COASTAL MARSH RESTORATION

An Ecosystem Approach for the Mid-Atlantic

Jointly authored by:
National Oceanic and Atmospheric Administration (NOAA)
United States Fish and Wildlife Service (USFWS)

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Coastal marsh serenity. Ray Hennessy

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EXECUTIVE SUMMARY

Marshes have been modified for hundreds of years for human use. Joe Smith/USFWS

Climate change and sea level rise, combined with centuries of human alterations of coastal ecosystems, are causing unprecedented changes and increasing threats to a host of species and the habitats upon which they rely. This, in turn, has major implications for the continued viability of many coastal communities. The National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NOAA Fisheries) and U.S. Fish and Wildlife Service (USFWS) are federal agencies with a shared interest in and regulatory responsibilities for conserving and restoring coastal species and habitats. Both agencies engage and support an array of partners implementing coastal habitat projects. NOAA Fisheries and USFWS strive to proactively address and mitigate these threats while fulfilling our mandates. **This document highlights the agencies' common goals, provides guidance for partners, and addresses some potential issues of concern (e.g. different species/habitat priorities).** Together, our primary focus is on the collective benefits of an ecosystem approach to habitat conservation and restoration, which requires balancing the risk of doing too little — or proceeding too slowly — with the mutual commitment to restore ecosystem function and the wide array of benefits while avoiding harm to our individual trust resources.

The intent of this document is to frame an approach to comprehensive, ecosystem-based coastal restoration that offers a greater likelihood of success at each project phase. We offer guidance to assist with project planning, design, permitting, monitoring, and adaptive management. While this guidance may apply to other coastal marsh settings, it has been developed primarily by practitioners from the U.S. Mid-Atlantic and southern New England coastal regions and is focused on techniques that have been successfully implemented within this geography. Guidance about the regulatory process is intended to support well-conceived and designed projects in obtaining the necessary authorization for construction. The technical guidance included about restoration techniques highlights the need to consider geomorphic, hydrologic, and ecological factors during project planning, design, and implementation. We also provide examples to develop a greater collective understanding of successful project approaches and desired outcomes among coastal restoration practitioners. Finally, we offer examples of monitoring and adaptive management including how these protocols can be developed and implemented post-construction.

INTRODUCTION: MOVING TOWARD AN ECOSYSTEM FOCUS IN COASTAL RESTORATION

Atlantic coast tidal marshes provide a variety of ecosystem services to human and wildlife communities. Marshes buffer coastal communities against extreme storm events, provide significant carbon sinks, and support significant fish and wildlife biodiversity. However, these coastal ecosystems are threatened by a long history of human use and modification paired with the ongoing and synergistic effects of sea level rise resulting in marsh degradation, fragmentation, and outright loss. The USFWS, NOAA Fisheries, and partners are therefore working to develop and scale up innovative restoration techniques to address the effects of sea level rise and other climate-related changes to these coastal landscapes.

Coastal marshes support many wildlife species while protecting coastal communities from storm events. Ray Hennessy

As the nation's trustees for the wide array of terrestrial, avian, and aquatic species supported by coastal estuaries, we work to balance our directives to restore ecosystem function with an understanding of both their current and anticipated conditions. Restoration of vegetated tidal wetlands by converting open water, intertidal mudflats, and other shallow water communities is often proposed to address significant, recent losses of saltmarsh along the coastline. Frequently, these shallow water areas may already provide important habitat to trust resources. **Because habitat use differs across taxa and life stages, the conversion of one aquatic habitat type to another typically does not affect all species equally and may be detrimental when developed for a single species, habitat or type, or a specific time period.** As a result, the short- and long-term ecological implications of habitat conversion should be considered during marsh restoration planning that result in a suite of system functions and services for terrestrial, avian and aquatic species.

There is an emerging need to establish a unified, ecosystem-based approach to developing projects that balance restoration objectives and habitat goals across agencies with different suites of trust resources. A commitment to prioritize ecosystem-level restoration over species-specific goals will help facilitate the implementation of restoration projects that can meet multiple priorities. **This guidance was developed for conservation and restoration partners to clarify collective goals for estuarine habitat restoration and inform the development of restoration approaches that benefit agency trust resources and conservation goals**. When appropriate we also provide specific suggestions for best practices during project development

RESTORATION PLANNING: THE KEY TO AN ECOSYSTEM-BASED APPROACH

The location and scale of restoration projects in the mid-Atlantic region are influenced by a variety of factors including property owner awareness, financial cost, resource availability, observed resource needs, partner alignment, and project goals. Restoration may be a targeted project to address a local need (e.g. marsh edge erosion) or may be far larger in scope to help meet regional conservation or restoration goals (e.g. maintain marsh acreage for buffering against storm events). While many of the principles discussed here can be applied to smaller projects, this guidance targets larger projects that represent landscape-scale coastal restoration efforts.

Fish and terrestrial wildlife have inherently different uses for coastal systems; during planning we often prioritize goals that help us achieve the mission of our individual agencies; NOAA Fisheries often prioritizes fish habitat through preservation of submerged aquatic vegetation (SAV), intertidal mud and sand flats, and low marsh, while USFWS often prioritizes bird/mammal habitat through preservation and enhancement of high marsh. This siloed strategy needs to change to achieve true ecosystem resiliency. During planning, project design should preserve and enhance connectivity and heterogeneity across the entire tidal marsh community. Planning efforts should reference regional resources that describe the existing heterogeneity of the coastal landscape (e.g. Correll et al. 2019, Abelson et al. 2020; Vozzo et al. 2023; Waltham et al. 2020) and evaluate previous restoration efforts along with local reference sites to guide planning and inform the end goal of restoration work.

Coordinating site visits with all interested partners from the beginning ensures that all regional priorities are being considered and the project can be successful on many fronts. Jonathan Watson/NOAA

A CLOSER LOOK AT RESTORATION

PROJECT PORTFOLIOS TO MAXIMIZE RESTORATION BENEFIT

Restoration projects are best developed within the context of other restoration work across the coastal landscape and contain objectives building towards ecosystem-based restoration goals. Consideration of both within-estuary (i.e. within a single watershed) and regional (i.e. across multiple watersheds or states) context is important for maximum restoration effectiveness.

Restoring Functional Coastal Systems – Estuary Scale

Restoration programs developed at the estuary scale allow for greater regional outcomes through focus on multiple goals simultaneously. Interconnected estuarine ecosystems generate geomorphic and trophic heterogeneity (diversity across space and time), stability, and resilience (the capacity to withstand or recover quickly from disturbance) at a landscape scale. Shoals, tidal flats, and low marshes attenuate wave energies and provide stability for high marshes which, in turn, buffer uplands from irregular flooding. Each community type (e.g. high marsh, low marsh) also supports unique insects, plants, fish, and wildlife that contribute to (and benefit from) a functional coastal system comprised of these diverse ecological communities. For example, high marsh habitat for Saltmarsh Sparrows is only one part of a functional coastal ecosystem which also includes low marsh, mudflat, pool/pannes, open water, and beach/dunes. Bundling multiple restoration approaches within a portfolio approach will enhance benefits for marsh systems and should help to garner support from the regulatory community.

High marsh habitat is only one part of a functional coastal ecosystem. NPS

Restoring Functional Coastal Systems – Regional Scale

Watershed/estuary plans - such as those developed by National Estuary Programs (e.g. SNEP 2021), state and federal land managers (e.g. ACJV 2023), and counties/municipalities - are a suitable platform to examine project goals at a landscape scale and can also serve as a major component of an alternatives analysis, which is a critical component of federal Clean Water Act permitting (see Monitoring, page 17). While more initial work (e.g. mapping, site evaluation, planning) is likely required to develop this regional framework, the overall outcome should be streamlining of subsequent projects. Also, by examining sources of marsh impairment at a regional scale, practitioners can prioritize restoration approaches more holistically to maximize long-term benefits (e.g. resilience, transgression pathways, marsh unit stability). While the approach will vary based on the needs of the subject estuary and the agencies/supporting partners involved, the overall project goals should help to place each individual restoration effort in larger context.

Site Selection, Assessment, And Restoration Scoping

Restoration efforts get underway at Prime Hook National Wildlife Refuge. Bart Wilson/USFWS

Proper project planning entails a demonstrated understanding of the ecological needs in the region and, if applicable (see Closer Look at Restoration, page 4), developing defensible prioritization criteria to identify sites and corresponding actions. Defining the existing ecological function and services currently provided along with any degradation observed in or around the project area is integral in initial concept design as well as in subsequent technical designs.

Restoration proponents often seek to restore historical functions to marsh. We recommend considering the current landscape context to determine whether such an approach is even feasible. For example, regulatory and resource agencies may not support a project that creates high marsh in an area where it has existed historically but not in the recent past (e.g. approximately 20 years). The impetus for habitat restoration can often be categorized by the following needs and approaches:

Regional Habitat and Species Enhancement - In instances where regional conservation objectives drive the project development process, site identification and methods may be heavily focused on single-species or single-habitat objectives. These programs are typically designed to benefit species of high conservation priority (e.g. obligate, high-marsh nesting bird species) and may be part of a regional habitat resiliency effort. A portfolio of projects is often developed through a landscape-scale desktop evaluation and further refined through the identification of interested property owners or land stewards. While this may be a suitable starting point, we also recommend that practitioners consider localized site needs/challenges to further refine the project development process.

Local Site Restoration - Tidal marsh restoration projects stemming from site-specific needs are common. Projects may range from shoreline erosion control to improving the resilience of existing marsh, sometimes including the preservation of infrastructure.

Beneficial Use of Dredged Material - There is an increasing recognition of the value of dredged sediments to enhance marsh elevation where needed to increase resilience to sea level rise. In cases where future dredging events are anticipated (e.g. maintenance of existing navigational channels), the dredged material can often be deposited as part of a marsh restoration project in lieu of traditional disposal methods (e.g. placement in an authorized upland dredged material containment facility, open water disposal). For each project, the suitability of the dredged material (e.g. volume, contaminants, grain size) should be assessed along with the actual need for the addition of dredged sediments to restore or sustain marsh function. Any placement of dredged material should be based on the needs of marsh (current or future) rather than the opportunistic desire to beneficially use the sediment.

Planning to Restore Stochasticity

Restoration projects or programs that are developed from an ecosystem perspective should aim to enhance resiliency by facilitating existing ecosystem function across time. Even when species-specific habitat goals are favored, the overall project should start with an evaluation of current habitat functions to ensure that the priority habitat(s) present the highest likelihood of long-term success. For example, a project targeting the creation of high marsh acreage that also facilitates restoration of stochastic coastal processes (i.e. the interaction of tidal prism dynamics, elevation, drainage network, and soil/porewater geochemistry) using a suite of approaches (see Table 1) will have a greater likelihood of ecological success as well as more likely support from the regulatory community. **Plans and supporting documents should present a discussion of both the initial impacts and long-term benefits of the project to the landscape, including anticipated future conditions in the project vicinity** (e.g. high marsh may eventually change to low marsh with sea-level rise). A thoughtful consideration of these topics during initial design will likely reduce the total resources needed for implementation across the life of the project (i.e. funding, staffing for regulator review and project oversight, sediments, time, etc.), ease regulatory concerns, and increase the likelihood of the restored ecosystem to evolve with the changing physical drivers associated with climate change.

Table 1: Common sources of marsh impairment, methods to evaluate their severity during initial planning phases, and conceptual approaches to address losses.

Source of Impairment	Documentation	Potential Approaches to Address
Edge erosion	State geological survey programs Aerial time-series imagery Visual observation Historical accounts	Near-shore bathymetric alteration Wave attenuation (low-profile sills [emergency intervention only], oyster reef, wave attenuation devices (WADs), etc.) Headland stabilization and stable embayments (see: Hardaway and Byrne 1999)
Low platform elevation	Digital elevation models plus analysis of tidal datums High UV/VR (see Ganju 2019)	Placement of suitable dredged sediment Assess upland interface for transgression potential
Hydrological – ditching	Digital elevation models Aerial imagery Water pressure sensors (surface and sub-surface)	Ditch remediation Runnelling Nature-like channel creation
Hydrological – flow restrictions (e.g. tide gates, culverted road crossings)	Infrastructure mapping resources Field observations Water pressure sensors (surface and sub-surface) Hydrodynamic modeling	Flow and tidal impediments/restrictions due to infrastructure (roads, rail-lines, undersized bridges, and culverts)
Invasive species	Vegetative surveys Seasonal LiDAR data	Glyophosate application or physical removal Site modifications to improve hydrology Replanting with suitable native vegetation Long-term management

DESIGN AND PERMITTING

Restoration design with an ecosystem focus seeks to fundamentally modify the physical landscape (i.e. hydrology, topography, channel/creek bathymetry, tidal hydrology, and vegetation cover) of coastal systems to restore long-term function. These changes aim to build resiliency through increased hydrodynamic and geochemical function resulting in a response by the supporting biota, including vegetation community types (e.g. low marsh, high marsh). Vegetation community conversion can create a juxtaposition of agency trust resources, where the creation of one habitat may appear to come at the expense of another. Thankfully, a functional coastal system includes habitats for all coastal species; the existence of one type of habitat does not negate the presence or importance of another, and the dynamic nature of coastal systems means that vegetated communities will transition over time from one to another (e.g. high marsh may eventually transition to low marsh over time). During design and permitting it is important to exhibit an understanding of these issues including an emphasis of resiliency of coastal habitats across a broad range of elevations and corresponding communities.

Developing Project Designs to Meet Coastal Challenges

Each marsh experiences ecological disturbance over time including sea level rise, subsidence, wave energy, herbivory, etc. Often this disturbance is beyond the resilience capacity of a marsh, creating a trajectory toward long-term degradation and eventual loss. In these instances, it is important to evaluate the different challenges facing the marsh during design and develop a suite of solutions that addresses each source of stress. Here we highlight common challenges to tidal marsh health and resilience and note some technical approaches to addressing each. Many restoration portfolios may include a combination of these approaches to address the combination of stressors evident at a particular site.

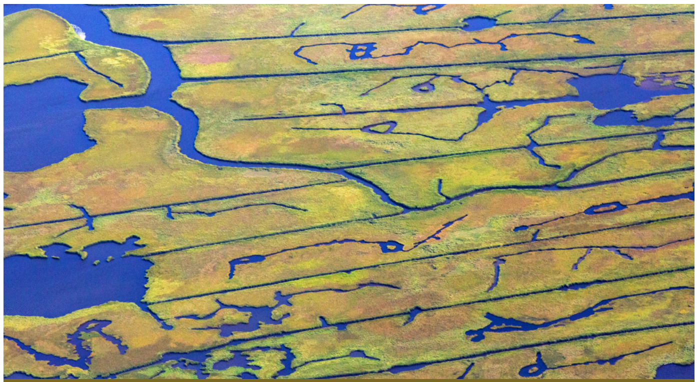
Challenge: Edge Erosion

Edge erosion can be addressed through the implementation of low-stone breakwaters, where necessary to preserve existing habitats and infrastructure. Jonathan Watson/NOAA

Erosion at the edge of the marsh platform is a common source of immediate marsh loss in areas with sufficient wave energies. Typically, wave energies are largely driven by wind and corresponding fetches (Leonardi et al. 2016), though boat wakes can also be a significant source (Bilkovic et al. 2019). The first step in developing a restoration design to address edge erosion is the identification of the sources of wave energies. Because wind-driven wave energies typically dominate the erosive forces on a given shoreline, the method to address shoreline erosion is largely determined by the predominant fetch(es). Decisions regarding approaches on individual marshes can be informed by existing guidance (see: Hardaway and Byrne 1999, Currin 2018) and through consultation with regional shoreline engineers. Approaches to mitigating edge erosion include wave attenuation (e.g. oyster reefs, WADs, log arrays), nearshore sediment placement, living shorelines, and/or structure shoreline protection (e.g. breakwaters). **The severity of the documented**

edge loss should inform the nature of the intervention. While marsh edge loss is typically seen as undesirable, the erosion process can also free sediment that, in turn, sustains marshes landward of the existing edge (Ganju 2019). This principal is not always valid, as hydrology modifications in the coastal marshes can negate the movement of sediment into intertidal systems. In cases where edge loss is extreme (e.g. > 1 m per year) and/or threatens the long-term persistence of valued habitats or infrastructure, addressing edge loss is likely necessary to improve and maintain stability of a marsh complex.

Challenge: Hydrological Modification


Coastal marshes were historically ditched for centuries for various human uses. Lauren Owens Lambert

Past hydrological modification of tidal salt marshes can present a persistent source of degradation and increase the vulnerability of marsh to other stressors (e.g. sea level rise; Smith et al. 2017, Portnoy 1999). Common sources of hydrological impairment include tidal restrictions, impoundments, channel straightening, channel widening, ditching, and ditch plugging. Altered marsh hydrology influences sediment supply to the marsh (and the ability to accrete over time), and impacts soil chemistry and plant communities such that significant hydrological modifications fundamentally alter the biogeochemical processes of a marsh (Portnoy 1999, Tognin et al. 2022). Restoring natural tidal inundation patterns to the marsh platform can help the marsh maintain elevation relative to sea level (Ray et al. 2007, Raposa et al. 2020), improve the access for fish and nekton (Raposa and Roman 2003, Minello et al. 2012), and increase carbon sequestration capacity of the marsh (Chmura et al. 2003, Mcleod et al. 2011).

The first step in developing a restoration design to repair marsh hydrology is the consideration of potential historical and contemporary influences of hydrological modification. Identifying these sources of hydrological stress may be simple in the case of visible features (e.g. road crossings, ditches) whereas historical influences (e.g. degraded impoundments) may be less evident. A review of historical aerial imagery, discussions with land managers, and a review of management records will help to develop a greater understanding of site history and identify whether hydrological modification should be addressed at a particular site. Pre-restoration assessment is critical to describe the hydrology of the existing marsh and develop restoration targets related to tidal inundation.

Removing impoundments or tidal restrictions can be integral to restoring tidal inundation and marsh function while also improving the resilience to sea level rise. **Removal of restrictions should be done only after consideration of the ecological context in which the tidal restriction exists**; for example, some wildlife (e.g. Saltmarsh Sparrows) can benefit from the shelter tidal restrictions provide from extreme flooding events. It is also imperative to assess elevation losses that have resulted on the marsh platform, due to sediment influx restrictions, carbon decomposition, and decreased biomass accumulation, before restoring tidal connections.

In cases where the configuration or density of tidal drainage networks on the marsh has been altered (e.g. ditching), approaches to restoring hydrology may involve channel reconfiguration, the construction of runnels to reduce ponding, and potentially the remediation of ditches. **The approach used will largely depend upon the configuration of the existing site**. Tidal range will also play an important role in determining how drainage network modifications should proceed. Careful consideration of existing and proposed sediment dynamics within the system will help to inform how further modifications can help to reduce sediment leaving the marsh over time and ultimately improve marsh resilience to sea level rise.

Challenge: Elevation Vulnerability

Along the U.S. Atlantic coast, many marshes are not able to build elevation at the current rate of sea level rise, resulting in a net loss in relative marsh elevation over time. This is due to a complex variety of factors, many of which are specific to the position of the marsh within the estuary (Kirwan and Megonigal 2013). These factors can include historical modifications (Smith et al. 2017, Adam 2019) which can be exacerbated in microtidal settings where sediment deposition is limited and/or organic sediment production is not ideal. Other factors such as animal herbivory of marsh plants (e.g. Coverdale et al. 2014) can also play a role in diminishing marsh platform elevation.

Placement of fine-grained sediment using spray nozzles at Pepper Creek in Delaware. Bart Wilson/USFWS

Elevation vulnerability is often identified through existing digital elevation models and corroborated through observation of marsh responses. Regularly flooded marshes that are currently situated too low in the tidal frame (e.g. below mid-tide level in microtidal systems) typically lack proper aeration to support robust plant growth (Morris et al. 2017). This, in turn, makes the marsh more vulnerable to peat collapse and subsidence (Defne et al. 2020). Marsh stress from elevation vulnerability can be manifested in a complex change of plant communities (Qi et al. 2020), though it most often leads to increased areas of open water ponding on the marsh surface (Defne et al. 2020, Smith and Niles 2016).

One approach to raising marsh elevation that is becoming increasingly implemented and understood is sediment placement, often termed thin-layer placement, or "TLP", which can be defined as placement of sediment across the marsh platform at thicknesses not to exceed 20 cm. Marshes experiencing additions of sediment at this depth or shallower have been shown to recover quickly from this disturbance (Raposa et al. 2023). The use of the term TLP can cause confusion within the planning and regulatory review of projects, as many projects could have localized or sections where thickness could exceed 20 cm to fill ditches, pools, or build higher elevation habitats. **We recommend avoiding the term TLP or thin-layer placement and instead using the term "sediment placement" to describe any addition of material to the marsh platform**. This simple change will negate these semantic issues from becoming a distraction in developing projects.

The location and design of sediment placement projects should be based upon the ecological needs of the subject marsh as well as the surrounding ecosystem. The beneficial use of dredged material is the main source of sediment used in marsh restoration work. Marsh restoration projects can be developed in tandem with dredge material opportunities; **however it is critical for practitioners to demonstrate that the addition of dredged material will improve the functioning of the marsh across a broad range of ecosystem services and values**. Sediment placement should not be used in a restoration project solely as a solution to a dredge material disposal problem; an identifiable need must exist through lost habitats, degraded condition, and/or building to maintain ecosystem distributions. Similarly, because dredging can create geomorphic and sediment transport instability in tidal systems and result in decreased sediment supply and marsh elevation loss in certain settings (Donatelli, et al., 2018), dredging for the sole purpose of elevating a nearby marsh unit is not typically advisable.

Sediment placement is best suited as one component of larger marsh conservation and management efforts that include other practices, such as land acquisition for inland marsh migration and non-structural measures to reduce marsh stressors. Practitioners and regulators must also consider the potential direct or secondary impacts of a sediment placement project to other shallow water communities that are managed through various statutory authorities (e.g. Magnuson-Stevens Fishery Conservation and Management Act, Fish and Wildlife Coordination Act) including seagrass beds and shellfish habitats. Projects that bolster the ecological functions of the target salt marsh while not negatively impacting other habitats of concern should be easier to permit (see Navigating the Regulatory Process, page 14).

The appropriateness of sediment placement at a particular marsh will likely change over time as ecological conditions change. Many currently healthy, functioning marshes in the region may not be able to keep pace with sea level rise or may be slowly subsiding. Short-term intervention through immediate restoration in these areas may not be advisable, but longer-term monitoring may identify the need for sediment placement in these areas in the future. Another important consideration, especially for sequenced projects that occur over several years, is the relative ratio of temporary (e.g. loss of habitat quantity and quality) and permanent (i.e. habitat conversion) impacts within a broad estuarine system.

Sediment placement may be most appropriate in areas where:

- Sediment inputs are lacking, typically due to ecosystem modifications.
- There is a technically based understanding of how sea level rise, marsh subsidence, and other factors are impacting the potential project site.
- Marsh elevation has been lost, resulting in a loss of marsh health.
- Rates of sea level rise are too great to allow for natural sediment accumulation and biological accretion resulting in substantially impaired function of the marsh.

Sediment placement is generally not appropriate where:

- There is no evidence of marsh degradation.
- The main cause of degradation is not lack of sediment supply or elevation deficiencies.
- No site-specific data on trends/trajectory of the marsh exists or is planned for collection, analysis, or evaluation.
- No pre- or post-construction monitoring is planned.

Utilizing hydraulic dredges to restore channel hydrology at Prime Hook National Wildlife Refuge. Bart Wilson/USFWS

A CLOSER LOOK AT RESTORATION

BEST MANAGEMENT PRACTICES FOR ELEVATION ENHANCEMENT THROUGH SEDIMENT PLACEMENT.

The means of increasing surface elevation through sediment placement can vary greatly due to site dynamics and topography. The sediment type and means of delivery can create the largest difference in how these projects are conducted. The process of sediment placement (through the addition of sand, fine grained, or heterogeneous sources) mimics the natural movement of sediment in tidal marshes through storm over wash or through waves and higher tide levels which increase suspended sediments. In many coastal settings, human development and engineering have restricted the occurrence of storm over-wash events, especially in systems where sand is a commodity for beach nourishment. Even in the fine-grained dominated systems of the Mid-Atlantic, coastal storms historically pushed sand into the marshes and resulted in large uplifts in elevation and conversions of the habitat to different tidal regimes (Nienhuis et al. 2021; Rogers et al. 2015; Schuerch et al. 2018; Walters and Kirwan, 2016).

Before and after examples of barrier island restoration at Prime Hook. Bart Wilson/USFWS

Matching sediment grain sizes of the existing marsh and the material to be placed can be complex. Any material placed on an existing tidal marsh can compact the existing platform with its weight and accelerate dewatering and consolidation, leading to elevation loss. This is a natural process that can be reduced or calculated; but should not negate the potential placement of sand over top of a fine-grained marsh because of elevation loss. If a project goal is to create a wide mosaic of vegetation communities, the addition of sand can more feasibly create higher elevation habitat within the restoration project than other types of material. The rate of underlying consolidation should be estimated, and the resulting values incorporated into the design to account for those elevation losses.

The use of fine-grained material (e.g. silts and clays delivered via hydraulic placement) also has inherent tradeoffs. Creating a large elevation change on the marsh platform with fine-grained material can be challenging; material will easily disperse during tide and precipitation events. The use of fine-grained material is also a challenge in targeting precise elevations or slope goals because it cannot be contoured or graded. It may also present significant challenges associated with acid-volatile sulfides. Fine-grained material, however, will flow over a larger area and will allow natural hydrology to establish more quickly post-placement.

There are examples of past beneficial use studies in Appendix A, and a catalogue of video tutorials outlining best practices for sediment placement in Appendix B.

Challenge: Invasive Species

One significant challenge to establishment, enhancement, and/or maintenance of salt marsh vegetation along the U.S. East Coast is the prevalence of invasive species, both native and exotic. Native species, especially fiddler and purple marsh crabs, are an emerging issue in destabilizing existing marshes in New England (Wasson et al. 2019). Some exotic wildlife species can be invasive in coastal marsh settings (e.g. European green crab [*Carcinus maenas*], nutria [*Myocastor coypus*]), however the exotic *Phragmites australis* (common reed, hereafter *Phragmites*) is an invasive exotic plant and ubiquitous stressor in coastal marshes across the entire Atlantic coastline. The expansion of *Phragmites* along the coast over the past several decades has been correlated with diminished wetland plant diversity (Silliman and Bertness 2004), fish density (Able and Hagan 2003), herpetofauna nesting suitability (Cook et al. 2017), and shifts in bird assemblages (Benoit and Askins 2002; Whyte et al. 2015). The prevalence of *Phragmites* likely also impedes the marsh transgression processes to some extent (Smith 2013). There are some limited benefits to the presence of *Phragmites* in some cases (e.g. to prevent erosion) but these are generally outweighed by the costs of biodiversity and habitat loss to the local and regional ecosystem.

The management of *Phragmites* is often an integral component of a restoration design. Successful control is challenging and depends on a combination of physical (e.g. elevation, tidal influence, proximity to seed sources) and human (e.g. upland development, management approach/frequency) factors. *Phragmites* monitoring and management is therefore often pursued as part of an adaptive management approach to ensure that native wetland vegetation dominates a restored site. ***The potential for Phragmites invasion into a restoration site should be evaluated among the challenges observed at a site and considered at each step of the design and management process***.

Phragmites is an invasive exotic plant and ubiquitous stressor in coastal marshes across the entire Atlantic coastline. Matt Rath/Chesapeake Bay Program)

Navigating the Regulatory Process

Site visits with conservation and regulatory partners to assess site conditions for future projects. Jonathan Watson/NOAA

The alteration of existing tidal habitats represents an impact to waters and wetlands regulated under Section 404 of the Clean Water Act (CWA), which necessitates authorization by state and federal regulatory agencies in consultation with resource agencies such as FWS, NOAA Fisheries, and state natural resource managers. **Early and frequent coordination with the regulatory and resource agencies responsible for the stewardship of these tidal habitats helps to facilitate the permitting process**. Tidal wetlands, mudflats, and SAV are all designated as special aquatic sites under the CWA. Typically, impacts to these aquatic habitats are to be avoided, minimized, and/or mitigated to the maximum extent possible and unavoidable impacts should be offset. The guidance in this document is intended to assist in the development of restoration projects that can be justified within these existing regulatory frameworks

Project Purpose and Need

The fundamental foundation of any project involves establishing project purpose and need. This begins with demonstrating that the site(s) and intervention approaches were selected based on a formal evaluation of current conditions and sources of degradation (see Monitoring, page 17). **Practitioners should describe current and historical site conditions and stressors to establish the purpose and need of the proposed project (example permit discussion included in Appendix C)**. In certain settings, anthropogenic degradation stemming from historical action (e.g. tidal restrictions, channeling, contamination) may be so substantial that there is little ecological value to the existing site. In these cases, the risk for further degrading a site may be low and the potential benefits of restoration/enhancement may be relatively easy to justify to the regulatory community, provided the underlying causes of degradation are a focus of the project. For sites that are currently functioning, but vulnerable to stressors such as marsh edge loss or sea level rise, the project justification is more rigorous. These sites will require additional field evaluation and design considerations to balance temporal loss with intended long-term benefits. Field surveys that fully document current functions are essential to justify the disturbance inherent to any restoration action.

Once a site has been selected and a suite of intervention measures examined, **project practitioners should engage with the regulatory community as soon as possible to receive feedback at regular intervals as the project design progresses**. For projects with substantial impacts (e.g. sediment placement planned on > 0.5 acres) and/or those that have multiple/complex components, practitioners would benefit from presenting at inter-agency review meetings (e.g. pre-application, Joint Permit Processing or Joint Evaluation meetings). These may be held at regular intervals, such as those in

Maryland, Delaware, and New Jersey, or scheduled as needed. A site visit may also be appropriate. These meetings allow the regulators opportunities to ask questions, provide insight based on past projects, and fully consider the proposed project as it is developed.

Least Environmentally Damaging Alternative

Depending on the permitting process, applicants may be required to evaluate a suite of alternatives from which the regulatory agencies can determine the Least Environmentally Damaging Practicable Alternative (LEDPA). The alternatives analysis for site-specific projects should consider restoration/enhancement actions that involve different, minimally disruptive approaches to aid in the determination of the LEDPA. Because the purpose of a restoration project is to improve conditions at a given site, the evaluation of off-site alternatives to the proposed action is not always required. In others, a project opportunity may arise from the availability of resources such as dredged sediments and/or restoration funding targeted for particular species. In those cases, **practitioners should evaluate a suite of sites to determine where the collective impacts to existing trust resources can be minimized while maximizing long-term project success**. This alternative site identification and prioritization process can be completed largely as a desktop exercise but, when possible, field verification at potential sites should occur to validate available data. While there may be logistical limitations associated with the proposed action(s) such as the length of pipeline to deliver dredged sediments or the quantity/texture of dredged sediments available, these limitations alone should not form the basis of the site prioritization, selection, and design process.

Evaluating a site for restoration is an important step to ensure that trust resources, like the Saltmarsh Sparrow, are minimally impacted. Ray Hennessy

Almost all restoration actions will cause a temporary disturbance to existing marsh. The framework of the CWA is inherently precautionary, so weight is given to preserving existing ecosystem functions whenever possible. **Project applications should therefore describe the presence of sensitive habitats (e.g. SAV, shellfish habitat) in the project vicinity and needs/concerns of the local human community in addition to the longer-term ecological benefit of the planned restoration action**. Mitigation measures may be required by regulators to ensure that proposed impacts are limited to the project site. These measures may include containment when sediments are placed and/or water quality monitoring with operational triggers if certain impact thresholds are observed. It may also include measures to minimize impacts to adjacent habitats during periods in which they are more sensitive to degradation.

In their assessment of the LEDPA, the regulatory community may consider historical, current, and potential future ecological function in their review of projects, especially where the goal is ecosystem restoration. This includes consideration of the predicted impacts of climate change. The "no-action" alternative described in permit applications should include some consideration of reasonably foreseeable stressors (e.g. near-term sea level rise) and specifically describe how they are anticipated to cause marsh loss over time. Overall, a well-developed suite of alternatives allows regulatory and resource agencies to weigh the temporary disturbance associated with different interventions against the "no-action" alternative.

Construction and Adaptive Management Plans

Applications should also define specific project success criteria (e.g. acreage goals) through the monitoring and adaptive management plans which reflect the overall goals of the project. The plans should specify how success will be monitored and define when corrective actions will be taken. Flexibility can be incorporated into adaptive management actions while still providing assurance of ecological function to the regulatory community. For example, a range for target goals may be established and success criteria may be based on site trajectories (e.g. increasing coverage/density of marsh vegetation each year) rather than rigid criteria (e.g. 85% coverage within three years). Further, the regulatory community is aware not all projects will achieve the stated goals or success criteria. **A description of planned monitoring and adaptive management information should be included with the goal of informing future projects**. An example of an approved adaptive management plan is provided in Appendix D.

Reeds Beach runnelling using a low pressure equipment. Bart Wilson/USFWS

MONITORING

Monitoring is an essential component of all restoration projects, but particularly important for documenting and assessing novel restoration approaches and those involving significant time lags between treatment and response (e.g. sediment placement). In projects with a significant amount of uncertainty about ultimate outcomes, the collection of quantitative data on project effectiveness is critical to minimizing regulatory barriers for future projects. Monitoring plans should follow CWA 404(b)(1) guidelines which includes an explicit discussion and description of goals/performance criteria and how they will be assessed. Further, monitoring is a critical component of adaptive management, as it is the fundamental way of identifying the need for corrective action. An integrated Monitoring and Adaptive Management Plan is therefore ideally developed before construction begins. **Monitoring efforts should assess 1) Implementation monitoring - was the project built to meet the design (and does it continue to do so over time as it matures), and 2) Effectiveness monitoring - is the project providing the intended benefits?**

Finally, **while we present best case scenario goals for monitoring in this document, it is possible to measure change using less intensive methods** (e.g. photo points to document vegetation changes, presence and absence surveys). It is imperative to share lessons learned from both implementation and effectiveness monitoring efforts to help inform future projects. Learning and sharing are successful outcomes for any restoration project, even though a project may not have achieved intended restoration goals.

Implementation Monitoring

Implementation monitoring describes a site's physical characteristics and usually includes a combination of marsh platform topography, channel/creek bathymetry, tidal hydrology, and vegetation cover. The specific parameters measured will be similar among projects and should at a minimum include metrics for elevation, tidal datum, shoreline position or project footprint, total areal extent of the entire project and/or of distinct biological communities within the project area, and documentation of vegetative community structure and extent (See Table 2 for full list of recommended parameters). There are multiple options for collecting these types of data and the approach will vary with project scale; for example, it may be feasible to monitor a small (< 2 acre) project site with ground measurements, while larger sites may require collection of aerial imagery and/or LiDAR for a comprehensive analysis of site dynamics. **We recommend monitoring occur before implementation and at least five years post-implementation**.

Table 2. Suggested parameters and associated metrics to include in all monitoring plans for measuring the results of salt marsh restoration implementation.

Parameter	Description
Topography	Documentation of as-built surface elevations within project area
Relative Tidal Elevation	Analysis of site surface elevation within the local tidal frame
Shoreline Position	Documentation of full extent of project footprint
Total project extent	Total spatial extent of project
Vegetative communities	Documentation of the type and spatial extent of vegetative communities present

Effectiveness Monitoring

Effectiveness monitoring quantifies the extent to which a project is providing the intended benefits. The goals for such monitoring should therefore be closely aligned with the overall project goals which may include creation of habitat for a specific target species (e.g. Saltmarsh Sparrow), restore a natural tidal inundation, increased resilience to sea level rise, and wave energy mitigation among others (most projects will have multiple defined goals). The monitoring approach required to evaluate whether those benefits are realized will vary by project along with the project goals.

Biologist survey a marsh for resident wildlife. USFWS

The spatial resolution and frequency of monitoring data collected will depend not only on project goals and spatial extent of the project, but also available resources and expertise of the project team. **We recommend monitoring occur before implementation and at least five years post-implementation**, however some effectiveness metrics (e.g. bird populations) will require a longer time after implementation to fully assess response to restoration and may not need to be assessed annually (e.g. vegetation cover). While a full listing of monitoring metrics is outside the scope of this document, there are several example monitoring plans and metrics that are available. The Hurricane Sandy Coastal Resilience Program (Hurricane Sandy Program) of the U.S. Department of the Interior (DOI) and the National Fish and Wildlife Foundation (NFWF) developed extensive monitoring metrics and plans that were developed in the implementation of 24 projects that focused on enhancing ecological resilience at marsh sites (Abt 2019a; Abt 2019b) . In Table 3 we provide examples of commonly used monitoring methods following the U.S. Environmental Protection Agency's tiered framework for wetland monitoring. Both level of effort required, and specificity of results increases with increasing tier. This table is not intended to be comprehensive, but rather to serve as an example of how monitoring efforts can be scaled to fit a variety of questions and budgets. We also include specific protocols for monitoring in Appendix E.

Table 3. Methods to evaluate the efficacy of restoration approaches with associated tier and a qualitative description of the level of effort required and the spatial resolution.

Parameter of Interest	Tier	Method	Level of Effort	Spatial Resolution
Shoreline position	1	Desktop analysis of available aerial imagery	Minimal	Low
	2	Erosion Stakes	Moderate	Moderate
	3	GNSS surveys	High	High
Vegetative Cover	1	Total extent of vegetated area from imagery	Minimal	Low
	2	Field-based visual estimates of cover by species present	Moderate	Moderate
	3	Plot/transect based stem counts by species	High	High
Topography	1	Desktop analysis of available LiDAR data	Moderate	Variable
	2	On the ground data collection using RTK-GPS or leveling	Moderate	Moderate
	3	Drone imagery and Photogrammetry	High	High
Biodiversity	1	Inventory of species present	Moderate	High
	2	Estimates of species' abundance	Moderate	High
	3	Estimates of reproductive success (breeding species only)	High	High

We note that not all parameters of interest will have multiple options and that many of the parameters that will be required to monitor effectiveness (e.g. target species) are time and labor intensive and often, don't have a Tier 1 option. Further, site characteristics can sometimes dictate the monitoring approach. For example, at sites where the shoreline is characterized by a well-vegetated edge, changes in shoreline position may be reliably identified and quantified from aerial imagery. When a shoreline is not vegetated, this becomes more challenging. In this example, it would be necessary to use the Tier 2 or 3 approach to accurately quantify shoreline change.

Project applicants are strongly encouraged to develop monitoring plans that will describe project success relative to stated goals. Monitoring efforts should involve collection of data until at least five years after project completion, with at least three data collection years occurring during that five-year period.

ADAPTIVE MANAGEMENT PLANNING

Adaptive management is a vital component of all coastal restoration planning; **a well-designed adaptive management plan must include an explicit monitoring plan to establish performance thresholds for parameters being monitored that necessitate corrective action to adjust the trajectory of a project toward the preferred or expected outcome**. Ideally, adaptive management will be implemented through all phases of a project (construction, post-construction, and long-term maintenance), though specific parameters and triggers will likely vary among phases (Table 4). Some degree of flexibility is important to maximize the adaptive management efforts and provide the best opportunity to attain the project's overall objectives.

A major limitation in many adaptive management plans is a narrow vision of project success. **Practitioners should aim for desirable conditions within a range of expected responses and allow for minor changes to improve outcomes**. For example, when restoring hydrology to a marsh, the goal could include establishing a range of tidal network densities based on the anticipated tidal prism, and determining whether further modification will help meet the initial goals. A modification could be as minor as placing small runnels in areas not draining as expected, or as large as dealing with variations in dredge material that can affect the overall elevation and slope of the project.

During all project phases, changing environmental conditions may necessitate a modification in the trajectory of a project. Accordingly, adaptive management plans are best designed as a living document that can be adjusted over time as a project progresses and a new understanding of site performance is gained. In most cases, restoration sites will evolve toward a state of relative equilibrium as they age; therefore, the need for corrective action will likely lessen over time. **We recommend that adaptive management plans, like monitoring programs, be designed with a minimum five-year time horizon**.

Table 4. Example monitoring metrics, effectiveness criteria, and potential adaptive management actions to be taken if criteria are not met.

Project Phase	Monitoring Metric	Performance Criteria	Adaptive Action
Construction	Target elevation	Placement depth meets target, based on field benchmarks (e.g. witness boards)	Adjust placement strategy to meet target
Post Construction	Vegetative cover	Percent cover of above ground biomass should increase from original planting densities to ≥ 60%* total aerial cover with native wetland flora within 3 years of planting	Conduct additional planting; consider use of different species if significant changes in elevation have occurred
Maintenance	Shoreline Position	Shoreline change rates should be less than 1 ft/yr*.	Stabilize shoreline against further erosion**

**Specific values of threshold criteria will vary by site; these are provided as examples.*
***This could involve the use of a temporary structure + additional planting, or a more permanent feature like an off-shore sill as appropriate for site wave energy conditions.*

Effective adaptive management requires a regular on-site presence to assess and reassess project effectiveness throughout its lifecycle. The most effective monitoring and adaptive management plans will also have funding available to support not just monitoring but any corrective actions needed in the short or long term. Ideally an adaptive management plan for a project will be overseen by the same individual or group who is leading project implementation. Corrective actions are often needed outside the construction period, and in some cases several years later. For example, additional planting is a common adaptive action required in restoration projects because freshly installed young plants are particularly susceptible to extreme weather events. Vigorous plant growth is often a key metric of success, as it stabilizes site conditions (e.g. disturbed ground or placed sediments) and is often the best indication that habitat is available to and functional for target species. Identifying and mitigating planting failures is therefore critical to short-term project success. Without someone present to evaluate planting success, and funding available to support the purchase and installation of additional plants, the opportunity to take this relatively simple corrective action could be missed and jeopardize the project outcome.

Ideally, the funds needed for monitoring are integrated into the overall project budget, along with design, permitting, and implementation costs. However, obtaining funds for monitoring can be a challenge in some cases (**see a "Closer Look at Restoration"** below; pages 22-23), and there may be a disconnect between the timeline(s) required by grantors (i.e. period of performance) and what is needed to evaluate either implementation or effectiveness monitoring in systems that take years to fully respond to restoration. This lack of support for extended monitoring is currently one of the main challenges in assessing the effectiveness of coastal restoration projects.

Monitoring young plants after a restoration project is important because they are susceptible to extreme weather events. Lauren Owens Lambert

A CLOSER LOOK AT RESTORATION

STRUCTURING GRANTS FOR ADAPTIVE MANAGEMENT

Restoration practitioners often say "every site is unique," because of the complex interaction of physical (e.g. site geology, hydrology, climate, and weather patterns) and biotic (e.g. plant and animal responses) factors involved. This document stresses the vital role of an adaptive management framework for implementing coastal ecosystem restoration. Only by monitoring throughout a project's implementation and response period can practitioners modify their approach to minimize negative and maximize positive outcomes. We recommend that monitoring is therefore planned, funded, and carried out with the same level of effort as project design and implementation.

Restored hydrology after the placement of sediment at Ninigret restoration project in Rhode Island. Bart Wilson/ USFWS

Unfortunately, not all funding sources support monitoring. The North American Wetland Conservation Act (NAWCA) and National Coastal Wetland Conservation Grant programs are two large, competitive wetland conservation grants administered by the USFWS, which collectively support projects costing >$100M (including grant and matching funds) each year. Neither program allows grant funds to be used for effectiveness monitoring, though basic implementation monitoring is eligible. Fortunately, many other grant programs do allow, encourage, and even mandate monitoring of project outcomes, including effectiveness monitoring. FWS, NOAA, other federal agencies, private businesses, and other organizations fund conservation projects through the National Fish and Wildlife Foundation (NFWF) which has several initiatives that collectively fund hundreds of millions of dollars in grants annually for conservation projects (matched by hundreds of millions of dollars in partner investments). NFWF considers reasonable and appropriate investments in monitoring as an important element of successful projects, and they allow and encourage different aspects of project monitoring as part of implementation projects, or as standalone projects, though they may not require it. NFWF grants can fund pilot or initiate larger-scale restoration monitoring programs but are not typically used to sustain ongoing monitoring over the medium to long-term.

NOAA has a variety of restoration funding opportunities (some of which are administered by NFWF). Some provide funds only for implementation monitoring. Others are more likely to fund effectiveness monitoring. For saltmarsh restoration, implementation metrics supported in NOAA granting opportunities are typically marsh platform topography, channel/ creek bathymetry, tidal hydrology, and vegetation cover. They may fund monitoring if a study addresses one or more emerging issues such as fish use, soil geo-chemistry, or other physical conditions. The NOAA Restoration Center has developed an established approach to monitoring based on different program needs and is built upon a tiered approach that distinguishes between implementation and effectiveness monitoring.

A CLOSER LOOK AT RESTORATION

Timing is one of the biggest challenges in funding post-project monitoring. The timeline for project completion and monitoring often does not line up with the constraints of a funding source; most funding opportunities have a two or three-year period of performance. However, most estuarine restoration projects take at least two years to get designed and permitted, plus a year to implement. A project can therefore take 3 years just to implement, plus an additional 5+ years to monitor after implementation is complete, requiring multiple funding cycles to support the full life cycle of a restoration project. Therefore, partners de-couple the funding of planting, monitoring, and adaptive management (including taking corrective actions) from construction implementation. However, most of the funding sources above are for implementation only. Describing a phased approach to any project in grant applications can help funders understand and plan for multiple rounds of applications for the same project over time. This ultimately results in better project assessment and reduces the risk of future projects failing or being suboptimal because of a lack of funds needed to understand and manage for success.

Post restoration monitoring is integral to learning and improving restoration efforts into the future. Amy Schwarzer

SUMMARY AND CONCLUSION


Active planning with our regulatory partners is critical to project delivery. Save the Bay

Atlantic coast tidal marshes, specifically those located in the Mid-Atlantic region, face a litany of stressors resulting in overall coastal degradation and loss over time. Marsh restoration is often the only option to help improve coastal ecosystems. Multiple federal agencies are involved in the restoration planning, implementation, and monitoring, including NOAA Fisheries and FWS, which both manage public trust resources. NOAA Fisheries serves two roles through different programs. The Habitat Division reviews marsh restoration projects as part of the consultation process associated with federal funding, permitting, and authorization and the Restoration Center pursues projects in collaboration with partners. NOAA often prioritizes fish habitat through preservation of SAV, intertidal mud and sand flats, and low marsh. FWS also drives restoration work on the marsh platform but prioritizes bird/mammal habitat through high marsh. This siloed strategy needs to change to achieve true coastal ecosystem resiliency.

Restoration projects occur in phases including project planning, design, permitting, implementation, and monitoring. During restoration planning, successful projects should aim to preserve and enhance connectivity and heterogeneity across the entire tidal marsh community and facilitate existing ecosystem function across time. Plans should also include informed consideration of both the short- and long-term benefits of the project to the landscape, and how the composition of coastal communities will change over time. Formal project designs should consider the different challenges facing the marsh including edge erosion, hydrological function, and elevation vulnerability, and develop a suite of solutions that addresses each source of stress.

Early and frequent coordination with the regulatory and resource agencies to assess and jointly address each set of stressors is integral to the timely and successful navigation of the permitting process. During permit application, practitioners should describe current and historical site conditions and stressors to establish the purpose and need of the proposed project. When needed, practitioners should also evaluate a suite of sites to determine where the collective impacts to existing trust resources can be minimized while maximizing long-term project success. Project applications should describe the presence of sensitive habitats (e.g. SAV, shellfish habitat) in the project vicinity and needs/concerns of the local human community in addition to the longer-term benefit of the planned restoration action. Applications should also define specific project success criteria (e.g. acreage goals) through the monitoring and adaptive management plans which reflect the overall goals of the project. After a permit is granted, project practitioners should engage with the regulatory community across the life of a restoration project to receive feedback at regular intervals as the project progresses.

Monitoring plans should include both implementation and effectiveness monitoring as well as plans for adaptive management of the restoration project over time. We recommend monitoring occur before implementation occurs and at least five years post-implementation. Project applicants are strongly encouraged to develop monitoring plans that will allow for analysis of the extent to which project goals are achieved. The adaptive management part of the monitoring plan must include an explicit monitoring plan to establish performance thresholds for parameters being monitored that necessitate corrective action to adjust the trajectory of a project. Practitioners should aim for desirable conditions within a range of expected responses and allow for minor changes to improve outcomes. Effective adaptive management requires a regular on-site presence to assess and reassess project effectiveness throughout its lifecycle. The most effective monitoring and adaptive management plans will also have funding available to support not just monitoring but any corrective actions needed in the short or long term.

As the restoration community moves forward in collective efforts to preserve and restore our coastal wetlands, this document should serve as a stepping stone and bridge between silos to identify common goals and ease miscommunication and misalignment during the permitting process for coastal ecosystem restoration projects. This document will be updated and edited over time to reflect changes and updates in the existing knowledge of the coastal restoration landscape.

Blue crab are an important species in the coastal marsh system. Brian Henderson, Creative Commons

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Restored marshes support recreational and commercial fisheries. Chesapeake Bay Program

APPENDICES

Appendix A. Examples Of Beneficial Use Of Dredged Sediment Case Studies

- Beneficial Use of Dredged Material Pilot Projects (New Jersey)
- Coastal Dredging and Beneficial Use of Dredged Material (Philadelphia District USACE Examples)
- Beneficial Use of Dredge Material Pilot Program (USACE Examples Nationwide)

Appendix B. Beneficial Use Learning Network Webinars from the New Jersey Coastal Resilience Collaborative

Webinar series topics:

- Maintaining Restoration Sites
- Restoring Marshes with Dredged Sediment: Lessons Learned Lightning Round and Nationwide Discussion Forum
- Selecting Sites and Justifying Projects
- Constructing Adaptively
- Designing Constructible Projects
- Foundations of Project Planning: Understanding Sediment
- Restoration Perspective: Avalon, Fortescue, and Ring Island, NJ
- Beneficial Use Learning Network Launch
- Restoration Perspective: Good Luck Point Part 1
- Restoration Perspective: Good Luck Point Part 2
- Restoration Perspective: Good Luck Point Part 3
- Restoration Perspective: Good Luck Point Part 4

Appendix C. Example Tidal Wetlands Permit Application

Maryland Department of Environment (MDE) application for Coates (Croppers Island)

Appendix D. Example Adaptive Management Plan

Forsythe NWR Good Luck Point Marsh Restoration Adaptive Management Plan

Appendix E. Summary of Relevant Monitoring Protocols

Coastal marsh. Jack Flanagan