Hudson-Raritan Estuary Ecosystem Restoration Feasibility Study

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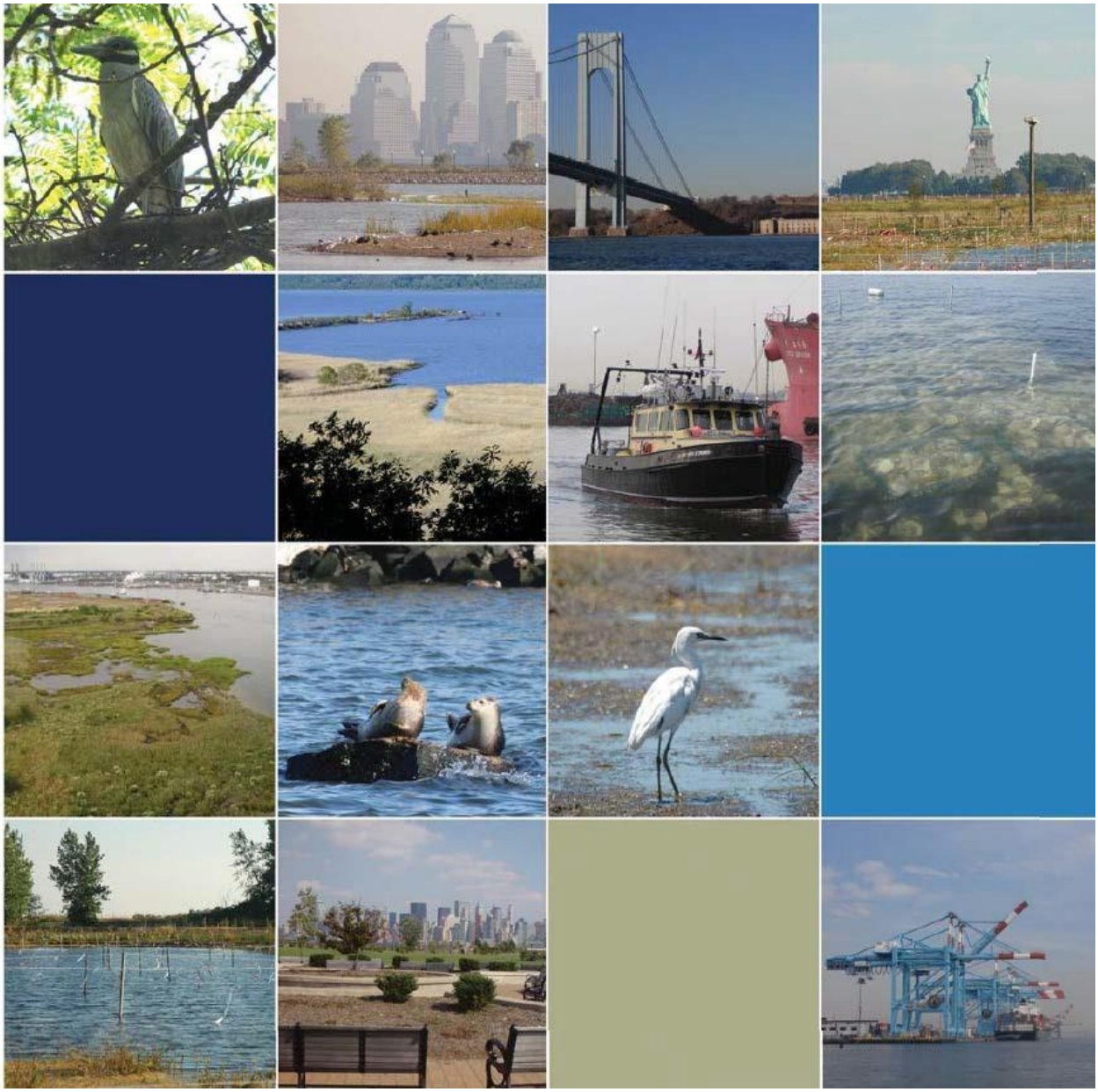
Appendix L
Monitoring and Adaptive Management

Final Integrated Feasibility Report &
Environmental Assessment
March 2020

Prepared by the New York District
U.S. Army Corps of Engineers

THE PORT AUTHORITY OF NY & NJ



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1.0 Introduction

This Monitoring and Adaptive Management Plan was prepared for the Hudson Raritan Estuary (HRE) Ecosystem Restoration Feasibility Report/Environmental Assessment (FR/EA). Section 2039 of Water Resource Development Act (WRDA) 2007 (as amended by Section 1161 of WRDA 2016) directs the Secretary of the Army to ensure, when conducting a feasibility study for a project (or component of a project) under the U.S. Army Corps of Engineers (USACE) ecosystem restoration mission, that the decision document include a monitoring plan to measure the success of the ecosystem restoration and to dictate the direction adaptive management should proceed, if needed. The Monitoring and Adaptive Management Plan shall include a description of the monitoring activities, the criteria for success, and the estimated cost and duration of the monitoring as well as specify that monitoring will continue until such time as the Secretary determines that the success criteria have been met.

Section 1161 of WRDA 2016 also directs USACE to develop an adaptive management plan for all ecosystem restoration projects. The adaptive management plan must be appropriately scoped to the scale of the project. The information generated by the monitoring plan will be used by the New York District (the District) in consultation with the federal and state resources agencies and the USACE North Atlantic Division (NAD) to guide decisions on operational or structural changes that may be needed to ensure that the ecosystem restoration project meets the success criteria.

An effective monitoring program is necessary to assess the status and trends of ecological health and biota richness and abundance on a per project basis, as well as to report on regional program success within the United States. Assessing status and trends includes both spatial and temporal variations. Gathered information under this monitoring plan will provide insights into the effectiveness of current restoration projects and adaptive management strategies, and indicate where goals have been met, if actions should continue, and/or whether more aggressive management is warranted.

Monitoring the changes at the project site is not a simple task. Restored wetlands can take decades to reach their dynamic equilibrium conditions, therefore the initial monitoring period of five years will be assessed as to whether the structural template has been established and if the site is on a trajectory toward ecological success. The task of tracking environmental changes can be difficult, and distinguishing the changes caused by human actions from natural variations can be even more difficult. This is why a focused monitoring protocol tied directly to the planning objectives needs to be followed.

The level of detail in this plan is based on currently available data and information developed during plan formulation as part of the feasibility study. Uncertainties remain concerning the exact project features, monitoring elements, and adaptive management opportunities. Components of the monitoring and adaptive management plan, including costs, were also estimated using currently available information. Uncertainties will be addressed in the preconstruction, engineering, and design (PED) phase, and a detailed monitoring and adaptive management plan, including a detailed cost breakdown, will be drafted as a component of the design document.

This Monitoring and Adaptive Management Plan describes the existing habitats and monitoring

methods that could be utilized to assess the project. By reporting on environmental changes, the results from this monitoring effort will be able to evaluate whether measurable results have been achieved and whether the intent of the Hudson Raritan Estuary Ecosystem Restoration project has been met.

Guidance

The following documents provide distinct USACE policy and guidance that are pertinent to developing this Monitoring and Adaptive Management Plan:

1. Section 1161 of WRDA 2016. Completion of Ecosystem Restoration Projects.

2. USACE. 2009. Planning Memorandum.

3. Implementation Guidance for Section 2039 of the Water Resources Development Act of 2007 (WRDA 2007) - Monitoring Ecosystem Restoration

4. Section 2039 of WRDA 2007 Monitoring Ecosystem Restoration

5. USACE. 2000. ER 1105-2-100, Guidance for Conducting Civil Works Planning Studies.

6. USACE. 2003a. ER 1105-2-404. Planning Civil Work Projects under the Environmental Operating Principles.

2.0 Project Area Description and Restoration Sites

The HRE project area is within the boundaries of the Port District of New York and New Jersey and is situated within a 25-mile radius of the Statue of Liberty National Monument. The study area includes eight (8) planning regions: 1) Jamaica Bay; 2) Harlem River, East River, and Western Long Island Sound; 3) Passaic River, Hackensack River, and Newark Bay; 4) Upper Bay; 5) Lower Bay; 6) Lower Raritan River; 7) Arthur Kill/Kill Van Kull; and 8) Lower Hudson River. Within this project area, 20 restoration sites in 5 planning regions have been recommended for construction:

Jamaica Bay Planning Region

Dead Horse Bay is adjacent to Floyd Bennett Field in Kings County, NY. Extensive historic landfilling activities across the entire site have resulted in marsh loss, a high proportion of invasive species, and extensive erosion. The recommended plan maximizes marsh habitat by creating a tidal channel in the northern portion of the site and re-grading the existing upland common-reed stand to salt marsh elevations to create a tidal marsh system. On the southern portion of the site, the National Park Service will be conducting an independent remedial action that will most likely include a protective cap consisting of clean material excavated from the northern portion of the site serving as a cost-effective placement location. The timing of this

restoration project and the potential remedial action will be coordinated to allow for the beneficial reuse of the excavated material.

Fresh Creek is located in and along the tidal wetlands and adjacent upland bordering Fresh Creek, a tributary to Jamaica Bay, in Kings County, NY. The recommended plan creates a tidal marsh system continuous around the basin and includes basin filling and re-contouring to improve low quality benthic habitat, provide fish and shellfish nurseries for species such as striped bass, winter flounder, summer flounder and forage fish while providing secondary benefits of improving water quality resulting from past dredging and fill activities. This plan also includes coastal scrub/shrub and maritime forest habitat and restores tidal channels and pools. In support of the restored habitats persistence, NYCDEP is currently implementing CSO abatement activities per their Long Term Control Plan and green infrastructure to control storm water runoff.

Jamaica Bay Marsh Islands- Duck Point, Stony Creek, Pumpkin Patch West, Pumpkin Patch East, and Elders Center have experienced rapid marsh loss. Overall island low marsh vegetation losses since 1974 averaged 38%, with smaller islands losing up to 78% of their vegetation cover. The recommended plan delivers clean fill to the five marsh islands to create low marsh, high marsh, and scrub shrub habitat.

Head of Jamaica Bay site is located in the northeast section of Jamaica Bay, adjacent to JFK Airport. Salt marsh habitat fringes much of the shoreline area. The bottom is steeply sloped close to the shoreline, with depths of up to 33 feet. The recommended plan creates 10.1 acres of oyster reef through the placement of spat on shell placed on a substrate composed of shell and crushed porcelain, oyster gabions, oyster castles, and super trays.

Harlem River, East River and Western Long Island Sound Planning Region

Bronx Zoo and Dam is located adjacent to the Bronx Zoo in Bronx County, NY. The site is an over-widened channel that experiences stagnation and constricted flow made worse by the two dams within the channel. Sewage sources and runoff from the Bronx Zoo have historically contributed to the waste infiltration and distinct sewage odor of the water. The wetlands and upland woodlands within the site are relegated to thin strips of land dominated by invasive species. The recommended plan will improve aquatic habitat (fish and shellfish nurseries) with secondary benefits of water quality through invasive vegetation removal with native plantings, debris removal, streambank restoration, and creation of emergent and forested wetlands. Additionally, a fish ladder will link area upstream of the dams to the river channel below the dams and open Bronx River access to anadromous (alewife and blueback herring) and catadromous fish such as the American eel.

Stone Mill Dam is located within a steep valley in the New York Botanical Garden in Bronx County, NY. The site consists of few, very small (less than 5 square feet) discontinuous pockets of emergent vegetation. The extreme channel habitats, including a sediment laden pond, fast moving rocky channel and dam, impede fish movement and provide low to moderate fish and wildlife habitat. The recommended plan for Stone Mill Dam increases and improves tributary connections, shorelines, and shallow water habitat. Fish ladder installation at this site is a critical

component of the fish passage projects along the Bronx River and links the slow-flowing pool upstream of dam and the faster-flowing channel downstream of the dam. The project site is further improved by invasive removal with native vegetation plantings.

Shoelace Park is adjacent to the Bronx River Parkway in Bronx County, NY. The site currently provides limited fish and wildlife habitat due to nearby urban development, significant habitat fragmentation, sedimentation issues, and dense growth of invasive species. The recommended plan increases and improves wetlands, public access, shoreline and shallows, and mudflat habitat through creation of forested and scrub/shrub wetlands, channel realignment, bed material replacement, bank stabilization and invasive species removal with native plantings. Additional restoration measures include installation of vegetation swales and emergent wetlands/bioretention basins along the east bank to reduce sediment loads reaching the river.

Bronxville Lake is within a park that is part of the Bronx River Parkway Reservation in Westchester County, NY. The site is subject to nutrient-enriched runoff from the park and several drainage pipes that empty into the lake from the parkway and upland areas. The recommended plan for Bronxville Lake will improve aquatic habitat, and flow regime with secondary benefits of water quality through restoration of emergent, forested, and scrub/shrub wetlands, dredging within the channel and adjacent lake bottom, installation of bedding stone along areas of the channel, a rip rap forebay in the river channel upstream of the lake, modification of the rock weir at the southern end of the lake to control hydrology and appropriate water levels in the lake, and invasive removal with native replantings. Additional measures include installation of vegetated swales, and emergent wetlands/bioretention basins to reduce sediment load to river, and improvements to public access.

Garth Woods/ Harney Road is part of the Bronx River Parkway Reservation in Westchester County, NY. The site is located north of Harney Road and is bordered by the Bronx River Parkway. The site contains thin strips of sparsely vegetated wetlands. The broad and shallow channel and narrow wetland areas provide limited habitat for aquatic species. At the Harney Road site, the river channel will be improved upstream of Harney Road through bed material replacement and construction of instream cross vanes. Modification of the existing weir at the southern end of site will control hydrology and downstream water levels. Shoreline softening will occur through replacement of a hardened shoreline with stacked rock wall with brush layer. Restoration of emergent wetlands and wet meadow along with invasive removal and native plantings will diversify the existing habitat. Installation of emergent wetlands/bioretention basins at the upstream end of the buried storm drain will control erosion and reduce sediment loads to the river.

The Garth Woods restoration project is restricted to the northernmost section of the site to complement future habitat restoration to be performed by Westchester County. Improvements include restoration of forested and scrub/shrub wetlands and invasive species removal with native plantings.

Flushing Creek is located in a highly urbanized area in Queens County, New York. In preparation for the World's Fair in 1939, there was significant stream straightening, filling of wetland areas, and headwater reconfiguration of Flushing Creek. Continued development in the

area has led to loss and degradation of tidal wetlands. The recommended plan includes conversion of existing common reed-dominated marsh to native wetland and scrub/shrub, and creation of maritime forest in areas of onsite material placement. Re-contouring along the mudflat will provide the appropriate hydrology necessary for persistence of the created habitat and provide secondary benefits of improved water quality.

Newark Bay, Hackensack River and Passaic River Planning Region

Oak Island Yards is located along approximately 900 feet of Newark Bay and is bordered by a shipping container yard, railroad tracks, and a HESS petroleum tank farm. A ditch with a tide gate is located adjacent to the site, below the railroad track embankment on the southeast border of the site. A pond surrounded by common reed is present in the center of the site. A small remnant smooth cordgrass marsh and panne present at the northeast corner of the site. A forested wetland area is located in the northeast portion of the site beyond the shoreline. This forested area has a canopy dominated by red maple and eastern cottonwood and a near monoculture of common reed in the understory. A small area of scrub/shrub wetland is found adjacent to the tide gate on the south side of the canal along the southern boundary of the site. The primary stressors at the site contributing to highly degraded wetlands and upland habitats include, invasive plants, nutrient inputs, and shoreline debris.

The recommended plan for this site includes the restoration of 5.32 acres of low marsh, 0.85 acres of high marsh, 0.44 acres of scrub/shrub habitat, with approximately 1.36 acres of tidal channels to feed the newly restored marsh habitat. Total excavation of 120,700 CY with 20,000 CY to be placed on-site restoring 2.85 acres of maritime forest and the remainder for offsite disposal. Construction is deferred following EPA Remedial Action.

Essex County Branch Brook Park site is a county park of Essex County, New Jersey, located in the North Ward of Newark, between the neighborhoods of Forest Hill and Roseville. The park is surrounded by commercial and residential developments and roadways. The stream and forest areas within the park are dominated by non-native, invasive vegetation and are littered with considerable amounts of trash. Ponds at the site suffer from algal blooms and eutrophication from excess nutrient runoff. The recommended plan for this site will restore both aquatic and terrestrial habitats through restoration of emergent and forested/ scrub/shrub wetlands, invasive species removal with native plantings, and bed restoration in the form of pond deepening and stream naturalization.

Metromedia Tract is located in Carlstadt, Bergen County, New Jersey. The site is bordered by the Hackensack River to the east and south and by the Marsh Resources Meadowlands Mitigation Bank to the north. The site is dominated by common reed. The property also likely contains fill from unknown sources during construction of nearby radio towers. The recommended plan will increase diversity and improve fish and wildlife habitat as well as providing secondary benefits of improving flood storage and water quality through the restoration of low marsh, high marsh, and scrub/shrub habitats.

Meadowlark Marsh is bounded to the south by Bellmans Creek, to the north and west by the New Jersey Turnpike – Eastern Spur, and to the east by 83rd street and active railroad tracks in

Ridgefield, Bergen County, NJ. The upland area of the site is currently used as a dirt track for off-road vehicles, limiting the habitat available in upland areas. Restoration efforts at the site will improve fish and wildlife habitat as well as secondary benefits of flood storage. The entire site will be graded, with 64,400 CY of excavated material taken off site. High marsh and upland areas will be brought up to grade and capped with clean material. Restoration of low marsh, high marsh, and forested and scrub/shrub habitat will increase habitat diversity. Additionally, work includes creation of tidal channels and culvert installation.

Upper Bay Planning Region

Bush Terminal site consists of eroding piers south of the Gowanus Canal on the western shore of Brooklyn, NY. The piers were used for shipping during the industrial era. Water depth at the site varies from shallow to deep allowing for good habitat diversity. The recommended plan for Bush Terminal creates a 31.9 acre oyster reef using spat-on shell and oyster gabions and would provide public access, awareness, and opportunities for future studies.

Lower Bay Planning Region

Naval Weapons Station Earle is located in Sandy Hook Bay, New Jersey. Water depths at this site from the pier out into the channel vary from 12 to 40 feet. Previous oyster restoration studies by NY/NJ Baykeeper have been conducted at NWS Earle. The recommended plan creates a 10 acre oyster reef through installation of oyster pyramids and spat-on-shell.

3.0 Monitoring Protocols

To meet the four planning objectives (see section 3.2 of Main Report), each proposed restoration alternative will contain a unique combination of one or more project elements (Table L-1) with each requiring specialized monitoring. Individual monitoring protocols for the project elements are summarized in sections 3.1 through 3.13 below.

Table L-1. Project Element by Site

Restoration Site	Low Marsh	High Marsh	Scrub/Shrub	Emergent Wetland	Wet Meadow	Forested Scrub/ Shrub	Bed Restoration & Instream Structures	Streambank Restoration	Emergent Wetland/Bioretention Basins	Sediment Forebay	Fishway	Oysters	Maritime Forest
Dead Horse Bay	x	x											
Fresh Creek	x	x	x										x
Duck Point	x	x	x										
Stony Creek	x	x	x										
Pumpkin Patch West	x	x	x										
Pumpkin Patch East	x	x	x										

Restoration Site	Low Marsh	High Marsh	Scrub/Shrub	Emergent Wetland	Wet Meadow	Forested Scrub/ Shrub	Bed Restoration & Instream Structures	Streambank Restoration	Emergent Wetland/Bioretention Basins	Sediment Forebay	Fishway	Oysters	Maritime Forest
Elders Center	x	x	x										
Bronx Zoo and Dam				x		x		x			x		
Stone Mill Dam							x				x		
Shoelace Park				x		x	x	x	x				
Bronxville Lake				x		x	x			x			
Garth Woods/Harney Road				x	x	x	x	x	x				
Flushing Creek	x	x	x										x
Oak Island	x	x	x										
Essex County Branch Brook Park				x		x	x						
Metromedia Tract	x	x	x										x
Meadowlark Marsh	x	x	x										
Naval Weapons Station Earle												x	
Bush Terminal												x	
Head of Jamaica Bay												x	

3.1 Tidal Wetlands Monitoring Protocol

Purpose

The purpose of this monitoring protocol is to assess the progress towards, and the success or failure of, the restoration of a tidal wetland habitat; including low marsh, high marsh, tidal channels, and littoral zones, and the achievement of acceptable standards of wetland structure and function. The monitoring protocol will assess the structure and function of the restored tidal wetland via three key ecological parameters of a functioning tidal wetland which include:

- Hydrophytic Vegetation
- Wetland Soils
- Wetland Hydrology

For sites in New York State, these parameters are identified in the USACE Wetlands Delineation Manual (Environmental Laboratory, 1987) and the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region* (USACE, 2012). In New Jersey, the parameters are identified in *1989 Federal Manual for Identifying and Delineating Jurisdictional Wetlands*:

General Monitoring Procedures

Monitoring will assess the success of the restored habitat using a modified version of the protocols proposed in 2000 by New York State Department of State and New York State Department of Environmental Conservation in their- *New York State Salt Marsh Restoration and Monitoring Guidelines Report* (Niedowski, 2000).

Pre-restoration monitoring protocols will obtain baseline data in order to establish the existing ecological conditions of the project site. This monitoring will take place within a one-year period prior to the start of project implementation. Alternatively, a reference site, such as a wetland benchmark identified during the Evaluation of Planned Wetlands field effort, could be established as a control.

Post-restoration monitoring will begin four to five weeks after tidal wetland restoration is completed, this initial monitoring event will include a site walk through to confirm as-builts, establish permanent photographic quadrats, and visual inspection. Monitoring will continue twice a year, including a fall monitoring event (August-October) and spring monitoring event (March-May), for five years post-restoration.

Transects will be evenly spaced across the site. Transects will run perpendicular to the main channel and/or parallel with the elevation gradient, from the seaward edge of the low marsh zone to the landward extent of the restoration site. Transect locations will be permanently marked, and easily located, at the landward and seaward edges. The landward and seaward markers of each transect will also be used as permanent photo stations for annual photographic monitoring, taken from the landward marker facing the seaward marker and vice versa. During monitoring events, a tape measure will run from the landward to seaward markers, with distance measurements originating from the landward marker.

A one square meter quadrat will be placed along a transect at a minimum of three different elevations and will include, as applicable, all vegetation zones. Quadrats will occur at a rate of one quadrat per five acres, or a minimum of five quadrats per vegetation community type, whichever is greater. Quadrats will be placed on a randomly chosen side of the transect within two meters. The landward and seaward corners closest to the transect line will be permanently marked.

Visual Assessment Procedures

A visual assessment to broadly track the site's development will occur once a year during the spring monitoring event; the following parameters will be monitored via visual assessment:

- General site hydrology (see wetland hydrology monitoring procedures below)
- Indication of soil erosion or instability
- Approximate percent coverage of invasive species
- Structural integrity of deer fence and/or goose fence

Hydrophytic Vegetation Monitoring Procedures

Investigations to track the establishment of hydrophytic vegetation will occur annually in fall. The performance target is for plantings and/or target hydrophytes, which are species native to the area and similar to ones identified on the planting plan, to have a minimum of 80% survival at the end of five years and 75% coverage after five years. As an interim response, the adaptive

management action for this metric may be triggered at the end of the two year construction contract guarantee and then once between years three and five. To ensure a successful vegetation effort, all plants shall be monitored and maintained as necessary for five years. During the fall monitoring event, the following parameters will be monitored:

- Percent vegetative cover in each transect
- Plant species occurring in each quadrat
- Signs of disease, predation, or other disturbance in each quadrat
- Stem density in randomly selected sub-quadrat (0.25 m^2) within each quadrat
- Plant height in randomly selected sub-quadrat (0.25 m^2) within each quadrat
- Vegetation zone transition distances along each transect

During the spring monitoring event, a visual assessment will be conducted to identify the approximate percent coverage of invasive species (see visual assessment procedures).

Wetland Soil Monitoring Procedures

Investigations to track the progression of hydric soil formation will occur once annually during the fall monitoring events, starting in year two. The performance target is for at least 80% of the area of disturbed soils to develop the wetland characteristics trending towards hydric soils by year 5. Measurements will be made twice in each quadrat placed along the transect line. The following parameters will be monitored in each quadrat:

- Soil characteristics including texture, color, structure, and hydric indicators such as redoximorphic features

Wetland Hydrology Monitoring Procedures

Monitoring of wetland hydrology will occur once a year during the spring monitoring events.

- Visual hydrologic surveys to characterize tidal inundation regimes, depth and duration of tidal inundation, and erosion/sedimentation processes across the site

Adaptive Management Procedures

In the event that the tidal wetland habitat fails to retain its designed structure or achieve its designed function, the following adaptive management procedures will be implemented.

Failure condition	**Adaptive management procedure**
Less than 80% survival or 75% coverage of target vegetation	Additional native vegetation will be planted. If issues of vegetation establishment persist beyond two years post construction, an ecologist will investigate the cause of failure and recommend modifications to the plant species as appropriate.
More than 20% coverage of non-native species in the restored habitat	Removal of invasive species via manual pulling or controlled herbicide application.
Failure to achieve wetland hydrological regimes and/or failure to achieve soils that	A hydrologist will investigate the cause of failure and recommend minor topographic modifications. Potential strategies include but are not limited to the addition of

Failure condition	Adaptive management procedure
trend towards wetland soil characteristics	runnels to increase water conveyance, small berms to hold back drainage, or drainage swales.

3.2 Scrub/Shrub (Coastal) Monitoring Protocol

Purpose

The purpose of this monitoring protocol is to assess the success or failure of the restoration of scrub/shrub habitats. An indication of the functional value of the restored habitat is the establishment and composition of vegetation.

The monitoring protocol will assess the survival of plantings, establishment of new species, and changes in the quality of the habitat.

Monitoring Procedure

Post-restoration monitoring will begin four to five weeks after the planting of shrubs is completed, this initial monitoring event will include a site walk through to confirm as-builts, establish permanent photographic quadrats, and visual inspection. Two monitoring events will be conducted each year:

- A fall monitoring event (August to October); and
- A spring monitoring event (March-May and approximately two weeks after full leaf out).

The vegetation will be assessed by observing long term quadrats in the shrub planting area. Three 10 meter by 10 meter quadrats will be established per acre. The corners of each quadrat will be permanently marked in the field[1], for ease of location. The end markers of each transect will be used as permanent photo stations for annual photographic monitoring, taken from the one end marker to the other and vice versa. During the fall monitoring event, survival monitoring of each planted shrub in the quadrat will occur. Scientists would note the percent cover type, stem density, plant height, species, and health of each planted shrub in the quadrats. Also, the scientists will identify any new shrub seedlings that are observed, recording species and percent coverage. The performance target is for plantings and/or target hydrophytes, which are species native to the area and similar to ones identified on the planting plan, to have a minimum of 80% planting survival, and 75% coverage after five years. As an interim response, the adaptive management action for this metric may be triggered at the end of the two year construction contract guarantee and then once between years three and five.

During the spring monitoring event, scientists will perform a visual assessment throughout the entire planted scrub/shrub area to evaluate site hydrology; soil erosion or gully formation; signs of disease, predation, or other disturbance; localized area planting failures, and the presence or absence of invasive species. If any of these factors are observed, scientists will recommend corrective actions. Quantitative measurements of quadrats during the fall monitoring events will be used to track the establishment of vegetation over the five-year monitoring period.

[1] The corners of the 10 meter x 10 meter quadrats should be marked with GPS or non-biodegradable devices (e.g., metal monuments) that are flush to the ground surface or metal stakes.

Adaptive Management Procedure

In the event that the scrub/shrub habitat fails to retain its designed structure or achieve its designed function, the following adaptive management procedures will be implemented.

Failure condition	Adaptive management procedure
Less than 80% survival or 75% coverage of target vegetation	Additional native vegetation will be planted. If issues of vegetation establishment persist beyond two years post construction, an ecologist will investigate the cause of failure and recommend modifications to the plant species as appropriate.
More than 20% coverage by non-native species in the restored habitat	Removal of invasive species via manual pulling or controlled herbicide application.

3.3 Emergent Wetland (Freshwater) Monitoring Protocol

Purpose

The purpose of this monitoring protocol is to assess the progress towards, and the success or failure of, the restoration of a non-tidal wetland habitat and the achievement of acceptable standards of wetland structure and function. The monitoring protocol will assess the structure and function of the restored wetland via three key ecological parameters of a functioning wetland as per the *USACE Wetlands Delineation Manual* (Environmental Laboratory, 1987) and the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region* (USACE, 2012), which include:

- Hydrophytic Vegetation
- Wetland Soils
- Wetland Hydrology

Monitoring Procedure

Monitoring will seek to assess the success of the restored habitat using a modified version of the protocols proposed in 2000 by New York State Department of State and New York State Department of Environmental Conservation.

Pre-restoration monitoring protocols will seek to obtain baseline data in order to establish the existing ecological conditions of the project site. This monitoring will take place within a one-year period prior to the start of project implementation. Alternatively, a reference site, such as a wetland benchmark identified during the Evaluation of Planned Wetlands field effort, could be established as a control.

Post-restoration monitoring will begin four to five weeks after wetland restoration is completed, this initial monitoring event will include a site walk through to confirm as-builts, establish permanent photographic quadrats, and visual inspection. Monitoring will continue twice a year, including a fall monitoring event (August-October) and spring monitoring event (March-May), for five years post-restoration.

Transects will be placed randomly across the restoration site. Transect locations will be permanently marked, and easily located, at each end. The end markers of each transect will also be used as permanent photo stations for annual photographic monitoring, taken from the one end marker to the other and vice versa. During monitoring events, a tape measure will run between each end marker, with distance measurements originating from the northern most marker for north-south oriented transects or the western most marker for east-west oriented transects.

A minimum of three one square meter quadrats will be placed randomly along the transect, at least three meters apart. Quadrats will occur at a rate of one quadrat per five acres, or a minimum of five quadrats per vegetation community type, whichever is greater. Quadrats will be placed on a randomly chosen side of the transect within two meters. Quadrats will be permanently marked at the corners closest to the transect line.

Visual Assessment Procedures

A visual assessment to broadly track the site's development will occur once a year during the spring monitoring event. The following parameters will be monitored via visual assessment:

- General site hydrology (see wetland hydrology monitoring procedures below)
- Indication of soil erosion or instability
- Presence or absence of invasive species
- Structural integrity of deer fence and/or goose fence

Hydrophytic Vegetation Monitoring Procedures

Investigations to track the establishment of hydrophytic vegetation will occur once a year during the fall monitoring event. The performance target is for plantings and/or target hydrophytes, which are species native to the area and similar to ones identified on the planting plan, to have a minimum of 80% survival at the end of five years and 75% coverage after five years. As an interim response, the adaptive management action for this metric may be triggered at the end of the two year construction contract guarantee and then once between years three and five. To ensure a successful vegetation effort, all plants shall be monitored and maintained as necessary for five years. During the fall monitoring event, the following parameters will be monitored:

- Percent vegetative cover in each transect
- Plant species occurring in each quadrat
- Signs of disease, predation, or other disturbance in each quadrat
- Stem density in randomly selected sub-quadrat (0.25 m^2) within each quadrat
- Plant height in randomly selected sub-quadrat (0.25 m^2) within each quadrat

During the spring monitoring events, a visual assessment will be conducted to identify the percent cover of invasive species (see visual assessment procedures).

Wetland Soil Monitoring Procedures

Investigations to track the progression of hydric soil formation will occur once annually during the fall monitoring events, starting in year two. The performance target is for at least 80% of the area of disturbed soils to develop the wetland characteristics trending towards hydric soils after

five years. Measurements will be made twice in each quadrat placed along the transect line. The following parameters will be monitored in each quadrat:

- Soil characteristics including texture, color, structure, and hydric indicators such as redoximorphic features

Wetland Hydrology Monitoring Procedures

Monitoring of wetland hydrology will occur once a year during the spring monitoring events.

- Visual hydrologic surveys to characterize water inundation or depth to groundwater and erosion/sedimentation processes across the site

Adaptive Management Procedure

In the event that the emergent wetland habitat fails to retain its designed structure or achieve its designed function, the following adaptive management procedures will be implemented.

Failure condition	**Adaptive management procedure**
Less than 80% survival or 75% coverage of target vegetation	Additional native vegetation will be planted. If issues of vegetation establishment persist beyond two years post construction, an ecologist will investigate the cause of failure and recommend modifications to the plant species as appropriate.
More than 20% coverage of non-native species in the restored habitat	Removal of invasive species via manual pulling or controlled herbicide application.
Failure to achieve wetland hydrological regimes and/or failure to achieve soils trending towards wetland characteristics	A hydrologist will investigate the cause of failure and recommend minor topographic modifications. Potential strategies include but are not limited to the addition of runnels to increase water conveyance, small berms to hold back drainage, or drainage swales.

3.4 Wet Meadow Monitoring Protocol

A wet meadow functions almost identically to that of an emergent wetland; the only noticeable difference (for this project) is that emergent wetlands are generally adjacent to open waters or hydrologically connected to a river through overland flooding during periods of high water. A wet meadow may gain its hydrology from the river through extreme flooding events, piping that connects to the river, groundwater and/or the runoff from adjacent areas of higher elevation. As the functions are similar, the proposed monitoring protocols are similar to that of an emergent wetland.

Purpose

The purpose of this monitoring protocol is to assess the success or failure of the restoration of non-tidal wetland habitats, and the achievement of acceptable standards of wetland structure and function. The monitoring protocol will assess the structure and function of the restored wetland via three key ecological parameters of a functioning wetland as per the *USACE Wetlands Delineation Manual* (Environmental Laboratory, 1987) and the *Regional Supplement*

to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region (USACE, 2012), which include:

- Hydrophytic Vegetation
- Wetland Soils
- Wetland Hydrology

Monitoring Procedure

Monitoring will seek to assess the success of the restored habitat using a modified version of the protocols proposed in 2000 by New York State Department of State and New York State Department of Environmental Conservation.

Pre-restoration monitoring protocols will be employed to obtain baseline data and document the existing ecological conditions of the project site, against which all post-monitoring results will be compared. This monitoring will take place during the growing season within a one-year period prior to the start of the project. Alternatively, a reference site, such as a wetland benchmark identified during the Evaluation of Planned Wetlands field effort, could be established as a control.

Post-restoration monitoring will begin four to five weeks after wetland restoration is completed, this initial monitoring event will include a site walk through to confirm as-builts, establish permanent photographic quadrats, and visual inspection. Monitoring will continue twice a year, including a fall monitoring event (August-September) and spring monitoring March-May, for five years post-restoration.

Transects will be placed randomly across the restoration site. Transect locations will be permanently marked, and easily located, at each end. The end markers of each transect will also be used as permanent photo stations for annual photographic monitoring, taken from the one end marker to the other and vice versa. During monitoring events, a tape measure will run between each end marker, with distance measurements originating from the northern most marker for north-south oriented transects or the western most marker for east-west oriented transects.

A minimum of three one square meter quadrats will be placed randomly along the transects, at least three meters apart. Quadrats will occur at a rate of one quadrat per five acres, or a minimum of five quadrats per vegetation community type, whichever is greater. Quadrats will be placed on a randomly chosen side of the transect within two meters. The corners closest to the transect line will be permanently marked.

Hydrophytic Vegetation Monitoring Procedures

Investigations to track the establishment of hydrophytic vegetation will occur once annually during the fall monitoring events. The performance target is for plantings and/or target hydrophytes, which are species native to the area and similar to ones identified on the planting plan, to have a minimum of 80% survival at the end of five years and 75% coverage after five years. As an interim response, the adaptive management action for this metric may be triggered at the end of the two year construction contract guarantee and then once between years three and five. To ensure a successful vegetation effort, all plantings shall be monitored and

maintained as necessary for five years. During the fall monitoring event, the quadrats will be monitored for the following parameters:

- Percent vegetative cover in each quadrat
- Plant species occurring in each quadrat
- Signs of disease, predation, or other disturbance in each quadrat
- Stem density in randomly selected sub-quadrat (0.25 m^2) within each quadrat
- Plant height in randomly selected sub-quadrat (0.25 m^2) within each quadrat

During the spring monitoring event, a visual assessment will be conducted to identify the percent cover of invasive species.

Each quadrat will be photographed during each monitoring event.

Wetland Soil Monitoring Procedures

Investigations to track the progression of hydric soil formation will occur once annually during the fall monitoring events, starting in year two. The performance target is for at least 80% of the area of disturbed soils to develop characteristics trending towards hydric soils after five years. Measurements will be made twice in each quadrat placed along the transect line. The following parameters will be monitored via soil cores taken of a depth of up to 20 inches below grown surface:

- Soil characteristics including texture, color, structure
- Other hydric indicators such as redoximorphic features

Wetland Hydrology Monitoring Procedures

Monitoring of wetland hydrology will occur once a year during the spring monitoring event. Monitoring will occur through use of visual cues, of the ground surface and of soil cores, in order to monitor the following parameters:

- Characterize water inundation patterns
- Measure depth to groundwater (same locations of the soil cores)

Note: To understand how the wet meadow habitat is performing, and to reduce ground disturbance, it is recommended that shallow monitoring wells with piezometers be installed within the wet meadow.

Visual Assessment Procedures

In addition to the more in-depth methods described above, scientists will conduct a visual assessment to broadly track the site's development once a year during spring monitoring events. The following parameters will be monitored via visual assessment:

- General site hydrology (see wetland hydrology monitoring procedures above)
- Indication of soil erosion or instability
- Localized areas of disturbance or planting failure
- Percent cover of invasive species
- Structural integrity of deer and/or goose exclusion fence

Adaptive Management Procedure

In the event that the wet meadow habitat fails to retain its designed structure or achieve its designed function, the following adaptive management procedures will be implemented.

Failure condition	Adaptive management procedure
Less than 80% survival or 75% coverage of target vegetation	Additional native vegetation will be planted. If issues of vegetation establishment persist beyond two years post construction, an ecologist will investigate the cause of failure and recommend modifications to the plant species as appropriate.
More than 20%coverage of non-native species in the restored habitat	Removal of invasive species via manual pulling or controlled herbicide application.
Failure to achieve wetland hydrological regimes and/or failure to achieve soils trending towards wetland characteristics	A hydrologist will investigate the cause of failure and recommend minor topographic modifications. Potential strategies include but are not limited to addition of runnels to increase surface water conveyance, lower elevation in areas to depth of groundwater.

3.5 Forested Scrub/Shrub (Freshwater) Monitoring Protocol

Purpose

The purpose of this monitoring protocol is to assess the success or failure of the restoration of riparian habitat including woody vegetation. The monitoring protocol will assess the function of the riparian habitat based on vegetation establishment and composition.

Monitoring Procedure

Post-restoration monitoring will begin four to five weeks after riparian restoration is completed and continue twice a year, including a fall monitoring event (August-October) and spring monitoring event (March-May), for five years post-restoration. During the spring monitoring event a visual assessment will evaluate site hydrology and the percent cover of invasive species. During the fall monitoring event, quadrat surveys will track the establishment of vegetation quantitatively. The performance target is for plantings and/or target hydrophytes, which are species native to the area and similar to ones identified on the planting plan, to have a minimum of 80% survival at the end of five years and 75% coverage after five years. As an interim response, the adaptive management action for this metric may be triggered at the end of the two year construction contract guarantee and then once between years three and five.

Quadrats will be placed randomly at a rate of one quadrat per five acres, or a minimum of five quadrats per vegetation community type, whichever is greater. The corners of each quadrat will be permanently marked, and easily located. The end markers of each transect will be used as permanent photo stations for annual photographic monitoring, taken from the one end marker to the other and vice versa. During the fall monitoring event the following parameters will be monitored for each transect:

- Percent vegetative cover
- Plant species occurring
- Signs of disease, predation, or other disturbance

- Stem density
- Plant height

Adaptive Management Procedure
In the event that the forested scrub shrub habitat fails to retain its designed structure or achieve its designed function, the following adaptive management procedures will be implemented.

Failure condition	Adaptive management procedure
Less than 80% survival or 75% coverage of target vegetation	Additional native vegetation will be planted. If issues of vegetation establishment persist beyond two years post construction, an ecologist will investigate the cause of failure and recommend modifications to the plant species as appropriate.
More than 20% coverage of non-native species in the restored habitat	Removal of invasive species via manual pulling or controlled herbicide application.

3.6 Maritime Forest Monitoring Protocol

Purpose
The purpose of this monitoring protocol is to assess the success or failure of the restoration of Maritime Forest habitat including understory vegetation. The monitoring protocol will assess the function of the maritime forest habitat based on vegetation establishment and composition. Monitoring and adaptive management of maritime forests will be the sole responsibility of the local sponsor, the protocol outlined below is intended as a guideline for the local sponsor and is not budgeted for in the project costs. The recommended techniques described below are a modified version of the field protocols proposed in 2018 by the U.S. Forest Service in- Urban Forests of *New York City. Resource Bullertin NRS-117 (Nowak et al. 2018).*

Monitoring Procedure
Post-restoration monitoring will begin four to five weeks after maritime forest restoration is completed this initial monitoring event will include a site walk through to confirm as-builts, establish permanent photographic quadrats, and visual inspection. Monitoring will continue once per year, during leaf on season (approximately May-September, for five years post-restoration.

The vegetation will be assessed by observing long term quadrats in the planting area. Monitoring will include a visual assessment to evaluate the percentage cover of invasive species, vegetative health (crown defoliation, discoloration and visible damages on the trees), and site condition assessment. Quadrat surveys will be conducted to track the establishment of vegetation quantitatively. The performance target is for plantings which are species native to the area and similar to ones identified on the planting plan, to have a minimum of 80% survival at the end of five years and 75% coverage after five years. As an interim response, the adaptive management action for this metric may be triggered at the end of the two year construction contract guarantee and if needed, is recommended to be triggered once between years three and five.

Data collection is recommended to take place in permanent, one-tenth-acre circular plots:

Tree data- Trees are defined as woody plants with a diameter at breast height (d.b.h.; measured at 4.5 feet above ground level) greater than or equal to 1 inch. For each tree in the plot the variables may include species, d.b.h., tree height, diameter and crown base height, percentage crown canopy missing and dieback, crown light exposure, and age class. Measurements of crown dimensions, percentage crown canopy missing, and crown dieback can be used to assess tree leaf area

For trees with more than six stems, tree stem diameter is measured below the fork with the height of the diameter measurement recorded. For multi-stemmed trees with two to six stems at breast height, each stem d.b.h. is measured and a quadratic mean d.b.h. calculated for the tree based on the basal area of each stem. Trees should be identified to the most specific taxonomic classification possible, e.g., the species or genus level.

Understory Canopy- Cover is estimated for two layer categories: woody understory (seedlings, saplings, shrubs) and ground cover (herbaceous species, litter, bare soil/sand, rock, water or wet soil). Cover estimates for the woody understory categories include all species present. Size class trends and species composition within the woody understory are captured by estimating cover by species. All vegetation whose canopy overhangs the plot area is included even if rooted outside the plot boundary. No single category of cover can exceed 100 percent; however, the total can exceed 100 percent since upper layers of some species or cover types may over-top lower layers of different species or cover types.

Adaptive Management Procedure

In the event that the Maritime Forest habitat fails to retain its designed structure or achieve its designed function, it is recommended that the following adaptive management procedures are implemented.

Failure condition	Adaptive management procedure
Less than 80% survival or 75% coverage of target vegetation	Additional native vegetation will be planted. If issues of vegetation establishment persist beyond two years post construction, an ecologist will investigate the cause of failure and recommend modifications to the plant species as appropriate.
More than 20% coverage of non-native species in the restored habitat	Removal of invasive species via manual pulling or controlled herbicide application.

3.7 Bed Restoration and In-stream Structures Monitoring Protocol

Purpose

The purpose of this monitoring protocol is to assess the success or failure of the installation of cross veins, j-hooks, riffle pool complexes, thalweg restoration, and bed material replacement.

Monitoring Procedure

Post-construction monitoring will be separated into two disciplines: Structural and Biological.

Structural – Monitoring will begin post construction with a confirmation of as-built design, visual inspection, and photo documentation. Monitoring will continue once annually and after major

flooding events (up to three events per year, assuming two major flooding events a year) for five years post-construction. The performance target is for landscape features to be stable, without significant migration or boulder loss. To that end, during each monitoring event visual inspections and photo documentation will occur to assess and document the stability of the features.

Biological – During the fall months (August-October), scientists will perform *the Stream Visual Assessment Protocol* (SVAP) in the same locations as baseline studies were conducted in 2015. The observers will note any changes to the site and continue to note inputs of environmental stressors from offsite locations (e.g., CSOs). The goal of the SVAP monitoring would be to note an increase in the ecological value of the segment of restored waterbody.

Adaptive Management Procedure
In the event that the bed restoration and in stream structures fail to retain their designed structure or achieve their designed functions, the following adaptive management procedures will be implemented.

Failure condition	**Adaptive management procedure**
Inadequate cross-sectional stability and structural integrity	Minor re-positioning or re-shaping, addition of material, vein and/or j hook adjustment- minor changes in elevation or location or repair.

3.8 Streambank Restoration Monitoring Protocol

Purpose
The purpose of this monitoring protocol is to assess the success or failure of the installation of bank stabilization techniques used for streambank restoration including: stacked rock wall with brush layer, tiered rock slope with native plant benches, brush mattress with rock toe, and shoreline softening. The monitoring protocol will assess the features based on structural integrity.

Monitoring Procedure
Monitoring will begin post construction with a confirmation of as-built design, visual inspection, and photo documentation. Monitoring will continue annually for five years post-construction. The performance target is for the structure to be physically intact and stable. During each monitoring event a visual inspection will occur to confirm the structure is intact, and free of any indicator of lack of integrity, including cracking, spalling, leaning, or slumping. If such examples of failures of structural integrity are observed, they will be noted and photo documented.

Adaptive Management Procedure
In the event that the streambank restoration fails to retain its designed structure or achieve its designed function, the following adaptive management procedures will be implemented.

Failure condition	**Adaptive management procedure**
Structural failure	Minor adjustments to structure, replace rocks, replace plantings, reinforcement with rocks at toe/other stabilization measures.

3.9 Emergent Wetland/Bioretention Basins Monitoring Protocol

Purpose

The purpose of this monitoring protocol is to assess the success or failure of the restoration of a non-tidal wetland habitat and the achievement of acceptable standards of wetland structure and function. The monitoring protocol will assess the structure and function of the restored wetland and has been adapted from the *USACE Wetlands Delineation Manual* (Environmental Laboratory, 1987). Due to the nature of how water flows into and through this habitat, it is anticipated that soil deposition would largely be alluvial and episodic, and subject to anthropogenic disturbance through periodic sediment and debris removal. Therefore, these wetlands would be subject to disturbance and traditional wetland soils and hydrology will not be monitored. In the USACE Federal Manual, Section F identifies wetland identification in Atypical Situations. Monitoring will consist largely of vegetation monitoring.

Monitoring Procedure

Monitoring will seek to assess the success of the restored habitat using a modified version of the protocols proposed by state agencies (e.g., New York State Department of Environmental Conservation.)

Pre-restoration monitoring protocols will seek to obtain baseline data in order to establish the existing ecological conditions of the project site, against which all post-monitoring results will be compared. This monitoring will take place during the growing season (preferably the fall) within a one-year period prior to the start of the project. Alternatively, a reference site, such as a wetland benchmark identified during the Evaluation of Planned Wetlands field effort, could be established as a control.

Post-restoration monitoring will begin four to five weeks after tidal wetland restoration is completed, this initial monitoring event will include a site walk through to confirm as-builts, photograph the site, and perform a visual inspection. Monitoring will continue twice a year, including a fall monitoring event (August-October) and spring monitoring event (March-May), for five years post-restoration.

Transects will be evenly spaced across the site. Transect locations will be permanently marked, and easily located. One square meter quadrat will be placed along a transect at a minimum of three different locations or to sufficiently include one quadrat in all vegetation zones.

Each quadrat will be photographed during each monitoring event.

Hydrophytic Vegetation Monitoring Procedures

Quantitative investigations to track the establishment of hydrophytic vegetation and invasive species coverage will occur once annually in the fall. The performance target is for plantings and/or target hydrophytes, which are species native to the area and similar to ones identified on the planting plan, to have a minimum of 80% survival at the end of five years and 75% coverage after five years. As an interim response, the adaptive management action for this metric may be triggered at the end of the two year construction contract guarantee and once between years three and five.

To ensure a successful vegetation effort, all plantings shall be monitored and maintained as necessary for five years. During monitoring events, the quadrats will be monitored for the following parameters:

- Percent vegetative cover in each quadrat
- Plant species occurring in each quadrat
- Signs of disease, predation, or other disturbance in each quadrat
- Stem density in randomly selected sub-quadrat (0.25 m^2) within each quadrat
- Plant height in randomly selected sub-quadrat (0.25 m^2) within each quadrat

A visual assessment will be conducted once annually during the spring monitoring season to assess the site for sedimentation or erosion, blockages to drainage, standing water, localized areas of disturbance or plant failures, and percent cover invasive species.

Adaptive Management Procedure

In the event that the emergent wetland/bioretention basin habitat fails to retain its designed structure or achieve its designed function, the following adaptive management procedures will be implemented.

Failure condition	**Adaptive management procedure**
Less than 80% survival or 75% coverage of target vegetation	Additional native vegetation will be planted. If issues of vegetation establishment persist beyond two years post construction, an ecologist will investigate the cause of failure and recommend modifications to the plant species as appropriate.
More than 20% coverage of non-native species in the restored habitat	Removal of invasive species via manual pulling or controlled herbicide application.
Sedimentation/erosion, blockage, drainage, standing water inspection results do not meet design standard/ physical index requirements	Investigate the cause of failure and recommend minor topographic modifications. Potential strategies to increase water conveyance, small berms to hold back drainage, or drainage swales.

3.10 Fish Ladder Monitoring Protocol

Purpose

The purpose of this monitoring protocol is to assess the success or failure of the installation of constructed fish ladders.

Monitoring Procedure

Post-construction monitoring will be separated into two disciplines: Structural and Biological.

Structural- The ladder will be inspected for structural integrity. Any debris or other materials that would cause an impediment to fish would be removed immediately. Any breaks, cracks, etc. will be noted, photographed, and repaired.

The stream bed will be inspected twice annually at the entryway (downstream edge) and receiving waters (upstream edge) to ensure appropriate conditions for entry to and exit from the passage structure.

Biological- Seasonally, the fish ladder will be examined to determine that fish are using the ladders. This would require observation to occur both during the day and at night. Scientists would observe fish that enter into the ladder and calculate the percent of individuals that swim up the ladder. Sampling might occur over a two-day period each season, following two-hour intervals over a 46-hr period.

- One hour before sunrise to one hour after sunrise
- On hour before midday to one hour after
- One hour before sunset to one hour after sunset
- Start three hours after sunset and continue for two hours.

Due to water clarity, it may not be feasible to visually see the fish. Under water sonar devices (Didson Cameras, etc.) may need to be stationed at the upstream and downstream end of the ladder. Also, for the spring sampling, scientists would time their observations to coincide (to the greatest extent practicable) with runs of anadromous fish.

Adaptive Management Procedure

In the event that the fish ladder fails to retain its designed structure or achieve its designed function, the following adaptive management procedures will be implemented.

Failure condition	**Adaptive management procedure**
Change to the structural integrity of the ladder that inhibits movement of fish or points to larger structural failure	Repair
Debris jamming in structure or inlet or any observable geomorphic changes (eg. scour hole) that inhibits movement of fish	Clear/repair
Significant hydraulic drop >1 foot at the downstream edge- fish can't make the jump into the ladder	Modification of inlet or outlet or manual regrading

3.11 Sediment Forebay Monitoring Protocol

Purpose

The purpose of this monitoring protocol is to assess the success or failure of the installation of the sediment forebay.

Monitoring Procedure

Immediately after construction the baseline depth and volume of accumulation in each forebay will be measured. The measurements would occur from either a small boat or scientists donning

waders. Using sediment probes and GPS, the scientists will select random locations throughout the forebay and record the position with GPS. Then, using a probe, the scientists will estimate how much sediment has accumulated since the previous monitoring effort. The monitoring will continue twice annually for five years.

Adaptive Management Procedure

In the event that the sediment forebay fails to retain its designed structure or achieve its designed function, the following adaptive management procedures will be implemented.

Failure condition	Adaptive management procedure
Greater than 12 inches sediment accumulation	Increase frequency of sediment removal from the forebay

3.12 Oysters Monitoring Protocol

Purpose

The purpose of this monitoring protocol is to assess the success or failure of the installation of oyster reefs. A successful oyster reef is a reef that sustains itself in perpetuity.

Monitoring Procedure

As there are several different oyster restoration methods to be used in the HRE, the monitoring protocols have been adapted from the *Oyster Habitat Restoration Monitoring and Assessment Handbook* (Baggett et al. 2014) and using protocol developed by project partners. Monitoring data collected by partners in nearby area or in other areas of concurrent HRE oyster restoration will be used as a reference. Monitoring applications would be initiated four to six weeks after the oyster reefs are built to confirm as-builts, photograph the site, and perform a visual inspection. Monitoring would continue twice annually in the late spring and late summer.

The basic monitoring principles of measuring success are the following:

(1) Physical Reef Structure (rugosity, burial, height);
(2) Density of live oysters;
(3) Survivability.

For physical reef measurements, scientists would measure the growth of the reef from the sea bed to the top of the reef. The scientists would mark their locations and perform the same measurement during each monitoring event. Measurements would be performed at a frequency of 1 per every 10 linear meters of reef. For spat on shell installations, rugosity measurements might occur over a 5-meter length of small link chain aid in a straight line over the reefs surface so that it conforms the various crenulations of the reef. Once the chain is in place a 10 meter tape would be stretched taught over the chain parallel to the water's surface. The tape would extend for ten meters; however, the chain, which has conformed to the varying topography of the reef, will be of a shorter distance then the tape. By measuring the differences in distance between the chain and tape, scientists can document the reef's surface three dimensionality. For structural installments such as oyster castles, structure monitoring will be measured through burial using sediment traps.

For every 10-20 square meters of reef, a 0.5 square meter quadrat would be placed on the reef's surface. Within the quadrat, the percent coverage of live oysters, dead oyster shells, or other

organisms will be estimated along with an assessment of diseased oysters. Then the shell length of each live oyster will be measured and recorded. Finally, all newly recruited oysters within the quadrat will be enumerated. All quadrats will be photographed.

Adaptive Management Procedure

In the event that the oyster restoration fails to retain its designed structure or achieve its designed function, the following adaptive management procedures will be implemented.

Failure condition	Adaptive management procedure
Reef fails to meet standard of growth and survivability performance metrics	Install new oyster stock, substrate, or structure. Minor adjustments to location or configuration of structures

4.0 Monitoring Costs

Required efforts and man-hours were determined and costs developed (Table 2) for the monitoring of each alternative for the five-year monitoring period. Summary of assumptions for monitoring costs is as follows:

1. Pre-construction baseline monitoring is assumed to take place twice on the year before the construction. Labor hours are assumed for one senior engineer and one wetland specialist for a day in the field and a day for reporting.
2. Post-construction monitoring frequencies for wetland (including emergent wetland) vegetation, soil, hydrology, scrub shrub and bed restoration as outlined in Section 3.0. Labor hours for onsite work and reporting are assumed for one senior engineer and one wetland specialist and depend on the size of each site.
3. Travel allowances include mileage, toll and boat rental needed for access to marsh islands. The boat rental cost is based on RS Means 2018 price adjusted for inflation.

Table L-2. Annual Monitoring Costs

Restoration Site	Total Annual Cost						Total
	Pre Construction	Year 1	Year 2	Year 3	Year 4	Year 5	
Dead Horse Bay (North)	$ 9,548.24	$ 19,096.48	$ 19,096.48	$ 19,096.48	$ 19,096.48	$ 19,096.48	$105,030.64
Fresh Creek	$ 9,548.24	$ 38,192.96	$ 38,192.96	$ 38,192.96	$ 38,192.96	$ 38,192.96	$200,513.04
Duck Point	$ 9,846.32	$ 24,829.84	$ 24,829.84	$ 24,829.84	$ 24,829.84	$ 24,829.84	$133,995.52
Stony Creek	$ 9,846.32	$ 24,829.84	$ 24,829.84	$ 24,829.84	$ 24,829.84	$ 24,829.84	$133,995.52
Pumpkin Patch West	$ 9,846.32	$ 19,692.64	$ 19,692.64	$ 19,692.64	$ 19,692.64	$ 19,692.64	$108,309.52
Pumpkin Patch East	$ 9,846.32	$ 19,692.64	$ 19,692.64	$ 19,692.64	$ 19,692.64	$ 19,692.64	$108,309.52
Elders Center	$ 9,846.32	$ 19,692.64	$ 19,692.64	$ 19,692.64	$ 19,692.64	$ 19,692.64	$108,309.52
Bronx Zoo and Dam	$ 9,548.24	$ 23,805.60	$ 23,805.60	$ 23,805.60	$ 23,805.60	$ 23,805.60	$128,576.24
Stone Mill	$ 9,548.24	14322.36	$ 14,322.36	$ 14,322.36	$ 14,322.36	$ 14,322.36	$ 81,160.04
Shoelace Park	$ 9,548.24	$ 23,805.60	$ 23,805.60	$ 23,805.60	$ 23,805.60	$ 23,805.60	$128,576.24
Bronxville Lake	$ 9,548.24	$ 23,805.60	$ 23,805.60	$ 23,805.60	$ 23,805.60	$ 23,805.60	$128,576.24
Garth Harney	$ 9,548.24	$ 23,805.60	$ 23,805.60	$ 23,805.60	$ 23,805.60	$ 23,805.60	$128,576.24
Flushing Creek	$ 9,548.24	$ 19,096.48	$ 19,096.48	$ 19,096.48	$ 19,096.48	$ 19,096.48	$105,030.64
Oak Island	$ 9,548.24	$ 14,257.36	$ 14,257.36	$ 14,257.36	$ 14,257.36	$ 14,257.36	$ 80,835.04
Branch Brook Park	$ 9,548.24	$ 28,644.72	$ 28,644.72	$ 28,644.72	$ 28,644.72	$ 28,644.72	$152,771.84
Metromedia Marsh	$ 9,548.24	$ 28,644.72	$ 28,644.72	$ 28,644.72	$ 28,644.72	$ 28,644.72	$152,771.84
Meadowlark Marsh	$ 9,548.24	$ 28,644.72	$ 28,644.72	$ 28,644.72	$ 28,644.72	$ 28,644.72	$152,771.84
Naval Station Earle	$ 6,264.52	$ 10,174.48	$ 10,174.48	$ 10,174.48	$ 10,174.48	$ 10,174.48	$ 57,136.92
Bush Terminal	$ 6,264.52	$ 20,348.96	$ 20,348.96	$ 20,348.96	$ 20,348.96	$ 20,348.96	$108,009.32
Naval Station Earle	$ 6,264.52	$ 10,174.48	$ 10,174.48	$ 10,174.48	$ 10,174.48	$ 10,174.48	$ 57,136.92

5.0 Adaptive Management Costs

Adaptive management costs for each alternative were calculated (Tables 3-6) based on efforts and criteria described in Section 3.0. Costs for measures specific to adaptive management and not typical to construction, including Topographic Modifications, Invasive Management, Bed Restoration, and In-Stream Structures, were developed by an Architectural Engineering firm. Summary of Assumptions is as follows:

1. Topographic Modifications
    a. Riverine Sites – Unit costs are based on the original construction price for the Shoelace Park & Bronxville Lake.
    b. Coastal Sites – Unit costs are based on the original construction price for the Fresh Creek.
    c. Marsh Islands – Unit costs are based on the original construction price for the Pumpkin Patch East site.
    d. Quantities are displayed in the back up files and were developed by the District PDT based on engineering judgment.
    e. Labor hours for engineering design and assessment are assumed for one senior engineer and one wetland specialist and are based on the size of each site. Labor rates are from the current NYS Department of Labor Occupational Employment Statistics (OES) Wage.
4. Invasive Management
    a. Invasive removal unit costs are based on RS Means data 2018, adjusted for inflation. Assumed two herbicide applicators and one wetland specialist. Quantities

are displayed in the back up files and were developed by the District PDT based on engineering judgment. Labor hours are based on the size of each site.

b. Invasive re-planting unit costs are based on the original planting cost of Bronxville Lake for Riverine sites, Fresh Creek for Coastal sites, and Pumpkin Patch East for Marsh Island sites. Quantities for re-planting are equal to those of invasive removal.

5. Bed Restoration and In-Stream Structures
    a. Unit costs are based on the original construction price for the Shoelace Park.
    b. Quantities are displayed in the back up files and were developed by the District PDT based on engineering judgment.
    c. Labor hours for engineering and assessment are for one senior engineer and are based on the size of each site.
6. Site Access (Mob/Demob) Costs are based on 10% of all the items applicable for each site.
7. No contingency has been considered at this stage of cost estimate.

Activities related to the adaptive management for measures including Vegetation, Bank Stabilization, Fish Ladder, Sediment Forebay, and Oysters were assumed to be similar in action to the project construction methods and costs were pulled directly from the MII files, more information regarding development is available in the Cost Engineering Appendix.

1. Vegetation- Planting costs are based on the original MII planting cost for each respective habitat type at each site. Quantities were developed by the District PDT based on engineering judgment. The project assumes replanting of 10% of each habitat type in years 1-5, replanting in years 1-2 are covered under the construction contract, leaving 6% to be included in the adaptive management costs for the project.
2. Bank Stabilization- Costs were based on the original MII cost for each sites specific bank stabilization feature (e.g., stacked rock wall with brush layer). The District PDT, based on engineering judgment, assumed 10% linear feet replacement of the total length of the feature.
3. Fish Ladder- Costs for structural repair were assumed to be 10% of the original MII total cost of the feature. Costs for regrading were based on topographic modifications at the Bronx Zoo site.
4. Sediment Forebay- Costs were based on the original MII cost for Bronxville Lake Sediment Forebay. The District PDT, based on engineering judgment, assumed increase in dredging in the amount of 10% of the total cost of the feature.
5. Oysters- Costs were based on the original MII costs for installation of stock and substrate and labor costs associated with structural adjustments.

Table L-3. Jamaica Bay Planning Region Adaptive Management Cost Years 1-5

Restoration Site	AM Action	Sub Total	Total AM
Dead Horse (North)	Topographic Mod.	$ 77,368.74	$ 234,306.13
	Invasives	$ 32,649.17	
	Vegetation	$102,987.65	
	Site Access	$ 21,300.56	
Fresh Creek	Topographic Mod.	$ 61,711.52	$ 223,823.43
	Invasives	$ 52,293.68	
	Vegetation	$ 89,470.65	
	Site Access	$ 20,347.58	
Duck Point	Vegetation	$131,331.95	$ 313,975.94
	Invasives	$ 36,511.11	
	Topographic Mod.	$117,589.61	
	Site Access	$ 28,543.27	
Stony Creek	Vegetation	$167,640.98	$ 438,832.12
	Invasives	$ 50,422.69	
	Topographic mod.	$180,874.63	
	Site Access	$ 39,893.83	
Pumpkin Patch West	Vegetation	$ 93,498.22	$ 218,136.08
	Invasives	$ 18,524.71	
	Topographic Mod.	$ 86,282.60	
	Site Access	$ 19,830.55	
Pumpkin Patch East	Vegetation	$ 93,498.22	$ 243,583.73
	Invasives	$ 27,606.23	
	Topographic Mod.	$100,335.30	
	Site Access	$ 22,143.98	
Elders Center	Vegetation	$ 92,065.67	$ 234,011.23
	Invasives	$ 23,739.05	
	Topographic Mod.	$ 96,932.76	
	Site Access	$ 21,273.75	

Table L-4. Harlem River, East River and Western Long Island Sound Planning Region Adaptive Management Costs Year 1-5

Restoration Site	AM Action	Sub Total	Total
Bronx Zoo and Dam	Bed Restoration In Stream	$ 10,083.16	$ 580,552.67
	Topographic	$ 62,580.36	
	Invasive	$ 132,059.31	
	Vegetation	$ 184,541.71	
	Bank Stabilization	$ 51,753.39	
	Fishway	$ 86,757.23	
	Site Access	$ 52,777.52	
Stone Mill Dam	Bed Restoration	$ 5,220.96	$ 66,403.52
	Fishway	$ 55,145.88	
	Site Access	$ 6,036.68	
Shoelace Park	Bed Restoration In Stream	$ 87,664.79	$ 1,331,206.77
	Topographic	$ 91,707.06	
	Invasive	$ 250,241.90	
	Vegetation	$ 159,092.49	
	Bank Stabilization	$ 621,481.73	
	Site Access	$ 121,018.80	
Bronxville Lake	Bed Restoration In Stream	$ 11,923.29	$ 669,064.81
	Topographic	$ 59,190.07	
	Invasive	$ 268,966.03	
	Vegetation	$ 251,011.45	
	Sediment Forebay	$ 6,074.05	
	Weir Modification	$ 11,075.85	
	Site Access	$ 60,824.07	
Garth Harney	Bed Restoration In Stream	$ 50,203.24	$ 621,275.15
	Topographic	$ 120,025.52	
	Invasive	$ 181,604.88	
	Bank Stabilization	$ 42,292.13	
	Vegetation	$ 159,593.97	
	Weir Modification	$ 11,075.85	
	Site Access	$ 56,479.56	
Flushing Creek	Topographic	$ 36,412.14	$ 65,559.44
	Invasive	$ 29,147.30	
	Site Access	$ 6,555.94	

Table L-5. Newark Bay, Hackensack River and Passaic River Planning Region Adaptive Management Costs Year 1-5

Restoration Site	AM Action	Sub Total	Total
Oak Island	Topographic	$ 32,045.86	$ 82,207.68
	Invasive	$ 21,156.56	
	Vegetation	$ 21,531.84	
	Site Access	$ 7,473.43	
Branch Brook Park	Topographic	$ 445,355.37	$ 3,189,258.08
	Invasive	$ 1,456,678.79	
	Bed Restoration	$ 97,906.68	
	Vegetation	$ 908,285.28	
	Site Access	$ 281,031.94	
Metromedia Marsh	Topographic	$ 100,524.26	$ 711,320.86
	Invasive	$ 121,422.21	
	Vegetation	$ 424,708.86	
	Site Access	$ 64,665.53	
Meadowlark Marsh	Topographic	$ 162,357.03	$ 367,751.96
	Invasive	$ 96,680.56	
	Vegetation	$ 75,282.38	
	Site Access	$ 33,432.00	

Table L-6. Oyster Reef Restoration Adaptive Management Costs Year 1-5

Restoration Site	AM Action	Sub Total	Total
Naval Station Earle	Install Stock and Substrate	$ 83,845.92	$272,095.94
	Structural Adjustments	$ 188,250.02	
Bush Terminal	Install Stock and Substrate	$ 73,563.91	$107,105.43
	Structural Adjustments	$ 33,541.53	
Head of Jamaica Bay	Install Stock	$ 130,566.75	$282,384.05
	Install Substrate	$ 11,409.22	
	Structural Adjustments	$ 140,408.07	

6.0 References

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