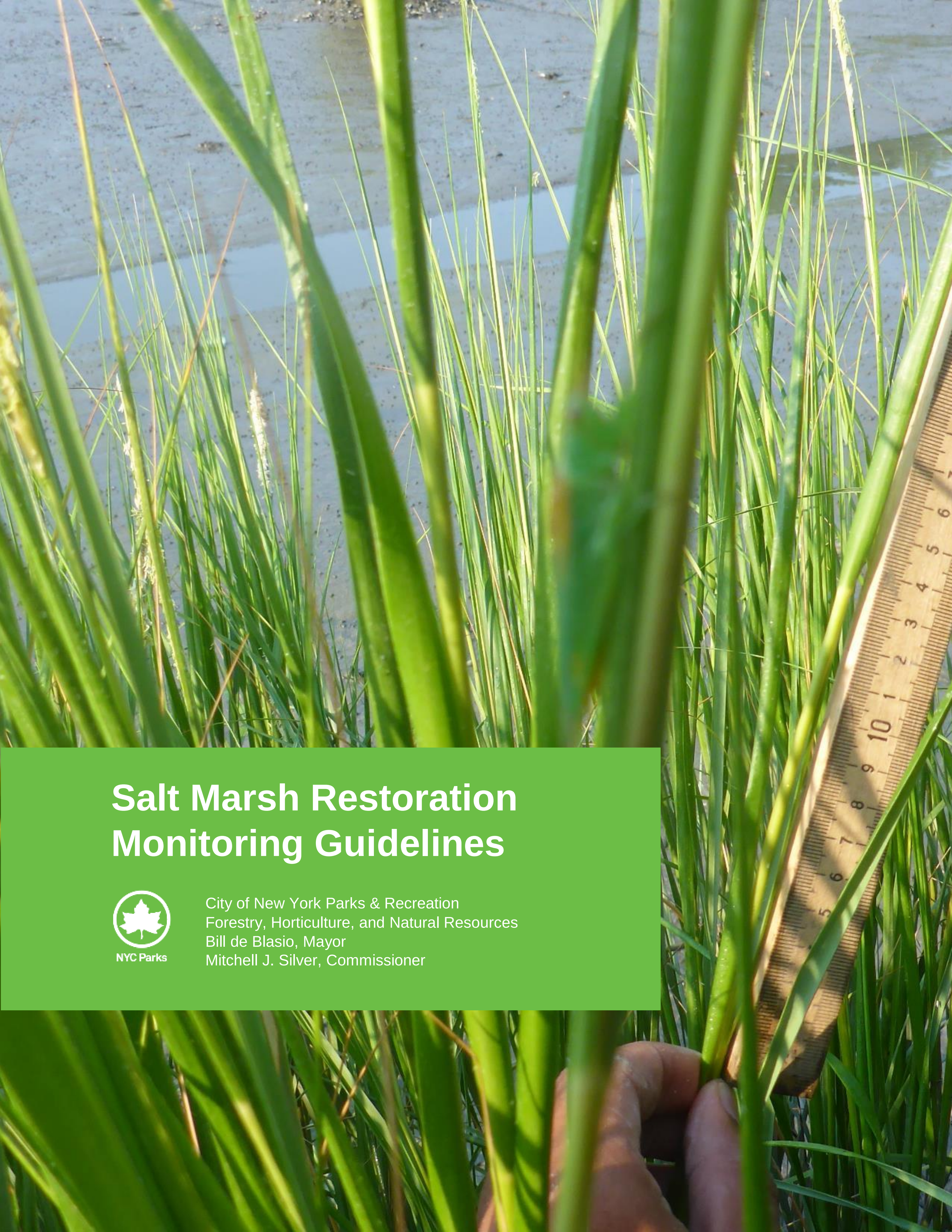

Salt Marsh Restoration Monitoring Guidelines

NYC Parks

City of New York Parks & Recreation
Forestry, Horticulture, and Natural Resources
Bill de Blasio, Mayor
Mitchell J. Silver, Commissioner

EXECUTIVE SUMMARY

The NYC Parks Salt Marsh Restoration Monitoring Guidelines, presented here, provide a framework for selecting and implementing monitoring approaches to help answer a range of questions applicable to salt marsh restoration design and management. These Monitoring Guidelines build upon the New York State 2000 Salt Marsh Restoration and Monitoring Guidelines and are informed by a 2015/2016 New York City Department of Parks & Recreation (NYC Parks) study of past salt marsh restoration projects on parklands. Our review found that clear project objectives and appropriate sampling designs, sampling frequency and duration, data management, and communication are vitally important for effective monitoring.

Salt marshes provide essential services for wildlife and coastal communities, including habitat for coastal species, buffering from coastal waves, and water filtration. Restoration is an important tool to protect and enhance these ecosystems and maintain the functions they provide. Salt marshes are one of the most threatened ecosystems; less than 20% of NYC's saltmarshes remain today – most were lost to development, and those that remain are now threatened by sea level rise.

Since 1990, more than 35 salt marsh restoration projects covering over 150 acres have been constructed on properties belonging to NYC Parks. In order to determine the success of these projects, practitioners use monitoring to collect information about salt marsh condition. Monitoring can answer basic questions about the establishment of vegetation in a restored salt marsh, as well as more complex questions concerning the function of a constructed salt marsh in the face of sea-level rise and extreme weather events.

The Monitoring Guidelines provide specific direction on designing and implementing a monitoring plan that reflects available resources and can meet a range of monitoring objectives, from rapid monitoring to assess how well a project was implemented, to more resource-intensive monitoring aimed at evaluating a project's effectiveness. The Monitoring Guidelines also include detailed recommendations for natural resource managers and restoration practitioners on how to develop and implement monitoring projects that inform adaptive management, allowing practitioners to more systematically learn from restoration projects.

The first six sections of the Monitoring Guidelines explain the critical steps in developing a monitoring plan. The last section is a case study of a monitoring project that follows these steps.

1. Identify restoration and monitoring objectives

Two fundamental monitoring objectives are described based on the framework developed by the National Oceanic and Atmospheric Administration (NOAA). The first is implementation monitoring, used to determine if the project was constructed as designed. The second is effectiveness monitoring to determine if the structure or conditions after restoration meet the project objectives and provide ecological functions.

2. Select monitoring strategy

An appropriate monitoring strategy considers the monitoring objective and the resources available for monitoring. This section combines the NOAA framework mentioned in the previous step with the U.S. Environmental Protection Agency's framework for wetlands monitoring and assessment into three tiers of monitoring strategies that increase in complexity and level of effort: Tier 1 addresses implementation monitoring objectives through desktop analyses, Tier 2 addresses implementation monitoring objectives through rapid field methods, and Tier 3 addresses effectiveness monitoring objectives through moderate or intensive field methods.

3. Select parameters, metrics, and methods

This section describes several parameters and associated metrics and protocols across the three monitoring strategy tiers. The parameters include vegetation, fauna, tidal channel geomorphology, hydrology, and soils.

4. Create a sampling plan

This section explains the components of a sampling plan including a description of Before-After, Control-Impact design; the frequency, duration, and timing of sampling across metrics; selecting the appropriate sampling unit and size across metrics; stratified sampling; fixed photo establishment; and creation of a quality assurance project plan.

5. Create a data analysis, management, and information sharing plan

This section outlines the methods for documenting, storing, and managing data and analyses; identifying information products; and employing different systems used to share this information.

6. Create an inspection and maintenance plan

This section discusses the development of an inspection protocol and maintenance plan to identify and address various management concerns raised during routine inspections.

7. Sunset Cove salt marsh case study

This case study provides an example of applying these guidelines in practice for NYC Parks' Sunset Cove Salt Marsh Restoration project in Broad Channel, Queens.

How to use these guidelines

This document is intended to assist natural areas managers and restoration practitioners with developing and implementing monitoring programs to evaluate the condition and performance of restoration projects. This document also describes how monitoring fits into an adaptive management framework for improving future restoration projects. Those who are already familiar with restoration monitoring can also use these guidelines to help develop monitoring plans to answer more specific questions about the long-term performance of salt marsh restoration projects and to inform adaptive management.

These guidelines are meant to serve as a reference for a variety of users, and can be used selectively, rather than to be followed as a protocol from beginning to end. For instance, following construction of a salt marsh restoration project, to assess whether the project was implemented as designed, refer to the Tier 1 and 2 monitoring strategy in Section 2. If the main concern, however, is whether the restored salt marsh is effectively performing specific functions of interest, an effectiveness monitoring strategy (Tier 3) may be most appropriate. Section 3 provides examples of parameter(s) that may be critical for effectiveness monitoring. Those aiming to use information from an ongoing monitoring program to more effectively inform project management may refer to the Introduction's section on Adaptive Management & Monitoring; Section 4 on Sampling Plans; and Section 5 on data management, analysis, and interpretation.

With these guidelines, NYC Parks aims to synthesize over 25 years of experience into a brief, practical overview of salt marsh restoration monitoring. Restoration practitioners and other interested parties are welcome to submit questions and suggestions or request the appendices by contacting the authors listed at the end of this document.

Cover Photo: Pugsley Creek, Bronx

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INTRODUCTION

Background

Coastal ecosystems, including salt marshes, are vitally important to wildlife and coastal human communities for the numerous ecosystem services they provide, such as foraging and breeding habitat for fish, birds, and mammals, and buffering from waves and flooding during storms. They are also severely threatened. In 2000, the New York State (NYS) Department of State (DOS), and the Department of Environmental Conservation (DEC) published the New York State Salt Marsh Restoration and Monitoring Guidelines (2000 Guidelines).[1,2] Since 2000, these guidelines and protocols have been used by the New York City (NYC) Department of Parks & Recreation (NYC Parks), as well as other restoration practitioners and city, state, and federal agencies, to monitor the success of salt marsh restoration and mitigation projects across NYC and other coastal regions of New York State. On NYC Parks' property alone, over 35 salt marsh restoration projects totaling over 150 acres have been constructed since 2000.[3] In 2015, with updated sea-level rise projections for New York State and a desire to improve management of natural areas through data-driven decision making and adaptive management, NYC Parks began a review of past salt marsh restoration projects, as well as the 2000 Guidelines, to collect lessons learned from evaluating nearly 20 years' of restoration projects. These Monitoring Guidelines are a direct result of the 2015 assessment effort. Components of the Monitoring Guidelines reflect findings from the field monitoring, as well as interviews with project managers about monitoring efforts for individual projects.

Specifically, our assessment confirmed that it takes time for restored salt marshes to attain ecosystem strucuture and fuctions comparable to naturally occurring salt marshes. Our main findings are summarized here:

- Both transect and random grid plots are equally effective sampling designs
- Past monitoring efforts that followed the 2000 Guidelines mainly focused on vegetation and benthic fauna with some data collected on birds (presence/absence) and limited data collected on fish and soils
- Past monitoring was commonly conducted for up to 5 years and produced final reports, but did not always state clear objectives, conclusions or recommendations
- Collected data was generally not statistically robust to compare within or across sites

From these findings we emphaszied the following approach in these Monitoring Guidelines:

- Provide guidance on setting monitoring objectives
- Use a tiered framework with desktop, and rapid and moderate/intensive field monitoring tiers to determine the appropriate monitoring approach and parameters according to objectives and available resources
- Provide guidance for sampling design including both transect and grid designs
- Provide guidance for the duration and frequency of sampling by parameter
- Provide guidance for data management and analysis

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[1] Niedowski, N.L. 2000. New York State Salt Marsh Restoration and Monitoring Guidelines. New York State Department of State, and New York State Department of Environmental Conservation. http://www.dec.ny.gov/docs/wildlife_pdf/saltmarsh.pdf

[2] New York/ New Jersey Harbor Estuary Program. 2001. Status Report: A Regional Model for Estuary and Multiple Watershed Management. Habitat Workgroup

[3] New York City Department of Parks & Recreation (NYC Parks). 2017. Salt Marsh Restoration in NYC: Assessment of Condition and Recommendations for Future Design and Monitoring. https://ofmpub.epa.gov/apex/grts/f?p=101:150:8913351273415::NO::P150_GRT_SEQ:103419

The 2000 Guidelines describe approaches to restoring and evaluating the success of salt marsh habitat restoration through assessments of vegetation, soils, benthic invertebrates, and other fauna.[4] Here, we build on this approach by detailing the steps involved in creating a monitoring plan that feeds back into adaptive management. Adaptive management is an iterative process used to improve management by implementing a management action (for example, a salt marsh restoration), monitoring and assessing the action and its outcomes, adjusting those actions, and repeating.[5] This process allows for management in the face of inevitable "surprises" or unexpected external factors such as extreme weather events or pests, where monitoring and analyzing iteratively enables managers to be more flexible and capable of adjusting management practices. There are many ways to implement adaptive management. For the purposes of salt marsh restoration, the adaptive management approach described in this document involves:

a. Defining the problem or issue that will be addressed by restoration;
b. Establishing objectives for restoration;
c. Implementing a restoration project to address objectives;
d. Monitoring the implementation and outcome of the restoration project;
e. Analyzing, synthesizing, and evaluating the information collected through monitoring;
f. Determining how to adjust actions so restorations can be more effective and efficient at addressing problems; and

Repeating a-f (see Figure 1).

Because the defining feature of adaptive management is a feedback between learning and decision making[4], we developed a monitoring framework that will allow information learned from monitoring to be more easily applied to decision-making. Each step of our monitoring framework links back to specific components of adaptive management:

1. Identify the monitoring objectives, which depend on the restoration objectives (i.e., how is a "successful" restoration defined) and the available resources for conducting monitoring (Section 1).
2. Determine the appropriate monitoring strategy and parameters based on the monitoring objectives. These steps ensure that the monitoring plan is feasible, and the information collected through monitoring is usable for decision making (Section 2 and 3).
3. Develop a sampling plan. This ensures that the information collected will be analyzed, synthesized, and interpreted to evaluate restoration success and allow comparisons across sites (Section 4).
4. Create a data management and information sharing plan, which helps organize, analyze, and distribute the information that was learned from monitoring and inform future management practices across projects (Section 5).
5. Create an inspection and maintenance plan to adjust management and maintenance practices within a single site or apply the lessons learned from maintenance to future projects (Section 6).

These updated guidelines are intended for natural resource managers and restoration practitioners who are generally familiar with restoration monitoring and are looking for guidance on designing and implementing monitoring plans that can answer more specific and in-depth questions about the long-term success of their salt marsh restoration projects and connect this information to adaptive management.

[4] Niedowski, 2000.
[5] Williams, B.K. 2011. Adaptive management of natural resources – framework and issues. Journal of Environmental Management. 92:1346-1353

Adaptive Management & Monitoring

Monitoring is a key component of adaptive management, an iterative and systematic approach of testing assumptions and learning from past decisions and actions to inform management.[6,7,8] Within the context of salt marsh restoration, designing and implementing a monitoring plan is an important step that enables managers to take lessons learned from restoration projects and apply that knowledge to other sites or adjust practices within the same site (Figure 1).

The Monitoring Guidelines presented here refine and expand upon the 2000 Guidelines by:

1) Recommending a tiered monitoring framework for selecting the monitoring strategy and measuring specific parameters based on available resources and expertise; and

2) Providing guidance on additional monitoring considerations (such as data management, information sharing, and inspection and maintenance plans) that help connect monitoring with adaptive management.

Although adaptive management is frequently cited as an important component of natural resources management, there is limited available guidance for how to put adaptive management into practice. These Monitoring Guidelines suggest how to implement adaptive management by using qualitative and quantitative data from monitoring and inspecting a salt marsh restoration site in order to inform decisions about long-term site management.

In this document, we outline key steps in designing and implementing a monitoring plan that connects with components of the adaptive management approach (Figure 2):

Step	Purpose
1. Identify restoration and monitoring objectives	Link the monitoring plan directly to the underlying objectives of the restoration to ensure that the information collected during monitoring is usable for decision making
2. Select monitoring strategy	Acknowledge available time and resources and clarify strategy to ensure that monitoring is feasible and can be implemented
3. Select parameters, metrics, and methods	Link the monitoring plan to the restoration goals and account for the specific characteristics of restoration site or project so that information collected during monitoring is usable for decision making
4. Create a sampling plan	Ensure that the information collected during monitoring can be easily analyzed, synthesized, and evaluated
5. Create a data analysis, management and information sharing plan	Ensure that the information collected during monitoring is analyzed, synthesized, evaluated, and disseminated
6. Create an inspection and maintenance plan	Help adjust inspection and site maintenance practices across projects and within a project or site

[6] Holling, C.S. 1978. Adaptive Environmental Assessment and Management. Caldwell, NJ: Blackburn Press.
[7] Lee, K.N. 1999. Appraising adaptive management. Conservation Ecology 3(2): art3
[8] Thom, R.M. 2000. Adaptive management of coastal ecosystem restoration projects. Ecological Engineering 15: 365-372.

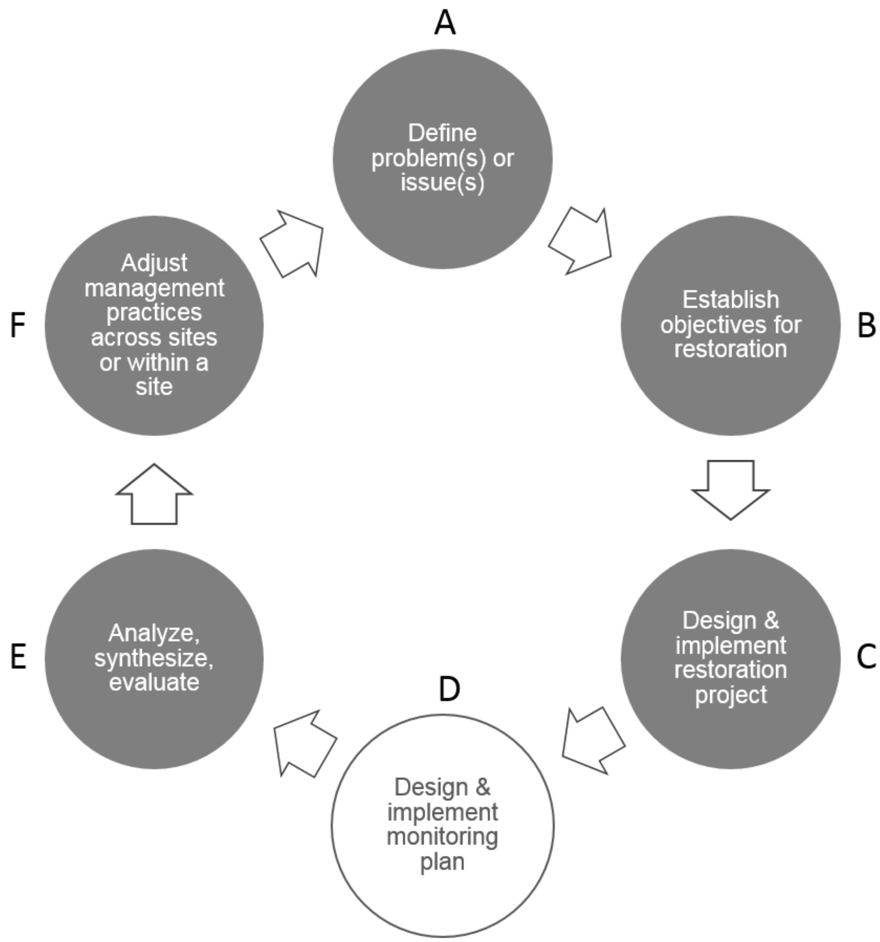

Figure 1. The role of monitoring within an adaptive management approach to salt marsh restoration. Adapted from the California Department of Fish and Wildlife's Ecosystem Restoration Program, http://www.dfg.ca.gov/erp/adaptive_management.asp.

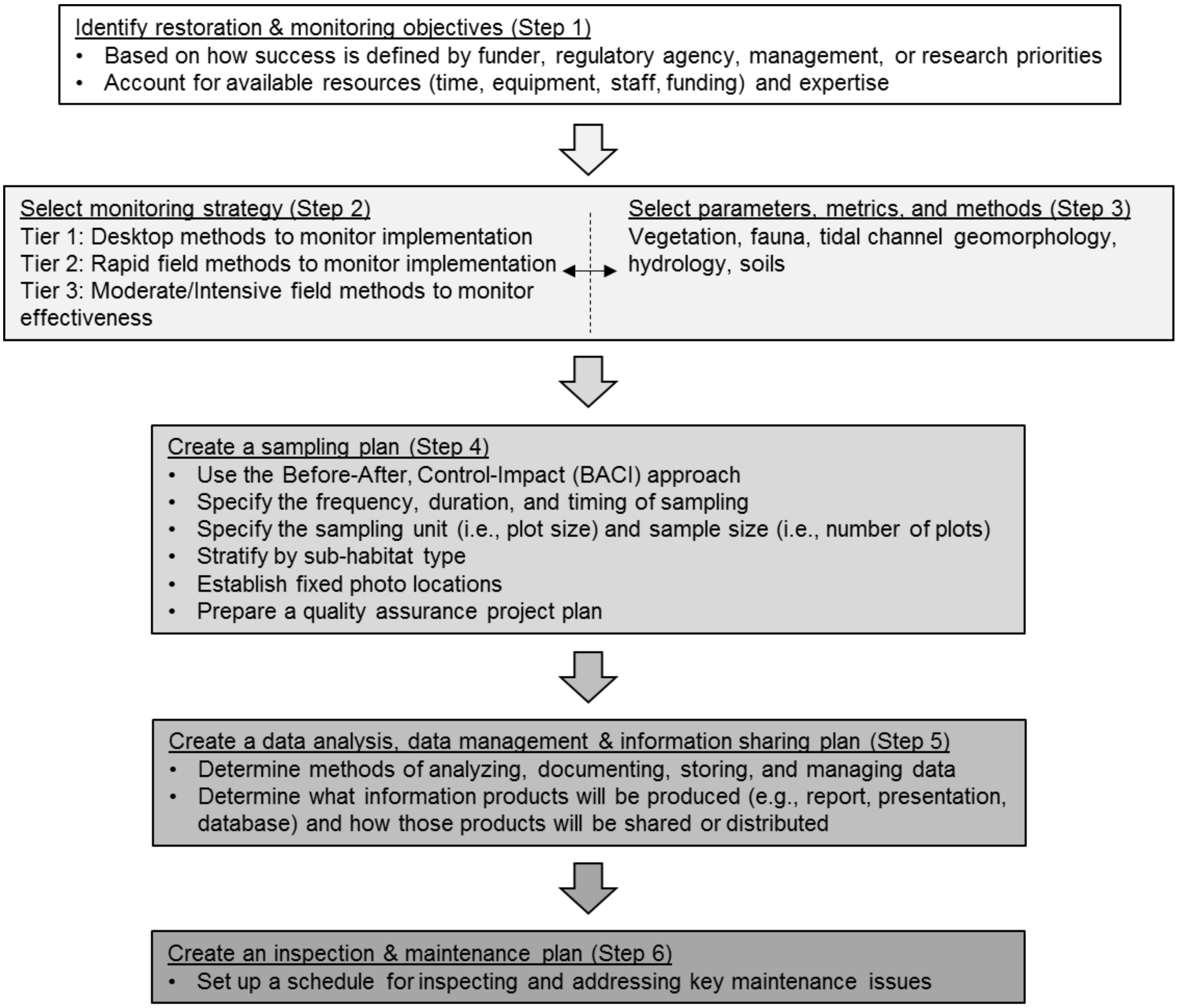

Figure 2. Steps to designing and implementing a monitoring plan. Some sub-steps, for example in Step 4, may vary according to monitoring objectives, strategy and parameters.

1.0 IDENTIFY RESTORATION AND MONITORING OBJECTIVES

The primary goal of monitoring is to ensure that information is available to evaluate whether the restoration objectives are met. The secondary goal of monitoring, for resource managers, is usually to identify potential problems, guide adaptive management, and improve long-term restoration outcomes. Thus, the first step in setting monitoring objectives is to account for restoration objectives. Broadly, the goal of salt marsh restoration is to successfully create functional salt marsh habitat. However, specific restoration objectives may define “success” and “functional salt marsh habitat” differently; objectives can vary from project to project depending on requirements of funders or regulatory agencies or various management or research priorities. In addition to accounting for restoration objectives, monitoring objectives must also account for available resources (e.g., time, equipment, staff, funding) and expertise, which will dictate what kind of monitoring can be conducted and what questions can be answered.

In this document, we use the framework developed by the National Oceanic and Atmospheric Administration (NOAA)[9] to classify monitoring objectives into two types:

<u>1. Implementation monitoring (Was the project built as per design?)</u> Salt marsh restoration projects require state and federal permits for construction and are often constructed as mitigation for wetland impacts. In the case of grant-funded and mitigation projects, the funder and/or regulator generally requires evidence that the project was implemented correctly as intended or designed. Therefore, monitoring must demonstrate that the project meets permit or contractual requirements and is constructed and performing as intended. This type of monitoring is usually relatively low effort and short term, is aimed at quality control and accountability, and addresses only limited questions about the restoration performance.

Examples:

- Plant survival monitoring to determine if a minimum of 85% native plant survival after 3 years, as typically required in permits by New York State Department of Environmental Conservation (DEC).
- Vegetation monitoring to verify that target species have comparable vegetation metrics as a reference site, for example, *Spartina alterniflora* in a restored site has similar percent cover, density, height, and/or diameter compared to the same species in a reference site.

<u>2. Effectiveness monitoring (Is the structure or condition established effective in meeting objectives and are ecological functions being met?)</u> Salt marsh restoration projects are often expected to perform ecological functions based on the values or priorities identified by regulatory or funder requirements or in regional or watershed management plans. In these cases, monitoring needs to demonstrate that the project is performing those functions, which frequently requires more effort and time. For example, project funding may have been intended for salt marsh restoration to expand bird or fish habitat. Therefore, monitoring may need to demonstrate evidence that the target species is using the restored salt marsh. Alternatively, salt marsh restoration may have been funded to help reduce wave energy and erosion, thus monitoring would involve a different set of parameters. Objectives may also address research questions that inform management such as monitoring to understand the differences in ecosystem services and function between naturally occurring and restored salt marshes.

Examples:

- Monitoring presence and/or extent of mussels after a given timeframe to determine if the restored site is providing habitat.
- Monitoring the extent and frequency of tidal inundation to determine if the restored hydrology will support native high marsh vegetation and suppress invasive species.
- Quantifying nitrogen reduction or carbon storage in restored versus naturally occurring marshes.
- Characterizing soil development in sites that required placement of clean sediment in order to achieve contaminant removal or a suitable planting medium compared to the soil conditions in a reference site over time.

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[9] National Oceanic and Atmospheric Administration (NOAA) Fisheries, Office of Habitat Conservation. Monitoring, Evaluation, Reporting and Feedback Framework. https://www.fisheries.noaa.gov/national/habitat-conservation/monitoring-and-evaluation-restoration-projects

Because a restoration project may have multiple objectives, it is possible that both implementation and effectiveness monitoring may be conducted for a single project.

2.0 SELECT MONITORING STRATEGY

Once the monitoring objectives have been identified, there are many ways to implement monitoring depending on available resources and expertise. In this step, we introduce a tiered monitoring approach that combines the NOAA framework mentioned in the previous step with the U.S. Environmental Protection Agency's (EPA) tiered framework for wetlands monitoring and assessment that increases in intensity with each tier.[10] This tiered framework is intended to be considered in concert with the following step (Section 3), which details the process of selecting which parameters (e.g., vegetation, fauna, tidal channel geomorphology, hydrology, soils) to be monitored, which metrics to be measured, and which methods to be used.

The three tiers are as follows, with Tiers 1 and 2 as different strategies for implementation monitoring, Tier 3 as a strategy for effectiveness monitoring, and each tier increasing in complexity and level of effort:

Tier 1: Desktop – Implementation. Tier 1 evaluates whether the project was constructed as designed, for example, by using desktop analyses and aerial photography to broadly characterize the project area and surrounding landscape.

Tier 2: Rapid Field Monitoring – Implementation. Tier 2 evaluates whether the project was constructed and initially established as designed by using a rapid field assessment to characterize basic metrics, such as vegetation cover or survival.

Tier 3: Moderate/Intensive Field Monitoring – Effectiveness. Tier 3 evaluates whether the project was successful in achieving specific ecological structure or functions. This approach requires moderate to intensive assessment methods, such as vegetation production, soil development, or characterizing populations of invertebrates, birds, or other fauna.

Because there may be multiple restoration objectives, a monitoring plan may involve monitoring different parameters at different tiers. For example, tidal channel geomorphology monitoring may be conducted using a Tier 1 strategy, faunal monitoring may be conducted using a Tier 2 strategy, and vegetation monitoring may be conducted using a Tier 3 strategy. This approach can be applied to a variety of objectives with different monitoring approaches, parameters, levels of effort and expertise (Table 1). By identifying the monitoring strategy early on, organizations are better able to implement adaptive management across a wide range of available resources and expertise.

[10] U.S. Environmental Protection Agency (EPA). 2015. Monitoring and Assessment. https://www.epa.gov/sites/production/files/2015-09/documents/monitoring_and_assessment_cef.pdf

3.0 SELECT PARAMETERS, METRICS, AND METHODS

In this step, we provide an overview of commonly used monitoring parameters, metrics, and methods for determining whether salt marsh restoration projects have been implemented correctly and whether they are performing as intended. The intention of this step is not to provide an exhaustive list of all possible parameters, metrics, and methods for monitoring salt marsh restoration projects, but to provide examples of each for addressing different project objectives given different levels of effort or expertise. Understanding the project monitoring objectives and how this monitoring fits into the tiered framework can help determine which methods are appropriate (Table 1). By carefully selecting the parameters, metrics, and methods that best match monitoring goals and available resources, the information collected during monitoring will be able to answer questions associated with decision making, which is key to adaptive management.

This section is organized in order of the most frequently monitored parameters in salt marshes: vegetation, fauna, tidal channel geomorphology, hydrology, and soils. Within each parameter, metrics are organized by the level of effort and expertise required to measure. Later, Step 4 will include information on the recommended frequency, duration, sampling unit, and sample size for these methods.

3.1 <u>Vegetation</u>

<u>Tier 1. Desktop Analysis</u>

3.1.1 Vegetation extent

Purpose: Determine the change in the restored marsh vegetated footprint and plant survival over time.

Definition: Vegetated footprint is the area of the project intended to be low or high marsh.

Metrics: The area (or footprint) of the restoration project that was planted.

Methods: Compare the vegetated marsh footprint from as-built surveys to that shown in the most recent available aerial imagery. An example full protocol is available in Appendix A.

<u>Tier 2. Rapid Field Monitoring</u>

3.1.2 Vegetation survival

Purpose: Determine if the vegetation planted during restoration has survived, usually to determine if a survival target or threshold set by regulators is met.

Definition: Vegetation survival is the percentage of planted plants alive in the restored area after restoration compared to the number originally planted.

Metrics: Percent of original plants installed that are alive.

Methods: Count the number of installed plants in plots or across the restoration area by species and compare with the planting plan or the originally quantities of plants to determine survival.

3.1.3 Invasive plants

Purpose: Identify and quantify invasive plant species that occur in the restored area after restoration.

Definition: Invasive plants are non-native species that degrade habitat by forming large single species stands with less habitat and functional value than restored native plants.

Metrics: Number or percent cover of invasive plants in the monitoring area.

Methods: Count the number of individual invasive plants by species in plots or across the site or estimate the percent coverage of invasive plants visually or by mapping the invasive species stands using a Global Positioning System (GPS) unit and determining the coverage based on the area of the restoration.

Tier 3. Moderate/Intensive Field Monitoring

3.1.4 Change in vegetation structure

Purpose: Characterize the restored vegetation communities and determine plant survival, cover, and density over time. Determine if the restoration successfully provides the function of vegetated habitat.

Definition: Vegetation structure is the cover, density, height, and diameter attributes of the vegetation.

Metrics:

i. Percent cover of vegetation, by species
ii. Stem density (number of stems per unit area), by species
iii. Stem height, by species
iv. Stem diameter, by species

Methods:

i. *Percent cover*

Characterize percent cover of vegetation and non-vegetation in plots (see Step 4 - Creating a Sampling Plan, Figure 4) using visual estimates of cover by individual species and by non-vegetation (bare ground, plant litter, organic wrack, garbage, etc.). Estimate percent cover to a midpoint of the agreed-upon vegetation class and come to a consensus on cover class for each species, for example, using the Ecological Society of America cover class midpoints (0.50%, 2.50%, 8.75%, 18.75%, 37.50%, 62.50%, 87.50%). Use midpoints of cover classes instead of the cover class range to facilitate data summary and analysis. Assign cover class midpoints for each species within a plot, rather than absolute values. Cover may be impacted based on structural diversity (e.g., species occur in different strata and may overlap), thus the plot total percent cover may be less than or greater than 100%.

ii. *Stem density*

Determine stem density by counting the number of individual stems for each plant species within the same plots used for percent cover (see Step 4 - Creating a Sampling Plan, Figure 4). Make separate counts of both the number of flowering and non-flowering stems.

iii. *Stem height*

Measure stem height from the bottom of the stem at the ground or above any exposed roots to the terminal leaf node (final leaf branching point) prior to the base of the inflorescence (flowering head). Measure the stem height of five random stems of the dominant species in plots (see Step 4 - Creating a Sampling Plan, Figure 4).

iv. *Stem diameter*

Measure stem diameter of the same five stems of the dominant species measured for stem height in the same plot. Measure the diameter at a quarter of the height of the stem (e.g., stem height=100cm, measure stem diameter 25cm from the ground) using millimeter calipers.

3.1.5 Plant biomass

Purpose: Quantify plant production above and belowground over time to answer more complex questions about plant physiology and allocation of resources for growth. Both live belowground biomass and dead belowground biomass can be measured to determine new belowground production and the contribution to soil development or accumulated organic material from past season's growth, respectively. The relative proportion of aboveground vs. belowground biomass can also be indicative of environmental issues such as nutrient enrichment or soil compaction (less belowground biomass due to high nutrient availability or highly compacted soils).

Definition: Plant biomass is the quantity (dry weight in grams) of living physical material in a plant.

Metrics:

i. Aboveground biomass
ii. Belowground biomass

Methods:

i. *Aboveground Biomass*

Clip all of the aboveground live stems from plots (see Step 4 - Creating a Sampling Plan, Figure 4) across the site. Store the clipped stems in labeled sample bags and transport them to the laboratory for processing. If samples are not processed immediately, they may be refrigerated for up to one week. Clean the plant material of soils, separate the stems by species, and dry the plant material in a drying oven at 60˚C for 48 hours. Weigh the dried materials to determine the aboveground dry weight per species. Determine the aboveground dry weight per square meter.

ii. *Belowground biomass*

Using a soil corer at least 10cm in depth with an 8cm or similar diameter (a majority of living plant belowground biomass is located in the top 10cm of the soil),[11,12] collect cores of individual plant species roots (e.g., homogenous *Spartina alterniflora* or *Spartina patens*) from random locations across the site (see Step 4 - Creating a Sampling Plan, Figure 4). Store the cores in labeled sample bags and transport them to the laboratory for processing. If samples are not processed

[11] Deegan, L. A., D.S. Johnson, R.S. Warren, B.J. Peterson, J,W. Fleeger, S. Fagherazzi, and W.M. Wollheim. 2012. Coastal eutrophication as a driver of marsh loss. Nature 490, 388–392.https://www.nature.com/articles/nature11533

[12] Wigand, C., Roman, C.T., Davey, E., Stolt, M., Johnson, R., Hanson, A., Watson, E.B., Moran, S.B., Cahoon, D.R., Lynch, J.C., & Rafferty, P. (2014) Below the disappearing marshes of an urban estuary: historic nitrogen trends and soil structure. *Ecological Applications 24* (4), 633-649.

immediately, they may be refrigerated for up to one week. Clean the soil from each core over a No. 10 (2mm) sieve to retain plant material. Separate live plant material from dead (live roots and rhizomes are white and swollen, dead materials are dark and limp) and dry them in a drying oven at 60˚C for 48 hours. Weigh the dried materials to determine belowground dry weight per sample.

3.2 Fauna

Tier 2. Rapid Field Monitoring

3.2.1 Benthic epifauna

Purpose: Verify whether benthic epifauna are colonizing the site, characterize the community and determine changes in density and size (e.g., mussel shell length) over time.

Definition: Benthic epifauna are invertebrate (without backbone) organisms that live above the sediment at the bottom of a body of water or flooded area that are visible to the eye without a microscope. For the purposes of this monitoring objective, these include mollusks or bivalves (e.g., mussels), crustaceans (e.g., crabs), and gastropods (e.g., snails).

Metrics:

i. Abundance of bivalves per area and average lengths
ii. Abundance of crab burrows per area, a proxy for counting individual crabs due to the flight response of crabs during monitoring
iii. Abundance of snails by species per area (e.g., *Tritia obsoleta* and *Melampus bidentatus*)
iv. Abundance of other benthic epifauna per area (e.g., amphipods, isopods, insects, etc.)

Methods

i. *Abundance of bivalves and lengths*
Count the number of individual bivalves by species (e.g., ribbed mussel, oyster, etc.), and measure the length of bivalves for each species in plots (see Step 4 - Creating a Sampling Plan, Figure 4) randomly distributed across the site.

ii. *Abundance of crab burrows*
Count the number of individual crabs by species (e.g., fiddler crab, blue crab, purple marsh crab, etc.) and count the number of crab burrows in plots randomly distributed across the site (see Step 4 - Creating a Sampling Plan, Figure 4).

iii. *Abundance of snails*
Count the number of individual snails by species (e.g., mud snail, eastern *Melampus*, etc.) in plots randomly distributed across the site (see Step 4 - Creating a Sampling Plan, Figure 4).

iv. *Abundance of other benthic epifauna*
Count the number of individuals of other invertebrate species (e.g., amphipods, isopods, insects, etc.) observed in plots randomly distributed across the site (see Step 4 - Creating a Sampling Plan, Figure 4).

3.2.2 Other fauna

Purpose: Use presence / absence, counts, and observations of behavior to determine whether fauna have returned to the site after restoration.

Definition: Other fauna includes birds, fish, mammals, amphibians, or benthic invertebrates.

Metrics: Abundance of individual fauna by species per area.

Methods: Record presence, or reasonable evidence of presence based on counts and/or observations of behavior, for any other fauna (birds, fish, small mammals, horseshoe crabs[13], terrapins) at the site. This method only produces qualitative data, in order to get quantifiable data for analysis more intensive methods are required (see Tier 3 below).

Tier 3. Moderate/Intensive Field Monitoring

3.2.3 Avifauna

Purpose: Document presence of bird species, characterize the bird communities at the site and determine if the restoration is providing breeding, nesting, and foraging habitat for generalist and specialist birds.

Definition: Avifauna are birds.

Metrics:

i. Abundance of birds and diversity of bird species per area and associated behavior (feeding, breeding, etc.): an indicator of habitat quality for generalist and salt marsh specialist species.
ii. Number of nests (e.g., salt marsh sparrow nests): a potential indicator of habitat quality for salt marsh specialist species.

Methods:

i. *Abundance & diversity of birds and associated behavior*

   Monitor birds from an inconspicuous landward vantage point adjacent to the restored area, if possible. Record the location of the monitoring site using a GPS unit or record the GPS coordinates. Record the presence, number of individuals, general location, activity, and length of stay for all bird species. Refer to the Standardized North American Marsh Bird Monitoring protocol by Conway (2011)[14] for more details on salt marsh bird monitoring, including wading birds.

ii. *Number of nests*

   Search the site for nests and count the number of nests and nesting bird species observed at the site. Mark nests when found using a physical marker and GPS unit. Count the number of eggs or chicks found in the nest (if any). For a more detailed

[13] Sclafani, M., K. McKown, B. Udelson. 2014. Horseshoe Crab (*Limulus polyphemus*) Spawning Activity Survey Protocol for the New York State Marine District. Cornell University Cooperative Extension of Suffolk County. New York State Department of Environmental Conservation. http://nyhorseshoecrab.org/NY_Horseshoe_Crab/Documents_files/Total%20Count%20Protocol.pdf

[14] Conway, C.J. 2011. Standardized North American Marsh Bird Monitoring Protocol. Waterbirds 34(3):319-346. http://www.bioone.org/doi/pdf/10.1675/063.034.0307

protocol on nest monitoring see the Salt Marsh Habitat & Avian Research Programs 2015 nest searching and monitoring protocol.[15]

3.2.4 Nekton

Purpose: Determine the presence of fish, characterize fish communities, determine if the restoration is providing breeding and foraging habitat for fish, and monitor the number of species and size of fish over time.

Definition: Nekton are organisms that actively swim in water and do not rely on the current or movement of water to travel. They provide prey for birds and other large fauna in salt marshes and they feed on organic materials and benthic fauna, thus transporting biomass across and out of estuaries.

Metrics:

i. Fish abundance per area or time
ii. Fish species composition and diversity
iii. Fish size

Methods: Collect fish using minnow traps and/or seine nets. Monitor the number of fish by species and measure the length of each fish caught from head to tail over a given unit of area and time. For more details on fish monitoring protocols refer, for example, to Raposa and colleagues' "Monitoring Nekton as a Bioindicator in Shallow Estuarine Habitats" [16] or Roman and colleagues' "Quantifying Vegetation and Nekton Response to Tidal Restoration of a New England Salt Marsh." [17]

[15] Saltmarsh Habitat & Avian Research Program. 2015. Nest Monitoring Standard Operating Procedure. https://www.tidalmarshbirds.net/?page_id=1596
[16] Raposa, K.B., C.T. Roman, Heltshe, J.F. 2003. Monitoring nekton as a bioindicator in shalLestuarine habitats. Environmental Monitoring and Assessment 81: 239-255. https://link.springer.com/chapter/10.1007/978-94-017-0299-7_21
[17] Roman, C.T., K.B. Raposa, S.C. Adamowicz, M.J. James-Pirri, J.G. Catena. 2002. Quantifying Vegetation and Nekton Response to Tidal Restoration of a New England Salt Marsh. Restoration Ecology 10(3):450-460.

Table 1. Examples of parameters, metrics, and levels of effort/expertise by monitoring intensity.

Monitoring Strategy	Parameter (Section)	Metric	Level of Effort	Level of Expertise
Tier 1 – Desktop Analysis				
Evaluate Project Implementation	Vegetation extent (3.1.1)	The area (or footprint) of the restoration project that was planted	Low	Low
	Channel form change (3.3.1)	Tidal channel width and length or area	Low	Low
	Tidal elevation (3.4.1)	Mean High Water (MHW), Mean Higher High Water (MHHW), Mean Tide Level (MTL), Mean Low Water (MLW), and inundation frequency	Low	Low
Tier 2 – Rapid Field Monitoring				
Evaluate Project Implementation	Vegetation survival (3.1.2)	Percent of original plants installed that are alive	Low	Low
	Invasive plants (3.1.3)	Number or percent cover of invasive plants in the monitoring area	Low	Low
	Benthic epifauna (3.2.1)	Abundance of bivalves per area and average lengths	Low	Moderate
		Abundance of crab burrows per area	Low	Moderate
		Abundance of snails by species per area (e.g., *Tritia obsoleta* and *Melampus bidentatus)*	Low	Moderate
		Abundance of other benthic epifauna per area (e.g., amphipods, isopods, insects, etc.)	Low	Moderate
	Other fauna (3.2.2)	Abundance of individual fauna by species per area	Low	Moderate
	Channel stability (3.3.2)	Tidal channel width and depth change over time	Low	Low
	Boat wake (3.4.2)	Boat wake height, frequency, and duration	Low	Low
Tier 3 – Moderate/Intensive Field Monitoring				
Evaluate Project Effectiveness	Change in vegetation structure (3.1.4)	Percent cover of vegetation, by species	Low	Moderate
		Stem density (number of stems per unit area), by species	Low	Moderate
		Stem height, by species	Low	Moderate
		Stem diameter, by species	Low	Moderate
	Plant biomass (3.1.5)	Aboveground biomass, belowground biomass	High	Moderate
	Avifauna (3.2.3)	Abundance & diversity of birds & associated behavior	Moderate to High	
		Number of nests	Moderate to High	
	Nekton (3.2.4)	Abundance of fish per area or time	High	High
		Species composition and diversity	High	High
		Size	High	High
	Benthic fauna (3.2.5)	Benthic fauna abundance, species composition, and diversity per area	High	High
	Tidal channel widening of shoreline change (3.3.3)	Channel edge vegetation retreat or expansion	Moderate	High
	Marsh surface elevation change (3.3.4)	Marsh surface elevation change (millimeters)	High	Moderate/High
		Height of sediment accretion on the marsh surface (millimeters)	High	Moderate
	Local tidal elevation (3.4.3)	MHW, MHHW, MTL, MLW, and inundation frequency	Moderate	Moderate
	Soil properties (3.5.1)	Soil organic content, texture, pH, % carbon, % nitrogen, salinity, cation exchange capacity	Moderate	High
	Contaminant testing in soils or plant and/or animal tissue (3.5.2)	Heavy metal concentrations	High	High
		Volatile organic compounds concentrations	High	High
		Semi-volatile organic compounds concentrations	High	High
		Pesticide concentrations	High	High
		Polychlorinated biphenyls concentrations	High	High

3.2.5 Benthic fauna

Purpose: Determine the presence of benthic fauna in soils (epifauna and infauna), characterize the benthic fauna communities, determine if the restoration is providing habitat for benthic fauna and monitor the abundance and number of species over time. Benthic fauna are a key food source for nekton and avifauna and important bioturbators for salt marsh sediments.

Definition: Benthic fauna include epifauna and infauna or invertebrate (without backbone) organisms that live on or above and in or below the sediment surface of the bottom of a body of water or flooded area that are visible to the eye without a microscope. For the purposes of this monitoring objective, epifauna include mollusks or bivalves (e.g., mussels), crustaceans (e.g., crabs), and gastropods (e.g., snails). Benthic infauna include annelids or segmented worms, such as oligochaetes and polychaetes, turbellaria or flatworms, larval insects, amphipods, and burrowing bivalves, such as clams.

Metrics:

i. Benthic fauna abundance per area
ii. Benthic fauna species composition and diversity per area

Methods: Collect soil cores (e.g., 6.6cm diameter push core to 5cm depth) at low tide and fix the samples with 10% formalin and Rose Bengal. Allow the samples to fix in the solution for at least two days. Process the samples by sieving them with a 500-μm sieve and count and identify benthic fauna to the lowest possible taxonomic level.[18, 19]

3.3 <u>Tidal Channel Geomorphology</u>

<u>Tier 1. Desktop Analysis</u>

3.3.1 Channel form change

Purpose: Determine if the tidal channel was constructed or currently exists as was intended in the design. Over time, determine if the channel is widening or narrowing through erosion or sedimentation.

Definition: Channel form change is how the footprint or area (including area, length and width) of the constructed, un-vegetated tidal channel changes over time.

Metrics:

i. Tidal channel width (distance from the vegetated edge of one side of the channel to the other)
ii. Tidal channel area or length (un-vegetated length of area of channel)

Methods: Use ortho-rectified imagery, ideally taken at low tide or the same tide point over time.

[18] Levin, L.A., D.Talley, G.Thayer. 1996. Succession of macrobenthos in a created salt marsh. Marine Ecology Progress Series 141:67-82.
[19] Deegan, L.A., J.L. Bowen, D. Drake, J.W. Fleeger, C.T. Friedrichs, K.A. Galván, J.E. Hobbie, C. Hopkinson, D.S. Johnson, J.M. Johnson, L.E. LeMay, E. Miller, B.J. Peterson, C.Picard, S. Sheldon, M. Sutherland, J. Vallino, R.S. Warren. 2007. Susceptibility of salt marshes to nutrient enrichment and predator removal. Ecological Applications 17(5):S42-S63.

i. *Tidal channel width*

Measure the width of the channel in ArcGIS by drawing a line from one side edge of the channel where the vegetation transitions to mudflat to the other. Determine how the channel width changes in the same location over time.

ii. *Tidal channel area or length*

Area can also be calculated by tracing the channel side of the vegetated edge on the channel bank to create a polygon in ArcGIS and calculate the area of the polygon. Channel bank is defined by the edge of continuous vegetation. Determine how the area changes over time.

<u>Tier 2. Rapid Field Monitoring</u>

3.3.2 Channel stability

Purpose: During initial channel establishment phase after construction, or over time, determine if the channel is widening or narrowing, and/or deepening or filling in through erosion or sedimentation.

Definition: Channel stability reflects a state of equilibrium, or approximate balance, between erosion and sedimentation, and no significant change in channel width and depth over time.

Metrics: Tidal channel width and depth change over time

Methods:

i. *Channel width*

Establish cross sectional transects, evenly spaced throughout a relatively uniform tidal channel reach (see Figure 3B). At each transect, measure the width of the channel by pulling a meter tape taut across the channel from one bank to the other with each end of the meter tape held at the top of the channel bank at the start of continuous vegetation (see Figure 3A).

ii. *Channel depth*

Measure channel depth, vertically, from the projected top of the marsh plane, or vegetated edge on the creek bank, to the bottom of the creek, at the same cross sections measured for width. Measure the depths at three locations across the cross section: the center of the creek, the midpoint between the center and each side of the creek (see Figure 3A: left quarter depth and right quarter depth). Use a GPS unit to record the location of each measurement point.

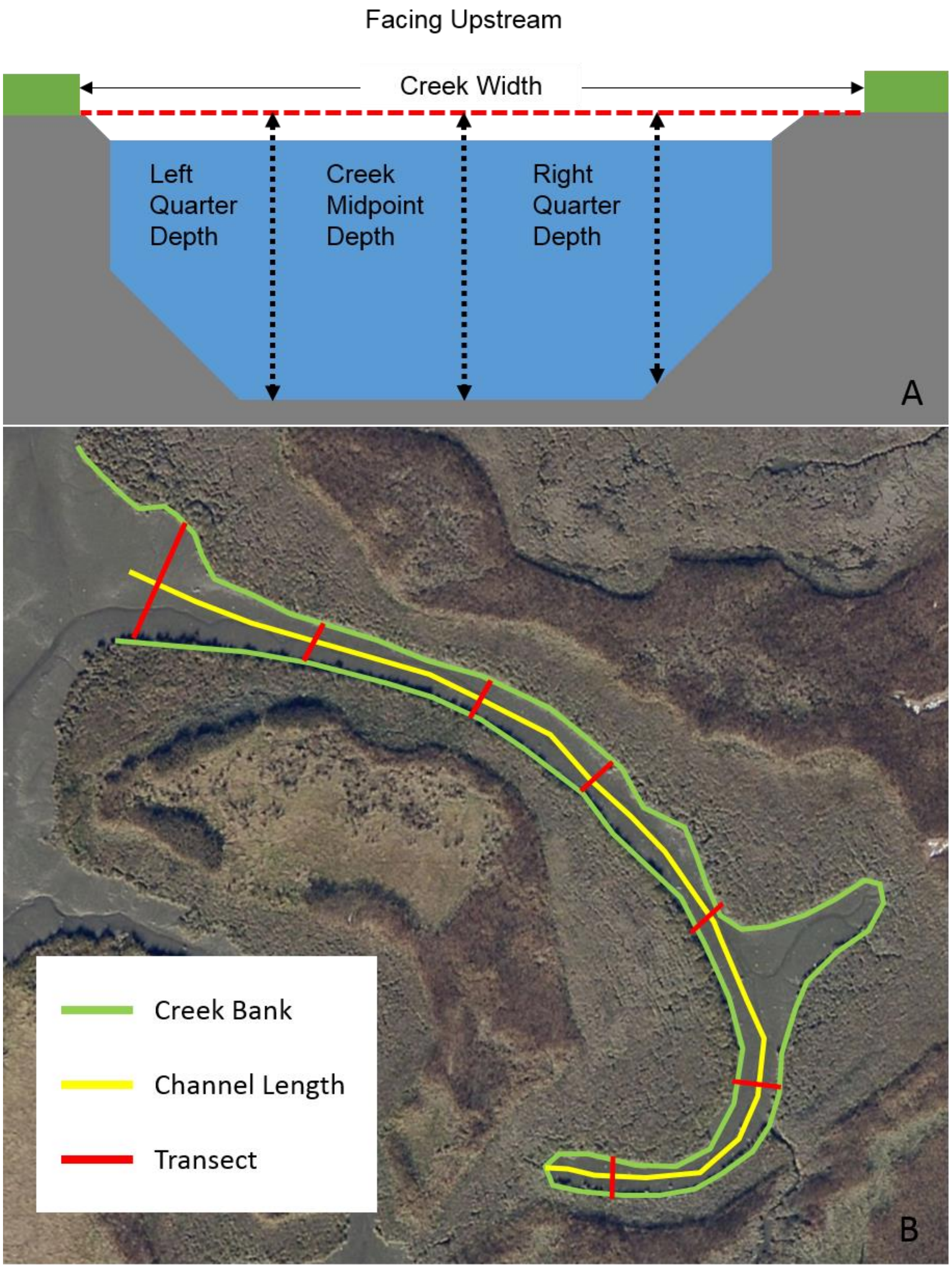

Figure 3. Channel measurements. A) Diagram of channel cross section showing creek width location, left quarter depth, creek midpoint depth, and right quarter depth, B) Diagram of example channel length with seven evenly distributed creek width transects.

Tier 3. Moderate/Intensive Field Monitoring

3.3.3 Tidal channel widening of shoreline change

Purpose: Determine if the tidal channel was constructed or currently exhibits the channel width as intended in the design. Determine if the channel edge or shoreline is retreating (vegetation loss) or expanding (vegetation increasing moving towards the water).

Definition: Change in tidal channel edge, or shoreline position over time.

Metrics: Distance of observed change in position of vegetation from initial channel or shoreline edge. This measurement translates into change in channel width, but is reduced channel vegetation retreat or expansion.

Methods: Install erosion pins transects (e.g., rebar poles) along the edge of the vegetation on the channel or shoreline. Measure percent cover of vegetation and bare ground in plots centered on each pin and the change in distance from the pin and the edge of vegetation over time. See Appendix B for an example erosion pin installation and monitoring protocol.

3.3.4 Marsh surface elevation change

Purpose: Quantify the change in the marsh surface elevation over time and determine if the marsh surface is accreting (increasing in elevation) or subsiding. Determine the ability of the marsh to maintain an elevation that supports salt marsh vegetation as sea levels rise. The increase in elevation of the marsh surface through sedimentation or accrual of organic matter on the marsh surface compared with marsh surface elevation can be used to calculate subsidence (e.g., if marsh surface elevation is decreasing despite sedimentation or accretion then the marsh is subsiding).

Definitions:

- Surface elevation tables (SET) are instruments that allow the measurement of the change in the elevation of the marsh surface relative to accretion (increase in marsh elevation by sedimentation and organic build up on the marsh surface) and subsidence (decrease in marsh elevation caused by processes deep in the peat such organic matter decomposition).
- Real time kinematic (RTK) positioning is a high precision navigation technique where a GPS unit with a global navigation satellite system is able to determine the horizontal (latitude/longitude) and vertical (elevation) position of assessment points with sub-centimeter accuracy.[20]

Metrics:

i. Marsh surface elevation change (millimeters)
ii. Height of sediment accretion on marsh surface (millimeters)

[20] Kreeger, D., J. Moody, M. Katkowski, M. Boatright and D. Rosencrance. 2015. Marsh Futures: use of scientific survey tools to assess local salt marsh vulnerability and chart best management practices and interventions. Partnership for the Delaware Estuary, Wilmington, DE. PDE Report No. 15-03

Methods:

i. *Marsh surface elevation change with SET*

   Install at least 3 SET units, consisting of a rod with a receiver for the instrument in the center of a plot, at the restoration site. Record the marsh surface elevation. See Appendix C for an example SET installation and measurement protocol.

ii. *Marsh surface elevation change with RTK*

   Measure marsh surface elevation using an RTK. See Appendix D for an example RTK elevation monitoring protocol or see the report by the Kreeger et al. (2015).[21]

iii. *Height of sediment accretion on marsh surface*

   Install marker horizons using feldspar powder at the restoration site. Record marsh accretion. See Appendix C for an example marker horizon installation and measurement protocol.

3.4 Hydrology

Tier 1 – Desktop Analysis

3.4.1 Tidal elevation

Purpose: Determine tidal datum using NOAA tide stations in close proximity to the site. Determine the elevation of average tides and assess the depth, duration and frequency of inundation to evaluate whether target hydrologic conditions were established for plant communities such as low mash and high marsh.

Definition: Datum is a reference base elevation used to determine heights or depths. Tidal datum are datum defined by phases of the tide (e.g., mean high tide, mean low tide). [22]

Metrics:

i. Mean Higher High Water (MHHW): the average of the higher high tide of the two that occur each tide day observed over the National Tidal Datum Epoch (specified 19 year period[23]).
ii. Mean High Water (MHW): average of all high tide levels observed over the National Tidal Datum Epoch.
iii. Mean Low Tide (MLT): the average of all low tide levels observed over the National Tidal Datum Epoch.
iv. Mean Tide Level (MTL): the average of MHW and MLW.
v. Inundation frequency: Number of times a high tide is higher than a specified elevation.

Methods: Identify the closest NOAA tide station to the restoration site and calculate MHHW, MHW, MLW, and MTL using the data available from the station. Methods can be found in the NOAA Computational Techniques for Tidal Datums Handbook (2003).[24] The data

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[21] Kreeger et al. 2015.

[22] National Oceanic and Atmospheric Administration. 2001. Tidal Datums and Their Applications. NOAA Spcieal Publication NOS CO-OPS 1. US Department of Commerce. https://tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf

[23] National Oceanic and Atmospheric Administration. 2003. Computational Techniques for Tidal Datums Handbook. NOAA Special Publication NOS CO-OPS 2. U.S. Department of Commerce. https://tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf

[24] National Oceanic and Atmospheric Administration, 2003.

can also be used to create an inundation frequency curve defined as the percentage of high tides that are higher than target elevation points (e.g., planting locations) over a period of one year or more.[25] The inundation frequency data can be calculated using the NOAA Inundation Analysis Tool (https://tidesandcurrents.noaa.gov/inundation/).

Tier 2 – Rapid Field Monitoring

3.4.2 Boat Wake

Purpose: Observe and characterize the height, frequency, and duration of waves created by boats at the site.

Definition: Boat wake is a wave created by the displacement of water by a boat propeller and boat frame as it moves through water.

Metrics: Boat wake height, frequency and duration: the average height of boat wakes observed at a site over a given period.

Methods: Install a staff gauge (instrument used to visually assess water height) or a water level data logger. Photograph and film the boat wakes while using the staff gauge to determine wave height, frequency of waves, and duration of wave events over the course of one tidal cycle (e.g., low to high tide).[26] See Appendix E for an example boat wake monitoring protocol.

Tier 3 – Moderate/Intensive Field Monitoring

3.4.3 Local tidal elevation

Purpose: Determine tidal datum using data from a localized water level data logger and NOAA tide stations in close proximity to the site. Determine the elevation of average tides and assess the depth, duration and frequency of inundation to evaluate whether target hydrologic conditions were established for plant communities such as low marsh and high marsh.

Definition: Datum is a reference base elevation used to determine heights or depths. Tidal datum are datum defined by phases of the tide (e.g., mean high tide, mean low tide). [27]

Metrics: MHHW; MHW; MLT; MTL; Inundation frequency (see 3.4.1 Tidal Elevation)

Methods: Install an automated water level data-logging device at the restoration site and record water level data. Identify the closest NOAA tide station to the restoration site and calculate MHHW, MHW, MLW, MTL, and inundation frequency using the data available from the station. Use the local data logger water level information to correct the tidal datum calculated from the NOAA station. An example tide level monitoring protocol can be found in Appendix F and the NOAA Computational Techniques for Tidal Datums Handbook (2003).[28]

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[25] Pétillon, J., R. Erfanzadech, A. Garbutt, J.P. Maelfait, M. Hoffman. 2010. Inundation Frequency Determines the Post-Pioneer Successional Pathway in a Newly Created Salt Marsh. Wetlands 30:1097-1105.
[26] LaPann-Johannessen, C., J.K. Miller, A. Rella, E. Rodriquez. 2015. Hudson River Wake Study. The Hudson River Sustainable Shoreline Project. NYSDEC HRNERR. https://www.hrnerr.org/wp-content/uploads/sites/9/2012/07/Hudson-River-Wake-Report.pdf
[27] National Oceanic and Atmospheric Administration, 2001.
[28] National Oceanic and Atmospheric Administration, 2003.

3.5 <u>Soils</u>

<u>Tier 3. Moderate/Intensive Field Monitoring</u>

3.5.1 Soil properties

Purpose: Characterize and determine if soil properties are changing over time. Determine if the restoration results in healthy salt marsh soils that are performing various soil functions (e.g., peat development, nutrient sequestration and retention, structural stability).

Definition: Soil properties that are commonly monitored include:

i. Soil organic content: a measure of the amount of organic material in the soil and an indicator of salt marsh peat or organic soil development.

ii. Texture: the relative abundance of sand (0.0625 to 2mm), silt (0.002 to 0.0625mm), and clay (<0.002mm) particles. It is an indicator of soil particle size and pore space size.

iii. pH: a measure of hydrogen ion concentration on a scale of 0 to 14. Lower pH (<7) indicates more acidic soils, and higher pH (>7) indicates more alkaline soils. Organic wetland soils generally have a low pH (acidic) and mineral wetland soils are more neutral or alkaline.

iv. % carbon: the percentage of carbon in the soil and an indicator of the marsh's ability to sequester carbon.

v. % nitrogen: the percentage of nitrogen in the soil and an indicator of the marsh's ability to sequester nutrients.

vi. Salinity: the concentration of salt in soils, which generally corresponds with the salinity of nearby salt water bodies. However, it may be higher in areas where water evaporates from the soil such as shallow pools or pannes. This metric can be indicative of the salt marsh extent or boundary and potential risk of invasion by the invasive plant *Phragmites australis,* which is less salt-tolerant than the native salt marsh plant species.

vii. Cation exchange capacity: a measure of the soil's capacity to retain exchangeable cations and is representative of the soil's ability to retain nutrients.

Metrics:

i. Soil organic content
ii. Texture (percent of silt, sand, and clay)
iii. pH (measure of acidity in the soil on a scale of 0 to 14)
iv. % carbon
v. % nitrogen
vi. Salinity (amount of salt)
vii. Cation exchange capacity

Methods: Collect a soil sample of at least 200g of soil (not including gravel/rocks) from each sampling unit (see Step 4) to account for soil heterogeneity within the plot. Samples are typically collected from the top 10cm where the majority of plant roots are located and collected during the growing season. Air dry the samples for a minimum of 48 hours (to prevent mold), and send the sample to a soils testing lab to be analyzed for soil organic content, texture (% sand, silt, clay), pH, % carbon, % nitrogen, salinity, and cation exchange capacity.

3.5.2 Contaminant testing in soils or plant and/or animal tissue

Purpose: Determine if contaminants have returned to the restoration site and if they are present in the tissue of plants and wildlife. Determine if the restoration successfully removed contaminants from the site.

Definition: Contaminants are a poisonous or polluting substance that can cause biological and environmental harm to plants and animals. Contaminants include, but are not limited to: heavy metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs).

Metrics:

i. Heavy metals concentrations: lead (Pb), chromium (Cr), arsenic (Ar), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni).
ii. VOC concentrations: formaldehyde, toluene, acetone, ethanol, and 2-propanol.
iii. SVOC concentrations: pesticides, phthalates, and PCBs.
iv. Pesticide concentrations: DDT and chlordane.
v. PCB concentrations: chemicals used in electrical, heat transfer or hydraulic equipment as well as plasticizers in paints or rubber products.

Methods: Collection methods for soils, plants, or other tissue will vary and should be conducted by professional staff from a qualified testing laboratory to test for contaminants including heavy metals, VOCs, SVOCs, pesticides, and PCBs.[29] An example project in NYC that includes soil and tissue sampling for contaminant testing is the Saw Mill Creek Pilot Wetland Mitigation Bank Staten Island, New York Mitigation Banking Instrument (2015).[30]

Example data sheets for vegetation structure (3.1.4), benthic epifauna (3.2.1), plant biomass (3.1.5), channel stability (3.3.2), channel edge erosion pins (3.3.3), marsh surface elevation change with SET (3.3.4), and boat wake (3.4.2) are in Appendix G.

4.0 CREATE A SAMPLING PLAN

This step summarizes the components of an ideal sampling plan. A well-designed sampling plan results in monitoring data that can be analyzed statistically to test various assumptions or hypotheses about restoration techniques, used to compare multiple sites and projects, and used to help make decisions about ongoing management (e.g., to identify emerging problems) and improve outcomes of future restorations.

[29] U.S. Fish and Wildlife Service, New Jersey Field Office. 2015. White paper: recontamination of mitigation sites in the Meadowlands https://www.fws.gov/northeast/njfieldoffice/pdf/MitigationMeadowlands2015.pdf
[30] New York City Economic Development Corporation: https://www.nycedc.com/project/marshes-initiative

4.1 Use the Before-After, Control-Impact (BACI) Design

The Before-After, Control-Impact study design, first introduced by Green (1979), combines pre- and post-restoration monitoring with the use of a control site (e.g., a reference site). A reference site is a target for restoration design, is naturally occurring, and will not be impacted by restoration. The reference site serves as a physical and ecological benchmark that can be used to compare with the results of the restored site. This comparison will help determine if the restoration site is moving towards similar conditions as the reference site. Pre-monitoring is essential for determining whether any observed changes in salt marsh conditions are the result of restoration or if these changes would have occurred without any intervention. The same sampling methods must be applied fully to a reference site for the entire duration of the restoration monitoring period (pre- and post-restoration).

4.1.1 Identify Reference Site(s)

Because a reference site serves as a model for a restoration site, it tends to have greater biodiversity and higher ecological functionality (e.g., higher soil organic content, greater plant biomass) than the restored site.[31] The reference site must be located adjacent to or near the restored site, and must be situated in a comparable hydrological context (e.g., interior sites may not be appropriate references sites for a restoration adjacent to a bay or estuary), have similar morphology and vegetation communities as the restored site (e.g., compare naturally occurring high marsh to restored high marsh, compare naturally occurring low marsh to restored low marsh, etc.). Reference sites are not always readily available for constructed wetlands in urban areas, but the closest approximate site should be used. If the restoration is taking place in an urban setting where all marsh sites are similarly degraded, then perhaps a degraded site located adjacent to or near the restored site could be used as a control to observe the outcome if no restoration or management action were to occur.

4.1.2 Alternatives to BACI design

In addition, in some situations, it may be impractical or impossible to do pre-monitoring. Depending on the monitoring objectives, other monitoring design approaches may also be considered. For example, an After-Control-Impact study design may be implemented if the site was not accessible or resources were unavailable before restoration to conduct pre-monitoring.

4.2 Specify the Frequency, Duration, and Timing of Sampling

Timing of monitoring for individual plant or animal species may differ depending on the species, the site, and the project goals. For example, fish may require monthly monitoring during spawning season and obligate nesting birds may require monthly monitoring during breeding season; however, soil properties can be tested year round. Regulatory and/or grant requirements and research questions for each individual project will specify the monitoring durations. We recommend that monitoring begin one growing season before restoration begins and for a minimum of 5 years after restoration is completed. Post-restoration monitoring should begin after the site is planted, or considered complete, if planting is not a part of the restoration approach. The following sections describe the frequency and timing of sampling across monitoring parameters.

[31] Society for Ecological Restoration Science & Policy Working Group. 2002. The SER Primer on Ecological Restoration. www.ser.org

4.2.1 Vegetation

For all vegetation parameters (vegetation extent; vegetation survival; invasive plants; change in vegetation structure; plant biomass; and tidal channel vegetation), monitoring should occur annually during the peak biomass season (late August – September). Vegetation survival measurements should be limited to two years post-restoration, because as plants establish and begin reproducing both by seed and vegetative growth, it becomes difficult to discern individual plants and determine survival of what was planted. Due to the destructive nature of plant biomass sampling, conduct biomass sampling during the first or second year of monitoring, to get a baseline measurement, and again in the fifth or final year of monitoring to determine change over time and to minimize the impact of sampling.

4.2.2 Fauna

Benthic epifauna, other fauna, and benthic fauna monitoring should occur annually at low tide during peak vegetation growing season (late August – September). Avifauna and nekton monitoring should occur at a minimum once per month from June to September. Breeding birds should ideally be observed consistently 30 minutes before or after sunrise[32], and wading birds should be observed for a 3 to 4 hour time period ideally around mid-tide (rising or falling tide). Fish should be monitored or sampled during the course of one entire tide, high to low or low to high.

4.2.3 Tidal Channel Geomorphology

For all tidal channel geomorphology parameters (short-term post-construction channel change and stability, shoreline change, and marsh surface elevation change), monitoring should occur at least once annually, ideally during the peak growing season (late August – September). Ideally, monitoring should also occur after large storm events, if resources allow.

4.2.4 Hydrology

For all hydrology parameters (tidal elevation, depth, duration, frequency and boat wake), monitoring should occur at least once before and after restoration. Local tidal elevation monitoring using data loggers should use a sampling frequency of 6 minutes for a minimum duration of 3 months, ideally during the peak growing season (July – September). Boat wake monitoring should be frequent enough to characterize the typical disturbance, for example at least three separate sampling events in the same month or season, ideally in the summer, using a sampling frequency of 1 second for the duration of at least one tidal cycle per monitoring event.

4.2.5 Soils

Soil properties should be monitored at least once before and at least twice after restoration is complete, ideally 5 to 10 years after construction, as some soil characteristics (e.g., organic content) can take time to develop in salt marshes with new or young soils. The frequency, duration and timing of contaminant testing depends on the project site and objectives. If the objective is to determine if soils are becoming cleaner over time after planting of salt marsh, for example, sampling could occur annually during peak growing season (late August – September).

[32] Conway, C.J. 2011. Standardized North American Marsh Bird Monitoring Protocol. Waterbirds 34(3):319-346 https://doi.org/10.1675/063.034.0307

4.3 Specify the Sampling Unit and Sample Size

4.3.1 General guidelines

Different monitoring methods and study designs have different sampling units. Monitoring methods requiring plots, such as vegetation and benthic invertebrate monitoring, typically employ $1m^2$ plots and $0.25m^2$ subplots (Figure 4).[33, 34] This sampling unit is consistent with the 2000 Guidelines and past assessments conducted by NYC Parks in naturally-occurring marshes.[35] Generally, at least 20 plots should be used in salt marsh monitoring, ideally more, so the data are statistically robust.[36] To determine an appropriate sample size, use sample size calculators[37] to calculate the number of samples necessary to meet a specified confidence interval using pre-existing monitoring data that were collected using the same methods or by using the site size. Using a sample size calculator will also allow for robust statistical analysis when comparing data between restored and references sites and over time.

Plot Configuration

For monitoring parameters in Tiers 2-3 that use plot sampling, there are two types of field sampling designs with random plot configurations that we typically use: fixed transects or grids (Figure 5). These plot configurations can be applied in the rapid, moderate, or intensive tiered field assessments, provided that plots or transects are placed randomly.[38]

Fixed Transects

The transect design consists of fixed permanent transects (usually >5), with fixed permanent $1m^2$ plots (usually >4 per transect for a total of > 20 plots per site) randomly distributed across the site, perpendicular to the shoreline along the shoreline-to-upland gradient. Transect and plot spacing is determined using a random number generator. Once transects and plots are established during the first monitoring event, they become permanent sampling points, so the same transects and plots will be sampled during each subsequent sampling event (Figure 5A).

Advantages:

- Plots can be found relative to physical markers established along a fixed transect and do not require a GPS unit.
- Allows for sampling across a habitat gradient and/or narrow sites with a clear shoreline to upland gradient.

[33] James-Pirri, M. and C.T. Roman. 2004. Monitoring salt marsh vegetation (Revision #1). A protocol for the National Park Service's long-term monitoring program, northeast coast and barrier network. https://www.nps.gov/caco/learn/nature/upload/protocol_saltmarshveg-2.pdf
[34] Roman, C.T., M.J. James-Pirri, & J. F. Heltshe. 2001. Monitoring Salt Marsh Vegetation: A Protocol for the Long-term Coastal Ecosystem Monitoring Program at Cape Cod National Seashore. Coordinated by the USGS Patuxent Wildlife Research Center, Coastal Research Field Station at the University of Rhode Island, Narragansett, RI 02882.
[35] New York City Department of Parks & Recreation (NYC Parks). 2017. Towards a Salt Marsh Management Plan. http://naturalareasnyc.org/content/3-in-print/3-partner-publications/nycparks_saltmarshstrategyreport_2017.pdf
[36] James-Pirri, MJ, Roman, C.T., Heltshe, J.F. (2007) Power analysis to determine sample size for monitoring vegetation change in salt marsh habitats. Wetlands Ecology and Management 15:335-345
[37] For example, see The Nature Conservancy's web-based sample size calculator: https://www.conservationgateway.org/ExternalLinks/Pages/creative-research-systems.aspx
[38] Kopecký, M., Macek, M. (2015) Vegetation resurvey is robust to plot location uncertainty. Diversity & Distributions 21(3):322-330

Disadvantages:

- Plots may not be evenly distributed across the site due to the transect locations.
- It can be difficult to set up transects that follow a continuous linear gradient across habitats (e.g., high marsh, low marsh, scrub shrub), depending on the shape of the site.

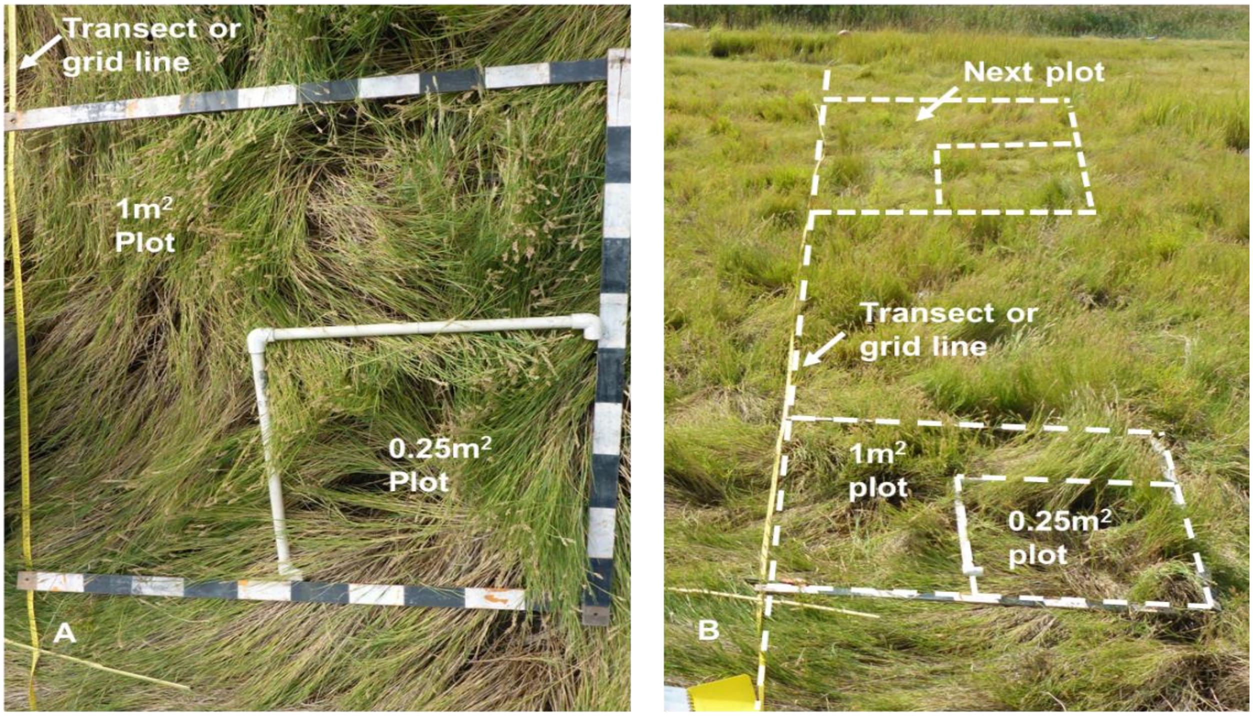

Figure 4. Sampling plots: A) An overview of 1m^2 plot and 0.25m^2 subplot, B) two plots along a transect or grid line. Transects or grids run perpendicular to the shoreline or channel edge so they are on a gradient from the water's edge to the upland. The subplot is assigned to bottom right corner in this diagram, but can be assigned to any quadrant so long as that same subplot quadrant is used across all plots at the site.

Grid Design

Within a grid design, systematically spaced plots (usually >20) are established along a grid with a random starting point. Plot spacing is dependent on the size of the site (e.g., spacing calculated by dividing the area of the site by the number of plots and taking the square root of that value). Because marshes are not uniform in width, grid lines will vary in length. For example, if the last plot on a grid line is 3 meters from the marsh edge (i.e., upland or water), and plots are 10 meters apart, the next plot will be 7 meters from the marsh edge (Figure 5B).

Advantages:

- Plots are evenly distributed across the sampling area while also capturing the shoreline to upland gradient.
- Plots can be relocated using a GPS unit and do not require setting up physical transects in the field.
- Allows for sampling in nonlinear or interior sites that lack a clear shoreline to upland gradient.

Disadvantages:

- This method ideally requires a GPS unit to relocate the plots during each sampling event because physical markers in the field may be lost between sampling seasons or difficult to locate in overgrown plants.
- It requires knowing the area of the site and calculating the plot distances prior to sampling.

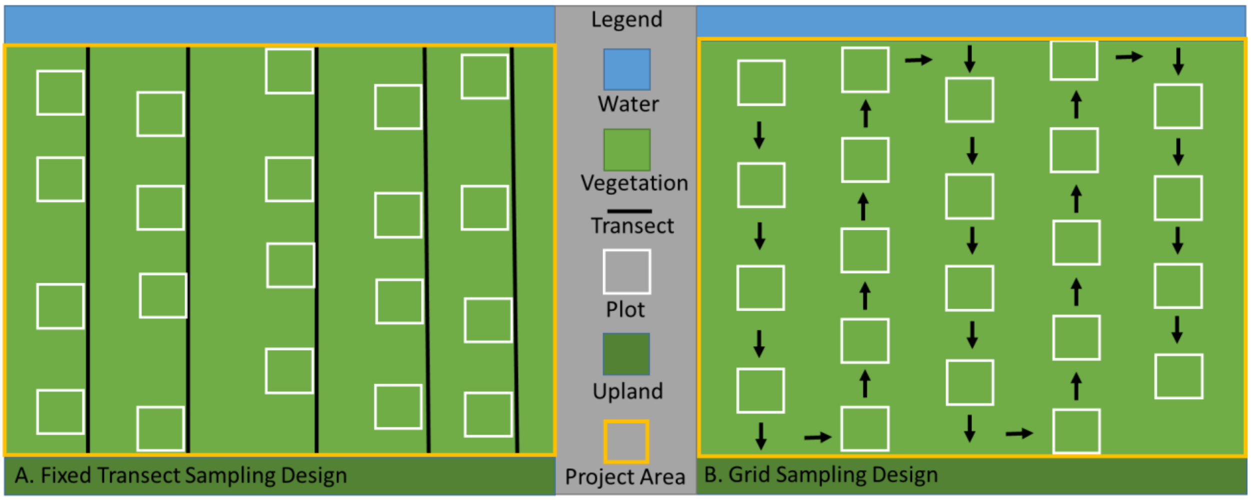

Figure 5. Plot configurations. A) Diagram of fixed transect sampling design. The legend shows the water (channel or shoreline) in blue, the vegetation (e.g., *Spartina alterniflora* or *Spartina patens*) in green, the minimum of five transect (black line), the minimum of four 1m^2 plots (white boxes), and the upland area (dark green). The total salt marsh project area where transects and plots should be placed is highlighted by an orange box. B) Diagram of a grid sampling design[39]. The legend shows the water (channel or shoreline) in blue, the vegetation (e.g., *Spartina alterniflora* or *Spartina patens*) in green, the minimum of 20 1m^2 plots (white boxes), and the upland area (dark green). Arrows indicate the sampling path along the grid, starting at a random point and following evenly spaced plots along a grid. The salt marsh project area within which plots should be placed is high-lighted by an orange box. (Not to scale.)

Stratifying samples

For Tier 2-3 parameters, monitoring should ideally be stratified by sub-habitat (e.g., high marsh, low marsh, scrub shrub). Stratification of monitoring can be applied to both a transect or grid design, or any other sampling design so long as the same number of samples are taken across each feature being compared. Stratifying across features allows for comparisons within a site, such as comparing the differences in vegetation percent cover over time across two different planting strategies (e.g., one foot on center versus cluster planting). Depending on available resources and monitoring goals, monitoring may also be stratified based on geography (e.g., watershed, region), site history, salt marsh restoration techniques (e.g., substrate type, planting strategies), and other variables of interest.

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[39] Natural Areas Conservancy Salt Marsh Assessment (NACSMA) (2013) in Partnership with City of New York, Division of Forestry Horticulture, and Natural Resources

The following sections describe suggested sampling units and sample sizes across monitoring parameters.

4.3.2 Guidelines for specific parameters

Vegetation

Vegetation monitoring should use a minimum of twenty (20) 1m^2 and 0.25m^2 subplots (Figure 4). Percent cover estimates should be made at 1m^2 plots, and stem density, height, diameter, and plant biomass can be sampled from 0.25m^2 plots. Ensure that the 0.25m^2 is in the same location within each plot (e.g., as in Figure 4, always the southeast or bottom right quadrant). Vegetation extent, vegetation survival, and invasive plants should be monitored on a site-wide scale. Survival and invasive plants can also be estimated through plots. Plots can also be stratified across vegetation communities (e.g., low marsh, high marsh, or scrub shrub), ideally applying 20 plots in each separate community.

Fauna

Benthic fauna monitoring should use a minimum of 20 1m^2 plots (Figure 4), which may be the same as those used for vegetation sampling. Other fauna, avifauna, and nekton should be monitored on a site-wide scale. For birds, sampling can occur at the plot level, but plots need to be spaced apart so that observations do not overlap. Ideally, nekton monitoring should be stratified by sub-habitat in the marsh (channel, low marsh, high marsh) and sample size should be based on objectives and variability in the fish population of the site.[40]

Tidal Channel Geomorphology

Physical channel monitoring to assess changes over time typically involve the installation of permanent pins or benchmarks re-surveyed over time.[41, 42] To assess average change in tidal channels over time across a site select, ideally, at least 3 sampling transects per homogenous channel reach. Sampling frequency depends on the objectives of the monitoring. To rapidly assess average changes in channel depth, one can use representative depths, e.g., three intervals: at ¼, ½, and ¾ of the channel width (Figure 3B). If the midpoint does not fall on the thalweg (lowest elevation of the channel), record an additional channel depth at the thalweg and record its location along the cross-section. Alternatively, if the intention is to quantify changes at one reach, one example approach is to install permanent cross-sections and re-survey the channel at precisely the same increment, e.g., every 1ft or every 10cm.

Hydrology

See section 4.2.1 for hydrology sampling frequency.

Soils

The number and distribution of soil sampling will depend on the project and monitoring objectives. For example, if the objective is to increase soil salinity to eradicate *Phragmites australis* in a formerly connected wetland by restoring the tidal flow, one would collect a

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[40] Raposa, K.B., C.T. Roman, Heltshe, J.F. 2003. Monitoring nekton as a bioindicator in shallow estuarine habitats. Environmental Monitoring and Assessment 81: 239-255. https://link.springer.com/chapter/10.1007/978-94-017-0299-7_21
[41] Gabet, E.J. 1998. Lateral Migration and Bank Erosion in a Saltmarsh Tidal Channel in San Francisco Bay, California. Estuaries 21(4B):745-753.
[42] Schenk, E.R., and C.R. Hupp. 2009. Legacy Effects of Colonial Millponds on Floodplain Sedimentation, Bank Erosion, and Channel Morphology, Mid-Atlantic, USA. Journal of the American Water Resources Association 45(3):597-606.

minimum of 5 randomly distributed soil samples, collected at the same tidal cycles, to test for soil salinity.

4.4 Establish Fixed Photo Locations

Establish fixed photo locations to provide overview photos of each sub-habitat (digital photos). Each plot and transect or grid line should also be photographed from above the plot, or the end of the transect/grid line (e.g., shoreline or water's edge) looking towards the transect/grid line (e.g., marsh). A white board or sheet of paper indicating the date, site, transect number, plot number, fixed photo station number, and photo direction should be included in or before each plot, transect, and fixed station photo. The purpose of these photos is to keep a clear visual record of the site as it changes over time. These photos are also useful for describing the project and project success in reports and presentations for a variety of audiences. The digital photo files should be organized by date and site location. Photo labeling and management are essential components of quality control and ensuring the accuracy and accessibility of the photographic record of the site. Fixed photo stations should be used across all monitoring tiers and established prior to restoration.

4.5 Prepare a Quality Assurance Project Plan

The monitoring plan should be developed by the project manager and reviewed by a senior technical expert in the relevant field. The protocol should be finalized prior to the implementation of the restoration project. The development of a monitoring plan and/or a quality assurance plan is often required as part of the permitting process or by the grantor; the U.S. Environmental Protection Agency (EPA), for example, requires a Quality Assurance Project Plan (QAPP) for all monitoring. The plan identifies a project manager, project ecologist, and quality assurance officer, and includes an overview of the restoration project, monitoring objectives, sampling design, sampling methods, quality assurance protocols (e.g., checking data for errors, chains of custody, etc.), and relevant references. Depending on the project objectives, the project may require a technical review committee. See Appendix H for an example of an EPA QAPP.

5.0 CREATE A DATA ANALYSIS, MANAGEMENT, & INFORMATION SHARING PLAN

Having a plan for managing data and sharing information is a key component of adaptive management because it ensures that the lessons learned from a monitoring project are easily accessible to those involved in decision making around salt marsh restoration. The reported monitoring data can inform future salt marsh restoration design and management.

5.1 Determine Method of Documenting, Storing, and Managing Data and Analyses

Field crews can collect data on paper or digitally using portable tablets or data loggers in the field. If using paper data sheets, use of waterproof paper sheets is advised to ensure data are not lost due to rain or other issues with water that may occur in the field. Field collected data should be checked for completeness prior to leaving the field site. The field collected data should be scanned or downloaded and stored digitally once monitoring is complete. Upon return from the field, data should be entered into a computer spreadsheet or database, and checked against the field collected data record by an independent observer for quality assurance. Quality assurance should reflect protocols outlined in the project QAPP, if one exists for the project.

All digital data (entered data, spatial data, photos, analysis, etc.) should be stored with metadata that describes the data and their source. Sampling metadata should define all column headers in data spreadsheets and spatial metadata should describe the spatial data type (point, line, polygon), what the data represent (sampling area, plots, transects, etc.), the source of the data (field location, collectors, and collection date), and any additional attributes.

Ideally, a plan for what type(s) of data analysis will be conducted should be developed before any data are collected. Data analysis can range from descriptive statistics and graphs that summarize metrics to inferential statistical analyses that test hypotheses regarding different restoration methods or site characteristics. For inferential statistics, picking an appropriate statistical model that is suitable for the data being collected ensures that the results are interpreted properly. For example, some statistical models assume that data are normally distributed. If a dataset does not meet that assumption, this can lead to erroneous results and interpretation. Finally, all analysis should be tracked and documented fully (include all formulas, computational language, and test results for statistical analyses). A case study reviewing a NYC Parks project is described below with descriptions of data analysis. There are also examples from the scientific literature that describe analysis of salt marsh restoration project data including change in area (desktop),[43] vegetation and nekton data (intensive field sampling),[44] and a meta-analysis of data across multiple projects.[45]

The interpretation of monitoring data and analysis is a critical component of adaptive management. This document focuses on the design and implementation of a monitoring plan, and therefore does not provide a rigorous overview of how to analyze, synthesize, and evaluate data to change restoration and management practices within or across sites. However, with careful planning and clear and targeted metrics in mind, even simple data summaries and basic analysis can reveal important information that can be used to improve future practices. For example, data interpretation and analysis using descriptive statistics and graphs could be used to determine whether a restoration was successful if there are clear and specific definitions of what constitutes a "success" (e.g., greater than 85% native plant survival on average across all restoration plots). Inferential statistics can also be used to determine success. For example, if there are no statistical differences between a pre-defined set of metrics in restored vs. reference plots, then the restoration could be considered a success. Inferential statistics can also be used to answer more targeted questions about specific restoration strategies or techniques. For example, all things being equal, if a pre-determined indicator of success is significantly different in restoration sites that used different restoration techniques, then one of those restoration techniques is likely to be better than the others. In the case study of Sunset Cove below, an example project with clear definitions of success and targeted questions about restoration strategies is described.

5.2 <u>Determine Information Products and Information Sharing/Distribution Process</u>

Monitoring reports should include a description of the purpose of the monitoring, and if it is a mitigation site, a description of the site history and reason for mitigation. Reports should also

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[43] Campbell, A., Y. Wang, M. Christiano, and S. Stevens. 2017. Salt Marsh Monitoring in Jamaica Bay, New York from 2003 to 2013: A Decade of Change from Restoration to Hurricane Sandy. Remote Sensing, 9(2): 20pgs. http://www.mdpi.com/2072-4292/9/2/131

[44] Roman et al. 2002.

[45] Konisky, R.A., D.M. Burdick, M. Dionne, and H.A. Neckles. 2006. A Regional Assessment of Salt Marsh Restoration and Monitoring in the Gulf of Maine. Restoration Ecology 14(4): 32pgs.

include documentation of methods, resulting data, figures, data summary, and photographs. An example monitoring report template can be found in Appendix I.

Monitoring reports should be written and submitted to the appropriate regulatory agency, grantor, or land owner, according to the specified reporting requirements, usually on an annual basis beginning with the first year of monitoring post-restoration. Reports should be stored in a database and be made publically available online, when possible.

The monitoring report information can also be distributed beyond those involved in the project by sharing findings through presentations at conferences or webinars, or through publication in the scientific literature or as a white paper or publically accessible document posted a website, database, or distributed through professional networks.

6.0 CREATE AN INSPECTION AND MAINTENANCE PLAN

Maintenance plans contribute to adaptive management within a single site by using inspections to identify issues and then modify management methods to address those needs. Maintaining a site and logging issues and management changes over time also contributes to adaptive management at a larger scale as the lessons learned from maintenance can then be applied to future projects. Plans should be reviewed by and shared with partners and/or responsible parties to coordinate inspections and maintenance.

To address management concerns over the short- or long-term (approximately five years to ten years or more), every restoration project should have a maintenance plan that is verified or updated annually (at a minimum) using information derived from site inspections. The plan should clearly define maintenance issues at the site that need to be addressed by the land manager following construction. Short-term maintenance issues include replacing plants or seed, maintaining herbivore fencing, maintaining erosion control features (fabric, fencing, coir log, etc.). Long-term maintenance issues include removing or mowing invasive species, removing accumulated organic wrack and algae, and removing marine debris at the site. The plan should also define:

1) the management area extent,
2) specific management actions,
3) responsible parties, and
4) a timeline for inspections and maintenance needs.

Future problems and ways of solving them should be anticipated and described in the plan as well. Quarterly or annual site inspections should flag issues at the site and result in an updated maintenance plan with specific actions to address new issues. An example inspection form can be found in Appendix G.

7.0 CASE STUDY: SUNSET COVE SALT MARSH RESTORATION

Background

Sunset Cove Park is a 12-acre parcel located on a derelict marina in Broad Channel, Queens, NY, the only populated community within the Jamaica Bay marsh islands (Figure 6); the site is surrounded by the Jamaica Bay National Wildlife Refuge. Formerly known as Schmitt's Marina, NYC Parks acquired the site in 2009, at the urging of the community, following prosecution of the owner for environmental and other violations. Construction fill, debris, and invasive vegetation with limited coastal protection and ecological function dominate the site. The restoration project began construction in July 2018. Project objectives include increased resiliency through the construction of a berm, restored native habitat (including over 3 acres of salt marsh and an additional 8 acres of restored coastal upland habitat), rehabilitated shoreline, and increased stewardship through community planting events.

Restoration Design

Restoration work will involve the removal of invasive species and debris, and the removal of historic fill, placement of clean sand (where over-excavation is required to remove contaminants), and grading to achieve the required tidal elevations to support salt marsh vegetation. The creation of a tidal channel will also allow tidal flow into the marsh. Along the shoreline, paved sections and large concrete rubble will be replaced with natural stone whereas natural, sandy slopes along the shoreline will be left intact. Following clearing and grading, native plant species will be installed based on the appropriate level of salt water inundation that they receive.

This project also includes an experimental design focusing on two parameters: planting substrate (soil) type and plant spacing. The restored low marsh and part of the high marsh will be excavated and replaced with clean sand to tidal elevations (Figure 7). The surrounding degraded high marsh will be grubbed leaving the existing substrate in place. Thus, two types of planting substrate exist at the site, placed clean sand and the existing substrate. Both placed clean sand and existing soils have been successfully used in past restorations, and with this design we want to determine if one is better than the other or if they are equally as effective, and why.

Two different types of plant spacing techniques will be used in the project including individual plants evenly spaced a set distance, in this case 18 inches apart, and clustering, or planting multiple plugs in close proximity, and spacing clusters 2 to 4 feet apart. Both individual evenly spaced planting and cluster planting have been successful in other restoration projects, and with this design we want to determine if one is better than the other or if they are equally as effective, and why.

As a result, each plant spacing type will be implemented in one portion of both the placed clean sand area and the existing substrate areas. The exact configuration of plant spacing across substrate types will be determined once the restoration site construction is complete, using an as-built drawing. The experimental planting will be implemented with volunteers and other local restoration practitioners including the American Littoral Society.

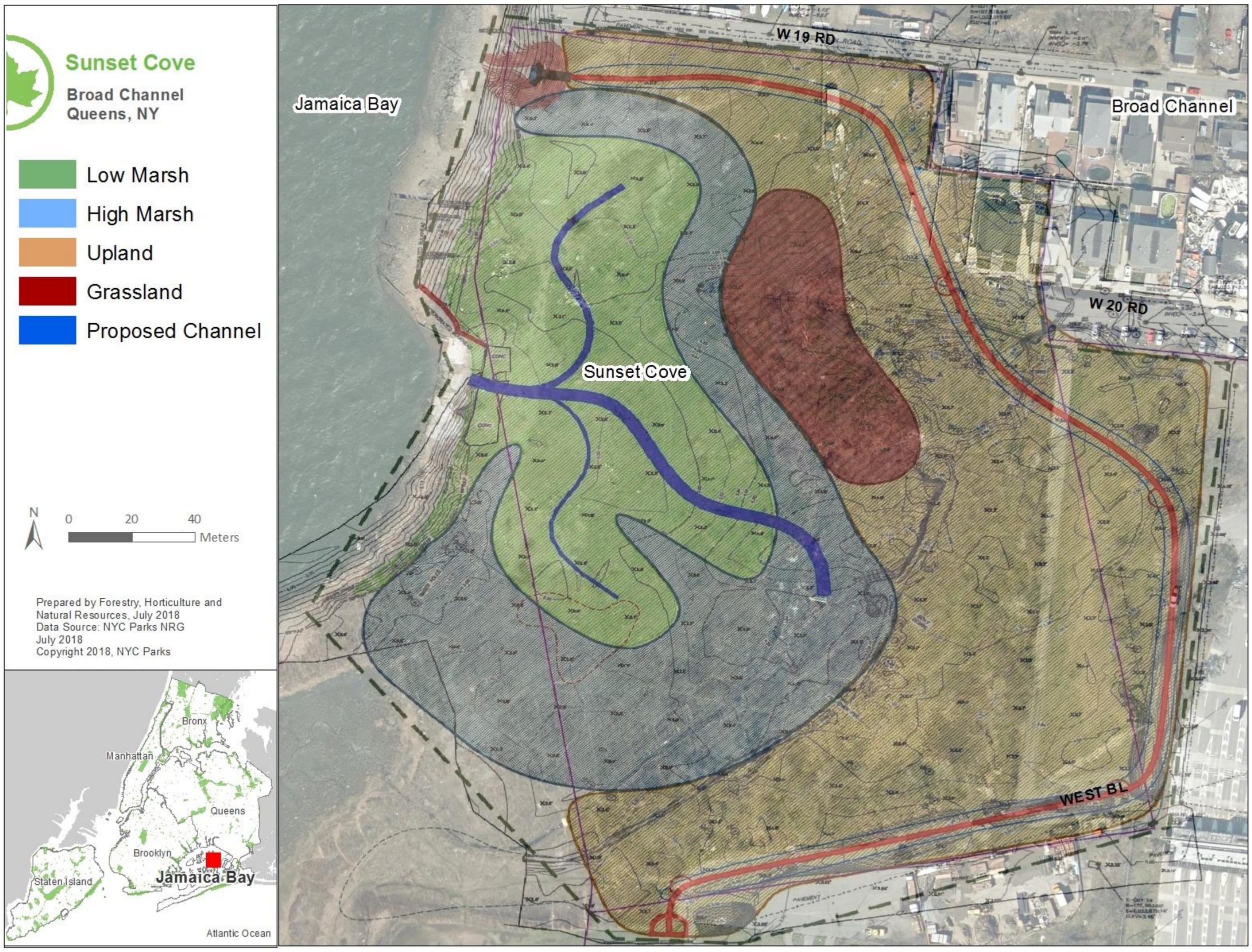

Figure 6. Restoration location in Sunset Cove Park in Broad Channel, Queens, NY.

Goals and Objectives

The goal of this project is to restore altered and degraded natural habitat to a salt marsh and native coastal upland ecosystem and to improve our understanding of the efficacy of different restoration strategies. The project objectives were developed in coordination with state and federal regulatory agencies:

- Objective 1. Achieve appropriate tidal elevations for salt marsh vegetation.
- Objective 2. Achieve 85% plant survival after two years and 85% cover by the fifth growing season post-restoration.
- Objective 3. Compare outcomes under different planting strategies (evenly spaced individual plants versus cluster planting).
- Objective 4. Compare outcomes on different substrate types (existing substrate versus placed clean sand).

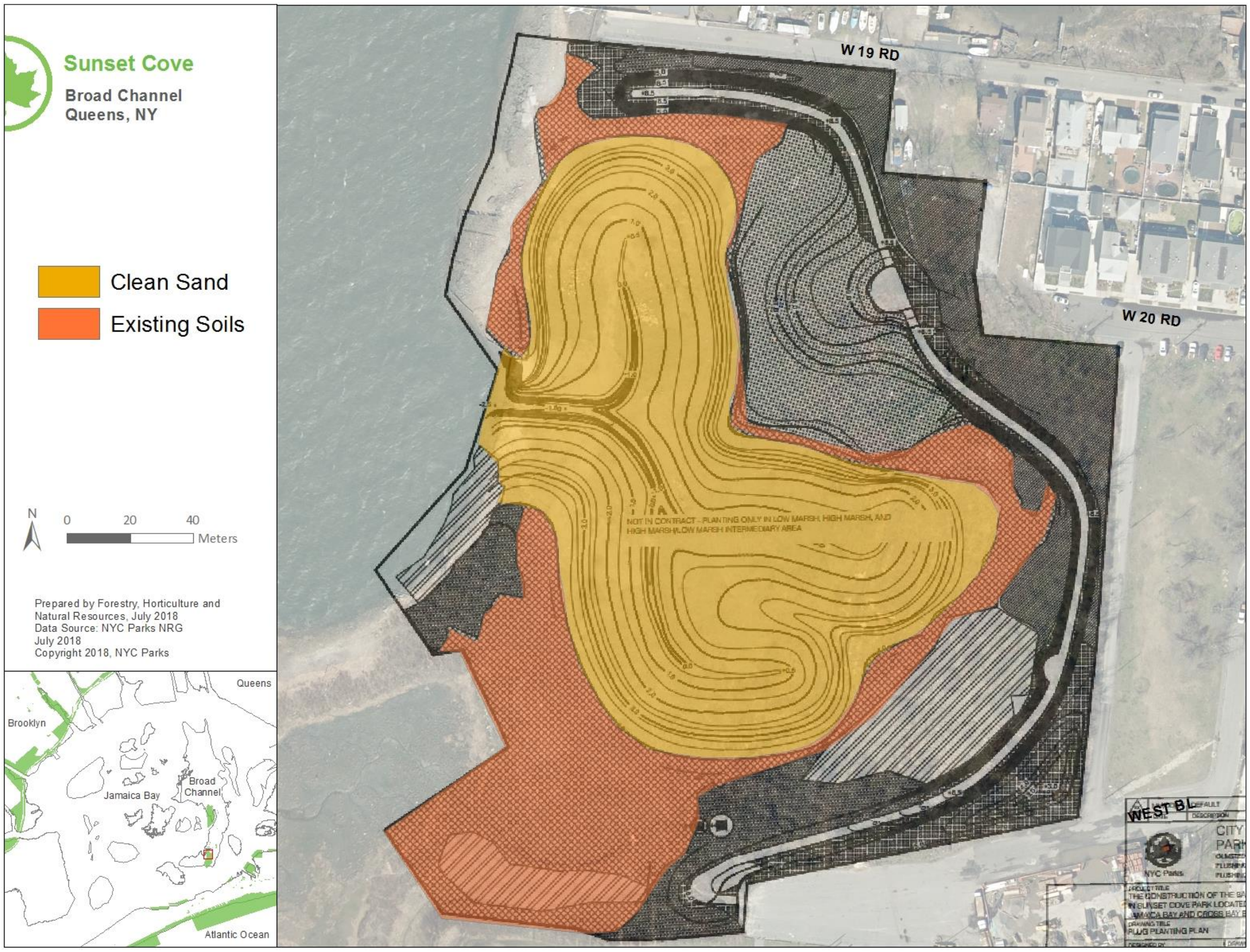

Figure 7. Sunset Cove restoration salt marsh substrate type map. Placed clean sand (gold) is where excavation will take place and the existing substrate (orange) will not be excavated.

Monitoring Strategy, Parameters, Metrics, Methods, and Sampling Plan

Tidal elevations (Objective 1) will be evaluated by comparing tide elevations and planting extent in the restoration designs to the as-built surveys immediately after construction. (Tier 1: Desktop methods to monitor implementation).

Plant survival (Objective 2) will be monitored by examining the percentage of original plants installed that are alive in 1m^2 plots along a grid design stratified by sub-habitat (low marsh versus high marsh). (Tier 2: Rapid field methods to monitor implementation). This will be done for two years after planting—beyond this period discerning individual plants is difficult.

Planting strategies and substrate type will be compared (Objectives 3 and 4) by measuring: percent cover of vegetation by species; stem density by species; stem height by species; and stem diameter by species (Tier 3: Intensive field methods to monitor effectiveness). The impact of different planting strategies and substrate types will also be evaluated using benthic epifauna by determining the abundance of bivalves (and determining their average length), crab burrows, snails, and other epifauna. Sampling will be conducted across 1m^2 plots in a grid design stratified by planting type and substrate type (as shown in Figure 8). (Tier 2: Rapid field methods to monitor implementation). Measurements will be taken annually during peak growing season (August to September) for five years after restoration is completed. Reference plots will also be established at Big Egg Marsh, a salt marsh with low and high marsh habitat that is located in Jamaica Bay, a few miles west of Sunset Cove.

Figure 8. Example experimental monitoring plan. Monitoring plots configured in a grid design stratified by substrate type.

Data Management, Analysis, and Interpretation

Digital data, such as as-built surveys, aerial imagery, and spatial data from a GPS unit, and data recorded on paper data sheets, such as vegetation and invertebrate data (Appendix G), will be uploaded or scanned and entered into digital spreadsheets and saved on the NYC Parks shared server. The spreadsheets will include a data dictionary or worksheet that defines all column headers, acronyms, codes, and abbreviations. Plot data will be recorded into spreadsheets with column representing a different parameters (e.g., date, plot number, percent cover of *Spartina alterniflora*, stem height, mussel abundance, etc.) and row representing separate plots.

The data collected to evaluate tidal elevations (Objective 1) will be analyzed by calculating the difference in elevations between the as-built conditions and target planting elevations in the design documents, and between the as-built salt marsh extent and previous salt marsh extent from recent aerial imagery. The data will be summarized as total change across the project area over time, or the years since restoration was completed.

The data collected to determine plant survival (Objective 2) will be analyzed by calculating the average survival of plants (number present each sampling year divided by the number originally planted) across plots within each sub-habitat (e.g., high marsh, low marsh).

The data collected to determine differences in planting strategies and substrate types (Objective 3 and 4) will be analyzed by averaging parameters (vegetation cover, density, height, and diameter, and abundance of bivalve, crab burrows, snails, and other benthic invertebrates) across plots within each planting and substrate type (individual and cluster planting, existing substrate and clean sand) and the reference site. Assuming the data are normally distributed, an analysis of variance (ANOVA) followed by post-hoc Tukey's Honest Significant Difference (HSD) tests will be used to test for significant differences between planting and substrate types and the reference site.

Once the data are collected and analyzed, they will be interpreted to evaluate the outcome of the restoration and success in meeting the objectives.

The appropriate tidal elevations (Objective 1) will be achieved if the data show that the elevations of as-built and target elevations match or have only minor differences (<5%).

Plant survival (Objective 2) will be achieved if the data show that plant survival is, on average per species, at least 85% by the second year of data collection and that percent cover is, on average per species, at least 85% by the fifth year of data collection.

The comparison of planting strategies and substrate types (Objective 3 and 4) will be achieved by identifying if and where there are significant differences between the two planting strategies, the two substrate types, and the reference site across the monitoring parameters. This comparison may lead to design recommendations. For example, if plant cover is significantly higher in the cluster planting plots compared to the individual planting plots (in the same or both substrate types and across plant species) and not significantly different from the planting cover in the reference site, then cluster planting may be recommended for future planting projects. If crab burrow abundance and vegetation survival is not significantly different in placed clean sand versus existing substrate (in the same or both planting types and across sub-habitats) or the reference site, this indicates that clean sand may not be critical, and may not be needed to enhance vegetation or habitat in similar future projects.

If the above example findings were only found in specific species or sub-habitats, then the recommendations would need to be limited to those situations. For example, if percent cover in cluster planting plots was significantly higher, but only in low marsh with clean sand, then the recommendation may only apply to those instances in future or existing projects. All of these interpretations and recommendations will be documented in annual reports.

Information Sharing Plan

NYC Parks will create an annual report for regulators (e.g., New York State Department of Environmental Conservation (NYSDEC)) that includes: the project purpose, site background, overview of the restoration activities and objectives, monitoring methods, monitoring results, discussion of findings, and recommendations. Recommendations may address additional planting needs due to herbivory or other die off, changes to the planting palette due to as-built changes in tidal hydrology or site condition than designed, installation or maintenance of herbivore fencing to improve plant survival, or installation or maintenance of erosion control features to stabilize soil. Results and subsequent recommendations from the analysis comparing parameters across substrate and planting type will also be included in the report. The report will also include site maps, completed data sheets, fixed plot and transect photographs from field data collection, and a maintenance plan.

The annual monitoring report will be shared with regulators and stakeholders via email. Interesting or relevant design and management findings will also be shared in a variety of forums within NYC Parks and with partners.

Site Inspection and Maintenance Plan

The project site will be inspected quarterly to assess the condition of native plants, herbivore fencing, and erosion control features, and to determine presence of invasive species and organic wrack and debris accumulation. Depending on the restoration design and project objectives, other issues may be inspected as well. The maintenance plan will also define: 1) the management area extent; 2) specific management actions and their location required to address issues or concerns; 3) responsible parties to resolve actions; and 4) a timeline for inspections and maintenance needs. An example maintenance plan can be found in Appendix J.

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APPENDICES

Appendix A. Restored vegetated footprint change protocol

Appendix B. Erosion pin installation and monitoring protocol

Appendix C. SET-MH installation and monitoring protocol

Appendix D. RTK monitoring protocol

Appendix E. Boat wake monitoring protocol

Appendix F. Tide level monitoring protocol

Appendix G. Example data sheets

Appendix H. Example EPA QAPP

Appendix I. Example monitoring report template

Appendix J. Example maintenance plan

Study of Historical Changes in Water-ward Extent of Restored Salt Marshes of New York City

Overview

New York City Parks & Recreation (NYC Parks) manages many fringing salt marshes in the NYC metropolitan area, some of which have been restored through excavation of historical fill, sometime to historical marsh sediments. More often at these sites historical fill is excavated by 1 to 2 feet below marsh grade due to contaminants or the shear depths of the fill and then replaced with clean sand to appropriate salt marsh elevation, and then planted with salt marsh vegetation. We have conducted an analysis of how the restored salt marsh extent or vegetated footprint, specifically on the water's edge, has changed since the completion of the restoration to 2014 at 22 marshes in New York City. At these sites, we estimate salt marsh change by comparing the vegetated marsh footprint on restoration design or as-built maps to that shown in aerial photos from 2014. Our goal is to determine the amount and proportion of salt marsh loss along the water-ward edge and to determine which wetland complexes in NYC have changed most and which have remained relatively stable over since they were restored.

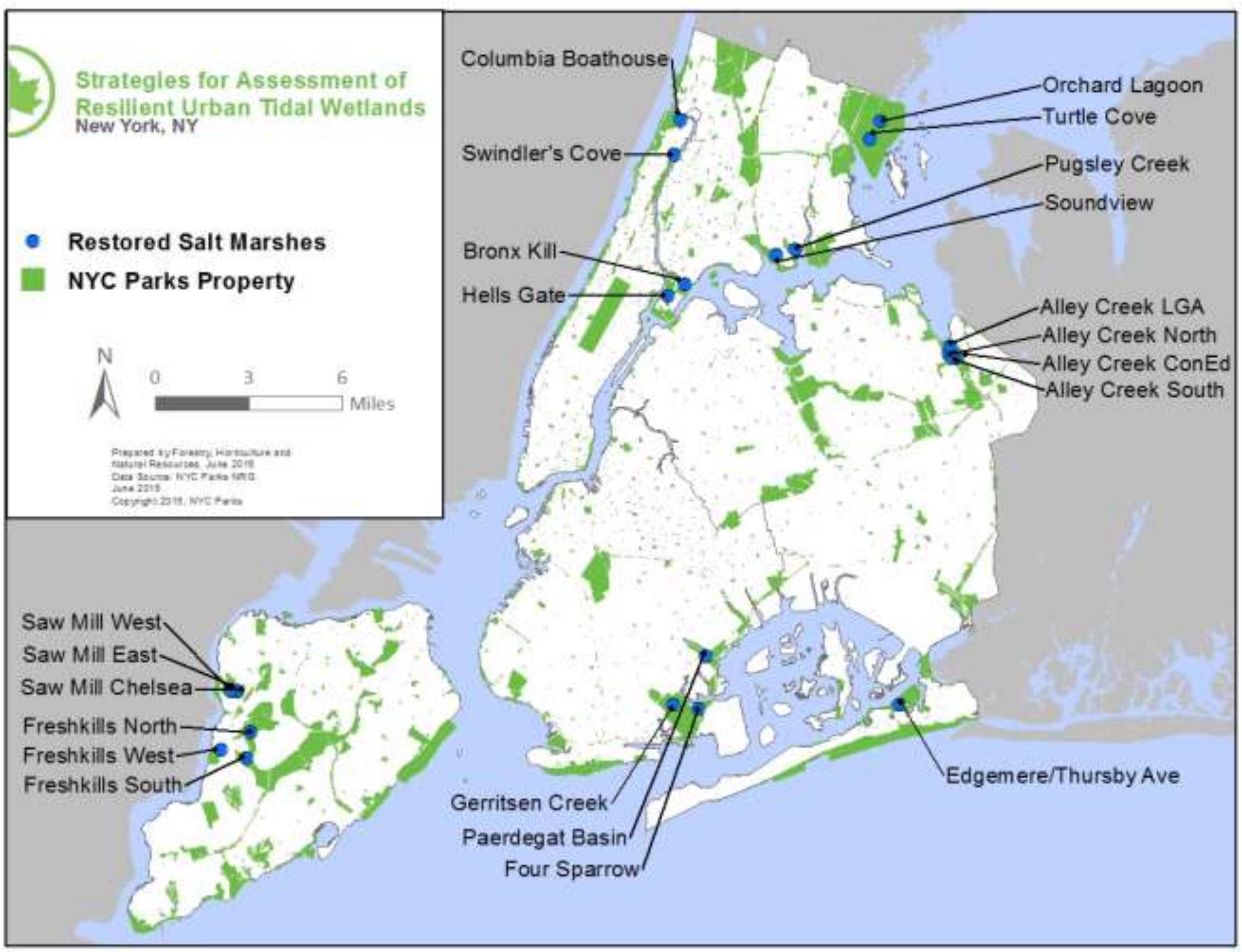


Figure 1: Restored tidal wetland complexes included in this study. These are under NYC Parks jurisdiction.

Objective:

1) To measure change in acreage of vegetated tidal marsh at the water-ward edge of 22 salt marsh complexes in NYC from restoration completion to 2014.
2) Identify which marshes have changed significantly and which have remained relatively stable.
3) Create consistent datasets that are comparable amongst other years.
    a. Conduct all digitization at a consistent scale (1:500).
    b. Maintain a level of detail and consistency amongst digitizers by reviewing digitized data before digitizing begins each session.
    c. Ensuring all spatial datasets and dataframes are in the same projection to limit distortions: NAD 83; StatePlane New York Long Island FIPS 3104; Linear Unit: Feet

Datasets

- Georeferenced planting plans and as-built drawing of the restoration projects
- Restoration vegetated footprint polygons created from the georeferenced design files
- 2012 color aerial images of New York City taken after Hurricane Sandy (tidally coordinated).
- 2014 color aerial images of New York City (not tidally coordinated)
- 2014 vegetated footprint polygons created using 2014 aerial images to estimate vegetation cover within the original restoration footprint

Methods

Steps for measuring salt marsh change:

1. We created the restored marsh footprint following these steps:
    a. Gather documentation of salt marsh restoration design (digital and hard copy)
    b. Digitize hard copies of planting plans and as-built drawing
    c. Georeference the designs using streets and buildings as control points when available
    d. Trace the design boundaries (combining low marsh and high marsh areas)
        i. Use aerial images from as close to the restoration date as possible to correct sites where georeferencing was difficult due to lack of street or building control points

2. The contemporary extent of the salt marsh was mapped through aerial photograph interpretation combined with field verification of the aerial photography maps. The wetland maps do not distinguish between low marsh and high marsh, but simply identify the contemporary marsh area within the original restoration boundary. The guidelines followed in this mapping included the following:
    a. In general, only indentations (for example: tributaries/tidal creeks, or mosquito ditches) into the vegetated marsh of greater than 2 meters (or 6 feet) wide should be drawn.
    b. When drawing the water-ward boundary line, include all clearly vegetated land, as shown by texture and/or color.

c. Exclude areas that are clearly mudflat or bare ground, which will appear as areas that are smooth and subject to inundation.
d. If areas are unclear as to whether they are vegetated or not, but there is a possibility they are, they should be included. We would like to err on the side of inclusion, rather than exclusion so that our estimate of marsh loss is conservative.
e. The upland edge of the marsh can be determined simply by tracing the restoration footprint polygon.

3. In summer 2015, field biologists traversed the marshes to conduct a conditions assessment of restored marsh vegetation health. This involved recording data in plots along a transect. The transects had a random start location and then were at regular intervals throughout the marsh. Trimble GPS units were used to take a GPS points at the start and finish of each transect, and intended to mark the boundaries of the study area. The field criteria used to determine extent of the study area were:

   - Dominant vegetation class Facultative-Wetland (FACW)/ Obligate (OBL) wetland species
   - Landward-extent determined by the restored footprint
   - Significant, obvious change in slope of land to above normal tidal inundations
   - Water-ward edge as determined by where *Spartina* species were growing at less than 30% cover, and the area was dominated by unvegetated mudflat.

   These points were then imported into ArcMap and used as a guide by the field biologist who took them to adjust the water-ward boundaries of the marsh.

4. In ArcGIS, we used the Union tool to analyze the water-ward marsh loss and gain between when the site was restored and 2014. The Union tool creates a new polygon dataset that shows wetland extent for both time periods with coding for whether the marsh area was present when restored or in 2014 or both time periods. Conducted the following steps to separate out water-ward loss to calculate the area of loss:
a. Combined all restored marsh polygons into one shapefile.
b. Prepared restored polygons to be combined into one file by entering attribute data for the complex name and code that match the 2014 marsh polygon attributes (Site_Name, Area_ac).
c. Save the file as “PastRestoredFootprint”.
d. Used the Union tool (Toolbox->Analysis tools->Overlay->Union) to union the restored footprint and 2014 polygons. Saved the shapefile in the 2014 EPA GIS Data folder as “RestoredFootprint_Union” and made the changes described below to this file.
e. In the attribute table, coded polygons as either marsh gain or loss by doing the following:
   i. Added a field for coding marsh gain/loss called “GainLoss”
   ii. Select by attribute polygons to code as LOSS where 2014 FID = -1 AND Restored FID >= 0. Edit the attributes of this selection to label these selected polygons as LOSS in the GainLoss field.

1. Bulk edit attributes by beginning editor, clicking attribute table, and then right clicking on the RestoredFootprint_Union file and editing the GainLoss field.

iii. Selected polygons to code as GAIN where 2014 FID >= 0 AND Restored FID = -1. Edit the attributes of this selection to label these selected polygons as GAIN in the GainLoss field.

f. Labeled all areas where there was no change as "SAME" in the GainLoss field.
g. Used Calculate Geometry tool to calculate the area (in acres) of all marsh polygons including areas of gain/loss, and areas that remained the same.
h. Exported attribute table in Excel and summarize data by categories.
i. Maps created for each complex (Figure 2).

Figure 2: Map of Alley Creek LGA showing areas of marsh water-ward loss and gain. The orange area shows the water-ward loss that was used in our calculations

5. Create a report showing maps of all complexes showing loss or gain along the water-ward edge.

Tidal channel widening of shoreline change

Purpose: Determine if the tidal channel was constructed as or currently exhibits the channel width intended in the design. Determine if the channel edge or shoreline is retreating (vegetation loss) or expanding (vegetation increasing moving towards the water).

Definition: Change in tidal channel edge, or shoreline position over time.

Metrics: Distance of observed change in position of vegetation from initial channel or shoreline edge. This measurement translates into change in channel width, but is reduced channel vegetation retreat or expansion.

Method:

a. Use Erosion Pins to establish benchmark and track change over time.
   Choose the largest one or two tidal channels at the site and randomly select five transects. Each transect will include three pins (rebar rods) proceeding from the channel edge into the marsh, perpendicular to the channel bank (Figure 1A). Place the first pin on the shoreline at the edge of the vegetation and then place the next two pins at 3m and 6m proceeding towards the interior marsh perpendicular from the shoreline. Record the location of the first pin using a GPS unit.
b. Data Collection
   Estimate percent cover of vegetation and non-vegetation in $1m^2$ plot centered over each pin (Figure 1B). In the years following installation, measure the first pin on the channel edge for vegetation retreat (erosion), expansion, or no change by measuring the distance between the erosion pin and the vegetated edge during peak growing season (Figure 1C & D, Figure 2). Take one photo from pin 3 towards the water, capturing all three pins. Additionally, take a photo from pin 1 looking landward by standing 3m waterward (in channel) from pin 1 at a height of about 1.5m, and always at low tide. Net change will be change in distance of the vegetated channel bank edge to the first pin (baseline-distance at subsequent time intervals). Measure erosion pins annually during peak growing season (August-September) for the duration of the monitoring period.
c. Analysis
   The change in distance of the vegetated channel edge relative to the installed erosion pins (net change per transect), will be averaged by site (restored versus reference) at each time interval and will be analyzed by one-way ANOVA for differences.

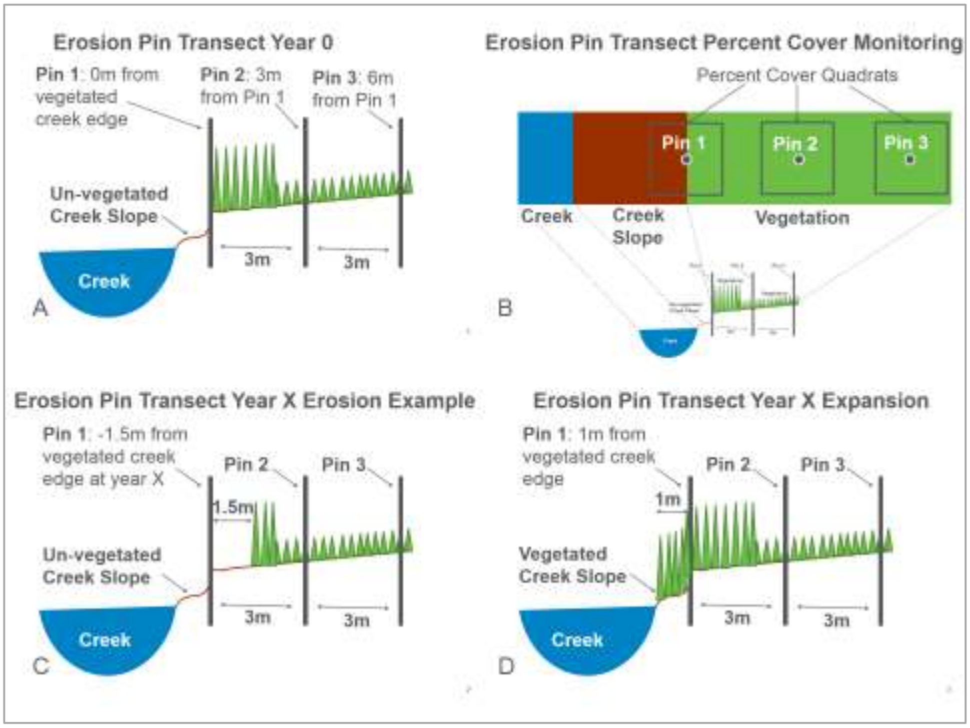


Figure 1. Diagrams of the erosion pin transects, A) cross section example of an erosion pin transect at year 0, B) birds-eye view of an erosion pin transect with location of percent cover quadrats used to monitor vegetation cover, C) cross section example of an erosion pin transect at year X where the vegetation has receded by 1.5m away from the channel, D) cross-section example of an erosion pin transect at year X where the vegetation has expanded by 1m towards the channel.

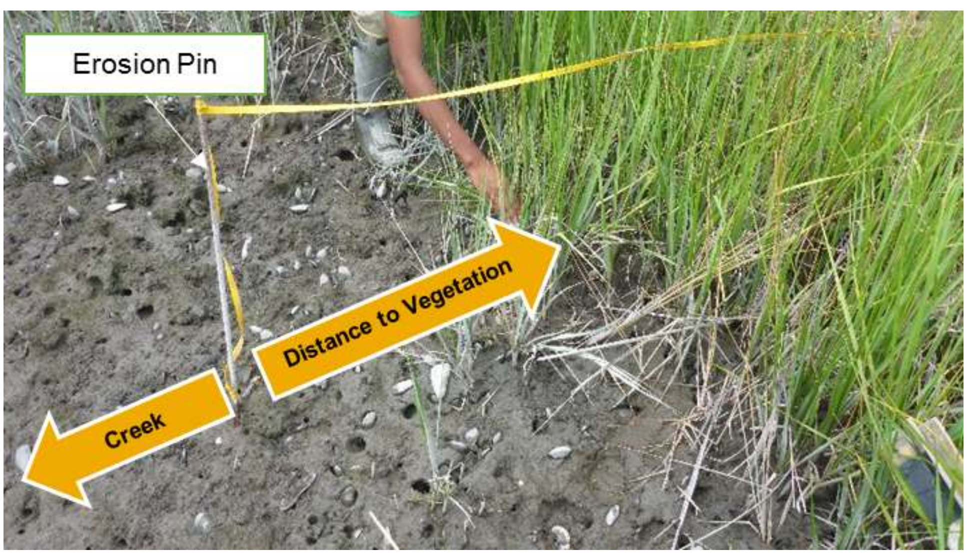


Figure 2. Illustration of the first channel erosion pin (closest to the creek) in an example erosion pin transect. Pin located in Pelham Bay Cove, installed in 2014 at the edge of the vegetation and measured each year to determine distance from the pin to the vegetation. This example shows the vegetation has receded away from the creek, as shown in Figure 1C.

Surface Elevation Table and Marker Horizons

Purpose: Quantify the change in the marsh surface elevation over time and determine if the marsh surface is accreting (increasing in elevation) or subsiding. Determine the ability of the marsh to maintain an elevation that supports salt marsh vegetation as sea levels rise. The increase in elevation of the marsh surface through sedimentation or accrual of organic matter on the marsh surface compared with marsh surface elevation can be used to calculate subsidence (e.g., if marsh surface elevation is decreasing despite sedimentation or accretion then the marsh is subsiding).

Definitions:

- Surface elevation tables (SET) are instruments that allow the measurement of the change in the elevation of the marsh surface relative to accretion (increase in marsh elevation by sedimentation and organic build up on the marsh surface) and subsidence (decrease in marsh elevation caused by processes deep in the peat such organic matter decomposition).
- Marker horizons are a technique for measuring accretion of the marsh surface over time by creating a white marker layer on the marsh surface at year zero in a small plot with feldspar powder. The feldspar powder remains in place over time and allows for repeated reading of sediment and organic peat accumulation on the marker horizon surface over time.

Metrics:

i. Marsh surface elevation change (millimeters)
ii. Height of sediment accretion on marsh surface (millimeters)

Methods:

Surface Elevation Tables

i. Installation
Install the SET by driving four-foot sections of stainless steel rods into the ground to the point of refusal or to 80 feet below the surface, whichever is first, and secure the top of the pins at the marsh surface with a cement cap and instrument receiver (Figure 1 & 2). Create a $3m^2$ plot with physical pole or stake markers in each corner, centered on the cement capped rod with the instrument receiver. Install at least 3 SETs per monitoring site.

ii. Data Collection
During monitoring events, use a long plank with stools on each end to avoid disturbing the marsh surface within the $3m^2$ plot. Attach the table arm to the receiver and read the instrument by recording the height of nine fiberglass rods placed through the table arm to the marsh surface and rotate 90 degrees to four locked positions for a total of 36 points (Figure 3 & 4).[1]

iii. Analysis
Calculate the change in rod height for each individual rod between sampling events. Average the change in height across all pins for each SET. Graph the elevation change over time and calculate a slope of a best fit line to determine the elevation change over time.

Marker horizons

i. Installation

[1] Cahoon, D.R., J.C. Lynch, , B.C. Perez, B.S. Segura, R.D. Holland, C. Stelly, G. Stephenson, and P. Hensel. 2002. High precision measurements of wetland sediment elevation: II. The rod surface elevation table. Journal of Sedimentary Research 72:734-739. https://doi.org/10.1306/020702720734

Place white feldspar on the marsh surface within a 0.25m^2 to 1m^2 plot at year zero or when the SET is installed, to create the MH (Figure 5). If installing MH with SET units, then place the feldspar plots in each of the four corners of the 3m^2 SET plot.

ii. Data Collection
During monitoring events, use a knife to cut into the MH and take four measurements of the thickness of the sediment that settled over each MH, if the MH is too deep to be visible with a cut, take a core using a knife and trowel or soil corer (Figure 6).[2]

iii. Analysis
Marker horizon measurements should be averaged by plot within each SET plot. Graph the accretion values over time and calculate a slope of a best fit line to determine the change over time. Subsidence can be calculated by subtracting the elevation change from accretion, a positive value indicates that the marsh surface is accreting or increasing in elevation and a negative value indicates the marsh surface is subsiding or decreasing in elevation.[3]

The SET-MH methodology is described in detail and with instructions by Cahoon and Lynch (2005) at: http://www.pwrc.usgs.gov/set/theory.html.[4]

[2] Cahoon, D.R. and R.E. Turner. 1989. Accretion and canal impacts in a rapidly subsisting wetland. II. Feldspar marker horizon technique. Estuaries 12(4): 260-268. https://link.springer.com/article/10.2307%2F1351905?LI=true

[3] Cahoon, D.R. and J.C. Lynch. 1997. Vertical accretion and shallow subsidence in a mangrove forest of southwestern Florida, USA. Mangroves and Salt Marshes 1:173-186. https://link.springer.com/article/10.1023/A:1009904816246

[4] Cahoon, D. and J. Lynch. 2005. Surface Elevation Table (SET). Petuxent Wildlife Research Center. http://www.pwrc.usgs.gov/set/

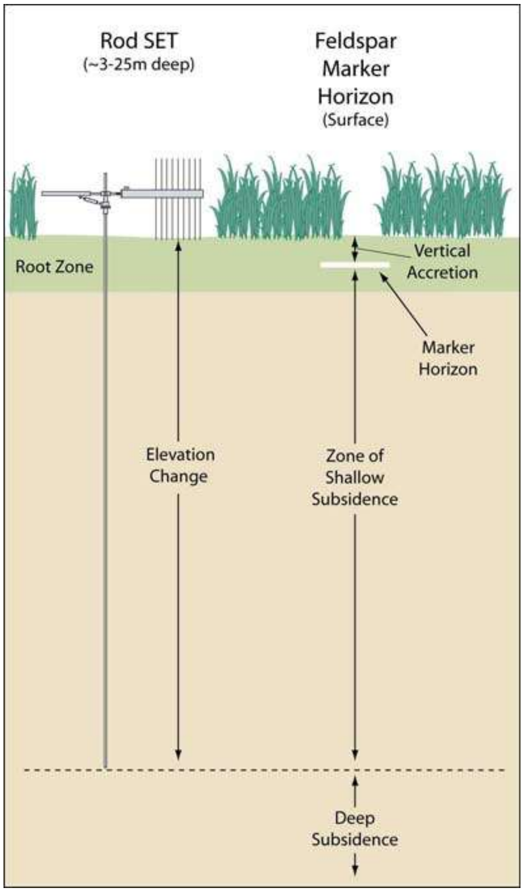


Figure 1. Illustration of Rod Surface Elevation Table (RSET) (3-25 m deep) and Feldspar Marker Horizon (Surface). Note that vertical accretion refers to the section above the marker horizon. The (surface) elevation change refers to the whole section between the rod depth (depending on how deeply it is placed—to the point of refusal or 25 m, whichever is achieved first during installation) and any vertical accretion. The zone of shallow subsidence is the section between the marker horizon and the depth of the rods. Deep subsidence is ignored. Source: http://www.pwrc.usgs.gov/set/theory.html

Figure 2. Installation of steel rods (4 foot sections are repeatedly threaded into the ground until point of refusal. A receiver is added the top and stabilized with concrete.

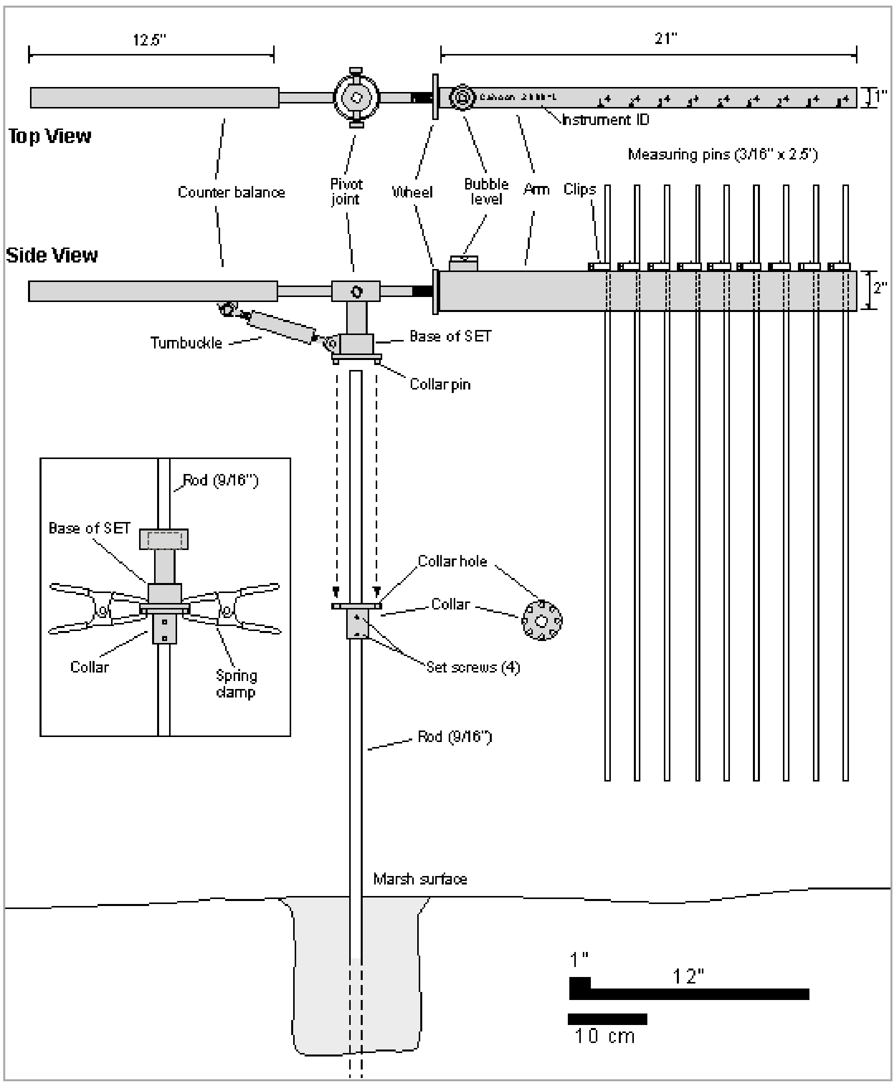


Figure 3. Diagram of the SET instrument and insert collar.
Source for Figure: http://www.pwrc.usgs.gov/set/SET/rod.html

Figure 4: Photo shows the fourth pin being slid through the SET table to rest gently on the substrate surface for measurement. This is repeated four times at 90 degree angles for a total of 36 measurements and averaged to obtain a single SET data point (up to three times per year).

Figure 5. Feldspar about to be poured within a plot near an SET to form a marker horizon.

Figure 6. Measurement of accretion following placement of feldspar that acts as a marker horizon. Photo source: Don Cahoon, USGS, http://www.pwrc.usgs.gov/set/theory.html.

December 29, 2014

Standard Operating Procedure– Water Level Recorder Elevation Data Collection and Online Data Entry

Version 1.1

Kelly Chadbourne

The objective of this SOP is to describe collection of elevation data on and surrounding water level recorders installed as part of the Salt Marsh Integrity project. This SOP consists of 3 components: 1) initial preparation procedures that include the set-up of the GPS-RTK system; 2) collection of the water level recorder elevation measurements and the field data form; and, 3) online data entry procedures.

1. Initial Preparation Procedures

Benchmark Establishment:

Base Station Benchmarks are used to set-up the GPS-RTK base receiver needed for Real-time Kinematic surveying. They are control points within centimeter accuracy, computed through the Online Positioning User Service (OPUS).

If a benchmark from the NGS Control Network is available for the area, it is recommended that it is used as a survey monument (control benchmark for the project). These are stable, identifiable points (usually metal disks) established by extremely accurate observations. To access the complete list of these benchmarks, go to the online interactive map at: http://www.ngs.noaa.gov/NGSDataExplorer/. Each benchmark has an associated PID (Permanent Identifier), and a datasheet that provides information on the coordinates and elevation, as well as a description of its location and when it was last accessed.

The surveyor should select control points that display both horizontal (coordinates) and vertical (elevation) information. Click the “View List” button to retrieve a list of available points, select the points with the highest level of accuracy, given by the lowest order number. This information is under the “HOrder” and “VOrder” columns, where H is the horizontal order, and V is the vertical order. More detailed information can be found on the monument datasheet pertaining to coordinates and elevation, and the Order and Class.

Control point for this project must be:

→ **2nd Order, Class 2 Vertical Control, or better**.*
*If there is a choice between 1st and 2nd Order, use the 1st Order control.

Use the information on the datasheet to locate the benchmark in the field. Read the description of the station location carefully and use a handheld GPS, and an updated georeferenced aerial photo to locate the metal disk in the field. In addition, if possible, it is a good idea to locate a second benchmark, within 1-2 miles of the control point. The RTK can be used to collect elevation data at this second benchmark, as a check, to ensure the accuracy of the data being collected at the water level recorders.

GPS-RTK Set-up:

Prior to the beginning of the survey, the GPS-RTK equipment must be physically configured and set up. Depending on the equipment and personnel available, and the area to be covered, the surveyor can set up the instrument in a variety of ways:

Base + Rover set-up: Uses one base station that is temporarily set-up in the field on a known location (control benchmark) and is sending corrections to the rover via a radio link. This set-up is adequate to survey up to a 10 km distance radius from the base station. As the distance increases, the atmospheric conditions at the rover and base station will become increasingly different, resulting in a decrease in accuracy. The base receiver must be set-up at a Base station Benchmark and located as close as feasible to the survey area.

Additionally, a radio repeater (e.g., TRIMMARK from Trimble) may be used to increase the broadcast range of a base radio by receiving the base transmission and then rebroadcasting it on the same frequency. The radio repeater should be set up at a high location and within the range of the broadcasting capability of the base station (e.g., 1.5 km for Trimble R8).

Multiple Bases + Rover set-up: Used when multiple base receivers are available, two (or more) reference stations can be established at Base Station Benchmarks, each operating independently. This is useful for surveying large areas as the surveyor can select the closest reference station and continue surveying, without the need to stop the survey.

Base (single or multiple) + multiple rovers: Used when more than one rover is in communication with one reference station at the same time. The existence of several rover units in the parks allows for teams of users to survey different areas at the same time, increasing the time efficiency of the data collection. The base receiver must be set-up at a Base Station Benchmark and located as close as feasible to the survey area.

Additionally, a rover can be configured to operate as a repeater to increase the broadcast range. The radio operating mode must be switched to “Repeater 1” using the Survey Controller to access Survey Styles menu for the rover’s internal radio.

Rover + cell phone correction: In the absence of a base receiver, or in cases where communication between rover and base is not possible (sometimes due to presence of obstacles such as high cliffs), the surveyor can access an external network of reference stations provided by the National Geodetic Survey (NGS), known as CORS network (Continuously Operating Reference Stations). The RTK correction is provided through the internet and accessed by the surveyor via a cell phone connected to the rover in the field. This option has cell phone associated costs, and requires a plan with a carrier that supports the type of data connection that is necessary.

Job Properties:

The following are the necessary inputs in the properties of the Job that will be created for running the survey and storing the points. The Job can be created in the office using Trimble Business Center and then transferred to the Survey Controller, or can be created directly on the Survey Controller.

There should be one Job per: ***Refuge SMI Unit***; and, **Water Level Recorder** (if an SMI unit has more than water level recorder).

JOB SETTINGS:

Name of the Job:	SMI_MSHHE_20120103 *“SMI”_”RefugeLitCode”+”SMI 2 Character Unit Code”_date (yyyymmdd)* If more than one well is being surveyed per SMI unit, add a well identifier to the end of the Job Name (e.g., _WellA)
Grid Coordinate System:	Universal Transverse Mercator (UTM)
UTM Zone Number*:	18N (CT, DE, MD, NJ, NY, PA, VA)
**Coastal Refuges*	19N (MA, ME, NH, RI)
Horizontal Datum:	North American Datum of 1983 (NAD83)
Vertical Datum:	North American Vertical Datum of 1988 (NAVD88)
Geoid Model:	GEOID12A
Units:	meters

The surveyor must ascertain that once the rover unit is started the Survey Controller must demonstrate that:

→ PDOP ≤ 2.0
→ Rms ≤ 0.01m
→ 7 or more satellites are available
→ Baseline distance of ≤ 10 km

2. Data Collection and the Field Data Form

Measure elevation at the following:

1. **Continuous water-level recorder**

→ 1 point is measured just inside the upper opening of the water level recorder PVC pipe.

- This is a plastic “lip” inside the upper end of the PVC pipe
- The water level recorder hangs down from this lip while it is deployed
- Use the pointed survey tip on the RTK Rover pole, balancing it on the “lip”, and using the bubble to level the rover pole
- If the PVC pipe is somewhat high above the marsh surface (e.g. > half meter) you may need to bring a stepstool to be able to see the bubble on the rover pole
-

Point Name: **MSHHE_Well**

[RefugeLiteralCode]+[SMIUnitAbbreviation]_Well

2. **Marsh surface** directly adjacent to the water level recorder

→ 1 point is measured directly adjacent to the water level recorder on the marsh surface.

Point Name: **MSHHE_WellS**

[RefugeLiteralCode]+[SMIUnitAbbreviation]_WellS

3. **Five points** in the immediate vicinity of the water-level recorder

→ 5 random points are measured starting at a random compass bearing and at a 10 meter distance from the water level recorder.

- From the random compass bearing, take a measurement at regular intervals of 72 degrees. For a total of 5 points in a 360 degree circle.
- Adjust measurements as needed to avoid recording elevation in a creek or pond– only take readings that are on a solid, vegetated surface.

Point Name: **MSHHE_R1**
[RefugeLiteralCode]+[SMIUnitAbbreviation]_R[Insert Point Number]

File Naming Convention – Additional Information and Refuge Literal Codes:

RefugeLiteralCode = 3 letter assigned abbreviation. See table below for literal codes of SMI Refuges.

SMIUnitAbbreviation = 2 letter code

Literal Codes:

- See the table below for a quick reference to refuge literal codes:

REFUGE/DIVISION	LITERAL CODE
Blackwater NWR	BLK
Bombay Hook NWR	BMH
Cape May NWR	CPY
Chincoteague NWR	CHN
Eastern Shore of VA	ESV
Edwin B. Forsythe	EBF
Fisherman Island	FSH
James River	JSR
Long Island NWRC	LIC
Long Island NWRC/Seatuck	STK
Long Island NWRC/Wertheim	WRT
Maine Coastal Islands	MEC
Moosehorn NWR	MSH
Parker River NWR	PKR
Plum Tree Island NWR	PTI
Prime Hook NWR	PMH
Rachel Carson NWR	RHC
Rhode Island NWRC	RIC

Storing Points:

1. Position the rover over the point and level.
2. Hit –***Measure***-
3. In the new screen, key in the following information:

Under ***–Point name***- key in the ID of the point:

Use the file naming convention outlined in the previous section to assign point names. *For example*, water level recorder, marsh surface, and random point elevation measurements at Moosehorn NWR's Hobart East unit are as follows, respectively: **MSHHE_Well**, **MSHHE_WellS**, **MSHHE_R1**

Under –***code***- enter SMI + Refuge Literal Code and the survey year (e.g., SMIMSH_2012)

Under –***method***- select –***rapid point***-

Verify that the **–*antenna height***- is set to the correct height (height of the rover pole)

Verify that the **–*Measured to***- is set to **–**bottom of antenna mount-

4. Go to the next point and repeat steps 1 through 3.

FIELD DATA FORMS:

SMI-FDF1-1: Salt Marsh Integrity-Well Elevations

The Field Data Form (FDF) is used for all field notations. This information is necessary for post-processing of the data and facilitates the generation of accurate metadata. There will be one FDF filled out per Job. At the beginning of the survey, complete the fields of the "Event Information" (except for "Survey End" time) and the "Survey Settings" sections of the FDF using the following formats:

Refuge Name = Use either the Refuge's full name or the 3 character Literal Code

Unit Name = Provide the complete unit name

Survey Date = mm/dd/yyyy

Observer Name = First Last

Datum = include both horizontal and vertical datum (e.g., NAD83 and NAVD88)

Logger/Well SN = Serial number specific to the continuous water level recorder

Many of the "Survey Settings" values may be entered prior to going into the field. The "Data Collection" section should be filled in as the surveyor conducts the survey. Any notes regarding equipment problems, obstacles encountered, etc., should be entered in the "Survey Notes" section, and the time from the GPS-RTK unit noted.

Field Data Form: Salt Marsh Integrity -Well Elevations

Event Information

Refuge Name:		Survey Date:	
Unit Name:		Survey Start:	
Observer 1:		Survey End:	
Observer 2:			

Survey Settings:

Unit Make:		Base Monument:	
Coordinate System:		PID:	
Datum:		Northing:	
Logger/Well SN:		Easting:	
		Ortho Height:	

Data Collection:

	Northing	Easting	Elevation:	Distance from Well:	Compass Bearing:
Well (Solinst Cap)					
Well (Marsh Surface)					
Random Point					
1					
2					
3					
4					
5					

Survey Notes:

3. Online Data Entry Procedures

Data recorded on the Field Data Forms should be electronically entered into the Well Elevation data entry form on R5's Salt Marsh Integrity SharePoint site. Form inputs are the same as the Well Elevation Field Data Form. Once entries have been verified as being correct, click the data validation button.

The URL to access the data entry forms is:

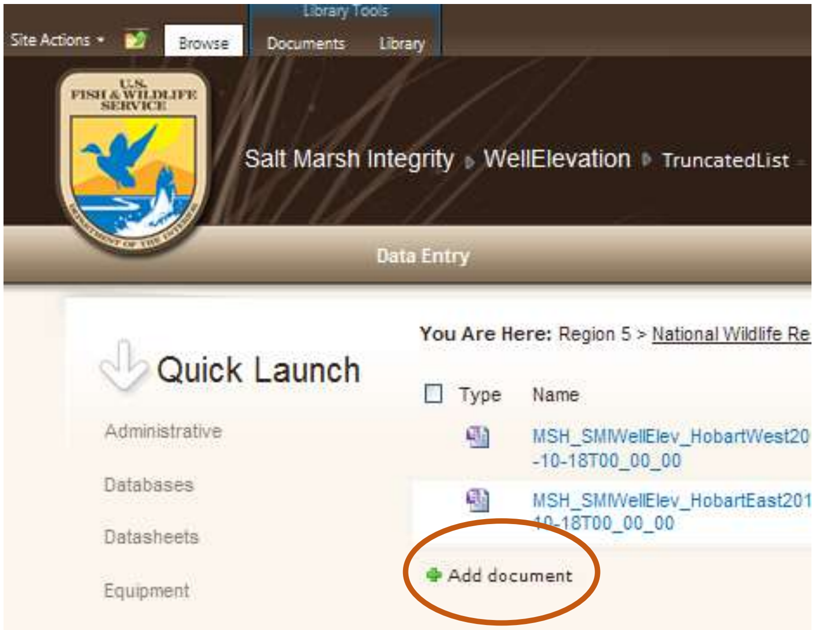
https://fishnet.fws.doi.net/regions/5/nwrs/im/SMI/WellElevation/

Online data entry and form submission steps:

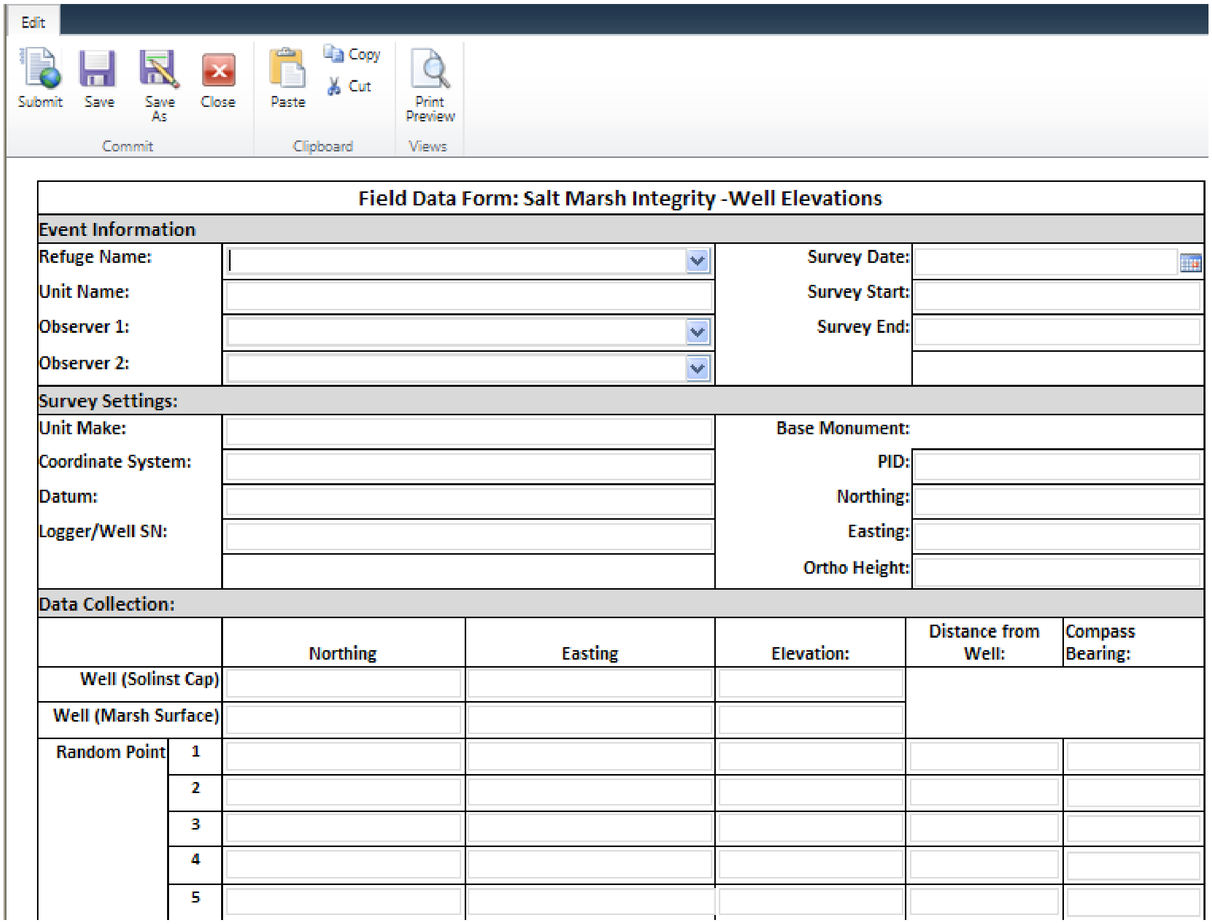
1. Hover mouse over the -***Data Entry***- Heading

2. Select -***WellElevation***- from the dropdown list.

3. Click -***Add Document***-



4. Fill in the Form and Click -***Submit*** -when finished.



Field Data Form: Salt Marsh Integrity -Well Elevations

Event Information			
Refuge Name:		Survey Date:	
Unit Name:		Survey Start:	
Observer 1:		Survey End:	
Observer 2:			

Survey Settings:			
Unit Make:		Base Monument:	
Coordinate System:		PID:	
Datum:		Northing:	
Logger/Well SN:		Easting:	
		Ortho Height:	

Data Collection:		Northing	Easting	Elevation:	Distance from Well:	Compass Bearing:
Well (Solinst Cap)						
Well (Marsh Surface)						
Random Point	1					
	2					
	3					
	4					
	5					

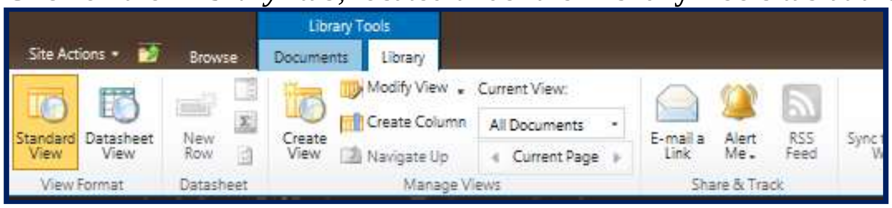
5. If you need to go back and edit/update a data entry form:

- Edit the form.
- When finished, click -***Save***- to capture the edits.
- Then -***Close***-.

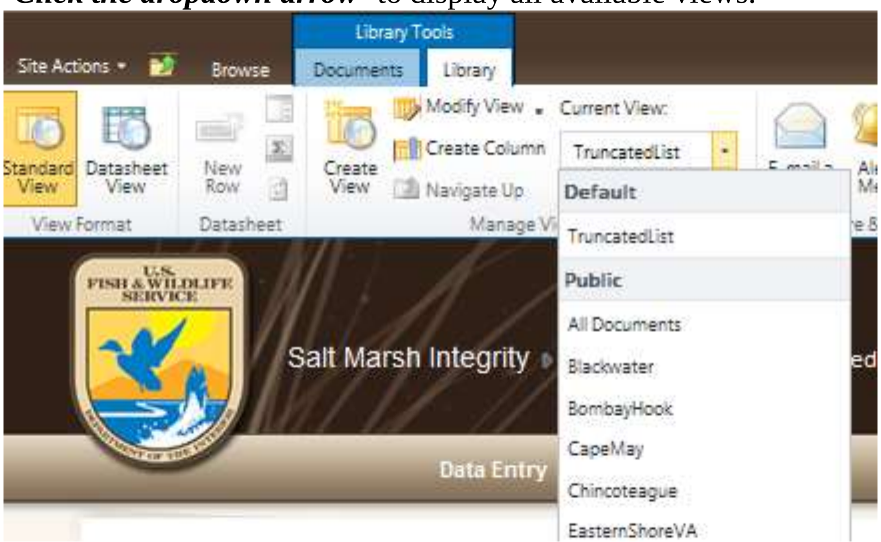
EXPORT DATA TO EXCEL

Select the view for your Refuge by following these steps:

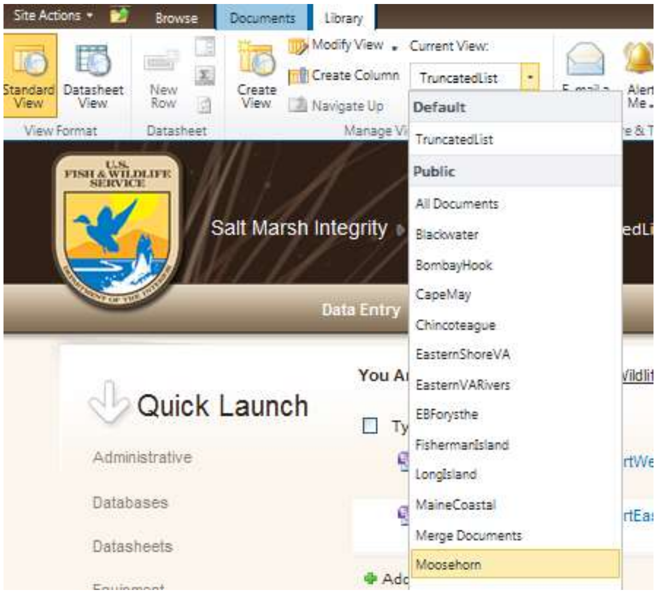
1. Click on the ***-Library-*** tab, located under the **Library Tools** tab at the top of the screen.



2. Under ***-Current View-***, in the **Manage Views** section:
-Click the dropdown arrow- to display all available views.



3. Select your Refuge from the list of available views.

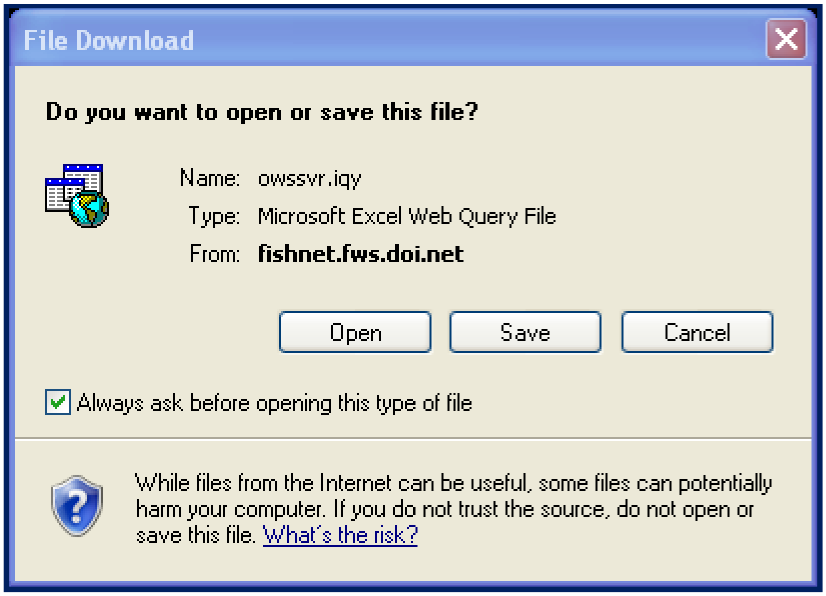


4. The view will update to only show records specific to your Refuge.

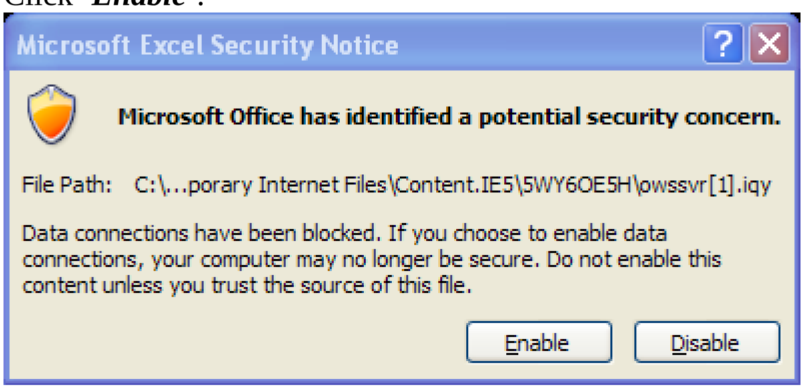
5. Click on the -***Library***- tab, located under the **Library Tools** tab at the top of the screen.

6. Click on -***Export to Excel***-, located in the **Connect & Export Section**.

7. Click -***Open***-.



8. Click -***Enable***-.



9. Check to make sure your information was exported properly and -***Save***-.

10. If you want to permanently disconnect the data from SharePoint, in the **External Table Data** section click
 -***Unlink***-.

Boat Wake Monitoring

Purpose: Observe and characterize the height, frequency, and duration of waves created by boats at the site.

Definition: Boat wake is a wave created by the displacement of water by a boat propeller and boat frame as it moves through water.

Metrics: Boat wake height, frequency and duration: the average height of boat wakes observed at a site over a given period.

Sampling Method Overview

Boat wake measurements are determined using staff gauges and/or by collecting local water level data at short intervals (typically with a depth sensor and data logger) and using the data to determine boat wake wave heights, frequency, and duration.

Sampling Design

- Measure boat wakes at one or more locations with one or more staff gauges and data loggers
- Place the staff gauge or data logger perpendicular to the direction of the waves
- Measure for the duration of at least one tide cycle (low tide to high tide), if possible
    - Timing should coincide with known large wave events that impact the site, e.g. shipping schedules, or summer boating activity

Sampling equipment

- Staff gauge (e.g. 4ft plate/scale secured to wood stake)
- Mallet or sledge hammer to place stake
- Digital camera with photo and video capabilities
- Measuring tape
- Meter or yard stick
- GPS unit
- Clipboard, datasheets, pencil/pen
- 2 HOBO Data Loggers – 1 air and 1 water
- HOBO logger data cable/computer connector with appropriate unit receiver
- Laptop with HOBOware software
- PVC well/housing for data logger
- Mallet or sledge hammer, drill, stainless steel brackets, nuts, and bolts to secure housing

Staff Gauge Installation

- Install staff gauge along the shoreline at low tide so that the bottom of the plate is just below the water line. Secure staff gauge at a stable location next to bridge footing or wood pilings or between rocks, and hammer into substrate in open water (Figure 1).
- Record the location of the staff gauge with the GPS unit.

- If possible, identify a known benchmark at or in close proximity to the staff gauge or site with a known elevation in vertical datum NAVD88.[1] Use surveying equipment (manual transit, self-leveling rotary laser level, or total station, and tripod and receivers) to survey the elevation of the known benchmark and the ground at the location of the staff gauge and calculate the elevation of the staff gauge location in vertical datum NAVD88. This elevation can then be used to determine the water level change relative to the elevation of the staff gauge location.

Water Level Logger Installation

- Install water logger housing (PVC pipe) along the shoreline (hammer PVS housing into substrate and secure using drill, brackets, nuts, and bolts to a stable location e.g. next to bridge footing or wood pilings) at low tide so that the bottom of the housing and logger will be below the water line at low tide (Figure 2).
- Install an air logger or barometric sensor on a structure in PVC housing in a secure location within 3 miles of the water logger (Figure 2B).
- Record the location of the logger housing with the GPS unit.
- Identify a known benchmark at or in close proximity to the logger or site with a known elevation in vertical datum NAVD88.
- Use surveying equipment (manual transit, self-leveling rotary laser level, or total station, and tripod and receivers) to survey the elevation of the known benchmark and the ground at the location of the data logger and calculate the elevation of the data logger location in vertical datum NAVD88. This elevation can then be used to determine the water level change relative to the elevation of the data logger location.
- Alternatively a real time kinematic (RTK – a GPS unit that can determine horizontal and vertical location with millimeter accuracy) can be used and points only need to be recorded at the known benchmark and at the data logger location.

[1] Zilkoski, D.B., J.H. Richards, and G.M. Young. 1992. Results of the General Adjustment of the North American Vertical Datum of 1988. American Congress on Surveying and Mapping, Surveying and Land Information Systems 32(3):133-149. https://www.ngs.noaa.gov/PUBS_LIB/NAVD88/navd88report.htm

Figure 1. Example of a staff gauge (white scale attached to wood stake in the foreground) located in the water on the shoreline as a large boat passes Bridge Park on the Harlem River in the Bronx.

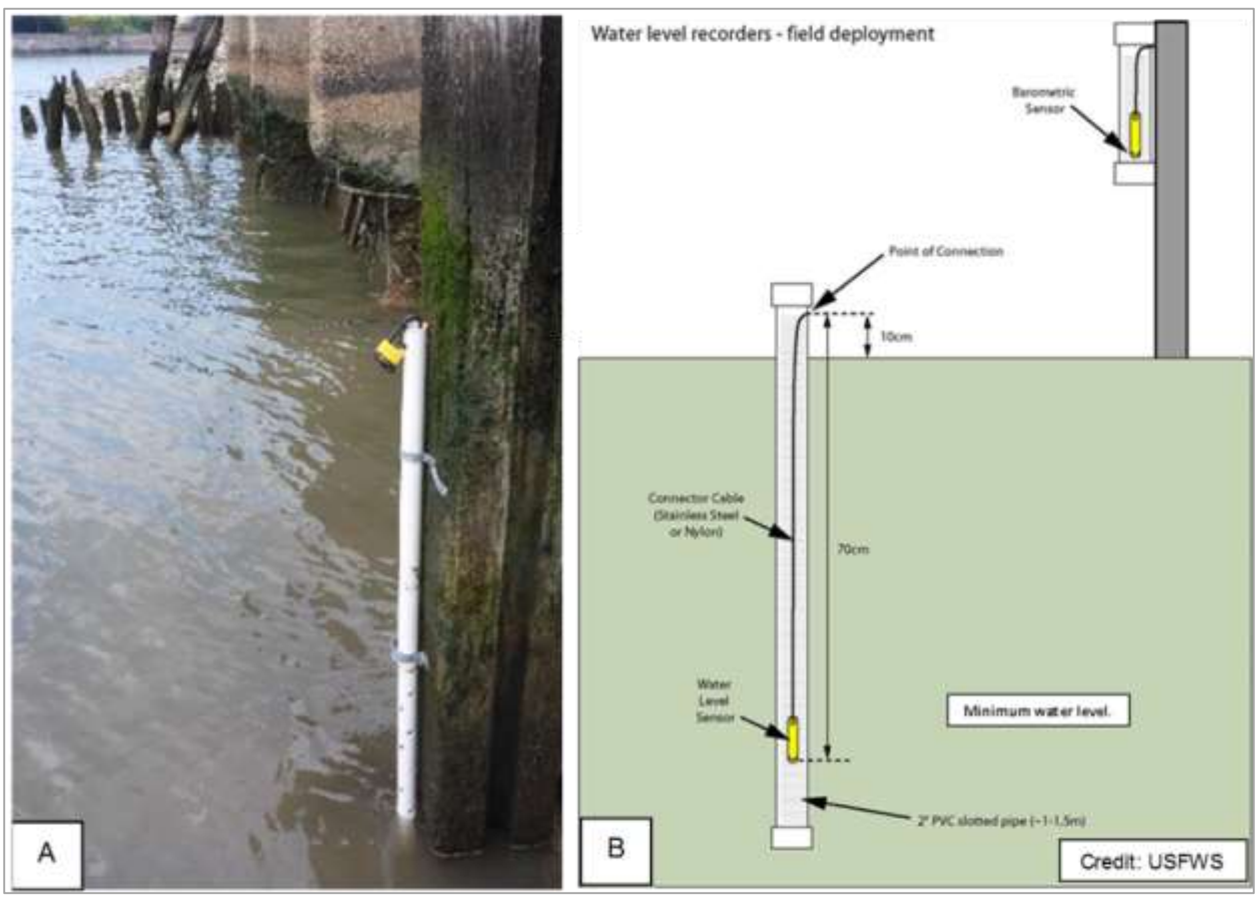


Figure 2. Data logger housing examples, A) water logger PVC housing attached to wood piling and B) diagram of logger housing in soil and the air or barometric sensor housing.

Staff Gauge Boat Wake Data Collection

- Record the start time and water depth on the staff gauge at low tide.
- Record the water depth on the staff gauge and take a photo from the same location every 15 minutes.
- At the end of sampling, record end time and water depth on staff gauge (e.g. high tide).
- As a boat or other vessel approaches the site, record the time and take a photo or record the water level.
- Note the approximate size of the boat (e.g. 0-20 feet, 20-50 feet, larger than 50 feet)
- Take video of staff gauge during boat wakes from fixed point from the start to the end of the wave action (calm water)
- Record the end time of the boat wake (or determine duration from video file)
- An example data sheet can be found in appendix A.

Water Level Logger Deployment and Data Collection

- Set up the water logger and air logger to log every 1 second
- Place the water logger in the housing securely (e.g. hanging from top of housing using steel cable)
- Measure the total length of the housing, total length of the logger and cable or hanging apparatus, and distance from the hanging point to the top of the housing (if applicable)
- Measure the height of the water and determine the distance from the top of the water to the bottom of the logger
- Allow the loggers to collect data for a minimum of one tidal cycle (e.g. low tide to high tide)
- Record the start and end time of boat wake events and note the approximate size of the boat
- A full protocol for setting up and collecting data using a Onset HOBO U20 series data logger can be found in Appendix A.[2]

Data Handling and Management

- Download all data from the GPS unit and camera and scan and enter the datasheets from the staff gauge data.
- Download and analyze data to determine tidal regime. An example protocol for retrieving or downloading data from and Onset HOBO U20 series data logger can be found in (Appendix A).

Analysis

Staff Gauge Data

- Review photos to determine water depth change from low to high tide and rate
- Review video to determine average wave height (highest point of each wave), frequency (number of waves in each boat wake event), and the duration (time from when the boat wake event begins and to when it ends) of the boat wake event.

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[2] http://www.onsetcomp.com/products/data-loggers/water-level

Water Level Logger Data

- Analyze the data to determine average wave height (highest point of each wave), frequency (number of waves in each boat wake event), and the duration (time from when the boat wake event begins and to when it ends) of the boat wake event.

Energy Conversion

- Convert wave height to wave energy (foot-pound-force) by multiplying the acceleration due to gravity (32.174 feet/second^2) by the density of sea water (64.08 pounds weight per cubic foot) by the measured wave height squared, and divide the result by eight (USACE 2002).
- Foot-pound-force can then be converted to joules by multiplying by 1.35582.

Quality Control

- Periodically during monitoring, manually measure water levels next to the data logger housing and record the time and date.
- Cross reference the manual measurements with the data logger data to check for major differences or errors in the data.

References

http://edis.ifas.ufl.edu/media/SG064/FieldProcedures.pdf

https://tidesandcurrents.noaa.gov/publications/8210_guide.pdf

https://www.pwrc.usgs.gov/resshow/neckles/gpac.pdf

US Army Corps of Engineers (Zeki Demerbilek & Linwood Vincent), "Water Wave Mechanics" Part 2, chapter 1 in volume 2 of Coastal Engineering Manual, Coastal & Hydraulics Laboratory, Vicksburg, Mississippi. Revised 1 June 2006 (version of 30 April 2002 is on websites in USA, KwaZulu Natal, & Thailand) http://boatwakes.homestead.com/files/form.htm

Zilkoski, D.B., J.H. Richards, and G.M. Young. 1992. Results of the General Adjustment of the North American Vertical Datum of 1988. American Congress on Surveying and Mapping, Surveying and Land Information Systems 32(3):133-149. https://www.ngs.noaa.gov/PUBS_LIB/NAVD88/navd88report.htm

Instruments / Equipment references:

https://www.geomatrix.co.uk/data-sheet/?q=/marine-products/oceanographic-and-hydrographic/tide-gauge/

http://www.onsetcomp.com/products/data-loggers/water-level

Appendix A. Example staff gauge monitoring data sheet

Date:			Tide:	Field Staff:
Start Time			End time	
Weather				

Event	Time	Resting Height (ft)	With Wave (ft)	Wave Height (ft)	Notes

Appendix B. Example full data logger protocol

HOBO water level logger

Directions for the operation of the Onset Computer Corporation, HOBOware Water Level Logger

Phase 1: Setup

- From the “Start” -> “All Programs” menu, select “Onset Applications” -> “HOBOware” -> “HOBOware”.

Phase 2: Connecting the Logger to a Computer

- Unscrew the black plastic cap from the logger by turning it counter clockwise.
- Attach the exposed optic couple to the Optic USB Base Station.
- Insert logger into coupler with the flat side of the exposed threading on the logger aligned with the arrow on the couple label. Gently twist the coupler to insure that it is properly seated in the coupler (it should not turn).
- Check Optic USB Base Station status window to make sure that the green light is on.

Phase 3: Status and Operation

- In the HOBOware toolbar click on “device status” and observe that the temperature corresponds to the temperature at your location and the absolute pressure corresponds to the barometric pressure (it is important to keep units and measurement systems in mind when making such comparisons).
- To launch the logger select “Launch” from the toolbar. A window will open allowing you to choose the description of the data and the operation parameters of the instrument.
- It is imperative to make sure that both the “Absolute Pressure” and the “Temperature 10K Thermistor” options are selected and checked as the pressure readings must be corrected for the influence of temperature (logging voltage is not essential).
- When the selections are complete, press “Launch”, remove the logger from the Optic USB Base Station and screw on the black plastic cap by turning it clockwise.

Phase 4: Field Operation

- Make sure the stilling well that the logger is placed in is vented to the atmosphere.
- Use a no stretch wire to suspend the logger in the well.
- Suspend the logger so that it is always under water but does not touch the sediment, ideally it should be suspended so that it is halfway its maximum measuring depth (7.5 ft for the 15 ft, and 15 ft for the 30 ft) below the water’s surface for the most accurate data collection.
- Measure the distance between the suspension point (hook) and the surface of the water.
- Lower logger into well or stilling well.

- Measure water depth from desired reference point (top of pipe, ground level or sea level).
- Measure water depth.
- Record deployment time.
- For lake, river and stream deployments if the water level is referenced to a point above the logger, such as the top of the stilling well, record the water level as a negative number.

Record the reference measurement date and time.

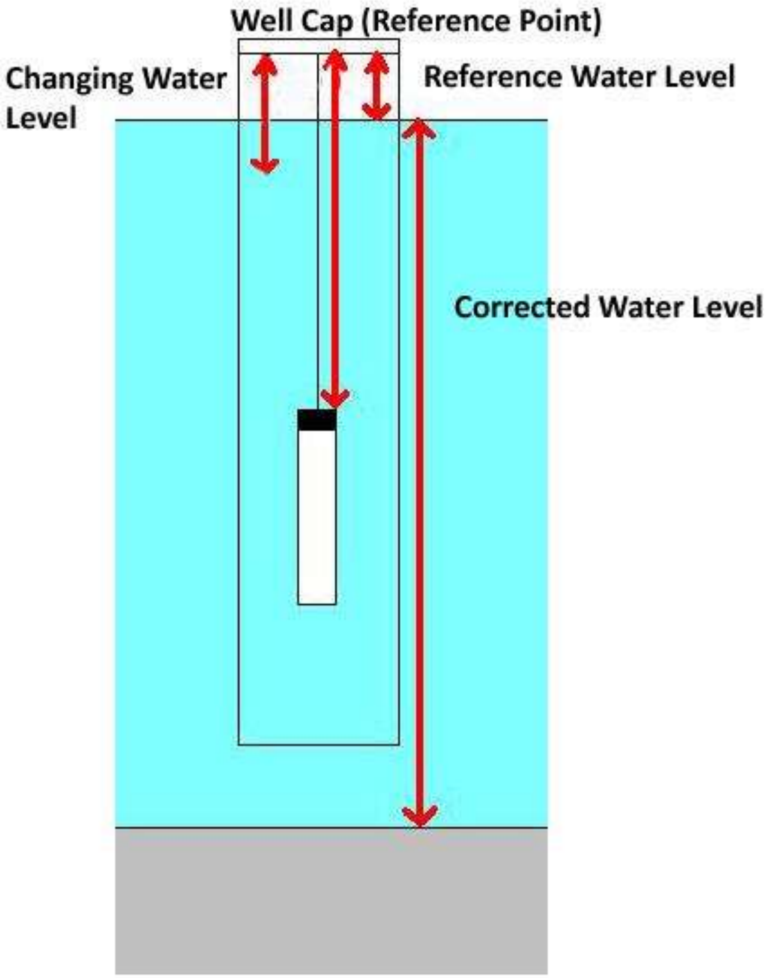

Fig 1. Collected field measurements and resulting measurements.

Phase 5: Retrieving the Data

- Measure the water depth using the original reference point.
    - This measurement is important for quantifying measurement error caused by manual measurement error, sensor drift, or change in suspension length and can be compared to calculated water level at the end of the plot.
- Record the date and time.

- Retrieve the data logger.
- Connect the logger to a computer (See **Phase 2: Connecting the Logger to a Computer**)
- Click on “Readout device” in the HOBOware toolbar.
- Select device “HOBO U20-001-01.
- Name a Text file for data storage.
- Double click on “Barometric Compensation Assistant”
    - Provide fluid density information by choosing water type (fresh, salt, brackish). It can also be manually entered, but really does not significantly affect the results.
    - Provide a reference water level which is the distance between a reference point (most commonly sea level or the height of the well cap of the HOBO’s housing) and the water’s surface.
        - If the water level is measured downward from a reference point above the water’s surface, such as a well cap, enter the water as a negative number.
        - If the water level is measured upward from a reference point below the water’s surface, such as the water’s height above sea level, enter the water level as a negative number.
        - If you don’t use a reference water level, the resulting series data will contain values for absolute sensor depth. For the most accurate results, use a reference water level.
    - Upload the barometric data file that was collected from the HOBO that was deployed in the air. A constant barometric pressure could be used, but would result in less accurate data.
    - Click “Create a New Series.”
    - **IMPORTANT NOTE: The resulting water level data that is calculated is the distance between the reference point and the surface of the water. To calculate the water level from the ground to the water’s surface, the data has to be converted by subtracting the resulting water level data from the distance between the reference point and the bottom of the water body.**
- You can change the output of the units (m/ft).
- Click “Plot”.
- Export the data into an excel spreadsheet.

Notes

- NOAA Barometric Pressure and Weather Stations
- **http://cdo.ncdc.noaa.gov/qclcd/QCLCD?prior=N**

- Depth to logger measured from the bottom of the hole in the black cap to the end of the wire connected to the hook.
- After launching data logger, measure time to deployment to compensate for erroneous data.
- The logger should be allowed to come to full temperature equilibrium (approximately 30 minutes) before the reference level is recorded.

Tide Level Monitoring

Objective

The objective of tide level monitoring is to determine the frequency and depth of tidal inundation when there is no nearby or adequate tidal information available from an existing tide station or gauge (e.g. operated or calibrated by a NOAA, USGS, etc.).

Water level data will typically be used to refine estimates for mean high water (MHW), mean low water (MLW), mean tide level (MTL), and mean higher high water (MHHW) for the design of tidal marsh restoration projects (Figure 1). In addition, water level data can be used to produce depth-duration-frequency curves to assess frequency of inundation, and can be used with detailed elevation data to determine the extent of the area that is flooded under a given tide, or a percent of time flooded over time (hydroperiod).

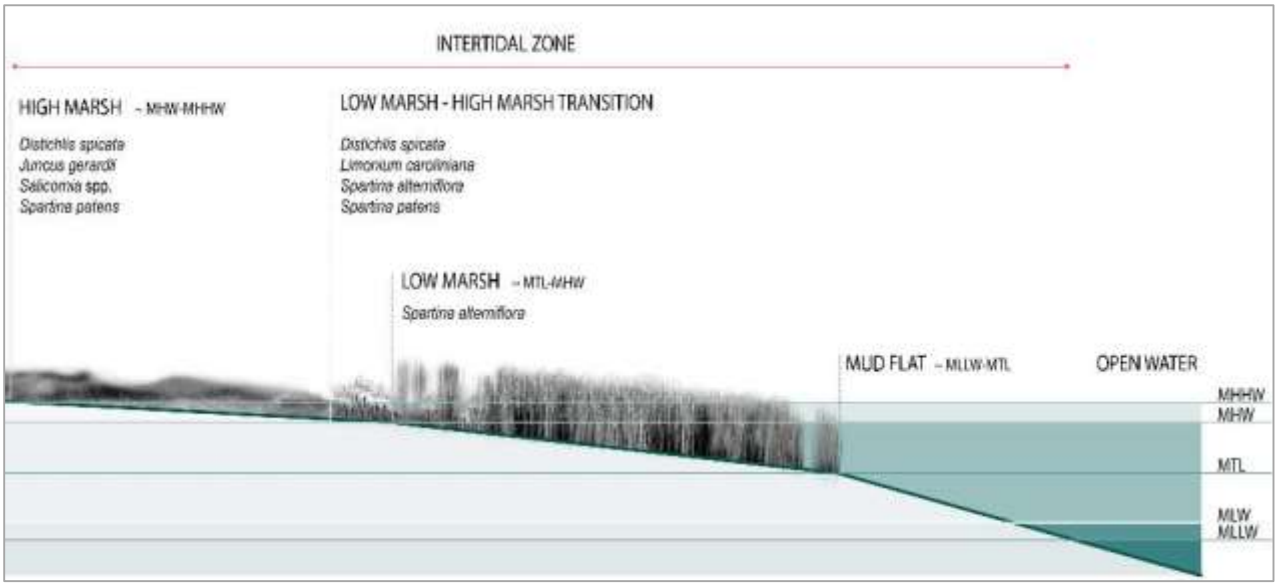

Figure 1. Typical profile of a natural intertidal zone. Salt marsh plant communities are defined relative to tidal inundation levels.

In most cases, adequate tidal data is available from regional tide gauge stations. Whether a tidal water monitoring is needed must be determined for each site. Criteria for determining whether local tidal monitoring is needed include proximity to NOAA tide station (within 3 miles) and configuration or exposure of the site to open water (the tides in back bay or narrow channel sites will be influenced by wind and other ambient factors that will reduce the accuracy of the NOAA tide stations).

Sampling Method Overview

The hydroperiod and tide levels are determined by collecting local water level data (typically with a depth sensor and data logger) and using the data to determine if there are differences between the local water level compared to the water level at the closest tide station (e.g. NOAA Tides & Currents[1]).

[1] https://tidesandcurrents.noaa.gov/tide_predictions.html?gid=1407

Sampling Design

Collect tide data at the site using at least one data logger in the water and one data logger in the air to correct for barometric pressure. The air pressure logger may be placed within 3 miles of the water logger.

- The data should be collected for at least 3 months to obtain and adequate sample and range of tidal cycles.
- Identify and collect data from the closest tide station(s).

At shallow water sites with very minimal water level changes or when resources are limited, an alternative method using a staff gauge (pole or wood stake with a plate or measuring scale attached to it) can be used to manually assess the change in the water level over time, rather than a data logger.

Sampling Equipment

- 2 HOBO Data Loggers – 1 air and 1 water (Use titanium or plastic for salt water)
- HOBO logger data cable/computer connector with appropriate unit receiver
- Laptop with HOBOware software
- Perforated PVC well/housing for data logger
- Mallet or sledge hammer, drill, stainless steel brackets, nuts, and bolts to secure housing
- Alternative to data logger: staff gauge (e.g. 4ft plate/measuring scale secured to stake)
- Digital camera
- Measuring tape
- Meter or yard stick
- GPS unit
- Clipboard, datasheets, pencil/pen

Installation of Data Logger & Housing

- Install water logger housing (PVC pipe) along the shoreline (hammer PVS housing into substrate and secure using drill, brackets, nuts, and bolts to a stable location e.g. next to bridge footing or wood pilings) at low tide so that the bottom of the housing and logger will be below the water line at low tide (Figure 1).
- Install an air logger or barometric sensor on a structure in PVC housing in a secure location within 3 miles of the water logger (Figure 1B).
- Record the location of the logger housing with the GPS unit.
- Identify a known benchmark at or in close proximity to the logger or site with a known elevation in vertical datum NAVD88.[2]
- Use surveying equipment (manual transit, self-leveling rotary laser level, or total station, and tripod and receivers) to survey the elevation of the known benchmark and the ground at the location of the data logger and calculate the elevation of the data logger location in vertical datum NAVD88. This elevation can then be used to determine the water level change relative to the elevation of the data logger location.

[2] Zilkoski, D.B., J.H. Richards, and G.M. Young. 1992. Results of the General Adjustment of the North American Vertical Datum of 1988. American Congress on Surveying and Mapping, Surveying and Land Information Systems 32(3):133-149. https://www.ngs.noaa.gov/PUBS_LIB/NAVD88/navd88report.htm

- Alternatively a real time kinematic (RTK – a GPS unit that can determine horizontal and vertical location with millimeter accuracy) can be used and points only need to be recorded at the known benchmark and at the data logger location.

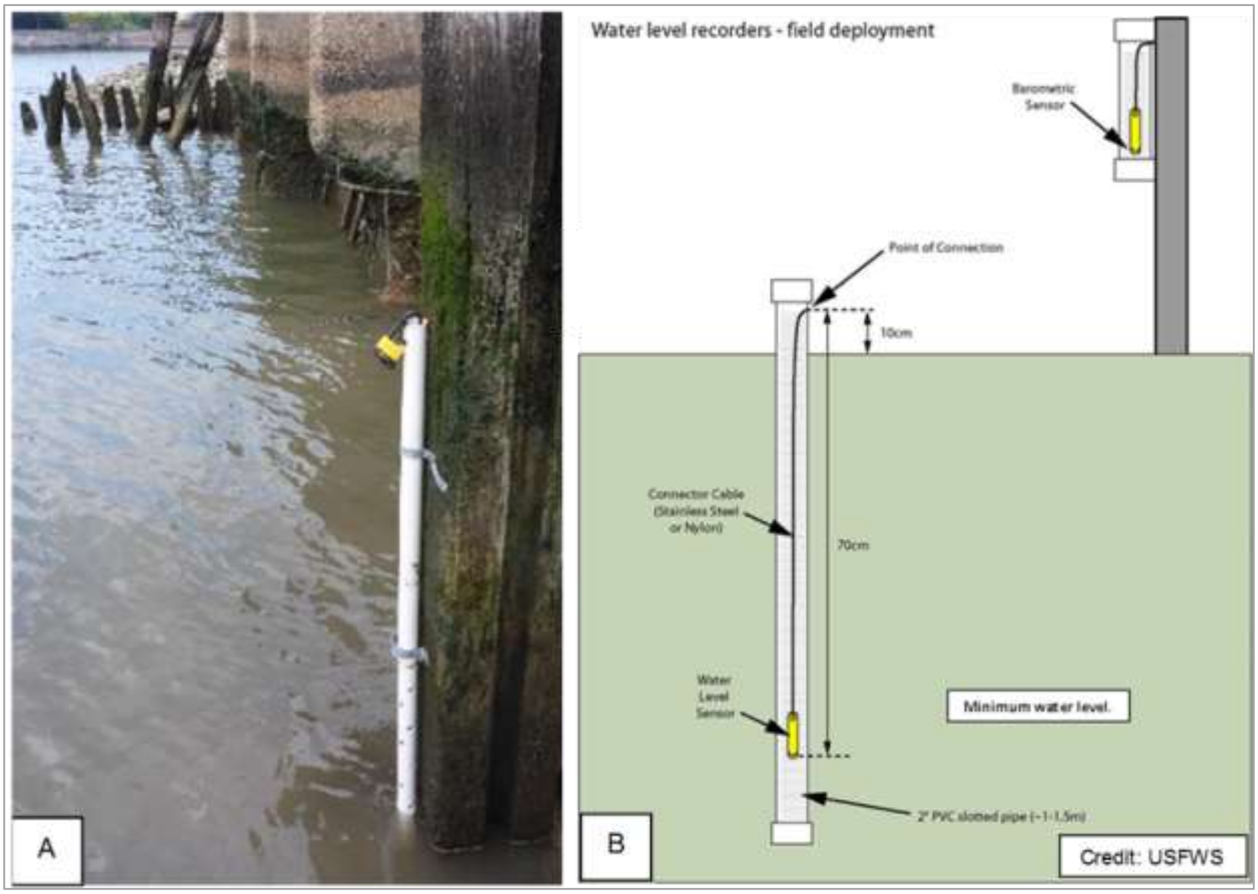

Figure 1. Data logger housing examples, A) water logger PVC housing attached to wood piling and B) diagram of logger housing in soil and the air or barometric sensor housing.

Deployment and Data Collection

- Set up the water logger and air logger to log every 6 minutes, delaying launch to a time when you can be sure installation will be completed. See Appendix A, Phases 1-3.
- Place the water logger in the housing securely (e.g. hanging from top of housing using steel cable).
- Measure the total length of the housing, total length of the logger and cable or hanging apparatus, and distance from the hanging point to the top of the housing (Appendix A).
- Measure and record the height of the water and determine the distance from the top of the water to the bottom of the logger when the logger is installed.
- Measure and record the distance from the bottom of the logger to ground to determine difference in height between the surveyed ground elevation and the height of the sensor to determine accurate water levels relative to surveyed benchmark with a known elevation.
- Place the air logger inconspicuously in a secure location (e.g. hanging from a tree, telephone pole, or fence either in a secure facility or a location that is not easily visible or accessible).

- Record the date and time of installation/initial water measurement.
- Return to download data a few days after initial deployment to ensure all equipment is operating correctly.
- Retrieve logger and download data at least once every two weeks to ensure that the loggers are still physically present and operating (see Appendix A, Phase 5). Clean logger and housing as needed using wire brush.
- Allow the loggers to collect data for a minimum of 90 days.
- A full protocol for setting up and collecting data using a Onset HOBO U20 series data logger can be found in Appendix A.[3]

Data Handling and Management

- Download all data from the GPS unit and camera and scan and enter the datasheets
- Download and analyze data to determine tidal regime. An example protocol for retrieving or downloading data from and Onset HOBO U20 series data logger can be found in (Appendix A).

Analysis

- Correct data for atmospheric pressure (see Appendix A, Phase 5).
- Convert to the appropriate unit and vertical datum (feet, NAVD88). See Appendix A, Phase 5.
- Determine the local MHW by averaging the high tide level in each tidal cycle.
- Determine the local MLW by averaging the low tide level in each tide cycle.
- Determine the local MTL by averaging MHW and MLW.
- Determine the local MHHW by averaging the higher of the two daily high tides within a tidal cycle.
- Compare local water level datums to biobenchmark data collected for the site, if applicable.
- Use the local water level datum to correct or verify the closest tide station datum for MHW, MLW, MTL, and MHHW. This is a complex task that requires careful quality control, see the NOAA Computational Techniques for Tidal Datums Handbook (2003).[4]

Quality Control

- Periodically during monitoring, manually measure water levels next to the data logger housing and record the time and date
- Cross reference the manual measurements with the data logger data to check for major differences or errors in the data.

References:

http://edis.ifas.ufl.edu/media/SG064/FieldProcedures.pdf

https://tidesandcurrents.noaa.gov/publications/8210_guide.pdf

https://www.pwrc.usgs.gov/resshow/neckles/gpac.pdf

[3] http://www.onsetcomp.com/products/data-loggers/water-level

[4] National Oceanic and Atmospheric Administration. 2003. Computational Techniques for Tidal Datums Handbook. NOAA Special Publication NOS CO-OPS 2. U.S. Department of Commerce. https://tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf

National Oceanic and Atmospheric Administration. 2003. Computational Techniques for Tidal Datums Handbook. NOAA Special Publication NOS CO-OPS 2. U.S. Department of Commerce. https://tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf

Zilkoski, D.B., J.H. Richards, and G.M. Young. 1992. Results of the General Adjustment of the North American Vertical Datum of 1988. American Congress on Surveying and Mapping, Surveying and Land Information Systems 32(3):133-149. https://www.ngs.noaa.gov/PUBS_LIB/NAVD88/navd88report.htm

Instruments / Equipment references:

https://www.geomatrix.co.uk/data-sheet/?q=/marine-products/oceanographic-and-hydrographic/tide-gauge/

http://www.onsetcomp.com/products/data-loggers/water-level

Appendix A. Example full data logger protocol

HOBO water level logger

Directions for the operation of the Onset Computer Corporation, HOBOware Water Level Logger

Phase 1: Setup

- From the "Start" -> "All Programs" menu, select "Onset Applications" -> "HOBOware" -> "HOBOware".

Phase 2: Connecting the Logger to a Computer

- Unscrew the black plastic cap from the logger by turning it counter clockwise.
- Attach the exposed optic couple to the Optic USB Base Station.
- Insert logger into coupler with the flat side of the exposed threading on the logger aligned with the arrow on the couple label. Gently twist the coupler to insure that it is properly seated in the coupler (it should not turn).
- Check Optic USB Base Station status window to make sure that the green light is on.

Phase 3: Status and Operation

- In the HOBOware toolbar click on "device status" and observe that the temperature corresponds to the temperature at your location and the absolute pressure corresponds to the barometric pressure (it is important to keep units and measurement systems in mind when making such comparisons).
- To launch the logger select "Launch" from the toolbar. A window will open allowing you to choose the description of the data and the operation parameters of the instrument.
- It is imperative to make sure that both the "Absolute Pressure" and the "Temperature 10K Thermistor" options are selected and checked as the pressure readings must be corrected for the influence of temperature (logging voltage is not essential).
- When the selections are complete, press "Launch", remove the logger from the Optic USB Base Station and screw on the black plastic cap by turning it clockwise.

Phase 4: Field Operation

- Make sure the stilling well that the logger is placed in is vented to the atmosphere.
- Use a no stretch wire to suspend the logger in the well.
- Suspend the logger so that it is always under water but does not touch the sediment, ideally it should be suspended so that it is halfway its maximum measuring depth (7.5 ft for the 15 ft, and 15 ft for the 30 ft) below the water's surface for the most accurate data collection.
- Measure the distance between the suspension point (hook) and the surface of the water.
- Lower logger into well or stilling well.

- Measure water depth from desired reference point (top of pipe, ground level or sea level).
- Measure water depth.
- Record deployment time.
- For lake, river and stream deployments if the water level is referenced to a point above the logger, such as the top of the stilling well, record the water level as a negative number.

Record the reference measurement date and time.

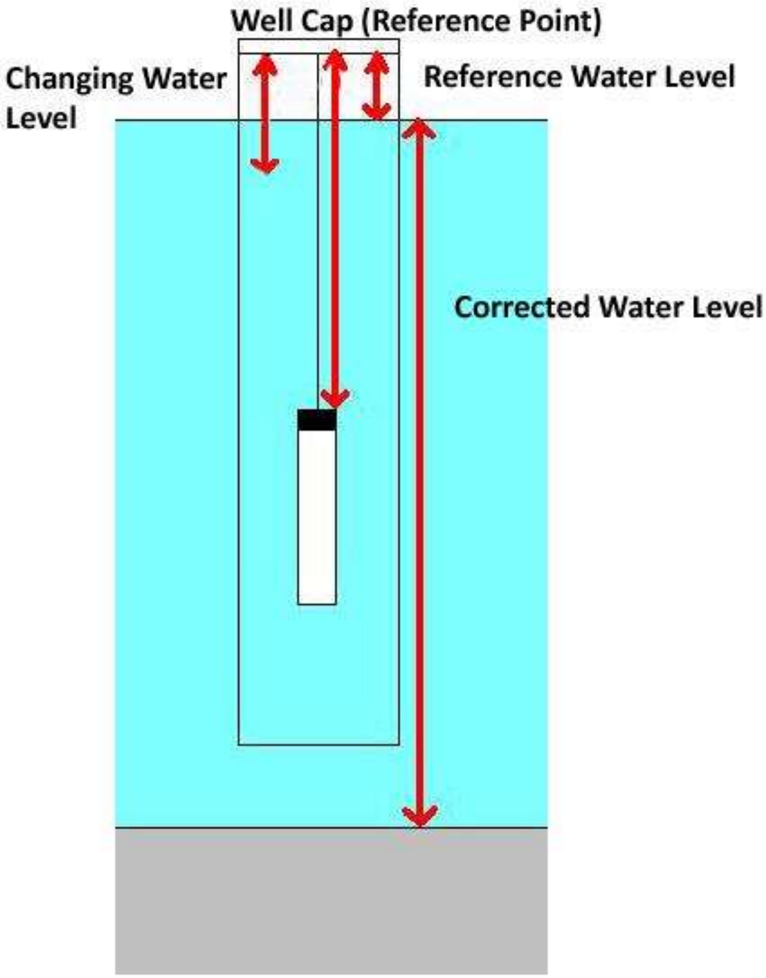

Fig 1. Collected field measurements and resulting measurements.

Phase 5: Retrieving the Data

- Measure the water depth using the original reference point.
  - This measurement is important for quantifying measurement error caused by manual measurement error, sensor drift, or change in suspension length and can be compared to calculated water level at the end of the plot.
- Record the date and time.

- Retrieve the data logger.
- Connect the logger to a computer (See **Phase 2: Connecting the Logger to a Computer**)
- Click on “Readout device” in the HOBOware toolbar.
- Select device “HOBO U20-001-01.
- Name a Text file for data storage.
- Double click on “Barometric Compensation Assistant”
    - Provide fluid density information by choosing water type (fresh, salt, brackish). It can also be manually entered, but really does not significantly affect the results.
    - Provide a reference water level which is the distance between a reference point (most commonly sea level or the height of the well cap of the HOBO’s housing) and the water’s surface.
        - If the water level is measured downward from a reference point above the water’s surface, such as a well cap, enter the water as a negative number.
        - If the water level is measured upward from a reference point below the water’s surface, such as the water’s height above sea level, enter the water level as a negative number.
        - If you don’t use a reference water level, the resulting series data will contain values for absolute sensor depth. For the most accurate results, use a reference water level.
    - Upload the barometric data file that was collected from the HOBO that was deployed in the air. A constant barometric pressure could be used, but would result in less accurate data.
    - Click “Create a New Series.”
    - **IMPORTANT NOTE: The resulting water level data that is calculated is the distance between the reference point and the surface of the water. To calculate the water level from the ground to the water’s surface, the data has to be converted by subtracting the resulting water level data from the distance between the reference point and the bottom of the water body.**
- You can change the output of the units (m/ft).
- Click “Plot”.
- Export the data into an excel spreadsheet.

Notes

- NOAA Barometric Pressure and Weather Stations
- **http://cdo.ncdc.noaa.gov/qclcd/QCLCD?prior=N**

- Depth to logger measured from the bottom of the hole in the black cap to the end of the wire connected to the hook.
- After launching data logger, measure time to deployment to compensate for erroneous data.
- The logger should be allowed to come to full temperature equilibrium (approximately 30 minutes) before the reference level is recorded.

Vegetation structure and benthic macroinvertebrate data sheet

Tidal Marsh Vegetation and Invertebrate Quadrat

Site: ______________________ **Field Crew:** ______________________

Date: ______________________ **Time:** ______________ **Date of Last Rain:** ______________________

Monitoring Year: (circle one) Pre 1st 2nd 3rd 4th 5th Other **Marsh Status:** (circle one) Pre-Existing Restored **Transect Photos Taken? (Y/N) Corner and Direction:** **Quadrat Photo Taken? (Y/N)**

Location according to site plan: (circle one) LM / HM / Transition

Transect ID: (circle one) 1 2 3 4 5 6 7 **Plot ID:** (circle one) a b c d e f **Transect Meter Mark:** ______ m **Quad Meter Mark:** ______ m

Vegetation Data:

Species	Percent Cover (%) in $1.0m^2$	# of all Stems in $0.25m^2$	# of Flowering Stems in $0.25m^2$	Basal area (cm) 5 random (1st year only)	Notes: Condition of vegetation, signs of disease, herbivory, etc.
Spartina alterniflora				/ / / /	
Distichlis spicata				/ / / /	
Spartina patens				/ / / /	
Iva frutescens				/ / / /	
Salicornia (sp.)				/ / / /	
Suaeda sp.				/ / / /	
Atriplex sp.				/ / / /	
Ulva sp.				/ / / /	
Phragmites australis				/ / / /	
Litter					
Bare Ground					
Wrack					
Other:				/ / / /	
Other:				/ / / /	
Other:				/ / / /	

***Spartina alterniflora* data:**

Heights & Stem Diameter in $0.25m^2$ (select 5 random stems)				
Stem #	Leaf Height (cm)	Stem Height (cm)	Inflorescence Height (cm)	Diameter @ 1/4 stem height (mm)
Stem 1				
Stem 2				
Stem 3				
Stem 4				
Stem 5				

Benthics Data

Species	Common Name	# of live Individuals in each $0.25m^2$				Lengths of 5 random mussels (cm) in $1.0m^2$					# of burrows in each $0.25m^2$			
Geukensia demissa	Ribbed Mussel													
Uca sp.	Fiddler Crab													
	Snails													
Other:														

Surface condition: (circle one) eroding; gullying; neither; other

Visual Assessment: Survey data collected (Y/N) ______ **Elevation according to site plan:** ______________ (ft)

Soil Sample Taken (1 per quadrat to 10 cm depth in center of NE 0.25m2 section of quad)? (Y/N)

Comments on overall site conditions:

Note % survival of Plants, Use sections of fencing to distinguish areas (note if <85%)

Appendix G. Example Data Sheets

Plant aboveground biomass data sheet (sample processing)

				Entered By:		Date Entered:	
				People Who:		Date Samples Were:	
Plot	Site	Bag Weight (g)	Dry Weight (g) (bag+sample)	Collected	Weighed	Collected	Weighed
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

Plant belowground biomass data sheet (sample processing)

						Entered By:		Date Entered:	
						People Who:		Date Samples Were:	
Plot	Site	Live Bag Weight (g)	Live Dry Weight (g) (bag+sample)	Dead Bag Weight (g)	Dead Dry Weight (g) (bag+sample)	Collected	Weighed	Collected	Weighed
1									
2									
3									
4									
5									

Appendix G. Example Data Sheets

Tidal channel stability monitoring data sheet (width and depth)

Date:
Time:
Low Tide:

Site Name:
Team:

Animals:

Creek Point ID	CreekWidth(m)	Midpt Length(cm)	Midpt Depth (m)	Left Length(m)	Left Depth(cm)	Left Slope	Right Length(cm)	Right Depth(cm)	Right Slope	Creek Bottom Depth (m)	Creek Bottom Length (m)	Substrate	Erosion

Substr: Peat, Sand, or Fill

Erosion: Undercutting, Slumping, Calving, Terracing
Built or Non-Natural Material

Appendix G. Example Data Sheets

Tidal channel edge vegetation/erosion pin monitoring data sheet

Date: Site Name: Animals:
Time: Team:
Low Tide:

T1a	HM/LM/UP	T1b	HM/LM/UP	T1c	HM/LM/UP	T2a	HM/LM/UP	T2b	HM/LM/UP
Species	%Cover	Species	%Cover	Species	%Cover	Species	%Cover	Species	%Cover
PHAU		PHAU		PHAU		PHAU		PHAU	
SPAL		SPAL		SPAL		SPAL		SPAL	
SPPA		SPPA		SPPA		SPPA		SPPA	
DISP		DISP		DISP		DISP		DISP	
IVFR		IVFR		IVFR		IVFR		IVFR	
SAEU		SAEU		SAEU		SAEU		SAEU	
JUGE		JUGE		JUGE		JUGE		JUGE	
ATPA		ATPA		ATPA		ATPA		ATPA	
BAHA		BAHA		BAHA		BAHA		BAHA	
Unveg		Unveg		Unveg		Unveg		Unveg	
CRK/Dit		CRK/Dit		CRK/Dit		CRK/Dit		CRK/Dit	
WRK		WRK		WRK		WRK		WRK	
GRB		GRB		GRB		GRB		GRB	
Litter		Litter		Litter		Litter		Litter	
Mussels		Mussels		Mussels		Mussels		Mussels	
PAN/Pool		PAN/Pool		PAN/Pool		PAN/Pool		PAN/Pool	
VegDist cm						VegDist cm			

T2c	HM/LM/UP	T3a	HM/LM/UP	T3b	HM/LM/UP	T3c	HM/LM/UP	T4a	HM/LM/UP
Species	%Cover	Species	%Cover	Species	%Cover	Species	%Cover	Species	%Cover
PHAU		PHAU		PHAU		PHAU		PHAU	
SPAL		SPAL		SPAL		SPAL		SPAL	
SPPA		SPPA		SPPA		SPPA		SPPA	
DISP		DISP		DISP		DISP		DISP	
IVFR		IVFR		IVFR		IVFR		IVFR	
SAEU		SAEU		SAEU		SAEU		SAEU	
JUGE		JUGE		JUGE		JUGE		JUGE	
ATPA		ATPA		ATPA		ATPA		ATPA	
BAHA		BAHA		BAHA		BAHA		BAHA	
Unveg		Unveg		Unveg		Unveg		Unveg	
CRK/Dit		CRK/Dit		CRK/Dit		CRK/Dit		CRK/Dit	
WRK		WRK		WRK		WRK		WRK	
GRB		GRB		GRB		GRB		GRB	
Litter		Litter		Litter		Litter		Litter	
Mussels		Mussels		Mussels		Mussels		Mussels	
PAN/Pool		PAN/Pool		PAN/Pool		PAN/Pool		PAN/Pool	
		VegDist cm						VegDist cm	

0-1%	0.50%	25-50%	37.50%
1-5%	2.50%	50-75%	62.50%
5-12.5%	8.75%	75-100%	87.50%
12.5-25%	18.75%		

Appendix G. Example Data Sheets

Surface Elevation Table monitoring data sheet

SURFACE ELEVATION TABLE (SET) DATA   Site____________________   Arrival time____________
Date___________________   Departure time____________

Marsh ______________________ SET # ___ Date________________ Start time______				
Direction	Pos _	Pos _	Pos _	Pos _
Bearing	______ Degrees	______ Degrees	______ Degrees	______ Degrees
Pin 1				
Pin 2				
Pin 3				
Pin 4				
Pin 5				
Pin 6				
Pin 7				
Pin 8				
Pin 9				
SET recorder:		SET reader:		
SET observer(s):			Low tide time:	

Marsh ______________________ SET # ___ Date________________ Start time______				
Direction	Pos _	Pos _	Pos _	Pos _
Bearing	______ Degrees	______ Degrees	______ Degrees	______ Degrees
Pin 1				
Pin 2				
Pin 3				
Pin 4				
Pin 5				
Pin 6				
Pin 7				
Pin 8				
Pin 9				
SET recorder:		SET reader:		
SET observer(s):				

Appendix G. Example Data Sheets

Marker Horizon monitoring data sheet

Sample Data Book Entries			
Plot	Readings(cm)	#Slices/Cores	Quality/Notes
Core 1a	0.4, 0.2, 0.2, 0.3	1	good layer
Core 1b	1.2, 1.1, 2.0, 0.6	1	good layer
Core 1c	2.5, 3.3, 2.4, 2.3	2	poor layer—watery
Core 1d	No data (blank)		
Core 2a	0.0, 0.0, 0.2, 0.0	1	feldspar at surface
Core 2b	Not found	3	could not find marker
Marsh ________________Date: ________________ SET #______			
Plot	Readings (cm)	#Cores	Quality/Notes
Core 1a			
Core 1b			
Core 1c			
Core 1d			
Notes			
Marsh ________________Date: ________________ SET #______			
Plot	Readings (cm)	#Cores	Quality/Notes
Core 2a			
Core 2b			
Core 2c			
Core 2d			
Notes			
Marsh ________________Date: ________________ SET #______			
Plot	Readings (cm)	#Cores	Quality/Notes
Core 3a			
Core 3b			
Core 3c			
Core 3d			
Notes			

Boat wake staff gauge monitoring data sheet

Date:				Tide:		Field Staff:
Start Time				End time		
Weather						
Event	Time	Resting Height (ft)	With Wave (ft)	Wave Height (ft)	Notes	

Adaptive management site inspection form

Quarterly Inspection, [DATE]

[SITE NAME], [BOROUGH/CITY], [STATE]

Inspected by:____________ Inspection date:____________________

Temperature/Weather/Tide (at time of inspection):____________________

Recent Significant Weather Events (e.g. Nor'easter):__________________

If Yes, Date(s), Describe:_______________________________________

Wetland Area Condition	S or U*	Corrective Action	Comment
Debris accumulation—logs and floatables			
Stressed, damaged, or missing plants			
Erosion			
Storm/wave/tide damage			
Herbivory damage			
Undesirable invasive or non-native plant growth			
Vandalism			
Other			
Vandalism			
Boardwalk, signs, benches			
Other			

*S=Satisfactory; U=Unsatisfactory; TBD=To Be Determined

Inspector Signature:_________________________________

Inspector Name:____________________________________

Contact Information:____________________ (e-mail) or ______________(office phone)

Inspection date: ___________________

NOTE - Inspections must be conducted by a qualified environmental professional.

Strategies for Assessment and Restoration of Resilient Urban Tidal Wetlands

Quality Assurance Project Plan

New York City Department of Parks & Recreation

Version: 3.0

Prepared by: Christopher Haight, Project Manager, Rebecca Swadek, Plant Ecologist, Marit Larson, Director of Wetlands and Riparian Restoration, New York City Department of Parks & Recreation, Natural Resources Group

Prepared for: United States Environmental Protection Agency, Region II

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<u>Project Management</u>

1.1 Quality Assurance Project Plan Approval Sheet

Project Title: Strategies for Assessment and Restoration of Resilient Urban Tidal Wetlands

Organization name: New York City Department of Parks & Recreation

Effective date:

Approval:

Project Start Date:

Project End Date:

Project Manager: ________________________________ Date: ________
Christopher Haight, Project Manager
NYCDPR Natural Resources Group

________________________________Date: ________
QA Officer: Marit Larson, Director
NYCDPR Natural Resources Group

EPA Project Officers:

________________________________ Date: ________
Kathleen Drake
EPA Wetland Protection Team, USEPA Region 2

EPA QA Officers: ________________________________ Date: ________
Carol Lynes
EPA Region 2

1.2 Distribution List

Name of Organization	Representative	Email

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NWIFC	Leah Beckett*	lbeckett@nwifc.org

*Technical review committee for methodologies and study design.

1.3 Project/Task Organization

NYCDPR Natural Resources Group (NRG) is adapting the Site Specific Intensive Monitoring (SSIM) protocol to evaluate the condition and function of restored salt marshes in New York City. The SSIM Quality Assurance Project Plan (QAPP) was developed and approved in 2014 under NRG's EPA Wetlands Program Development Grant (US EPA/NYCDPR 2012 WPDG). NRG will implement this QAPP through training and supervision by NRG and Natural Areas Conservancy (NAC) staff who developed and implemented the SSIM protocol. In addition, NRG and NAC staff are implementing a salt marsh wide vegetation monitoring protocol called the Natural Area Conservancy Salt Marsh Assessment (NACSMA) which was conducted for the past two summers in NYC salt marshes, and which will be included in this QAPP. The roles and relationships of the main partners and project managers for the assessment are summarized in Figure 1 and identified below. The principal investigators responsible for scientific guidance and analysis are Marit Larson, Rebecca Swadek, and Christopher Haight.

Project Managers

Marit Larson, Director of Wetlands and Riparian Restoration, New York City Department of Parks & Recreation, Natural Resources Group. Larson is overseeing the work of the project manager and project team and directing development of the overall strategy for the marsh assessment project. She also enforces quality assurance practices in the field and checks QA of the data in the office. She does not directly collect or use the data. It would be ideal if the QA Manager did not oversee those collecting and working with the data, however it is not feasible for a separate individual to serve as QA Officer.

Christopher Haight, Project Manager, New York City Department of Parks & Recreation, Natural Resources Group. He is managing the project logistics, grant management, and reporting. He also developed the restored salt marsh assessment protocols and is leading the field team that is collecting the field data, enforcing quality assurance practices in the field, and processing and analyzing the data collected.

Rebecca Swadek, Plant Ecologist, New York City Department of Parks & Recreation. She is managing the NRG spatial data for QA, specifically the restored marsh loss trends analysis and NRG generated shapefiles and associated metadata.

<u>Collaborator – Subawardees and Associates:</u>
Helen Forgione, Senior Project Manager, Natural Areas Conservancy, is a partner of the NYCDPR Natural Resources Group and is leading the Natural Areas Conservancy marsh-wide ecological assessment for New York City and advising on the other aspects of the restoration site assessments for the city.

<u>State Partners:</u>
New York State Department of Environmental Conservation Region 2: Steven Zahn, Deputy Regional Director

<u>Federal Partners:</u>
US EPA Region 2: Kathleen Drake, Wetlands Protection Team, is managing the EPA grant funding this work, and a reviewer of the QAPP.
US EPA Region 2: Carol Lynes, EPA QA Officer, is the reviewer of this QAPP from EPA.

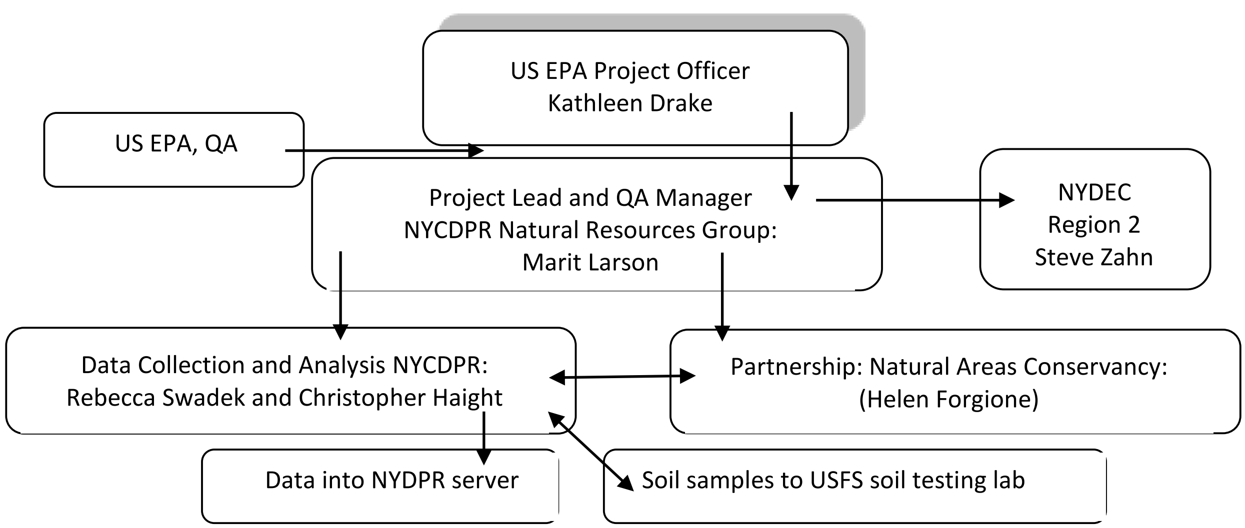

Figure 1: Organizational chart for this project.

1.4 <u>Problem Definition/Background</u>

1.4.1 Problem Definition

The NYC Department of Parks & Recreation Natural Resources Group (NRG) has received an EPA Wetlands Program Development Grant to study restored NYC salt marsh systems. The objective of this project is to quantify ecological conditions and functions in restored marshes of varying types and ages in order to: (1) compare restoration projects to one another and to existing non-restored salt marshes; (2) develop salt marsh restoration design guidelines to take into account sea level rise and climate change; (3) review and refine monitoring guidelines for restoration projects. NRG will develop a monitoring protocol for quantitative sampling of representative functional metrics that will allow for statistical comparison between marshes on NYC Parks property that have been restored in the last 20 years and existing non-restored marshes in NYC. "Restored" in this project is defined as a degraded wetland that has been improved through fill, debris, and/or invasive plant removal and planting with native species, having a minimum 85% cover of vegetation 3 years after restoration work is complete, as per the New York State restoration contract requirements. This work will help inform NYC's Wetland Strategy and the Hudson Raritan Estuary Comprehensive Restoration Plan (CRP), as well as NYC's efforts to increase the climate resilience of its natural shoreline systems under The Special Initiative for Resiliency and Recovery and some elements of Mayor de Blasio's OneNYC plan. We aim to collect information that can help us understand the conditions and functions of restored sites and how best to increase resiliency of these and future restoration sites using the most effective strategies.

From 2013-2014, the NYC Department of Parks and Recreation Natural Resources Group (NRG) conducted an ecological assessment of salt marsh conditions across New York City, with funding from an EPA WPDG, focusing on 25 of the largest salt marsh complexes. Over the course of this study, it became clear that the conditions assessment was missing an opportunity to also assess the condition of restored wetlands. The protocol to assess conditions at naturally occurring salt marshes needed to be modified slightly for restored salt marshes. This QAPP will focus on protocols to assess restored salt marshes on NYC Parkland to both include them in the city-wide assessment of salt marsh condition and to use this information to help inform future salt marsh restoration design.

1.4.2 Background

Historically, over 90% of salt marshes in NYC have been lost or filled. The remaining approximately 4,000 acres[1] of salt marshes in NYC play a significant role in the regional ecology, habitat and biodiversity. However, our tidal wetlands are steadily declining in area due to sea level rise (SLR), development, encroachment, nutrient overloading and other factors[2]. Preliminary evidence indicates that salt marsh area has been decreasing at a rate of 1-2% a year since 1974 for a total loss of around 160 acres from NYC Park's fringe marshes.[3] NYC salt marshes are critical to maintaining populations of marsh-dependent plants and animals in New York State and regionally, including over 40 animal species that are targets of the New York State Wildlife Conservation Plan, such as the Seaside Sparrow and Diamondback Terrapin. The NYSDEC has designated NYC tidal wetlands as *Significant and Sensitive, Significant Coastal Fish and Wildlife Habitat* and as *Special Natural Waterfront Areas* in acknowledgement of the value of these marshes to New York State.

---

[1] As mapped by the National Wetlands Inventory. NYSDEC 1974 Regulatory Tidal Wetland maps show approximately 3,750 acres of intertidal and high marsh in New York City.

[2] Deegan et al. 2012, USEPA, 2009, Hartig et al., 2002

[3] Hartig, et al. 2002; USEPA/NYCDPR 2012 WPDG

The most recent reports about New York coastal resources issued by the USACE, HEP, the US Department of the Interior, NPS, NYSDEC, and the City identify salt marshes as an important natural resource in NYC for which there is not adequate information on the extent and condition to ensure appropriate regulation, restoration, and protection. For example, the NY State Sea Level Rise Task Force Report to the Legislature in 2010 found that "existing maps of NY State's coast….are inaccurate, out of date, not detailed enough for planning…, and fail to incorporate historic and projected sea level rise." These documents also describe the need for better protecting and restoring coastal wetlands.

1.5 Project/Task Description

The Natural Resources group will modify the NACSMA and SSIM assessment protocols used in natural salt marshes as part of the 2012 EPA WPDG project. This modified protocol will include parameters and sampling approaches from both the natural salt marsh assessment protocols and the existing NYS restoration monitoring protocol, which will allow for comparison of data across projects from today and in the past. NRG will apply this protocol to restored sites with the objectives of: 1) comparing the conditions and function of restored marshes to one another and to existing non-restored salt marshes, 2) develop salt marsh restoration design guidelines that take into account sea-level rise and climate change.

Objective 1

Field data on the conditions and functions (Table 1) of restored and natural sites will be collected during the growing season and restored sites will be compared with one another and with naturally occurring sites using statistical analyses (ANOVA or non-parametric analysis TBD). The condition and function metrics/sampling methods being used in this assessment are important and common methods that have been used in other restoration studies from the literature and in past assessment by NYCDPR.

Table 1. List of sampling methods to be used to quantify the conditions and functions of restored and naturally occurring marshes

Function	Assessment Objective	Sampling Methods	References
Habitat – presence and use of marsh by plants and fauna	A. Characterize vegetation community	- Percent cover of vegetation and non-vegetation - Measure stem heights - Aboveground biomass	Bergen et al. 2000, Cole 2002, Neckles et al. 2002, NPS Protocol
	B. Count Fauna	- Ribbed mussel counts - Fiddler crab burrow counts	Staszak & Armitage 2013, Jordan & Valiela 1982, NPS Protocol
Marsh Structural Stability – resistance to erosion and maintenance of vegetated spatial extent (staying power)	C. Determine belowground biomass of *Spartina alterniflora*	- Root cores and processing for live and dead root dry weight	Deegan et al. 2012, Wigand et al. 2014, Valiela et al. 1976, NPS Protocol
	D. Characterize soil structure	- Bulk density - Organic content (loss on ignition) - Texture (clay, silt, sand)	Morgan et al. 2011, Deegan et al 2012, Wigand et al. 2014
	E. Characterize the change in	- Measure width of constructed tidal creeks	USEPA/NYCDPR 2012 WPDG

	vegetated extent of the restored wetland	- Conduct a marsh loss trends analysis of restored sites	

Sampling Design:

- Percent cover of vegetation and non-vegetation and fauna counts will be conducted at 14 restored sites across the city in June and July (Figure 2).
- Percent cover, stem heights, fauna counts, above and belowground biomass, and soil cores will be collected from 8 additional restored sites and at 6 reference sites in August and September (Figure2).

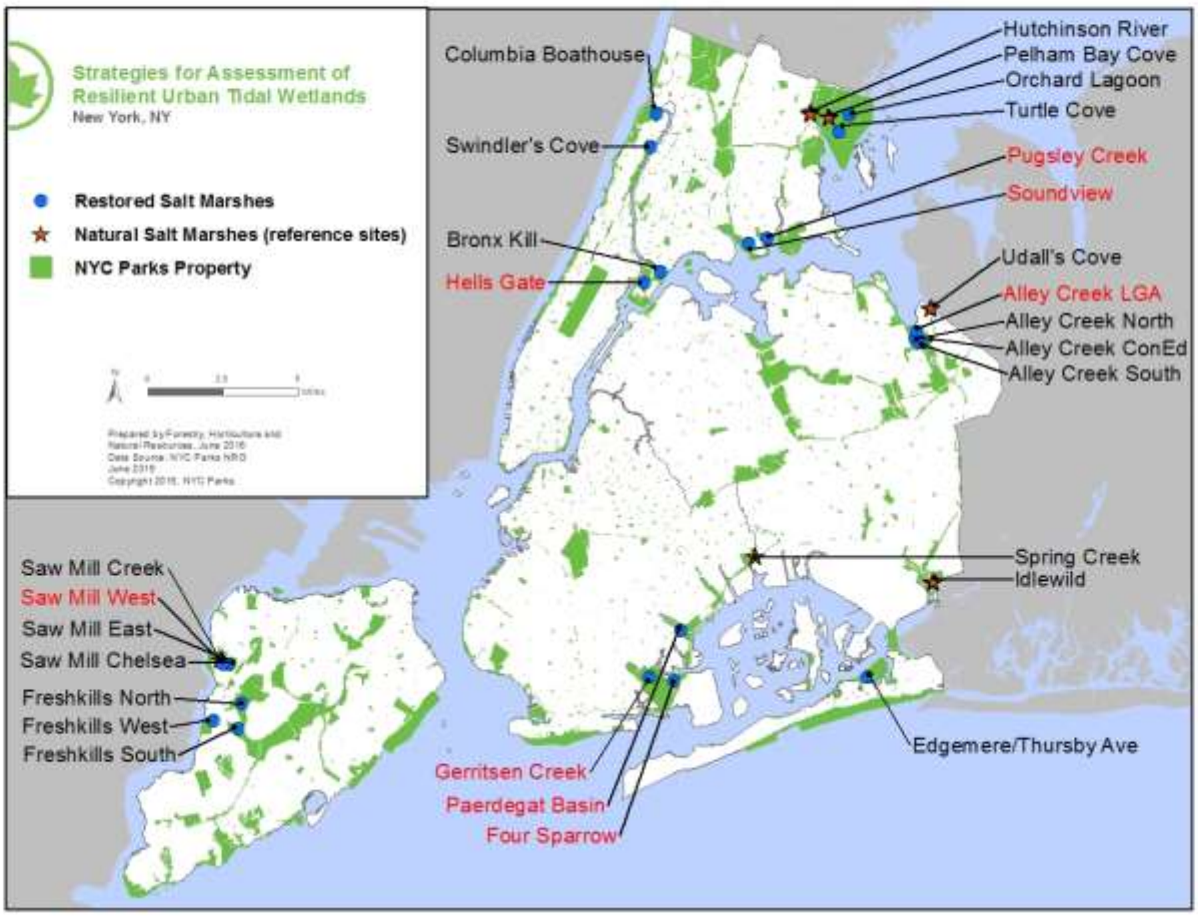

Figure 2. Location of A) 14 restored sites to be assessed for the percent cover and fauna in June and July (blue symbols labeled in black), B) 8 restored sites to be assess for percent cover, stem height, fauna, above and belowground biomass, and soil characteristics in August and September (blue symbols labeled in red), C) 6 reference sites to be assessed for percent cover, stem height, fauna, soil characteristics and above and belowground biomass (star symbols).

Objective 2

Each salt marsh restoration project in New York City was designed and constructed based on different parameters. This project will use multiple mixed models to evaluate how these different parameters influence the condition and function of these restored sites. Specifically the mixed models will be used to determine which restoration design parameters are the best predictors of the ecological data collected at these sites. The field data collected during this study will serve as the response variables in the mixed models and the different restoration design parameters will serve as the predictor variables (Table 2).

The restoration parameters being examined in this assessment are important and common parameters that have been shown to influence condition and function in other restoration studies from the literature and anecdotally from the knowledge of NYCDPR staff (see Table 2 footnotes).

The project timeline is located in Appendix IV.

Table 2. List of the response variables and predictor variables (fixed and random) that will be used in the mixed models to compare across restored sites.

<table>
<tr><th>Response Variables</th><th>Predictor Variables</th><th>Description</th></tr>
<tr><td rowspan="13">Habitat Metrics
Vegetation community
- Percent cover
- Stem height
- Aboveground biomass
Fauna counts
- Ribbed mussels
- Fiddler crab burrows
Marsh Structural Stability Metrics
Belowground biomass
Soil characteristics
- Bulk density
- Organic content
- Texture (clay, silt, sand)
Change in marsh extent and tidal creeks</td><td colspan="2">Fixed Effects</td></tr>
<tr><td>Substrate[4]</td><td>Restored by planting into added clean sand or restored by planting into native soils (no added sand)</td></tr>
<tr><td>Exposure[5]</td><td>Site located in the interior of a marsh (landlocked or not on a major channel), on the shore on a tributary, or on an open water shoreline</td></tr>
<tr><td>Planting Elevation[6]</td><td>Elevation at which plants were planted relative to the Mean High Water (MHW) elevation</td></tr>
<tr><td>Channel Metrics[7]</td><td>Constructed channel density (channel length by area)</td></tr>
<tr><td>Year Completed</td><td>Year in which construction of site was completed</td></tr>
<tr><td>Age</td><td>Number of years that have passed since the restoration construction was completed</td></tr>
<tr><td>Size[8]</td><td>Area in acres</td></tr>
<tr><td>Existing Fringing Shoreline</td><td>Whether or not there is a preserved salt marsh fringing shoreline adjacent to the restoration</td></tr>
<tr><td colspan="2">Random Effects</td></tr>
<tr><td>Borough</td><td>Borough of NYC where site is located (Bronx, Manhattan, Queens, Brooklyn, Staten Island)</td></tr>
<tr><td>Waterbody</td><td>Major waterbody where site is located (Long Island Sound, East River, Jamaica Bay, Arthur Kill)</td></tr>
<tr><td>Lead Agency</td><td>Agency that lead the restoration planning and completion</td></tr>
</table>

[4] Barko et al 1977
[5] Bergen et al. 2000
[6] Neckles et al. 2002, Bergen et al. 2000
[7] MacBroome 2012
[8] Monero-Matoes et al. 2012, Neckles et al. 2002

	Park	The NYC Park in which the site is located

1.6 Quality Objectives and Criteria for Measurement Data

The project quality objective is to collect accurate and precise data in order to determine the condition and function of restored and natural wetlands in New York City. A goal of this project is to take field data and accurately transfer it to a computer database without error. This will be accomplished by following through with established quality assurance checks throughout the project. These checks will include checking of data sheets in the field before leaving a study site. The field team leader and one other team member will independently inspect field data collection sheets to ensure that all fields are filled in. Team members who collect raw data will be required to sign the bottom of each field sheet to signify that they have verified that all data has been recorded for that site.

Following data entry, a data entry check will be made (once per dataset) by a non-interested party of 10% of the data once it is in digital format to ensure that the data were entered correctly. If any errors are identified, a full comparison will be made between the raw data sheets and the digital dataset. Quality checks will be documented by the non-interested party by signing with his/her name, initials, date and documenting which data they have specifically checked on the last page of the field data sheet in which they have QC'ed.

Where we are using newly prepared field protocols and study designs, they will be reviewed by a technical committee (see distribution list) of non-interested wetland scientists. The field team will consist of trained individuals and will always include the same staff scientist to ensure consistency across all estuary sites.

Only by being precise in our acquisition of data from the field, will the data be able to be compared throughout this study. This study acknowledges that wetlands are a living environment and that the strength and rigor of resulting data will depend on numerous repeated measures in time and space across the larger system.

We also aim to link this monitoring program together with other tidal marsh monitoring efforts in MACWA and the nation.

Precision

Precision is the measure of the degree to which two or more measurements are in agreement. Precision is assessed through the collection and measurement of field replicates. Every tenth sample quadrat for vegetation and fauna, every fifth sample of soil and belowground biomass, and each candidate predictor variable (Table 2) will be assessed twice to ensure accuracy. Relative Percent Difference (RPD) shall be calculated for each of the replicates collected for all the parameters analyzed. Precision in the laboratory is assessed through the calculation of RPD for matrix spikes and matrix spike duplicates and of the field split samples. An error tolerance of ±5% , expressed in units corresponding to each parameter, will be acceptable. In addition, after every five restoration sites sampled, a previously sampled site will be sampled a second time so that field staff as well as QA staff and experts from the wetlands office at NYC Parks can assess the precision, accuracy, and bias of the field crews measurements and calibrate measurement techniques before continuing sampling at the next restoration site.

RPD is calculated using the equation from Stribling 2011, $RPD = [|A - B| / ((A+B)/2)]*100$

Where:
A = measurement value (% cover, count, height, etc.) of original sample
B = measurement value (% cover, count, height, etc.) of duplicate sample

Accuracy
Accuracy is the degree of agreement between an observed value and an accepted reference value. However, for the planned monitoring there are no established reference methods. For new condition or functional measures for which there are no established benchmarks (i.e. for high versus low condition), we will assess the relative differences among the sample population and thereby begin to establish ranges for estimation of base accuracy for true condition. As data are collected for various groups of salt marshes (based on adjacent water body), the highest scoring values will be considered as high references and the lowest scoring values will be considered as low references. The range between the two should be broad enough to define the full gradient, per metric.

Accuracy in the field will be assured by the ability of the measures to yield values that best represent the true values, as determined by a weight of evidence approach using data from similar measurement techniques used in the region from literature and our own measures from past projects. In addition, after every five restoration sites sampled, a previously sampled site will be sampled a second time so that field staff as well as QA staff and experts from the wetlands office at NYC Parks can assess the precision, accuracy, and bias of the field crews measurements and calibrate measurement techniques before continuing sampling at the next restoration site.

Bias
Systematic or persistent distortion of a measurement process causing errors in one direction (bias) is not anticipated in this analysis. Data collectors will be trained to be objective and only record true observations. All personnel who will participate in collecting data must pass an annual field team audit. In addition, after every five restoration sites sampled, a previously sampled site will be sampled a second time so that field staff as well as QA staff and experts from the wetlands office at NYC Parks can assess the precision, accuracy, and bias of the field crews measurements and calibrate measurement techniques before continuing sampling at the next restoration site. During this process individual staff measurements will be compared to check for bias.

Repeated measures by different teams (e.g., for 10% precision tests) will ensure that the results are not biased by any individual or team. Some of the new field metrics being developed will require this repeated measures approach (using different field teams to reassess the same metric) to examine the level of bias, which will be evaluated to the best of our ability. Any adjustments that are deemed necessary to reduce bias will be refined during field season by the NRG workgroup, and any appropriate changes will be incorporated to reduce bias. If and when acceptance criteria are revised or established, the QAPP will be revised to include those criteria. In addition, the final report will describe the manner in which bias was evaluated for the project.

Representativeness
Representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. Representativeness is dependent upon the proper design of the

sampling program and will be satisfied by ensuring that the sampling and analysis plan is followed and that proper sampling techniques are used. To avoid jeopardizing the representativeness the study design will select sites and plot locations at random within the study area and from the known information that is available, thus representativeness in this project is limited to populations of known restored sites in NYC and the information that is available for them.

Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount of data that was expected to be obtained under normal conditions. Field completeness is a measure of the amount of valid measurements obtained from all the measurements taken in the field.

Completeness will be assessed for all field data and lab data. Completeness will be calculated as the ratio of the number of valid sample results or field observation records to the total number of samples or field observation records. Following completion of all data collections for a given station sampling or project, the percent completeness will be calculated by the following equation:

$$Completeness = (V/P) \times 100$$

Where:
V = Number of valid samples or field observation records.
P = Number of planned samples or field observation records.

Comparability

Comparability is an expression of the confidence with which one data set can be compared with another. Comparability is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the field sampling plan is followed by all personnel and that proper training and measuring techniques are used consistently. Resulting data will be determined to be comparable when similar sampling and analytical methods are used, documented in the QAPP, and when assessment data outcomes for similar types of assessments within the sample frame yield similar condition or functionality results. Comparability is also dependent on similar QA objectives. Data from this project will be compared to data collected using similar methods for the 2012 EPA WPDG. During the sampling period field crews will periodically review the protocol and the QAPP to be reminded of the necessary QA steps during field sampling, and the QA manager or similar field sampling expert will accompany the field staff at random sampling events to observe and discuss the quality of sampling.

Sensitivity

The sensitivity for each analytical metric can be found in the appropriate SOP (see Appendix III). For field measurements, if the location of the sample plot does not fall within the correct habitat type of each parameter then the sample point will not be used in the analysis (e.g. if a plot falls in an area that inherently will not have vegetation or fauna such as a tidal creek or mudflat). Alternatively, when the location of a sample plot is in the appropriate habitat type all relevant parameters will be measured and any absences will be recorded as zero and not discarded. Limitations and challenges to field observations include field staff's ability to identify species that are cryptic/rare/ or similar to other species, as well are accurately assessing plots with very high or low densities. For lab samples if the minimum concentration cannot be measured that specific sample will not be used in analysis. If it is determined that a sampling protocol is not capturing a majority of samples then the metric will be reevaluated by the NRG group.

GPS Unit Accuracy

The GPS unit being used is the Trimble GeoExplorer GeoXT 2008 series handheld using a radio antenna connected to the unit. This GeoXT handheld uses EVEREST multipath rejection technology to provide sub-meter accuracy.

1.7 Special Training Needs/Certification

Special training is needed to execute the measurements associated with the assessment protocols. These include:

- Overview of the wetland monitoring program
- Botanical, soil, hydrological and other field survey skills
- Identification of wetland stressors
- Proficiency in field sampling, sample processing, and data collection procedures
- Proper completion of data forms
- Quality assurance skills
- Safety and first aid procedures

Christopher Haight (Natural Resources Group), project manager, will ensure that project staff are properly trained and have the proper skills to conduct this work. The training will consist of reviewing and discussing the protocol prior to going out in the field, gathering, organizing, and reviewing equipment and how it will be used in the field, and conducting test sampling by conducting a full run through of the protocol at a test site prior to beginning official sampling. Staff must complete the full protocol at a site prior to official sampling. Staff will also be provided with digital and hard-copies of the protocol and QAPP for review and reference during the field sampling period.

1.8 Reporting, Documents, Records & Reports to Management

Field log books will be kept for all field activities. The field log will include observations about the weather, what site was sampled, which data and metrics were collected that day, and exact latitude and longitude to be later put into GIS.

GPS coordinates will be taken at the location of soil samples taken. GPS points taken will assist with tracking the relative location of field samples taken, but will not be expected to be used to find the exact location. GPS points will also be taken to field verify the existing boundary of the restored sites, specifically on waterward edges. All points will be taken with a Trimble GeoXT.

Field data sheets (See Appendix I) will be filled out in the field along with the log book. If a log book is used to record data the following will be present at the top of each page: staff present, marsh complex and date. All field data sheets, including data sheets, maps, and field notebook notes, will be scanned in and entered on the NRG internal network drive at the end of each day upon returning from the field.

All data entered on the GPS unit will be checked in and checked out in ArcGIS at the beginning and end of each day. Data will be saved on the NRG internal network drive.

All data collected will be organized and tracked by NRG, and will be shared with NAC after QA/QC procedures have been followed.

NRG will review data and reports internally, and all raw and final data will be retained at the Manhattan, NY, offices of NRG. Electronic versions of all data will be backed up electronically every six hours on the NRG server for 10 years.

A final report will be prepared for this project in a legible font and font size. This will describe methods and results, summarize any field and lab data, report about the field audit, and include copies of the field log and data sheets. Data obtained from this project is also expected to be furnished to the public after QA review in reports and web-based information products. The PI's and key partners might also draft manuscripts for submission to peer review journals. Electronic formats of data will include MS Excel files, MS Word documents, MS Access files, shapefiles, csv files, and jpgs.

All data and reports will include information as to the appropriate project name, revision number, date of publication, number of pages, and contact information of the project manager.

Marit Larson (QA manager and Director of NRG Wetlands Team) will ensure that all data (hard copy and electronic) is stored at NRG for a period of not less than 10 years after the conclusion of the project.

Monitoring and Assessment data will be in the following documentation:

- Field data sheets
- Field log books
- Field validation sheets
- Site maps
- Sample preparation notes
- Laboratory analysis reports
- QC checks of laboratory results
- Calibration of instrument results
- Instrument printouts
- QAPP reports
- Computer database of field data
- Computer files of background papers and reports
- Yearly Reports
- Final Report

The field team and project manager will be responsible for compiling all assessments. The project manager will write these reports and provide them to the Director of Wetlands and Riparian Restoration and technical advisors for review. In any annual progress reports that are prepared for the EPA, this compellation will be included.

2 Data Generation and Acquisition

2.1 Sampling Process Design/Monitoring Process Design (Experimental Design)

Salt marshes of New York City, both natural and restored, exist in close proximity to densely populated communities within the most densely populated city in the United States. Ecological data are needed to understand how these marshes function, the influence of restoration design parameters on those functions, the impacts of urban stressors, and whether they will be resilient to future stressors, questions that still have a limited amount of data to answer them. The aims of this restored site assessment are to address these unknowns.

Metrics were developed based around specific questions and objectives that have been identified as proxies or indicators of important functional features and processes of New York City wetlands. These functions include the provision of suitable habitat for plants and animals, and structural stability or the ability to maintain a physical and vegetated extent. The associated metrics include percent cover of vegetation and non-vegetation, stem heights, above and belowground biomass, fauna counts, soil characteristics, and estimated waterward loss since restoration was complete (Table 1). There will also be an evaluation of the influence of restoration design parameters on these functional metrics. Design parameters include, substrate type, level of exposure, planting elevation, channel construction, and others (Table 2).

The study design establishes a network of sites in representative salt marsh subpopulations of the City. These sites are intended to represent the diversity of prevailing conditions and restoration design parameters as well as differing inherent conditions such as geomorphology and adjacent water body. A majority of the sites have been restored, however some natural or non-restored sites will be assessed as well to serve as references. The goal of this study is to better understand the current condition and function of restored salt marshes across Long Island Sound (Bronx and Queens), Arthur Kill (Staten Island), and Jamaica Bay (Brooklyn and Queens), and to update and create more comprehensive guidelines for future restoration and assessment.

The measurements and metrics to be used are considered standard. Use of standard metrics will ensure that useful data will be collected for comparative purposes to other historical and current data sources.

There will be two sets of sampling designs applied across the city, a simple sampling design, examining percent cover of vegetation and non-vegetation and fauna counts, will be applied to 14 restored sites across the city (Figure 2). A second more intensive sampling design examining above and belowground biomass, stem height and soil characteristics in addition to the same metrics as the simple design, will be applied to 8 restored sites and 6 reference or non-restored sites (Figure2). The number of sites and the sample sizes for field sampling were determined using a sample size calculator that determines the necessary sample size to meet a specified confidence interval (Table 3). A confidence interval of 20% and existing data collected using the same sampling methods as this study were used as input for the calculator. Using two sets of sampling designs allows for the inclusion of a greater number of restored sites, and it is expected that the more intensive data can be extrapolated to give an idea for the overall functional condition of restored salt marshes in New York City. Resulting data will aid decision making and priority setting regarding land use planning, climate adaptation planning, and fisheries management.

The array of sites is designed to fairly represent the subpopulations and to take advantage of past and ongoing monitoring data that exist in the vicinity of some of the stations. For example, NYC Parks and NAC collected percent cover data from 25 sites across the city and NYC Parks has also established long-term monitoring sites at the 6 reference sites being used in this assessment.

Percent cover and fauna count readings at the 14 sites will be collected in June and July, which is consistent with previously collected percent cover data from the 2012 EPA WPDG ecological assessment of natural salt marshes in NYC. The more intensive biomass sampling at the smaller set of restored sites and reference sites will be collected during peak growing season (August and September). The materials collected for biomass assessment will be processed in a lab at the USDA Forest Service Northern Research Station following field collection. Plant processing in the lab will be done following established protocols found in the literature and protocols used in the region (i.e. National Park Service).

Laboratory analyses of soil samples will be performed by a qualified partner with whom NYCDPR has a contract, such as USDA Forest Service. Soil samples or data will be delivered to USDA Forest Service Northern Research Station staff within hours of collection (per SOPs) for processing. Samples will be held for a minimum of 4 weeks to allow for air drying. They will then be sent to the processing lab to be analyzed.

Table 3. List of assessment factors and the number of plots/samples per site, total for 14 restored sites, and for additional 8 restored sites and 6 reference sites.

Factor	**Sample Size Per Site**	**Total Sample Size (14 restored)**	**Total Sample Size (8 restored)**	**Total Sample Size (6 reference)**
Percent Cover	30 plots	420 plots	240 plots	180plots
Fauna Counts	15 plots	210 plots	120 plots	90 plots
Aboveground Biomass	15 plots	NA	120 plots	90 plots
Stem Height	15 plots	NA	120 plots	90 plots
Belowground Biomass	5 cores	NA	40 cores	30 cores
Soil Characteristics	5 cores	NA	40 cores	30 cores

Experimental Design

Sites

Site locations were chosen from known wetland restoration projects that took place on NYC Parks property. Sites were selected so that they were representative of the waterbodies in NYC (Long Island Sound, Jamaica Bay, and Arthur Kill) and so that they include a diverse array of restoration design parameters. Sites with accessible design/construction maps were prioritized because important information can be determined from these maps. We understand that due to the limited amount of information available for these restoration sites that there may be some unexpected bias in focusing on sites with the most complete information, specifically bias in the fixed effects variables, however we believe the selected sites do represent a diverse array of restoration locations and agencies. We will document all of our research efforts for finding information on restoration projects. Maps provide a baseline footprint that can be used to determine where sampling should occur and to assess waterward loss since restoration completion. Other restoration parameters can be determined from these maps including level of exposure, planting elevation, channel construction, and size. The restored sites where biomass sampling will take place were selected from the same waterbodies as the 6 reference sites. Thus sites were selected so that they were representative of all restored sites across NYC and so that they are comparable to the reference sites.

The six reference sites are distributed across NYC and have been previously assessed for condition as part of our Site-Specific Intensive Monitoring (SSIM). These sites have existing data collected in 2014 on percent cover of vegetation and non-vegetation, stem heights, and bulk density, loss on ignition (organic content), and soil texture data from soil cores. These sites were selected as reference because they have existing data and they have previously established assessment areas detailed in the SSIM QAPP.

Restored study sites will be established in marsh areas where restoration took place (one continuous study area within restoration boundary per site). Reference sites are defined as a one acre area of continuous salt marsh vegetation surrounding the three surface elevation table locations: the area used in the SSIM study design. Plots will be randomly arrayed throughout the study sites.

Random Sampling Design

Sample spacing will be systematic with a random start and will depend on the size of the site and the calculated sample size. Plots will be located in a systematic grid design; the first transect location, forming the basis of the grid, is selected randomly. The subsequent plots will be spaced a set number of meters apart; however, given that grid lines are of varying length (i.e., the marsh is not a uniform width), when the end of one grid line is reached, the plot will fall on the following parallel grid line the remaining number of meters from the study area edge (i.e., upland or water) ("snaking around").

2.2 Sampling Methods/ Monitoring Methods

Overview of Objectives

The objective of this assessment is to understand the conditions and functions of restored marshes in NYC. The functions of habitat, or presence and use of salt marshes by plants and fauna, and marsh structural stability, or resistance to erosion and maintenance of vegetated spatial extent (staying power), will be examined. Habitat will be assessed by characterizing the vegetation community and counting fauna. Marsh structural stability will be assessed by determining belowground biomass of *Spartina alterniflora*, characterizing soil structure, and quantifying the change in the vegetated extent of the marshes since restoration was complete.

The methods for each of these objectives are described in detail below.

Habitat

A. Vegetation Community

Percent Cover:

Percent cover of vegetation and non-vegetation will be characterized at 30 – 1m^2 plots randomly placed across the restored sites. Each quadrat will be assessed using visual percent cover estimates to determine the cover of vegetation by individual species and non-vegetation (bare ground, plant litter, organic wrack, garbage, etc.) in each quadrat. Percent cover will be estimated be team members and midpoint of agreed-upon vegetation class (team members will come to a consensus on cover class for each species). Ecological Society of America cover classes will be utilized (Appendix 1A). Percent cover values will be averaged (n=30 per site) across sites to determine differences in vegetation communities. We are comfortable with averaging across all plots as most restoration projects focus on the restoration of low marsh or *Spartina* *alterniflora* habitat, however plot locations will be recorded with a GPS unit and plots can be averaged across gradients or transition zones if appropriate.

Stem height:

Stem height will be measured from a 0.25m^2 subplot in the same plots assessed for percent cover. Stem heights will be measured in 15 plots across each site. The stem height (measured from the stem base to the terminal leaf node) of 5 random *Spartina alterniflora* stems will be measured in each plot. Plant heights will be collected only at the smaller subset of restored sites in August and September. Data previously collected from the reference sites (SSIM) in the Fall of 2014 will be used to compare with the restored sites.

Aboveground biomass:

a. Aboveground biomass field sampling:

Aboveground biomass will be determined by clipping all aboveground live stems from 15 – 0.25m^2 subplots in the same plots where percent cover and stem height were measured. The collected plants will be stored in labeled sample bags and transported to the USDA Forest Service Northern Research Station for processing. Aboveground plant materials will be collected at both restored and reference sites.

b. Aboveground biomass sample processing:

The collected aboveground plant material will be cleaned of soils, dried in a drying oven at 80˚C for 24 hours and measured for aboveground dry weight. The aboveground dry weight per m^2 (n=15 per site) will be determined and compared across sites.

B. Fauna Counts

Fauna will be counted in 15 – 0.25m^2 subplots in the same plots where percent cover, stem heights, and aboveground biomass were collected. Ribbed mussels and fiddler crab burrows will also be counted in each quadrat. Presence of *Uca* or *Sesarma* crab species as well as snails or other invertebrates will be recorded when observed. Mussels, crab burrow, and snail counts are good indicators of habitat use because these species are commonly found in tidal wetland habitat and they serve as prey for other wildlife such as nursery and predatory fish, wading and nesting birds, and mammals. Fauna counts (n=15) will be averaged and compared across sites.

Marsh Structural Stability

C. Belowground Biomass

At each restoration and reference site, 5 cores of *Spartina alterniflora* roots will be taken at random from the same plots where the other metrics were collected. Cores will be processed to determine belowground biomass.

a. Belowground biomass field sampling:

The root material of an individual plant will be collected using a soil corer (8cm diameter and 10 cm depth). The sample will be placed into a labeled sampling bag, packaged in a cooler, and transported to the USDA Forest Service Northern Research Station for storage and processing.

b. Belowground biomass sample processing:

Each core will be cleaned of soil over a No. 10 (2mm) sieve to catch any plant material, live plant material will be separated from dead and the separated roots will be dried in a drying oven at 80˚C for 24 hours and measured for belowground dry weight at each depth. Belowground dry weights (n=5) will be averaged and compared across sites.

E. Soil Organic Content

At each restoration site, five soil samples will be taken at random across the site. A set volume of soil (8cm diameter and 10 cm depth) will be taken using a PVC corer for analysis of bulk density, loss on ignition (organic content), and soil texture. Soil samples will be placed into sealed ziplock bags in the field, packaged in a cooler and transported within 24 hours to the U.S. Forest Service for analysis. Soil properties will be averaged by site and compared across sites. Previously collected soils data from the reference sites (2014 SSIM) will be used to compare with the restored sites.

G. Marsh Loss Trends

A desktop analysis will characterize the change in the vegetated extent of the restored sites by comparing the planned or built extent of the restored site with the current/existing extent. The original extent of the restored marsh will be generated from acquired as-built or construction drawings. These documents will be georeferenced in ArcGIS using appropriate control points (street centerlines, buildings) and digitized at a 1:500 scale resolution. The current vegetated extent of the restored sites will be determined using 2012 post-Sandy aerial imagery (2014 imagery will be used if it becomes available) and field verified GPS points of the waterward edge (to be collected in the summer). The waterward marsh loss will be calculated in ArcGIS by performing a union analysis on polygons from past and current digitized vegetated extent of the restored sites. Polygons will be reclassified to reflect appropriate changes in the vegetated marsh (e.g. waterward or shoreline loss; creek expansion; tidal pool expansion; etc.).

H. Tidal Creeks

The desktop analysis will also examine the length and width of tidal creeks from as-built drawings when available. Widths will be measured at even intervals, which will be determined in the office from a desktop analysis prior to field data collection. Width of the tidal channel will be measured perpendicular to flow beginning and ending at the edge of vegetation on either side of the tidal creek. Depths will be measured at 1 foot intervals or at clear changes in slope across each cross section to discern slope of the tidal creek.

2.3 Field Quality Control

If problems arise in implementing the protocols in the field, these will be addressed by the project manager. If cell phone reception is accessible the project manager will call the Director of Wetlands and Riparian Restoration or project plant ecologist and discuss problems. If the director or plant ecologist cannot be accessed, the project manager and field team will use their best judgment and record any and all deviations from the methodologies. When the field team returns, the situation will be fully discussed with the director and plant ecologist, and any changes in protocol or sample points will be discussed. If any material changes in methods are needed, they will be fully disseminated to all field team members and the QAPP will be adjusted accordingly. Problems will be documented in the team field notebook and digitized upon return to the office. Problems that may be encountered include issues with equipment or site conditions that prohibit the ability of the field team to collect data, such an issue would be resolved by repairing or replacing equipment and/or re-scheduling field sampling when conditions have been remedied or improved.

NRG staff, and all project partners, will routinely clean field gear prior to leaving field sites to avoid unintentional dispersal of invasive species and disease transmission, particularly seeds from plants. Cleaning includes washing gear, boots, and other apparel with brushes and a solution of tap water and bleach taken to the field for this purpose, and ensuring that no ambient water or mud is trapped in gear or boots and carried among locations. All field equipment will be cleaned before entering a new site, to prevent disease transmission or dispersal of seeds.

2.4/2.5 Analytical Methods/ Analytical Quality Control

Many of the analyses, or data generating steps, will be done in the field, with the exception of above and belowground biomass and soil sample collection. Data analysis for each parameter is described in methods above. Analyses described below are anticipated basic statistical analyses; however, further analysis may be necessary that is not currently anticipated. For example, identifying potential relationships among various parameters may warrant regression analyses to determine the strength of the relationship.

A. Vegetation Community

- The percent cover plot data for individual and aggregate plant species as well as non-vegetation cover values will be averaged by site (n=30 per site) and visualized in graphs and/or tables
- The aboveground plant dry weight and stem height per $0.25m^2$ plot data will be averaged by site (n=15 per site) and visualized in graphs and/or tables
- Statistical analyses will be used to determine differences across restored sites and between restored and reference sites (ANOVA or non-parametric analysis TBD)

B. Fauna Counts

- The fiddler crab burrow and ribbed mussel count data will be averaged by site (n=30 per site) and visualized in graphs and/or tables
- Statistical analyses will be used to determine differences across restored sites and between restored and reference sites (ANOVA or non-parametric analysis TBD)

C. Belowground Biomass

- The root dry weight values of live and dead roots per root core will be averaged by site (n=5 per site) and visualized in graphs and/or tables
- Statistical analyses will be used to determine differences across restored sites and between restored and reference sites (ANOVA or non-parametric analyses TBD)

E. Soil Organic Content

- Laboratory analyses will be conducted using standard operating procedures by the US Forest Service (Appendix III)
- The bulk density, loss on ignition (organic content), and soil texture data from the soil cores will be averaged by site (n=5 per site) and visualized in graphs and/or tables
- Statistical analyses will be used to determine differences across restored sites and between restored and reference sites (ANOVA or non-parametric analyses TBD)

G.Marsh Loss Trends

- The total amount of marsh change will be calculated in ArcGIS for each category and the results will be presented in area (acres or square meters), percentage of change per site, and rate of change per site.
- Statistical analyses will be used to determine differences across restored sites (ANOVA or non-parametric analysis TBD)

H. Tidal Creek

- The width and depth of creeks will be averaged by site and visualized in graphs and/or tables.
- Statistical analyses will be used to determine differences across restored sites and between restored and reference sites (ANOVA or non-parametric analyses TBD)

2.6 Sample Handling and Custody Requirements

Data collected on data sheets and log books will be kept in project specific bags that will be taken on each field day so that all data will be kept in one place. Every two weeks, the project manager or NRG science staff will collect all data sheets and log books to be copied twice to ensure backup of all data, and these copies will be kept at the NRG office.

Sample Handling

Soil and plant samples will be taken. No other materials will be removed from the sites. Other tests will be taken *in situ*. Test equipment will be cleaned to prevent contamination.

Soil samples will be taken following SOPs and utilizing the following protocol for sample quality control:

1) Collect 2 bags of soils from field.

•Bag #1: 500cm^3 of soil for bulk density

•Bag #2: Composite sample of at least 200 g of soil (not including gravel/rocks) for the remaining base tests

Bags will be labeled with site name, unique tracking number (generated from the NRG soil sample database intake database), date, and analysis to be conducted.

2) Write down important information about soil samples (e.g., GPS coordinates) in notebook or on hard copy of soil intake form.

•GPS unit will be set down while sampling to increase the accuracy of collection points

3) Enter information from notebook/soil intake form into Access database form. The access database will automatically assign a tracking number. Record tracking number in log book.

4) Write the tracking number on both bags.

5) Immediately drop off soils to staff person of USDA Forest Service's Northern Research Station.

Plant samples will be taken following the protocol described in Section 2.2 of this QAPP. Plant materials will be stored in a refrigerator and dried in a drying oven at the USDA Forest Service's Northern Research Station.

All sample types will be tracked using NRG chain-of-custody forms (Appendix II). This form is entered into a digital database that generate a unique identification code for each sample. Each sample is then labeled with the individual identification codes that can be referenced back to the information in the digital database. Samples will be delivered to the USDA Forest Service Northern Research Station or other partners (e.g. Urban Field Station) to be analyzed. A representative from the partner entity will sign the chain-of-custody form when receiving all samples and verify that they have been handled according to the form.

2.7 Testing, Inspection, Maintenance and Calibration Requirements

Chris Haight will be responsible for maintaining and storing equipment in the storage space at the NYC Parks Arsenal North office in room 228A. Any equipment and tools associated with the restoration assessment will be tested, inspected and maintained by the guidelines set out in each piece of equipment's user manual. Additionally, equipment will be calibrated annually. Digital calibration logs documenting the calibration procedures and efforts will be recorded and stored on the NYC Parks server for each piece of equipment that needs calibrating. Each item of equipment will be given a specific identification code that will be used to track calibration according to each piece of equipment.

Any GPS unit that is used will be calibrated by using the "calibrate compass" function found on all GPS units. This function will be performed at the start of each field day as well as if a need arises to change the batteries in the middle of the day, the GPS unit will then be re-calibrated. At any site where data is collected a GPS mark will be input into the unit and those coordinates will be written into the log book as well. The written coordinates will be read back to another field crew to check that the latitude/longitude was recorded correctly. The GPS units used must have spatial accuracy that is within one meter of the data collection point. The GPS unit will be tested for accuracy and calibrated after every five restoration sites sampled by recording the location of the 10 points with pre-established benchmarks (Surface Elevation Table installation points, shoreline erosion monitoring pin locations, contractor grading points and constructed features) at a previously sampled site as described in section 1.6 of this QAPP.

2.8 Non-direct Measurements

Sources of Existing Data

The existing data for this project were sourced internally from NRG, specifically percent cover of vegetation and non-vegetation, plant heights, and soil characteristics data collected from the 6 reference sites (SSIM sites) in the summer of 2014.

Intended Use of Existing Data

These data will be used to compare with percent cover, plant height, and soil data collected at the restored sites.

Acceptance criteria for Using Existing Data

The following is a list of criteria for acceptance of existing data:

- The data is in a format that is supported by appropriate software (e.g. Excel)
- Data covers the applicable study areas (6 reference marshes)
- Any errors or duplicates are removed

Data limitations and errors encountered will be documented, error and duplicate detection will be performed by cross referencing data with any available field or raw data sheets or data published in literature.

Limitations on Use of Existing Data

For all data generated by NYCDPR and NAC:

Use Constraints/Limitations

The data remains at all times the property of the NYCDPR. In addition, this data may not be used for any commercial or private purposes. The data must remain within the user's office. The data shall not to be copied or used for any purpose that is outside the user's official duties at/for NYCDPR or the City of New York. The user must obtain permission from NYCDPR to publish any data independently from the contracted work. If publication permission is granted, NYCDDPR must be properly credited and funders for work done by NYCDPR must be acknowledged. The user assumes responsibility for the proper maintenance and security of the data, including any sharing within user's office. Portions of the data may comprise a national security risk. As a result, any use or sharing outside of the NYCDPR is only permitted upon express authorization from NYCDPR Legal Council's office (212-360-1313) or MIS (212-830-7911). The user must notify MIS immediately if the data becomes defective, corrupted, lost or stolen.

Legal Constraints/Access Constraints

This data can only be utilized by parties that have permission from NYCDPR to use this dataset.

3.0 Data Management

The data management plan for this study is as follows. Field crews will collect data on paper in the field. The data sheets as well as log books will be taken to NRG offices. The project manager will make two copies of all data and will check 10% of the data at least every two weeks during the active field season.

Data will then be entered into a computer database, such as MS Excel. At least 10% of these data will then be checked by an independent observer. Data will then be analyzed for content and at least 10% of the final data will also be checked by the project manager or NRG science staff as well as the NRG QA officer. NRG staff will put all electronic data to be saved and backed up on the NRG server, as well as backed up on a thumb drive. All data will be kept on the NRG server under J:\NRG\Grants\EPA WPDG Region 2 2014\07 Design (or Plan for Studies)\Field Data. All documents will be named with 2014EPAWPDG followed by a description of their content. All raw data will be kept at NRG offices. Upon request, copies will be given to partners and to US EPA at the end of each specific project (as per Addendum QAPPs.) The project manager or trained science staff will be in charge of filing and archiving all data.

3.1 Assessments and Response Actions

Preparation for each field outing will initiate with a check of equipment functionality as well as a review of the task checklist. To ensure accuracy and precision all field crew members will have been trained previous to working.

At each field outing there will be an NRG representative who has been properly trained in that methodology who is responsible for that specific method. If problems arise the representative will note so in the log book.

All field assessments and schedules will routinely be shared with the Director of the Wetlands and Riparian Restoration and plant ecologist. The project manager will verify the accuracy of data being collected according to methods described in section 1.6 of this QAPP. If the proper assessments are not being performed, further data collection will be stopped until proper procedures can be followed. The proper procedures refer to the quality assurance audit where, after every five restoration sites sampled, a previously sampled site will be sampled a second time so that field staff as well as QA staff and experts from the wetlands office at NYC Parks can assess the precision, accuracy, and bias of the field crews measurements and calibrate measurement techniques before continuing sampling at the next restoration site. The project manager, lead science staff at NRG and NAC, and the Director of Wetland and Riparian Restoration will meet annually to discuss the project's progress and ensure that all approved assessment procedures are being followed. If corrective actions need to be made, then the project manager, Director of Wetland and Riparian Restoration and plant ecologist will work to address any changes deemed necessary.

3.2 Reports to Management

The project manager will be responsible for compiling all assessments. The project manager will write these reports and provide it to the Director of Wetlands and Riparian Restoration, plant ecologist, and other science staff for review. In annual progress reports for the project prepared for EPA, this compellation will be included

4 Data Review, Verification, Validation and Usability

4.1 Data Review, Verification, Validation and Usability

All data, laboratory and field, will be recorded electronically or manual and will be checked for accuracy by the project manager. Any laboratory data received from subcontractors will be QA checked by their internal systems as well. Regardless of the means with which data were initially recorded, all field data will be entered into a computer system within one week after collection.

A subset of data will then be checked for completeness and accuracy by the project manager. Data will only be considered valid if all datasheets are completely filled out or all information from an analytical lab is complete.

Data will be accepted if they meet the following criteria:

1. Field data sheets are complete.
2. Field data and laboratory data were validated
3. Actual sample locations and collection procedures match the proposed sample locations and collection procedures identified in section “Data Generation and Acquisition”
4. Sample handling procedures documented on chain-of-custody forms, the field activity report, and case narrative match the proposed sample handling procedures identified in section “Data Generation and Acquisition”
5. Field QC was conducted as described in section 1.6 of this QAPP
6. Any incomplete data or deviations will be reported on the quality assurance audits or the analytical report. The project managers will verify the content

4.2 <u>Verification and Validation Methods</u>

Laboratory analysis will follow each respective lab’s verification and validation methods set out in their own QAPP. Other field data not covered under the labs QAPP will be verified by the project manager or field team members before they leave the site that all data has been filled in correctly. The project manager will review and verify all field sheets, field log, scanned data sheets, transcribed data, and analytical reports in the office. The Director of Wetlands and Riparian Restoration and the plant ecologist will verify a subset of this data. Any problems, incomplete data or deviations will be flagged by the project manager in the digitized version of the data by highlighting or altering the data in a standard fashion. The flagged data will be discussed with the project team and errors will be corrected by cross referencing with field data sheets when appropriate. Errors that cannot be addressed will be considered for secondary field sampling if time allows or that data will be excluded from further analysis or use. No data will be deleted but if data are inconsistent or not verifiable the data will be flagged and excluded from future use. The project manager will be responsible for not only the data but for verifying and validating the chain-of-custody forms and any calibration data as well.

Data validation criteria:

- Field data sheet was reviewed for errors or missing values in the field and the office
- Digitized data was reviewed and cross referenced with field data sheets
- Any errors were addressed by being corrected or flagged and excluded from further use

4.3 <u>Reconciliation with user Requirements</u>

Data will be QA checked according to this document. Then, a meeting of the project group (PI’s and advisors) will be called to discuss, reconcile, and refine any data analyses. This group will then determine if any parts of the data need to be adjusted or discarded because of any documented errors, field constraints, or equipment malfunctions. Since any changes or omissions of original data may limit the utility of study results by scientists and managers, any such alterations of data or data products will be fully disclosed to anyone who procures the data.

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Appendix I: Sample Data Sheets

A. Vegetation, Fauna Count, and Stem Height Plots Data Sheets Example

Date: Site Name:
Time: Team:
Low Tide:

Plot 1	HM/LM/UP	Plot 2	HM/LM/UP	Plot 3	HM/LM/UP	Plot 4	HM/LM/UP	Plot 5	HM/LM/UP
Species	%Cover	Species	%Cover	Species	%Cover	Species	%Cover	Species	%Cover
PHAU		PHAU		PHAU		PHAU		PHAU	
SPAL		SPAL		SPAL		SPAL		SPAL	
SPPA		SPPA		SPPA		SPPA		SPPA	
DISP		DISP		DISP		DISP		DISP	
IVFR		IVFR		IVFR		IVFR		IVFR	
SAEU		SAEU		SAEU		SAEU		SAEU	
JUGE		JUGE		JUGE		JUGE		JUGE	
ATPA		ATPA		ATPA		ATPA		ATPA	
BAHA		BAHA		BAHA		BAHA		BAHA	
Unveg		Unveg		Unveg		Unveg		Unveg	
CRK/Dit		CRK/Dit		CRK/Dit		CRK/Dit		CRK/Dit	
WRK		WRK		WRK		WRK		WRK	
GRB		GRB		GRB		GRB		GRB	
Litter		Litter		Litter		Litter		Litter	
Mussels		Mussels		Mussels		Mussels		Mussels	
PAN/Pool		PAN/Pool		PAN/Pool		PAN/Pool		PAN/Pool	
# Mussels		# Mussels		# Mussels		# Mussels		# Mussels	
# CrabBur		# CrabBur		# CrabBur		# CrabBur		# CrabBur	
SPAL H1		SPAL H1		SPAL H1		SPAL H1		SPAL H1	
SPAL H2		SPAL H2		SPAL H2		SPAL H2		SPAL H2	
SPAL H3		SPAL H3		SPAL H3		SPAL H3		SPAL H3	
SPAL H4		SPAL H4		SPAL H4		SPAL H4		SPAL H4	
SPAL H5		SPAL H5		SPAL H5		SPAL H5		SPAL H5	

Plot 6	HM/LM/UP	Plot 7	HM/LM/UP	Plot 8	HM/LM/UP	Plot 9	HM/LM/UP	Plot 10	HM/LM/UP
Species	%Cover	Species	%Cover	Species	%Cover	Species	%Cover	Species	%Cover
PHAU		PHAU		PHAU		PHAU		PHAU	
SPAL		SPAL		SPAL		SPAL		SPAL	
SPPA		SPPA		SPPA		SPPA		SPPA	
DISP		DISP		DISP		DISP		DISP	
IVFR		IVFR		IVFR		IVFR		IVFR	
SAEU		SAEU		SAEU		SAEU		SAEU	
JUGE		JUGE		JUGE		JUGE		JUGE	
ATPA		ATPA		ATPA		ATPA		ATPA	
BAHA		BAHA		BAHA		BAHA		BAHA	
Unveg		Unveg		Unveg		Unveg		Unveg	
CRK/Dit		CRK/Dit		CRK/Dit		CRK/Dit		CRK/Dit	
WRK		WRK		WRK		WRK		WRK	
GRB		GRB		GRB		GRB		GRB	
Litter		Litter		Litter		Litter		Litter	
Mussels		Mussels		Mussels		Mussels		Mussels	
PAN/Pool		PAN/Pool		PAN/Pool		PAN/Pool		PAN/Pool	
# Mussels		# Mussels		# Mussels		# Mussels		# Mussels	
# CrabBur		# CrabBur		# CrabBur		# CrabBur		# CrabBur	
SPAL H1		SPAL H1		SPAL H1		SPAL H1		SPAL H1	
SPAL H2		SPAL H2		SPAL H2		SPAL H2		SPAL H2	
SPAL H3		SPAL H3		SPAL H3		SPAL H3		SPAL H3	
SPAL H4		SPAL H4		SPAL H4		SPAL H4		SPAL H4	
SPAL H5		SPAL H5		SPAL H5		SPAL H5		SPAL H5	

0-1%	0.50%	25-50%	37.50%
1-5%	2.50%	50-75%	62.50%
5-12.5%	8.75%	75-100%	87.50%

B. Aboveground Biomass processing datasheet

				Entered By:		Date Entered:	
				People Who:		Date Samples Were:	
Plot	Site	Bag Weight (g)	Dry Weight (g) (bag+sample)	Collected	Weighed	Collected	Weighed
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

				Entered By:		Date Entered:	
				People Who:		Date Samples Were:	
Plot	Site	Bag Weight (g)	Dry Weight (g) (bag+sample)	Collected	Weighed	Collected	Weighed
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

C. Belowground biomass processing data sheet

						Entered By:		Date Entered:	
						People Who:		Date Samples Were:	
Plot	Site	Live Bag Weight (g)	Live Dry Weight (g) (bag+sample)	Dead Bag Weight (g)	Dead Dry Weight (g) (bag+sample)	Collected	Weighed	Collected	Weighed
1									
2									
3									
4									
5									

						Entered By:		Date Entered:	
						People Who:		Date Samples Were:	
Plot	Site	Live Bag Weight (g)	Live Dry Weight (g) (bag+sample)	Dead Bag Weight (g)	Dead Dry Weight (g) (bag+sample)	Collected	Weighed	Collected	Weighed
1									
2									
3									
4									
5									

						Entered By:		Date Entered:	
						People Who:		Date Samples Were:	
Plot	Site	Live Bag Weight (g)	Live Dry Weight (g) (bag+sample)	Dead Bag Weight (g)	Dead Dry Weight (g) (bag+sample)	Collected	Weighed	Collected	Weighed
1									
2									
3									
4									
5									

Appendix II: Chain of Custody Example for Soil Samples

Soil Sampling Form

***Required fields**

Basic Information	
Soil Tracking #: (ID # will be generated by database)	
Name of Sample Collector*:	**Contractor's Name (if applicable):**
Project Name:	**Other IDs (if applicable):**
Project Manager Name:	**Team (pick one)*: Central Forestry Field Station Forest Restoration GNPC Horticulture Wetland Other: _____**
Site Information	
Sampling Date*:	**Park Name:**
Sampling Time*:	**Park ID:**
Temperature: °F	**Habitat type (pick one)*:** Construction site Greenhouse Landscaped area (lawns, beds, gardens, Greenstreets) Playground Street Tree Pits/Bioswales Upland Forest/Meadow/Shrubland/Vineland Wetland Other: _____
GPS Latitude*: **GPS Longitude*:** For the latitude and longitude, please make sure your coordinates are in NAD 1983 State Plane New York Long Island FIPS 3104 Feet and use at least 3 decimal places.	
Soil Information for Bulk Density Sample	
Sample Depth (pick one)*: 0-10 cm 10-20 cm 20-30 cm Other:__________	**Sample Volume*: cm^3** Volume = pi*([diameter of soil corer in cm]/2)*[sample depth in cm]

Appendix III: Summary of Lab Protocols From US Forest Service

Soil pH. We will measure soil pH in 0.01 M $CaCl_2$. 5 mL sieved, air dried soil:10 mL $CaCl_2$ solution (20 mL for organic soils). After stirring and equilibration, pH is measured.

Soil Soluble Salt. By the 1:1 (V:V) Soil:Water Extract Method (Dahke and Whitney, 1998). 20 mL of air dried, sieved soil mixed with 20 mL de-ionized water. After 20 minutes of equilibration, conductivity is measured with a conductivity meter.

Loss on Ignition (LOI)/Organic Content. A known mass of dried soil will be put in a muffle furnace at 440 C for 8-12 hours. Following combustion the sample is cooled in a desiccator and weighed. %LOI = (Dry Mass – Ash Mass)/Dry Mass

NH4OAc Extractable elements. Soil will be extracted using 1.25 M NH4OAc (pH 4.8) and a vacuum extractor. The extract will be analyzed on an ICP-OES for the elements of interest (routinely this is Al, Ca, K, Mg, Mn, Na, P, Sr).

Exchangeable Acidity (EA). 5 grams of air dried, sieved soil will be extracted in 125 mL 1MKCl. The extract solution will be titrated to pH 7 and the amount of NaOH titrated is used to calculate EA.

Cation Exchange Capacity. Calculate CEC from values of Ca, Mg, K obtained from NH4OAc (pH 4.8) extracts plus Exchangeable Acidity (EA). CECe (meq/ 100 g or cmolc/kg) = (Ca ppm /200) + (Mg ppm / 120) + (K ppm / 390) + EA

CN – Soil/plant tissue. Homogenized samples will be dried overnight at 60 C. known masses will be analyzed on a CN Elemental analyzer (Thermo FlashEA CN analyzer).

DOC/TDN water. Filtered samples will be analyzed on a Shimadzu TOCV with TN module. Analysis technique is usually referred to as High Temperature Catalytic Oxidation.

NH4. Will be measured colorimetrically using the automated phenolate method. Similar to EPA 350.1 on a Lachat 8500 flow injection analyzer.

PO4. Will be measured colorimetrically using the automated ammonium molybdate, ascorbic acid method. Similar to EPA 365 on a Lachat 8500 flow injection analyzer.

NO3, Cl, SO4/Anions. Ion Chromatography with suppressed conductivity detection. EPA 300.1

NO3+NO2 (KCl Extracts). Colorimetrically by Cd-Cu reduction on a Lachat 8500 flow injection analyzer.

Appendix IV: Project Timeline

Tasks	Time	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**
1. Collect data at restoration sites and reference sites.	12 weeks														
2. Lab analysis of soil samples	6 weeks														
3. Analyze data	12 weeks														
4. Report on restored marsh condition	12 weeks														
5. Monitoring and design guidelines	12 weeks														
Total	54 weeks														

Site (refer to full name on permit application)

Borough, NY

Monitoring and Assessment Report
Year

By: Author

City of New York
Parks & Recreation
Bill de Blasio, Mayor
Mitchell J. Silver, Commissioner

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1. Introduction

Site and restoration activities, including location map (Figure 1). Details should include when the site was completed, who the funder was, amount of funding, what habitats restored, and the respective acres of habitat restored (Figure 2).

If the restoration was completed to mitigate for wetland impacts elsewhere, include what the mitigation was for, and reference documentation (including permit numbers) of NYS Department of Environmental Conservation approval for the mitigation.

1.1 Purpose

Purpose of the report, including any requirements set forth in the NYSDEC permit and/or approved mitigation plan.

2. Site Background

Site location/setting, history, and habitat pre-restoration

3. Restoration

Start and end date of restoration, list restoration activities (e.g. shoreline stabilization, sand placement, erosion control, low marsh restoration, high marsh restoration, transition zone, maritime grassland, etc).

3.1 Objectives

Restoration objectives and targets.

3.2 Restoration Activity 1

Restoration techniques, areas, quantities of items placed, species planted/seeded, methods for habitats restored.

3.3 Restoration Activity 2

Restoration techniques, areas, quantities of items placed, species planted/seeded, methods for habitats restored.

3.4 Post-Restoration Maintenance Activities

E.g. goose fencing installed/repaired, mowing, plants replaced, invasive species managed, volunteer events organized.

4. Monitoring Methods

4.1 Frequency

Date of surveys

4.2 Plot Locations

Numbers, locations, and size of plots (Figure 3 – template map for plot and transect locations). Indicate restored and reference sites. Indicate photo points.

4.3 Parameters

Parameters monitored (e.g. percent cover, stem height, stem density) and methods for estimating.

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5. Results and Discussion

5.1 Habitat 1

Results for applicable monitoring parameters for each habitat. Include tables and graphs as appropriate. Describe trends observed over time with each monitoring period. (Figure 4 – template chart for results)

5.2 Habitat 2

Results for applicable monitoring parameters for each habitat. Include tables and graphs as appropriate. Describe trends observed over time with each monitoring period.

6. Conclusion and Recommendations

Summary of observations and trends, total cover for each habitat, as well as potential causes for observed results. Based on this criteria, determine if site is meeting restoration objectives and NYSDEC permit/mitigation requirements.

6.1 Adaptive Management Habitat 1

Suggest recommendations for adaptive management, timing, specific activities, and additional monitoring, as needed.

6.2 Adaptive Management Habitat 2

Suggest recommendations for adaptive management, timing, specific activities, and additional monitoring, as needed.

7. References

8. Appendix

8.1 Data sheets

Completed data sheets

8.2 Photographs

Plot and fixed photo station photographs

Inspection Date:________________________ Time: __________________________ Inspectors ___________________________________

SALT MARSH RESTORATION PROJECT MAINTENANCE OVERVIEW FOR DREIER OFFERMAN

The Boro oversees Park-wide maintenance and will contact NRG at 212-360-1481 if conditions at the coastal habitat restoration project site warrant attention. NRG will conduct inspections once in the Spring, Summer, Fall, and after severe storms to identify potential issues as listed below. See attached site map for locations listed in the elements column below. NRG will also monitor salt marsh condition each fall for five years after project completion.

LOCATION	ISSUE	ACTION	LEAD	FREQUENCY
Entire Area	Trash/debris in upland	Remove trash/debris in upland.	Boro	As needed
Shoreline edge	Areas of bare soil where previously planted, visible erosion and/or gullies	Stabilize the soil with biodegradable erosion control fabric and re-seed or replant.	NRG	As needed
Marsh Vegetation	Dead, diseased or dying plants	Determine cause and replace plant material.	NRG with Boro	As needed
	Phragmites australis (common reed) threatens salt marsh plants	Clear *Phragmites* using the schedule below as a guide. Clear dead standing plant debris Dec-March. Cut to below six inches three times: May-June, mid-July, and early September (when reeds are green). Herbicide in September if needed but no less than six weeks after last mow (requires tidal wetland permit).	NRG	Three times per year as described
	A thick alga covers areas of the marsh, smothering the plants	Manually remove the algae during low tide in summer months and dispose material off-site.	NRG	Every 2 weeks in summer or as needed
	Geese eating the marsh plants	Install or secure waterfowl barrier.	NRG	As observed
	Excessive trash / debris	NRG will either clear debris or determine needed action especially after storm events.	NRG	At least three times per year and after storms
Upland Vegetation	Drought is threatening survival of newly planted vegetation	Water newly planted vegetation (arrange with Borough M & O crews).	NRG with Boro	As needed
	Mugwort invades area	Cut/mow repeatedly (June to September).	Boro with NRG	1/month in summer
Paths/Trails	Gravel overflow	Rake back into path	Boro	As needed
	Erosion of path	Regrade and install water bars if necessary. Contact NRG if vegetation is impacted.	Boro	As needed
Interpretive Sign	Graffiti	Remove graffiti.	Boro	As needed
Other				

Inspector comments:

Appendix J. Example Maintenance Plan

Created by Katie Conrad December 2, 2013