Prime Hook NWR Marsh Restoration Project Summary & Monitoring Plan

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Contacts: Susan Guiteras, Supervisory Wildlife Biologist, USFWS – Coastal DE NWR Complex
Susan_Guiteras@fws.gov (302) 653-9345
Annabella Larsen, Wildlife Biologist, USFWS – Prime Hook NWR
Annabella_Larsen@fws.gov (302) 684-8419

RESTORATION PROJECT BACKGROUND

Introduction and History

Prime Hook National Wildlife Refuge (NWR) is located on the Delaware Bay coast in Sussex County, DE (Figure 1). The refuge will undertake a substantial multi-phase tidal wetland restoration project that will impact approximately 4000 acres in two units (Unit II and Unit III) which were previously managed as freshwater impoundments. These wetland units were converted to saline conditions following a series of dune breaches that have grown over the course of the past few years, most notably following Hurricane Sandy. The rapid and dramatic nature of the changes resulted in considerable marsh collapse in the interior of the wetland units, with the creation of shoals near the breaches and the reappearance of salt marsh vegetation in some limited areas.

Historically, the wetlands on the refuge were almost entirely brackish or salt marsh. They were subjected to numerous impacts and alterations over many decades, such as ditching, draining, mosquito management, grazing and haying, trapping, and hunting. In the 1980's, the two central units - Unit II and Unit III - were converted to freshwater impoundments through the installation of new water control structures. This was done to combat *Phragmites* and provide waterfowl habitat, and was very successful. Dunes were supplemented at that time, at the request of the State. The dunes along the eastern edge of the wetland complex have undergone minor repair/restoration several times since, typically following storm damage: 1992, 1998, 2006, 2008, 2011* (*the 2011 repair was short-lived).

In 2006, hurricane Ernesto formed an overwash north of Fowler Beach Road in Unit I. In May 2008, the "Mother's Day storm" worsened the breach in Unit I, and created a moderate overwash in Unit II. The Unit II overwash was repaired that fall. However, in the fall of 2009 back-to-back nor'easters in October and then November created substantial breaches in Unit II. A fall 2011 attempt to repair the Unit II breaches with on-site material was short-lived, but the breaches remained relatively stable through the following year. In October 2012, hurricane Sandy created substantially more damage, forming two new breaches in Unit II, for a total of four breaches in the unit previously managed as a freshwater impoundment. Meanwhile, the breach in Unit I has repaired itself.

In 2013, the refuge finalized its Comprehensive Conservation Plan, adopting a preferred alternative that highlights proactive restoration of the impounded wetland complex to brackish and salt marsh. The refuge worked with a number of partners and a private engineering firm to determine an appropriate course of action for marsh restoration, which will occur in multiple phases over several years.

The **Shoreline Recovery Phase** of the marsh restoration project will focus on closing the large dune breaches in Unit II. Dredged material from a nearby borrow area will be used to close the breaches in the dune. This is anticipated to create a back barrier marsh platform about 300 feet wide. The dune will be planted with *Ammophila breviligulata*. A back barrier area approximately 50 acres will be planted with *Spartina alterniflora, S. patens*, *Panicum virgatum, P. amarum* and other vegetation.

The **Coastal Marsh Resilience Phase** of the marsh restoration project will involve the creation of conveyance channels and a network of tidal channels throughout the wetland units to improve circulation and distribution of salinity and sediment, in conjunction with the dune and marsh platform work. This marsh restoration design was evaluated through hydrodynamic modeling conducted by Atkins Global on behalf of the refuge, which indicated that conditions conducive to salt marsh development would likely result (Atkins 2014). Material that is dredged during this process will be utilized on-site to supplement marsh elevation in the interior of the units. Sediment will be sprayed

directly from the channels during dredging operations, into unvegetated areas identified as suitable to receive the material for an improvement in marsh elevation capital. No active planting of these areas is planned, although that may be considered in some areas as initial response is monitored.

The restoration design is described in detail in an Environmental Assessment developed by the Service (USFWS 2015). Additional background information about the refuge wetlands and management units is available in the Prime Hook NWR Final CCP (USFWS 2013).

Project Site Overview

Figure 1. – Overview and Vicinity Map, showing the refuge units and location of shoreline breaches

CCP Goals, Objectives, & Strategies

The Refuge's Comprehensive Conservation Plan (CCP) was finalized in 2013. The following are CCP goals and objectives relevant to the marsh restoration project. Goal 1 focuses on existing barrier beach island and salt marsh habitats, and identifies proactive salt marsh restoration as a strategy. Goal 3 focuses on the refuge's impounded wetland complex, which will be restored to a mix of salt marsh and brackish marsh to improve conditions to a more sustainable state, despite that these wetlands will remain at least partly impounded. The implementation of this large marsh restoration project represents the intersection of meeting these two important goals. Specifically, elements identified under Objective 3.1, which addresses marsh restoration, will serve as the foundation for much of the monitoring plan. This is less true for Unit III, which is addressed in more detail below.

Goal 1. Manage, enhance and protect the dynamic barrier beach island ecosystem for migratory birds, breeding shorebirds and other marine fauna and flora. Perpetuate the biological integrity, diversity and environmental health of North Atlantic high and low salt marsh communities.

Objective 1.1 Barrier Beach Communities: Overwash, Sandy Beach, and Mudflat

Permit the natural evolution and functioning of sandy beach, overwash, dune grassland, and mudflat habitats along approximately 1.5 miles of refuge coastline in Unit I to conserve spawning horseshoe crabs and listed BCR 30 migratory bird species. Over time, permit the development of these features and communities along an additional approximately 1.5 miles of the shore of Unit II, as salt marsh restoration is pursued.

Objective 1.3 (North Atlantic Low and High Salt Marsh Habitats)

By 2020, enhance and restore the quality and natural function of 2,200 acres of salt marsh by 10%, as measured by Region 5's Salt Marsh Index of Ecological Integrity and consistent with local reference sites by maintaining a mix of North Atlantic high and low salt marsh vegetation comprised of less than 5% invasive species cover, and pool, panne, and irregularly flooded tidal salt shrub communities to provide breeding, migrating and wintering habitats for key species (seaside sparrow, salt marsh sharp-tailed sparrow, clapper rail, shorebirds, and waterfowl), and passage and rearing habitats for diadromous and prey fish species and marine invertebrates.

- *Increase cover of native vegetation to greater than 95% by controlling the presence of invasive plant species. Native plant species found in high salt marsh communities include:* Spartina patens, Distichlis spicata, *and* Juncus gerardii *with lower densities of* Aster tenuifolius, A. subulatus, Atriplex patula, Solidago sempervirens, *and* Panicum virgatum. *In low marsh communities, native plant species include* Spartina alterniflora, *with low densities of* Distichlis spicata, Salicornia martima, Juncus gerardii, *and* J. roemerianus.
- *Special emphasis will be given to conserving and protecting small patches of remnant high salt marsh areas on the Refuge that are less common than low marsh communities*
- *For breeding obligate passerines, maintain extensive stands of salt-meadow hay with scattered shrubs or clumps of black needle rush and salt grass.*
- *Develop up to 4,000 acres of additional salt marsh within the refuge impounded wetland complex through active wetland restoration efforts; these efforts will be guided by a restoration plan developed with assistance from state and federal coastal scientists and other subject matter experts.*

Goal 3. Maintain the quality of the wetland habitats within and surrounding the refuge's wetland impoundment complex for migrating shorebirds, breeding rails, wading birds, American black ducks, and migrating and wintering waterfowl consistent with Biological Integrity, Diversity and

Environmental Health (BIDEH) policy. Support other native wetland dependent species and provide fish passage and nursery habitats for anadromous fish species.

Objective 3.1

Provide up to 4,200 acres of healthy impounded/semi-impounded brackish wetlands and salt marsh to meet the needs of a wide variety of wetland-dependent migratory birds, including rails, bitterns, terns, migrating shorebirds, and migrating and wintering waterfowl, by restoring salt marsh vegetation communities and natural wetland processes in the impounded wetlands in Units II and III. Successful restoration will include the following elements:

- *Restoration of the natural tidal range and salinity with a physical connection with the marine environment for exchange of nutrients, organic matter, and biota*
- *Restoration of the natural sediment budget to counter wetland subsidence*
- *Improvement of water quality realized by restored salinity and pH*
- *Control of invasive plants to less than 5% cover, once salt marsh vegetation is established*
- *Re-establishment of native salt marsh vegetation communities, with a moderate (20-25%) component of open water/mudflats*
- *Return of native salt marsh wildlife species, including salt marsh obligate birds*
- *Improvement of estuarine fish and shellfish habitat*

Objective 3.2

Over the next 15 years protect and improve the water quality of 6,000 acres of impounded marsh and waterways, aquatic habitats and delineated buffer zones to provide clean water to safeguard and enhance the quality of breeding and nursery habitats for river herring (alewife, blue-back herring), American and hickory shad, striped bass, and other fishery resources, to conserve healthy populations of fish, breeding and migrating birds and resident wildlife.

Restoration Project Goal

Combining goals and objectives first outlined in our CCP, along with new and detailed information about the restoration project site, we propose the following overall restoration project goal:

Create environmental conditions in Units II and III where each unit can realize its maximum potential for biological integrity, diversity and environmental health (BIDEH) by reestablishing tidal regimes. Restoring tidal flow and other physical processes like sedimentation are targeted to conserve and enhance each unit's capacity for BIDEH, self-repair and sustainability when perturbed by coastal storms. This will eventually lead to minimal external support (chronic breach repairing) for the health of barrier island and back-barrier salt marsh habitats in Unit II and brackish hemi-marsh conditions in Unit III.

From hydrological modeling runs based on refuge-specific abiotic data and other information about current conditions versus post restoration actions, we project the creation of a self-sustaining meso-polyhaline marsh system in Unit II and an oligo-mesohaline system in Unit III.

Restored Unit II salt marsh areas will have to perform as an accretionary marsh relying on positive sedimentation rates to ensure self-sustainability. Restored self-sustaining units will be guided by adaptive management toward desired performance standards.

Enhancing tidal flow and drainage systems in Units II and III are connected to restoring sedimentary processes expected to build marsh platform to appropriate levels that facilitate and support rapid

colonization by *Spartina alterniflora* in Unit II and promotes desirable vegetation in Unit III. Restoring physical and ecological integrity of Units II and III wetlands will, in turn, support positive biological responses of vegetation, birds, estuarine nekton, invertebrates and other wetland-dependent wildlife.

Restoration Project Objectives

These restoration project objectives are based largely on objective 3.1 in the CCP, with the exception of restoration objective number 7 which is based on objective 1.1, and restoration objective number 8 which addresses Unit III. Whereas restoration objectives 1-7 apply primarily to Unit II, Unit III is unique due to substantial freshwater input, as described above under the restoration project goal.

1. Restore tidal range and salinity conditions sufficient to support salt marsh vegetation, including a physical connection with the marine environment for exchange of nutrients, organic matter, and biota
2. Restore sediment budget and transport processes sufficient to promote salt marsh sustainability through vertical accretion
3. Improvement of water quality realized by restored salinity and pH
4. Re-establish native salt marsh vegetation communities, with a moderate (20-35%) component of open water/mudflats and less than 5% cover of invasive species
5. Provide habitat for native salt marsh wildlife species, including salt marsh obligate birds
6. Improve estuarine fish and shellfish habitat
7. Restore natural and self-sustaining dynamic shoreline processes along the refuge shoreline
8. Restore a self-sustaining an oligo-mesohaline wetland system within Unit III, with a gradient of salinity conditions expected between the area of freshwater input in the west and salt marsh in the east

Given the high-profile nature of the restoration project, the unprecedented scale and unique contributing factors, and significant interest of neighboring communities, the following secondary project objectives are acknowledged. These objectives contribute to learning and sharing within the wetland restoration science community and with the public. They will be met opportunistically through scientific publications, conference presentations, academic partnerships, public restoration project updates, and public educational/outreach events.

1. Test results of restoration predictive models, including hydrodynamic, climate change adaptation, vegetation, sediment, channel allometry, and biotic response, as applicable (Woo et al 2011)
2. Provide opportunities for wetland restoration knowledge creation and transfer
3. Create opportunities for the public to experience and learn about wetland restoration

Monitoring Program Goals & Objectives

The goals of the Prime Hook NWR Marsh Restoration Project monitoring program are (Ellis 2011):

A. *Implementation Monitoring* - Ensure that the project components are built as designed and to document any deviations from the design. Much of this monitoring may be completed by contractors and/or as part of permit requirements during each phase of project construction.

B. *Effectiveness Monitoring* - Determine if the project objectives are being met. Most of the monitoring program efforts are focused on this goal.

C. *Adaptive Management* - Provide information critical for adaptive management. Effectiveness monitoring serves to inform management decisions and actions if appropriate performance criteria trigger points have been identified.

Pre-Existing Data and Information

There is extensive existing data and information about the refuge wetlands and the project area in particular. Data sets include historic wildlife surveys, data from organized refuge research and monitoring projects, and more recent water monitoring data. Details about the refuge's recent hydrodynamic model can be found in the modeling project report (Atkins 2014). The restoration design is described in detail in an Environmental Assessment developed by the Service (USFWS 2015). A table outlining these existing sources of data and information is found in Appendix A, and information about each dataset is available in more detail separately.

Monitoring Design

Shoreline Recovery Planted Restoration Site

About 50 acres adjacent to the marsh side of a 6000 linear foot of restored duneline will be planted with *Spartina* and Panicum during Shoreline Recovery phase of the restoration project. This area will require a more rigorous monitoring approach and sampling design in order to quantify plant survival and to carefully track establishment of this critical area of salt marsh. Some of this monitoring will likely be done by contractors as part of implementation monitoring, but continued monitoring will be important.

Salt Marsh Integrity Monitoring

The Salt Marsh Integrity (SMI) monitoring program, coordinated by the U.S. Fish and Wildlife Service, was developed through a structured decision making (SDM) to guide selection of monitoring variables and management priorities for salt marshes within the National Wildlife Refuge System in the northeastern USA (Neckles et al. 2013, Neckles et al. 2014). Through this SDM process, SMI program developers identified salt marsh attributes that were applicable to monitoring National Wildlife Refuges on a regional scale and that targeted management needs. As such, SMI can be a useful framework for monitoring the integrity of the restored marshes over time. A related effort is the Salt marsh Habitat and Avian Research Program (SHARP), which is a joint effort among several universities, including the University of Delaware, to provide critical information for the conservation of tidal-marsh birds throughout the northeast. Although some of the associated protocols will not be practical or particularly informative initially, the sampling design associated with SMI/SHARP can serve as the basis for establishing a network of monitoring sites. At these monitoring sites, additional parameters will be measured instead of and/or in addition to the SMI/SHARP protocols, particularly during the active years of restoration and in the initial years post-restoration. SMI can be continued into the future.

Under the SMI protocols, points in large marsh units are spaced at least 300-400 meters apart, with a minimum of 10 points per unit. Marsh units that are 1500-2000 acres in size generally have 12-20 bird survey points. The SMI protocol calls for 6 vegetation sampling points within a marsh unit that is >125 hectares. Monitoring programs associated with other large restoration projects include anywhere from 6-30 vegetation transects or plots within the project area, although most include 20-30. In 2014 we established 32 monitoring sites throughout the Unit II salt marsh restoration unit, consistent with the SMI protocol. Eleven of these points are focused in the area proposed for Shoreline Recovery phase of the restoration project, where dredged sand deposition and grass planting will be concentrated. There are 5 sites right on Prime Hook Road, which divides Units II and III. These points were all visited in 2014 for at least one bird survey and at least a general vegetative cover survey. These will be revisited in

2015 to conduct photopoints and repeat rapid vegetation surveys. Similarly, we will establish 20-25 monitoring sites in Unit III in 2015, although the SMI protocols will not be strictly applicable without some modification. These locations will be visited in 2015 to conduct a series of photo points and collect rapid vegetation data as feasible, to provide a pre-restoration baseline. These points in Units II and III will serve as the basis for long-term monitoring utilizing SMI and/or SHARP protocols, as deemed appropriate. Additional marsh condition data will be collected at a subset of points (see the section on MidTRAM, below).

We established restoration monitoring sites for pre-restoration data collection before locations of tidal channels planned for dredging were finalized. Thus in future years, not all of these point locations may be appropriate for long-term monitoring utilizing the SMI program, and the SMI program may never be appropriate for parts or all of Unit III. It is likely that some points will be dropped from future monitoring as the channel network is developed, and/or as open water areas naturally form in the resulting restored marsh. But the sampling design can be adjusted accordingly over time, and meanwhile these monitoring sites will provide valuable pre-restoration baseline data. Baseline data collected with SMI and MidTRAM protocols exists for both Unit I and Unit IV, and can be collected again routinely, which may be helpful for comparisons over time.

Mid-Atlantic Tidal Rapid Assessment Method

The Mid-Atlantic Tidal Rapid Assessment Method (MidTRAM) was developed as part of a collaborative effort among the Delaware Department of Natural Resources and Environmental Control, Maryland Department of Natural Resources and the Virginia Institute of Marine Sciences to assess the condition of tidal wetlands in the Mid-Atlantic region. Assessment of wetlands in watersheds around the refuge has included data collected at points in Units I, III, and IV on the refuge (Rogerson et al. 2013). Select metrics associated with the Habitat Attribute of the Mid-American Tidal Rapid Assessment Method (MidTRAM) will be measured at a subset of monitoring points throughout the refuge wetland units, in cooperation with the DNREC's Wetland Assessment section (Rogerson et al. 2010). Points in Unit I, III, and IV visited in the past will be revisited. A subset of points established in Unit II for SMI/SHARP will be selected for MidTRAM data collection. Metrics to be measured and data to be gathered include: bearing capacity, horizontal vegetation obstruction, and belowground biomass cores. Additionally, photopoints from the center point and at each biomass core site will be taken, and RTK elevation will be collected in a small grid around each biomass core. These metrics provide a more rigorous assessment of marsh health than SMI alone, but are too labor intensive to be conducted at all points.

Qualitative vs. Quantitative Monitoring

From Woo et al. 2011: "*Qualitative monitoring often is described as a "lesser" form of monitoring, because it doesn't cost very much and often doesn't involve advanced technologies. Yet, many important restoration questions may be answered with by simple, systematic observation. Qualitative monitoring can play an important role in all wetland restoration projects, and in many projects, it may be sufficient to provide information on project results. Quantitative monitoring becomes important when there are key uncertainties that need to be addressed, risks that need to be minimized, complex adaptive management choices that need to be made, or opportunities for regionally significant lessons that could change restoration practice. This monitoring plan attempts to strike a balance, focusing on qualitative monitoring where simple answers are sufficient or where the cost of quantitative monitoring exceeds the benefit to TNC's mission. Quantitative monitoring will be focused on issues where more rigorous information is needed to document changes created by the restoration or when detailed learning opportunities inform the general practice of wetland restoration.*"

We will take advantage of two forms of photographic qualitative monitoring techniques. Photo points will be established throughout the wetland units, to be revisited annually over the years to come. Opportunistically collected oblique aerial photography will provide valuable visual evidence of progress, response to tide and storm events, and for public outreach, even when georeferenced aerial photography is not available or cannot be rapidly collected.

Monitoring Partnerships

Many aspects of this restoration monitoring program are being conducted directly by, or with the assistance of, a number of state and academic partners. Through a cooperative agreement, DNREC Delaware Coastal Program is coordinating many aspects of hydrodynamic, sediment flux, and fish monitoring. Specifically, they are handling the acoustic fish tagging, providing support for the water monitoring network and water quality monitoring, and additional data collection such as marsh elevations. Dr. Bob Scarborough is the project officer for this cooperative agreement. DNREC's Wetland Assessment section is also part of the agreement, providing assistance with marsh health assessment and biomass sampling per the MidTRAM protocols. Through this cooperative agreement, we are working with the University of Delaware on several additional components of monitoring. Dr. Chris Sommerfield is leading the work to characterize and monitor sediment fluxes in the marsh system. Dr. Tom McKenna is conducting an evaluation of groundwater influxes into the marsh system. Under a separate cooperative agreement which also includes Forsythe NWR and Cape May NWR (and is administered by Forsythe NWR), Dr. Chris Williams of the University of Delaware is conducting wintering waterfowl food availability sampling and analysis. Under a contract coordinated by the Regional Inventory & Monitoring Program, Dr. Greg Shriver and the SHARP program based at the University of Delaware are conducting salt marsh passerine and secretive marsh bird surveys and associated vegetation surveys. Dr. Norb Psuty of Rutgers University provided training and early support to the refuge (and other Region 5 refuges) on shoreline position monitoring, although the refuge continues implementing this protocol on its own, to be analyzed with regional support. Robust monitoring of a restoration project of this magnitude would not be possible without these many strong partnerships.

MONITORING FRAMEWORK

Implementation Monitoring

The following questions will be answered by appropriate means following each phase of project implementation. This monitoring may or may not be conducted by refuge staff; some monitoring may be conducted by contractors tasked with project implementation.

Shoreline Recovery Phase:

Was the dune and beach constructed according to final design dimensions?
Was the marsh platform behind the dune constructed to target elevation and slope?
Has >85% of planted vegetation (*Spartina*) survived after one year?

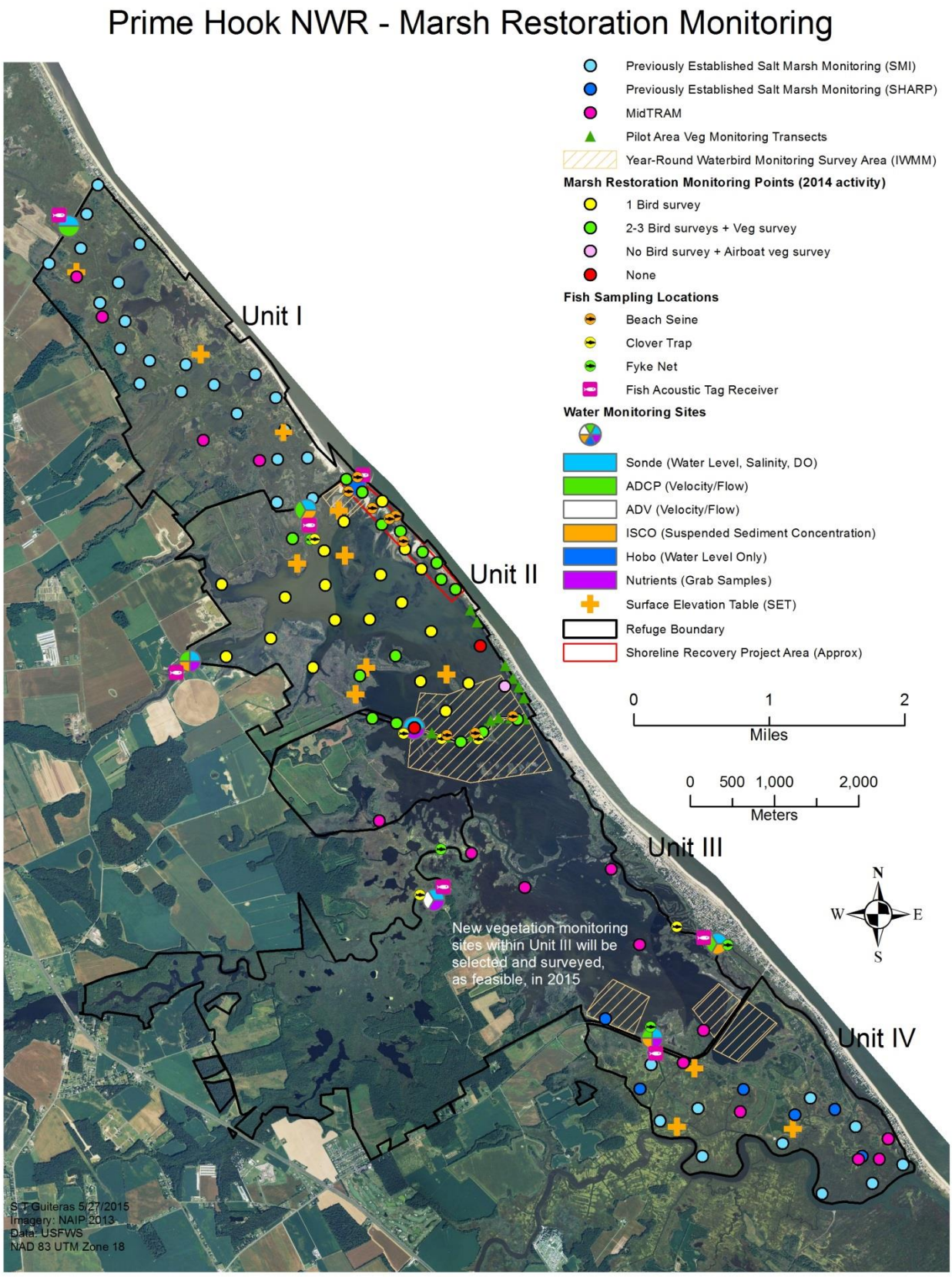
Coastal Marsh Resilience Phase:

Were tidal channels constructed according to final design dimensions?
Was material dredged during channel construction placed in target locations, at desired depth/volume?
What channel order, density, stream length, bifurcation ratio and sinuosity is present after one year?
Longer term monitoring for this phase is expected, as elevation and channel features continue to develop

Effectiveness Monitoring

This section describes, for each project objective, the questions that direct the monitoring of progress toward meeting the objective. For each question, performance metrics and monitoring methods are identified. It is also likely that the details of some monitoring efforts will change in response to changes in staff, opportunities, and priorities. Monitoring methods and protocols are summarized in Appendix B, provided in more detail in separate documents, incorporated here as appendices or by reference, and many will eventually be incorporated into a formal Refuge Inventory and Monitoring Plan (IMP). The spatial distribution of many aspects of effectiveness monitoring efforts is summarized in Figure 2 below.

Figure 2. – Map of bird, vegetation, water, and fish monitoring locations



Project Objective 1 – Tidal Range & Salinity: Restore tidal range and salinity conditions sufficient to support salt marsh vegetation, including a physical connection with the marine environment for exchange of nutrients, organic matter, and biota

Question 1: Are the predicted (to be quantified from modeling results) water levels being achieved? If not, where and why not?

Monitoring Metrics:

- Average daily and monthly tide range within the wetland complex
- Distribution of water levels across the wetland complex throughout the lunar tide cycle, under various levels of freshwater input, and following storm events

Monitoring Methods:

- YSI sonde monitoring network (may be reconfigured following completion of Phase I)
- 5 sonde locations, including 3 locations incorporated into a real-time monitoring network

Monitoring Protocol(s) – DNREC - Monitoring Cooperative Agreement

Question 2: Are the desired (25-27 ppt) salinity levels being achieved? If not, where and why not?

Monitoring Metrics:

- Minimum and maximum salinity at water monitoring stations
- Distribution of salinity across the wetland complex throughout the lunar tide cycle, under various levels of freshwater input, and following storm events

Monitoring Methods:

- YSI sonde monitoring network
- Salinity transects

Monitoring Protocol(s) Reference – DNREC - Monitoring Cooperative Agreement

Project Objective 2 – Sediment Processes: Monitor sediment budget and transport processes to assess if it is sufficient to promote marsh sustainability through vertical accretion

Many aspects of sediment processes are the subject of cooperative research and monitoring efforts with the University of Delaware, directed by Dr. Chris Sommerfield.

Question 1: Are desired levels of suspended sediment concentration (target is average 20 mg/L) present in the water moving throughout the wetland channel network?

Monitoring Metrics:

- Suspended Sediment Concentration

Monitoring Methods:

- Grab samples (by hand and through Isco deployment, during both typical tide and storm events)
- YSI sonde monitoring network (ADCP backscatter, requires calibration)

Monitoring Protocol(s) Reference – DNREC / Univ of DE – Monitoring Cooperative Agreement

Question 2: Are desired levels of suspended sediment concentration reaching areas of vegetated marsh?

Monitoring Metrics:

- Suspended Sediment Concentration

Monitoring Methods:

- Grab samples (by hand and periodically through Isco deployment, such as during storm events)
- YSI sonde monitoring network

Monitoring Protocol(s) Reference – DNREC / Univ of DE – Monitoring Cooperative Agreement

Question 3: Is aboveground accretion contributing to marsh elevation increases?

Monitoring Metrics:

- Measured vertical accretion at various time scales

Monitoring Methods:

- Marker horizons at SET locations
- Additional feldspar marker horizons, potentially
- Sediment plates or pins, potentially

Monitoring Protocol(s) Reference – DE NWR Complex SET Protocol & USGS SET Protocol (http://www.pwrc.usgs.gov/set/)

Question 4: Is average elevation throughout the project site increasing over time at a rate greater than the local rate of relative sea level rise?

Monitoring Metrics:

- Marsh surface (bare earth) elevation
- Bathymetry of shallow water areas

Monitoring Methods:

- Surface Elevation Tables
- LiDAR
- Echosounder
- RTK surveys

Monitoring Protocol(s) Reference – DE NWR Complex SET Protocol, FWS R5, and USGS SET Protocols (http://www.pwrc.usgs.gov/set/); DNREC - Monitoring Cooperative Agreement

Question 5: How is the reconstructed shoreline responding to both routine tidal forces and periodic storms over time?

Monitoring Metrics:

- 1-D Shoreline Position
- 2-D Shoreline Position and Topography

Monitoring Methods:

- Precision GPS shoreline position mapping (NPS 1-D shoreline position protocol)
- RTK surveys (NPS 2-D shoreline topography protocol)
- LiDAR

Monitoring Protocol(s) Reference – NPS Shoreline Position (Psuty et al. 2010) and Shoreline Topography (Psuty et al. 2012) Protocols

Project Objective 3 – Water Quality: Improve water quality by sustaining appropriate pH and sufficient dissolved oxygen

Question 1: Are dissolved oxygen levels necessary for survival and growth achieved of aquatic life throughout the restored wetland complex (threshold >4.8 mg/L sustained average dissolved oxygen?)?

Monitoring Metrics:

- Continuous (Persistent) dissolved oxygen levels
- Frequency and magnitude of reduced dissolved oxygen levels (hypoxic events)
- Distribution of dissolved oxygen levels throughout marsh complex

Monitoring Methods:

- YSI sonde monitoring network
- Periodic manual sampling, especially during conditions conducive to hypoxia

Monitoring Protocol(s) Reference – DNREC - Monitoring Cooperative Agreement

Question 2: What levels of nutrients are present in the water throughout the wetland complex?

Monitoring Metrics:

- Nitrogen
- Phosphorus
- Silica concentrations
- Chlorophyll a content
- Total suspended solids

Monitoring Methods:

- Biweekly grab samples
- Combination of in-lab processing (TSS) and sent out for independent lab analysis (VMI)

Monitoring Protocol(s) Reference – DNREC - Monitoring Cooperative Agreement; (Additional?)

Question 3: Where is the groundwater discharge in and around the restoration project site, and how do groundwater influxes impact restoration outcomes?

Monitoring Metrics:

- Locations of groundwater discharge into wetland complex

Monitoring Methods:

- Forward Looking Infrared (FLIR) thermal imaging, via aircraft in winter, to determine locations of groundwater discharge into the impounded wetland system (This project is coordinated and conducted by Dr. Tom McKenna, University of DE / DGS)
- Piezometers, 3 paired upland/wetland locations, to track groundwater changes (proposed)

Monitoring Protocol(s) Reference – DGS – Monitoring Cooperative Agreement [Identifying Groundwater Discharge Proposal (McKenna 2014)]

Project Objective 4 – Salt Marsh Vegetation: Re-establish native salt marsh vegetation communities, with a moderate (20-35%) component of open water/mudflats and less than 5% cover of invasive species

Question 1: Does >85% of salt marsh vegetation planted during the Shoreline Recovery phase continue to thrive, beyond the timeframe of implementation monitoring?

Monitoring Metrics:

- Percent cover of vegetated salt marsh in Shoreline Recovery restoration area
- Potential additional vegetated cover and survival metrics

Monitoring Methods:

- Aerial Photography interpretation
- Vegetation surveys – quadrats and overhead imagery along transects
- Photopoints

Monitoring Protocol(s) Reference – Initially, this will likely be the responsibility of the contractor as a requirement of permitting.

Question 2: How much natural recruitment of tidal marsh vegetation is occurring following implementation of restoration activities?

Monitoring Metrics:

- Percent cover of *Spartina alterniflora* and other desirable macrophytes throughout Unit II
- Percent of marsh edge colonized by desired salt marsh species (e.g., *Spartina spp.*)

Monitoring Methods:

- Aerial Photography interpretation
- Vegetation surveys (per IWMM, SMI, SHARP, and/or MidTRAM protocols)
- Marsh edge survey (quantify % of edge with desired vegetation)
- Photopoints

Monitoring Protocol(s) Reference – IWMM (Vegetation Survey), SMI/SHARP (Vegetation Monitoring), MidTRAM (Habitat Attribute)

Question 3: How does marsh survival and recruitment compare between planting techniques (plugs, seeding, hummock transplants, unplanted)?

Monitoring Metrics:

- Percent cover of vegetated salt marsh between treatment types
- Potential additional vegetated cover and survival metrics

Monitoring Methods:

- Vegetation surveys – quadrats and areal photos along transects
- Photopoints

Monitoring Protocol(s) Reference – TBD; This is an optional monitoring component yet to be developed, depending on time and resources available.

Question 4: Did the restored processes bring about habitat development trajectories towards targeted habitat composition?

Monitoring Metrics:

- Percent cover of *Spartina alterniflora* and other desirable macrophytes throughout Unit II
- Percent cover of open water/mudflats at low tide
- Progression of channel order, density, stream length, bifurcation ratio and sinuosity
- Post restoration changes in drainage network and higher order channel configuration
- Diversity of salt marsh species and distribution of low marsh and high marsh

Monitoring Methods:

- Aerial Photography interpretation
- Vegetation surveys (per IWMM, SMI, SHARP, and/or MidTRAM protocols)
- Photopoints

Monitoring Protocol(s) Reference – IWMM (Vegetation Survey), SMI/SHARP (Vegetation Monitoring), MidTRAM (Habitat Attribute)

Question 5: Were *Phragmites* and other invasive plants effectively detected and their establishment reduced or controlled to <5% cover?

Monitoring Metrics:

- Percent cover of *Phragmites,* and other invasives if detected

Monitoring Methods:

- Aerial Photography interpretation
- Rapid presence/absence invasive plant surveys (qualitative/opportunistic) (Ellings 2011)
- Vegetation surveys
- Photopoints

Monitoring Protocol(s) Reference – IWMM (Vegetation Survey), SMI/SHARP (Vegetation Monitoring), MidTRAM (Habitat Attribute)

Question 6: Does the salt marsh vegetation exhibit robust belowground productivity?

Monitoring Metrics:

- Belowground biomass
- Bearing capacity

Monitoring Methods:

- DNREC Marsh Vulnerability Index (MVI) sampling (RTK and biomass samples)
- MidTRAM Habitat Attribute – Bearing Capacity

Monitoring Protocol(s) – MidTRAM (Habitat Attribute), Delaware Marsh Vulnerability Index (MVI) (Wilson 2015)

Project Objective 5 – Salt Marsh Birds: Provide habitat for native salt marsh wildlife species, including salt marsh obligate birds

Question 1: Is the restored salt marsh supporting a robust salt marsh bird community, particularly obligate salt marsh species?

Monitoring Metrics:

- Breeding bird diversity and abundance
- Marsh Bird Community Integrity Index (Wiest and Shriver, *unpub/thesis?*)
- Migrating and wintering bird diversity and abundance

Monitoring Methods:

- IWMM roadside bird surveys
- SMI/SHARP Point count & callback bird surveys

Monitoring Protocol(s) Reference – IWMM (Waterbird surveys), SMI/SHARP (Avian surveys)

Question 2: How are wintering waterfowl, especially American black ducks, utilizing the restored marsh, and does relative food availability for these species change as a result of restoration?

Monitoring Metrics:

- Benthic core biomass
- Vegetation
- Nekton
- Relative abundance of waterfowl species
- Behavior budget of waterfowl species (For possible future consideration)

Monitoring Methods:

- Benthic core sampling, sorting, and weighing
- Vegetation surveys
- Nekton surveys
- Waterfowl surveys included in IWMM
- Waterfowl behavior scan sampling (For possible future consideration)

Monitoring Protocol(s) Reference – The wintering waterfowl food availability component of marsh restoration monitoring is being coordinated and conducted in cooperation with the University of Delaware (Dr. Chris Williams); Also, IWMM

Question 2: Is the restored salt marsh supporting breeding salt marsh passerine productivity?
(For possible FUTURE consideration)

Project Objective 6 – Estuarine Fish & Shellfish: Improve estuarine fish and shellfish habitat, particularly for species identified in the CCP as target resources of concern (river herring, striped bass, American eel)

Question 1: What are the changes in fish communities over time with respect to assessing the effects of restoration activities, primarily in Unit II? What is the fish response to restoration actions during pre and post restoration habitat conditions, especially in Unit II? What are the seasonal changes in abundance and species composition of both transient and resident fish species for pre and post restoration periods?

Monitoring Metrics:

- Fish abundance, species richness, and species composition differences

Monitoring Methods:

- Seine nets, Fyke nets, Clover traps
- Throw traps and Ditch nets (eventually, via SMI)

Monitoring Protocol(s) Reference – Most of this aspect of the marsh restoration monitoring is being conducted in cooperation with the Delaware National Estuarine Research Reserve, and the USFWS Maryland Fisheries Resource Office (MDFRO); The nekton protocol of SMI may eventually be utilized as well.

Question 2: Based on the hypothesis that Unit III will have a greater salinity gradient from fresh (0-5 ppt), to brackish (5-8 ppt), to saltwater (> 18 ppt) compared to Unit II (= entire unit > 18 ppt), what are the spatio-temporal patterns of fish health, distribution and responses to the more pronounced salinity gradients in Unit III?

Monitoring Metrics:

- Same as Project Question 1 – this is a "subset" of that monitoring

Monitoring Methods:

- Same as Project Question 1 – this is a "subset" of that monitoring

Monitoring Protocol(s) Reference – Most of this aspect of the marsh restoration monitoring is being conducted in cooperation with the Delaware National Estuarine Research Reserve, and the USFWS Maryland Fisheries Resource Office (MDFRO); The nekton protocol of SMI may eventually be utilized as well.

Question 3: How are target fish species moving throughout and utilizing the wetland complex? Is the restored marsh a population sink for anadromous fish?

Monitoring Metrics:

- Documentation of encounters and movements of tagged fish

Monitoring Methods:

- Acoustic tag monitoring in target fish species

Monitoring Protocol(s) – DNREC Cooperative Agreement;

Project Objective 7 – Coastal Processes*:* Establish a dune and backbarrier beach complex along northern Unit II, stable enough to withstand routine tide and storm surges and, ultimately, overwash processes while retaining a functioning backbarrier salt marsh.

Question 1: Is the shoreline along Unit II eroding at a pace slower than, faster than, or comparable to before restoration?

Monitoring Metrics:

- Neap tide high tide swash line position

Monitoring Methods:

- NPS Shoreline Position 1D survey protocol (GPS, semiannually)

Monitoring Protocol(s) Reference – NPS Shoreline Position Monitoring Protocol (Psuty et al. 2010)

Question 2: Is the restored dune retaining average intended constructed height and width over time?

Monitoring Metrics:

- Dune crest elevation
- Shoreline cross section topography

Monitoring Methods:

- NPS Shoreline Position 2D survey protocol (RTK)

Monitoring Protocol(s) Reference – NPS Coastal Topography Monitoring Protocol (Psuty et al. 2012)

Project Objective 8 – Unit III: Restore a self-sustaining oligo-mesohaline wetland system within Unit III, with a gradient of salinity conditions expected between the area of freshwater input in the west and salt marsh in the east

Question 1: What is the distribution of salinity throughout Unit III throughout the lunar tide cycle, under various levels of freshwater input, and following storm events?

Monitoring Metrics:

- Minimum and maximum salinity at water monitoring stations
- Distribution of salinity across the wetland complex throughout the lunar tide cycle, under various levels of freshwater input, and following storm events

Monitoring Methods:

- YSI sonde monitoring network
- Salinity transects

Monitoring Protocol(s) Reference – DNREC - Monitoring Cooperative Agreement

Question 2: What is the distribution of vegetation communities throughout Unit III? Do open water and associated tidal flats constitute $\leq$ 50% of the unit?

Monitoring Metrics:

- Percent cover of a range of wetland communities
- Percent cover of open water/mudflats
- Diversity of fresh, brackish, and salt marsh species

Monitoring Methods:

- Aerial Photography interpretation
- Vegetation surveys (Per IWMM, SMI, SHARP, and/or MidTRAM protocols)
- Photopoints

Monitoring Protocol(s) Reference – IWMM (Vegetation Survey), SMI/SHARP (Vegetation Monitoring), MidTRAM (Habitat Attribute)

Sampling Protocols

The refuge will utilize a variety of monitoring protocols, developed either by the USFWS (e.g., SMI) or by partners (e.g., MidTRAM). Some monitoring efforts are focused programs designed through cooperative agreements. In some cases, local implementation will involve a modification of the associated monitoring protocol. As the monitoring plan is fully developed and finalized, the protocols will be incorporated in more detail into the refuge's Inventory and Monitoring Plan. A table in Appendix B

summarizes the protocols (monitoring program name and/or source citation) that can be utilized to implement monitoring activities (Appendix B).

Adaptive Management

These are Draft Performance Criteria Trigger Points discussed thus far, which would prompt action or change in management in future years, following restoration. These will be reviewed and revised as restoration is implemented

[Unit II]

- No less than 65% of Unit II boundary will be colonized by desirable vegetation (mostly *Spartina alterniflora*).
- *Phragmites* coverage will be < 5% of total vegetated areas of Unit II.
- Open water and associated intertidal flats of restored Unit II boundary will be < 35%.

[Unit III]

- No less than 50% of total marsh areas will be colonized by desirable vegetation (perennial and annual mix of brackish wetland plants)
- *Phragmites* cover will be < 10% of total vegetation area of Unit III.
- Hemi-marsh condition for open water and associated intertidal flats will be < 50%.

Restoration and Monitoring Activity Anticipated Schedule

Year	Restoration Activities	Monitoring Activities
2012	None	• SMI baseline monitoring (birds, veg, nekton) in Unit I and Unit IV • Water level and salinity monitoring (est. 2010) • Water quality grab samples • SET readings • Shoreline position (1-D)
2013	None	• Vegetation Monitoring in potential restoration demo site (SE portion of Unit II) • Water level and salinity monitoring • SET readings (Unit II only) • IWMM bird & veg surveys • Shoreline position (1-D)
2014 (Spring / Summer)	None	• Establish distribution of monitoring station sites • SHARP/SMI Marshbird surveys (Unit I, II, IV) • Vegetation community monitoring (SMI rapid protocol); Units I & IV SMI implementation points, new points in Units II • Photopoints, as feasible • Repeat veg surveys in “proposed demo area” • Water level and salinity monitoring • Initiate sediment budget data collection • Fish community survey • Initiate acoustic tagging program • SET readings • IWMM bird & vegetation surveys • Shoreline position (1-D)
2014	None	• Sediment budget monitoring continues

Year	Restoration Activities	Monitoring Activities
(Fall / Winter)		• Fish community survey • SET readings • IWMM bird & vegetation surveys • Black duck food availability pre-restoration sampling (planned) • Shoreline position (1-D)
2015 (Spring / Summer)	Demonstration area *Spartina* planting in Unit II, along northern and southern road buffers (spring) Coastal Marsh Resilience Phase – Channel construction begins	• SHARP/SMI Marshbird surveys (Unit I, IV) • Veg community monitoring, including points in Unit III • Photopoints in Units II and III • Repeat veg surveys in "proposed demo area" • MidTRAM vegetation transects, bearing capacity, and RTK (all Units) • Baseline belowground biomass data collection • Expanded/reconfigured water level and salinity monitoring • Continue sediment budget data collection • Fish community survey • Acoustic fish tagging • SET readings • IWMM bird & vegetation surveys • Shoreline position (1-D)
2015 (Fall / Winter)	Shoreline Recovery Phase – Breach closure and marsh platform planting (planned)	• Implementation monitoring of Shoreline Recovery construction • Sediment budget monitoring continues • Fish community survey • SET readings • IWMM bird & vegetation surveys • Shoreline position (1-D)
2016 (Spring / Summer)	DelDOT bridge construction (planned)	• Plant survival / recruitment surveys • Vegetation community monitoring • Initial post-restoration belowground biomass data collection • MidTRAM vegetation transect and quadrat surveys, bearing capacity, and RTK (all Units) • Expanded/reconfigured water level and salinity monitoring • SET readings • IWMM bird & veg surveys • Shoreline position (1-D)
2016 (Fall / Winter)		• SET readings • IWMM bird & vegetation surveys • Shoreline position (1-D) • Shoreline position (2-D, if not still part of Implementation monitoring) • Black duck food availability post-restoration sampling (planned)

Data Analysis and Reporting:

Data will be analyzed by refuge staff and/or cooperators and basic summary reports prepared annually. Some monitoring activities will require more in depth analysis than others, and some data will be incorporated into the refuge's annual habitat work plan.

References:

Many of these are available online at www.tidalmarshmonitoring.org (Turner et al. 2012)

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APPENDIX A – Existing Data & Baseline Information:

Summary of existing data sets and sources of baseline information associated with the refuge marsh restoration project

Data	Description	Date Collected	Data Collector	Notes
Wildlife Surveys, Studies, & Monitoring Programs				
Historic bird surveys	[Weekly surveys?? Get info from Annie]		Refuge staff	
SMI	Salt Marsh Integrity (SMI) program	2008, 2009, 2012	Refuge staff, including seasonal staff; In cooperation with USGS, UD	Both pilot data (2008-2009) and implementation baseline data (2012) exist for Units I and IV (Neckles et al. 2013; DRAFT SMI Report from R5)
IWMM	Integrated Waterbird Monitoring & Management; Roadside bird surveys and basic vegetation response survey	2010 - Present	Refuge staff	Loges et al. 2014 http://iwmm.ning.net/ (2010-2014 surveys done with initial draft protocols, protocols finalized for 2015 season)
OMWM Study	Birds, mosquitoes, what else?	2001-2006; Updated in 2010	Refuge staff and seasonal staff; In cooperation with Dr. Mary-Jane James-Pirri	James-Pirri, M.-J. 2012. Salt marsh responses to hydrological alterations at Atlantic Coast (USA) US Fish and Wildlife Refuges: 2010 summary and comparison to previous monitoring data (2001-2006). Report to US Fish and Wildlife Service, Region 5, Newington, NH. May 2012
Winter Waterfowl /Black Ducks	Winter waterfowl bird populations, behavior, and food availability	2011, 2012, 2013	University of Delaware	Pending thesis by Mark Livolsi
Vegetation Data				
Study-specific Veg	Data collected in conjunction with SMI, IWMM,	OMWM 2001-2006, 2010 (OMWM), SMI (2008, 2009,		

Data	Description	Date Collected	Data Collector	Notes
	OMWM	2012), IWMM (2010 – present)		
Winter waterfowl food availability	Winter waterfowl bird populations, behavior, and food availability	2011, 2012, 2013(?)	University of Delaware	Project with Chris Williams; Possibly to extended with Sandy funds Pending thesis by Mark Livolsi
Baseline belowground biomass	DNREC Marsh Vulnerability Index study			In Unit I and Unit IV only Bart Wilson dissertation
Landscape, Hydrology, and Habitat metrics; Photopoints	Mid-Atlantic Tidal Marsh Rapid Assessment Method (MidTRAM)	2010 (Unit IIII and IV) 2012 (Unit I)	DNREC Wetland Assessment Section	MidTRAM protocol, as well as Broadkill and Mispillion watershed reports, are available online; Raw data available from DNREC.
NVCS original vegetation map		2005	Robert Coxe (DNREC)	
NVCS vegetation map update		Pre-Sandy 2012 (report in 2013)	Robert Coxe (DNREC)	
NVCS historic vegetation maps		Representing 1937, 2002, and 2012	Robert Coxe (DNREC)	
Water Monitoring				
Continuous water level & salinity	YSI network of real-time monitoring sondes measuring water level and salinity; 7 monitoring sites	2010 - Present	In partnership with DNREC DE Coastal Programs and YSI, Inc (Chris Hyer)	Current Site: https://stormcentral.waterlog.com/public/USFWS Archived Data: http://www.ysieconet.com/public/WebUI/Default.aspx?hidCustomerID=236
Water quality grab samples	List metrics			
Salinity transects	Series of discrete salinity readings taken from airboat	2011	DNREC DE Coastal Programs	

Data	Description	Date Collected	Data Collector	Notes
Elevation & Shoreline Position				
Surface Elevation Tables (SETs)	Installed and read per USGS protocol; 3 in Unit I, 6 in Unit II			SETs in Units I and II have been read since 2011 installation Additional SETs installed in Unit IV in 2012, readings to begin there 2015
Statewide LiDAR	LiDAR flow by state of DE	2007	DNREC DE Coastal Programs	Found to be unreliable in marsh environments, but good for upland
RTK transects		2010	DNREC DE Coastal Programs	
Sonar-collected bathymetry		Summer/Fall 2012	DNREC DE Coastal Programs	Sonar-collected bathymetry, site-specific LiDAR, Hydrographic surveys combined by Atkins to form project area DEM for hydro modeling
Site-specific LiDAR	Collected as part of the Breach Analysis contract	January 2013	Atkins Global	
Hydrographic surveys		January 2013	Atkins Global	
Shoreline Position (1D)	GPS survey of High tide swash line	April 2011 - present	Refuge staff	Conducted each spring and fall, per NPS protocol
Hydrodynamic Modeling				
Delft3D model results	Base model calibrated against existing data and simulated tides and storms; restoration scenario testing forms basis of restoration design	2013 (report in 2014)	Atkins Global	See full report "Hydrodynamic Modeling of Prime Hook National Wildlife Refuge Final Report" https://app.box.com/s/frclxl03g8a07diuxaq2
Environmental Assessment				
Project Description and EA for NEPA compliance	Description of restoration design, assessment of environmental impacts	2015	USFWS	Available at http://www.fws.gov/hurricane/sandy/projects/PrimeHookBarrierBeach.html

APPENDIX B – Summary of monitoring protocols and associated source/citation

Monitoring Activity	**Monitoring Protocol**	**Source / Citation**	**Comments**
Water level monitoring	Continuous monitoring via EXO2 sonde network	NERR YSI SOP; Roegner et al 2008 has good summary	YSI sonde network in place since 2010 was updated in 2014
Salinity monitoring	Continuous monitoring via EXO2 sonde network	Roegner et al 2008 has good summary	YSI sonde network in place since 2010, was updated in 2014
Salinity monitoring	DNREC DCP salinity transect SOP	Informal protocol	
Sediment availability	SSC grab sample SOP	Standard Test Methods for Determining Sediment Concentration in Water Samples (ASTM) ???	
Sediment availability	Continuous monitoring via ADCP backscatter interpretation (with calibration)		Requires periodic calibration
SETs	USGS SET protocol	http://www.pwrc.usgs.gov/set/ Also see DE NWR SOP	Includes marker horizons; FWS protocol forthcoming
Surface accretion	Sediment pins or plates, and/or marker horizons??	See Takekawa	Potential monitoring, not yet planned
Elevation	RTK (transects and/or at target features like vegetation plots)		
Shoreline Position (1D)	NPS Shoreline Position I&M Protocol	Psuty et al. 2010	
Shoreline Topography (2D)	NPS Shoreline Topography I&M Protocol	Psuty et al. 2012	
Vegetation Surveys	SMI/SHARP vegetation protocol (circular plot and point intercept transects); MidTRAM vegetation cover and bearing capacity; IWMM habitat quality/quantity;	SHARP: www.tidalmarshbirds.net MidTRAM (Rogerson et al. 2010) IWMM: http://iwmm.ning.net/ Loges et al. 2014	(Also, see FWS SMI protocols)
Vegetation	Delaware Marsh	Wilson, B. 2015 (pending	In combination with RTK

Monitoring Activity	**Monitoring Protocol**	**Source / Citation**	**Comments**
Productivity	Vulnerability Index protocol	PhD thesis)	
Photopoints	Photopoint monitoring SOP;	MidTRAM (Rogerson et al. 2010), and other sources	Photos in each cardinal direction;
Landscape analysis	Aerial imagery and interpretation		
Waterbird diversity and abundance	IWMM	http://iwmm.ning.net/ Loges et al. 2014	2010-2014 surveys done with initial draft protocols, protocols finalized for 2015 season
Obligate marsh bird diversity and abundance	SHARP/SMI	SHARP: www.tidalmarshbirds.net SMI: Neckles et al. 2013	
Winter waterfowl food availability	University of Delaware core sampling and analysis, per cooperative agreement	Livolsi 2015	Multi-refuge cooperative agreement with FOR, CPM, and PMH
Nekton community sampling	Fyke nets, clover traps, seine nets	USFWS MDFRO protocols	
Nekton movement monitoring	Accoustic tag monitoring		Need citations/protocol from DNERR, if possible
POTENTIAL:			
Soil characteristics			Possible monitoring, ask Al
Plant survival / natural recruitment		Potential future monitoring	Potential monitoring beyond Implementation contract in planted Shoreline Recovery area (and corresponding unplanted control area if comparing techniques);
Plant survival / natural recruitment	Overhead imagery at quadrats	Potential future monitoring	Potential monitoring beyond Implementation contract in planted Shoreline Recovery area (and possibly corresponding unplanted control area);