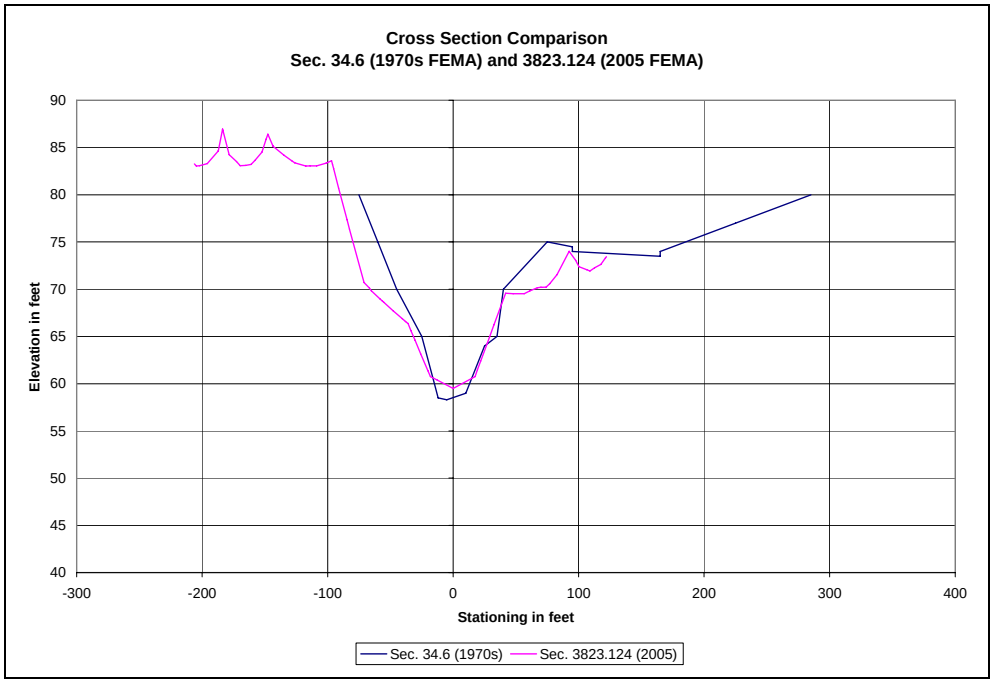


Figure 3. Comparative cross section site 2.

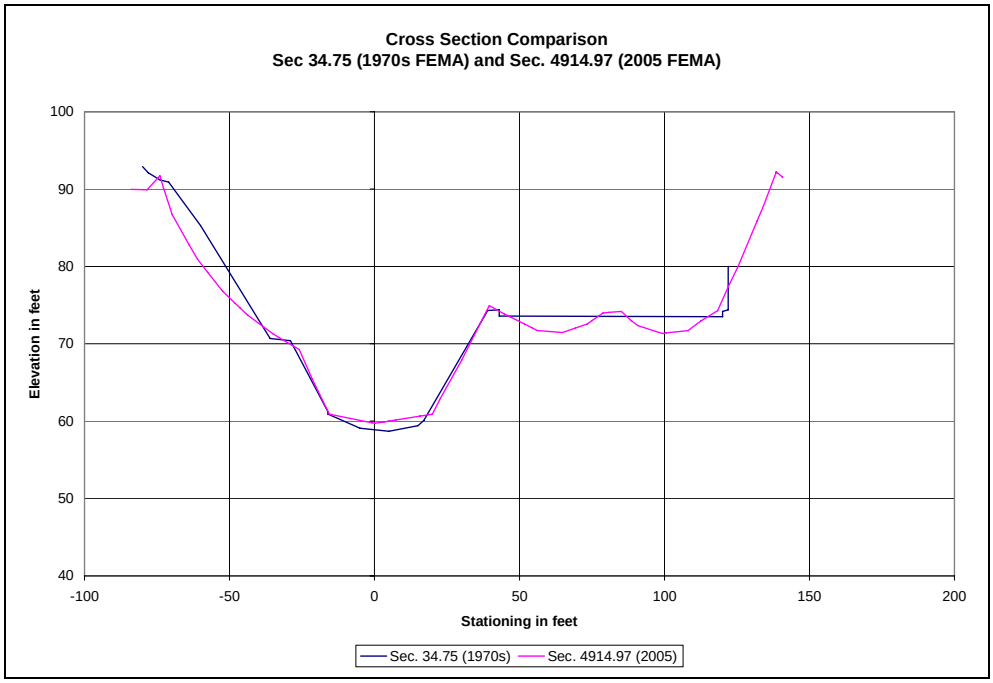


Figure 4. Comparative cross section site 3.

4.1.4 Sediment Sources. An attempt was made to identify sediment sources and estimate sediment loads within the watershed. These estimates serve as the basis for the

SIAM sediment load input data. Based on the data collection effort, there is limited published quantitative data on bank and watershed sediment supply for this basin. Five potential sediment sources were identified during the field investigation: (1) stream banks, (2) tributaries, (3) watershed (upland), (4) railroad grades, and (5) re-suspension of sediment from the channel.

Stream banks. In general, bank instability along the Bronx River is limited to a few isolated locations, primarily in sharp curvature bends where flow impingement occurs at the toe of sparsely vegetated banks. No areas of stream bank erosion due to watershed-scale instabilities such as channel bed incision and channel widening were noted. Bank samples were collected at locations of observed instability during the field investigation, and a sieve analysis of each sample was conducted in the laboratory. The locations of the bank samples are shown in Figure 5 and the bank gradations are shown in Figure 6. The bank material gradation curves illustrate the distribution of particle sizes in the bank material by relating the percentage of the sample that is smaller than a given grain diameter. In general, most banks are composed of medium and fine sands, silt and clay. The range of bank material gradations indicate that 75 percent or more of the bank material is medium sand or finer, 25 to 80 percent is very fine sand or finer, and 15 to 55 percent is silt or clay. The exception is sample Bank 3, taken near Garth Woods, which gradation shows only 32 percent of the bank to be medium sand or finer. This sample was taken on an exposed slope area well above the active channel bank.

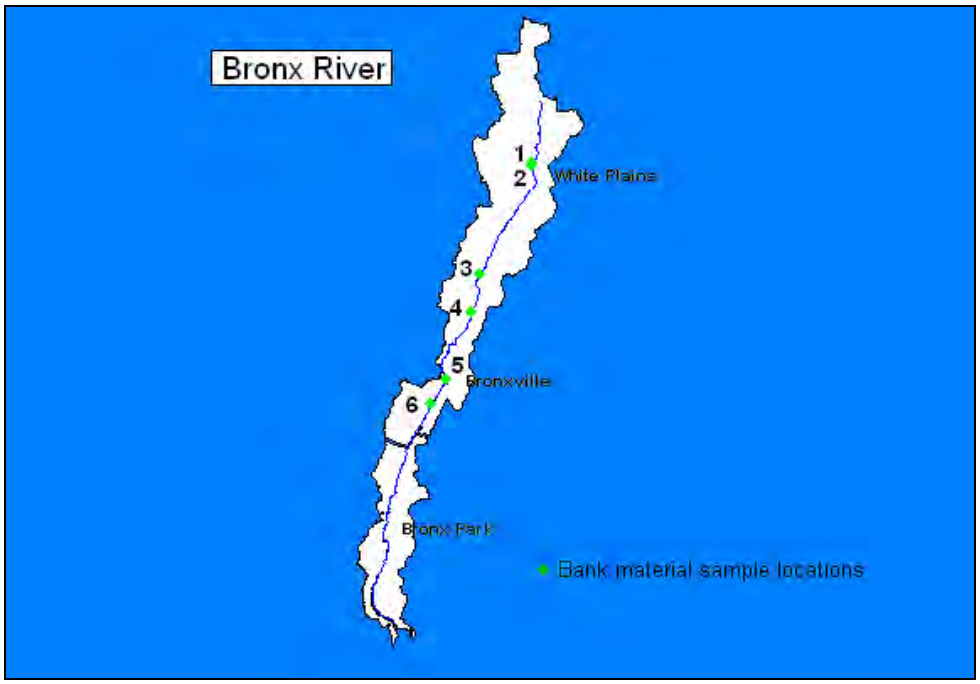


Figure 5. Bank material sample locations.

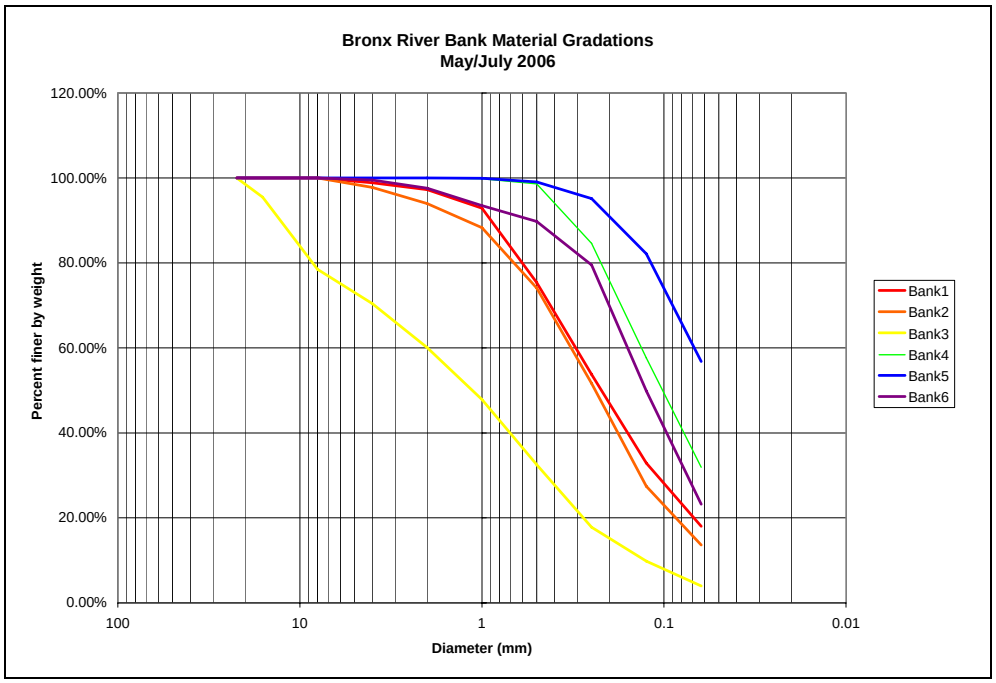


Figure 6. Bank material gradations.

Based on field observations, the average erosion rate at the limited areas of active erosion is estimated to be approximately 1 to 2 inches per year. This value was estimated mainly on the degree of exposed tree roots observed at areas of erosion. There were no bank erosion pin measurements or other survey data by which to verify this estimate. Bank heights in the study reach vary, but on average range from about 3 to 6 feet. Because of the small bank heights and estimated average erosion rate, the eroding stream banks are considered to be a minor contributor to sediment deposition in the impoundment areas along the Bronx River.

To illustrate this assessment, the average annual contribution of sediment from the eroding bank at Scout Field near Bronxville (Bank 5 sample) was estimated. The eroding bank at Scout Field was one of the most active areas of bank erosion observed during the field investigation. The approximate length of eroding bank is 150 feet, and assuming the estimated 2 inch per year erosion rate and 4 feet bank height yields an eroded volume of 100 cubic feet annually. Assuming a ratio of bank material density to deposited material density of 2, the volume of deposition is 200 cubic feet. If the 200 cubic feet were deposited to a depth of 0.25 inch, the area of deposit would cover only 9600 square feet, an area less than 100 feet by 100 feet square. Since most of the impoundments areas are much larger than 9600 square feet, the actual annual depth of deposit would be even less. Based on this approximation, and the limited locations of actively eroding channel bank observed during the field investigation, bank erosion contributes very little to the annual sediment deposition in the impoundment areas of the Bronx River.

In order to more accurately determine bank erosion rates, a system of erosion pins or other monument-type surveyed reference markers could be established at an active

erosion site and surveyed on a regular basis and after large run-off events. Comparative aerial photography can also be used to determine relative changes in bank locations, but the minor changes actually occurring in the study area would be difficult to distinguish.

Typical areas of observed bank instability are shown in Figures 7 through 9.



Figure 7. Stream bank erosion near Westchester County Center (site of sample Bank2).



Figure 8. Stream bank erosion at Scout Field near Bronxville (site of sample Bank5).



Figure 9. Upper bank slope erosion near Garth Woods (site of sample Bank3).

Tributaries. Another potential source of sediment to the Bronx River system is the tributaries. During the field investigation, several tributaries were identified that contribute to the sediment load of the Bronx River. The three tributaries that appear to be the main contributors are the Westchester County Center tributary, Troublesome Brook and Sprain Brook.

The Westchester County Center tributary is the 2nd tributary that enters the Bronx River from the right descending bank upstream of the county center in White Plains. This tributary appears to contribute the most sediment of the main three tributaries identified. The sediment entering the Bronx River at the mouth of the tributary consists of sand and gravel (Figure 10). The depth of sediment in the tributary was estimated at 4 feet by probing the channel bed with a metal rod. The watershed area of the tributary was investigated to determine the sources of sediment, but the commercial and residential density of the area made access difficult except at road crossings. No obvious source of the gravel was found, and bank erosion activity was minor, similar to that on the main river. No published sediment or discharge data was found for this tributary.



Figure 10. Sediment source from Westchester County Center tributary.

Troublesome Brook enters the Bronx River directly into Crestwood Lake on the right descending bank (Figure 11). Inspection of the lower 1000 feet of the tributary revealed a couple areas of very minor bank instabilities, and a channel bed of mainly sand and gravel with a few small cobbles. The sediment depth is approximately 2 feet. Qualitatively, the sediment delivery from Troublesome Brook appears approximately 75 percent less than the sediment delivered from Westchester County Center tributary. All of the sediment load from Troublesome Brook will deposit in the pool of Crestwood Lake, with the possible exception of the fine silts and clays. No published sediment or discharge data was found for this tributary.

Sprain Brook enters the Bronx River from the right descending bank just upstream of Dewitt Avenue near Bronxville (Figure 12). It is the largest of the 3 tributaries discussed in this section. A reservoir, Grassy Sprain Reservoir, is located on the tributary. This reservoir is most likely trapping sediments from the upper tributary watershed. Heavy residential density and major transportation arteries immediately adjacent to the tributary downstream of the reservoir limited access for field inspection to a few road crossings. Sediment from the tributary was similar in composition to that of Troublesome Brook. Qualitatively, the sediment delivery from this tributary is equal to

or slightly greater than that of Troublesome Brook. No published sediment or discharge data was found for this tributary.

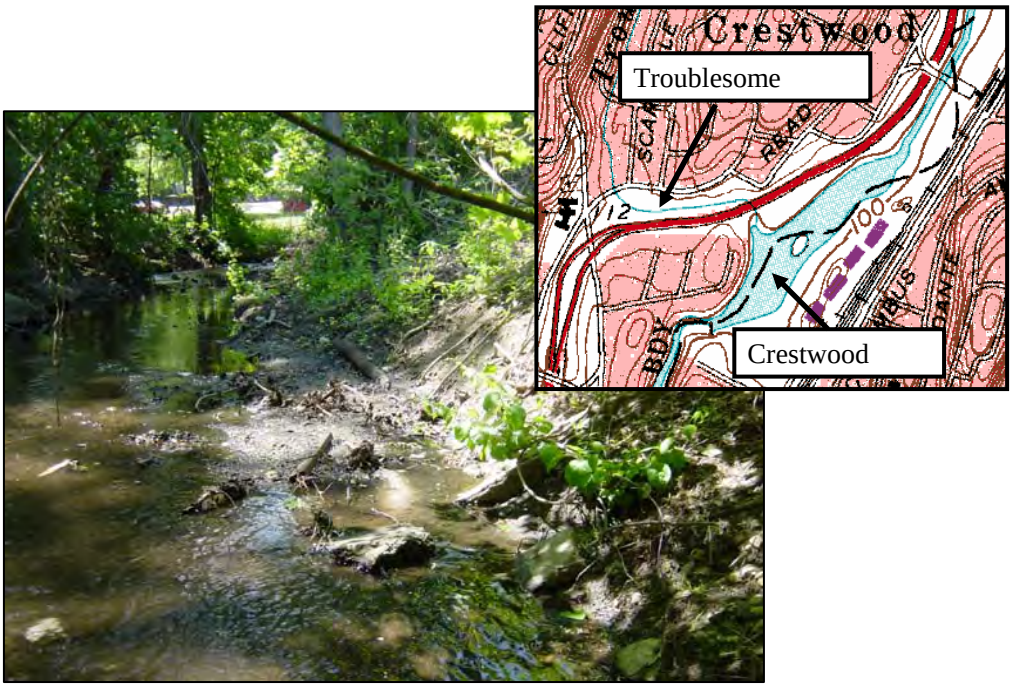


Figure 11. Minor bank erosion on Troublesome Brook.

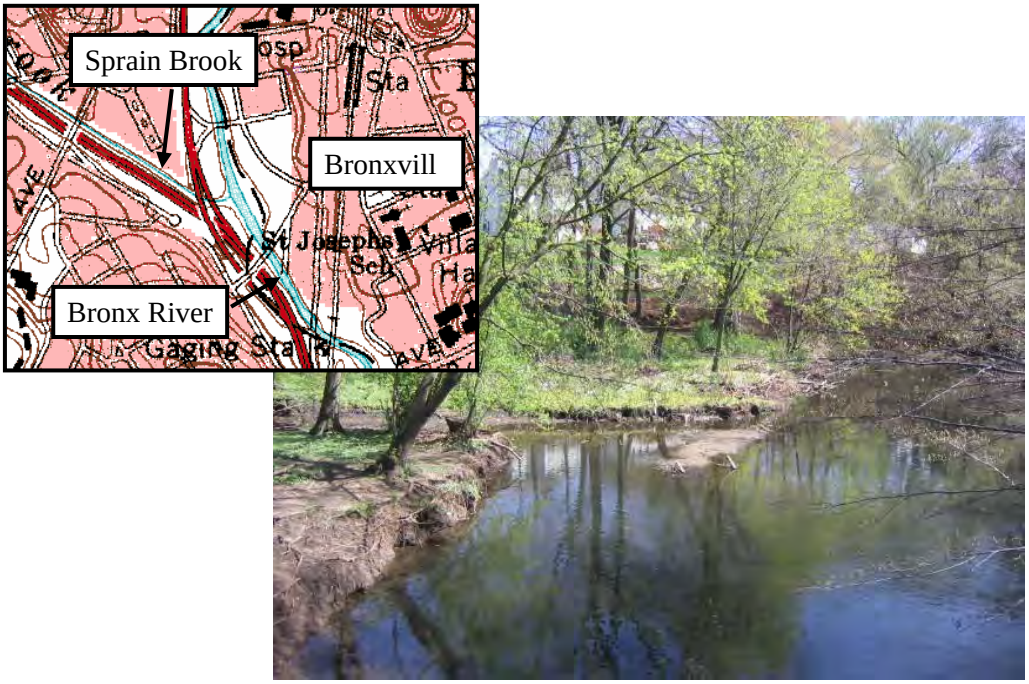


Figure 12. Sprain Brook tributary near confluence with Bronx River.

It is evident from the inspection of the tributaries that they are a source of sediment to the Bronx River. However, it is difficult to quantify the sediment contribution with the available data. The Westchester County Center tributary contributes the most sediment of the 3 tributaries discussed. The sediment from Troublesome Brook is a direct contributor to the sediment deposition in Crestwood Lake.

Watershed. The Bronx River watershed is highly urbanized and therefore, sediment delivery from surface erosion is not widespread. However, there are localized areas where surface erosion is providing sediment to the system. The primary localized sediment source is the many small gullies adjacent to the river. The gullies were generally shallow, but depths of 1 foot were observed (Figure 13). Many of the gullies were formed by concentrated run-off from parking lots and walk paths near the river, drain holes from overhead bridges and walkways, as well as drainage from the Bronx River Parkway (Figure 14). The volume of sediment from these gullies was generally small, but their numerous occurrences along the river system may have a cumulative impact. Quantifying the sediment volume and delivery rate from these localized areas would require extensive mapping and measuring the individual gullies. It would be better to determine the overall sediment yield from the watershed from long-term data collected at a sediment sampling station located at a river gage. However, no published data or study results of this nature are available.



Figure 13. Typical gully erosion under Bronx River Parkway overpass.



Figure 14. Roadway surface erosion along Bronx River Parkway.

Sediment yield from general surface erosion within the watershed area does not seem to be widespread due to the urbanized condition of the watershed and the high degree of impervious surface area. However, it does seem reasonable to expect that surface erosion was greater in years past when the watershed area along the river corridor was being heavily developed. In addition, it seems reasonable that road sand used during the winter could be a seasonal source of sediment, particularly in light of the many areas where drainage from bridges and roadways can directly enter the river. The Natural Resources Conservation Service (NRCS) and the USGS often publish the results of watershed studies that can be used to estimate sediment yield from surface areas, but no such data was located for the urbanized Bronx River watershed. Sediment yield from a watershed area is usually determined from long-term sediment sampling data collected at outlets of the river or tributaries. Sediment concentrations at such stations can be used to develop sediment ratings that can be coupled with the flow record to calculate sediment yield. However, no such sediment sampling stations exist or have exited on the Bronx River or tributaries.

Railroad Grades. Another potential source of sediment that was identified during the field investigations was erosion along the base of the railroad grades. Figure 15 shows a location at Hartsdale Station where the Bronx River channel is adjacent to the railroad grade and washes in the railroad embankment are occurring. While some sediment, primarily course material, is delivered to the system from these sources, they are limited in spatial extent, and therefore are not considered to be a major factor with respect to sediment supply to the system. Quantifying reliable estimates of how much of this material gets into the river system is very problematic.



Figure 15. Potential source of course sediment is railroad embankment immediately adjacent to channel (Hartsdale Station).

Re-suspension of In-channel Sediments. There are a number of pools along the Bronx River formed by small dams and weirs. These pools serve as sediment traps and, in many instances the sediment has filled up to the weir invert of the dam (Figure 16). The impoundments that were observed in the field investigation were Fisher Lane, Green Acres, Ardsley Road, Harney Road, Crestwood Lake, Bronxville Lake, and Dams 2, 3 and 4 in Bronx Park. Sediment deposition is evident in all the pools, with Crestwood Lake being the most extensive degree of deposition and Dam 4 being the least extensive. In general, the sediments in the upper portions of the pools were sand and fine gravel, and deposits in the lower portions of the pools near the dams contained fines and organic material. The deposition volumes within the pools could not be determined due to the lack of historical channel surveys in the area. In addition, no dredging records or data where maintenance was performed by the local authorities were located. Several of the impoundments are 60 to 70 years old, and the time required to fill these pools is not known. Probing the upper portion of the pools of Crestwood and Bronxville Lakes,

Harney Road and Ardsley Road indicated sediment depths of at least 4 feet. The lower portions of the pools could not be probed due to the depth of the pools. Dredging records or repetitive channel surveys would be very valuable not only in determining the volume of deposits within the pools, but also in estimating sediment yield rates from the watershed.

Because there appears to be considerable volume of sediment deposited in most of the pools, it is possible that the deposits themselves may act as a source of sediment. It is possible that at high flows some of the sediment may become re-entrained and transported downstream to the next deposition site. By this process the sediment in the Bronx River may actually move in slugs during periods of high flow, and may take a lengthy period of time to do so. The discharge that would be required to entrain the deposited sediments and how much sediment is then transported is not known. A detailed numerical model of some of these pools would be needed to provide more insight into this complex process. Models such as the HEC 1-dimensional model HEC-RAS Sediment Transport and the ERDC 2-dimensional ADH model could be used to determine the conditions necessary for sediment re-suspension.



Figure 16. Sediment deposition in pool at Harney Road.

4.1.5 Bed Material Samples. Bed material samples were collected during the field investigation and the samples were sieved in the laboratory to develop bed material

gradations along the Bronx River. The bed material samples consist of grab samples of the surface sediments taken at evenly spaced intervals across the channel and combined into a representative sample. The location of the bed material samples is shown in Figure 17 and the gradations are shown in Figure 18 and 19. In addition, pebble counts were conducted in the reaches with coarser bed material. In general, the bed material is very coarse in the steeper reaches of the river, consisting of gravels and cobbles. The milder sloped reaches contain bed material that is somewhat finer, generally consisting of sands and fine gravels. Bed material in the pooled areas above the dams consists of sand and fine gravel, silt and organic material. Laboratory analyses of the bed material sample provided only grain size distribution information. No analyses were conducted to determine the mineralogical characteristics of the sediments to determine the sources of origin.

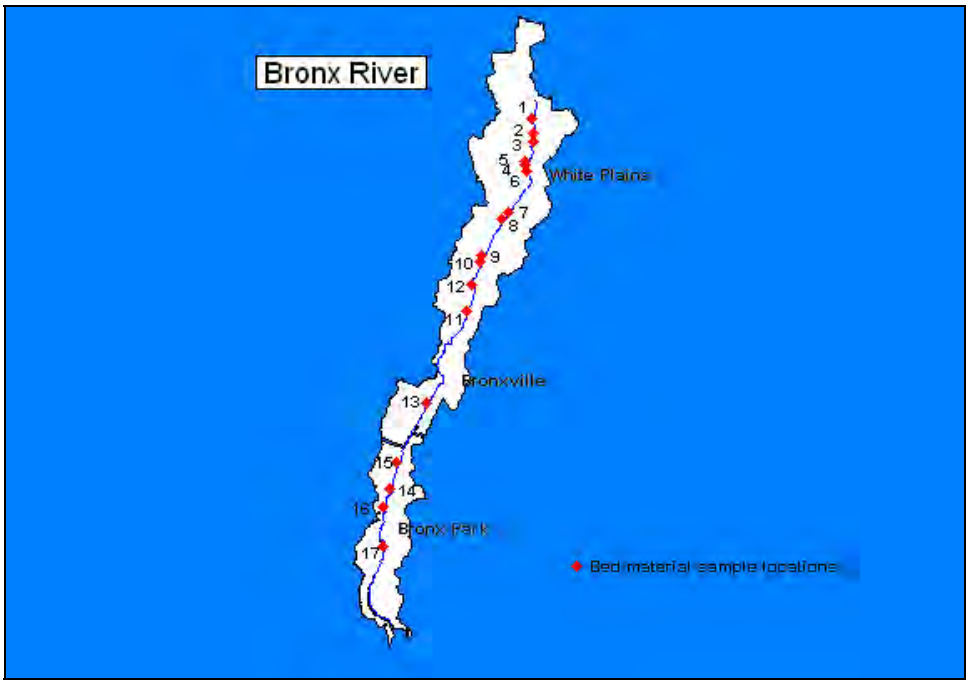


Figure 17. Bed material sample locations.

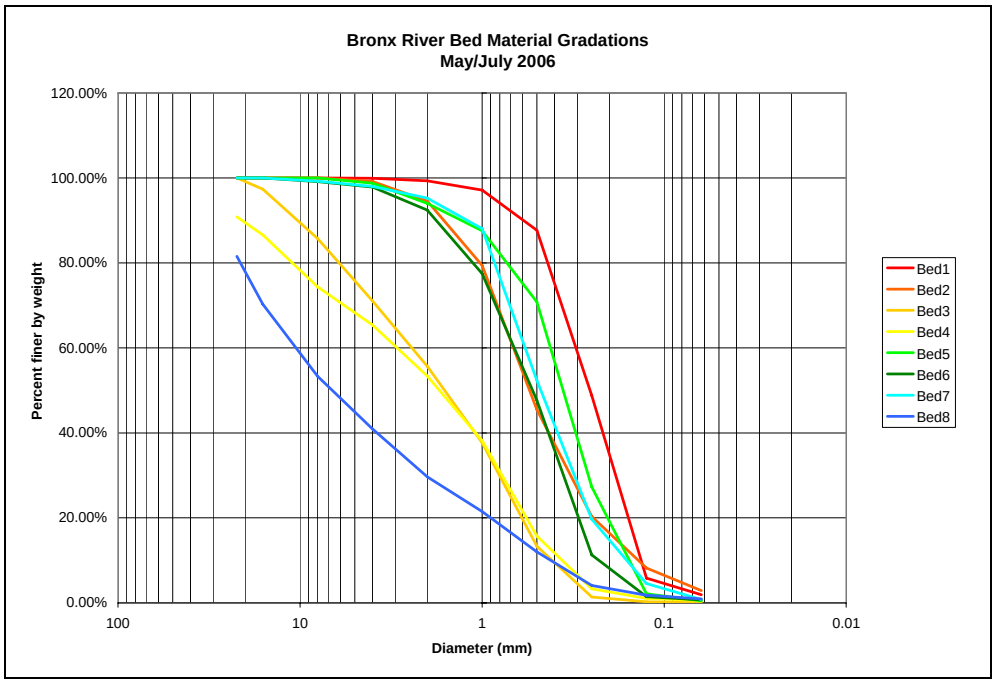


Figure 18. Bed material gradations (Bed1 through Bed8).

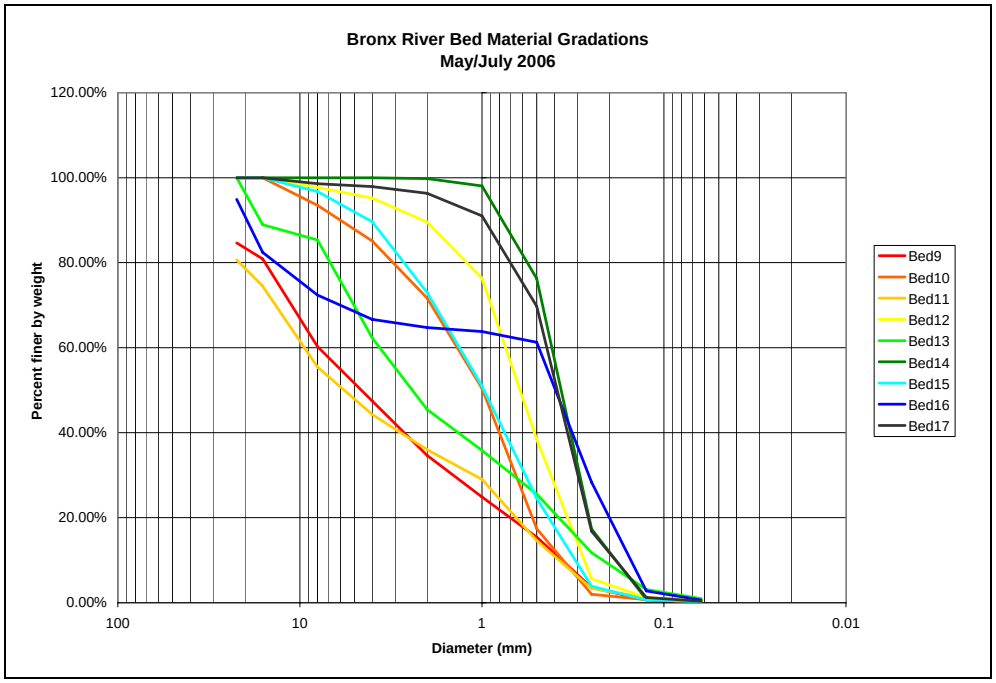


Figure 19. Bed material gradations (Bed9 through Bed17).

4.1.6 Sediment Transport Characteristics. During the field investigation, an assessment of the basic sediment transport characteristics occurring in the study area was conducted. Three very basic types of sediment transport mechanisms within the reaches were identified: (1) through-put reaches, (2) alluvial reaches, and (3) pool reaches.

Through-put Reaches. The throughput reaches are characterized by a very steep channel slope, coarse gravel and cobble bed material, and very little fine sediment (sands and fine gravels) storage in the bed. Consequently, the bed is very stable in these reaches. Through-put reaches act as conduits of the finer sediment that is supplied from the various sources in the watershed. The transport capacity in these reaches far exceeds the supply of sediment, and therefore, most all the sediment that is supplied to these reaches is transported through them to the next lower energy environment downstream. Figure 20 shows a typical throughput reach.



Figure 20. Typical through-put reach.

Alluvial Reaches. The alluvial reaches are generally characterized by a much flatter slope, and a significant depth of fine sediment (sand and gravels) in the bed. The depth of sediment is generally greater than 1 to 2 feet. Field observations did not reveal any indicators of significant active channel degradation or aggradation in these reaches. Sediment delivery through these reaches is directly proportional to the sediment transport capacity of the reach. A typical alluvial reach is shown in Figure 21.



Figure 21. Typical alluvial reach.

Pool Reaches. The third general channel type is the pool reach. The pool reaches are depositional environments created upstream of the small dams or weirs located throughout the Bronx River. A typical pool reach is shown in Figure 22. The pool reaches are lower energy depositional areas that act as sediment traps for sediment being delivered from upstream reaches. In many instance, these pool reaches are completely filled with fine sediments. As discussed earlier, it is possible that the sediment deposited in the pool reaches can be re-suspended and transported to areas downstream.

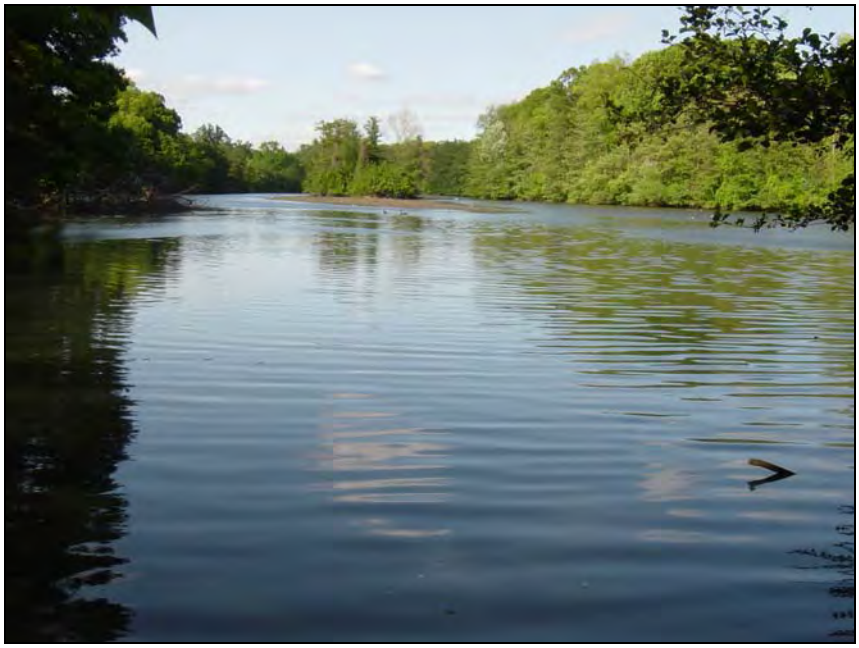


Figure 22. Typical pool reach.

4.1.7 Geomorphic Reaches. The Bronx River study reach was divided into 26 geomorphic reaches, primarily based on information from the field investigation and the data search. Factors considered in the identification of the geomorphic reaches included plan form determined from aerial photography, channel slope determined from the HEC-RAS geometry data, sediment transport characteristics, tributary locations, and channel structures (dams). The geomorphic reaches provide the basis for organizing the SIAM model reach structure and input data. The location of the geomorphic reaches is shown in Figures 23 through 31, and a brief qualitative description of each reach is provided.



Figure 23. Location of geomorphic reaches 1 through 4.

Reach 1. The reach extends from Kensico Dam to upper end of Fisher Lane pool. It is characterized as an alluvial reach with localized areas of shallow sand deposits. A minor bank erosion sources was observed in the vicinity of Virginia Road. Bed sediment depth is generally less than 1 foot, and bank heights are 2 to 3 feet and stable. A potential sediment source from the Metro North railroad bed was observed just downstream of Virginia Road. Sample Bed1 is located in this reach, and indicates that approximately 50 percent of the bed material is composed of fine sand (0.25 mm) or finer material.

Reach 2. The reach runs from the upper portion of Fisher Lane pool to Fisher Lane. It is a pool reach with sediment depths greater than 4 feet. No channel bank

erosion sediment sources were observed. Sample Bed2 is located in this reach, and indicates that approximately 45 percent of the bed material is medium sand (0.5 mm) or finer.

Reach 3. Located from Fisher Lane to Cemetery Road, this reach is a steep, through-put reach with negligible sediment depths. No bank erosion sources of sediment were observed. A potential minor sediment source exists in the tributary at downstream end of North White Plains parking lot. Run-off from the adjacent parking lots directly enters the tributary. Sample Bed3 is located in this reach. The bed material is coarser than the previous upstream reaches, with approximately 45 percent of the bed material being larger than very coarse sand (2 mm).

Reach 4. The reach extends from Cemetery Road to the Bronx River Parkway (BRP) bridge downstream of I-287. It is a steep, through-put reach with negligible sediment depths. No obvious sources of sediment were observed originating within this reach.

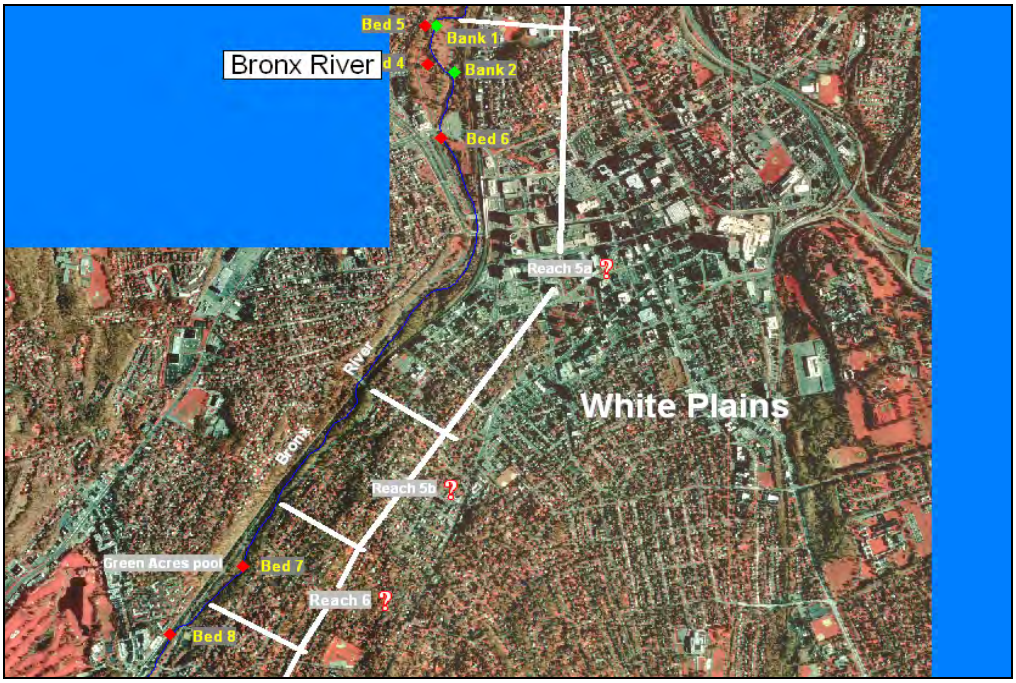


Figure 24. Location of geomorphic reaches 5a through 6.

Reach 5a. Located from the BRP bridge below I-287 to the 3rd BRP crossing above Hartsdale Station, this reach is classified as an alluvial reach, with sediment depths between 2 and 4 feet. Intermittent areas of minor bank erosion exist in the portion of the reach from the parking lot bridge at Westchester County Center to a couple hundred feet upstream of the Westchester County Center tributary. Bank material samples Bank1 and Bank2 are located in this reach upstream and downstream of the tributary confluence. The bank material samples indicate that approximately 50 percent of the bank material is fine sand or finer. Channel bank heights are 3 to 6 feet. The Westchester County Center

tributary enters in this reach and is a sediment source. Bed material sample Bed4, taken in the tributary near the confluence, shows that approximately 45 percent of the tributary bed material is larger than very course sand. By contrast, bed material samples Bed5 and Bed6 indicate that the bed material in the Bronx River consists of only 8 percent that is coarser than very coarse sand.

Reach 5b. The reach extends from the 3rd BRP crossing above Hartsdale Station to the 2nd BRP crossing above Hartsdale Station. It is a steep, through-put reach, with minimum sediment depth in channel. No bank erosion sediment source was observed.

Reach 6. The reach extends from the 2nd BRP bridge above Hartsdale Station to the dam near Green Acres. It is a pool reach in the area above the dam. No significant bank erosion was observed. Sample Bed7 was collected in the upper end of the Green Acres impoundment. The sample indicates that approximately 50 percent of the bed material is larger than medium sand. The gradation of the bed material at this location is very consistent with the gradation of the bed samples in Reach 5a.

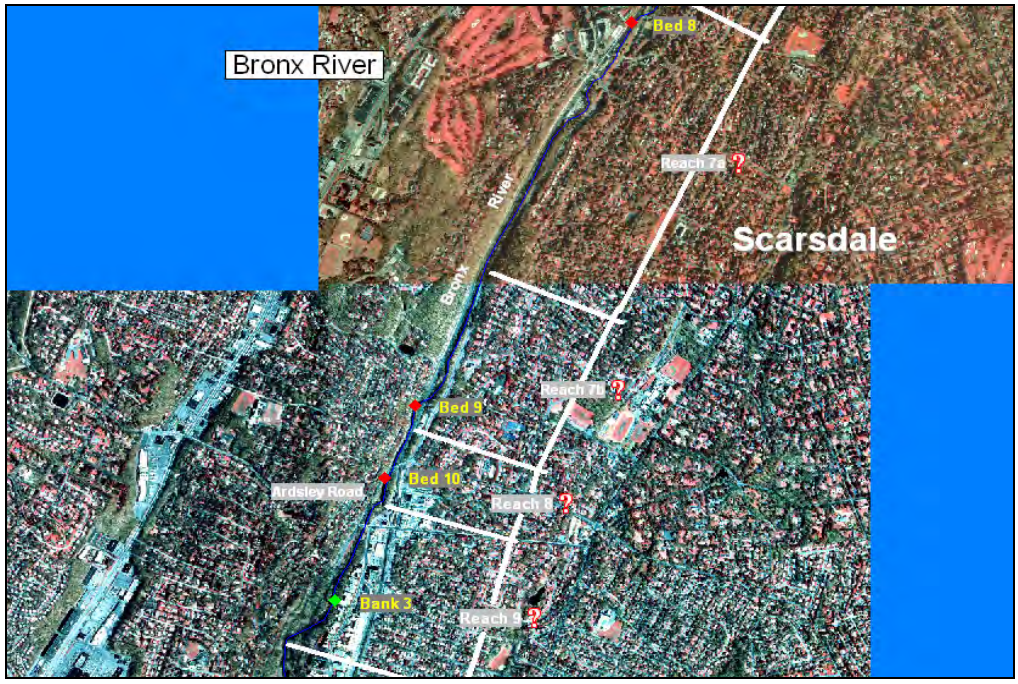


Figure 25. Location of geomorphic reaches 7a through 9.

Reach 7a. The reach extends from the Green Acres dam to approximately 2200 feet above 1st Metro North crossing above Crane Road. It is a steep, through-put reach, with minimum sediment depths. Minor bank erosion was observed upstream of Crane Road. The railroad embankment immediately adjacent to the river contained eroded areas, which indicates the embankment is a potential minor sediment source. It is unknown how much of the eroded material is actually delivered to the river bed. Sample Bed8 is located in this reach. The sample is indicative of a through-put reach, with approximately 50 percent of the bed material larger than fine gravel (7 mm).

Reach 7b. This is a very steep, through-put reach that runs from approximately 2200 feet above the 1st Metro North crossing above Crane Road to the Metro North crossing. The reach has minimum sediment depths, and no significant bank erosion source was observed. A potential sediment source is the railroad embankment. Sample Bed9 is located in this reach, indicating a bed material composed of approximately 40 percent coarser than fine gravel.

Reach 8. Located from the Metro North crossing above Crane Road to the Ardsley Road dam, this is a pool reach upstream of the Ardsley Road dam. Bed deposits are primarily sand, silt, and organic material with depths greater than 4 feet. No significant bank erosion was observed. Sample Bed10 is located in upper portion of the sediment deposit area of Ardsley Road impoundment. Approximately 50 percent of the deposited material is larger than coarse sand (1 mm).

Reach 9. The reach extends from Ardsley Road dam to approximately 1250 feet above Harney Road dam. It is a steep, through-put reach with negligible sediment depths and course bed material. Areas of slope erosion exist along the heavily wooded east bank in the Garth Woods area. Sample Bank3 was collected at the exposed slope area and shows that approximately 50 percent of the material is larger than coarse sand. The quantity of potential sediment from this area is unknown.



Figure 26. Location of geomorphic reaches 10 through 12.

Reach 10. The reach extends from approximately 1250 feet above Harney Road dam to Harney Road dam. It is a pool reach upstream of dam, with sediment depths greater than 4 feet. The channel is filled level with the weir crest. No bank erosion of

other sources of sediment were observed. Sample Bed12 is located in this reach. The sample indicates that the sediment deposited in the pool is approximately 40 percent fine sand or finer material.

Reach 11. Located from Harney Road dam to approximately 5000 feet above Crestwood dam, this reach is a through-put reach with course gravel and small cobbles in channel bed and negligible sediment depths. Bank material sample Bank4 was collected near the lower end of this reach and indicates that the bank composition is approximately 80 percent fine sand or finer material. Bed material sample Bed11 was collected at the same location and indicates that approximately 55 percent of the bed material is larger than very fine gravel (4 mm), indicative of a through-put reach.

Reach 12. The reach extends from approximately 5000 feet above Crestwood dam to Crestwood dam. It is a pool reach upstream of Crestwood dam. Sediment depths in the upper part of the pool area are 4 feet or greater. The sediment deposition in Crestwood Lake is by far the most extensive of all the pools along the Bronx River. Fine gravel and sand is deposited in the upper portion of the pool and fine sand, silt and organic material is deposited in lower portion of the pool. Troublesome Brook feeds directly in Crestwood Lake near the lower end of the pool. No dredging or maintenance records were located for the lake.



Figure 27. Location of geomorphic reaches 13a through 15.

Reach 13a. This alluvial reach extends from Crestwood dam to the concrete weir upstream of Scarsdale Road (Old Yonkers mill?). The channel is confined in this reach with concrete walls in lower end. The channel banks are well protected and no sediment sources were observed. The concrete weir provides some pool effects.

Reach 13b. Located from the concrete weir upstream of Scarsdale Road to the BRP exit ramp downstream of Scarsdale Road, this reach is a through-put reach with course bed material. No bank erosion sources were observed.

Reach 14. The reach extends from the BRP exit ramp downstream of Scarsdale Road to Bronxville dam. It is a pool reach upstream of Bronxville dam. Sediment deposits within the pool are sand, silt and organic material. Sediment depth is greater than 4 feet.

Reach 15. Located from Bronxville dam to Sprain Brook confluence, this reach is classified as a through-put reach. No significant bank erosion source was observed. Sprain Brook tributary enters in this reach. The sediment entering from the tributary is similar in composition to that of Troublesome Brook. No data was found to determine sediment yield from this tributary.

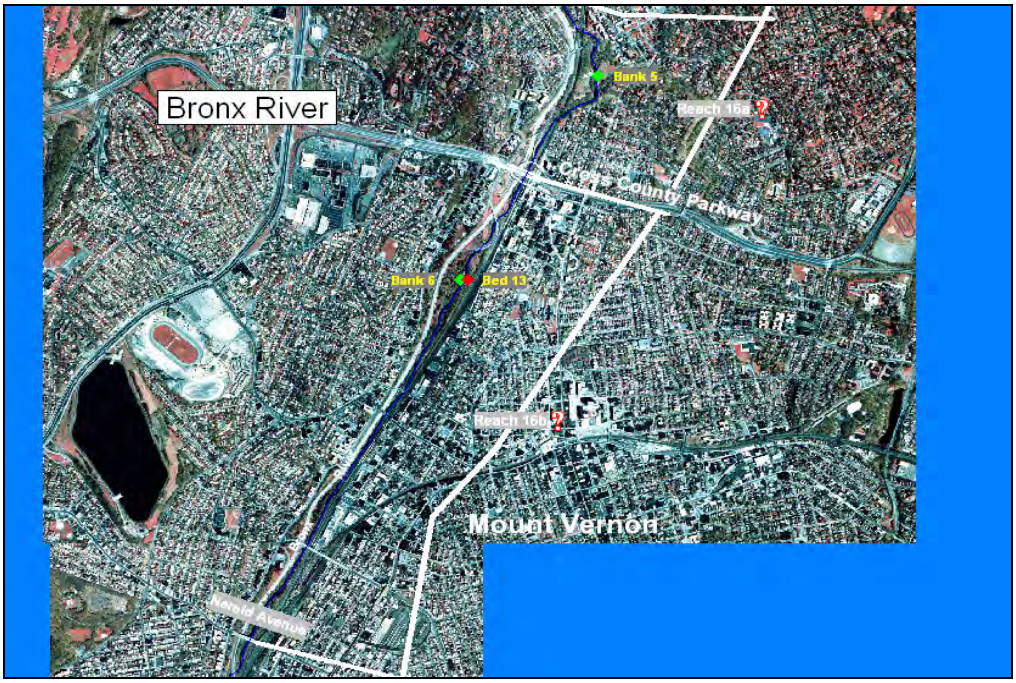


Figure 28. Location of geomorphic reaches 16a and 16b.

Reach 16a. The reach extends from Sprain Brook confluence to Cross County Parkway. It is classified as an alluvial reach. An area of moderate bank erosion was observed at the Scout Field ballparks. Bank material sample Bank5 was collected at the Scout Field site, and indicates that approximately 80 percent of the bank composition is very fine sand (0.125 mm) or finer material. The bank at this site was composed of the most finer material of any bank sampled during the investigation. On average, very fine sand composes less than 10 percent of all the bed material samples along the river. This indicates that over 50 percent of the material eroded from this bank will be easily swept

downstream as wash load and will deposit only in the most slack water areas of the downstream pools.

Reach 16b. The reach extends from Cross County Parkway to Nereid Avenue. It is an alluvial reach. Minor bank erosion was observed between Cross County Parkway and Oak Street. Bank material sample Bank6 taken in this reach indicates that the bank material is approximately 80 percent fine sand or finer material. Bed material sample Bed13 in this reach shows that the bed composition is 60 percent very fine gravel or finer material.



Figure 29. Location of geomorphic reach 17.

Reach 17. The reach is classified as an alluvial reach and extends from Nereid Avenue to Gun Hill Road. Minor bank erosion was observed along Shoelace Park approximately 1000 feet downstream of 233rd Street. Existing bioengineering type bank stabilization measures were observed along most of the Shoelace Park frontage. Bed material sample Bed15 was collected near the upper end of this reach and Bed14 was taken near the lower end. Bed15 sample indicates that 50 percent of the bed material in the upper portion of the reach is larger than coarse sand, while Bed14 indicates that only 5 percent of the bed material in the lower portion of the reach is larger than coarse sand.



Figure 30. Location of geomorphic reaches 18 through 20.

Reach 18. Located from Gun Hill Road to Dam 4 in the Bronx Park, this reach is a depositional reach above Dam 4. No significant bank erosion sources were noted. Existing bioengineering bank stabilization measures were observed in this reach, and appeared to be functioning well. Bed material sample Bed16 is located in this reach, and indicates that 60 percent of the bed composition is medium sand or finer material.

Reach 19. The reach extends from Dam 4 in the Bronx Park to just upstream of Fordham Road. It is a very steep, through-put reach with coarse bed material. No bank erosion sources were noted.

Reach 20. The reach extends from just upstream of Fordham Road to Dam 3 in the Bronx Park. It is a depositional reach within the pooled area upstream of Dam 3. No bank erosion sources were noted.



Figure 31. Location of geomorphic reaches 21 and 22.

Reach 21. Located from Dam 3 in the Bronx Park to Dam 2 in the Bronx Park, this reach is a depositional reach within the pooled area upstream of Dam 2. No bank erosion sources were observed. Bed material sample Bed17 was taken in the pool area of Dam 2, and indicates approximately 75 percent of the deposits in this area are medium sand or finer material.

Reach 22. The reach extends from Dam 2 in the Bronx Park to Dam 1 near 174th Street. It is an alluvial reach, and is primarily a confined reach with almost continual bank protection. The lower end of the reach is impacted by the tidal cycle from the East River.

4.1.8 Geomorphic Summary. The geomorphic assessment did not reveal any significant indicators of active channel incision along the study reach. The primary reason for this vertical stability is the coarse gravel and cobble bed material found through most of the area, as well as the periodic grade control provided by the dams. This lack of vertical incision also contributes to the overall stability of the stream banks in the study area. Overall, bank erosion in the study area is limited to a few isolated areas, and estimated erosion rates are very low (2 inches per year). No active bank line meanders or other indicators of recent changes in channel location were observed, indicating that the position of the river has changed little over the recent years, at least by natural processes. In consideration of the significant amount of sediment deposits observed in the pool areas and the observed stability of the channel banks, the assessment is that the channel banks are a minor to insignificant contributor of sediment to the deposits in the pools.

There are numerous small dams or weirs located throughout the study reach. These dams form pools which act as sediment traps, and sediment deposits of 4 feet or more were observed in most of the pools. It was not possible to determine how long these deposits have existed or how quickly the pools originally filled due to the lack of historical channel surveys or dredging records. The assessment that the channel banks are not a significant source of sediment to the pools suggests that the material came from the watershed and/or the tributaries. It is not known if the material has been delivered consistently over the years, or if yields were greater during years of the heaviest development of the watershed. The data collection effort located no reliable published estimates of the loading from any of these sources. Therefore, it is difficult to quantify the relative magnitudes of these sources with any certainty. Re-suspension of in-channel sediment deposited in the pools may also be a significant source, but the relative contribution of this potential source is uncertain without conducting more advanced computer models to determine the flow conditions that result in re-entrainment of the sediment.

4.2 Sediment Impact Assessment (SIAM Model). The sediment impact assessment for the Bronx River was conducted using the SIAM model. Using sediment data and other information garnered in the geomorphic assessment phase, the SIAM model was used to determine the sediment continuity for each geomorphic reach. The SIAM model was constructed from the 1970s HEC-2 model and the 2005 HEC-RAS model provided by NAN, and covered the study area from Dam 2 in Bronx Park to Kensico Dam.

4.2.1 SIAM Model Description. SIAM is a reach-based sediment accounting model that has been embedded in the Hydraulic Design module of HEC-RAS, and provides an expedient means of determining average annual sediment impacts for stream networks. It provides a framework to combine sediment sources and computed sediment transport capacities in order to evaluate sediment balances and downstream sediment yields for different alternatives. The model uses the 1-dimensional hydraulic computations from HEC-RAS to compute average annual sediment transport capacity for each reach, and sediment continuity is determined by comparing the capacity to the sediment supply for each reach. Computations are made by grain size, allowing the fate of a particular size particle to be traced. The SIAM model is currently available in HEC-RAS Version 4.0 Beta.

4.2.2 SIAM Input Data. SIAM input data for each sediment reach consists of bed material composition, hydrology/flow duration, sediment properties, sediment loading from local sources and reach average hydraulic parameters.

4.2.2.1 Bed Material. Bed material gradations associated with each reach were determined from bed samples collected during the field investigations. Gradations for alluvial reaches with predominantly sand and gravel beds were determined from sieve analyses of the bed samples. For steep reaches with bed material consisting of course gravel and small cobbles, pebble counts were used along with sub-layer gradations to

describe the bed material gradation. The bed material gradations used for the SIAM reaches are shown in Figure 32.

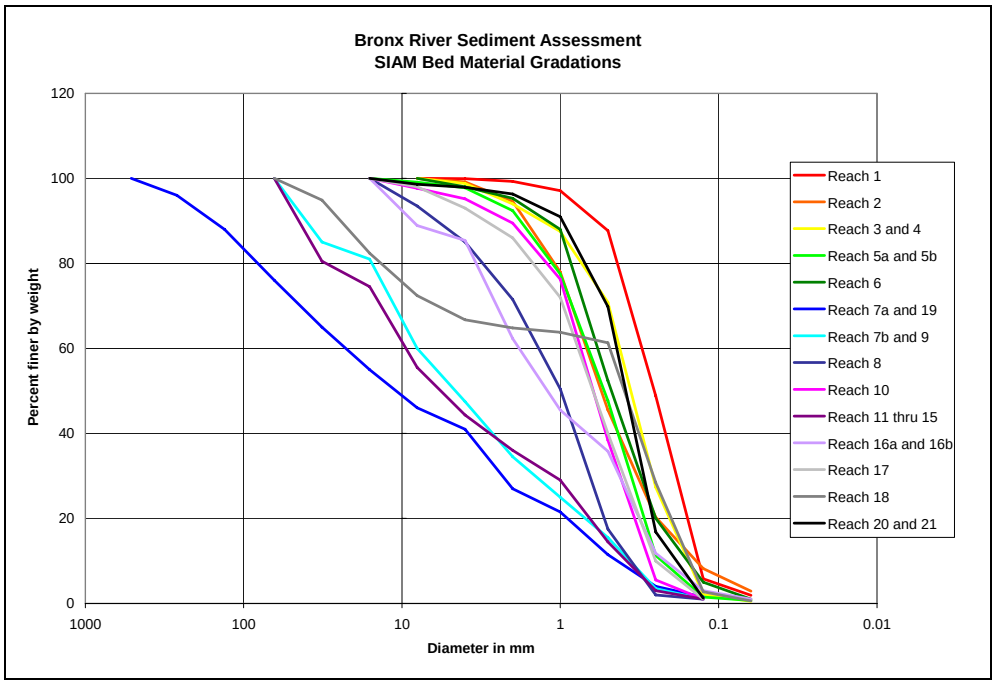


Figure 32. SIAM bed material gradations

4.2.2.2 Discharge Duration. Discharge duration was determined from daily discharge data for the USGS Bronx River at Bronxville stream gage. The period of record for the gage is 1944 to 1989. The minimum and maximum discharge for the period of record was determined, and the resulting range of discharge was divided into 9 discharge bins. The daily discharge record was evaluated to determine the number of days that discharge occurred in each bin, and the average annual duration in days was determined for the representative flow of each bin. The discharge at other points upstream and downstream of Bronxville was determined by adjusting the Bronxville discharge by the ratio of drainage areas. Each discharge was modeled in HEC-RAS, and the corresponding average annual days were entered in the SIAM hydro data table for each reach. The discharges at Bronxville and the corresponding SIAM input durations in days are shown in Table 2.

Table 2. SIAM flow duration input (from Bronxville gage).

Discharge (cfs)	Duration (days)
5.5	22.1
10.8	66.6
21.3	101.8
41.7	100.2
81.9	49.7
160.8	17

315.5	5
619.2	1.3
1215.2	0.3

4.2.2.3 Sediment Properties. Sediment properties input data describe the selected sediment transport function, particle fall velocity, and wash load threshold diameter. The Laursen-Copeland bed material transport function was selected for the SIAM computations. The function is a total bed material load predictor that is applicable for the range of sand and gravel bed material present within the study reach. Particle fall velocity was set to the default values for the Laursen-Copeland transport function. The wash load threshold diameter represents the smallest particle size that is present in the channel bed material in any appreciable quantity. Einstein (1950) suggested that the D_{10} diameter of the bed material is a good value for this threshold. The wash load threshold is important in how SIAM segregates the sediment loads within each reach as wash load or bed material load. Wash load is generally dependent only on supply, and quickly passes through the system with little effect on the morphology of the channel, having more of an impact on water quality and aesthetics. Bed material load is dependent on the transport capacity of the stream, typically moves more slowly through the system, and has a significant influence on channel morphology. The wash load threshold functionality of SIAM accommodates changes in threshold values from reach to reach, effectively allowing sediment to transition from wash load to bed material load and vice versa.

The wash load threshold diameters used in the SIAM model are shown in Table 3. Reaches that were classified as alluvial reaches or pool reaches in the geomorphic assessment were given a wash load threshold value that approximated the D_{10} diameter of the bed material in the reach. Reaches that were classified as through-put reaches were assigned the maximum wash load threshold diameter currently allowed in SIAM of 2.0 mm (very coarse sand). By definition, a through-put reach simply "flushes" all sediments that enter to the next reach downstream, effectively transporting the material as wash load. By definition, a through-put reach is stable due to the very coarse bed material, even though the computed sediment transport capacity is very large and much greater than the bed material supply to the reach. At present, SIAM computations do not allow for true through-put reaches; that is, the bed material supplied to a downstream reach is computed in SIAM to be equal to the transport capacity of the current reach. This assumes that sufficient material is available in the bed to satisfy the required transport capacity. In the case of through-put reaches, which are supply limited, this results in unrealistically high bed material supply to reaches downstream of through-put reaches. To account for this, the SIAM results were post-processed to account for the through-put characteristics. This will be discussed in the SIAM results section.

Table 3. Wash load threshold diameters for SIAM reaches

Reach	Wash Load Diameter (mm)	Through-put reach?
1	0.125	N
2	0.125	N
3	2.0	Y

4	2.0	Y
5a	0.25	N
5b	2.0	Y
6	0.125	N
7a	2.0	Y
7b	2.0	Y
8	0.25	N
9	2.0	Y
10	0.25	N
11	2.0	Y
12	0.25	N
13a	0.25	N
13b	2.0	Y
14	0.25	N
15	2.0	Y
16a	0.25	N
16b	0.25	N
17	0.25	N
18	0.125	N
19	2.0	Y
20	0.125	N
21	0.125	N

4.2.2.4 Sediment Sources. Sediment sources for the Bronx River SIAM model were estimated from field investigations and information collected during the data collection. This aspect of the sediment assessment proved to be the most challenging. As discussed earlier in this report, the contribution from stream bank erosion is minimal throughout the study area, except for a few reaches where low to moderate erosion was observed. Although bank erosion is not considered a significant contributor of sediment to the system, a bank erosion input source for SIAM was estimated for the areas were erosion was observed. The reaches where a bank erosion sediment source was used as a SIAM input are Reaches 1, 5a, 16a, 16b, and 17. For these reaches an average yearly recession rate of 2 inches was assumed for a bank height of 4 feet to estimate an average annual sediment rate per linear foot of eroding bank of 0.01 tons/year/foot. This sediment load was then distributed by grain size for SIAM input based on two gradations representative of bank material samples located in the reaches where bank erosion was observed. The gradation for Reaches 1 and 5a was a slightly coarser gradation, while the gradation for Reaches 16a, 16b, and 17 was finer. For each reach a length of eroding bank was estimated, and this length was used as a scalar multiplier with the sediment rate per linear foot to compute an estimated sediment load from bank erosion. The sediment source from bank erosion used as SIAM input is shown in Table 4.

Table 4. SIAM input for bank erosion sediment source.

Reach	Est. length of eroding bank (ft)	Distributed bank erosion sediment source in tons/yr/ft (total load is 0.01 tons/yr/ft). Grain diameters in mm.									
		0.016	0.032	0.0625	0.125	0.25	0.5	1.0	2.0	4.0	8.0
Reach 1	300			0.0016	0.0014	0.0023	0.0022	0.0016	0.0005	0.0003	0.0002
Reach 5a	1000			0.0016	0.0014	0.0023	0.0022	0.0016	0.0005	0.0003	0.0002
Reach 16a	300	0.001	0.001	0.002	0.0026	0.0021	0.0007	0.0002	0.00015	0.00015	
Reach 16b	750	0.001	0.001	0.002	0.0026	0.0021	0.0007	0.0002	0.00015	0.00015	
Reach 17	500	0.001	0.001	0.002	0.0026	0.0021	0.0007	0.0002	0.00015	0.00015	

Potential sediment sources from tributaries, upland areas, and railroad embankments were also identified during the field investigation. However, very little published data was available with which to estimate annual sediment loads, and development of sediment yield models for the areas was beyond the scope of this study. Therefore, these three sources were combined as a single watershed sediment source for SIAM input purposes. Due to the lack of published data for the Bronx River, the watershed source loading rate was estimated from a sediment study conducted for the Nashville District on Pistol Creek at Maryville, TN (2004). The Pistol Creek watershed is an urban watershed, although the degree of development is less dense than the Bronx River study area. The watershed sediment rate used in the Pistol Creek study was 107 tons/year/mi^2. This rate was determined from USGS and NRCS data for the Pistol Creek area. Although this load may be slightly high for the Bronx River watershed, it is thought to be representative enough to be used as SIAM input. The load was distributed by grain size using the gradation from bank material sample Bank3, which was taken on an exposed slope area near Garth Woods (Reach 9). The load for each SIAM reach was determined by multiplying the watershed sediment rate by the estimated contributing area for each reach. The contributing drainage area for each reach was estimated by multiplying the total basin area of 56 square miles by the ratio of reach length to total length. An attempt was made to use the HMS basin delineations provided by NAN to determine the areas for each reach, but it was difficult to distinguish which HMS areas were associated with each reach due to storm sewer outfalls and re-routed drainage paths. The areas weighted by the ratio of reach length to total length do not give a completely accurate drainage, but are sufficient for approximating watershed sediment loads within the accuracy of the given sediment data. The watershed sediment loads for each SIAM reach are shown in Table 5.

Table 5. SIAM input for watershed sediment source.

Reach	Distributed watershed sediment source in tons/yr (total rate is 107 tons/yr/mi^2). Grain diameters in mm.									
	0.0625	0.125	025	0.5	1.0	2.0	4.0	8.0	16.0	32.0
Reach 1	7.8	11.3	15.7	28.7	30.1	23.5	20.4	15.7	33.2	8.8
Reach 2	5.5	7.9	11.0	20.0	21.0	16.4	14.3	11.0	23.2	6.1
Reach 3	9.4	13.6	18.9	34.5	36.3	28.3	24.6	18.9	40.0	10.5
Reach 4	4.2	6.1	8.4	15.4	16.1	12.6	11.0	8.4	17.8	4.7
Reach 5a	18.4	26.6	36.9	67.3	70.7	55.3	48.0	36.9	78.0	20.6
Reach 5b	8.0	11.5	16.0	29.1	30.6	23.9	20.8	16.0	33.8	8.9
Reach 6	4.5	6.5	9.0	16.4	17.3	13.5	11.7	9.0	19.1	5.0
Reach 7a	15.3	22.0	30.5	55.8	58.6	45.8	39.8	30.5	64.6	17.0
Reach 7b	5.2	7.5	10.3	18.9	19.8	15.5	13.5	10.3	21.9	5.8
Reach 8	6.9	10.0	13.9	25.4	26.7	20.8	18.1	13.9	29.4	7.8
Reach 9	8.1	11.7	16.2	29.6	31.1	24.3	21.1	16.2	34.3	9.0
Reach 10	3.7	5.3	7.3	13.3	14.0	11.0	9.5	7.3	15.5	4.1
Reach 11	12.0	17.3	24.0	43.9	46.1	36.1	31.3	24.0	50.9	13.4
Reach 12	15.9	23.0	31.8	58.1	61.1	47.8	41.5	31.8	67.4	17.8
Reach 13a	3.1	4.5	6.3	11.5	12.0	9.4	8.2	6.3	13.3	3.5
Reach 13b	2.8	4.0	5.5	10.1	10.6	8.3	7.2	5.5	11.7	3.1
Reach 14	7.5	10.8	15.0	27.4	28.8	22.5	19.6	15.0	31.8	8.4
Reach 15	6.1	8.7	12.1	22.1	23.2	18.2	15.8	12.1	25.6	6.8
Reach 16a	12.9	18.6	25.8	47.0	49.4	38.6	33.5	25.8	54.5	14.4
Reach 16b	29.1	42.0	58.3	106.4	111.8	87.4	75.9	58.3	123.3	32.5
Reach 17	19.0	27.4	38.0	69.4	73.0	57.0	49.5	38.0	80.5	21.2
Reach 18	16.9	24.4	33.9	61.8	65.0	50.8	44.1	33.9	71.7	18.9

Reach 19	3.6	5.2	7.2	13.1	13.8	10.8	9.3	7.2	15.2	4.0
Reach 20	4.6	6.6	9.1	16.7	17.5	13.7	11.9	9.1	19.3	5.1
Reach 21	10.2	14.8	20.5	37.4	39.3	30.7	26.7	20.5	43.3	11.4

4.2.2.5 Hydraulics. Hydraulic parameters used in the SIAM model calculations are automatically populated from the results of the HEC-RAS simulation. Each discharge specified in the hydrology input corresponds to a flow profile modeled in HEC-RAS. Mean hydraulic values for each profile are determined for each SIAM reach through a reach length weighted averaging scheme within HEC-RAS. The reach-averaged values are used in the sediment transport capacity computations.

4.2.3 SIAM Computations. The scenarios for which SIAM computations were made are 1) existing conditions, 2) no bank erosion contribution (assumes 100 percent of eroding banks are stabilized), 3) same as scenario 2 plus 25 percent of watershed sediment source controlled, and 4) same as scenario 2 plus 50 percent of watershed sediment source controlled. Scenario 2 assumes that all the eroding channel banks observed in the field investigation are stabilized. Scenarios 3 and 4 assume that reductions of 25 and 50 percent of watershed derived sediments are achievable, and also provide a limited sensitivity analysis of the SIAM results to changes in sediment loads.

The values computed for each SIAM reach are local balance, bed material supply and wash load, all in tons/year. Local balance indicates the state of bed sediment continuity, and is computed by subtracting the average annual transport capacity from the average annual bed material supply for a reach. A positive local balance indicates an excess in bed material supply for a reach, and suggests that the reach may have a tendency for deposition. Likewise, a negative local balance indicates an excess of transport capacity for a reach, and suggests that the reach may have a tendency to degrade. Local balance provides an indication of average annual sediment continuity assuming average flow conditions and average annual sediment source loadings. The bed material supply and wash load values indicate the total load of bed and wash material to a given reach for the year. Bed material forms and interacts with the channel boundary, is generally dependent upon transport capacity, and has a greater impact on channel morphology. Wash load is generally dependent only upon the supply source. It has little to no impact on the morphology of the stream, but has more of an impact on water quality and aesthetics.

Additional post-SIAM computations include conversion of local balance values to approximate sediment deposition depths for the reaches that contain the pool areas at Fisher Lane, Ardsley Road, Harney Road, Crestwood Lake and Dam 3. The approximate deposition depths were determined by assuming an average stream width for the length of reach where deposition is estimated to occur, and computing the depth required for producing a volume equivalent to the local balance. An assumed density of sediment of 90 pounds per cubic foot was used to convert the local balance to a volumetric equivalent. It should be noted again that SIAM is not an erosion/deposition model, and therefore does not adjust the model cross sections. The calculated deposition depths in the pools are intended simply to illustrate the relative deposition trends for the

impoundment areas, and caution is urged in estimating annual sediment maintenance requirements from the results.

4.2.4 SIAM Results. The results of the SIAM computations for bed material local balance, bed material supply, and wash load for each scenario are shown in Tables 6 through 8, respectively. These results reflect conditions of sediment continuity for average annual conditions, and extreme rainfall events and/or major geomorphic changes within the watershed would be expected to alter these conditions. In addition, the SIAM results should be viewed with care due to uncertainties in the preliminary geometry data used in the HEC-RAS model as well as errors in estimating sediment sources loadings. However, the SIAM results do give a reasonable indication of the general sedimentation trends for the reaches and the expected channel response to changes in the sediment regime due to potential restoration activities.

4.2.4.1 Local Balance Discussion. The bed material local balance results of the SIAM computations for all scenarios are shown in Table 6.

Table 6. SIAM results for Local Balance in tons/year.

Reach	Scenario 1 Existing Conditions	Scenario 2 No bank erosion	Scenario 3 No bank + 25% watershed control	Scenario 4 No bank + 50% watershed control
1	-559	-562	-605	-639
2	750	750	719	696
3	---	---	---	---
4	---	---	---	---
5a	393	388	225	101
5b	---	---	---	---
6	-34047	-34047	-34107	-34200
7a	---	---	---	---
7b	---	---	---	---
8	9936	9936	9836	9691
9	---	---	---	---
10	947	947	887	842
11	---	---	---	---
12	2379	2379	2236	2129
13a	2643	2643	2627	2615
13b	---	---	---	---
14	-2630	-2630	-2683	-2722
15	---	---	---	---
16a	113	112	34	-26
16b	551	550	428	337
17	-6865	-6867	-7008	-7113
18	12818	12818	11949	11523
19	---	---	---	---
20	15966	15966	15920	15886
21	-436	-436	-493	-537

Neutral local balance Positive local balance Negative local balance

The local balance values are color coded for easy identification of sediment trends for the reaches. A blue highlight indicates a reach with a positive local balance, or a tendency for sediment deposition. A red highlight indicates a reach with a negative local balance, or a tendency for sediment erosion/bed scour. A green highlight indicates a reach with a neutral local balance, assumed to be +/- 200 tons/year, and indicates a stable reach from a sediment continuity standpoint. Local balance for through-put reaches is shown as "---"and uncolored, since the through-put reaches are, by definition, stable.

In general, the trends from the SIAM local balance results agree within reason with field observations and the geomorphic assessments for the reaches, with a few noted exceptions. Reaches 1 through 5a represent a section of the Bronx River from Kensico Dam to White Plains that has a relatively moderate and consistent channel slope, and for the most part is very stable. Reach 2 indicates the tendency for sediment deposition in the Fisher Lane pool. The Fisher Lane pool was one of several sites identified in the NAN Scoping Document for the Bronx River Ecosystem Restoration Study (2004) as potential restoration sites. Reach 5a is the reach where the Westchester County Center tributary is a sediment source. The local balance results for Scenarios 4 indicates that control of 50 percent of the watershed sediment load can have a significant impact on sediment deposition trends in this reach.

Beginning with Reach 5b, the Bronx River gradient becomes fairly steep. However, the field observations and the geomorphic assessment clearly show no indicators of active channel incision within the reaches. In the steep, high energy reaches the sediment transport capacity is certainly greater, but the coarse bed material is basically non-alluvial and not easily eroded from the bed. The negative local balance of Reach 6 is questionable, because the Green Acres dam is located in this reach. One potential explanation is that the reach extent includes a significant portion of steep, high velocity channel upstream of the pool that influences the average channel hydraulics and thus increases the computed transport capacity. In addition, the bed material sample used to determine SIAM bed gradation for Reach 6 was collected in the deposition area of Green Acre pool, which included fine material. Including this material in the transport capacity computations greatly increases the transport capacity magnitude, and thus the large negative local balance. Field observations verify that sediment deposition is occurring in the Green Acres pool. This is also a site identified in the scoping document.

Reaches 7a and 7b encompass a steep reach of river between Green Acres pool and Ardsley Road pool. They were identified in the field investigation as through-put reaches, which would basically flush all material through to the impoundment at Ardsley Road. The positive local balance of Reach 8 indicates the deposition trend on the Ardsley Road pool.

After a steep section in Reach 9, the Bronx River slope moderates through the reaches encompassing the pools of Harney Road, Crestwood, and Bronxville. These ponds are some of the largest in the system, and they serve as significant sediment traps. The reaches between the pools are typically steeper in gradient, and function as through-put reaches. The local balance results for Reaches 10, 12, and 14 (Harney Road,

Crestwood, and Bronxville, respectively) all indicate deposition trends except for Reach 14 (Bronxville Lake). A potential reason for this is similar to that for the case of the Green Acres pond reach, in that there may be a significant portion of steep reach included in the average hydraulic parameters that increases the computed transport capacity for the reach. In addition, the deposition that occurs in Reach 12 (Crestwood Lake) and Reach 13a (Old Yonkers Mill ?) accounts for most of the available bed material, and the bed material supply to Reach 14 (Bronxville Lake) is less than the computed transport capacity, resulting in the negative balance. Field observations clearly indicate that Reach 14 is a depositional reach.

After a short through-put reach downstream of Bronxville Lake, the Bronx River has moderate channel slope through the areas of Shoelace Park until the pool at Dam 4 in the Bronx Park. Reach 16a has a neutral local balance, and Reach 16b has just a slight depositional trend. Reach 17 has a negative local balance, indicating a degradation tendency. This is the reach that encompasses Shoelace Park. The increased bank erosion that was observed in the vicinity of Shoelace Park may be an indicator of the excess in erosion energy in the reach. Reach 18 is the reach encompassing the pool of Dam 4 in Bronx Park and shows a significant depositional trend, as verified by the field observations

Reach 19 is a very steep through-put reach between Dam 4 and Dam 3. Reach 20, the reach where Dam 3 pool is located, indicates a significant depositional trend. Reach 21 is also a reach with a pool (Dam 3), but the local balance indicates the reach has a slight degradation tendency. This is due to the small amount of bed material supply coming from Reach 20 (Dam 3) that is not able to off-set the computed transport capacity of Reach 21. However, field observations clearly indicate that Reach 21 is depositional.

The sequence of local balance for the reaches containing the pools of Dams 2, 3, and 4 indicates that bed material tends to pass through the pool of Dam 4 and deposit in the pool of Dam 3, since both reaches indicate a positive local balance. However, it appears that bed material does not pass through the pool of Dam 3 as readily, as indicated by the negative balance of Reach 21 containing the pool of Dam 2. Clearly, all of the pools have significant sediment trapping capability, but these results suggest that the pool of Dam 3 may exhibit a greater potential for sediment retention.

Local balance results for Scenario 2 (no bank erosion contribution, all banks stabilized) indicate that stabilizing all eroding banks does very little to impact the overall sediment continuity within the system. The most logical reasons for this are 1) the degree of erosion is minor and the volume of eroded material is not significant, and 2) the bank material is composed mainly of fines that are in the wash load, and therefore do not impact the local balance. Field observations support the conclusion that the degree of bank instability within the system is minor and sediment contribution from bank erosion is minimal, particularly in regard to the balance of bed material. It should be noted that stabilization of eroding banks will reduce the contribution of fines and thus have an impact on water quality and stream aesthetics, although the degree to which this will occur is unknown.

Local balance results for Scenarios 3 and 4 indicate that control of watershed derived sediment sources will have a more noted impact on sediment continuity, although the extent to which it influences sediment continuity will be mild. For example, the local balance for Reach 5a (Westchester tributary reach) shows that by controlling 50 percent of the watershed sediment load the trend of the reach moves from slightly depositional to within neutral balance. It is very difficult to quantify these impacts from the results of a sediment budget model such as SIAM. An attempt to quantify the impacts by computing depths of deposition for some of the pool areas will be presented and discussed later in the report.

4.2.4.2 Wash Load Discussion. The wash load results from the SIAM computations are shown in Table 7. Wash load is the portion of the sediment supply to a reach that is composed of material that is smaller (finer) in size than the material found in the channel bed. It is material that "washes" through the reach very little interaction with the channel bed and therefore has little impact on channel geomorphic processes.

Table 7. SIAM results for Wash Load in tons/year

Reach	Scenario 1 Existing Conditions	Scenario 2 No bank erosion	Scenario 3 No bank + 25% watershed control	Scenario 4 No bank + 50% watershed control
1	20	19	14	11
2	33	33	24	18
3	379	378	311	261
4	484	483	390	320
5a	246	240	196	164
5b	758	752	658	588
6	145	141	106	80
7a	35297	35293	35065	34103
7b	35425	35422	35138	34199
8	20067	20063	19948	19297
9	25864	25860	25657	25044
10	20119	20115	19977	19336
11	25307	25303	25034	24449
12	20243	20239	20047	19429
13a	20257	20253	20055	19440
13b	20828	20825	20596	19994
14	20303	20299	20081	19474
15	23796	23792	23508	22930
16a	22276	22269	21984	21406
16b	22518	22504	22116	21583
17	20614	20597	20248	19698
18	557	543	407	305
19	19221	19207	19049	18930
20	577	563	422	317
21	602	588	441	331

As expected, the wash load results indicate that reducing the sediment sources reduces wash load, with reduction of watershed derived sediment having a greater impact on wash load than reduction of bank erosion sediment. Also evident is that the wash load increases in the steeper through-put reaches of the Bronx River, beginning in Reach 7a. The wash load level increases in Reaches 7a and 7b, then reduces slightly through Reach 8, the pool at Ardsley Road. The same sequence is noted for Reaches 10, 12, 18 and 20 (Harney Road pool, Crestwood Lake, Dam 4 and Dam 3 pools, respectively), where the wash load magnitude is high coming into the pool reach, then is reduced as it passes through the pool reach. The sequence is also observed for Reach 14 (Bronxville Lake), although the degree of reduction is not as significant. Note the significant reduction of wash load in Reaches 18 and 20, the pools of Dams 4 and 3 within Bronx Park. This indicates the sediment trapping potential of the pools, which is verified by field observations.

4.2.4.3 Bed Material Supply Discussion. The bed material supply from the SIAM computations is shown in Table 8. Bed material is the portion of sediment supply to a reach that is composed of material that is similar in size to material found in the channel bed.

Table 8. SIAM results for Bed Material Supply in tons/year

Reach	Scenario 1 Existing Conditions	Scenario 2 No bank erosion	Scenario 3 No bank + 25% watershed control	Scenario 4 No bank + 50% watershed control
1	178	176	132	99
2	861	861	830	807
3	---	---	---	---
4	---	---	---	---
5a	706	701	537	414
5b	---	---	---	---
6	725	722	636	572
7a	---	---	---	---
7b	---	---	---	---
8	15532	15532	15031	15287
9	---	---	---	---
10	5836	5836	5776	5731
11	---	---	---	---
12	5460	5460	5317	5210
13a	3883	3145	3129	3117
13b	---	---	---	---
14	713	713	660	621
15	---	---	---	---
16a	1844	1844	1764	1705
16b	2220	2220	2098	2006
17	4052	4050	3910	3804
18	31396	31392	30524	31097
19	---	---	---	---
20	18757	18757	18712	18677
21	3022	3022	2964	2921

"---" Through-put reach. Bed material not computed.

Information that can be gleaned from bed material supply results is very similar to that of local balance results, since bed material supply is used to compute local balance. Bed material supply gives an indication of the amount of material entering a reach that will need to be "processed" by the reach. It is most useful in determining the impact on reaches that are defined as depositional reaches with minimal transport capacity, since in most cases all or most of the bed material is assumed to be deposited in the reach. Reaches 8, 10, 12, 18, and 20 (Ardsley Road pool, Harney Road pool, Crestwood pool, and Dam 4 and 3 pools, respectively) are the top 5 reaches for the greatest bed material supply, and therefore may be susceptible to depositional problems. Once again, the Bronxville Lake reach (Reach 14) does not show the degree of depositional trend as other pool areas, although field observation clearly substantiate the reach to be quite depositional. Typical bed material reductions for the scenarios of 25 percent and 50 percent control of watershed sediments range from 100 to 200 tons/year.

4.2.4.4 Conversion of Local Balance to Average Annual Deposition Depth. It is often difficult to visualize the potential sediment impacts to a given reach from the local balance values themselves. It is helpful to convert the local balance values into an average annual depth of deposition (or degradation) which is more readily understood. This was accomplished by converting the annual local balances in tons to an equivalent volume using an assumed sediment density of 90 pounds per cubic foot. This equivalent volume was then divided by the product of the average reach length and the average reach width determined from aerial photography to arrive at an average annual depth of deposition in feet. This type of calculation assumes that the deposition will occur uniformly over the length and width of the reach. Potential sediment deposition in the flood plain is not accounted for in this procedure. It should be noted that SIAM is not an erosion or deposition model, and the computed depths should only be used as estimates of potential deposition. The computed depths do, however, help in verifying the reasonableness of the SIAM results. The computed deposition depths for the selected pool areas for each scenario are shown in Table 9.

Table 9. Estimated average annual deposition depths from Local Balance.

Reach	Pool	Average annual deposition depth in feet for each scenario			
		Existing	No Bank	No Bank + 25% watershed control	No Bank + 50% watershed control
2	Fisher Lane	0.08	0.08	0.07	0.07
8	Ardsley Road	1.64	1.64	1.62	1.60
10	Harney Road	0.15	0.15	0.14	0.13
12	Crestwood Lake	0.12	0.12	0.11	0.11
20	Dam 3	1.89	1.89	1.89	1.88

The average annual deposition depths appear reasonable with the exception of Reach 8 and 20 (Ardsley Road pool and Dam 3 pool, respectively). The annual depth of deposition computed for Reaches 8 and 20 is most likely overstated based on field observations. The reasons for this could be the estimated length and width of the deposition area is too small, or the local balance is too high due to either excessive bed material supply or insufficient transport capacity computed for the reach. Considering

the length of time that the pools have been in place, the approximate 0.1 foot per year rate of deposition computed for Reaches 2, 10 and 12 seems reasonable. The computed depths for Reaches 8 and 20 are not beyond reason for a given year, but it seems very unlikely that deposition would continue at that rate for very many years in succession. Re-suspension of deposited sediments, as discussed in the geomorphic assessment results, would likely begin to occur. This possibility would need to be addressed with a more detailed sediment transport model. Considering the computed deposition depths as computed, the pool with the most potential for depositional problems is Dam 3, followed by Ardsley Road, Harney Road, Crestwood and Fisher Lane. Very little impact to the computed depths is shown for the scenarios addressing control of bank erosion and watershed derived sediment sources.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Sediment Sources. The results from the geomorphic assessment indicate that the Bronx River is stable in plan form and profile. No significant indicators of channel incision were observed, and no active channel migration was observed. Bank erosion observed during the field investigation was very minor local erosion primarily in tight curvature bends with little existing vegetation. Reaches where bank stabilization measures, both hard and soft, currently exist appear to be performing satisfactory. Although difficult to quantify, recession rates at bank erosion sites were estimated to be on the order of 2 inches annually. Bank material sample gradations indicate that 30 to 90 percent of the bank material is wash load based on the wash load threshold values used in the SIAM model. As wash load, the material will likely flush through the system and deposit only in the most slack water areas. Results from the SIAM computations indicate that control of bank erosion sediment sources has little impact on the average annual bed material sediment balance of the system. In consideration of all observations and data, there is no evidence that enough bank caving exists or once existed that would result in the banks being considered a significant contributor to the sediment deposits in the Bronx River.

Given that bank erosion is not considered a significant contributor of sediment, it appears that the primary source of sediment deposited in the pools is mainly from the watershed. It is unclear, however, whether the watershed contribution was greater in years past when urban development was more active than at the present. Sediment generation within the watershed was observed at localized gullies formed by concentrated run-off from parking lots, roadways and walking paths adjacent to the river, as well as railroad embankments immediately adjacent to the river. Observations of sediment delivered from tributaries also suggest that the watershed contributes sediment. In particular, the Westchester County Center tributary was noted as a substantial contributor of sediment to the system, but the sediment load could not be quantified since sediment sampling gages or other flow gages do not exist in the basin. Estimating the annual sediment yield from the watershed areas was difficult due to the unavailability of published data, and development of watershed yield models was beyond the scope of this study. Estimates of watershed sediment loads for the SIAM computations were estimated

from study results of a similar urbanized area. SIAM computation scenarios assuming 25 percent and 50 percent control of watershed sediment sources show modest reductions in bed material supply for the reaches ranging from 100 to 700 tons/year, with the typical reduction being 100 to 200 tons/year.

5.2 Sediment Deposition in Pools. The pool areas located throughout the system serve as sediment traps, and apparently have done so for many years. Field observations show that sands and fine gravels deposit in the upper reaches of the pooled areas, while the fine sands and silts deposit in the lower reaches. Sediment depths were in excess of 4 feet, but actual depths were not determined due to the lack of historic channel surveys or dredging records. Sediment deposition immediately upstream of most of the major impoundment dams and weirs was level or near level with the crest of the dam/weir. In some of the larger impoundments, sizable middle bars or low islands have developed and been vegetated. SIAM computations also verify these deposition areas. The primary areas of deposition that were identified are Fisher Lane (Reach 2), Ardsley Road (Reach 8), Harney Road (Reach 10), Crestwood Lake (Reach 12), Bronxville Lake (Reach 14), and Dams 2 and 3 (Reaches 21 and 20, respectively) in the Bronx Park. Depths of annual deposition estimated from SIAM results for these areas range from approximately 1 to 2 tenths of a foot to 1.8 feet per year; however, the depth of 1.8 feet is probably excessive based on observations of existing pools, and an average annual depth of deposition of 0.1 to 0.2 feet is considered more reasonable. An important but unknown aspect of the pool areas is the possibility for deposited sediments to re-suspend during major flood events. The degree to which this may occur should be investigated with a more detailed numerical sediment transport model such as HEC-RAS Sediment Transport or ADH.

5.3 SIAM Results. In general, the results of the SIAM computations were considered reasonable and representative of conditions documented not only by the geomorphic assessment, but also by NAN observations noted in the restoration project scoping document. Uncertainties in the SIAM results are due to the preliminary nature of the geometry data in the HEC-RAS model, and to errors in the estimation of watershed sediment source magnitudes and distributions. Watershed sediment was lumped into one source loading for the SIAM analysis due to lack of additional data, whereas actual individual sources within the watershed could vary significantly in composition and yield. Although the magnitudes of computed sediment balances may be at best approximations, the trends of sediment deposition are considered very indicative of those observed in the study area.

5.4 Specific Questions from Westchester County, NYC Department of Parks/Recreation, and USAED, New York. The specific questions listed in the Objectives section of this report are addressed in consideration of the results of the geomorphic and sediment assessment.

- *What and where are the sources of sediment?* Bank erosion was determined not to be a significant source of sediment. Based on estimated bank erosion rates and the stability of the channel banks, the potential sediment that would be generated from these sources is insufficient to contribute to the deposited volume of material

in the pools to any significant degree. Watershed derived sediment is likely the main contributor to the pool deposits, but it is unknown whether the contribution was greater in past years of heavy urban development than at present. Sediment yield from watershed areas is best determined from sediment sampling station data collected over time that can be used to develop sediment discharge relations. No such sampling stations exist on the Bronx River or tributaries, and no such historic data was located. Quantitative estimates of the watershed sediment load were not attempted due to the lack of published data. Reasonable estimates could be made if the filling rates of the pool areas were known; however, no historic channel surveys or dredging records were located.

- *What are the characteristics of the sediment?* The sediment deposits in the pool areas are generally sand and fine gravel in the upper portions of the pools, and fine sand, silt and organic material in the lower portions of the pools. Although the actual sediment depths are unknown due to the unavailability of historic channel surveys, the depth in the upper portion of most of the pools was 4 feet or more.
- *Where are the primary areas of erosion and deposition within the river system? Are some impoundments filling more rapidly than others?* In general, active erosion within the river system is very limited. The general areas of bank erosion were the reach from the Westchester County Center tributary downstream to the Westchester County Center parking lot bridge, the vicinity of Scout Field, and between Cross County Parkway and Oak Street. Deposition occurs at most of the pool areas formed by the dams and weirs. Crestwood Lake is the most extensive area of deposit, and Dam 4 is the least extensive deposit. Deposits at Ardsley Road, Harney Road, and Green Acres were filled even with the crest of the weir/dam. The rate of filling for the different pools cannot be determined without repetitive surveys or dredging records. It is unknown whether the pools filled to the current extent over a short period in years past, or have been filling at a consistent rate.
- *What are the rates of deposition?* The rates of deposition are unknown due to the unavailability of repetitive historic surveys or dredging records. Such information would be very valuable not only in determining filling rates in the pools, but also in estimating sediment rates from the watershed. SIAM model results of bed material continuity were used to estimate an average annual deposition rate of 0.1 to 0.2 feet per year.
- *How does land use within the watershed affect sediment?* The watershed area of the Bronx River is a highly developed urban area with a significant percentage of impervious area; therefore sediment erosion from these areas would be very little. However, the urbanized area does increase and concentrate run-off, resulting in local areas of gully erosion near overpasses and bridges. Areas that are actively under construction are more likely to contribute sediment unless adequate erosion control measures are used. The potential sediment production from these areas can only be quantified with watershed erosion models, either lumped parameter 1-dimensional models such as HEC's HMS, or 2-dimensional gridded models such as ERDC's GSSHA. Comprehensive studies of this nature can be resource and data intensive.

- *Which tributaries are the primary sediment producers?* The Westchester County Center tributary is the primary sediment producer. Sprain Brook and Troublesome Brook also contribute sediment, but approximately 75 percent less than Westchester County Center tributary. No sediment sampling station data were available for the tributaries to determine sediment yields quantitatively. Without such data, the sediment yield can be estimated using detailed watershed erosion models such as discussed above.
- *Can re-suspension of sediment deposits within the impoundments be a sediment source?* Due to the abundant sediment deposits in most of the pools, it seems reasonable that re-suspension of the sediments could occur. Since the hydrology of the Bronx River is fairly flashy, it is expected that any sediment that is re-suspended will be transported short distances and re-deposited in pool areas located farther downstream. The through-put reaches that exist between the impoundments would flush any material that enters it into the next pool area. It is unknown at what flow rate this re-suspension may occur. For most of the pools the 1-dimensional model HEC-RAS Sediment Transport could be used to investigate the process of re-suspension. For larger pool areas such as Crestwood Lake and Bronxville Lake the 2-dimensional model ADH could be used.
- *Is sediment concentration correlated with seasonal conditions or stream flow?* No sediment sampling data exists to determine any such correlation.
- *How will potential physical modifications to the channel system and sediment sources impact sediment movement within the system?* This could be addressed with the HEC-RAS Sediment Transport model. Potential physical modifications can be reflected in the model geometry to determine the relative changes to sediment transport characteristics with the system, particularly the pooled areas. The potential physical modifications to the channel were not available for this study. However, any such modification that creates more of a confined channel through the larger pools will increase the sediment transport capacity through the pools.

5.5 Recommendations.

- Determine if any dredging records, channel maintenance records, or historic channel surveys exist for the impoundments, particular the larger pools like Crestwood Lake. The data search conducted for this study did not locate any such data. This data would be valuable in addressing two critical unknowns: 1) the rate and time sequence of sediment deposition and 2) the sediment load from the watershed area upstream of the location.
- Develop sediment transport models of selected pools to address the potential for sediment re-suspension. Modeling with 1-dimensional models such as HEC-RAS Sediment Transport would be sufficient for most pools. These models could also be used to determine the changes of sediment transport due to potential channel modifications within the system.
- Establish sediment survey ranges that can be regularly surveyed for selected impoundments. This can help determine deposition rates that are currently occurring.

- Establish sediment sampling stations on Westchester County Center tributary and the Bronx River. Ideally, a sampling station near the outlet of the tributary and one downstream of the tributary on the Bronx River would be needed to collect data to quantify sediment yields from the watershed. A sampling station near the outlet of the Bronx River would help determine overall sediment yield from the basin.

6. REFERENCES

Einstein, H.A. (1950). "The Bed-load Function for Sediment Transport in Open Channel Flows", U.S. Dept. of Agriculture, Soil Conservation Service, Technical Bulletin No. 1026.

Federal Emergency Management Agency (2001), Flood Insurance Study, City of New York, New York, Revised version 2001.

U.S Army Engineer Research and Development Center, Coastal & Hydraulics Laboratory (2004), Pistol Creek Sediment Impact Assessment, 3909 Halls Ferry Road, Vicksburg, MS, 39180.

U.S. Army Corps of Engineers, New York District, (2004), Scoping Document for Bronx River Ecosystem Restoration Study, 26 Federal Plaza, New York, NY 10278-0090.

SUPPLEMENTAL INFORMATION

Interactive GIS maps showing study reach limits and locations of bed and bank material samples are provided on the following CDs.

Attachment C-6
HRE
Bronxville Lake Hydrologic and Hydraulic Analysis

Bronx River Ecosystem Restoration Feasibility Study
Draft Interim Letter Report
Hydrologic & Hydraulic (H&H) Analysis for Bronxville Lake
25 November 2015

Following the field investigations and initial development of conceptual alternatives in Task 2: Ecological Functional Assessment- Evaluation of Planned Wetlands (EPW) a Hydrologic & Hydraulic (H&H) analysis was conducted to improve design and cost estimate accuracy. This summary provides the results of the H&H analysis for Bronxville Lake.

A. Site Overview

The Bronxville Lake site is located along the Bronx River, in the Village of Bronxville and the City of Yonkers, Westchester County, NY. The site is bounded by the Bronx River Parkway to the west, Tuckahoe Road to the north, Metro North Railroad to the east and private properties to the south. At this location, the Bronx River flows through a broad valley (~400 feet wide), the sides of which are twenty to forty (20-40) feet high. The weir across the River at the southern end of the site creates a broad and shallow lake in the southern two-thirds (2/3) of the proposed Bronxville Lake site. The stone weir is 48 feet wide and approximately 5.5 feet high at the highest elevation and the Bronxville Lake as approximate surface area of 7 acres. Figure 1 shows the stone weir controlling the lake. The lake is surrounded by a park, which is part of the Bronx River Parkway Reservation and is maintained by the Westchester County Department of Parks, Recreation, and Conservation. The park consists largely of maintained lawns with trees, with several pockets of emergent wetlands that are landscaped and mowed.

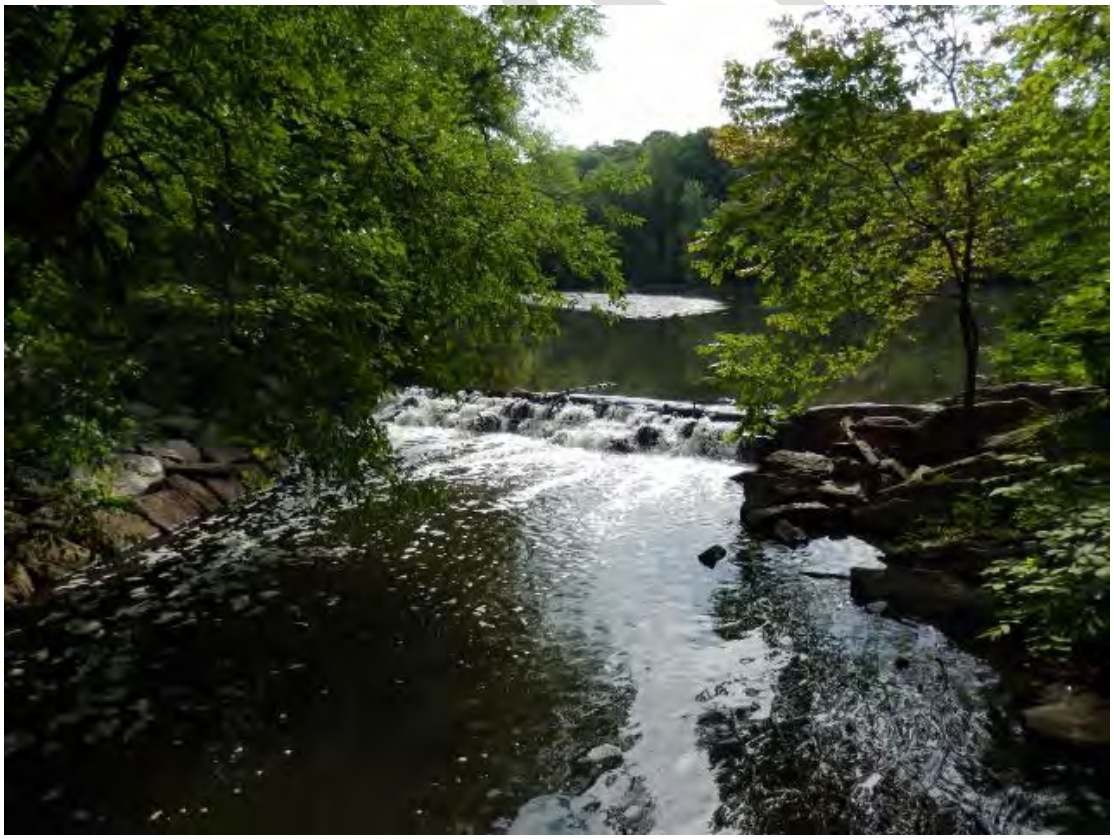


Figure 1: Existing Stone Weir Bronxville Lake

B. Analysis

1. Field Survey & Historic data Collection

As part of data collection for Group A – Bronxville Lake, Crestwood Lake, & Garth Woods/Harney Road (Optional Tasks 3c, 3d, & 3e), the A/E performed a field survey for Bronxville Lake on October 23, 2015. Data collection included five (5) east/west cross-sections (bathymetric & topographic) across the Bronxville Lake, and a weir survey consisting of an upstream cross-section, a downstream cross-section and the top of the weir section. The coordinate system used for data acquisition is the New York State Plane (NAD1983) NY EAST horizontal datum and NAVD 88 vertical datum.

The field data collected during this effort includes:

- Lake/channel bathymetry
- Riparian/floodplain topography (over bank grades along the cross-sections)
- Sediment thickness in lakes
- Location/presence of thalweg
- Weir dimensions and materials
- Topography/bathymetry immediately upstream and downstream of existing weir
- Field photographs
- Changes in slope, top of bank, toe of bank, thalweg, water's edge, and limits of existing path
- Sediment depth across the section within lake/channel boundaries using appropriate sediment probe (n/a for Garth Woods)

A number of data sources were reviewed to provide an understanding of the existing and pre-existing site characteristics. These included:

- Federal Emergency Management Agency's (FEMA) 2007 Flood Insurance Study (FIS) HEC-RAS hydraulic models.
- FEMA Hydraulic model back up GIS data including Topographic Triangulated Irregular Network (TIN) Surface, Survey and Cross-section geometry.
- NYD – Provided 1meter Digital Elevation Model (DEM) for project area
- USGS 1:24,000 Quadrangles
- NYSOGS 2013 Orthoimagery
- FEMA Flood Insurance Study (Westchester County)

2. Hydrologic Model & Flow Rates

Existing hydrologic analyses available from FEMA FIS and USACE-NYD Bronx River SIAM model were used for the Bronx River H&H analyses. The Bronx River has a contributing area of approximately 34 square miles at Bronxville Lake that includes developed and undeveloped area in central Westchester County.

a. FEMA Hydrology

The effective FEMA 2007 hydrologic analysis was based on an updated Log-Pearson type – III analysis on Bronxville gage located just downstream of the Bronxville Lake site. Peak flows for the 10 year, 50 year, 100 year and 500 year flood events established by FEMA and used in the effective FEMA HEC-RAS model, were directly incorporated into the current project model without any changes.

DRAFT

b. USACE-NYD Hydrology

USACE-NYD had developed a detailed HEC-1 model for the Bronx River watershed as a part of their Bronx River Ecosystem Restoration Study, July 2010. The HEC-1 model was calibrated for the rainfall events and used to predict hypothetical peak discharges for 1 year, 2 year, 5 year, 10 year, 25 year, 50 year, 100 year, 250 year and 500 year events. USACE-NYD provided the A/E with the HEC-1 model and the SIAM HEC-RAS model for possible use and guidance. From these models, this analysis utilized the hypothetical peak flood volumes and the nodes where the rate of flow changes to determine the flood volumes at the cross section locations.

3. Hydraulic Model Setup

The existing FEMA model was used as a basis for this analysis. The FEMA model was developed on the latest GIS-based hydraulic analysis platform, using the USACE's HECGeoRAS and HEC-RAS model interfaces. In order to set up the base analysis for this project, the effective FEMA model was imported in the USACE HEC-RAS version 4.1 and ran using the steady state hydraulic analysis. The backup FEMA GIS data along with FEMA's Topographic data (TIN) were used to develop project specific data at Bronxville Lake.

The general steps followed in the development of the project specific analyses at Bronxville Lake are summarized below.

- The field survey was imported in ARCGIS map and the survey shapefiles for the project area were extracted.
- Initial project setup was performed using effective FEMA data, field survey and other recent basemap data acquired in task 1. The project specific cross-section location plan along with field survey data is provided in Attachment A.
- After initial set up of the hydraulic analysis, the channel cross-sections from Bronxville site were removed manually from the HEC-RAS model and Bronx River GIS dataset.
- New cross-sections based on the field survey were added in GIS for the data processing.
- The cross-section geometry for the HEC-RAS hydraulic model was developed from two data sources, surveyed cross-sections and FEMA Bronx River TIN elevation data.
- No changes were made to the existing cross-sections and structure on the Bronx River outside the project area within the Bronx River Model and database.
- The weir profile was then modified in HEC-RAS to match the recently surveyed data and field observations.
- Upon completion of the geometric data input of the model the Channel Manning's n values and in-effective flow areas were updated on each affected cross-sections following the guidance provided in the HEC-RAS user's manual.
- Two different models scenario with FEMA and USACE-NYD hydrology were simulated to evaluate different flow conditions through the lake and establishment of the base flood elevations for the selected frequencies.
- The result of the hydraulic analysis using USACE-NYD hydrology is provided in Attachment B.

DRAFT

C. Results

As part of Bronxville Lake study, the following items were reviewed and evaluated using the field survey data and the H&H model results. The HEC-RAS summary output table, cross-sections and flood profiles for 1 year through 500 year simulation run are provided in Attachment B.

- **Stream Thalweg:** The stream thalweg represents the existing channel invert along the stream through the site. A GIS feature line representing the location of existing stream invert was developed using the field survey and ArcGIS application. At Bronxville Lake, the existing thalweg line is mostly in the center of the stream/lake in the north and central portion of the Bronxville Lake. However, in the southern portion of the lake, the thalweg shifts close to the left overbank in the weir vicinity. The maximum depth surveyed is approximately 6.5 feet +/- closer to the weir (XS#19575.24), whereas a minimum depth of 3.5 feet +/- was observed at the upper portions of the lake (XS#20678.07).
- **Channel Banks:** The average bottom of the bank elevations along the Bronxville Lake is 85.0 feet +/- whereas the average top of the bank elevation ranges from 87.3 to 87.8 feet. A GIS feature line representing the edge of banks is plotted on the map in Attachment A.
- **Sediment Depths:** The maximum sediment depth (refusal depth) observed ranged from 3 to 7 feet.
- **Bank full Flows:** Based on hydraulic model simulations, the average bank full flood event is a 1 year flood with an average maximum depth of 6 feet along the cross-section.
- **Extreme Floods:** Bronxville Lake and the adjacent park land would be submerged in flood event greater than the 5-year recurrence interval level. During extreme flood events such as the 500-year interval, the predicted flood depth varies spatially from approximately 8 to 12 feet above the normal lake surface.
- **Channel Velocities:** The channel velocity along the Bronxville Lake varies from below 1 ft./sec at the widest portion of the lake to approximately 3.5 ft./sec at the weir.

D. Recommendation for Design

Based on the review of the existing condition H&H results, and field collected data we offer the following recommendations for design of alternatives.

- **Channel Realignment/Bed Restoration:** Maintain the existing thalweg on north and central portion of the lake, and move the proposed thalweg to the center of the lake in southern portion.
- **Emergent/Forested Wetland Creation:** Consider keeping proposed wetland elevations below the 1 year flood level to ensure frequent inundation.
- **Wetland/Upland plantings:** Consider wetland/upland plant and tree species capable of withstanding the stream velocities of 3.5 ft. /sec or higher.
- **Sediment Forebay:** Based on stream channel velocities and flow depth a minimum of 18" diameter stones is recommended in the forebay.
- **Sediment Dredging**: Utilize the cross-sections provided in Attachment B to define the sediment depth at the proposed sediment dredging areas in the lake.

The design alternatives are to incorporate these recommendations and the recommendations of the USACE PDT.

DRAFT

E. References

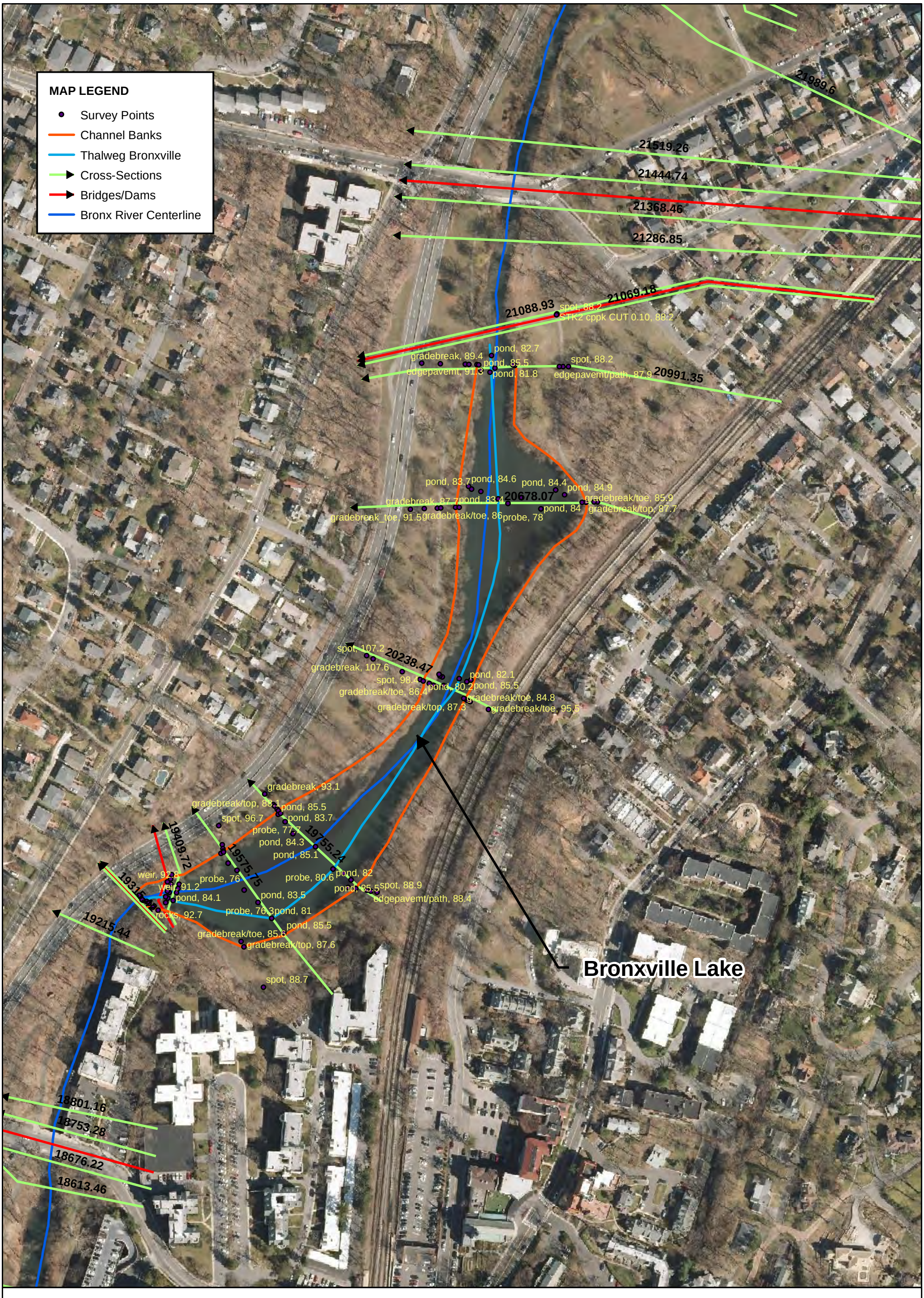
1. Federal Emergency Management Agency (FEMA), Flood Insurance Study Westchester County, NY September 28, 2007.
2. Hydrologic Engineering Center (HEC), HEC-RAS User's Manual, version 4.1 January, 2010.
3. Hydrologic Engineering Center (HEC), HECGeoRAS User's Manual, version 10 May 2012.
4. Bronx River – SIAM hydraulic Models, developed by USACE, New York District, July 2014.
5. Draft EPW Report – Bronx River Ecosystem Restoration study, e4sciences/AECOM January 2015

F. Attachments

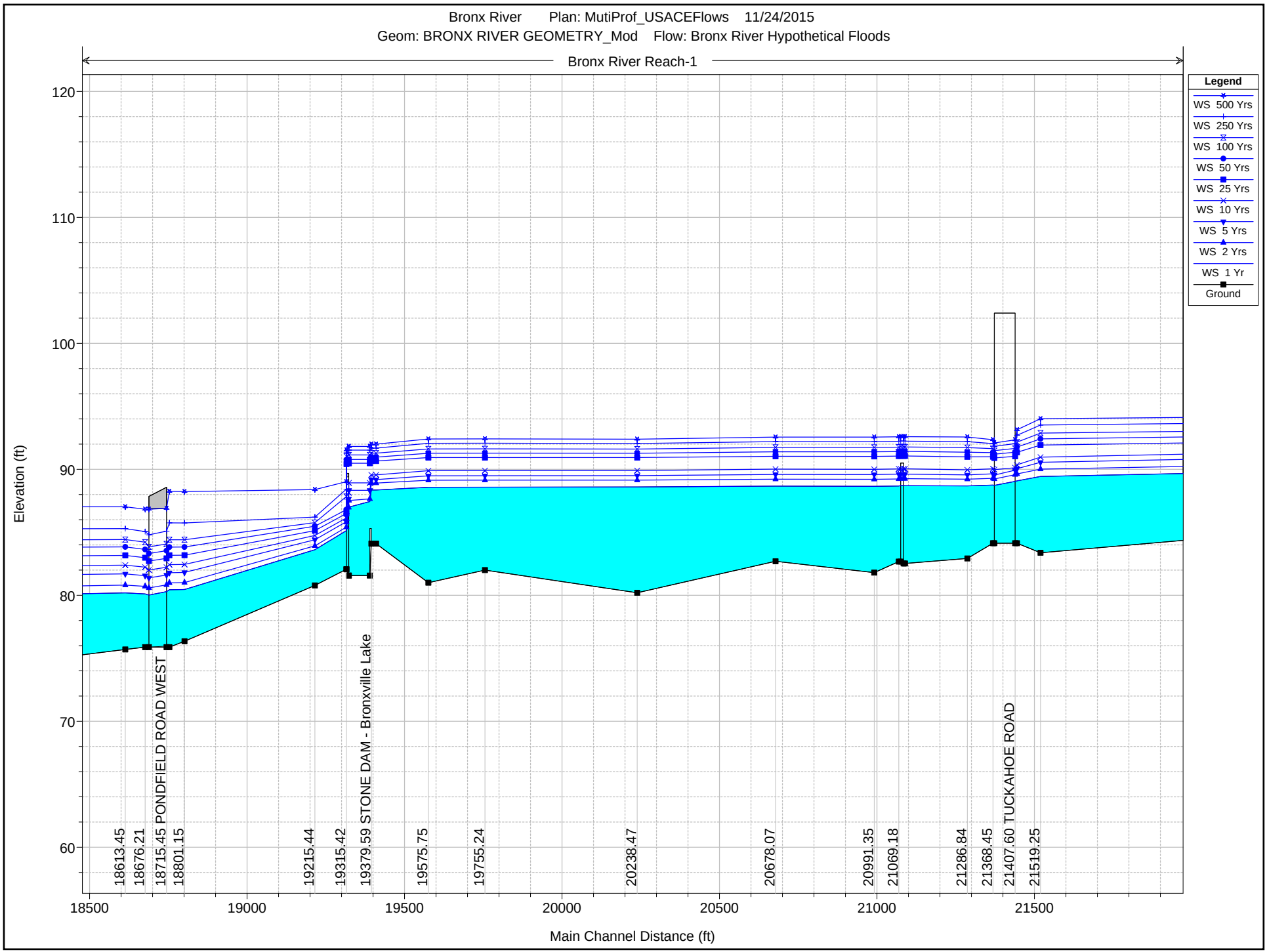
A. Cross-Section Location Map – Bronxville Lake
B. HEC-RAS Output – Summary Table, Cross-Section Plot and Profile through Bronxville Lake.

DRAFT

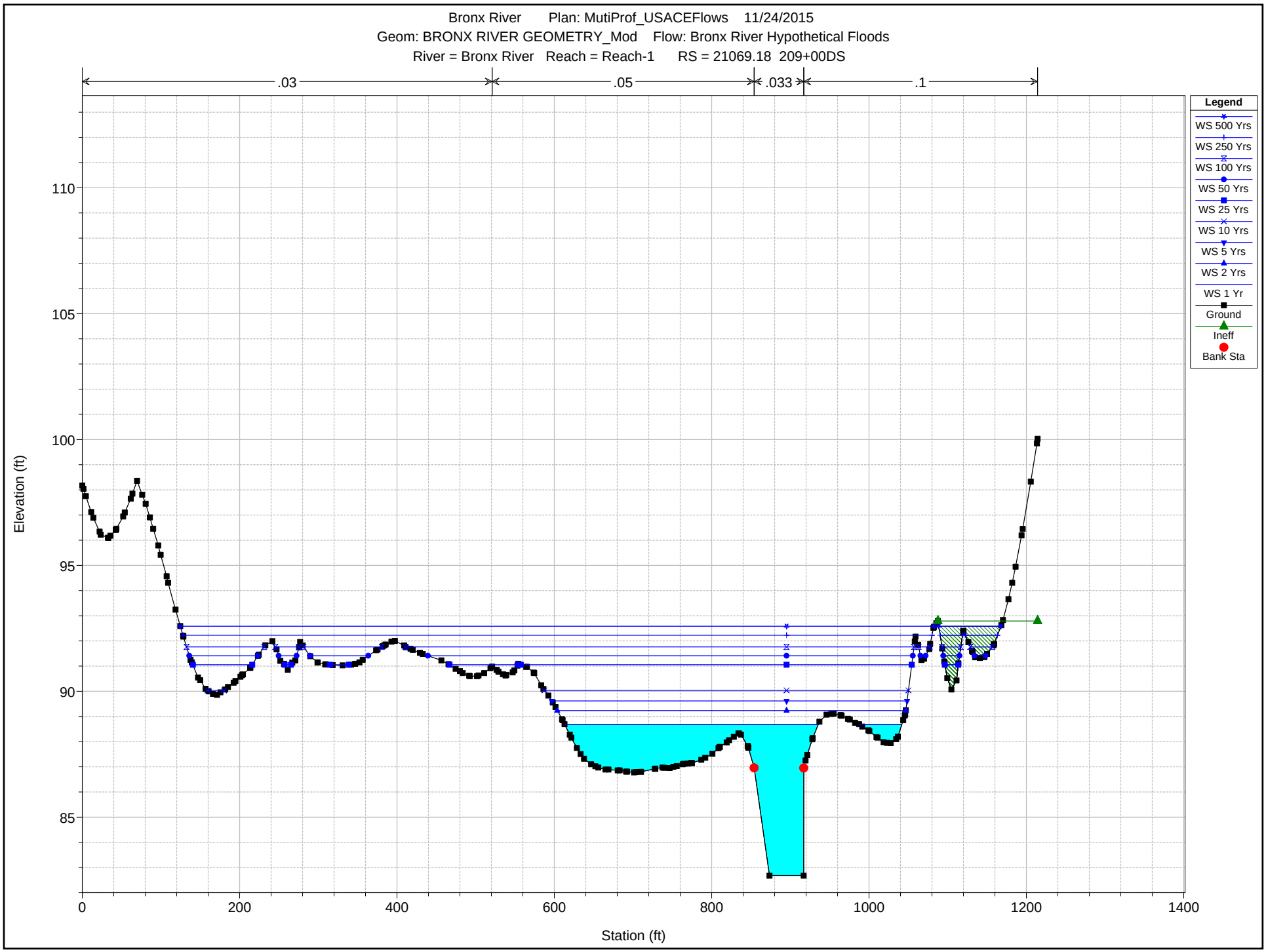
ATTACHMENT : A


MAP LEGEND
Survey Points
Channel Banks
Thalweg Bronxville
Cross-Sections
Bridges/Dams
Bronx River Centerline
21989.6
21519.26
21444.74
21368.46
21286.85
21088.93
21069.18
spot, 88.2
STK2 cppk CUT 0.10, 88.2
pond, 82.7
gradebreak, 89.4
pond, 85.5
edgepavemt, 91.3
pond, 81.8
spot, 88.2
edgepavemt/path, 87.9
20991.35
pond, 83.7
pond, 84.6
pond, 84.4
pond, 84.9
gradebreak, 87.7
pond, 83.4
20678.07
gradebreak/toe, 85.9
gradebreak/top, 87.7
gradebreak_toe, 91.5
gradebreak/toe, 86
probe, 78
pond, 84
spot, 107.2
20238.47
gradebreak, 107.6
spot, 98.4
pond, 80.2
pond, 82.1
pond, 85.5
gradebreak/toe, 86.4
gradebreak/toe, 84.8
gradebreak/top, 87.3
gradebreak/toe, 95.5
gradebreak, 93.1
gradebreak/top, 88.1
pond, 85.5
spot, 96.7
pond, 83.7
probe, 77.7
19409.72
19755.24
pond, 84.3
19575.75
pond, 85.1
weir, 92.8
probe, 76
probe, 80.6
pond, 82
weir, 91.2
pond, 83.5
pond, 85.5
spot, 88.9
edgepavemt/path, 88.4
pond, 84.1
probe, 76.3
pond, 81
rocks, 92.7
19215.44
pond, 85.5
gradebreak/toe, 85.6
gradebreak/top, 87.6
spot, 88.7
Bronxville Lake
18801.16
18753.28
18676.22
18613.46
CROSS-SECTION LOCATION MAP - BRONXVILLE LAKE
0
200
400 Feet

ATTACHMENT : B

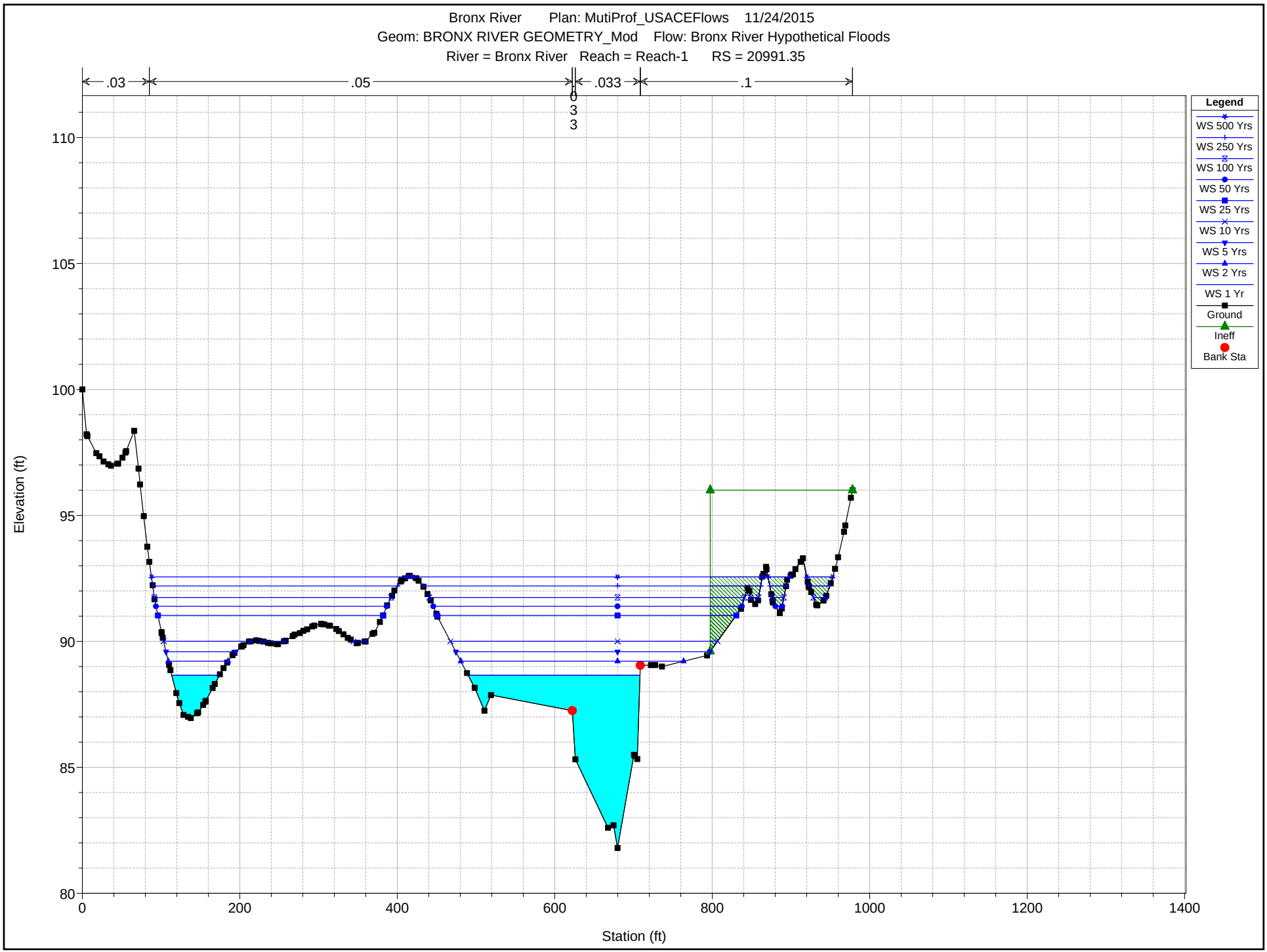


1 in Horiz. = 400 ft 1 in Vert. = 10 ft



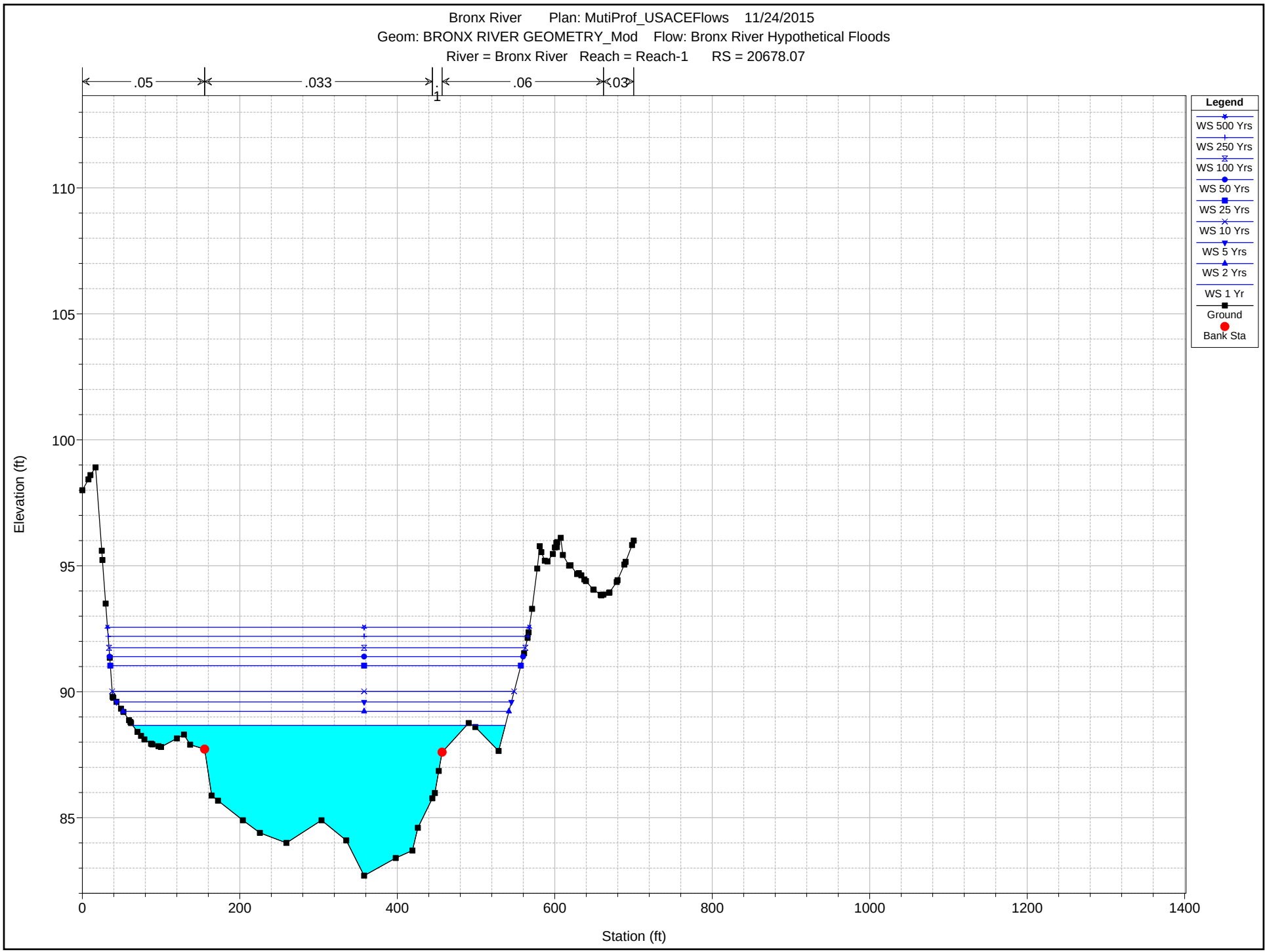
1 in Horiz. = 160 ft 1 in Vert. = 5 ft

Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 20991.35



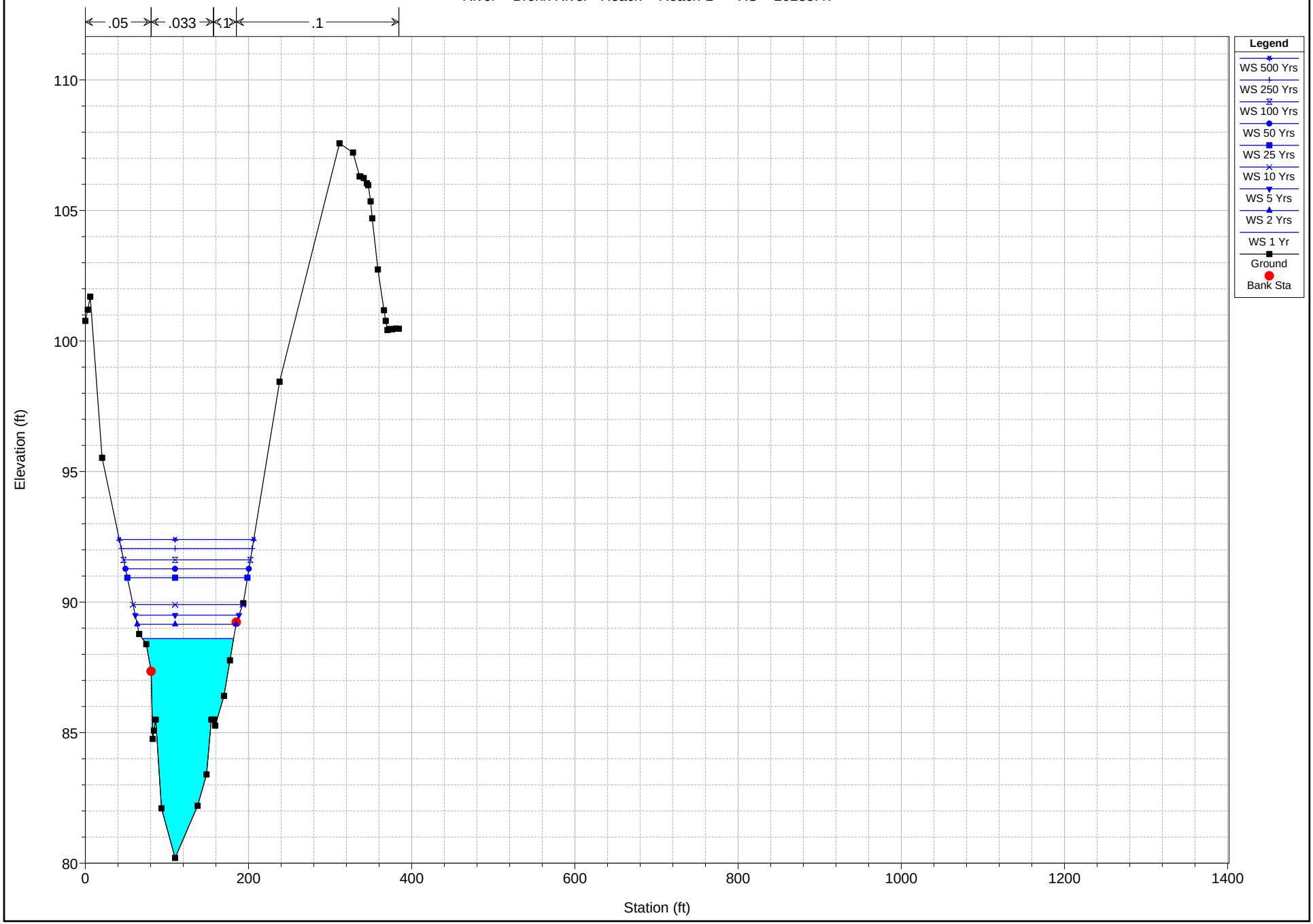
1 in Horiz. = 160 ft 1 in Vert. = 5 ft

Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 20678.07



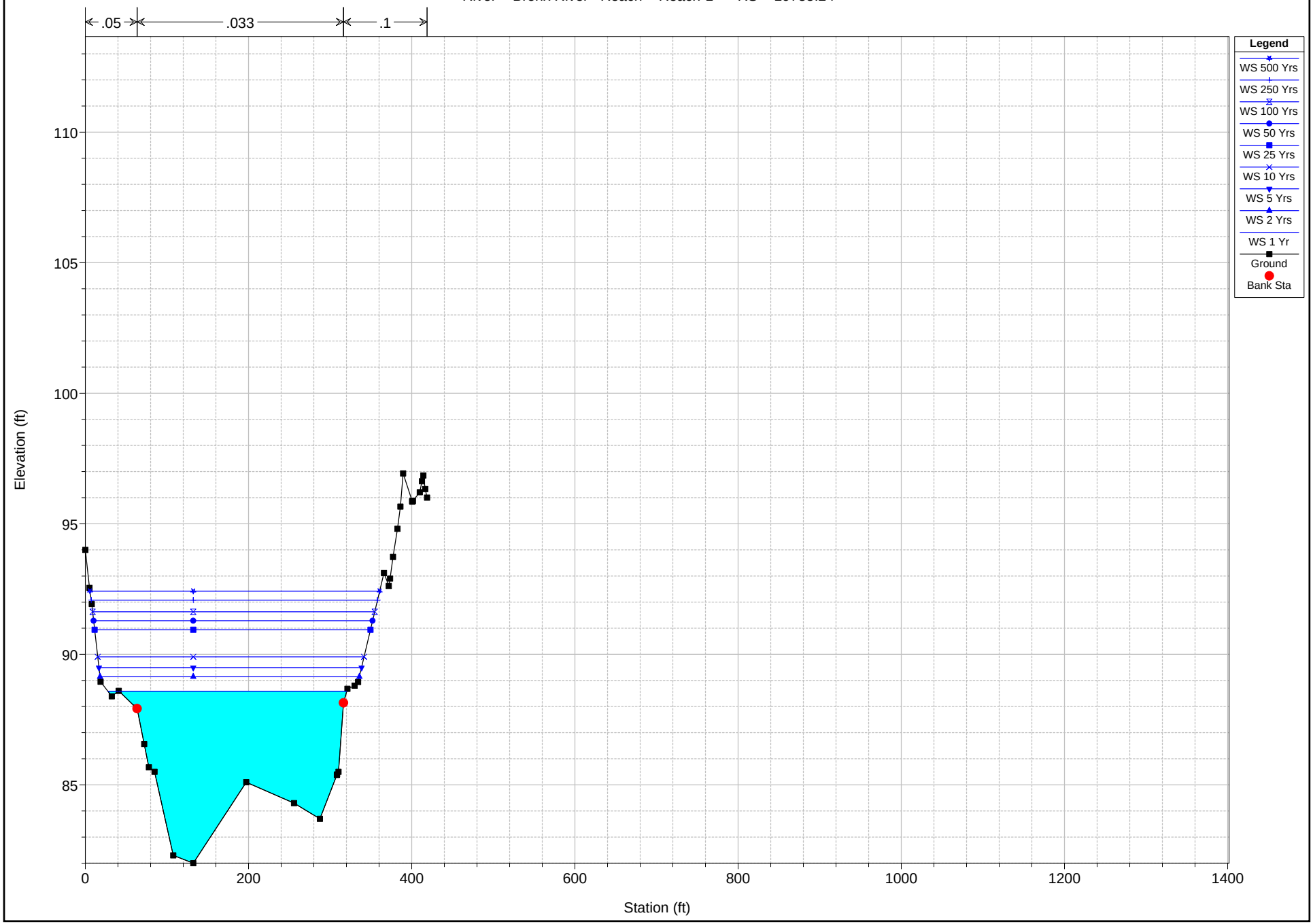
1 in Horiz. = 160 ft 1 in Vert. = 5 ft

Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 20238.47

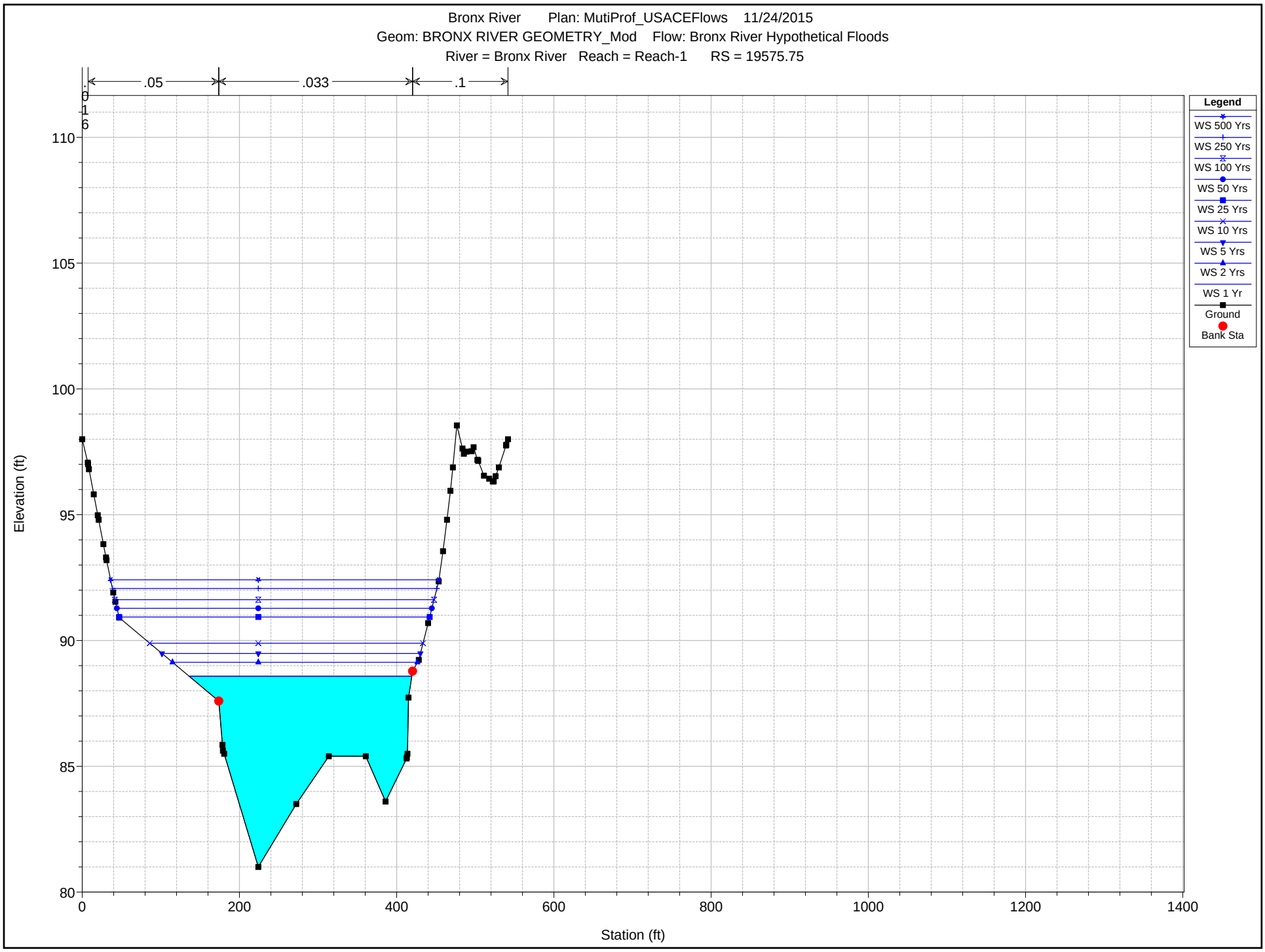


1 in Horiz. = 160 ft 1 in Vert. = 5 ft

Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 19755.24

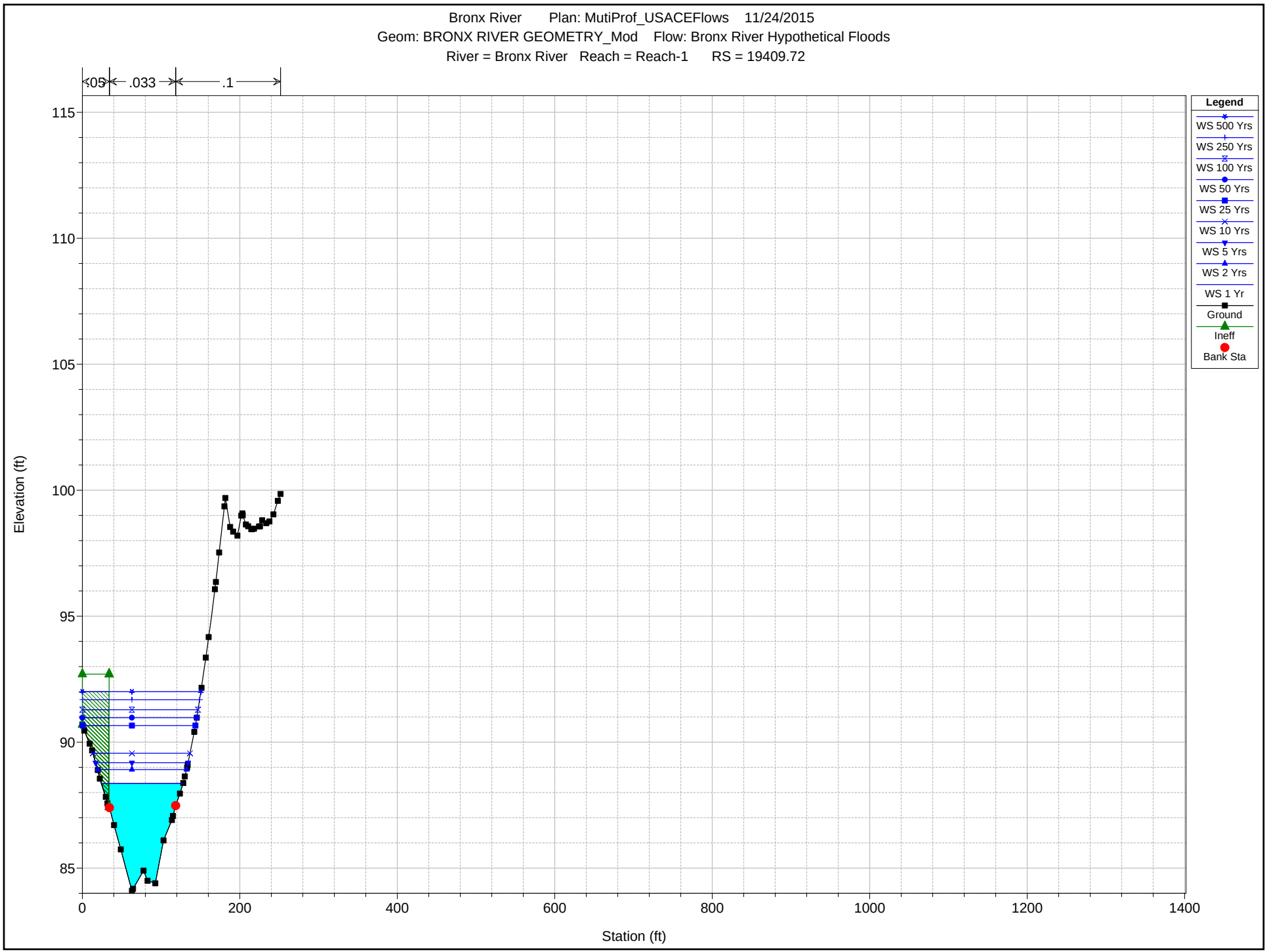


1 in Horiz. = 160 ft 1 in Vert. = 5 ft



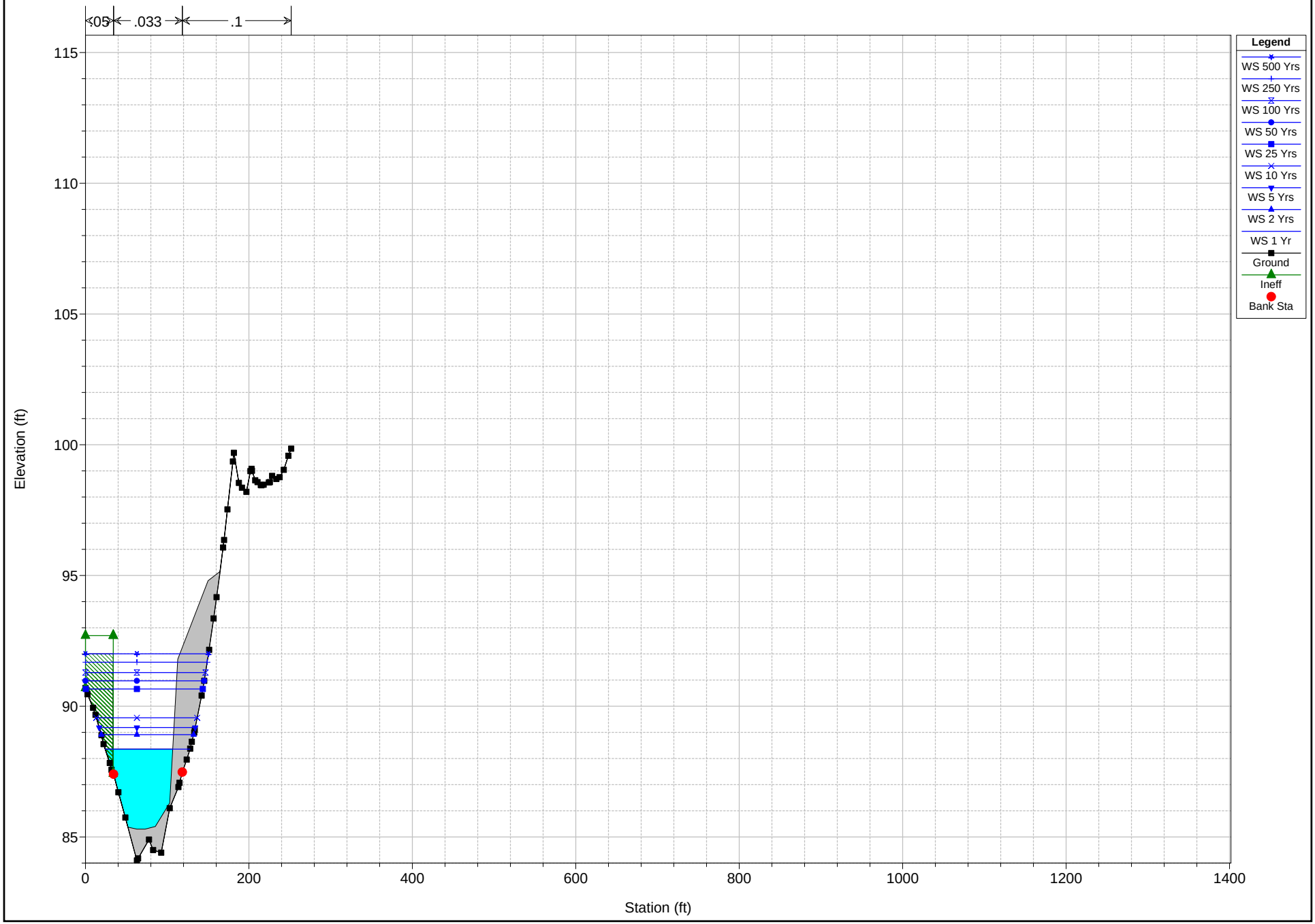
1 in Horiz. = 160 ft 1 in Vert. = 5 ft

Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 19409.72

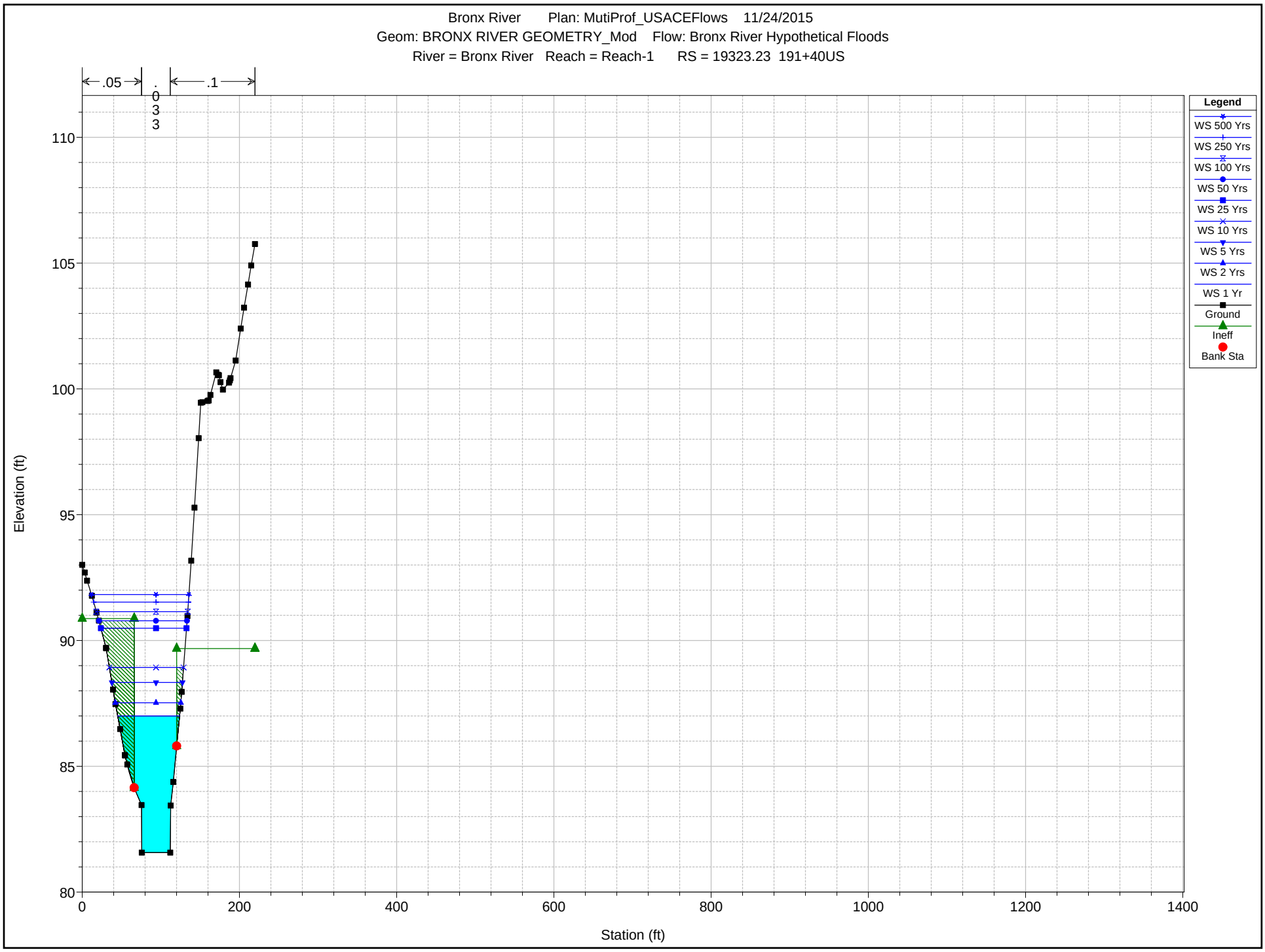


1 in Horiz. = 160 ft 1 in Vert. = 5 ft

Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 19379.59 IS 191+95DAM STONE DAM - Bronxville Lake



1 in Horiz. = 160 ft 1 in Vert. = 5 ft



1 in Horiz. = 160 ft 1 in Vert. = 5 ft

HEC-RAS Plan: Multi_USACE River: Bronx River Reach: Reach-1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Max Chl Dpth	Vel Total	Vel Chnl	Top Width	Flow Area	Area Channel
			(cfs)	(ft)	(ft)	(ft)	(ft/s)	(ft/s)	(ft)	(sq ft)	(sq ft)
Reach-1	21069.18 209+00DS	1 Yr	870.00	82.68	88.68	6.00	1.23	2.01	376.11	706.72	336.37
Reach-1	21069.18 209+00DS	2 Yrs	1040.00	82.68	89.23	6.55	1.11	1.96	442.97	935.30	371.46
Reach-1	21069.18 209+00DS	5 Yrs	1320.00	82.68	89.62	6.94	1.19	2.18	451.58	1106.27	395.56
Reach-1	21069.18 209+00DS	10 Yrs	1540.00	82.68	90.04	7.36	1.18	2.22	483.75	1301.12	422.13
Reach-1	21069.18 209+00DS	25 Yrs	1800.00	82.68	91.03	8.35	2.85	3.33	110.69	632.06	484.48
Reach-1	21069.18 209+00DS	50 Yrs	2040.00	82.68	91.41	8.73	0.96	2.00	842.08	2133.16	508.62
Reach-1	21069.18 209+00DS	100 Yrs	2260.00	82.68	91.76	9.08	0.93	1.97	941.15	2432.75	530.87
Reach-1	21069.18 209+00DS	250 Yrs	2590.00	82.68	92.22	9.54	0.91	1.95	1021.48	2861.36	559.86
Reach-1	21069.18 209+00DS	500 Yrs	2840.00	82.68	92.58	9.90	0.89	1.89	1037.50	3205.07	582.54
Reach-1	20991.35	1 Yr	870.00	81.80	88.66	6.86	1.44	1.93	278.86	602.61	402.93
Reach-1	20991.35	2 Yrs	1040.00	81.80	89.21	7.41	1.35	1.92	359.04	771.72	450.79
Reach-1	20991.35	5 Yrs	1320.00	81.80	89.59	7.79	1.44	2.18	410.99	917.67	483.16
Reach-1	20991.35	10 Yrs	1540.00	81.80	90.01	8.21	1.40	2.25	495.26	1098.52	519.42
Reach-1	20991.35	25 Yrs	1800.00	81.80	91.07	9.27	1.05	1.94	668.16	1714.04	611.15
Reach-1	20991.35	50 Yrs	2040.00	81.80	91.39	9.59	1.06	2.00	693.56	1920.66	639.05
Reach-1	20991.35	100 Yrs	2260.00	81.80	91.74	9.94	1.05	2.01	741.93	2149.86	669.45
Reach-1	20991.35	250 Yrs	2590.00	81.80	92.20	10.40	1.05	2.04	787.84	2455.02	709.00
Reach-1	20991.35	500 Yrs	2840.00	81.80	92.56	10.76	1.05	2.06	829.04	2700.36	739.87
Reach-1	20678.07	1 Yr	870.00	82.70	88.67	5.97	0.63	0.67	465.48	1371.93	1277.03
Reach-1	20678.07	2 Yrs	1040.00	82.70	89.22	6.52	0.63	0.70	490.08	1638.78	1444.29
Reach-1	20678.07	5 Yrs	1320.00	82.70	89.60	6.90	0.72	0.81	501.57	1825.67	1557.92
Reach-1	20678.07	10 Yrs	1540.00	82.70	90.02	7.32	0.76	0.86	510.49	2038.56	1684.47
Reach-1	20678.07	25 Yrs	1800.00	82.70	91.07	8.37	0.70	0.82	521.78	2583.61	2002.86
Reach-1	20678.07	50 Yrs	2040.00	82.70	91.39	8.69	0.74	0.88	525.22	2752.02	2099.85
Reach-1	20678.07	100 Yrs	2260.00	82.70	91.74	9.04	0.77	0.92	528.77	2936.69	2205.50
Reach-1	20678.07	250 Yrs	2590.00	82.70	92.20	9.50	0.81	0.98	533.11	3178.94	2343.05
Reach-1	20678.07	500 Yrs	2840.00	82.70	92.56	9.86	0.84	1.01	535.80	3369.45	2450.51
Reach-1	20238.47	1 Yr	870.00	80.20	88.60	8.40	1.64	1.65	111.68	530.18	525.36
Reach-1	20238.47	2 Yrs	1040.00	80.20	89.15	8.95	1.75	1.78	121.14	594.59	581.65
Reach-1	20238.47	5 Yrs	1320.00	80.20	89.50	9.30	2.07	2.12	127.05	638.01	618.25
Reach-1	20238.47	10 Yrs	1540.00	80.20	89.90	9.70	2.23	2.31	134.46	691.05	660.63
Reach-1	20238.47	25 Yrs	1800.00	80.20	90.97	10.77	2.14	2.28	147.59	841.53	772.00
Reach-1	20238.47	50 Yrs	2040.00	80.20	91.28	11.08	2.30	2.47	151.25	887.23	803.96
Reach-1	20238.47	100 Yrs	2260.00	80.20	91.62	11.42	2.41	2.61	155.31	939.19	839.38
Reach-1	20238.47	250 Yrs	2590.00	80.20	92.05	11.85	2.57	2.82	160.56	1008.32	885.12
Reach-1	20238.47	500 Yrs	2840.00	80.20	92.40	12.20	2.67	2.96	164.68	1064.29	921.08
Reach-1	19755.24	1 Yr	870.00	82.00	88.59	6.59	0.77	0.78	291.98	1123.50	1113.89
Reach-1	19755.24	2 Yrs	1040.00	82.00	89.14	7.14	0.80	0.83	317.87	1294.08	1253.78

HEC-RAS Plan: Multi_USACE River: Bronx River Reach: Reach-1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Max Chl Dpth	Vel Total	Vel Chnl	Top Width	Flow Area	Area Channel
			(cfs)	(ft)	(ft)	(ft)	(ft/s)	(ft/s)	(ft)	(sq ft)	(sq ft)
Reach-1	19755.24	5 Yrs	1320.00	82.00	89.49	7.49	0.94	0.97	321.82	1406.59	1342.76
Reach-1	19755.24	10 Yrs	1540.00	82.00	89.90	7.90	1.00	1.05	326.41	1539.33	1446.36
Reach-1	19755.24	25 Yrs	1800.00	82.00	90.98	8.98	0.95	1.02	338.47	1896.77	1718.34
Reach-1	19755.24	50 Yrs	2040.00	82.00	91.29	9.29	1.02	1.10	341.94	2002.12	1796.67
Reach-1	19755.24	100 Yrs	2260.00	82.00	91.63	9.63	1.07	1.16	345.79	2120.02	1883.41
Reach-1	19755.24	250 Yrs	2590.00	82.00	92.07	10.07	1.14	1.25	350.87	2274.53	1995.62
Reach-1	19755.24	500 Yrs	2840.00	82.00	92.42	10.42	1.18	1.31	355.01	2397.61	2083.84
Reach-1	19575.75	1 Yr	870.00	81.00	88.58	7.58	0.78	0.79	283.35	1112.88	1094.16
Reach-1	19575.75	2 Yrs	1040.00	81.00	89.13	8.13	0.81	0.84	311.61	1277.04	1230.47
Reach-1	19575.75	5 Yrs	1320.00	81.00	89.48	8.48	0.95	0.99	328.69	1389.07	1316.66
Reach-1	19575.75	10 Yrs	1540.00	81.00	89.89	8.89	1.01	1.07	347.63	1527.37	1417.49
Reach-1	19575.75	25 Yrs	1800.00	81.00	90.97	9.97	0.93	1.03	395.71	1928.97	1683.26
Reach-1	19575.75	50 Yrs	2040.00	81.00	91.28	10.28	0.99	1.11	400.64	2052.06	1759.47
Reach-1	19575.75	100 Yrs	2260.00	81.00	91.62	10.62	1.03	1.16	406.05	2190.32	1843.98
Reach-1	19575.75	250 Yrs	2590.00	81.00	92.07	11.07	1.09	1.25	412.70	2371.81	1953.27
Reach-1	19575.75	500 Yrs	2840.00	81.00	92.41	11.41	1.13	1.30	417.64	2516.61	2039.24
Reach-1	19409.72	1 Yr	870.00	84.10	88.36	4.26	3.47	3.52	103.81	251.00	246.36
Reach-1	19409.72	2 Yrs	1040.00	84.10	88.91	4.81	3.42	3.53	113.07	304.45	293.09
Reach-1	19409.72	5 Yrs	1320.00	84.10	89.18	5.08	3.99	4.15	117.45	331.09	315.63
Reach-1	19409.72	10 Yrs	1540.00	84.10	89.56	5.46	4.17	4.39	123.36	369.34	347.31
Reach-1	19409.72	25 Yrs	1800.00	84.10	90.70	6.60	3.67	3.99	143.81	490.93	443.44
Reach-1	19409.72	50 Yrs	2040.00	84.10	90.97	6.87	3.92	4.29	145.32	520.61	466.01
Reach-1	19409.72	100 Yrs	2260.00	84.10	91.29	7.19	4.06	4.49	146.91	556.05	492.59
Reach-1	19409.72	250 Yrs	2590.00	84.10	91.68	7.58	4.31	4.80	148.91	601.32	526.01
Reach-1	19409.72	500 Yrs	2840.00	84.10	92.00	7.90	4.45	4.99	150.51	638.24	552.84
Reach-1	19379.59 191+95DAM		Inl Struct								
Reach-1	19323.23 191+40US	1 Yr	870.00	81.57	87.00	5.43	3.50	3.50	78.81	248.87	248.87
Reach-1	19323.23 191+40US	2 Yrs	1040.00	81.57	87.53	5.96	3.75	3.75	83.48	277.37	277.37
Reach-1	19323.23 191+40US	5 Yrs	1320.00	81.57	88.33	6.76	4.11	4.11	89.74	320.98	320.98
Reach-1	19323.23 191+40US	10 Yrs	1540.00	81.57	88.93	7.36	4.36	4.36	94.42	353.30	353.30
Reach-1	19323.23 191+40US	25 Yrs	1800.00	81.57	90.53	8.96	4.09	4.09	54.11	439.88	439.88
Reach-1	19323.23 191+40US	50 Yrs	2040.00	81.57	90.78	9.21	4.18	4.42	112.07	488.27	453.55
Reach-1	19323.23 191+40US	100 Yrs	2260.00	81.57	91.14	9.57	3.31	3.90	116.35	683.37	473.13
Reach-1	19323.23 191+40US	250 Yrs	2590.00	81.57	91.53	9.96	3.55	4.23	120.56	728.58	493.78
Reach-1	19323.23 191+40US	500 Yrs	2840.00	81.57	91.82	10.25	3.71	4.45	123.90	764.95	509.88

Attachment C-7
HRE
Garth Harney Hydrologic and Hydraulic Analysis

Bronx River Ecosystem Restoration Feasibility Study
Draft Interim Letter Report
Hydrologic & Hydraulic (H&H) Analysis for Harney Pond/Garth Woods
25 November 2015

Following the field investigations and initial development of conceptual alternatives in Task 2: Ecological Functional Assessment - Evaluation of Planned Wetlands (EPW) a Hydrologic & Hydraulic (H&H) analysis was conducted to improve design and cost estimate accuracy. This summary provides the results of the H&H analysis for Harney Pond.

A. Site Overview

The Harney Pond site is located along the Bronx River in the City of Yonkers and Town of Eastchester, Westchester County, NY. The site is bounded by the Bronx River Parkway to the east and west, Garth Woods to the north, and Harney Road at the south side of the lake. At the Harney Pond site, the river flows through a broad valley (~400 to 600-feet wide), the sides of which are approximately 20 feet in elevation. The channel in this site is over-widened and shallow, with a ponded area upstream of the weir located immediately south of Harney Road bridge. A paved path and park on the east side of the river are part of the Bronx River Parkway Reservation maintained by the Westchester County Department of Parks, Recreation, and Conservation. The concrete weir is 50 feet wide and approximately 5.0 feet high at the highest elevation and the Harney Pond as approximate surface area of 2.0 acres. Figure 1 shows the masonry weir controlling the pond.



Figure 1: Existing Masonry Weir Harney Pond

B. Analysis

1. Field Survey & Historic data Collection

As part of data collection for Group A – Bronxville Lake, Crestwood Lake, & Garth Woods/Harney Road (Optional Tasks 3c, 3d, & 3e) the A/E performed a field survey for Harney Pond on October 22, 2015. Data collection included five (5) east/west cross-sections (bathymetric & topographic) across the Harney Pond, and a weir survey consisting of an upstream cross-section, a downstream cross-section and the top of the weir section. The Interim Report – Determination of Recommendation of Minimum H&H Field Data Collection, Analysis Methods and Assumptions (April 2015) did not support additional H&H analysis for the Garth Woods portion of the Garth Woods/Harney Road site. Therefore, no field measurements or analysis were made north of Harney Pond. The coordinate system used for data acquisition is the New York State Plane (NAD1983) NY EAST horizontal datum and NAVD 88 vertical datum.

The field data collected during this effort includes:

- Lake/channel bathymetry
- Riparian/floodplain topography (over bank grades along the cross-sections)
- Sediment thickness in lakes
- Location/presence of thalweg
- Weir dimensions and materials
- Topography/bathymetry immediately upstream and downstream of existing weir
- Field photographs
- Changes in slope, top of bank, toe of bank, thalweg, water's edge, & limits of existing path
- Determine sediment depth across the section within lake/channel boundaries using appropriate sediment probe (n/a for Garth Woods)

A number of data sources were reviewed to provide an understanding of the existing and pre-existing site characteristics. These included:

- Federal Emergency Management Agency's (FEMA) 2007 Flood Insurance Study (FIS) HEC-RAS hydraulic models.
- FEMA Hydraulic model back up GIS data including Topographic Triangulated Irregular Network (TIN) Surface, Survey and Cross-section geometry.
- NYD – Provided 1meter Digital Elevation Model (DEM) for project area
- USGS 1:24,000 Quadrangles
- NYSOGS 2013 Orthoimagery
- FEMA Flood Insurance Study (Westchester County)

2. Hydrologic Model & Flow Rates

Existing hydrologic analyses available from FEMA FIS and USACE-NYD Bronx River SIAM model were used for the Bronx River H&H analysis. The Bronx River has a contributing area of approximately 29 square miles at Harney Pond that includes developed and undeveloped area in central Westchester County.

a. FEMA Hydrology

The effective FEMA 2007 hydrologic analysis was based on an updated Log-Pearson type – III analysis on Bronxville gage located just downstream of the Bronxville Lake site. Peak flows for the 10 year, 50 year, 100 year and 500 year flood events established by FEMA and used in the effective FEMA HEC-RAS model were directly incorporated into the current project model without any changes.

DRAFT

b. USACE-NYD Hydrology

USACE-NYD had developed a detailed HEC-1 model for the Bronx River watershed as a part of their Bronx River Ecosystem Restoration Study, July 2010. The HEC-1 model was calibrated for the rainfall events and used to predict hypothetical peak discharges for 1 year, 2 year, 5 year, 10 year, 25 year, 50 year, 100 year, 250 year and 500 year. USACE-NYD provided the A/E with the HEC-1 model and the SIAM HEC-RAS model for possible use and guidance. From these models, this analysis utilized the hypothetical peak flood volumes and the nodes where the rate of flow changes to determine the flood volumes at the cross section locations.

3. Hydraulic Model Setup

The existing FEMA model was used as basis for this analysis. The FEMA model was developed on the latest GIS-based hydraulic analysis platform, using the USACE's HECGeoRAS and HEC-RAS model interfaces. In order to set up the base analysis for this project, the effective FEMA model was imported in the USACE HEC-RAS version 4.1 and ran using the steady state hydraulic analysis. The backup FEMA GIS data along with FEMA's Topographic data (TIN) were used to develop project specific data at Crestwood Lake The general steps followed in the development of the project specific analyses at Harney Pond are summarized below.

- The field survey was imported in ARCGIS map and the survey shapefiles for the project area were extracted.
- Initial project setup was performed using effective FEMA data, field survey and other recent basemap data acquired in task 1. The project specific cross-section location plan along with field survey data is provided in Attachment A
- After initial set up of the hydraulic analyses the channel cross-section were removed manually from the HEC-RAS model and Bronx River GIS dataset.
- New cross-sections based on the field survey were in GIS for the data processing.
- The cross-section geometry for the HEC-RAS hydraulic model was developed from two data sources, surveyed cross-sections and FEMA Bronx River TIN elevation data.
- No changes were made to the existing cross-sections and structure on the Bronx River outside the project area within the Bronx River Model and database.
- The weir profile was then modified in HEC-RAS to match the recently surveyed data and field observations.
- Upon completion of the geometric data input of the model the Channel Manning's n values and in-effective flow areas were updated on each affected cross-sections following the guidance provided in the HEC-RAS user's manual.
- Two different models scenario with FEMA and USACE-NYD hydrology were simulated to evaluate different flow conditions through the lake and establishment of the base flood elevations for the selected frequencies.
- The result of the hydraulic analyses using USACE-NYD Hydrology is provided in Attachment B.

C. Results

As part of Harney Pond study, the following items were reviewed and evaluated using the field survey data and the H&H model results. The HEC-RAS summary output table, cross-sections and flood profiles for 1 year through 500 year simulation run is provided in Attachment B.

DRAFT

- **Stream Thalweg:** The stream thalweg represent the existing channel invert along the stream through the site. A GIS feature line representing the location of existing stream invert was developed using the field survey and ArcGIS application. At Harney Pond the existing thalweg line is in the center of the stream/pond for the north portion and moves closer to the left overbank in central portion of Harney Pond. However in the southern portion of the pond it shifts to the center as passes beneath Harney Road. The maximum depth on the pond observed from the survey data is approximately 10.5 feet closer to the weir (XS#35451.72), whereas a minimum depth of approximately 2.5 feet was observed at the middle portions of the pond (XS#35892.15).
- **Channel Banks:** The average bottom of the bank elevations along the Harney Pond is approximately 112.0 feet, whereas average top of the bank elevations are in the range of 113.9. to 117.5 feet. A GIS feature line representing the edge of banks are plotted on the Cross-Section Location Map in Attachment A.
- **Sediment Depths:** The maximum sediment depth (refusal depth) observed is in the range of 1 to 3 feet.
- **Bank full Flows:** Based on the hydraulic model simulations, the average bank full flood event is 1 year flood with an average maximum depth along the cross-section of 5 feet, with the maximum depth at cross section 35432.17 of 8.6 feet.
- **Extreme Floods:** Harney Pond and the adjacent park land would be submerged during the flood event greater than the 5 year recurrence interval level. During extreme flood events such as the 500-year interval, the predicted flood depth varies spatially from approximately 8 to 11.5 feet, with the maximum depth of 13.5 feet at cross-section 35432.17.
- **Channel Velocities:** The channel velocities along the Harney Pond are mostly between 2 feet / sec and 3 feet /sec at all of the cross-sections with exception of 4.5 feet. /sec at the weir.

D. Recommendation for Design

Based on the review of the existing condition H&H results, and field collected data we offer the following recommendations for design of alternatives.

- **Channel Realignment/Bed Restoration:** Maintain the existing thalweg on north portion of the lake and move the proposed thalweg to the center of the existing channel and update the stream alignment to follow more geomorphic channel shape through the pond.
- **Emergent/Forested Wetland Creation:** Consider keeping proposed wetland elevations below the 1 year flood level to ensure frequent inundation.
- **Wetland/Upland plantings:** Consider wetland/upland plant and tree species capable of withstanding the stream velocities of 3.0 feet /sec or higher.

The design alternatives are to incorporate these recommendations and the recommendations of the USACE PDT.

E. References

1. Federal Emergency Management Agency (FEMA), Flood Insurance Study Westchester County, NY September 28, 2007.
2. Hydrologic Engineering Center (HEC), HECRAS User's Manual, version 4.1 January, 2010.
3. Hydrologic Engineering Center (HEC), HECGeoRAS User's Manual, version 10 May, 2012.
4. Bronx River – SIAM hydraulic Models, developed by USACE, New York District, July 2014.
5. Draft EPW Report – Bronx River Ecosystem Restoration study, e4sciences/AECOM January 2015

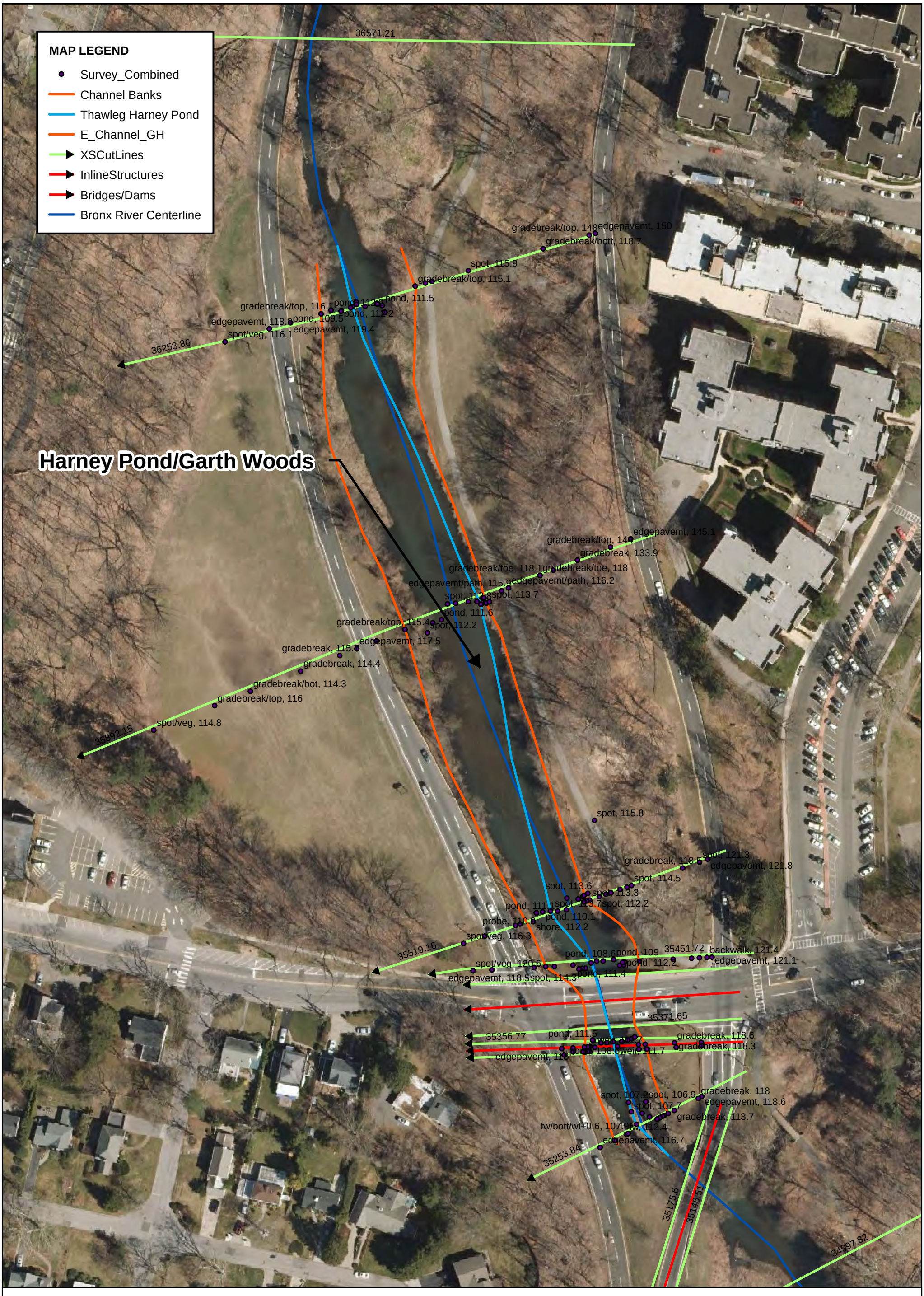
DRAFT

F. Attachments

A. Cross-Section Location Map – Harney Pond
B. HEC-RAS Output – Summary Table, Cross-Section Plot and Profile through Harney Pond.

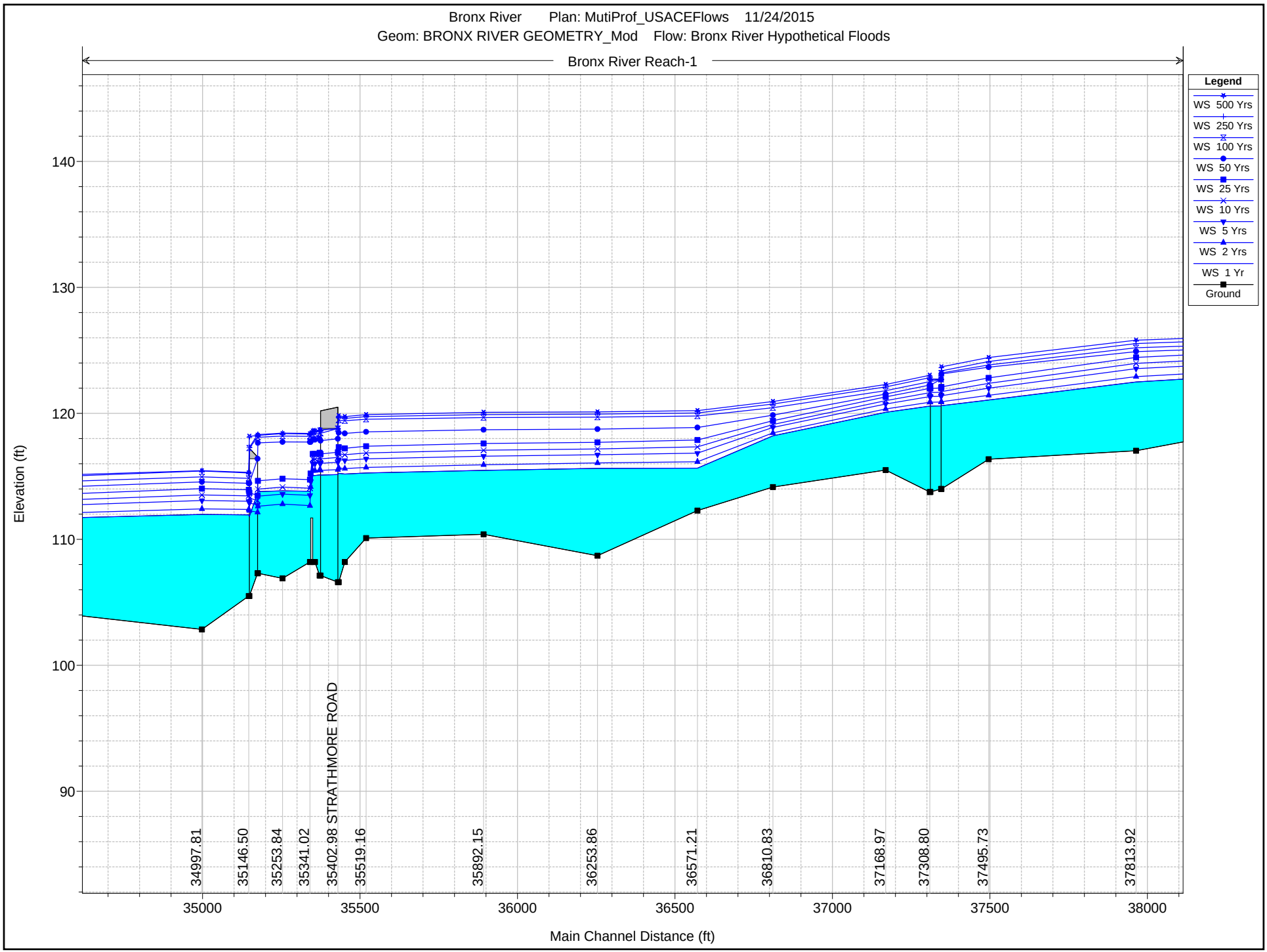
DRAFT

ATTACHMENT : A

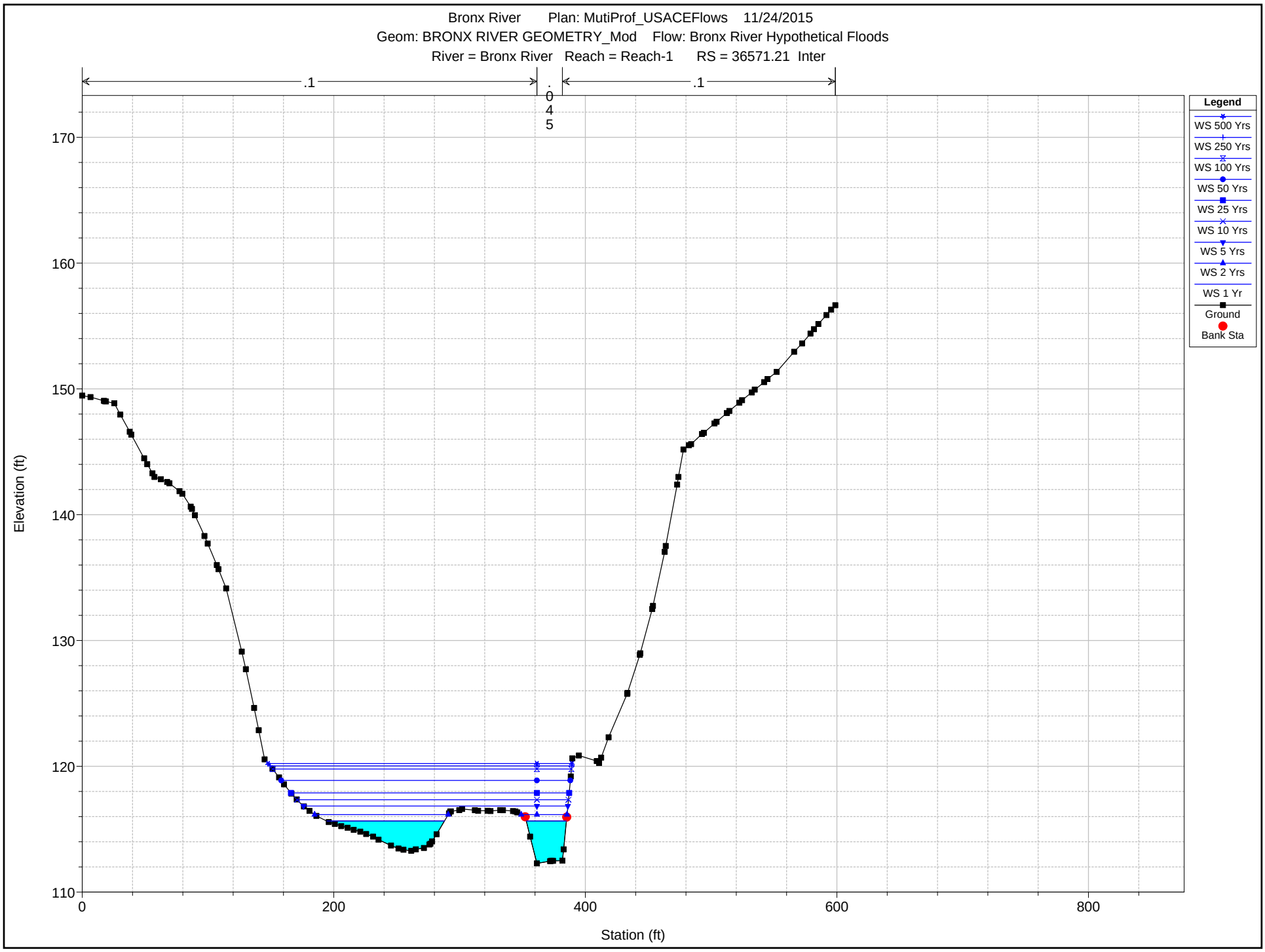


CROSS-SECTION LOCATION MAP - HARNEY POND/GARTH WOODS

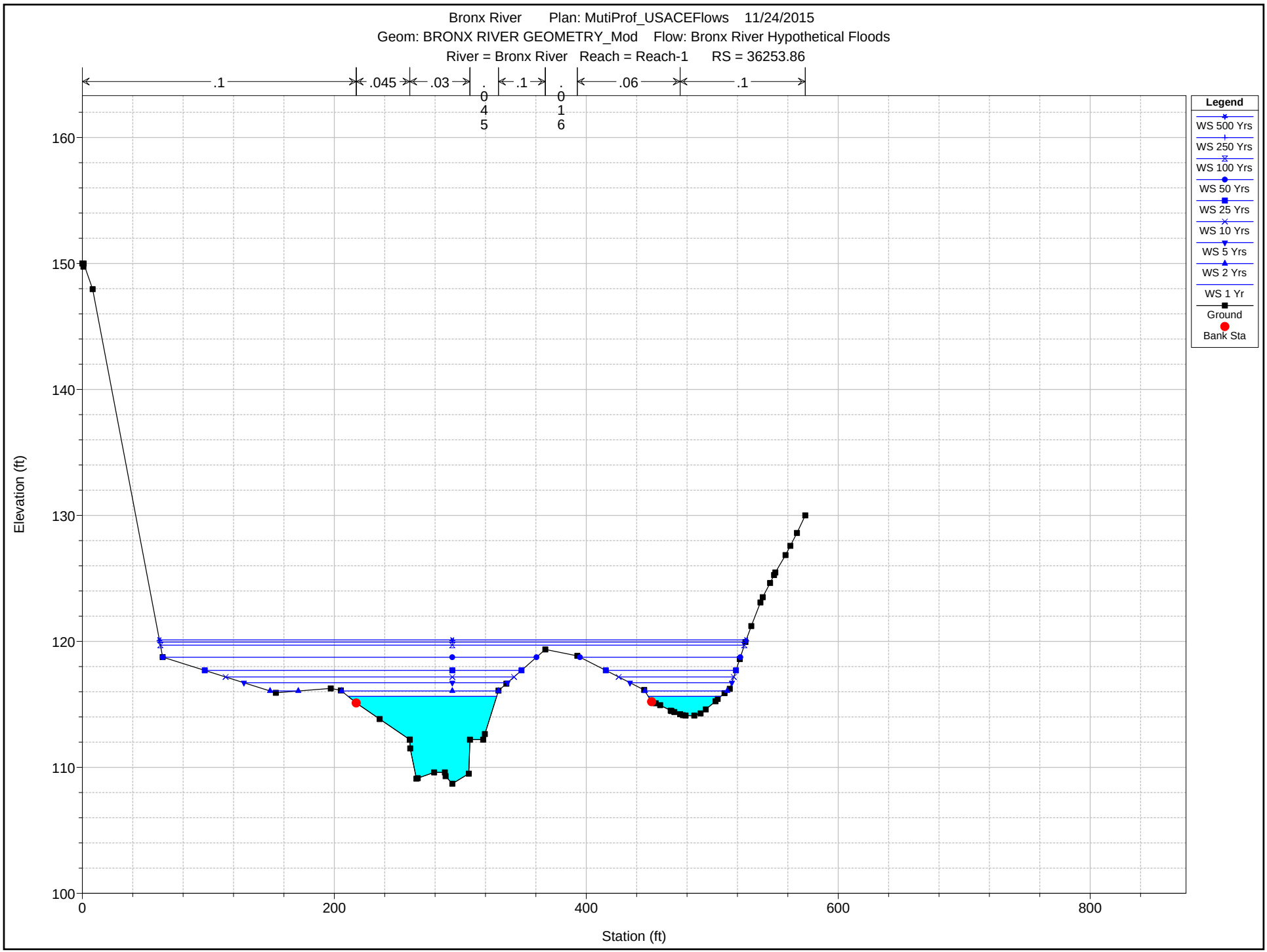
ATTACHMENT : B



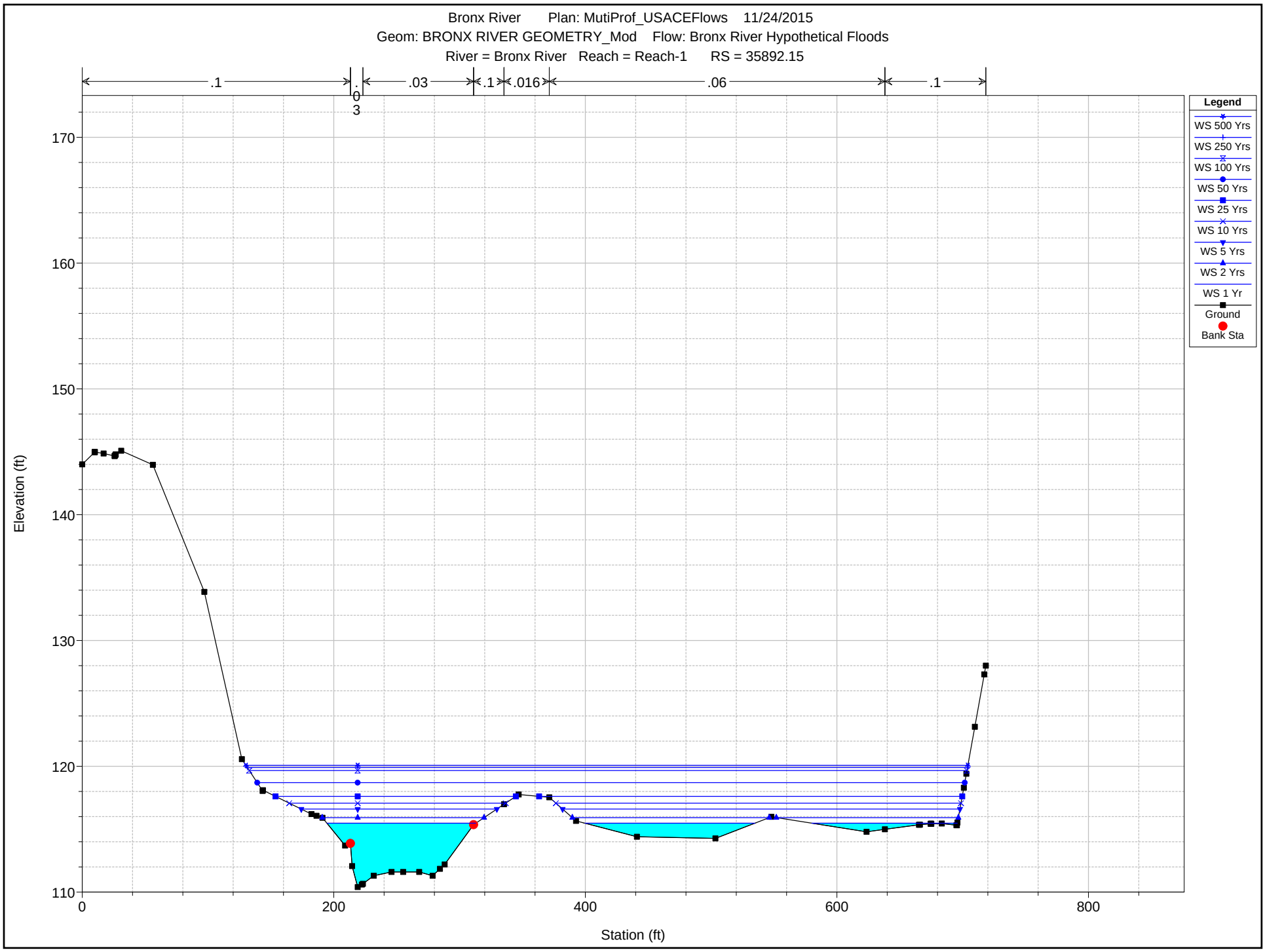
1 in Horiz. = 400 ft 1 in Vert. = 10 ft



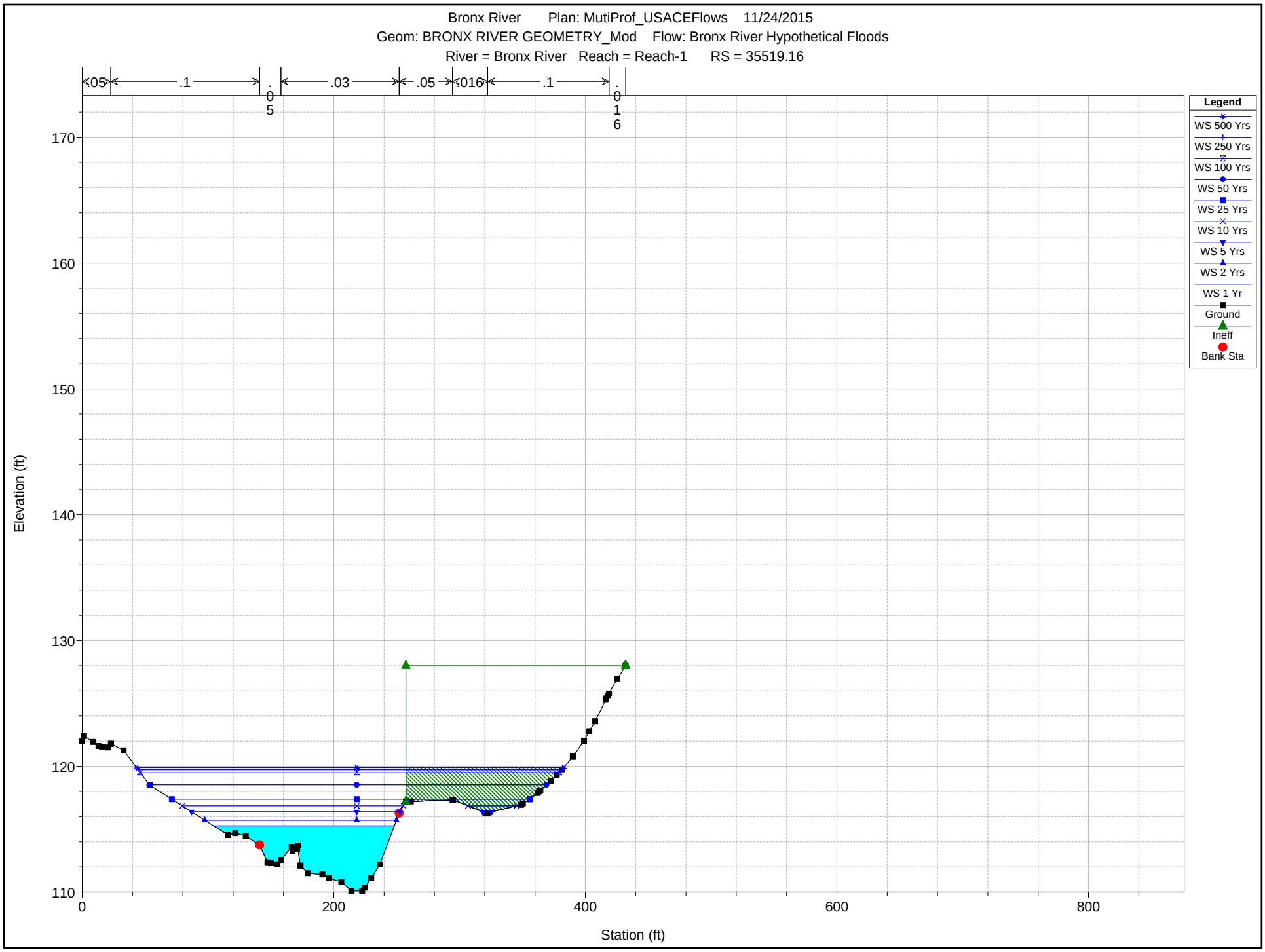
1 in Horiz. = 100 ft 1 in Vert. = 10 ft



1 in Horiz. = 100 ft 1 in Vert. = 10 ft

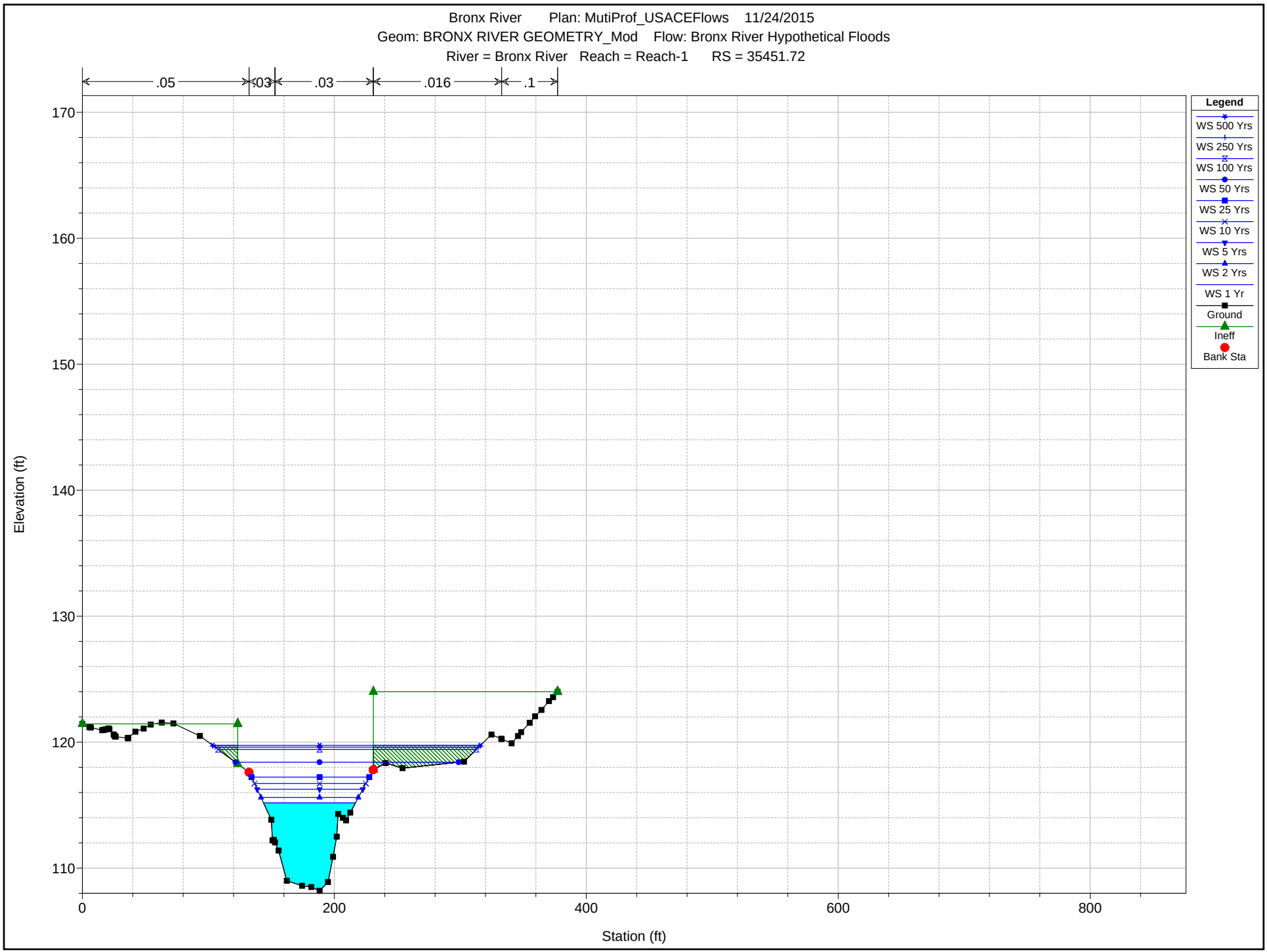


1 in Horiz. = 100 ft 1 in Vert. = 10 ft



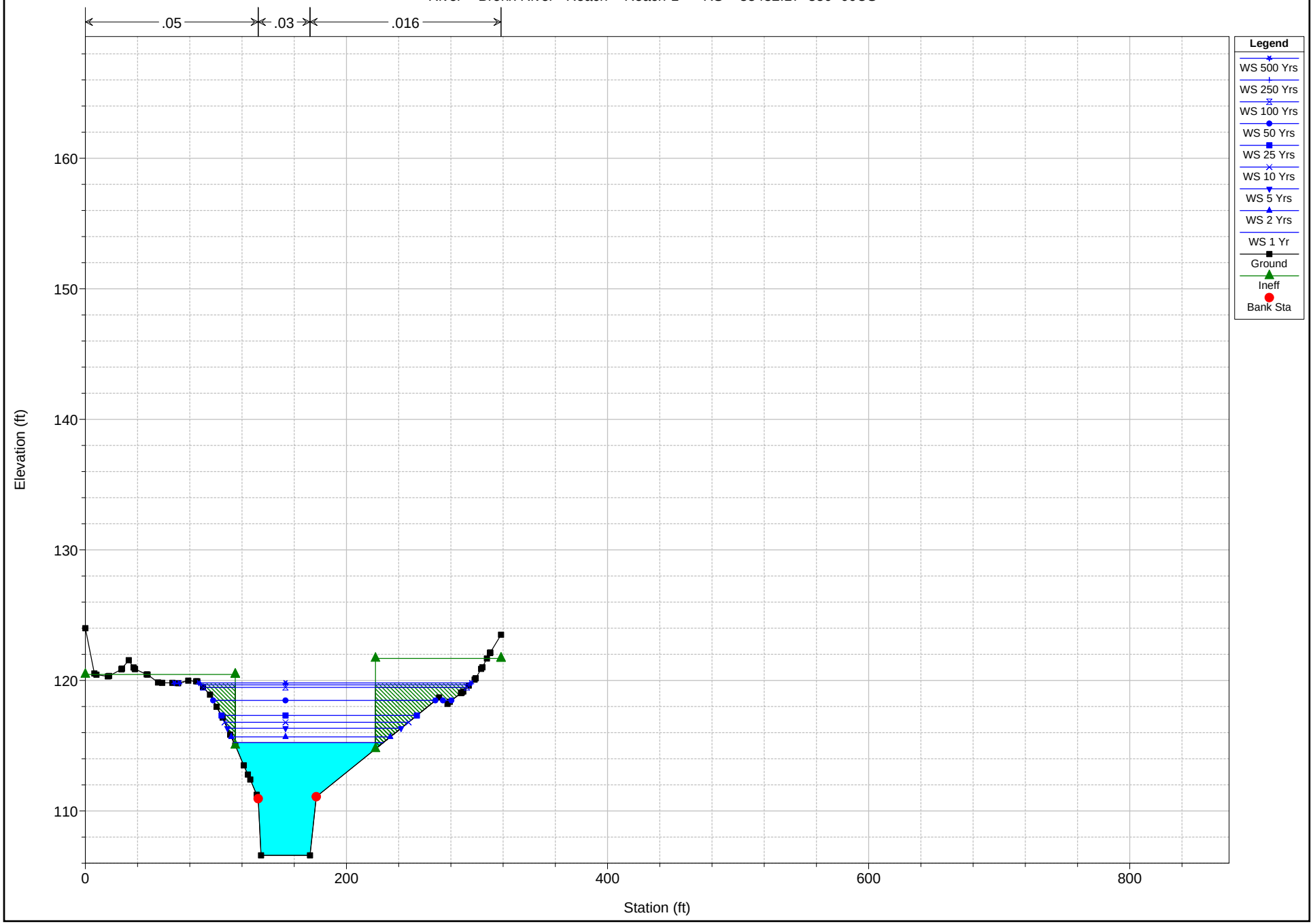
1 in Horiz. = 100 ft 1 in Vert. = 10 ft

Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 35451.72



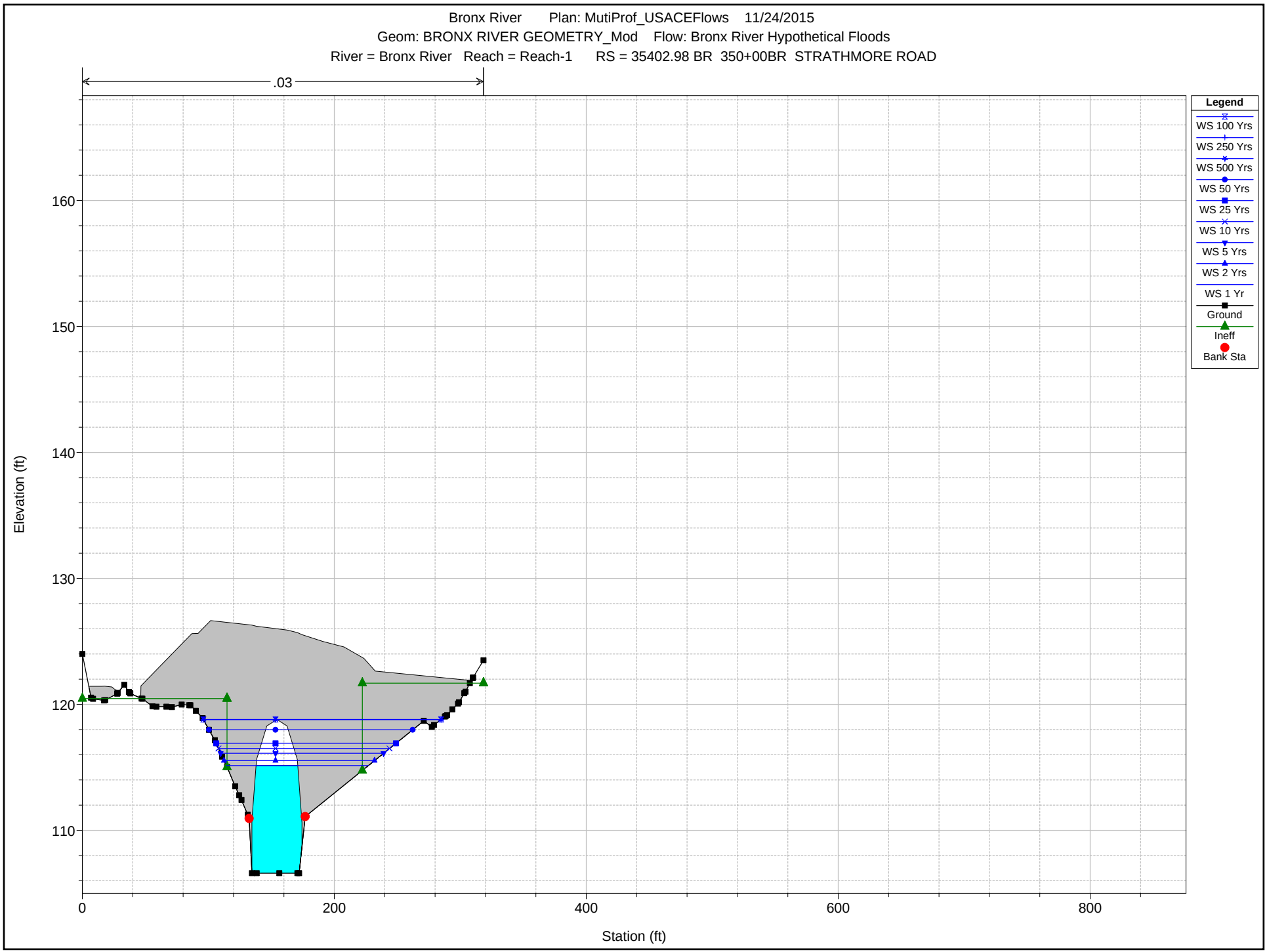
1 in Horiz. = 100 ft 1 in Vert. = 10 ft

Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 35432.17 350+00US



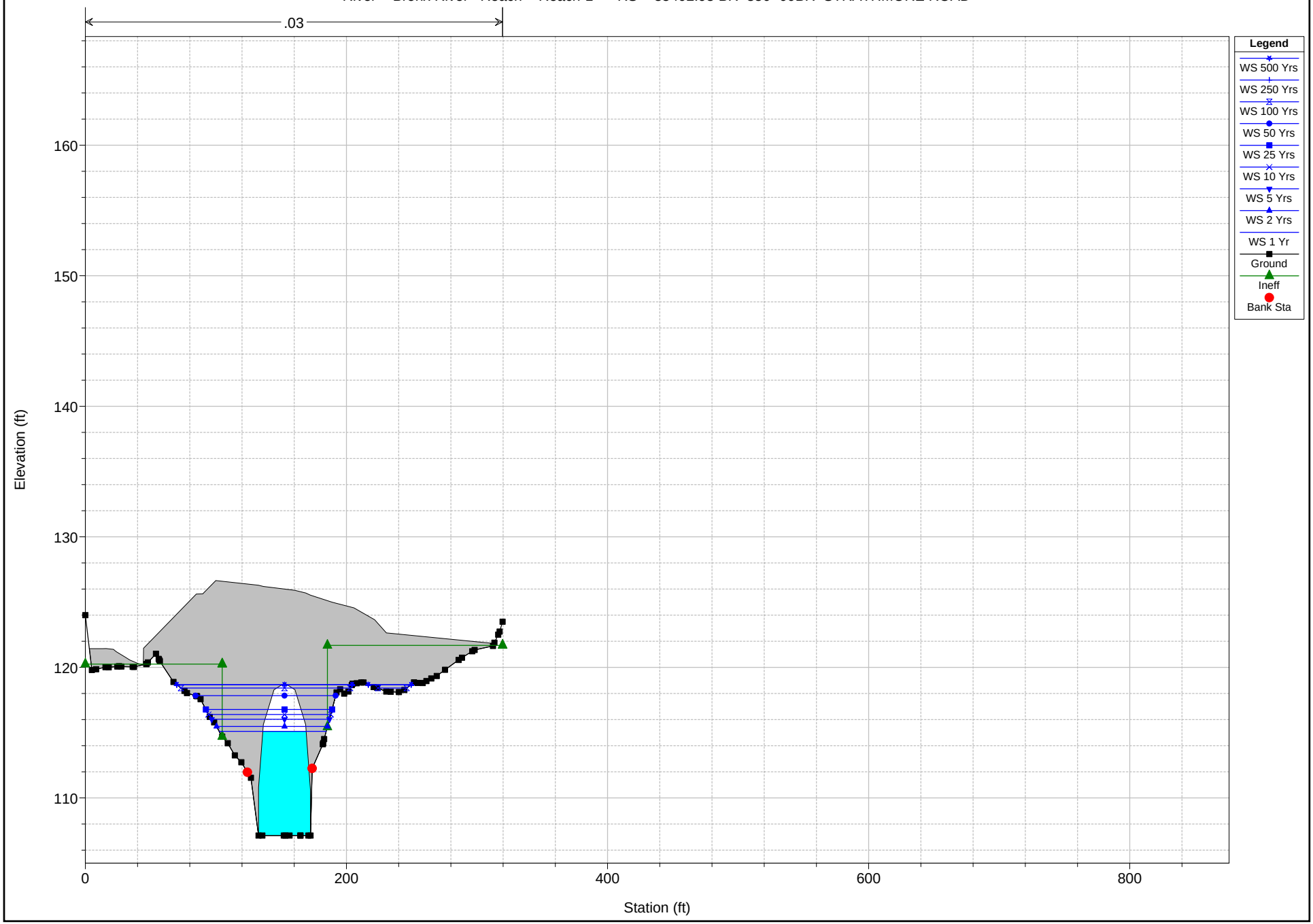
1 in Horiz. = 100 ft 1 in Vert. = 10 ft

Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 35402.98 BR 350+00BR STRATHMORE ROAD



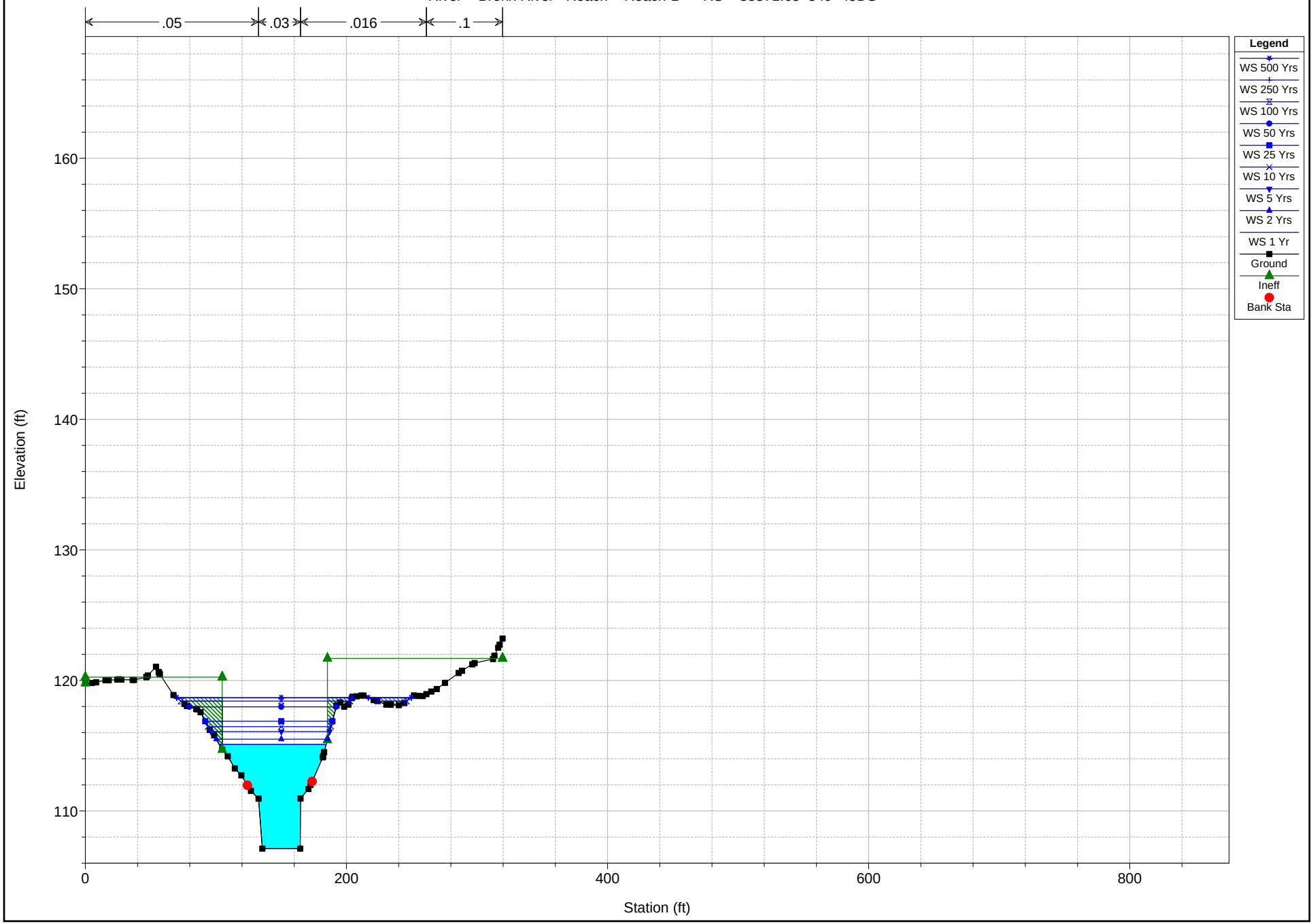
1 in Horiz. = 100 ft 1 in Vert. = 10 ft

Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 35402.98 BR 350+00BR STRATHMORE ROAD



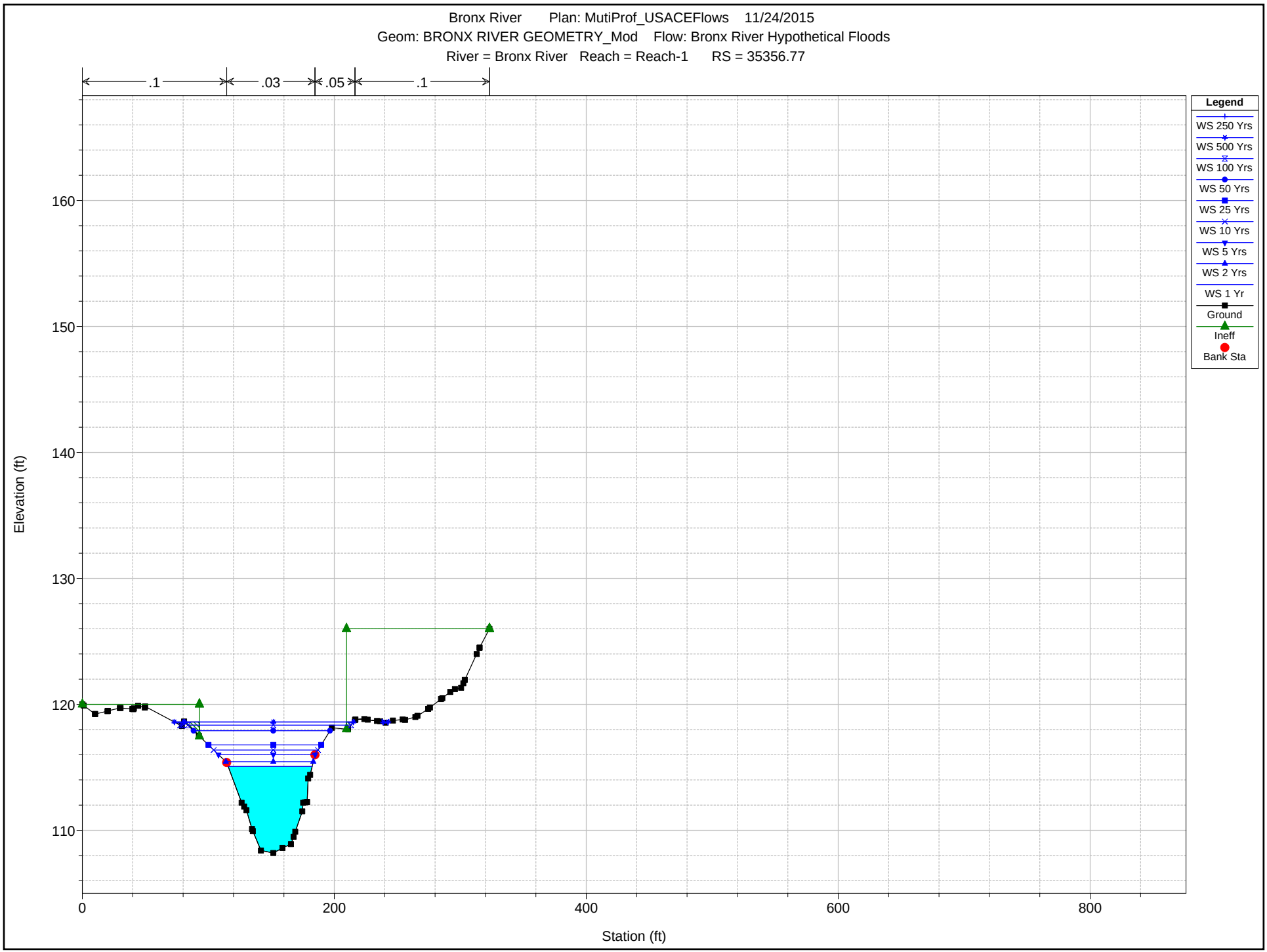
1 in Horiz. = 100 ft 1 in Vert. = 10 ft

Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 35371.65 349+45DS

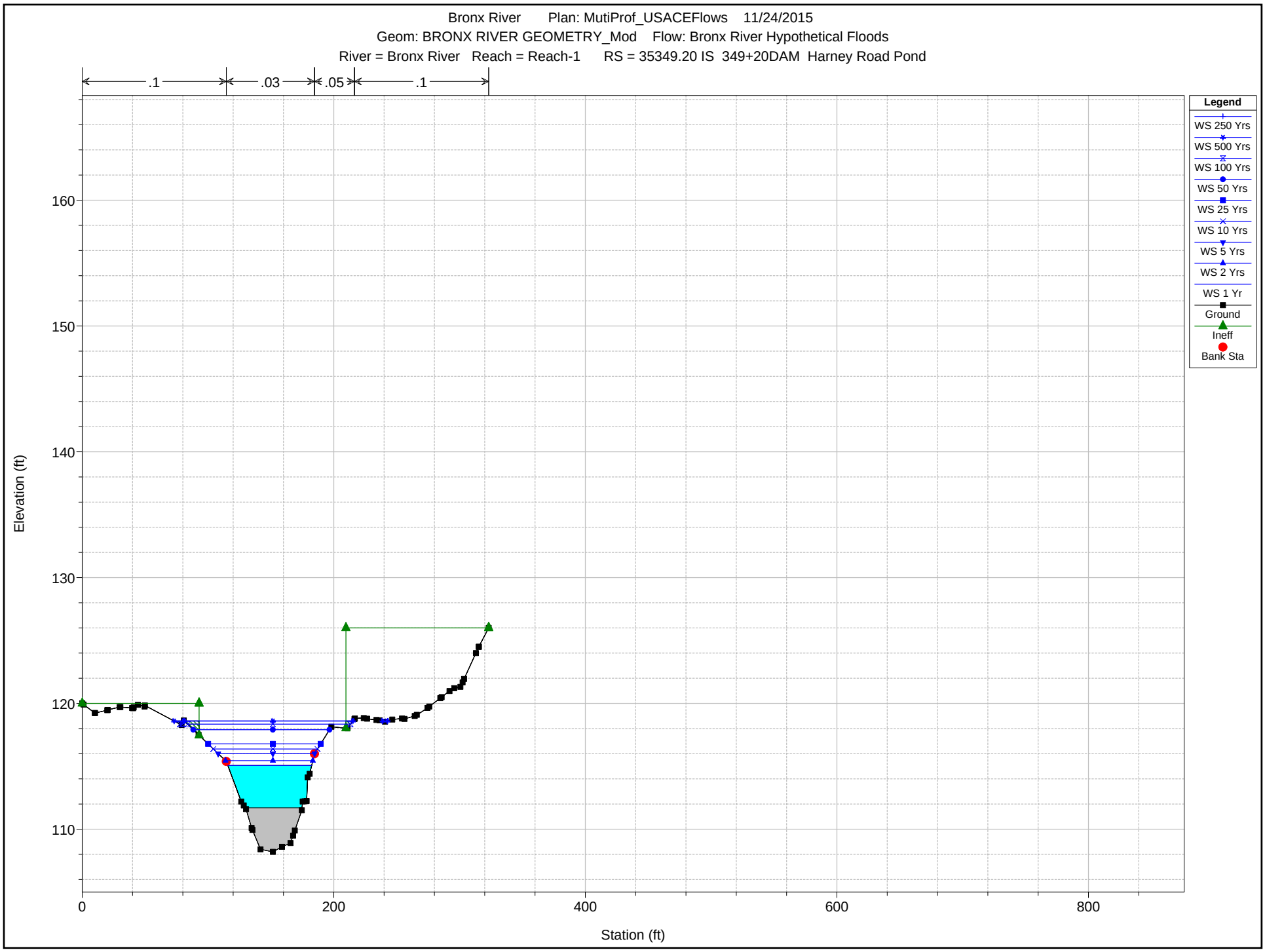


1 in Horiz. = 100 ft 1 in Vert. = 10 ft

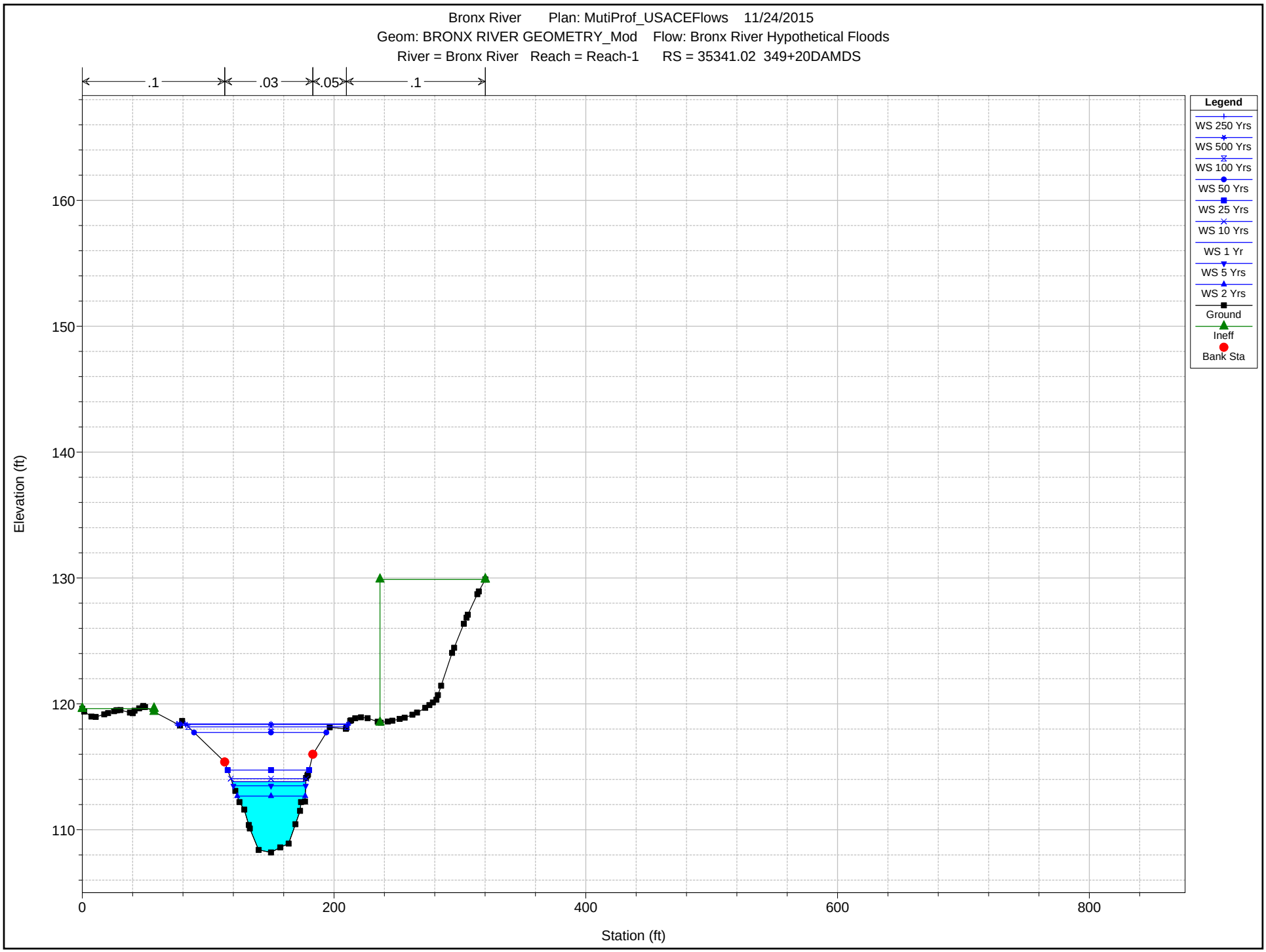
Bronx River Plan: MutiProf_USACEFlows 11/24/2015
Geom: BRONX RIVER GEOMETRY_Mod Flow: Bronx River Hypothetical Floods
River = Bronx River Reach = Reach-1 RS = 35356.77



1 in Horiz. = 100 ft 1 in Vert. = 10 ft



1 in Horiz. = 100 ft 1 in Vert. = 10 ft



1 in Horiz. = 100 ft 1 in Vert. = 10 ft

HEC-RAS Plan: Multi_USACE River: Bronx River Reach: Reach-1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Max Chl Dpth	Vel Total	Vel Chnl	Top Width	Flow Area	Area Channel
			(cfs)	(ft)	(ft)	(ft)	(ft/s)	(ft/s)	(ft)	(sq ft)	(sq ft)
Reach-1	36571.21 Inter	1 Yr	940.00	112.28	115.65	3.37	4.51	6.67	125.38	208.39	84.69
Reach-1	36571.21 Inter	2 Yrs	1130.00	112.28	116.16	3.88	4.08	6.05	142.69	276.73	101.41
Reach-1	36571.21 Inter	5 Yrs	1450.00	112.28	116.84	4.56	3.64	6.13	210.16	398.45	123.87
Reach-1	36571.21 Inter	10 Yrs	1690.00	112.28	117.34	5.06	3.34	5.56	215.81	505.69	140.49
Reach-1	36571.21 Inter	25 Yrs	1980.00	112.28	117.63	5.35	6.83	9.69	115.75	289.70	150.09
Reach-1	36571.21 Inter	50 Yrs	2230.00	112.28	118.87	6.59	2.63	4.23	229.86	847.16	191.01
Reach-1	36571.21 Inter	100 Yrs	2480.00	112.28	119.79	7.51	2.34	3.70	237.54	1060.74	221.18
Reach-1	36571.21 Inter	250 Yrs	2810.00	112.28	120.04	7.76	2.51	3.97	239.84	1120.12	229.39
Reach-1	36571.21 Inter	500 Yrs	3030.00	112.28	120.22	7.94	2.60	4.11	241.54	1164.12	235.43
Reach-1	36253.86	1 Yr	940.00	108.70	115.64	6.94	1.90	2.12	175.54	493.77	435.62
Reach-1	36253.86	2 Yrs	1130.00	108.70	116.06	7.36	1.97	2.26	212.34	573.52	485.34
Reach-1	36253.86	5 Yrs	1450.00	108.70	116.72	8.02	1.95	2.42	290.06	745.24	568.50
Reach-1	36253.86	10 Yrs	1690.00	108.70	117.17	8.47	1.91	2.48	320.27	884.93	634.58
Reach-1	36253.86	25 Yrs	1980.00	108.70	117.59	8.89	1.94	2.59	347.47	1022.51	699.60
Reach-1	36253.86	50 Yrs	2230.00	108.70	118.75	10.05	1.52	2.15	423.97	1469.59	910.67
Reach-1	36253.86	100 Yrs	2480.00	108.70	119.70	11.00	1.31	1.87	463.58	1898.11	1123.00
Reach-1	36253.86	250 Yrs	2810.00	108.70	119.94	11.24	1.40	2.00	464.83	2008.99	1179.01
Reach-1	36253.86	500 Yrs	3030.00	108.70	120.12	11.42	1.45	2.07	465.82	2091.98	1220.83
Reach-1	35892.15	1 Yr	940.00	110.40	115.47	5.07	1.85	2.55	368.90	506.97	340.89
Reach-1	35892.15	2 Yrs	1130.00	110.40	115.92	5.52	1.65	2.57	429.95	684.81	384.31
Reach-1	35892.15	5 Yrs	1450.00	110.40	116.60	6.20	1.46	2.55	471.34	994.22	451.01
Reach-1	35892.15	10 Yrs	1690.00	110.40	117.07	6.67	1.38	2.53	494.20	1221.82	497.15
Reach-1	35892.15	25 Yrs	1980.00	110.40	117.49	7.09	1.38	2.61	514.33	1431.25	537.79
Reach-1	35892.15	50 Yrs	2230.00	110.40	118.70	8.30	1.06	2.08	562.50	2098.26	656.18
Reach-1	35892.15	100 Yrs	2480.00	110.40	119.67	9.27	0.94	1.83	570.55	2648.29	751.19
Reach-1	35892.15	250 Yrs	2810.00	110.40	119.90	9.50	1.01	1.97	572.51	2782.59	774.19
Reach-1	35892.15	500 Yrs	3030.00	110.40	120.08	9.68	1.05	2.05	573.97	2883.77	791.46
Reach-1	35519.16	1 Yr	940.00	110.10	115.27	5.17	2.40	2.55	143.65	392.01	365.51
Reach-1	35519.16	2 Yrs	1130.00	110.10	115.71	5.61	2.47	2.69	152.31	457.81	413.54
Reach-1	35519.16	5 Yrs	1450.00	110.10	116.39	6.29	2.56	2.90	173.10	565.51	488.17
Reach-1	35519.16	10 Yrs	1690.00	110.10	116.86	6.76	2.62	3.04	214.49	645.45	540.14
Reach-1	35519.16	25 Yrs	1980.00	110.10	117.25	7.15	2.76	3.27	256.40	716.34	583.86
Reach-1	35519.16	50 Yrs	2230.00	110.10	118.53	8.43	2.31	2.90	315.74	965.03	726.14
Reach-1	35519.16	100 Yrs	2480.00	110.10	119.53	9.43	2.12	2.75	333.37	1172.20	836.89
Reach-1	35519.16	250 Yrs	2810.00	110.10	119.74	9.64	2.31	3.02	337.09	1216.45	860.05
Reach-1	35519.16	500 Yrs	3030.00	110.10	119.90	9.80	2.42	3.18	339.62	1250.63	877.82
Reach-1	35451.72	1 Yr	940.00	108.20	115.19	6.99	2.98	2.98	73.06	315.43	315.43
Reach-1	35451.72	2 Yrs	1130.00	108.20	115.61	7.41	3.25	3.25	77.32	347.46	347.46

HEC-RAS Plan: Multi_USACE River: Bronx River Reach: Reach-1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Max Chl Dpth	Vel Total	Vel Chnl	Top Width	Flow Area	Area Channel
			(cfs)	(ft)	(ft)	(ft)	(ft/s)	(ft/s)	(ft)	(sq ft)	(sq ft)
Reach-1	35451.72	5 Yrs	1450.00	108.20	116.26	8.06	3.63	3.63	83.83	399.84	399.84
Reach-1	35451.72	10 Yrs	1690.00	108.20	116.71	8.51	3.85	3.85	88.34	438.63	438.63
Reach-1	35451.72	25 Yrs	1980.00	108.20	117.08	8.88	4.20	4.20	92.01	471.71	471.71
Reach-1	35451.72	50 Yrs	2230.00	108.20	118.40	10.20	3.69	3.71	177.05	604.33	600.10
Reach-1	35451.72	100 Yrs	2480.00	108.20	119.42	11.22	3.48	3.53	204.86	713.37	699.89
Reach-1	35451.72	250 Yrs	2810.00	108.20	119.60	11.40	3.83	3.89	209.20	733.12	717.97
Reach-1	35451.72	500 Yrs	3030.00	108.20	119.74	11.54	4.05	4.12	212.60	748.59	732.12
Reach-1	35432.17 350+00US	1 Yr	940.00	106.60	115.24	8.64	1.83	2.03	114.36	512.93	368.54
Reach-1	35432.17 350+00US	2 Yrs	1130.00	106.60	115.67	9.07	2.02	2.22	121.84	559.70	387.90
Reach-1	35432.17 350+00US	5 Yrs	1450.00	106.60	116.34	9.74	2.30	2.49	133.02	630.92	417.38
Reach-1	35432.17 350+00US	10 Yrs	1690.00	106.60	116.79	10.19	2.48	2.66	140.69	680.08	437.74
Reach-1	35432.17 350+00US	25 Yrs	1980.00	106.60	117.06	10.46	4.13	4.29	49.52	479.08	449.67
Reach-1	35432.17 350+00US	50 Yrs	2230.00	106.60	118.47	11.87	2.59	2.66	176.72	859.82	512.15
Reach-1	35432.17 350+00US	100 Yrs	2480.00	106.60	119.47	12.86	2.56	2.58	202.01	967.17	556.59
Reach-1	35432.17 350+00US	250 Yrs	2810.00	106.60	119.66	13.06	2.84	2.85	205.69	987.85	565.15
Reach-1	35432.17 350+00US	500 Yrs	3030.00	106.60	119.81	13.21	3.02	3.01	212.59	1003.87	571.78
Reach-1	35402.98 350+00BR		Bridge								
Reach-1	35371.65 349+45DS	1 Yr	940.00	107.12	115.11	7.99	2.57	2.80	82.01	365.14	314.16
Reach-1	35371.65 349+45DS	2 Yrs	1130.00	107.12	115.50	8.38	2.85	3.12	85.27	396.45	333.50
Reach-1	35371.65 349+45DS	5 Yrs	1450.00	107.12	116.08	8.96	3.27	3.60	90.82	442.86	362.04
Reach-1	35371.65 349+45DS	10 Yrs	1690.00	107.12	116.46	9.34	3.57	3.92	94.21	473.62	380.95
Reach-1	35371.65 349+45DS	25 Yrs	1980.00	107.12	116.76	9.64	5.00	5.00	49.52	395.94	395.94
Reach-1	35371.65 349+45DS	50 Yrs	2230.00	107.12	117.97	10.85	3.75	4.09	112.48	595.44	455.87
Reach-1	35371.65 349+45DS	100 Yrs	2480.00	107.12	118.41	11.29	3.93	4.28	151.70	630.81	477.62
Reach-1	35371.65 349+45DS	250 Yrs	2810.00	107.12	118.68	11.56	4.31	4.68	167.15	651.97	490.63
Reach-1	35371.65 349+45DS	500 Yrs	3030.00	107.12	118.68	11.56	4.65	5.05	167.16	651.99	490.64
Reach-1	35356.77	1 Yr	940.00	108.20	115.06	6.86	3.10	3.10	66.69	303.00	303.00
Reach-1	35356.77	2 Yrs	1130.00	108.20	115.45	7.25	3.44	3.44	69.48	328.93	328.90
Reach-1	35356.77	5 Yrs	1450.00	108.20	116.01	7.81	3.92	3.94	76.70	369.81	367.77
Reach-1	35356.77	10 Yrs	1690.00	108.20	116.38	8.18	4.23	4.29	82.85	399.38	393.76
Reach-1	35356.77	25 Yrs	1980.00	108.20	116.78	8.58	4.56	4.68	89.47	433.78	421.76
Reach-1	35356.77	50 Yrs	2230.00	108.20	117.91	9.71	4.09	4.40	108.23	544.61	501.06
Reach-1	35356.77	100 Yrs	2480.00	108.20	118.35	10.15	4.18	4.59	131.22	593.93	532.02
Reach-1	35356.77	250 Yrs	2810.00	108.20	118.61	10.41	4.50	5.01	146.47	624.02	550.08
Reach-1	35356.77	500 Yrs	3030.00	108.20	118.59	10.39	4.87	5.42	144.98	622.44	549.14
Reach-1	35349.20 349+20DAM		Inl Struct								

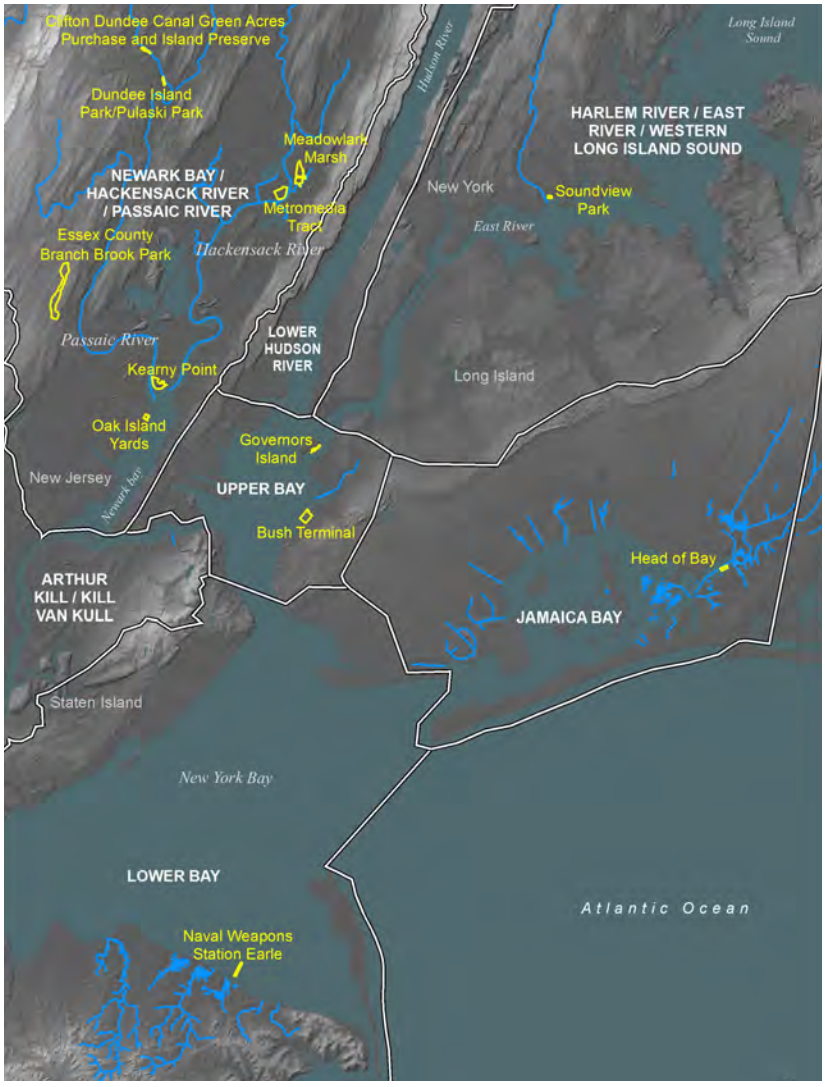
HEC-RAS Plan: Multi_USACE River: Bronx River Reach: Reach-1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Max Chl Dpth	Vel Total	Vel Chnl	Top Width	Flow Area	Area Channel
			(cfs)	(ft)	(ft)	(ft)	(ft/s)	(ft/s)	(ft)	(sq ft)	(sq ft)
Reach-1	35341.02 349+20DAMDS	1 Yr	940.00	108.20	113.82	5.62	4.18	4.18	58.73	224.92	224.92
Reach-1	35341.02 349+20DAMDS	2 Yrs	1130.00	108.20	112.67	4.47	7.04	7.04	53.99	160.51	160.51
Reach-1	35341.02 349+20DAMDS	5 Yrs	1450.00	108.20	113.49	5.29	7.04	7.04	57.37	205.88	205.88
Reach-1	35341.02 349+20DAMDS	10 Yrs	1690.00	108.20	114.06	5.86	7.06	7.06	59.73	239.30	239.30
Reach-1	35341.02 349+20DAMDS	25 Yrs	1980.00	108.20	115.66	7.46	5.75	5.76	72.18	344.17	343.76
Reach-1	35341.02 349+20DAMDS	50 Yrs	2230.00	108.20	117.72	9.52	4.24	4.53	105.10	525.56	487.80
Reach-1	35341.02 349+20DAMDS	100 Yrs	2480.00	108.20	118.18	9.98	4.30	4.72	126.08	576.27	519.61
Reach-1	35341.02 349+20DAMDS	250 Yrs	2810.00	108.20	118.41	10.21	4.64	5.17	132.69	606.00	535.78
Reach-1	35341.02 349+20DAMDS	500 Yrs	3030.00	108.20	118.36	10.16	5.05	5.61	130.90	600.00	532.60
Reach-1	35253.84	1 Yr	940.00	106.90	113.85	6.95	2.96	3.06	70.92	317.16	305.05
Reach-1	35253.84	2 Yrs	1130.00	106.90	112.80	5.90	4.51	4.54	59.28	250.54	248.89
Reach-1	35253.84	5 Yrs	1450.00	106.90	113.59	6.69	4.83	4.96	67.77	300.26	291.34
Reach-1	35253.84	10 Yrs	1690.00	106.90	114.15	7.25	5.01	5.22	74.78	337.53	321.18
Reach-1	35253.84	25 Yrs	1980.00	106.90	115.69	8.79	4.39	4.80	98.04	450.69	403.58
Reach-1	35253.84	50 Yrs	2230.00	106.90	117.73	10.83	3.37	4.08	189.24	661.61	513.06
Reach-1	35253.84	100 Yrs	2480.00	106.90	118.20	11.30	2.97	4.19	209.13	834.58	538.16
Reach-1	35253.84	250 Yrs	2810.00	106.90	118.43	11.53	3.17	4.59	216.72	885.17	550.88
Reach-1	35253.84	500 Yrs	3030.00	106.90	118.39	11.49	3.46	4.98	215.36	876.48	548.72
Reach-1	35175.60 347+60US	1 Yr	940.00	107.31	113.79	6.48	3.04	3.07	59.99	308.95	305.77
Reach-1	35175.60 347+60US	2 Yrs	1130.00	107.31	112.63	5.32	4.66	4.66	54.38	242.28	242.27
Reach-1	35175.60 347+60US	5 Yrs	1450.00	107.31	113.42	6.11	5.05	5.07	58.15	287.03	285.58
Reach-1	35175.60 347+60US	10 Yrs	1690.00	107.31	113.98	6.67	5.28	5.34	60.92	320.31	315.99
Reach-1	35175.60 347+60US	25 Yrs	1980.00	107.31	115.57	8.26	4.92	4.92	54.54	402.66	402.23
Reach-1	35175.60 347+60US	50 Yrs	2230.00	107.31	117.66	10.35	3.83	4.18	215.81	582.99	516.04
Reach-1	35175.60 347+60US	100 Yrs	2480.00	107.31	118.10	10.79	3.97	4.42	248.31	624.55	540.08
Reach-1	35175.60 347+60US	250 Yrs	2810.00	107.31	118.31	11.00	4.35	4.88	264.57	645.65	551.56
Reach-1	35175.60 347+60US	500 Yrs	3030.00	107.31	118.25	10.94	4.74	5.31	261.73	639.20	548.10

Attachment C-8
HRE
Lower Passaic River: Geotechnical and Geological Report

Department Of The Army
New York District Corps of
Engineers
Jacob K. Javits Federal Building
26 Federal Plaza
New York, NY 10278-0090

Contract: W912DS-12-D-0002 – Task Order 0022
Hudson Raritan Estuary and HRE-Lower Passaic River Ecosystem Restoration Feasibility Studies:
Geotechnical and geological report



August 18, 2016

e4sciences | Earthworks, LLC
27 Glen Road, North Entrance
Sandy Hook, Connecticut 06482
P.O. Box 178, Newtown, CT 06470
(203) 270-8100, Fax (203) 364-0480
www.e4sciences.com

All interpretations are opinions based on inferences from available geological data in literature. We cannot, and do not, guarantee the accuracy or correctness of any interpretation. We shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretations made by any of our officers, agents or employees.

Executive summary

The United States Army Corps of Engineers (USACE-NAN) is planning to restore ecosystems within the Hudson Raritan Estuary in New York and New Jersey.

e4sciences (e4) reviewed the geological and geotechnical context in which the restorations are planned. e4 investigated the geology, the surficial geology, the water quality, and the proximity to contamination sites. The restorations focus on the Passaic River, the Hackensack River, the Naval base at Earle, Jamaica Bay, the mouth of the Bronx River, Brooklyn's waterfront, and Governors Island. The study does not make recommendations, but it provides the information critically relevant to planning and design.

Abstract

The United States Army Corps of Engineers (USACE-NAN) is planning to restore ecosystems within the Hudson Raritan Estuary in New York and New Jersey.

The USACE-NAN chose to recommend twelve sites for further consideration for ecosystem rehabilitation, which they then assigned e4sciences (e4) to evaluate. Five of these sites are considered for oyster habitat restoration and are located in New York waterways. The other seven sites are considered for ecosystem rehabilitation within the Newark Bay, Hackensack River and Passaic River watersheds in New Jersey. Table A-1 lists oyster habitat restoration sites and Table A-2 lists the ecosystem restoration sites. Figure 1 shows the location of these sites with respect to their watersheds. This report is a desktop study of the geology and the geotechnical properties of the rocks and sediments at the twelve sites of interest. e4 mapped the geology from literature and field observations, topography using LiDAR, and soils from literature.

Table A-1. List of proposed oyster habitat restorations sites in the New York waterways.

Oyster habitat restoration site	Watershed	Sub-watershed/water body
Site 864. Governors Island	Hudson River	Upper New York Bay/ Buttermilk Channel
Site 154. Bush Terminal	Hudson River	Upper New York Bay/ Bay Ridge Channel
Unnumbered site: Soundview Park	Bronx River	Confluence of Bronx and East Rivers
Unnumbered site: Head of Bay	Jamaica Bay	Hook Creek-Head of Bay
Unnumbered site: Naval Weapons Station Earle	NY Lower Bay	Compton Creek-Sandy Hook Bay

Table A-2. List of proposed ecosystem restorations sites in the Newark Bay watershed.

Ecosystem restoration site	Watershed	Sub-watershed
Site 719. Meadowlark Marsh	Hackensack	Bellmans Creek
Site 721. Metromedia Tract	Hackensack	Hackensack River (Route 3 to Bellmans Creek)
Site 865. Kearny Point	Newark Bay	Confluence of Passaic and Hackensack Rivers
Site 866. Oak Island Yards	Newark Bay	Newark Bay
Site 887. Essex County Branch Brook Park	Passaic River	Branch Brook (First River)
Site 900. Dundee Island Park/Pulaski Park	Passaic River	Lower Passaic River
Site 902. Clifton Dundee Canal Green Acres Purchase & Island Preserve	Passaic River	Lower Passaic River (Saddle R. to Dundee Dam)

Oyster Habitat Restoration Sites

The southern termination of the last Pleistocene glacier (Wisconsin) is marked by the glacial terminal moraine extending along Staten Island and Long Island. North of this, Pleistocene glaciers have scraped down to bedrock or to the semi-consolidated Tertiary and Cretaceous Coastal Plain Group sediments. On land there are minor Holocene sediments, and true soils are relatively thin. Surficial sediments are predominantly Pleistocene glacial tills, glacial lake sediments and Holocene fluvial, estuarine, and marine sediments. Underwater, the Holocene coarser sediments are reworked Pleistocene sands and gravels. The fine-grained sediments are estuarine deposits. In the Hudson River channel, these Holocene deposits are up to 300ft thick. At the oyster habitat restoration sites, Holocene deposits are relatively thin (0 to 20ft).

In New York, the area south of the terminal moraine is blanketed by deposits of glacial outwash sands and silts that "washed out" from glaciers and the terminal moraine. On land there are very minor Holocene sediments, and true soils are relatively thin. Underwater Holocene deposits at Jamaica Bay are estimated to be 20ft thick.

The New Jersey coast south of New York Bay is predominantly erosive. On land, the soils have variable thickness and lie on the Coastal Plain Group deposits. Holocene stream deposits are relatively minor. Underwater, the Holocene is dominated by reworked sands of the Coastal Plain Group.

All of the oyster habitat restoration sites are adjacent to built-up shorelines and are in channels with varying degrees of marine vessel traffic. Naval Weapons Station Earle and Governors Island sites are adjacent to active piers. The Bush Terminal site is in an underwater field of pier "ruins" adjacent to piers re-purposed as a park.

The Governors Island oyster restoration site lies between the rip-rap lined seawall of the island and Buttermilk Channel. The site is underlain by schist (Hartland formation) that is 0 to 40ft below the bay floor. At the northern end of the site, rock is exposed on the channel floor. Overlying the rock is variable thicknesses of interlayered Pleistocene glacial deposits that include glacial lake clay and silt, glacial outwash sand and silt, and glacial till. Overlying Holocene sediments are generally less than 10ft thick. Coarse Holocene sediments appear to be reworked Pleistocene sediments. Locally, a thin layer of black silt overlies the Holocene sands.

Governors Island, specifically Fort Jay, is considered a State Superfund Program site. Due to its history as an active military base for over 200 years, the subsurface of the island contains various heavy metals and harmful organic compounds. It is unknown if these contaminants affect the overall health of the offshore oyster habitat restoration site.

The Bush Terminal oyster restoration site includes pier ruins between the Bay Ridge Channel and the re-purposed Bush Terminal Pier Park. Bedrock (Hartland Formation) is greater than 120ft deep. Overlying the rock is a thick sequence of Pleistocene sediments dominated by glacial lake clay and silt. This is overlain by Holocene sands and Holocene black silt. The surface of Bush Terminal Piers Park is made up of the Laguardia soil unit, which is an artifactual coarse sandy loam (fill).

Bush Terminal Piers Park is both a State Superfund Program site and an Environmental Restoration Program site. It is also considered a NYS Open Petroleum Spill location. The effect of the contamination on the overall health of the oyster habitat restoration site is not known.

The Soundview Park oyster restoration site is part of the Bronx sub-watershed within the larger Atlantic Ocean/Long Island Sound watershed system. The site is underlain by shallow bedrock composed of schist (Hartland formation). This is overlain by Holocene estuarine sands and silts. The land surface of Soundview Park is made up of the Laguardia soil unit.

Approximately 900ft to the west of the proposed oyster site, there is a NYS Remediation site, and also to the west and north of the site are NYS Brownfield Opportunity areas. How these areas affect the overall health of the offshore oyster habitat restoration site is not known.

The Head of Bay oyster restoration site is part of the Hook Creek-Head of Bay sub-watershed within the larger Jamaica Bay watershed system. The site is adjacent to JFK airport where construction started in the 1940s. The site is underlain by estuarine sands and over 100ft-thick glacial-outwash deposits, which are on top of older Pleistocene sediments and Cretaceous Coastal Plain Sediments. The top of crystalline rock is over 600ft deep. The surface of the Queens County north shore of Jamaica Bay in the Head of Bay area is made up of the Jamaica sand soil unit.

The Naval Weapons Station Earle oyster habitat restoration site is part of the Sandy Hook-Staten Island sub-watershed within the larger Monmouth watershed system. The site is underlain by the Cretaceous Coastal Group sand, silt and clay.

The Naval Weapons Station Earle site is classified as a New Jersey Superfund site due to the toxic materials associated with military activities and wastes that have been buried in landfills. The contaminants found at this site include heavy metals and organic compounds. It is unknown if these Superfund contaminants affect the overall health of the oyster habitat restoration site.

Newark Bay/Lower Passaic River/Hackensack River Restoration Sites

The Passaic and Hackensack Rivers flow into the northern end of Newark Bay at Kearny Point (Site 865). Newark Bay, the lower 14 miles of the Hackensack River, and the lower Passaic River are tidal. The upper Hackensack River is dammed north at the Oradell Dam. The Passaic River has multiple dams, the most downstream of which is Dundee Dam.

The underlying bedrock of all three water bodies consists of the Newark Series Triassic-Jurassic sedimentary rocks deposited in the Newark Basin and intrusive and volcanic Jurassic igneous basalts and diabases. The igneous rocks and the surrounding contact metamorphic rocks are the most resistant, and form ridges. The least resistant are the fine-grained sedimentary rocks of the Passaic Formation. These shales and siltstones underlie valleys. The eastern edge of the Newark Bay watershed is underlain by the Lockatong Formation, whereas the rest is underlain either by the Passaic Formation or the igneous dikes and sills that cross-cut the Passaic Formation.

Newark Bay, the lower 14 miles of the Hackensack River, the lower 1 mile of the Passaic River, northern Arthur Kill, and associated wetlands lie in a subtle valley between north-east trending ridges. The eastern ridge is the Palisades diabase. The western limit of the valley is formed by small ridges underlain by the Passaic Formation shales and sandstones. The eastern edge of the valley is underlain by the Lockatong Formation. The remaining majority is underlain by the shale-dominated Passaic subunits. This valley is tidally influenced and includes the Meadowlands between the Passaic and Hackensack Rivers.

The main strike of the strata is 36° east of north and beds dip 15° to the northwest. The area consists of buried northeast trending ridges and valleys of bedrock. The top of rock is mantled by Pleistocene Glacial till. The valleys are filled with Pleistocene glacial lake deposits, the majority of which are varved clays and silts. Locally, these are interbedded with glacial lake delta deposits of sands and tills. The clay unit may be as thick as 200ft. These lake deposits are interbedded with tills and are overlain by outwash silts and sands.

The Pleistocene outwash sands transition to Holocene fluvial and estuarine sands that grade vertically into finer estuarine silts and clays and marsh deposits. In the last few hundred years, much of the low-lying marsh and shallow waters areas have been filled to build up the land for roads, railroads, industrial sites, airports, and port facilities. Bridges are generally built where bedrock is shallow.

Locally, either bedrock or Pleistocene sediments are exposed in Newark Bay and in the Hackensack River. In Newark Bay, these units were uncovered by dredging, whereas in the Hackensack River, the units were uncovered both by dredging and by river currents eroding overlying sediments. Such scouring is deep at bridges.

The movement and storage of groundwater in this area occurs primarily in the interconnected network of openings that form along joints, fractures, and other channels in the Passaic Formation.

The shallower upper Pleistocene and Holocene silts and sands in addition to the historic fill form shallow groundwater aquifers that are generally laterally discontinuous. Where bedrock is deep

the relatively impermeable, Pleistocene varved clays and silts are thick and create barriers atop the bedrock aquifers. Where rock is shallow, the Pleistocene clay and silt may be thin or completely eroded and bedrock aquifers are more vulnerable to infiltration and contamination from the surface.

Much of the contaminated sediment and groundwater is in the shallower aquifers. The historic fill was usually placed for industrial use and is commonly found at the surface of contaminated sites.

The Meadowlark Marsh site is a poorly drained, frequently flooded marsh that is located above mucky peat and some sand. While there are groundwater contamination sites nearby, the extent of the effects of contamination on the health of Meadowlark Marsh is unknown.

The Metromedia Tract site is a poorly drained, frequently flooded marsh that is located above peat, muck, and some fill material (gravel and debris). The marsh deposits are approximately 10ft thick. The closest known contamination site is 1,400ft southeast of the border of the Metromedia Tract site.

The Kearny Point site is located on top of historic fill, and is the site of a decommissioned industrial facility. The fill material is approximately 20ft thick and is underlain by marshy deposits. NJDEP recognizes a Known Contaminated Site (KCS) within the boundaries of the Kearny Point site with an identified contaminated plume. There is a deed notice to the site that prohibits the drilling of water wells and places restrictions on any drilling through the plume.

The Oak Island Yards site is located on top of a mix of fill, salt-marsh, sand, and gravel deposits. The water quality around Oak Island Yards is mostly suitable for aquatic life, however the turbidity has been measured high at times. Northwest of the site is the Newark Energy Center, where many contaminants have been measured in the soil/groundwater. It is unknown if these contaminants affect Oak Island Yards site.

The Essex County Branch Brook Park site is underlain by about 10ft of marshy loam deposits, which are above gravelly and sandy loam deposits. On the eastern, northern, and western edges of the park, there are KCS's with groundwater contamination.

The Dundee Island Park/Pulaski Park site is underlain by fill material, which is above silty sand deposits. There are no marshy deposits at this site. There are no KCS's within the site, however there are KCS's west, northeast, east, and southeast of the site.

The Clifton Dundee Canal Green Acres Purchase and Island Preserve site is underlain by silty and clayey sands. There is a KCS on the southern edge of the site and there are several southeast of the site. It is unknown if the contamination affects the health of this site.

Table of contents

Disclaimer ii
Executive summary iii
Abstract iv
Table of Contents viii
List of figures viii
List of tables x
1.0 Introduction 1
2.0 Oyster Habitat Restoration Sites 6
2.1 Upper New York Bay 13
2.1.1 Site 864. Governors Island 13
2.1.2 Site 154. Bush Terminal 22
2.2 Bronx River Basin 30
2.2.1 Soundview Park 30
2.3 Jamaica Bay 36
2.3.1 Head of Bay 36
2.4 Lower New York Bay 44
2.4.1 Naval Weapons Station Earle 44
3.0 Newark Bay, Lower Passaic River and Hackensack River Restoration Sites 50
3.1 Hackensack River 57
3.1.1 Site 719. Meadowlark Marsh 57
3.1.2 Site 866. Oak Island Yards 83
3.2 Lower Passaic River 90
3.2.1 Site 887. Essex County Branch Brook Park 90
3.2.2 Site 900. Dundee Island Park/Pulaski Park 100
3.2.3 Site 902. Clifton Dundee Canal Green Acres Purchase and Island Preserve 107
Appendix I. Site 864. Governors Island A1-1
Appendix II. Site 154. Bush Terminal A2-1
Appendix III. Soundview Park A3-1
Appendix IV. Head of Bay, Jamaica Bay A4-1
Appendix V. Naval Weapons Station Earle A5-1
Appendix VI. Site 719. Meadowlark Marsh A6-1
Appendix VII. Site 721. Metromedia Tract A7-1
Appendix VIII. Site 865. Kearny Point A8-1
Appendix IX. Site 866. Oak Island Yards A9-1
Appendix X. Site 887. Essex County Branch Brook Park A10-1
Appendix XI. Site 900. Dundee Island Park/Pulaski Park A11-1
Appendix XII. Site 902. Clifton Dundee Canal Green Acres Purchase & Island Preserve A12-1

List of Figures

Figure 1. Location map of the proposed restoration sites and HRE Planning Regions boundaries
Figure 2. Watershed map of the proposed restoration sites
Figure 3. Regional bedrock geology map

Figure 2.0-1. 1911 oyster map of New York Harbor
Figure 2.0-2. Location map of oyster habitat restoration candidate sites
Figure 2.0-3. Watershed map and oyster habitat restoration sites
Figure 2.0-4. Bedrock geology and the oyster habitat restoration sites

Figure 2.0-5. Surficial geology and the oyster habitat restoration sites

Figure 2.1.1-1. 1845 and 1906 historic nautical charts of Governors Island
Figure 2.1.1-2. 1912 and 2014 historic nautical charts of Governors Island
Figure 2.1.1-3. Surficial geology of Governors Island site
Figure 2.1.1-4. Side-scan orthosonograph of bay floor surrounding Governors Island
Figure 2.1.1-5. Wetland areas and contamination site at Governors Island

Figure 2.1.2-1. Historic nautical charts of the Bush Terminal area
Figure 2.1.2-2. Surficial geology of the Bush Terminal site
Figure 2.1.2-3. Side-scan orthosonograph of bay floor adjacent to Bush Terminal Piers Park
Figure 2.1.2-4. Wetland areas and contamination site at Bush Terminal

Figure 2.2.1-1. Historic nautical charts of the Soundview Park area
Figure 2.2.1-2. Surficial geology of the Soundview Park site
Figure 2.2.1-3. Wetland areas and contamination site near the Soundview Park site

Figure 2.3.1-1. Location map of the Head of Bay site
Figure 2.3.1-2. Historic nautical charts of Head of Bay
Figure 2.3.1-3. Surficial geology of the Head of Bay site
Figure 2.3.1-4. Regional geological cross section through Jamaica Bay
Figure 2.3.1-5. Wetland areas and contamination sites near Head of Bay

Figure 2.4.1-1. Historic nautical charts of NWS Earle area
Figure 2.4.1-2. Surficial geology of the NWS Earle site
Figure 2.4.1-3. Wetland areas and contamination sites near the NWS Earle site

Figure 3.0-1. Location map of ecosystem restoration sites
Figure 3.0-2. Watershed map and ecosystem restoration sites
Figure 3.0-3. Bedrock geology map and the ecosystem restoration sites
Figure 3.0-4. Surficial geology map and the ecosystem restoration sites
Figure 3.0-5. West-to-east cross section through the Newark Basin

Figure 3.1.1-1. Historic topographic maps of the Meadowlark Marsh area
Figure 3.1.1-2. Surficial geology of the Meadowlark Marsh site
Figure 3.1.1-3. Geological cross section along the Hackensack River
Figure 3.1.1-4. Wetland areas and contamination sites near the Meadowlark Marsh site

Figure 3.1.2-1. Historic topographic maps of the Metromedia Tract area
Figure 3.1.2-2. Surficial geology of the Metromedia Tract site
Figure 3.1.2-3. Geological cross section along the Hackensack River
Figure 3.1.2-4. Wetland areas and contamination sites near the Metromedia Tract site

Figure 3.2.1-1. Historic topographic maps of the Kearny Point area
Figure 3.2.1-2. Surficial geology of the Kearny Point site
Figure 3.2.1-3. Geological cross section along the Hackensack River.
Figure 3.2.1-4. Wetland areas and contamination sites at and near the Kearny Point site

Figure 3.2.2-1. Historic topographic maps of the Oak Island Yards area

Figure 3.2.2-2. Surficial geology of the Oak Island Yards site
Figure 3.2.2-3. Wetland areas and contamination sites near the Oak Island Yards site

Figure 3.3.1-1. Historic topographic maps of Essex County Branch Brook Park
Figure 3.3.1-2. Surficial geology of Essex County Branch Brook Park
Figure 3.3.1-3. Wetland areas and contamination sites in Essex County Branch Brook Park

Figure 3.3.2-1. Historic topographic maps of the Dundee Island Park and Pulaski Park area
Figure 3.3.2-2. Surficial geology of the Dundee Island Park and Pulaski Park site
Figure 3.3.2-3. Wetland areas and contamination sites near Dundee Island Park and Pulaski Park

Figure 3.3.3-1. Historic topographic maps of the area around Clifton Dundee site 902
Figure 3.3.3-2. Surficial geology of Clifton Dundee site 902
Figure 3.3.3-3. Wetland areas and contamination sites near Clifton Dundee site 902

List of Tables

Table A1. Proposed oyster habitat restorations sites in New York waterways
Table A2. Proposed ecosystem restoration sites in the Newark Bay watershed

Table 1. Proposed oyster habitat restorations sites in New York waterways
Table 2. Proposed ecosystem restoration sites in the Newark Bay watershed

Table 2.0-1. Proposed oyster habitat restorations sites in this report

Table 2.1.1-1. Key information for the Governors Island site
Table 2.1.1-2. General stratigraphy of the Governors Island site
Table 2.1.1-3. Borings and sample sites in or near the Governors Island site
Table 2.1.1-4. Soil profile of Governors Island's Urban land soil type
Table 2.1.1-5. Summary of properties of the Urban land soil type
Table 2.1.1-6. Soil profile of the Laguardia soil type
Table 2.1.1-7. Summary of properties of the Laguardia soil type
Table 2.1.1-8. Water quality summary of the Governors Island site

Table 2.1.2-1. Key information for the Bush Terminal site
Table 2.1.2-2. General stratigraphy of the Bush Terminal site
Table 2.1.2-3. Borings and sample sites in or near the Bush Terminal site
Table 2.1.2-4. Soil profile of the Laguardia soil unit
Table 2.1.2-5. Summary of properties of the Laguardia soil unit

Table 2.2.1-1. Key information for the Soundview Park site
Table 2.2.1-2. General stratigraphy of the Soundview Park site
Table 2.2.1-3. Soil profile of the Laguardia soil unit
Table 2.2.1-4. Summary of properties of the Laguardia soil unit
Table 2.2.1-5. Water quality summary of the Soundview Park site

Table 2.3.1-1. Key information for the Head of Bay site
Table 2.3.1-2. General stratigraphy of the Head of Bay site
Table 2.3.1-3. Soil profile of the Jamaica Sand soil unit

Table 2.3.1-4. Summary of soil properties the Jamaica Sand soil unit
Table 2.3.1-5. Water quality summary of the Head of Bay site

Table 2.4.1-1. Key information for the Naval Weapons Station (NWS) Earle site
Table 2.4.1-2. General stratigraphy of the NWS Earle site
Table 2.4.1-3. Borings near the NWS Earle site
Table 2.4.1-4. Soil profile of the Hooksan sand soil unit
Table 2.4.1-5. Summary of soil properties of the Hooksan sand soil unit

Table 3.0-1 Proposed ecosystem restoration sites in this report

Table 3.1.1-1. Key information for the Meadowlark Marsh site
Table 3.1.1-2. General stratigraphy of the Meadowlark Marsh site
Table 3.1.1-3. Borings in or near the Meadowlark Marsh site
Table 3.1.1-4. Soil profile of the Westbrook soil type.
Table 3.1.1-5. Summary of properties of the Westbrook soil type
Table 3.1.1-6. Soil profile of the Ipswich soil type
Table 3.1.1-7. Summary of properties of the Ipswich soil type
Table 3.1.1-8. Soil profile of the Sandyhook soil type
Table 3.1.1-9. Summary of properties of the Sandyhook soil type
Table 3.1.1-10. Water quality summary of Hackensack River near Meadowlark Marsh
Table 3.1.1-11. Highest measured concentrations of contaminants at Sier-Bath Gear Co. site
Table 3.1.1-12. Highest measured concentrations at the Vince Lombardi Service Area

Table 3.1.2-1. Key information for the Metromedia Tract site
Table 3.1.2-2. General stratigraphy of the Metromedia Tract site
Table 3.1.2-3. Borings in or near the Metromedia Tract site
Table 3.1.2-4. Soil profile of the Westbrook soil type.
Table 3.1.2-5. Summary of properties of the Westbrook soil type
Table 3.1.2-6. Soil profile of the Ipswich soil complex
Table 3.1.2-7. Summary of properties of the Ipswich soil type
Table 3.1.2-8. Soil profile of the Sandyhook soil complex
Table 3.1.2-9. Summary of properties of the Sandyhook soil type
Table 3.1.2-10. Water quality summary of the Hackensack River sub-watershed

Table 3.2.1-1. Key information for the Kearny Point site
Table 3.2.1-2. General stratigraphy of the Kearny Point site
Table 3.2.1-3. Borings in or near the Kearny Point site
Table 3.2.1-4. Soil profile of Secaucus artifactual fine sandy loam (0-3% slope)
Table 3.2.1-5. Soil profile of Secaucus artifactual fine sandy loam (3-8% slope)
Table 3.2.1-6. Summary of properties of Kearny Point's Secaucus artifactual fine sandy loam
Table 3.2.1-7. Water quality summary of Kearny Point site
Table 3.2.1-8. Highest measured concentrations of contaminants at the BASF Corporation site
Table 3.2.1-9. Highest measured concentrations of contaminants at the NY Daily News Inc. site

Table 3.2.2-1. Key information for the Oak Island Yards site
Table 3.2.2-2. General stratigraphy of the Oak Island Yards site
Table 3.2.2-3. Borings in or near the Oak Island Yards site
Table 3.2.2-4. Soil profile of the Udorthents soil unit
Table 3.2.2-5. Summary of properties of the Udorthents soil unit
Table 3.2.2-6. Water quality summary of the Newark Bay/Kill Van Kull sub-watershed

Table 3.2.2-7. Highest measured concentrations of contaminants near the Oak Island Yards site

Table 3.3.1-1. Key information for the Essex County Branch Brook Park site
Table 3.3.1-2. General stratigraphy of the Essex County Branch Brook Park site
Table 3.3.1-3. Borings in or near the Essex County Branch Brook Park site
Table 3.3.1-4. Soil profile of the Boonton Red Sandstone Lowland soil type
Table 3.3.1-5. Soil profile of the Boonton Red Sandstone Lowland soil type
Table 3.3.1-6. Summary of properties of the Boonton Red Sandstone Lowland soil type
Table 3.3.1-7. Soil profile of Udorthents Boonton Red Sandstone Lowland soil type
Table 3.3.1-8. Summary of Udorthents Boonton Red Sandstone Lowland Substratum soil type
Table 3.3.1-9. Soil profile of Udorthents Loamy Fill Substratum soil type
Table 3.3.1-10. Summary of properties of Udorthents Loamy Fill Substratum soil type
Table 3.3.1-11. Soil profile of Urban Land Boonton Red Sandstone Lowland Substratum soil
Table 3.3.1-12. Summary of Urban Land Boonton Red Sandstone Substratum Lowland soil type
Table 3.3.1-13. Water quality of Lower Passaic River (4th St to Second R.) subwatershed
Table 3.3.1-14. Highest measured concentrations of contaminants at the NJ Transit site
Table 3.3.1-15. Highest measured concentrations of contaminants at the Meineke site
Table 3.3.1-16. Highest measured concentrations at Branch Brook Maintenance Garage
Table 3.3.1-17. Highest measured concentrations of contaminants at the Getty Service Station

Table 3.3.2-1. Key information for the Dundee Island Park/Pulaski Park site
Table 3.3.2-2. General stratigraphy of the Dundee Island Park/Pulaski Park site
Table 3.3.2-3. Borings in or near the Dundee Island Park/Pulaski Park site
Table 3.3.2-4. Soil profile of the Urban land soil type
Table 3.3.2-5. Soil profile of the Riverhead soil type
Table 3.3.2-6. Summary of the Riverhead soil type
Table 3.3.2-7. Water quality summary at the PVSC building on the Passaic River
Table 3.3.2-8. Highest measured concentrations at Roberto Clemente Field site
Table 3.3.2-9. Highest measured concentrations of contaminants near Kalama Chemical Inc.

Table 3.3.3-1. Key information for the Clifton Dundee site 902
Table 3.3.3-2. General stratigraphy of the Clifton Dundee site 902
Table 3.3.3-3. Borings in or near the Clifton Dundee site 902
Table 3.3.3-4. Soil profile of the Urban land soil type
Table 3.3.3-5. Soil profile of the Riverhead soil type
Table 3.3.3-6. Summary of Riverhead soil type
Table 3.3.3-7. Water quality summary of the Lower Passaic River sub-watershed
Table 3.3.3-8. Highest measured concentrations of contaminants at the Clifton Dundee site 902

1. Introduction

The United States Army Corps of Engineers (USACE-NAN) is planning to restore ecosystems within the Hudson Raritan Estuary in New York and New Jersey.

The USACE-NAN assigned e4sciences (e4) to evaluate five sites for oyster habitat restoration in New York waterways and seven sites for ecosystem rehabilitation within the Newark Bay, Hackensack River and Passaic River watersheds in New Jersey. Table 1 lists oyster habitat restoration sites and Table 2 lists the ecosystem restoration sites. Figure 1 shows the location of these sites with respect to HRE Planning Regions. Figure 2 shows the sites with respect to watersheds. Figure 3 shows the sites with respect to the regional bedrock geology. This report is a desktop study of the geology and the geotechnical properties of the rocks and sediments at the 12 sites of interest. e4 mapped the geology from literature and field observations, topography, and soils from literature.

Table 1. List of proposed oyster habitat restorations sites in the New York waterways.

Oyster habitat restoration site	Watershed	Sub-watershed/water body
Site 864. Governors Island	Hudson River	Upper New York Bay/ Buttermilk Channel
Site 154. Bush Terminal	Hudson River	Upper New York Bay/ Bay Ridge Channel
Unnumbered site: Soundview Park	Bronx River	Confluence of Bronx and East Rivers
Unnumbered site: Head of Bay	Jamaica Bay	Hook Creek-Head of Bay
Unnumbered site: Naval Weapons Station Earle	NY Lower Bay	Compton Creek-Sandy Hook Bay

Table 2. List of proposed restorations sites in the Newark Bay watershed.

Ecosystem restoration site	Watershed	Sub-watershed
Site 719. Meadowlark Marsh	Hackensack River	Bellmans Creek
Site 721. Metromedia Tract	Hackensack River	Hackensack River (Route 3 to Bellmans Creek)
Site 865. Kearny Point	Newark Bay, Hackensack,	Confluence of Passaic and Hackensack Rivers
Site 866. Oak Island Yards	Newark Bay	Newark Bay
Site 887. Essex County Branch Brook Park	Passaic River	Branch Brook (First River)
Site 900. Dundee Island Park/Pulaski Park	Passaic River	Lower Passaic River
Site 902. Clifton Dundee Canal Green Acres Purchase & Island Preserve	Passaic River	Lower Passaic River (Saddle R. to Dundee Dam)

This report summarizes all data that was available for each site. This includes geotechnical data, bedrock geology, surficial geology, soil quality, associated contamination, and surficial and groundwater quality. Not all information was available for each site.

The geotechnical report was to only focus on data available for locations and regions where sites were recommended for construction (Lower Passaic River, Hackensack Meadowlark and Metromedia, and Governors Island, including the additional areas selected for oyster habitat restoration, i.e. Bush Terminal, Soundview Park, Jamaica Bay, and Naval Weapons Station Earle).

This task did not include the Flushing Creek, Liberty State Park, and Jamaica Bay sites apart from the locations for oyster habitat restoration. However, the geotechnical information presented in the Draft Flushing Creek and Jamaica Bay Feasibility Studies were to be summarized and incorporated into the Draft Feasibility Report/Environmental Assessment (FR/EA) (Task 18.a in the Planning Task order). Bronx River information from the Bronx River Study was also to be compiled into the overall FR/EA.

The activities stated above were done in accordance with the following references:

- ER 1110-2-1150 Engineering and Design of Civil Works Projects
- EM 1110-1-1804 Geotechnical Investigations

Assumptions at the current stage of planning for the restoration sites are that the existing geological and soil information is sufficient for the development of the conceptual plan and therefore no additional soil borings, soil sampling or testing were obtained. Risks associated with these assumptions have been documented in the Risk Register (covered under a separate Planning Task Order). Any additional geotechnical investigation would be included in a future phase.

e4 conducted a literature search and compiled references on the geology and geotechnical aspects of the 12 sites. The results of the literature search including references, boring logs and other supporting material are in the appendices. Each site has a brief description and separate appendix and is designed to be "stand-alone", in that each site's descriptive narrative and associated appendix can be easily separated.

The primary sources of geotechnical and geology data are records of borings, wells and sediment cores obtained by the U.S. Army Corps of Engineers New York District (USACE-NAN), the New Jersey Department of Transportation (NJDOT), the New Jersey Department of Environmental Protection (NJDEP), NJDEP Geological Survey, U.S. Geological Survey (USGS), and e4sciences. This data is also represented in geological maps from all the sources in addition to the New York State Geological Survey. e4sciences compiled and modified this data to produce the geological maps in this report including the bedrock geological map shown in Figure 3. The NYS bedrock geological map and compilations incorporating it are either out of date or have not accepted revisions in the New York City area based on mapping and numerous publications by Baskerville (e.g., Baskerville, 1994, USGS map), Merguerian (e.g. Merguerian and Baskerville, 1987), Sanders (e.g. Merguerian and Sanders, 1991) and Moss (e.g. Moss and Merguerian, 2010). e4 updated and modified the New York State bedrock geology maps with the above mentioned revisions and based on e4sciences' local knowledge, much of which is related to USACE-NAN contracts. Key USACE reports are included in the references.

The primary source(s) on soil mappings were from U.S. Department of Agriculture's Natural Resources Conservation Service's (USDA-NRCS) Soil Survey Geographic (SSURGO) database.

The primary source(s) of associated contamination were the New Jersey Department of Environmental Protection (NJDEP) Site Remediation Program (SRP). Contaminant levels were obtained through the NJ Open Public Records Act (OPRA) program, and, in New York, through the New York State Superfund Program. Some data was also available in publicly published scientific investigations.

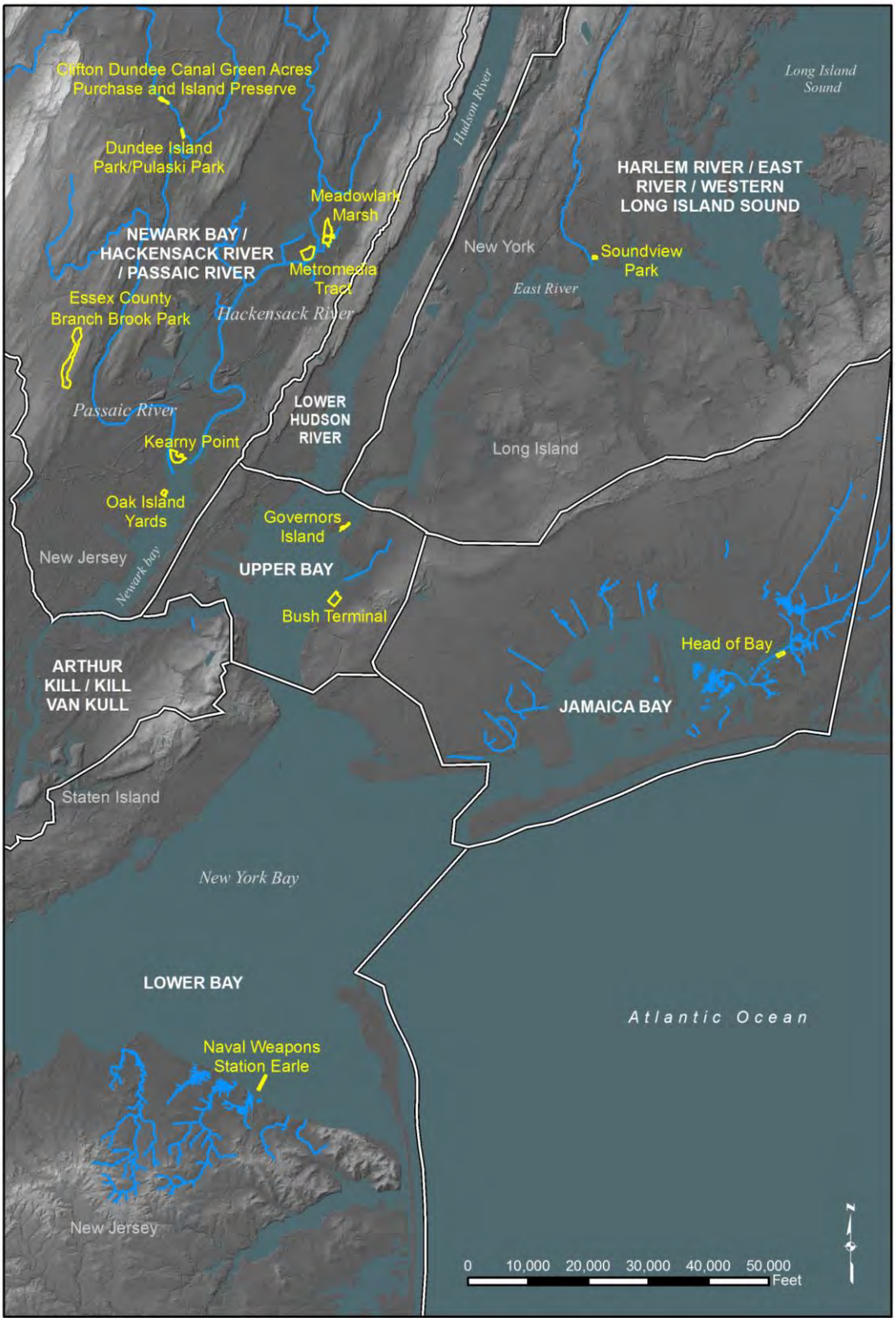


Figure 1. Location map of the HRE restoration sites in this report and corresponding HRE Planning Regions. Yellow lines outline the restoration sites, white lines outline the HRE Planning Regions, and blue lines highlight smaller rivers, streams and creeks in the areas of interest.

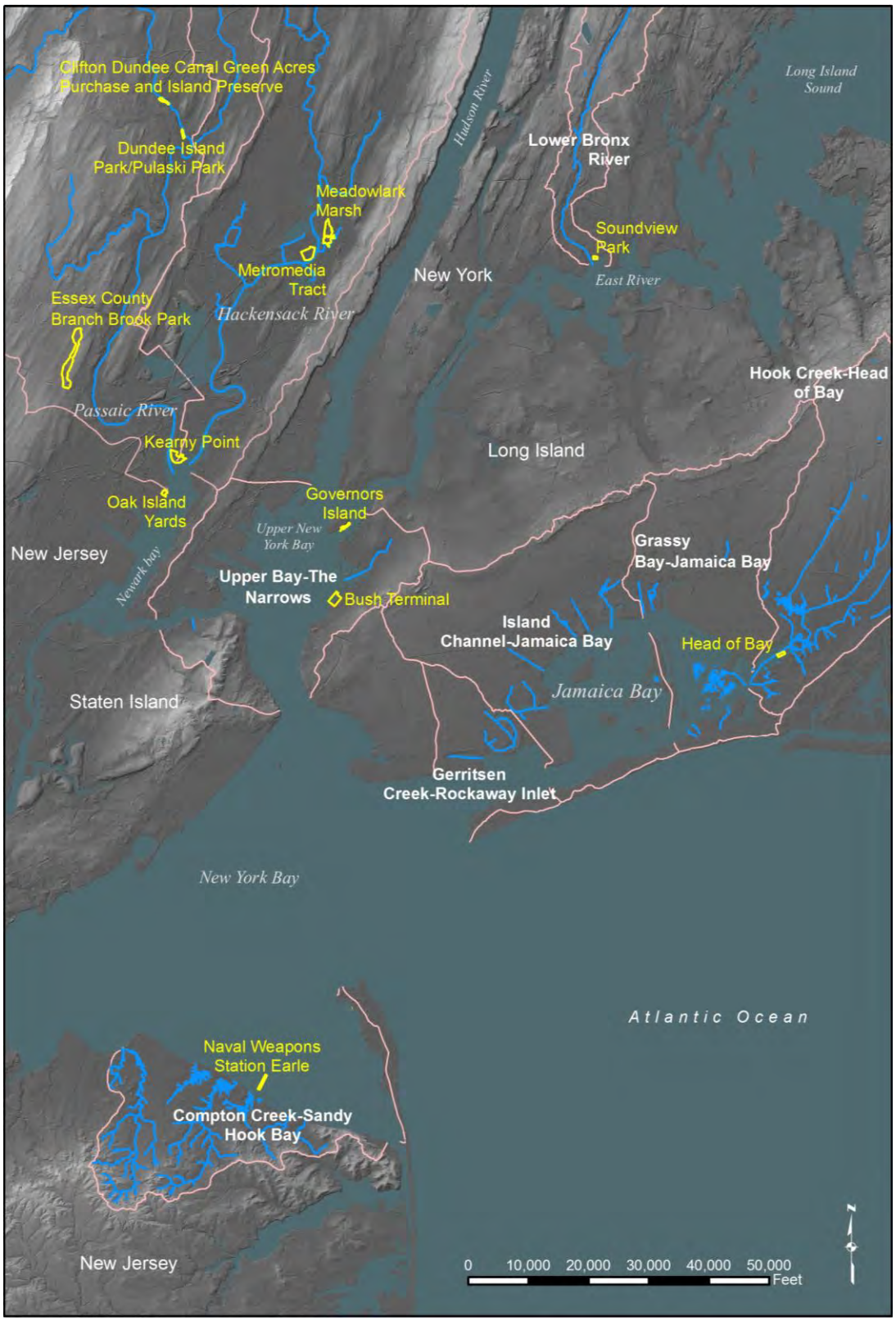
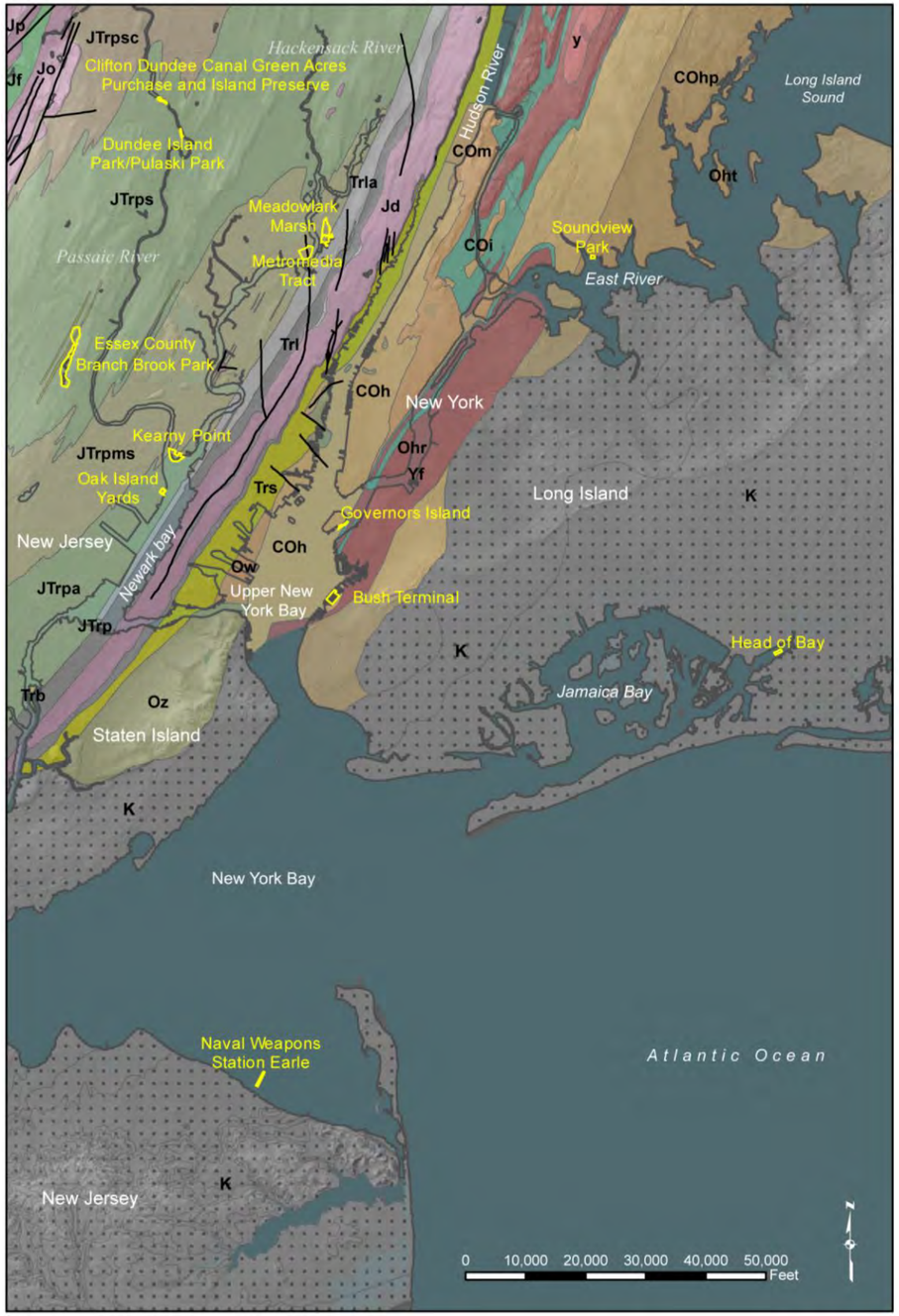


Figure 2. Location map of the HRE restoration sites in this report and corresponding watersheds. Yellow polygons indicate restoration sites, pink lines delineate watershed boundaries and blue lines highlight smaller rivers, streams and creeks in the watersheds of interest. Watershed data is from USDA Watershed Boundary Dataset (February 2016).



Bedrock Geology

Geologic Age	Label	Unit	Rock or Sediment Type
Cretaceous	K	Coastal Plain Group	clay, silt and sand
Jurassic	Jd	Palisade Diabase	diabase
	Jo		basalt
	Jp		basalt
	Jf		silistone
Lower Jurassic Upper Triassic	JTrp: JTrpsc	Passaic Formation	shale and conglomorate
	JTrp: JTrpms		shale and silstone
	JTrp: JTrps		shale and sandstone
	JTrp: JTrpa		shale with silstone and sandstone
Upper Triassic	Trl: Trl	Lockatong Formation	argillite
	Trl: Trla		sand stone
Triassic	Trs	Stockton Formation	sandstones and shales
Ordovician	Oz	Serpintinite	serpintinite
	Ow	Walloomsac Formation	graphite schist
Cambrian-Ordovician	COh: COh	Hartland Formation	gneiss and schist
	COh: COhp		
	COm	Manhattan	schist
	COi	Inwood Marble	marble
	CO?		undifferentiated metamorphics
PreCambrian	Yf	Fordham Gneiss	gneiss

Fault Lines
Oyster Sites

0 7,500 15,000 30,000 45,000 60,000 Feet

Figure 3. Regional bedrock geology map and HRE restoration sites. The bedrock geology was compiled and modified from various sources (see text for sources).

2. Oyster Habitat Restoration Sites

The USACE-NAN is considering five sites for oyster habitat restoration. Historically, Upper and Lower New York Bay was known for its oysters, which covered an extensive area along the shoreline (Figure 2.0-1). Around the 1770s, 765 million oysters per year were harvested from the waters of New York Bay (Sanderson 2016). Since then, oysters have nearly disappeared due to overharvesting, water quality deterioration, sedimentation, and other factors. Restoring the oyster population in New York Bay is considered to be advantageous for both ecosystem health and protecting New York City's shoreline.

Two of the five proposed oyster habitat restoration sites are located in Upper New York Bay. The remaining sites are at the mouth of the Bronx River, in Head of Bay within Jamaica Bay, and at Naval Weapons Station Earle in Lower New York Bay. All sites are in tidal waters of the Hudson Raritan Estuary, and border man-made structures and altered shorelines. Nearby soils on land are described, as they are potential sediment sources.

Table 2.0-1 lists the oyster restoration sites and their watersheds and associated waterways. Figure 2.0-2 shows the locations of the oyster restoration sites with respect to HRE Planning Regions. Figure 2.0-3 is a topographic map showing the oyster habitat restoration sites and their corresponding watersheds.

Table 2.0-1. List of proposed oyster habitat restorations sites in the New York waterways.

Oyster habitat restoration site	Watershed	Sub-watershed/water body
Site 864. Governors Island	Hudson River	Upper New York Bay/ Buttermilk Channel
Site 154. Bush Terminal	Hudson River	Upper New York Bay/ Bay Ridge Channel
Unnumbered site: Soundview Park	Bronx River	Confluence of Bronx and East Rivers
Unnumbered site: Head of Bay	Jamaica Bay	Hook Creek-Head of Bay
Unnumbered site: Naval Weapons Station Earle	Lower NY Bay	Compton Creek-Sandy Hook Bay

Figure 2.0-4 shows the map of bedrock underlying the oyster restoration sites. e4sciences compiled and modified this map based on numerous sources including the bedrock geology maps of the NJDEP Geological Survey and the New York State Geological Survey. The NYS bedrock geological map and compilations incorporating it are either out of date or have not accepted revisions in the New York City area based on mapping and numerous publications by Baskerville (e.g., Baskerville, 1994, USGS map), Merguerian (e.g. Merguerian and Baskerville, 1987), Sanders (e.g. Merguerian and Sanders, 1991) and Moss (e.g. Moss and Merguerian, 2010). e4 modified the map in Figure 2.0-4 with the above mentioned revisions and based on e4sciences' local knowledge, much of which is related to USACE-NAN contracts. Key USACE reports are included in the references.

Figure 2.0-5 shows the map of surficial geology encompassing the oyster habitat restoration sites. The southern termination of the last Pleistocene glacier (Wisconsin) is marked by the glacial terminal moraine (Qwtm) extending along Staten Island and Long Island. North of this, Pleistocene glaciers have scraped down to bedrock or to the semi-consolidated Tertiary and Cretaceous Coastal Plain Group sediments. North of the terminal moraine, Pleistocene glacial tills drape the bedrock and glacial lake sediments filled valleys. As the glacier receded, it also deposited a blanket of outwash sands and silts that "washed out" from the glaciers. These Pleistocene sediments overlie Coastal Plain Group strata.

On land, north of the terminal moraine, Holocene sediments are predominantly fluvial, estuarine, and marine deposits. The Holocene sediments are thin and true soils are relatively thin.

Underwater, north of the Terminal moraine, the Holocene coarser sediments are marine reworked Pleistocene sands and gravels. The fine-grained sediments are estuarine deposits. In the Hudson River channel, these Holocene deposits are up to 300ft thick. At the oyster habitat restoration sites, Holocene deposits are relatively thin (0 to 20ft). Black silt deposited during is deposited in lows and current shadows.

On land, south of the terminal moraine, there are minor Holocene sediments and true soils may be thick. Underwater Holocene deposits are predominately sands and marsh deposits. Sands are reworked out wash sands and Coastal Plain Group strata. At Jamaica Bay Holocene sediments are estimated to be 20ft thick.

The New Jersey coast south of New York Bay is predominantly erosive. On land, the soils have variable thicknesses and lie on the Coastal Plain Group deposits. Holocene stream deposits are relatively minor. Underwater along the New Jersey Coast the Holocene is dominated by reworked sands of the Coastal Plain Group.

All of the oyster habitat restoration sites are adjacent to built-up shorelines and docks or are adjacent to navigation channels with varying degrees of daily marine vessel traffic. Naval Weapons Station Earle and Governors Island sites are adjacent to active piers. The Bush Terminal restoration site is in an underwater field of pier “ruins” adjacent to piers that have been re-purposed as Bush Terminal Piers Park, which opened to the public in 2014. All of the oyster restoration sites are in shallow waters outside navigation channels and therefore should not affect marine vessel traffic.



Figure 2.0-1. Historic map of the New York Bay area depicting major oyster habitats in 1911. Shaded areas indicate the principal sources of oysters (Metropolitan Sewerage Commission 1911).



Figure 2.0-2. Location map the proposed oyster habitat restoration sites and the HRE planning regions. Base map images are 2014 orthorectified aerial images for NY (NYSDOP, 2014) and March-May 2015 orthorectified images for NJ (NJGIN, 2015), as well as images from USGS EROS (2014).

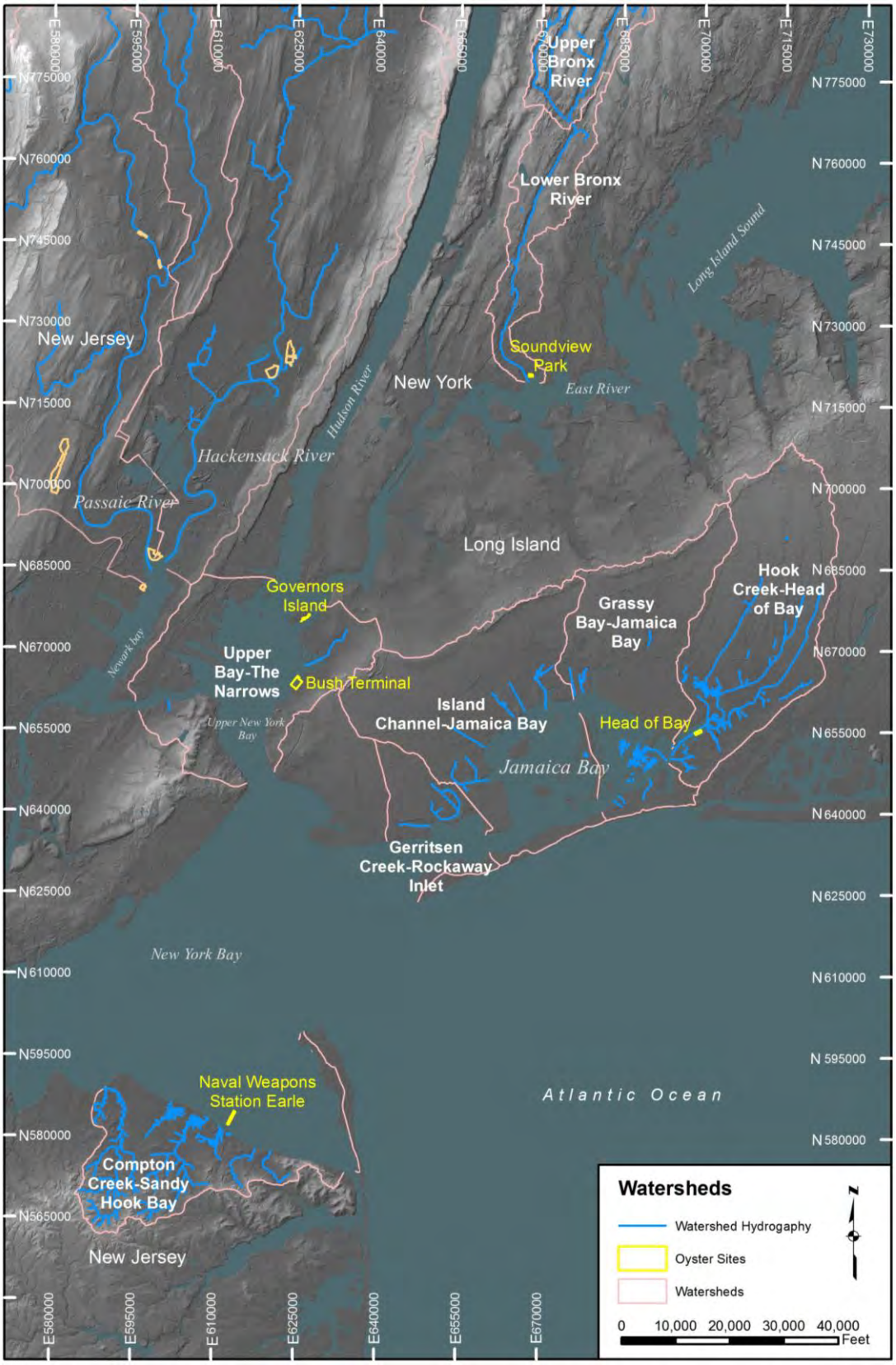
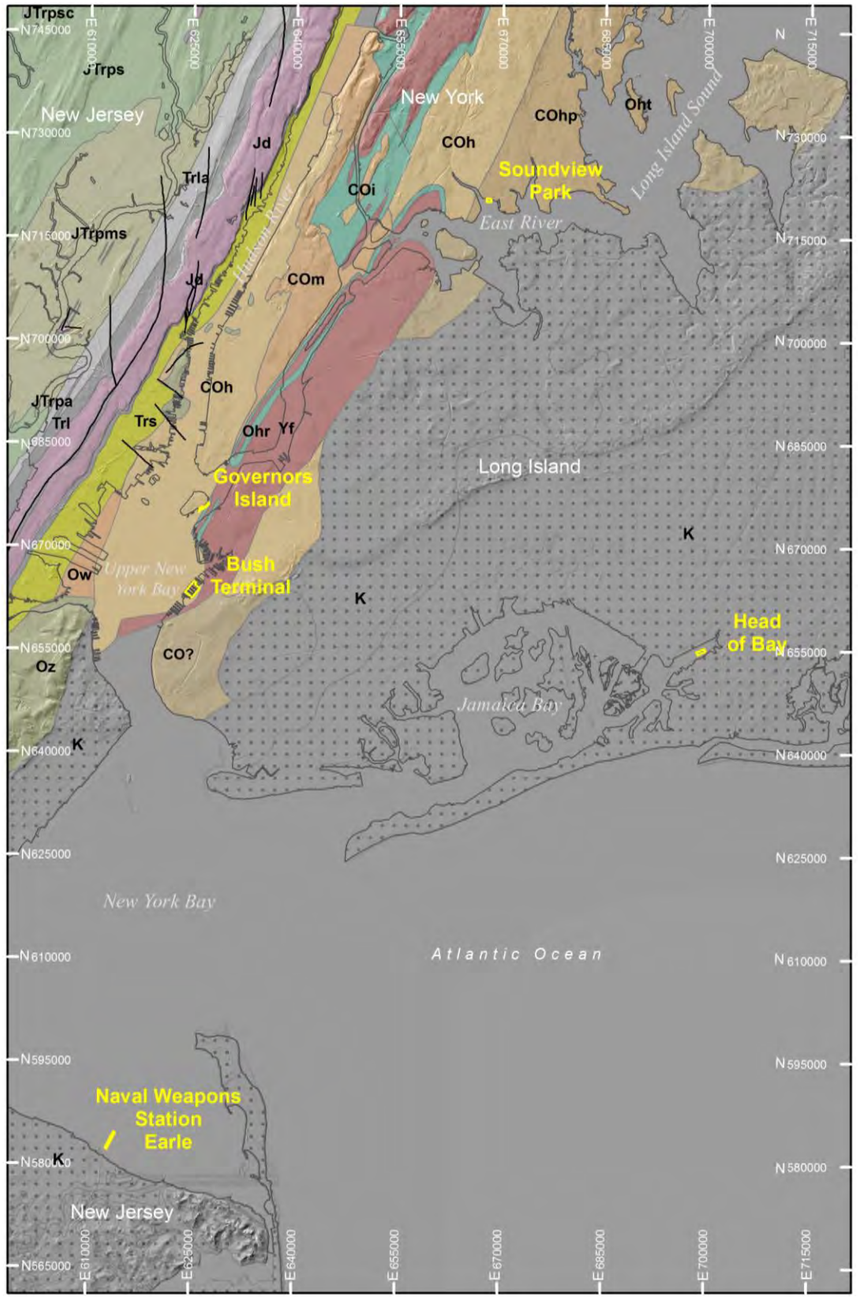


Figure 2.0-3. HRE restorations sites and associated watersheds in New York Harbor and Jamaica Bay area. Watershed boundaries are from USDA Watershed Boundary Dataset (February 2016).



Bedrock Geology

Geologic Age	Label	Unit	Rock or Sediment Type
Cretaceous	K	Coastal Plain Group	clay, silt and sand
Jurassic	Jd	Palisade Diabase	diabase
Lower Jurassic Upper Triassic	JTrp	Passaic Formation	shale and conglomorate
	JTrpsc		shale and silstone
	JTrpms		shale and sandstone
	JTrps		shale with silstone and sandstone
	JTrpa		
Upper Triassic	Trl	Lockatong Formation	argillite
	Trla		sand stone
Triassic	Trs	Stockton Formation	sandstones and shales
Ordovician	Oz	Serpintinite	serpintinite
	Ow	Walloomsac Formation	graphite schist
Cambrian-Ordovician	COh	Hartland Formation	gneiss and schist
	COh		
	COhp		
	COm	Manhattan	schist
	COi	Inwood Marble	marble
	CO?		undifferentiated metamorphics
PreCambrian	Yf	Fordham Gneiss	gneiss

Fault Lines

Oyster Sites

0 7,500 15,000 30,000 45,000 60,000 Feet

N

Figure 2.0-4. Bedrock geology map and the New York oyster ecosystem restoration sites. Map is compiled from multiple sources (see text for sources).

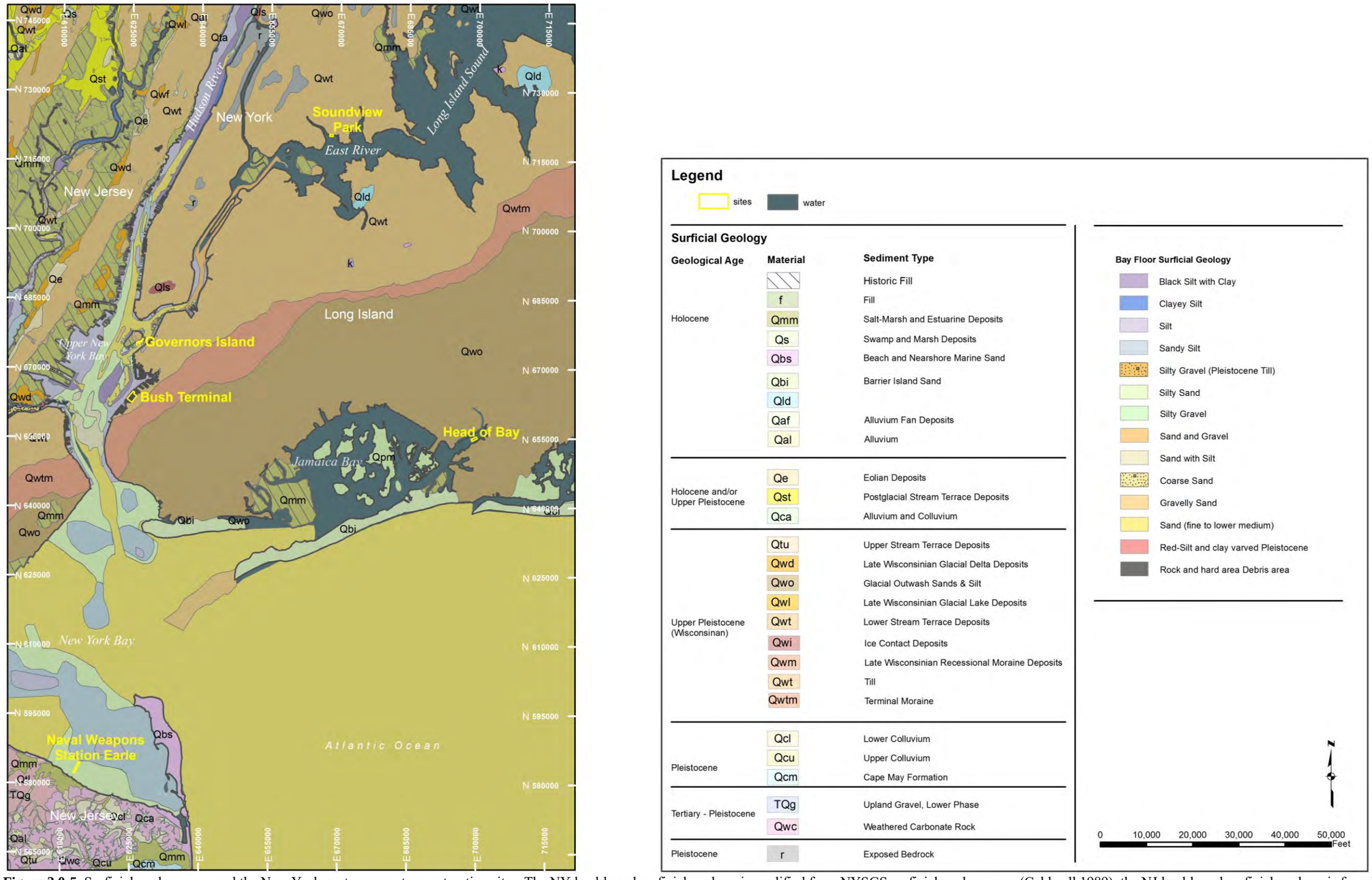


Figure 2.0-5. Surficial geology map and the New York oyster ecosystem restoration sites. The NY land-based surficial geology is modified from NYSGS surficial geology map (Caldwell 1989), the NJ land-based surficial geology is from NJDEP Gelogical Survey surficial geology map of New Jersey (DGS07-2). The water-based NYNJ Harbor bay and river floor geology map was compiled for an ongoing USACE-NAN project (e4sciences, 2016). NYSGS geology boundaries were modified to align with orthoimagery (NYSDOP 2014, NJGIN 2015, USGS EROS 2014).

2.1 Upper New York Bay

The two Upper New York Bay sites under consideration for oyster habitat rehabilitation are Site 864. Governors Island and Site 154. Bush Terminal. Both sites are between historic piers and active secondary channels.

2.1.1. Site 864. Governors Island

The proposed Governors Island oyster reef site extends from inside the "inverted-Y" pier to north along the shore. The site lies north of the southwest-northeast trending Buttermilk Channel. Table 2.1.1-1 lists key information for the Governors Island site.

Table 2.1.1-1. Key information and references for the Governors Island oyster restoration site and its surrounding area.

Feature/reference type	Name/reference
Borough	Manhattan
County	New York
State	New York
Coordinates of site	40.6877869 N 74.019521 W
USGS Quad (ID)	Jersey City (o40074f1)
NOAA charts	12327, 12334, 12335
Geological map	I-2306
USACE reports	USACE, 1999,
Watershed/water body	Hudson River /Upper New York Bay
Sub-basin/water body	Buttermilk Channel
Tidal range[a]	5.05ft

[a] MHHW-MLLW ft based on the 1983-2001 tidal epoch at NOAA/NOS/CO-OPS tidal station 8518750,The Battery, NY.

Figures 2.1.1-1 and 2.1.1-2 show nautical charts from 1845, 1906, 1912, and 2014 outlining the Governors Island oyster restoration site in New York Harbor. As seen in the 1845 chart, the original island covered just the northeastern quarter of modern-day Governors Island. The rest of the island was built up above sea level with fill between 1906 and 1912. The proposed oyster restoration site lies just offshore of both the area of the original island, and the filled-in island. Much of the area is in waters shallower than 15ft deep, although on the south side, the bottom slopes down to a 40ft-deep channel. The water depth of present-day Buttermilk Channel appears to be no more than 5ft deeper than in 1845. Another 1.59 feet should be added to that change to account for relative sea level change between 1845 and 2016 (based on NOAA's average sea level rise of 2.84mm per year determined from continuous measurements just north of Governors Island at The Battery tidal station (8518750) from 1856 to the present). The USACE-NAN maintains the Buttermilk channel with periodic dredging.

Geology

The general stratigraphy of the Governors Island oyster habitat restoration site is outlined in Table 2.1.1-2. Figure 2.0-4 shows the map of bedrock underlying Governors Island. Figure 2.1.1-3 shows a map of the surficial geology of the area. Governors Island is underlain by bedrock of schist and gneiss of the Hartland Formation and is overlain by varying thicknesses of glacial lake clay and silts and interlayered glacial outwash sands and two glacial till layers. The Hartland Formation is considered to be dominantly gray-weathering, fine-to-coarse grained, well-layered muscovite-biotite-quartz-plagioclase-garnet schist, gneiss and granofels that contains layers of greenish amphibolite and/or garnet (Merguerian and Baskerville, 1987). Note that the Baskerville, 1994, map I-2306 shows incorrectly that the uppermost bedrock beneath Governors Island is the Manhattan Schist instead of the Hartland Formation.

Table 2.1.1-2. General stratigraphy of the Governors Island oyster site based on borings along the battery tunnel, USACE 1998 borings in Buttermilk Channel and e4sciences 2015 NYCDEP report.

Age	Thickness (ft)	Geologic Unit	Description
Holocene- historic	0-10	Rip rap	Protected barrier along sea wall.
Holocene	0-4.1	Black silt	Organic silt
Holocene	0-1.7	Black silt and gravel	Organic silt and gravel
Holocene	0-3	Marine sands	Silty sands
Holocene	0-6	Marine gravel	Sandy gravel with shells
Pleistocene	0-20	Glacial outwash sand	Stratified sand and silty sands
Pleistocene	0-10	Glacial till	Silty sand and gravel to clayey gravel with cobbles & boulders
Pleistocene	0->22	Glacial lake deposits	Silt and fine sand
Cambrian-Ordovician	n.a.	Hartland Formation	Bedrock: gneiss, schist and pegmatites

The general stratigraphy of Governors Island is recorded in borings drilled for the construction of the Brooklyn-Battery tunnel that runs east of the northeastern edge of Governors Island (Sanborn, 1950; Berkey, 1948; and reinterpreted by Merguerian, 2003). The tunnel is less than 1,000ft from the oyster habitat restoration site. The sediment making up the original core of Governors Island is known from trenching for archeological studies (Thieme, 2008).

The shallow subsurface in the vicinity of the oyster site is also recorded in USACE 1998 geotechnical borings in the Buttermilk Channel that were drilled for the feasibility study of the harbor deepening project (USACE, 1999). The USACE borings are listed in Table 2.1.1-3 and shown in Figure 2.1.1-3. Logs of these borings are available in the digital Appendix I-b.

Table 2.1.1-3. Borings and sampling sites in or near the Governors Island site.

Boring ID	Source	Distance from site (ft)
BC-98-24A	USACE 1999	0
GI-14-09 sediment core	e4sciences 2015 for NYCDEP/NYSDEC	0ft, At center of "Y" in pier
GI-14-09 benthic sample	e4sciences 2015 for NYCDEP/NYSDEC	0ft, At center of "Y" in pier
GI-14-09 SPI sample	e4sciences 2015 for NYCDEP/NYSDEC	0ft, At center of "Y" in pier
BC-98-23A	USACE 1999	150
BC-98-22A	USACE 1999	540
BC-98-19	USACE 1999	600
GI-14-08 sediment core	e4sciences 2015 for NYCDEP/NYSDEC	800
GI-14-08 benthic sample	e4sciences 2015 for NYCDEP/NYSDEC	800
GI-14-08 SPI sample	e4sciences 2015 for NYCDEP/NYSDEC	800
BC-98-18	USACE 1999	1300
BC-98-17	USACE 1999	1050

For the last 16 years New York State Department of Conservation (NYSDEC) benthic habitat studies have sampled the sediments and biota just offshore Governors Island (Bell et al. 2000, 2003, 2004a, 2004b; e4sciences, 2015). The latter study was conducted by e4sciences in 2014 and 2015 for NYSDEC and New York City Department of Environmental Protection (NYCDEP). e4 produced bathymetrical maps and sonar images of the bay floor surrounding Governors Island, and e4 seismically imaged and interpreted the shallow subsurface (Figure 2.1.1-4, Appendix I-e, e4sciences, 2015). Interpretation of the stratigraphy was based on the borings in Table 2.1.1-3. The sonar image map shows that outside the riprap along the shore, the bay floor is mainly sand or sand and gravel locally covered with black silt. On the north end of the oyster site, rock is exposed in and at the edge of Buttermilk Channel. Overall, the sediment type of the area of the oyster site includes black silt, sand, silty sand, rip rap, and "hard bottom" of man-made debris and exposed bedrock (Appendix I-f, e4sciences, 2015).

At sample site GI-14-09, on the out-board side of the Y-shaped pier at the southwest end of the oyster site, e4 collected a) a sediment core, b) a grab sample for grain size and benthic invertebrate analysis, and c) made sediment profile images (SPI). The analysis of GI-14-09 shows that the grain size of the top 10cm of surface sediment is 1.4% gravel, 27.7% sand, 50.8% silt, and 20.0% clay. The GI-14-09 sample site has an intermediate Organism-Sediment Index (OSI)

stress level classification, whereas the nearby GI-14-08 sample site, which is southwest of GI-14-09, is considered a stressed site (Appendix I-g).

Soil analysis

According to the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) SSURGO database[1], the closest land to the proposed oyster site is made up of Urban Land and Laguardia soil types. The Urban land soil type originates from asphalt over human-transported material, the Laguardia type comes from loamy human-transported material (fill). Soil profiles and properties of the two soil types can be found in Tables 2.1.1-4 to 2.1.1-7. Complete soil reports of each type of soil found at this site are Appendix I-c. The distribution of the two soil types within the Governors Island oyster site is unmapped.

Table 2.1.1-4. Soil profile of Governors Island's Urban Land soil type, which is located on the coast closest to the offshore proposed oyster restoration site.

Soil Layer	Depth (inches)	Description
Surface	0-15	Cemented material
Subsurface	15-79	Gravelly sandy loam

Table 2.1.1-5. Summary of properties of the urban land soil type located on closest shore of Governors Island to the offshore proposed oyster restoration site.

Property	Description
Slope	0-3%
Available water capacity	Very low (about 0.0 inches)
Surface Runoff	Very high
Organic matter content	0.10%
Percent clay	5.00% of clay, silt and sand fraction
Percent sand	70.00% of clay, silt and sand fraction
Percent silt	25.00% of clay, silt and sand fraction

Table 2.1.1-6. Soil profile of the Laguardia soil type located on closest shore of Governors Island to the offshore proposed oyster restoration site.

Soil Layer	Depth (inches)	Description
Surface	0-8	Cobbly-artifactual coarse sandy loam
Subsurface	8-79	Very cobbly-artifactual coarse sandy loam

Table 2.1.1-7. Summary of properties of the Laguardia soil type located on closest shore of Governors Island to the offshore proposed oyster restoration site.

Property	Description
Natural drainage class	Well drained
Flooding	None
Slope	0-3%
Depth to water table	>80 inches
Available water capacity	Low (about 3.1 inches)
Surface Runoff	Low
Organic matter content	09.15%
Percent clay	07.60% of clay, silt and sand fraction
Percent sand	75.50% of clay, silt and sand fraction
Percent silt	16.90% of clay, silt and sand fraction

[1] Information about the types of soil found at the Governors Island oyster site was obtained through the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS). The USDA-NRCS operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of U.S. counties and is produced by the National Cooperative Soil Survey.

The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

Surface water quality data

The Governors Island oyster site is part of the estuarine Upper New York Bay. The New York Harbor Sea, Estuary, Air, and Land (SEALs) Voluntary Environmental Monitoring Program has been measuring water, air, and sediment quality parameters as part of the Upper Hudson River Estuary Water/Air Quality Monitoring Program. One of their monitoring sites is on the eastern shore of Governors Island (station G2), approximately 750ft away from the proposed oyster restoration site. The key measurements are listed in Table 2.1.1-8. These parameters were measured every few minutes on certain sampling days from February, 2013, to April 2014; the measured values are averaged by month in Table 2.1.1-8. Complete surface water quality reports containing individual data points are in Appendix I-d.

Table 2.1.1-8. Summary of water quality parameters in February 2013 – April 2014, measured on the eastern shore of Governors Island at station G2 by the NY Harbor SEALs Voluntary Environmental Monitoring Program.

Date	02/26/13	03/21/13	4/18/13	09/26/13	10/22/13	11/19/13	12/05/13	3/12/14	4/29/14
Acidity (pH)	7.60	6.80	7.0	6.20	6.80	6.20	6.50	7.00	7.03
DO Conc. (ppm)	16.00	14.00	-	8.40	6.90	6.00	8.33	-	-
Temperature (°F)	39.20	44.60	45.50	45.50	66.20	21.80	47.61	-	48.65

Groundwater quality data

Figure 2.1.1-5 shows the locations of known contamination sites in or near the Governors Island site (NYSDEC 2013). Governors Island (more specifically Fort Jay) is listed as a state superfund site. Governors Island was used as an active military base for over 200 years, which included a variety of activities of environmental concern (fuel storage, maintenance, etc.). A subsurface investigation conducted in 2011 identified heavy metals, semi-volatile organic compounds (SVOC's), pesticides, polychlorinated biphenyls (PCBs) and residual petroleum. In addition, there remains the possibility of unexploded ordnance (UXO) both on land and in the waters surrounding Governors Island, which is described in the "Proposed Phased Redevelopment of Governors Island" (2011). However, this study does not mention specific environmental testing performed on the study area.

Summary

1. The Governors Island oyster restoration site lies between the rip-rap lined seawall of the island and Buttermilk Channel.
2. The site is underlain by schist (Hartland Formation) that is 0 to 40ft below the bay floor. At the northern end of the site, rock is exposed on the channel floor. Overlying the rock are variable thicknesses of interlayered Pleistocene glacial deposits that include glacial lake clay and silt, glacial outwash sand and silt, and glacial till. The overlying Holocene sediments are generally less than 10ft thick. Coarse Holocene sediments appear to be reworked Pleistocene sediments. Locally, a thin layer of black silt overlies the Holocene sands.
3. The land surface of Governors Island that is adjacent to the oyster site is made up of Urban Land and Laguardia soil complexes (fill).
4. Governors Island, specifically Fort Jay, is considered a State Superfund Program site. Due to its history as an active military base for over 200 years, the subsurface of the island contains various heavy metals and harmful organic compounds. It is unknown if these contaminants affect the overall health of the offshore oyster habitat restoration site.

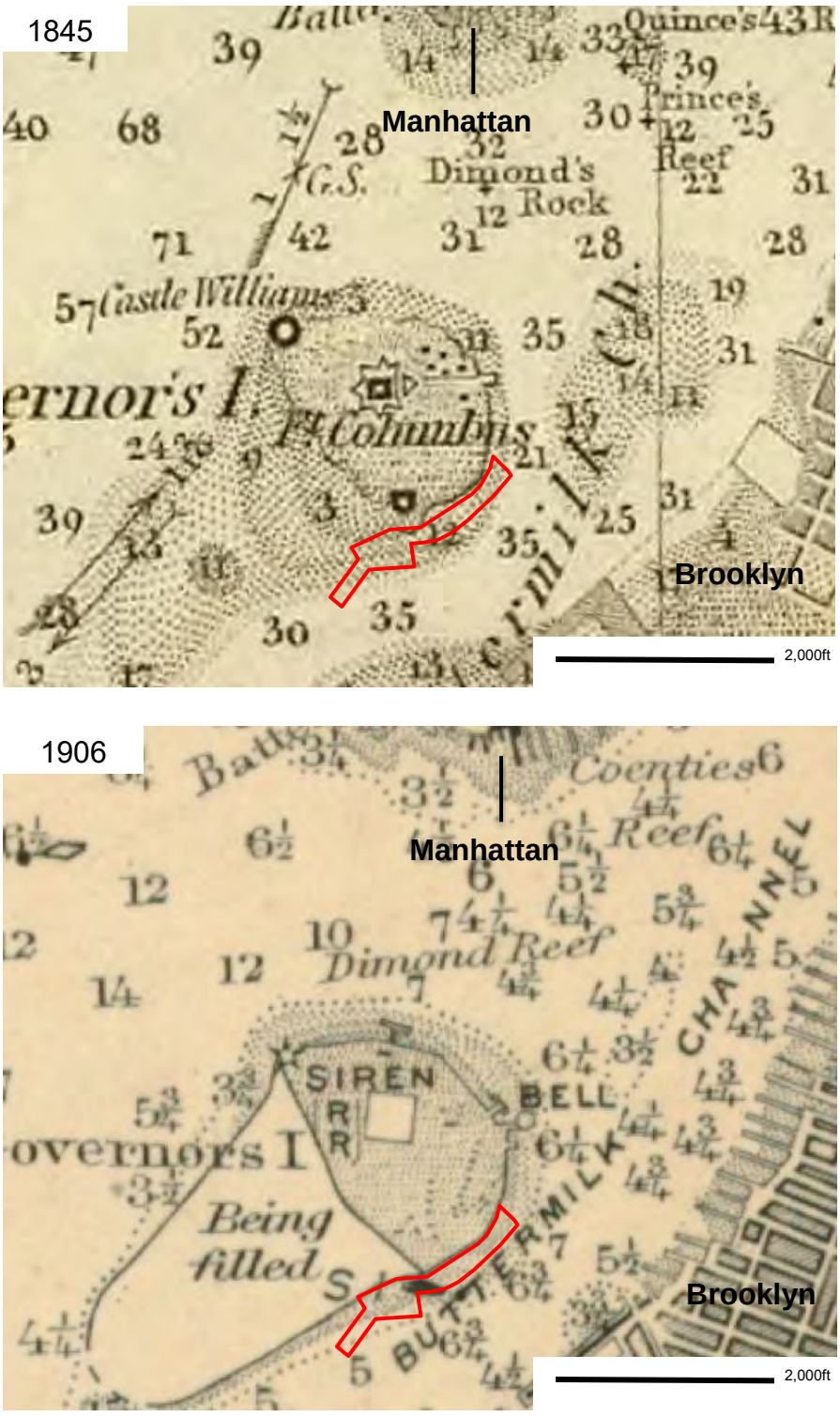


Figure 2.1.1-1. NOAA nautical charts from 1845 and 1906 (No. 120) showing Governors Island and its surrounding bathymetry in New York Harbor. Red lines delineate the area of oyster restoration opportunity.

In the 1845 chart, depth soundings are in feet below MLW; in the 1845 chart, MLW was at the lowest spring tides observed during the survey, and mean sea level was approximately 1.6ft lower than it is today (based on mean sea level records at The Battery, NY 1856-2014). In 1906, depth soundings are in fathoms below MLW.

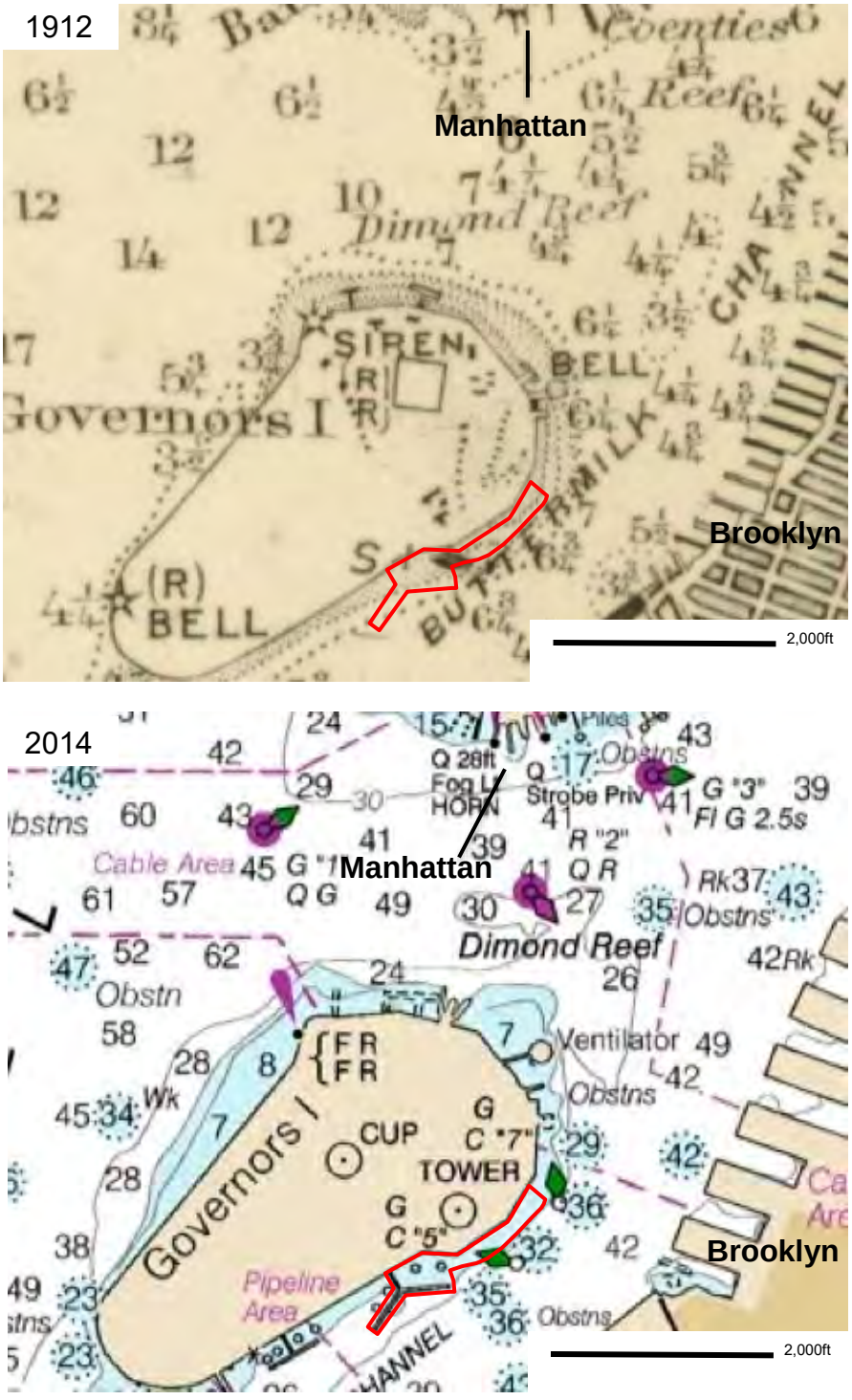


Figure 2.1.1-2. NOAA nautical charts from 1912 (No. 120) and 2014 (No. 12327) showing Governors Island and its surrounding bathymetry in New York Harbor. Red lines delineate the area of oyster restoration opportunity.

In the 1912 chart, depth soundings are in fathoms below MLW and in the 2014 chart, depth soundings are in feet below MLLW.

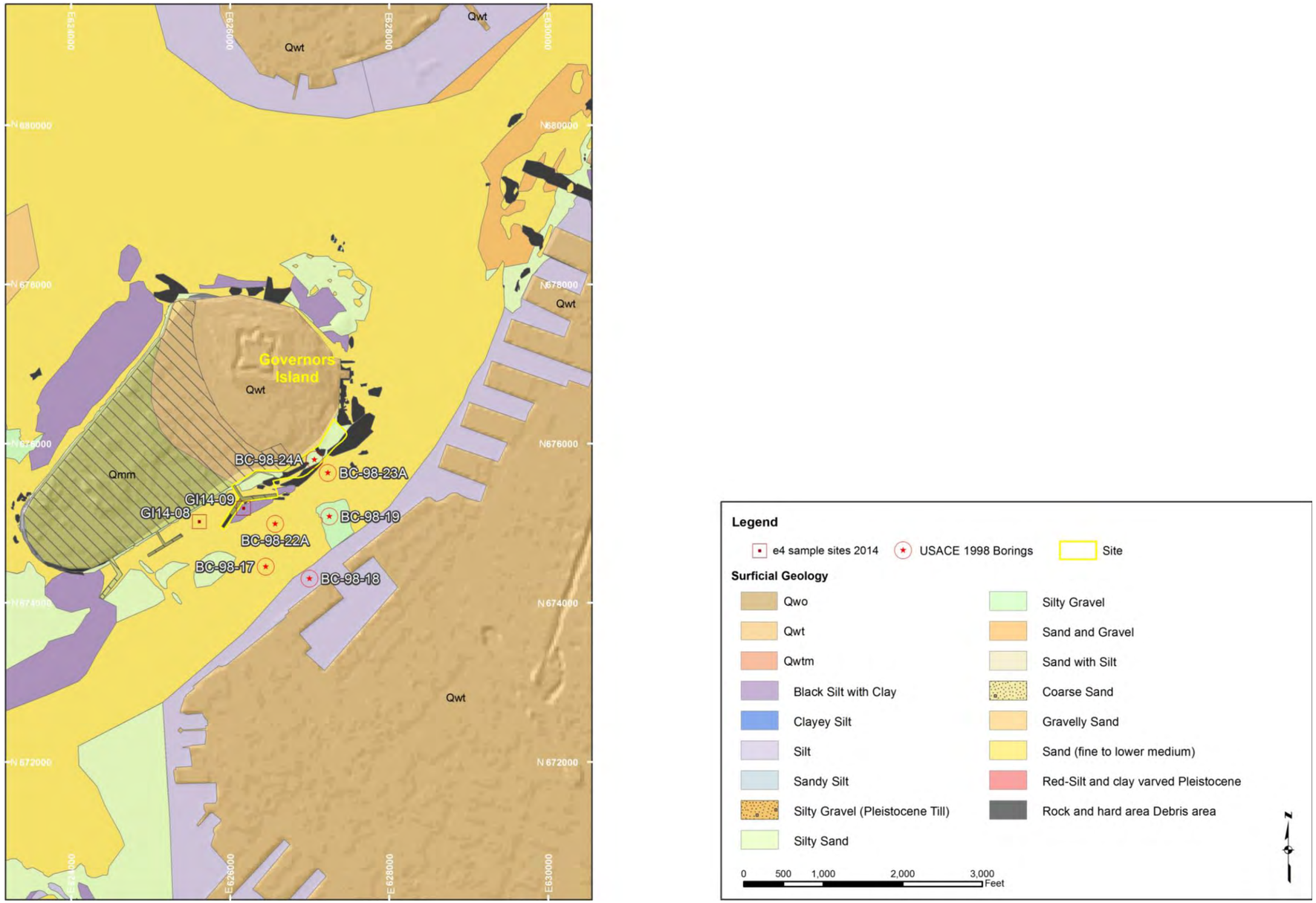


Figure 2.1.1-3. Surficial geology and boring locations of the Governors Island site. Land surficial geology is from a NYSGS surficial geology map (Caldwell 1989). Bay floor sediment map is from an ongoing USACE-NAN project (e4sciences, 2016), Boundaries were modified to align with orthoimagery (NYSDOP 2014, USGS EROS 2014).



Figure 2.1.1-4. Side-scan orthosonograph of channel floor adjacent to the south shore of Governors Island. The channel floor was insonified from the south and east (e4sciences, 2015). White circles indicate sample sites.



Figure 2.1.1-5. Wetland areas and the NYSDEC recognized Known Contaminated Site at Governors Island site. Base map images are 2014 orthorectified aerial images (NYSDOP, 2014), as well as images from USGS EROS (2014). Wetland data is from U.S. Fish and Wildlife Service, National Wetlands Inventory (2011). Groundwater contamination information is from NYSDEC Environmental Site Database Search (Remediation Site Boundaries, 2013).

2.1.2 Site 154. Bush Terminal

The proposed Bush Terminal oyster habitat restoration site is located between Bay Ridge Channel and Bush Terminal Piers Park on the shore of the Sunset Park neighborhood in Brooklyn, NY. Table 2.1.2-1 lists key information for the Bush Terminal site.

Table 2.1.2-1. Key information and references for the Bush Terminal oyster restoration site and its surrounding area.

Feature/reference type	Name/reference
Borough	Brooklyn
County	Kings
State	New York
Coordinates of site	40.6540861N 74.020731W
USGS Quad (ID)	Jersey City (o40074f1)
NOAA charts	12327, 12334
Geological map	I-2306
USACE reports	USACE, 1999
Watershed/water body	Hudson River /Upper New York Bay
Sub-basin/water body	Buttermilk Channel
Tidal range[a]	5.05ft

[a] MHHW-MLLW ft based on the 1983-2001 tidal epoch at NOAA tidal station 8518750 The Battery, NY.

Figure 2.1.2-1 shows nautical charts from 1845, 1894, 1924, and 2014 outlining the Bush Terminal oyster restoration site in Brooklyn, NY. The coastline of Sunset Park in Brooklyn changed significantly between 1845 and 1894 with the development of piers and gridded streets. The number of piers along this coastline increased between 1894 and 1924, but some of these piers have collapsed and become submarine "ruins" as indicated by dotted lines in the 2014 nautical chart (Figure 2.1.2-1). The current plan for the oyster site envisions the pier ruins as being the foundation for the gabion blocks, oyster condos, and spat-on-shell structures of the proposed oyster site.

The USACE-NAN maintains the Bay Ridge channel with periodic dredging of black silt and sand.

Geology

The general stratigraphy of the Bush Terminal proposed oyster habitat restoration site is outlined in Table 2.1.2-2. Figure 2.0-4 is a geological map showing bedrock underlying the Bush Terminal site. Figure 2.1.2-2 shows a map of the surficial geology of the area. Beneath the Bush Terminal site at a depth greater than 120ft lies bedrock of schist and gneiss of the Hartland Formation, overlain by a thick sequence of Pleistocene glacial deposits. The Pleistocene deposits include a thick layer of glacial lake clay and silts and thinner layers of glacial outwash sands and glacial till. The Pleistocene is overlain by up to 20ft of Holocene deposits. The Holocene deposits consist of marine estuarine sands and silty sands that contain shells. Overlying the sands is black silt that locally includes hydrocarbons, as evidenced by petroleum odors.

Table 2.1.2-2. General stratigraphy of the Bush Terminal oyster site based on USACE borings and e4sciences, 2015.

Age	Thickness (ft)	Geologic Unit	Description
Holocene- historic	Varying	Fallen piers and debris	Ruins of historic piers
Holocene- historic	3-10	Black silt	Organic silt, locally with petroleum odor
Holocene	3-20	Marine sands	Silty sand and sand with shells
Pleistocene	0-20	Glacial outwash sand	Stratified sand and silty sands
Pleistocene	>65	Glacial lake deposits	Varved silt and clay
Pleistocene	Unknown	Glacial till	Silty sand and gravel to clayey gravel with cobbles & boulders
Cambrian-Ordovician	n.a.	Hartland Formation	Bedrock: gneiss, schist ands pegmatites

The Hartland Formation is considered to be dominantly gray-weathering, fine-to-coarse grained, well-layered muscovite-biotite-quartz-plagioclase-garnet schist, gneiss and granofels that contains layers of greenish amphibolite and/or garnet (Merguerian and Baskerville, 1987).

The general stratigraphy of the Bush Terminal oyster site is sampled by USACE 1998 geotechnical borings in the Bay Ridge Channel that were drilled for the feasibility study of the harbor deepening project (USACE, 1999). The USACE borings are listed in Table 2.1.2-3 and shown in Figure 2.1.2-2. Logs of these borings are available in the digital Appendix II-b.

Table 2.1.2-3. Borings and sampling sites in or near the Bush Terminal site.

Boring or sample ID	Source	Distance from site (ft)
SPW14-04 sediment core	e4sciences 2015 for NYCDEP/NYSDEC	0
SPW14-04 benthic sample	e4sciences 2015 for NYCDEP/NYSDEC	0
SPW14-04 SPI sample	e4sciences 2015 for NYCDEP/NYSDEC	0
SPW14-05 sediment core	e4sciences 2015 for NYCDEP/NYSDEC	0
SPW14-05 benthic sample	e4sciences 2015 for NYCDEP/NYSDEC	0
SPW14-05 SPI sample	e4sciences 2015 for NYCDEP/NYSDEC	0
SPW14-06 sediment core	e4sciences 2015 for NYCDEP/NYSDEC	70
SPW14-06 benthic sample	e4sciences 2015 for NYCDEP/NYSDEC	70
SPW14-06 SPI sample	e4sciences 2015 for NYCDEP/NYSDEC	70
BR-98-34	USACE 1999	150
BR-98-35	USACE 1999	350
SPW14-03 sediment core	e4sciences 2015 for NYCDEP/NYSDEC	350
SPW14-03 benthic sample	e4sciences 2015 for NYCDEP/NYSDEC	350
SPW14-03 SPI sample	e4sciences 2015 for NYCDEP/NYSDEC	350
BR-98-33	USACE 1999	450
BR-98-29	USACE 1999	700
BR-98-30	USACE 1999	1010

For the last 16 years New York State Department of Conservation (NYSDEC) benthic habitat studies have sampled the sediments and biota just offshore of Sunset Park Brooklyn in the area of Bush Terminal (Bell et al 2000, 2003, 2004a, 2004b, e4sciences, 2015 The latter study was conducted by e4sciences in 2014 and 2015 for NYSDEC and New York City Department of Environmental Protection (NYCDEP). e4 produced bathymetrical maps and sonar images of the bay floor along Sunset Park, and e4 seismically imaged and interpreted the subsurface (Figure 2.1.2-3, Appendix II-e, e4sciences, 2015). Interpretation of the stratigraphy was based on the borings in Table 2.1.2-3. The sonar image map shows the collapsed piers and debris partially covered by black silt. Black silt lies between the pier ruins. Overall, the sediment type in the area of the oyster site includes black silt, silt, sand, silty sand, and “hard bottom” of man-made debris and fallen piers (Appendix II-f, e4sciences, 2015).

e4 also collected a) a sediment core, and b) a grab sample for grain size and benthic invertebrate analysis, and made sediment profile images (SPI) at several sites. Two of the sediment cores, SPW14-04 and SPW14-05, were collected within the proposed oyster site and are located approximately 500ft and 250ft east of the edge of Bush Terminal Piers Park, respectively. An analysis of both SPW14-04 and SPW14-05 shows that the sediment cores were composed of almost 90% silt. The remaining 10% consisted of mostly clay and sand. In addition, the sediment type in the area of the oyster site is black silt and silt (e4sciences 2015; Appendix II-f.).

The SPW14-04 and SPW14-05 sample sites both had an intermediate OSI stress level classification. Nearby SPW14-03 and SPW14-06 sample sites were of the low stressed classification (Appendix II-g).

Soil analysis

According to the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) SSURGO[2] database, the Laguardia soil unit is found on the shore of Bush Terminal Piers Park. The parent material of this complex is loamy-skeletal human-transported material (fill). A soil profile and additional properties of the Laguardia soil unit can be found in Tables 2.1.2-4 and 2.1.4-5. Complete soil reports of each type of soil that occur at this site are in Appendix II-c.

Table 2.1.2-4. Soil profile of the Laguardia soil unit, which is located on the shore of Bush Terminal Piers Park that is closest to the offshore proposed oyster restoration site.

Soil Layer	Depth (inches)	Description
Surface	0-8	Cobbly-artifactual coarse sandy loam
Subsurface	8-79	Very cobbly-artifactual coarse sandy loam

Table 2.1.2-5. Summary of soil properties of shore (Laguardia soil unit) of Bush Terminal Piers Park closest to the offshore proposed oyster restoration site.

Property	Description
Natural drainage class	Well drained
Flooding	None
Slope	8-15%
Depth to water table	More than 80 inches
Available water capacity	Low (about 3.1 inches)
Surface Runoff	Medium
Organic matter content	09.15%
Percent clay	07.60% of clay, silt and sand fraction
Percent sand	75.50% of clay, silt and sand fraction
Percent silt	16.90% of clay, silt and sand fraction

Surface water quality data

The Bush Terminal oyster site is part of the estuarine Upper New York Bay. The NYC Department of Environmental Protection (DEP) has been collecting and publishing water quality data from 70 sampling stations all over New York Harbor every year since 2004 as part of the Harbor Water Quality Survey. One of these sites, G2, is located at the Gowanus Canal, which is approximately 1.2 miles up the Kings County coast from the proposed oyster restoration site at Bush Terminal Piers Park. This water data is in Appendix II-d.

Groundwater quality data

Figure 2.1.2-4 shows the locations of known contamination sites in or near the Bush Terminal site. Bush Terminal is listed as an Environmental Restoration Program site. The address of the restoration site is 47th to 52nd Street and 1st Ave to Gowanus Bay, Kings County New York. The site code is B00031. The site name is Bush Terminal Landfill Piers 1-4. This report did not identify the exact nature and extent of the contamination. Remediation activities are ongoing.

[2] Information about the types of soil found at the Bush Terminal oyster site was obtained through the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS). The USDA-NRCS operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of U.S. counties and is produced by the National Cooperative Soil Survey.

The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

The same site is also listed as a State Superfund Program. The site code is 224011. The site name is Rear of Bush Terminal Building. The known contaminants include 2,4,-Dimethylphenol, Napthalene, Phenol, 4-Methylphenol, and heavy metals.

There is also a NYS Open Petroleum Spill Location noted at the Bush Terminal site. The spill name is Brooklyn West 07 DOS-DDC, the spill number is 9614638, and the spill address is 5100 1st Avenue. The spill occurred on 03/19/1997 and involved an unknown amount of gasoline and diesel fuel. The record was closed on 03/04/2014 after sufficient remediation activities had occurred.

Summary

1. The Bush Terminal oyster restoration site includes pier ruins between the Bay Ridge Channel and the re-purposed Bush Terminal Piers Park.
2. Bedrock (Hartland Formation), is greater than 120ft deep. Overlying the rock is a thick sequence of Pleistocene sediments that is dominated by glacial lake clay and silt. This sequence is overlain by Holocene sands and Holocene black silt.
3. The surface of Bush Terminal Piers Park is made up of the Laguardia soil complex (fill).
4. Bush Terminal Piers Park is both a State Superfund Program site and an Environmental Restoration Program site. It is also considered a NYS Open Petroleum Spill Location. How this affects the overall health of the site is unknown.

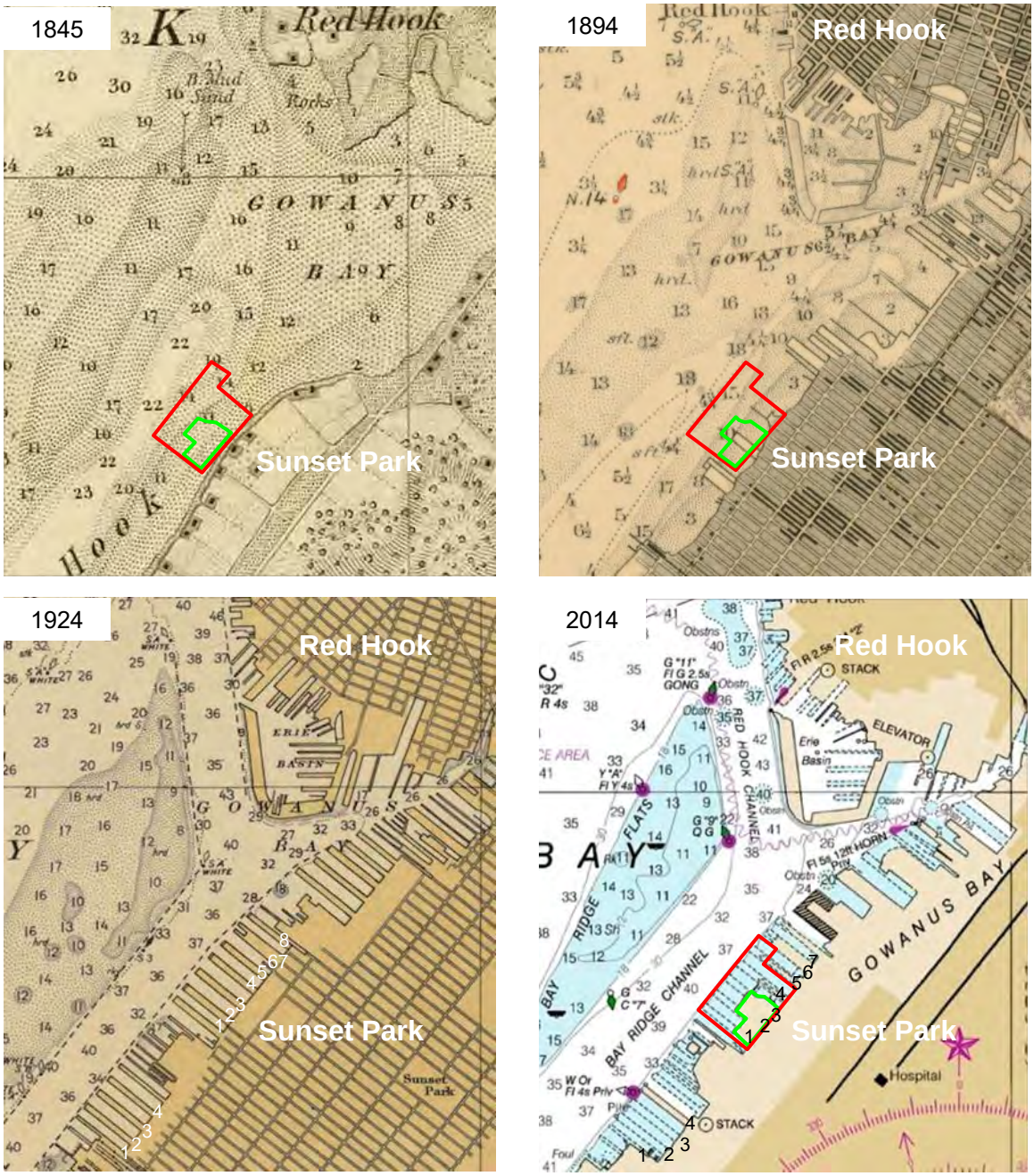


Figure 2.1.2-1. Left to right starting with top row: NOAA nautical charts from 1845, 1894 (No. 120), 1924 (No. 369), and 2014 (No. 12327) highlighting Bush Terminal Piers Park and its surrounding bathymetry in New York Harbor. Green lines mark the perimeter of Bush Terminal Piers Park and red lines delineate the area of potential oyster restoration opportunity. Numbers correspond to piers.

In the 1845 chart, depth soundings are in feet below MLW; in 1845, MLW was at the lowest spring tides observed during the survey, and mean sea level was approximately 1.6ft lower than it is today (based on mean sea level records at The Battery, NY 1856-2014). In the 1894 chart, depth soundings are in fathoms below MLW. In the 1924 chart, depth soundings are in feet below MLW. In the 2014 chart, depth soundings are in feet below MLLW.

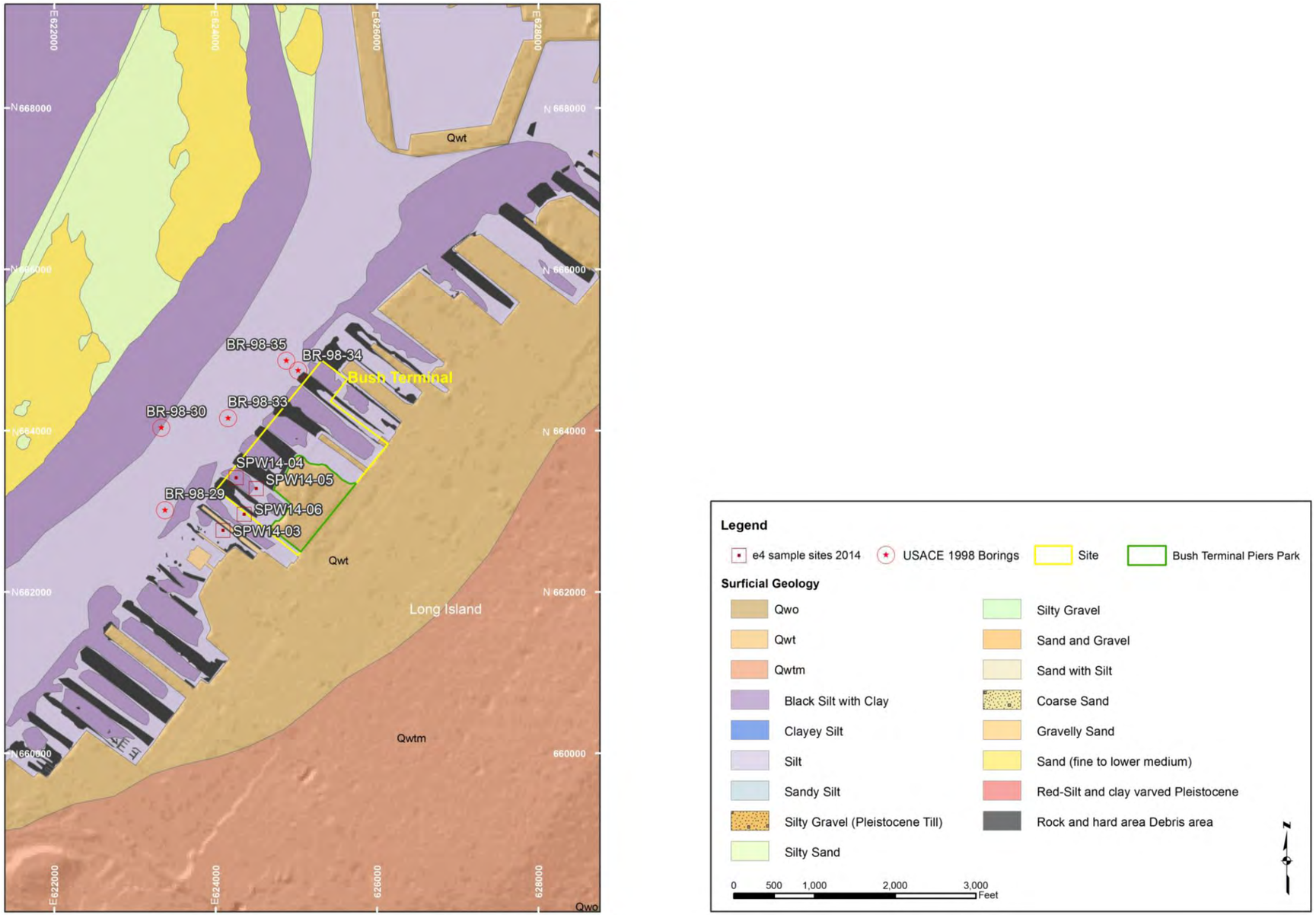


Figure 2.1.2-2. Surficial geology and boring locations of the Bush Terminal site. . The NY land-based surficial geology is modified from NYSGS surficial geology map (Caldwell 1989). The water-based NYNJ Harbor bay and river floor geology map was compiled for an ongoing USACE-NAN project (e4sciences, 2016). NYSGS geology boundaries were modified to align with orthoimagery (NYSDOP 2014, USGS EROS 2014).

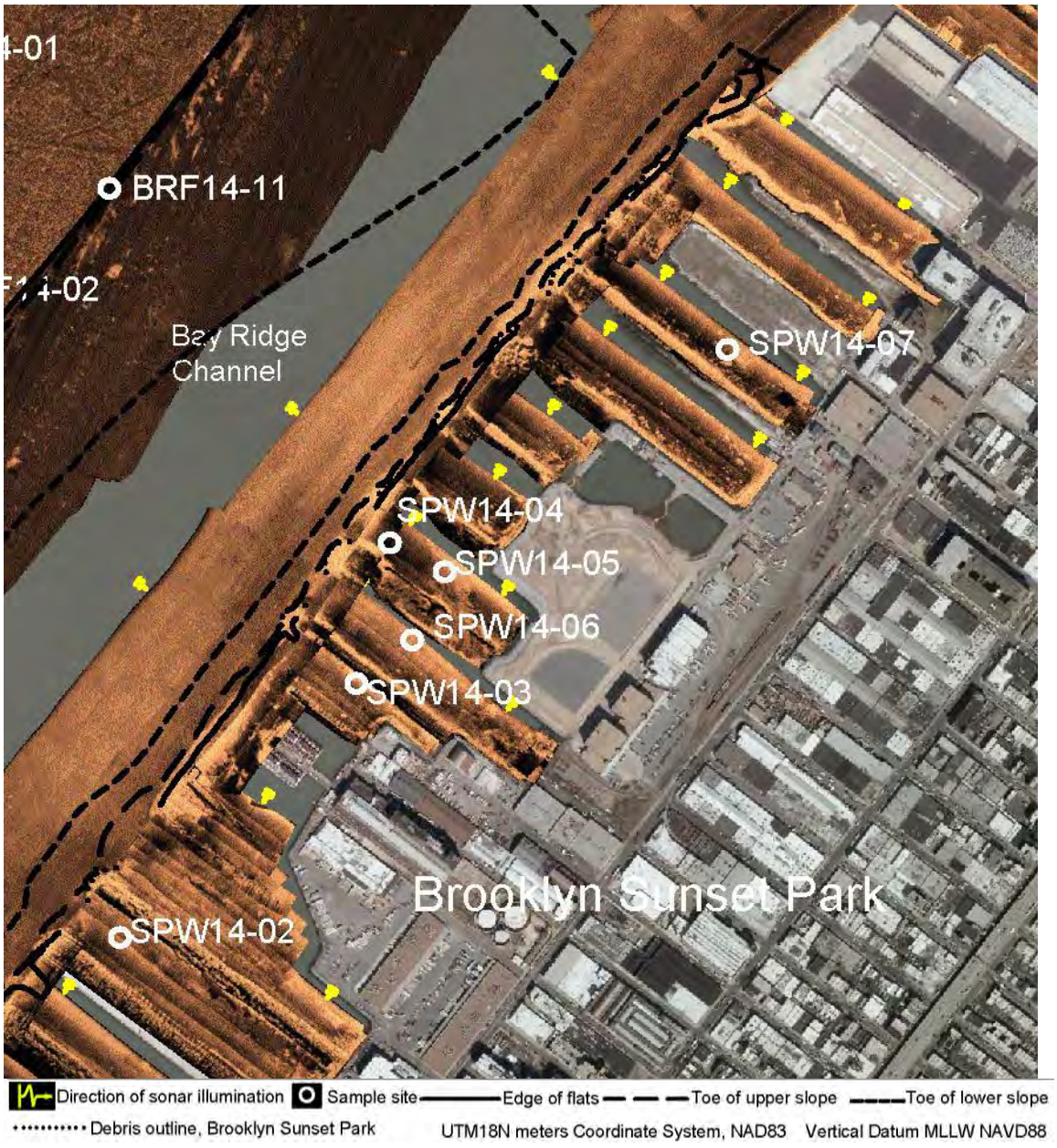


Figure 2.1.2-3. Side-scan orthosonograph of the bay floor and the pier "ruins" of Bush Terminal Piers Park, insonified from the north and west (e4sciences, 2015). White circles indicate sample sites.



Figure 2.1.2-4. Wetland areas and the Known Contaminated Site at the Bush Terminal site. Base map images are 2014 orthorectified aerial images (NYSDOP, 2014), as well as images from USGS EROS (2014). Wetland data is from U.S. Fish and Wildlife Service, National Wetlands Inventory (2011). Groundwater contamination data is from NYSDEC Environmental Site Database Search (Remediation Site Boundaries, 2013).

2.2 Bronx River Basin

2.2.1 Soundview Park

The proposed Soundview Park oyster site is located just offshore of Soundview Park in Bronx, NY, where the Bronx River meets the East River. Table 2.2.1-1 contains key information for the Soundview Park site.

Table 2.2.1-1. Key information and references for the Soundview Park oyster restoration site and its surrounding area.

Feature/reference type	Name/reference
Borough/City	Bronx, New York City
County	Bronx
State	New York
Coordinates of site	40.806386 N 73.861499W
USGS Quad (ID)	Flushing (o40073g7)
NOAA chart	12339
Geological map	I-2003
USACE reports	e4sciences, 2014
Watershed/water body	Bronx River
Sub-watershed	Bronx River/East River
Tidal range[a]	7.39ft

[a] MHHW-MLLW ft based on tides recorded May 2014 – July 2014 at NOAA/NOS/CO-OPS tidal station 8517251 Worlds Fair Marina, Flushing Bay, NY. For live tides see NOAA/NOS/CO-OPS tidal station 8516945 Kings Point, NY.

Figure 2.2.1-1 shows nautical charts from 1861, 1910, 1934, 1946, 1958, and 2013 outlining the Soundview Park oyster restoration site in Bronx, NY. The coastlines of present-day Soundview Park and Hunts Point have changed significantly since 1861. For Soundview Park, the largest change occurred between 1934 and 1946 when the marsh area was filled in to raise the land to create the present-day Soundview Park (Figure 2.2.1-1).

Geology

The general stratigraphy of the Soundview Park proposed oyster site is outlined in Table 2.2.1-2. Figure 2.0-4 is a geological bedrock map showing the rock underlying the Soundview Park site. Figure 2.2.1-2 shows a map of the surficial geology of the area and the locations of borings.

The lowermost Bronx River valley was carved into the bedrock after the Pleistocene (Merguerian and Sanders 1996a). Therefore, the presence of Pleistocene sediments is unlikely in the area and Holocene sediments are thin (e4sciences, 2014). Bedrock is Hartland Formation that consists of brown to tan-weathering, gray muscovite-biotite-quartz-plagioclase-garnet schist and gneiss with layers of greenish amphibolite (Merguerian and Baskerville 1987). The type of bedrock beneath Soundview Park site is from Baskerville, 1992. This study has not identified any boring records in the immediate area of the Soundview Park site.

Table 2.2.1-2. General stratigraphy of the Soundview Park site based on bedrock geology (I-2003, Bronx River Ecosystem Restoration Feasibility Study: Geotechnical and geological report).

Age	Depth (ft)	Geologic Unit	Description
Holocene historic	<20; varying unknown thickness	Fill	Construction fill
Holocene	<15; varying unknown thickness	Estuarine marsh	Marsh silts and peats
Holocene	<15; varying unknown thickness	Estuarine sands	Sands and silt sands
Pleistocene	~ 0.0	Glacial deposits	
Middle Ordovician to Lower Cambrian	n.a.	Hartland formation	Schist and gneiss

Soil analysis

According to the SSURGO database[1], the Laguardia soil unit, an artifactual coarse sandy loam (fill), is found on the shore of Soundview Park in Bronx, NY. The parent material of this unit is loamy-skeletal human-transported material. Tables 2.2.1-3 and 2.2.1-4 show a soil profile and additional properties of the Laguardia soil complex. Complete soil reports of each type of soil found at this site are in Appendix III-b.

Table 2.2.1-3. Soil profile of Laguardia soil unit of northern section of closest shore to Soundview Park's proposed oyster restoration site.

Soil Layer	Depth (inches)	Description
Surface	0-8	Cobbly artifactual coarse sandy loam
Subsurface	8-79	Very cobbly artifactual coarse sandy loam

Table 2.2.1-4. Summary of properties of Laguardia soil unit located in northern section of closest shore in Bronx County, NY to Soundview Park's proposed oyster restoration site.

Property	Description
Natural drainage class	Well drained
Flooding	None
Slope	3-8%
Depth to water table	> 80 inches
Available water capacity	Low (about 3.1 inches)
Surface runoff	Medium
Organic matter content	09.15%
Percent clay	07.60% of clay, silt and sand fraction
Percent silt	16.90% of clay, silt and sand fraction
Percent sand	75.50% of clay, silt and sand fraction

Surface water quality data

The Soundview Park oyster site is part of the estuarine and marine deepwater wetland, as shown in Figure 2.2.1-3.

Table 2.2.1-5 shows water quality data acquired at site E14 (Mouth of Bronx River Buoy N"2") at the intersection of Bronx and East Rivers for the Harbor Water Quality Survey in 2015. Site E14 is the site located closest to the proposed oyster restoration site offshore Soundview Park in Bronx, NY. Complete surface water quality reports containing individual data points are in Appendix III-c. The DO concentration at the surface of the E14 monitoring site ranged from 5.45 to 12.87mg/L; the lower end of this range is considered stressful for aquatic species, while the upper end of this range exceeds the concentration needed to support abundant fish populations.

Table 2.2.1-5. Water quality data acquired at site E14 (Mouth of Bronx River Buoy N"2").NY.

Date	Jan	Feb	Mar	Apr	May	June	July
DO Concentration (mg/L)	10.20	12.87	11.30	11.28	7.20	6.04	5.45
Fecal Coliform (#/100mL)	212	11	33	1	9	10	1
Enterococcus (#/100mL)	106	8	17	1	2	1	1
Transparency (ft)	3.0	2.0	6.0	5.5	4.5	3.5	3.5

[1] The U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of U.S. counties and is produced by the National Cooperative Soil Survey.

The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

Groundwater quality data

This study has not found any records of groundwater measurements in the immediate area of the Soundview Park site.

Figure 2.2.1-3 shows the locations of known contamination sites in or near the Soundview Park site. Approximately 900ft west of the proposed site there is a New York State Remediation site. The site is part of the Voluntary Cleanup Program. The site name is CE – Hunts MGP. The site address is "Between Bronx River, East River, and East Bay Ave". The site code is V00554. The site is owned and operated by Consolidated Edison. Con Ed and NYSDEC came to an agreement and entered the site into a Voluntary Cleanup Agreement (VCA) in 2014. There had been previous investigation and remediation. The scope and magnitude of contamination is unknown.

In addition, the South Bronx Waterfront, both to the north and west of the proposed oyster site is a New York State Brownfield Opportunity Area (BOA).

Summary

1. The Soundview Park oyster restoration site is part of the Bronx sub-watershed within the larger Atlantic Ocean/Long Island Sound watershed system.
2. The site is underlain by shallow bedrock composed of schist (Hartland Formation). This is overlain by Holocene estuarine sands and silts.
3. The land surface of Soundview Park is made up of the Laguardia soil complex, which is an artifactual coarse sandy loam (fill).
4. A surface water quality assessment conducted at the mouth of the Bronx River shows that the DO concentrations range from being stressful for aquatic species to supporting abundant fish populations. These conclusions can only be made assuming that the surface water quality parameters measured in 2015 reflect the average water quality of the site, and that the methods used to measure the parameters were carried out correctly.
5. Approximately 900ft to the west of the proposed oyster site, there is a NYS remediation site, and also to the west and north of the site is a NYS Brownfield Opportunity Area. How this affects the overall health of the site cannot be determined definitively.

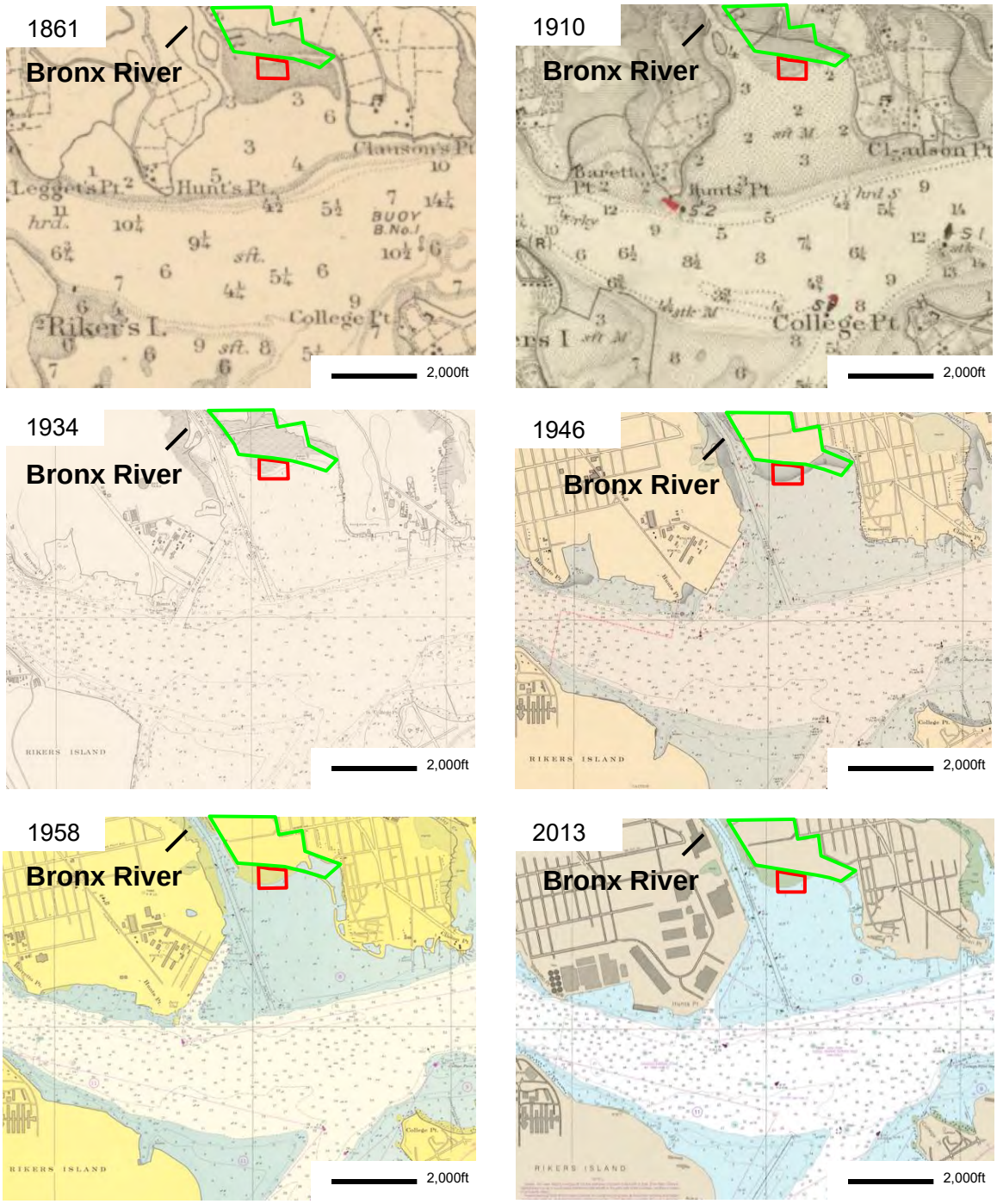


Figure 2.2.1-1. Left to right, starting with top row: NOAA nautical charts from 1861 (No. 21), 1910 (No. 120), 1934 (No. 226), 1946 (No. 226), 1958 (No. 226), and 2013 (No. 12339) highlighting Soundview Park in Bronx, NY and its surrounding bathymetry in the Bronx and East Rivers. Green lines mark the perimeter of Soundview Park and red lines delineate the area of potential oyster restoration opportunity.

In the 1861 chart, depth soundings are in feet below MLW until 18 feet, and then are in fathoms below MLW. In 1910, soundings are in fathoms below MLW. In the 1934, 1946, and 1958 charts, depth soundings are in feet below MLW. In 2013, soundings are in feet below MLLW.



Figure 2.2.1-2. Surficial geology of the Soundview Park site. New York surficial geology information was obtained from a NYSGS surficial geology map (Caldwell 1989). Boundaries were modified to align with orthoimagery (NYSDOP 2014, USGS EROS 2014).



Figure 2.2.1-3. Wetland areas and the one Known Contaminated Site near the Soundview Park site. Base map images are 2014orthorectified aerial images (NYSDOP, 2014), as well as images from USGS EROS (2014). Wetland data is from U.S. Fish and Wildlife Service, National Wetlands Inventory (2004, 2011). Groundwater contamination data is from NYSDEC Environmental Site Database Search (Remediation Site Boundaries, 2013).

2.3 Jamaica Bay

2.3.1 Head of Bay

The proposed Jamaica Bay oyster site is located in Head of Bay just south of John F. Kennedy International Airport. Head of Bay is located in both Queens and Nassau counties, but the oyster restoration site itself is located in Nassau County. Figure 2.3.1-1 shows the location of Head of Bay with respect to Jamaica Bay, NY. Table 2.3.1-1 contains basic information for the Jamaica Bay site.

Table 2.3.1-1. Key information and references for the Head of Bay oyster restoration site and its surrounding area.

Feature/reference type	Name/reference
City	Hamlet of Inwood
County	Nassau
State	New York
Coordinates of site	40.623551N 73.763791W
USGS Quad (ID)	Jamaica (o40073f7)
NOAA chart	12350
Geological map	I-2306
USACE reports	e4sciences, 2011
Watershed/water body	Jamaica Bay
Sub-watershed/waterbody	Hook Creek-Head of Bay
Sub-watershed	Jamaica Bay
Tidal range[a]	0.1-5.8ft

[a] MHHW-MLLW ft based on tides recorded Sept 2013 – Dec 2013 at NOAA/NOS/CO-OPS tidal station 8516891 Norton Point, Hook Creek, NY. For live tides see USGS water level station 01311850 Jamaica Bay at Inwood, NY.

Figure 2.3.1-2 shows nautical charts from 1845, 1885, 1910, 1937, 1954, and 2011 outlining the Jamaica Bay oyster restoration site in Queens, NY. The shores of Head of Bay and of the various marsh-islands in Jamaica Bay have changed significantly since 1845. The most notable change took place between the 1937 and 1954 nautical charts (Figure 2.3.1-2). In April 1942, hydraulic fill was placed over the marshy tidelands just north of Head of Bay in preparation of the construction of what later became John F. Kennedy International Airport. Head of Bay was also deepened during this time.

Geology

The general stratigraphy of the Head of Bay oyster site is outlined in Table 2.3.1-2. A map of bedrock underlying the Jamaica Bay site and other oyster sites can be found in Figure 2.0-4. Figure 2.3.1-3 shows a map of the surficial geology of the area and the locations of borings.

Table 2.3.1-2. General stratigraphy of Head of Bay oyster restoration site, determined from the records of five borings drilled nearby, as well as from e4sciences, 2011.

Age	Thickness (ft)	Geologic Unit	Description
Holocene historic	Unknown thicknesses	Fill	Construction fill
Holocene	~ 10	Estuarine marsh deposits	Sands
Holocene	~5-20	Estuarine sands	Sands
Upper Pleistocene	>100	Glacial outwash deposits	Glacial outwash deposits
Pleistocene	Unknown thicknesses	Gardiners Clay	Clay and silt
Pleistocene	Unknown thicknesses	Jameco	Gravel
Upper Cretaceous	n.a.	Magothy-Matawan formation	Sand, silty sand
Upper Cretaceous	n.a.	Raritan Clay member	Clay, silty clay
Upper Cretaceous	n.a.	Raritan Lloyd Sand member	Sand
Paleozoic	Deeper than 600	Bedrock	

Top of crystalline bedrock beneath Jamaica bay is over 600ft deep. Above bedrock lies Cretaceous-aged semi-consolidated Coastal Plain Sediments. This sequence is overlain by Pleistocene sediments. The upper 100ft consist of Wisconsin-aged Pleistocene glacial outwash sands and silts. These are overlain and reworked by Holocene sands and silts and local estuarine marsh deposits. Figure 2.3.1-4 is a regional geological cross section of Jamaica Bay near Plumb Beach (Cartwright, 2002).

The shallow subsurface in the area is recorded by a series of borings drilled approximately 4 miles west of the site, just west of Bergen Basin in Queens. Borings 20980, 21001, 21002, 21003, and 21004 were drilled from July 1988 to February 1990 (digital Appendix IV-b). The general stratigraphy of the site is also informed by a subsurface and geophysical investigative USACE-NAN report on Plumb Beach in Jamaica Bay, conducted in 2011 by e4sciences.

Aerial photographs reveal sand deposits on both shores and sand waves along the south shore of Head of Bay.

Soil analysis

According to the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) SURGO database[2], the Jamaica Sand soil unit is found on the Queens County-side shore of Jamaica Bay in the Head of Bay area, and the parent material of this complex is sandy dredge spoils. A soil profile and additional properties of the Jamaica Sand complex can be found in Tables 2.3.1-3 and 2.3.1-4. Complete soil reports of each soil type are in Appendix IV-c.

Table 2.3.1-3. Soil profile of Jamaica Sand soil unit, which is located on shore in Queens County, NY, closest to the Head of Bay site.

Soil Layer	Depth (inches)	Description
Surface	0-3	Sand
Subsurface	3-27	Sand
Subsurface	27-65	Fine sand

Table 2.3.1-4. Summary of properties of Jamaica Sand soil unit located on shore in Queens County, NY, closest to the Head of Bay site.

Property	Description
Natural drainage class	Poorly drained
Flooding	None
Slope	0-3%
Depth to water table	0-10 inches
Available water capacity	Low (about 3.9 inches)
Surface Runoff	Negligible
Organic matter content	00.35%
Percent clay	00.00% of clay, silt and sand fraction
Percent sand	99.40% of clay, silt and sand fraction
Percent silt	00.60% of clay, silt and sand fraction

[2] The U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of U.S. counties and is produced by the National Cooperative Soil Survey.
The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

Surface water quality data

The Jamaica Bay oyster site is part of the estuarine and marine deepwater wetland, as shown in Figure 2.3.1-5. Table 2.3.1-5 lists 2010 National Park Service Water Resources Division water measurements at station GATE_NPS_JB-12A, (Jo Co Marsh South), which is approximately 2,380ft (0.45 miles) west of the Head of Bay site. Complete surface water quality reports are in Appendix IV-d.

Table 2.3.1-5. Water quality data acquired in Head of Bay, Jamaica Bay by the National Park Service Water Resources Division in June-September 2010. These measurements were made 1-4 times each month during the survey period and are averaged by month.

Month	Jun	Jul	Aug	Sept	Marine average
Acidity (pH)	7.83	7.71	7.22	7.42	7.4 to 8.4
Dissolved oxygen concentration (mg/mL)	6.87	6.09	6.62	8.79	
Salinity (ppt)	29.30	28.85	29.43	28.20	
Surface water temperature (°F)	76.64	81.23	76.69	80.06	
Turbidity (FTU)	7.50	31.00	14.67	9.00	

Groundwater quality data

No information was available on groundwater quality near the proposed Jamaica Bay Oyster site. Figure 2.3.1-5 shows the locations of known contamination sites in or near the Jamaica Bay site.

A study performed by the Department of Geology and Geophysics of Yale University in the early 1980s measured the amount of heavy metals in Jamaica Bay sediments that likely came from liquid sewage effluent and stormwater runoff (Appendix IV-e, Seidemann, 1991). The sample site closest to the Head of Bay oyster site was located approximately 7,000ft to the southwest.

Summary

1. The Head of Bay oyster restoration site is part of the Hook Creek – Head of Bay sub-watershed within the larger Jamaica Bay watershed system.
2. The site is considered part of Nassau County and is adjacent to JFK airport, where construction started in the 1940s.
3. The site is underlain by Holocene estuarine sands and over 100ft of Pleistocene glacial outwash deposits, which are on top of older Pleistocene sediments and Cretaceous Coastal Plain Sediments. Top of crystalline rock is over 600ft deep.
4. The surface of the Queens County-side shore of Jamaica Bay in the Head of Bay area is made up of the Jamaica Sand soil unit.

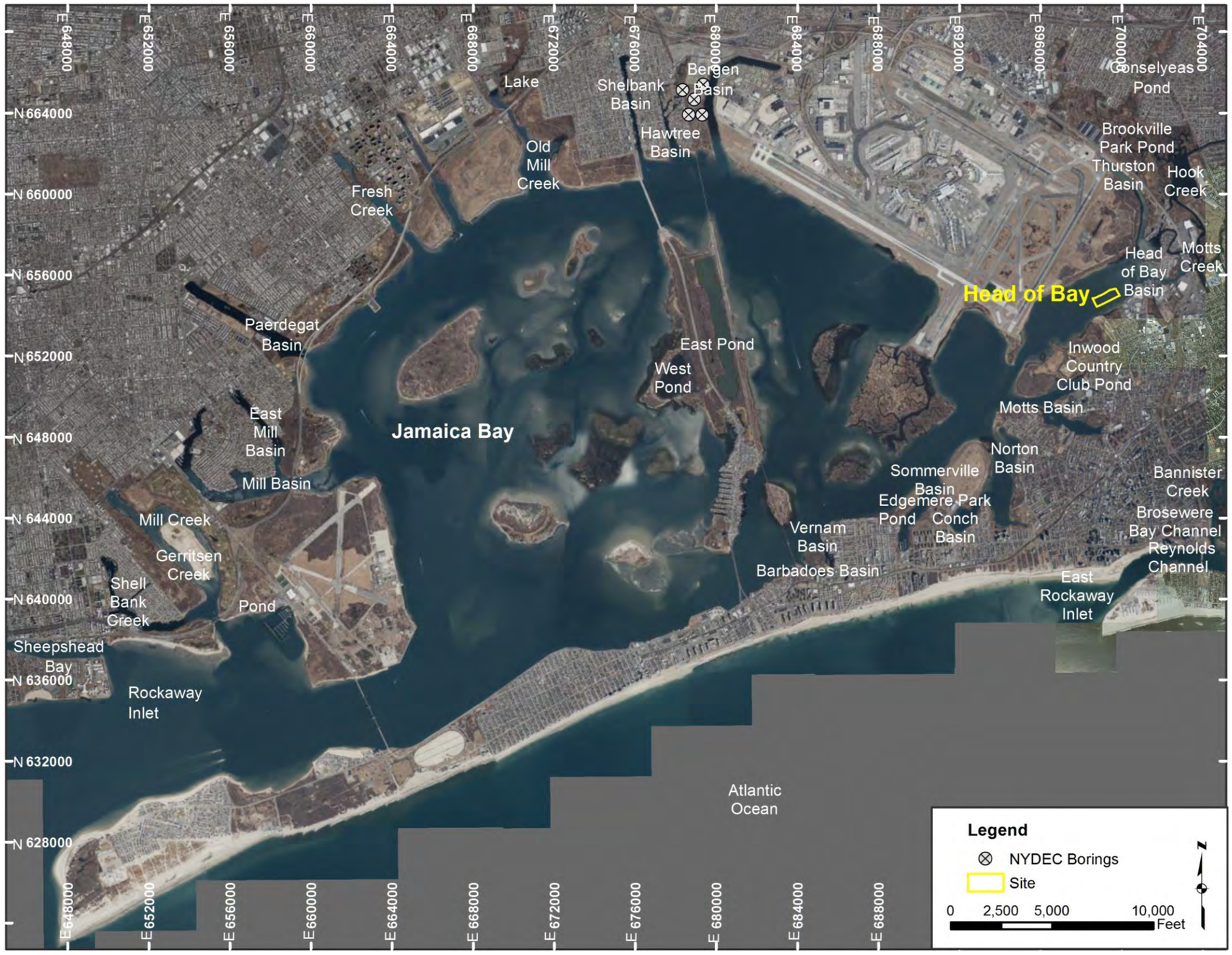


Figure 2.3.1-1. Location map of Head of Bay oyster restoration site with respect to Jamaica Bay, NY. Base map images are 2014 orthorectified aerial images (NYSDOP), as well as images from USGS EROS (2014).

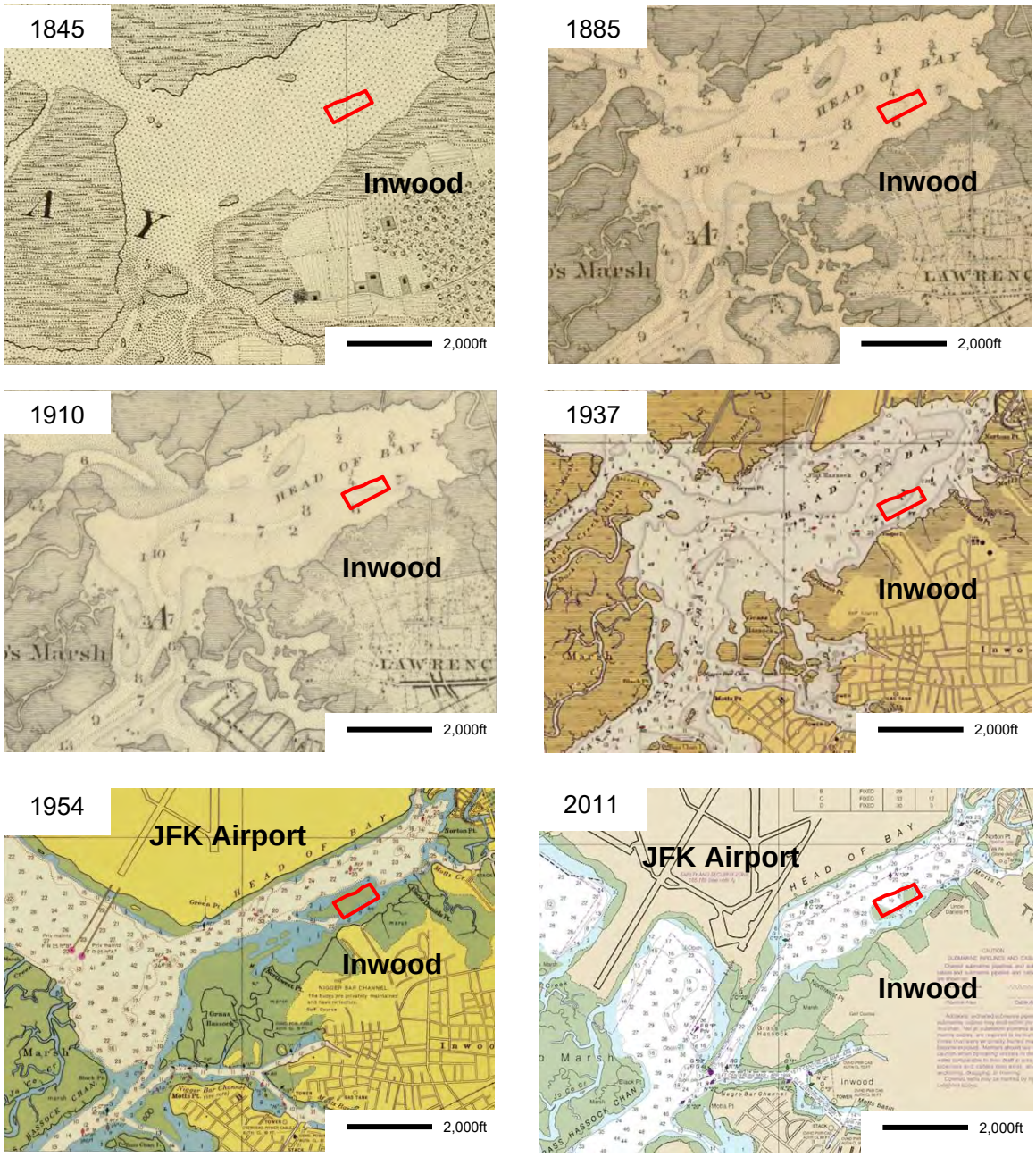


Figure 2.3.1-2. Left to right starting with top row: NOAA nautical charts from 1845, 1885 (No. 120), 1910 (No. 120), 1937 (No. 542), 1954 (No. 542), and 2014 (No. 12327) showing Head of Bay in the eastern-most region of Jamaica Bay. Red lines delineate the area of potential oyster restoration opportunity.

In the 1845, 1937, and 1954 charts, depth soundings are in feet below MLW; in 1845, MLW was at the lowest spring tides observed during the survey, and mean sea level was approximately 1.6ft lower than it is today (based on mean sea level records at The Battery, NY 1856-2014). In 1885 and 1910, depth soundings are in feet below MLW for dotted surfaces and fathoms below MLW everywhere else. In 2011, depth soundings are in feet below MLLW.



Figure 2.3.1-3. Surficial geology of the Head of Bay site. New York surficial geology is from NYSGS surficial geology map (Caldwell 1989). Boundaries were modified to align with orthoimagery (NYSDOP 2014, USGS EROS 2014).

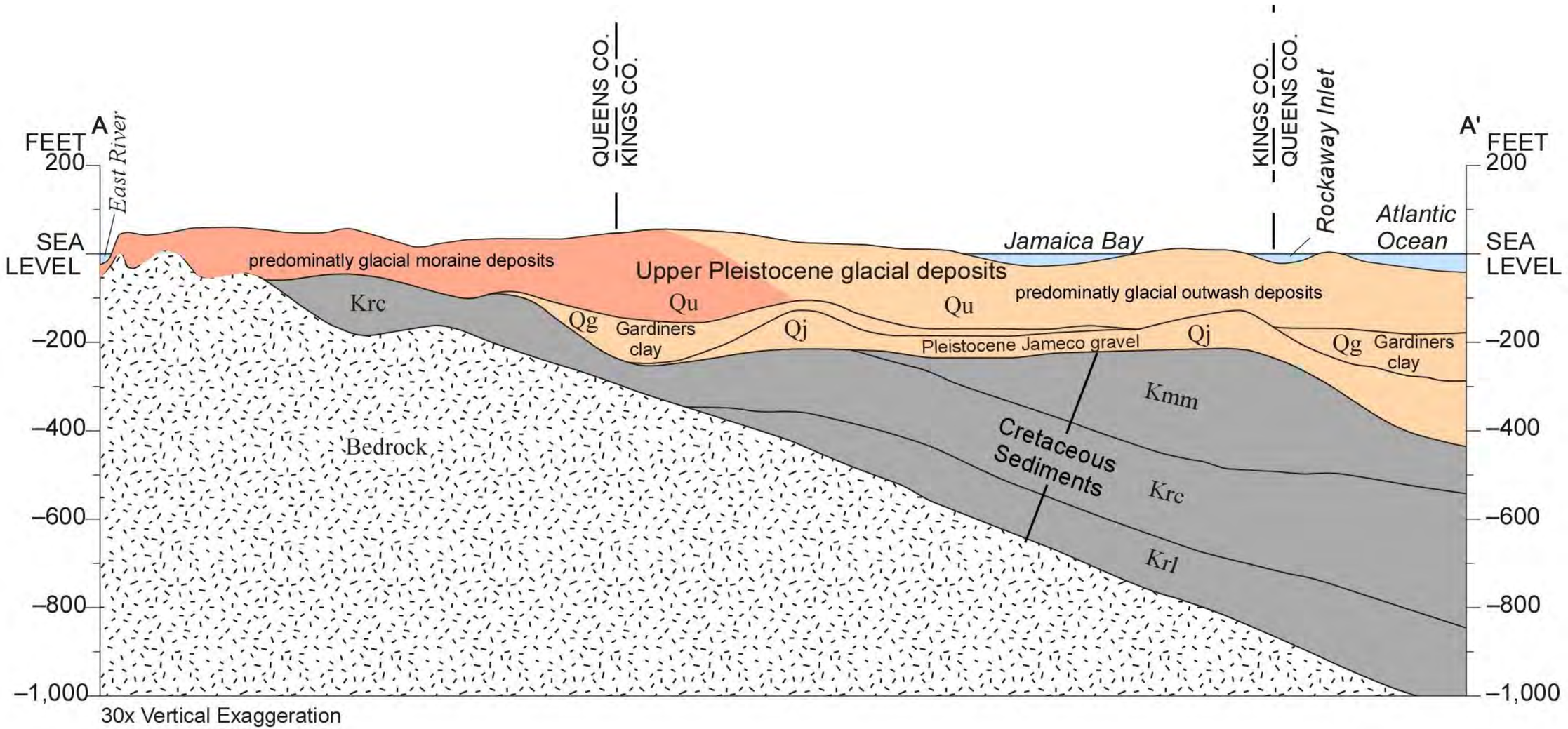


Figure 2.3.1-4. Regional geological cross section of Jamaica Bay (modified from Cartwright, 2002, used in e4sciences, 2011).



Figure 2.3.1-5. Wetland areas and Known Contaminated Sites near the Head of Bay site. Base map images are 2014 orthorectified aerial images (NYSDOP, 2014), as well as images from USGS EROS (2014). Wetland data is from U.S. Fish and Wildlife Service, National Wetlands Inventory (2004). Groundwater contamination data is from NYSDEC Environmental Site Database Search (Remediation Site Boundaries, 2013).

2.4 New York Lower Bay

2.4.1 Naval Weapons Station Earle

The proposed Naval Weapons Station (NWS) Earle oyster site is located inside the Leonardo Piers Complex, which protrudes approximately 2 miles from the coast of Belford, NJ. Table 2.4.1-1 lists key information for the NWS Earle site.

Table 2.4.1-1. Key information and references for the NWS Earle oyster restoration site and its surrounding area.

Feature/reference type	Name/reference
City	Belford, Middletown Township
County	Monmouth
State	New Jersey
Coordinates of site	40.446275N 74.068243 W
USGS Quad (ID)	Sandy Hook (o40074d1)
NOAA chart	12401, 12327
Geological map	Bulletin 1276-Plate 1, GMS 13-1
USACE reports	n.a.
Watershed/water body	New York Lower Bay
Sub-watershed/waterbody	Sandy Hook-Staten Island
Tidal range[a]	5.23ft

[a] MHHW-MLLW ft based on tides recorded Jan 1983 – Dec 2001 at NOAA/NOS/CO-OPS tidal station 8531680 Sandy Hook, NJ.

Figure 2.4.1-1 shows nautical charts from 1845, 1917, 1933, and 2014 highlighting the NWS Earle oyster restoration site in Sandy Hook Bay, NJ. Most notably, NWS Earle's Leonardo Piers Complex was built in the 1940s during World War II and additional piers were added in 1981, 1990, and 1993. Additionally, the area of the proposed oyster site shoaled a little bit between 1845 and 1917, and then deepened slightly between 1933 and 2014 (Figure 2.4.1-1).

Geology

The general stratigraphy of the NWS Earle proposed oyster site is outlined in Table 2.4.1-2. A map of bedrock underlying the NWS Earle site and other oyster sites can be found in Figure 2.0-4. Figure 2.4.1-2 shows a map of the surficial geology of the area.

The New Jersey coast south of New York Bay is predominantly erosive. On land, the soils are of variable thicknesses and lie on the Coastal Plain Group deposits. Holocene stream deposits are relatively minor. Underwater, the Holocene is dominated by reworked sands of the Coastal Plain Group.

Table 2.4.1-2. General stratigraphy of the NWS Earle site based on NJDOT borings, surficial geology (Bulletin 1276-Plate 1), and bedrock geology (GMS 13-1).

Age	Depth (ft)	Geologic Unit	Description
Holocene	variable	Marine muds	Silts and clays
Holocene	~5-20+	Marine	Marine sands
Pleistocene	Unknown thickness[a]		
Tertiary		Riverine deposits	River deposits of quartz, quartzite, sandstone, schist, shale
Upper Cretaceous		Englishtown	Sandy clay
Upper Cretaceous		Magothy Formation	Sand
Lower Cretaceous		Potomac Formation	Sand

[a] Regionally, thickness of Pleistocene deposits varies from 0->100ft. The thickness at this site is unknown.

The shallow subsurface of the closest shore to the NWS Earle oyster restoration site is recorded by four nearby NJDOT borings. The borings are listed in Table 2.4.1-3 and the locations are shown in Figure 2.4.1-2. Borings logs are in digital Appendix V-b. In addition, Boring 13, which is labeled in a surficial geology map of the area (Bulletin 1276, Plate 1), is located at the tip of one of the piers in the Leonardo Piers Complex and is approximately 2,800ft (0.53 miles) from the NWS Earle oyster site.

Table 2.4.1-3. Borings near the NWS Earle site.

Boring ID	Permit	Distance from Site (ft)
B-6A	B0018974	>1000ft
B-6B	B0018975	>1000ft
B0019045	B0019045	>1000ft
B0019045	B0019048	>1000ft
Bulletin 1276- boring 13	n.a.	2,800ft

Soil analysis

According to U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) Soil Survey Geographic SSURGO database[3], the Hooksan Sand soil unit is found on the closest shore to the NWS Earle site, and the parent material of this unit is sandy beach sand. A soil profile and additional properties of the Hooksan Sand unit can be found in Tables 2.4.1-4 and 2.4.1-5. Complete soil reports of each type of soil found at this site are in Appendix V-c.

Table 2.4.1-4. Soil profile of Hooksan Sand soil unit located onshore in Monmouth County, NJ, closest to NWS Earle's proposed oyster restoration site.

Soil Layer	Depth (inches)	Description
Surface	0-6	Grayish brown sand
Subsurface	6-36	Pale yellow sand
Substratum	36-60	Light yellowish brown and pale yellow sand

Table 2.4.1-5. Summary of properties of Hooksan Sand soil unit located onshore in Monmouth County, NJ, closest to NWS Earle's proposed oyster restoration site.

Property	Description
Natural drainage class	Excessively drained
Flooding	Rare after severe storms
Slope	0-5%
Depth to water table	More than 80 inches
Available water capacity	Very low
Surface Runoff	Negligible
Organic matter content	00.30%
Percent clay	03.00% of clay, silt and sand
Percent sand	96.20% of clay, silt and sand
Percent silt	00.80% of clay, silt and sand

[3] The U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of U.S. counties and is produced by the National Cooperative Soil Survey.

The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

.

Surface water quality data
The NWS Earle oyster site is part of the estuarine and marine deepwater wetland, as shown in Figure 2.4.1-3.

In June 2004, the Environmental Monitoring and Assessment Program of the Environmental Protection Agency (EPA) collected water quality measurements at station NJ04-0003-A, Sandy Hook Bay, which is approximately 1.25mi east of the proposed oyster site. These measurements included acidity, DO concentration, salinity, temperature of the surface water, and turbidity. These parameters were measured twice on June 30, 2004. Complete surface water quality reports are in Appendix V-d.

Groundwater quality data
No groundwater quality information was found for the proposed NWS Earle oyster site.

Figure 2.4.1-3 shows the locations of known contamination sites in or near the NWS Earle site. NWS Earle is a New Jersey Superfund site, due to toxic materials that have been buried in landfills as a result of military activities. The site name is Naval Weapons Station Earle (Site A). The site address is Tyler Lane and Texas Road in the city of Colts Neck, New Jersey. The site ID is NJ0170022172. The superfund site was established in 1984. The known contaminants include chromium, cobalt, lead, manganese, pentachorophenol, titanium, zinc and others, but the scope and magnitude of the contamination is unknown. At least three areas are currently undergoing remediation under the Resource Conservation and Recovery Act (RCRA). The status of the cleanup operations is unknown.

Summary
1. The Naval Weapons Station Earle oyster habitat restoration site is part of the Sandy Hook-Staten Island sub-watershed within the larger Monmouth watershed system.
2. The site is underlain by the Cretaceous Coastal Group sand, silt and clay.
3. The surface of the closest shore to the NWS Earle site is made up of the Hooksan Sand unit.
4. The Naval Weapons Station Earle site is classified as a New Jersey Superfund site due to the toxic materials associated with military activities and wastes that have been buried in landfills. The contaminants found at this site include heavy metals and organic compounds. Effects of the contamination sites on the overall health of the oyster habitat restoration site is unknown.

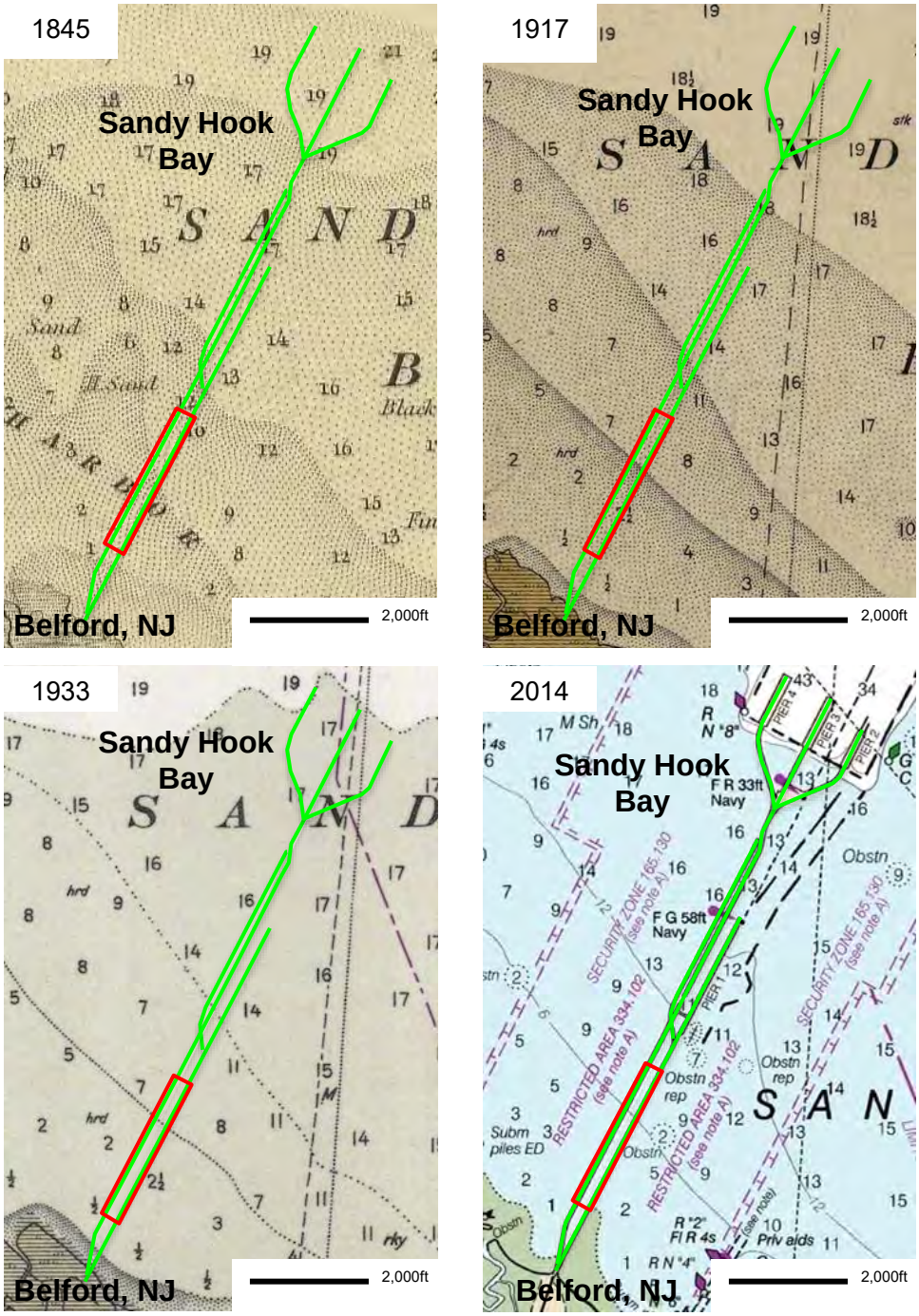


Figure 2.4.1-1. Left to right starting with top row: NOAA nautical charts from 1845, 1917 (No. 369), 1933 (No. 369), and 2014 (No. 12327) showing Naval Weapons Station (NWS) Earle and the surrounding bathymetry in Sandy Hook Bay, NJ. Green lines mark the Leonardo Piers Complex of NWS Earle and red lines delineate the area of potential oyster restoration opportunity.

In the1845, 1917, and 1933 charts, depth soundings are in feet below MLW. In 1845, MLW was at the lowest spring tides observed during the survey, and MSL was approximately 1.6ft lower than it is today (based on MSL records at The Battery, NY 1856-2014). In 2014, depth soundings are in feet below MLLW.

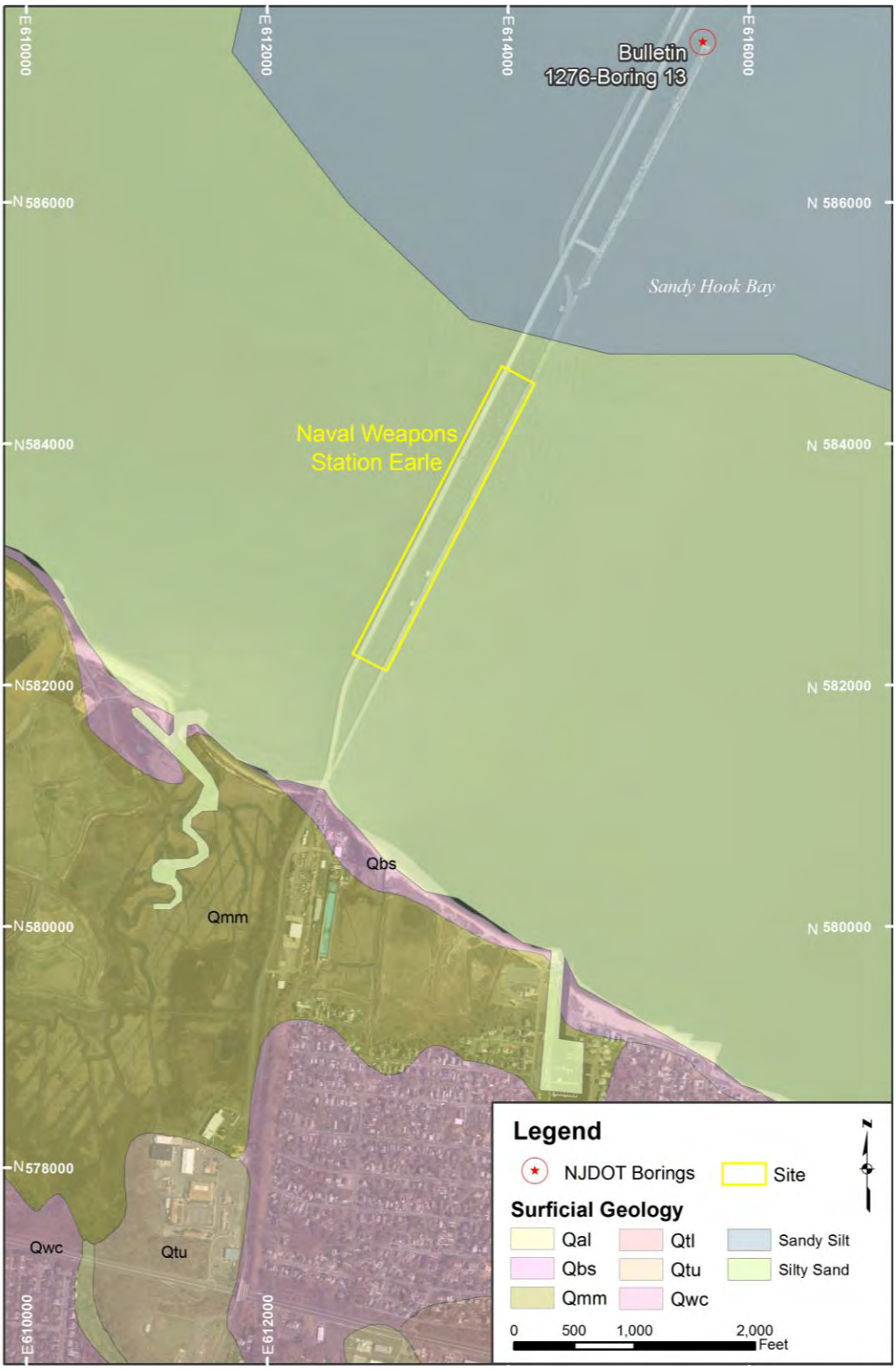


Figure 2.4.1-2. Surficial geology and boring locations of the Naval Weapons Station Earle site. The NJ land-based surficial geology is from NJDEP surficial geology of New Jersey (DGS07-2). The water-based bay floor geology was compiled by e4sciences in an ongoing USACE-NAN project (e4sciences, 2016). The land boundaries were modified to align with orthoimagery (NJGIN, 2015).



Figure 2.4.1-3. Wetland areas and NJDEP-recognized Known Contaminated Sites near the Naval Weapons Station Earle site. Base map images are 2015 orthorectified aerial images (NJGIN, 2015), as well as images from USGS EROS (2014). Wetland data is from U.S. Fish and Wildlife Service, National Wetlands Inventory (2004). Groundwater contamination data is from NJDEP Digital Data Downloads (Known Contaminated Sites List, 2014).

3. Newark Bay, Lower Passaic River and Hackensack River Restoration Sites

The seven proposed restoration sites listed in Table 3.0-1 are in the Newark Bay watershed that includes the lower Passaic River and the Hackensack River. Figure 3.0-1 shows the locations of the ecosystem restoration sites. Figure 3.0-2 is a topographic map showing the sites and their corresponding watersheds. All but one of the seven sites (Essex County Branch Brook Park) are in or adjacent to tidal waters.

Table 3.0-1. List of proposed restorations sites in the Newark Bay watershed.

Site	Watershed	Sub-watershed
Site 719. Meadowlark Marsh	Hackensack River	Bellmans Creek
Site 721. Metromedia Tract	Hackensack River	Hackensack R. – Rt. 3 to Bellmans Creek
Site 865. Kearny Point	Newark Bay	Confluence of Passaic and Hackensack
Site 866. Oak Island Yards	Newark Bay	Newark Bay
Site 887. Essex County Branch Brook Park	Passaic River	Branch Brook First River
Site 900. Dundee Island Park/Pulaski Park	Passaic River	Lower Passaic River
Site 902. Clifton Dundee Canal Green Acres Purchase & Island Preserve	Passaic River	Lower Passaic R Saddle R. to Dundee Dam

Figure 3.0-3 shows the map of bedrock underlying the ecosystem restoration sites. With the exception of Newark Bay and Upper NY Bay, e4sciences (e4) compiled this map primarily from the NJDEP Geological Survey and the New York State Geological Survey bedrock geology map. The submerged part of Newark Bay is compiled from e4's studies related to the Harbor Deepening Project (USACE, 1999, Earthworks, 2006, e4sciences, in progress USACE harbor sedimentation study).

Figure 3.0-4 shows a surficial geology map encompassing the ecosystem restoration sites. This map is primarily based on the NJDEP Geological Survey and the New York State Geological Survey bedrock geology map.

The Passaic and Hackensack Rivers flow into the northern end of Newark Bay at Kearny Point (Site 865). Newark Bay, the lower 14 miles of the Hackensack River, and the lower Passaic River are tidal. The upper Hackensack River is dammed north at the Oradell Dam. The Passaic River has multiple dams, the most downstream of which is Dundee Dam.

The underlying bedrock of all three water bodies consists of the Newark Series Triassic-Jurassic sedimentary rocks deposited in the Newark Basin and intrusive and volcanic Jurassic igneous basalts and diabases. Figure 3.0-5 is a west to east cross section through the Newark Basin sediments. The igneous rocks and the surrounding contact metamorphic rocks are the most resistant, and form ridges. The least resistant are the fine-grained sedimentary rocks of the Passaic Formation. These shales and siltstones underlie valleys. The eastern edge of the Newark Bay watershed is underlain by the Lockatong Formation, whereas the rest is underlain either by the Passaic Formation or the igneous dikes and sills that cross cut the Passaic Formation.

Newark Bay, the lower 14 miles of the Hackensack River, the lower 1 mile of the Passaic River, northern Arthur Kill and associated wetlands lie in a subtle valley between north-east trending ridges. The eastern ridge is the Palisades diabase. The western limit of the valley is formed by small ridges underlain by the Passaic Formation's shales and sandstones. The eastern edge of the valley is underlain by the Lockatong Formation. The remaining majority is underlain by the shale-dominated Passaic subunits (JTp and JTpms). This valley is tidally influenced and includes the Meadowlands between the Passaic and Hackensack Rivers.

The main strike of the strata is 36º east of north and beds dip 15º to the northwest. The area consists of buried northeast trending ridges and valleys of bedrock. The top of rock is mantled by Pleistocene glacial till. The valleys are filled with Pleistocene glacial lake deposits, the majority of which are varved clay and silts. Locally these are interbedded with glacial lake delta deposits of sands and tills. The clay unit may be as thick as 200ft. These lake deposits are interbedded with tills and are overlain by outwash silts and sands.

The Pleistocene outwash sands transition to Holocene fluvial and estuarine sands that grade vertically into finer estuarine silts and clays and marsh deposits. In the last few hundred years, much of the area comprising low-lying marsh and shallow water areas have been filled to build up the land for roads, railroads, industrial sites, airports, and port facilities. Bridges are generally built where rock is shallow.

Locally, either bedrock or Pleistocene sediments are exposed in Newark Bay and in the Hackensack River. In Newark Bay these units were uncovered by dredging, whereas in the Hackensack River the units were uncovered both by dredging and by river currents eroding overlying sediments. Such scouring is deep at bridges. However, the deepest spot on the Hackensack River (~70ft deep) is away from bridges and that depth has existed for over 150 years (e4sciences USACE report, 2008).

The movement and storage of groundwater in this area occurs primarily in the interconnected network of openings that form along joints, fractures, and other channels in the Passaic Formation. Beneath the meadowlands the estimate of thickness of the groundwater-producing zone in the bedrock is between 200 and 600ft (NJMC Master Plan, 2004).

The shallower upper Pleistocene and Holocene silts and sands, in addition to the historic fill form shallow groundwater aquifers that are generally laterally discontinuous.

Where bedrock is deep, the relatively impermeable Pleistocene varved clays and silts are thick and create barriers atop the bedrock aquifers. Where rock is shallow, the Pleistocene clay and silt may be thin or completely eroded, and bedrock aquifers are more vulnerable to infiltration and contamination from the surface.

Much of the contaminated sediment and groundwater is in the shallower aquifers. The historic fill was usually placed for industrial use and is commonly found at the surface of contaminated sites.

The following section reviews each of the seven sites.

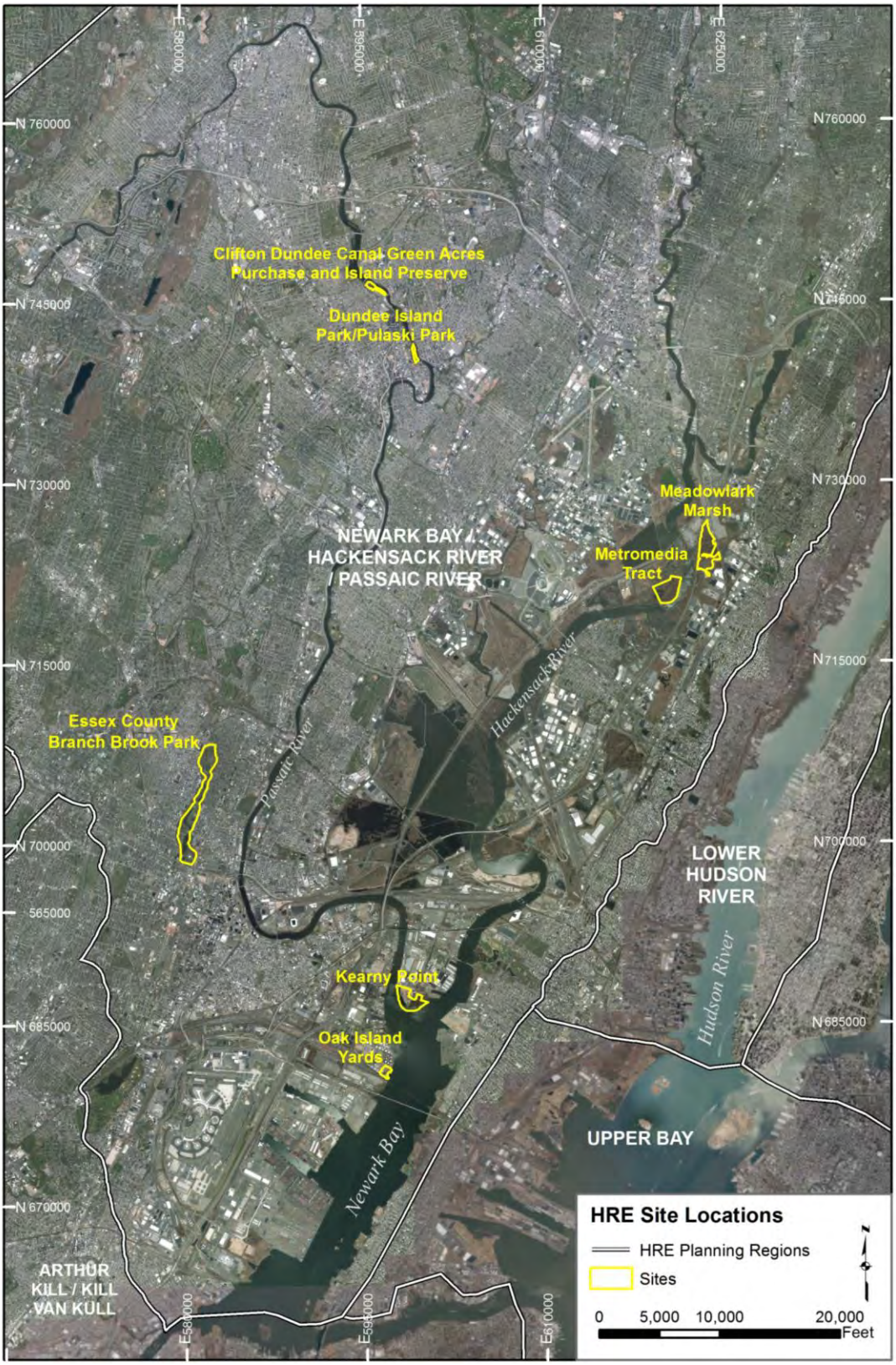


Figure 3.0-1. Location map the proposed ecosystem restoration sites discussed in this report and the HRE planning regions. Base map images are March-May 2015 orthorectified images for NJ (NJGIN, 2015) and 2014 orthorectified aerial images for NY (NYSDOP, 2014), as well as images from USGS EROS (2014).

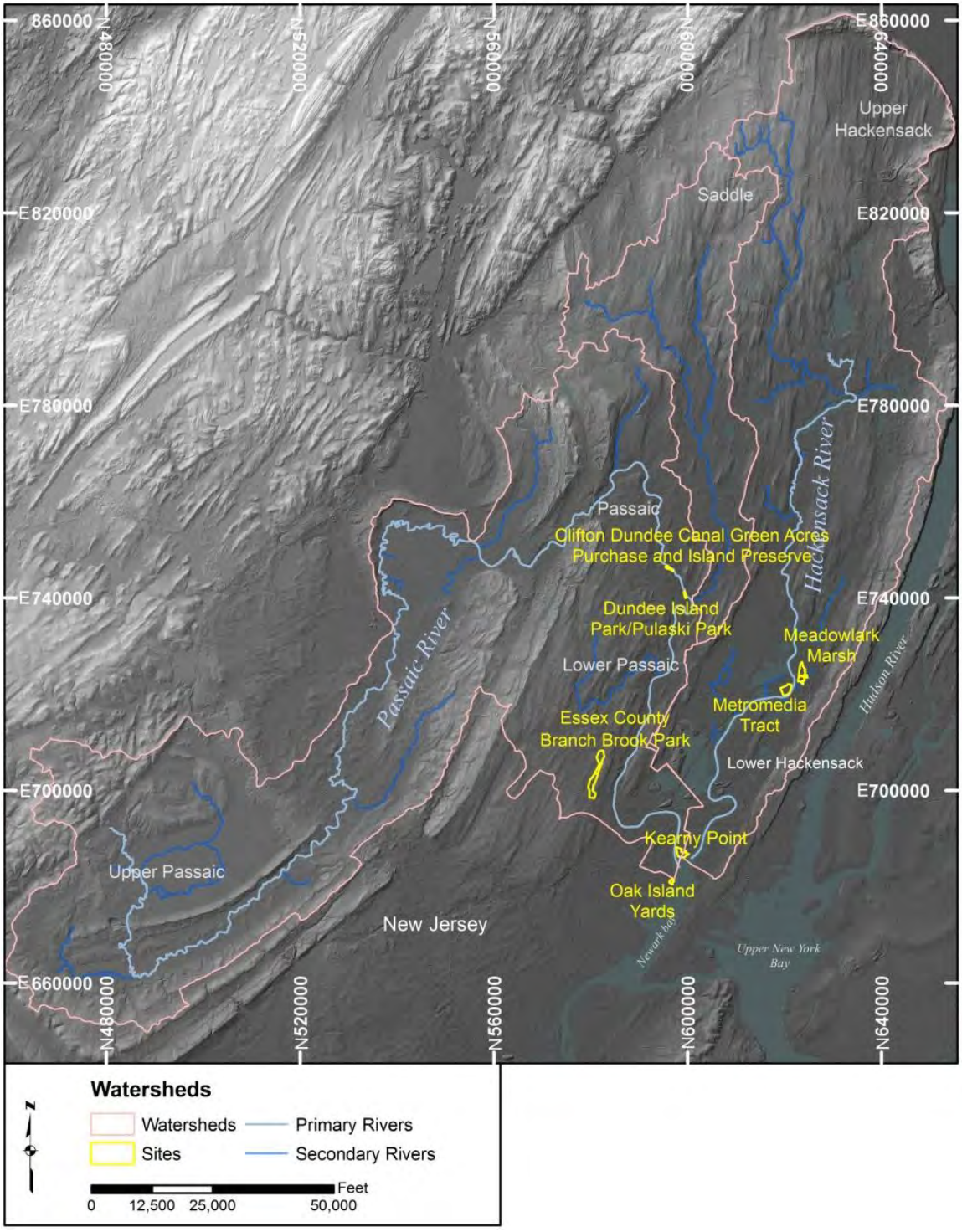
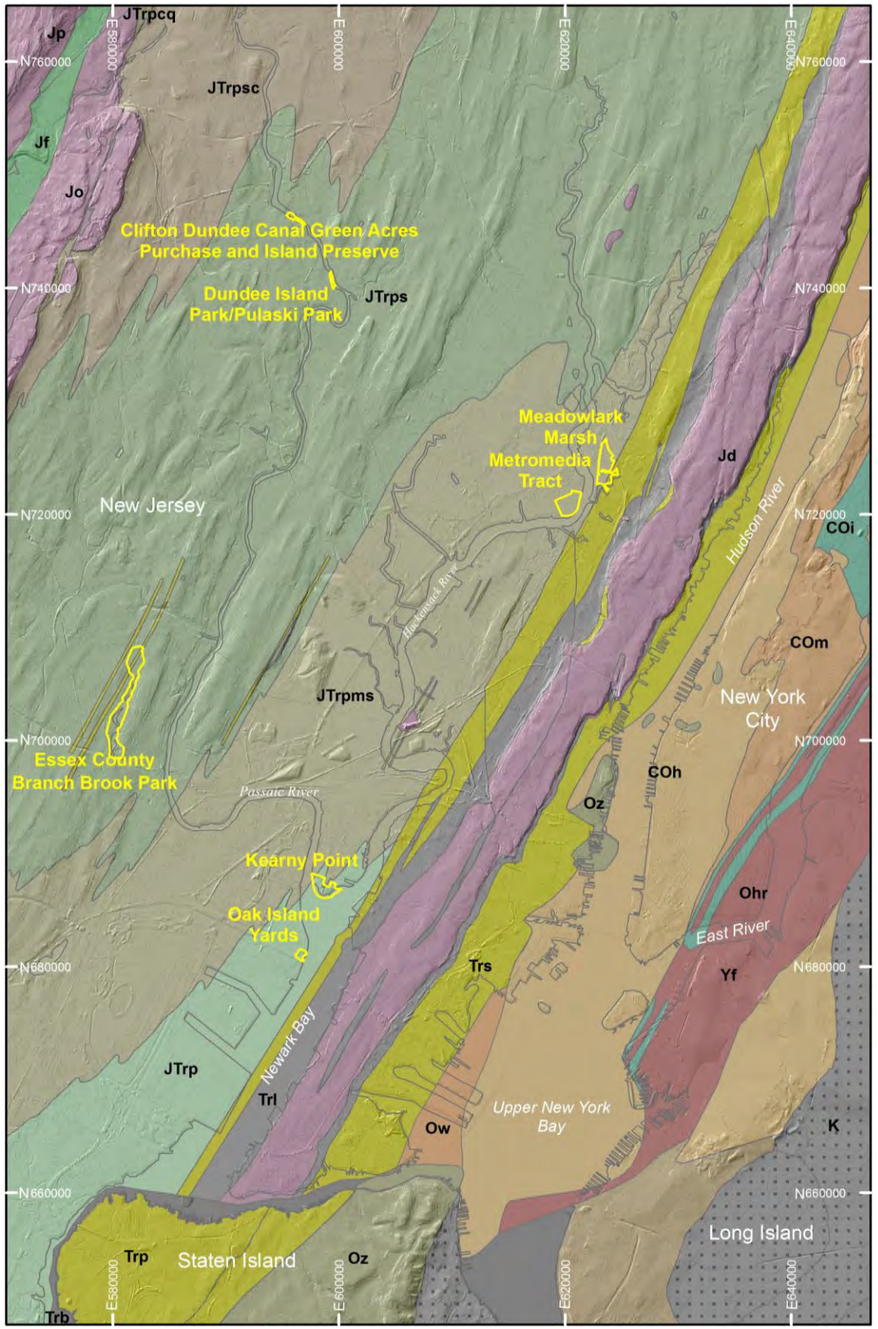


Figure 3.0-2. Watersheds of the Hackensack, Passaic and Saddle Rivers and ecosystem restoration sites. Watershed boundaries are from USDA, Natural Resources Conservation Service, 2016.



Legend

Fault Lines

Oyster Sites

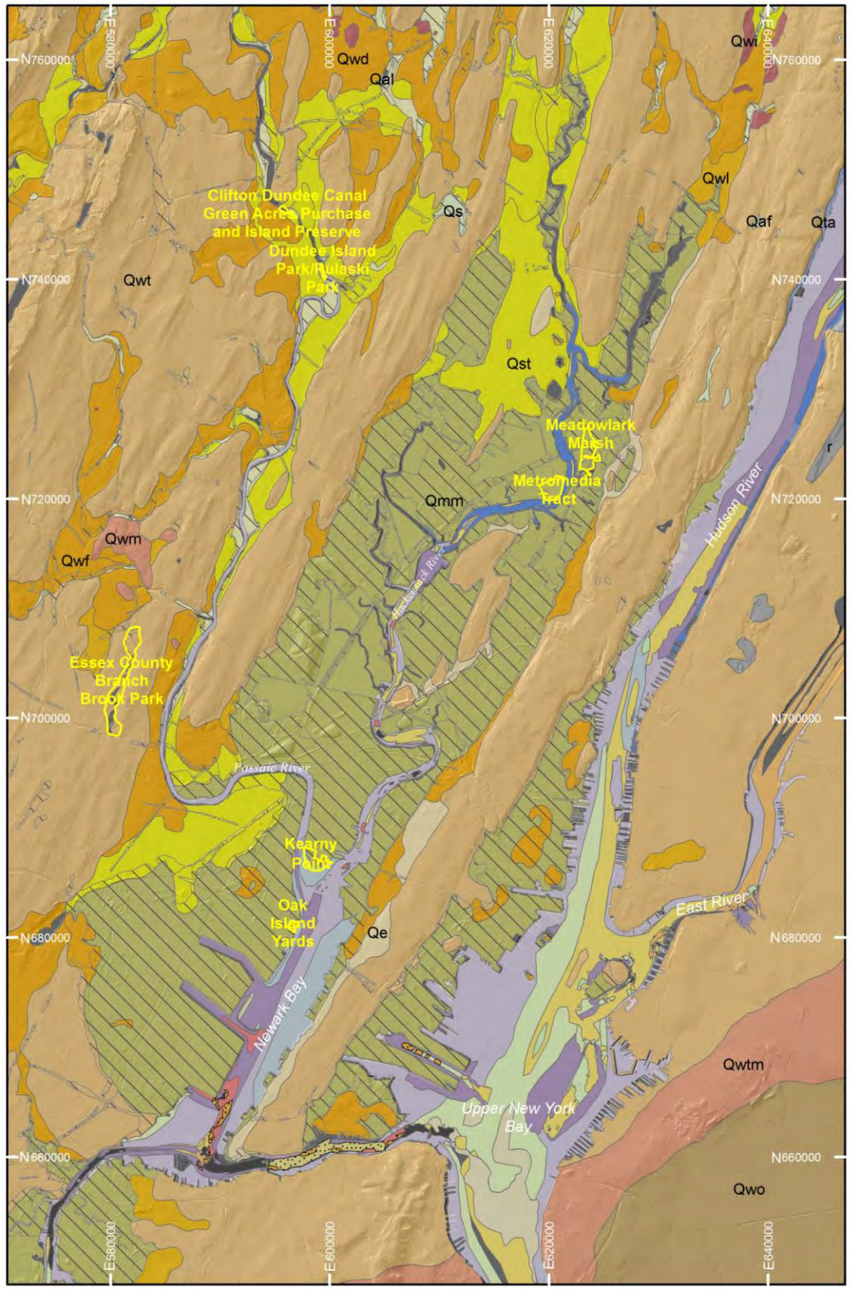
0 5,000 10,000 20,000 30,000 40,000 Feet

N

Bedrock Geology

Geologic Age	Formation	Label	Rock or Sediment Type
Cretaceous	Coastal Plain Group	K	clay or mud
Jurassic	Palisade Diabase	Jd	diabase
		Jo	basalt
		Jp	basalt
		Jf	silistone
Lower Jurassic Upper Triassic	Passaic Formation	JTrpsc	shale and conglomorate
		JTrps	shale and sandstone
		JTrpms	shale and silstone
		JTrp	shale with silstone and sandstone
Upper Triassic	Lockatong Formation	Trl	argillite
Triassic - Jurassic	Stockton Formation	Trs	sandstones and shales
Ordovician	Serpintinite	Oz	serpintinite
Cambrian-Ordovician	Hartland Formation	COh	schist
	Walloomsac Formation	Ow	schist
	Manhattan Scheist	COm	schist
		COhp	schist
	Inwood Marble	COi	marble
PreCambrian	Fordham Gneiss	Yf	gneiss
		CO?	undifferentiated metamorphics

Figure 3.0-3. Bedrock geology of the Newark Bay, Lower Passaic and Hackensack River ecosystem restoration sites. Map compiled and modified from various sources (see text for sources).



Legend

sites

water

0 10,000 20,000 40,000 Feet

N

Surficial Geology

Geological Age	Material	Sediment Type
Holocene		Historic Fill
	Qmm	Salt-Marsh and Estuarine Deposits
	Qs	Swamp and Marsh Deposits
	Qaf	Alluvium Fan Deposits
	Qal	Alluvium
Holocene and/or Upper Pleistocene	Qe	Eolian Deposits
	Qst	Postglacial Stream Terrace Deposits
Upper Pleistocene (Wisconsinan)	Qwd	Late Wisconsinian Glacial Delta Deposits
	Qwf	
	Qwo	Glacial Outwash Sands & Silt
	Qwl	Late Wisconsinian Glacial Lake Deposits
	Qwi	Ice Contact Deposits
	Qwm	Late Wisconsinian Recessional Moraine Deposits
	Qwt	Till
	Qwtm	Terminal Moraine
	r	Exposed Bedrock

Figure 3.0-4. Surficial geology map and the New Jersey ecosystem restoration sites. The NJ land-based surficial geology is from NJDEP Gelogical Survey surficial geology map of New Jersey (DGS07-2) and the NY land-based surficial geology is modified from NYSGS surficial geology map (Caldwell 1989). The water-based NYNJ Harbor bay and river floor geology map was compiled for an ongoing USACE-NAN project (e4sciences, 2016). NYSGS geology boundaries were modified to align with orthoimagery (NYSDOP 2014, NJGIN 2015, USGS EROS 2014).

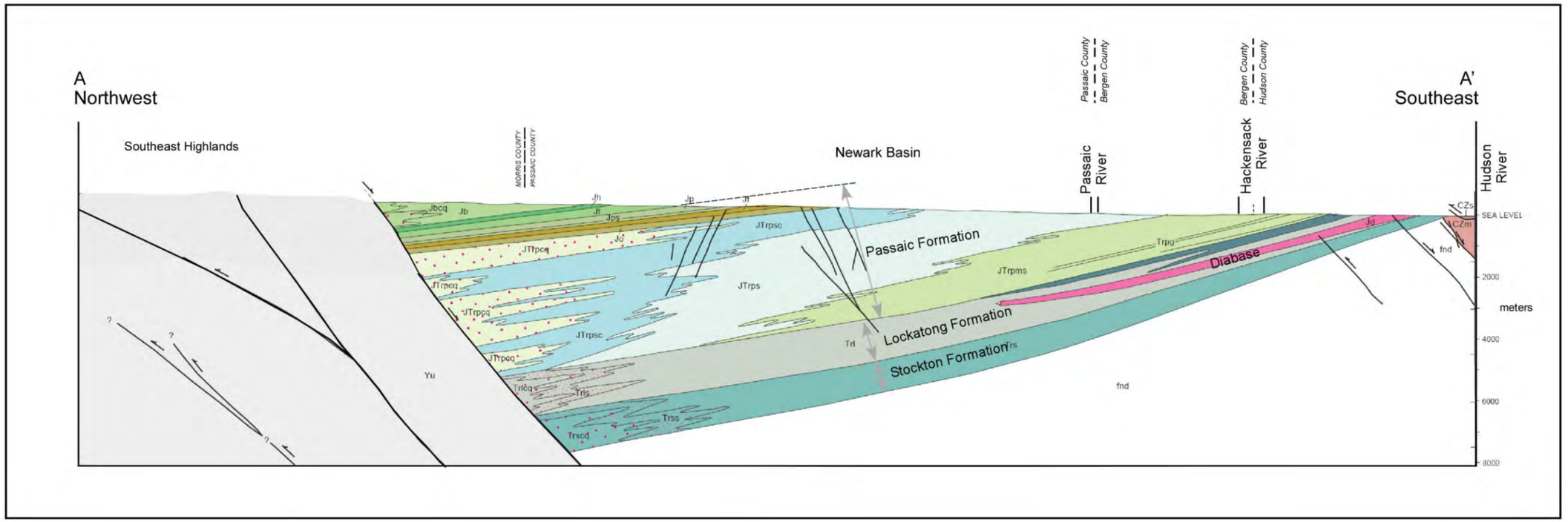


Figure 3.0-5. West to east cross section through the Newark Basin. From NJDEP bedrock geology map bedrock geology (I-2306) updated in 2009.

3.1 Hackensack River

3.1.1 Site 719. Meadowlark Marsh

The proposed HRE restoration site 719, Meadowlark Marsh, is east of the Hackensack River on the north shore of Bellmans Creek, and in between the NJ Turnpike Eastern Spur (I-95) and the Conrail Northern railroad track. Bellmans Creek, a tidal creek, flows into the Hackensack River. This site is approximately 1,200ft (0.23 miles) east of Site 721, Metromedia Tract. Table 3.1.1-1 lists key information of the Meadowlark Marsh site.

Table 3.1.1-1. List of basic information about the Meadowlark Marsh restoration site and its surrounding area.

Feature/reference type	Name/reference
City	Ridgefield
County	Bergen
State	New Jersey
Coordinates of site	40.8212803N 74.024407W
Size of site	90 acres
USGS Quad (ID)	Weehawken (o40074g1)
Geological map	OFM 13, I-2306, HFM-42
USACE reports	Earthworks 2007, Earthworks 2008
Watershed	Hackensack River
Sub-watershed	Bellmans Creek
Tidal range[a]	6.29ft

[a] MHHW-MLLW ft based on tides recorded Sept 1994 – Oct 1994 at NOAA/NOS/CO-OPS tidal station 8530528 Carlstadt, Hackensack River, NJ.

Figure 3.1.1-1 shows topographic maps from 1896, 1935, 1968, and 2014 outlining the Meadowlark Marsh restoration site in Ridgefield, NJ. The Meadowlark Marsh site is part of the Hackensack Meadowlands and is not developed in any of the topographic maps in Figure 3.1.1-1. While the Hackensack River has narrowed slightly in the vicinity of the Meadowlark Marsh site since 1896, Bellmans Creek (which hugs the southern border of the site) has had no significant changes in the past 120 years.

The railroad was already in place in 1896 and its raised bed defines the eastern edge of the marsh area. There were no major barriers on land between the marsh and the Hackensack River to the west until highway I-95 was constructed. An east-west pipeline bisects the site and appears to restrict surface water drainage to Bellmans creek. The pipelines were identified by magnetic field mapping, where the pipes cross the Hackensack River (Earthworks, 2008). The pipes appear to be tied to a surface structure (perhaps a pumping station) adjacent to the eastern edge of the site.

Geology

The general stratigraphy of the Meadowlark Marsh restoration site is described in Table 3.1.1-2. Figure 3.0-3 shows the map of bedrock underlying the Meadowlark Marsh site. Figure 3.1.1-3 shows the rock formations in a west-to-east cross section through Newark Basin. Figure 3.1.1-4 shows a map of the surficial geology of the area.

Table 3.1.1-2. General stratigraphy of the Meadowlark Marsh site based on borings in Table 3.1.1-3..

Age	Thickness (ft)	Geologic Unit	Description
Holocene	0-11	Estuarine marsh deposits	Peat, silt and sand
Holocene	5-13	Estuarine sands	sand
Pleistocene	14->120	Glacial lake deposits	Varved silt and clay
Pleistocene		Glacial Till	Silty sands and gravels
Lower Jurassic/Upper Triassic	n.a.	Passaic formation (Newark Group)	Siltstone, shaly siltstone, shale and sandstone

The references in Table 3.1.1-1 show that the underlying bedrock in the Meadowlands consists of Passaic Formation of the Newark Group. The Passaic Formation, which is included in the Newark Group, forms most of the bedrock of the Hackensack River basin and is composed of sandstone, mudstone, siltstone, and conglomerate.

The shallow subsurface of the Meadowlark Marsh site can be determined from the map of Surficial Geology of the Weehawken and Central Park Quadrangles (OFM 13), as well as from the records of monitoring wells, borings and sediment cores collected at in or near the site, as shown in Table 3.1.1-3 (NJDEP, Earthworks 2008, Ward et al, 1962). The records of the monitoring wells, borings and sediment cores are available in the digital Appendix VI-b.

Table 3.1.1-3. Borings and monitoring wells in or near the Meadowlark Marsh site.

Boring or sample id	Permit number	Source	Distance from site (ft)
OFM-13 124	N 26-14-145	NJ OFM-13	on site
Ward62-TOR-77	n.a.	Ward et al, 1962	on site
Ward62-07-H	n.a.	Ward et al, 1962	10
Ward62-06-H	n.a.	Ward et al, 1962	75
MW-41	E201507277		370
OFM-13 125	N 26-14-148a	NJ OFM-13	400
MW-43D	E201507276		532
OFM-13 262	26-10251	NJ OFM-13	640
OFM-13 120	N 26-14-116a	NJ OFM-13	652
HR07-sed-095	n.a.	Earthworks, 2008	660
OFM-13 119	N 26-14-116b	NJ OFM-13	684
OFM-13 130	N 26-14-154b	NJ OFM-13	754
HR07-sed-096	n.a.	Earthworks, 2008	773
MW-42	E201507275		786
OFM-13 131	N 26-14-154a	NJ OFM-13	850
Ward62-09-H	n.a.	Ward et al, 1962	850
OFM-13 121	N 26-14-127	NJ OFM-13	864
Ward62-12-B	n.a.	Ward et al, 1962	876
HR07-sed-097	n.a.	Earthworks, 2008	894
HR07-sed-98B	n.a.	Earthworks, 2008	1,040
OFM-13 261	26-10249	NJ OFM-13	1,120
OFM-13 126	N 26-14-148b	NJ OFM-13	1,305
Ward62-08-H	n.a.	Ward et al, 1962	1,580
HR07-sed-092	n.a.	Earthworks, 2008	1,782
HR07-sed-093	n.a.	Earthworks, 2008	1,787
HR07-sed-094	n.a.	Earthworks, 2008	1,922
OFM-13 127	N 26-14-171	NJ OFM-13	1,936
OFM-13 128	N 26-14-173b	NJ OFM-13	2,180
HR07-sed-099	n.a.	Earthworks, 2008	2,300
HR07-sed-100	n.a.	Earthworks, 2008	2,420
HR07-sed-103	n.a.	Earthworks, 2008	2,440
HR07-sed-101	n.a.	Earthworks, 2008	2,650
HR07-sed-102	n.a.	Earthworks, 2008	2,760
OFM-13 093	n.a.	NJ OFM-13	3,132
OFM-13 075	N 26-13-333	NJ OFM-13	3,175
OFM-13 092	N 26-13-333	NJ OFM-13	3,180
Ward62-09-H	n.a.	Ward et al, 1962	4,468
OFM-13 117	N 26-13-396	NJ OFM-13	4,935

Boring Ward62-TOR-77 the top of rock (TOR) is deeper than 77ft below the ground surface. The rock strata dips to the northwest. In boring Ward62-08H rock is deeper than 120ft below ground surface.

Much of the shallow strata consists of Pleistocene glacial lake varved clay and silt deposits. Locally this unit is over 100ft thick. The top of the unit ranges from about 5ft below the surcae to about 25ft below the surface. In boring Ward62-07H the Pleistocene glacial lake deposit was 7ft

below the surface. This unit is exposed on the river bottom in the adjacent Hackensack River (Earthworks, 2008) and, based on aerial photographs, the unit also appears to be exposed on the floor of the pond adjacent to the eastern edge of the site.

Overlying the Pleistocene are estuarine fluvial and silts overlain by marsh deposits. Fill has rasied the land along the pipeline road and powerline road that cross the site/

Soil analysis

The surface expression of the Holocene estuarine salt-marsh deposits at the Meadowlark Marsh site consists of soils of mucky peat underlain by muck, silt, or sand. The distribution of the sand is likely defined by tidal tributaries. The further away from the historic channels, the less sand and silt. This is documented by the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) soil survey database, SSURGO[1], which identifies that the soil unit at the site is composed of three soil types: Westbrook, Ipswich, and Sandyhook. Each type is 64% organic matter, and the remainder consists of clay, silt, and/or sand. Each type makes up 30% of the overall composition.

The Westbrook and Ipswich soil types originated from partly decomposed herbaceous organic material (marsh plants), whereas the Sandyhook type came from sandy estuarine deposits. Soil profiles and additional properties of the Westbrook, Ipswich, and Sandyhook soil types are listed in Tables 3.1.1-4 - 3.1.1-9. The detailed geographic distribution of each soil type within the Meadowlark Marsh site is has not been mapped. The water table is at the surface and is tidally influenced. Complete soil reports of each soil type at this site are in the digital Appendix VI-c.

Table 3.1.1-4. Soil profile of Meadowlark Marsh's Westbrook soil type.

Soil Layer	Depth (inches)	Description
Surface	0-19	Mucky peat
Subsurface	19-59	Silt loam

Table 3.1.1-5. Summary of properties of Meadowlark Marsh's Westbrook soil type.

Property	Description
Natural drainage class	Very poorly drained
Flooding	Very frequent
Slope	0-2%
Depth to water table	About 0 inches (tidal)
Available water storage	High (about 9.1 inches)
Surface runoff	Negligible
Organic matter content	64%

Table 3.1.1-6. Soil profile of Meadowlark Marsh's Ipswich soil type.

Soil Layer	Depth (inches)	Description
Surface	0-42	Mucky peat
Subsurface	42-59	Muck

[1] Information about the types of soil found at the Meadowlark Marsh site was obtained through the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS). The USDA-NRCS operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of the U.S. counties and is produced by the National Cooperative Soil Survey.

The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

Table 3.1.1-7. Summary of properties of Meadowlark Marsh's Ipswich soil type.

Property	Description
Natural drainage class	Very poorly drained
Flooding	Very frequent
Slope	0-2%
Depth to water table	About 0 inches (tidal)
Available water storage	Very high (about 26.6 inches)
Surface runoff	Negligible
Organic matter content	64%

Table 3.1.1-8. Soil profile of Meadowlark Marsh's Sandyhook soil type.

Soil Layer	Depth (inches)	Description
Surface	0-4	Mucky peat
Subsurface	4-8	Sand
Subsurface	8-11	Mucky coarse sand
Subsurface	11-51	Sand
Subsurface	51-59	Coarse sand

Table 3.1.1-9. Summary of properties of Meadowlark Marsh's Sandyhook soil type.

Property	Description
Natural drainage class	Very poorly drained
Flooding	Very frequent
Slope	0-2%
Depth to water table	About 0 inches (tidal)
Available water capacity	Low (about 5.2 inches)
Surface runoff	Negligible
Organic matter content	64%

Surface water quality data

Bellmans Creek and the Hackensack River have a tidal range of 6.29ft. While there is limited available surface water quality data, the data of a single day in August 2014 is in the digital Appendix VI-d. Due to limited freshwater inflow and the lack of a direct connection with the open ocean, the lower Hackensack River area is susceptible to pollutants introduced to the watershed. Sources of pollution tend to be sewage treatment plants, industrial discharges, landfills, and surface runoff (NJMC Master Plan, 2004).

Groundwater quality data

The movement and storage of groundwater in the Meadowlands District occurs primarily in the interconnected network of openings that form along joints, fractures, and other channels in the Passaic Formation. The estimate of thickness of the groundwater-producing zone in the bedrock is between 200 to 600 feet (NJMC Master Plan, 2004).

The bedrock is separated from the surface by the relatively impermeable glacial lake clays and silt. The main groundwater aquifer in bedrock (NJMC Master Plan, 2004) is separated from the surface by over 70ft of impermeable Pleistocene glacial lake clay and silts. The main transport between the surface and the aquifer would be by wells or pilings that penetrated the Pleistocene.

Figure 3.1.1-4 shows the locations of NYDEP recognized Known Contamination Site (KCS) near the Meadowlark Marsh site. Within 200ft of the Meadowlark Marsh site, NYDEP recognizes two KCSs that have contaminated groundwater in the Pleistocene and Holocene near-surface sediments.

Approximately 180ft east of the Meadowlark Marsh site, there is a KCS with ground water contamination. The address of the site is 9252 John F Kennedy Blvd in the city of North Bergen, New Jersey. The Program Interest (PI) name is Sier-Bath Gear Co. The known contaminants are listed in (Table 3.1.1-10). This KCS site encompasses 696 acres and the remediation status is unknown. This site is only separated from the Meadowlark Marsh restoration site by Bellmans Creek and therefore could be a potential concern.

Table 3.1.1-10. Greatest contamination values measured at the KCS described above at the time of Groundwater Classification Exception Area (CEA) establishment on 8/25/1999.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Arsenic	13	8
Bis (2-ethylhexyl) phthalate	2,300	30
Dichloroethylene (*cis*-1,2)	8,000	2
Ethyldiene dichloride	120	70
Lead	17	10
Trichloroethane (1,1,1)	140	30
Trichloroethylene	440	1
Vinyl chloride	890	5
Vinyldiene chloride	33	2

[1] The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeological characteristics of the groundwater resource and designated uses of the classification area.

Approximately 180ft west of the Meadowlark Marsh there is another KCS with groundwater contamination. The address of this site is NJ Turnpike MM 116.0, in the city of Ridgefield, New Jersey. The Program Interest (PI) name is Vince Lombardi Service Area 13. The known contaminants are listed in Table 3.1.1-11. The KCS site encompasses 4.9 acres. At the surface the NJ Turnpike I-95 physically separates this KCS from the Meadowlark Marsh restoration site.

Table 3.1.1-11. The following contamination values were the greatest measured at the site described above at the time of Groundwater Classification Exception Area (CEA) establishment on 9/4/2013.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Benzene	300	1
Tert-butyl alcohol	3,200	100

[1]The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeological characteristics of the groundwater resource and designated uses of the classification area.

Summary

1. The Meadowlark Marsh restoration site consists of 90 acres of marsh on the north shore of Bellmans Creek and is sandwiched between the NJ Turnpike to the west and the Conrail railroad to the east.
2. These structures restrict surface waters from mainly draining into Bellmans Creek, which is adjacent to the site. The marsh is tidally influenced.
3. The site is underlain by siltstone, shale, and coarse-grained sandstone (Passaic formation), which is underneath layers of Pleistocene glacial till and glacial lake deposits and Holocene fluvial and estuarine and salt-marsh deposits.
4. The surface of the Meadowlark Marsh site is made up of the Westbrook, Ipswich, and Sandyhook soil complexes, which are all flooded very frequently, as is characteristic of marshes.
5. There are two NJDEP recognized Known Contaminated Sites in the vicinity of the Meadowlark Marsh site. The shallow groundwater of these two sites contains concentrations of certain compounds that exceed their respective GWQS. Concern is warranted in that there is a KCS adjacent to the site separated only by Bellmans Creek. It is unknown if the contamination affects the health of Meadowlark Marsh.

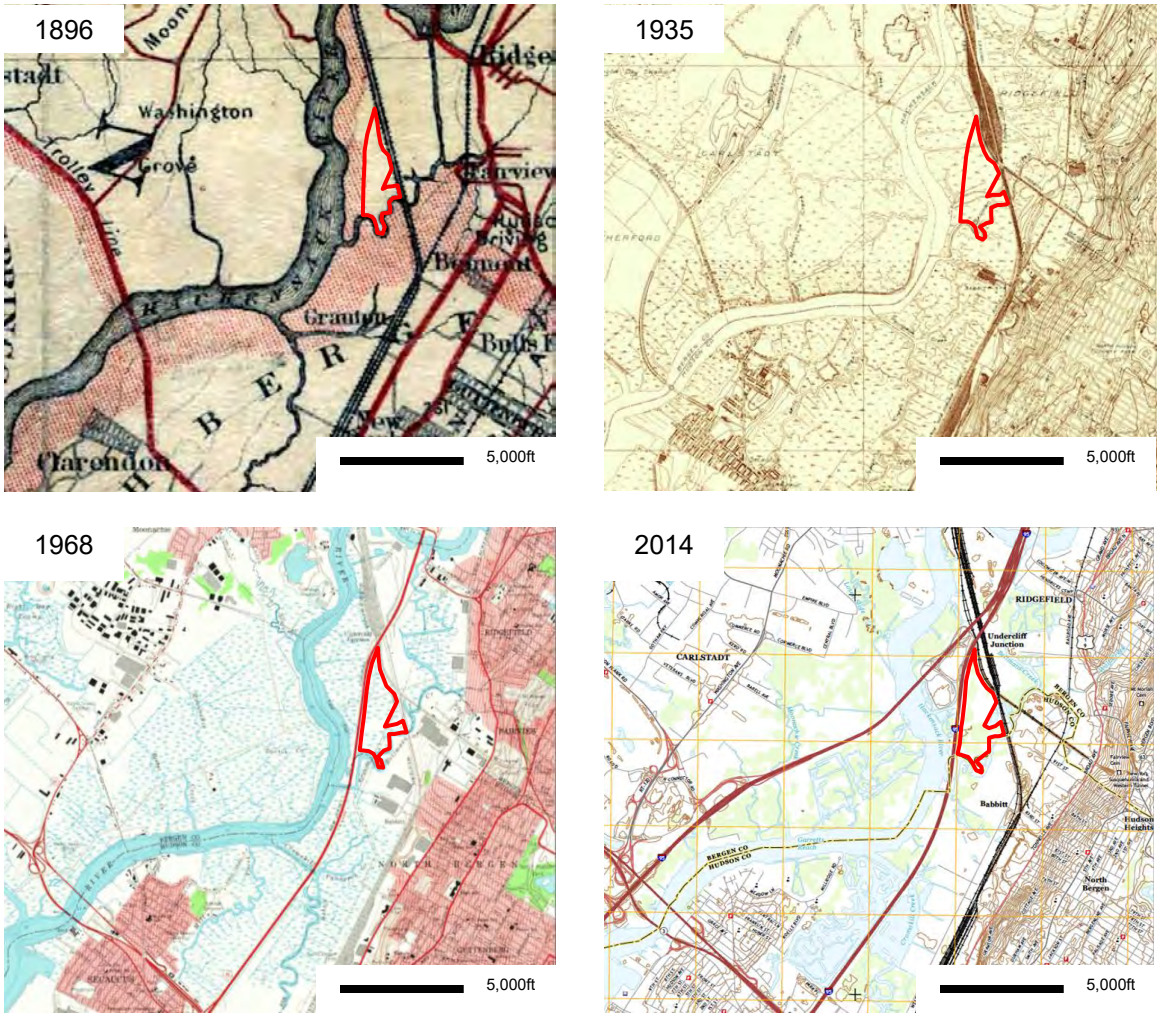


Figure 3.1.1-1. Left to right starting with top row: Colton's Road Map of Bergen County, NJ from 1896, USGS topographic map of Weehawken, NJ Quadrangle 7.5-minute maps from 1935, 1968, and 2014. Red lines delineate the Meadowlark Marsh HRE restoration site.

There is no datum information for Colton's road map from Bergen County, NJ in 1896. In 1935 and 1968, the contour interval is every 10ft, the datum is MSL (equivalent to the vertical datum of NGVD29), and the horizontal datum is NAD27. In 2014, the contour interval is every 10ft, the vertical datum is NAVD88, and the horizontal datum is NAD83.

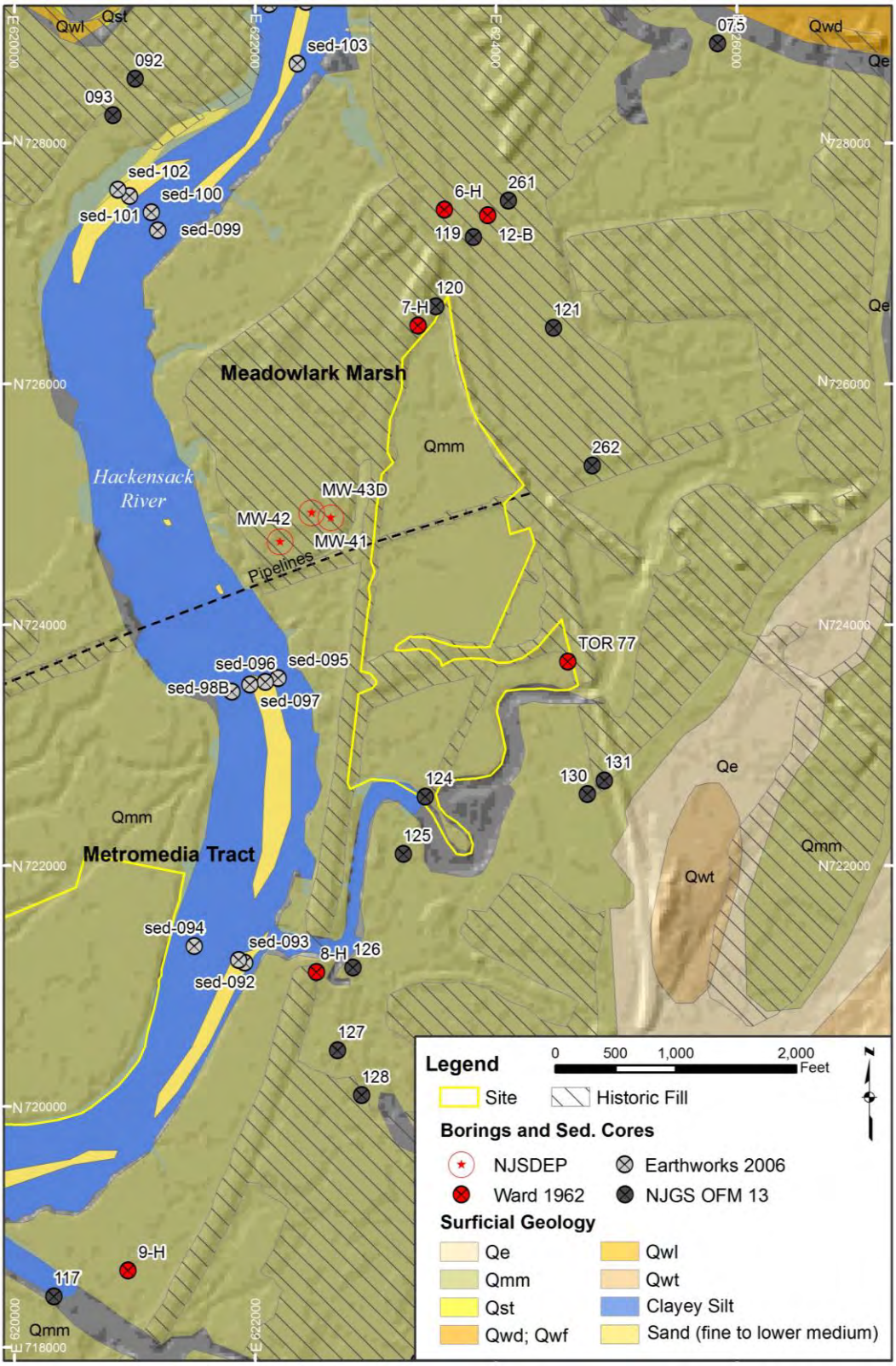


Figure 3.1.1-2. Surficial geology and boring locations of the Meadowlark Marsh site. The NJ land-based surficial geology is from NJDEP Geological Survey surficial geology map of New Jersey (DGS07-2).and (DGS04-7). River bed sediment map is from Earthworks, 2008, and e4sciences, 2016. Boundaries were modified to align with orthoimagery.

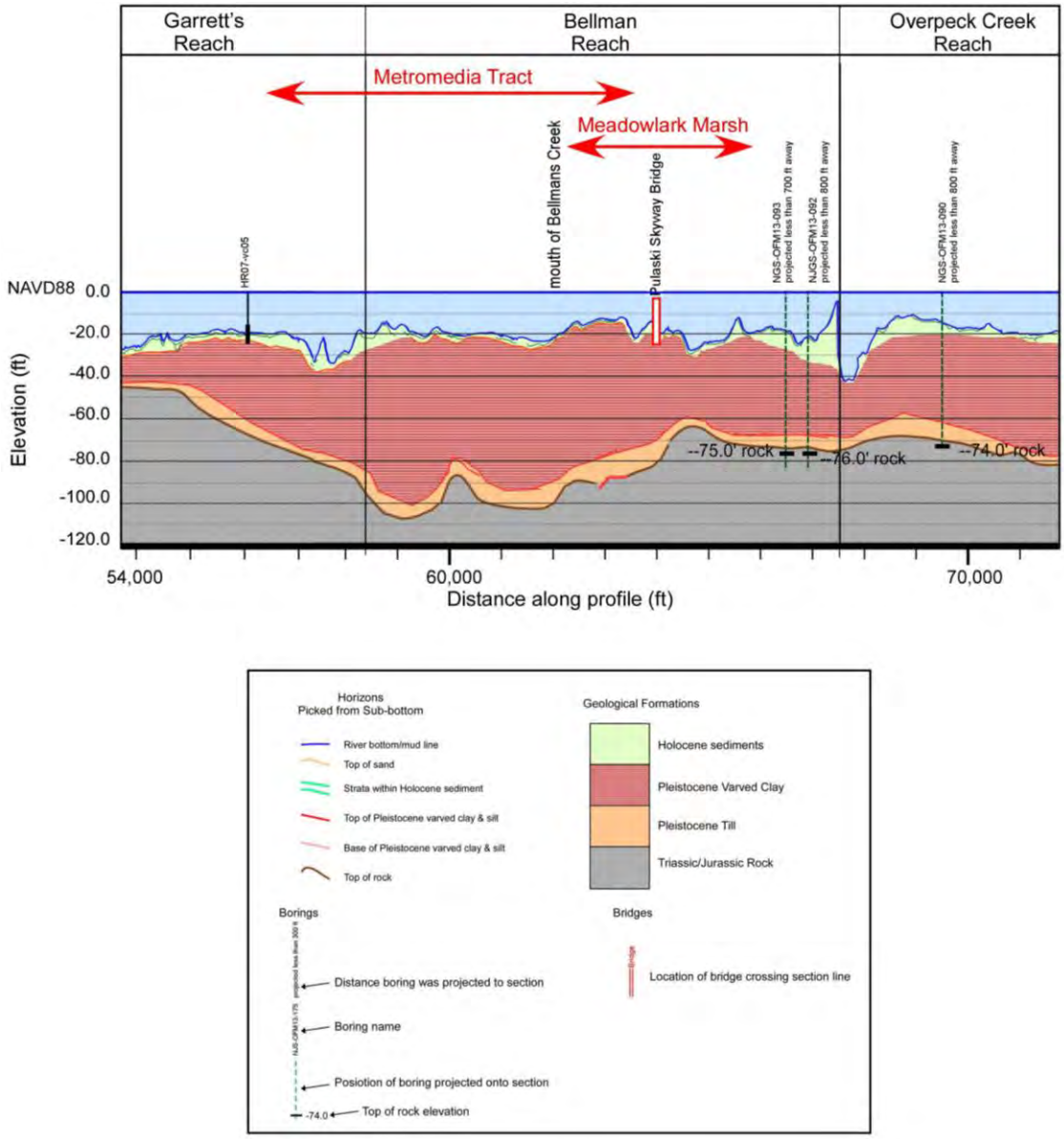


Figure 3.1.1-3. Geological cross section along the Hackensack River and adjacent to the Meadowlark Marsh site. The section is based on seismic surveys, sediment cores and grab samples, and historic borings (Earthworks, 2008). The red arrows indicate the approximate extent of the two HRE restoration sites.



Figure 3.1.1-4. Wetland areas and NJDEP recognized Known Contaminated Sites in the area of the Meadowlark Marsh. Base map images are March-May 2015 orthorectified images (NJGIN, 2015). Wetland data is from U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010.

3.1.2 Site 721. Metromedia Tract

The proposed Metromedia Tract HRE restoration site (721) is located on the western shore of the Hackensack River, across from the mouth of Bellmans Creek, and in between the main NJ Turnpike and its Eastern Spur. It is 0.23 miles (1,200ft) to the west of the Meadowlark Marsh HRE Site 719. Table 3.1.2-1 list the key information for the Metromedia Tract site.

Table 3.1.2-1. List of key information about the Metromedia Tract restoration site and its surrounding area.

Feature/reference type	Name/reference
City	Carlstadt
County	Bergen
State	New Jersey
Coordinates of site	40.8117078N 74.036839W
Size of site	74 acres
USGS Quad (ID)	Weehawken (o40074g1)
Geological map	OFM 13, I-2306, HFM-42
USACE reports	Earthworks 2007, Earthworks 2008
Watershed	Hackensack River
Sub-watershed	Hackensack River (Route 3 to Bellmans Creek)
Tidal range[a]	6.29ft

[a] MHHW-MLLW ft based on tides recorded Sept 1994 – Oct 1994 at NOAA/NOS/CO-OPS tidal station 8530528 Carlstadt, Hackensack River, NJ.

Figure 3.1.2-1 shows topographic maps from 1896, 1935, 1968, and 2014 outlining the Metromedia Tract restoration site in Carlstadt, NJ. The Metromedia Tract site is part of the Hackensack Meadowlands and is not developed in any of the topographic maps in Figure 3.1.2-1. The width of the Hackensack River at the Metromedia Tract site has decreased between 1896 and 1935, but has remained relatively steady since. The extent to which the Metromedia Tract marsh area has been flooded has varied over the years, as shown by the changes in degree of prevalence of streams/waterways that radiate from the Hackensack River through the Metromedia Tract site area (Figure 3.1.2-1).

Geology

The general stratigraphy of the Metromedia Tract restoration site is described in Table 3.1.2-2. Figure 3.0-3 shows the map of bedrock underlying the Metromedia Tract site. Figure 3.1.2-2 shows a map of the surficial geology of the area. Figure 3.1.2-3 shows a cross section along the Hackensack River based on data from Earthworks, 2008.

Table 3.1.2-2. General stratigraphy of the Metromedia Tract site.

Age	Thickness (ft)	Geologic Unit	Description
Holocene historic	0-5	Fill	Fill; concrete debris and gravel
Holocene	5-15	Estuarine and Salt-Marsh Deposits	Peat and silt
Holocene	5-13	Estuarine and Salt-Marsh Deposits	Stiff fine gray sand
Pleistocene	14->78	Glacial lake deposits	Silt and clay
Pleistocene	unknown	Glacial Till	Silty sands and gravels
Lower Jurassic/Upper	n.a	Passaic formation (Newark Group)	Siltstone, shaly siltstone, shale, coarse-grained sandstone

We can determine from the surficial geology (OFM 13) and bedrock geology (I-2306) maps that the top of bedrock at this site, which in this case is Passaic formation, is approximately 50- 60ft below the surface.

We can also determine the makeup of the shallow subsurface from the records of 39 monitoring wells and borings that are all less than 5,000ft from the site, as shown in Table 3.1.2-3 (NJDEP, Earthworks 2008, Ward 1962). The records of these monitoring wells and borings are available in digital Appendix VII-b.

Table 3.1.2-3. Borings and monitoring wells in or near the Metromedia Tract site.

Boring, well or sample ID	Permit Number	Source	Distance from Site (ft)
Ward62-TOR-56	n.a.	Ward et al. 1962	on site
Ward62-TOR-50	n.a.	Ward et al. 1962	150
HR07-sed-094	n.a.	Earthworks, 2008	240
HR07-sed-091	n.a.	Earthworks, 2008	278
HR07-sed-090	n.a.	Earthworks, 2008	384
HR07-sed-093	n.a.	Earthworks, 2008	610
HR07-sed-092	n.a.	Earthworks, 2008	665
HR07-sed-089A	n.a.	Earthworks, 2008	700
HR07-sed-089B	n.a.	Earthworks, 2008	700
Ward62-TOR-60	n.a.	Ward et al. 1962	740
HR07-vc-05	n.a.	Earthworks, 2008	856
Ward62-TOR-61	n.a.	Ward et al. 1962	1,050
Ward62-8-H	n.a.	Ward et al. 1962	1,276
Ward62-TOR-46	n.a.	Ward et al. 1962	1,378
Ward62-9-H	n.a.	Ward et al, 1962	1,395
Ward62-TOR-50	n.a.	Ward et al. 1962	1,410
HR07-sed-088	n.a.	Earthworks, 2008	1,480
HR07-sed-98B	n.a.	Earthworks, 2008	1,535
HR07-sed-087	n.a.	Earthworks, 2008	1,540
OFM-13-126	N26-14-148b	NJDEP OFM-13	1,550
OFM-13-117	N26-13-396	NJDEP OFM-13	1,585
OFM-13-127	N26-14-171	NJDEP OFM-13	1,600
Ward62-TOR-53	n.a.	Ward et al. 1962	1,625
HR07-sed-097	n.a.	Earthworks, 2008	1,640
MW-4	P200903236		1,670
HR07-sed-096	n.a.	Earthworks, 2008	1,710
MW-3	P200903235		1,750
HR07-sed-095	n.a.	Earthworks, 2008	1,780
MW-2	P200903234		1,800
Ward62-TOR-43	n.a.	Ward et al. 1962	1,835
OFM-13-125	N26-14-148a	NJDEP OFM-13	1,840
MW-1	P200903233		1,870
OFM-13-128	N26-14-173b	NJDEP OFM-13	1,890
OFM-13-124	N26-14-145	NJDEP OFM-13	2,110
OFM-13-228	n.a.	NJDEP OFM-13	2,120
OFM-13-189	N24-14-726	NJDEP OFM-13	3,084
OFM-13-256	26-5173	NJDEP OFM-13	3,580
Ward62-7-H	n.a.	Ward et al. 1962	4,920
HR07-sed-099	n.a.	Earthworks, 2008	5,280

Soil analysis

The surface expression of the Holocene estuarine salt-marsh deposits at the Metromedia Tract site consists of mucky peat underlain by muck, silt, or sand. The distribution of the sand is likely defined by tidal tributaries. Areas farther away from the historic channels are characterized by less sand and silt. This is documented by the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) Soil Survey Geographic (SSURGO) database[2], which

[2] Information about the types of soil found at the Meadowlark Marsh site was obtained through the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS). The USDA-NRCS operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of the U.S. counties and is produced by the National Cooperative Soil Survey.

The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

identifies that the soil unit at the site is composed of three soil types: Westbrook, Ipswich, and Sandyhook.

Each type is 64% organic matter and the remainder is composed of clay, silt and sand. Each type makes up 30% of the overall composition. The Westbrook and Ipswich types originated from partly decomposed herbaceous organic material (marsh plants), whereas the Sandyhook type came from sandy estuarine deposits. Soil profiles and additional properties of the Westbrook, Ipswich, and Sandyhook soil types are listed in Tables 3.1.2-4 - 3.1.2-9. The detailed geographic distribution of each soil type within the Metromedia Tract has not been mapped. The water table is at the surface and is tidally influenced. Complete reports of each soil type at this site are in Appendix VII-c.

Table 3.1.2-4. Soil profile of Metromedia Tract's Westbrook soil type.

Soil Layer	Depth (inches)	Description
Surface	0-19	Mucky peat
Subsurface	19-59	Silt loam

Table 3.1.2-5. Summary of properties of Metromedia Tract's Westbrook soil type.

Property	Description
Natural drainage class	Very poorly drained
Flooding	Very frequent
Slope	0-2%
Depth to water table	About 0 inches
Available water storage	High (about 9.1 inches)
Surface runoff	Negligible
Organic matter content	64%

Table 3.1.2-6. Soil profile of Metromedia Tract's Ipswich soil type.

Soil Layer	Depth (inches)	Description
Surface	0-42	Mucky peat
Subsurface	42-59	Muck

Table 3.1.2-7. Summary of properties of Metromedia Tract's Ipswich soil type.

Property	Description
Natural drainage class	Very poorly drained
Flooding	Very frequent
Slope	0-2%
Depth to water table	About 0 inches
Available water storage	Very high (about 26.6 inches)
Surface runoff	Negligible
Organic matter content	64%

Table 3.1.2-8. Soil profile of Metromedia Tract's Sandyhook soil type.

Soil Layer	Depth (inches)	Description
Surface	0-4	Mucky peat
Subsurface	4-8	Sand
Subsurface	8-11	Mucky coarse sand
Subsurface	11-51	Sand
Subsurface	51-59	Coarse sand

Table 3.1.2-9. Summary of properties of Metromedia Tract's Sandyhook soil type.

Property	Description
Natural drainage class	Very poorly drained
Flooding	Very frequent
Slope	0-2%
Depth to water table	About 0 inches
Available water capacity	Low (about 5.2 inches)
Surface runoff	Negligible
Organic matter content	64%

Surface water quality data

The Metromedia Tract site is part of the estuarine and marine wetland, as shown in Figure 3.1.2-4. Complete surface water quality reports containing individual data points are in digital Appendix VI-d.

Groundwater quality data

Figure 3.1.2-4 shows the locations of known contamination sites in or near the Metromedia Tract site. The movement and storage of groundwater in the Meadowlands District occurs primarily in the interconnected network of openings that form along joints, fractures, and other channels in the Passaic Formation. The estimate of thickness of the groundwater-producing zone in the bedrock is between 200 and 600ft (NJMC Master Plan, 2004).

Due to limited freshwater inflow and the lack of a direct connection with the open ocean, the lower Hackensack River area is susceptible to pollutants introduced to the watershed. Sources of pollution tend to be sewage treatment plants, industrial discharges, landfills, and surface runoff (NJMC Master Plan, 2004).

There are no NJDEP recognized Known Contaminated Sites (KCS) within 1,000ft of the Metromedia Tract site. The KCS (with groundwater contamination) that is south and east of Meadowlark Marsh is 1,400ft from the edge of Metromedia Tract. The address of the site is 9252 John F Kennedy Blvd in the city of North Bergen, New Jersey. The Program Interest (PI) name is Sier-Bath Gear Co. The known contaminants are listed in (Table 3.1.2-10). This KCS site encompasses 696 acres and the remediation status is unknown. The fact that this site borders Bellmans Creek, which is connected to the Hackensack River, could be a potential concern.

Table 3.1.2-10. Greatest contamination values measured at the KCS described above at the time of Groundwater Classification Exception Area (CEA) establishment on 8/25/1999.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Arsenic	13	8
Bis (2-ethylhexyl) phthalate	2300	30
Dichloroethylene (*cis*-1,2)	8000	2
Ethyldiene dichloride	120	70
Lead	17	10
Trichloroethane (1,1,1)	140	30
Trichloroethylene	440	1
Vinyl chloride	890	5
Vinyldiene chloride	33	2

[1] The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeologic characteristics of the groundwater resource and designated uses of the classification area.

Summary

1. The Metromedia Tract restoration site is 74 acres in size and is in the Hackensack-River-Route-3-to-Bellmans-Creek sub-watershed. This site is managed by the Meadowlands district.
2. The site is underlain by siltstone, shale, and coarse-grained sandstone (Passaic formation), which is underneath layers of estuarine and salt-marsh deposits and fill.
3. The surface of the Metromedia Tract site is made up of the Westbrook, Ipswich, and Sandyhook soil complexes, which are all flooded very frequently, as is characteristic of marshes.
4. The closest NJDEP recognized Known Contaminated Site is 1,400ft east of the Metromedia Tract site.

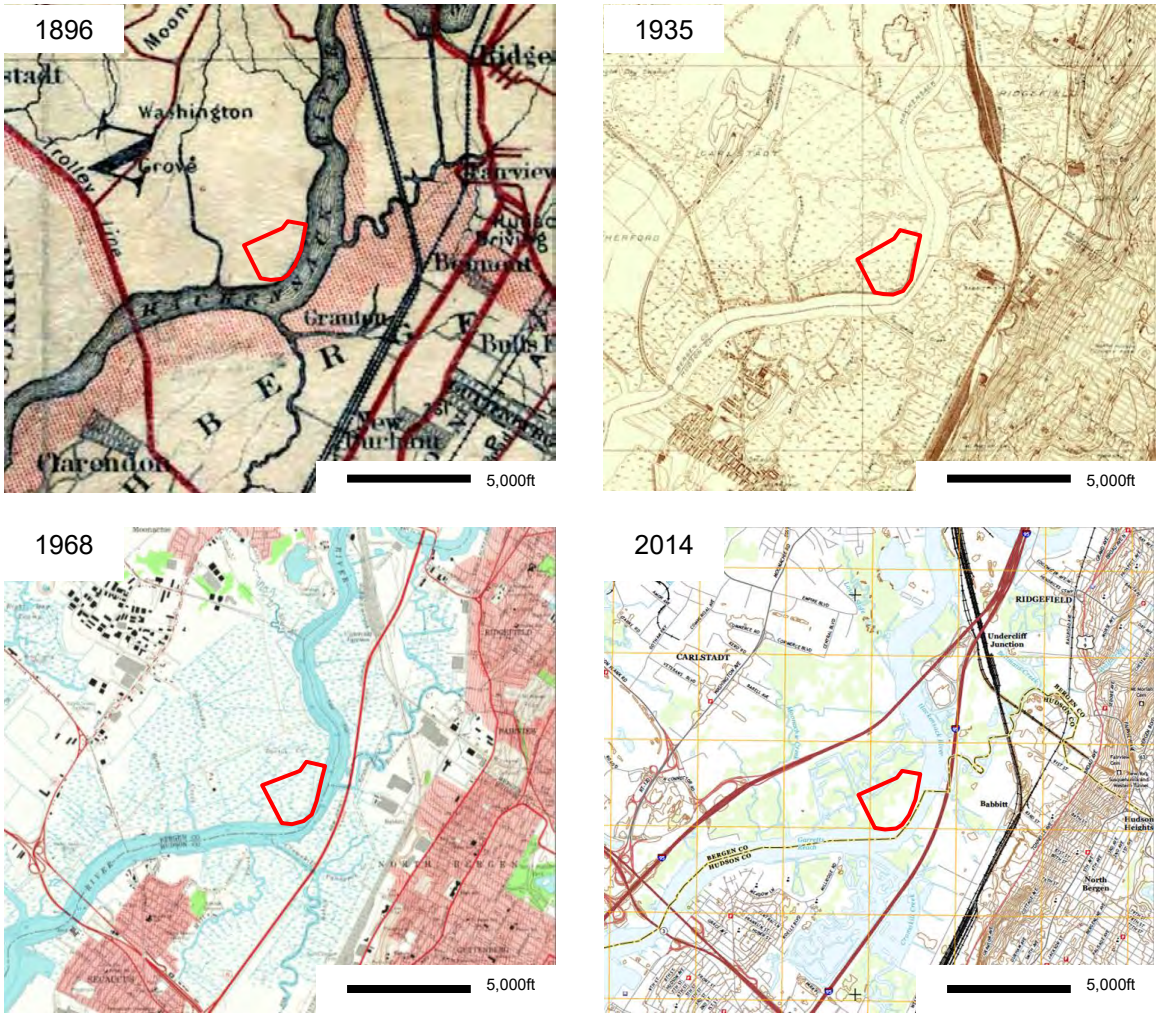


Figure 3.1.2-1. Left to right starting with top row: Colton's Road Map of Bergen County, NJ from 1896, USGS topographic map of Weehawken, NJ Quadrangle 7.5-minute maps from 1935, 1968, and 2014. Red lines delineate the Metromedia Tract HRE restoration site.

There is no datum information for Colton's road map from Bergen County, NJ in 1896. In 1935 and 1968, the contour interval is 10 feet, the datum is MSL (equivalent to the vertical datum of NGVD29), and the horizontal datum is NAD27. In 2014, the contour interval is 10 feet, the vertical datum is NAVD88, and the horizontal datum is NAD83.

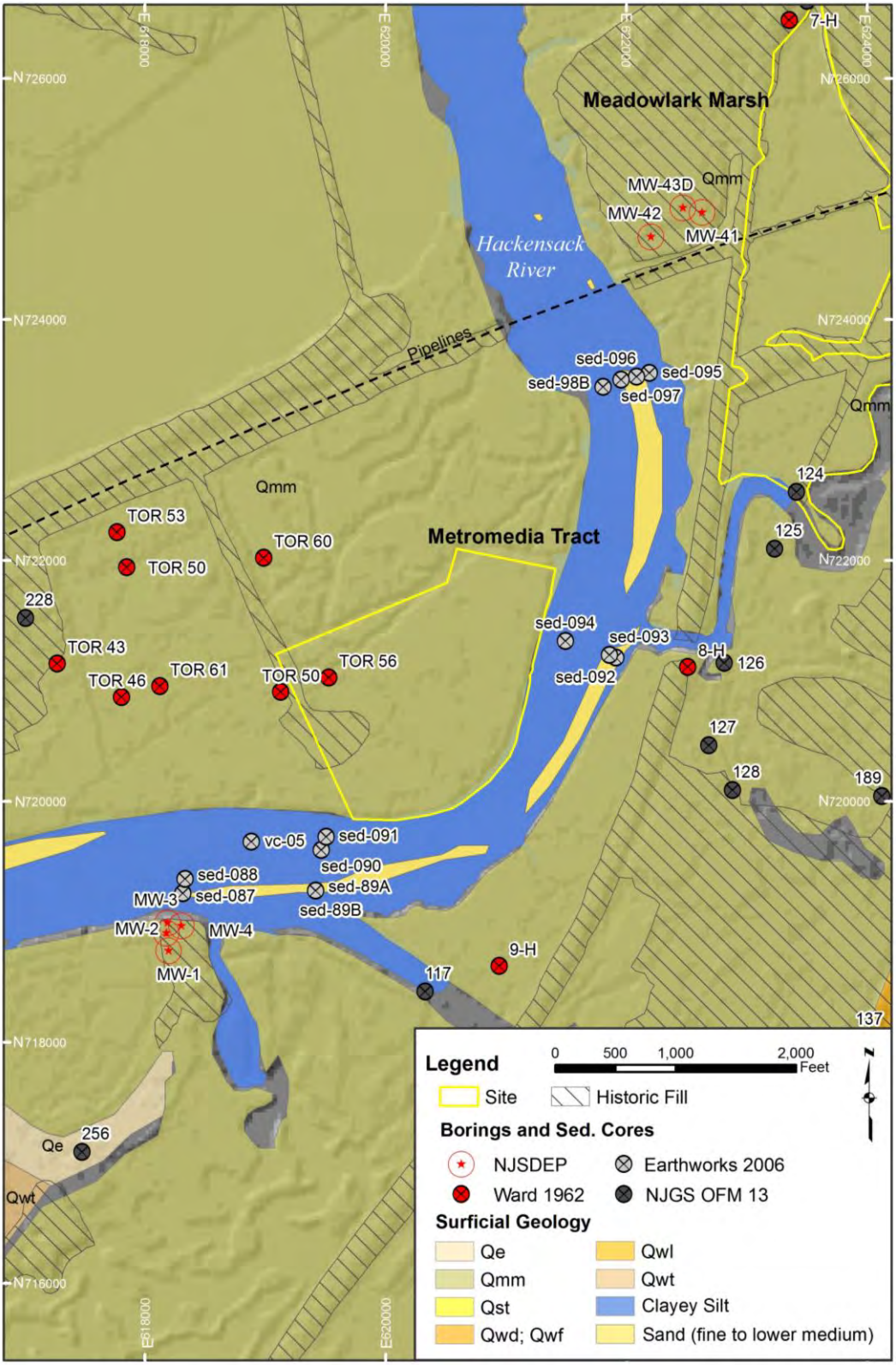


Figure 3.1.2-2. Surficial geology and boring locations of the Metromedia Tract site. The NJ land-based surficial geology is from NJDEP Geological Survey surficial geology map of New Jersey (DGS07-2).and (DGS04-7). River bed sediment map is from Earthworks, 2008, and e4sciences, 2016. Boundaries were modified to align with orthoimagery.

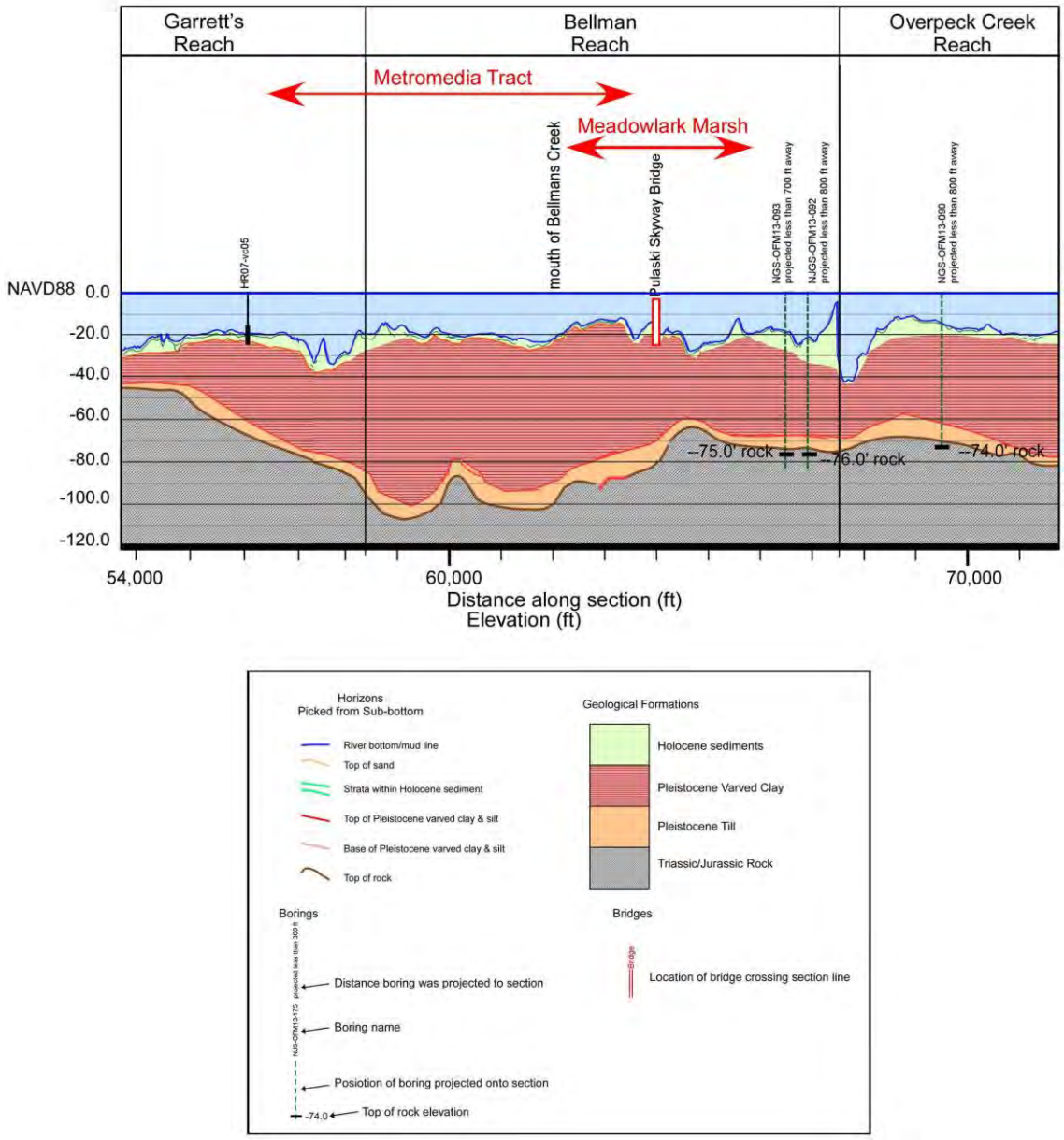


Figure 3.1.2-3. Geological cross section borings along the Hackensack River adjacent to the Metromedia Tract site. The section is based on seismic surveys, sediment cores and grab samples and historic borings (Earthworks, 2006). The red arrows indicate the approximate extent Meadowlark Marsh and Metromedia Tract sites.



Figure 3.1.2-4. Wetland areas and NJDEP recognized Known Contaminated Sites in the area of the Metromedia Tract site. Base map images are March-May 2015 orthorectified images (NJGIN, 2015). Wetland data is from U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010.

3.2 Newark Bay

3.2.1 Site 865. Kearny Point

The Kearny Point proposed HRE restoration Site 865 is located at the confluence of the Passaic and Hackensack Rivers at the northern end of Newark Bay. The Kearny Point restoration site is built entirely of historic fill and is a decommissioned industrial facility. Table 3.2.1-1 contains the key information for the Kearny Point site.

Table 3.2.1-1. List of key information and references for the Kearny Point restoration site and its surrounding area.

Feature/reference type	Name/reference
City	Kearny
County	Hudson
State	New Jersey
Coordinates of site	40.7192532N 74.114763W
Size of site	110 acres
USGS Quad (ID)	Jersey City (o40074f1)
USGS maps	N4037.5–W7400/7.5
Geological maps	OFM 20, I-2540-A, HFM-53
USACE reports	Earthworks 2006, Earthworks 2007, Earthworks 2008
Watersheds	Hackensack River, Passaic River Lower and Newark Bay
Sub-watersheds	Hackensack R. (below Amtrak Bridge),Passaic R. Lower (Newark Bay to 4th Street Bridge) and Newark Bay
Tidal range[a]	5.10ft

[a] MHW-MLW ft based on tides recorded Oct 2005 – Sept 2013 at USGS tidal station 01392650 Passaic Valley Sewerage Commission.

Figure 3.2.1-1 shows topographic maps from 1845, 1899, 1955, and 2014 outlining the Kearny Point restoration site in Kearny, NJ, which is located at the southern tip of the peninsula that protrudes into northern Newark Bay. As depicted in the 1845 and 1899 topographic maps, Kearny Point used to be marshland/meadowland, but was then filled in and constructed on between 1899 and 1955. Today the area is very industrial, and includes many warehouses, manufacturing plants and shipbuilding yards, as well as the Pulaski Skyway running north of the area.

Geology

The general stratigraphy of the Kearny Point restoration site is described in Table 3.2.1-2. Figure 3.0-3 shows the map of bedrock underlying the Kearny Point site. Figure 3.2.1-2 shows a map of the surficial geology of the area. . Figure 3.2.1-3 shows a cross section along the Hackensack River based on data from Earthworks, 2008. This site is underlain by the Passaic Formation of the Newark Group. The Passaic formation is mostly made up of cyclical lacustrine strata, with some fluvial strata consisting of conglomerate towards the northeast. Facies changes in the Passaic formation are significant both laterally and vertically; there is a decrease in the frequency of gray and black units moving northeast through the formation, as well as in the frequency of thick black shales deposited by deep lakes moving upward through the formation (Schlische 1992, Olsen 2004).

Table 3.2.1-2. General stratigraphy of the Kearny Point site based on NJDEP monitoring wells and geotechnical borings, surficial geology (OFM 20, HFM-53), and bedrock geology (I-2540-A).

Age	Thickness (ft)	Geologic Unit	Description
Holocene historic	15-20	Artificial fill	Silty sands, sand-silt mixtures
Holocene	5-10	Estuarine and salt-marsh deposits	Organic silts and organic silty clays
Pleistocene	5-20	Outwash Sands	Sands
Pleistocene	20	Glacial lake-deposits	Inorganic clay and, silt
Pleistocene	20->50	Glacial Till	Silty sands and gravel
Lower Jurassic/Upper Triassic	n.a.	Passaic Formation	Shale

The shallow subsurface of the Kearny Point site can be determined from surficial (OFM 20), historic fill (HFM-53), and bedrock (I-2540-A) geology maps of the area. In addition the geologic unit descriptions of Table 3.2.1-2 are reflected by the cross section in Figure 3.2.1-3. Subsurface characteristics can also be verified by the records of 14 monitoring wells and geotechnical borings drilled within the site boundaries, as well as ten geotechnical borings drilled less than 5,000ft away from the site (Table 3.2.1-3). The records of the on-site borings are kept by the NJDEP and are available in digital Appendix VIII-b. The geologic logs of the borings from OFM 20 can also be found in digital Appendix VIII-b.

Table 3.2.1-3. Monitoring wells and geotechnical borings in or near the Kearny Point site.

Boring, well or sample ID	Permit number	Source	Distance from site (ft)
MW-20	E201015891	NJDEP	on site
MW-21	E201015886	NJDEP	on site
MW-22	E201015887	NJDEP	on site
MW-23	E201015888	NJDEP	on site
MW-24	E201015889	NJDEP	on site
MW-25	E201015890	NJDEP	on site
MW-26	E201015892	NJDEP	on site
SB-7	E201202196	NJDEP	on site
SB-8	E201202197	NJDEP	on site
MTB-2	E201218127	NJDEP	on site
CPT AGC-1C	E201412748	NJDEP	on site
CPT AGC-2C	E201412749	NJDEP	on site
CPT AGC-3C	E201412750	NJDEP	on site
CPT AGC-4C	E201412751	NJDEP	on site
OFM-20-095	n.a.	NJDEP OFM-20	86
OFM-20-096	n.a.	NJDEP OFM-20	320
OFM-20-094	n.a.	NJDEP OFM-20	582
OFM-20-097	n.a.	NJDEP OFM-20	764
OFM-20-092	n.a.	NJDEP OFM-20	1,360
OFM-20-093	n.a.	NJDEP OFM-20	1,854
OFM-20-113	n.a.	NJDEP OFM-20	2,115
OFM-20-077	26-7005	NJDEP OFM-20	4,015
OFM-20-084	n.a.	NJDEP OFM-20	4,770
OFM-20-082	n.a.	NJDEP OFM-20	5,116

Soil analysis

The presence of surficial Holocene artificial fill in the general stratigraphy of the Kearny Point site is consistent with the soil type that U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) Survey Geographic (SSURGO) database[3] identifies as being present at the site; Secaucus artifactual fine sandy loam soil, 0-3% slope and 3-8% slope. The Secaucus artifactual fine sandy loam soil with a slope of 0-3% is located in the western half of the site, and the 3-8% slope is located in the eastern half. This soil type most likely originated from human activity. Soil profiles and additional properties of the Secaucus artifactual fine sandy loam type can be found in Tables 3.2.1-4 - 3.2.1-6. Complete soil reports of each type of soil

[3] Information about the types of obtained through the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS). The USDA-NRCS operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of the U.S. counties and is produced by the National Cooperative Soil Survey.

The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

found at this site are in Appendix VIII-ii. The distribution of the two soil types within the Kearny Point site is unmapped.

Table 3.2.1-4. Soil profile of Kearny Point's Secaucus artifactual fine sandy loam soil type (0-3% slope), located in the western half of the site.

Soil Layer	Depth (inches)	Description
Surface	0-6	Gravelly-artifactual fine sandy loam
Subsurface	6-17	Very artifactual fine sandy loam
Subsurface	17-65	Extremely cobbly-artifactual fine sandy loam

Table 3.2.1-5. Soil profile of Kearny Point's Secaucus artifactual fine sandy loam soil type (3-8% slope), located in the eastern half of the site.

Soil Layer	Depth (inches)	Description
Surface	0-6	Artifactual fine sandy loam
Subsurface	6-17	Very artifactual fine sandy loam
Subsurface	17-65	Extremely artifactual fine sandy loam

Table X 3.2.1-6. Summary of properties of Kearny Point's Secaucus artifactual fine sandy loam soil types, both 0-3% and 3-8% slopes.

Property	Description
Natural drainage class	Moderately well-drained
Flooding	None
Depth to water table	18-39 inches
Available water capacity	Very low (about 2.8 inches)
Surface runoff	Medium
Organic matter content	0.83%
Percent clay	5.9% of clay, silt and sand
Percent sand	68.6% of clay, silt and sand
Percent silt	25.5% of clay, silt and sand

Surface water quality data

Parts of the Kearny Point site are considered estuarine and marine wetlands, as shown in Figure 3.2.1-4. Since September 2004, MERI has been operating a 24/7 real-time water quality-monitoring network in the lower Hackensack River. This system has made possible the identification and quantification of adverse effects of the nearby District landfills on the water quality of the area. Water quality parameters such as acidity, DO concentration, salinity, temperature of surface waters, and turbidity are measured hourly at the Kearny Point site and are averaged by month in Table 3.2.1-7. A complete surface water quality report containing individual data points that were averaged to produce the tabulated values is in Appendix VIII-c.

Table 3.2.1-7. Summary of water quality parameters from March 2013 to February 2014, measured at Kearny Point, NJ by MERI.

Month/Year	2013 Mar	2013 Apr	2013 May	2013 June	2013 July	2013 Aug	2013 Sept	2013 Oct	2013 Nov	2013 Dec	2014 Jan	2014 Feb
Acidity (pH)	8.91	8.92	8.51	8.62	8.82	8.82	8.94	8.52	8.28	8.38	8.42	8.40
DO Conc. (mg/L)	10.41	9.46	6.06	5.18	4.64	5.12	5.37	6.55	8.68	9.38	10.77	10.21
Salinity (ppt)	14.31	14.91	13.12	8.61	12.11	12.41	12.19	13.80	18.10	14.77	12.67	15.14
Temperature (°F)	42.64	51.98	61.94	71.46	79.57	75.71	71.64	63.31	49.60	40.87	35.09	34.93
Turbidity (FTU)	13.49	16.24	23.05	24.50	132.25	389.55	1066.91	512.41	11.96	14.69	16.97	14.88

Groundwater quality data

Figure 3.2.1-4 shows the locations of known contamination sites in or near the Kearny Point site. Inside of the western half of the Kearny Point site, there is a Known Contaminated Site (KCS) with groundwater contamination. The address of the site is 50 Central Ave in the city of Kearny, New Jersey. The PI name is BASF Corporation. The known contaminants include are shown in Table 3.2.1-8. The site encompasses 24.6 acres, and is the eastern half of the restoration site.

In 2014 the LSRP for the site and the site has been deed restricted. Water wells are prohibited and monitoring wells and borings are restricted in the area of a contaminated plume.

Table 3.2.1-8. The following contamination values were the greatest measured at the site described above at the time of Groundwater Classification Exception Area (CEA) establishment on 12/24/2013.

Contaminant	Concentration	GWQS[1]
Benzene	6.3 µg/L	1.0 µg/L
Bis (2-ethylhexyl) phthalate	8.8 µg/L	3.0 µg/L
pH	8.69 units	6.50 units
Synthetic Organic Chemicals – Non Carcinogen [Total]	1,087 µg/L	500 µg/L
Xylenes [Total]	3,800 µg/L	1,000 µg/L

[1]The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeologic characteristics of the groundwater resource and designated uses of the classification area.

There is another KCS with groundwater contamination 500ft northeast of the Kearny Point site. The address of this site is Hackensack Ave, in the city of Kearny, New Jersey. The Program Interest (PI) name is New York Daily News Incorporated. The known contaminants include benzene and xylenes (Table 3.2.1-9). The site encompasses 13.8 acres. The CEA was closed/lifted on 8/1/2014.

Table 3.2.1-9. The following contamination values were the greatest measured at the site described above at the time of Groundwater Classification Exception Area (CEA)_ establishment on 1/8/1997.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Benzene	119	1
Xylenes (total)	350	1,000

[1]The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeologic characteristics of the groundwater resource and designated uses of the classification area.

Summary

1. The Kearny Point restoration site is 110 acres in size and is located at the confluence of the Hackensack and Passaic Rivers, and is part of the Hackensack River (below Amtrak Bridge), Passaic River Lower (Newark Bay to 4th Street Bridge), and Newark Bay/Kill van Kull (74° 07'30") sub-watersheds.
2. The site is underlain by shale (Passaic formation), which is underneath layers of lake-bottom deposits, estuarine and salt-marsh deposits, and artificial fill.
3. The surface of the Kearny Point site is made up of the Secaucus artifactual fine sandy loam soil complex (fill).
4. There are two NJDEP recognized Known Contaminated Sites in close proximity to the Kearny Point site. These sites contain concentrations of certain compounds that exceed their respective GWQS. How this affects the overall health of the site cannot be determined definitively.

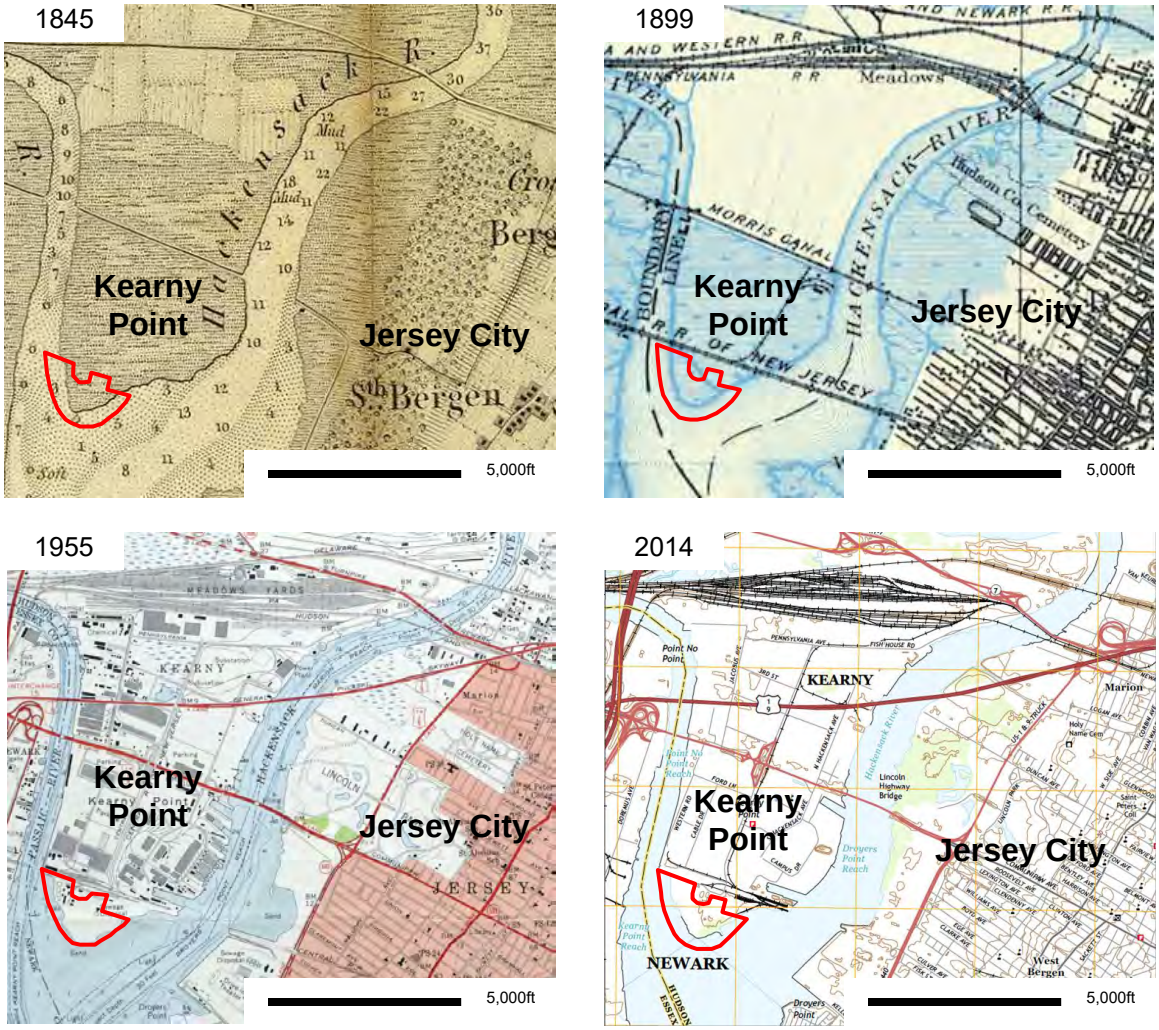


Figure 3.2.1-1. Left to right starting with top row: NOAA nautical chart from 1845, USGS topographical Staten Island Quadrangle 15-minute map from 1899, and USGS topographical Jersey City Quadrangle 7.5-minute maps from 1955 and 2014 highlighting Kearny Point, NJ. Red lines delineate the Kearny Point HRE restoration site.

In 1845, depth soundings are in feet below MLW; in 1845, MLW was at the lowest spring tides observed during the survey, and mean sea level was approximately 1.6ft lower than it is today (based on mean sea level records at The Battery, NY 1856-2014). In 1899, the contour interval is 20 feet and the datum is MSL (equivalent to the vertical datum of NGVD29). In 1955, the contour interval is 10 feet, the datum is MSL (equivalent to the vertical datum of NGVD29), and the horizontal datum is NAD27. In 2014, the contour interval is 10 feet, the vertical datum is NAVD88, and the horizontal datum is NAD83.

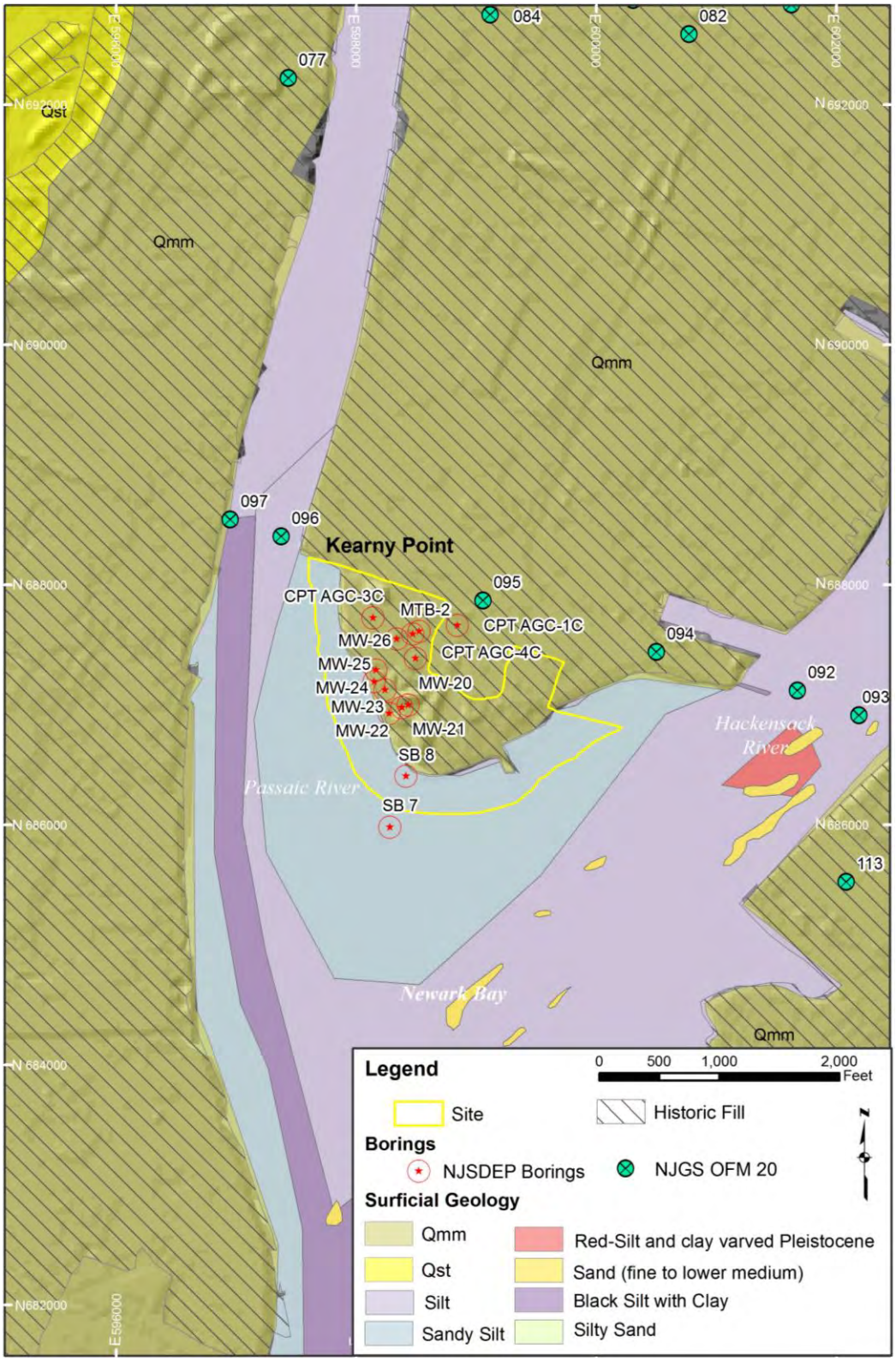


Figure 3.2.1-2. Surficial geology and boring locations of the Kearny Point site. The NJ land-based surficial geology is from NJDEP Geological Survey surficial geology map of New Jersey (DGS07-2).and (DGS04-7). River bed and bay floor sediment map is from Earthworks, 2008, and e4sciences, 2016. Boundaries were modified to align with orthoimagery.

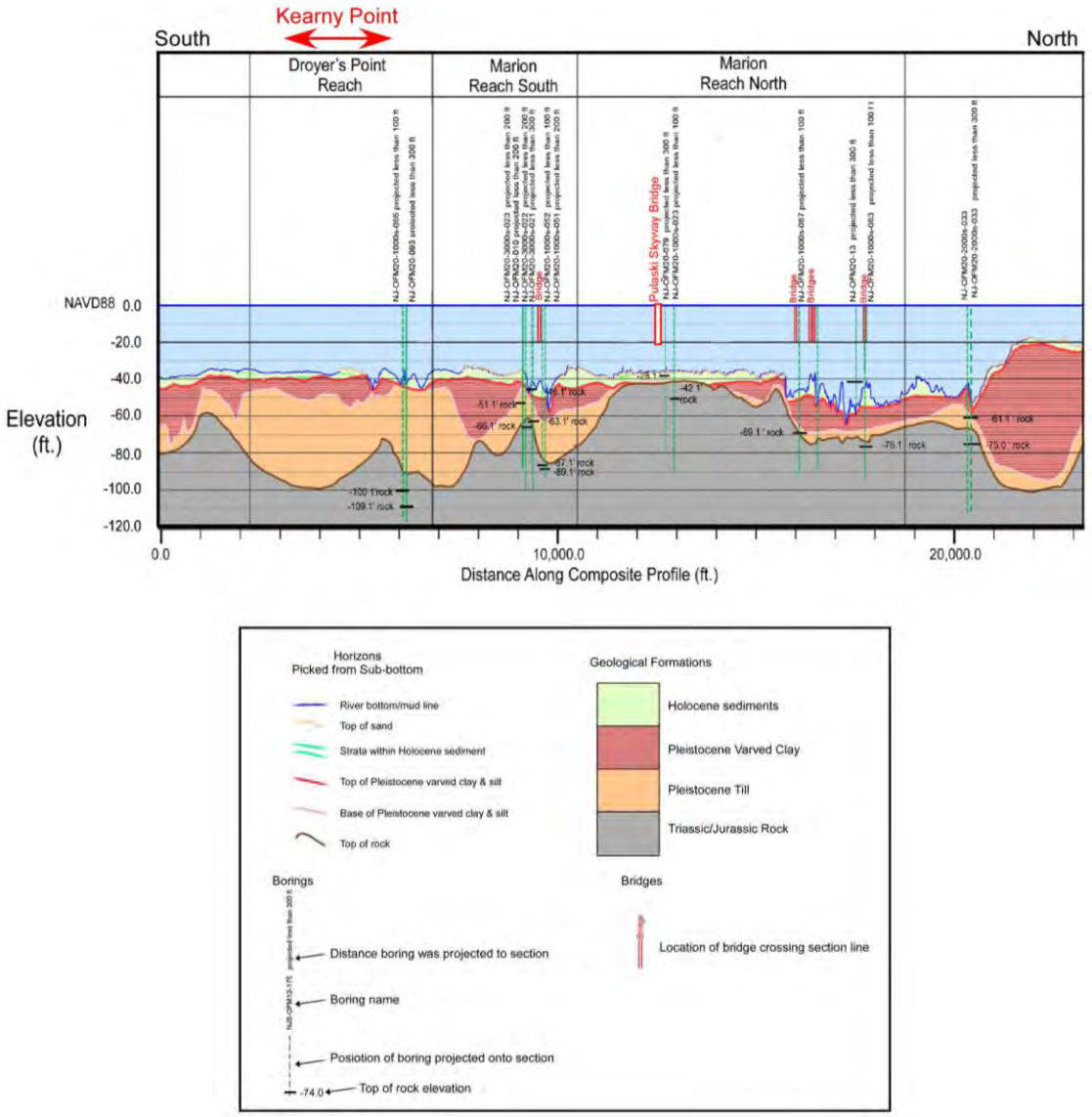


Figure 3.2.1-3. Geological cross section along the Hackensack River adjacent to eastern side of Kearny Point. The section is based on seismic surveys, sediment cores and grab samples and historic borings (Earthworks, 2006). The red arrow indicates the approximate extent of the Kearny Point sites. The thick Pleistocene glacial till includes Pleistocene outwash sands.

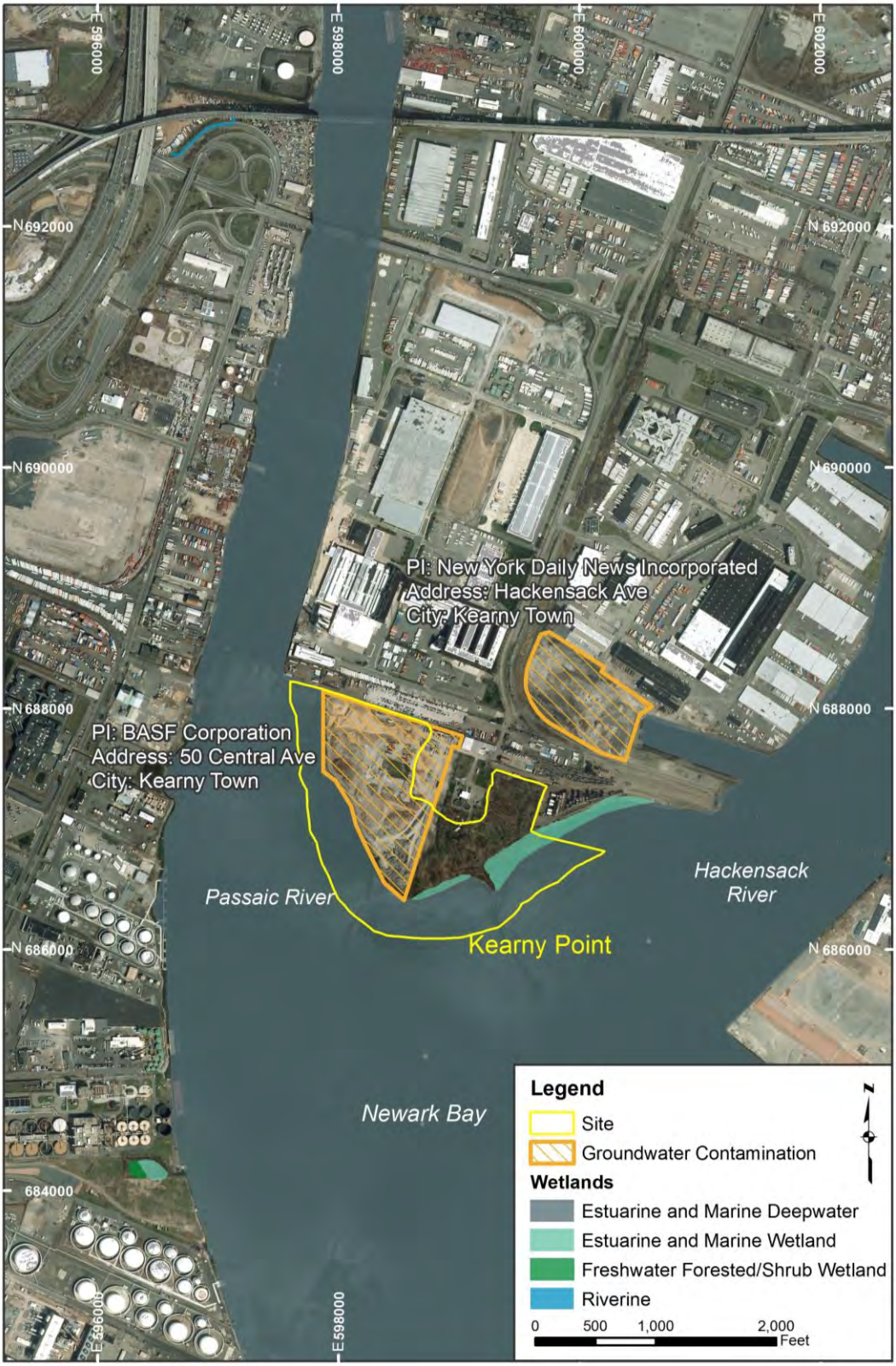


Figure 3.2.1-4. Wetland areas and NJDEP Known Contaminated Sites in the area of the Kearny Point site. Orthophoto obtained from NJGIN Clearinghouse Web Map Services, 2015. Wetland information obtained from U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010.

3.2.2 Site 866. Oak Island Yards

The proposed Oak Island Yards HRE restoration site is located on the western shore of Newark Bay, just north of the Lehigh Valley Railroad Bridge. Table 3.2.2-1 lists the key information for the Oak Island Yards site.

Table 3.2.2-1. List of key information and references for Oak Island Yards restoration site and its surrounding area.

Reference type	
City	Newark
County	Essex
State	New Jersey
Coordinates of site	40.7024161N 74.122993W
Size of site	39 acres
USGS Quad (ID)	Jersey City (o40074f1)
USGS maps	N4037.5–W7400/7.5
Geological map	OFM 20, I-2540-A, HFM-53
USACE reports	Earthworks 2001, Earthworks 2006
Watershed	Lower Passaic and Saddle
Sub-watershed	Newark Bay/Kill Van Kull (74° 07'30")
Tidal range[a]	5.74ft

[a] MHHW-MLLW ft based on tides recorded Jan 1976 – Nov 1976 at NOAA/NOS/CO-OPS tidal station 8530743 Point No Point, Passaic River, NJ.

Figure 3.2.2-1 shows topographic maps from 1845, 1899, 1932, and 2014 outlining Oak Island Yards, which is south of Kearny Point and on the western shore of Newark Bay in Newark, NJ. A comparison of the topographic maps reveals a drastic change in both the east and west shorelines of Newark Bay. The shallows of the western part of Newark Bay were filled in between 1899 and 1932, which created the land that makes up Oak Island Yards.

Geology

The general stratigraphy of the Oak Island Yards restoration site is described in Table 3.2.2-2. Figure 3.0-3 shows the map of bedrock underlying the Oak Island Yards site. Figure 3.2.2-2 shows a map of the surficial geology of the area.

Table 3.2.2-2. General stratigraphy Oak Island Yards site.

Age	Thickness (ft)	Geologic Unit	Description
Holocene historic	15-20	Artificial fill	Silty sands, sand-silt mixtures
Holocene	5-10	Estuarine and salt-marsh deposits	Organic silts and organic silty clays
Pleistocene	5-20	Outwash sands	
Pleistocene	Up to 50	Glacial lake-deposits	Inorganic clay and, silt
Pleistocene	Unknown thickness	Glacial Till	Silty sands and gravel
Lower Jurassic/Upper Triassic	n.a	Passaic formation	Shale

This stratigraphy of the Oak Island Yards site is based on NJDEP monitoring wells and geotechnical borings, surficial geology (OFM 20, HFM-53), and bedrock geology (I-2540-A). The referenced NJDEP monitoring wells and geotechnical borings are listed in Table 3.2.2-3 and their records are available in Appendix IX-b.

Table 3.2.2-3. Borings and wells near the Oak Island Yards site.

Boring, well or sample ID	Permit Number	Source	Distance from Site (ft)
OW-1	E201013548	NJDEP	850
OW-2	E201013549	NJDEP	810
OW-3	E201114659	NJDEP	740
B-7	E201213111	NJDEP	1,500
B-8	E201213112	NJDEP	1,530
OFM-20-017	n.a.	OFM-20	2,306

This site is underlain by the Passaic formation, which is the upper-most formation of the Newark Group. The Passaic formation is mostly made up of cyclical lacustrine strata, with some fluvial strata consisting of conglomerate towards the northeast. Facies changes in the Passaic formation are significant both laterally and vertically; there is a decrease in the frequency of gray and black units moving northeast through the formation, as well as in the frequency of thick black shales deposited by deep lakes moving upward through the formation (Schlische 1992, Olsen 2004).

Soil analysis

The Oak Island Yards site's Holocene estuarine salt-marsh deposits consist of clay and silty sands. This is corroborated by the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) Soil Survey Geographic (SSURGO) database,[4] which identifies the Udorthents soil unit, a loamy fill substratum, as being the dominant soil unit at the site. The Udorthents series is the product of past dredge-and-fill activities, and so the parent material of this complex is loamy-skeletal human-transported material. A soil profile and additional properties of the Udorthents unit can be found in Tables 3.2.2-4 and 3.2.2-5. Complete soil reports of each type of soil found are in Appendix IX-c.

Table 3.2.2-4. Soil profile of Oak Island Yards' Udorthents soil unit.

Soil Layer	Depth (inches)	Description
Surface	0-12	Loam
Subsurface	12-60	Silty clay

Table 3.2.2-5. Summary of properties of Oak Island Yards' Udorthents soil unit.

Property	Description
Natural drainage class	Well drained
Flooding	None
Slope	0-8%
Depth to water table	48-122 inches
Available water capacity	Moderate (about 8.4 inches)
Surface runoff	Medium
Organic matter content	1.52%
Percent clay	42.1% of clay, silt and sand fraction
Percent sand	13.3% of clay, silt and sand fraction
Percent silt	44.6% of clay, silt and sand fraction

[4] Information about the types of obtained through the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS). The USDA-NRCS operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of the U.S. counties and is produced by the National Cooperative Soil Survey.

The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

Surface water quality data

In 2013, the New Jersey Harbor Dischargers Group (NJHDG) took a variety of field measurements in rivers, bays, and harbors in New Jersey and New York according to sub-watershed classification as part of the Ambient Water Quality Monitoring Program. These water measurements included acidity, DO concentration, salinity, temperature of the surface water, turbidity, and amount of fecal coliform. The measurements were made multiples times throughout each month and are averaged by month in Table 3.2.2-6. Complete surface water quality reports containing individual data points are in Appendix IX-iv. Turbidity was measured in terms of the concentration of total suspended solids, and enterococcus values were measured in terms of number of colony forming units found in 100mL.

Table 3.2.2-6. Summary of water quality parameters measured from January to December 2013 in the sub-watershed of the Newark Bay/Kill Van Kull (74°7'30").

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Acidity (pH)	6.04	7.67	7.73	7.87	7.50	7.48	7.60	7.61	7.52	7.52	7.74	7.58
DO Concentration (mg/L)	11.57	12.18	11.45	11.28	7.14	6.43	5.48	5.77	6.07	6.67	9.56	9.13
Salinity (ppt)	21.86	20.74	19.38	19.30	21.34	15.79	21.72	23.91	25.05	25.91	27.85	25.44
Temperature (°F)	43.97	37.26	40.57	43.05	58.64	66.63	74.61	73.26	69.21	66.67	50.16	45.00
Turbidity (mg/L)	48.22	-	29.00	47.22	30.67	50.11	50.54	49.67	47.52	49.50	49.11	59.25
Enterrococcus (cfu/100mL)	15.78	11.60	-	-	91.60	15.00	12.50	11.14	-	-	-	-

Groundwater quality data

There are no Known Contaminated Sites (KCS) within the Oak Island Yards site. Figure 3.2.2-3 shows the locations of known contamination sites near the Oak Island Yards site. Less than 1,000ft northwest of the site there is a KCS with groundwater contamination associated with the Newark Energy Center constructed between 2012 and 2014. The address of the site is 921 1111 Delancy St, in the city of Newark, New Jersey. The PI name is ARCO Petroleum Products – Hess. The known contaminants include are listed in Table 3.2.2-7. The KCS encompasses 22.8 acres.

Table 3.2.2-7. The following contamination values were the greatest measured at the site described above at the time of Groundwater CEA establishment on 8/22/2012.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Aluminum	6,740	200
Arsenic	74.1	3
Benzo(a)anthracene	72.5	0.1
Benzo(a)pyrene	66.7	0.1
Benzo(b)fluoranthene	92	0.2
Benzo(k)pyrene	42.4	0.5
Bis (2-ethylhexyl) phthalate	1,290	3
Cadmium	116	4
Chromium	80.9	70
Chrysene	88.4	5
Dibenzo(a,h)anthracene	19.9	0.3
Indeno(1,2,3-cd)pyrene	50.9	0.2
Iron, pentacarbonyl	896,000	300
Lead	2,480	5
Manganese	7,650	50
Mercury	5.9	2
Methylnaphthalene (2-)	10,000	30
Sodium	320,000	50,000
Synthetic Organic Chemicals - Carcinogen [Total]	22,150	100
Synthetic Organic Chemicals - Non Carcinogen [Total]	9,030	500
Tert-butyl alcohol	1,320	100
Zinc	2,020	2,000

[1]The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeologic characteristics of the groundwater resource and designated uses of the classification area.

Summary

1. The Oak Island Yards restoration site is 39 acres in size and belongs to the Newark Bay watershed.
2. The site is underlain by shale of the Passaic formation, which is overlain by Pleistocene glacial deposits and layers of Holocene estuarine and salt-marsh deposits.
3. The surface of the Oak Island Yards site is made up of the Udorthents soil complex, which is a loamy fill substratum.
4. There is a NJDEP recognized Known Contaminated Site within 1,000ft of the Oak Island Yards site. The site contains concentrations of certain compounds that exceed their respective GWQS. How this affects the overall health of the site cannot be determined definitively.

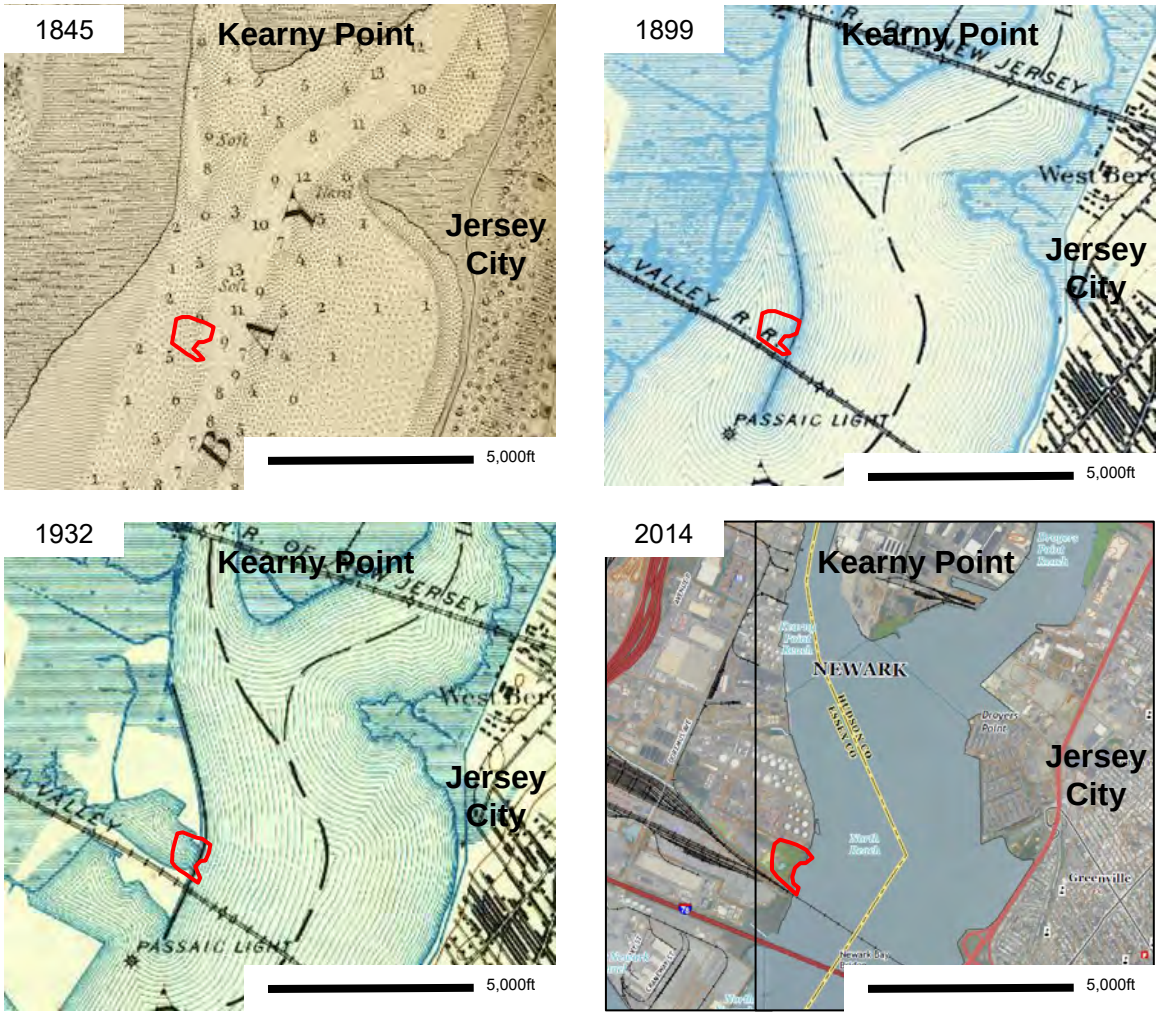


Figure 3.2.2-1. Left to right starting with top row: NOAA nautical chart from 1845, USGS topographical Staten Island Quadrangle 15-minute map from 1899, USGS topographical map of New Jersey-New York Staten Island Quadrangle from 1932, and a USGS topographical Elizabeth Quadrangle 7.5-minute map from 2014 (left panel) adjacent to a USGS topographical Jersey City Quadrangle 7.5-minute map from 2014 (right panel). Red lines delineate the Oak Island Yards HRE restoration site.

In 1845, depth soundings are in feet below MLW; in 1845, MLW was at the lowest spring tides observed during the survey, and mean sea level was approximately 1.6ft lower than it is today (based on mean sea level records at The Battery, NY 1856-2014). In 1899 and 1932, the contour interval is 20 feet, the datum is MSL (equivalent to the vertical datum of NGVD29), and the horizontal datum is NAD27. In 2014, for both Jersey City and Elizabeth quadrangle maps, the contour interval is 10 feet, the vertical datum is NAVD88, and the horizontal datum is NAD83.

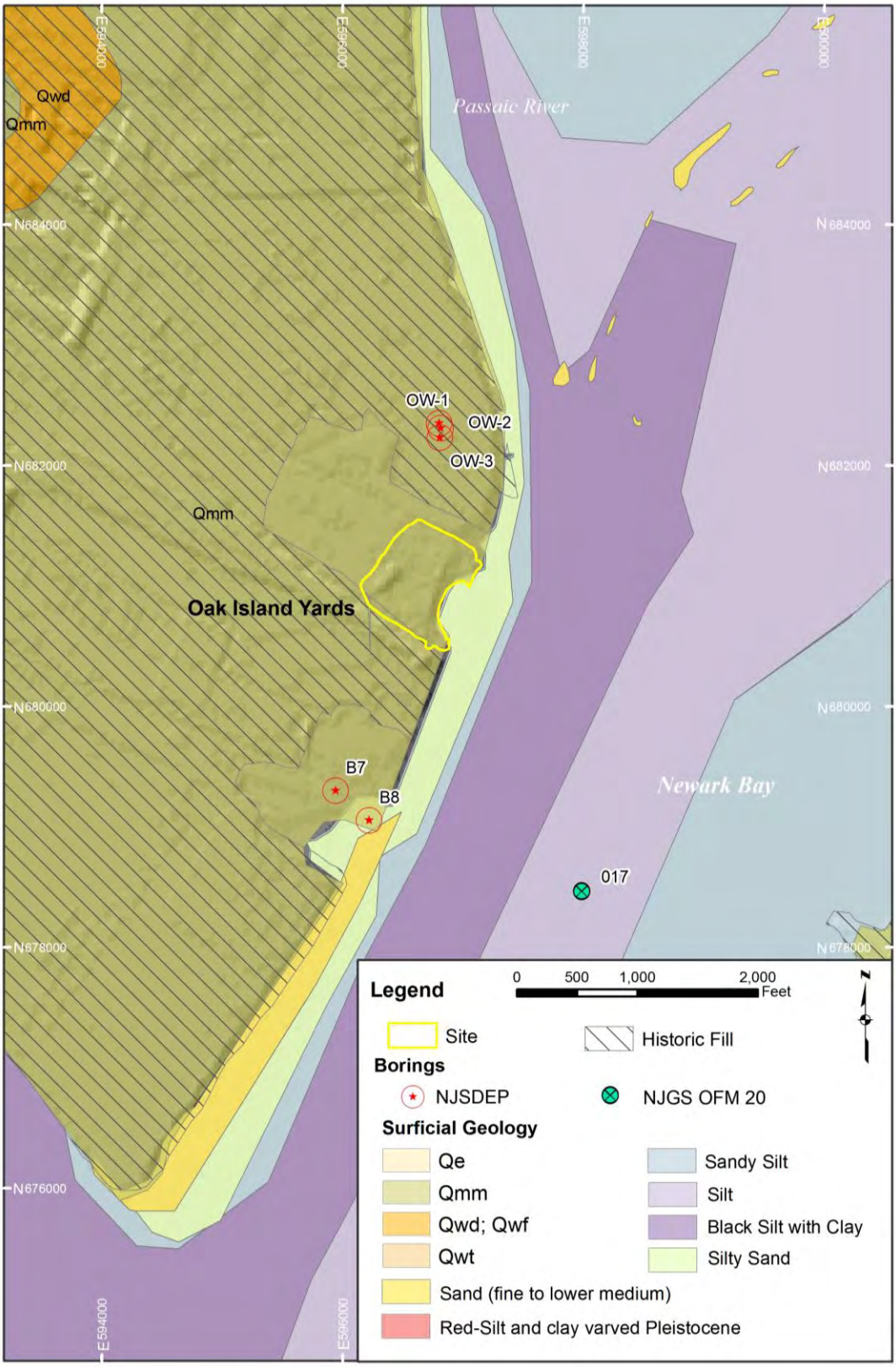


Figure 3.2.2-2. Surficial geology and boring locations of the Oak Island Yards site. Surficial geology and historic fill data were obtained from NJDEP/NJGWS (DGS07-2), updated 2013, and NJDEP/NJGWS (DGS04-7), updated 2009, respectively. Layer was modified to align with orthoimagery.



Figure 3.2.2-3. Wetland areas and NJDEP Known Contaminated Sites in the area of the Oak Island Yards site. Orthophoto obtained from NJGIN Clearinghouse Web Map Services, 2015. Wetland information obtained from U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010.

3.3 Lower Passaic River

3.3.1 Site 887. Essex County Branch Brook Park

The proposed Essex County Branch Brook Park HRE restoration site is located about 1.2 miles to the west of the Passaic River, in between the Garden State Parkway and Route 21 in Newark, NJ. The most up-to-date report of Branch Brook Park was conducted in August 2008 by Rhodeside and Harwell (Branch Brook Park Waterway Rehabilitation Feasibility Study) and is available in digital Appendix X-a. Table 3.3.1-1 contains the key information for the Essex County Branch Brook Park site.

Table 3.3.1-1. List of basic information and references for the Essex County Branch Brook Park restoration site and its surrounding area.

Feature/reference type	Name/reference
City	Newark
County	Essex
State	New Jersey
Coordinates of site	40.7638866N 74.178758W
Size of site	360 acres
USGS Quad (ID)	Orange (o40074g2)
Geological map	OFM 41, GMS 07-1, HFM-41
USACE reports	n.a.
Watershed	Passaic River Lower (4th St. to Second River)
Sub-watershed	Branch Brook (First River)
Tidal range	Non-tidal

Figure 3.3.1-1 shows topographic maps from 1870-1887, 1947, 1982, and 2014 outlining Essex County Branch Brook Park, which is located approximately 0.75 miles west of the Passaic River in Newark, NJ. The Morris canal borders the west side of the park. The canal was in place by the 1830's before the park development. The canal was drained in the 1920s after the parks pond systems were in place. The draining of the canals lowered the water table in the Park and changed the behavior of the pond and drainage system. The site consists of the western two thirds of the modern Branch Brook Park. The site occupies what was historically the First River that flowed into the lower Passaic. Now the river is buried in conduits. The northern end of the park that is outside of the restoration area flows into the Second River.

While the shoreline of the Passaic River depicted in Figure 3.3.1-1 has changed over the past 140 years or so, the boundary of Essex County Branch Brook Park has not. Essex County Branch Brook Park was originally owned by the Newark Aqueduct Board and was used as a training ground for Civil War volunteer soldiers between 1862 and 1864. Afterwards, the land was designated as a park (Branch Brook Park Alliance Cultural Landscape Report, 2002).

Geology

The general stratigraphy of the Essex County Branch Brook Park restoration site is described in Table 3.3.1-2. Figure 3.0-3 shows the map of bedrock underlying the Essex County Branch Brook Park site. Figure 3.3.1-2 shows a map of the surficial geology of the area. Thin Pleistocene and Holocene sediments overlie shallow bedrock of Passaic formation shale. The Passaic formation is mostly made up of cyclical lacustrine strata, with some fluvial strata consisting of conglomerate towards the northeast. Facies changes in the Passaic formation are significant both laterally and vertically; there is a decrease in the frequency of gray and black units moving northeast through the formation, as well as in the frequency of thick black shales deposited by deep lakes moving upward through the formation (Schlische 1992, Olsen 2004).

Table 3.3.1-2. General stratigraphy of the Essex County Branch Brook Park site.

Age	Thickness (ft)	Geologic Unit	Description
Holocene historic	Unknown thickness	Fill	Construction fill
Holocene	<10-15	Swamp deposits	Organic silts and organic silty clays
Pleistocene	<10-15	Glacial Till	Fine sand, clay, broken red shale
Lower Jurassic/ Upper Triassic	75	Passaic formation	Shale

The shallow subsurface of the Essex County Branch Brook Park site can be determined from the records of seventeen NJDEP monitoring wells in or near the site, as well as from surficial (OFM 41), historic fill (HFM-41), and bedrock (GMS 07-1) geology maps of the area (Table 3.3.1-2).

The seventeen monitoring wells in or near the site are listed in Table 3.3.1-3. The records for these borings are kept by NJDEP, and are available in digital Appendix X-b.

Table 3.3.1-3. Monitoring wells in or near the Essex County Branch Brook Park site.

Boring, well or sample ID	Permit Number	Source	Distance from Site (ft)
MW-43	E201002778	NJDEP	on site
MW-26D	E201201286	NJDEP	on site
HRW-1	E201302004	NJDEP	on site
HRW-2	E201302005	NJDEP	on site
HRW-3	E201302006	NJDEP	on site
HRW-4	E201302007	NJDEP	on site
MW-26DD	E201400117	NJDEP	on site
MW-15D	E201400243	NJDEP	on site
MW-48D	E201400244	NJDEP	on site
MW-43D	E201002778	NJDEP	1
MW-19	E201117605	NJDEP	50
MW-45	E201016684	NJDEP	140
MW-46	E201016685	NJDEP	170
VMP-2	E201014694	NJDEP	210
VMP-3	E201014695	NJDEP	230
MW-3	E201012242	NJDEP	250
MW-1	E201403904	NJDEP	300

Soil analysis

The Essex County Branch Brook Park site's Holocene swamp deposits consist of organic silts and organic silty clays. This is corroborated by the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS). Soil Survey Geographic (SSURGO) database[1], which identifies five soil types present at the site: Boonton Red Sandstone Lowland with 0-8% slope, Boonton Red Sandstone Lowland with 8-15% slope, Udorthents Boonton red sandstone lowland substratum, Udorthents loamy fill substratum, and Urban land Boonton red sandstone lowland substratum. Both Boonton red sandstone lowland types come from coarse loamy till derived from sandstone and shale, both Udorthents types come from loamy material transported by human activity, and the Urban land soil type originates from surfaces covered by man-made structures such as pavement, concrete, and buildings that are underlain by disturbed and natural soil material. Soil profiles and additional properties of each soil type can be found in Tables 3.3.1-4 - 3.3.1-11. Complete soil reports of each type of soil found at this site are in digital

[1] Information about the types of obtained through the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS). The USDA-NRCS operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of the U.S. counties and is produced by the National Cooperative Soil Survey.

The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

Appendix X-c. The geographic distribution of the five soil types within the Essex County Branch Brook Park site is unmapped.

Table 3.3.1-4. Soil profile of Essex County Branch Brook Park's Boonton red sandstone lowland soil types, both 3-8% and 8-15% slopes.

Soil Layer	Depth (inches)	Description
Surface	0-1	Slightly decomposed plant material
Subsurface	1-3	Silt loam
Subsurface	3-10	Loam
Subsurface	10-27	Gravelly loam
Subsurface	27-67	Gravelly fine sandy loam
Subsurface	67-83	Gravelly sandy loam

Table 3.3.1-5. Summary of properties of Essex County Branch Brook Park's Boonton red sandstone lowland soil types, both 3-8% and 8-15% slopes.

Property	Description
Natural drainage class	Well drained
Flooding	None
Depth to water table	More than 80 inches
Available water capacity	Low (about 4.8 inches)
Surface runoff	Medium
Organic matter content	1.72%
Percent clay	7.8%
Percent sand	57.4%
Percent silt	34.8%

Table 3.3.1-6. Soil profile of Essex County Branch Brook Park's Udorthents Boonton red sandstone lowland substratum soil type.

Soil Layer	Depth (inches)	Description
Surface	0-12	Loam
Subsurface	12-83	Gravelly sandy loam

Table 3.3.1-7. Summary of properties of Essex County Branch Brook Park's Udorthents Boonton red sandstone lowland substratum soil type.

Property	Description
Natural drainage class	Well drained
Flooding	None
Slope	0-8%
Depth to water table	>80 inches
Available water capacity	Moderate (about 6.4 inches)
Surface runoff	Medium
Organic matter content	0.49%
Percent clay	5.4%
Percent sand	61.9%
Percent silt	32.8%

Table 3.3.1-8.. Soil profile of Essex County Branch Brook Park's Udorthents loamy fill substratum soil.

Soil Layer	Depth (inches)	Description
Surface	0-12	Loam
Subsurface	12-60	Silty clay

Table 3.3.1-9. Summary of properties of Branch Brook Park's Udorthents loamy fill substratum soil type.

Property	Description
Natural drainage class	Well-drained
Flooding	None
Slope	0-8%
Depth to water table	About 48-122 inches
Available water capacity	Moderate (about 8.4 inches)
Surface runoff	Medium
Organic matter content	0.79%
Percent clay	42.1%
Percent sand	13.3%
Percent silt	44.6%

Table 3.3.1-10. Soil profile of Essex County Branch Brook Park's Urban land Boonton red sandstone lowland substratum soil type.

Soil Layer	Depth (inches)	Description
Surface	0-12	Material
Subsurface	12-67	Gravelly loam
Subsurface	67-83	Gravelly sandy loam

Table 3.3.1-11. Summary of properties of Essex County Branch Brook Park's Urban land Boonton red sandstone lowland substratum soil type.

Property	Description
Slope	0-8%
Organic matter content	1.25%
Percent clay	9.6%
Percent sand	53.4%
Percent silt	36.9%

Surface water quality data

The Essex County Branch Brook Park site contains freshwater ponds and freshwater forested/shrub wetland areas, as shown in Figure 3.3.1-3. Between 2003 and 2006, the NJHDG conducted the Ambient Water Quality Monitoring Program, which involved taking a variety of field measurements in rivers, bays, and harbors in New Jersey and New York according to sub-watershed classification. These water measurements included acidity, DO concentration, salinity, temperature of the surface water, turbidity, and amount of fecal coliform. Turbidity was measured in terms of the concentration of total suspended solids, and fecal coliform values were measured in terms of the number of colony forming units (cfu) found in 100mL.

The measurements were made multiples times throughout each month and are averaged by month in Table 3.3.1-12. Complete surface water quality reports containing individual data points that were averaged to produce the values tabulated below are in digital Appendix X-d.

Table 3.3.1-12. Summary of water quality parameters measured in January – December 2004 in the sub-watershed of the Passaic River Lower (4th Street to Second River).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Acidity (pH)	6.31	6.44	6.86	6.58	6.97	7.24	7.61	7.12	6.65	-	8.01	7.59
DO Concentration (mg/L)	14.22	13.96	11.76	8.62	6.81	6.95	5.66	5.40	7.91	9.67	10.82	11.83
Salinity (ppt)	0.20	0.80	0.45	0.20	0.85	-	0.50	1.67	0.37	0.23	0.16	0.15
Temperature (°F)	35.96	34.43	42.17	53.60	65.75	71.00	74.54	73.66	65.48	57.28	49.32	43.61
Turbidity (mg/L)	4.00	11.00	8.00	14.50	17.50	37.80	28.33	20.25	19.00	8.50	19.33	16.00
Fecal coliform (cfu/100mL)	100.00	50.00	480.00	530.00	257.50	206.00	2066.67	678.00	923.33	120.00	280.00	2000.00

Groundwater quality data
Figure 3.3.1-3 shows the locations of known contamination sites in or near the Essex County Branch Brook Park site.

On the eastern edge of Essex County Branch Brook Park, adjacent to Bloomfield Ave, there is a Known Contaminated Site (KCS) with groundwater contamination associated with the Lake St. Bus Garage. The address of the site is 228 Bloomfield Ave, in the city of Newark, New Jersey. The PI name is NJ Transit. The known contaminants include Benzene, Cyclohexane, diesel fuel, Lead, Methylcyclohexane, Synthetic Organic Chemicals (carcinogenic), Synthetic Organic Chemicals (non-carcinogenic), Toluene, and Xylenes (Table 3.3.1-13). The site encompasses 4.0 acres.

Table 3.3.1-13. The following contamination values were the greatest measured at the site described above at the time of Groundwater CEA establishment on 9/10/2007.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Benzene	30.3	1.0
Cyclohexane	1,000	100
Diesel Fuel	10,000	0
Lead	708	5
Methylcyclohexane	665	100
Synthetic Organic Chemicals – Carcinogen [Total]	15,490	500
Synthetic Organic Chemicals – Non Carcinogen [Individual]	2,300	100
Toluene	1,600	600
Xylenes (total)	2,660	1,000

[1]The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeologic characteristics of the groundwater resource and designated uses of the classification area.

On the eastern edge of Essex County Branch Brook Park, adjacent to Bloomfield Ave, there is another KCS with groundwater contamination associated with the former Exxon service station. The address of the site is 241 Bloomfield Ave, in the city of Newark, New Jersey. The PI name is Meineke Mufflers. The known contaminants include Benzene, Ethylbenzene, Synthetic Organic Chemicals (non-carcinogenic), Toluene, and Xylenes (Table 3.3.1-14). The site encompasses 0.9 acres.

Table 3.3.1-14. The following contamination values were the greatest measured at the site described above at the time of Groundwater CEA establishment on 9/10/2007.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Benzene	850	1.0
Ethylbenzene	959	700
Synthetic Organic Chemicals – Non Carcinogen [Total]	5,810	500
Toluene	2,700	500
Xylenes (total)	3,710	1,000

[1]The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeologic characteristics of the groundwater resource and designated uses of the classification area.

On the northern edge of Essex County Branch Brook Park, there is another KCS with groundwater contamination associated with the Branch Brook Maintenance Garage. The address of the site is 30 Heller Pkwy, in the city of Newark, New Jersey. The PI name is Branch Brook Maintenance Garage. The known contaminants include Aluminum, Arsenic, Benzene, Benzo(a)anthracene, Benzo(a)pyrene, Bis(2-ethylhexyl)phthalate, Cadmium, Ethylbenzene, Hexachlorobenzene, Iron, Lead, Manganese, Methyl tert-butyl ether, Naphthalene, Nitrate, Sodium, Synthetic Organic Chemicals (non-carcinogenic), Toluene, and Xylenes (Table 3.3.1-15). The site encompasses 2.5 acres.

Table 3.3.1-15. The following contamination values were the greatest measured at the site described above at the time of Groundwater CEA establishment on 5/8/2002.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Aluminum	7,220	200
Arsenic	9.6	3.0
Benzene	1,530	1.0
Benzo(a)anthracene	0.48	0.1
Benzo(a)pyrene	0.22	0.1
Bis (2-ethylhexyl)phthalate	86	3
Cadmium	26.3	4.0
Ethylbenzene	2,070	700
Hexachlorobenzene	64	0.02
Iron	173,000	300
Lead	2,110	10
Manganese	36,200	50
Methyl tert-butyl ether	442	70
Naphthalene	350	300
Nitrate	13,3000	10,000
Sodium	4,600	50,000
Synthetic Organic Chemicals – Non Carcinogen [Total]	11,307	500
Toluene	3,700	1,000
Xylenes (total)	5,500	1,000

[1]The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeologic characteristics of the groundwater resource and designated uses of the classification area.

On the western edge of Essex County Branch Brook Park, adjacent to Bloomfield Ave, there is another KCS with groundwater contamination associated with the Getty Service Station. The address of the site is 315 Bloomfield Ave, in the city of Newark, New Jersey. The PI name is Getty Service Station #95337. The known contaminants include Benzene, Ethylbenzene, Lead, Synthetic Organic Chemicals (non-carcinogenic), Toluene, and Xylenes (Table 3.3.1-16). The site encompasses 1.0 acres.

Table 3.3.1-16. The following contamination values were the greatest measured at the site described above at the time of Groundwater CEA establishment on 1/30/2001.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Benzene	290	1.0
Ethylbenzene	3,380	700
Lead	1,440	100
Synthetic Organic Chemicals – Non Carcinogen [Individual]	1,250	100
Synthetic Organic Chemicals – Non Carcinogen [Total]	3,455	500
Toluene	18,500	1,000
Xylenes (total)	22,300	1,000

[1]The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeologic characteristics of the groundwater resource and designated uses of the classification area.

Summary

1. The Essex County Branch Brook Park restoration site consists of 360 acres and is between the Garden State Parkway and Route 21 in Newark, NJ. The site belongs to the Passaic River Lower (4th Street to Second River) sub-watershed.
2. The site is underlain by shale (Passaic formation), which is underneath layers of Pleistocene till and Holocene swamp deposits.
3. The surface of the Essex County Branch Brook Park site is made up of four different types of soil units: Boonton Red Sandstone Lowland, Udorthents Boonton Red Sandstone Lowland Substratum, Udorthents loamy fill substratum, and Urban land Boonton red sandstone lowland substratum.

4. NJDEP recognizes four known contaminated sites adjacent to the Essex County Branch Brook Park site. These sites contain concentrations of certain compounds that exceed their respective GWQS. How this affects the overall health of the site cannot be determined definitively.

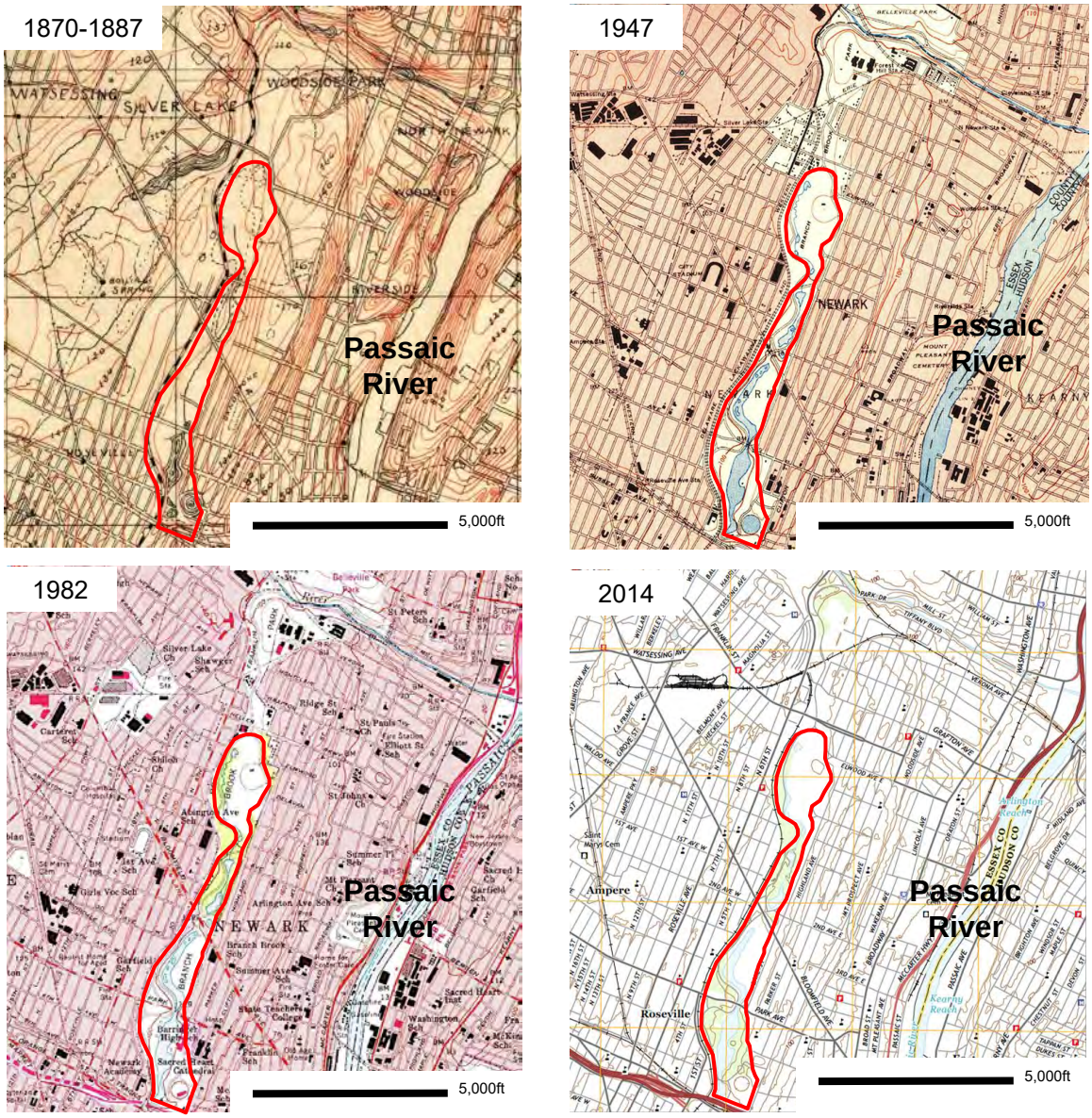


Figure 3.3.1-1. Left to right starting with top row: historical topographic map from between 1870-1887 (C.C. Vermeule), USGS topographic Orange, NJ Quadrangle 7.5-minute maps from 1947, 1982, and 2014. Red lines delineate the Essex County Branch Brook Park HRE restoration site.

There is no datum information for the historical topographic map from between 1870-1887. In the 1947 map, the contour interval is 20 feet, the datum is MSL (equivalent to the vertical datum of NGVD29), and the horizontal datum is NAD27. In the 1982 map, the contour interval is 20 feet, the vertical datum is NGVD29, and the horizontal datum is NAD27. In the 2014 map, the contour interval is 20 feet, the vertical datum is NAVD88, and the horizontal datum is NAD83.

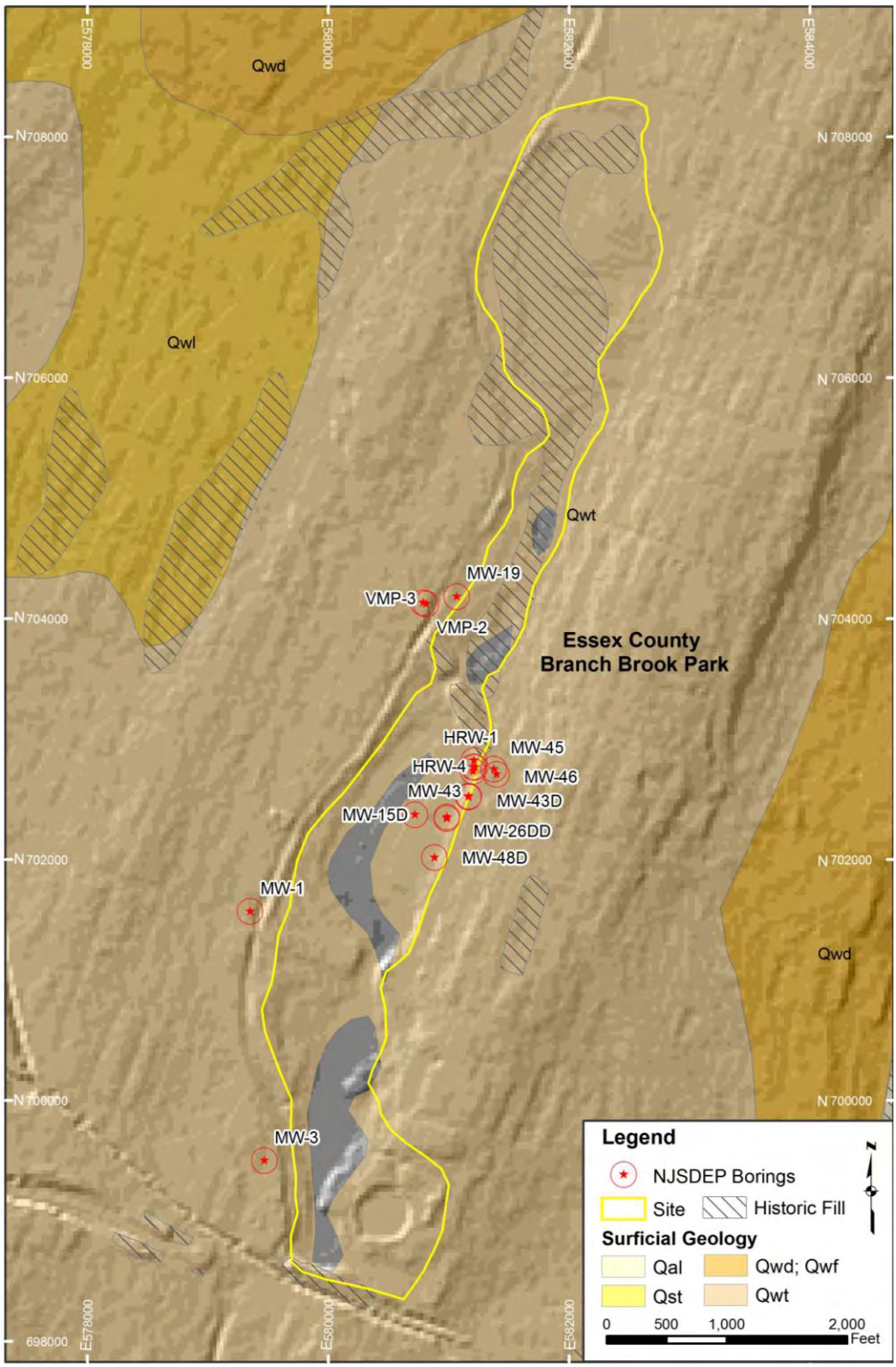


Figure 3.3.1-2. Surficial geology and boring locations of the Essex County Branch Brook Park site. The surficial geology is from NJDEP Geological Survey surficial geology map of New Jersey (DGS07-2) updated 2009. Boundaries were modified to align with orthoimagery.



Figure 3.3.1-3. Wetlands and NJDEP recognized Known Contamination Sites in the area of the Essex County Branch Brook Park site. Base map images are March-May 2015 orthorectified images (NJGIN, 2015).Wetland information obtained from U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010.

3.3.2 Site 900. Dundee Island Park/Pulaski Park

The proposed Dundee Island Park/Pulaski Park HRE restoration site is a stretch of green on the western shore of the Passaic River between the Monroe Street and Wall Street bridges in Passaic, NJ. Table 3.3.2-1 contains key information for the Dundee Island Park/Pulaski Park site.

Table 3.3.2-1. List of key information and references for the Dundee Island Park/Pulaski Park restoration site and its surrounding area.

Feature/reference type	Name/reference
City	Passaic
County	Passaic
State	New Jersey
Coordinates of site	40.866061N 74.112180W
Size of site	5.9 acres
USGS Quad (ID)	Weehawken (o40074g1)
Geological map	OFM 13, I-2540-A, HFM-42
USACE reports	n.a.
Watershed	Lower Passaic and Saddle
Sub-watershed	Passaic River Lower (Saddle River to Dundee Dam)
Tidal range[a]	6.48ft

[a] MHHW-MLLW ft based on tides recorded Aug 1994 – Oct 1994 at NOAA/NOS/CO-OPS tidal station 8530403 East Rutherford, Passaic River, NJ.

Figure 3.3.2-1 shows topographic maps from 1888, 1900, 1935, and 2014 outlining the Dundee Island Park/Pulaski Park site and the bend in the Passaic River at Wallington, NJ. The island in the Passaic River that is shown in the 1888 and 1900 topographic maps is the original Dundee Island. Not only has the meandering behavior of the Passaic River changed over time (especially between 1935 and 1989), but the branch of the Passaic River west and south of Dundee Island has also been filled in to create the modern-day Pulaski Park and Dundee Island Park.

Geology

The general stratigraphy of the Dundee Island Park/Pulaski Park restoration site is described in Table 3.3.2-2. Figure 3.0-3 shows the map of bedrock underlying the Dundee Island Park/Pulaski Park site. Figure 3.3.2-2 shows a map of the surficial geology of the area. This site is underlain by the Passaic formation of the Newark Group. The Passaic formation is mostly made up of cyclical lacustrine strata, with some fluvial strata consisting of conglomerate towards the northeast. Facies changes in the Passaic formation are significant both laterally and vertically; there is a decrease in the frequency of gray and black units moving northeast through the formation, as well as in the frequency of thick black shales deposited by deep lakes moving upward through the formation (Schlische 1992, Olsen 2004).

Table 3.3.2-2. General stratigraphy of the Dundee Island Park/Pulaski Park site.

Age	Thickness (ft)	Geologic Unit	Description
Holocene historic	Unknown thickness	Artificial Fill	Silty sands
Holocene	Unknown thickness	Estuarine marsh	Silts and peat
Holocene	Unknown thickness	Estuarine-Fluvial sands	Sands
Pleistocene	Unknown thickness	Glacial Outwash deposits	Sands and silts
Pleistocene	Unknown thickness	Glacial Lake deposits	Inorganic silt and clay
Pleistocene	Unknown thickness	Glacial Till	Silty sand and gravel
Lower Jurassic/Upper Triassic	n.a.	Passaic Formation	Sandstone

The shallow subsurface of the Dundee Island Park/Pulaski Park site is determined by records of ten monitoring wells drilled near the site, as well as from surficial (OFM 13), historic fill (HFM-42), and bedrock (I-2540-A) geology maps of the area (Table 3.3.2-2). The ten monitoring wells

near the site are listed in Table 3.3.2-3. The logs of these borings are kept by NJDEP, and are available in Appendix XI-b.

Table 3.3.2-3. Monitoring wells in or near the Dundee Island Park/Pulaski Park site.

Boring, well or sample ID	Permit Number	Source	Distance from Site (ft)
MW-3	E201201428	NJDEP	300
MW-4	E201201429	NJDEP	300
MW-51D2R	E201014342	NJDEP	350
MW-1	E201104313	NJDEP	350
MW-64D2R	E201114258	NJDEP	350
MW-2	E201201427	NJDEP	350
MW-5	E201307855	NJDEP	350
MW-1	E201509866	NJDEP	400
EPA-19-OB	E201205310	NJDEP	560
EPA-19-BR	E201205309	NJDEP	580

Soil analysis

The Dundee Island Park/Pulaski Park site's Holocene artificial fill consists of silty sands. This is corroborated by the SSURGO soil database[2], which identifies two soil types present at the site: Urban land (60%) and Riverhead (40%). The parent material of the Urban land type is a surface covered by man-made structures such as pavement, concrete, and buildings underlain by disturbed and natural soil material. There was no soil property information available for the Urban land type. The Riverhead soil type comes from glaciofluvial deposits derived from granite and gneiss. Soil profiles and additional properties of the Urban land and Riverhead types can be found in Tables 3.3.2-4 -3.3.2-6. Complete soil reports of each type of soil found at this site can be found in digital Appendix XI-c. The geographic distribution of the two soil types within the Dundee Island Park/Pulaski Park site is unmapped.

Table 3.3.2-4. Soil profile of Dundee Island Park/Pulaski Park's Urban land soil type.

Soil Layer	Depth (inches)	Description
Surface	0-60	Variable

Table 3.3.2-5. Soil profile of Dundee Island Park/Pulaski Park's Riverhead soil type.

Soil Layer	Depth (inches)	Description
Surface	0-10	Sandy loam
Subsurface	10-36	Gravelly sandy loam
Subsurface	36-60	Gravelly sand

Table 3.3.2-6. Summary of properties of Dundee Island Park/Pulaski Park's Riverhead soil type.

Property	Description
Natural drainage class	Well drained
Flooding	None
Slope	3-8%
Depth to water table	More than 80 inches
Available water capacity	Low (about 5.8 inches)
Surface runoff	Low
Organic matter content	0%

[2] Information about the types of obtained through the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS). The USDA-NRCS operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of the U.S. counties and is produced by the National Cooperative Soil Survey.

The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

Surface water quality data
While the Dundee Island Park/Pulaski Park site is adjacent to the Passaic River, the site itself does not contain any wetland areas, as shown in Figure 3.3.2-3.

The Stevens Institute of Technology's Davidson Laboratory operates the New York Harbor Observing and Prediction System (NYHOPS), which produces historic, real-time, and forecasted meteorological and oceanographic conditions of areas throughout New York Harbor and New Jersey's coastal regions. NYHOPS takes water quality data, among other types, measured at various sites, including the Passaic Valley Sewerage Commission building on the Passaic River. This site is approximately 1.5 miles downstream of the Dundee Island Park/Pulaski Park site. The parameters measured by NYHOPS include acidity, DO concentration, salinity, temperature of surface water, and turbidity. The measurements are taken every day at 15-minute intervals and are averaged by month in Table 3.3.2-7. Complete surface water quality reports containing individual data points that were averaged to produce the values tabulated below are in digital Appendix XI-d.

Table 3.3.2-7. Summary of water quality parameters in 2015, measured as part of the NYHOPS Data Time Series at the Passaic Valley Sewerage Commission building on the Passaic River.

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Acidity (pH)	7.64	8.11	8.14	7.68	10.07	11.08	7.55	7.45	7.38	7.55	7.57	7.64
DO Conc. (mg/L)	6.77	9.98	10.38	10.83	5.90	5.03	5.13	4.89	4.73	5.95	7.12	8.07
Salinity (ppt)	19.26	19.65	17.21	16.07	21.04	17.68	18.81	21.52	20.99	21.45	19.08	17.92
Temperature (°F)	37.40	36.35	38.99	42.98	66.13	68.78	71.99	77.21	74.93	62.15	55.50	50.35
Turbidity (FTU)	18.29	13.74	8.58	6.36	7.03	11.16	9.69	7.98	8.30	10.35	9.82	11.47

Groundwater quality data
There are no Known Contaminated Site (KCS) within the boundaries of the Dundee Island Park/Pulaski Park site. Figure 3.3.2-3 shows the locations of known contamination sites near the Dundee Island Park/Pulaski Park site.

Approximately 50ft west of the Dundee Island Park/Pulaski Park restoration site, there is a KCS with groundwater contamination. The address of the site is Adjacent to 6th St, in the city of Passaic, New Jersey. The PI name is Roberto Clemente Field. The known contaminants include Aluminum, Arsenic, Beryllium, Iron, Lead, and Manganese (Table 3.3.2-8). The site encompasses 4.6 acres.

Table 3.3.2-8. The following contamination values were the greatest measured at the site described above at the time of Groundwater CEA establishment on 5/27/2015.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Aluminum	20,900	200
Arsenic	5.2	3.0
Beryllium	1.9	1.0
Iron	41,000	300
Lead	27	5
Manganese	5,100	50

[1]The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeologic characteristics of the groundwater resource and designated uses of the classification area.

There is another known contamination site with groundwater contamination approximately 250ft northeast of the Dundee Island Park/Pulaski Park site. The address of the site is 290 River Drive, in the city of Passaic, New Jersey. The PI name is Kalama Chemical Inc. The known contaminants include Benzene, Biphenyl, Bis(2-ethylhexyl) phthalate, Dimethyl phthalate,

Formaldehyde, Methyl alcohol (Methanol), Methyl phenol, Phenol, Salicylic acid, and Toluene (Table 3.3.2-9). The site encompasses 8.2 acres.

Table 3.3.2-9. The following contamination values were the greatest measured at the site described above at the time of Groundwater CEA establishment on 10/21/2008.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Benzene	420	1
Biphenyl	5,250	400
Bis(2-ethylhexyl)phthalate	26	3
Dimethyl phthalate	847	100
Formaldehyde	221	100
Methyl alcohol (Methanol)	4,010	4,000
Methyl phenol	169	100
Phenol	192,000	2,000
Salicylic acid	187,000	100
Toluene	126,000	600

[1]The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeologic characteristics of the groundwater resource and designated uses of the classification area.

Approximately 250ft east of the Dundee Island Park/Pulaski Park site, adjacent to River Drive, there is another KCS. The address of the site is 271 River Drive, in the city of Garfield, New Jersey. The PI name is Ravi Oil Co. Inc. The contaminants and scope of the contamination are unknown. The case was opened on 4/1/1999 and oversight continues as of 12/2/2015.

Approximately 250ft southeast of the Dundee Island Park/Pulaski Park site, adjacent to River Drive, there is another KCS. The address of the site is 218 River Drive, in the city of Garfield, New Jersey. The PI name is Litho Prep Services Incorporated. Just like with the Ravi Oil Co. Inc. KCS, this site's contaminants and its scope of the contamination are unknown. The case was opened on 10/28/1991 and oversight continues as of 5/16/2014.

Summary

1 The Dundee Island Park/Pulaski Park restoration site is 5.9 acres in size and is located on the western shore of the Passaic River. The site belongs to the Passaic River Lower (Saddle River to Dundee Dam) sub-watershed.
2 The site is underlain by sandstone (Passaic formation), which is underneath layers of artificial fill, Holocene estuarine-fluvial sands and Pleistocene till.
3 The surface of the Dundee Island Park/Pulaski Park site is made up of Urban land and Riverhead soil units.
4 The NJDEP recognizes four known contaminated sites near the Dundee Island Park/Pulaski Park site. These sites contain concentrations of certain compounds that exceed their respective GWQS. How this affects the overall health of the site cannot be determined definitively.

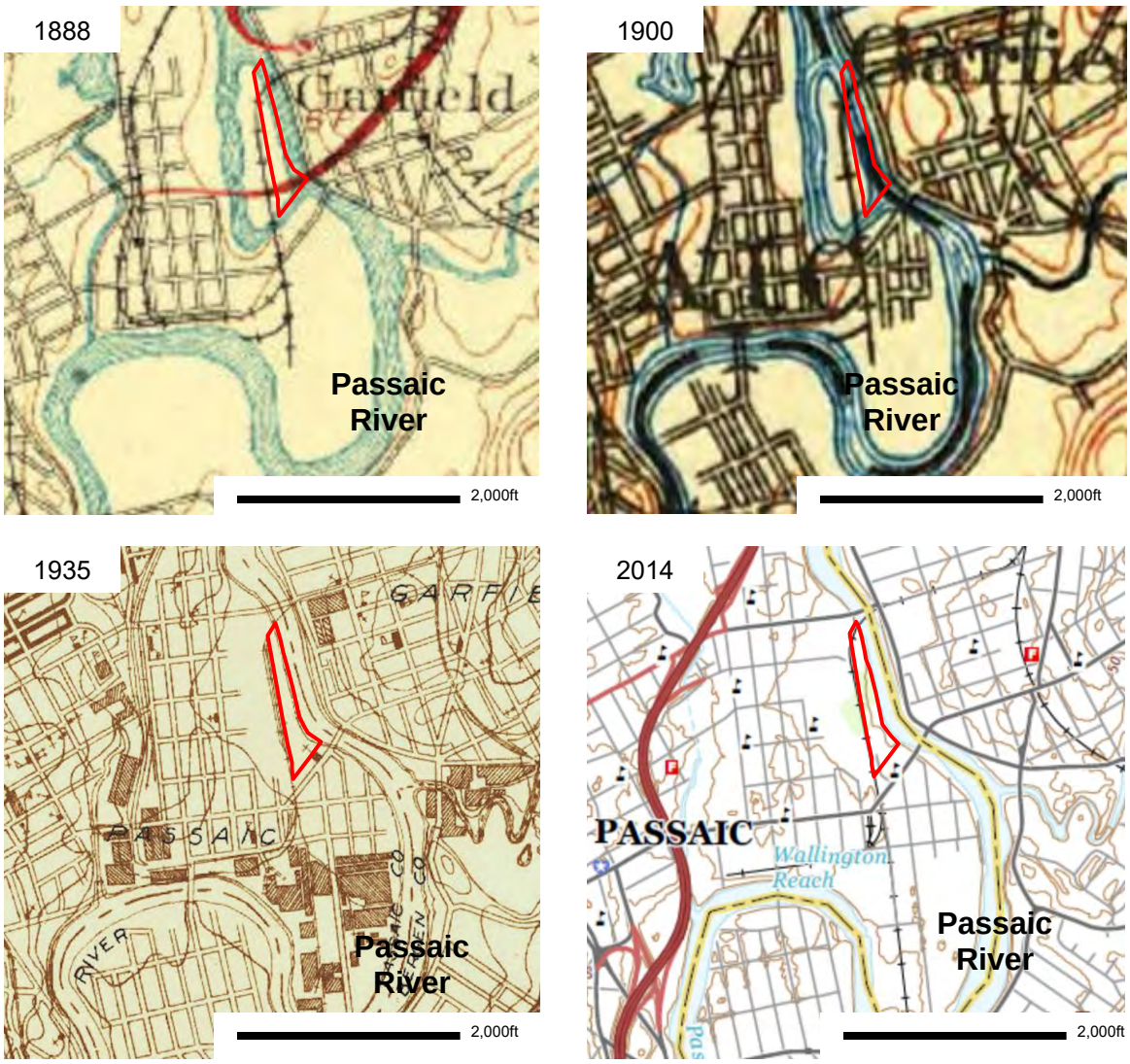


Figure 3.3.2-1. Left to right starting with top row: New Jersey-New York Passaic Quadrangle topographic maps from 1888 and 1900 and New Jersey-New York Weehawken Quadrangle 7.5-minute series topographic maps 1935 and 2014. Red lines delineate the Dundee Island Park/Pulaski Park HRE restoration site.

In the 1888 and 1900 maps, the contour interval is 20 feet and the datum is MSL (equivalent to the vertical datum of NGVD29). In the 1935 map, the contour interval is 10 feet, the datum is MSL (equivalent to the vertical datum of NGVD29), and the horizontal datum is NAD27. In the 2014 map, the contour interval is 10 feet, the vertical datum is NAVD88, and the horizontal datum is NAD83.

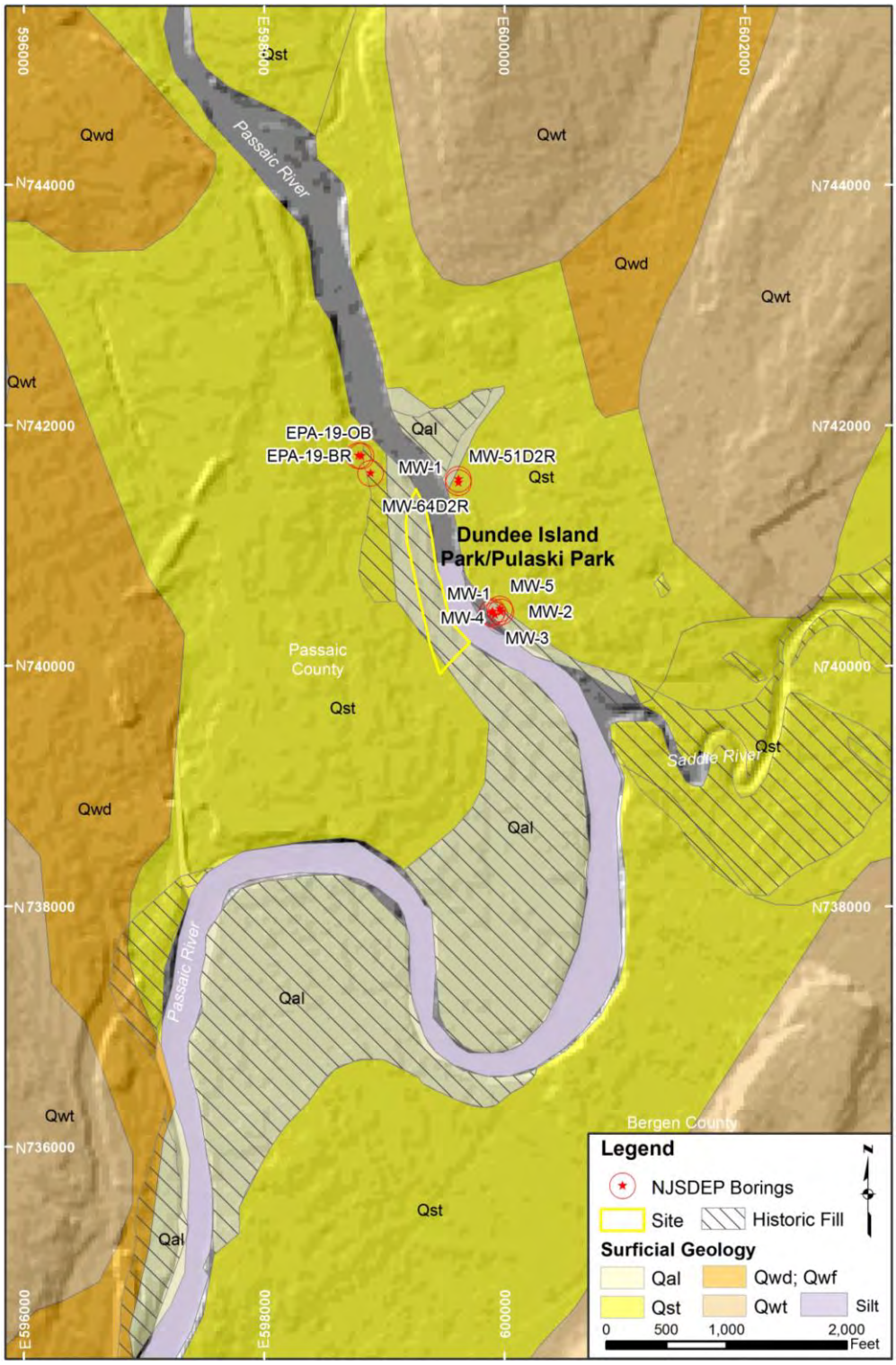


Figure 3.3.2-2. Surficial geology and boring locations of the Dundee Island Park/Pulaski Park site. The surficial geology is from NJDEP Geological Survey surficial geology map of New Jersey (DGS07-2) updated in 2013. Boundaries were modified to align with orthoimagery.



Figure 3.3.2-3. Wetlands and NJDEP recognized Known Contamination Sites in the area of the Dundee Island Park/Pulaski Park site. Base map images are March-May 2015 orthorectified images (NJGIN, 2015). Wetland data is from U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010.

3.3.3 Site 902. Clifton Dundee Canal Green Acres Purchase and Island Preserve

The proposed Clifton Dundee Canal Green Acres Purchase and Island Preserve HRE restoration site is a park on the western shore of the Passaic River just south of Dundee Dam and north of the Outwater Lane Bridge in Garfield, NJ. It straddles the Hackensack and Paterson quadrangles. Table 3.3.3-1 lists key information for the Clifton Dundee Canal Green Acres Purchase and Island Preserve site.

Table 3.3.3-1. List of key information and references for the Dundee Canal Green Acres Purchase and Island Preserve restoration site and its surrounding area.

Feature/reference type	Name/reference
City	Garfield
County	Passaic
State	New Jersey
Coordinates of site	40.8811554N 74.112180W
Size of site	5.9 acres
USGS Quads (ID)	Hackensack (o40074h1); Paterson (o40074h2)
Geological maps	OFM 14, OFM 109, HFM-31, OFM 54, GMS 06-6, HFM-30
USACE reports	n.a.
Watershed	Passaic
Sub-watershed	Passaic River Lower (Saddle River to Dundee Dam)
Tidal range[a]	6.48ft

[a] MHHW-MLLW ft based on tides recorded Aug 1994 – Oct 1994 at NOAA/NOS/CO-OPS tidal station 8530403 East Rutherford, Passaic River, NJ.

Since the Clifton Dundee Canal Green Acres Purchase and Island Preserve site straddles the Paterson and Hackensack quadrangles, topographic maps from both quadrangles (from 1900, 1934, 1938, 1963, 1965, and 2014) were used in order to investigate the changes that have occurred in the area where the restoration site is located (Figure 3.3.3-1). In the early 1830s, the Dundee Manufacturing Company built the Dundee Dam as well as the Dundee Canal, a 12ft deep, half-mile long canal bordering the southwest side of the modern-day Dundee Canal Green Acres Purchase and Island Preserve site (National Park Service Historical American Engineering Record, 1997).

The canal was further constructed (lengthened) between 1858 and 1861. The primary purpose of the canal was to provide a water supply for the Dundee Water Power and Land Company and other textile companies in the area. Ownership of the canal changed hands many times and little by little, the canal started being filled in starting in the 1930s. In the 1930s, part of the northern end of the canal was filled in and paved over due to a build-up of trash. In 1974, another part of the canal was demolished due to deterioration and in the mid-1980s, the upper canal basin was filled in (National Park Service Historical American Engineering Records, 1997). Today, a small portion of the old canal can still be found at the northwestern end of the restoration site, as well as to the south of the site, running alongside the west side of Route 21, as seen in Figure 3.3.3-3.

Geology

The general stratigraphy of the Clifton Dundee Canal Green Acres Purchase and Island Preserve restoration site is described in Table 3.3.3-2. Figure 3.0-3 shows the map of bedrock underlying the Clifton Dundee Canal Green Acres Purchase and Island Preserve site. Figure 3.3.3-2 shows a map of the surficial geology of the area.

This site is underlain by the Passaic Formation of the Newark Group. The Passaic formation is mostly made up of cyclical lacustrine strata, with some fluvial strata consisting of conglomerate towards the northeast. Facies changes in the Passaic formation are significant both laterally and

vertically; there is a decrease in the frequency of gray and black units moving northeast through the formation, as well as in the frequency of thick black shales deposited by deep lakes moving upward through the formation (Schlische 1992, Olsen 2004).

Table 3.3.3-2. General stratigraphy of the Clifton Dundee Canal Green Acres Purchase and Island Preserve site.

Age	Thickness (ft)	Geologic Unit	Description
Holocene historic	n.a.	Fill	Sands
Holocene	n.a.	Marsh	Organic silts and peat
Holocene	n.a.	Alluvial fan deposits	Silty sands
Holocene	n.a.	Fluvial/ estuarine sands	Silty sands
Pleistocene	n.a.	Glacial lake deposits	Clayey sands
Pleistocene	n.a.	Glacial Till	
Lower Jurassic/ Upper Triassic	n.a.	Passaic Formation	Sandstone, pebble conglomerate, siltstone, shale

The shallow subsurface of the Clifton Dundee Canal Green Acres Purchase and Island Preserve site can be determined from the records of thirteen monitoring wells drilled near the site, as well as from surficial (OFM 14, OFM 54), historic fill (HFM-30, HFM-31), and bedrock (OFM 109, GMS 06-6) geology maps of the area (Table 3.3.3-2.).

The thirteen monitoring wells near the site are listed in Table 3.3.3-3. The records of these borings are kept by NJDEP, and are available in digital Appendix XII-b.

Table 3.3.3-3. Borings and wells near the Clifton Dundee Canal Green Acres Purchase and Island Preserve site.

Boring, well or sample ID	Permit Number	Source	Distance from Site (ft)
B3-109	E201218952	NJDEP	220
B3-110	E201218416	NJDEP	220
MW-1	E201506284	NJDEP	250
MW-1	E201102372	NJDEP	250
MW-6	E201413719	NJDEP	250
MW-7	E201413720	NJDEP	250
MW-6D	E201413723	NJDEP	250
MW-7D	E201413724	NJDEP	250
MW-1D	E201211288	NJDEP	270
MW1	E201506284	NJDEP	460
MW-5A	E201413718	NJDEP	460
MW-11	E201317376	NJDEP	550
MW-9	E201211290	NJDEP	600

Soil analysis

The Clifton Dundee Canal Green Acres Purchase and Island Preserve site's Holocene deltaic/alluvial fan deposits consist of silty sands. This is corroborated by the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS). The USDA-NRCS Survey Geographic (SSURGO) database[3], which identifies two soil types present at the site: Urban land (60%) and Riverhead (40%). The parent material of the Urban Land soil type is a

[3] Information about the types of obtained through the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS). The USDA-NRCS operates the Soil Survey Geographic (SSURGO) database, which contains soil data covering more than 95 percent of the U.S. counties and is produced by the National Cooperative Soil Survey.

The soil information in the SSURGO database was collected by walking over the land and observing the soil, at scales ranging from 1:12,000 to 1:63,360. Soil properties were determined by sample analysis in laboratories, in conjunction with use of the Java Newhall Simulation Model (jNSM) to better understand soil climate. jNSM is a mesoscale model whose output reports consist of soil moisture, temperature regime classification and precipitation/potential evapo-transpiration climographs.

surface covered by man-made structures such as pavement, concrete, and buildings underlain by disturbed and natural soil material. There was no soil property information available for Urban land soil. The Riverhead complex comes from glaciofluvial deposits derived from granite and gneiss. Soil profiles and additional properties of the Urban Land and Riverhead soil types can be found in Tables 3.3.3-4 -3.3.3-6. Complete soil reports of each type of soil found at this site can be found in digital Appendix XII-c. The geographic distribution of the two soil types within the Clifton Dundee Canal Green Acres Purchase and Island Preserve site is unmapped.

Table 3.3.3-4. Soil profile of the Clifton Dundee Canal Green Acres Purchase and Island Preserve site's Urban Land soil type.

Soil Layer	Depth (inches)	Description
Surface	0-60	Variable

Table 3.3.3-5. Soil profile of Clifton Dundee Canal Green Acres Purchase and Island Preserve site's Riverhead soil type.

Soil Layer	Depth (inches)	Description
Surface	0-10	Sandy loam
Subsurface	10-36	Gravelly sandy loam
Subsurface	36-60	Gravelly sand

Table 3.3.3-6. Summary of properties of Clifton Dundee Canal Green Acres Purchase and Island Preserve site's Riverhead soil type.

Property	Description
Natural drainage class	Well drained
Flooding	None
Slope	3-8%
Depth to water table	More than 80 inches
Available water capacity	Low (about 5.8 inches)
Surface runoff	Low
Organic matter content	0%

Surface water quality data

The Clifton Dundee Canal Green Acres Purchase and Island Preserve site contains some riverine and lake wetland areas, as shown in Figure 3.3.3-3.

In 2003-2006, the NJHDG conducted the Ambient Water Quality Monitoring Program, which involved taking a variety of field measurements in rivers, bays, and harbors in New Jersey and New York according to sub-watershed classification, such as the Passaic River Lower (Saddle River to Dundee Dam) sub-watershed. These water measurements included acidity, DO concentration, salinity and temperature of the surface water, turbidity, and amount of fecal coliform. Turbidity was measured in terms of the concentration of total suspended solids and fecal coliform values were measured in terms of the number of colony forming units (cfu) found in 100mL.

The measurements were made multiples times throughout each month and are averaged by month in Table 3.3.3-7. Complete surface water quality reports containing individual data points are in digital Appendix XII-d.

Table 3.3.3-7. Summary of water quality parameters measured between January – December 2004 in the sub-watershed of the Passaic River Lower (Saddle River to Dundee Dam) by the NJHDG.

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Acidity (pH)	5.80	6.67	6.52	6.71	7.02	7.98	7.30	6.81	6.98	-	-	-
DO Concentration (mg/L)	12.52	13.85	12.41	10.94	8.43	8.40	3.50	7.97	10.50	10.45	11.20	9.61
Salinity (ppt)	0.30	0.30	0.30	0.25	0.20	-	-	-	0.15	0.24	0.20	0.10
Temperature (°F)	-	40.01	43.43	50.63	66.98	77.36	74.90	79.16	67.13	54.45	48.50	42.62
Turbidity (mg/L)	5.00	37.50	5.00	10.50	11.33	15.75	19.50	19.20	28.33	7.50	14.33	4.00
Fecal Coliform	40.00	40.00	75.00	300.00	213.33	382.50	3512.50	880.00	853.33	190.00	173.33	70.00

Groundwater quality data

Figure 3.3.3-3 shows the locations of known contamination sites near the Clifton Dundee Canal Green Acres Purchase and Island Preserve site.

On the southern edge of the Dundee Canal Green Acres Purchase and Island Preserve site, adjacent to Route 21 and within the parking lot of the facility, there is a known contaminated site (KCS). The address of the site is 2 Ackerman Ave, in the city of Clifton, New Jersey. The PI name is Safas Corp. The contaminants and scope of the contamination are unknown. The case was opened on 8/17/1987 and oversight continues as of 7/16/2014.

On the southeastern edge of the restoration site and on the other side of Ackerman Ave, there is another KCS. The address of the site is 1 Ackerman Ave, in the city of Clifton, New Jersey. The PI name is Recycled Paperboard Inc. Similar to the previously mentioned KCS, this site's contaminants and its scope of contamination are unknown. The case was opened on 12/14/1987 and oversight continues as of 11/15/2012.

Approximately 800ft southeast of the restoration site, adjacent to River Drive, there is another KCS with groundwater contamination. The address of the site is 627 River Drive, in the city of Garfield, New Jersey. The PI name is Custom Oil Co. The known contaminants include Benzene and both carcinogenic and non-carcinogenic Synthetic Organic Chemicals (Table 3.3.3-8). The site encompasses 0.7 acres.

Table 3.3.3-8. The following contamination values were the greatest measured at the site described above at the time of Groundwater CEA establishment on 9/10/2007.

Contaminant	Concentration (µg/L)	GWQS[1] (µg/L)
Benzene	208	1.0
Synthetic Organic Chemicals – Carcinogen [Total]	605	500
Synthetic Organic Chemicals – Non Carcinogen [Individual]	180	100

[1]The concentration of each contaminant found is compared to the Ground Water Quality Standard (GWQS), which was created by the NJDEP Division of Water Monitoring and Standards and establishes classes of groundwater according to hydrogeologic characteristics of the groundwater resource and designated uses of the classification area.

Summary

1. The Clifton Dundee Canal Green Acres Purchase and Island Preserve restoration site is 5.9 acres in size and is located on the western shore of the Passaic River, just downstream of Dundee Dam. The site belongs to the Passaic River Lower (Saddle River to Dundee Dam) sub-watershed.
2. The site is underlain by Passaic formation sandstone, pebble conglomerate, siltstone, and shale, which are overlain by layers of Pleistocene till and Holocene alluvial sands.
3. The surface of the Clifton Dundee Canal Green Acres Purchase and Island Preserve site is made up of Urban Land and Riverhead soil units.

4. The NJDEP recognizes three known contaminated sites adjacent to or near the Clifton Dundee Canal Green Acres Purchase and Island Preserve site. These sites contain concentrations of certain compounds that exceed their respective GWQS. How this affects the overall health of the site cannot be determined definitively.

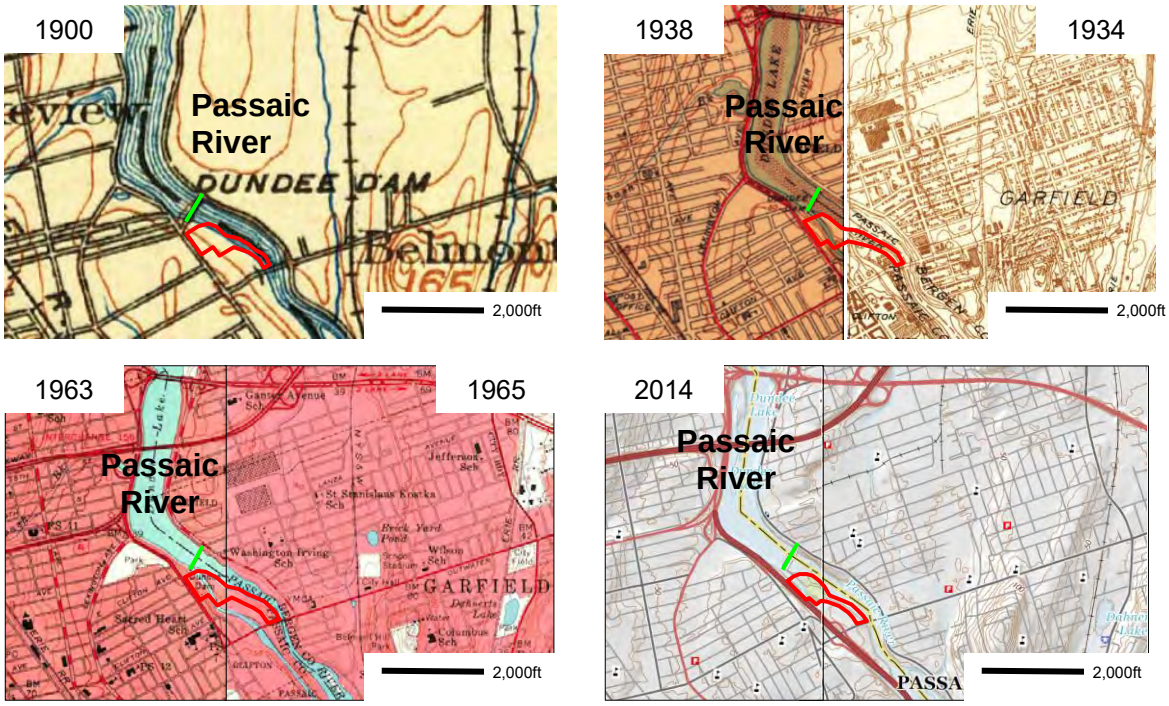


Figure 3.3.3-1. Left to right starting with top row: USGS topographic New Jersey-New York Passaic Quadrangle map from 1900 and USGS topographic Paterson, NJ Quadrangle 7.5-minute series topographic maps from 1938, 1963, and 2014 (left panel) adjoining USGS topographic Hackensack, NJ Quadrangle 7.5-minute series topographic maps from 1934, 1965, and 2014 (right panel). Green lines delineate Dundee Dam and red lines delineate the Clifton Dundee Canal Green Acres Purchase and Island Preserve HRE restoration site.

In the 1900 map, there is no datum information, but the contour interval is 20 feet. In the 1934, 1938, 1963, and 1965 maps, the contour interval is 10 feet, the datum is MSL (equivalent to the vertical datum of NGVD29), and the horizontal datum is NAD27. In the 2014 map, the contour interval is 10 feet, the vertical datum is NAVD88, and the horizontal datum is NAD83.

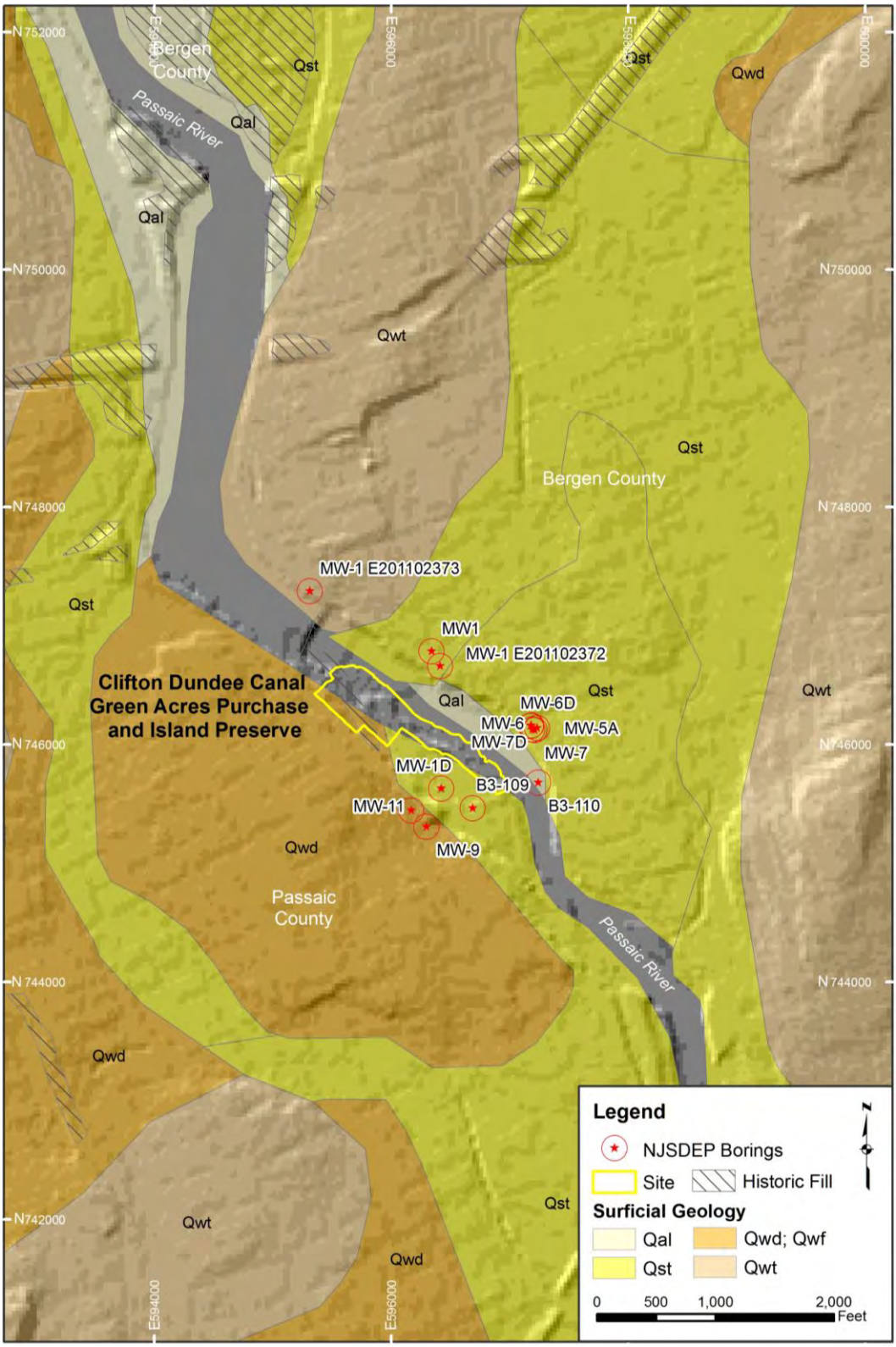


Figure 3.3.3-2. Surficial geology and boring locations of the Clifton Dundee Canal Green Acres Purchase and Island Preserve site. The surficial geology is from NJDEP Geological Survey surficial geology map of New Jersey (DGS07-2) updated in 2013. Boundaries were modified to align with orthoimagery.

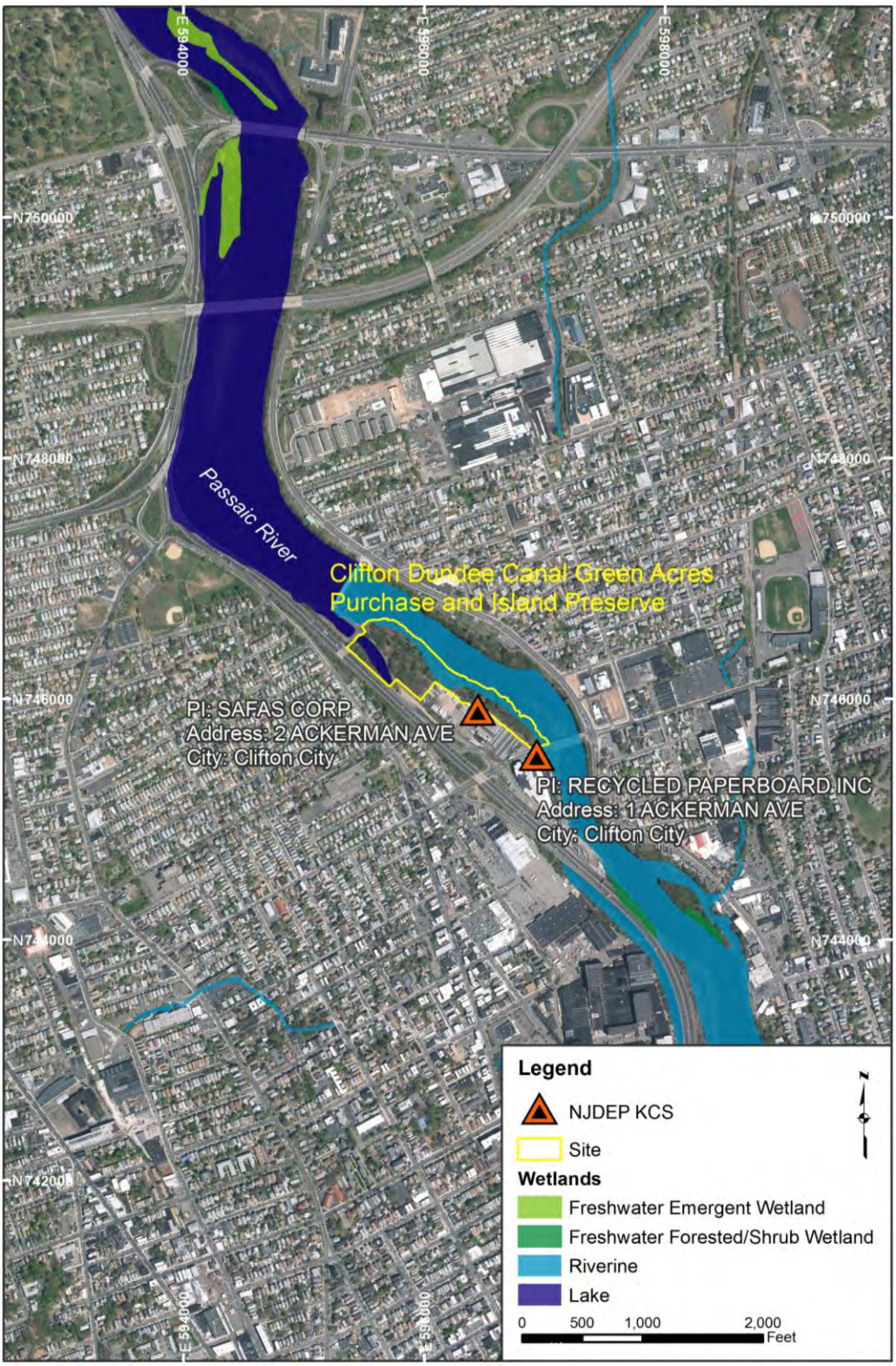


Figure 3.3.3-3. Wetlands and NJDEP recognized Known Contamination Sites (KCS) in the area of the Clifton Dundee Canal Green Acres Purchase and Island Preserve site. Base map images are March-May 2015 orthorectified images (NJGIN, 2015). Wetland data is from U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010

Appendix I: Site 864. Governors Island

Appendix I-a References A1-2
Appendix I-b Relevant boring log A1-4
Appendix I-c Soil reports A1-4
Appendix I-d Surface water quality A1-4
Appendix I-e Bathymetry figures A1-4
Appendix I-f Sediment type figures A1-4
Appendix I-g Organism stress classification figure A1-4

I-a. Site 864. Governors Island references

Geology and general information

Bell, R. E., Flood, R. D., Carbotte, S. M., Ryan, W. B. F., McHugh, C., Cornier, M., Versteeg, R., Chayes, D., Bokuniewicz, H., Ferrini, V., and Thissen, J., 2000, Hudson River Estuary Program Benthic Mapping Project Final Report. NY State Department of Environmental Conservation.

Bell, R.E., R.D. Flood, S.M. Carbotte, W.B.F. Ryan, F.O. Nitsche, S. Chillrud, R. Arko, V. Ferrini, A. Slagle, C. Bertinato, M. Turrin, 2003, Hudson River Estuary Program Benthic Mapping Project Phase II-Repor1-March 2003, New York State Department of Environmental Conservation.

Bell, R.E., R.D. Flood, S.M. Carbotte, W.B.F. Ryan, F.O. Nitsche, S. Chillrud, R. Arko, V. Ferrini, A. Slagle, T. Kenna, C. Bertinato, M. Turrin, 2004a, Hudson River Estuary Program Benthic Mapping Project Phase III-Report 1-June 2004, New York State Department of Environmental Conservation.

Bell, R.E., R.D. Flood, S.M. Carbotte, W.B.F. Ryan, F.O. Nitsche, S. Chillrud, R. Arko, V. Ferrini, A. Slagle, T. Kenna, C. Bertinato, M. Turrin, 2004b, Hudson River Estuary Program Benthic Mapping Project New York Upper Harbor Area Sub-Report, New York State Department of Environmental Conservation.

Berkey, C.P., 1948, Engineering geology in New York City, Excursion No. 4, Guidebook of Excursions: Geological Society of America Annual Meeting, 61st, New York City. (reinterpreted by Merguerian, 2003)

e4sciences|Earthworks, 2015, Shallow water benthic mapping: West side Manhattan and Brooklyn waterfront, prepared for New York State Department of Conservation.

Merguerian, Charles, 2003, The Narrows Flood – Post-Woodfordian Meltwater Breach of the Narrows Channel, NYC.

Merguerian, Charles, C.A. Baskerville, 1987, Geology of Manhattan Island and the Bronx, New York City, New York, Geological Society of America Centennial Field Guide – Northeastern Section.

National Oceanic and Atmospheric Administration. Tides & Currents, Station Info. The Battery, NY – Station ID: 8518750. Available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8518750. Accessed [04/07/16].

National Oceanic and Atmospheric Administration. Tides & Currents, Tides/Water Levels. Mean Sea Level Trend 8518750 The Battery, New York. Available online at https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8518750. Accessed [04/07/16].

New York State Department of Environmental Conservation. Oil & Gas Searchable Database: Wells Data Search. Available online at http://www.dec.ny.gov/cfmx/extapps/GasOil/search/wells/index.cfm. Last accessed [03/17/16].

New York State Department of Environmental Conservation. Arthur Kill/Upper Bay Watershed.

New York State Geological Survey, 1989, *Surficial Geologic Map of New York*. [map]. 1:250,000. Map and Chart Series #40. NYSGS.

NYC Department of Environmental Protection, 2012, The State of the Harbor 2012.

Sanborn, James F., 1950, Engineering Geology in the design and construction of tunnels. In Application of Geology to Engineering Practice, edited by S. Paige, pp. 45-82. Boulder: Geological Society of America. (reinterpreted by Merguerian, 2003)

Thieme, Donald M, 2008, Governors Island in New York Bay - Formation of the Island and of Some Historical Archaeological Contexts, University of Florida Press volume, Geoarchaeology in Historical and Urban Contexts, edited by A. Gilbert and J. Schuldenrein.

USACE-NAN, 1999, New York and New Jersey Harbor Navigation Study Feasibility Report and Final Environmental Impact Statement.

U.S. Environmental Protection Agency. My WATERS Mapper. Available online at https://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=02030101&extraLayers=null. Last accessed [03/30/16].

U.S. Geological Survey, 1994, *Bedrock and Engineering Geologic Maps of New York County and Parts of Kings and Queens Counties, New York, and Parts of Bergen and Hudson Counties, New Jersey*. [map]. 1:24,000. Map I-2306. U.S. Department of the Interior. USGS.

Soil analysis

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

Surface water quality data

NYHS Harbor SEALS. Harbor SEALS Water Quality. New York SEALS Upper Hudson River Estuary Water/Air Quality Monitoring Program. Available online at http://harborseals.org/05-projects/on-going-projects/citizen-science-water-quality-monitoring-of-the-upper-hudson-river-estuary/. Accessed [03/30/16].

NYHS Harbor SEALS. SEALS Water Quality. Available online at http://harborseals.org/data/water-quality/harbor-seals-water-quality/. Accessed [03/30/16].

U.S. Environmental Protection Agency. My WATERS Mapper. Available online at https://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=02030101&extraLayers=null. Accessed [03/30/16].

Groundwater quality data

The Phased Redevelopment of Governors Island: Project Description, City Environmental Quality Review, NYC Mayor's Office of Sustainability, 2011.

Nautical charts

2014, National Oceanic and Atmospheric Administration - National Ocean Service, *New York Harbor*. [nautical chart]. 1:40,000. Coastal Chart No. 12327. U.S. Department of Commerce, NOAA-NOS.

1912, U.S. Coast and Geodetic Survey, *New York Bay and Harbor, New York*. [nautical chart]. 1:80,000. Coastal Chart No. 120.

1906, U.S. Coast and Geodetic Survey, *New York Bay and Harbor, New York*. [nautical chart]. 1:80,000. Coastal Chart No. 120.

1845, U.S. Coast Survey, *Map of New-York Bay and Harbor and the Environs*. [nautical chart]. 1:80,000. USCS.

GIS data

New York Orthophotos –New York Statewide Digital Orthoimagery Program (NYSDOP) 2014
http://www.orthos.dhses.ny.gov/
USGS Earth Resources Observation Systems (EROS) 2014
https://lta.cr.usgs.gov/high_res_ortho

New York Bedrock Geology Layer – U.S. Geological Survey (USGS)
http://mrdata.usgs.gov/geology/state/state.php?state=NY

New York Surficial Geology Layer
– NYSGS New York Lower Hudson Surficial Geology (Scale 1:250,000)
http://www.nysm.nysed.gov/research-collections/geology/gis
– New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS)
Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13
http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm
– ongoing e4sciences project, 2016

Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016

http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/

Wetlands information – U.S. Fish and Wildlands Service, National Wetlands Inventory, 2010
http://www.fws.gov/wetlands/

I-b. Relevant boring logs

GovernorsIsland_Boring_SampleSite_Logs.pdf
USACE_GovernorsIsland_BC-98-17.pdf
USACE_GovernorsIsland_BC-98-18.pdf
USACE_GovernorsIsland_BC-98-19.pdf
USACE_GovernorsIsland_BC-98-22A.pdf
USACE_GovernorsIsland_BC-98-23A.pdf
USACE_GovernorsIsland_BC-98-24A.pdf
e4sciences_GovernorsIsland_GI-14-08.pdf
e4sciences_GovernorsIsland_GI-14-09.pdf

I-c. Soil reports

USDA-NRCS_GovernorsIsland_UrbanLand_Laguardia.pdf

I-d. Surface water quality data

NYHarborSEALS_GovernorsIsland_SurfaceWaterQuality_data.pdf

I-e. Bathymetry figures

GovernorsIsland_SideScan_Insonification_NW.pdf
GovernorsIsland_SideScan_Insonification_ES.pdf
GovernorsIsland_Sediment_DifferenceMap.pdf

I-f. Sediment type figure

GovernorsIsland_SedimentType_GrainSizeDistribution.pdf

I-g. Organism stress classification figure

GovernorsIsland_Organism_StressClassification.pdf

Appendix II: Site 154. Bush Terminal

Appendix II-a References ……..……..... A2-2
Appendix II-b Relevant boring log ……...……..... A2-3
Appendix II-c Soil reports …...…….…….....… A2-4
Appendix II-d Surface water quality …….……..…….……...…..... A2-4
Appendix II-e Bathymetry figures ……...…….……...……..…..... A2-4
Appendix II-f Sediment type figures ……..……..……..…….....… A2-4
Appendix II-g Organism stress classification figure ……...……..….....… A2-4

II-a. Site 154. Bush Terminal references

Geology and general information

Bell, R. E., Flood, R. D., Carbotte, S. M., Ryan, W. B. F., McHugh, C., Cornier, M., Versteeg, R., Chayes, D., Bokuniewicz, H., Ferrini, V., and Thissen, J., 2000, Hudson River Estuary Program Benthic Mapping Project Final Report. NY State Department of Environmental Conservation.

Bell, R.E., R.D. Flood, S.M. Carbotte, W.B.F. Ryan, F.O. Nitsche, S. Chillrud, R. Arko, V. Ferrini, A. Slagle, C. Bertinato, M. Turrin, 2003, Hudson River Estuary Program Benthic Mapping Project Phase II-Repor1-March 2003, New York State Department of Environmental Conservation.

Bell, R.E., R.D. Flood, S.M. Carbotte, W.B.F. Ryan, F.O. Nitsche, S. Chillrud, R. Arko, V. Ferrini, A. Slagle, T. Kenna, C. Bertinato, M. Turrin, 2004a, Hudson River Estuary Program Benthic Mapping Project Phase III-Report 1-June 2004, New York State Department of Environmental Conservation.

Bell, R.E., R.D. Flood, S.M. Carbotte, W.B.F. Ryan, F.O. Nitsche, S. Chillrud, R. Arko, V. Ferrini, A. Slagle, T. Kenna, C. Bertinato, M. Turrin, 2004b, Hudson River Estuary Program Benthic Mapping Project New York Upper Harbor Area Sub-Report, New York State Department of Environmental Conservation.

e4sciences|Earthworks, 2015, Shallow water benthic mapping: West side Manhattan and Brooklyn waterfront, prepared for New York State Department of Conservation.

Merguerian, Charles, C.A. Baskerville, 1987, Geology of Manhattan Island and the Bronx, New York City, New York, Geological Society of America Centennial Field Guide – Northeastern Section.

National Oceanic and Atmospheric Administration. Tides & Currents, Tides/Water Levels. Mean Sea Level Trend 8518750 The Battery, New York. Available online at https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8518750. Accessed [04/07/16].

National Oceanic and Atmospheric Administration. Tides & Currents, Station Info. The Battery, NY – Station ID: 8518750. Available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8518750. Accessed [04/07/16].New York State Department of Environmental Conservation. Arthur Kill/Upper Bay Watershed.

New York State Department of Environmental Conservation, 2016, Oil & Gas Searchable Database: Wells Data Search. Available online at http://www.dec.ny.gov/cfmx/extapps/GasOil/search/wells/index.cfm. Accessed [03/17/16].

New York State Geological Survey, 1989, *Surficial Geologic Map of New York*. [map]. 1:250,000. Map and Chart Series #40. NYSGS.

NYC Department of Environmental Protection, 2012, The State of the Harbor 2012.

USACE-NAN, 1999, New York and New Jersey Harbor Navigation Study Feasibility Report and Final Environmental Impact Statement.

U.S. Environmental Protection Agency, 2016, My WATERS Mapper. Available online at https://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=02030101&extraLayers=null. Accessed [03/30/16].

U.S. Geological Survey, 1994, *Bedrock and Engineering Geologic Maps of New York County and Parts of Kings and Queens Counties, New York, and Parts of Bergen and Hudson Counties, New Jersey*. [map]. 1:24,000. Map I-2306. U.S. Department of the Interior.

Soil analysis

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

Surface water quality data

NYC Department of Environmental Protection. Harbor Water Sampling Data. Available Online at http://www.nyc.gov/html/dep/html/harborwater/harbor_water_sampling_results.shtml. Accessed [03/30/16].

U.S. Environmental Protection Agency. My WATERS Mapper. Available online at https://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=02030101&extraLayers=null. Accessed [03/30/16].

Groundwater quality data

Division of Environmental Remediation 2013/2014 Annual Report. NYDEC.

Responsiveness Summary. Bush Terminal Landfill Piers 1-4 Environmental Restoration Site. Brooklyn, Kings County, New York. Site No. B00031-2.

Nautical charts

2014, National Oceanic and Atmospheric Administration - National Ocean Service. *New York Harbor*. [nautical chart]. 1:40,000. Coastal Chart No. 12327. U.S. Department of Commerce, NOAA-NOS.

1924, U.S. Coast and Geodetic Survey. *New York Harbor.* [nautical chart]. 1:40,000. Coastal Chart No. 369. UCGS.

1894, U.S. Coast and Geodetic Survey. *New York Bay and Harbor, New York.* [nautical chart]. 1:80,000. Coastal Chart No. 120. UCGS.

1845, U.S. Coast Survey. *Map of New-York Bay and Harbor and the Environs.* [nautical chart]. 1:80,000.

GIS data

New York Orthophotos –New York Statewide Digital Orthoimagery Program (NYSDOP) 2014
http://www.orthos.dhses.ny.gov/
USGS Earth Resources Observation Systems (EROS) 2014
https://lta.cr.usgs.gov/high_res_ortho

New York Bedrock Geology Layer – U.S. Geological Survey (USGS)
http://mrdata.usgs.gov/geology/state/state.php?state=NY

New York Surficial Geology Layer
– NYSGS New York Lower Hudson Surficial Geology (Scale 1:250,000)
http://www.nysm.nysed.gov/research-collections/geology/gis
– New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS)
Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13
http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm
– ongoing e4sciences project, 2016

Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/

Wetlands information – U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010
http://www.fws.gov/wetlands/

II-b. Relevant boring logs

BushTerminal_Boring_SampleSite_Logs.pdf
USACE_BushTerminal_BR-98-29.pdf
USACE_BushTerminal_BR-98-30.pdf
USACE_BushTerminal_BR-98-33.pdf
USACE_BushTerminal_BR-98-34.pdf
USACE_BushTerminal_BR-98-35.pdf

e4sciences_BushTerminal_SPW14-03.pdf
e4sciences_BushTerminal_SPW14-04.pdf
e4sciences_BushTerminal_SPW14-05.pdf
e4sciences_BushTerminal_SPW14-06.pdf

II-c. Soil reports

USDA-NRCS_BushTerminal_Laguardia.pdf

II-d. Surface water quality data

NYCDEP_BushTerminal_SurfaceWaterQuality_data.pdf

II-e. Bathymetry figures

BushTerminal_SideScan_Insonification_NW.pdf
BushTerminal_SideScan_Insonification_ES.pdf
BushTerminal_Bathymetry.pdf

II-f. Sediment Type figure

BushTerminal_SedimentType_GrainSizeDistribution.pdf

II-g. Organism stress classification figure

BushTerminal_Organism_StressClassification.pdf

Appendix III: Soundview Park

Appendix III-a References ……..……..... A3-2
Appendix III-b Soil reports …..……..…….....… A3-4
Appendix III-c Surface water quality ……..……..……..……...…..... A3-4

III-a. Soundview Park references

Geology and general information

Baskerville, C. A., 1982a, The foundation geology of New York City, in Legget, R. F., ed., Geology under cities: Geological Society of America Reviews in Engineering Geology, v. 5, p. 95-117.

Baskerville, C. A., 1992, *Bedrock and engineering geologic maps of Bronx County and parts of New York and Queens counties, New York*: U.S. Geological Survey Miscellaneous Investigations Series Map I-2003 (scale 1:24,000).

Baskerville, C. A., and R. H. Fakundiny. 2003. Engineering Geology of New York City: Continuing Value of Geologic Data. In *Earth Science in the City: A Reader*. Special Publication Series 56, edited by G. Heinken, R. Fakundiny, and J. Sutter, pp. 43-59. American Geophysical Union, Washington, D.C.

e4sciences|Earthworks, 2014, Bronx River Ecosystem Restoration Feasibility Study: Geotechnical and geological report; Department of the Army, USACE-NAN. Contract #W912DS-12-D-0002, Task Order #0019.

Little, C.D., D.S. Biedenham, 2007, Geomorphic Assessment and Sediment Impact Assessment for Bronx River, Final Report, New York, U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.

Merguerian, Charles, 1983a, The structural geology of Manhattan Island, New York City (NYC), New York (abstract): Geological Society of America Abstracts with Programs, v. 15, p. 169 (only).

Merguerian, Charles; and Charles A. Baskerville, 1987, The geology of Manhattan Island and the Bronx, New York City, New York, p. 137-140 in Roy, D. C., ed., Northeastern Section of the Geological Society of America, Centennial Field guide, v. 5, 481 p.

Merguerian, Charles; and Sanders, J. E., 1991, Trip 16: Geology of Manhattan and the Bronx, 21 April 1991: New York Academy of Sciences Section of Geological Sciences Trips on the Rocks Guidebook, 141 p.

Merguerian, Charles; and Sanders, J. E., 1993a, Trip 26, Geology of Cameron's Line and the Bronx Parks, 08 May 1993 (revision of Trip 21, 24 November 1991): New York Academy of Sciences Section of Geological Sciences Trips on the Rocks Guidebook, 126 p.

Merguerian, Charles; and Sanders, J. E., 1996a, Diversion of the Bronx River in New York City - evidence for postglacial surface faulting?, p. 131-145 in Hanson, G. N., chm., Geology of Long Island and metropolitan New York, 20 April 1996, State University of New York at Stony Brook, NY, Long Island Geologists Program with Abstracts, 177 p.

National Oceanic and Atmospheric Administration. Tides & Currents, Station Info. Kings Point, NY – Station ID: 8516945. Available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8516945. Accessed [04/07/16].

National Oceanic and Atmospheric Administration. Tides & Currents, Station Info. Worlds Fair Marina, NY – Station ID: 8517251. Available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8517251. Accessed [04/07/16].

New York State Geological Survey, 1989, *Surficial Geologic Map of New York*. [map]. 1:250,000. Map and Chart Series #40. NYSGS.

NYS Department of Environmental Conservation. Oil and Gas Home. Oil & Gas Searchable Database. Wells Data Search. Available online at http://www.dec.ny.gov/cfmx/extapps/GasOil/search/wells/index.cfm. Accessed [03/30/16].

NYS Department of Environmental Conservation. Arthur Kill/Upper Bay Watershed.

U.S. Environmental Protection Agency. My WATERS Mapper. Available online at https://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=02030101&extraLayers=null. Accessed [03/30/16].

U.S. Geological Survey, 1992, *Bedrock and Engineering Geologic Maps of Bronx County and Parts of New York and Queens Counties, New York*. [map]. 1:24,000. Map I-2003. U.S. Department of the Interior, USGS.

Soil analysis

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

U.S. Department of Agriculture and Natural Resources Conservation Service, 2006, Soil Survey of Bronx River Watershed, Bronx, New York.

Surface water quality data

NYC Department of Environmental Protection. Harbor Water Sampling Data. Available Online at http://www.nyc.gov/html/dep/html/harborwater/harbor_water_sampling_results.shtml. Accessed [03/30/16].

U.S. Environmental Protection Agency. My WATERS Mapper. Available online at https://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=02030101&extraLayers=null. Accessed [03/30/16].

Groundwater quality data

Hunts Point MGP Site – Operable Unit No. 6, Marine Transfer Site, NYSDEC Site #V00554. Fact Sheet. conEdison, NYSDEC, DOH, September 2014.

New Jersey Department of Environmental Protection, Bureau of GIS. NJDEP Digital Data Downloads in ArcGIS Shape file format. Brownfield Development Areas (Extents). Available online at http://www.state.nj.us/dep/gis/stateshp.html. Accessed [03/15/16].

Nautical charts

2013, National Oceanic and Atmospheric Administration - National Ocean Service. *East River, Tallman Island to Queensboro Bridge, New York*. [nautical chart]. 1:10,000. Coastal Chart No. 12339. U.S. Department of Commerce, NOAA-NOS.

1958, U.S. Coast and Geodetic Survey. *East River, Tallman Island to Queensboro Bridge, New York*. [nautical chart]. 1:10,000. Coastal Chart No. 226. UCGS, 1958.

1946, U.S. Coast and Geodetic Survey. *East River, Tallman Island to Queensboro Bridge, New York*. [nautical chart]. 1:10,000. Coastal Chart No. 226.

1934, U.S. Coast and Geodetic Survey. *East River, Tallman Island to Queensboro Bridge, New York*. [nautical chart]. 1:10,000. Coastal Chart No. 226.

1910, U.S. Coast and Geodetic Survey. *New York Bay and Harbor, New York*. [nautical chart]. 1:80,000. Coastal Chart No. 120.

1861, U.S. Coast and Geodetic Survey. *New York Bay and Harbor, New York*. [nautical chart]. 1:80,000. Coastal Chart No. 120.

Topographic maps

2013, U.S. Geological Survey. *Central Park quadrangle, New York-New Jersey* [map]. Photorevised 2011. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS, 2013.

1947, U.S. Geological Survey. *Central Park quadrangle, New York-New Jersey* [map]. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS, 1947.

2013, U.S. Geological Survey. *Flushing quadrangle, New York* [map]. Photorevised 2011. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1947, U.S. Geological Survey. *Flushing quadrangle, New York* [map]. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1901, U.S. Geological Survey. *Harlem quadrangle, New York-New Jersey* [map]. 1:625,000. 15 Minute Series. U.S. Department of the Interior, USGS.

1897, U.S. Geological Survey. *Harlem quadrangle, New York-New Jersey* [map]. 1:625,000. 15 Minute Series. U.S. Department of the Interior, USGS.

1891, U.S. Geological Survey. *Harlem quadrangle, New York-New Jersey* [map]. 1:625,000. 15 Minute Series. U.S. Department of the Interior, USGS.

GIS data

New York Orthophotos –New York Statewide Digital Orthoimagery Program (NYSDOP) 2014
http://www.orthos.dhses.ny.gov/
USGS Earth Resources Observation Systems (EROS) 2014
https://lta.cr.usgs.gov/high_res_ortho

Bronx Geology Map GIS data
http://data.geocomm.com/catalog/US/61061/816/index.html
http://3dparks.wr.usgs.gov/nyc/highlands/manhattan.htm
http://dukelabs.com/Publications/PubsPdf/CMCAB1987_DNAG_GeolManhattanBronx.pdf

New York Bedrock Geology Layer – U.S. Geological Survey (USGS)
http://mrdata.usgs.gov/geology/state/state.php?state=NY

New York Surficial Geology Layer
– NYSGS New York Lower Hudson Surficial Geology (Scale 1:250,000)
http://www.nysm.nysed.gov/research-collections/geology/gis
– New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS)
Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13
http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm
– ongoing e4sciences project, 2016

Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/

Wetlands information – U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010
http://www.fws.gov/wetlands/

III-b. Soil reports

USDA-NRCS_SoundviewPark_Laguardia.pdf
USDA_NRCS_BronxRiverWatershed_SoilSurvey_2006.pdf

III-c. Surface water quality data

NYCDEP_SoundviewPark_SurfaceWaterQuality_data.pdf

Appendix IV: Head of Bay, Jamaica Bay

Appendix IV-a References A4-2
Appendix IV-b Relevant boring logs A4-3
Appendix IV-c Soil reports A4-4
Appendix IV-d Surface water quality A4-4
Appendix IV-e Heavy metal concentrations found in Jamaica Bay sediments A4-4

IV-a. Head of Bay, Jamaica Bay references

Geology and general information

Buxton, H.T. and P.K. Shernoff, 1999, Ground-water resources of Kings and Queens Counties, Long Island. New York: Water Supply Paper 2498, pp. 3-12.

Cartwright, Richard A., 2002, History and Hydrologic Effects of Ground-Water Use in Kings, Queens, and Western Nassau Counties, Long Island, New York, 1800's through 1997. NYCDEP, USGS.

e4sciences|Earthworks, 2011, Subsurface & Geophysical Investigation of Plumb Beach., Department of the Army, USACE-NAN Contract #W912DS-09-D-0001, Task Order #0022.

Jamaica Bay Research and Management Information Network Jamaica Bay bibliographic database http://www.ciesin.org/jamaicabay/bibliography.jsp
The Jamaica Bay bibliographic database contains more than 1,500 citations to journal articles, reports, working papers, web sites, data, and software applications addressing past and current research in and around the Jamaica Bay Wildlife Refuge. This Bibliography is primarily based upon compilations by Dr. George W. Frame and interns Patricia Luce, Christina Sippel, Tamas Torma, and Anjil Mahaju, Jamaica Bay Ecological Research and Restoration Team (JABERRT), Division of Natural Resources, Gateway National Recreation Area, NY and NJ.

Jamaica Bay Research and Management Information Network (JBRMIN) Data Catalog http://www.ciesin.org/jamaicabay/data.jsp

Jamaica Bay Research and Management Information Network (JBRMIN) Map Catalog http://www.ciesin.org/jamaicabay/maps.jsp

National Oceanic and Atmospheric Administration. Tides & Currents, Tides/Water Levels. Mean Sea Level Trend 8518750 The Battery, New York. Available online at https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8518750. Accessed [04/07/16].

National Oceanic and Atmospheric Administration. Tides & Currents, Station Info. Norton Point, Hook Creek, New York, NY – Station ID: 8516891. Available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8516891. Accessed [04/07/16].

New York State Geological Survey, 1989, *Surficial Geologic Map of New York*. [map]. 1:250,000. Map and Chart Series #40. NYSGS.

NYS Department of Environmental Conservation. Arthur Kill/Upper Bay Watershed. Available online at www.dec.ny.gov/docs/water_pdf/wiatllisakub.pdf. Accessed [04/04/16].

NYS Department of Environmental Conservation. Oil and Gas Home. Oil & Gas Searchable Database. Wells Data Search. Available online at http://www.dec.ny.gov/cfmx/extapps/GasOil/search/wells/index.cfm. Accessed [03/30/16].

Port Authority of NY & NJ. John F. Kennedy International Airport. History of JFK International Airport. Accessible online at http://www.panynj.gov/airports/jfk-history.html. Accessed 03/30/16].

U.S. Environmental Protection Agency. My WATERS Mapper. Available online at https://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=02030101&extraLayers=null. Accessed [03/30/16].

U.S. Geological Survey. National Water Information System: Web Interface. USGS 01311850 Jamaica Bay at Inwood, NY. Available online at http://waterdata.usgs.gov/nwis/dv/?site_no=01311850&agency_cd=USGS&referred_module=sw. Accessed [04/07/16].

Soil analysis

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

Surface water quality data

U.S. Environmental Protection Agency. My WATERS Mapper. Available online at https://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=02030101&extraLayers=null. Accessed [03/30/16].

U.S. Environmental Protection Agency. Water Quality Criteria. Developing Water Quality Criteria for suspended and bedded sediments (SABs); Potential Approaches. Appendix 2: Summary of Water Quality Guidelines for turbidity, suspended, and Benthic sediments; British Columbia, Canada. 2001.

U.S. Environmental Protection Agency. Water. Wetlands, Oceans, & Watersheds. Monitoring and Assessing Water Quality. STORET. Station Information. National Park Service Water Resources Division. GATE_NPA_JB-12A. Jo Co Marsh – South. Available online at https://iaspub.epa.gov/storpubl/storet_wme_pkg.Display_Station?p_station_id=GATE_NPS_JB-12A&p_org_id=11NPSWRD_WQX. Accessed [03/30/16].

Groundwater quality data

Seidemann, David E., 1991, Metal pollution in sediments of Jamaica Bay, New York, USA – An urban estuary: Environmental Management, v. 15, pp. 73-81.

Nautical chart

2011, National Oceanic and Atmospheric Administration. *Jamaica Bay and Rockaway Inlet*. [nautical chart]. 1:20,000. Coastal Chart No. 12350. U.S. Department of Commerce.

1954, U.S. Coast and Geodetic Survey. *Jamaica Bay and Rockaway Inlet*. [nautical chart]. 1:20,000. Coastal Chart No. 542.

1937, U.S. Coast and Geodetic Survey. *Jamaica Bay and Rockaway Inlet*. [nautical chart]. 1:20,000. Coastal Chart No. 542.

1910, U.S. Coast and Geodetic Survey. *New York Bay and Harbor, New York*. [nautical chart]. 1:80,000. Coastal Chart No. 120.

1885, U.S. Coast and Geodetic Survey. *New York Bay and Harbor, New York*. [nautical chart]. 1:80,000. Coastal Chart No. 120

1845, U.S. Coast Survey. *Map of New-York Bay and Harbor and the Environs.* [nautical chart]. 1:80,000. USCS.

GIS data

New York Orthophotos –New York Statewide Digital Orthoimagery Program (NYSDOP) 2014
http://www.orthos.dhses.ny.gov/
USGS Earth Resources Observation Systems (EROS) 2014
https://lta.cr.usgs.gov/high_res_ortho

New York Surficial Geology Layer
– NYSGS New York Lower Hudson Surficial Geology (Scale 1:250,000)
http://www.nysm.nysed.gov/research-collections/geology/gis
– New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS)
Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13
http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm
– ongoing e4sciences project, 2016

Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/

Wetlands information – U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010
http://www.fws.gov/wetlands/

IV-b. Relevant boring logs

JamaicaBay_Boring_SampleSite_Logs.pdf
NYSDEP_JamaicaBay_20980.pdf

NYSDEP_JamaicaBay_21001.pdf
NYSDEP_JamaicaBay_21002.pdf
NYSDEP_JamaicaBay_21003.pdf
NYSDEP_JamaicaBay_21004.pdf

IV-c. Soil reports

USDA-NRCS_JamaicaBay_JamaicaSand.pdf

IV-d. Surface water quality data

NPS_EPA_JamaicaBay_SurfaceWaterQuality_data.pdf

IV-e. Heavy metals in Jamaica Bay sediments

Seidemann_JamaicaBay_HeavyMetals_1981-1982.pdf

Appendix V: Naval Weapons Station Earle

Appendix V-a References ……..... A5-2
Appendix V-b Relevant boring logs …...……...…….…….....… A5-3
Appendix V-c Soil reports …….…….…….…..…….……..…...…..... A5-3
Appendix V-d Surface water quality …….……..……..…..……....…..... A5-3

Appendix V: Naval Weapons Station Earle

V-a. Naval Weapons Station Earle references

Geology and general information

Commander, Navy Installations Command. Naval Weapons Station Earle. Operations and Management. Available online at http://www.cnic.navy.mil/regions/cnrma/installations/nws_earle/om.html. Accessed [03/30/16].

Minard, James P., 1969, *Geology of Sandy Hook quadrangle in Monmouth County, New Jersey*: Geological Survey Bulletin 1276.

National Oceanic and Atmospheric Administration. Tides & Currents, Station Info. Sandy Hook, NJ – Station ID: 8531680. Available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8531680. Accessed [04/07/16].

NJ Department of Environmental Protection and New Jersey Geological and Water Survey, *Aquifer Correlation Map of Monmouth and Ocean Counties, New Jersey*. [map]. 1:150,000. GMS 13-1. DEP, Water Resources Management, NJGWS.

NJ Department of Transportation. Geotechnical Data Management System Viewer. Available online at https://njgin.state.nj.us/DOT_GDMS/. Accessed [03/17/16].

U.S. Geological Survey, *Geologic Map and Section of the Sandy Hook Quadrangle in Monmouth County, New Jersey*. [map]. 1:24,000. Bulletin 1276, Plates 1-2. Reston, VA. U.S. Department of the Interior, USGS, 1969.

U.S. Environmental Protection Agency. My WATERS Mapper. Available online at https://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=02030101&extraLayers=null. Accessed [03/30/16].

Soil analysis

United States Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

Surface water quality data

U.S. Environmental Protection Agency. Environmental Monitoring & Assessment Program. Available online at https://archive.epa.gov/emap/archive-emap/web/html/. Accessed [03/30/16].

U.S. Environmental Protection Agency. My WATERS Mapper. Available online at https://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=02030101&extraLayers=null. Accessed [03/30/16].

U.S. Environmental Protection Agency. Water. Wetlands, Oceans, & Watersheds. Monitoring and Assessing Water Quality. STORET. Station Information. Environmental Monitoring and Assessment Program. NJ04-003-A. Sandy Hook Bay. Available online at https://ofmpub.epa.gov/storpubl/storet_wme_pkg.Display_Station?p_station_id=NJ04-0003-A&p_org_id=EMAP_CS_WQX. Accessed [03/30/16].

Groundwater quality data

U.S. Environmental Protection Agency. 2016. Superfund Sites, Superfund Information Systems. Naval Weapons Station Earle (Site A). Available online at https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.contams&id=0201160. Accessed [03/18/16].

Nautical charts

2014, National Oceanic and Atmospheric Administration. *New York Harbor*. [nautical chart]. 1:40,000. Coastal Chart No. 12327. U.S. Department of Commerce, NOAA.

1933, U.S. Coast and Geodetic Survey. *New York Harbor*. [nautical chart]. 1:40,000. Coastal Chart No. 369.

1917, U.S. Coast and Geodetic Survey. *New York Harbor*. [nautical chart]. 1:40,000. Coastal Chart No. 369.

1845, U.S. Coast Survey. *Map of New-York Bay and Harbor and the Environs.* [nautical chart]. 1:80,000. USCS.

GIS data

New Jersey Bedrock Geology Layer – U.S. Geological Survey (USGS)
http://mrdata.usgs.gov/geology/state/state.php?state=NJ

New Jersey Historic Fill Layer – NJDEP Historic Fill for New Jersey as of February 2009
http://www.state.nj.us/dep/njgs/geodata/dgs04-7.htm

New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS) Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13
http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm

NJ Orthophotos – New Jersey Geographic Information Network Web Map Service 2015
https://njgin.state.nj.us/NJ_NJGINExplorer/jviewer.jsp?pg=wms_instruct
USGS Earth Resources Observation Systems (EROS) 2014
https://lta.cr.usgs.gov/high_res_ortho

Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/

Wetlands information – U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010
http://www.fws.gov/wetlands/

V-b. Relevant boring logs

NavalWeaponsStationEarle_Boring_SampleSite_Logs.pdf
NJDOT_NWSEarle_B0018974.pdf
NJDOT_NWSEarle_B0018975.pdf
NJDOT_NWSEarle_B0019045.pdf
NJDOT_NWSEarle_B0019048.pdf
USGS_SandyHookQuad_Bulletin1276_Plate1_Boring13_1954_key.pdf

V-c. Soil reports

USDA-NRCS_NWSEarle_HooksanSand.pdf

V-d. Surface water quality data

EMAP_EPA_NWSEarle_SurfaceWaterQuality_data.pdf

Appendix VI: Site 719. Meadowlark Marsh

Appendix VI-a References …….……..……..... A6-2
Appendix VI-b Relevant boring logs …...……..……..….....… A6-4
Appendix VI-c Soil reports …….…….……..……,,,.…...…..... A6-4
Appendix VI-d Surface water quality …….……..…….…..……....…..... A6-4

VI-a. Site 719. Meadowlark Marsh references

Geology and general information

Earthworks, 2007, Benthic Community Investigation Hackensack River Enhancement Project, Department of the Army, USACE-NAN Contract #W912DS-06-D-0001, Task Order #0006.

Earthworks, 2008, Geophysical Investigation as part of the Design of the Hackensack River Enhancement Project, Department of the Army, USACE-NAN Contract #W912DS-06-D-0001, Task Order #0005.

Hudson-Raritan Estuary Comprehensive Restoration Plan Potential Restoration Opportunities Project Summary Sheets for Newark Bay, Passaic, & Hackensack. Site 719. Meadowlark Marsh. Project Summary Sheet. 2014.

National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services. ODIN Station Map, Tide Predictions. Available online at https://tidesandcurrents.noaa.gov/gmap3/index.shtml?type=TidePredictions&region=. Accessed [04/07/16].

National Oceanic and Atmospheric Administration. Tides & Currents, Station Info. Carlstadt, Hackensack River, NJ – Station ID: 8530528. Available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8530528. Accessed [04/07/16].

New Jersey Department of Environmental Protection. *New Jersey's Watersheds, Watershed Management Areas, and Water Regions.* [map]. Scale unknown. NJDEP, Division of Watershed Management, 2007.

New Jersey Department of Environmental Protection, Open Public Records Act. DEP Data Miner. XY Well Search. Available online at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

New Jersey Geological Survey. *Bedrock Map, Hackensack Meadows Area, New Jersey.* [map]. Geologic Report Series #1. 1:24,000. New Jersey Geological Survey, Bureau of Geology and Topography. 1959.

New Jersey Geological Survey. Bedrock Map of the Hackensack Meadows. Geologic Report Series No. 1. Section Descriptions. New Jersey Geological Survey, Department of Environmental Protection. 1959.

New Jersey Geological Survey. *Historic Fill of the Weehawken Quadrangle.* [map]. Photorevised 1981. 1:24,000. NJ Department of Environmental Protection and Energy, Land Use Management, NJGS, 2004.

New Jersey Geological Survey. *Surficial Geology of the Weehawken and Central Park Quadrangles, Bergen, Hudson, and Passaic Counties, New Jersey.* [map]. Photorevised 1979, 1981. 1:24,000. NJ Department of Environmental Protection and Energy, Division of Science and Research, NJGS, 1993.

New Jersey Meadowlands Commission, NJMC Master Plan, Chapter 5: Environmental Preservation and Enhancement, 2004.

U.S. Geological Survey, 1994, *Bedrock and Engineering Geologic Maps of New York County and Parts of Kings and Queens Counties, and Parts of Bergen and Hudson Counties, New Jersey.* [map]. Photorevised 1979, 1981. 1:24,000. Reston, Va: U.S. Department of the Interior, USGS.

Ward, J.S., 1962, Foundation Reconnaissance Investigation Hackensack Meadows, New Jersey. United States Army Engineer District, New York. Consulting Soils and Foundation Engineers. Project No. C6205-10.

Soil analysis

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].
U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

Surface water quality data

Meadowlands Environmental Research Institute, 2013, MERI Surface Water Quality Report, Hackensack River (Bellmans Creek to Fort Lee Road) Watershed. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].
New Jersey Meadowlands Commission, NJMC Master Plan, Chapter 5: Environmental Preservation and Enhancement, 2004.

Groundwater quality data

New Jersey Department of Environmental Protection, Bureau of GIS. NJDEP Digital Data Downloads in ArcGIS Shape file format. Groundwater Contamination Areas (CEA). Available online at http://www.state.nj.us/dep/gis/stateshp.html. Accessed [03/15/16].
New Jersey Department of Environmental Protection, Division of Water Monitoring and Standards, Bureau of Environmental Analysis, Restoration, and Standards. Ground Water Quality Standards. Available online at http://www.nj.gov/dep/wms/bears/gwqs.htm. Accessed [03/15/16].
New Jersey Department of Environmental Protection. Open Public Records Act. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].
New Jersey Meadowlands Commission, NJMC Master Plan, Chapter 5: Environmental Preservation and Enhancement, 2004.

Topographic maps

1896, Colton, G.W. and C.B. Colton. *Colton's Road Map of Bergen County, New Jersey.* [map]. 1.5mi:1inch. New York, New York: G.W. & C.B. Colton & Co.
2014, U.S. Geological Survey. *Weehawken quadrangle, New York-New Jersey* [map]. Photorevised 2010, 2013. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.
1968, U.S. Geological Survey. *Weehawken quadrangle, New York-New Jersey* [map]. Revised 1966 by New York Department of Transportation. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.
1935, U.S. Geological Survey. *Weehawken quadrangle, New York-New Jersey* [map]. 1:24,000. U.S. Department of the Interior, USGS.

GIS data

New Jersey Bedrock Geology Layer – U.S. Geological Survey (USGS),
http://mrdata.usgs.gov/geology/state/state.php?state=NJ
New Jersey Historic Fill Layer – NJDEP Historic Fill for New Jersey as of February 2009,
http://www.state.nj.us/dep/njgs/geodata/dgs04-7.htm
New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS) Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13
http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm
NJ Orthophotos – New Jersey Geographic Information Network Web Map Service 2015
https://njgin.state.nj.us/NJ_NJGINExplorer/jviewer.jsp?pg=wms_instruct
USGS Earth Resources Observation Systems (EROS) 2014
https://lta.cr.usgs.gov/high_res_ortho
Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/
Wetlands information – U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010
http://www.fws.gov/wetlands/

VI-b. Relevant boring logs

719_MeadowlarkMarsh_Borings_GeologicLogs.pdf
NJDEP_MeadowlarkMarsh_E201507275_MW-42.pdf
NJDEP_MeadowlarkMarsh_E201507276_MW-43D.pdf
NJDEP_MeadowlarkMarsh_E201507277_MW-41.pdf

VI-c. Soil reports

USDA-NRCS_MeadowlarkMarsh_Westbrook_Ipswich_Sandyhook.pdf
USDA_NRCS_BergenCounty_SoilSurvey_1995.pdf

VI-d. Surface water quality data

MERI_MeadowlarkMarsh_SurfaceWaterQuality_data.pdf

Appendix VII: Site 721. Metromedia Tract

Appendix VII-a References A7-2
Appendix VII-b Relevant boring logs A7-4
Appendix VII-c Soil reports A7-4
Appendix VII-d Surface water quality A7-4

VII-a. Site 721. Metromedia Tract references

Geology and general information

Earthworks, 2007, Benthic Community Investigation Hackensack River Enhancement Project, Department of the Army, USACE-NAN Contract #W912DS-06-D-0001, Task Order #0006.

Earthworks, 2008, Geophysical Investigation as part of the Design of the Hackensack River Enhancement Project, Department of the Army, USACE-NAN Contract #W912DS-06-D-0001, Task Order #0005.

Hudson-Raritan Estuary Comprehensive Restoration Plan Potential Restoration Opportunities Project Summary Sheets for Newark Bay, Passaic, & Hackensack. Site 721. Metro Media Tract. Project Summary Sheet. 2014.

National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services. ODIN Station Map, Tide Predictions. Available online at https://tidesandcurrents.noaa.gov/gmap3/index.shtml?type=TidePredictions&region=. Accessed [04/07/16].

National Oceanic and Atmospheric Administration. Tides & Currents, Station Info. Carlstadt, Hackensack River, NJ – Station ID: 8530528. Available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8530528. Accessed [04/07/16].

New Jersey Department of Environmental Protection. *New Jersey's Watersheds, Watershed Management Areas, and Water Regions.* [map]. Scale unknown. NJDEP, Division of Watershed Management, 2007.

New Jersey Department of Environmental Protection, Open Public Records Act. DEP Data Miner. XY Well Search. Available online at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

New Jersey Geological Survey. *Bedrock Map, Hackensack Meadows Area, New Jersey.* [map]. Geologic Report Series #1. 1:24,000. New Jersey Geological Survey, Bureau of Geology and Topography. 1959.

New Jersey Geological Survey. Bedrock Map of the Hackensack Meadows. Geologic Report Series No. 1. Section Descriptions. New Jersey Geological Survey, Department of Environmental Protection. 1959.

New Jersey Geological Survey. *Historic Fill of the Weehawken Quadrangle.* [map]. Photorevised 1981. 1:24,000. NJ Department of Environmental Protection and Energy, Land Use Management, NJGS, 2004.

New Jersey Geological Survey. *Surficial Geology of the Weehawken and Central Park Quadrangles, Bergen, Hudson, and Passaic Counties, New Jersey.* [map]. Photorevised 1979, 1981. 1:24,000. NJ Department of Environmental Protection and Energy, Division of Science and Research, NJGS, 1993.

New Jersey Meadowlands Commission, Meadowlands Environmental Site Investigation Compilation, Metro Media Tract, Prepared by U.S. Army Corps of Engineers. Available online at http://meri.njmeadowlands.gov/mesic/sites/candidate-restoration-sites/metro-media-tract-2/. Accessed [03/17/16].

New Jersey Meadowlands Commission, NJMC Master Plan, Chapter 5: Environmental Preservation and Enhancement, 2004.

U.S. Geological Survey, 1994, *Bedrock and Engineering Geologic Maps of New York County and Parts of Kings and Queens Counties, and Parts of Bergen and Hudson Counties, New Jersey.* [map]. Photorevised 1979, 1981. 1:24,000. Reston, Va: U.S. Department of the Interior, USGS.

Ward, J.S., 1962, Foundation Reconnaissance Investigation Hackensack Meadows, New Jersey. United States Army Engineer District, New York. Consulting Soils and Foundation Engineers. Project No. C6205-10.

Soil analysis

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].
U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].
U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

Surface water quality data

Meadowlands Environmental Research Institute, MERI Surface Water Quality Report, Hackensack River (Route 3 to Bellmans Creek) Watershed, 2013. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

Groundwater quality data

New Jersey Department of Environmental Protection, Division of Water Monitoring and Standards, Bureau of Environmental Analysis, Restoration, and Standards. Ground Water Quality Standards. Available online at http://www.nj.gov/dep/wms/bears/gwqs.htm. Accessed [03/15/16].
New Jersey Department of Environmental Protection, Bureau of GIS. NJDEP Digital Data Downloads in ArcGIS Shape file format. Groundwater Contamination Areas (CEA). Available online at http://www.state.nj.us/dep/gis/stateshp.html. Accessed [03/15/16].
New Jersey Department of Environmental Protection. Open Public Records Act. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].
New Jersey Meadowlands Commission, NJMC Master Plan, Chapter 5: Environmental Preservation and Enhancement, 2004.

Topographic maps

1896, Colton, G.W. and C.B. Colton. *Colton's Road Map of Bergen County, New Jersey.* [map]. 1.5mi:1inch. New York, New York: G.W. & C.B. Colton & Co.
2014, U.S. Geological Survey. *Weehawken quadrangle, New York-New Jersey* [map]. Photorevised 2010, 2013. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.
1968, U.S. Geological Survey. *Weehawken quadrangle, New York-New Jersey* [map]. Revised 1966 by New York Department of Transportation. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.
1935, U.S. Geological Survey. *Weehawken quadrangle, New York-New Jersey* [map]. 1:24,000. U.S. Department of the Interior, USGS.

GIS data

New Jersey Bedrock Geology Layer – U.S. Geological Survey (USGS)
http://mrdata.usgs.gov/geology/state/state.php?state=NJ
New Jersey Historic Fill Layer – NJDEP Historic Fill for New Jersey as of February 2009
http://www.state.nj.us/dep/njgs/geodata/dgs04-7.htm
New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS) Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13
http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm
NJ Orthophotos – New Jersey Geographic Information Network Web Map Service 2015
https://njgin.state.nj.us/NJ_NJGINExplorer/jviewer.jsp?pg=wms_instruct
USGS Earth Resources Observation Systems (EROS) 2014
https://lta.cr.usgs.gov/high_res_ortho
Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/
Wetlands information – U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010
http://www.fws.gov/wetlands/

VII-b. Relevant boring logs

721_MetromediaTract_Borings_GeologicLogs.pdf
NJDEP_MetromediaTract_P200903233_MW-1.pdf
NJDEP_MetromediaTract_P200903234_MW-2.pdf
NJDEP_MetromediaTract_P200903235_MW-3.pdf
NJDEP_MetromediaTract_P200903236_MW-4.pdf

VII-c. Soil Reports

USDA-NRCS_MetromediaTract_Westbrook_Ipswich_Sandyhook.pdf
USDA_NRCS_BergenCounty_SoilSurvey_1995.pdf

VII-d. Surface water quality data

MERI_MetromediaTract_SurfaceWaterQuality_data.pdf

Appendix VIII: Site 865. Kearny Point

Appendix VIII-a References A8-2
Appendix VIII-b Relevant boring logs A8-3
Appendix VIII-c Soil reports A8-4
Appendix VIII-d Surface water quality A8-4

VIII-a. Site 865. Kearny Point references

Geology and general information

Earthworks, 2006, Geomorphological,/Geophysical Characterization of the Nature and Dynamics of Sedimentation and Sediment Transport in Newark Bay focusing on the Effects related to Continued and Future Federal Navigation Channel Deepening and Maintenance, Department of the Army, USACE-NAN Contract #W912DS-06-D-0001, Task Order #0004.

Earthworks, 2007, Benthic Community Investigation Hackensack River Enhancement Project, Department of the Army, USACE-NAN Contract #W912DS-06-D-0001, Task Order #0006.

Earthworks, 2008, Geophysical Investigation as part of the Design of the Hackensack River Enhancement Project, Department of the Army, USACE-NAN Contract #W912DS-06-D-0001, Task Order #0005.

New Jersey Department of Environmental Protection. *New Jersey's Watersheds, Watershed Management Areas, and Water Regions.* [map]. Scale unknown. NJDEP, Division of Watershed Management, 2007.

New Jersey Department of Environmental Protection, Open Public Records Act. DEP Data Miner. XY Well Search. Available online at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

New Jersey Geological Survey. *Historic Fill of the Jersey City Quadrangle.* [map]. Photorevised 1981. 1:24,000. NJ Department of Environmental Protection and Energy, Land Use Management, NJGS, 2004.

New Jersey Geological Survey. *Surficial Geology of the Jersey City Quadrangle, Hudson and Essex Counties, New Jersey.* [map]. Photorevised 1981. 1:24,000. NJ Department of Environmental Protection and Energy, Division of Science and Research, NJGS, 1995.

New York-New Jersey Harbor Estuary Program. Lower Passaic River Restoration Planning Summary of Restoration Opportunities. Site 1. Kearny Point. 2011.

Olsen, Paul E., Dennis V. Kent, and Jessica H. Whiteside, 2004, The Newark Basin, The Central Atlantic Magmatic Province, and the Triassic-Jurassic Boundary: A Field Trip, Run on May 23, 2004, in Conjunction with the 8th Annual DOSECC Workshop on Continental Scientific Drilling.

Schlische, Roy W., 1992, Structural and stratigraphic development of the Newark extensional basin, eastern North America; Evidence for the growth of the basin and its bounding structures: Geological Society of American Bulletin, v. 104, p. 1246-1263.

U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, NJ Department of Engineers. Lower Passaic River Restoration Project: Draft Final Restoration Opportunities Report. 2006.

U.S. Geological Survey, 1996, *Bedrock Geologic Map of Northern New Jersey.* [map]. 1:100,000. Reston, Va: U.S. Department of the Interior, USGS.

U.S. Geological Survey. National Water Information System: Web Interface. USGS 01392650 Passaic River at PVSC at Newark, NJ. Available online at http://waterdata.usgs.gov/nwis/dv/?site_no=01392650&agency_cd=USGS&referred_module=sw. Accessed [04/07/16].

Soil analysis

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

Surface water quality data

Meadowlands Environmental Research Institute, Water Quality Monitoring. Available online at http://meri.njmeadowlands.gov/projects/continuous-water-monitoring-stations/. Accessed [03/17/16].

Meadowlands Environmental Research Institute, Environmental Data Service, Kearny Water Quality. NJMC Vista Data Vision. Available online at http://meriems.njmeadowlands.gov/vdv/Index.php. Accessed [03/17/16].

Groundwater quality data

New Jersey Department of Environmental Protection, Bureau of GIS. NJDEP Digital Data Downloads in ArcGIS Shape file format. Groundwater Contamination Areas (CEA). Available online at http://www.state.nj.us/dep/gis/stateshp.html. Accessed [03/15/16].

New Jersey Department of Environmental Protection, Division of Water Monitoring and Standards, Bureau of Environmental Analysis, Restoration, and Standards. Ground Water Quality Standards. Available online at http://www.nj.gov/dep/wms/bears/gwqs.htm. Accessed [03/15/16].

New Jersey Department of Environmental Protection. Open Public Records Act. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

Topographic maps

1845, U.S. Coast Survey. *Map of New-York Bay and Harbor and the Environs.* [nautical chart]. 1:80,000. USCS, 1845.

2014, U.S. Geological Survey. *Jersey City Quadrangle, New York-New Jersey* [map]. Photorevised 2010, 2011. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS

1955, U.S. Geological Survey. *Jersey City Quadrangle, New York-New Jersey* [map]. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1899, U.S. Geological Survey. *Staten Island Quadrangle, New York-New Jersey* [map]. Revised 1898. 1:625,000. 15 Minute Series.

GIS data

New Jersey Bedrock Geology Layer – U.S. Geological Survey (USGS), http://mrdata.usgs.gov/geology/state/state.php?state=NJ

New Jersey Historic Fill Layer – NJDEP Historic Fill for New Jersey as of February 2009, http://www.state.nj.us/dep/njgs/geodata/dgs04-7.htm

New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS) Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13 http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm

NJ Orthophotos – New Jersey Geographic Information Network Web Map Service 2015 https://njgin.state.nj.us/NJ_NJGINExplorer/jviewer.jsp?pg=wms_instruct
USGS Earth Resources Observation Systems (EROS) 2014 https://lta.cr.usgs.gov/high_res_ortho

Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016 http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/

Wetlands information – U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010 http://www.fws.gov/wetlands/

VIII-b. Relevant boring logs

865_KearnyPoint_Borings_GeologicLogs.pdf
NJDEP_KearnyPoint_E201015886_MW-21.pdf
NJDEP_KearnyPoint_E201015887_MW-22.pdf
NJDEP_KearnyPoint_E201015888_MW-23.pdf
NJDEP_KearnyPoint_E201015889_MW-24.pdf

NJDEP_KearnyPoint_E201015890_MW-25.pdf
NJDEP_KearnyPoint_E201015891_MW-20.pdf
NJDEP_KearnyPoint_E201015892_MW-26.pdf
NJDEP_KearnyPoint_E201202196_SB-7.pdf
NJDEP_KearnyPoint_E201202197_SB-8.pdf
NJDEP_KearnyPoint_E201218127_MTB-2.pdf
NJDEP_KearnyPoint_E201412748_CPT-AGC-1C.pdf
NJDEP_KearnyPoint_E201412749_CPT-AGC-2C.pdf
NJDEP_KearnyPoint_E201412750_CPT-AGC-3C.pdf
NJDEP_KearnyPoint_E201412751_CPT-AGC-4C.pdf

VIII-c. Soil reports

USDA-NRCS_KearnyPoint_Secaucus_artifactual_fine_sandy_loam_0-3.pdf
USDA-NRCS_KearnyPoint_Secaucus_artifactual_fine_sandy_loam_3-8.pdf

VIII-d. Surface water quality data

MERI_KearnyPoint_SurfaceWaterQuality_data.pdf

Appendix IX: Site 866. Oak Island Yards

Appendix IX-a References A9-2
Appendix IX-b Relevant boring logs A9-3
Appendix IX-c Soil reports A9-4
Appendix IX-d Surface water quality A9-4

IX-a. Site 866. Oak Island Yards references

Geology and general information

Earthworks, 2001, Seismic Investigation of the Top-of-Rock, Newark Bay CDF, The Port Authority of New York and New Jersey, PA Agreement #415-99-032, ECI Number: 3, PA Charge Code: S42.223.222, Purchase Order Number: 4500005990.

Earthworks, 2006, Geomorphological,/Geophysical Characterization of the Nature and Dynamics of Sedimentation and Sediment Transport in Newark Bay focusing on the Effects related to Continued and Future Federal Navigation Channel Deepening and Maintenance, Department of the Army, USACE-NAN Contract #W912DS-06-D-0001, Task Order #0004.

National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services. ODIN Station Map, Tide Predictions. Available online at https://tidesandcurrents.noaa.gov/gmap3/index.shtml?type=TidePredictions&region=. Accessed [04/07/16].

National Oceanic and Atmospheric Administration. Tides & Currents, Station Info. Point No Point, Passaic River, NJ – Station ID: 8530743. Available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8530743. Accessed [04/07/16].

New Jersey Department of Environmental Protection, 2007, *New Jersey's Watersheds, Watershed Management Areas, and Water Regions.* [map]. Scale unknown. NJDEP, Division of Watershed Management.

New Jersey Department of Environmental Protection, Open Public Records Act. DEP Data Miner. XY Well Search. Available online at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

New Jersey Geological Survey, 2004, *Historic Fill of the Jersey City Quadrangle.* [map]. 1:24,000. NJ Department of Environmental Protection and Energy, Land Use Management, NJGS.

New Jersey Geological Survey, 1995, *Surficial Geology of the Jersey City Quadrangle, Hudson and Essex Counties, New Jersey.* [map] 1:24,000. NJ Department of Environmental Protection and Energy, Division of Science and Research, NJGS.

New York-New Jersey Harbor Estuary Program. Lower Passaic River Restoration Planning Summary of Restoration Opportunities. Site 2. Oak Island Yards. 2011.

Olsen, Paul E., Dennis V. Kent, and Jessica H. Whiteside, 2004, The Newark Basin, The Central Atlantic Magmatic Province, and the Triassic-Jurassic Boundary: A Field Trip, Run on May 23, 2004, in Conjunction with the 8th Annual DOSECC Workshop on Continental Scientific Drilling.

Schlische, Roy W., 1992, Structural and stratigraphic development of the Newark extensional basin, eastern North America; Evidence for the growth of the basin and its bounding structures: Geological Society of American Bulletin, v. 104, p. 1246-1263.

U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, NJ Department of Engineers. Lower Passaic River Restoration Project: Draft Final Restoration Opportunities Report. 2006.

U.S. Geological Survey, 1996, *Bedrock Geologic Map of Northern New Jersey.* [map]. 1:100,000. Reston, VA: U.S. Department of the Interior, USGS.

Soil analysis

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

Surface water quality data

New Jersey Harbor Dischargers Group. 2012 Water Quality Monitoring NY/NJ Harbor. Newark Bay/Kill Van Kull (74° 07'30") Watershed. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

New Jersey Passaic Valley Sewerage Commission. New Jersey Harbor Dischargers Group. Ambient Water Quality Monitoring Program. Available online at http://www.nj.gov/pvsc/what/njhdg/. Accessed [03/17/16].

Groundwater quality data

New Jersey Department of Environmental Protection, Bureau of GIS. NJDEP Digital Data Downloads in ArcGIS Shape file format. Groundwater Contamination Areas (CEA). Available online at http://www.state.nj.us/dep/gis/stateshp.html. Accessed [03/15/16].

New Jersey Department of Environmental Protection, Division of Water Monitoring and Standards, Bureau of Environmental Analysis, Restoration, and Standards. Ground Water Quality Standards. Available online at http://www.nj.gov/dep/wms/bears/gwqs.htm. Accessed [03/15/16].

New Jersey Department of Environmental Protection. Open Public Records Act. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

Topographic maps

2014, U.S. Geological Survey. *Elizabeth Quadrangle, New York-New Jersey* [map]. Photorevised 2013. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

2014, U.S. Geological Survey. *Jersey City Quadrangle, New York-New Jersey* [map]. Photorevised 2013. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1845, U.S. Coast Survey. *Map of New-York Bay and Harbor and the Environs.* [nautical chart]. 1:80,000. USCS.

1932, U.S. Geological Survey. *Staten Island Quadrangle, New York-New Jersey* [map]. 1:625,000. 15 Minute Series. USGS.

1899, U.S. Geological Survey. *Staten Island Quadrangle, New York-New Jersey* [map]. Photorevised 1898. 1:625,000. 15 Minute Series. USGS.

GIS data

New Jersey Bedrock Geology Layer – U.S. Geological Survey (USGS),
http://mrdata.usgs.gov/geology/state/state.php?state=NJ

New Jersey Historic Fill Layer – NJDEP Historic Fill for New Jersey as of February 2009,
http://www.state.nj.us/dep/njgs/geodata/dgs04-7.htm

New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS) Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13
http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm

NJ Orthophotos – New Jersey Geographic Information Network Web Map Service 2015
https://njgin.state.nj.us/NJ_NJGINExplorer/jviewer.jsp?pg=wms_instruct
USGS Earth Resources Observation Systems (EROS) 2014
https://lta.cr.usgs.gov/high_res_ortho

Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/

Wetlands information – U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010
http://www.fws.gov/wetlands/

IX-b. Relevant boring logs

866_OakIslandYards_Borings_GeologicLogs.pdf
NJDEP_OakIslandYards_E201013548_OW-1.pdf
NJDEP_OakIslandYards_E201013549_OW-2.pdf
NJDEP_OakIslandYards_E201114659_OW-3.pdf

NJDEP_OakIslandYards_E201213111_B-7.pdf
NJDEP_OakIslandYards_E201213112_B-8.pdf

IX-c. Soil reports

USDA-NRCS_OakIslandYards_Udorthents.pdf
USDA_NRCS_EssexCounty_SoilSurvey_2007.pdf

IX-d. Surface water quality data

NJHDG_OakIslandYards_SurfaceWaterQuality_data.pdf

Appendix X: Site 887. Essex County Branch Brook Park

Appendix X-a References A10-2
Appendix X-b Relevant boring logs A10-3
Appendix X-c Soil reports A10-4
Appendix X-d Surface water quality A10-4

X-a. Site 887. Essex County Branch Brook Park references

Geology and general information

Branch Brook Park Alliance. Cultural Landscape Report, Treatment, and Management Plan for Branch Brook Park, Newark, New Jersey. Volume 2: History of the Park and Critical Periods of Development. 2002.

New Jersey Department of Environmental Protection. *New Jersey's Watersheds, Watershed Management Areas, and Water Regions.* [map]. Scale unknown. NJDEP, Division of Watershed Management, 2007.

New Jersey Department of Environmental Protection, Open Public Records Act. DEP Data Miner. XY Well Search. Available online at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

New Jersey Geological Survey. *Historic Fill of the Orange Quadrangle.* [map]. Photorevised 1981. 1:24,000. NJ Department of Environmental Protection and Energy, Land Use Management, NJGS, 2004.

New Jersey Geological Survey. *Surficial Geology of the Orange Quadrangle, Essex, Passaic, Hudson, and Bergen Counties, New Jersey.* [map]. Photorevised 1981. 1:24,000. NJ Department of Environmental Protection and Energy, Division of Science, Research, and Technology, NJGS, 2001.

New York-New Jersey Harbor Estuary Program. Lower Passaic River Restoration Planning Summary of Restoration Opportunities. Site 23. First River Branch Brook Park. 2011.

Olsen, Paul E., Dennis V. Kent, and Jessica H. Whiteside, 2004, The Newark Basin, The Central Atlantic Magmatic Province, and the Triassic-Jurassic Boundary: A Field Trip, Run on May 23, 2004, in Conjunction with the 8th Annual DOSECC Workshop on Continental Scientific Drilling.

Rhodeside & Harwell, 2008, Branch Brook Park, Waterway Rehabilitation Feasibility Study

Schlische, Roy W., 1992, Structural and stratigraphic development of the Newark extensional basin, eastern North America; Evidence for the growth of the basin and its bounding structures: Geological Society of American Bulletin, v. 104, p. 1246-1263.

U.S. Geological Survey. *Bedrock Geologic Map of the Orange Quadrangle, Essex, Passaic, Bergen, and Hudson Counties, New Jersey.* [map]. 1:24,000. U.S. NJ Department of Environmental Protection and Energy, Land Use Management, NJGS, 2007.

Soil analysis

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

Surface water quality data

New Jersey Harbor Dischargers Group. 2003-2006 Water Quality Monitoring NY/NJ Harbor. Passaic River Lower (4th Street to Second River) Watershed. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

New Jersey Passaic Valley Sewerage Commission. New Jersey Harbor Dischargers Group. Ambient Water Quality Monitoring Program. Available online at http://www.nj.gov/pvsc/what/njhdg/. Accessed [03/17/16].

Groundwater quality data

New Jersey Department of Environmental Protection, Bureau of GIS. NJDEP Digital Data Downloads in ArcGIS Shape file format. Groundwater Contamination Areas (CEA). Available online at http://www.state.nj.us/dep/gis/stateshp.html. Accessed [03/15/16].

New Jersey Department of Environmental Protection, Division of Water Monitoring and Standards, Bureau of Environmental Analysis, Restoration, and Standards. Ground Water Quality Standards. Available online at http://www.nj.gov/dep/wms/bears/gwqs.htm. Accessed [03/15/16].

New Jersey Department of Environmental Protection. Open Public Records Act. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

Topographic maps

2014, U.S. Geological Survey. *Orange Quadrangle, New Jersey* [map]. Photorevised 2010, 2013. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1982, U.S. Geological Survey. *Orange Quadrangle, New Jersey* [map]. Photorevised 1981. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1947, U.S. Geological Survey. *Orange Quadrangle, New Jersey* [map]. 1:24,000. 7.5 Minute Series. USGS.

1870-1887, Vermeule, C.C. *Topographic Manuscript Maps of New Jersey: Map 24.* [map]. 1:21,120. NJ Department of Environmental Protection.

GIS data

New Jersey Bedrock Geology Layer – U.S. Geological Survey (USGS)
http://mrdata.usgs.gov/geology/state/state.php?state=NJ

New Jersey Historic Fill Layer – NJDEP Historic Fill for New Jersey as of February 2009
http://www.state.nj.us/dep/njgs/geodata/dgs04-7.htm

New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS) Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13
http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm

NJ Orthophotos – New Jersey Geographic Information Network Web Map Service 2015
https://njgin.state.nj.us/NJ_NJGINExplorer/jviewer.jsp?pg=wms_instruct
USGS Earth Resources Observation Systems (EROS) 2014
https://lta.cr.usgs.gov/high_res_ortho

Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/

Wetlands information – U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010
http://www.fws.gov/wetlands/

X-b. Relevant boring logs

887_EssexCountyBranchBrookPark_Borings_GeologicLogs.pdf
NJDEP_EssexCounty_BranchBrookPark_E201002778_MW-43.pdf
NJDEP_EssexCounty_BranchBrookPark_E201002779_MW-43D.pdf
NJDEP_EssexCounty_BranchBrookPark_E201012242_MW-3.pdf
NJDEP_EssexCounty_BranchBrookPark_E201014694_VMP-2.pdf
NJDEP_EssexCounty_BranchBrookPark_E201014695_VMP-3.pdf
NJDEP_EssexCounty_BranchBrookPark_E201016685_MW-46.pdf
NJDEP_EssexCounty_BranchBrookPark_E201117605_MW-19.pdf
NJDEP_EssexCounty_BranchBrookPark_E201201286_MW-26D.pdf
NJDEP_EssexCounty_BranchBrookPark_E201302004_HRW-1.pdf
NJDEP_EssexCounty_BranchBrookPark_E201302005_HRW-2.pdf
NJDEP_EssexCounty_BranchBrookPark_E201302007_HRW-4.pdf
NJDEP_EssexCounty_BranchBrookPark_E201400243_MW-15D.pdf
NJDEP_EssexCounty_BranchBrookPark_E201400244_MW-48D.pdf

NJDEP_EssexCounty_BranchBrookPark_E201403904_MW-1.pdf

X-c. Soil reports

USDA-NRCS_BranchBrookPark_Boonton_RedSandstone_Lowland_3-8.pdf
USDA-NRCS_BranchBrookPark_Boonton_RedSandstone_Lowland_8-15.pdf
USDA-NRCS_BranchBrookPark_Udorthents_Boonton_RedSandstone_Lowland_Substratum.pdf
USDA-NRCS_BranchBrookPark_Udorthents_Loamy_Fill_Substratum.pdf
USDA-NRCS_BranchBrookPark_Urban_Land_Boonton_RedSandstone_Lowland_0-8.pdf
USDA_NRCS_EssexCounty_SoilSurvey_2007.pdf

X-d. Surface water quality data

NJHDG_EssexCountyBranchBrookPark_SurfaceWaterQuality_data.pdf

Appendix XI: Site 900. Dundee Island Park/Pulaski Park

Appendix XI-a References A11-2
Appendix XI-b Relevant boring logs A11-3
Appendix XI-c Soil reports A11-4
Appendix XI-d Surface water quality A11-4

XI-a. Site 900. Dundee Island Park/Pulaski Park references

Geology and general information

Auerbach, Mark S. Passaic City Historian THE CITY OF PASSAIC from "The Castle Genie," Newsletter of The Passaic County Historical Society Genealogy Club Vol. 8, No. 4. Available online at http://www.rootsweb.ancestry.com/~njpchsgc/pce/passaic_cityof.htm. Accessed [03/17/16].

National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services. ODIN Station Map, Tide Predictions. Available online at https://tidesandcurrents.noaa.gov/gmap3/index.shtml?type=TidePredictions&region=. Accessed [04/07/16].

National Oceanic and Atmospheric Administration. Tides & Currents, Station Info. East Rutherford, Passaic River, NJ – Station ID: 8530403. Available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8530403. Accessed [04/07/16].

New Jersey Department of Environmental Protection. *New Jersey's Watersheds, Watershed Management Areas, and Water Regions.* [map]. Scale unknown. NJDEP, Division of Watershed Management, 2007.

New Jersey Department of Environmental Protection, Open Public Records Act. DEP Data Miner. XY Well Search. Available online at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

New Jersey Geological Survey. *Historic Fill of the Weehawken Quadrangle.* [map]. Photorevised 1981. 1:24,000. NJ Department of Environmental Protection and Energy, Land Use Management, NJGS, 2004.

New Jersey Geological Survey. *Surficial Geology of the Weehawken and Central Park Quadrangles, Bergen, Hudson, and Passaic Counties, New Jersey.* [map]. Photorevised 1979, 1981. 1:24,000. NJ Department of Environmental Protection and Energy, Division of Science and Research, NJGS, 1993.

Olsen, Paul E., Dennis V. Kent, and Jessica H. Whiteside, 2004, The Newark Basin, The Central Atlantic Magmatic Province, and the Triassic-Jurassic Boundary: A Field Trip, Run on May 23, 2004, in Conjunction with the 8th Annual DOSECC Workshop on Continental Scientific Drilling.

Schlische, Roy W., 1992, Structural and stratigraphic development of the Newark extensional basin, eastern North America; Evidence for the growth of the basin and its bounding structures: Geological Society of American Bulletin, v. 104, p. 1246-1263.

U.S. Geological Survey. *Bedrock Geologic Map of Northern New Jersey.* [map]. 1:100,000. Reston, Va: U.S. Department of the Interior, USGS, 1996.

Soil analysis

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

Surface water quality data

Stevens Institute of Technology. Davidson Laboratory. Urban Ocean Observatory. NYHOPS Data Time Series and Downloads. Passaic Valley Sewerage Commission building site. Available online at http://hudson.dl.stevens-tech.edu/maritimeforecast/PRESENT/data.shtml. Accessed [03/17/16].

New Jersey Passaic Valley Sewerage Commission. New Jersey Harbor Dischargers Group. Ambient Water Quality Monitoring Program. Available online at http://www.nj.gov/pvsc/what/njhdg/. Accessed [03/17/16].

Groundwater quality data

New Jersey Department of Environmental Protection, Bureau of GIS. NJDEP Digital Data Downloads in ArcGIS Shape file format. Groundwater Contamination Areas (CEA). Available online at http://www.state.nj.us/dep/gis/stateshp.html. Accessed [03/15/16].

New Jersey Department of Environmental Protection, Division of Water Monitoring and Standards, Bureau of Environmental Analysis, Restoration, and Standards. Ground Water Quality Standards. Available online at http://www.nj.gov/dep/wms/bears/gwqs.htm. Accessed [03/15/16].

New Jersey Department of Environmental Protection. Open Public Records Act. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

Topographic maps

2014, U.S. Geological Survey. *Weehawken Quadrangle, New York-New Jersey* [map]. Photorevised 2013. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1935, U.S. Geological Survey. *Weehawken Quadrangle, New York-New Jersey* [map]. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1900, U.S. Geological Survey. *Passaic Quadrangle, New Jersey-New York* [map]. 1:125,000. 30 Minute Series. USGS.

1888, U.S. Geological Survey. *Paterson Quadrangle, New Jersey-New York* [map]. 1:62,500. 15 Minute Series. USGS.

GIS data

New Jersey Bedrock Geology Layer – U.S. Geological Survey (USGS)
http://mrdata.usgs.gov/geology/state/state.php?state=NJ

New Jersey Historic Fill Layer – NJDEP Historic Fill for New Jersey as of February 2009
http://www.state.nj.us/dep/njgs/geodata/dgs04-7.htm

New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS) Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13
http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm

NJ Orthophotos – New Jersey Geographic Information Network Web Map Service 2015
https://njgin.state.nj.us/NJ_NJGINExplorer/jviewer.jsp?pg=wms_instruct
USGS Earth Resources Observation Systems (EROS) 2014
https://lta.cr.usgs.gov/high_res_ortho

Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/

Wetlands information – U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010
http://www.fws.gov/wetlands/

XI-b. Relevant boring logs

900_DundeeIslandPark_Borings_GeologicLogs.pdf
NJDEP_DundeeIslandPark_PulaskiPark_E201014342_MW-51D2R.pdf
NJDEP_DundeeIslandPark_PulaskiPark_E201104313_MW-1.pdf
NJDEP_DundeeIslandPark_PulaskiPark_E201114258_MW-64D2R.pdf
NJDEP_DundeeIslandPark_PulaskiPark_E201201427_MW-2.pdf
NJDEP_DundeeIslandPark_PulaskiPark_E201201428_MW-3.pdf
NJDEP_DundeeIslandPark_PulaskiPark_E201201429_MW-4.pdf
NJDEP_DundeeIslandPark_PulaskiPark_E201205309_EPA-19-BR.pdf
NJDEP_DundeeIslandPark_PulaskiPark_E201205310_EPA-19-OB.pdf
NJDEP_DundeeIslandPark_PulaskiPark_E201307855_MW-5.pdf
NJDEP_DundeeIslandPark_PulaskiPark_E201509866_MW-1.pdf

XI-c. Soil reports

USDA-NRCS_DundeeIslandPark_Urbanland_Riverhead.pdf
USDA_NRCS_PassaicCounty_SoilSurvey_2007.pdf

XI-d. Surface water quality data

NYHOPS_DundeeIslandPark_PulaskiPark_SurfaceWaterQuality_data.pdf

Appendix XII: Site 902. Clifton Dundee Canal
Green Acres Purchase and Island Preserve

Appendix XII-a References A12-2
Appendix XII-b Relevant boring logs A12-4
Appendix XII-c Soil reports A12-4
Appendix XII-d Surface water quality A12-4

XII-a. Site 902. Clifton Dundee Canal Green Acres Purchase and Island Preserve references

Geology and general information

National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services. ODIN Station Map, Tide Predictions. Available online at https://tidesandcurrents.noaa.gov/gmap3/index.shtml?type=TidePredictions&region=. Accessed [04/07/16].

National Oceanic and Atmospheric Administration. Tides & Currents, Station Info. East Rutherford, Passaic River, NJ – Station ID: 8530403. Available online at https://tidesandcurrents.noaa.gov/stationhome.html?id=8530403. Accessed [04/07/16].

National Park Service, 1997, Historical American Engineering Record, Dundee Canal Industrial Historic District: Photographs and Written Historical and Descriptive Data, HAER No. NJ-131.

New Jersey Department of Environmental Protection, 2007, *New Jersey's Watersheds, Watershed Management Areas, and Water Regions.* [map]. Scale unknown. NJDEP, Division of Watershed Management.

New Jersey Department of Environmental Protection, Open Public Records Act. DEP Data Miner. XY Well Search. Available online at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

New Jersey Geological and Water Survey, 2015, *Bedrock Geologic Map of the Hackensack Quadrangle, Passaic and Bergen Counties, New Jersey.* [map]. 1:24,000. U.S. NJ Department of Environmental Protection, Water Resources Management, NJGWS.

New Jersey Geological Survey, 2006, *Bedrock Geologic Map of the Paterson Quadrangle, Passaic, Essex, and Bergen Counties, New Jersey.* [map]. 1:24,000. U.S. NJ Department of Environmental Protection, Land Use Management, NJGS.

New Jersey Geological Survey, 2004, *Historic Fill of the Hackensack Quadrangle.* [map]. Photorevised 1970. 1:24,000. NJ Department of Environmental Protection, Land Use Management, NJGS.

New Jersey Geological Survey, 2004, *Historic Fill of the Paterson Quadrangle.* [map]. Photorevised 1981. 1:24,000. NJ Department of Environmental Protection, Land Use Management, NJGS.

New Jersey Geological Survey, 1994, *Surficial Geology of the Hackensack Quadrangle, Bergen and Passaic Counties, New Jersey.* [map]. Photorevised 1970. 1:24,000. NJ Department of Environmental Protection and Energy, Division of Science and Research, NJGS.

New Jersey Geological Survey, 2003, *Surficial Geology of the Paterson Quadrangle, Passaic, Bergen, and Essex Counties, New Jersey.* [map]. Photorevised 1970. 1:24,000. NJ Department of Environmental Protection, NJGS.

Olsen, Paul E., Dennis V. Kent, and Jessica H. Whiteside, 2004, The Newark Basin, The Central Atlantic Magmatic Province, and the Triassic-Jurassic Boundary: A Field Trip, Run on May 23, 2004, in Conjunction with the 8th Annual DOSECC Workshop on Continental Scientific Drilling.

Schlische, Roy W., 1992, Structural and stratigraphic development of the Newark extensional basin, eastern North America; Evidence for the growth of the basin and its bounding structures: Geological Society of American Bulletin, v. 104, p. 1246-1263.

Soil analysis

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Java Newhall Simulation Model (jNSM): A Traditional Soil Climate Simulation Model. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053559. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. jNSM Background. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053558. Accessed [03/17/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Soils. Description of SSURGO Database. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627. Accessed [03/14/16].

U.S. Department of Agriculture, Natural Resources Conservation Service. Web Soil Survey. Available online at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. Accessed [03/14/16].

Surface water quality data

New Jersey Harbor Dischargers Group. 2003-2006 Water Quality Monitoring NY/NJ Harbor. Passaic River Lower (Saddle River to Dundee Dam) Watershed. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

New Jersey Passaic Valley Sewerage Commission. New Jersey Harbor Dischargers Group. Ambient Water Quality Monitoring Program. Available online at http://www.nj.gov/pvsc/what/njhdg/. Accessed [03/17/16].

Groundwater quality data

New Jersey Department of Environmental Protection, Bureau of GIS. NJDEP Digital Data Downloads in ArcGIS Shape file format. Groundwater Contamination Areas (CEA). Available online at http://www.state.nj.us/dep/gis/stateshp.html. Accessed [03/15/16].

New Jersey Department of Environmental Protection, Division of Water Monitoring and Standards, Bureau of Environmental Analysis, Restoration, and Standards. Ground Water Quality Standards. Available online at http://www.nj.gov/dep/wms/bears/gwqs.htm. Accessed [03/15/16].

New Jersey Department of Environmental Protection. Open Public Records Act. Available online through DEP dataminer at http://datamine2.state.nj.us/dep/DEP_OPRA/. Accessed [03/15/16].

Topographic maps

2014, U.S. Geological Survey. *Hackensack Quadrangle, New Jersey* [map]. Photorevised 2013. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1965, U.S. Geological Survey. *Hackensack Quadrangle, New Jersey* [map]. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1934, U.S. Geological Survey. *Hackensack Quadrangle, New Jersey* [map]. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1900, U.S. Geological Survey. *Passaic Quadrangle, New Jersey-New York* [map]. 1:125,000. 30 Minute Series. USGS.

2014, U.S. Geological Survey. *Paterson Quadrangle, New Jersey* [map]. Photorevised 2013. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1963, U.S. Geological Survey. *Paterson Quadrangle, New Jersey* [map]. 1:24,000. 7.5 Minute Series. U.S. Department of the Interior, USGS.

1938, U.S. Geological Survey. *Paterson Quadrangle, New Jersey* [map]. 1:31,680. 7.5 Minute Series. U.S. Department of the Interior, USGS.

GIS data

New Jersey Bedrock Geology Layer – U.S. Geological Survey
http://mrdata.usgs.gov/geology/state/state.php?state=NJ

New Jersey Historic Fill Layer – NJDEP Historic Fill for New Jersey as of February 2009
http://www.state.nj.us/dep/njgs/geodata/dgs04-7.htm

New Jersey Surficial Geology Layer – NJDEP / NJ Geological and Water Survey (NJGWS) Surficial Geology of New Jersey (Scale 1:100,000) Updated 10-03-13
http://www.state.nj.us/dep/njgs/geodata/dgs07-2.htm

NJ Orthophotos – New Jersey Geographic Information Network Web Map Service 2015
https://njgin.state.nj.us/NJ_NJGINExplorer/jviewer.jsp?pg=wms_instruct
USGS Earth Resources Observation Systems (EROS) 2014
https://lta.cr.usgs.gov/high_res_ortho

Watershed information – USDA NRCS Watershed Boundary Dataset (WDB) February 2016
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/

Wetlands information – U.S. Fish and Wildlife Service, National Wetlands Inventory, 2010
http://www.fws.gov/wetlands/

XII-b. Relevant boring logs

902_CliftonDundeeCanal_Borings_GeologicLogs.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201102372_MW-1.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201102373_MW-1.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201211288_MW-1D.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201211290_MW-9.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201218416_B3-110.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201218952_B3-109.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201317376_MW-11.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201413718_MW-5A.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201413719_MW-6.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201413720_MW-7.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201413723_MW-6D.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201413724_MW-7D.pdf
NJDEP_CliftonDundeeCanal_GreenAcresPurchase_IslandPreserve_E201506284_MW-1.pdf

XII-c. Soil reports

USDA-NRCS_DundeeCanal_Urbanland_Riverhead.pdf
USDA_NRCS_PassaicCounty_SoilSurvey_2007.pdf

XII-d. Surface water quality data

NJHDG_CliftonDundeeCanal_SurfaceWaterQuality_data.pdf

Attachment C-9
HRE
Meadowlark Marsh H&H Analysis

Hudson Raritan Estuary Ecosystem Restoration Feasibility Study
Draft Interim Letter Report
Hydrologic & Hydraulic (H&H) Analysis for Meadowlark Marsh
11 April 2016

Following the field investigations and initial development of three conceptual restoration alternatives in Tasks 3c – Baseline data collection for Ecologic Evaluation for Planned Wetlands (EPW) and Stream Visual Assessment Protocol (SVAP) and in conjunction with Task 3d - Development and Assessment of Alternatives, a Hydrologic & Hydraulic (H&H) Analysis was conducted to improve design accuracy and to reduce risk in the conceptual design process. Further in depth hydrologic and hydraulic analysis will need to be completed in the Preliminary Engineering Design phase (PED) of the Tentatively Selected Plan (TSP). This summary provides the H&H Analysis and the results for Meadowlark Marsh.

A. Site Overview

The approximately 85-acre Meadowlark Marsh is located within the Hackensack Meadowlands in Ridgefield, Bergen County, New Jersey. It is fed by the Hackensack River through Bellman's Creek and the Vince Lombardi channel (tributaries to the Hackensack River) and is confined on the west and east by the New Jersey Turnpike – Eastern Spur (Turnpike) and Westside Avenue/New Jersey Transit Rail Line, respectively.

Meadowlark Marsh is owned by the New Jersey Meadowlands Commission (now known as the New Jersey Sports and Exposition Authority). The site is mostly undeveloped and dominated by an invasive common reed (*Phragmites australis*) monoculture (**Figure 1**), limiting ecological value. The site includes powerline and pipeline right-of-ways and associated access roads. Approximately ten feet of herbicide overspray from the utility right-of-way into the site was observed during the 2015 EPW field assessment. A mowed grass upland access road (over a Williams' natural gas pipeline) divides the northern third of the site. A small, approximately 3 acre, forested upland area is adjacent to the Turnpike within the southern third of the site. This upland forested area is found above historic fill material and is dominated by black cherry (*Prunus serotina*), black locust (*Robinia pseudoacacia*) and gray birch (*Betula populifolia*).

Site visits were conducted as part of the EPW to collect environmental characteristics, such as dominant plant species and marsh types. Topographic surveys of the site were performed by US Army Corps of Engineers (USACE) in 2008 for site topography within the marsh and existing marsh channels, and a survey of additional cross sections in 2015 to collect data of Bellman's Creek, the Vince Lombardi channel (west of the Turnpike) and key H&H culvert features identified within the marsh during the EPW field assessment (**Figure 2**).



Figure 1: Invasive Common reed (*Phragmites australis*) at Meadowlark Marsh

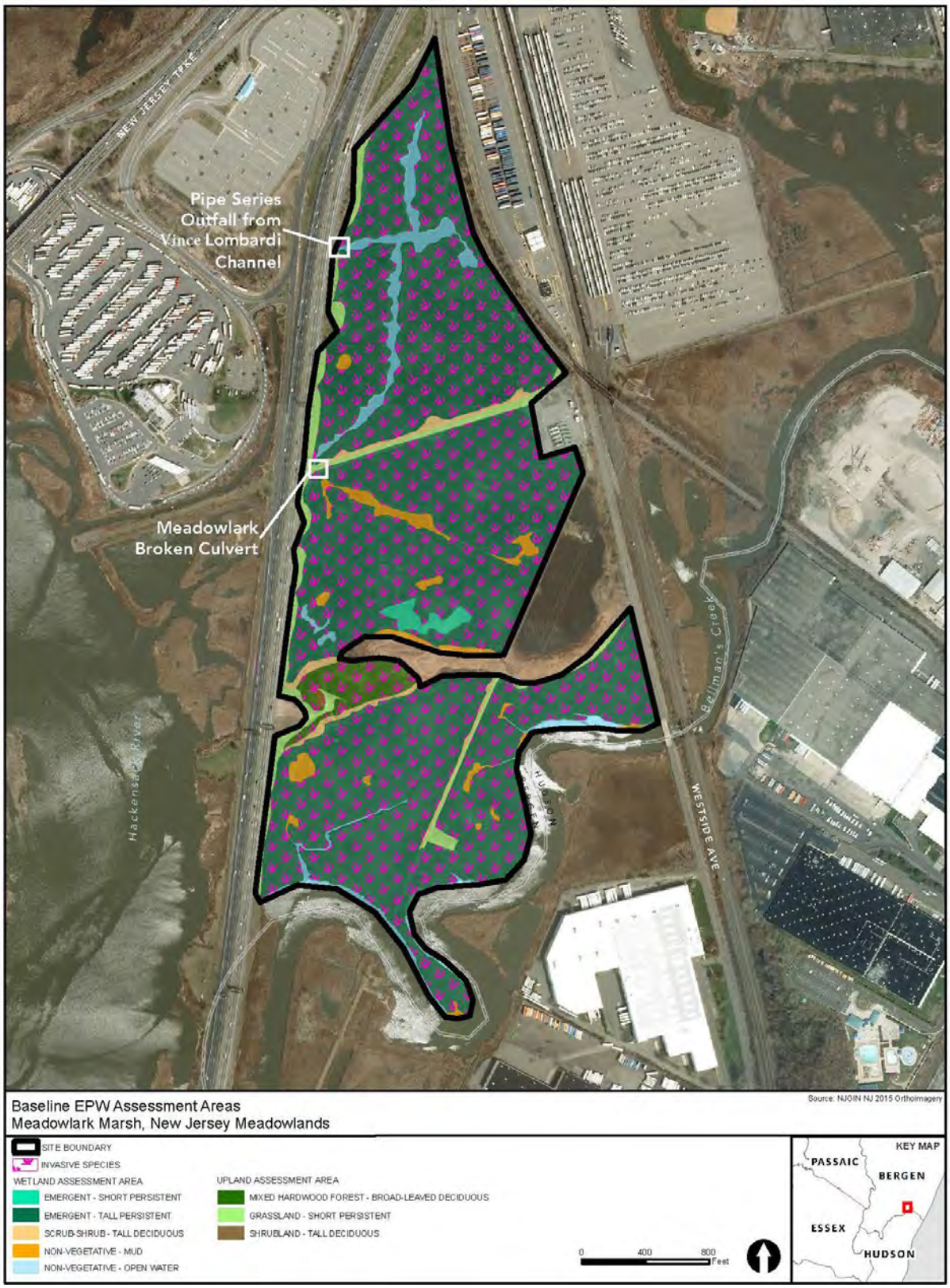


Figure 2: EPW results identifying key hydraulic culverts

B. Analysis

1. Methodology

Using the baseline studies performed with the EPW, by the USACE, and the H&H water surface elevation data collected by USACE in 2008, a two-dimensional hydraulic/hydrodynamic model using Surface-water Modeling Systems (SMS) Coastal Modeling System (CMS) was established to assess the existing site conditions and three conceptual designs to restore H&H ecological function to the Meadowlark Marsh site. The CMS model was used in place of the RMA2 platform as CMS uses a finite element size and pattern within the two-dimensional grid, which results in a more stable simulation. RMA2 does not use a finite element size, which can significantly decrease the stability of the two-dimensional model and cause it to fail. In addition, compared to RMA2, CMS provides a better platform for the modeling of culvert structures, several of which are present at Meadowlark Marsh. The platform switch was presented to the USACE after review of their RMA2 model of the Hackensack Meadowlands. In the provided USACE RMA2 model, only one element represented the entire Meadowlark Marsh site. The significant alterations required to modify this would most likely cause the model to fail due to the large size of the model. Therefore, the need for a new Meadowlark Marsh model was identified instead of using the RMA2 model provided.

2. Data Sources

A number of data sources were reviewed to provide an understanding of the existing and proposed site conditions. These included, but were not limited to, the following:

- On-site topographic and cross-section survey conducted by Rogers Surveying, P.L.L.C. in 2008;
- Cross-section and culvert survey conducted by Johnson, Mirmiran & Thompson in December 2015;
- Water Surface Elevation data collected by the USACE in December 2008 for the Hackensack River and Meadowlark Marsh Site;
- NJDEP NJGIN 2012 Orthoimagery;
- FEMA Flood Insurance Study (Bergen County);
- Topographic data in the North American Vertical Datum of 1988 (NAVD88 datum);
- Biobenchmark data collected by Louis Berger in 2009;
- Site inundation periods, biobenchmark data, and planting elevations for nearby wetland restoration sites (within 1 mile) previously designed and monitored by Louis Berger within the last 5 years (2011-2016);
- *Design Guidelines for Tidal Channels in Coastal Wetlands* (Philip Williams & Associates, January 1995); and
- *Hydraulic geometry: a geomorphic design tool for tidal marsh channel evolution in wetland restoration projects* (Williams et. al. 2002).

3. H&H Model Setup

The SMS CMS-Flow version 11.2.8 model (a two-dimensional hydraulic/hydrodynamic model used in the simulation of currents, water level, sediment transport, and morphology in coastal areas) was used to simulate tidal flow in and out of the Meadowlark Marsh site for existing and proposed conditions. The CMS-Flow model is a product of the Coastal Inlets Research Program (CIRP) at the USACE Research and Development Center (ERDC) in Vicksburg, Mississippi (Militello et al., 2004). CMS-Flow is a finite-volume, depth-averaged model that calculates combined circulation (current and water surface elevation), waves, flow velocity, sediment transport, and geomorphology change at tidal areas through the SMS interface.

The following steps were performed to establish existing conditions and assess the conceptual design.

a. Cartesian Grid Establishment

Scatter point data collected through the topographic and bathymetric survey were used to establish a Cartesian grid module to simulate water surface elevation data. Cross-sectional data was interpolated within Bellman's Creek and the Vince Lombardi channel between where cross-sections were collected in order to provide elevation data where gaps occurred within the channels. All elevations in NAVD88 were converted to a depth in meters based on elevation 0 feet NAVD88 as required by the CMS-Flow model.

A telescoping grid was utilized within the site for all alternatives in order to provide more detailed elevation data within open water and channel areas (**Figure 3**). Open water areas typically vary in elevation within a smaller surface area, which requires a smaller grid cell size (maximum of 1X1 meter dimension for interior channels, 2X2 meter dimension in Bellman's Creek) to account for the changes. Open marsh areas and upland areas show more unified elevations over larger surface areas, which allow for larger grid cells (7.5X7.5 meter dimensions) and aid in the reduction of the computational time to simulate a time period.

b. CMS-Flow Boundary Condition

Water surface elevation data collected by the USACE in 2008 was utilized as the forcing boundary condition for simulation of flow. The boundary condition was set along the western grid in two locations, the area of the Hackensack River connecting to Bellman's Creek and the area of the mouth of the Vince Lombardi channel. **Figure 4** depicts the locations of the levelogger water surface elevation data provided by the USACE, as well as the selected boundary conditions of the models.

Levelogger data collected at 15-minute intervals from the Hackensack River in 2008 a mile downstream of the site was utilized. The water surface elevation from the Hackensack River gage provided by the USACE varies slightly compared to gage data along Bellman's Creek and within the site (slightly larger peak elevations downstream compared to high water level peaks in Bellman's Creek). The peak elevation differences are expected (due to travel time and change in local topography compared to downstream); however, although not entirely representative of the site water levels, the downstream data was used in the model as it provides the necessary full tidal cycles to simulate high and low tide peaks. The Hackensack River gage data will suffice in simulation of the tidal flow through Bellman's Creek until representative data is collected during the PED. All water surface elevations were converted to SI units to comply with CMS-Flow requirements.

c. Manning's Roughness Coefficient for Cartesian Grid

Roughness coefficients are used within the CMS-flow Cartesian grid to define various vegetation and land types with relationship to the ability to convey flows. Two roughness values were used for all alternatives, as shown in **Table 1**, with a third roughness coefficient used in Alternative B for the bottom roughness of the proposed culvert replacement. Values were selected from typical Manning's Roughness Coefficients for clean, winding channels (open water), medium to dense brush in the summer (marsh area for simulation period), and a concrete culvert listed in the Federal Highway Administration publication FHWA-NHI-08-090, June 2008.

Table 1: Manning's Roughness Coefficient

Land Type	Roughness Coefficient
Open Water	0.04
Marsh Vegetation	0.1
Concrete Culvert Bottom*	0.013

*: Used in **Alternative B** only

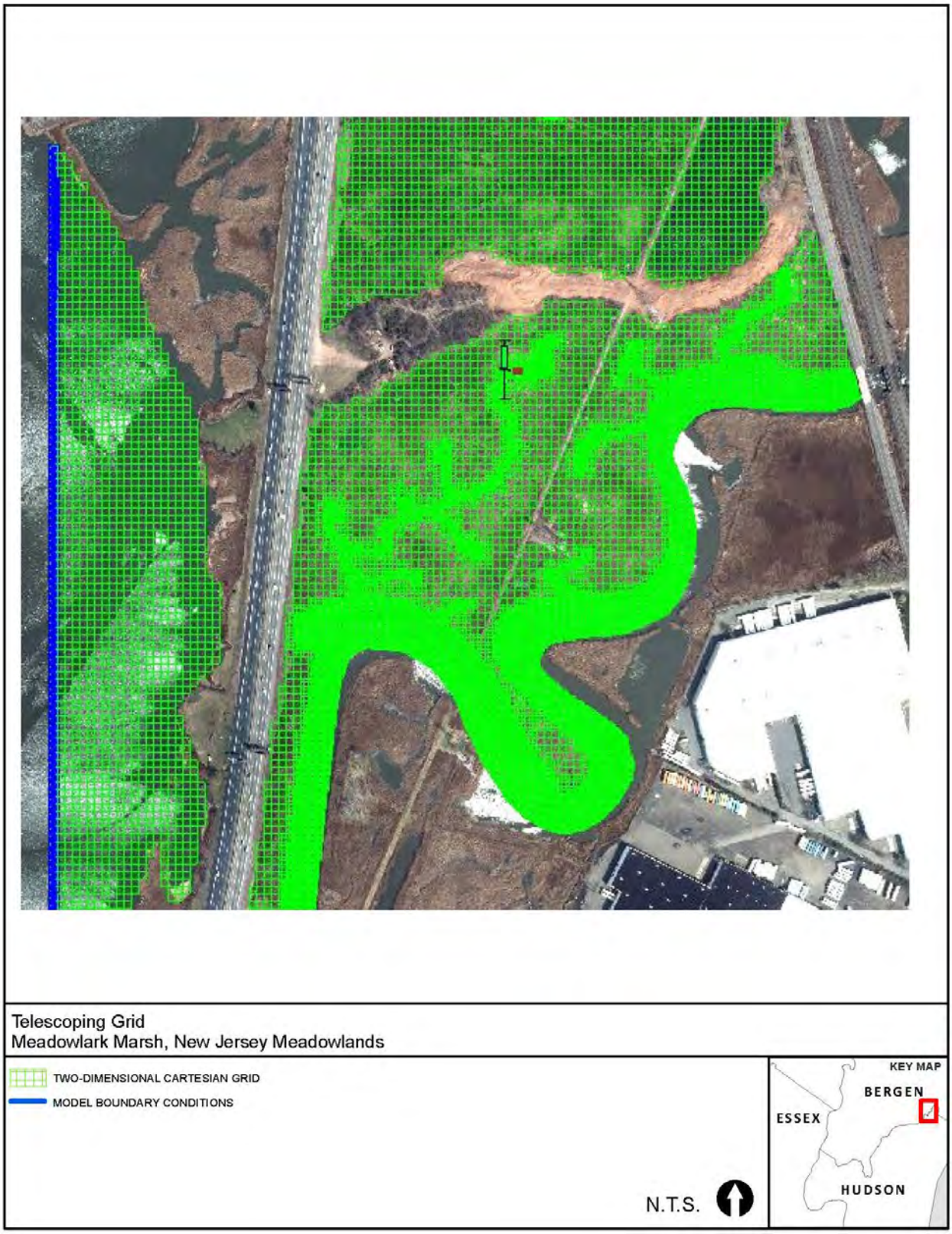


Figure 3: Telescoping grid example: existing conditions model

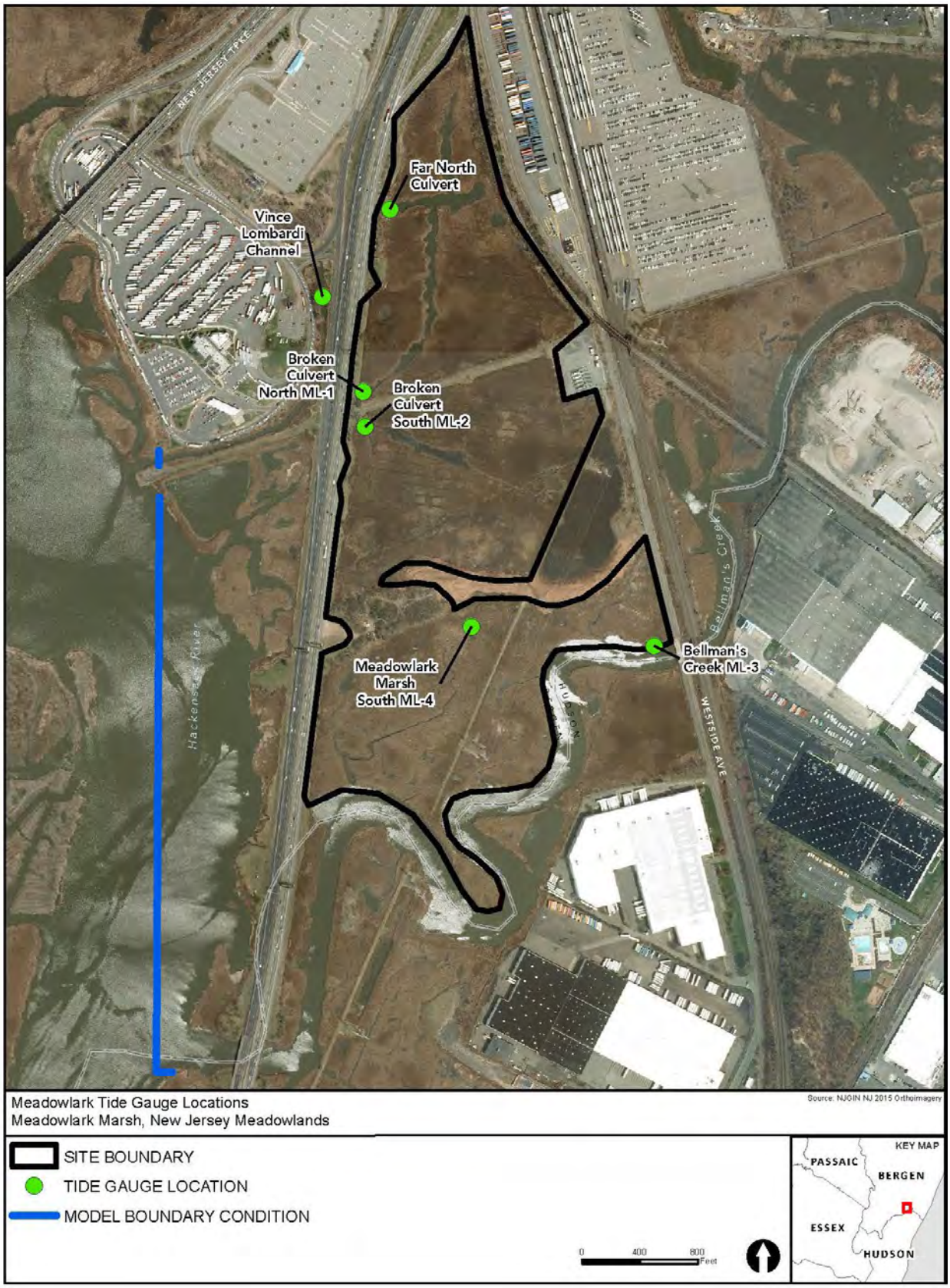


Figure 4: Levelogger and boundary condition locations

d. Simulation Period

The simulation period for all three models was for a 30-day period (one month) between the months of September and October 2008. Start dates varied based on peak tides (existing conditions and Alternative C began on September 13, 2008 with a peak tide at 2.964 Feet NAVD88, Alternatives A and B began on September 19, 2008 with a peak tide of 3.388 Feet NAVD88), but ran for a duration of 30 days to verify a full tidal lunar period under normal conditions. The modeling of Alternatives A and B began after the completion of modeling the existing conditions and Alternative C, and were modeled at a point in time with a higher tide to insure the start of the more detailed Alternative simulations. The first 12 hours of this simulation were omitted in the evaluation of the results as the model takes a designated amount of time to ramp up into a simulation. This "ramping period" is specified in the model parameters and can be adjusted based on the results, if needed, to allow for more or less time to calibrate the simulation process.

These months were selected for the simulation time frame as they contained some of the highest water surface elevation data at the beginning of the cycle period for the data collected. By using this time period, the model has a greater success rate in running as it considers most of the site as wet or underwater during its ramping period.

e. Advanced Model Parameters

Advanced model parameters are specific to the designated site simulation and conceptual design. The following explains the considerations and assumptions specific to each alternative, as well as advanced cards (advanced model features and options that can be coded into the program that have not been incorporated into the basic features of the SMS interface) used within the CMS-Flow program, for each site. The assumptions listed here and in the Proposed H&H Analysis will also be identified within the Project's Risk Register. Figures of the alternatives depicting the layout used in the modeling can be found in Appendix A.

i. Existing Conditions and Alternative C

In order to generate flows through the existing pipes (inlet and outlet flow of pipe series underneath the Turnpike from the Vince Lombardi channel to the northern marsh area, and the broken culvert series underneath the Transco access road between the northern and central marsh sections), an advanced card of the CMS-Flow module was used to code the culvert characteristics and parameters to convey flow. This code, displayed below in **Figure 5**, follows the procedures specified by Li et al. in the *Implementation of Structures in the CMS: Part III, Culvert* (August 2013). The following calculations were made based on assumptions:

- Head loss values arbitrarily selected and modeled based on culvert types. These will be modified to calibrate the pipe flow;
- Pipe lengths for the series of pipes from the Vince Lombardi Channel under the Turnpike were estimated based on angles of pipe placement surveyed;
- Darcy friction factors were determined based on pipe characteristics surveyed and assumed lengths of the pipe series when they were not identified in the topographic survey collected; and

- All pipe characteristics were converted to SI units to comply with CMS-Flow requirements.

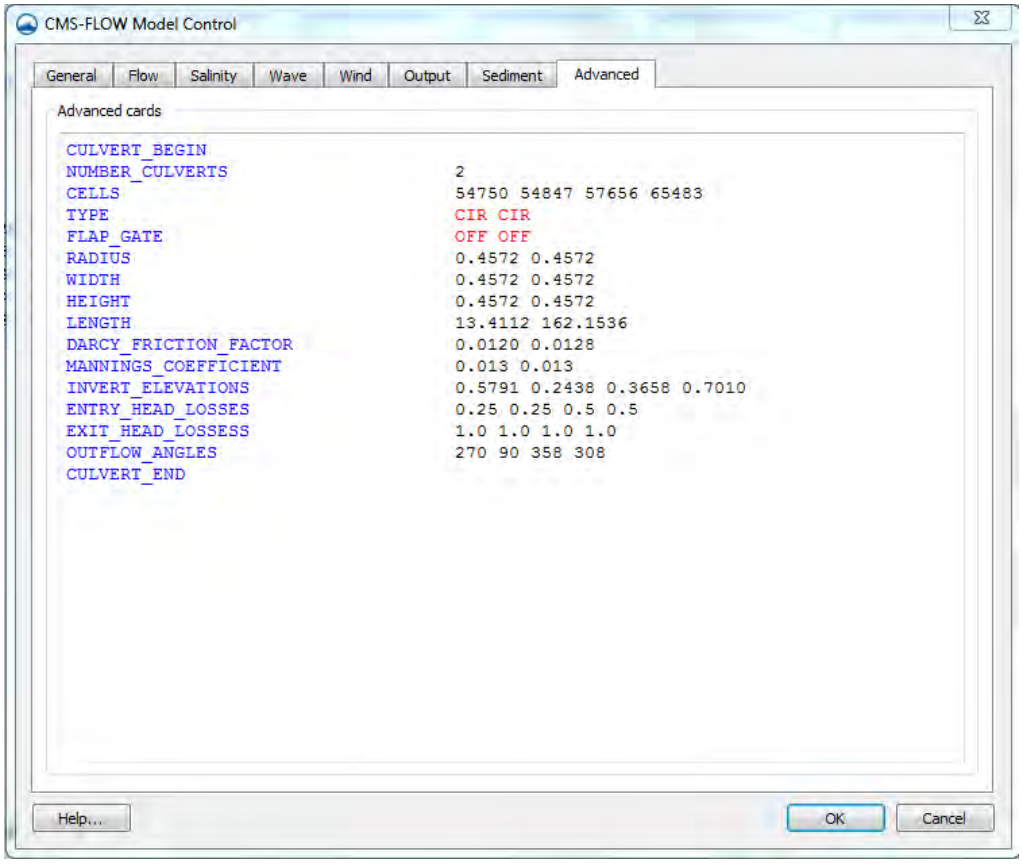


Figure 5: Existing conditions and alternative C CMS-Flow advanced card for culvert coding

Alternative C proposes clearing of the existing channels within the interior marsh areas and replacing the existing culvert under the Transco access road. It is assumed that a single box culvert spanning 12 feet in width with an elevation bottom placed at the existing channel bed (approximately -2.0 feet NAVD88) will allow for the conveyance of the required tidal cycle between the northern and central marsh areas. It is assumed that, under normal tidal conditions, the box culvert will have a free board allowance above the water to allow free flow within the culvert.

Alternative C was not modeled, as there is insufficient data to validate the correct flow into the northern channel under the existing conditions (needed to correct and validate the design for a replacement culvert). Details for the inlet and outlet of the pipe series underneath the Turnpike were collected, but information on how the pipe series runs under the ground is not known and must be assumed. Lengths and directions of the pipes in the series under the Turnpike must be identified, as well as the type and size of additional pipes or basins within the series that are not identified in the 2015 topographic survey due to being buried beneath the Turnpike. This was identified by the 2015 topographic survey as the inlet and outlet culverts are of different size, type, and identified by placement angles on the site that would not connect the inlet and outlet through two pipes alone. Once this information is obtained, the existing conditions

model can be calibrated and Alternative C will be an iteration of the existing conditions model with a new culvert coded under the Transco access road.

ii. Alternative B

Alternative B proposes a new inlet and channel originating from Bellman's Creek, and a culvert replacement under the Transco access road. It is assumed that the culvert replacement will allow for a twin concrete box culvert, fully enclosed and allowing a depth of the culvert at the depth of channel bottom (elevation -4.5 feet NAVD88). It is assumed that, under normal tidal conditions, the box culvert will have a free board allowance above the water. Box culvert widths are taken as 12 feet in width. It is assumed that the Transco pipeline underneath the access road is at a depth below elevation -4.5 feet NAVD88 in order to avoid a pipeline sag requirement (lowering of the Transco pipeline in the vicinity of the proposed culvert) to construct this culvert.

As the new tidal channel through the site will control the hydraulic capacity, as well as control the ebb flow and water surface elevations within the site, the advanced card for the pipe culverts was removed to reduce error possibility within the CMS-Flow model. It is also assumed for this alternative that the channel will not require a crossing structure (i.e. a bridge) to maintain access within the upland section of the site between the southern and central marsh portions.

iii. Alternative A

Similar to Alternative B, Alternative A proposes a new inlet channel through all three portions of the marsh. This alternative is a "best case" scenario, which will allow for a new open channel free of debris and structures inhibiting the hydraulic capacity of the site. Again, it is assumed the gas pipeline underneath the Transco access road is at a depth low enough not to require a sag of the gas pipeline in the vicinity of the proposed channel and will allow for a channel bottom elevation at -4.5 feet NAVD88.

Two crossings, one along the Transco pipeline access road and one along the upland portion of the site between the southern and central marsh areas, are assumed to be open span structures allowing free flow under normal tidal conditions. Again, the advanced card for the culvert pipe is removed to reduce error possibility in the model as the channel will dictate the hydraulic capacity of the site, not the existing culvert.

C. Results

The following briefly describes the results of each CMS-Flow modeled alternatives, as well as discusses the next measures required for the alternative to finalize the calibration and move into full site designs and permit applications.

1. Existing Conditions/Alternative C

As previously addressed, many assumptions were made for the pipe series for conveyance of tidal flow from the Vince Lombardi channel to the northern marsh. As not all characteristics of this pipe series are known, as well as having poor quality of site water surface elevation data to calibrate the outflow (and source of water to the northern and central marsh areas), the CMS-Flow model has been developed as a starting point to the existing site conditions and Alternative C models that will allow

for quick adjustments in the advanced card code and cartesian grid to finalize calibration of the hydraulic capacity for these two conditions. As Alternative C will still utilize the pipe series under the Turnpike from the Vince Lombardi Channel, a separate model will not be developed from the existing conditions for this alternative until calibration is finalized.

Under the existing conditions model, calibration of the boundary condition and grid within the southern marsh, Bellman's Creek, and Vince Lombardi Channel was performed. In all scenarios, an observation point (a node ordinate placed within the model that displays simulation results at the designated location) was located at a point in Bellman's Creek that was deep enough to capture the full tidal cycle and to compare the simulated water surface elevation with the observed boundary condition data (**Figure 6**).

The simulated water surface elevations were compared to the observed ones using a linear regression analysis (**Figure 7**). Recorded and simulated tidal cycles were also compared for the high and low peak tides (**Figure 8**).

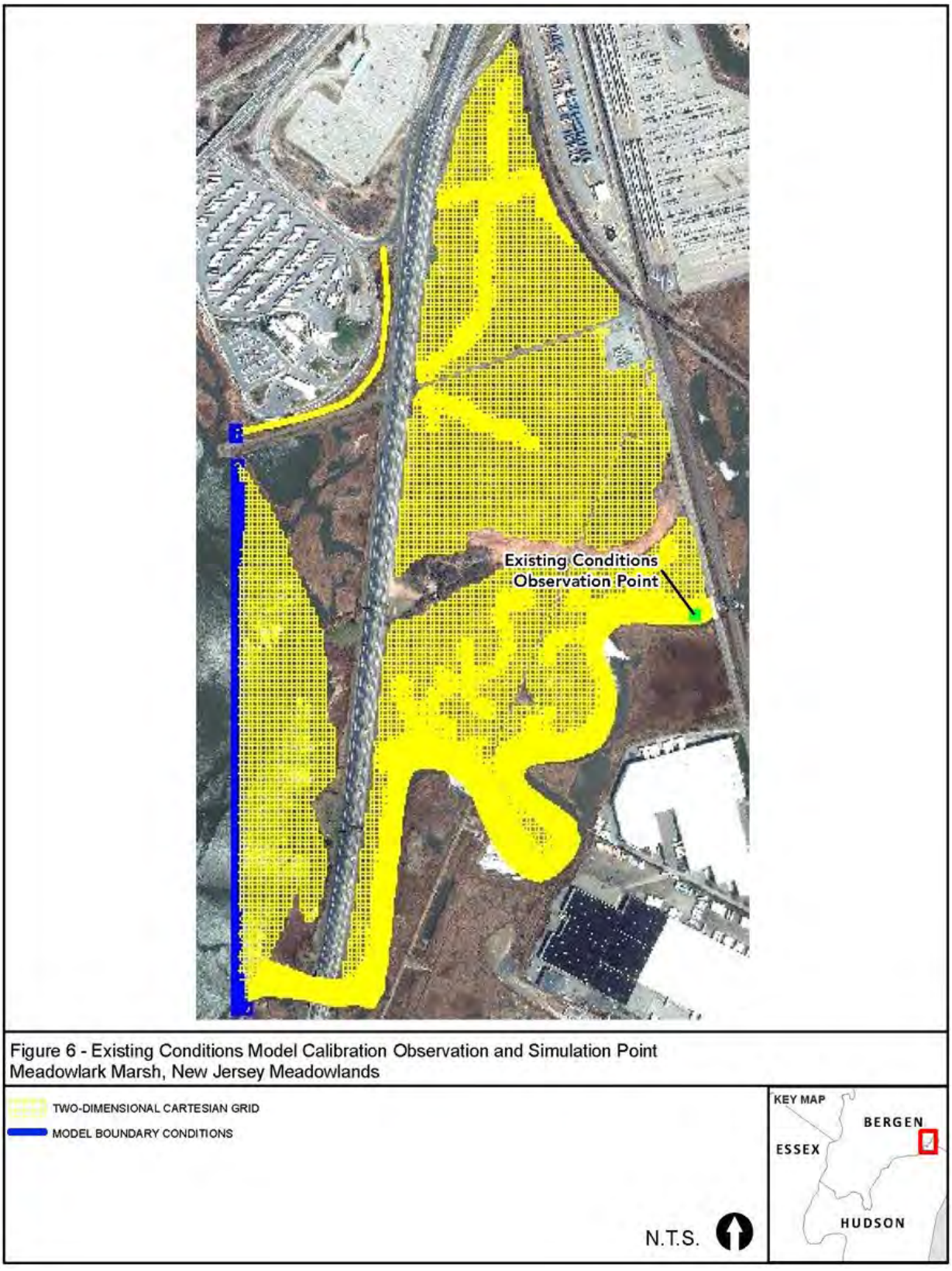


Figure 6 - Existing Conditions Model Calibration Observation and Simulation Point
Meadowlark Marsh, New Jersey Meadowlands

Figure 6: Existing condition model calibration, observation and simulation point

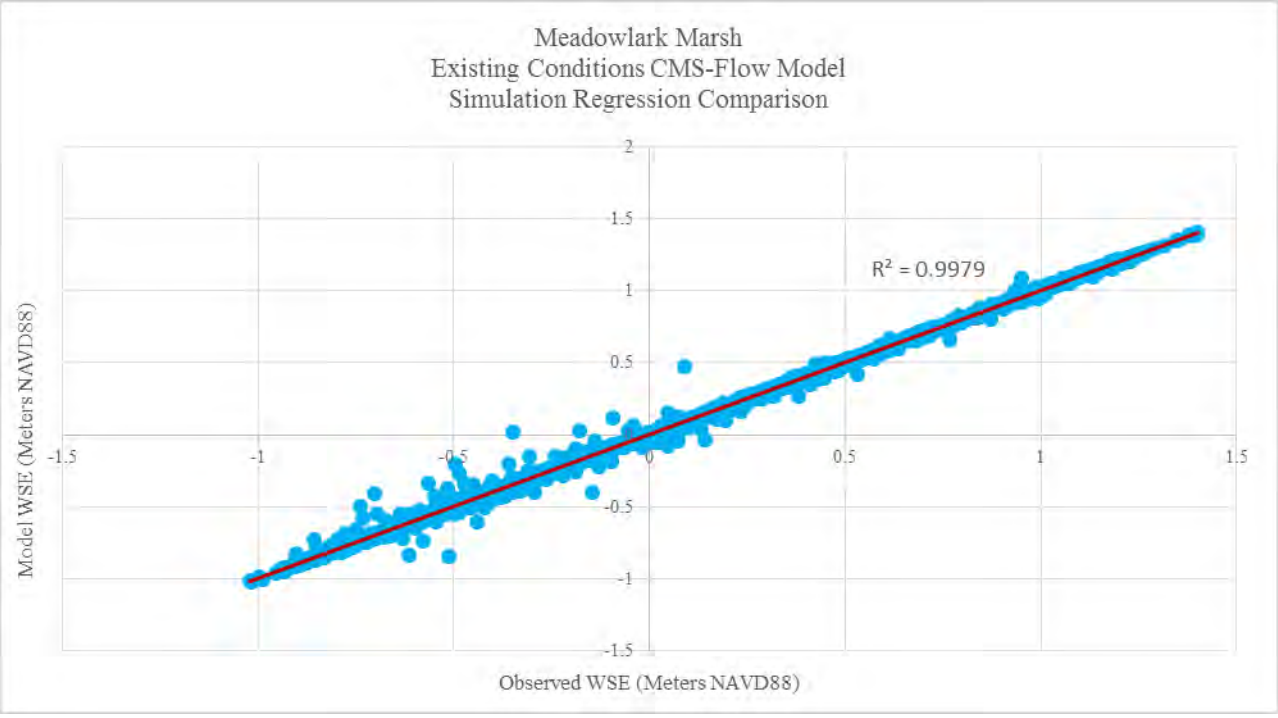


Figure 7: Linear regression comparison of existing conditions (observed vs. simulated)

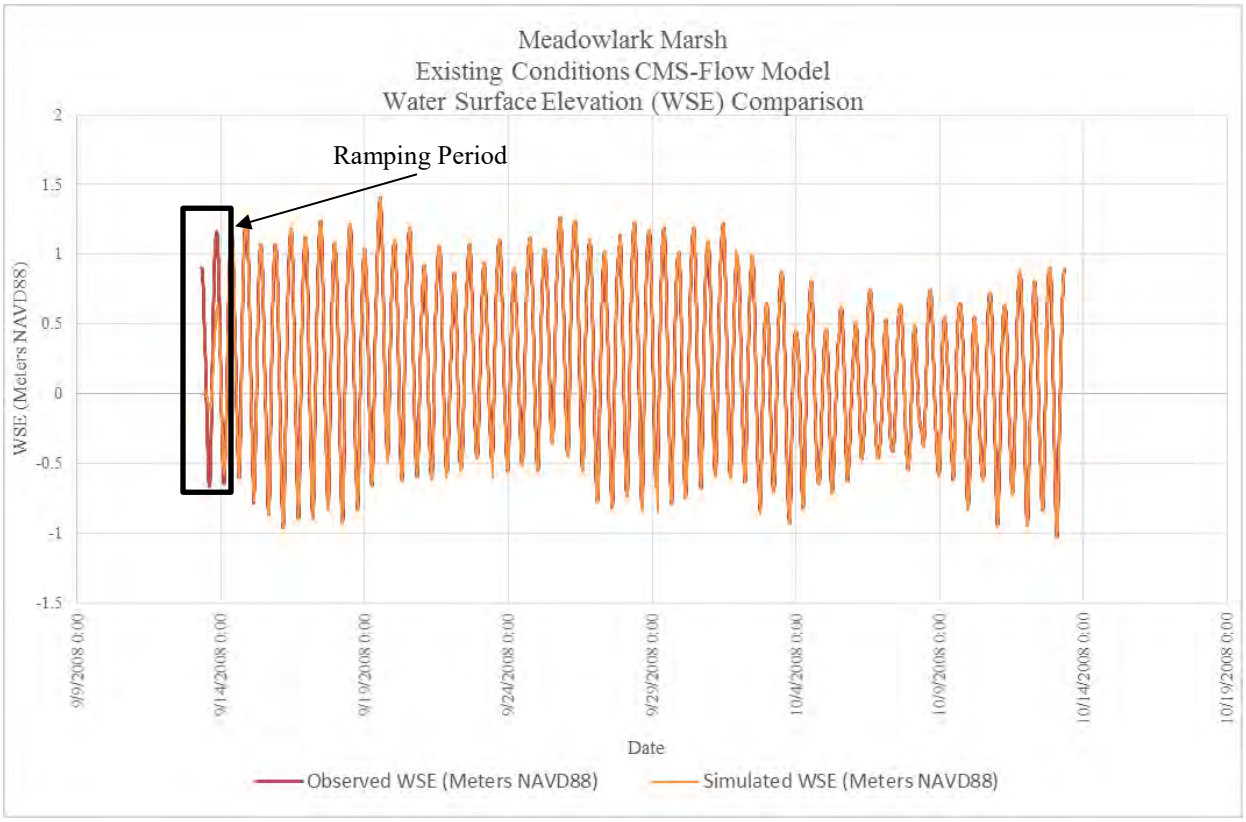


Figure 8: Exiting conditions water surface elevation peak flow comparisons (observed vs. simulated)

As demonstrated in figures 7 and 8, the model for the southern portion of the site, also including the Vince Lombardi channel and Hackensack River, are calibrated to simulate existing conditions hydraulic capacity within an error of 0.21%. **Figure 9** and **Figure 10** show the extent of tides at low and high tide, respectively, as simulated by the existing conditions model. As can be seen, the southern marsh shows inundation of the site parameters as needed for support of marsh vegetation, however the interior marsh areas show excessive ponding. The interior marsh water surface elevation simulation still requires further calibration due to a lack of data on the source of water conveyance into these areas, but should still show the lack of an inundation period upon calibration. Table 2 demonstrates the existing biobenchmarks for vegetation collected at the site and the surrounding sites. Table 3 represents the planting range for the targeted plant species.

Table 2 Biobenchmark data for selected sites in the Meadowlands District

	Spartina alterniflora lowest	*Spartina alterniflora* highest	*Phragmites australis* lowest	*Phragmites australis* dense (average)
Anderson Creek Marsh	-1.50	1.50	1.10	2.20
Lyndhurst Riverside Marsh	-0.07	1.61	0.77	2.32
Meadowlark Marsh	0.85	2.34	1.43	1.83
MRI – Phases 1 & 2	-0.65	2.67	0.79	2.54
MRI – Phase 3	-1.12	1.60	-0.21	2.54
Metromedia Tract	0.61	2.61	1.39	2.57
Secaucus High School	-0.11	1.13	1.78	2.67

Note: These elevations, in feet, are in North American Vertical Datum of 1988 (NAVD88).

Table 3 Planting range for Meadowlark Marsh

Low Marsh	High Marsh	Scrub Shrub
0.0	3.0	4.0
3.0	4.0	5.0

Note: These elevations, in feet, are in North American Vertical Datum of 1988 (NAVD88).

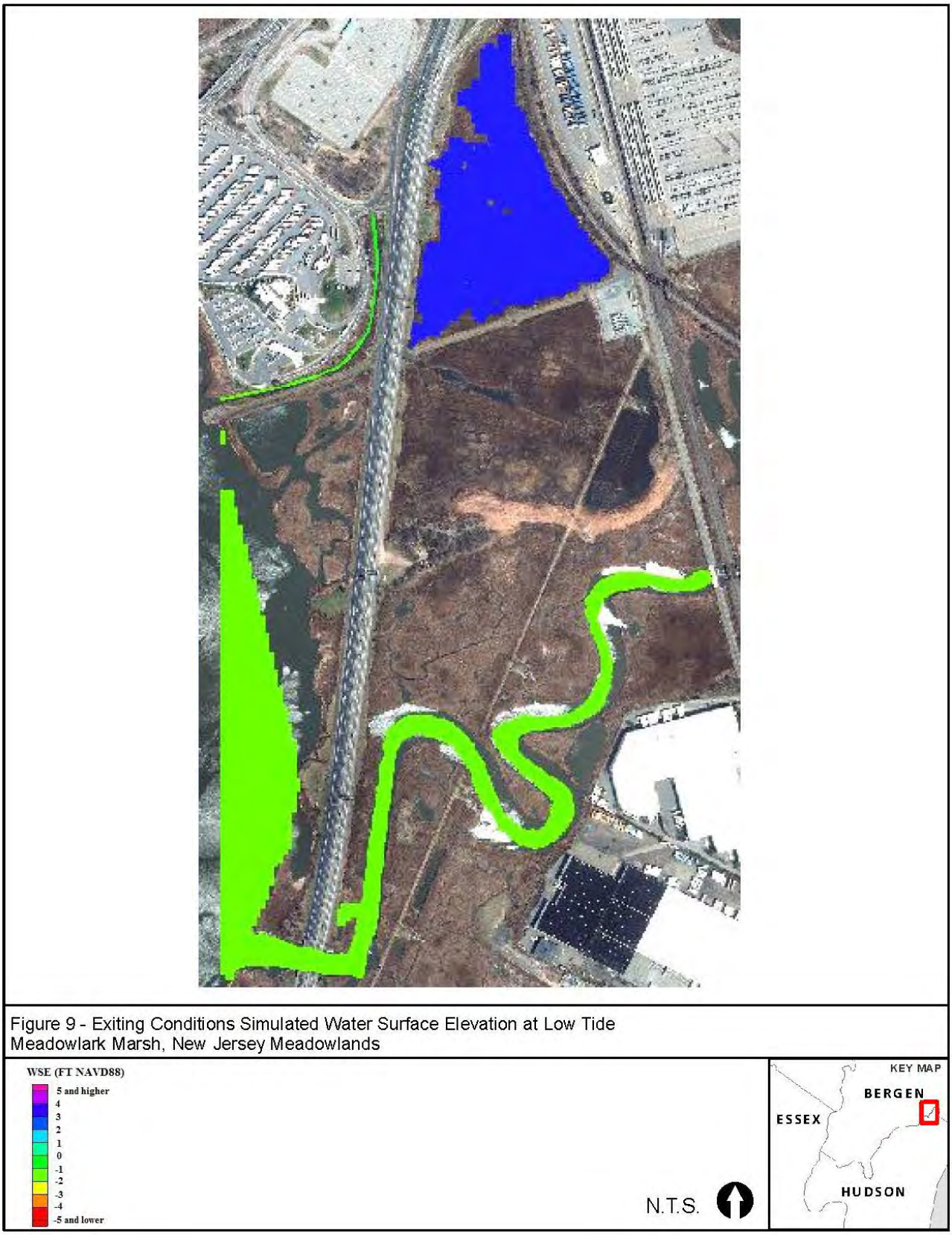


Figure 9. Existing conditions simulated water surface elevation at low tide

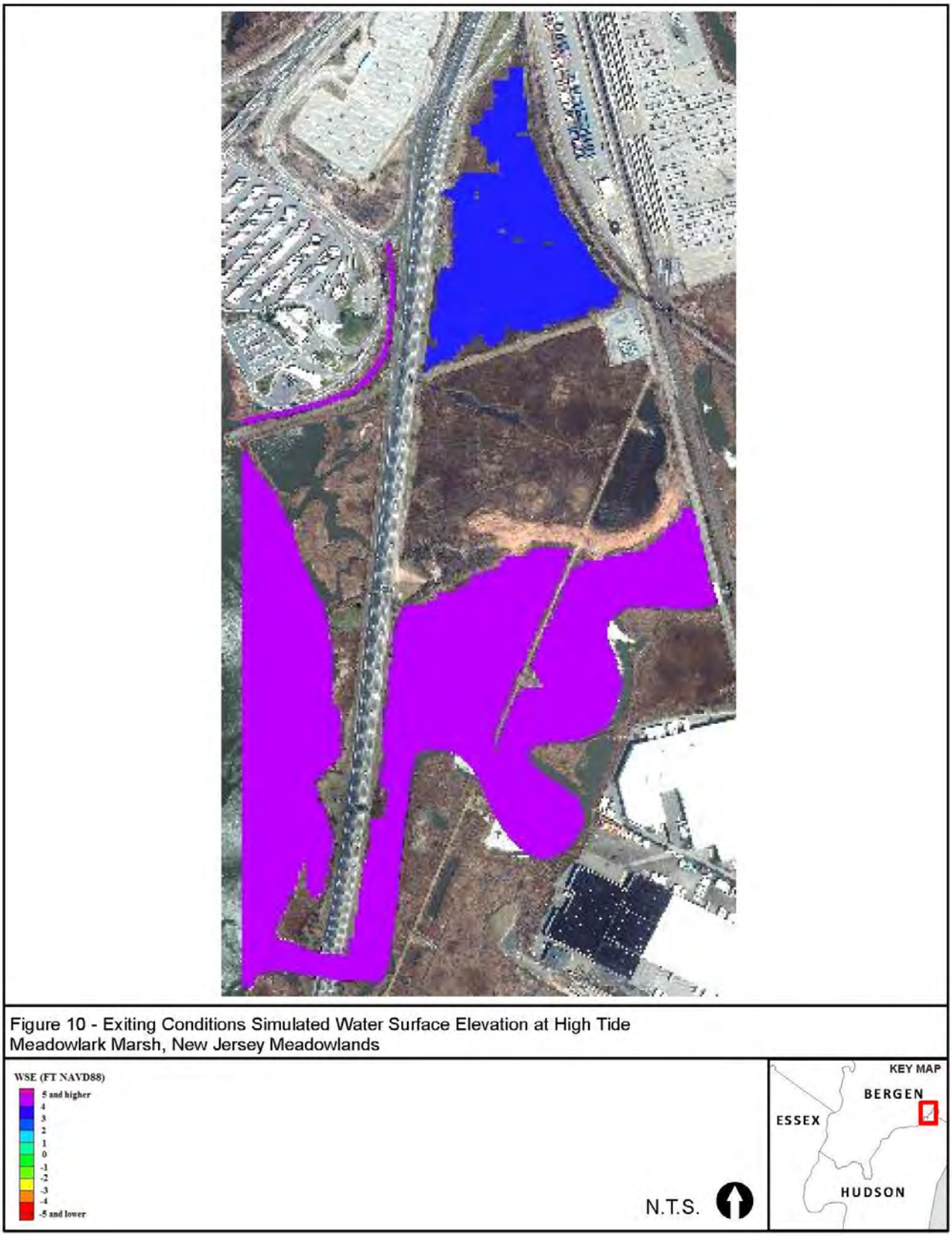


Figure 10. Existing conditions simulated water surface elevation at high tide

2. Alternative B

Similar to the Existing Conditions/Alternative C model, an observation point is placed within the proposed channel inlet (at the deepest portion of the channel and furthest point the water will reach within the channel) in order to compare the simulated water surface elevation to the observed/boundary condition water surface elevation (**Figure 11**).

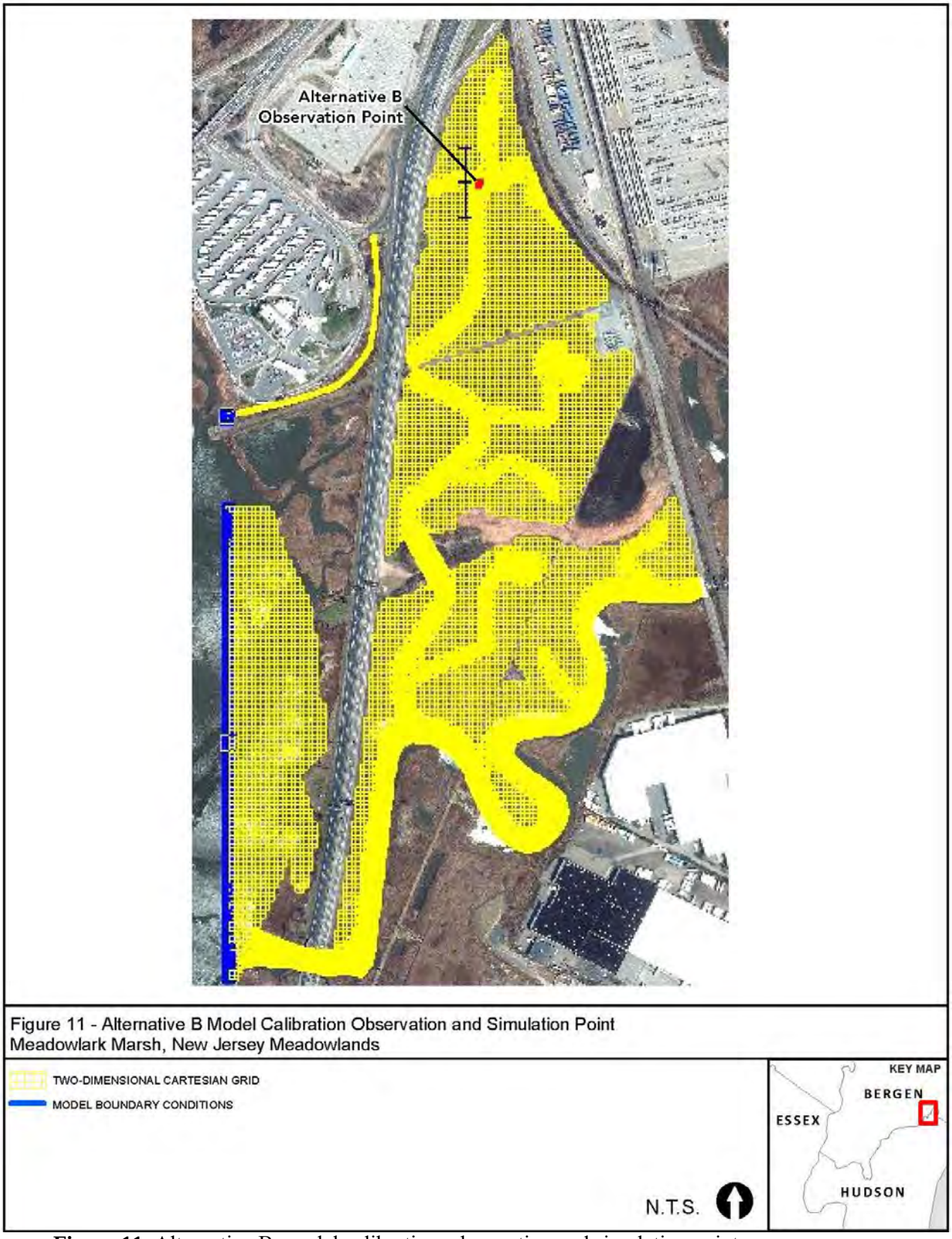


Figure 11. Alternative B, model calibration, observation and simulation point

Similarly to the Existing Conditions/Alternative C model, linear regression and peak tide comparisons were performed in order to determine the success of the proposed restoration designs for a full tidal cycle (**Figure 12** and **Figure 13**, respectively). This is specific to this site as the distance between the observation point and the boundary condition is not long enough to create a significant time lag in peak flows.

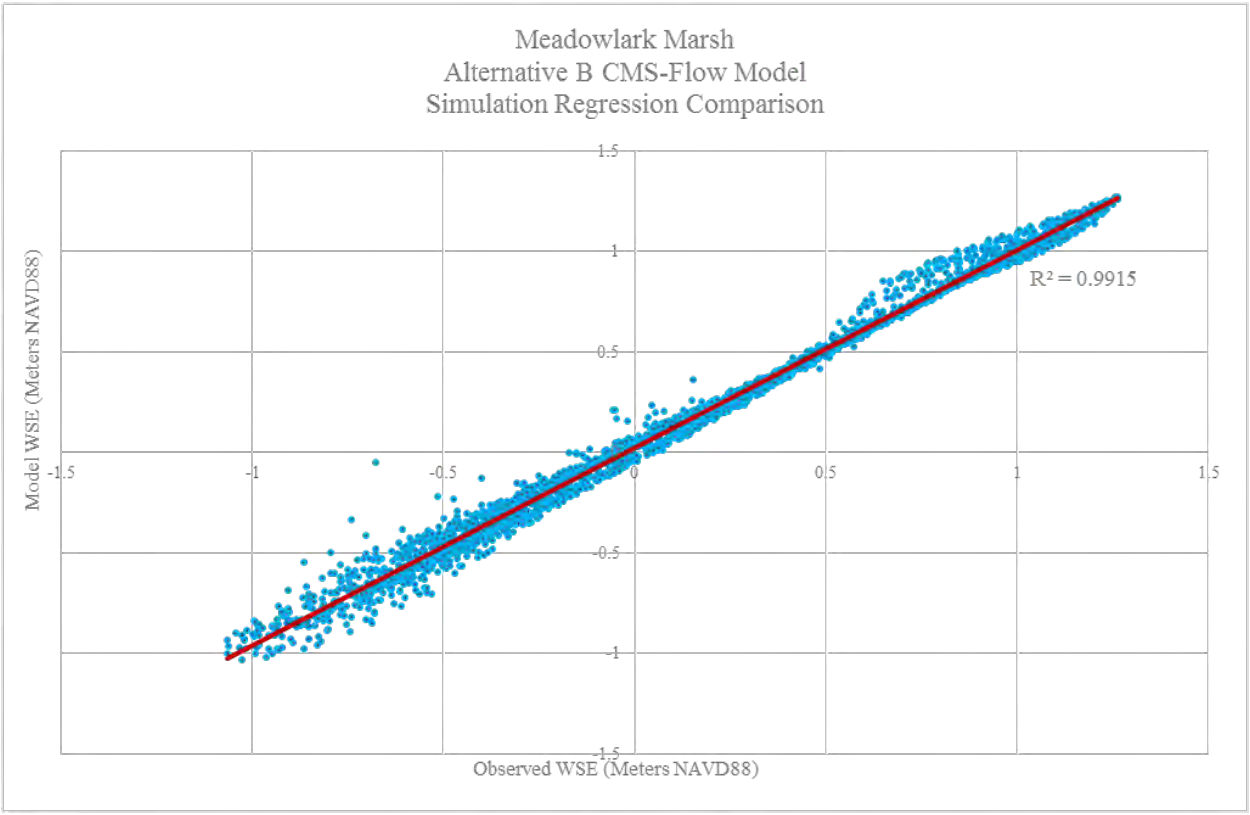


Figure 12: Linear regression comparison of alternative B (observed vs. simulated)

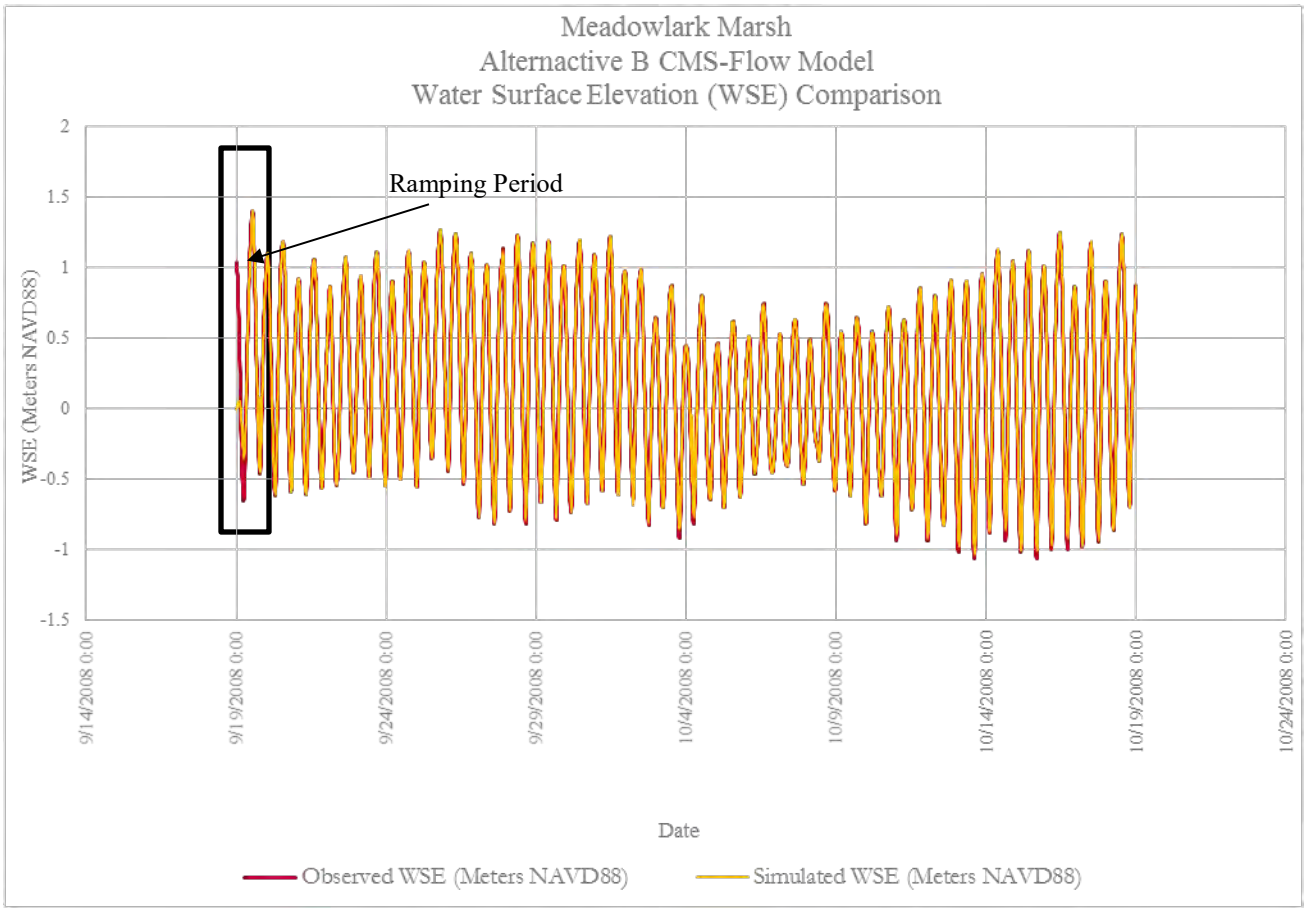


Figure 13: Alternative B water surface elevation peak flow comparisons (observed vs. simulated)

As can be seen with the linear regression comparison, the simulation of proposed Alternative B restores the tidal inundation period and hydraulic/hydrodynamic capacity of the interior marsh areas (with an error of 0.85%). The restoration of the tidal inundation period and hydraulic/hydrodynamic capacity to the interior marsh will provide a hydrologic cycle that will allow for vegetation planting and the marsh restoration. **Figure 14** and **Figure 15** depict the simulated and restored tidal cycle for Alternative B at low and high tides, respectively.

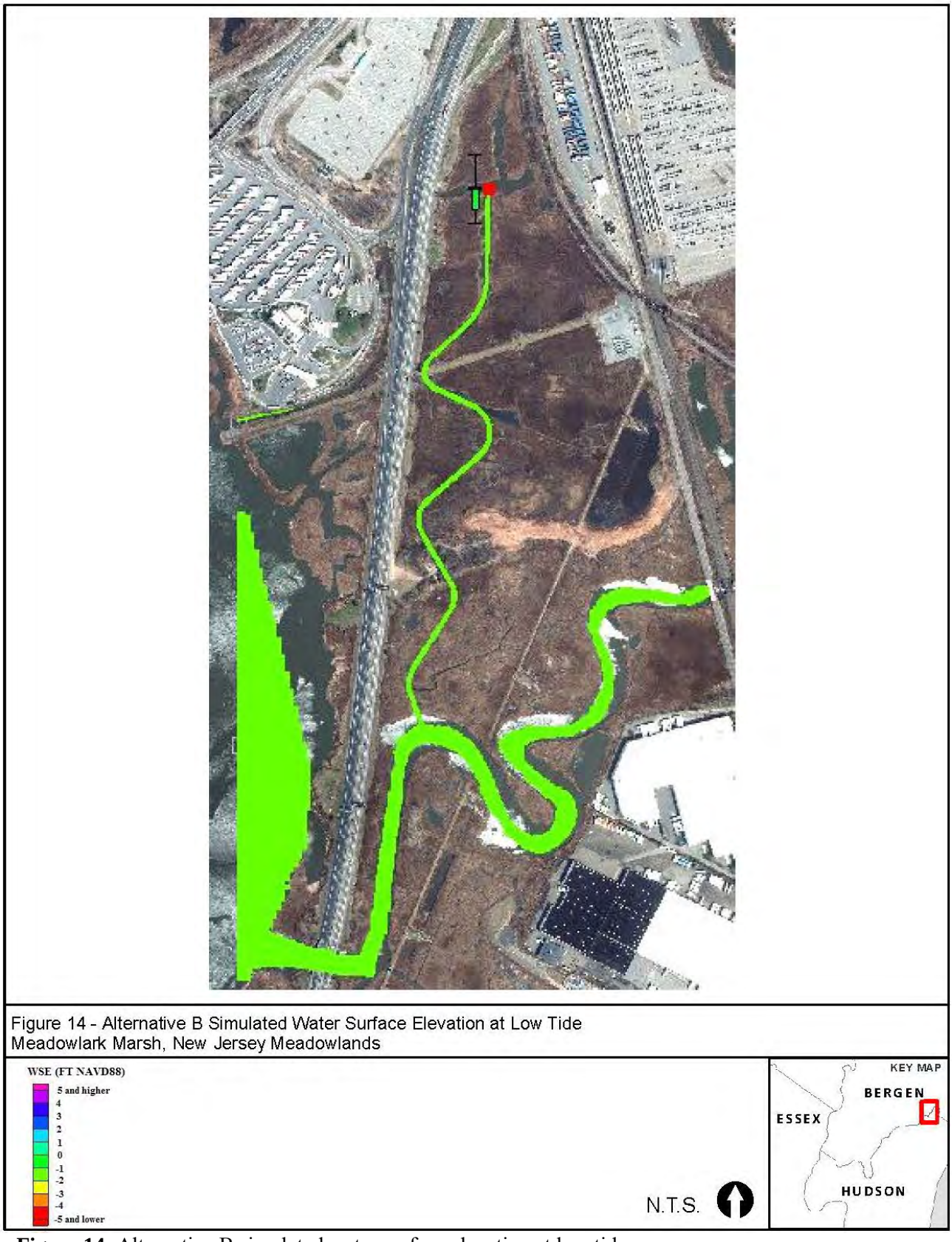


Figure 14: Alternative B simulated water surface elevation at low tide

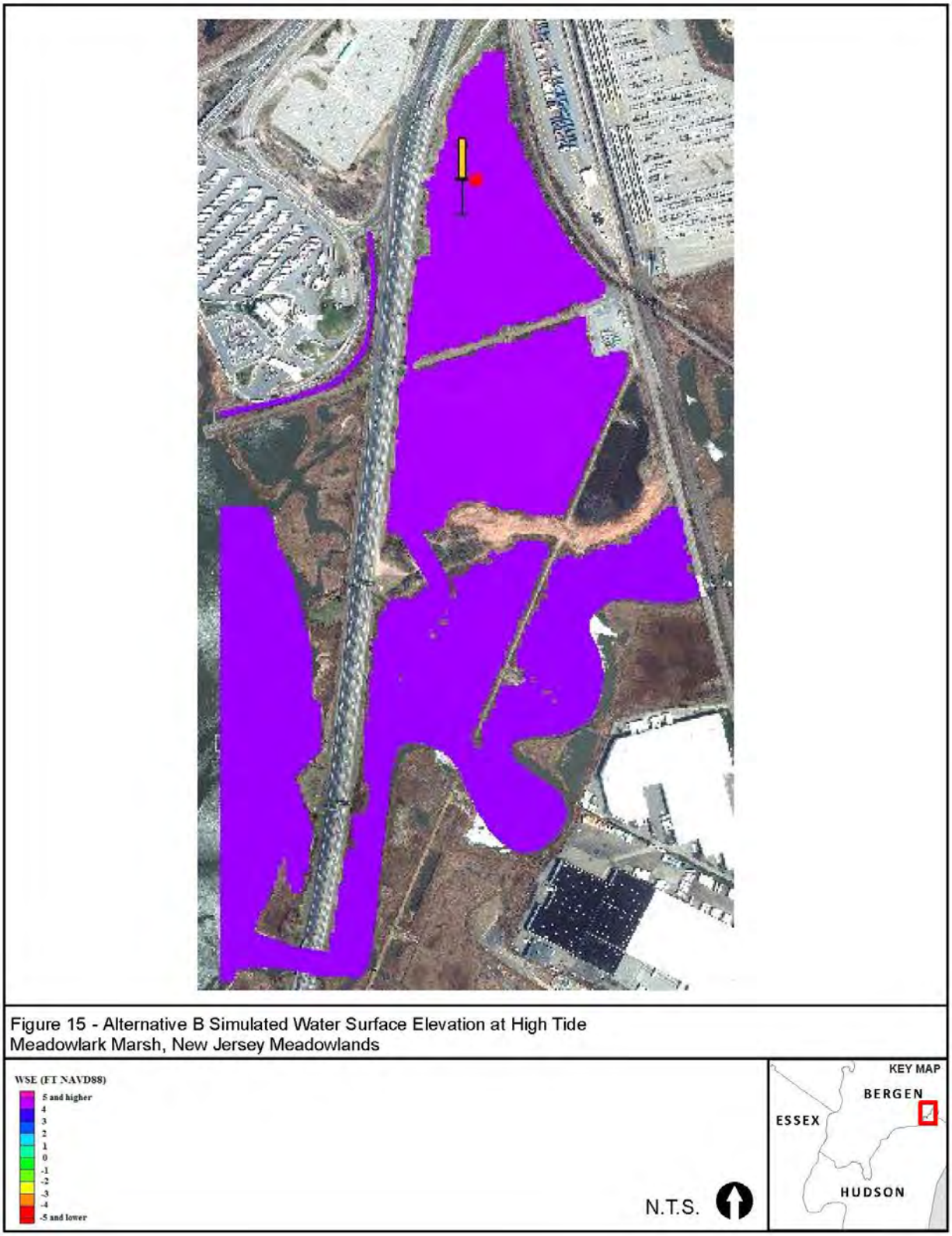


Figure 15: Alternative B simulated water surface elevation at high tide

3. Alternative A

Similar to the Alternative B model, an observation point is placed within the proposed channel inlet (at the deepest portion of the channel and furthest point the water will reach within the channel) in order to compare the simulated water surface elevation to the observed/boundary condition water surface elevation (**Figure 16**).

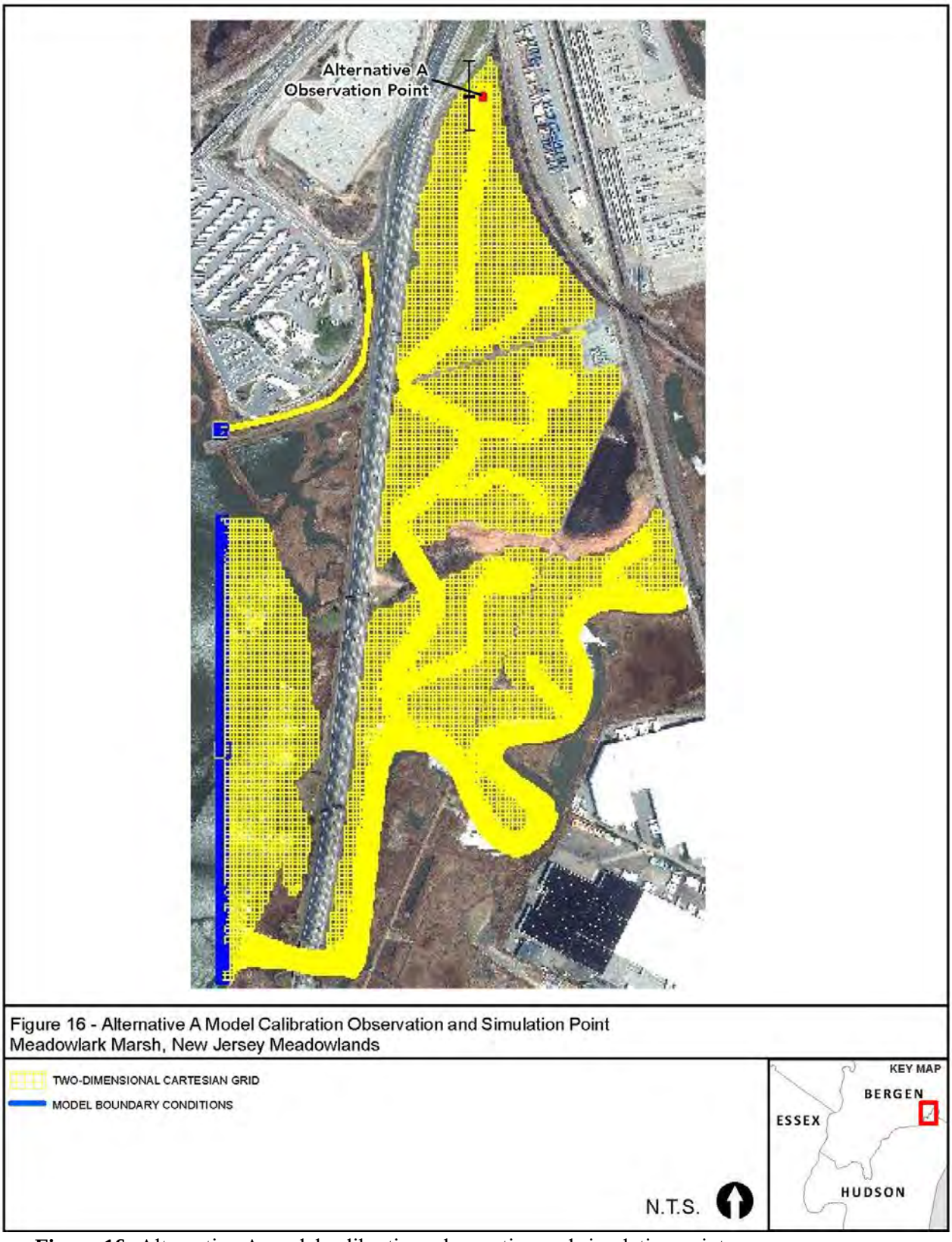


Figure 16: Alternative A model calibration, observation and simulation point

Similarly to the Existing Conditions/Alternative C and Alternative B models, linear regression and peak tide comparisons were performed in order to determine the success of the proposed restoration designs for a full tidal cycle (**Figure 17** and **Figure 18**, respectively). This is specific to this site as the distance between the observation point and the boundary condition is not long enough to create a significant time lag in peak flows.

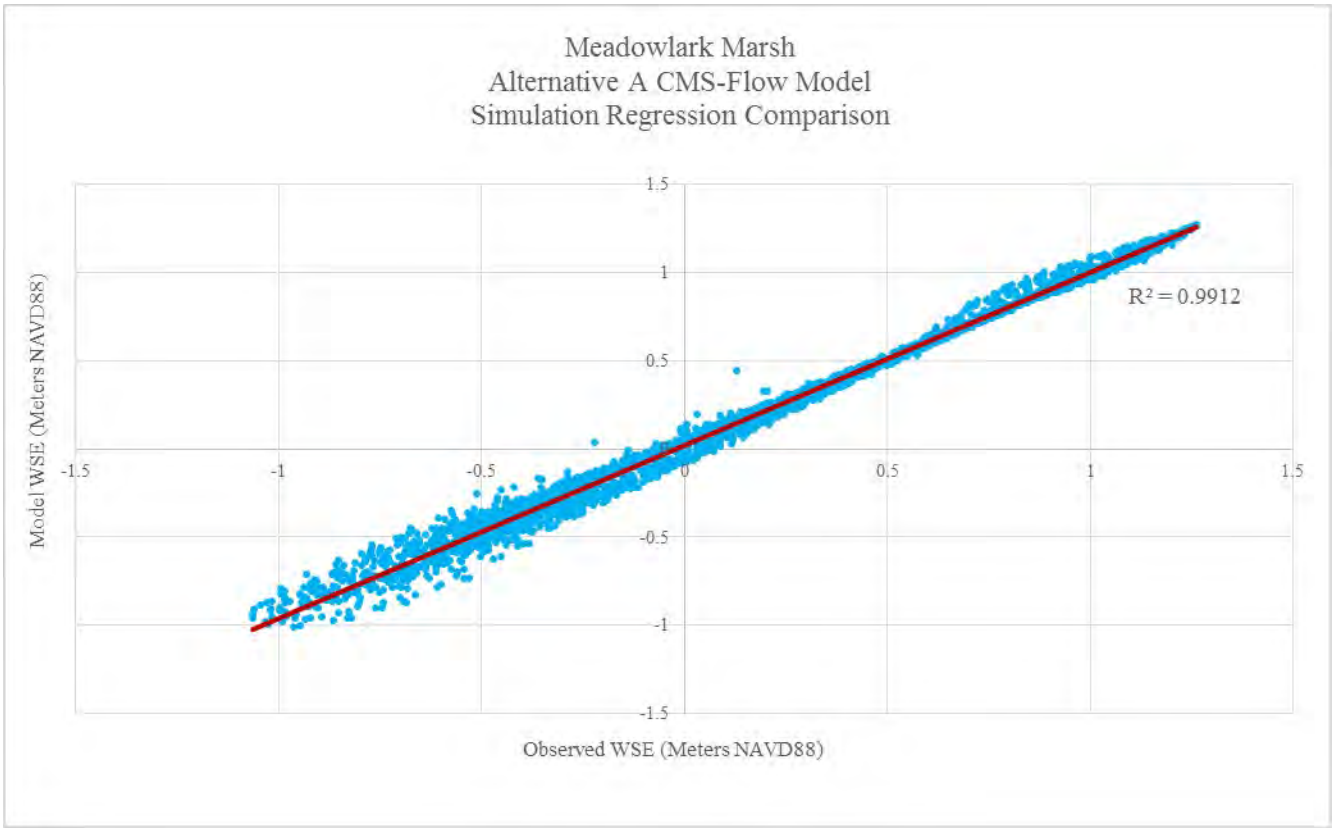


Figure 17: Linear regression comparison of alternative A (observed vs. simulated)

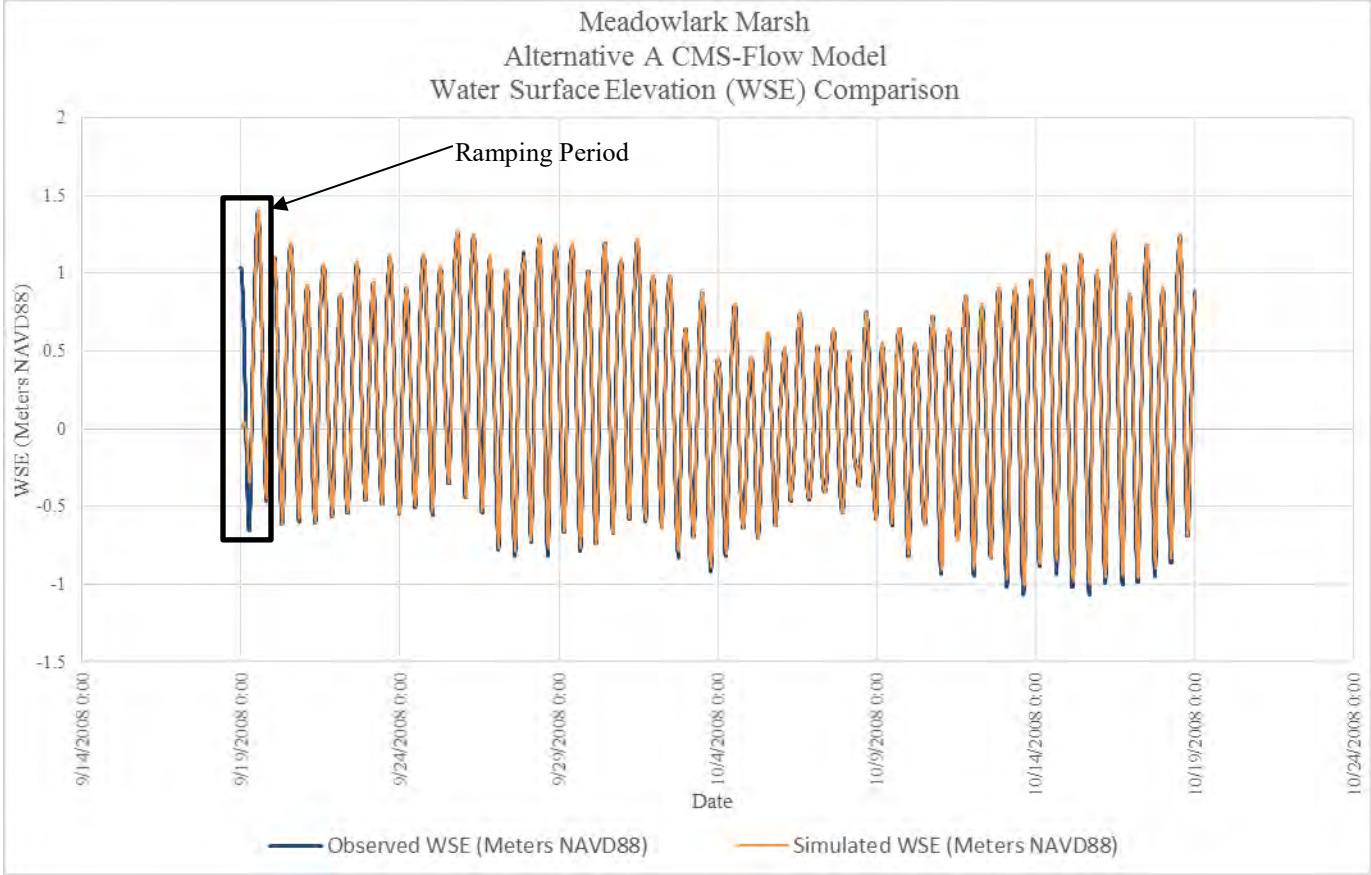


Figure 18: Alternative A water surface elevation peak flow comparisons (observed vs. simulated)

As can be seen with the linear regression comparison, the simulation of proposed Alternative A restores the tidal inundation period and hydraulic/hydrodynamic capacity of the interior marsh areas (with an error of 0.88%). The restoration of the tidal inundation period and hydraulic/hydrodynamic capacity to the interior marsh will provide a hydrologic cycle that will allow for vegetation planting and the marsh restoration. **Figure 19** and **Figure 20** depict the simulated and restored tidal cycle for Alternative A at low and high tides, respectively.

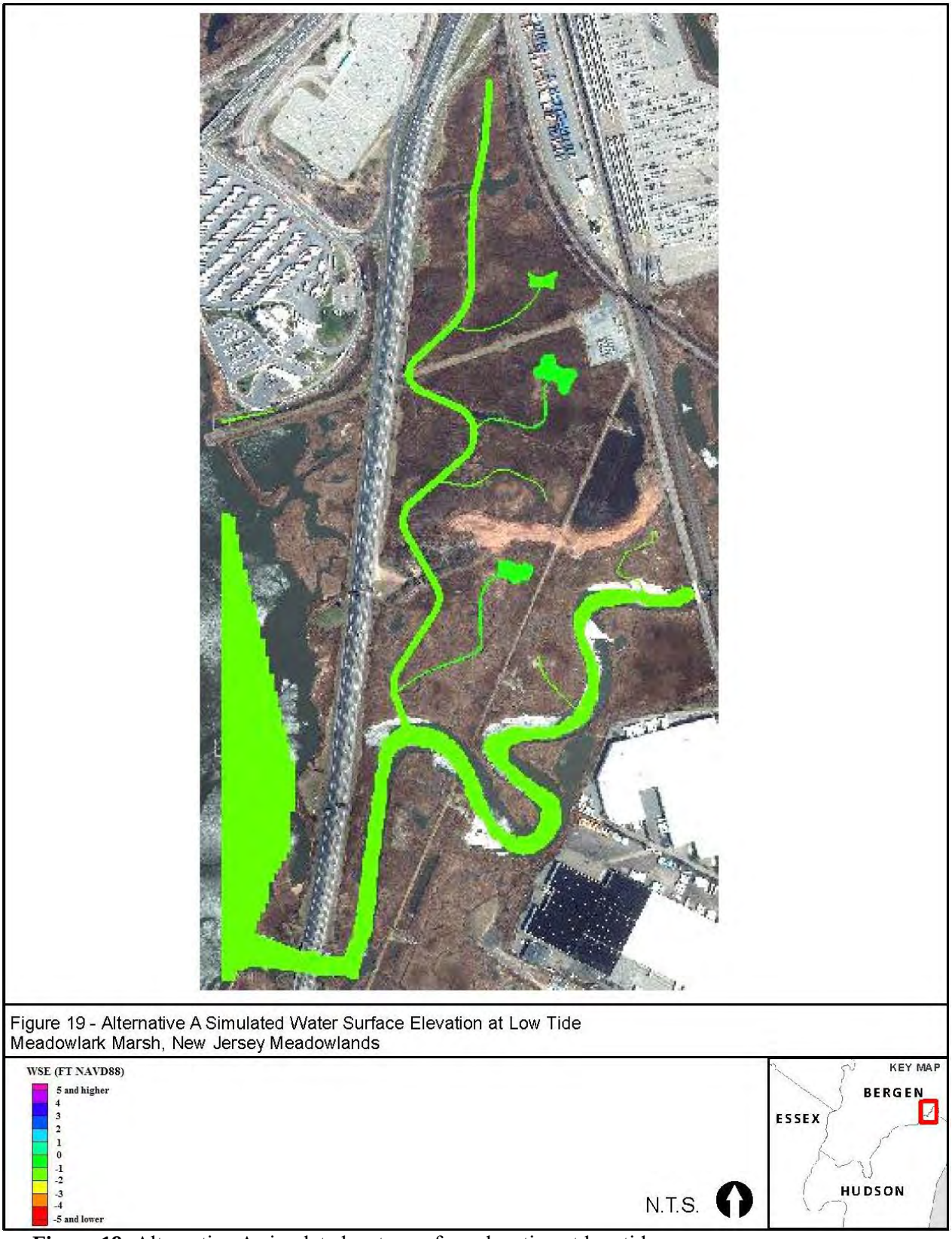


Figure 19: Alternative A simulated water surface elevation at low tide

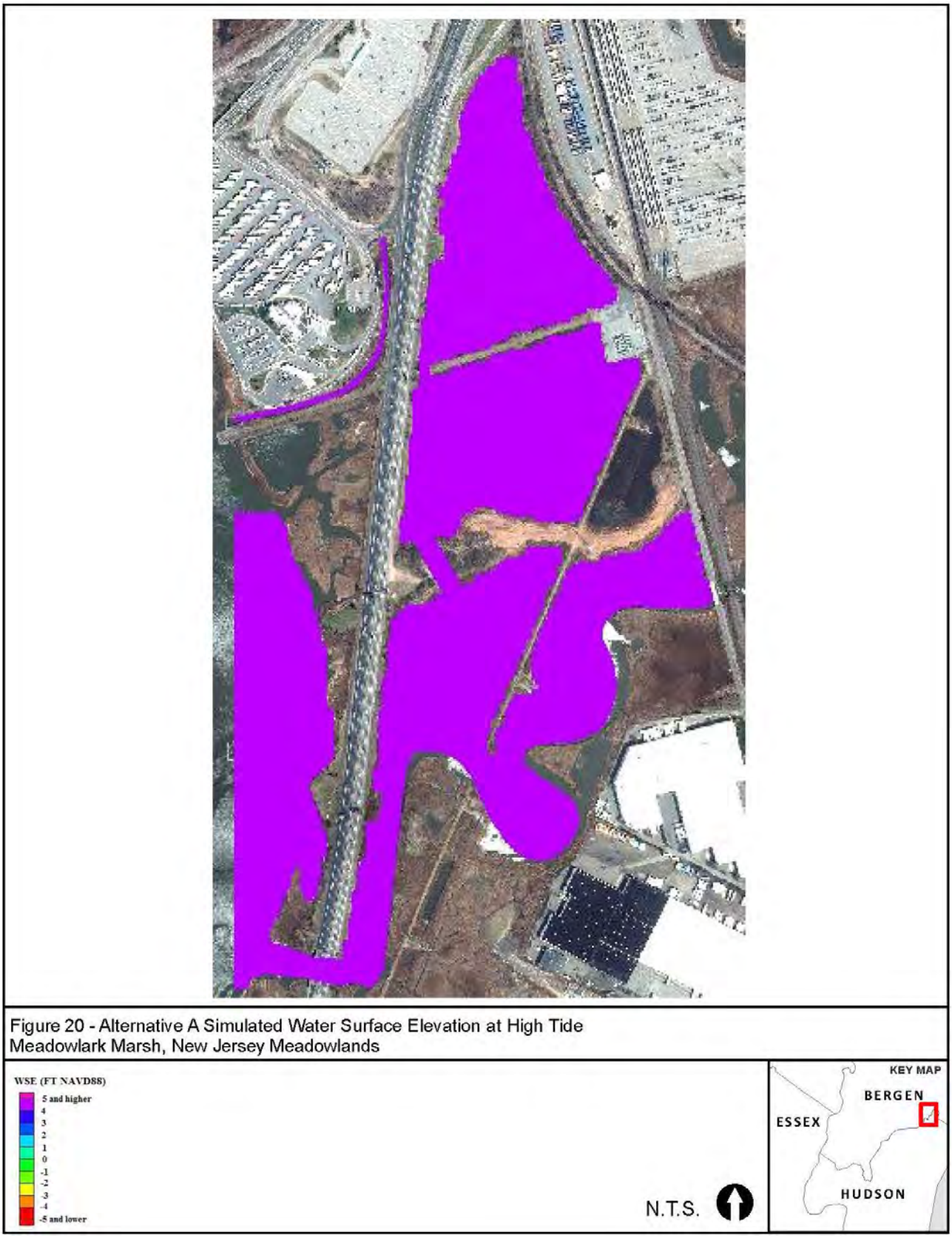


Figure 20: Alternative A simulated water surface elevation at high tide

D. Summary and Next Steps

The H&H analysis indicates that the proposed conceptual restoration alternatives will provide sufficient tidal inundation, drainage, and the hydraulic/hydrodynamic capacity to the interior marsh to support a native tidal salt marsh, including low marsh, high marsh and scrub-shrub marsh.

Based on the feasibility-study field analyses and previous experience with ecosystem restoration projects, it appears the risk for the Meadowlark site could be sufficiently mitigated for in the PED phase using the following strategy, as will be addressed in the Project's Risk Register.

- Additional water surface elevation data collection within the Hackensack River, Bellman's Creek, and various on-site locations (either side of the culverts, the north end of the site and southern end of the site) to finalize calibration (including the existing model and the alternative selected as the TSP). This data will supplement the data collected by the USACE in 2008 with more current site specific information that correlates all water surface elevation data to the same elevation datum and provides more complete tidal period records.
- Research and identify the additional pipes and characteristics within the series of pipes from the Vince Lombardi channel to the northern marsh. Based on the 2015 topographic survey identifying the culvert inlet and outlet from the Vince Lombardi channel to the northern marsh area of Meadowlark Marsh, the path of flow cannot be identified and it is assumed multiple pipes in series extend underneath the Turnpike to convey the flow between the two culverts. Collaboration with New Jersey Turnpike Authority will be required to identify the additional pipes and their characteristics (type, inverts, dimensions, and placement) of the pipe series in order to finalize calibration of the existing conditions model, and in turn fine tune the selected TSP model. It is assumed the New Jersey Turnpike Authority will have the details of the structure on file or will be readily able to collect the information listed above.
- Collaboration with Transco Williams Gas Pipeline to determine depths of the gas pipeline along the Transco access road to determine viability of the conceptual channel depths, as well as depths allowed for the culvert replacement or if a sag will be required in the pipeline to restore the hydraulic connection.
- This information will be utilized, along with best professional judgment, to finalize the two-dimensional hydraulic and hydrodynamic model and establish the preliminary designs for the project site for permit applications.
- Proven bioengineering measures and stream-stabilization techniques will be utilized.

E. References

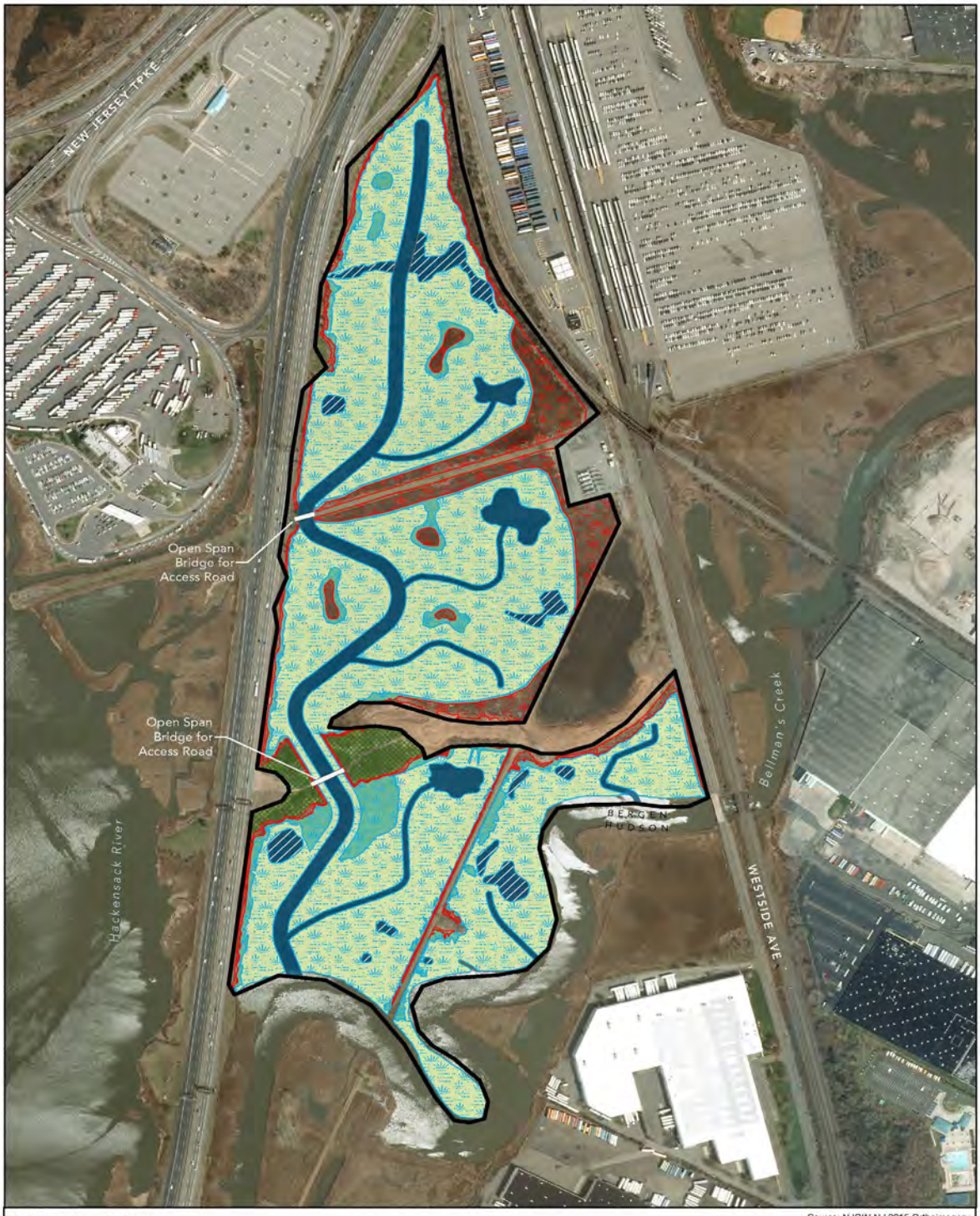
Federal Highway Administration. Publication No. FHWA-NHI-08-090 (2008). “Hydraulic Design Series No. 4 Introduction to Highway Hydraulics”. U.S. Department of Transportation. (June 2008) http://www.fhwa.dot.gov/engineering/hydraulics/pubs/08090/HDS4_608.pdf

Li, H., A. Sanchez, W. Wu, and C. Reed. 2013. “Implementation of Structures in the CMS: Part III, Culver”. Coastal and Hydraulics Laboratory Technical Report ERDC/CHL CHETN-IV-95. US Army Engineer Research and Development Center. (August 2013).

Philip Williams & Associates, Ltd. R. Coats, P.Williams, C. Cuffe, J.Zedler, D.Reed (1995). "Design Guidelines for Tidal Channels in Coastal Wetlands” For the U.S. Army Corps of Engineers Waterways Experiment Station. Philip Williams & Associates, Ltd. (January 1995).

Williams, P.B., M.K. Orr, and N.J. Garrity. 2002. “Hydraulic geometry: a geomorphic design tool for tidal marsh channel evolution in wetland restoration projects”. Restoration Ecology 10:577-590.

Appendix A
Site Alternatives and EPW Baseline



Source: NJGIN NJ 2015 Orthoimagery

Alternative A Map
Meadowlark Marsh, New Jersey Meadowlands

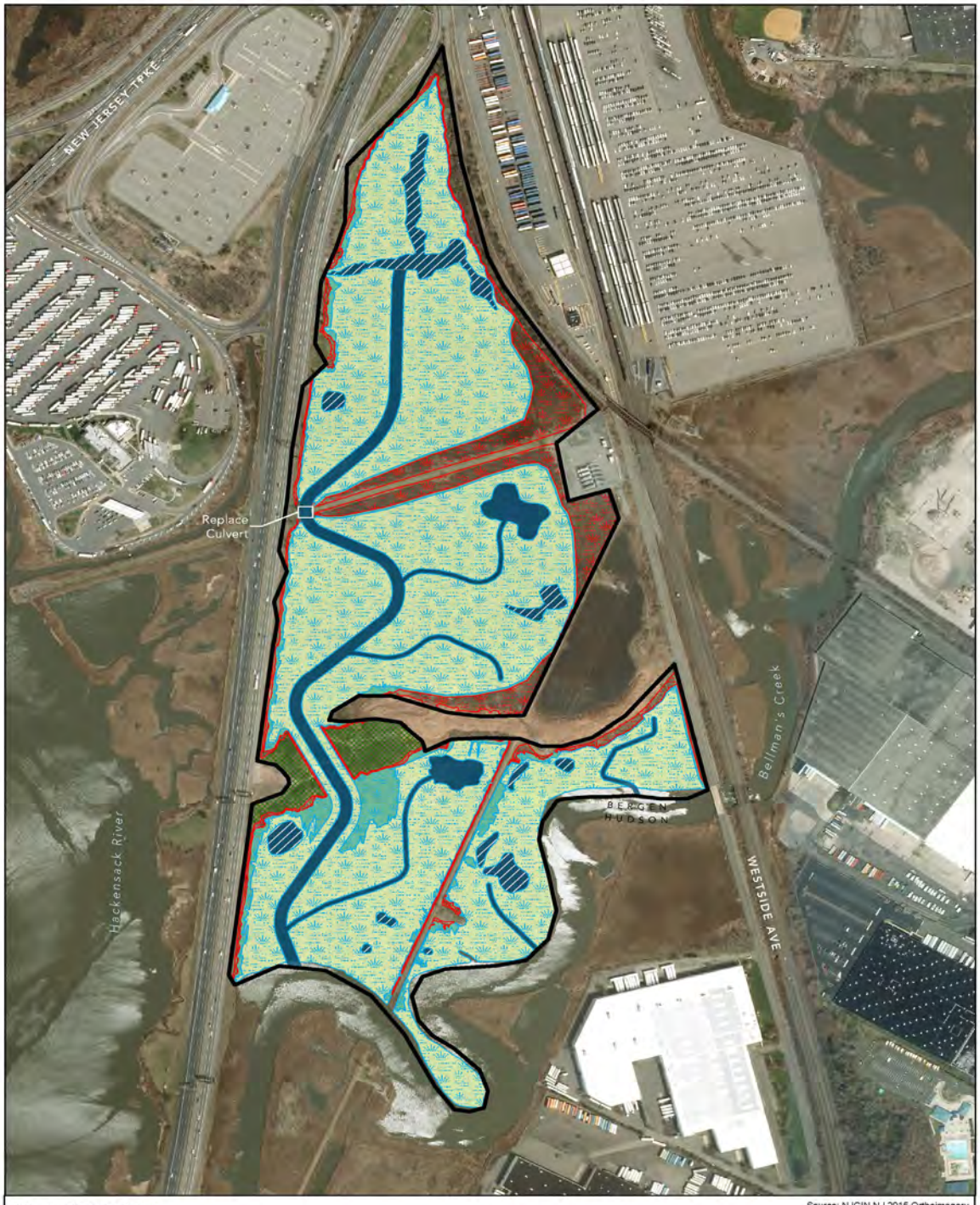
PROPOSED MEASURES LEGEND

- SITE BOUNDARY
- FORESTED AND SCRUB/SHRUB WETLAND
- EMERGENT WETLAND (HIGH MARSH)
- EMERGENT WETLAND (LOW MARSH)
- COASTAL AND MARITIME FOREST
- EXISTING HABITAT FOR FISH, CRAB AND LOBSTER
- HABITAT FOR FISH, CRAB AND LOBSTER

0 250 500 Feet

KEY MAP





Alternative B Map
Meadowlark Marsh, New Jersey Meadowlands

Source: NJGIN NJ 2015 Orthoimagery

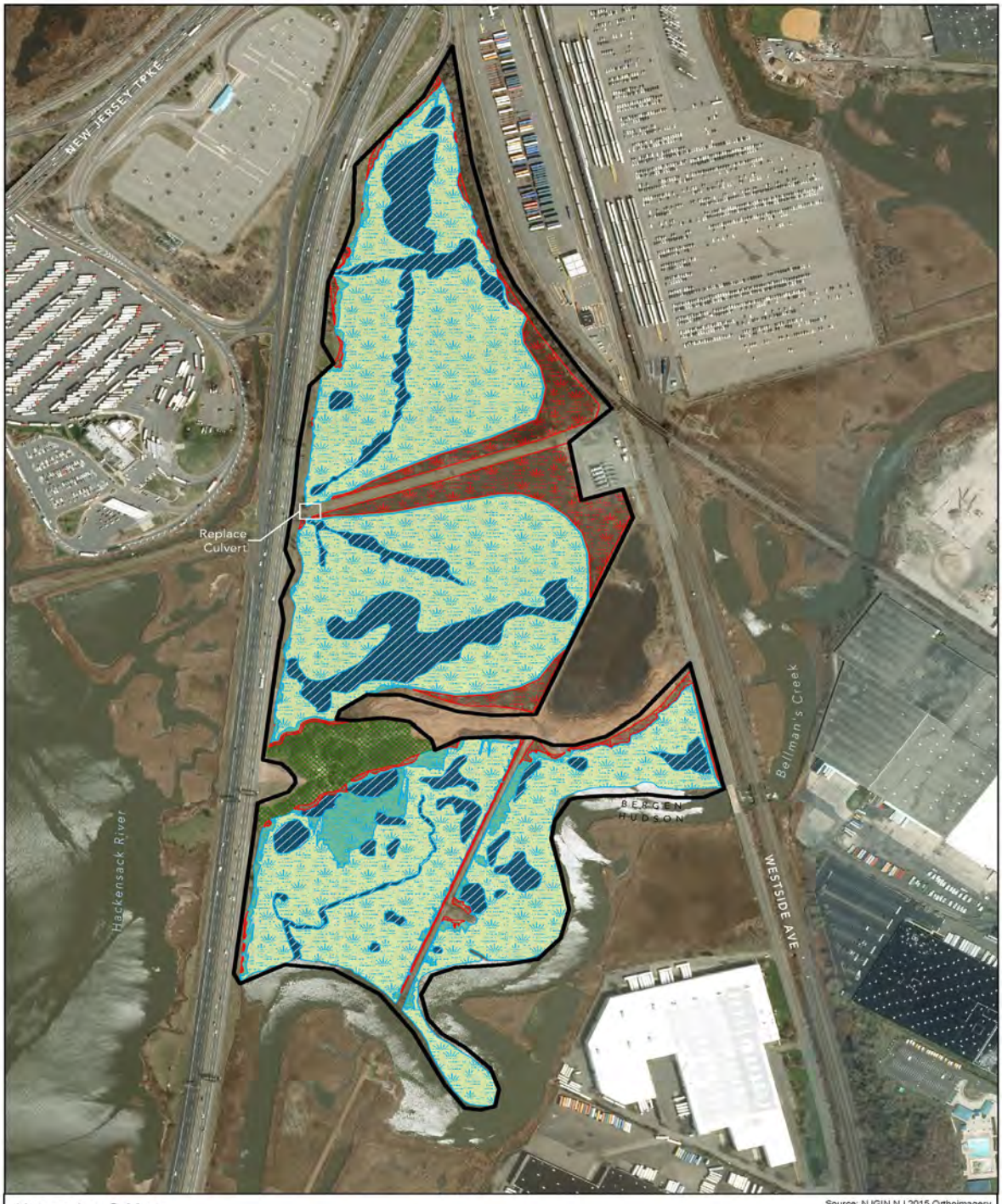
PROPOSED MEASURES LEGEND

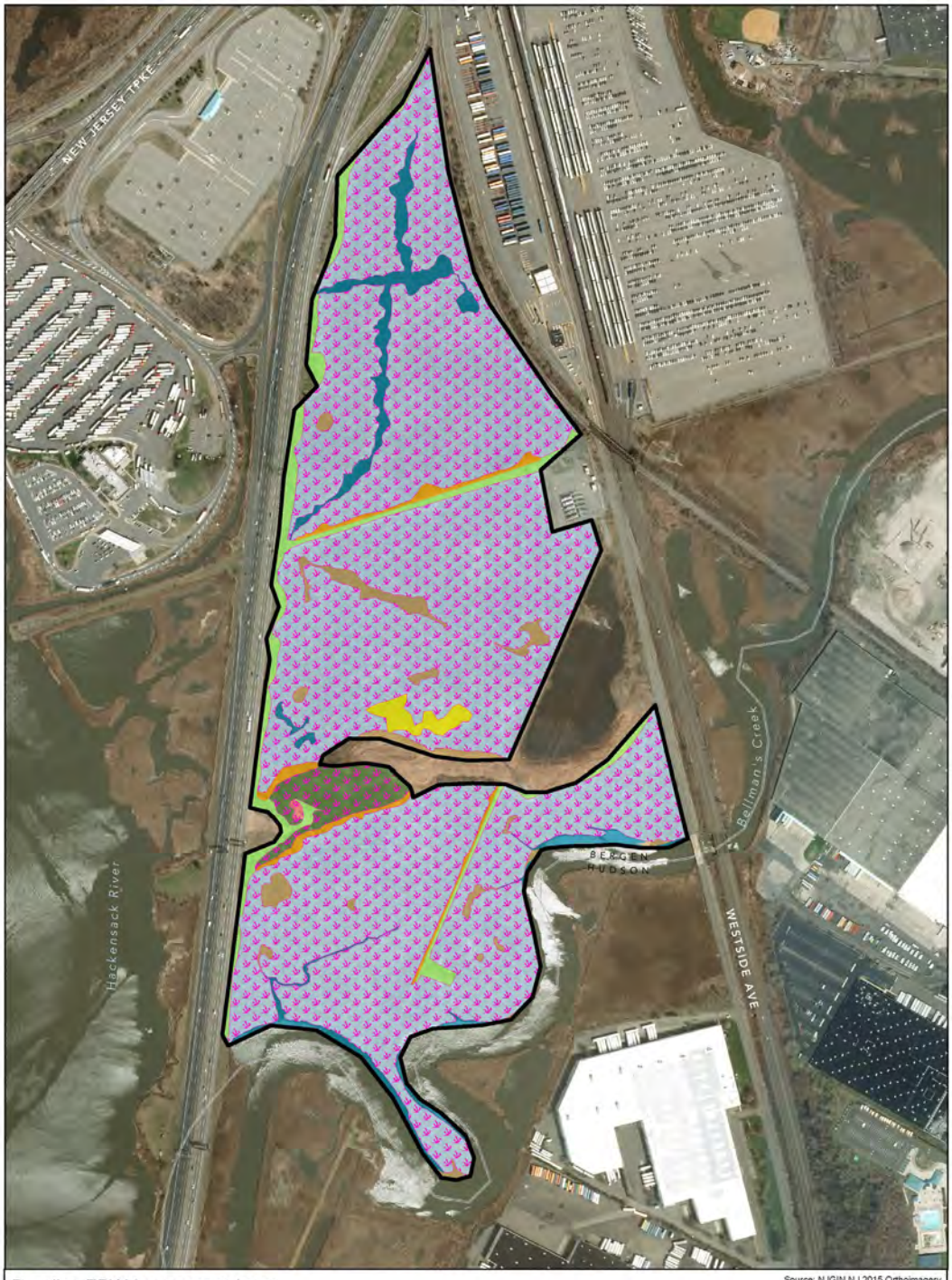
- SITE BOUNDARY
- FORESTED AND SCRUB/SHRUB WETLAND
- EMERGENT WETLAND (HIGH MARSH)
- EMERGENT WETLAND (LOW MARSH)
- COASTAL AND MARITIME FOREST
- EXISTING HABITAT FOR FISH, CRAB AND LOBSTER
- HABITAT FOR FISH, CRAB AND LOBSTER

0 250 500 Feet

KEY MAP




NEW JERSEY TPKE
Replace Culvert
Hackensack River
Bellman's Creek
BERGEN
HUDSON
WESTSIDE AVE
Source: NJGIN NJ 2015 Orthoimagery
Alternative C Map
Meadowlark Marsh, New Jersey Meadowlands
PROPOSED MEASURES LEGEND
SITE BOUNDARY
FORESTED AND SCRUB/SHRUB WETLAND
EMERGENT WETLAND (HIGH MARSH)
EMERGENT WETLAND (LOW MARSH)
COASTAL AND MARITIME FOREST
EXISTING HABITAT FOR FISH, CRAB AND LOBSTER
HABITAT FOR FISH, CRAB AND LOBSTER
0 250 500 Feet
KEY MAP
PASSAIC
BERGEN
ESSEX
HUDSON



Source: NJGIN NJ 2015 Orthoimagery

Baseline EPW Assessment Areas
Meadowlark Marsh, New Jersey Meadowlands

SITE BOUNDARY
INVASIVE SPECIES

WETLAND ASSESSMENT AREA
EMERGENT - SHORT PERSISTENT
EMERGENT - TALL PERSISTENT
SCRUB-SHRUB - TALL DECIDUOUS
NON-VEGETATIVE - MUD
NON-VEGETATIVE - OPEN WATER

UPLAND ASSESSMENT AREA
MIXED HARDWOOD FOREST - BROAD-LEAVED DECIDUOUS
GRASSLAND - SHORT PERSISTENT
SHRUBLAND - TALL DECIDUOUS

0 250 500 Feet

KEY MAP
PASSAIC
BERGEN
ESSEX
HUDSON

Attachment C-10
HRE
Oyster Restoration: Geotechnical Report

All interpretations are opinions based on inferences from available geological data in literature. We cannot, and do not, guarantee the accuracy or correctness of any interpretation. We shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretations made by any of our officers, agents or employees.

Executive summary

The United States Army Corps of Engineers (USACE-NAN) is planning to restore ecosystems within the Hudson Raritan Estuary in New York and New Jersey.

e4sciences (e4) reviewed the geological and geotechnical context in which the restorations are planned. e4 investigated the geology, the surficial geology, the water quality, and the proximity to contamination sites. The restorations focus on the Passaic River, the Hackensack River, the Naval base at Earle, Jamaica Bay, the mouth of the Bronx River, Brooklyn's waterfront, and Governors Island. The study does not make recommendations, but it provides the information critically relevant to planning and design.

Abstract

The United States Army Corps of Engineers (USACE-NAN) is planning to restore ecosystems within the Hudson Raritan Estuary in New York and New Jersey.

The USACE-NAN chose to recommend twelve sites for further consideration for ecosystem rehabilitation, which they then assigned e4sciences (e4) to evaluate. Five of these sites are considered for oyster habitat restoration and are located in New York waterways. The other seven sites are considered for ecosystem rehabilitation within the Newark Bay, Hackensack River and Passaic River watersheds in New Jersey. Table A-1 lists oyster habitat restoration sites and Table A-2 lists the ecosystem restoration sites. Figure 1 shows the location of these sites with respect to their watersheds. This report is a desktop study of the geology and the geotechnical properties of the rocks and sediments at the twelve sites of interest. e4 mapped the geology from literature and field observations, topography using LiDAR, and soils from literature.

Table A-1. List of proposed oyster habitat restorations sites in the New York waterways.

Oyster habitat restoration site	Watershed	Sub-watershed/water body
Site 864. Governors Island	Hudson River	Upper New York Bay/ Buttermilk Channel
Site 154. Bush Terminal	Hudson River	Upper New York Bay/ Bay Ridge Channel
Unnumbered site: Soundview Park	Bronx River	Confluence of Bronx and East Rivers
Unnumbered site: Head of Bay	Jamaica Bay	Hook Creek-Head of Bay
Unnumbered site: Naval Weapons Station Earle	NY Lower Bay	Compton Creek-Sandy Hook Bay

Table A-2. List of proposed ecosystem restorations sites in the Newark Bay watershed.

Ecosystem restoration site	Watershed	Sub-watershed
Site 719. Meadowlark Marsh	Hackensack	Bellmans Creek
Site 721. Metromedia Tract	Hackensack	Hackensack River (Route 3 to Bellmans Creek)
Site 865. Kearny Point	Newark Bay	Confluence of Passaic and Hackensack Rivers
Site 866. Oak Island Yards	Newark Bay	Newark Bay
Site 887. Essex County Branch Brook Park	Passaic River	Branch Brook (First River)
Site 900. Dundee Island Park/Pulaski Park	Passaic River	Lower Passaic River
Site 902. Clifton Dundee Canal Green Acres Purchase & Island Preserve	Passaic River	Lower Passaic River (Saddle R. to Dundee Dam)

Oyster Habitat Restoration Sites

The southern termination of the last Pleistocene glacier (Wisconsin) is marked by the glacial terminal moraine extending along Staten Island and Long Island. North of this, Pleistocene glaciers have scraped down to bedrock or to the semi-consolidated Tertiary and Cretaceous Coastal Plain Group sediments. On land there are minor Holocene sediments, and true soils are relatively thin. Surficial sediments are predominantly Pleistocene glacial tills, glacial lake sediments and Holocene fluvial, estuarine, and marine sediments. Underwater, the Holocene coarser sediments are reworked Pleistocene sands and gravels. The fine-grained sediments are estuarine deposits. In the Hudson River channel, these Holocene deposits are up to 300ft thick. At the oyster habitat restoration sites, Holocene deposits are relatively thin (0 to 20ft).

In New York, the area south of the terminal moraine is blanketed by deposits of glacial outwash sands and silts that "washed out" from glaciers and the terminal moraine. On land there are very minor Holocene sediments, and true soils are relatively thin. Underwater Holocene deposits at Jamaica Bay are estimated to be 20ft thick.

The New Jersey coast south of New York Bay is predominantly erosive. On land, the soils have variable thickness and lie on the Coastal Plain Group deposits. Holocene stream deposits are relatively minor. Underwater, the Holocene is dominated by reworked sands of the Coastal Plain Group.

All of the oyster habitat restoration sites are adjacent to built-up shorelines and are in channels with varying degrees of marine vessel traffic. Naval Weapons Station Earle and Governors Island sites are adjacent to active piers. The Bush Terminal site is in an underwater field of pier "ruins" adjacent to piers re-purposed as a park.

The Governors Island oyster restoration site lies between the rip-rap lined seawall of the island and Buttermilk Channel. The site is underlain by schist (Hartland formation) that is 0 to 40ft below the bay floor. At the northern end of the site, rock is exposed on the channel floor. Overlying the rock is variable thicknesses of interlayered Pleistocene glacial deposits that include glacial lake clay and silt, glacial outwash sand and silt, and glacial till. Overlying Holocene sediments are generally less than 10ft thick. Coarse Holocene sediments appear to be reworked Pleistocene sediments. Locally, a thin layer of black silt overlies the Holocene sands.

Governors Island, specifically Fort Jay, is considered a State Superfund Program site. Due to its history as an active military base for over 200 years, the subsurface of the island contains various heavy metals and harmful organic compounds. It is unknown if these contaminants affect the overall health of the offshore oyster habitat restoration site.

The Bush Terminal oyster restoration site includes pier ruins between the Bay Ridge Channel and the re-purposed Bush Terminal Pier Park. Bedrock (Hartland Formation) is greater than 120ft deep. Overlying the rock is a thick sequence of Pleistocene sediments dominated by glacial lake clay and silt. This is overlain by Holocene sands and Holocene black silt. The surface of Bush Terminal Piers Park is made up of the Laguardia soil unit, which is an artifactual coarse sandy loam (fill).

Bush Terminal Piers Park is both a State Superfund Program site and an Environmental Restoration Program site. It is also considered a NYS Open Petroleum Spill location. The effect of the contamination on the overall health of the oyster habitat restoration site is not known.

The Soundview Park oyster restoration site is part of the Bronx sub-watershed within the larger Atlantic Ocean/Long Island Sound watershed system. The site is underlain by shallow bedrock composed of schist (Hartland formation). This is overlain by Holocene estuarine sands and silts. The land surface of Soundview Park is made up of the Laguardia soil unit.

Approximately 900ft to the west of the proposed oyster site, there is a NYS Remediation site, and also to the west and north of the site are NYS Brownfield Opportunity areas. How these areas affect the overall health of the offshore oyster habitat restoration site is not known.

The Head of Bay oyster restoration site is part of the Hook Creek-Head of Bay sub-watershed within the larger Jamaica Bay watershed system. The site is adjacent to JFK airport where construction started in the 1940s. The site is underlain by estuarine sands and over 100ft-thick glacial-outwash deposits, which are on top of older Pleistocene sediments and Cretaceous Coastal Plain Sediments. The top of crystalline rock is over 600ft deep. The surface of the Queens County north shore of Jamaica Bay in the Head of Bay area is made up of the Jamaica sand soil unit.

The Naval Weapons Station Earle oyster habitat restoration site is part of the Sandy Hook-Staten Island sub-watershed within the larger Monmouth watershed system. The site is underlain by the Cretaceous Coastal Group sand, silt and clay.

The Naval Weapons Station Earle site is classified as a New Jersey Superfund site due to the toxic materials associated with military activities and wastes that have been buried in landfills. The contaminants found at this site include heavy metals and organic compounds. It is unknown if these Superfund contaminants affect the overall health of the oyster habitat restoration site.

Newark Bay/Lower Passaic River/Hackensack River Restoration Sites
The Passaic and Hackensack Rivers flow into the northern end of Newark Bay at Kearny Point (Site 865). Newark Bay, the lower 14 miles of the Hackensack River, and the lower Passaic River are tidal. The upper Hackensack River is dammed north at the Oradell Dam. The Passaic River has multiple dams, the most downstream of which is Dundee Dam.

The underlying bedrock of all three water bodies consists of the Newark Series Triassic-Jurassic sedimentary rocks deposited in the Newark Basin and intrusive and volcanic Jurassic igneous basalts and diabases. The igneous rocks and the surrounding contact metamorphic rocks are the most resistant, and form ridges. The least resistant are the fine-grained sedimentary rocks of the Passaic Formation. These shales and siltstones underlie valleys. The eastern edge of the Newark Bay watershed is underlain by the Lockatong Formation, whereas the rest is underlain either by the Passaic Formation or the igneous dikes and sills that cross-cut the Passaic Formation.

Newark Bay, the lower 14 miles of the Hackensack River, the lower 1 mile of the Passaic River, northern Arthur Kill, and associated wetlands lie in a subtle valley between north-east trending ridges. The eastern ridge is the Palisades diabase. The western limit of the valley is formed by small ridges underlain by the Passaic Formation shales and sandstones. The eastern edge of the valley is underlain by the Lockatong Formation. The remaining majority is underlain by the shale-dominated Passaic subunits. This valley is tidally influenced and includes the Meadowlands between the Passaic and Hackensack Rivers.

The main strike of the strata is 36° east of north and beds dip 15° to the northwest. The area consists of buried northeast trending ridges and valleys of bedrock. The top of rock is mantled by Pleistocene Glacial till. The valleys are filled with Pleistocene glacial lake deposits, the majority of which are varved clays and silts. Locally, these are interbedded with glacial lake delta deposits of sands and tills. The clay unit may be as thick as 200ft. These lake deposits are interbedded with tills and are overlain by outwash silts and sands.

The Pleistocene outwash sands transition to Holocene fluvial and estuarine sands that grade vertically into finer estuarine silts and clays and marsh deposits. In the last few hundred years, much of the low-lying marsh and shallow waters areas have been filled to build up the land for roads, railroads, industrial sites, airports, and port facilities. Bridges are generally built where bedrock is shallow.

Locally, either bedrock or Pleistocene sediments are exposed in Newark Bay and in the Hackensack River. In Newark Bay, these units were uncovered by dredging, whereas in the Hackensack River, the units were uncovered both by dredging and by river currents eroding overlying sediments. Such scouring is deep at bridges.

The movement and storage of groundwater in this area occurs primarily in the interconnected network of openings that form along joints, fractures, and other channels in the Passaic Formation.

The shallower upper Pleistocene and Holocene silts and sands in addition to the historic fill form shallow groundwater aquifers that are generally laterally discontinuous. Where bedrock is deep

the relatively impermeable, Pleistocene varved clays and silts are thick and create barriers atop the bedrock aquifers. Where rock is shallow, the Pleistocene clay and silt may be thin or completely eroded and bedrock aquifers are more vulnerable to infiltration and contamination from the surface.

Much of the contaminated sediment and groundwater is in the shallower aquifers. The historic fill was usually placed for industrial use and is commonly found at the surface of contaminated sites.

The Meadowlark Marsh site is a poorly drained, frequently flooded marsh that is located above mucky peat and some sand. While there are groundwater contamination sites nearby, the extent of the effects of contamination on the health of Meadowlark Marsh is unknown.

The Metromedia Tract site is a poorly drained, frequently flooded marsh that is located above peat, muck, and some fill material (gravel and debris). The marsh deposits are approximately 10ft thick. The closest known contamination site is 1,400ft southeast of the border of the Metromedia Tract site.

The Kearny Point site is located on top of historic fill, and is the site of a decommissioned industrial facility. The fill material is approximately 20ft thick and is underlain by marshy deposits. NJDEP recognizes a Known Contaminated Site (KCS) within the boundaries of the Kearny Point site with an identified contaminated plume. There is a deed notice to the site that prohibits the drilling of water wells and places restrictions on any drilling through the plume.

The Oak Island Yards site is located on top of a mix of fill, salt-marsh, sand, and gravel deposits. The water quality around Oak Island Yards is mostly suitable for aquatic life, however the turbidity has been measured high at times. Northwest of the site is the Newark Energy Center, where many contaminants have been measured in the soil/groundwater. It is unknown if these contaminants affect Oak Island Yards site.

The Essex County Branch Brook Park site is underlain by about 10ft of marshy loam deposits, which are above gravelly and sandy loam deposits. On the eastern, northern, and western edges of the park, there are KCS's with groundwater contamination.

The Dundee Island Park/Pulaski Park site is underlain by fill material, which is above silty sand deposits. There are no marshy deposits at this site. There are no KCS's within the site, however there are KCS's west, northeast, east, and southeast of the site.

The Clifton Dundee Canal Green Acres Purchase and Island Preserve site is underlain by silty and clayey sands. There is a KCS on the southern edge of the site and there are several southeast of the site. It is unknown if the contamination affects the health of this site.

Table of contents

Disclaimer ii
Executive summary iii
Abstract iv
Table of Contents viii
List of figures viii
List of tables x
1.0 Introduction 1
2.0 Oyster Habitat Restoration Sites 1
2.1 Upper New York Bay 13
2.1.1 Site 864. Governors Island 13
2.1.2 Site 154. Bush Terminal 22
2.2 Bronx River Basin 30
2.2.1 Soundview Park 30
2.3 Jamaica Bay 36
2.3.1 Head of Bay 36
2.4 Lower New York Bay 44
2.4.1 Naval Weapons Station Earle 44
3.0 Newark Bay, Lower Passaic River and Hackensack River Restoration Sites 50
3.1 Hackensack River 57
3.1.1 Site 719. Meadowlark Marsh 57
3.1.2 Site 866. Oak Island Yards 83
3.2 Lower Passaic River 90
3.2.1 Site 887. Essex County Branch Brook Park 90
3.2.2 Site 900. Dundee Island Park/Pulaski Park 100
3.2.3 Site 902. Clifton Dundee Canal Green Acres Purchase and Island Preserve 107
Appendix I. Site 864. Governors Island A1-1
Appendix II. Site 154. Bush Terminal A2-1
Appendix III. Soundview Park A3-1
Appendix IV. Head of Bay, Jamaica Bay A4-1
Appendix V. Naval Weapons Station Earle A5-1
Appendix VI. Site 719. Meadowlark Marsh A6-1
Appendix VII. Site 721. Metromedia Tract A7-1
Appendix VIII. Site 865. Kearny Point A8-1
Appendix IX. Site 866. Oak Island Yards A9-1
Appendix X. Site 887. Essex County Branch Brook Park A10-1
Appendix XI. Site 900. Dundee Island Park/Pulaski Park A11-1
Appendix XII. Site 902. Clifton Dundee Canal Green Acres Purchase & Island Preserve A12-1

List of Figures

Figure 1. Location map of the proposed restoration sites and HRE Planning Regions boundaries
Figure 2. Watershed map of the proposed restoration sites
Figure 3. Regional bedrock geology map

Figure 2.0-1. 1911 oyster map of New York Harbor
Figure 2.0-2. Location map of oyster habitat restoration candidate sites
Figure 2.0-3. Watershed map and oyster habitat restoration sites
Figure 2.0-4. Bedrock geology and the oyster habitat restoration sites

Figure 2.0-5. Surficial geology and the oyster habitat restoration sites

Figure 2.1.1-1. 1845 and 1906 historic nautical charts of Governors Island
Figure 2.1.1-2. 1912 and 2014 historic nautical charts of Governors Island
Figure 2.1.1-3. Surficial geology of Governors Island site
Figure 2.1.1-4. Side-scan orthosonograph of bay floor surrounding Governors Island
Figure 2.1.1-5. Wetland areas and contamination site at Governors Island

Figure 2.1.2-1. Historic nautical charts of the Bush Terminal area
Figure 2.1.2-2. Surficial geology of the Bush Terminal site
Figure 2.1.2-3. Side-scan orthosonograph of bay floor adjacent to Bush Terminal Piers Park
Figure 2.1.2-4. Wetland areas and contamination site at Bush Terminal

Figure 2.2.1-1. Historic nautical charts of the Soundview Park area
Figure 2.2.1-2. Surficial geology of the Soundview Park site
Figure 2.2.1-3. Wetland areas and contamination site near the Soundview Park site

Figure 2.3.1-1. Location map of the Head of Bay site
Figure 2.3.1-2. Historic nautical charts of Head of Bay
Figure 2.3.1-3. Surficial geology of the Head of Bay site
Figure 2.3.1-4. Regional geological cross section through Jamaica Bay
Figure 2.3.1-5. Wetland areas and contamination sites near Head of Bay

Figure 2.4.1-1. Historic nautical charts of NWS Earle area
Figure 2.4.1-2. Surficial geology of the NWS Earle site
Figure 2.4.1-3. Wetland areas and contamination sites near the NWS Earle site

Figure 3.0-1. Location map of ecosystem restoration sites
Figure 3.0-2. Watershed map and ecosystem restoration sites
Figure 3.0-3. Bedrock geology map and the ecosystem restoration sites
Figure 3.0-4. Surficial geology map and the ecosystem restoration sites
Figure 3.0-5. West-to-east cross section through the Newark Basin

Figure 3.1.1-1. Historic topographic maps of the Meadowlark Marsh area
Figure 3.1.1-2. Surficial geology of the Meadowlark Marsh site
Figure 3.1.1-3. Geological cross section along the Hackensack River
Figure 3.1.1-4. Wetland areas and contamination sites near the Meadowlark Marsh site

Figure 3.1.2-1. Historic topographic maps of the Metromedia Tract area
Figure 3.1.2-2. Surficial geology of the Metromedia Tract site
Figure 3.1.2-3. Geological cross section along the Hackensack River
Figure 3.1.2-4. Wetland areas and contamination sites near the Metromedia Tract site

Figure 3.2.1-1. Historic topographic maps of the Kearny Point area
Figure 3.2.1-2. Surficial geology of the Kearny Point site
Figure 3.2.1-3. Geological cross section along the Hackensack River.
Figure 3.2.1-4. Wetland areas and contamination sites at and near the Kearny Point site

Figure 3.2.2-1. Historic topographic maps of the Oak Island Yards area

Figure 3.2.2-2. Surficial geology of the Oak Island Yards site
Figure 3.2.2-3. Wetland areas and contamination sites near the Oak Island Yards site

Figure 3.3.1-1. Historic topographic maps of Essex County Branch Brook Park
Figure 3.3.1-2. Surficial geology of Essex County Branch Brook Park
Figure 3.3.1-3. Wetland areas and contamination sites in Essex County Branch Brook Park

Figure 3.3.2-1. Historic topographic maps of the Dundee Island Park and Pulaski Park area
Figure 3.3.2-2. Surficial geology of the Dundee Island Park and Pulaski Park site
Figure 3.3.2-3. Wetland areas and contamination sites near Dundee Island Park and Pulaski Park

Figure 3.3.3-1. Historic topographic maps of the area around Clifton Dundee site 902
Figure 3.3.3-2. Surficial geology of Clifton Dundee site 902
Figure 3.3.3-3. Wetland areas and contamination sites near Clifton Dundee site 902

List of Tables

Table A1. Proposed oyster habitat restorations sites in New York waterways
Table A2. Proposed ecosystem restoration sites in the Newark Bay watershed

Table 1. Proposed oyster habitat restorations sites in New York waterways
Table 2. Proposed ecosystem restoration sites in the Newark Bay watershed

Table 2.0-1. Proposed oyster habitat restorations sites in this report

Table 2.1.1-1. Key information for the Governors Island site
Table 2.1.1-2. General stratigraphy of the Governors Island site
Table 2.1.1-3. Borings and sample sites in or near the Governors Island site
Table 2.1.1-4. Soil profile of Governors Island's Urban land soil type
Table 2.1.1-5. Summary of properties of the Urban land soil type
Table 2.1.1-6. Soil profile of the Laguardia soil type
Table 2.1.1-7. Summary of properties of the Laguardia soil type
Table 2.1.1-8. Water quality summary of the Governors Island site

Table 2.1.2-1. Key information for the Bush Terminal site
Table 2.1.2-2. General stratigraphy of the Bush Terminal site
Table 2.1.2-3. Borings and sample sites in or near the Bush Terminal site
Table 2.1.2-4. Soil profile of the Laguardia soil unit
Table 2.1.2-5. Summary of properties of the Laguardia soil unit

Table 2.2.1-1. Key information for the Soundview Park site
Table 2.2.1-2. General stratigraphy of the Soundview Park site
Table 2.2.1-3. Soil profile of the Laguardia soil unit
Table 2.2.1-4. Summary of properties of the Laguardia soil unit
Table 2.2.1-5. Water quality summary of the Soundview Park site

Table 2.3.1-1. Key information for the Head of Bay site
Table 2.3.1-2. General stratigraphy of the Head of Bay site
Table 2.3.1-3. Soil profile of the Jamaica Sand soil unit

Table 2.3.1-4. Summary of soil properties the Jamaica Sand soil unit
Table 2.3.1-5. Water quality summary of the Head of Bay site

Table 2.4.1-1. Key information for the Naval Weapons Station (NWS) Earle site
Table 2.4.1-2. General stratigraphy of the NWS Earle site
Table 2.4.1-3. Borings near the NWS Earle site
Table 2.4.1-4. Soil profile of the Hooksan sand soil unit
Table 2.4.1-5. Summary of soil properties of the Hooksan sand soil unit

Table 3.0-1 Proposed ecosystem restoration sites in this report

Table 3.1.1-1. Key information for the Meadowlark Marsh site
Table 3.1.1-2. General stratigraphy of the Meadowlark Marsh site
Table 3.1.1-3. Borings in or near the Meadowlark Marsh site
Table 3.1.1-4. Soil profile of the Westbrook soil type.
Table 3.1.1-5. Summary of properties of the Westbrook soil type
Table 3.1.1-6. Soil profile of the Ipswich soil type
Table 3.1.1-7. Summary of properties of the Ipswich soil type
Table 3.1.1-8. Soil profile of the Sandyhook soil type
Table 3.1.1-9. Summary of properties of the Sandyhook soil type
Table 3.1.1-10. Water quality summary of Hackensack River near Meadowlark Marsh
Table 3.1.1-11. Highest measured concentrations of contaminants at Sier-Bath Gear Co. site
Table 3.1.1-12. Highest measured concentrations at theVince Lombardi Service Area

Table 3.1.2-1. Key information for the Metromedia Tract site
Table 3.1.2-2. General stratigraphy of the Metromedia Tract site
Table 3.1.2-3. Borings in or near the Metromedia Tract site
Table 3.1.2-4. Soil profile of the Westbrook soil type.
Table 3.1.2-5. Summary of properties of the Westbrook soil type
Table 3.1.2-6. Soil profile of the Ipswich soil complex
Table 3.1.2-7. Summary of properties of the Ipswich soil type
Table 3.1.2-8. Soil profile of the Sandyhook soil complex
Table 3.1.2-9. Summary of properties of the Sandyhook soil type
Table 3.1.2-10. Water quality summary of the Hackensack River sub-watershed

Table 3.2.1-1. Key information for the Kearny Point site
Table 3.2.1-2. General stratigraphy of the Kearny Point site
Table 3.2.1-3. Borings in or near the Kearny Point site
Table 3.2.1-4. Soil profile of Secaucus artifactual fine sandy loam (0-3% slope)
Table 3.2.1-5. Soil profile of Secaucus artifactual fine sandy loam (3-8% slope)
Table 3.2.1-6. Summary of properties of Kearny Point's Secaucus artifactual fine sandy loam
Table 3.2.1-7. Water quality summary of Kearny Point site
Table 3.2.1-8. Highest measured concentrations of contaminants at the BASF Corporation site
Table 3.2.1-9. Highest measured concentrations of contaminants at the NY Daily News Inc. site

Table 3.2.2-1. Key information for the Oak Island Yards site
Table 3.2.2-2. General stratigraphy of the Oak Island Yards site
Table 3.2.2-3. Borings in or near the Oak Island Yards site
Table 3.2.2-4. Soil profile of the Udorthents soil unit
Table 3.2.2-5. Summary of properties of the Udorthents soil unit
Table 3.2.2-6. Water quality summary of the Newark Bay/Kill Van Kull sub-watershed

Table 3.2.2-7. Highest measured concentrations of contaminants near the Oak Island Yards site

Table 3.3.1-1. Key information for the Essex County Branch Brook Park site
Table 3.3.1-2. General stratigraphy of the Essex County Branch Brook Park site
Table 3.3.1-3. Borings in or near the Essex County Branch Brook Park site
Table 3.3.1-4. Soil profile of the Boonton Red Sandstone Lowland soil type
Table 3.3.1-5. Soil profile of the Boonton Red Sandstone Lowland soil type
Table 3.3.1-6. Summary of properties of the Boonton Red Sandstone Lowland soil type
Table 3.3.1-7. Soil profile of Udorthents Boonton Red Sandstone Lowland soil type
Table 3.3.1-8. Summary of Udorthents Boonton Red Sandstone Lowland Substratum soil type
Table 3.3.1-9. Soil profile of Udorthents Loamy Fill Substratum soil type
Table 3.3.1-10. Summary of properties of Udorthents Loamy Fill Substratum soil type
Table 3.3.1-11. Soil profile of Urban Land Boonton Red Sandstone Lowland Substratum soil
Table 3.3.1-12. Summary of Urban Land Boonton Red Sandstone Substratum Lowland soil type
Table 3.3.1-13. Water quality of Lower Passaic River (4th St to Second R.) subwatershed
Table 3.3.1-14. Highest measured concentrations of contaminants at the NJ Transit site
Table 3.3.1-15. Highest measured concentrations of contaminants at the Meineke site
Table 3.3.1-16. Highest measured concentrations at Branch Brook Maintenance Garage
Table 3.3.1-17. Highest measured concentrations of contaminants at the Getty Service Station

Table 3.3.2-1. Key information for the Dundee Island Park/Pulaski Park site
Table 3.3.2-2. General stratigraphy of the Dundee Island Park/Pulaski Park site
Table 3.3.2-3. Borings in or near the Dundee Island Park/Pulaski Park site
Table 3.3.2-4. Soil profile of the Urban land soil type
Table 3.3.2-5. Soil profile of the Riverhead soil type
Table 3.3.2-6. Summary of the Riverhead soil type
Table 3.3.2-7. Water quality summary at the PVSC building on the Passaic River
Table 3.3.2-8. Highest measured concentrations at Roberto Clemente Field site
Table 3.3.2-9. Highest measured concentrations of contaminants near Kalama Chemical Inc.

Table 3.3.3-1. Key information for the Clifton Dundee site 902
Table 3.3.3-2. General stratigraphy of the Clifton Dundee site 902
Table 3.3.3-3. Borings in or near the Clifton Dundee site 902
Table 3.3.3-4. Soil profile of the Urban land soil type
Table 3.3.3-5. Soil profile of the Riverhead soil type
Table 3.3.3-6. Summary of Riverhead soil type
Table 3.3.3-7. Water quality summary of the Lower Passaic River sub-watershed
Table 3.3.3-8. Highest measured concentrations of contaminants at the Clifton Dundee site 902