US ARMY CORPS
OF ENGINEERS
NEW YORK DISTRICT

LIBERTY STATE PARK, HUDSON-RARITAN ESTUARY

ECOSYSTEM RESTORATION

DRAFT INTEGRATED FEASIBILITY REPORT & ENVIRONMENTAL IMPACT STATEMENT

Engineering Appendix

July 2004

Liberty State Park, Hudson-Raritan Estuary

Ecosystem Restoration

Draft Integrated Feasibility Report & Environmental Impact Statement

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New York District
U.S. Army Corps of Engineers

July 2004

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Executive Summary

New York District has completed this draft Integrated Feasibility Report/Environmental Impact Statement (FR/EIS) for the Liberty State Park Ecosystem Restoration Project in accordance with the requirements of NEPA to assess the need for modifying the existing degraded habitat, to evaluate the effects of restoration activities, and to establish a plan that maximizes environmental benefits while minimizing economic costs.

The purpose of the project is to ameliorate the adverse impacts associated with past filling activities on the project site, with the overall purpose of improving the environmental quality of the area. This previous mudflat was altered due to past fill activities and is consequently a less productive habitat. The site is dominated by invasive species, which are expected to expand and overwhelm the various vegetative habitats on site without the implementation of ecological management measures described in the plan recommended in this report.

Liberty State Park (LSP) Ecosystem Restoration Project is part of the Hudson-Raritan Estuary (HRE) Ecosystem Restoration Feasibility Study being carried out under the U.S. Army Corps of Engineers General Investigations Program. This feasibility study was authorized in a resolution of the Committee on Transportation and Infrastructure of the U.S. House of Representatives, dated 15 April 1999, which reads in part, "Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That, the Secretary of the Army (the U.S. Army Corps of Engineers) is requested to……..(determine) the feasibility of environmental restoration and protection relating to water resources and sediment quality within the New York and New Jersey Port District (much of the lower Hudson Raritan Estuary), including but not limited to creation, enhancement and restoration of aquatic, wetland and adjacent upland habitats." The LSP project is the first implementation of the goals of the HRE Comprehensive Restoration Implementation Plan as defined in the Needs and Opportunities Report (PANYNJ, 2003).

The proposed LSP restoration project is located in Jersey City, Hudson County, New Jersey, on the western side of Upper New York Bay. It is located on the waterfront across the Upper Bay from lower Manhattan and adjacent to the Statue of Liberty and Ellis Island. The proposed project area is approximately 234 acres of mostly undeveloped semi-degraded parkland within Liberty State Park's 598 terrestrial acres. Liberty State Park has an additional 523 tidal acres, for a total of 1,121 acres. The park itself is bounded by the New Jersey Turnpike to the west, by the Morris Canal to the north, by the Upper Bay to the east and by the "Black Tom" cove to the south.

Numerous surveys, studies, and extensive literature surveys have been conducted to establish necessary baseline information to identify potential restoration options and evaluate the potential for control of invasive species and conversion to more desirable habitats currently underrepresented in the HRE. These underrepresented habitats include salt marsh, deep-water emergent palustrine marsh and significantly enhanced terrestrial habitats such as maritime grassland, scrub-shrub and hardwood forest, with a superior mix of native and wildlife-friendly species. Some of the biological tasks conducted include literature review, existing vegetative community mapping, jurisdictional wetland delineations, faunal surveys, and existing and proposed project habitat evaluation. The results indicate strong opportunities for increasing habitat functionality at this site. Implementation of the plan recommended in this report is expected to increase and restore more desirable communities, provide more cover, nesting, and breeding habitat for wildlife, and increase species richness. Some of the engineering tasks conducted included a topographic and bathymetric survey, geotechnical and HTRW analysis, water level and water quality monitoring, hydraulic, hydrologic and hydrodynamic modeling.

Technical screening analysis was performed throughout the project development stages for each of three implementation phases of the proposed project: tidal marsh, fresh water wetlands and terrestrial habitat. For the tidal marsh, the single-inlet creek was determined to be the most efficient solution, meeting both technical and biological requirements the most successfully. Subsequently, the shape, width and length of the proposed tidal channel, and its associated intertidal flats, low marsh and high marsh habitat were refined through hydrodynamic modeling. The tidal channel is designed to maximize functional habitat value of the proposed tidal marsh area by maintaining the largest feasible tidal range, and regular tidal flooding and drainage through the maximum area available.

For the fresh water wetland phase, four separate plans were technically analyzed, each delivering different amounts of acceptable quality fresh water to the target area in the central portion of interior of the site. The selected freshwater plan provides the most amount of water for habitat creation and enhancement without expensive and high-maintenance mechanical pumping from already-stressed municipal water supplies. The recommended plan incorporates a self-maintaining gravity-based system for supplying adequate quality water. This water-delivery system gathers additional water from the NJ Transit parking area, which is then filtered in an enhanced wetland area adjacent to the Liberty Science Center (LSC). The levels of the LSC wetland are controlled by a self-adjusting weir, which directs water through a diversion pipe underneath Phillip Street to an additional *Phragmites* dominated bio-filter wetland. This biofilter wetland removes remaining suspended sediment, potential toxicants and unwanted nutrients. From the biofilter, a created swale will deliver the substantially enhanced volume and quality of water to a created permanent deep-water emergent marsh. The deep marsh will provide fish, reptile and other habitat not currently found in Liberty State Park. During high-flow periods, excess water will drain out of the deep-emergent marsh into an infiltration basin, in effect creating an additional, periodically flooded wetland. The high permeability of the infiltration basin soil will allow water to penetrate underlying groundwater, in turn feeding an existing jurisdictional freshwater wetland.

The third phase of this restoration project involves improving ecological functional value on the terrestrial portions of the site. Measures include the selective removal of invasive species and other undesirable vegetation. If monitoring indicates that further measures are necessary, the District will consider addition of topsoil and/or sand to selected areas to discourage unwanted vegetation, and promotion of native vegetation through replanting and/or seeding. A berm is planned for the southwestern portion of the site, using the material excavated from the proposed tidal marsh area. The excavated material will be completely encapsulated within the berm. The berm will act as an isolation barrier for sensitive species and add topographical relief to a relatively flat site. Most terrestrial habitats will be maintained in the same vegetative community type, while simultaneously controlling invasive species and encouraging native species. Thus, a mosaic of high-functional value terrestrial habitat will be established including hardwood and maritime forest, scrub-shrub, maritime grassland and old field. Where possible, grassland habitat to be enhanced will be contiguous to enhance feeding areas for raptors and isolation for ground nesting birds. The functional integrity of the existing forested areas will be maintained and enhanced.

The District's National Ecosystem Restoration (NER) plan will result in a significant increase in wildlife habitat and estuarine functional value when compared to existing habitat. The NER plan will increase the availability of cover, foraging, nesting and breeding habitat for Federal and state threatened and endangered species; restore USEPA designated priority wetlands (e.g., salt marsh); improve water quality; increase the value and availability of spawning and nursery habitat for anadromous fish species; enhance wetland habitat for migratory waterfowl; assist in the enhancement of wildlife habitat corridors; and increase aesthetics and opportunities for passive recreation; and promote science education. In addition the NER plan will meet the goals and objectives for many programs, acts and policies on institutional, public and technical levels.

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LIBERTY STATE PARK, HUDSON-RARITAN ESTUARY ECOSYSTEM RESTORATION

DRAFT INTEGRATED FEASIBILITY REPORT & ENVIRONMENTAL IMPACT STATEMENT

ENGINEERING APPENDIX

1. INTRODUCTION

1.1 General

The New York District Corps of Engineers is presently conducting a Feasibility Study of ecosystem restoration opportunities within the Hudson-Raritan Estuary, which is delineated as the surrounding greater metropolitan New York City region, within an approximate 25-mile radius of the Statue of Liberty (Figure 1.1). During the reconnaissance phase, the District conducted an extensive restoration-opportunity identification and screening process within the study area, in cooperation with Federal and state resource agencies, and environmental interest groups. The reconnaissance study identified over 80 sites that may meet Federal budgetary criteria and were recommended for inclusion in the Feasibility Study. The non-Federal sponsor for this feasibility phase, the Port Authority of New York and New Jersey (PANYNJ), in consensus with the New York/New Jersey Harbor Estuary Program (HEP) Habitat Work Group and agencies from both states, identified 13 sites as initial Building Blocks of the Feasibility Study's Comprehensive Restoration Implementation Plan (CRIP).

Liberty State Park is the first site to move through the Feasibility Study phase. The New Jersey Department of Environmental Protection (NJDEP) has expressed interest in becoming the non-federal cost sponsor for the final design and construction phases of the project. The Liberty State Park site is located in Jersey City, New Jersey approximately two (2) miles south of the Holland Tunnel Crossing and on the mainland, just west of Ellis Island. The 1,122-acre park is at the confluence of the Hudson River and the Upper New York Bay in Jersey City, New Jersey (see Figures 1.1 and 1.2). It is bounded by Morris Canal to the north and Black Tom to the south. The east side of the park faces New York Harbor, and the potential restoration site is within the boundaries of Liberty State Park on a section of property generally bounded by Audrey Zapp Drive on the north side, Phillip Drive on the west side, Thomas McGovern Drive on the south side and Freedom Way along the east side (Figure 1.3). The interior 225 acres of the park are restricted for public access due to the presence of sediment contaminants that exceed residential exposure levels. The overall study focuses on environmental restoration opportunities within the 225 acres and the existing wetland area adjacent to Liberty Science Center, which is immediately west of the park.

Figure 1.1 Location Map of Hudson-Raritan Estuary, as Defined in the Hudson-Raritan Estuary Reconnaissance Study of 2000 (next page)

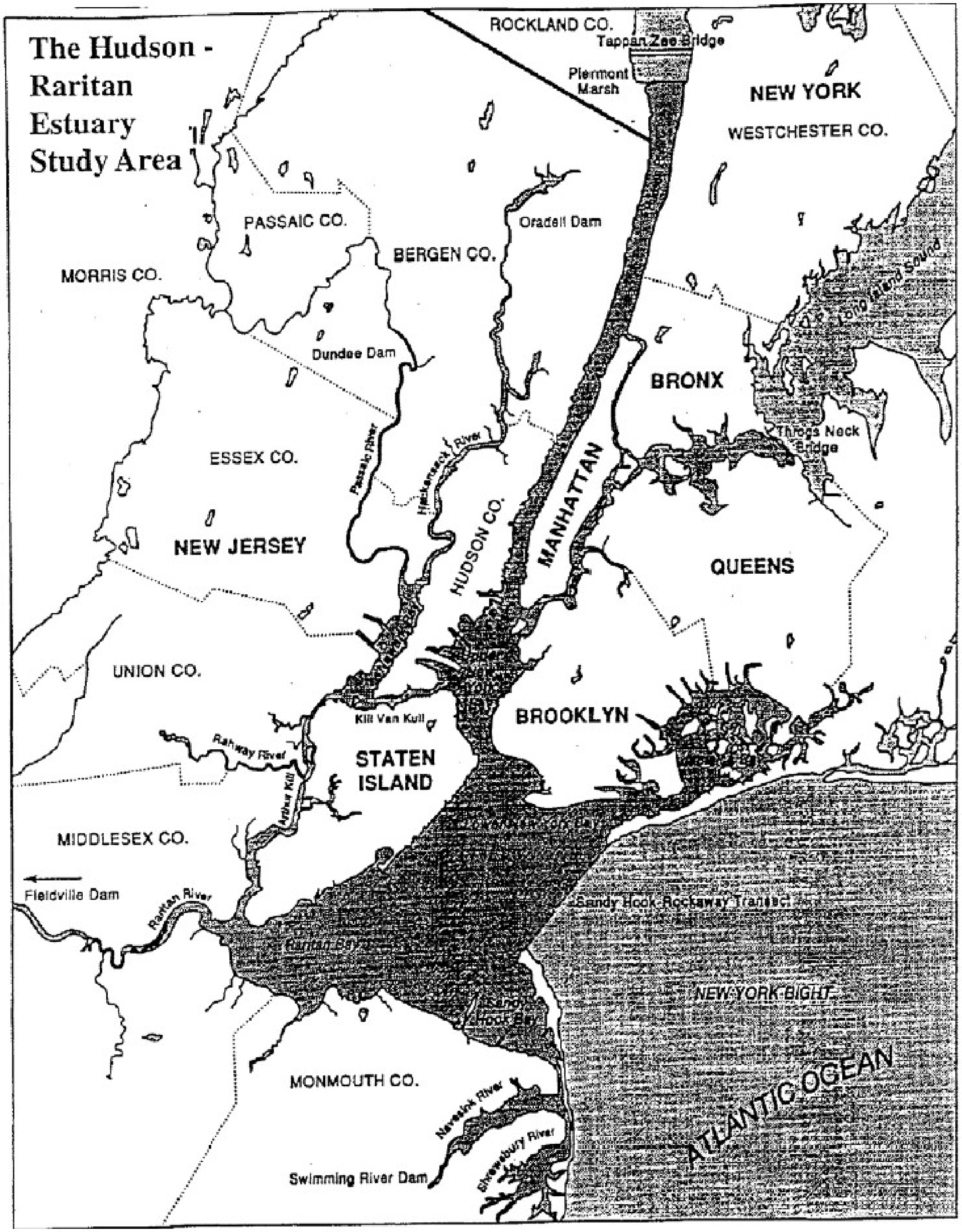


Figure 1.1 Location Map of Hudson-Raritan Estuary, as defined in the Hudson-Raritan Estuary Reconnaissance Study of 2000

Figure 1.2 Location Map of Liberty State Park

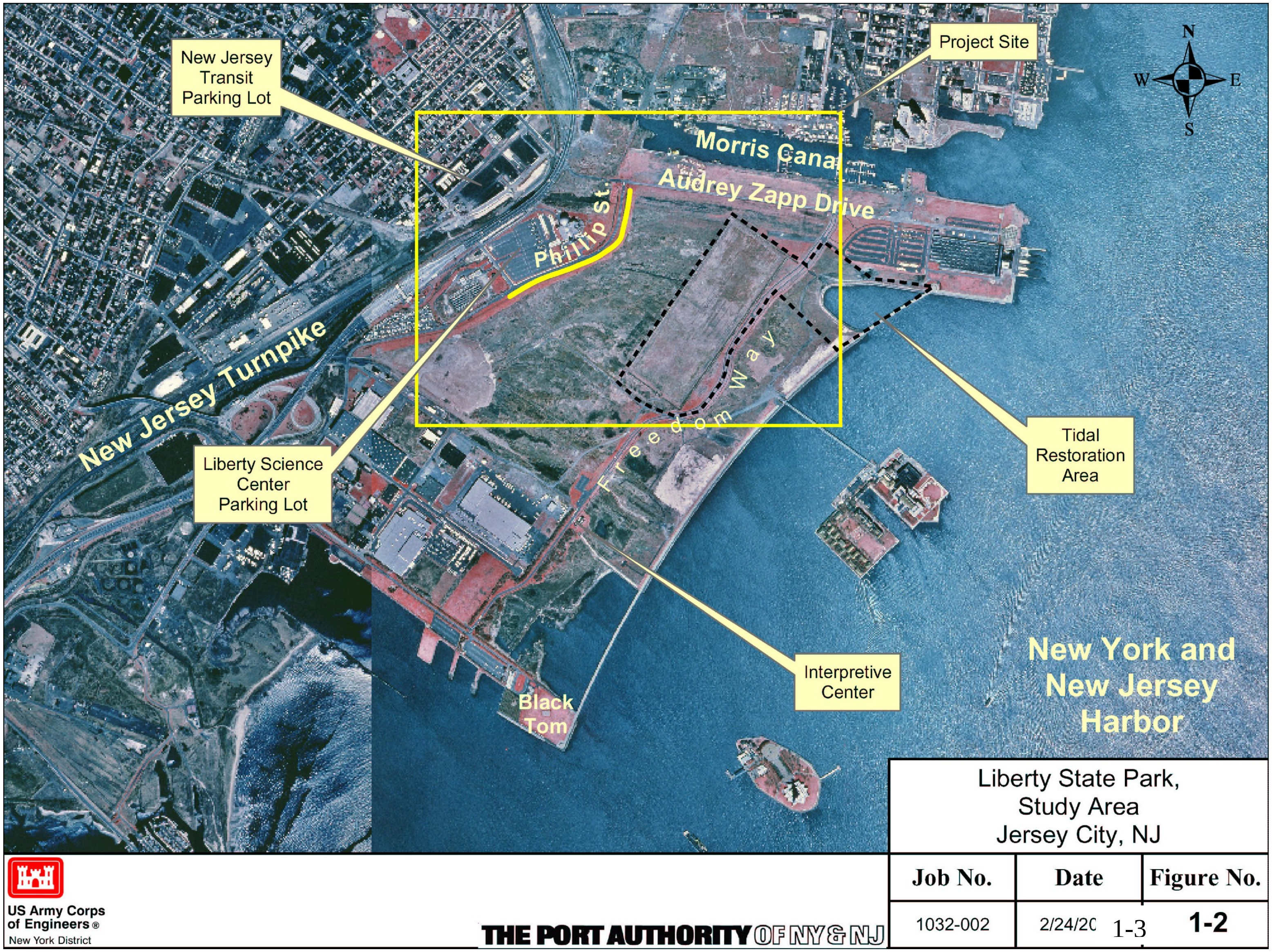


Figure 1-3 Details of Liberty State Park Ecosystem Restoration Project

1.2 Project Objectives

Environmental restoration opportunities being considered for Liberty State Park include the creation of a tidal marsh in the center of the park, and enhancements to the uplands and freshwater wetlands within the undeveloped area in the park. Materials will be excavated from the proposed tidal marsh area, capped and used to create a grassland berm in the southwestern section of the park. A narrow channel will connect the tidal marsh to the North Cove. Storm water will be collected from adjacent areas and will be diverted to feed freshwater wetlands on the site, creating shallow and deep emergent marshes. Nuisance plant species will be controlled, and native grasslands, shrublands and forests will be planted. The uniqueness of the three primary restoration components in analysis, function, and habitat, requires that each be evaluated separately. Therefore, the restoration feasibility analysis and evaluation has been broken into three separate components: (1) a tidal wetland, (2) a freshwater wetland system, and (3) upland areas.

2. SITE DESCRIPTION

2.1 General

Liberty State Park was an intertidal mud flat and salt marsh that was filled and used as a railroad yard during the growth of the New York City metropolitan area. A majority of the soil within the park consists of historic fill materials that were deposited to stabilize the surface between 1860 and 1919 (MacFarlane 2001). Materials from construction projects and refuse from New York City were also included in the fill material. Between 1864 and 1967, the Central Railroad of New Jersey (CRRNJ) used the site as a rail yard for both freight and passenger service. In 1967, the CRRNJ discontinued operations at the site, and over the next few years, the land was abandoned and subsequently acquired by the New Jersey Department of Environmental Protection (NJDEP) Division of Parks and Forestry (NJDPF) (LSP 2003).

The area in the center of the park has remained undeveloped and access is restricted to the public due to the presence of polynuclear aromatic hydrocarbons (PAHs), pesticides, and metals that exceed the NJDEP residential clean up criteria (MacFarlane 2001). Some of the fill in the undeveloped area is comprised of materials dredged from the Upper Bay during construction of the LSP causeway.

2.2 Topography/Bathymetry

A topographical survey was collected during the summer and fall of 2003. For the entire proposed project site, except for the North Cove, a 1 inch = 30 ft scale map was developed using GPS Real Time Kinematic techniques to establish photogrammetric mapping, with surveyed points not more than 100 ft apart. The contour intervals were in 1 ft increments. Conventional survey by angle and distance method was performed to obtain roadway and ditch cross sections, existing storm and sanitary sewer structure locations, tide gages, utilities and other features not depicted in the base map developed by the photogrammetry. A combined topographic/bathymetric survey is displayed in Figures 2.1 – 2.5 (see enclosures for 1:100 scale maps of Figures 2.2-2.5). Information about the survey can be found in Liberty State Park: The Ground Survey Control Report (USACE 2004).

The GPS field observations were conducted and/or using as guidelines with modifications the specifications given in the "Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques", Version 5.0, August 1, 1989, for First-Order, Class 1, surveys having a relative accuracy between project stations of at least 10mm + 1:100,000 at the 95% confidence level for each component of the measured vector. The accuracy standard of the orthometric heights relative to the vertical control used for this project is +/-2 cm in elevation. The horizontal datum is referenced to the New Jersey State Plane Coordinate System, North American Datum of 1983. The vertical datum is referenced to the North American Vertical Datum of 1988.

The bathymetric map is a result of sounding from bank-to-bank profiles taken every 50 ft in the North Cove in November 2003. The sounding data was collected using class 2 survey standards in accordance with EM 1110-2-1003, using a survey vessel, innerspace Model 448 Echo Sounder, Garmin GPSMAP76S and the Coastal Oceanographics "HYPACK" Software.

The park is relatively level as a result of its historical use. Small, linear berms between the old railroad tracks were created during the construction of the railroad yard. Changes in elevation exist typically only as a result of the additional deposition of dredged materials or construction of dredged material containment berms following cessation of rail operations. Additional changes in the relief within the park occurred with the commencement of development of the park, which included the creation of the shorefront promenade and the removal of the pier system that serviced the rail operations.

Inland from the flat ground of the park, the elevations increase gradually. The slope of the land draining to the exterior of the park generally ranges from only 0 to 2%. The highest point in the area which drains toward the park, with the exception of the nearby elevated NJ turnpike and Conrail rail line, is within the NJ Transit Light Rail parking lot, at 20.4 ft NAVD1988. The lowest point in the area is at the outlet to the Morris Canal, at elevation –1.56 ft NAVD1988. The slope of the drainage ditches on either side of Phillip Street is approximately 0.2 %.

The North Cove is body of water on the western shore of Upper New York Bay with a riprap on all its shores. It is completely open to the bay, with the exception of the Liberty State Park Causeway – a pedestrian walkway that has bridge piers spaced approximately every 30-40 ft. The cove is approximately 550 ft wide in the middle and 900 ft wide at its opening to the bay. Boat wakes from the passenger ferries taking commuters to lower Manhattan impact the shores of the cove, which is why its shores are armored with riprap. It is –7 ft NAVD88 in the middle (approximately –9 ft MLLW). The –3.5 ft NAVD88 contour is approximately 50 ft from the western banks of the cove in the proximity where the tidal channel is proposed. The maximum depth of the cove is -11 ft NAVD88, and it has an average slope of 1V:100H. Information about the survey can be found in the Liberty State Park: The Ground Survey Control Report (USACE 2004)

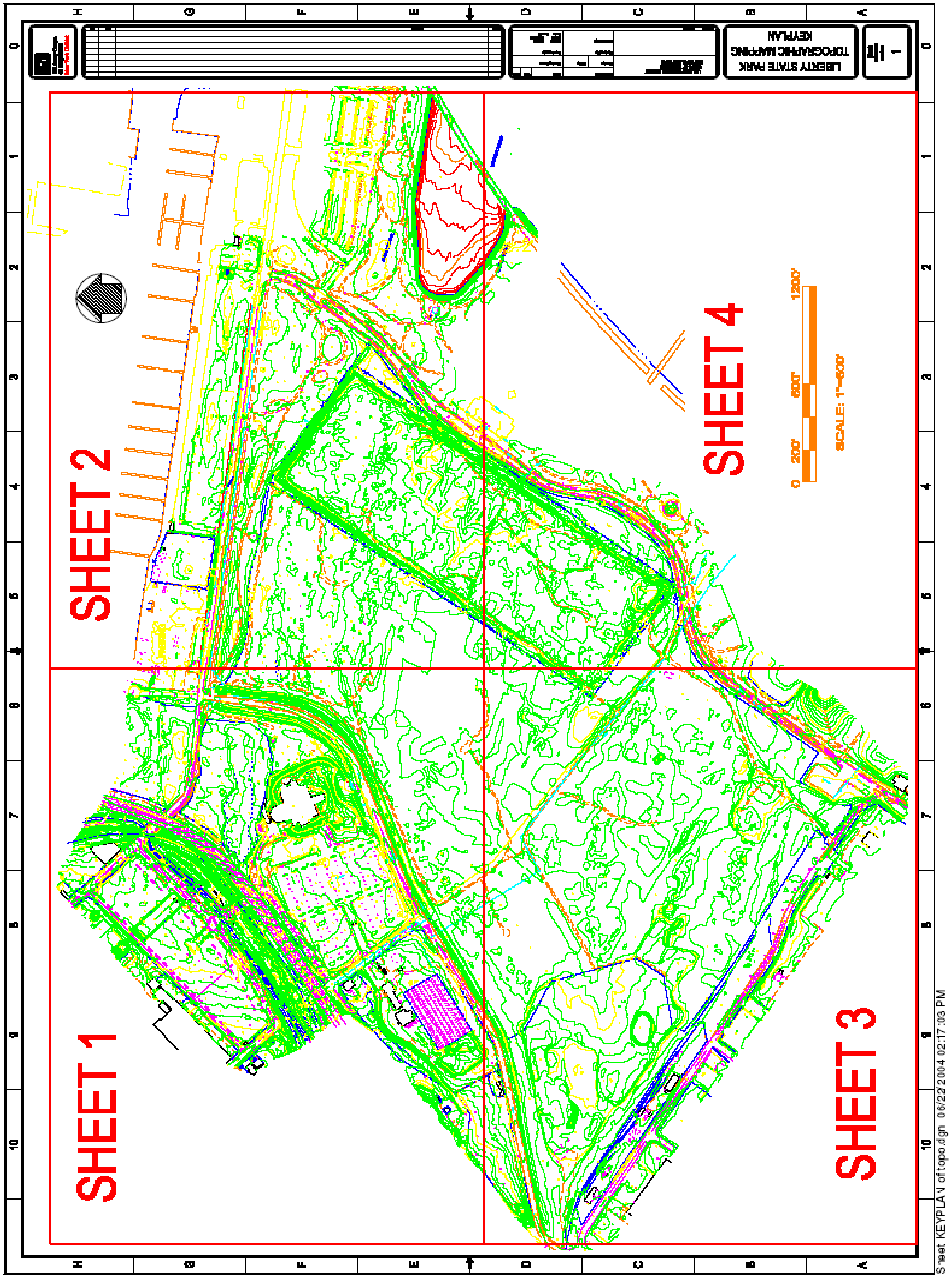


Figure 2.1 – Overview of LSP topographic/bathymetric maps

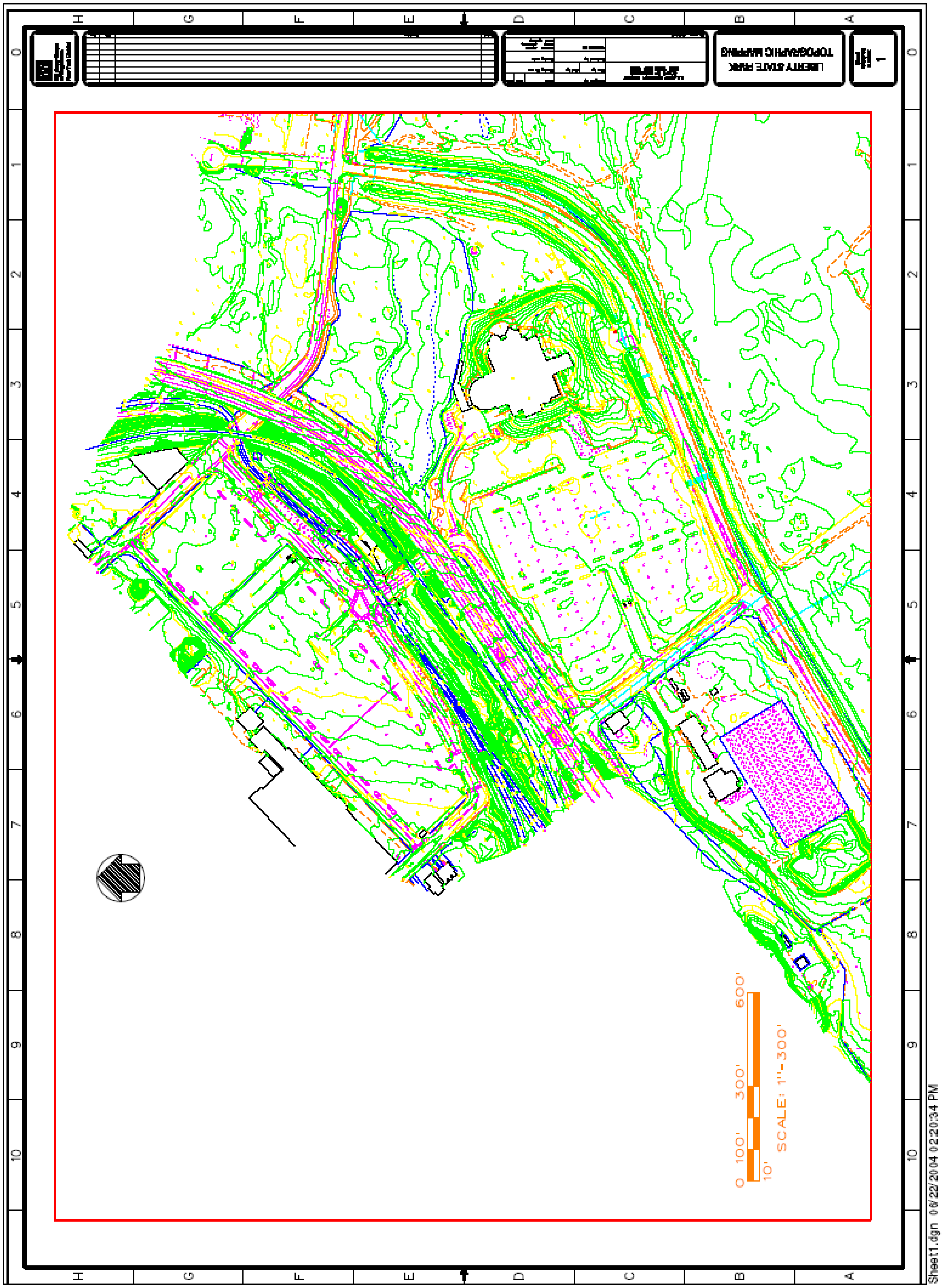


Figure 2.2 – LSP Topographic/Bathymetric Map, Sheet 1

Figure 2.3 – LSP Topographic/Bathymetric Map, Sheet 2

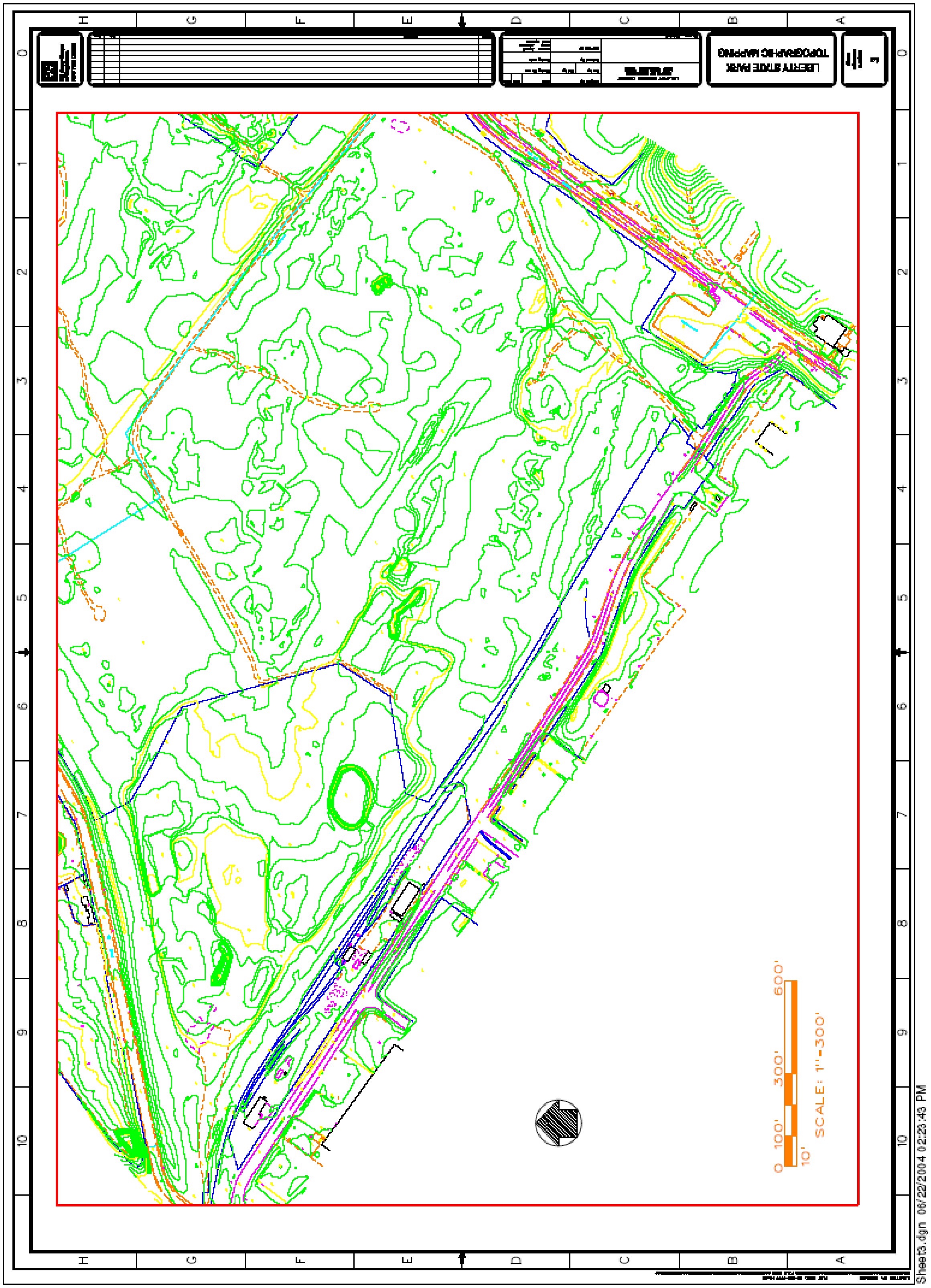


Figure 2.4 – LSP Topographic/Bathymetric Map, Sheet 3

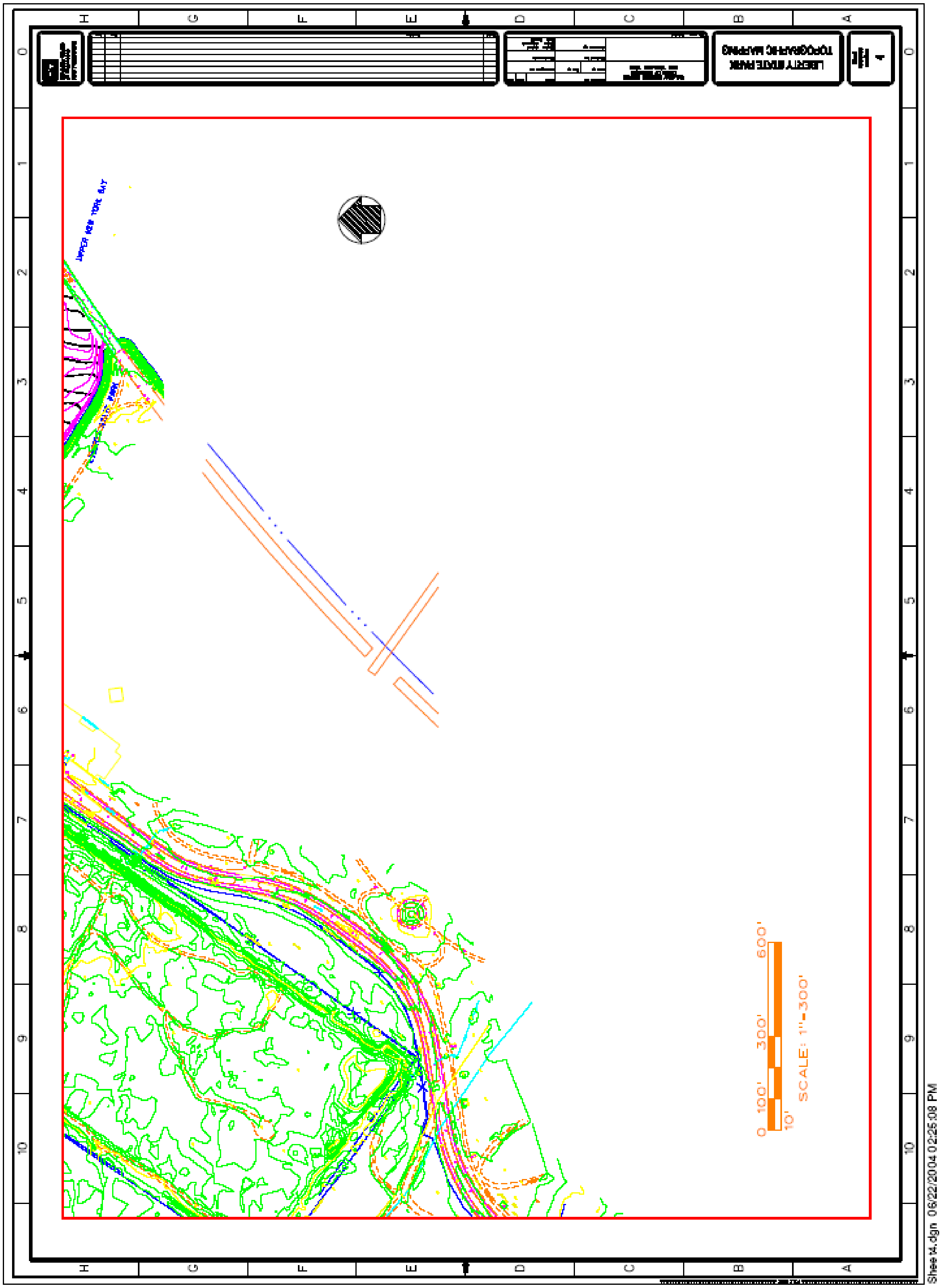


Figure 2.5 – LSP Topographic/Bathymetric Map, Sheet 4

2.3 Soils

The results of the geotechnical analysis indicate that the soils vary considerably across the site. Both fine-grained and course grained soils are present. Soils in virtually all of USCS soil classification are found on site. The project site is overlain with coarse-grained (sands, silty sands, silty gravels, etc.) soils. Average thickness of this coarse-grained layer is about 14-ft, although local variations exist with both thinner layers (3-ft) and thicker layers (30-ft plus) encountered. Underlying this coarse-grained layer is a layer of fine-grained soil (clay, clay with traces of shells, sand, and gravel, etc.). This fine-grained layer was observed in about 85% of the drill holes. On average, this fine-grained layer was encountered at a depth of about 13-ft, although local variations exist. Average thickness of this fine-grained layer is about 12-ft, although local variations exist with both thinner layers (1.5-ft) and thicker layers (27-ft plus) encountered. Subsequent lower layers of coarse-grained and then fine-grained soils were occasionally encountered. Man-made debris (refuse) materials were found in about 27 of the 49 total drill holes. Near surface excavation of this material should present no unusual excavation problems. However, deeper excavations, notably excavation of the proposed tidal inlet in the vicinity of the North Cove, may require additional earth moving and dewatering equipment to allow excavation to take place within the soft clay layer. An initial phase (Phase I) of drilling and sampling program was performed during August and September of 2003. Thirty-eight drill holes were completed and a comprehensive geotechnical testing program was performed. An additional phase (Phase II) of drilling and sampling program was performed in February 2004. The results of the geotechnical investigation can be found in the Geotechnical Site Investigation, Liberty State Park, Jersey City, NJ. Final Report. (USACE 2004).

2.4 HTRW Testing

A full explanation of the HTRW testing and analysis can be found in the main report – the Draft Integrated Feasibility Report and Environmental Impact Statement, June 2004. In summary, the NJDEP has conducted numerous environmental investigations within LSP since 1978. The results from these studies show evidence of relatively widespread soil contamination, but generally at levels below applicable hazardous-waste thresholds. Heavy metals, including arsenic, lead, zinc, and copper, and polynuclear aromatic hydrocarbons (PAHs) are nearly ubiquitous in fill materials at the site, and commonly occur at concentrations above the applicable NJDEP Soil Cleanup Criteria (SCC), the NJDEP Non Residential Soil Cleanup Criteria (NRSCC). The concentrations of PAHs and metals in common fill materials are generally within the ranges listed in the NJDEP Historic Fill Database, and appear to meet the general definition of "historic fill" under Technical Rules for Site Remediation (N.J.A.C. 7:26E App.D). Therefore, soils other than those containing chromate chemical production waste (CCPW) or petroleum free-product can be probably managed on site, such as by capping with a layer of clean soil and establishing vegetative cover. However, soils that are saturated with petroleum or which contain CCPW generally require either off-site disposal or on-site stabilization. Results from NJDEP investigations are extensive and provide detailed soil contamination data to an approximate depth of five feet below ground surface (bgs) throughout the site. However, because potential ecosystem restoration alternatives consider removal of fill in the 45-acre area to historic marsh and tidal levels, which are at least 12-15 ft bgs, New York District conducted more intensive site HTRW investigations for the feasibility study.

During the first phase in August 2003, 40 soil/sediment contaminant samples were taken throughout LSP, 38 on land, 2 in the North Cove (Figure 2.6).[1] Samples were taken from 30 feet bgs for two reasons: 1) to find the original, historic surface layer and 2) the assumption that over time, amounts of contamination, spilled fuel oil, hexavalent chromium, other heavy metals and VOA's would have migrated downward through the back fill. All samples were analyzed for: Volatile Organics Library + 15 (VOA+15), Acid Base Neutral Library +25 (ABN+25), Pesticides/PCB's (Pest/PCB), Total Petroleum Hydrocarbons (TPHC), RCRA Metals, Percent Solids (% solids). Considering the known chrome contamination additional analyses would be conducted for hexavalent chromium. The analysis for hexavalent chromium was sent to a laboratory specializing in that particular analysis. The results from this phase showed a relatively low number of borings, 16 out of 38, with measurable contamination at 30 feet bgs. No PCBs or VOAs were found in any of the samples. TPHC, dieldrin, Acid Base Neutrals, arsenic, cadmium, copper, lead, mercury, and nickel were sparsely scattered throughout the site and few exceeded NJDEP IGWSCC/NRDCSCC thresholds. It is worth noting that hexavalent chromium, the primary concern of this HTRW investigation, came in below the threshold of 10ppm for all samples in which it was detected. One sample (#20 in North Cove) had significant test results and is located at the entrance of the proposed tidal creek.

A second phase was conducted in February 2004, based on results of the August 2003 investigations (Figure 2.7). This round focused on the route of the proposed tidal creek and collected continuous samples from the surface to 15 feet bgs. No pesticides, PCBs, or Volatile Organics were detected in this round. Two areas of concern were identified in the second round, in the area of North Cove and the 45-acre containment area. Samples collected in the second round closest to sample point 20 from the first round showed the highest levels of metals, including hexavalent chromium, arsenic, lead, copper, and zinc. Other materials include petroleum hydrocarbons and semi-volatile organics, also in the North Cove and the 45-acre containment area. At the time of construction, procedures should be in place to manage excavations from this area to ensure that minimal amounts of soil/sediment are released to the general environment and that excavated materials are disposed of properly and securely in the park's on-site placement area.

[1] HTRW samples were taken concurrently with Geotechnical samples.

Figure 2.6. 1st Round Geotechnical and HTRW sampling locations

Figure 2.7. 2nd Round HTRW sampling locations

2.5 Groundwater

As part of the geotechnical analysis (USACE, 2004), twelve (12) piezometers were installed as permanent piezometers in existing drill holes for long-term groundwater level monitoring and for future use in determining permeability (hydraulic conductivity) of the soil, if required. An additional eight (8) temporary piezometers were also installed in selected existing drill holes. Groundwater depths ranged from about 1.3-ft below existing grade to about 5.5-ft below existing grade, as measured from the twenty piezometers installed throughout the site. Fluctuations in groundwater levels up to 3.1-ft were observed in the piezometers. Groundwater gradients between piezometers were typically very flat. Groundwater flow direction and average gradient calculations suggests that groundwater flow direction is about N35^{o} and discharges towards the adjacent Morris Canal (Figure 2.8). A plan view of the groundwater contour map of the 15 November 2003 groundwater readings is shown in Figure 2.9. Due to the possibility of contamination in the ground water and/or proposed excavation elevations and soil contamination, the proposed plan includes an impervious clay layer to be placed where excavation will be necessary for the fresh water and tidal wetlands.

Figure 2.8 LSP Groundwater Flow Direction

Figure 2.9 LSP Groundwater Contours (ft NAVD88)

2.6 General Watershed Description

The area surrounding Liberty State Park is essentially fully developed with little room for additional development. Commercial and industrial development is immediately adjacent to the park to the west and south. Due to the historic use of the park as a rail yard, there is little historic drainage from outside the park into the park. Recent construction, such as the Liberty Science Center and the New Jersey Transit Light Rail Terminal and parking lot, contribute stormwater runoff to the fringes of the park but not to the interior.

Currently, the project site is encompassed within the interior of Liberty State Park. The streets adjacent to the park drain into ditches that discharge either into Morris Canal or into the Harbor.

2.7 Climatology and Precipitation

The climate of Jersey City, New Jersey is characteristic of the Middle Atlantic seaboard. Marked changes in weather are frequent, particularly during the spring and fall. The winters are moderate, and the summers are hot and humid with frequent thunderstorms. Precipitation is also moderate, with about 45 inches falling annually, well distributed throughout the year. Summer totals of precipitation are slightly higher than winter totals. Average monthly temperature ranges from 38 to 78 degrees F with extremes ranging from 22 degrees below zero to 105 degrees F at Newark, NJ. The growing season averages 174 days and the mean annual relative humidity varies from 53 to 73 percent. Prevailing winds are from the northwest with an average annual velocity of approximately 10 miles per hour. The number of days with rainfall of 0.01 inch or greater averages about 122 per year.

2.8 Tidal and Storm Surge Influences

The project is located on the banks of Upper New York Harbor, at the mouth of the Hudson River, which has a drainage area of xxx square miles. While the area originally was a tidal mudflat, filling activities and hardening of the shoreline disconnected the area from the tide. For this study, water level recorders placed in the North Cove, the South Cove and in Morris Canal observed tidal signals for a period of 6-14 weeks. Unfortunately the North Cove gage malfunctioned, and the data was not recoverable. Thus, the South Cove gage was the closest gage to the proposed tidal creek inlet in the North Cove. The results of the tidal analysis at the South Cove gage revealed that the diurnal tide range, great diurnal tide range, and spring tide range at Liberty State Park for the period of record 31-July 2003 to 11-Sept. 2003 was 4.69, 4.82 and 6.39 ft, respectively.

All the tidal datums computed can be found in table 2.1. Mean High Water (MHW) and Mean Low Water (MLW) are calculated by averaging the highest water level and lowest water level for each tide cycle in the period of record. Diurnal Tide Range (RangeM) is the difference between the MHW and MLW datums. In this region of the North Atlantic Ocean, there is one slightly higher tide within each two tide cycle segments. Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW) are calculated by averaging the highest water level and lowest water level within each two tide cycle segments. Great Diurnal Tide Range (RangeGD) is the difference between the MHHW and MLLW datums. Mean High Water Spring (MHWS) and Mean Low Water Spring (MLWS) are calculated by averaging the highest water level and lowest water level that occurs during each full and new moon (approximately twice a month). Spring Tide Range (RangeS) is the difference between the MHWS and MLWS datums.

The observations from the other gages were compared to the NOAA Tide Station 8518750 at The Battery, NY, 2000 ft accross the bay, and the signals were extrapolated to the 1983-2001 Tidal Epoch using the NOAA ,modified range ratio method. The results of the extrapolation revealed that the 1983-2001 Tidal Epoch for the South Cove diurnal tide range, great diurnal tide range, and spring tide range at Liberty State Park is 4.51, 4.84 and 5.60 ft, respectively. All the datums observed and calculated can be found in Table 2.1

The purpose of installing temporary water level recorders is to observe how the tide signal differs from published water level observations from nearby long-term stations. Having a few redundant water level recorder instruments installed is important to review the quality of the data, and to account for malfunctions in equipment that often occur in the marine environment. Morris Canal gage recorded water levels for over 3 months. Unfortunately the South Cove gage malfunctioned in the last 6 weeks of the data collection time period, and a North Cove gage malfunctioned for the entire data collection period. Table 2.1 shows that the Morris Canal behaves very similar (-/+ 0.1 ft) to the Battery gage, both in the first 6 week and the entire 17-week periods of record. However, the mean tide level for the South Cove was 0.4 and 0.45 feet lower than the battery and Morris Canal, respectively. Yet, the South Cove MTL was only 0.2 ft lower than the Tidal Epoch MTL at the Battery. The South Cove gage was considerably closer to the proposed project, and to the reference area used to design the tidal wetland portion of the project. Thus, the South Cove reconstructed tidal datums were used to evaluate the tidal wetland design. One higher water level event was analyzed (see section 5), to evaluate the flooding/drying and velocity patterns in the proposed marsh when those events occur.

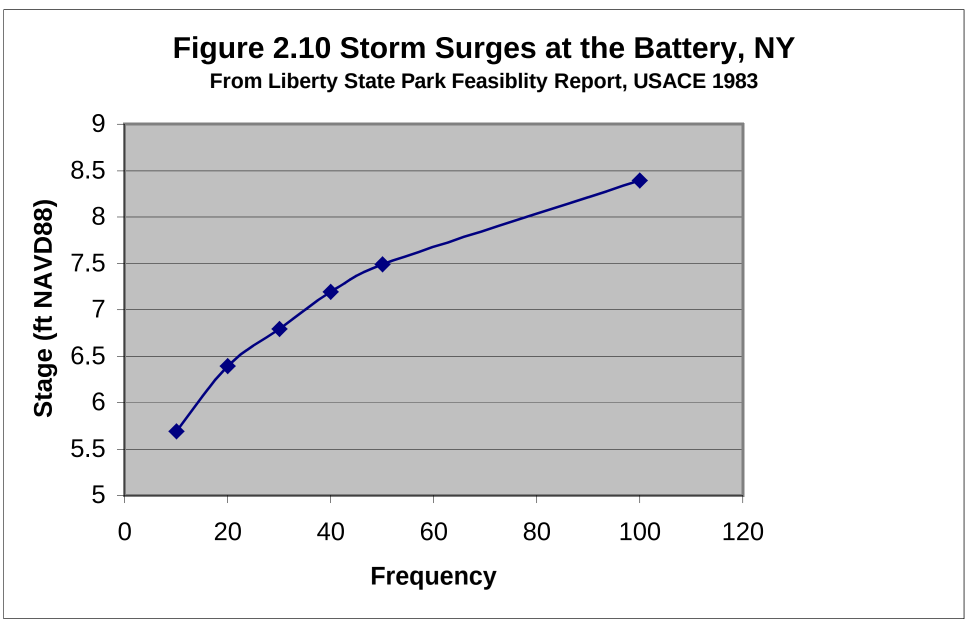
2.9 Storm Surges

Hurricanes and Northeaster storm events frequently influence the tide stage in Upper New York Harbor. The Liberty State Park Causeway Project (USACE, 1983) determined the frequency of these high water events (Figure 2.10). Morris Canal and the North Cove will experience similar stages for the same storm surge events. Audrey Zapp Drive on the north side, Phillip Street on the west side, Thomas McGovern Drive on the south side and Freedom Way along the east side all lie at elevations between +8 to +10 ft NAVD88. These surrounding roadways act as levees for more frequent storm surge events. The proposed tidal wetland will be connected to the bay via the proposed tidal creek inlet in the North Cove, thus creating a break in the levee system created by the surrounding roads. Fortunately, the existing elevations of the upland adjacent areas surrounding the proposed tidal wetland currently are about +10ft NAVD88, and the proposed plan places an additional 3 ft of fill on top of these areas. Thus, for lower frequency events, the proposed tidal wetland will flood, but the floodwaters would be contained within the wetland. It is anticipated that the wetland will be resilient enough to withstand these flood events, just as natural tidal wetlands currently do in the vicinity of Liberty State Park. In the proposed Fresh Water Wetland area, the scenario is the same as the fresh water wetland, except it does not break the levee system created by the surrounding roads.

Location	Morris Canal	South Cove	NOAA-NOS Battery, NY	Morris Canal	NOAA-NOS Battery, NY	NOAA-NOS Battery, NY	Reconstructed* South Cove
start	31-Jul	31-Jul	31-Jul	31-Jul	31-Jul	1983 to	1983 to
finish	11-Sep	11-Sep	11-Sep	21-Nov	21-Nov	2001	2001
MHWS	3.01	2.72	3.14	3.17	3.28	2.44	2.29
MHHW	2.36	1.96	2.58	2.24	2.43	2.28	1.91
MHW	2.25	1.84	2.24	2.19	2.12	1.95	1.75
MTL	-0.06	-0.51	-0.11	-0.08	-0.08	-0.31	-0.51
MLW	-2.37	-2.85	-2.46	-2.34	-2.27	-2.57	-2.77
MLLW	-2.39	-2.86	-2.46	-2.36	-2.47	-2.78	-2.93
MLWS	-3.20	-3.67	-3.14	-3.26	-3.24	-3.06	-3.31
RangeM	4.62	4.69	4.70	4.53	4.39	4.52	4.51
RangeGD	4.75	4.82	5.04	4.60	4.90	5.06	4.84
RangeS	6.21	6.39	6.28	6.43	6.52	5.50	5.60

*Reconstructed South Cove Tidal Datums were used for the design of the tidal wetland. They were obtained by comparing the South Cove and Battery datums from 31-Jul-2003 to 11-Sep-2003, and reconstructing them to the 1983-2001 tidal epoch, using the Battery as the primary record.
**All elevations are in ft NAVD88

Table 2.1 Tidal Datums from Water Level Recorders in the Vicinity of Liberty State Park



3.SELECTED NER PLAN

The Federal objectives in making investments in water resource/ecosystem restoration projects are to contribute to National Ecosystem Restoration (NER) and National Economic Development (NED). USACE planning objectives must be consistent with Federal, State, and local laws and policies, and technical, economic, environmental, regional, social, and institutional considerations. Recommended restoration plans should maximize benefits to the environment and meet local preferences to the fullest extent possible. The Draft Integrated Feasibility Report and Environmental Impact Statement discusses at length the process and analysis that took place to arrive at the Selected NER Plan. Figure 3.1 is the Selected NER Plan.

The Selected NER Plan can be broken down into 3 components: 1) Fresh Water Wetland, 2) Tidal Wetland, and 3) Upland Management Area. The proposed Fresh Water Wetland is located in the Northwest section of the park. The proposed construction activities are to create the following palustrine communities noted in Figure 3.1: Deep Emergent Marsh, Shallow Emergent Marsh, and Shrub Swamp. Maritime Grass, a terrestrial community, is also a component of the Fresh Water Marsh. Figure 3.2 is a close-up of the proposed Fresh Water Wetland plan.

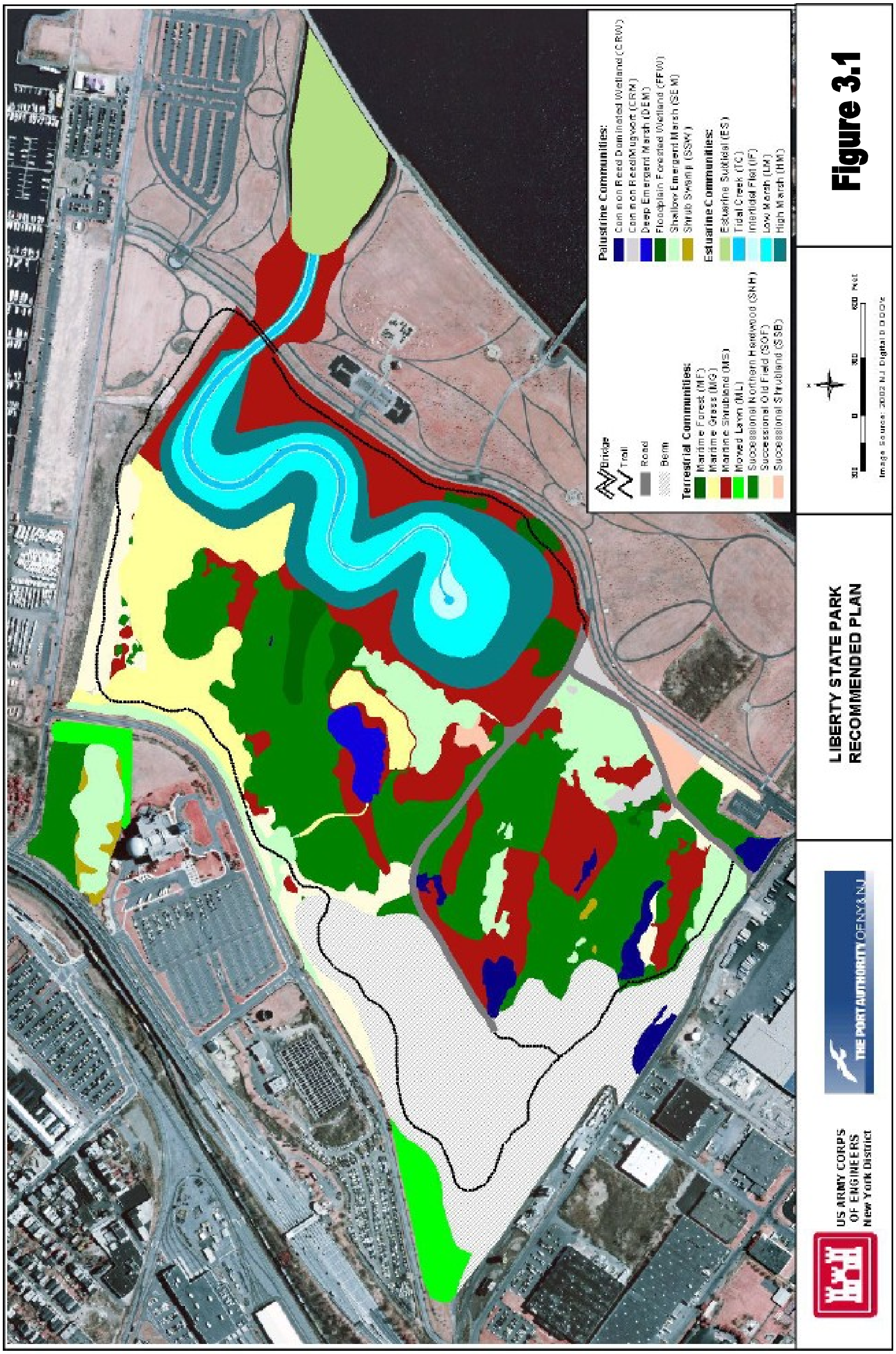
The proposed Tidal Wetland is located in the northeast section of the park. The proposed construction activities are to create the following estuarine communities noted in Figure 3.1: Estuarine Subtidal, Tidal Creek, Intertidal Mudflat, Low Marsh and High Marsh. The fill material that is removed to create the estuarine communities will be placed in the southwest corner of the site, as noted in Figure 3.1. Maritime grassland is proposed on top of disposal area.

The remaining area show in figure 3.2 not included in the fresh water wetland, tidal wetland, and disposal area, with the exception of the mowed lawn parcels, incorporates the upland management areas. The proposed construction activities in the upland management area are currently limited to clearing and grubbing of invasive species. The clearing and grubbing will enhance the terrestrial and palustrine communities that currently exist on the site.

Many restoration alternatives were evauluated, which are discussed in the main report. The firstconceptual layouts for the project were first based on biological/ecological considerations, in accordance with the *General Design Memorandum for the Parks Interior Sections*.(NJDEP 2001) Next, the fetidal wetlandasibility of these conceptual plans were evaluated, based on hydraulic, hydrologic, hydrodynamic, geotechnical, topographical/bathymetrical and construction costs considerations. For the fresh water wetland, the engineering analysis of the alternatives evaluated the topography, soils and the potential fresh water sources needed for a Deepwater Emergent Marsh (DEM). Other restoration features were added to enhance either the DEM or to independly improve habitat (see Liberty State Park Hydrology and Hydraulics for Fresh Water Wetlands, USACE 2004). For the tidal wetland, the local sponsor reserved a 45 acre dredge disposal area in the center of the park for this activity (see rectangle in Figure 1.3). The alternatives that created a tidal wetland in the 45-acre rectangle ranged from having 2 inlets discharing into NY Harbor to having an upland island surrounded by tidal creeks with one inlet. The two inlet option was screened out because the second inlet discharged witin 500 ft from the

Jersey City combined sewage/storm outfall, and the additional concern that maintaining 2 inlet openings would be more difficult and costly. The upland island plan was also eliminated because of the concern that phraagmities may invade the island and tidal marsh from this area. Also, additional upland habitat was planned in other sections of the park. Having more low and high marsh would add more diversity.

Once the general layout of the tidal marsh was agreed upon by the project delivery team, channel widths between 15-150 ft wide were evaluated in the vicinity of where the tidal marsh connects to New York Harbor.


Palustrine Communities:
Common Reed Dominated Wetland (CRW)
Common Reed/Mugwort (CRM)
Deep Emergent Marsh (DEM)
Floodplain Forested Wetland (FFW)
Shallow Emergent Marsh (SEM)
Shrub Swamp (SSW)
Estuarine Communities:
Estuarine Subtidal (ES)
Tidal Creek (TC)
Intertidal Flat (IF)
Low Marsh (LM)
High Marsh (HM)
Bridge
Trail
Road
Berm
Terrestrial Communities:
Maritime Forest (MF)
Maritime Grass (MG)
Maritime Shrubland (MS)
Mowed Lawn (ML)
Successional Northern Hardwood (SNH)
Successional Old Field (SOF)
Successional Shrubland (SSB)
Feet
Image Source: 2002 NJ Digital DOQ's
Figure 3.1
LIBERTY STATE PARK
RECOMMENDED PLAN
THE PORT AUTHORITY OF NY & NJ
US ARMY CORPS
OF ENGINEERS
New York District

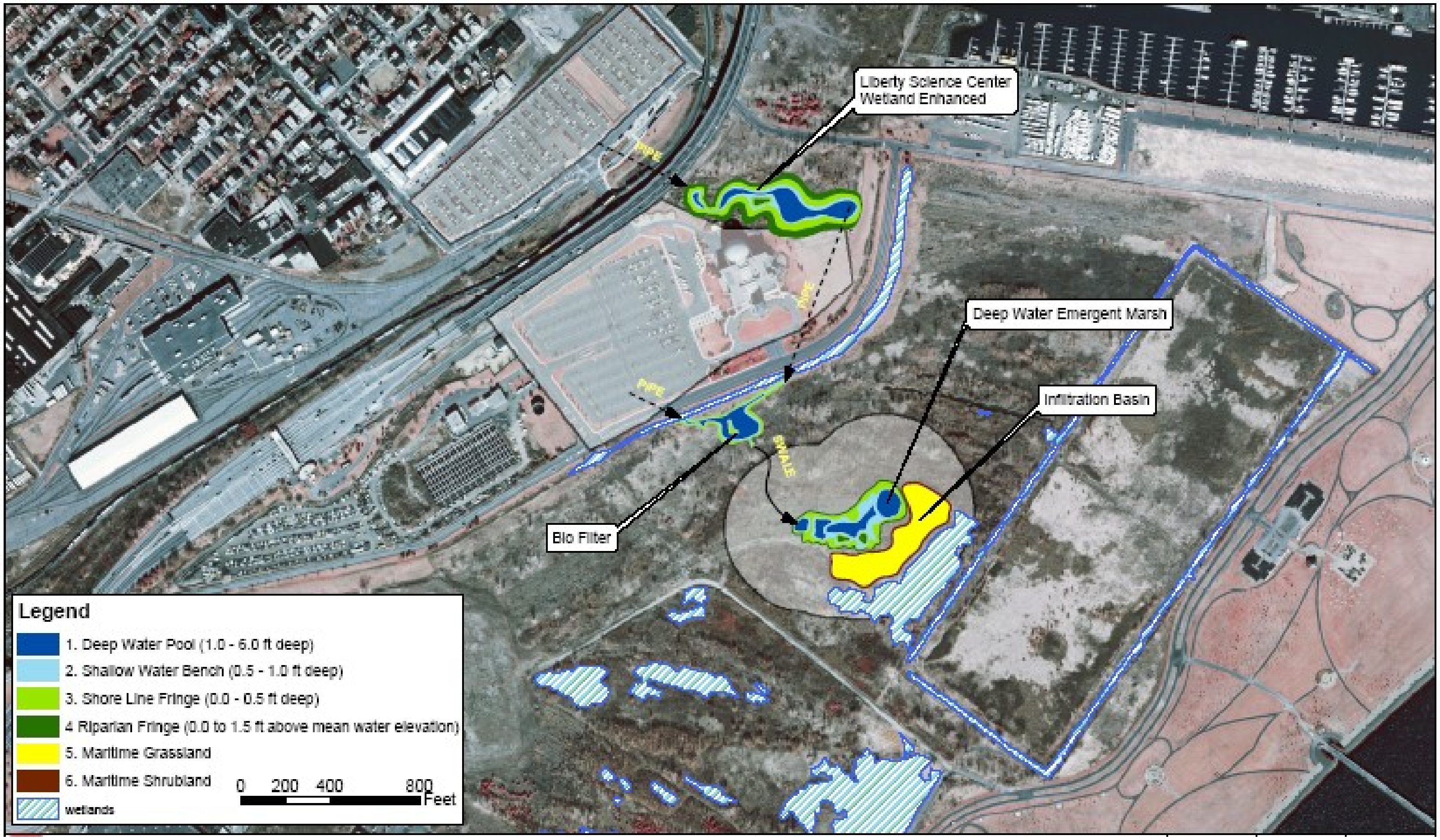


Figure 3.2 Fresh Water Wetland Components: Close-up

4. FRESH WATER WETLAND

4.1 Objectives

One goal of the ecosystem restoration project was to enhance/restore/create fresh water wetlands at the site. The southeast section of the 225-acre restricted area contains a significant number of small wetlands. The number of existing wetlands in this area and its distance from additional stormwater runoff sources precluded this area from consideration for wetlands enhancement. In the center of the park, a natural freshwater wetland area (shallow emergent marsh) exists immediately west of the 45-acre dredge spoil area being evaluated for saltwater wetland restoration (see Figure 1-3.) The enhancement and expansion of existing freshwater wetlands near this wetland has been proposed by the State of New Jersey as part of the overall Liberty State Park environmental restoration plan. The enhancement is expected to require additional water sources; thus, the Liberty State Park Science Center and the nearby New Jersey Transit (NJ Transit) Light Rail Terminal parking lot are being considered as potential sources of stormwater runoff.

An evaluation of the existing and potential sources of freshwater was necessary to determine the feasibility of the wetlands expansion. A hydrologic budget was developed to analyze the viability of various wetland restoration alternatives with regard to wetland sustainability. The objectives of the hydraulic design process for the fresh water wetlands were to establish conduit dimensions for transporting stormwater runoff, evaluate the hydraulic impacts (e.g., flooding or draining) to existing areas, and analyze the expected hydraulic performance of the wetland system. The hydraulic performance of the system helped determine the target vegetative structure and wetland functions.

Within Liberty State Park, the natural reclamation process is resulting in a gradual improvement of the environment. Outside the park is an urban environment, which has developed independent of the park ecological system. The intent of this project is to accelerate the natural reclamation processes in combination with restoring some of the historical ecological functions to the park through the redirection of some of the stormwater drainage from the adjacent, urban areas. However, the stormwater drainage in the urban environment has been designed to meet regulatory drainage requirements. Therefore, the effort to redirect the stormwater drainage requires marrying the hydrologic needs of the enhanced wetlands with the regulatory drainage requirements in the urban areas.

The stormwater drainage for the Liberty Science Center and parking lot, and the NJ Transit Light Rail Terminal and parking lot was not necessarily designed for wetland sustainability, but rather, it was designed for maximum drainage to prevent flooding. Any constrictions or diversion of flow from these urban sources will require that no induced flooding occur up to the original design criteria.

Wetland hydraulic design is an iterative process, consisting of: (1) developing a proposed hydraulic design, (2) conducting a site drainage analysis and surface flow hydrodynamic analysis with the proposed features in place, (3) evaluation of the proposed design against the design criteria, and (4) modification of the proposed design. The development of the proposed wetland alternatives was based on typical wetland environmental, hydrologic, and hydraulic design criteria.

4.2 Hydrologic Analysis

The basic hydrologic data analyzed for the fresh water wetlands includes precipitation, surface runoff, the development of annual and monthly runoff volumes, and runoff routing in the derivation of existing and improved conditions. Inflows include direct rainfall and snowmelt; rainfall and snowmelt runoff from tributary areas; and groundwater inflow. Outflows are evaporation, groundwater infiltration, and surface runoff. These computations were accomplished using two techniques, the Simple Method and a Stormwater & Wastewater Management Model (SWMM).

The Simple Method and SWMM were selected for this analysis in order to attempt to accurately predict and model runoff *volumes* available for input to the proposed wetlands. Other models, such as HEC-1, HEC-HMS, and TR-55 are typically event-driven models, more appropriate for drainage capacity design for predicted events. The Simple Method and SWMM model were used to model annual and monthly runoff volumes and detention within the proposed wetlands system.

The watersheds that are a part of the proposed project consist of four catchment areas: (1) the interior of Liberty State Park, (2) the Liberty Science Center (LSC) and parking lot, (3) the existing wetland area immediately adjacent to the Science Center, and (4) the NJ Transit parking lot and adjacent drainage area (Figure 4.1). In the interior of Liberty State Park, there are several small drainage areas within the park itself due to the lack of significant relief within the park and the presence of old berms, dredged material mounds, and other debris mounds. There are numerous small drainage areas and several existing freshwater wetlands areas that will be retained in the proposed plan. North and west of this wetland is upland area. This upland area presented itself as a likely place for restoration due to the lack of existing freshwater wetlands and its relatively close proximity to potential sources of additional freshwater runoff. The drainage area for the existing, two-acre shallow emergent marsh is approximately 20 acres. This area is 100% pervious as it is entirely within the 215-acre restricted area. No additional impervious areas provide runoff to this area. No significant source of runoff is currently routed to the proposed tidal wetland.

The drainage area within the LSC complex can be divided into two main subcatchment areas: the LSC parking lot and the LSC itself, which consists of roof drains, walkways, and nearby mowed areas. The LSC parking lot is approximately 10.4 acres, 89% of which is impervious. Along Phillip Drive is a drainage ditch referred to as the East Ditch. This ditch primarily provides the conduit for runoff from the LSC parking lot to the Morris Canal. The drainage area of the LSC itself is approximately 8.48 acres, with 50% impervious. Runoff from the LSC has two destinations: either to the West Ditch along Phillip Drive or to the adjacent wetland.

An existing wetland is currently located immediately north of the LSC. The wetland area is approximately 2.3 acres in size, with an immediate drainage area consisting of the New Jersey Transit parking lot and a small adjacent area totaling approximately 11.13 acres.

Across the NJ Turnpike from the Liberty Science Center is the NJ Transit Light Rail Liberty State Park Station, which provides service to Bayonne, Jersey City and Hoboken. The terminal consists of an outdoor station and an approximately 800-car parking lot. The NJ Transit terminal area is divided into the three-subcatchment areas: the parking lot and interior detention basin, the southern terminal area and detention basin, and the northern terminal area and drainage swale.

4.3 Precipitaiton, Infiltration and Evapotranspiration

Monthly and hourly precipitation data was obtained from the National Climatic Data Center for the period 1948-2003 for Newark International Airport (cooperative station ID 286026), approximately 7 miles to the west of the study area. The average annual precipitation for the study area is approximately 45.65 inches. The observed extreme annual values were 65.50 inches in 1983 and 31.44 inches in 2001. The monthly extremes ranged from 0.36 to 11.53 inches.

Development of the hydrologic budget involved in quantifying sources of inflow or outflow to the deep emergent marsh. Runoff from the catchment (including snowmelt), direct precipitation on the wetlands, evapotranspiration, and groundwater inflow were defined by a combination of National Weather Service data, in-situ measurements, and model results. The period 1971 – 2002, for which all meteorological parameters (precipitation, snowfall, temperature, and pan evaporation) needed to develop the hydrologic budget were available, was used as the period of record to select dry and wet years.

Newark Airport (7 miles south of site) was selected as the data station for this study since the record was more complete than other stations of closer proximity. Inflows in the hydrologic budget include precipitation falling directly on the wetland, surface water runoff, groundwater, and pumped flow. Both direct precipitation and surface water runoff may be composed of rainfall and snowmelt.

Subcatchment infiltration is the water that infiltrates into the ground and does not become runoff (directly) during a precipitation event. Due to the heterogeneous nature of the fill material within the park as a result of years of fill, an effort was made to measure infiltration rates within the limited-access area. A series of 11 double ring infiltrometer tests were conducted within the park. The results and discussion of the infiltrometer tests can be found in the Liberty State Park Hydrology and Hydraulics of Fresh Water Wetland Report, (USACE 2004.)

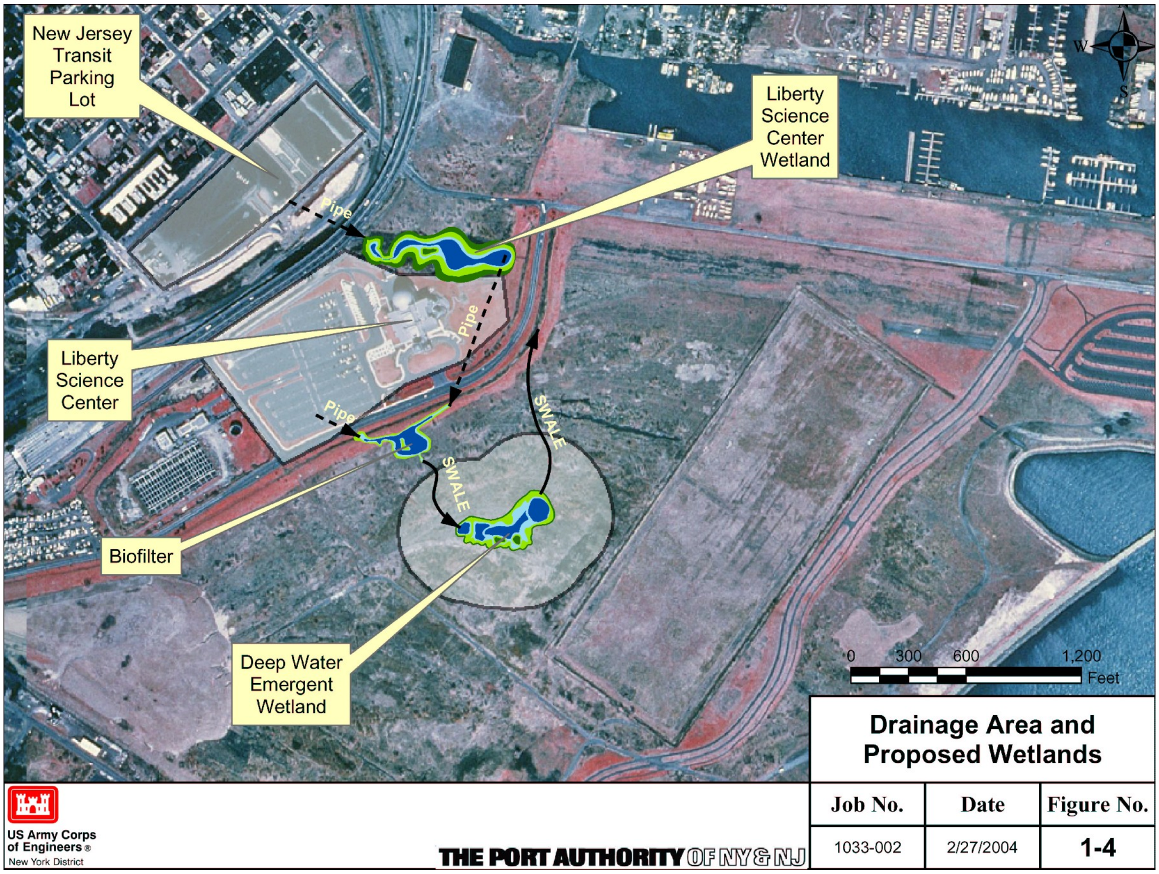


FIGURE 4.1 Liberty State Park Catchment Areas.

4-1

For the SWMM modeling, the maximum and minimum infiltration rates of 4.5 and 0.02 inches per hour, respectively, were used within the wetland areas of park. These rates are typical of a relatively impervious clay or other geo-lining, as planned for the wetlands. The typical maximum and minimum values of 3.0 and 0.02 inches per hour, respectively were used for the pervious, mowed surfaces outside the park. These values are consistent for landscaped turf. The decay coefficient was set at 4 hr^{-1} which is equivalent to a decline in infiltration of 98 percent towards the limiting value after the first hour.

From the results of the analysis, it is assumed that due to the high infiltration rates and relatively shallow grades that there will be minimal runoff from the drainage areas within the park. Outflows may include surface water, groundwater, and evapotranspiration. A model developed at the Northeast Regional Climate Center was used to provide estimates of monthly pan evaporation (DeGaetano 1994). Evapotranspiration was then calculated as 75% of pan evaporation estimates based on research results by others (Hammer 1992, Hubbard et al. 1988).

4.4 Estimated Runoff Volume

Runoff volumes for the subcatchments in the study area were initially estimated using the Stormwater Manager's Resource Center's Simple Method. The Simple Method provides an easy way to evaluate potential runoff from the watershed using annual and monthly precipitation values.

The Simple Method (SMRC 2003) is generally used to estimate stormwater runoff pollutant loads for urban areas. For the hydrologic budget, the method was used to calculate runoff only; for sediment transport calculations described Liberty State Park: Hydrology and Hydraulics of Fresh Water Wetlands Report (USACE 2004) the Simple Method was also used to simulate total suspended solids. The technique requires a modest amount of information, including the subwatershed drainage area and impervious cover, and annual precipitation. It provides reasonable estimates of stormwater runoff volumes. Unlike other hydrologic methods, preliminary volumes can be estimated based on average rainfall rather than specific storm events.

Computed volumes were checked by comparison to XP-SWMM model results for one scenario. Although significant disparities between SWMM and Simple Method results are sometimes seen for individual months, the total yearly volumes for the simple method are only 12% higher than SWMM for 1976 and 15% lower than SWMM for 1983. In light of the inherent differences between the two modeling approaches, these differences are relatively small. Therefore, the Simple Method results are validated by the SWMM computations.

4.5 Environmental Design Criteria

As indicated in the General Management Plans, NJDEP, 2001, water depth and draw down must be controlled to the degree that will maintain a viable and attractive wetland and pond community and to provide wildlife habitat value to the park.

The deepwater emergent pond/wetland has been designed to provide a permanent source of water with a depth of approximately 4-6 feet. This, along with very shallow (5%) side slopes will provide a controlled proportion of deeper and shallower habitats throughout the growing season.

The Threatened and Endangered listed bird species do not have habitat requirements that include a specific hydroperiod. They can be expected to use wetland or upland habitats if the vegetative structure of these habitats meets their needs. For example, the northern harriers prefer grassland habitat with few trees and shrubs. Harriers will nest in either uplands or wetlands, but the pair nesting at Liberty State Park seems to prefer uplands for nesting. For winter roosts, harriers prefer upland sites. Many sources indicate harriers prefer to nest and roost in fields that are 50 acres or more in size; however, the species has also been documented to nest in habitat blocks as small as 20 acres.

Aside from the northern harrier, none of the other Threatened and Endangered bird species of special concern that were observed during inventory surveys have been documented as breeding in the park. As mentioned previously, their use of habitat relies more on habitat with the correct vegetative structure and adequate food resources rather than hydroperiod.

One listed plant species, Torrey's rush, was found on the site. This species has hydrologic requirements and is adapted to specific types of soils. It is a facultative wetland (FACW) species, which means it has the probability of being found in a wetland 67-99% of the time. The

Natural Resource Conservation Service's (NRCS) Plant Database indicates this species is adapted to medium to coarse-textured soils and has a low-tolerance for drought conditions. The NRCS lists the minimum and maximum amount of precipitation needed as 14 and 50 inches per year, respectively. The minimum root depth is 10 inches and the species is intolerant of both shade and salinity. This species was identified in a freshwater wetland on-site. That wetland area should be protected during construction while also considering the habitat requirements for the species when enhancing other freshwater wetland habitats on-site.

4.6 Hydrologic Design Criteria

The minimum water requirements for wetland sustainability are determined by a combination of factors that need to be balanced. In order to maintain a wetland with a permanent pool of water and sufficient flow to maintain good water quality, sufficient drainage area is required. Without supplementing the water supply through pumping, a minimum watershed of about ten acres is required for maintaining a year round permanent pool of approximately one acre. A second rule of thumb is that four acres of contributing watershed are needed for each acre-foot of storage (Md SCS, 1976; Schueler, 1987). For this plan, from five to nine acres of contributing urban watershed are available for each acre-ft of planned wetland storage. This range of ratios suggests that the watershed is sufficiently large to support the planned wetlands. Relying on a smaller watershed than this would make maintaining a permanent pool difficult and would produce large fluctuations in the water level due to evaporation and infiltration losses. Examination of the water balance diagrams (Appendix A in Liberty State Park: Hydrology and Hydraulics of Fresh Water Wetlands Report (USACE 2004) indicates that the base flow entering the wetland would run out during the summer months, and input cannot compensate for gradual drawdown. The result may be poor water quality, the production of algal matting and odor problems. During extremely dry periods such as 1976, it is possible that the existing wetland may completely dry up i.e., have almost no standing water yet still have saturated substrate, as do most of the existing wetlands on the site.

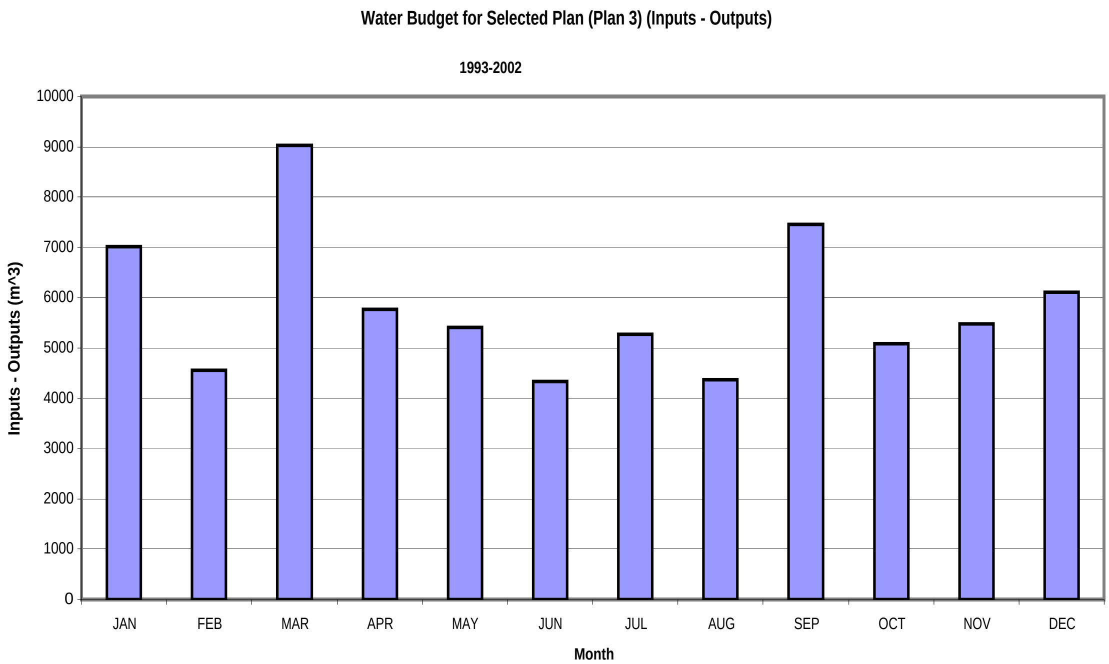


Figure 4.2 Sample Water Budget Used to Develop the Freshwater Wetland.

There are many hydrologic and hydraulic considerations important to wetland restoration and construction. The primary list of design criteria includes the following basic interrelated elements.

- Hydrologic setting,
- Flood duration and timing,
- Flooding depth,
- Flow velocities and hydraulic retention time,
- Storage capacity and surface area.

Hydrologic Setting: The hydrologic setting of the wetland describes the location of the wetland in relation to other water bodies. The hydrologic setting is important to all wetland functions, but is of particular importance to groundwater recharge/discharge, sediment retention, flood-flow alteration, and production export. The existing and proposed freshwater wetlands within Liberty State Park are generally independent of any other water body (e.g., stream, river, lake, etc.). They occur in typically heterogeneous material that has a relatively shallow water table. Thus, they are presumably influenced by a fluctuating water table. The proposed wetlands would be constructed in the same general area (park interior) as the existing wetland in similar substrate types.

Flooding Duration and Timing: The existing wetlands within Liberty State Park are typically seasonally wet (i.e., during the spring and fall), with the exception of the Liberty Science Center wetland, which is frequently flooded from runoff from the NJ Transit terminal and parking lot.

Similarly, the drainage ditches along Phillip Street are frequently flooded with runoff from the Liberty Science Center. Based on the hydrologic budget analysis, diversion of stormwater runoff from the parking lots adjacent to the park into the proposed wetlands will result in the proposed wetlands maintaining measurable pool depths most of the year.

Water Depth: Water depth is an important factor in determining the types and extent of vegetation supported by the wetland. The existing wetlands are shallow, seasonal wetlands, most likely augmented by a rising water table during the wet seasons of the year. The proposed wetland system would have both shallow and deepwater areas to support a greater abundance of plants and wildlife than the existing wetlands.

Flow Velocity and Hydraulic Retention Time (HRT): Maintaining a low velocity related level of flowing water shear stress is important to several wetland functions. As a result of the shallow gradient of the park and the detention-design of the wetlands, velocities will be minimal. The HRT is defined as the average amount of time that a parcel of water stays within the wetland before exiting. The HRT is the key design criteria for water quality enhancement functions such as sediment/toxicant removal and nutrient removal/transformation. For this feasibility analysis, the focus was on flood frequency and duration, and depth. It is expected that the wetland system will cause a measurable increase in HRT, which will further result in improved water quality entering the Harbor. Obviously, excessive HRT in the wetland could result in wetland water quality problems such as low dissolved oxygen and the production of sulfide and methane gases. However, frequent runoff is expected to provide frequent flushing of the wetland system.

Storage Capacity and Surface Area: The storage capacity is most important in the flood-flow alteration function because the amount of available storage in the wetland determines how much of the runoff can be routed into and through the wetlands. The storage capacity may also affect aquatic abundance and diversity, in that larger wetlands will have more potential for groundwater recharge, greater volume and surface area, and may support more aquatic organisms. Storage capacity was used in this analysis to reach design water surface elevations based on seasonal inflows. The wetland bottom area is important for groundwater recharge and discharge. Ground water recharge was not a primary concern of the proposed designs; it is anticipated that the wetlands will be lined with a low permeability liner. Runoff inflows were expected to be sufficient to overcome evapotranspiration, even during the drier months of the year.

4.7 Fresh Water Wetland System: Components of Proposed Alternatives

In order to maximize habitat function and value, the freshwater wetland system may have four primary components: (1) an enhanced Liberty State Park wetland, (2) a Biofilter (BF) wetland, (3) a Deep Emergent Marsh (DEM), and (4) natural connecting swales. The proposed freshwater wetland system should be located in the center of the park, in close proximity to the proposed tidal wetland. Ideally, the DEM should be at least 400 or 500 feet away from the nearest road or heavily used area so there is a buffer between fast moving vehicles and the inhabitants of the wetland.

The proposed freshwater wetlands will contain a number of hydrologic/habitat zones, as follows:

- Zone 1. Deep Water Pool (1-6 feet deep), to support submerged aquatic plants such as wild celery, sago pondweed, and redhead grass.

- Zone 2. Shallow Water Bench (6-12 inches between groundwater level and the discharge invert), to support emergent aquatic plants. Proposed plants are obligates and are relatively intolerant to drawdowns. Typical plants in this zone include: Pickerelweed (*Pontederia cordata*), Duck potato, (*Sagittaria latifolia*), Three square (*Scirpus pungens* (*S. americanus*)), and Soft stem bulrush (*Scirpus validus*).

- Zone 3. Shoreline Fringe. This is the regularly inundated area, which supports wet meadow scrub-shrub wetland, including plants such as sedges, switchgrass, and buttonbush. This zone is typically between the discharge invert and an overflow elevation.

- Zone 4. Riparian Fringe. This is the periodically inundated area, which supports wet soils or scrub-shrub transition, including plants such as red osier dogwood, red maple, and swamp oak. This zone is typically above the overflow elevation.

Enhanced LSC Wetland (Wetland 1): The wetland will be enhanced through the removal of the common reed, regrading, and replanting. The enhanced wetland will contain Zones 1 through 4 as described above. Figures 4.3 and 4.4 shows the enhanced LSC wetland. The area of the wetland will be 2.27 acres.

Biofilter Wetland. (Wetland 2): The second wetland will be designed for water quality pre-treatment and contain wetland Zones 1 through 3 as described above. The wetland will provide pre-treatment by removing coarser sediments, trash, and debris. This pre-treatment should also provide for the significant removal of particulate pollutants. The deeper areas of the wetland will function as either a permanent pool or shallow marsh areas. The deep area will enhance the removal of soluble phosphorus and nitrogen. Figures 4.5 and 4.6 shows the Biofilter wetland. The area of the wetland will be 0.79 acres.

Deepwater Emergent Marsh (Wetland 3): The mean water elevation of the DEM will be approximately 5.0 ft NAVD with bottom elevation around 0.0 ft NAVD. The wetland area is about 1.8 acres and average volume is approximately 32,700 cubic feet. These dimensions include all of the four-wetland zones (Figures 4.7 and 4.8). The DEM will include all four wetland zones discussed above. The deep water areas of the wetland should be permanently flooded. The zone between the typical low level and the overflow outlet may be seasonally flooded. Above the overflow elevation will be a transition zone to upland areas.

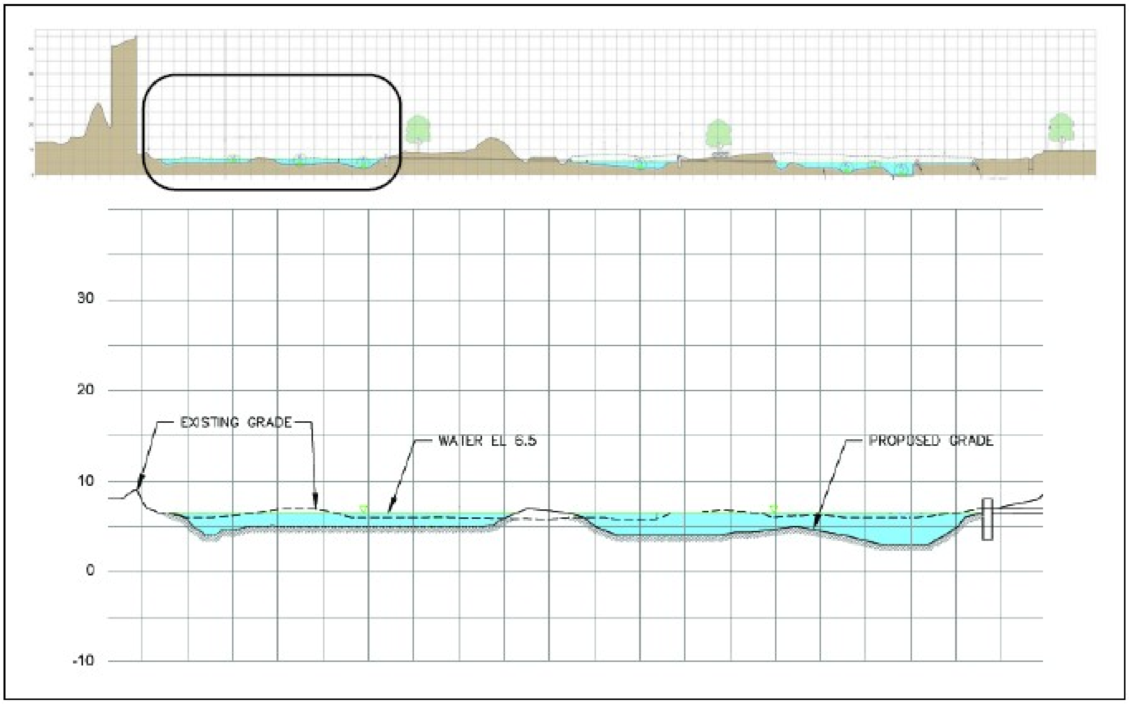


Figure 4.3 LSC Wetland, Plan View

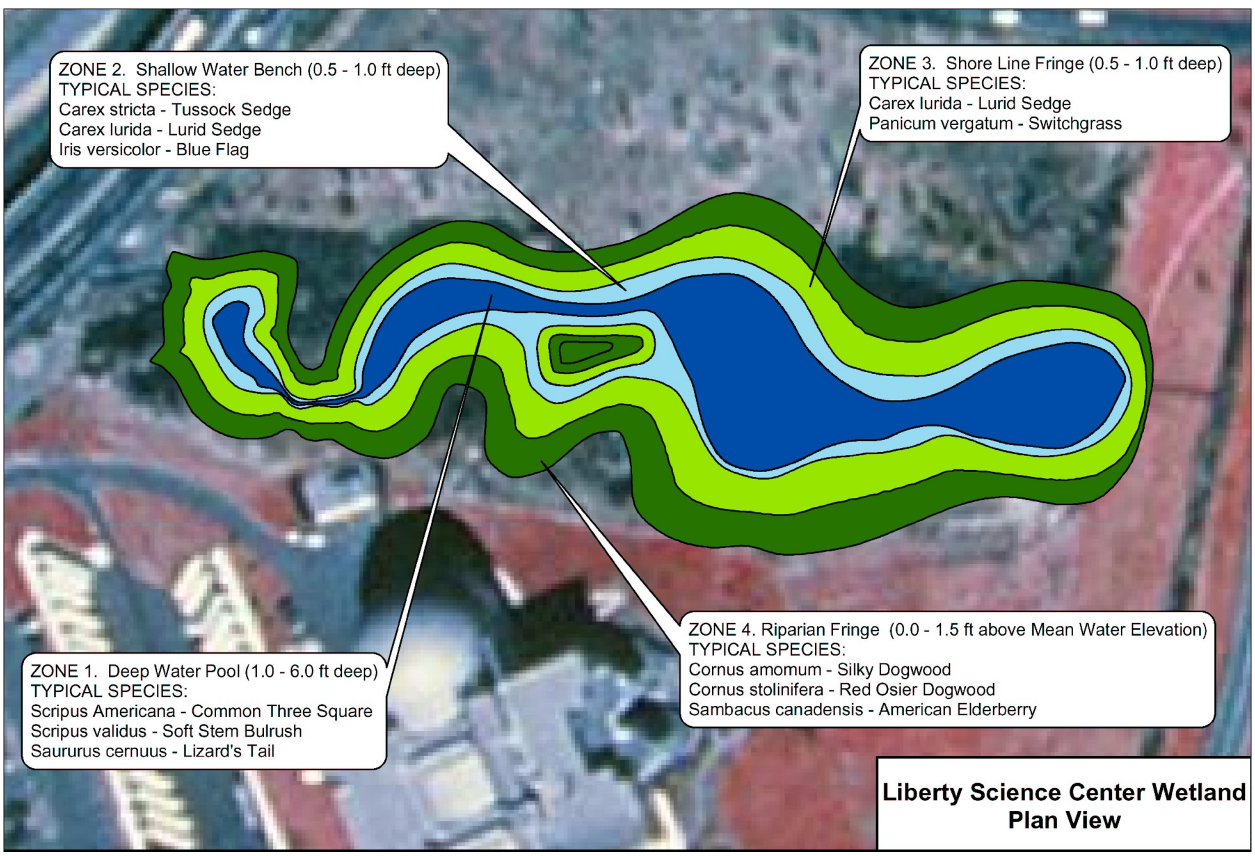


Figure 4.4. LSC Wetland, Profile View

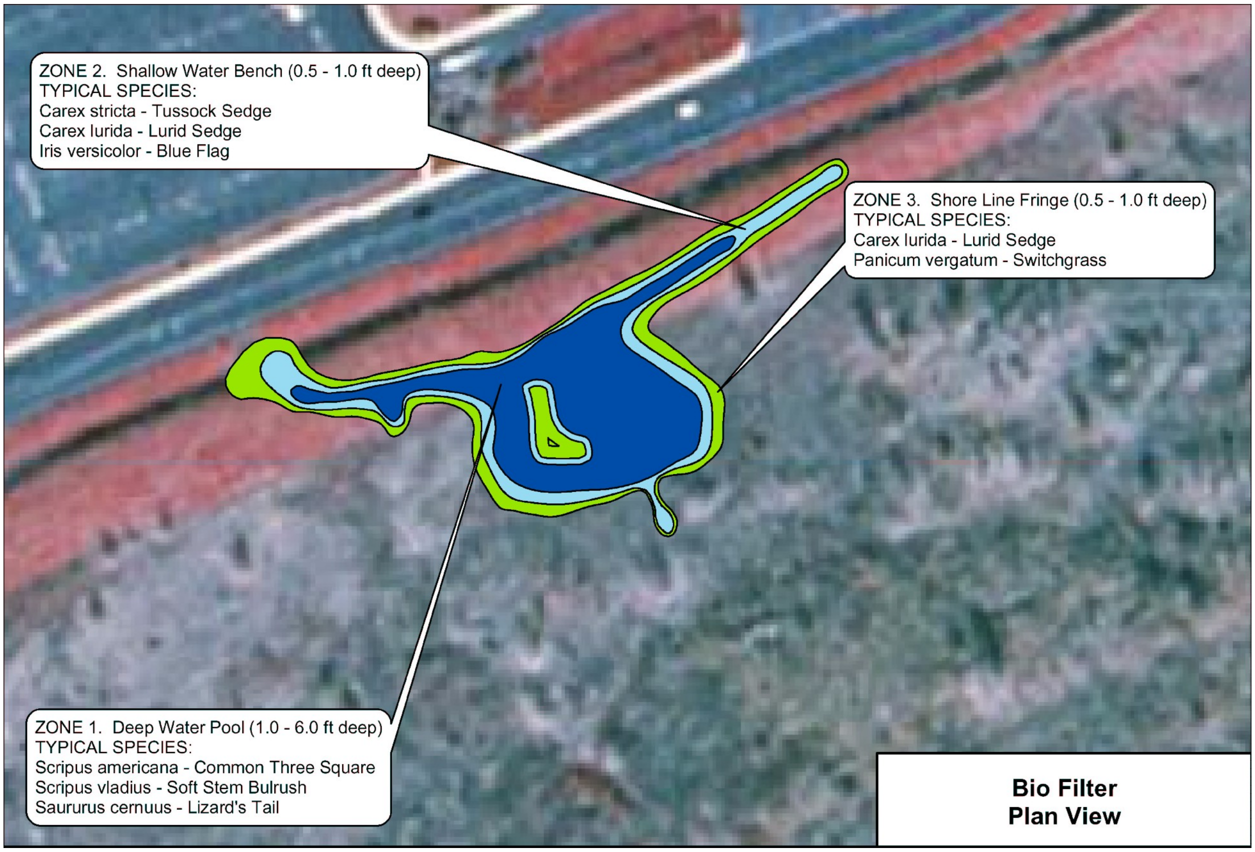


Figure 4.5 Biofilter, Plan View

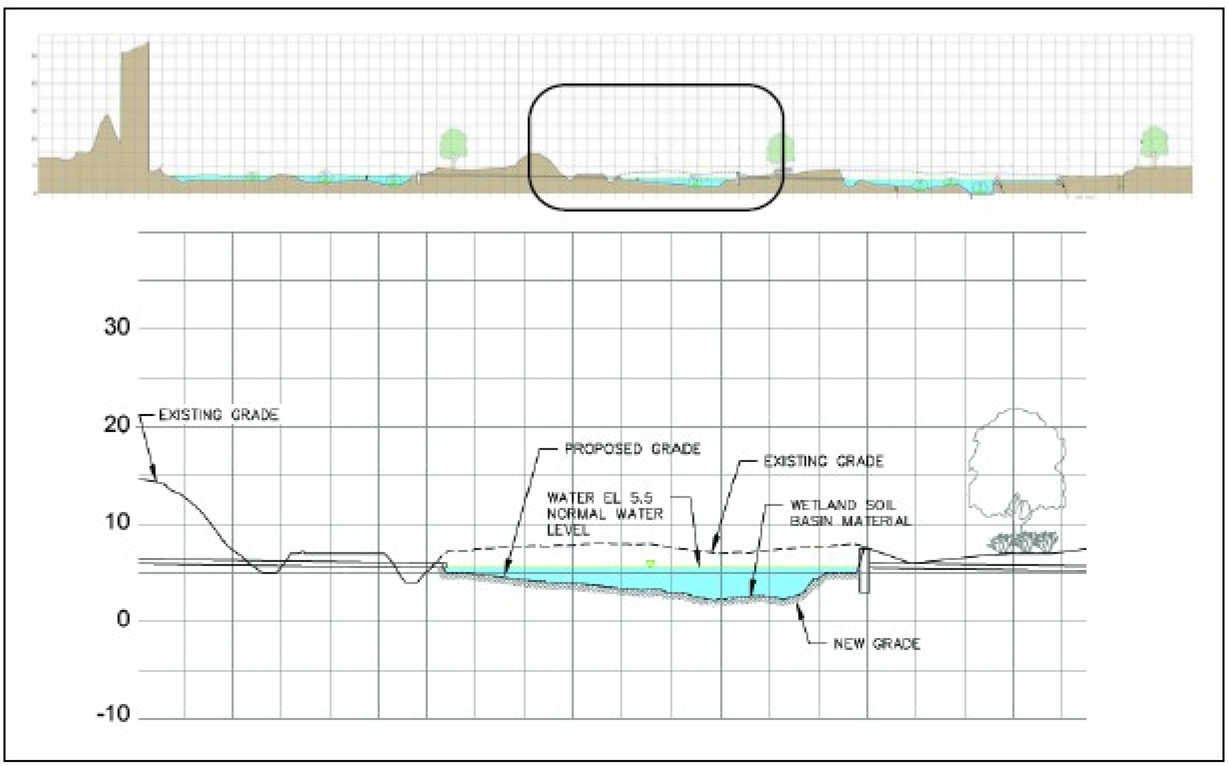


Figure 4.6 Biofilter, Profile View

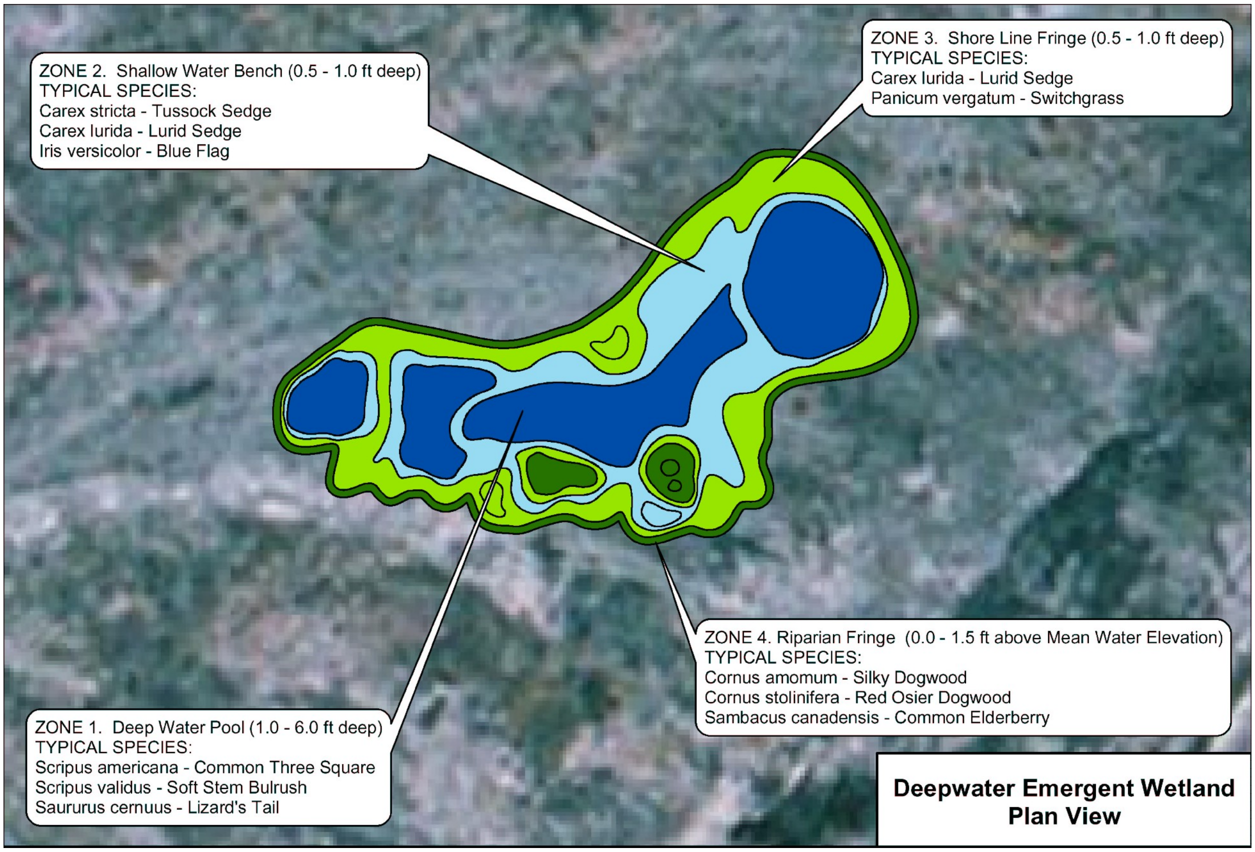


Figure 4.7 Deepwater Emergent Marsh, Plan View

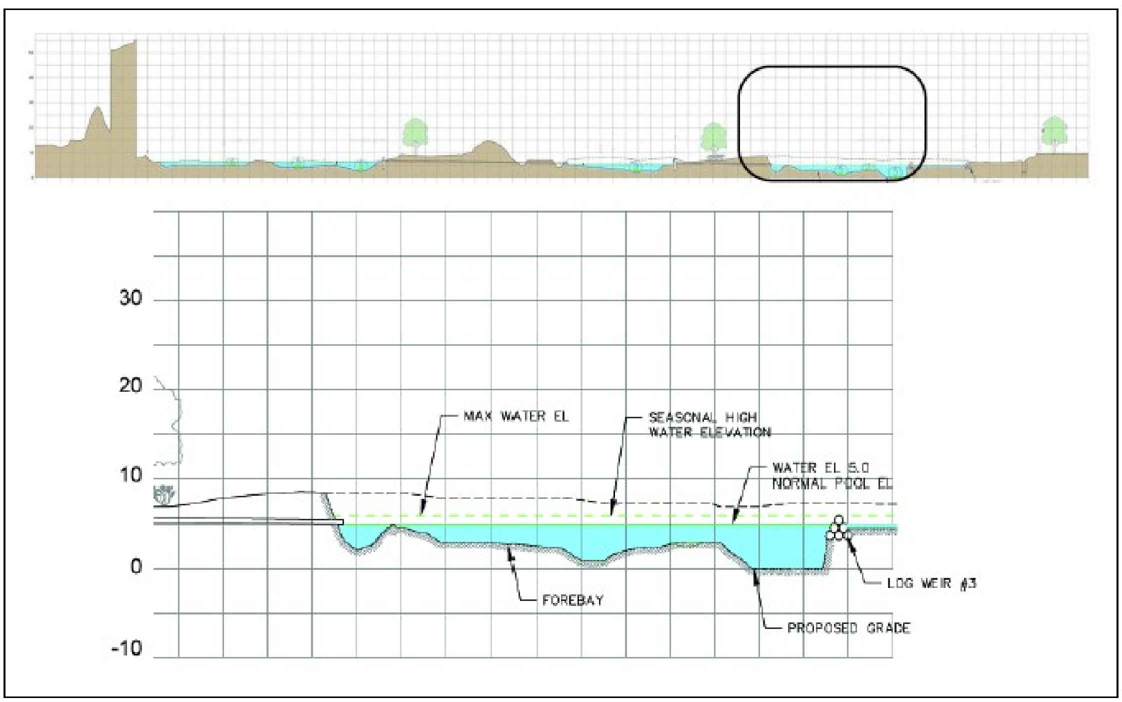


Figure 4.8 Deepwater Emergent Marsh, Profile View

Connecting Swales: Natural swales will connect the wetland system within the park to limit the need for structural components in the freshwater system, provide additional functional value, and maintain the ecological nature of the site. Swale slopes should be graded as close to zero (1:500) as drainage will permit. The side slopes would be 1V:3H. Between the biofilter (5.5 ft NAVD) and the deep emergent marsh (5.0 ft NAVD) there is a half foot elevation drop in about 400 feet or a slope of about 0.125%. Side slopes of the swale will be about 3:1 (h:v) or less. The swales will be planted with a dense cover of water tolerant, erosion resistant grass. This grass will not be mowed close to the ground to avoid impeding the filtering and hydraulic functions of the swale. Since the system will use parking lot runoff, sensitive grass species with a low salt tolerance such as bluegrass, should be avoided. Reed canary grass is ideal but is also considered an invasive species.

Infiltration Basin: One method of returning excess stormwater to the interior of the site would be to direct this excess to an infiltration basin. This would ensure that the water is being discharged to an area with high permeability and allow quick groundwater recharge. Infiltration basins are also effective in removing both soluble and fine particulate pollutants that may still be in the stormwater discharged. The basin would be receiving this water during wet months and/or during larger storms. While this water will have been treated by the other constructed wetlands, the discharge may still contain some pollutants during large storms. In this case, the basin would serve as a final polishing system along with providing control of peak discharges for large design storms. The high permeability soils are well suited for use as an infiltration basin with little soil augmentation required. The infiltration basin, shown in Figures 4.9 and 4.10, would provide an impoundment by excavating the soil to an elevation of approximately elevation of 4.5 NAVD. The impoundment will store a defined quantity of about 3 acre feet of runoff, allowing it to slowly infiltrate through the permeable soils of the basin floor. The floor would be graded as flat as possible and a dense native grass cover would be established to promote infiltration, add habitat value and bind up deposited sediments.

The vegetative zones and elevations associated with each of the proposed wetlands are presented in Liberty State Park Hydrology and Hydraulics of Fresh Water Wetlands: Appendix C (USACE 2004).

Existing conditions and four different scenarios were evaluated and modeled during the feasibility study. The alternatives considered for the fresh water wetland component of this feasibility study are modifications of one primary freshwater wetland system consisting some or all of the five previously described components. The alternatives primarily differ in their source or sources of stormwater. For information regarding Alternatives A, B and C, see Liberty State Park Hydrology and Hydraulics of Fresh Water Wetlands: (USACE 2004). Alternative D was chosen by the Project Delivery Team, as it offered the most habitat units for the cost (see main report).

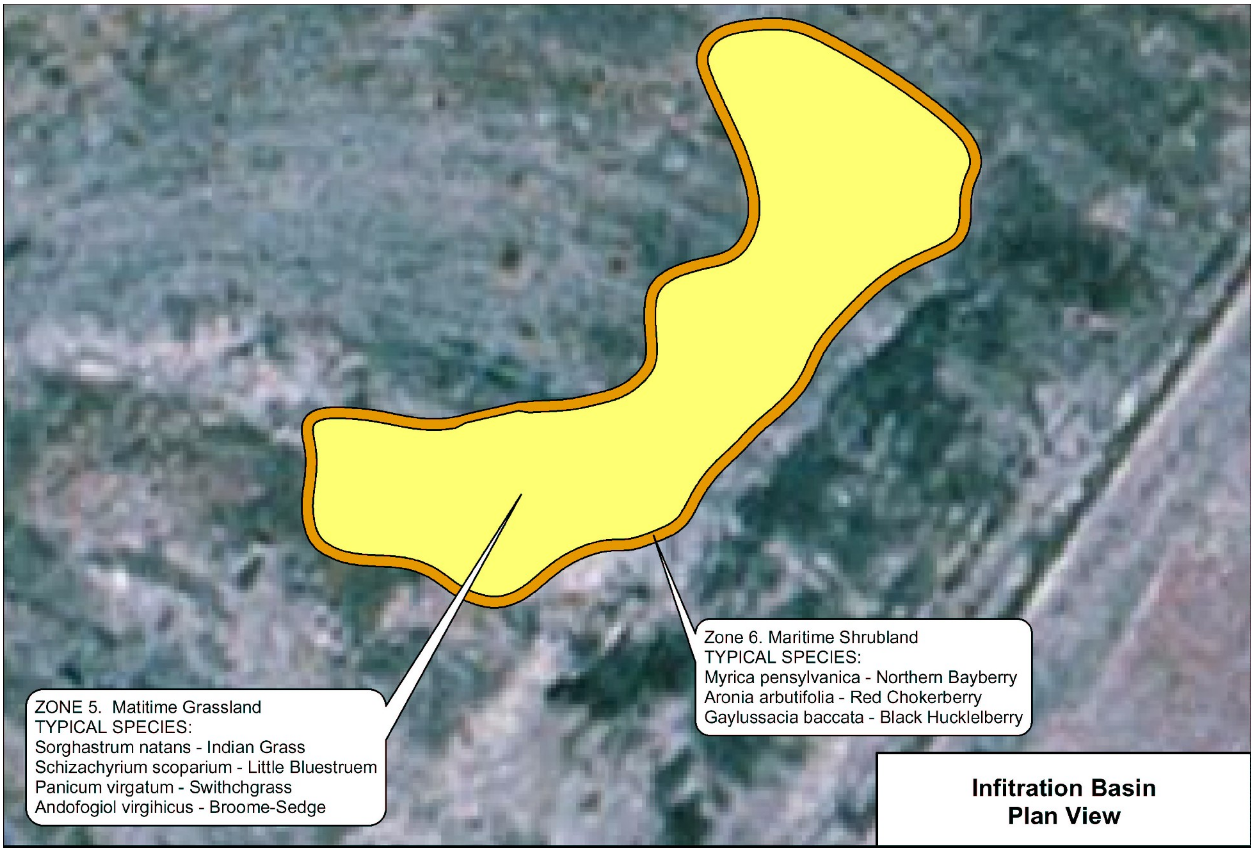


Figure 4.9 Infiltration Basin, Plan View

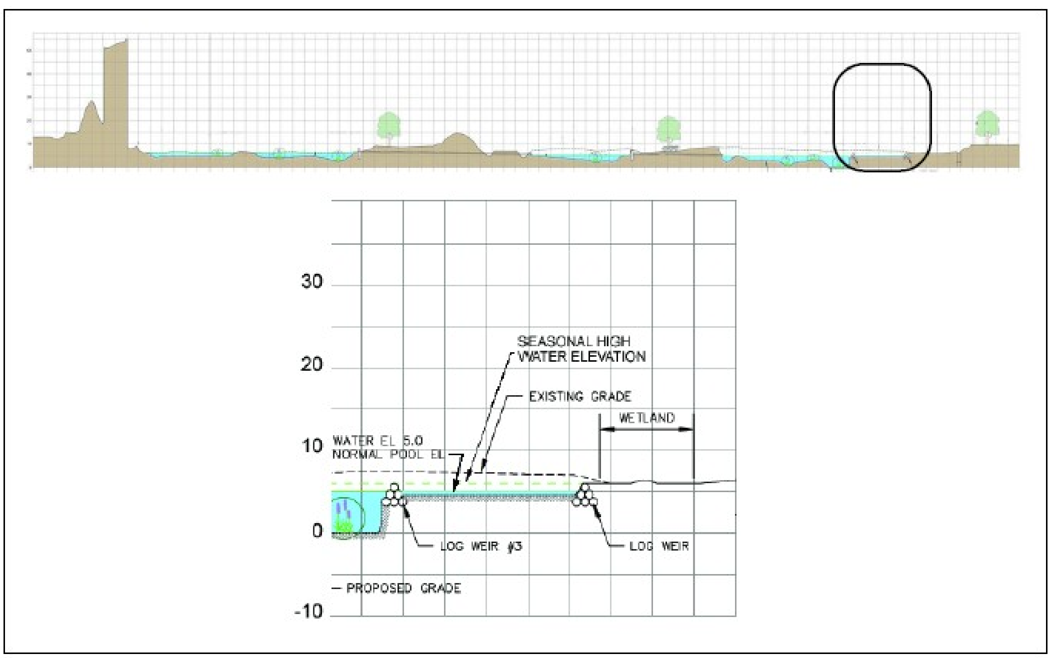


Figure 4.10 Infiltration Basin, Profile View

Selected Alternative (Alternative D)

All features discussed above are included in the selected alternative. LSC Wetland (Wetland 1) will be enhanced by increasing the hydraulic retention time of water reaching the wetland by building stop log weirs, removing invasive species, and planting of plants that offer more habitat value. Stormwater from the NJ Transit parking lot currently drains to the LSC wetland, which maintains a surface water elevation from 5.6 to 7.5 feet NAVD. The runoff from the LSC wetland will then be routed via an 800 ft long culvert, with an upstream invert of 6.5 ft NAVD, under Philips St to the biofilter. The LSC Wetland will have a bottom invert elevation at approximately 3.0 feet NAVD. The LSC wetland area will be about 2.3 acres and the storage volume and perimeter will be approximately 110,000 cubic feet and 2,000 feet, respectively.

In addition to LSC Wetland runoff, the biofilter also will accept runoff from the LSC Building and Parking, also via a 150 ft long culvert traversing under Phillips St. The mean water elevation of the Biofilter will be approximately 5.5 feet NAVD with bottom elevation of approximately 3.0 feet NAVD. The wetland area is about 0.8 acres and the storage volume is approximately 59,800 cubic feet. The perimeter is approximately 1,400 feet. The Biofilter and DEM are connected via a natural swale 430 ft long.

The excess water that is not detained in the DEM by the log and stone weir will be discharged to an infiltration basin adjacent to the DEM. The new bottom elevation of the basin will be approximately 4.5 feet NAVD with an overflow invert elevation at approximately 6.0 feet NAVD. The basin area is about 2.2 acres and the storage volume is approximately 134881 cubic feet. The perimeter is approximately 1,703 feet. If water does go over the spillway, it will be directed to the adjacent existing freshwater wetland.

4.8 Hydraulic Analysis and Design

For this analysis, the hydraulic evaluation of the proposed freshwater wetland alternatives was conducted using XP Software's Stormwater & Wastewater Management Model (XP-SWMM or SWMM). The SWMM results were used in conjunction with the hydrologic budget analysis to evaluate the potential performance of the proposed wetland alternatives.

4.8.1 Basis of Design

The analysis presented herein is based on the concepts and guidelines contained in U.S. Army Corps of Engineers' Engineer Research and Development Centers' *Wetlands Engineering Handbook* (USACE 2001).

Initial stormwater runoff volumes used in the hydrologic budget were estimated using the Simple Method. The Simple Method values were checked for reasonableness using the SWMM output, as discussed previously. The performance of the existing and proposed conduits, such as pipes, drainage ditches, and swales integral to the freshwater wetland system were analyzed using SWMM. Typically, conduits proposed as additions to the existing drainage network were sized to convey the modeled volumes and maintain the wetland system target water surface elevations. The objective of the conduit sizing was not to provide drainage to meet any regulatory requirements (e.g., providing sufficient drainage for a specific frequency event); rather, the conduits were sized to adequately convey the typical runoff volumes without inducing flooding. The only design limitation was to ensure that changes in the drainage as a result of the rerouting of runoff did not result in induced flooding in the drainage area during the 10-year NJDOT design event (NJDOT 2003; 5.25 in./24 hr).

4.8.2 Hydraulic Design Criteria

Man-made wetlands require means to control the quantity and depth of water at a given location. Consequently, hydraulic structures are a basic part of creating, restoring, and enhancing wetlands. The following sections describe the hydraulic design criteria and assumptions for the Liberty State Park freshwater wetlands system.

4.8.2.1 Water Containment

Due to the relatively flat topography of the site, the inverts of the existing drainage structures, and the distances between drainage areas and the wetlands, it is expected that the proposed wetlands would be constructed primarily by excavation. Levees or berms to retain water were not considered in the design with the exception of berms adjacent to outlet structures where it was necessary to direct and control outflow.

4.8.2.2 Sediments and Debris

Reduced flow velocities found in wetlands allow sediments transported into the wetland with the inflow to settle to the bottom. Trapped sediments eventually occupy part of the wetland volume, thereby reducing its effectiveness at removing future sediments from the inflow. Therefore, the inclusion of a forebay in the Biofilter wetland is necessary to trap incoming sediments and prevent them from settling in the main section of the wetland and potentially moving downstream to the deepwater wetland.

Wetlands immediately adjacent to impervious surfaces such as roadways and parking lots are also subject to the inclusion of debris and trash in stormwater runoff. The construction of a forebay will also help capture debris which would otherwise enter the wetland system and potentially degrade habitat and threaten wildlife.

4.8.2.3 Design Event

Hydraulic drainage structures are typically designed to routinely pass flow up to some design event. For the proposed freshwater wetlands at Liberty State Park, the construction of the wetlands within the environmental area of the park reduces the need to design the wetlands for a specific event because any potential overflow of the wetlands would occur within the existing ecological area. The only area of concern is in the vicinity of Phillip Street, which may be impacted if the outflow structures cannot convey flow quickly enough during extreme precipitation events, and flooding occurs. To reduce the potential for induced flooding during extreme events, the existing drainage ditches along Phillip Street will remain in place, separated from the wetland system by overflow berms or weirs. This will allow any overflow from the wetlands to drain through the drainage ditches before flooding the roadways.

Current New Jersey Department of Transportation guidance (NJDOT 2003) requires that longitudinal systems and cross drain pipes for land service highways be of sufficient capacity to pass the runoff from a storm with a 10-year recurrence interval. Therefore, the performance of the freshwater wetland system was analyzed to ensure that no induced roadway flooding occurs during the design event (5.25in/24hr).

4.8.2.4 Conduits

Ideally, the conduits between the wetlands and the outlets should be environmentally beneficial, that is, natural. Therefore, the wetland system was designed using natural, trapezoidal channels to convey flow within the park. These channels are expected to contain vegetative growth and were modeled using a roughness coefficient (Manning's n-value) to reflect vegetation similar to the vegetation presently in the existing drainage ditches within the park. Vegetated swales were designed with a 5-foot bottom width and 1:4 side slope. The channels will initially be lined with grass; however, additional vegetation growth is expected over time. Flow under the roadways will be conveyed through pipes.

4.8.2.5 Materials

Pipes are needed to convey the flows beneath the roadways. For this analysis, it is assumed that the outlet pipes are reinforced concrete pipes (RCP). The outlet weirs within the wetlands will be constructed of natural materials, such as logs or stones.

4.8.2.6 Infiltration Basin

An infiltration basin is a facility constructed within highly permeable soils that provides temporary storage of runoff during rain events. The basin does not normally have a structural outlet to discharge runoff except during very high flow events. Instead, outflow from an infiltration basin is through the surrounding soil. Preliminary infiltration rates measured at the site indicate relatively high surface permeability; however, the permeability of the soils at and below the basin invert must be measured to ensure adequate basin performance. Typical tests such as a percolation test, pit-bailing test, or piezometer test, as outlined in N.J.A.C. 7:9A *Standards for Individual Subsurface Sewage Disposal Systems*, are necessary to ensure adequate soil permeability. For this analysis, a conservative infiltration rate of 1 in/hr was used based on preliminary infiltration measurements.

4.8.3 Groundwater

Preliminary data indicates that the groundwater table within Liberty State Park is relatively shallow. It is likely that the groundwater table may even rise above the lowest land surfaces within the park during the wettest periods of the year. However, there is not yet sufficient data to confirm this fact. Furthermore, there is no groundwater quality data available to date. Therefore, for this analysis it is assumed that the wetlands are constructed with a clay or other impervious liner to limit groundwater flow to the wetlands. Potential hydrostatic or buoyant forces on the liner as a result of groundwater are expected to be offset by the presence of water within the wetlands. It is also assumed that groundwater will not impact the infiltration basin.

4.8.4 SWMM Model Development

The model used for the hydraulic analysis of the proposed wetlands alternatives is a version of the EPA-SWMM: XP-SWMM2000, version 8.52. This version of SWMM has both graphical input and output routines making it easier to make changes in the model and to visualize results. SWMM is a comprehensive model that can perform both hydrologic and hydraulic calculations.

The Liberty State Park SWMM used the RUNOFF and HYDRAULICS (known as EXTRAN in other versions) blocks. The HYDRAULICS block solves the complete St. Venant (Dynamic Flow) equations throughout the drainage network and includes modeling of backwater effects, flow reversal, surcharging, looped connections, pressure flow and tidal outfalls and interconnected ponds. The existing conditions SWMM network is shown in Figure 4.11

4.9 Analysis of Selected Alternative

The four freshwater wetland system alternatives were each modeled with hydrologic input for a wet year and a dry year to evaluate performance. The success of an alternative was predicated on: (1) maintaining the water surface elevation within the Biofilter wetland throughout a majority of the year, (2) maintaining a measurable depth of water within the Deep Emergent Marsh (DEM) throughout the entire year, and (3) achieving some periodic outflow through the DEM overflow in order to achieve circulation or flushing of the DEM. The Liberty State Park: Hydrology and Hydraulics of Fresh Water Wetlands Report (USACE 2004) shows how each alternative performed in meeting the success criteria. The alternative analysis concluded that alternative D best met the design criteria. The environmental benefits and construction cost comparison of the 4 alternatives found in the main body of this report also demonstrates that Alternative D is the best alternative. The SWMM network for Alternative D is shown in Figure 4.12.

In Alternative D, the biofilter maintains a design WSEL of 5.5 feet NAVD throughout much of a dry rain year, as shown in Figures 4.13 Using both the Liberty Science Center and the NJ Transit Parking Lot as sources of stormwater to the freshwater wetland system, it increases the time the DEM maintains the design WSEL and increases outflow from the DEM, improving circulation and flushing. As shown in Figures 4.14 and 4.15, the DEM maintains the design WSEL of 5.0 feet NAVD during most of the wet year of precipitation and during the dry year the DEM WSEL is at the design elevation for 10 of 12 months.

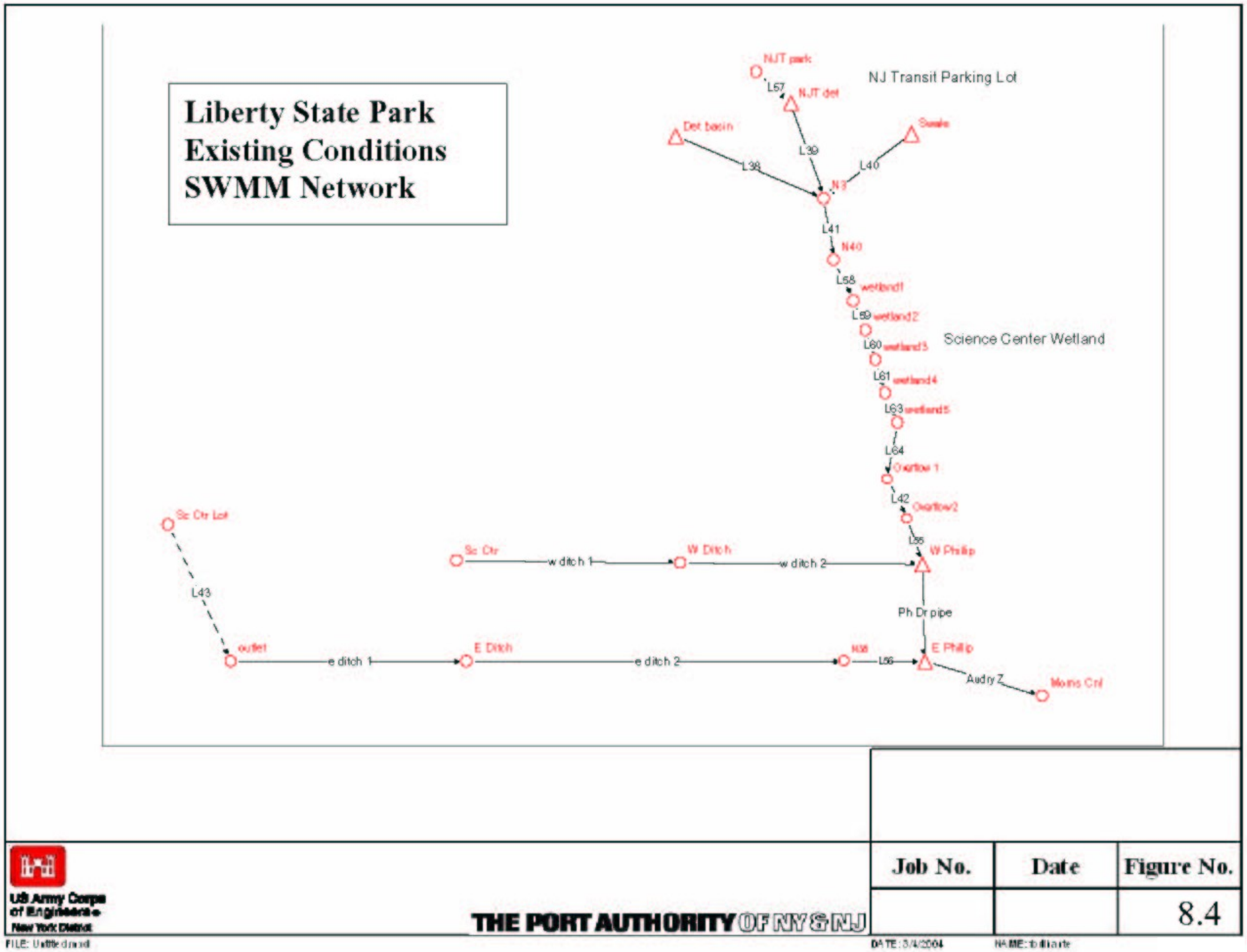


Figure 4.11 SWMM Network for Existing Conditions

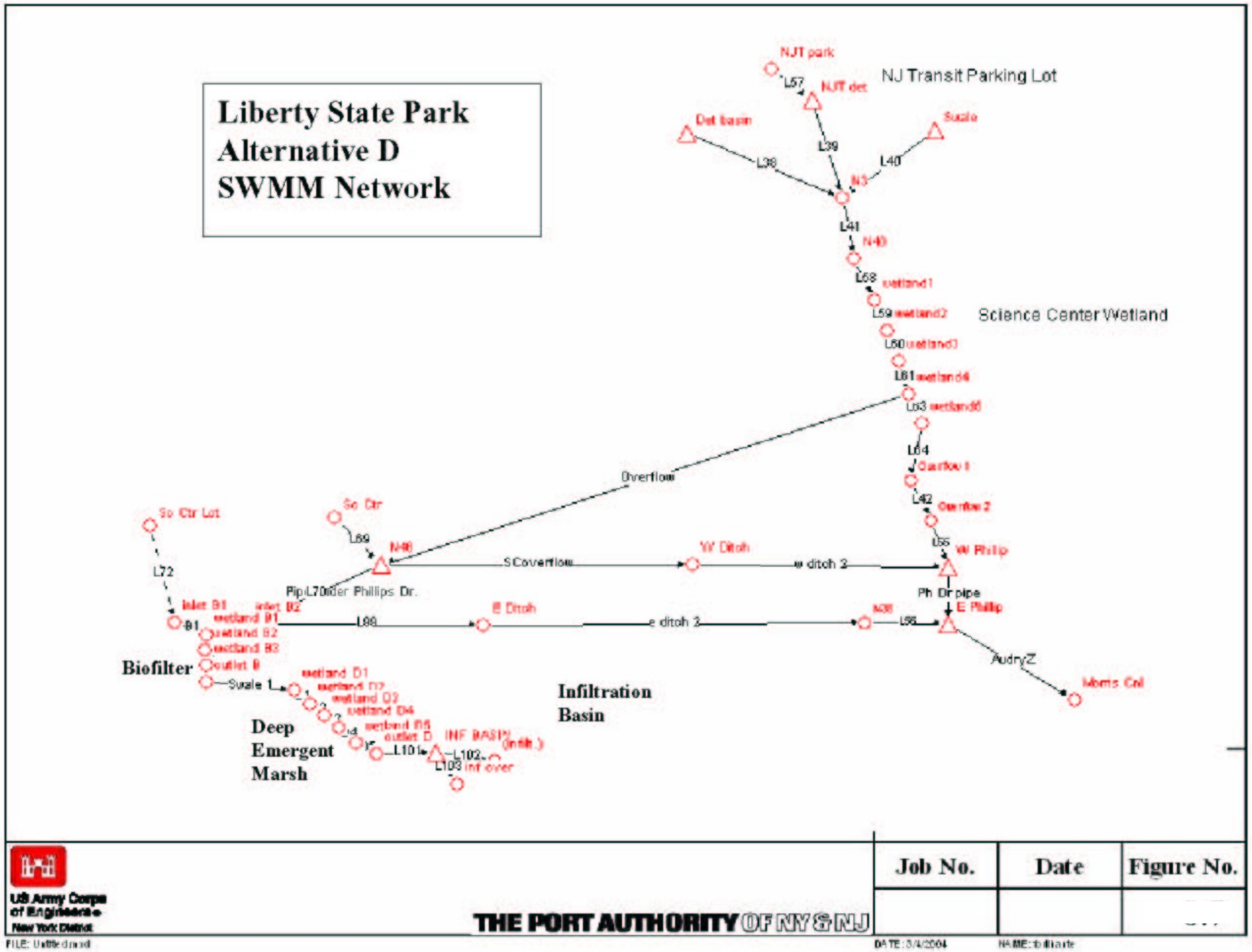


Figure 4.12 SWMM Network for Proposed Conditions (Alternative D)

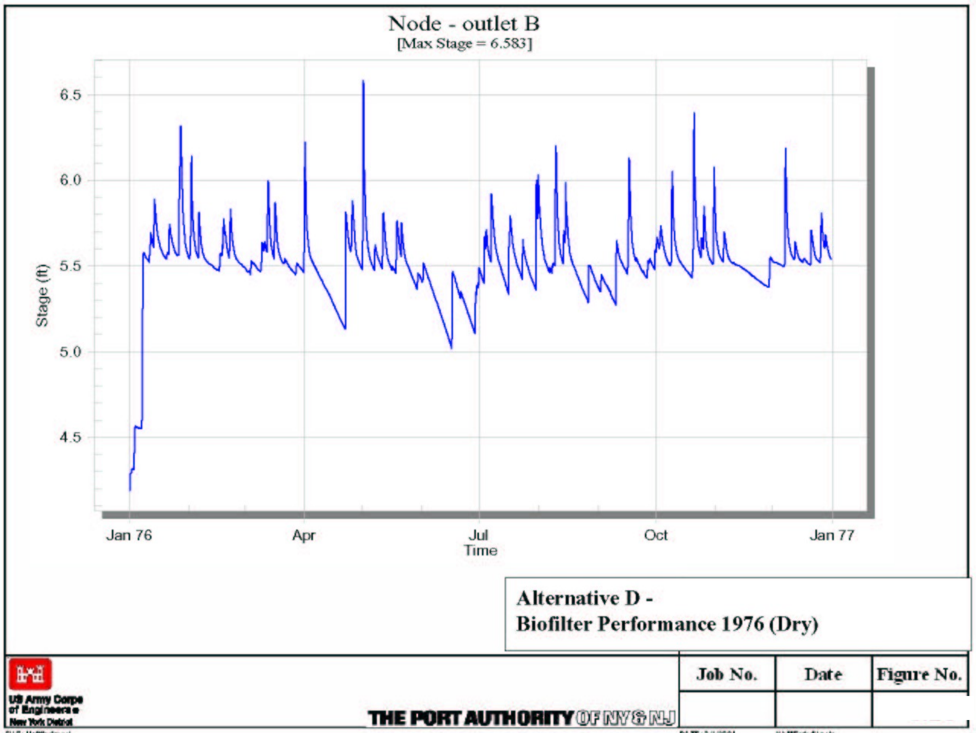


Figure 4.13 Biofilter Performance During a Dry Year for Chosen Alternative

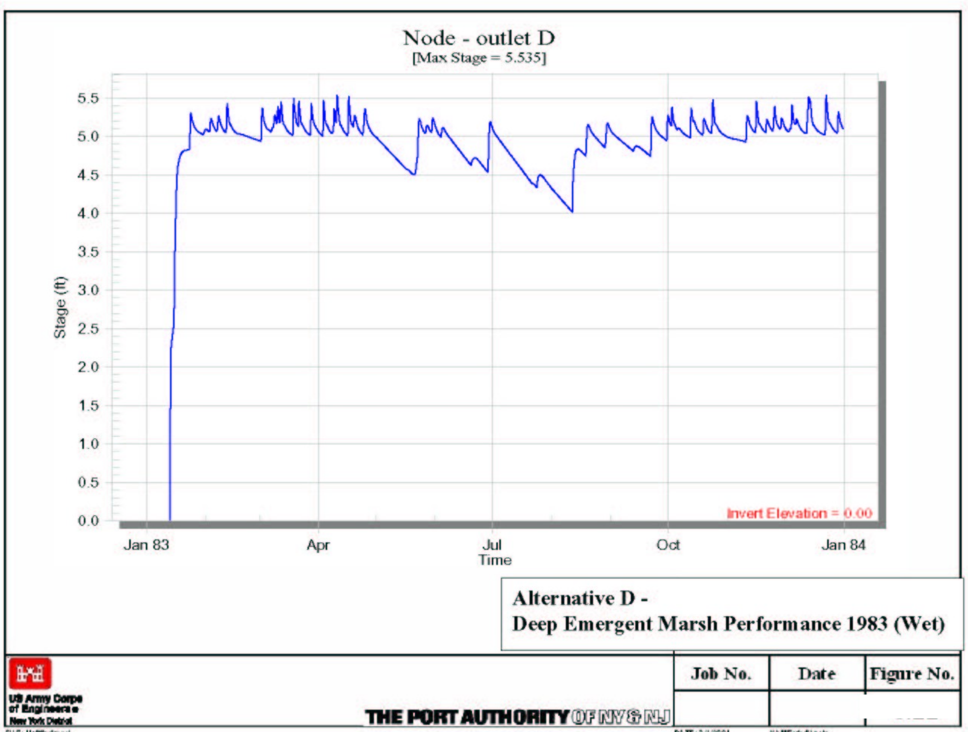


Figure 4.14 DEM for a Wet Year

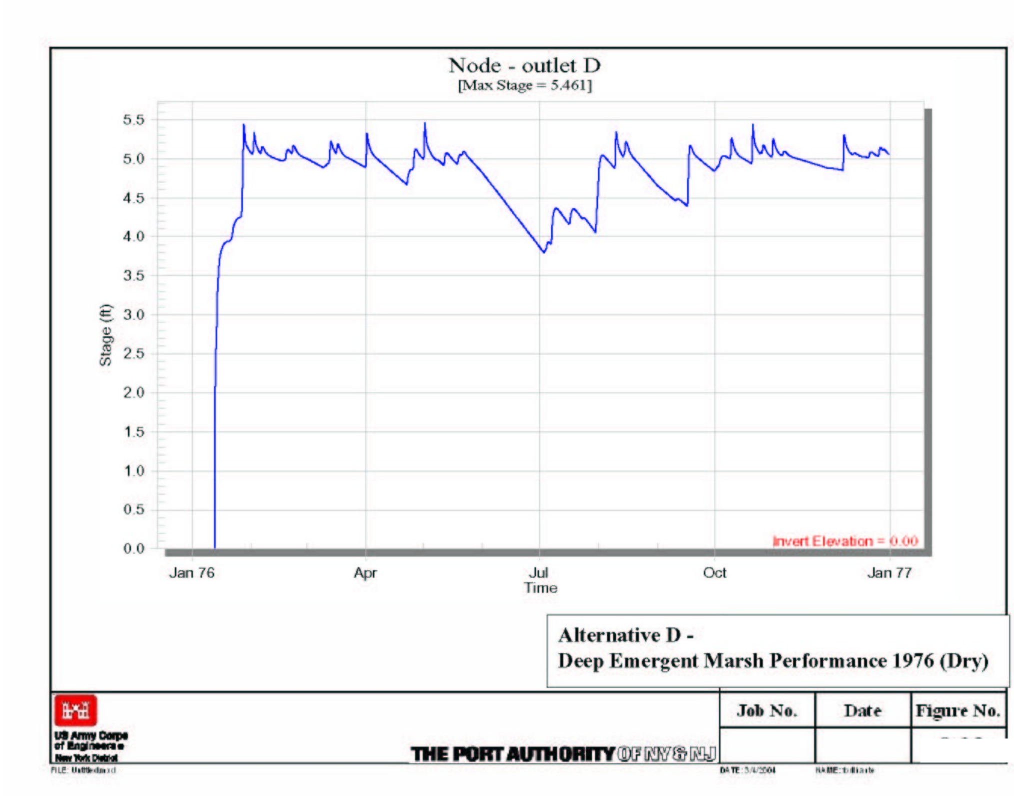


Figure 4.15 DEM for a Dry Year

Overflow from the DEM enters the infiltration basin and is lost from the system through infiltration. As shown in Figure 4.16, periods of higher rainfall surcharge the infiltration basin above the design WSEL of the DEM for brief periods of time.

For the dry model year, input to the infiltration basin is less frequent . Subsequently, there is less infiltration. See Liberty State Park Hydrology and Hydraulics of Fresh Water Wetlands Report (USACE 2004) for the stage/time plots for all the SWMM nodes for wet, dry and normal rain years.

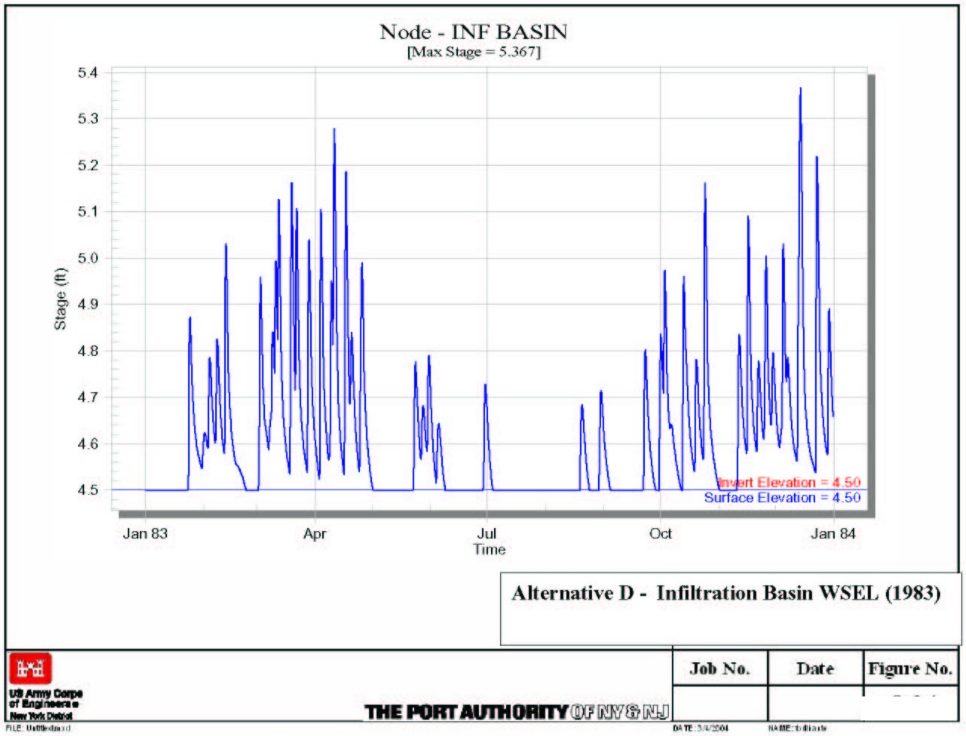


Figure 4.16 Infiltration Basin for a Wet Year

4.10 10-year NJDOT Design Event Performance

The performance of the freshwater wetland system was evaluated to ensure that no induced roadway flooding occurs during the NJDOT roadway design event. The NJDOT design event is a 10-year/24-hour rainfall event of approximately 5.25 total inches of rainfall. Unlike the annual models, the design event was modeled using SWMM's "hot-start" feature, which enabled modeling of the events with antecedent conditions in the wetlands. Starting the model with existing water in the wetland more realistically represents the behavior of the WSELs in the system.

The primary areas of concern in the wetland system are: 1) the Biofilter and, 2) the detention/ponding area west of Phillip Drive (the upstream end of the Phillip Drive pipe). Excessive backwater flooding in these areas could overtop Phillip Drive as a result of the proposed wetland system. The WSELs of both the Biofilter and upstream detention area just reach the minimum curb height of 7.0 feet NAVD along Phillip Drive as a result of the 10-year/24-hour storm runoff in each alternative. From these results, it is assumed that flooding is not likely to occur at Phillip Drive following a 10-year/24-hour storm event as a result of the freshwater wetland system construction.

4.11 Sensitivity Analysis

Uncertainty has been incorporated into the hydrology through the use of precipitation from extreme wet and dry years of record. Evaporation uncertainty is incorporated through the use of monthly averages. However, at this point in the analysis there is some degree of uncertainty associated with the potential infiltration of the proposed infiltration basin. Small changes in the infiltration rate are not expected to be critical to the wetland system performance; however, a sensitivity analysis is appropriate to demonstrate the impact of potential changes in filtration.

As defined, a sensitivity analysis is a technique of varying assumptions to examine the effects of alternative assumptions on the determined outcome. In this case, a sensitivity analysis was used to show how the wetland system will perform if the infiltration of the proposed infiltration basin is changed. To evaluate the system sensitivity to a change in the infiltration rate, the proposed infiltration rate was modeled during the wet year (1983) with an outlet sized for a maximum outflow of approximately 1 cfs at 1.5 feet of head, which is equivalent to maximum infiltration rate of 0.5 in/hr over the 2 acre infiltration basin, or half of the assumed infiltration rate of 1 in/hr.

Infiltration is half the rate originally modeled for this sensitivity run; however, the WSEL elevation increase in the infiltration basin is only approximately 0.4 feet during the largest storm. The greatest impact is a backwater impact into the DEM; however, this is minimal and quickly dissipates as the infiltration basin WSEL drops. It can be assumed that an increase in the infiltration rate will have the opposite effect on the WSEL of the infiltration basin and DEM during a given year. Regardless, minor changes in the infiltration rate should not detrimentally impact the freshwater system.

5. TIDAL WETLAND

5.1 Objectives

The study team determined that creation of a Tidal Creek/Salt Marsh would increase biodiversity, improve water quality in the immediate vicinity by augmenting tidal circulation and restore underrepresented habitat in Liberty State Park, three of the major goals for the area and for the Hudson-Raritan Estuary Ecosystem Restoration Project. The proposed location for this feature is the northeast corner of the site starting in the North Cove. It extends into the southern half of the existing 45-acre dredged material containment area. The creation of low marsh, high marsh, mudflat and tidal creek habitat, and the enhancement of sub-tidal habitat are proposed in the selected NER plan (Figure 5.1)

5.2 Tidal Analysis, Runoff and Groundwater

5.2.1 Tidal Analysis

Section 2.8 discusses the analysis of tidal influences in the Upper New York Harbor, adjacent to the proposed tidal wetland. DH-21 Water Level Recorders were used to collect the data. The output files can be found in appendix A. The reconstruction of the tidal epoch was done using the “datum reduction method” (National Ocean Service, NOAA). The use of the datum reduction method results in local tidal datums that provide estimates of what would have been observed over the 1983-2001-epoch period. It was found that the effect of heavy precipitation events on the observed tide data was negligible. Table 5.1 restates the computed tidal datums used for the tidal wetland analysis and design.

Figure 5.1 Proposed Tidal Wetland for Liberty State Park

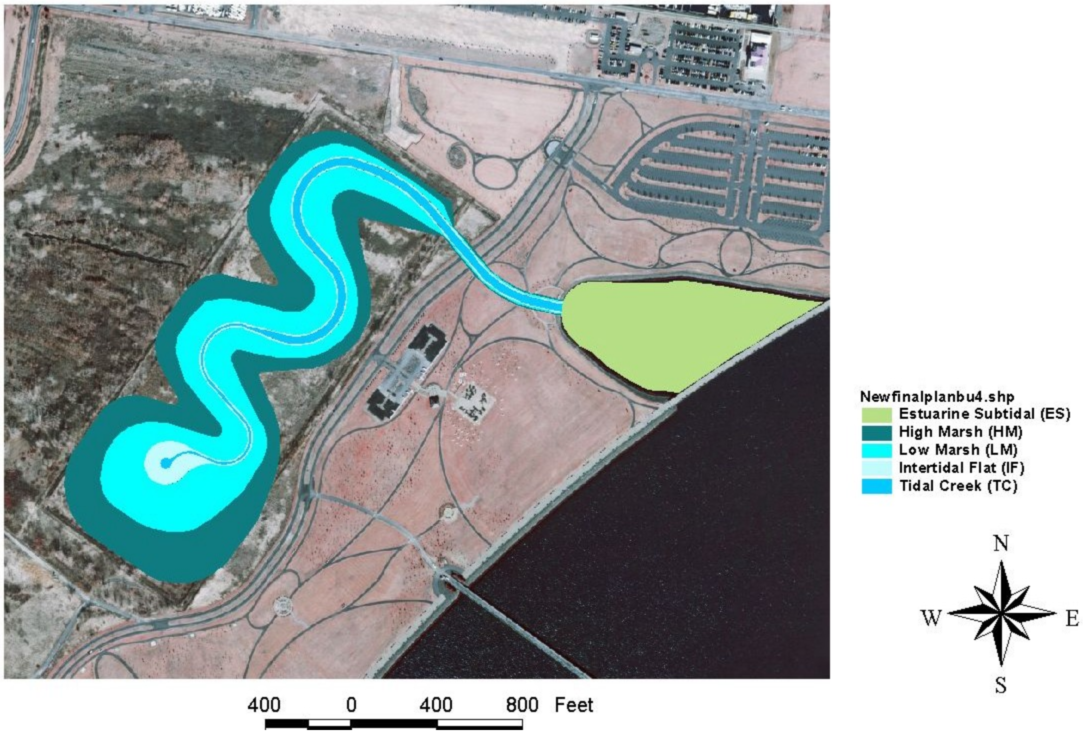


Table 5.1 Tidal Datums for Liberty State Park* (ft NAVD88)

Mean High Water Spring	2.29
Mean Higher High Water	1.91
Mean High Water	1.75
Mean Tide Level	-0.51
Mean Low Water	-2.77
Mean Lower Low Water	-2.93
Mean Low Water Spring	-3.31
Diurnal Tide Range	4.51
Great Diurnal Tide Range	4.84
Spring Tide Range	5.60

* Reconstructed South Cove Tidal Datums were used for the design of the tidal wetland. They were obtained by comparing the South Cove and Battery datums from 31-Jul-2003 to 11-Sep-2003, and reconstructing them to the 1983-2001 tidal epoch, using the Battery as the primary record.

The project site's proximity to the long-term NOS Battery gage allowed for more tidal analyses than what has been done in past feasibility studies. The dependence of high marsh on episodic events less frequent that spring tide events has been observed by scientists (Tiner, 1985), and will be discussed in the next sub-section. Figure 5.2 looks at 1 year of data from the Battery gage, adjusted to represent the south cove by subtracting 0.2 ft from the elevations (the derived from the datum reduction routine). The highest water level observed in the South Cove from July 31 to September 11 was 3.16 ft. That translates to the 6% exceedence value on Figure 5.2. The corresponding low water for this event was 3.16 ft. Where the biobenchmarks fall within figure 5.2 and within the computed tidal datums is discussed in the next sub-section.

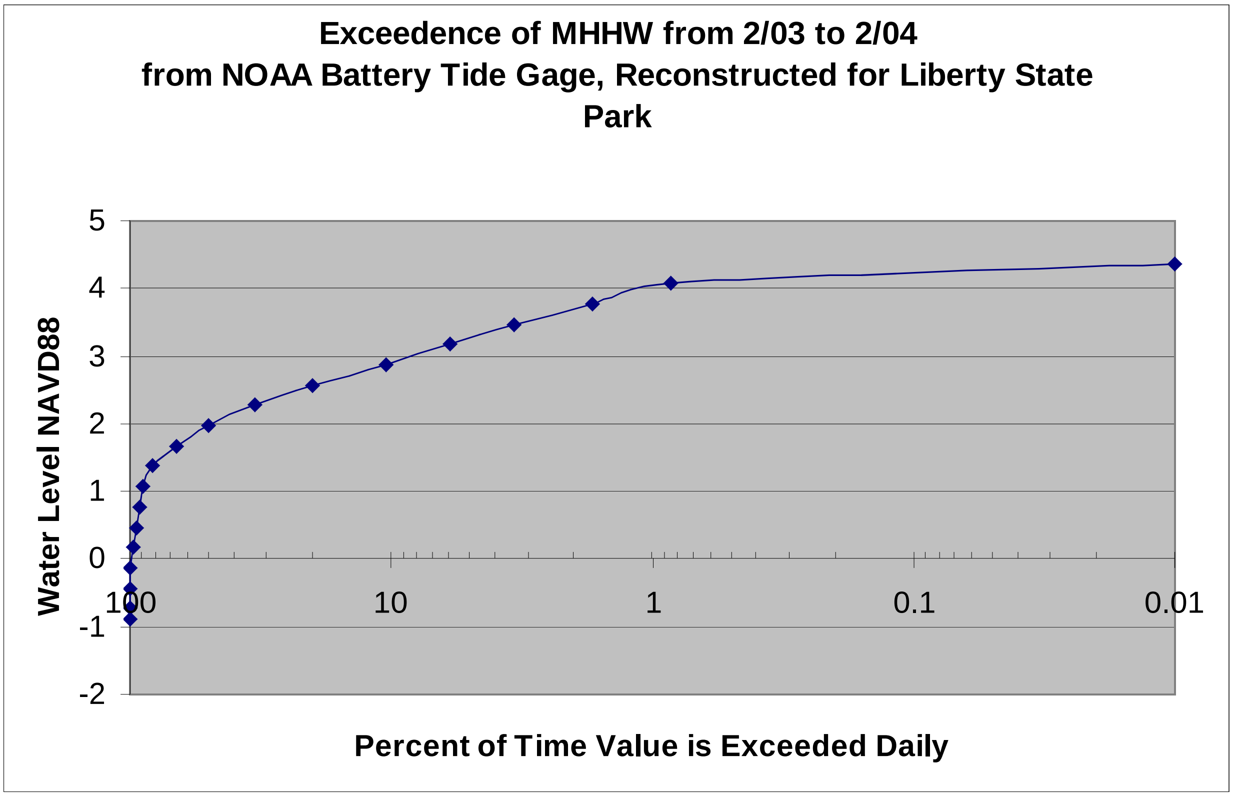


Figure 5.2 Frequency of MHHW Elevations, Reconstructed for the South Cove, LSP

5.2.2 Runoff

As discussed previously, there is very little topographical relief within Liberty State Park. The presence of Philip Street on the western perimeter of the project site (and its adjacent drainage ditches that discharge into Morris Canal) prevents significant runoff from entering the interior of the park and the proposed tidal marsh area. When compared to a tidal range of over 4.5 ft, the effect of rainfall on the proposed tidal wetland design is negligible. The slight topographical relief in the park in the immediate vicinity of the proposed tidal wetland will be accounted for by specifying the routing of the runoff via the regrading plans to be developed in the next phase of the study.

5.2.3 Groundwater

Groundwater monitoring wells observed water level and water quality parameters. The wells were installed in April, 2004, and they will still be recording when this document is released.

The preliminary results show that groundwater is 5 ft below ground surface in the vicinity of the proposed tidal wetland site (approximately +5 ft NAVD88). In most locations, more than 5 ft will be excavated, so groundwater will be encountered. Because of the potential of contaminants found in the groundwater, the tidal marsh will be hydraulically disconnected from the groundwater. A 1-ft thick impervious clay liner will be placed in the footprint of the tidal wetland. In addition, a 1-ft thick cap of sand will be placed on the impervious clay layer, on the footprint of the tidal wetland to provide a substrate for the wetland plants to take root without disturbing the integrity of the impervious clay liner.

5.3 Environmental and Hydraulic Design Criteria

Salt marsh vegetation communities are tightly coupled with the tidal regime. Water levels fluctuate over the daily and monthly tidal cycle, flooding the shoreline for different periods of time. The period of inundation is dictated by elevation contours, and zonation among plant species occurs along these contours. The location of plant species along the gradient is determined by the species' tolerance to salinity and water (frequency, duration, and/or depth of inundation). Species that are tolerant to water and salinity occur at lower elevations in the intertidal zone, between the Mean High Water (MHW) level and the Mean Low Water (MLW) level. Less tolerant species occur at higher elevations, which are inundated only during spring-tide high water levels.

The success of a salt marsh restoration effort greatly depends upon the location of the planted vegetation along the shoreline gradient. Since local conditions vary (salinity, tidal amplitude, etc), biological benchmarks, measured from surrounding local marsh vegetation and local tidal information, should be used as a guide for determining the elevations for vegetation replanting. Elevation ranges of plant communities in reference wetlands can be duplicated in the restored salt marsh.

Thriving wetland communities throughout the Hudson-Raritan Estuary were surveyed to collectively establish the general environmental design criteria and flow prescription for the four proposed tidal wetland communities. To account for varying local conditions, two sites were chosen as reference sites for the tidal salt marsh: One was in the South Cove of Liberty State Park and the second was just south west of the site in Port Liberté. Their characteristics were documented on 17 and 25th September 2003 and 14 October 2003. The results of this biobenchmarking effort is documented in Appendix G of the Liberty State Park Environmental Resource Inventory Report, USACE 2004, and is summarized in Figure 5.3 and Figure 5.4

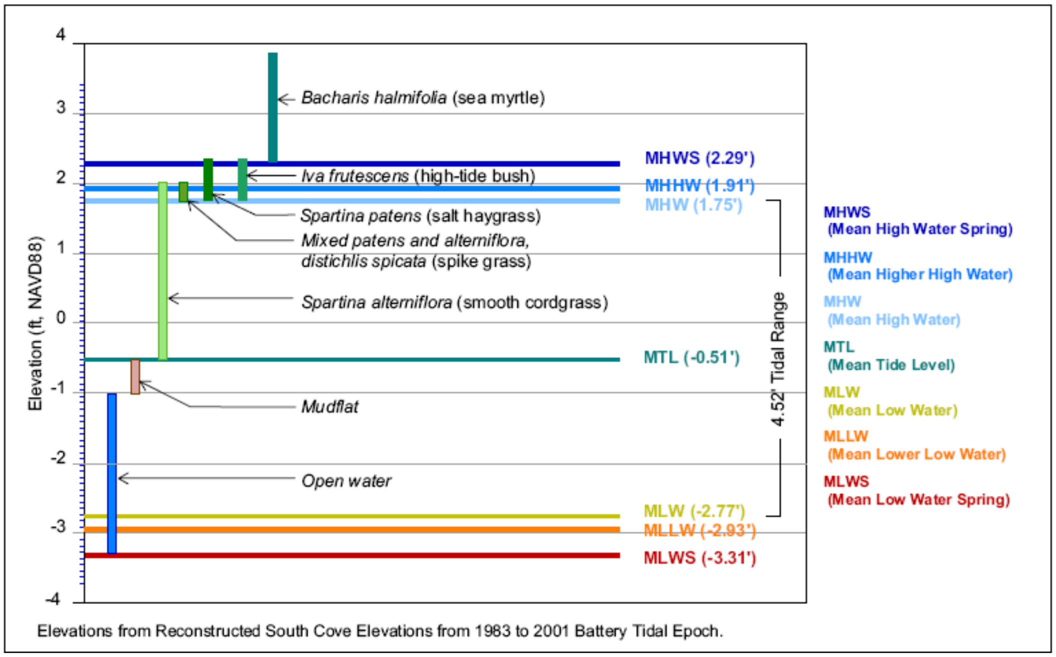


Figure 5.3 LSP Benchmarking and Tidal Datums

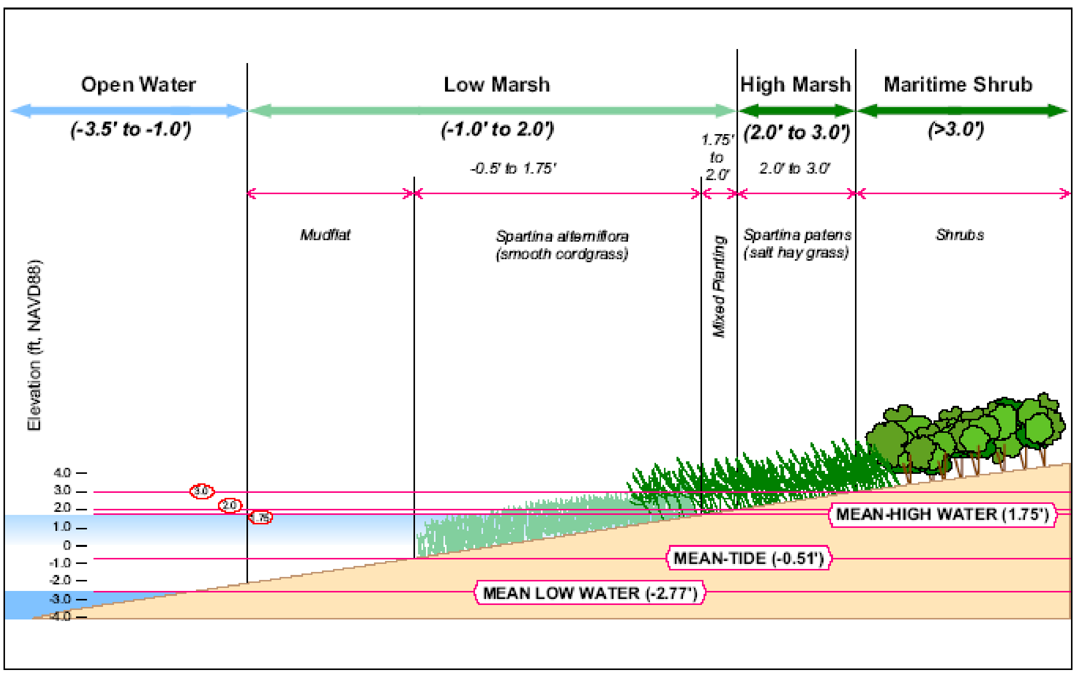


Figure 5.4 LSP Salt Marsh Profile

The following describe the design criteria for each proposed tidal salt marsh community.

1. Tidal Creeks. Tidal Creeks are permanently flooded for the mean tide range (MHW to MLW). The creeks offer a place for fish to congregate at low water. The substrate of the tidal creeks should be able to retain sufficient Dissolved Oxygen and other water quality parameters to support benthic populations, and to have the proper conditions for sub-aquatic vegetation to eventually take root. The velocities in the creek should not be so great as to trigger unrecoverable deposition and erosion in the

channel so that parts of the wetland become hydraulically disconnected from the tide. However, circulation within the marsh is encouraged to facilitate better water quality and to avoid stagnant water. Sinuosity of the creek layout is an important feature as it maximizes fringe habitat, it slows down the high velocities in the creek, and also encourages greater water circulation.

2. Mudflats. Mudflats connect the tidal creeks and low marsh. They will dry out at low tide, although they usually are flooded for more than half of the tide cycle. The mudflats also should be able to retain sufficient Dissolved Oxygen and other water quality parameters to support benthic populations.
3. Low Salt Marsh. In the Hudson-Raritan Estuary and in other estuaries in the Northeast United States, the dominant low salt marsh species is *Spartina alterniflora*. *Spartina alterniflora* needs both wet and dry conditions every day, and it is usually found growing between MTL and MHW. The extent of the tall and short form of *Spartina alterniflora* biobenchmarking data was used to determine the regrading and planting plan for low marsh (see Figure 5.3 and Figure 5.4).
4. High Salt Marsh. In the Hudson-Raritan Estuary and in other estuaries in the Northeast United States, the dominant high salt marsh species is *Spartina patens*. However this zone is usually much less homogeneous than the low marsh, and is often a mosaic of a number of species including salt hay grass (*Spartina patens*), spike grass (*Distichlis spicata*), a short form of smooth cordgrass, black grass (*Juncus gerardii*), switchgrass (*Panicum virgatum*), high tide bush (*Iva frutescens*) and common reed (*Phragmites australis*) (Tiner, 1985). *Spartina patens* grows at a minimum to mean high water spring (elevation +2.29ft NAVD88) but often occurs up to the extreme high tide. This upper boundary may be inundated infrequently, in some locations as little as once or twice annually. Such inundation usually occurs during the spring tide cycle (highest annual tides or MHWS) and during the severe storm events. This is confirmed for New Jersey salt marshes by Tiner (1985), who states that the upper margins of the high marsh may be flooded only during storm tides which are more frequent in winter. Extreme high tide is not specifically recorded in the regional tide data. While the highest observed water level was actually over 4 feet above MHWS, about one foot above MHWS or an elevation of 3.3 ft is a reasonable estimate of the extreme high tide, and a possible upper limit for the high marsh. The 6% MHHW Exceedence tide, or the highest tidal cycle observed in the monitoring period will be analyzed in the hydrodynamic model to determine if the upper reaches of Spartina *patens* will be inundated in the selected plan. The Spartina *patens* biobenchmark results are also found in Figure 5.3 and Figure 5.4. The regrading and planting plan for high marsh also was developed by merging the tidal datum and biobenchmarking information, and by incorporating the observations of scientists in the region studying salt marshes.

5.4 Alternatives

The alternatives analyzed by the study team for the tidal wetland design ranged in plan view from a wetland that had two inlets open to Upper New York Harbo,r to a creation of an upland habitat island in the center of the tidal creek system. In the two-inlet system, the southern inlet would need to be cut through a seawall adjacent to the Harbor, risking the stability of the seawall. There is a combined sewage outfall in the vicinity of the southern inlet which should be avoided if possible. Thus, that alternative was eliminated. The island system was eliminated because of the potential for 1 side of the creek to be favored, resulting in the siltation and drying out of the creek on the other side of the island and its surrounding marsh. A one-inlet meandering creek layout offered the least potential risks of failure.

The tidal creek cross sections were evaluated next. A 75ft wide tidal creek promised to function properly within the 50-year project life from a duration-of-flooding perspective, but there were concerns about its biological benefits. Based on visual observations and the experience of the PDT members, a 75ft wide creek for a 42-acre marsh is wider than the naturally occurring tidal creeks in the area. There were concerns that so much open water would detract from the amount of desirable salt marsh habitat. Thus, the 75 ft wide tidal creek was eliminated in the preliminary screening. A preliminary HEC-RAS analysis showed that a 25 ft wide creek would significantly dampen the tidal signal, risking the success of the low and high marsh in the upstream reaches of the wetland. A 50' tidal creek, though slightly wider than naturally occurring tidal creeks in the region, was determined to provide both adequate water for proper tidal flushing and ensure that natural sedimentation would not impair its functionality. A hydrodynamic model, discussed later, validates this design.

Lastly, disposal options for the material removed to create the tidal wetland were evaluated. Because of the contaminated nature of the material, the placement of dredged material is limited by the stipulations of a Consent Decree. [2] The Consent Decree defines how the contaminated material must be treated in the case that there is any disruption of the site. The contamination of the soil makes off-site disposal prohibitively expensive. As a result, the study team had to formulate alternatives that would allow for the placement of dredged material from the tidal creek in an environmentally sensitive manner. In addition, the area from which the tidal creek would be excavated is currently capped with physically unstable material. This area will need to be re-capped within the next five years if this project does not go forward. The southwest corner of the park was chosen as the disposal area for this material. The material will be placed in a manner so it will replicate a natural berm. Maritime grassland is the proposed habitat for the berm. The southwest corner currently does not hold significant ecological value. The berm creates an opportunity to re-place this material in an environmentally sensitive manner for the long term.

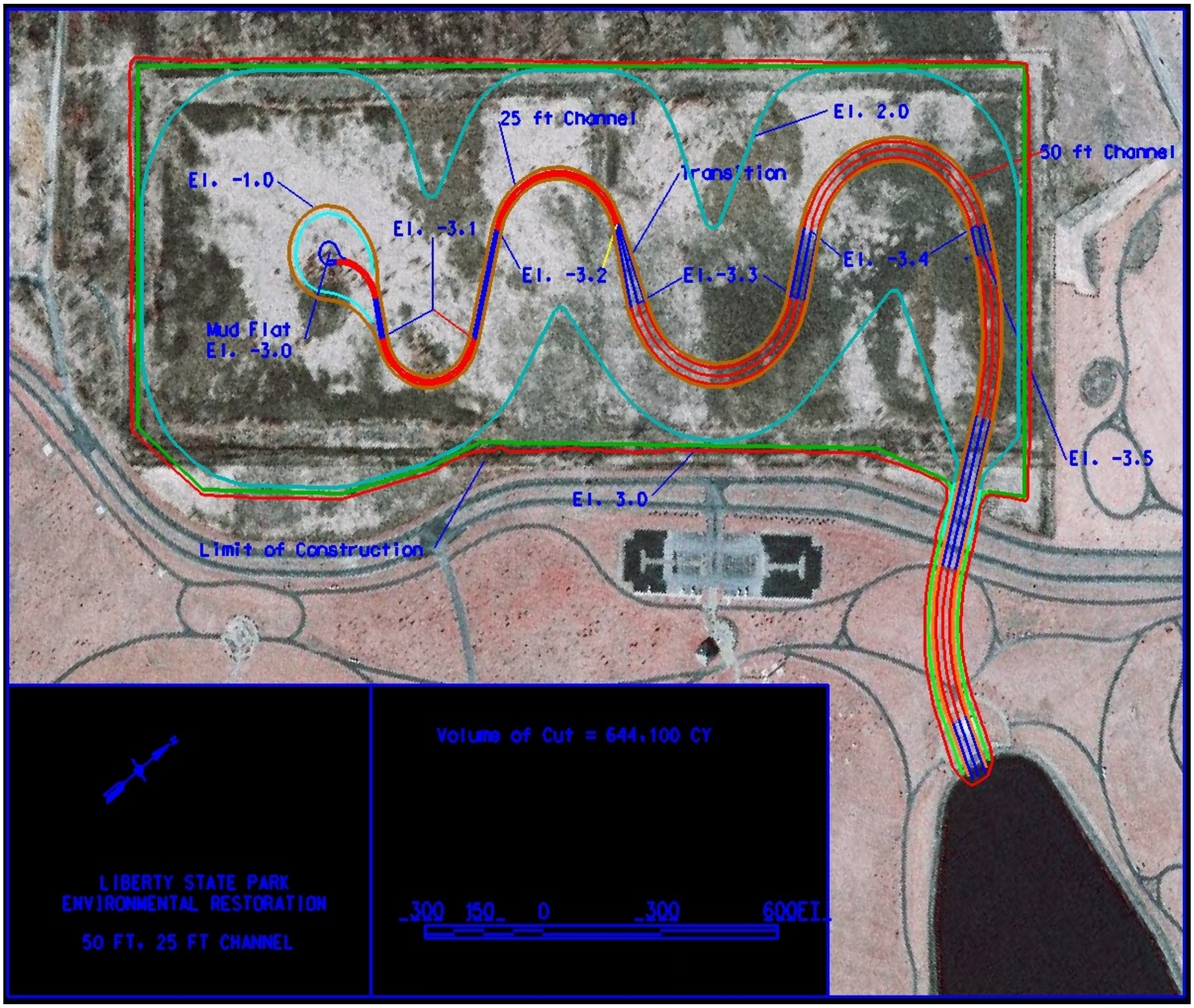
5.5 Components of Proposed Alternative

A channel width of 50 ft at the North Cove confluence, tapering to 25 ft at the upstream end of the marsh was found to convey sufficient flooding to the proposed low and high marsh throughout the site (Figure 5.5). A 48 ft wide bridge will be constructed to facilitate the creation of the tidal creek under Freedom Way. The bridge is necessary to allow the tidal waters from the North Cove to reach the proposed tidal marsh within the rectangle. The proposed bridge will span 50 ft to allow one lane of vehicular traffic in both directions. The channel will have a natural bottom consistent with the sandy bottom proposed for the entire length of the tidal

[2] Liberty State Park Consent Decree 33-35

channel. The roadway will be supported over the channel by means of a reinforced concrete arch bridge (Figure 5.6).

Figure 5.5 Tidal Creek Depths and Width (top of bank)



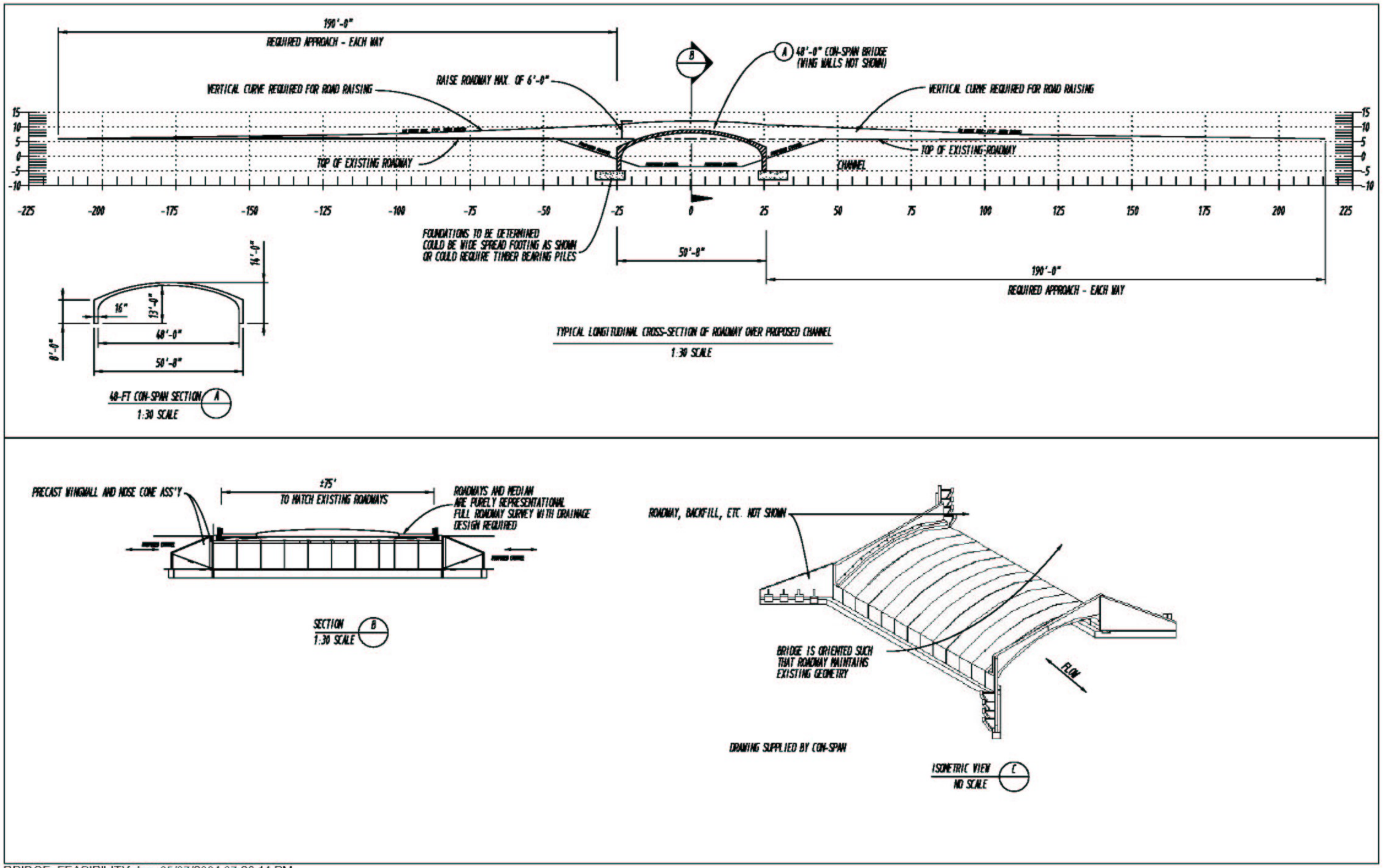


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Figure 5.6 Tidal Creek Bridge Design and Sections

Natural tidal marsh channels in the region have very mild slopes in the longitudal direction. The proposed LSP tidal channel slope is 0.0001 ft/ft. The proposed sinuosity, or the ratio between the tidal channel length and the tidal valley length is 1.7, also similar to natural tidal channels in the region.

The maximum channel side slope used in the design of the mudflats was 1V:3H. The geotechnical investigation revealed that unconsolidated, silty material lies in the location of the proposed tidal creek outlet. A 1V:3H slope was suggested by contractors as the steepest slope at which their earth moving equipment can operate comfortably. The marsh will undergo an adjustment period after a few tidal cycles whereby equilibrium slopes will form, and it is anticipated that minimal adjustments will be made to the planting plan to adjust to the equilibrium process. Natural tidal mudflats in the region vary considerably in slope. However, well established *Spartina alterniflora* dominated tidal marshes have the root structure in the soil to support much steeper slopes. These slopes cannot be constructed without the use of hard structures. Monitoring the slope of the mudflats will be a part of the monitoring plan, and efforts will be made to guide the mudflat slopes to mimic natural systems. A mudflat feature was created at the upstream extent of the tidal channel. This feature adds more essential fish habitat and more diversity to the tidal marsh plan.

The low and high marsh regrading plan was discussed in the previous section. To stabilize the slopes and to out-compete phragmitites, *Spartina alterniflora* and *Spartina patens* will be densely planted, at a spacing of 18 inches on-center for each plug. To account for contingencies in the regrading equilibrium process, in the elevation zones between low marsh and high marsh, both *Spartina alterniflora* and *Spartina patens* will be planted. Similarly, in the elevation zones between high marsh and maritime scrub/shrub, *Spartina patens*, spike grass (*Distichlis spicata*), a short form of smooth cordgrass, black grass (*Juncus gerardii*), switchgrass (*Panicum virgatum*), high tide bush (*Iva frutescens*), sea myrtle (*Baccharis halimifolia*), rose mallow (*Hibiscus moscheutos*), and seaside goldenrod (*Solidago sempervirens*) will be planted.

Low levels of contamination have been found during previous HTRW investigations at Liberty State Park. For added security, to minimize exposing the proposed tidal marsh to contaminants, a one-foot layer of compacted cohesive material will line the footprint of the tidal marsh. A one-ft layer of clean sand will be placed on top of the cohesive material to provide a more common substrate for tidal marsh plants to take root.

The HTRW testing conducted for this feasibility report indicated that low levels of contamination might be present in the North Cove. To prevent this material from entering the proposed tidal marsh, and to provide a more suitable substrate for benthic habitats, the entire North Cove below MLLW, out to the Liberty State Park Causeway will also be capped with 1 ft of clean sand.

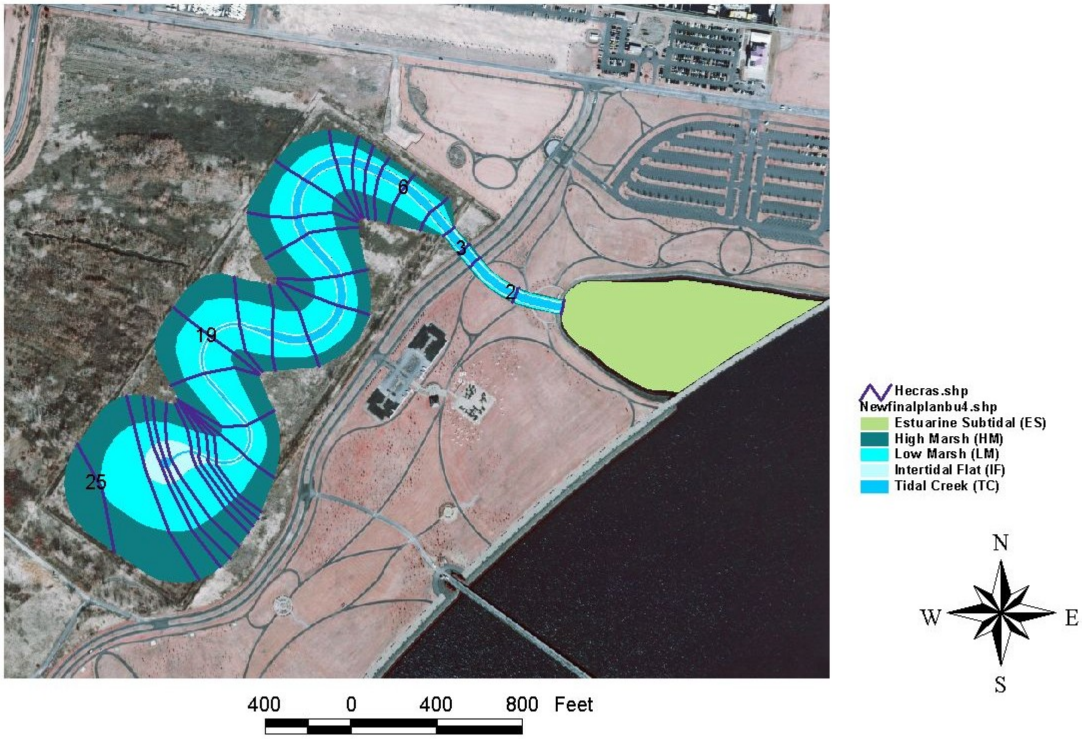
5.6 HEC-RAS Model Development

The USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) software was used to size the channel and bridge so water will be conveyed from NY Harbor to the tidal wetland. The software performs one-dimensional steady and unsteady flow hydraulic computations to simulate stage and flow through a network of channels The numerical algorithms solve the one-dimensional energy equation. Friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head) contribute to the energy losses. When the water surface profile varies rapidly, the momentum equation is utilized. Rapidly varying profiles occur at bridges, culverts, weirs, river confluences, or at sudden changes in slope or bottom friction.

An unsteady flow simulation tool was used to evaluate the tidal cycle on the proposed channel system. The unsteady flow equation solver was adapted from Dr. Robert L. Barkau's Unet model (Barkau, 1992, HEC 1997). These equations are based on the conservation of mass (continuity), and the conservation of momentum. The unsteady flow simulation tool was developed for subcritical flows.

The plan view for the tidal marsh was developed by the study team (see Figures 5.1 and 5.5). The proposed habitats (low marsh, high marsh, mudflat and tidal creeks) were laid out to mimic natural systems. By obtaining the horizontal coordinates of the habitat boundaries via the GIS file (Figure 5.7), and assigning the boundaries the elevations from the biobenchmarking analysis (Figures 5.3 and 5.4), the creek cross sections were coded into HEC-RAS. The reinforced concrete arched bridge cross sections for the 48 ft wide span was available from the CON-SPAN manufacturer. The ineffective flow areas were assigned in the channel sections upstream and downstream from the bridge. The layout of the channel in HEC-RAS and the channel station numbers is shown in Figure 5.8. The Manning's friction coefficient used for the creek bottom (a l-ft sand cap is proposed over the entire site) is 0.2, and the low and high marsh areas in the cross sections have an assigned Manning's friction coefficient of 0.5, typical of highly vegetative banks. (Chow, 1959). Since the bridge will have a natural bottom, 0.2 was also used for the bridge cross sections. The Manning's coefficients are the least know variable in the analysis. A sensitivity test is done on this variable later in this report.

Figure 5.7 HEC-RAS Cross Sections as measured from GIS layout



Five cross sections have been selected to represent the output of the model. Cross section 25 was the most upstream cross section. The model validated whether the tide adequately flooded the low and high marsh in that area of the marsh. Cross section 19 was at a meander in the creek, where the wetland was fairly wide. Again, the model validated whether the tide adequately flooded the low and high marsh in that section. Cross section 6 showed how the tidal signal was affected by the bridge restriction, upstream from the structure, far enough away from the localized phenomenon associated with a channel restriction. Cross section 3 was the closest cross section to the bridge. The results from that cross section shows what was happening at the bridge restriction. Cross section 2 displayed the tide in the narrow channel, downstream from the bridge.

Three flow regimes were run in this study. MHW-MLW was the flow regime that dictates the low marsh, as low marsh usually begins growing at mean tide, and stops at MHW. Spring tide (MHWS-MLWS) usually dictates the limit of high marsh, with the MHWS datum being the upland limit of high marsh. However, the biobenchmarking data showed high marsh growing at elevations higher than MHWS. Based on the observations found in Tiner (1985), the 6% Exceedence of MHHW tide regime was also run in this study. This value was the highest observed water level during the 6-week monitoring period from 31 July to 11 Sept, 2003. The summary of the flow regimes is found in table 5.2. The tidal stage was the downstream boundary condition, applied at cross section 1. For all runs an initial upstream flow boundary condition of 2 cfs was applied at cross section 25, which tapered to 0.1 cfs in 1hour. Thus, after the first hour, this boundary replicates upland drainage that is a result of the topography sloping towards the creek.

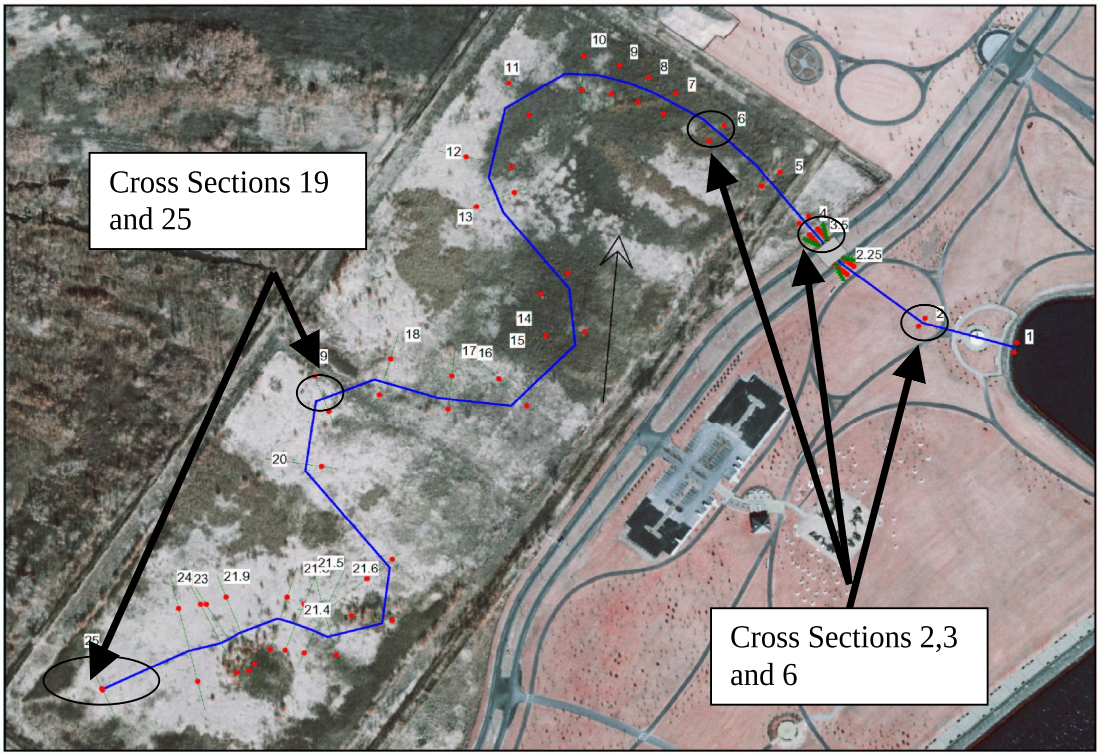


Figure 5.8 Tidal Channel Reach Layout in HEC-RAS

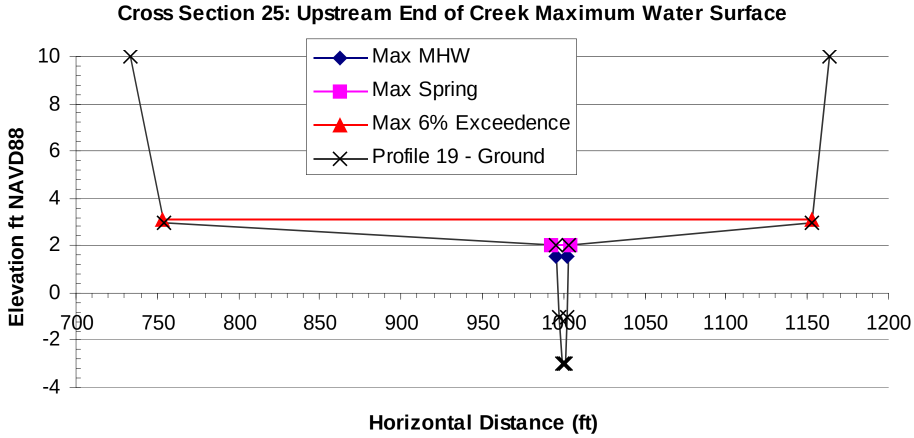
Table 5.2 Tidal Boundary Conditions Used for HEC-RAS Analysis

	Maximum Stage	Mean Tide	Minimum Stage	Range
MHW-MLW	1.75	-0.5	-2.75	4.5
Spring Tide	2.29	-0.5	-3.31	5.6
6% Exceedence	3.17	0	-3.17	6.34

* All Elevations in NAVD88
** The actual tidal period is 12.24 hours. 12 hours was used because it allowed for equal time increments of 0.25 hours. By using 12 hours the velocities could be slightly higher thus making the model tidal period a conservative assumption.

5.7 Analysis of the Selected Plan

Figure 5.9 shows the cross sections indicated in Figures 5.7 and 5.8, and the maximum water surface reached for the three flow regimes tested by the HEC-RAS Model. Initially the model was used to size the bridge opening. The 48 ft wide opening was selected because smaller openings would dampen the tidal signal, thus limiting the amount of low and high marsh that can survive upstream of the bridge. By comparing cross section 2 and 6, upstream and downstream from the bridge, the maximum water surface for the MHW-MLW, Spring Tide, and 6% Exceedence level dropped by 0.08, 0.12 and 0.02 ft, respectively, after going under the bridge. With a 4.5 ft tide range, that amount of head loss is acceptable.



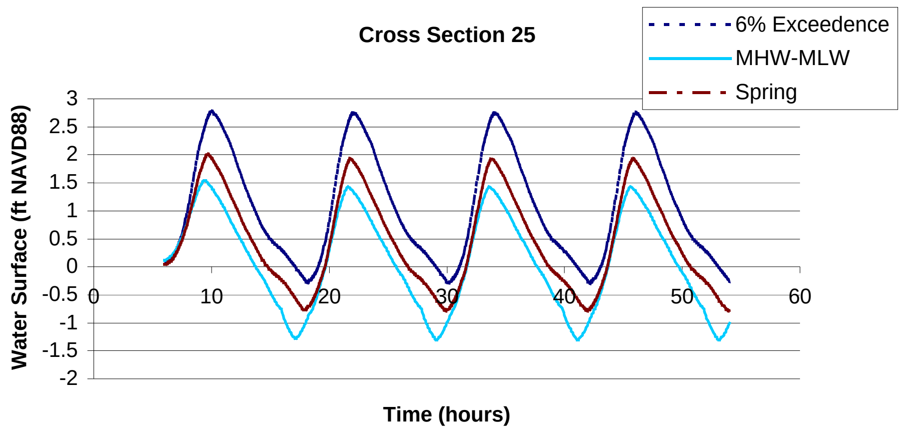
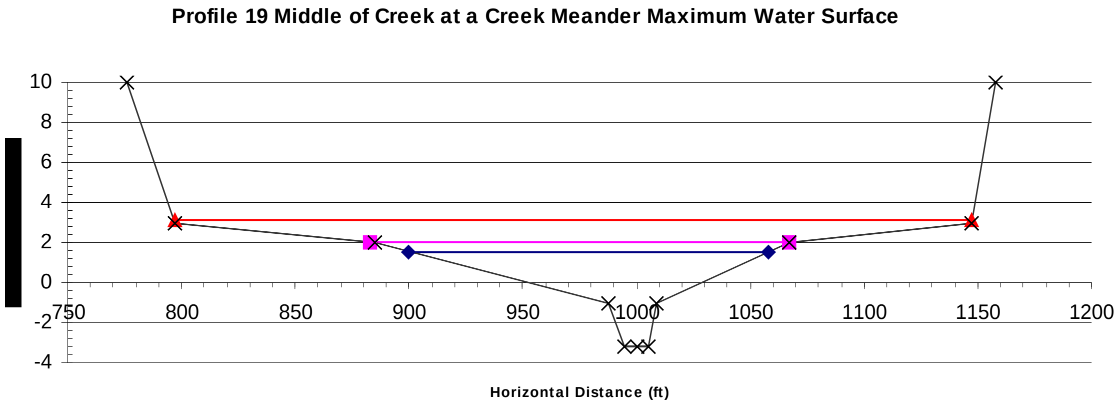


Figure 5.9 Cross Section 25 Water Surface Elevation Plots.



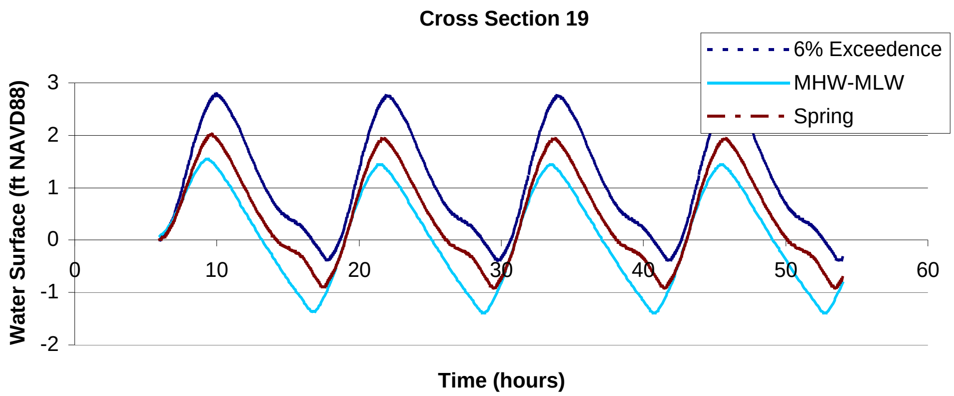
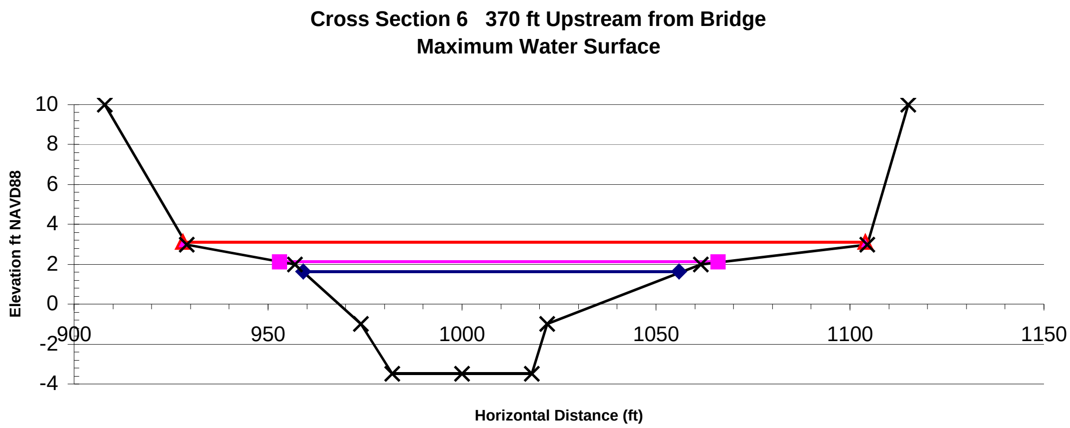


Figure 5.9 (continued) Cross Section 19 Water Surface Elevation Plots.



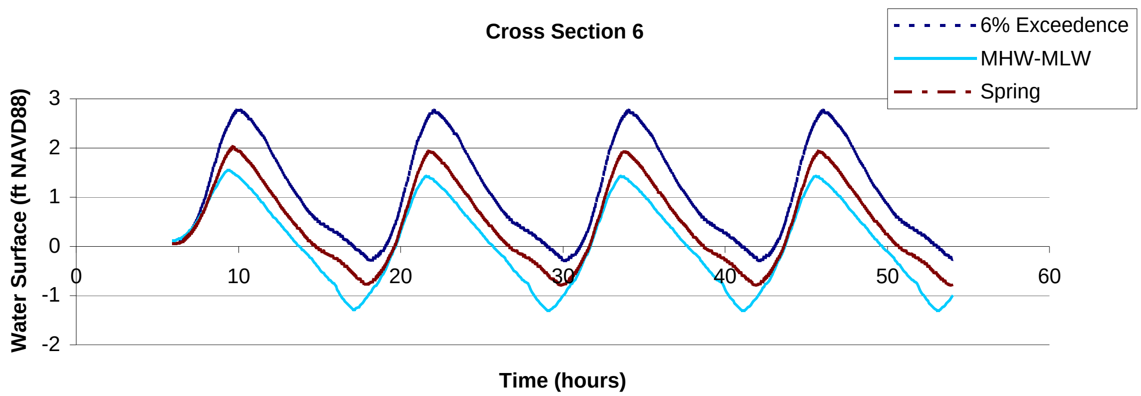
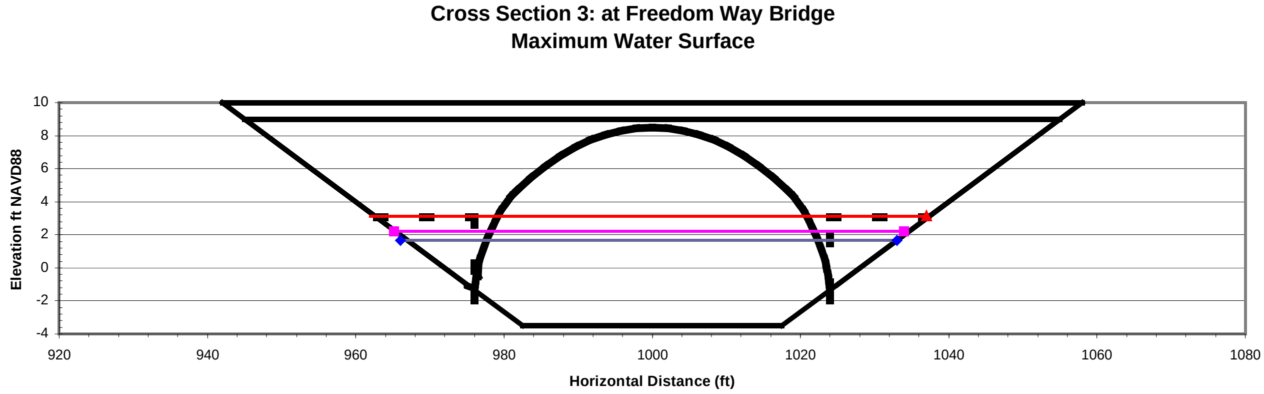


Figure 5.9 (continued) Cross Section 6 Water Surface Elevation Plots



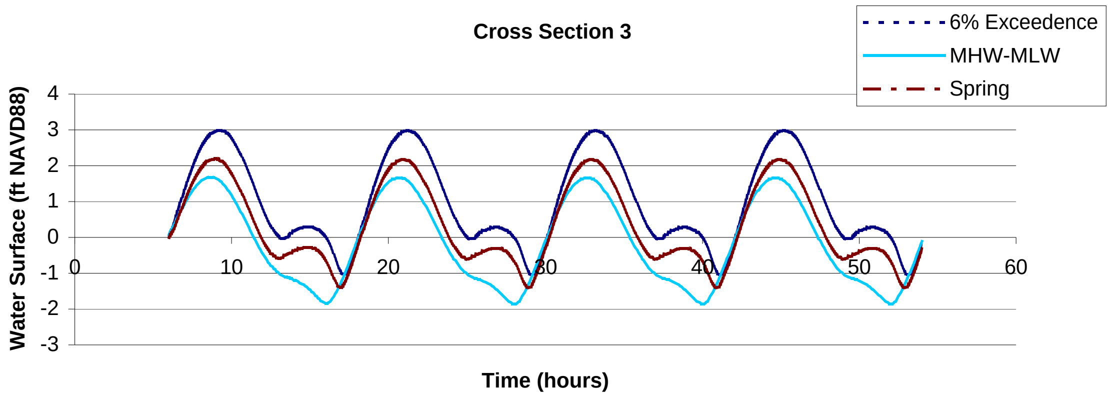
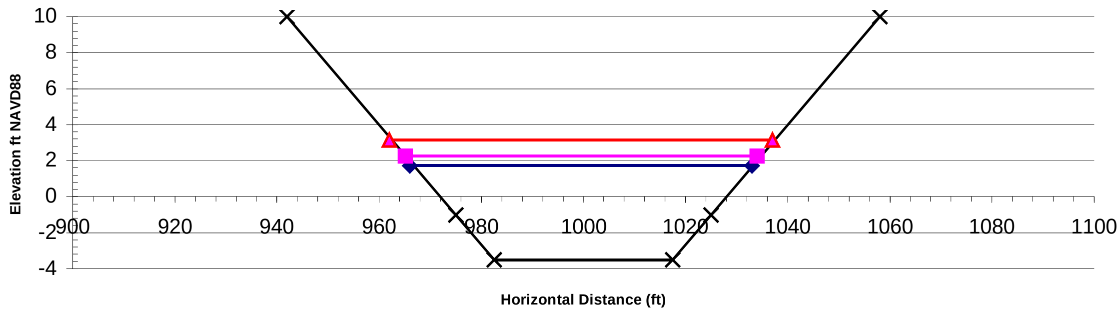


Figure 5.9 (continued) Cross Section 3 Water Surface Elevation Plots



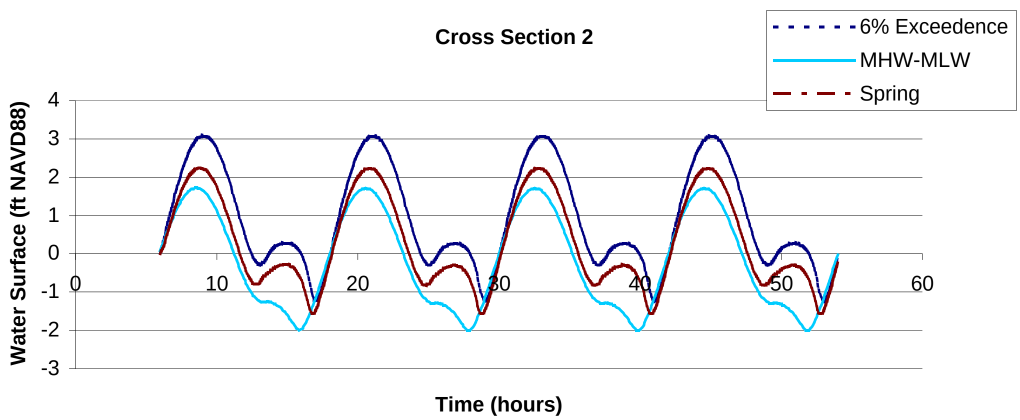


Figure 5.9 (continued) Cross Section 2 Water Surface Elevation Plots.

Figures 5.10 through 5.15 show the extent of flooding throughout the marsh for the highest and lowest stage experienced for the three flow regimes. These perspective plots demonstrate that the marsh adequately drains and floods through the 3 flooding regimes tested. To be certain that the correct duation of flooding will be achieved for the desired vegetative zone, the percent of time a contour is inundated (Table 5.3) is compared to the bipbenchmarking results (Table 5.4). With the exception of the 6% exceedence flood inundating the back portions of the marsh at higher durations than the reference marsh, since the 6% exceedence is an infrequent occurance, it is anticipated that the back marsh will be resilient enough to withstand a high duration of flooding for that low frequency event. Cross Sections 2 and 3 were not evaluated for this analysis because the proposed plan only specifies a small fringe low and high marsh for these cross sections.

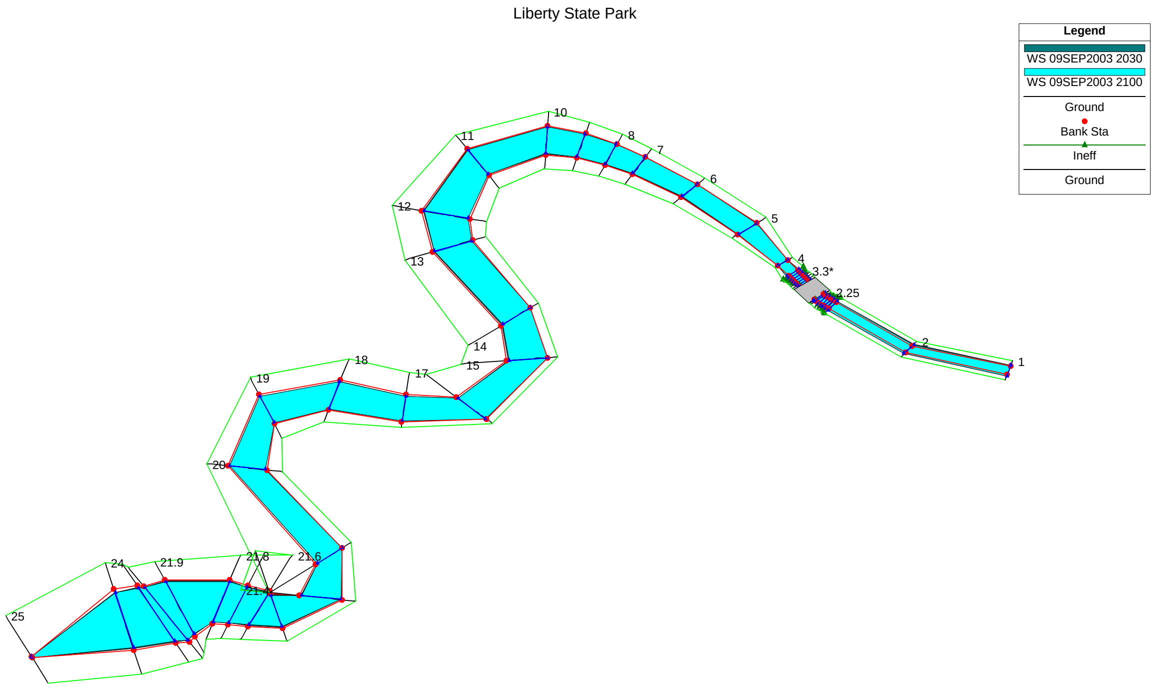


Figure 5.10 MHW-MLW Maximum Flooding of Site

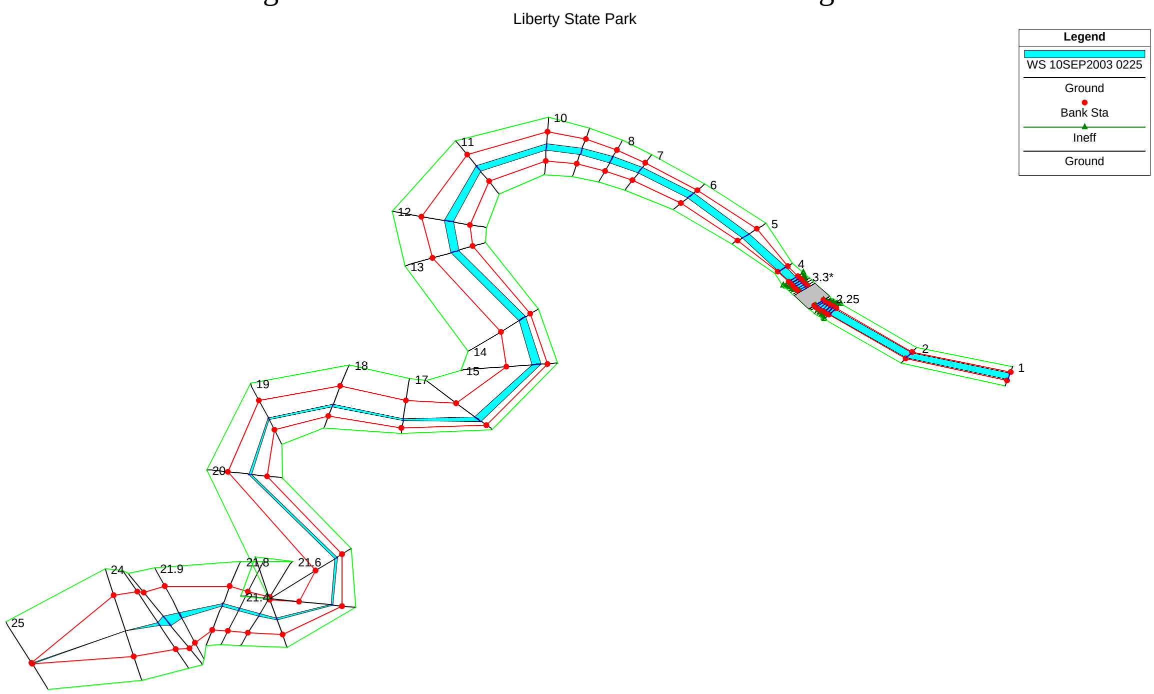
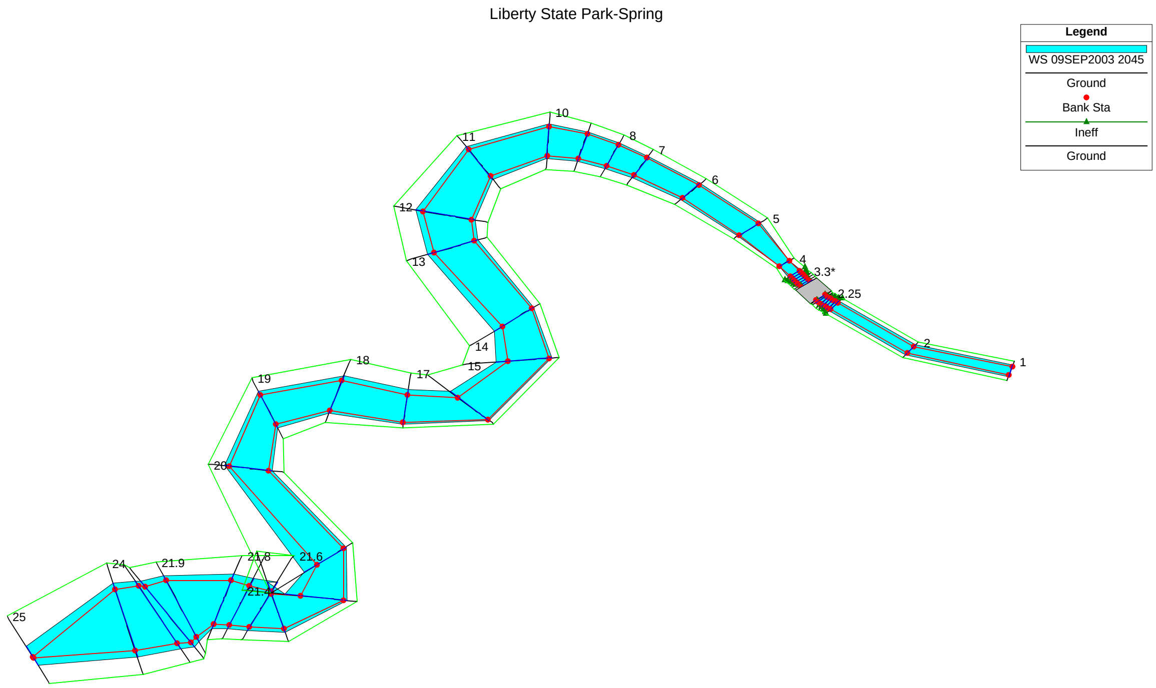


Figure 5.11 MHW-MLW Minimum Flooding of Site



Spring

Figure 5.12 Tide Maximum Flooding of Site

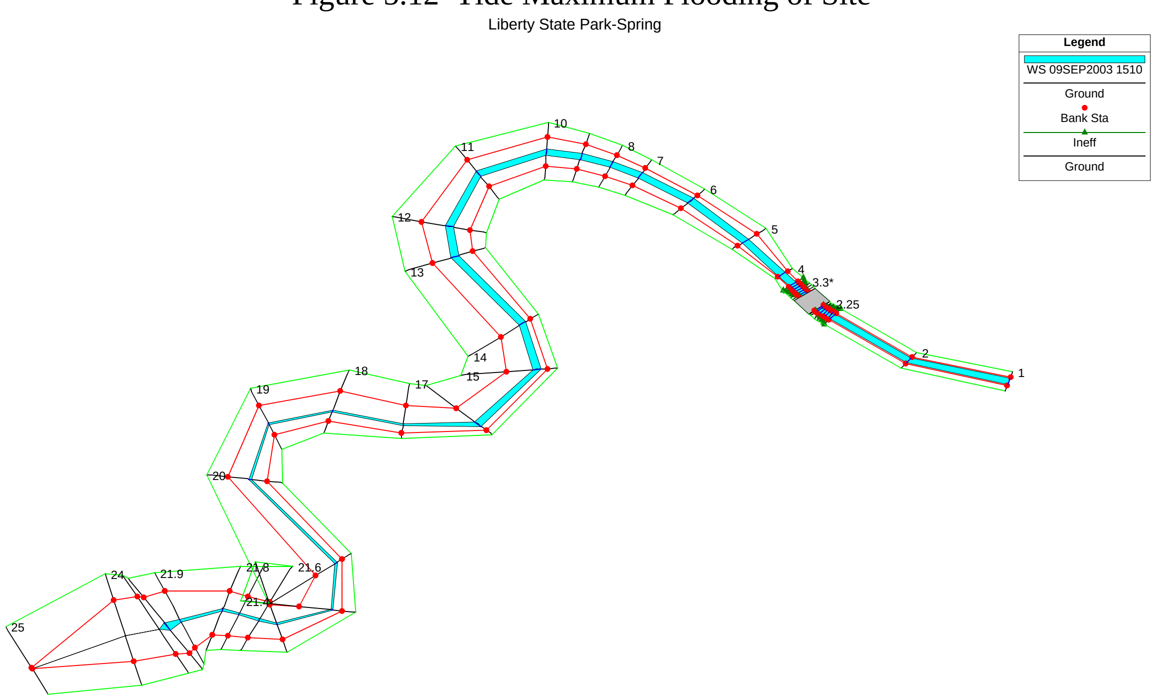


Figure 5.13 Spring Tide Minimum Flooding of Site

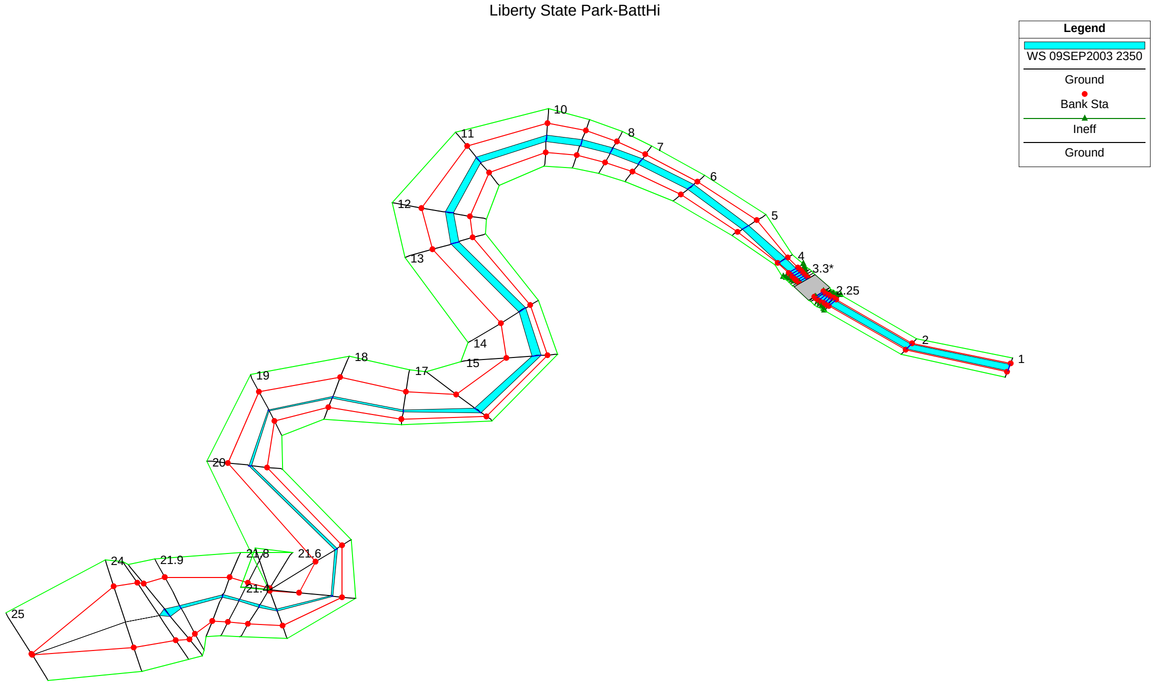


Figure 5.14 6% Exceedence Minimum Flooding of Site

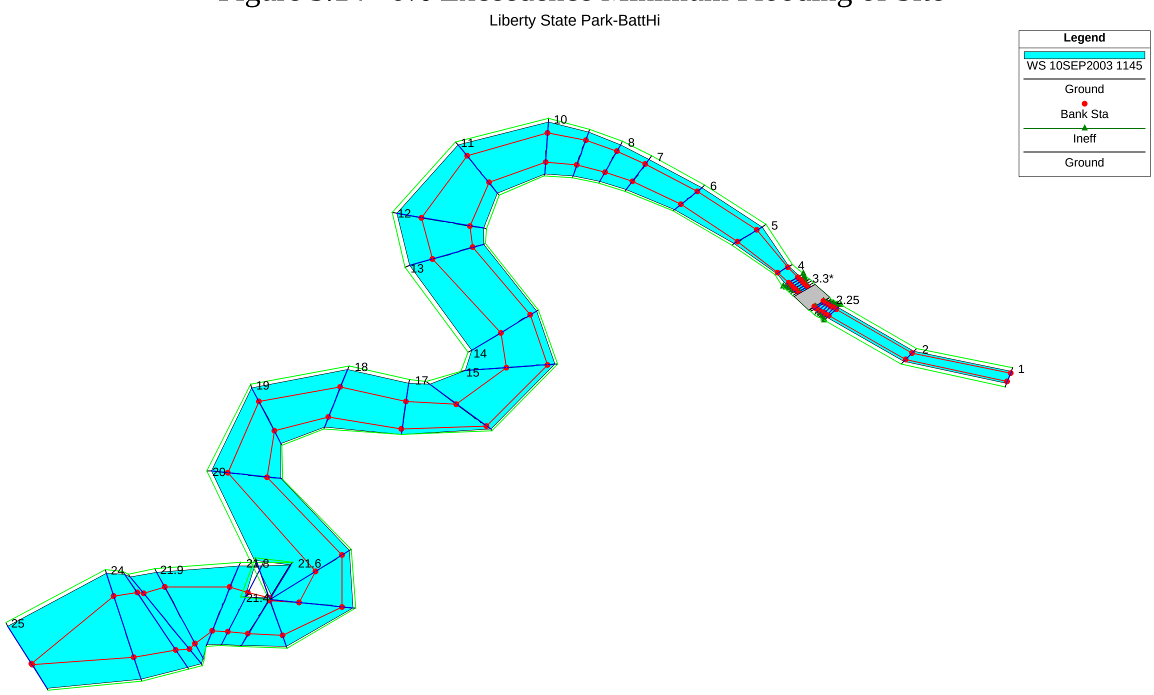


Figure 5.15 6% Exceedence Maximum Flooding of Site

Duration of Flooding - Directly from Biobenchmarking Results

	elevation (ft NAVD88)		duration of flooding of the tide cycle					
			Mean Tide Range		Spring Tide Range		6% Exceedence of MHHW	
	lowest	highest	max	min	max	min	max	min
Spartina alternaflora	-1.5	3.6	65%	0%	61%	0%	66%	2%
Spartina patens	1.9	4.6	0%	0%	18%	0%	45%	0%

Duration of Flooding - Environmental Resources Inventory Suggested Ranges:

	elevation (ft NAVD88)		duration of flooding of the tide cycle					
			Mean Tide Range		Spring Tide Range		6% Exceedence of MHHW	
	lowest	highest	max	min	max	min	max	min
low marsh	0	2.4	21%	0%	48%	0%	28%	22%
mid marsh	1.9	2.4	0%	0%	18%	0%	30%	22%
high marsh	1.9	3	0%	0%	18%	0%	22%	9%

Table 5.3 Target Duration of Flooding Based on Biobenchmarking an Environmental Design Recommendations

Table 5.4 Duration of Flooding at Three Representative Cross Sections

			duration of flooding of the tide cycle						
	elevation (ft NAVD88)		Mean Tide Range		Spring Tide Range		6% Exceedence of MHHW		
Cross Section 25	lowest	highest	max	min	max	min	max	min	Conclusion
low marsh	0	2.4	50%	0%	59%	2%	92%	27%	Floods too much on 6% Exceedence Tide
mid marsh	1.9	2.4	0%	0%	2%	0%	27%	22%	Gets wet at Spring and 6% Exceedence Tide
high marsh	1.9	3	0%	0%	2%	0%	27%	0%	Gets wet at Spring and 6% Exceedence Tide
Cross Section 19	lowest	highest	max	min	max	min	max	min	
low marsh	0	2.4	51%	0%	59%	0%	83%	16%	Floods too much on 6% Exceedence Tide
mid marsh	1.9	2.4	0%	0%	3%	0%	28%	16%	Gets wet at Spring and 6% Exceedence Tide
high marsh	1.9	3	0%	0%	3%	0%	28%	0%	Gets wet at Spring and 6% Exceedence Tide
Cross Section 6	lowest	highest	max	min	max	min	max	min	
low marsh	0	2.4	46%	0%	49%	0%	83%	2%	Floods too much on 6% Exceedence Tide
mid marsh	1.9	2.4	0%	0%	13%	0%	30%	2%	Gets wet at Spring and 6% Exceedence Tide
high marsh	1.9	3	0%	0%	13%	0%	30%	0%	Gets wet at Spring and 6% Exceedence Tide

The marsh also should be able to drain to give the spartina alternaflora roots periods in the tide cycle whereby their roots can be exposed to air. Adequate drainage of the marsh also stimulates water circulation, which improves water quality for flora and fauna. Table 5.5 shows that for all tides analyzed, a signifcant amount of the mudflat is exposed, which starts at elevation 1.0 ft NAVD88. For the MHW-MLW tide cycle, a significant amount of the the marsh drains so that there is 1.7 ft of water in the back of the marsh at cross section 25, and 1.81 ft and 1.5 ft for cross sections 19 (mid creek) and 2 (near creek mouth), respectively. For the other 2 flow regimes, drainage occurs less than the mean tide cycle, but both runs expose the mudflat at all cross sections.

Lastly, the velocities for all the flow regimes, for all the cross sections were calculated by the HEC-RAS model for all of the cross sections. There is a concern that excessive velocities can mobilize sediment and then deposit the sediment in locations that can impede the proper flooding low and high marsh areas. Since a 1-ft thick cap is being placed on the entire channel and marsh surface, the sediment size can be specified so that minimal channel scouring will occur. For sediment sizes between 0.1-1.0 mm (silty sand to sandy gravel), the velocity needed for incipient motion of particles is between using the Sheilds equation .The channel velocities of the selected cross sections for various degrees in water temperaturein

Maximum and Minimum Water Surface (ft NaVD88)

Flow Regime	MHW-MLW		Spring Tide		6% Exceedence	
Profile	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
25*	1.54	-1.3	2.01	-0.79	2.77	-0.29
19	1.55	-1.39	2.01	-0.91	2.78	-0.39
6	1.64	-1.74	2.12	-1.28	2.89	-0.88
3	1.68	-1.85	2.19	-1.41	2.99	-1.04
2	1.72	-2	2.24	-1.57	3.08	-1.24

Maximum and Minimum Velocities(fps)

Flow Regime	MHW-MLW		Spring Tide		6% Exceedence	
Profile	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
25*	0.15	n/a	0.16	n/a	0.16	n/a
19	0.23	-0.23	0.2	-0.25	0.18	-0.27
6	0.33	-0.29	0.33	-0.34	0.44	-0.41
3	0.4	-0.36	0.48	-0.44	0.61	-0.58
2	0.46	-0.36	0.54	-0.43	0.68	-0.55

Table 5.5 Maximum and Minimum Water Surfaces and Velocities as Selected Cross Sections

5.8 Sensitivity Analysis

A sensitivity analysis was done for the Manning's friction coefficient. This study used a value of 0.2 for the channels and 0.5 for the vegetative marsh surface. When the HEC-RAS model was run using 0.1 and 0.2 for the channels and vegetative marsh surfaces, respectively, there was less dampening of the tidal signal, thus more flooding of the site. Due to the invasive nature of phragmities, the plant the project will be eradicating in the project area, a conservative design errors on the wetter design. Thus, the higher n value design is the conservative design. Yet, the lower n value results did produce slightly higher velocities, approaching 1 fps, with the maximum velocity occurring at cross section 19. Since this occurred at one of the meanders of the creek, it may be possible to change the geometry of the creek slightly in that area to minimize the velocities. Or, gravel can line the channel at its critical locations.. These issues will be addressed in the next phase of the study.

6 UPLAND MANAGEMENT AREA

In order to create a more contiguous ecosystem within Liberty State Park, the remaining 131 acres within the undeveloped section of the park should mimic natural upland systems found in maritime systems in the Northeast United States. Currently within the 131 acres, invasive species such as phragmities and mugwort are thriving. The presence of these very aggressive invasive species, so close to the proposed tidal and fresh water wetlands, imposes a great risk to the sustainability of these communities. Therefore, the selected LSP plan proposes to clear out these and other species that do not offer high habitat values. This area, along with the tidal and fresh water systems, will be managed in the years following construction to minimize the reintroduction of invasive species. If monitoring of the cleared upland areas show that additional measures are required, a mixture of clean fill and topsoil could be brought in where needed, and maritime scrub/shrub plants could be planted in the places where vegetation of low habitat value currently exists.

As mentioned in previous sections, Liberty State Park is losing biodiversity and habitat value to invasive species. Existing maritime grassland communities are located adjacent to monocultures of the invasive species common reed and mugwort. Without human intervention, invasive species is likely to encroach upon the grasslands and eventually out compete them for resources, and the maritime grasslands will likely be rare or non-existent in Liberty State Park as little as ten years. The no-action alternative would produce a negative habitat value, so all Upland Management options presented include clearing and grubbing to remove invasive species. Without this step, any other upland option is bound to fail.

Beyond removal of invasive species, there are three alternatives for the upland area of the site. These measures could be used together for increased habitat value. These are landscaping and planting of native species, topsoil/sand treatment to cap some habitats in order to prevent the recurrence of some of the more stubborn invasive species, and erosion control. No matter the Upland Management alternative chosen, monitoring will have to be a significant element in order to ensure the success of the program.

7 DESCRIPTION OF COSTS

Implementation costs for each restoration scenario were calculated based on estimates of location, mobilization/demoblization, site access, site preparation and excavation, disposal, planting, erosion and sediment control and monitoring costs. These project construction costs were estimated as part of the planning phase for the purpose of determining project feasibility, and to provide a means of comparing proposed restoration options. The chosen alternative will be designed further, and the quantities and costs will be refined in the cost appendix. However, for the alternative analysis, all alternatives have the same quantity and cost assumptions. A contingency cost of 20% was included to account for uncertainties in the final design and/or implementation of the selected NER Plan. Preliminary Engineering and Design (PED) and Management during construction were assumed as 8% and 7% respectively, of the total construction costs. An escalation factor of 3% was included to project the present day construction costs to the estimated midpoint of construction. All labor, material, equipment, overhead, bond and profit costs were considered in the costs. The costs were based on the cost estimate on experience at other projects and published estimating tools such as RS Means©.

The following describes the assumptions considered in the calculation of costs.

Costs Associated with All Proposed Restoration Areas and Activities:

Real Estate and Location

- The local sponsor owned the site prior to the start of the project, so no real estate costs were considered. However, all costs include an area cost factor of 3.6% to account for the higher cost of living in the project area (RS Means©).

Mobilization/Demobilization

- Mobilization and demobilization costs were the lump sum costs associated with the initiation and cessation of activities at the site, including obtaining and transporting equipment, and the removal of temporary site features and equipment upon completion of the Project.

Staging/Storage/Refueling Area

- A 4 in layer of gravel in an estimated 2500 sf area within Liberty State Park would be placed over a flat area before heavy machinery arrived at the site.
- Temporary chain link fencing would be erected around the site.

Temporary Erosion and Sediment Control

- During the earth movement phase of the project, the erosion of sediment will be minimized by controlling the runoff and turbidity that leaves the site. Erosion and sediment control is assumed to be required along the perimeters of the work zones. They will include staked straw bales, reinforced silt fencing, sediment traps with filters and maintenance of control measures

Site Access

- New access roads and maintenance costs were projected for the project area. The use of timber mats was included to allow heavy construction equipment to traverse the unconsolidated marsh surface.

Clearing and Grubbing

- Site preparation included the costs associated with the removal of *Phragmities Australis* and other existing vegetation in the proposed regrading locations. The assumption was made that this task, to be done for the entire proposed site, will entail herbicide treatments, clearing of existing vegetation by mowing above grade, stockpiling, shredding, loading and hauling to a designated area in the park. Herbicide and mechanical removal techniques will be used. Productivity is assumed to be at 82% to account for delays incurred while handling contaminated material.
- The additional cost of excavation of thatch material, including the rhizomes when indicated and other root material, is included in the locations that do not have cut/fill activities. Herbicide and mechanical removal techniques will be used. Productivity is assumed to be at 82% to account for delays incurred while handling contaminated material.

Monitoring Project Site

- Monitoring costs were assumed to be 1% of construction costs.

Tidal Wetland Costs

Earthwork

- Earthwork costs assumed that in the proposed low and high marsh areas, 60% of the material being excavated would be dry, and 40% would be wet, which is based on when groundwater was encountered in the geotechnical borings taken in the Fall 2003. The material would be hauled 0.5 miles round trip or less. The excavation locations will be finely graded/shaped and surveyed. The deposition area will be roughly graded.

Productivity is assumed to be at 82% to account for delays incurred while handling contaminated material. The volume of material to be excavated was calculated from the 2003 site survey. For the low and high marsh, the proposed excavation depths were based on excavating the site to the range in which *Spartina alternaflora* and *Spartina patens* will most likely thrive. These elevations are based on bio-benchmarking and tidal datum data, plus an additional foot to allow room for a cap of clean clay fill 1 ft deep to be placed in all excavated areas, and another foot to allow room for a cap of clean sand fill 1 ft deep. A survey crew will be on site to confirm cut and fill placement elevations.

Clean Clay and Sand Fill Placement

- 1 ft of clean clay fill will be placed in the channel, mudflat, low and high marsh areas. The project expenses for this task include purchase/load/haul/spread/compact/shape the clean fill as per the plans and specifications. The placed clay will be compacted to create an impervious subsurface.
- 1 ft of clean sand fill will be placed in the channel, mudflat, low and high marsh areas. The project expenses for this task include purchase/load/haul/spread/compact/shape the clean fill as per the plans and specifications.
- 3 ft of clean sand fill will be placed in the upland scrub/shrub areas. The project expenses for this task include purchase/load/haul/spread/compact/shape the clean fill as per the plans and specifications.

Dewatering

- Dewatering will be necessary due to the high water table. It is assumed that 4 dewatering systems will operate for 12 months in the proposed tidal wetland area.

Temporary Cofferdam at Tidal Inlet

- Temporary sheeting will be installed at the mouth of the main inlet to prevent tidal inundation into the site while the earthwork is being completed.

Rip-Rap and Filter Fabric

- Rip-Rap and geotextile filter fabric will be placed at the tidal creek opening to stabilize the side slopes of the inlet to the North Cove. The costs include labor, equipment and materials for loading, hauling and placement.

Planting

- The costs for plants within the low and high marsh zones were based on plugs to be planted 18 in o.c. The cost includes the purchase of the plug or peat pod stock, fertilizer, seeding, vector, pest control, weeding, watering and a restoration specialist. The high marsh will also have planted 100 shrubs/acre.
- The costs for plants within the maritime scrub/shrub zone were based on shrubs to be planted 8 ft o.c. The cost includes the purchase of the shrubs, fertilizer, seeding, vector, pest control, weeding, watering and a restoration specialist.

Bird Control – Plant Protection

- The costs for protecting the young plugs from Waterfowl were based on methods used by the New York City Department of Parks and Recreation Department. Temporary goose exclusion fences will be placed at 25ft spacing intervals.

Hydraulic Placement of Fill

- The costs to place a 1ft thick clean sand cap in the North Cove assumes the material will be placed hydraulically using off-shore based equipment.

Bridge Construction

- The bridge will be fabricated from precast concrete sections and wingwalls assembled on-site. Foundations (spread footings or timber pile-supported footings, depending on the results of design analyses) would be cast-in-place. These precast sections are pre-engineered and are readily available from nearby suppliers. The pre-engineered bridge can accommodate a wide range of highway loadings (HS20-44, etc.). A 48-foot span provides an adequate hydraulic section for the channel. The 75-foot wide bridge's construction duration is estimated as less than a week.

Upland Management Area and Disposal Area Costs

Top Soil/Sand Treatment

- It is assumed that either 2 ft of topsoil, or 3 ft of clean sand fill will be placed in the upland management areas. The project expenses for this task include purchase/load/haul/spread/compact/shape the clean fill as per the plans and specifications.

Planting

- The costs for plants within the maritime forest zone were based the following planting scheme;
  - Canopy trees 1.5-2 inches diameter, spaced 10 ft o.c., for 10% of the upland management area
  - Canopy trees, 1-4 ft diameter, spaced 10 ft o.c., for 30% of the upland management area
  - Canopy trees, 5-6 ft diameter, spaced 10 ft o.c., for 30% of the upland management area
  - Understory trees, spaced 10 ft o.c., for 20% of the upland management area
  - Ferns/Forbs, spaced 3 ft o.c., for 5% of the upland management area
  - Shrubs, spaced 8 ft o.c., for 5% of the upland management area
  - The cost for all of the upland management plants listed above include the purchase of the stock, fertilizer, seeding, vector, pest control, weeding, watering and a restoration specialist.

Disposal Area Costs

Top Soil

- It is assumed that 1 ft of topsoil will be placed in the upland management areas. The project expenses for this task include purchase/load/haul/spread/compact/shape the clean fill as per the plans and specifications.

Planting

- Grass seed and fertilizer will be placed on the disposal berm. It will be watered, and a jute mesh will be placed on it to minimize erosion.

Fresh Water Wetland Area

Earthwork

- Earthwork costs assumed that in the proposed fresh water areas, 80 % of the material being excavated would be dry, and 20% would be wet, which is based on when groundwater was encountered in the geotechnical borings taken in the Fall 2003. This ratio will vary with the season and depend on when the actual construction is carried out. The material would be hauled 0.5 miles round trip or less. The excavation locations will be finely graded/shaped and surveyed. The deposition area will be roughly graded. Productivity is assumed to be at 82% to account for delays incurred while handling contaminated material. The volume of material to be excavated was calculated from the 2003 site survey. The proposed regrading elevations are based on the existing drainage patterns within the site and the necessary hydrology to maintain the proposed ecosystems, plus an additional foot to allow room for a cap of clean clay fill 1 ft deep to be placed in all excavated areas, (and another foot to allow room for a cap of clean sand fill 1 ft deep on the average depending on specific soil conditions) A survey crew will be on site to confirm cut and fill placement elevations.

- Specialized equipment is needed to grade the wetland areas to 0.1 ft accuracy

Clean Clay and Sand Fill Placement

- 1 ft of clean clay fill will be placed in the drainage swales and area below Mean High Water.. The project expenses for this task include purchase/load/haul/spread/compact/shape the clean fill as per the plans and specifications. The placed clay will be compacted to create an impervious subsurface. Above this will be 6 inches of sandy loam or topsoil.

Dewatering

- Dewatering will be necessary due to the high water table. It is assumed that 4 dewatering systems will operate for 3 months.
- Planting
- The costs for plants within the biofilter are based on plugs to be planted 18 o.c . (The cost includes the purchase of the plug or peat pod stock, fertilizer, seeding, vector, pest control)
- The costs for plants within the deep emergent marsh are based on plugs to be planted 18 o.c (The cost includes the purchase of the plug or peat pod stock, fertilizer, seeding, vector, pest control)
- The costs for plants within the swales are based on seeding and net anchoring. (The cost includes seedbed prep, mulch, anchoring, fertilizer, one post germination watering)
- The costs for plants within the liberty science center wetland are based on plugs to be planted 18 o.c (The cost includes the purchase of the plug or peat pod stock, fertilizer, seeding, vector, pest control)

Bird Control – Plant Protection

- The costs for protecting the young plugs from Waterfowl were based on methods used by the New York City Department of Parks and Recreation Department. Temporary goose exclusion fences will be placed at 25ft spacing intervals.

Culverts

- The costs for the culverts assume they are 30 in diameter culverts, and it includes purchase, mob/demob, and installation.

Access Road:

Costs assume unbound base course of 1-1/2" stone base compacted 8" deep. ($9.00 per square yard [RS Means]. Assuming 9 foot wide access road or $9.00 per linear foot.

Biofilter:

Costs include:

- Excavation volume assume 3,541 CY based on over excavation by 1 foot. (under excavation costs)
- Clearing and grubbing area .95 acres or 20% larger area then the area within mean high water level.(under clearing and grubbing)
- Existing topsoil to be stockpiled and used to dress Riparian zone.
- Assume an additional 6 inch topsoil layer

Infiltration Costs:

- For LSP a full infiltration basin design can be used since infiltration tests indicate extremely permeable soils.
- The only outlet is and emergency spillway which passes larger storm (greater then 2 year design storm) events .
- A rip-rap apron is needed near the inlet to reduce incoming runoff velocities to promote more uniform infiltration. There is no need for other features for routing stormflow or baseflow through the structure.

Components include:

- Flat basin floor roto-tilled to ensure high permeability
- Based on infiltration test minimum sand is required (assume 4" of sand added)
- Dense grass turf to be seeded throughout the basin bottom.
- Inlet structure from adjacent deep emergent marsh
- Rip –rap area around the inlet
- Erosion control mat along embankment
- Emergency spillway
- Excavation volume assume 4,995 CY. Overexcavation is not needed (under excavation costs)
- Clearing and grubbing area 2.64 acres. Assume 20% greater than

Infiltration Costs:

Infiltration costs were estimated based on the dry pond cost equation (Schueller, 1987); particularly for basing with greater the 10,000 cubic feet in volume. The following equation has been used:

C = 10.7 Vs**0.69

C=Cost in dollars

Vs = storage volume up to the crest of the of the emergency spillway in the basin (including any dead storage reserved for exfiltration purposes)

C = 10.7 (4,995)**0.69

Log Weirs:

25 Low weir is made up of three layers of logs; length varies; 30 feet long

- Bottom layer; 3 logs 12 feet' long - 12-14" dia.
- 2nd layer 4 logs 6 ft long -10-14" dia.
- 3rd layer 2 logs 6 feet long - 8-12" dia.
- 4th layer 2 logs - 4 long; 4-6" dia

Assumes installation will be implemented by a crew with a backhoe

Stone Weirs

Boulders set in place
6” gravel base

Assumes installation will be implemented by a crew with a backhoe

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 critera:

- Successful establishment of each habitat type(tidal marsh: low marsh, high marsh, mudflat, tidal creek, estuarine subtital,; fresh water marsh: deep water pool, shallow water bench, shoreline fringe and riparian fringe; upland: maritime forest, maritime grass, martime srub/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

The restoration site will need to be closely monitored during the first year after construction to ensure proper establishment of tidal and fresh water marsh vegetation, as well as upland habitiats. Inspections would involve site checks by the project biologist and hydraulic 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 TIDAL WETLAND 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. The South Cove has been used as a reference marsh for this feasilbility study. Either the south cove or an existing productive tidal marsh closer in size to the planned tidal marsh 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. Six (6) cross sections will be surveyed in the project area in similar locations as the 5 selected cross sections discussed in section 5 of this report. One cross section will be in the North Cove. 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. Eight (8) spot elevations will be surveyed in each cross section to be used as biobenchmarks. Six (6) cross sections will be surveyed in the reference marsh, along with 8 biobenchmark spot elevations in each of the cross sections. 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 area and an equal number of reaches at the reference area. 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.

9.3.3 Hydrology/hydraulics/hydrodynamics Monitoring

The hydrology/hydraulics/hydrodynamics of the tidal marsh is an integral part of the success of the tidal marsh habitat survival. Five (5) water level recorders will be placed in the project site for a 3 month period, and three (3) water level recorders will be placed in the reference site during the same time interval. The duration of flooding throughout the project and reference site 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 site, and 3 (3) geotechnical samples will be taken at the reference site. 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 FRESH WATER WETLAND ONE, THREE, FIVE AND TEN YEARS POST CONSTRUCTION

There are similar environmental factors that control the establishment, viability, and success of fresh water wetland habitats as well. 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 freshwater wetland establishment. An existing productive fresh water marsh closer in size to the planned tidal marsh will be chosen and used as a reference site during the monitoring phase.

9.4.1 Topographic/Bathymetric Monitoring

A topographic/bathymetric survey is planned one year post construction. Four (4) cross sections will be surveyed in the project area in similar locations in each of the freshwater wetland features (LSP Wetland, Biofilter, DEM, and Infiltration Basin). . 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. Eight (8) spot elevations will be surveyed in each cross section to be used as biobenchmarks. Six (6) cross sections will be surveyed in the reference marsh, along with 8 biobenchmark spot elevations in each of the cross sections. 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.

9.4.2 Hydrology/hydraulics Monitoring

The hydrology/hydraulics of the fresh water 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 site for a 12 month period, and three (3) water level recorders will be placed in the reference site during the same time interval. The duration of flooding throughout the project and reference site will be evaluated and compared with the established plant communities. Topographic/bathymetric monitoring is planned one, five and ten years after construction.

9.4.3 Geotechnical Monitoring

Three (3) geotechnical samples will be taken at the project site, and 3 (3) geotechnical samples will be taken at the reference site. 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.

9.5 UPLAND MANAGEMENT AREA ONE AND FIVE YEARS POST CONSTRUCTION

The success of the habitats planned for the upland management 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 srub/shrub. Geotechnical monitoring is planned one, and five years after construction.

9.7 MONITORING COSTS

Table 9.1 summerizes 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 Constr'n	3 years Post Constr'n	5 years Post Constr'n	10 years Post Constr'n	Total
First Year Post-Construction Site Assessment	$20,000	$0	$0	$0	$20,000
Low/High Marsh, Mudflat, Tidal Creek, Estuarine Subtidal					
Topographic Survey	$ 12,000	N/A	$ 12,000	$ 12,000	$36,000
Sinuosity Assessment	$ 5,000	$ 5,000	$ 5,000	$ 5,000	$20,000
Geotechnical Assessment	$ 10,000	N/A	$ 10,000	N/A	$20,000
Hydrology Assessment	$ 12,000	N/A	$ 12,000	$ 12,000	$36,000
Subtotal	$ 39,000	$ 5,000	$ 39,000	$ 29,000	$112,000
Deep Water Pool, Shallow Water Bench, Shoreline Fringe and Riparian Fringe					
Topographic Survey	$7,000	N/A	$7,000	7000	$21,000
Geotechnical Assessment	$3,000	N/A	$3,000	N/A	$6,000
Hydrology Assessment	$10,000	N/A	$10,000	$10,000	$30,000
Subtotal	$20,000	$0	$20,000	$17,000	$57,000
Upland Management Area					
Geotechnical Assessment	$3,000	N/A	$3,000	N/A	$6,000
Total	**$64,463**	**$54,069**	**$81,099**	**$27,030**	**$307,760**

9.8 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 wier 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.

9.9 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.

9.10 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.

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