Beneficial Use of Dredged Material for Salt Marsh Restoration and Creation in Connecticut

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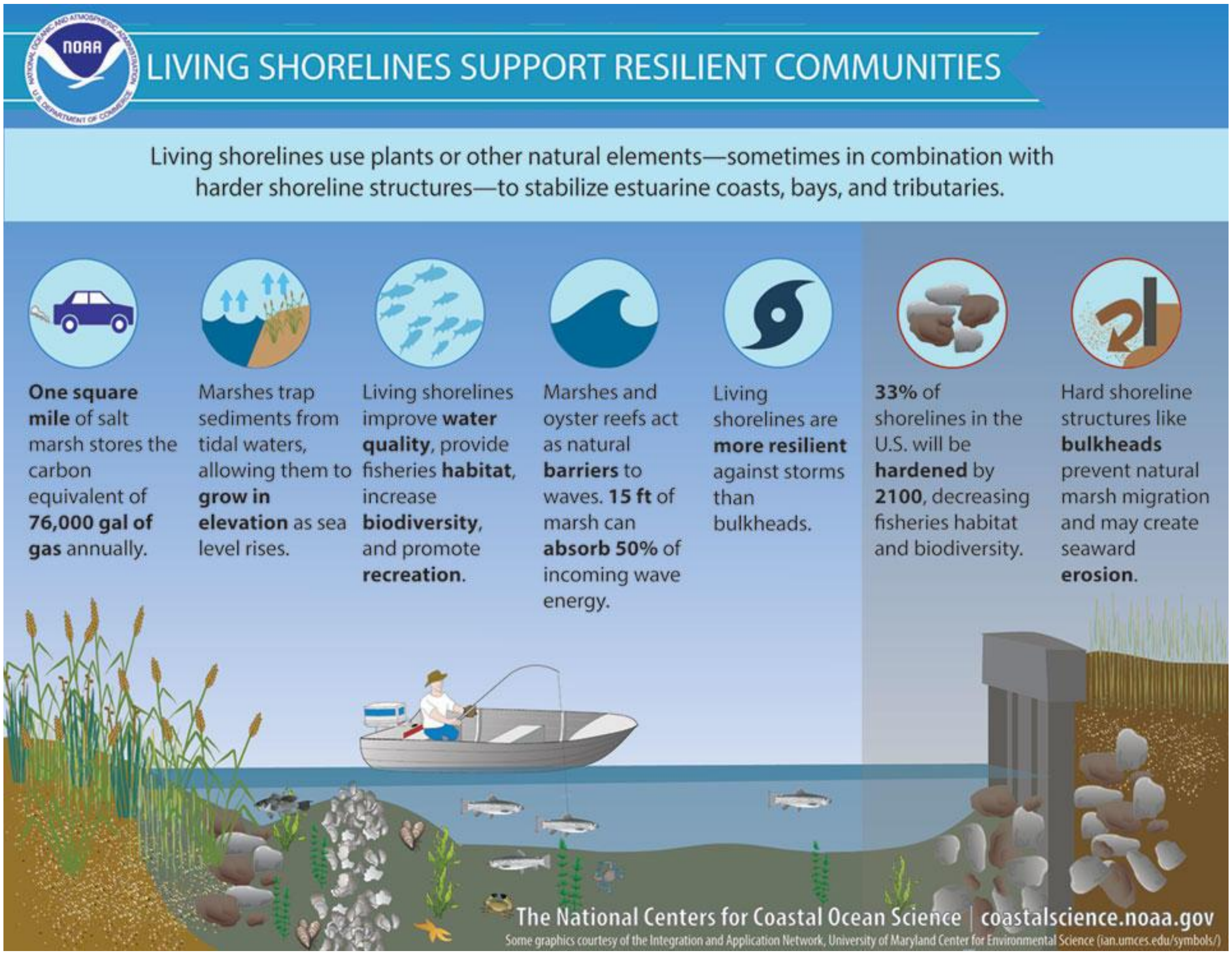
1 Introduction

Wetland vegetation provides coastal protection by reducing wave heights and flooding of critical infrastructure. Wetlands slow and absorb flooding from storm surges by reducing flood peaks and durations through storage and drainage of flood waters (Shepard et al., 2011; Wamsley et al., 2010). Even fringe marshes have been shown to provide significant wave attenuation (Gedan et al., 2011; Möller and Spencer, 2002).

Loss of wetlands and the ecosystem services they provide, such as coastal protection, erosion control, water purification, habitat for nesting and foraging, are a significant concern in Long Island Sound. The Connecticut shoreline has lost 27% of its tidal wetlands since the 1980s (Basso et al., 2015). Beneficial use of dredged material provides an opportunity to restore the tidal wetlands. Restored, Created, or enhanced tidal wetlands can protect the improve the resilience of the Connecticut shoreline by mitigating coastal erosion and providing storage for coastal flooding, storm surge and stormwater runoff while increasing habitats for shorebirds and wetlands species. As a green infrastructure approach, beneficial use of dredged material could contribute to the long term recovery and economic revitalization of affected areas by providing green space and ecosystem services. Wetlands and marsh islands are a green infrastructure technique, also known as living shorelines. The November 13, 2013 Federal Register notice for CDBG-DR Sandy includes wetlands and vegetation in its description of green infrastructure and states that "protecting, retaining, and enhancing natural defenses should be considered as part of any coastal resilience strategy."

This project was undertaken to understand and document the feasibility, benefits and costs, design alternatives, and permitting needs for using dredge materials to build fringe wetlands or offshore islands to prevent erosion along coastlines. The project consisted of a feasibility study of wetlands and wetlands island creation using dredge material, design considerations, and community outreach. The feasibility study includes a literature review of the ecosystems services provided by wetlands in Long Island Sound including services provided to the natural community of marine plants and animals and recreational and economic benefits to humans. In addition, the physical, biochemical and engineering aspects of created wetlands are reviewed. Regulatory and permitting policies of neighboring states are reviewed and policy recommendations for Connecticut are discussed. Design parameters such as wetlands gradient, site exposure and soil parameters are addressed as well as marsh stabilization structures. Community outreach programs provide educational activities to ensure meaningful participation of stakeholders in discussing projects and potential alternatives, including the long-term impacts of climate change on Connecticut's coast are discussed. The impact of beneficial use of marsh restoration or creation on the health and safety of vulnerable populations is evaluated. The project culminates in guidelines for municipalities to use when evaluating the beneficial use of dredge materials for tidal wetlands restoration and creation.

The project was funded by a Community Development Block Grant Disaster Recovery (CDBG-DR) after Hurricane Sandy through the Connecticut Department of Housing.



2 Tidal Wetlands as a Resilience Strategy

Tidal wetlands are highly productive and environmentally important habitats which provide nesting and foraging for shorebirds and other terrestrial and aquatic species. Tidal wetlands are typically located in low wave energy environments and are subjected to varying water levels due to tidal and non-tidal events. In addition to ecological and economic benefits, tidal wetlands provide social benefits to coastal communities such as bird watching, boating, fishing as well as aesthetic and public health benefits. Tidal wetlands increase coastal resilience by improving water quality and reducing wave energy, providing storage for coastal floodwaters and stormwater runoff, shoreline stabilization, and surface and groundwater filtration.

Since the 1880s, Connecticut has lost approximately 27% of its tidal wetlands (Basso et al., 2015). These losses combined with the recognition of the importance of tidal wetlands and thus an increasing emphasis on environmental management has resulted in a change of perspective whereas dredged material is now perceived as a resource for restoring or creating tidal wetlands (Burt, 1996; USEPA and USACE, 2004). Marsh restoration, creation and enhancement have been defined in a variety of ways, but are commonly defined as:

- Restoration - Rebuilding a degraded wetland or previously existing wetland to its former condition or as close to its former condition as possible.
- Creation – Construction of a wetland where one did not exist previously.
- Enhancement – Improving wetland functions beyond what currently or previously existed.

Beneficial use of dredged material for marsh restoration, creation or enhancement has been used to offset wetlands losses and thereby help maintain the benefits of wetlands and their surrounding ecosystems, while increasing the resilience of coastal areas by mitigating erosion and the impacts of storms on shoreline communities (Kentula, 2002; Mitsch and Gosselink, 1993; Rikard, 2014).

2.1 Marsh Ecosystem Services

Tidal marshes as a component of living shorelines support resilient communities by providing a number of ecosystem services. Ecosystem services have been defined as, "benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al., 1997). These services include coastal protection, erosion control, water purification, maintenance of fisheries, and carbon sequestration (Barbier et al., 2011). The increase in habitat area for plants and animals is important for increasing biodiversity, but also provides psychological, cultural, and health benefits to local residents (Craft, 2016a; Millenium Ecosystem Assessment, 2005). In addition to providing protection from erosion and storm surge, living shorelines can be self-maintaining and have the potential to repair themselves following storm damage (Sutton-Grier et al., 2015). The minimum value[1] of tidal wetlands is on the order of $16,900/ha to $29,600/ha ranging to a high estimate of $195,700/ha; with storm protection estimated at around $33,000/ha (Barbier et al., 2011; Costanza et al., 2008; Gedan and Bertness, 2009; Kocian et al., 2015; Sutton-Grier et al., 2015).

Hybrid living shoreline with rip rap. Image credit: Jesse baud, *living shoreline*, https://www.flickr.com/photos/151809992@N06/37911236174, (CC0 1.0).

Tidal marshes regulate the impact of storm surges and associated erosion from wind waves along the coast (Gedan et al., 2011; Shepard et al., 2012). With the addition of an offshore sill of riprap or an oyster reef, the living shorelines are even more effective. During small storm events, a living shoreline may completely absorb and abate the energy of waves and flooding water. During

[1] All dollar values have been adjusted to US$20

larger events, the marsh may be overtopped by water, but it still provides some reduction of energy and supports built protections located further inland against storm surges (Gittman et al., 2014; Sutton-Grier et al., 2015). In an urban setting, wetlands have the potential to store or convey surface runoff. In addition to acting as a sponge to excess quantities of water, marshes also act as a filter, removing some of the nutrients and toxins carried in surface runoff before it reaches coastal waters (Craft, 2016b).

The ecosystem services provided by marshes are more fully reviewed in ***Appendix A – Ecosystem Services of Tidal Marshes***.

2.2 Managing Marshes for Coastal Resilience

2.2.1 Why Use Marshes?

Given the drawbacks and expense of shoreline stabilization, coastal municipalities are increasingly turning to natural, or nature-based, shoreline protection as a cost-effective and multifunctional solution (Sutton-Grier et al., 2015). Rising sea levels and large storm events such as Superstorm Sandy emphasized the value of salt marsh as both valuable habitat and a means to attenuate waves and buffer uplands from adjacent waters (Bridges et al., 2015). In the aftermath of Superstorm Sandy, federal, state, and local governments as well as non-governmental organizations emphasized increasing coastal resilience – defined as the ability of a coastal community to prepare for, resist, and recover from disturbances such as storms – as part of storm recovery planning. Salt marsh management is increasingly being incorporated into a 'natural infrastructure' approach to coastal resiliency; in terms of sustaining the marsh ecosystem services described above and for protecting adjacent built infrastructure (Gedan et al., 2011, Sutton-Grier et al., 2015).

Coastal marshes are resilient to storms and sea level rise and can effectively decrease damages associated with coastal storms (Narayan et al, 2017). In addition to serving as a buffer against sea level rise (SLR), storm surges, and extreme weather events, salt marshes are one of the most productive ecosystems in the world, and provide critical ecological functions and services. These include a variety of ecosystem services such as improving water quality via excess nutrient removal and sediment trapping, providing nursery grounds for juvenile fin- and shellfish, habitat for birds and wildlife including threatened and endangered species, and support of food webs locally and in adjacent waters (Minello et al., 2003; Mitsch and Gosselink, 2000; Tobias and Neubauer, 2009). More recently, the ability of salt marshes to sequester carbon dioxide (CO_2) in their sediment for hundreds to thousands of years has resulted in national and international efforts to protect and conserve these habitats as a means to reduce atmospheric greenhouse gases (GHG) and mitigate the impacts of climate change (Nellemann et al., 2009). The high plant production rates found in marsh habitats, coupled with their ability to increase sediment volume over time, results in higher carbon burial rates per area in salt marshes than any terrestrial ecosystem, including tropical rainforests (McLeod et al., 2009; Hopkinson et al., 2012). This burial of atmospheric carbon in marshes, mangroves, and seagrasses is termed 'blue carbon'. The loss of sediment carbon alone in existing marshes, has been estimated to be 0.02 – 0.24 Pg CO_2 yr^{-1} globally, representing an economic cost of 0.7 to 10 billion US $ yr^{-1} (Pendleton et al., 2012). The importance of marshes as a 'blue carbon' sink, is matched by the ability of marshes to retain excess nutrients' both nitrogen and phosphorous through the same mechanism of marsh accretion (Craft, 2007; Tobias and

Neubauer, 2009). These functions are contingent on the ability of marshes to vertically accrete at a rate that keeps pace with the local rate of sea level rise.

Traditional approaches to protect wetland coast lines often involve shoreline hardening, which have adverse impacts on coastal ecosystems and may leave them more vulnerable to coastal storms than natural habitats. Recent research has demonstrated that conventional hardened structures (sea walls, bulkheads and riprap revetments) to protect coastal infrastructure often provide less protection against coastal storms and flooding than coastal marshes, while simultaneously compromising ecosystem function (Gittman et al., 2014). The function of coastal marshes, however, is reliant on the marshes' ability to accrete sediment. There is disruption of sediment availability by man-made barriers, shoreline armoring, and disposal of dredged sediments in deep water (Slocum, 2005; Croft et al., 2006; Weston, 2014). This results in reduced sediment supply leading to marsh submergence, shoreline retreat/erosion, fragmentation, and ultimately loss of function (Kirwan et al., 2010). As traditional approaches to shoreline protection underperform and sediment supplies are constrained, the use of dredged sediment has proven beneficial for managing coastal marsh elevation and function.

2.2.2 Why Do Marshes Need to be Adaptively Managed?

Coastal salt marshes occupy the intertidal zone, approximately between mean sea level and mean high water. Positive feedbacks between tidal inundation, marsh plant production, and sediment trapping, have resulted in the current intertidal distribution of salt marsh habitat (Morris et al., 2002). Multiple factors control the distribution and condition of marsh systems (Silvestri et al., 2005; Morris et al., 2002; among others). Hydroperiod, sediment supply, and peat production via plant growth interact to govern wetland sustainability and function. Marshes are typically considered either minerogenic, they build elevation by trapping sediment, or peat forming, they build elevation by making below ground biomass. Connecticut marshes are a mix of both and rely on both high rates of plant productivity and sediment availability. There are physical limits on accretion rates provided through net growth (Morris et al., 2016). In many coastal areas, and under current and predicted future conditions, suspended sediment concentrations are insufficient to balance the downward repositioning of the marsh platform within the tidal frame (Weston, 2014). Experimental studies in the field and laboratory demonstrate that there is a 'tipping point', or marsh position within the tidal frame, where local conditions of Sea Level Rise (SLR) and sediment supply are such that marshes can no longer keep up with SLR and drown (Morris et al., 2002; Kirwan et al., 2010; Schile et al., 2014; Figure 1). With the drowning of marshes, so goes the shoreline protection and ecological benefits they provide. Thus, it is critical that some marshes are managed to prevent them from reaching this 'tipping point'.

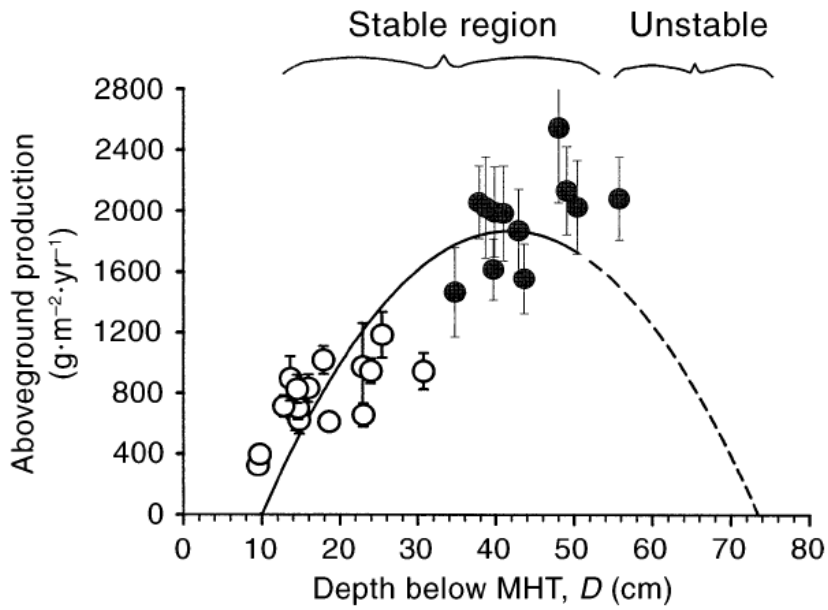


Figure 1. Relationship between elevation and marsh stability, as measured by plant production. MHT = mean high tide. Modified from Morris et al. 2002.

Salt marshes have the ability to increase their surface elevation via sediment trapping and belowground biomass production. However, in many areas, sediment movement has been disrupted by man-made barriers. Suspended sediment concentrations are often insufficient to support necessary accretion rates to maintain marsh elevation, and there are physical limits on the accretion rates via net growth. Regardless of the cause, lack of sediment can affect marsh's resilience to SLR and its ability to provide ecosystem services, including infrastructure protection. One technology that can be used to provide sediment to maintain or increase marsh elevation is by repurposing dredged sediment.

2.2.3 How Can Dredged Sediment Help?

With sufficient sediment, coastal marshes have the ability to increase their surface elevation, enabling them to keep pace with SLR over millennia (Morris, 2002). This resiliency provides a low maintenance and self-sustaining natural infrastructure that protects coastlines and associated built and natural infrastructure. Using dredged material to enhance or create coastal marshes also presents an opportunity for the beneficial use (BU) of that sediment. The disposal of uncontaminated sediment onto uplands, spoil islands, or open water as a byproduct of dredging is increasingly being recognized as misappropriation of a resource in environments where marsh sustainability relies on sediment supply in already constrained sediment environments (Childs, 2015; USACE and NOAA, 2017). There is a need to find alternate uses of sediment as disposal sites are costly to maintain and have limited capacity. The American Society of Civil Engineers recognizes sediment as a resource and endorses its beneficial use (BU) for coastal areas to ensure ecosystem and development sustainability. Beneficial use of dredged sediment is also a priority for the USACE (Childs, 2015). Thus, there is a confluence of the need for protection of coastal assets, awareness of the efficacy of 'natural infrastructure's ability to provide a host of services, the adoption of BU as a natural infrastructure alternative to manage deteriorated marshes and marshes vulnerable to SLR, and the need for reuse of an important sediment resource. While a full spectrum of engineered responses will be required to address the scale of coastal shoreline threats and loss of essential habitat in CT, adaptively managing natural coastal marshes can be a pivotal part of that strategy. If given adequate sediment supply, coastal marshes can be a self-sustaining natural infrastructure that protects coastlines and built infrastructure (Gedan et al., 2011; Arkema et al., 2013; Temmerman et al., 2013; Bridges et al.. 2015; Sutton-Grier et al., 2015).

Coupling salt marsh restoration projects to the management of dredged sediment has increased in frequency and scope over the past 2 decades. Such nature-based shoreline management can take the form of Living Shorelines, Thin Layer Placement (TLP) of sediment on existing marshes and/or construction of new marshes on subtidal habitat.

2.2.3.1 Living Shorelines

Living shorelines consist of small scale alternatives to armoring unvegetated shorelines. They are principally implemented as an alternative to bulkheading to stem the rate of shoreline retreat. Typically a few to 10 meters in width, they are composed of usually a rock or shell sill with a narrow strip of salt marsh planted behind it. Because of their relatively small size, their use as a repository for dredge material is limited at best and largely impractical as a disposal alternative. There is a rich body of literature on the successes, failures and lessons learned from 30 years of constructing living shorelines. The reader is referred to CT SeaGrant and NOAA resources, and Currin et al. (2017) for further review of Living Shorelines: https://oceanservice.noaa.gov/facts/living-shoreline.html, https://seagrant.uconn.edu/focus-areas/healthy-coastal-ecosystems/.

Figure 2. Living shoreline. Photo credit – NC Coastal Federation

2.2.3.2 Thin Layer Placement (TLP)

By far the most common BU for marshes consists of the placement of a thin-layer (typically<50 cm) of sediment to provide 'elevation capital' to shallow intertidal areas, in order to improve the resiliency of existing coastal wetlands. Thin Layer Placement (TLP) has become a catchall term used to describe augmenting existing marshes with dredged sediment. It is sometimes also applied to small-medium scale marsh creation projects. For existing marsh systems, TLP thicknesses are typically limited to 20 cm or less but greater lifts are utilized in subtidal areas. For marsh new marsh construction on subtidal areas and/or in conjunction with barrier island building, the depth of sediment and thus BU of dredged material is much larger. Sediment can be hydraulically deposited on the marsh or manually applied and graded.

Marshes that are low in the tidal frame and/or accreting at rates slower than sea level rise are good candidates for TLP. The first goal is to raise the marsh surface elevation of each site to the optimal elevation for plant growth to increase the marsh's resilience to SLR (Schile et al., 2014). The second goal is to maintain/enhance core ecosystem functions provided by coastal marshes which include habitat for animals, high rates of ecosystem production, and carbon/nutrient sequestration.

This approach has been used with increasing frequency over the past decade with primary objectives being either enhancement of wetlands or simply a disposal option for dredge material. At present, TLP projects constitute only a small fraction of dredged sediment use. The TLP approach to enhance marsh resilience and associated services has been demonstrated in one-off projects with increasing frequency over the past decades (Stagg and Mendelssohn. 2011). Past projects have been conducted in several regions, and at multiple scales from tens to hundreds of thousands of m^3 of sediment (Croft et al., 2006; Stagg and Mendelssohn, 2011). The method provides an attractive option for protection of coastal assets against SLR and storm events, and that coastal marsh management can be a part of that protection.

Past and recent projects have served to validate various approaches and offer solutions to some of the technical hurdles that hindered early efforts to implement the technology, although there is currently no robust one-size-fits-all guidance on how to implement a BU project (Bridges et al., 2015). Previous work has shown coastal marshes can respond and adapt to a wide range of sediment additions. Studies from isolated sites going back to the 1980s show a consistent positive marsh response from two to 10 years following TLP (Ray, 2007). ***Appendix B – History of Managing Marshes for Coastal Resilience*** provides further information on the history of beneficial use of dredged sediment for tidal marshes. Information on past marsh restorations in Connecticut can be found in ***Appendix B***. ***Appendix C – Case Study Matrix*** contains summaries of marsh restoration projects location around the United States.

3 Policy, Permitting, and Engagement

Wetlands created or restored using dredged sediments are subject to the regulatory framework governing the coastal zone of Connecticut. Although policy pushing for greater consideration of green infrastructure and living shorelines as a floodplain management strategy as opposed to further hardening of the shoreline, their unique position as a project that could also be considered as fill in a wetland presents challenges for obtaining permits. The mixed political history of the disposal of dredged sediments and projects in wetland and coastal areas also demands early engagement with stakeholders in a project and innovative approaches to increase understanding of this relatively new approach to enhancing shoreline resilience.

3.1 Policy and Permitting Framework

In Connecticut policies are driven by the Structures, Dredging and Fill Act; Tidal Wetlands Act; and Coastal Management Act, including recent amendments on the use of living shorelines as an erosion control measure. At the federal level wetlands restoration and creation projects using dredge materials are regulated under Section 404 of the Clean Water Act since they would involve fill in tidal waters. The certification requirements for activities under Section 404 require certification by the State as described in Section 401 of the Clean Water Act. Connecticut requires certification under both the Clean Water Act and the Connecticut Water Quality Standards, including anti-degradation policies. Placement of dredge materials is also regulated by the State's environmental media management regulations as defined by the Connecticut Remediation Standard Regulations (RSRs).

As would be expected from the current governing policies, projects that are at a scale and type that would have little to no environmental impact can proceed easily through the permitting process through predetermined categories of general permits. For example, marsh restoration projects, including elevating marsh surfaces, under the supervision of the Connecticut Department of Energy and Environmental Protection can proceed with no further review. In contrast, projects that would be seen as placing fill in special aquatic sites are regulated by volume and extent under general permits from the US Army Corps and may require an individual permit, which includes a full environmental assessment and opportunity for public comment. All projects that involve dredge materials must also obtain a water quality certificate and the dredge materials must be managed according to the RSR and water quality anti-degradation policies. These regulations further constrain the contamination level of the dredge materials that can be used and where those materials can be placed and therefore these criteria should be considered in the design phase of a project.

Policy, regulations, and permitting at the state and federal level are reviewed more fully in ***Appendix D – Policy and Regulatory Framework for the Creation and Restoration of Wetlands and Wetland Islands Using Dredge Material*** with a focus on the most relevant points for the creation and restoration of wetlands and wetland islands using dredged materials.

The University of Connecticut and Connecticut Institute for Resilience and Climate Adaptation (CIRCA) organized a free workshop on the Beneficial Use of Dredged Materials for Resilient Tidal Marsh Restoration and Creation on September 28, 2017 at the Maritime Aquarium in Norwalk, CT. The workshop brought together case study presentations of projects from Rhode Island, New York, and New Jersey, and a feasibility study for the State of Connecticut. Project planning, design, permitting, implementation and monitoring were discussed by representatives from fellow state and federal regulatory agencies, funding organizations, and researchers. The workshop was designed to provide opportunities to network with fellow mangers while sharing lessons learned, and to build future collaborations. A summary of the September workshop proceedings is provided in ***Appendix E – A Report on the Workshop on Beneficial Use Of Dredged Material for Marsh Restoration and Creation in Connecticut***.

3.2 Ten Policy Recommendations

Adding dredged sediments to wetlands for the purpose of increasing the marsh's resilience to sea level rise or for flood or erosion control should not be considered fill or disposal and be reviewed as exempt or expedited for permits meant to regulate fill or disposal in tidal wetlands. There is no doubt that the continued commitment to protecting and preserving our remaining wetlands remains a high priority, but statutes underlying the current permitting process assumed a static climate system and sea level. Now that we know the baseline is changing, we must review the statutes with that in mind.

When appropriate, projects should be done as a wetlands restoration with co-benefits of flood and erosion control to ensure focus on habitat enhancement and conservation and for ease of permitting within the current regulatory framework. The above recommendation for exemption still stands, but with no changes to the current regulatory framework, it is clear that wetlands restoration projects are the best option for permitting and achieving the co-benefits of flood and erosion control.

Creation of wetlands where no existing evidence that wetlands existed historically should be permitted as a living shoreline or nature-based feature technique for floodplain management. Rather than declaring outright that if an area has never supported a wetland before that it is inherently inappropriate for that purpose, it should be looked at as an alternative approach to floodplain management in place of shoreline hardening or building walls. Living shorelines are the emerging option for permitting these types of projects, but, as advised above, restoration is preferable, if any evidence can be found to justify that path.

Habitat tradeoffs for both restoration and creation of wetlands at a site should be weighed against benefits to flood and erosion control through nature-based approaches or other design alternatives at the site, particularly hard structures. Regulators and planners should be aware that disallowing a project for a habitat tradeoff in a mudflat or open water area might move individuals towards building hard structures upland out of a regulatory jurisdiction. Although this approach takes the project out of federal or state regulatory areas, it does not mean that the overall ecosystem has not been harmed. Moreover, with rising sea levels, upland structures are tomorrow's sea walls.

Connecticut Water Quality Standards should include flood and erosion control/mitigation and sea level rise resiliency as benefits that should be protected or enhanced and these benefits should be weighed against near-term lowering of water quality, if any. The Connecticut Water Quality Standards provide guidance for dredging activities and discharges into wetlands and therefore provide guidance for protection of these resources similar to the Tidal Wetlands Act and Coastal Management Act. However, both of these acts mention flood and erosion control as a benefit. To better align the Connecticut Water Quality Standards with the goals of these Acts, the Standards should also include that benefit. Wetlands are generally recognized to improve water quality over the long-term as natural filters. Regulatory decisions on water quality should balance short-term lowering of water quality against long-term benefits. However, wetland creation or restoration projects should not permanently degrade wetlands below state water quality standards.

Connecticut should consider creating specific criteria for testing and use of dredged sediments for beneficial use with the end use project type in mind as other states have done. Maryland (MDE, 2017) and Rhode Island-(RIDEM, 2003) have specific criteria for dredged sediments intended for beneficial use. Creating the criteria would ensure both the safety of the materials for their intended use and allow for use of dredged sediments in wetlands where they do not match the background concentration of soils. The justification for this change is again that restoration of degraded wetlands or creation of new wetlands is expected to enhance water quality over the long-term. It is not meant to loosen standards such that there is any increased exposure to harmful elements in the dredged sediments.

The Connecticut Water Quality Certificate should not further limit the size of projects that can be conducted under the Programmatic General Permit for projects already considered to have minimal environmental impacts. If wetlands restoration or creation projects using dredged sediments continue to be subject to permitting statutes governing fill or disposal in tidal wetlands, then at a minimum, Connecticut should align its project size constraints with the federal government guidelines. Self-verification projects, already categorized as such due to low environmental impacts, are limited to ≤50 feet under the Connecticut Water Quality Certificate.

Additional economic and social co-benefits to communities of wetland restoration and creation projects should be evaluated when considering cost-effectiveness and permitting. The US Army Corps is requesting this information as part of their pilot projects under the 2016 WIIN Act, recognizing that green infrastructure or nature-based approaches may not be justifiable on up front project costs alone. Requiring an evaluation of the additional co-benefits recognizes the community-wide impacts of a project, rather than just the capital cost of installing a flood and erosion control structure.

Community engagement should be required at all stages of a project, not just during a required public comment period. The interviews conducted in this study revealed that projects that invested in meetings with interested stakeholders in early stages were more likely to be successful. Especially given the inherent negative connotation of dredged sediments, it is important to be transparent and engage community members in a project area early and often.

Project monitoring should be required for new projects to ensure that the assertions on improved flood and erosion control and water quality improvement are verified. It is still early days in the use of dredged sediments for the creation and restoration of wetlands as a resiliency practice. Nature-based approaches are seen as an inherently better alternative than hard structures, however, there are few published studies on project success. These policy recommendations, which are based on likely benefits from these projects, need to be verified with in situ monitoring studies.

3.3 Public Outreach and Engagement

When are public review, comment and hearing required?

State or Federal Individual Permit. If an applicant requires a Connecticut individual permit for a project in the coastal zone, including any project in tidal wetlands or navigable waters, then there is a process for public comment (CTDEEP, 2016). When an application is filed, then a Notice of Application must be placed in a local newspaper and the chief elected official of the municipality where the project is located must be notified. When the application is complete, the CT DEEP will publish a Notice of Tentative Determination and the public will have the opportunity to provide public comment on the application and a public hearing may be held.

A federal individual permit may be required under section 404 of the Clean Water Act for projects with a potential significant environmental impact. Public hearings regarding individual permits are held at the discretion of the USACE district commander and are only held when they would provide additional information for the permit decision (NRC, 2001). A 2001 National Research Council (NRC) (2001) report suggested that in place of holding a formal public hearing to engage objectors to a project or specific issues, that informal workshops or public meetings be held with these groups because they are much less expensive and could provide a higher level of interaction with constituents.

Section 7 of this report, *A Public Health Perspective*, reviews a number of issues often raised by the general public and includes literature reviews pertinent to responding to public concerns and questions.

Innovative Best Practices for Public Outreach and Engagement

The types of informal workshops and meetings described in the NRC report are encouraged by the Federal Department of Housing and Urban Development. A recent report from the Office of Economic Resilience pulled case studies from HUD grantees on best practices for public engagement strategies (USHUD, 2016). This list encompasses strategies that go beyond a presentation and question and answer in a town hall to incorporate hands-on activities and communications approaches that can be used to get the word out to the public in a variety of settings. Letters in the abbreviated list below refer to the tables that follow in Section 3.3.1 where a lengthier description and links to additional resources are provided:

A. Minority and underrepresented groups targeted with local events
B. Promotional movie to show in theatre previews
C. “Meeting in a bag” with constituent groups at forums hosted by those groups
D. Public art display
E. Live, interactive key-pad polling
F. Artists-in-residence as engagement leaders
G. Dedicated funding for community organizations to do community engagement particularly to underrepresented and marginalized communities of color
H. Project wrap-up video
I. Incorporate local stories into reports
J. *Livable Communities Corps* for community mapping
K. Comprehensive strategy: Open houses, surveys and visioning exercises
L. Make a game with scenario planning
M. Engage youth
N. Utilize college student service-learning programs
O. Create a magazine to present plans
P. Fund positions dedicated to equity in engagement

3.3.1 Public Engagement Strategies

The following tables summarize information compiled by the Office of Economic Resilience which pulled case studies from HUD grantees on best practices for public engagement strategies (USHUD, 2016).

A. Minority and underrepresented groups targeted with local events	
Organization:	South Florida Regional Planning Council
Location:	Hollywood, FL
Resources:	
Description: **Southeast Florida has unique equitable outreach efforts.** Outreach included a Haitian Summit, a millennial event, participation by the team in City-sponsored events such as parking-day, presence of Seven50 in the Climate Compact Summit and other partner's organization conferences, highlight of the project in numerous conferences. Outreach efforts also extended to local churches and community groups who either specifically asked for information or who were interested in actively participating in the process.	

B. Promotional movie to show as theatre previews	
Organization:	South Florida Regional Planning Council
Location:	Hollywood, FL
Resources:	View the video: https://www.youtube.com/watch?v=hBxXBvdEPF4
Description: **South Florida's Broward MPO created a short promotional video about transportation planning to be shown in movie theatre previews.** In partnership with the Palm Beach MPO and South Florida Commuter Services, the Broward MPO produced a short information video about the MPO. The video appeared in select FL cinemas the July 4 weekend, 2015. The video talks about the purpose of a metropolitan planning organization in long-term transportation planning, and encourages viewers to get involved with the future planning of their city.	

C. Meeting with constituent groups at forums hosted by those groups – "meeting in a bag"	
Organization:	City of New Orleans
Location:	New Orleans, LA
Resources:	http://www.livableclaiborne.com/
Description: **City of New Orleans successfully engages Mardi Gras Indian community.** During the outreach efforts for the Livable Claiborne Communities, it became clear that there were many segments of the community that preferred for the LCC project team to meet with them at their own forums and learn directly from their constituencies, whether those constituent groups were place-based or formed around a social, cultural or economic interest. As part of the "Meeting in a Bag" outreach method, the LCC project team and city agency representatives were hosted by different groups during the study. Perhaps the most transformational series of meetings occurred with the New Orleans Black Indians (also known as the Mardi Gras Indians), whose skills, commerce, and industry have supported the tradition of these New Orleans Culture Bearers for generations.	

D. Public art display	
Organization:	Franklin Regional Council of Governments
Location:	Greenfield, MA
Resources:	http://frcog.org/program-services/land-use-planning-zoning/

Description: **Franklin Regional COG's arts-based public engagement.** A key piece of FRCOG's public engagement was a public art display. Community Action, one of the project partners, organized a youth group that helped select the winning artist and participated in the creation of the art. The selected artist created a mosaic design that incorporated the handprints of many county residents, including the youth group. The youth group worked closely with the artist, cutting glass pieces to create the hands contained in the mosaic. The art display was unveiled in a ceremony at the Franklin County Transit Center (the first net-zero energy transit center in the nation). Another Community Action youth group assisted in the presentation of the display during the ceremony with a choreographed dance and music. Large posters of the mosaic were created and attached to the sides of the Franklin Regional Transit Authority buses for several weeks during the public comment period for the draft Plan in order to help publicize the Open Houses and the Sustainable Franklin County Plan.

E. Live, interactive key-pad polling	
Organization:	Metropolitan Area Planning Council
Location:	Boston, MA
Resources:	http://www.mapc.org/metrofuture

Description: **Metro Boston Grantee Elects New Consortium Members with Key-Pad Polling.** Metro Boston (MAPC), a HUD Regional Grantee, elected at-large representatives for its consortium, using live, interactive key-pad polling.

F. Artists-in-residence as engagement leaders	
Organization:	City of Flint
Location:	Flint, MI
Resources:	http://www.mlive.com/entertainment/flint/index.ssf/2013/02/resident_artists_picked_to.html

Description: **Flint, MI, Engages Artists in Helping the City Plan for its Future.** Flint, MI, a FY10 Community Challenge Grantee, is engaging artists in helping the city plan for its future. Through a complementary grant from the National Endowment for the Arts (NEA), Flint has secured nine artists-in-residence for its nine wards to help engage residents in exploring the role arts play in the city's future, and providing input into the city's first masterplan in 50 years!

G. Dedicated funding for community organizations to do community engagement particularly underrepresented and marginalized communities of color	
Organization:	Metropolitan Council
Location:	St. Paul, MN
Resources:	http://www.corridorsofopportunity.org
Description: **Corridors of Opportunity Community Engagement Team engages thousands of Twin Cities area residents to ensure that underrepresented communities are a powerful voice in creating an equitable regional transit system.** The Corridors of Opportunity Community Engagement Team is led by the Alliance for Metropolitan Stability, the Minnesota Center for Neighborhood Organizing and Nexus Community Partners. The CET's goal is to transform community engagement in the Twin Cities region so that all residents — particularly underrepresented and marginalized communities (low-income, communities of color, immigrant communities, persons with disabilities) — are empowered and equipped to participate in transitway planning. The CET manages a community engagement and outreach grant making process and has established a steering committee of community leaders whose goals are to ensure that underrepresented communities are a powerful voice in creating an equitable regional transit system. Among other things, the Metropolitan Council dedicated $750,000 of its HUD grant towards funding 17 community organizations in order to support community engagement of traditionally underrepresented populations in mostly low-income, largely minority neighborhoods that will be served by the new transit lines.	

H. Project wrap-up video	
Organization:	Mid-America Regional Council
Location:	Kansas City, MO
Resources:	http://www.youtube.com/watch?list=UUrxMZ4dbP_zVy82ejLpQ6Gg&v=9RPG_CaIaPY
Description: **MARC releases a YouTube video: "Creating Sustainable Places: From Vision to Reality."** Mid-America Regional Council's Creating Sustainable Places project focused on these three qualities of sustainability. This project wrap-up video offers an explanation of Creating Sustainable Places and its impact on the Kansas City region. Answers to the question "Where do we go from here?" are examined, and concrete ideas offered for how we can continue to work together creating the reality of sustainability.	

I. Incorporate local stories into reports	
Organization:	Nashua Regional Planning Commission
Location:	Merrimack, NH
Resources:	http://granitestatefuture.org/
Description: **Granite State Future/Nashua Region created a Storytelling companion to their final plan.** As part of the plan they developed under the Granite State Future project, the Nashua Regional Planning Commission created a shorter companion piece to their regional plan that prioritized accessibility and concision in an effort to make the plan readable and understandable by area residents. "The Nashua Region: A story worth telling" includes an introduction to key issues and trends from the Nashua Regional Plan and incorporates stories from area residents that illustrate how regional planning is relevant to regular people's lives.	

J. Livable Communities Corps *for community mapping*	
Organization:	Upper Valley Lake Sunapee Regional Planning Commission
Location:	Lebanon, NH
Resources:	http://www.uvlsrpc.org/project/Municipal_Policy_Audits_24/?fromSearch=true&/search_projects/=&town=19

Description: **Livable Communities Corps uses GPS equipment to conduct walkability assessments and collect healthy food access data.** Upper Valley Lake Sunapee Planning Commission trained a cadre of volunteers called a Livable Communities Corps. These volunteers collected data with GPS and along the way were taught about local policies, how to become more involved in policymaking, and opportunities to impact the quality of life in their communities. Healthy communities can also be encouraged by mapping healthy food choice options. The initiative was part of a larger project that will assist community leaders to implement policy changes that locate housing supply and new food source options to be within walking distance of one another.

K. Comprehensive strategy: Open houses, surveys and visioning exercises	
Organization:	City of Henderson
Location:	Henderson, NV
Resources:	http://www.southernnevadastrong.org/

Description: **Southern Las Vegas has exemplary comprehensive communications and engagement activities.** There were fifteen open houses conducted throughout the first half of 2014 giving residents the opportunity to provide input through Metroquest surveys, visioning exercises and discussions with staff. Over 48,000 flyers (4,000 households for each event) were handed out around twelve of the meeting locations along with newspaper notices and social media posts. Jurisdictions noticed the events on websites and via council newsletters. Eight additional events were attended by staff (back to school fair, health fair, Asian chamber, etc., to provide information and an opportunity to receive additional input through iPad surveys and visioning exercises. Project leaders participated in fourteen speaking engagements at various business associations, city councils, chambers of commerce and governmental organizations. Targeted Hispanic outreach included over ten additional events that engaged the community and included radio, newspaper, and social media coverage in Spanish. More than 2500 surveys were completed over this period and more than 500 people signed the sign in sheets for the fifteen open houses. But several more actually attended as groups and families often had only one person sign in.

L. Make a game with scenario planning	
Organization:	Niagara Frontier Transportation Authority
Location:	Buffalo and Niagara Falls, NY
Resources:	http://www.oneregionforward.org/
Description: **One Region Forward Scenario Planning in Slow Growth Regions.** One Region Forward's team at the University at Buffalo Regional Institute customized an interactive scenario planning game that featured maps, stickers, markers, and other "game board" elements that made the exercise understandable, fun, and pertinent to local conditions. As participants considered what type of change they would like to see for the region over the next forty years, they were forced to consider how to shape development where little or no growth is expected and the overhang of vacant land, housing, and industrial property is significant. The activity was "played" by nearly 1,000 citizens at large "Community Congress" forums and at local block club meetings, rural town halls, church and cafeteria basements, and individual citizens' homes.	

M. Engage youth	
Organization:	City of Knoxville
Location:	Knoxville, TN
Resources:	http://www.planeasttn.org/
Description: **Plan East Tennessee engages youth in their regional planning.** Several Sustainable Communities grantees, including Tampa, Florida, and East Tennessee (PlanET) are involving high school students in envisioning how they would like their communities to grow and change in the future. The videos were produced by Austin East High School students as part of the Digital Storytelling Project presented by Plan East Tennessee with support from the Carpertbag Theater, Inc. and Project GRAD Knoxville.	

N. Utilize college student service-learning programs	
Organization:	City of Austin
Location:	Austin, TX
Resources:	http://austintexas.gov/colonypark
Description: **City of Austin engages students to do community outreach as part of service-learning partnership with local community college.** The City of Austin engaged a Public Engagement Team comprised of students and faculty at UT to conduct outreach and public engagement for their HUD SCI project. As part of this, the students were required to attend an orientation to learn more about the Colony Park community and to receive training on developing, administering and collecting surveys. Students conducted the survey in Spanish and English and went door-to-door throughout the neighborhood to educate residents on the neighborhood master plan and to conduct a survey.	

O. Create a magazine to present plans	
Organization:	City of Burlington
Location:	Burlington, VT
Resources:	http://issuu.com/tpudc/docs/planbtv_downtownwaterfrontmasterpla
Description: **Burlington's "PlanBTV Downtown and Waterfront Guide Final Plan" doubles as a beautiful magazine distributed around town.** PlanBTV is using a magazine format intentionally, to make this document as accessible as possible to the public, stakeholders, policy-makers and city staff. This plan builds on years of hard work and is intended to be actively used.	

P. Fund positions dedicated to equity in engagement	
Organization:	Puget Sound Regional Council
Location:	Seattle, WA
Resources:	http://www.psrc.org/growth/growing-transit-communities/ http://pugetsoundequity.org/ http://www.psrc.org/growth/growing-transit-communities/regional-equity/ http://www.psrc.org/about/advisory/gtc-committees/equity-net-sc
Description: **PSRC created and staffed a Regional Equity Network to encourage underrpresented groups to participate. A central element of the Growing Transit Communities work program has been to create and staff a Regional Equity Network to increase participation of historically underrepresented communities in regional planning activities, build local capacity, and give voice to community priorities.** The Regional Equity Network has been directly resourced by grant funds through two contracts with Impact Capital, a sub-recipient and project partner. One contract, in the amount of $290,000, was used to fund a staff position at Impact Capital, the Equity Network Manager, to coordinate the development of the Regional Equity Network and to administer a community equity grant program.	

4 Construction Issues

Unlike most construction projects, the outcome of a marsh restoration/creation project is not entirely predictable. Therefore, the planning and construction of a wetlands project require flexibility. The goals of the project should be defined in terms of wetlands functions, with quantifiable and qualifiable metrics in order to evaluate the success of the project. However, achievement of precise values may not be feasible so the stated objectives should be conservative and flexible. Otherwise, failure to attain the stated objectives may result in excessive maintenance costs and, potentially, legal liability. Attempts to over design and landscape the wetlands into performing functions that do not occur naturally or are not suited to the project location are likely to result in partial or complete failure of the project (Mitsch and Gosselink, 1993).

Marsh restoration or creation using dredged material unites two challenges – disposal of dredged material and the degradation or loss of tidal wetlands – into one opportunity. Before potential wetland sites are evaluated, the suitability of the dredged material for beneficial use must be assessed. If the material is found to be suitable for beneficial use, the appropriate use must be identified. Only if the material is found to be suitable for marsh restoration or creation is the identification and evaluation of wetlands sites necessary. A ***User's Guide for Beneficial Use of Dredged Material for Marsh Restoration or Creation*** can be found in ***Appendix F***. The User's Guide provides detailed information on the steps to necessary to use dredged material for marsh restoration or creation, starting with the evaluation of the dredged material disposal needs and evaluation of the material for beneficial use, including the appropriate beneficial use for the material. It then discusses site selection criteria, design issues, construction considerations and lessons learned.

4.1 Site Suitability

By far the most difficult aspect of beneficial use of dredged material for marsh restoration or creation is the identification of suitable site (USACE, 1987). Wetland restoration/creation is a long-term process which requires the establishment or reestablishment of conditions suitable for the development and natural sustainability of a viable wetland ecosystem (Hayes et al., 2000). Beneficial use of dredged material further contributes to the challenges due to cost and material suitability considerations.

The selection of a suitable wetland restoration/creation site depends upon the existing site characteristics and the ability to modify these characteristics to produce a functioning wetland system (Shisler, 1989). Low energy, shallow-water sites are the most suitable; however, cost may become a deciding factor if the distance between the dredge and the placement sites are significant or protective structures are required to mitigate wave energy (USACE, 1987). Thus projects adjacent to established and functioning wetland systems which can be used as design models offer the greatest likelihood of long-term success. Wetlands creation where one doesn't exist, either currently or historically, indicates that the conditions inhibiting wetlands must be identified and addressed in the design process if the wetlands creation is to succeed (Shisler, 1989).

Analyzing existing site conditions for marsh restoration is different from that for a creation project. Since wetlands were present historically, the investigation must determine what conditions led to the degradation of the wetlands and whether the present conditions including substrate, circulation and sedimentation, can be modified to re-establish and maintain the restored habitat (Shisler, 1989; USEPA and USACE, 2004). Due to the importance of site conditions on the long-term success of the habitat, restoration of a wetland site is likely to be more successful than creation of a wetland at a site where one had not previously existed (Kusler and Kentula, 1989).

Evaluation of a potential wetland creation site requires assessment of existing conditions that may preclude wetlands development and determination if modification of these conditions to create a suitable wetlands environment is economically and environmentally acceptable (Shisler, 1989). Marsh development frequently results in the destruction of an existing habitat to create questionably functional habitat. Evaluating the relative benefits of the existing and proposed habitats is likely to be subjective and based on the knowledge and opinions of local authorities (USACE, 1987).

Wetland development must compare the environmental conditions at the proposed sites with those which are essential for the development of the natural biological, chemical and physical functions that enable the created wetlands become a natural, sustainable ecosystem (Hayes et al., 2000; Shisler 1989;). Critical aspects which should be considered in site selection are listed in Table 1.

Table 1. Critical Aspects of Site Selection

Logistical Considerations	• Availability for marsh restoration/creation (USACE, 1978) • Dredging volume versus beneficial use requirements (USEPA and USACE, 2004). • Jurisdiction concerns (Mohan et al., 2007) • Proximity to dredging area (USACE, 1978, USEPA and USACE, 2004, 2007b) • Site accessibility (USEPA and USACE, 2004) • Equipment compatibility (USEPA and USACE, 2004)	• Scheduling of dredging operations with marsh construction (Broome, 1989) • Public acceptability (Broome, 1989; USEPA and USACE, 2004, 2007b) • Costs (Broome, 1989) • Presence of cultural or archeological resources (Mohan et al., 2007) • Material rehandling requirements (USEPA and USACE, 2004)
Physical Considerations	• Topography: tide elevation determines suitable plant species (Broome, 1989). • Shape and orientation of shoreline (Broome, 1989) • Wave climate, currents, boat wakes and storm surge: susceptibility to erosion and potential necessity of protective structures (Broome 1989; USACE, 1987) • Hydrology (i.e., circulation and sedimentation)	• Salinity: influences plant species composition (Broome, 1989; USACE 1987) • Slope, tidal range and water depth: affect size of intertidal zone, suitable plant species, drainage and susceptibility to erosion (Broome, 1989)
Environmental Impact on Existing Habitat	• Potential impacts on water quality • Presence of contaminants at the site • Relative value of existing and proposed habitats (USACE, 1978)	• Presence of domestic or wildlife animals, and foot or vehicular traffic (Broome, 1989)
Geotechnical Considerations	• Existing soil chemical properties (Broome, 1989). • Soil physical properties: sediment type and characteristics, and potential for consolidation and instability (Broome, 1989).	• Sediment supply and littoral drift (Broome, 1989) • Foundation characteristics: site's ability to support construction activities or structures. (USACE, 1987)
Habitat Development Potential	• feasibility and level of effort to create or restore sustainable marsh (Hunt et al., 1978)	

4.2 Technical Challenges for Implementing Beneficial Use in CT Marshes

Beneficial use (BU) is not in its infancy but there still remains some learning to do with respect to engineering constraints and how to assess the efficacy and duration of the resilience and ecological benefits derived from the BU. Consequently, even though BU implementation itself has matured, it is relatively immature for most geographical areas and particularly in regards to our understanding of its effects on ecosystem function and the duration over with the elevation benefits of the BU are sustained

(Stagg and Mendelssohn, 2011; see summaries in the Ray 2007). Some of the technical challenges associated with implementing BU include sediment selection, targeting and achieving the appropriate new elevation, and monitoring designs to gauge effectiveness of the BU.

4.2.1 Existing Conditions and Sediment Characteristics Matter

Sediment grain size and geochemistry have proven important for successful implementation. Recent findings from USACE projects in NJ and elsewhere suggest that while marshes typically trap fine grained sediment, higher success rates, as measured by time for vegetation to re-establish, has been achieved using the placement of coarser grained material. This finding poses a challenge given the desire to repurpose large volumes of fine-grained dredge material. Sediment geochemistry is also important. Some projects have reported localized sediment acidification after deposition. The source of the acidity comes from sediments that have high iron sulfide mineral levels. These can be more common but not limited to finer grained marine sediments. When sediments containing high iron sulfide minerals are exposed to air, bacteria in the sediment naturally convert the sulfur in these minerals to sulfuric acid. This is analogous to the process that produces acid mine drainage found throughout Appalachia. This acid production drops the pH dramatically, leaches metals and causes deleterious effects to plants and animals. Past work suggests that this acidification is temporary although the timescale for pH return to normal will vary site by site. The ultimate goal of marsh BU is to raise the elevation of a site to, or slightly above, the optimal elevation for plant growth. The 'optimal' elevation varies with site conditions, including tidal amplitude, suspended sediment supply, and the elevation:plant biomass relationship (Davis et al., 2017). Thus, site selection and characterization is the critical first step in the process that aligns a dredging effort with a suitable coastal marsh site(s).

4.2.2 Hitting the Right Height

Targeting different post-BU elevations has implications for the restoration success as does under or overshooting those target elevations. One tradeoff is the lifespan of elevation capital gained by the sediment addition vs the risk of adding too much sediment. The objective of the BU is to attain site elevation that is optimal for plant growth. Although observations and models indicate that salt marshes generally are optimized for growth when they are positioned at mean local sea level, there are differences in optimum elevation of specific plant types. The final target elevation may be dependent on the drivers of the restoration. For example, those designed for restoration of salt marsh sparrow habitat would typically target elevations near the upper end of the tidal range to optimize response the salt hay high marsh (*Spartina Patens*) habitat optimal for that species. Targeting final elevations lower than that promotes saltmarsh cordgrass (*Spartina alterniflora*) which is flooded more frequently, more efficiently traps nutrients and sediment, and provides better support of fin and shellfish. With respect to shoreline protection, the higher canopy and drag of the *Sp. alterniflora* likely dampens wave energy more efficiently per linear distance than high marsh. However targeting elevations that are lower in the tidal frame that are most favorable to *Sp. alterniflora* mean the that the elevation benefits gained from the TLP may be shorter lived if local sediment supplies are inadequate to keep sediment trapping high and thus continued vertical accretion of the marsh. Adding too much sediment, runs the risk of burying existing vegetation to the point where it cannot re-emerge, although good one year plant regrowth has been observed following placements of 20cm. More importantly a rapid elevation gain well above the spring-tide high water mark can promote vegetation shift from *Spartina* species to invasive *Phragmites spp*. Pre placement knowledge of grain size and water content help to refine final post placement elevations but this seemingly simple target can be elusive. But actively grading with GPS guided equipment can result in relatively precise final sediment elevations. It is not entirely clear however, how the higher amounts of elevation achieved through BU extend the lifespan of a given marsh. Ideally, a one-time addition of sediment would permit enhanced plant production that more efficiently traps natural sediment loads and accelerates accretion accordingly. This scenario represents an effective jumpstart the system that then accretes at a rate on par with rising seas. It's not clear though that this would be the case at potential CT sites. Most BU projects have not been around long enough with sufficient monitoring to assess whether a one-time elevation gain through BU buys 100 years of marsh sustainability, and extant ecosystem services, or this is a ten year renewable proposition or somewhere in between. Knowing the tradeoff between investment and time horizon of benefit is a critical piece of information that holds the key to how tractable and wise of a management tool it is.

4.2.3 The Edge Problem

An additional challenge when determining the utility of BU at site with existing marsh is the edge problem. TLPs are proposed for marshes whose accretion rates are 'elevationally challenged'. But marsh loss and thus marsh restoration or adaptive management of marshes can be a two-dimensional problem. Marsh elevation challenges can be coupled to edge loss. And total marsh area decline can be as much attributable to lateral marsh retreat as it is subsidence, fragmentation and disappearance associated with marsh drowning (Finkelstein and Hardaway, 1988; Ganju et al., 2017). In areas where marsh restoration is considered for the purpose of buffering shorelines against wave induced erosion, this two-dimensional problem is particularly relevant. To compound this problem many marshes particularly in CT have high slope land-marsh boundaries, and/or built infrastructure that prevents marsh migration landward to offset seaward edge losses. In regions where loss of seaward marsh edge is documented and landward marsh migration is not possible, BU designed to provide elevation capital to these vertically and horizontally challenged marshes should incorporate the kind of edge stabilization typical of smaller scale living shoreline designs. A recent 10 yr analysis provided to Coastal DOD installations offered the recommendation that marshes be allowed to migrate into uplands with rising sea level as much as could be accommodated. In areas where this is not possible, the seaward edge be stabilized and BU be considered an option for augmenting elevation as needed. The final recommendation is that erosive shorelines that are not lined with marsh habitat be permitted to erode, again as allowable given upland infrastructure, in order to provide sediment to the local sediment supply (Currin, 2013). When BU is considered as an option, it should be done within a broader suite of shoreline management tools.

4.2.4 Monitoring - Did it Work?

Among BU projects, few utilize common post monitoring metrics, limiting conclusions that can be drawn more broadly across multiple studies. There has historically been limited used of Before After Control (BACI) monitoring designs which has proven useful when implemented in conjunction with Development of an Ecological Integrity Index (Staszak and Armitage, 2013; Sutula et al., 2006; Wigand et al., 2011; Figure 3). This Index ranks characteristics divided into categories such as landscape limitations, hydrology, habitat, belowground processes are ranked/scored either qualitatively (high, low, moderate) or quantitatively (Diversity indices, biomass, etc.). These values are compiled into a weighted hierarchical scoring framework that yields an overall index that is comparable between restored and reference sites and/or along a continuum.

	Old Restored	Young Restored	Reference
L1: No. of barriers per site	0.8 ± 0.2	0.7 ± 0.2	0.8 ± 0.3
L2: No. of structures per site	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0
H1: No. of severe modifications per site	0.2 ± 0.2	0.4 ± 0.3	0.3 ± 0.2
H2: % Area with moderate hydrological modifications	25.0 ± 7.9	50.0 ± 15.4	33.3 ± 12.4
W1: % Vegetation cover	65.5 ± 11.9	64.4 ± 5.5	62.2 ± 4.6
W2: Vegetation diversity (Simpson's Index)	0.35 ± 0.09	0.14 ± 0.04	0.11 ± 0.06
W3: % Cover of invasive species	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
W4: Density of epifauna + burrows (no./m^2)	5.1 ± 5.1	0.0 ± 0.0	58.9 ± 15.3
B1: Soil stability (psi)	1.3 ± 0.3	0.7 ± 0.2	0.5 ± 0.1
B2: 2–4-cm plant roots (mL)	20.3 ± 3.2	14.3 ± 2.7	18.7 ± 1.6
B3: 25–27-cm plant roots (mL)	8.7 ± 3.2	8.9 ± 0.8	11.1 ± 2.9
B4: Porewater salinity (ppt)	29.7 ± 2.4	33.7 ± 2.2	25.5 ± 1.4
B5: Porewater pH	7.1 ± 0.3	7.2 ± 0.1	6.6 ± 0.1

Figure 3. Example of Ecological Integrity Index from Staszak and Armitage, 2013; Table 3.

Plant community metrics have typically been the most commonly measured response variable. Results from different projects have been mixed but indicate that in some instances, plant response to BU can mimic control plant communities on 1-2 year timescales (Pezeshki et al., 1992; Leonard et al., 2002; Slocum et al., 2005; Dawe et al., 2000). Examples documenting nutrient retention in BU treated marshes are sparse but an Alabama marsh restoration of black needlerush marsh showed efficient nutrient trapping within six months of construction, even before full plant regrowth (Sparks et al., 2013). Projects conducted within the past few years have more robust post BU monitoring programs that include soil, hydrologic, plant, faunal, and elevation measurements but there remains room for improvement. While some of the plant and nutrient benefits can be re-established relatively quickly, rebuilding marsh food webs may take more time. When faunal populations of marsh restorations of different ages have been examined, the time horizon for re-establishing 'natural conditions' is on the scale of decades rather than years (Craft and Sacco, 2003; Broome and Craft, 2009; Figure 4).

There is a consensus among coastal scientists and managers that existing approaches for monitoring ecosystem recovery following wetland restoration needs improvement and standardization. In light of the massive marsh restoration efforts in the Gulf of Mexico following Deep Water Horizon, the National Academies of Sciences Engineering and Medicine Gulf Research Program released new monitoring guidelines in 2017. While not all measurements are tractable and relevant for CT projects, these guideline so summarize many of the important marsh attributes that permit assessment of a "successful" BU project.

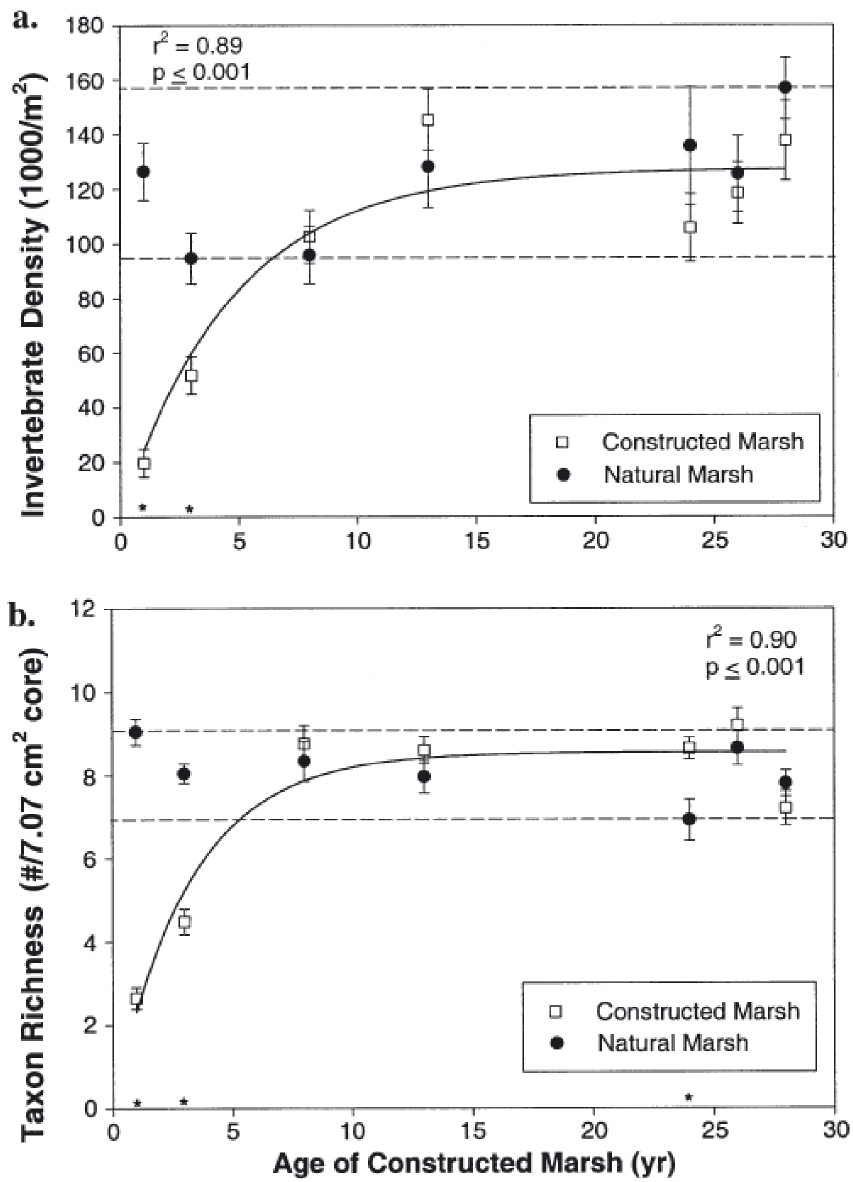


Figure 4. Food web recovery trajectories in constructed marshes – from Craft and Sacco 2003

Ideally, standardizing a monitoring framework to quantify a range of ecosystem functions in a consistent and coherent way across wetland restoration sites would be beneficial and should:

- Capture process-level spatial and temporal heterogeneity on scales at which ecological functions, operate.
- Be methodologically transferable among sites distributed across CT
- Align with recent NASEM guidance that stresses ecosystem processes and function as restoration endpoints
- Leverage existing monitoring efforts where possible and be consistent with state coastal planning policies.

5 Cost Issues

Most costs of using dredged material for marsh restoration/creation would be incurred during any confined dredged material disposal project (USACE, 1978). The relative cost of beneficial use instead of open water or contained disposal is of interest in beneficial use planning. Project cost estimates should include:

These costs include:

- Site acquisition and preparation: clearing, grubbing, and dewatering if needed
- Engineering and design including contour mapping surveys and construction staking preparations of construction drawings and specifications
- Preparation and distribution of bid requests and advertisements
- Construction activities for major project components, for instance, weirs/dikes, water controls, roadways, spillways, visitor facilities, etc., as needed
    - materials
    - equipment
    - transport
    - labor
    - supervision and administration
    - overhead percentages
- Planting wetlands vegetation and revegetating disturbed areas

(Hayes et al., 2000). Costs specific to habitat development can vary greatly depending on a number of factors:

- Site accessibility
- Distance between the dredge site and the marsh construction site
- Characteristics of the dredged material and the foundation
- Energy regime at marsh site
- Cost of protective structure
- Availability and accessibility of equipment

Ninigret Pond, Charleston, RI

Dredging and Marsh Restoration Project

Costs for restoring approximately 20 acres of marsh

Design, Engineering and Permitting	$110,453
Construction	
Mobilization/Demobilization	$334,400
Dredging, spreading and grading of material	$543,900
Alternate dredging	$530,812
Planting	$100,000
TOTAL:	$1,619,565

(Chaffee and Frisell 2017)

- Local labor

(Hayes et al., 2000). For instance, depending on the site conditions (exposure to wave energy and currents, foundation characteristics), the cost of protective structures can be low for a hydraulically placed sand dike too high for a large rock dike. On the other hand, standards for estimating, excavation, construction and planting are common and straightforward (Hayes et al., 2000).

For Congressional approval there must be an economic benefit to the federal government and the local community (Collins et al., 2015). In general, the cost of the construction can be estimated using established engineering industry techniques. Estimating the costs associated with monitoring and maintenance, and the value of the completed project is more challenging. Although the value of wetlands to society is well-documented, determination of the financial worth of the proposed wetland's functions is subjective (Hayes et al., 2000). The valuation is highly dependent on the evaluation technique used, and potentially on the interests of the party performing the economic analysis (Mitsch and Gosselink, 1993).

The U.S. Army Corps of Engineers (USACE) will only support beneficial use projects that meet the Federal Standard and/or have non-federal funding support and federal established authorizations, agreements, plans and budgets (Collinset al., 2015). The Federal Standard is defined in USACE regulations as, "the least costly dredged material disposal or placement alternative identified by USACE that is consistent with sound engineering practices and meets all Federal environmental requirements, including those established under the Clean Water Act (CWA) and the Marine Protection, Research, and Sanctuaries Act (MPRSA)" (USEPA and USACE, 2007b). The term "base plan" may be a more useful operational definition since it delineates the dredging and disposal or placement costs for the portion of the project which is for "navigation purpose" (Collins et al., 2015). The costs assigned to the navigational purpose of the project are distributed between the federal and the non-federal sponsor of the project, with allocation dependent on the type and scale of the project (see Table 2) (USEPA and USACE, 2007b). The Federal Standard is not the only metric which determines federal support of a dredging project. The USACE planning guidance identifies habitat restoration as one of its primary missions (USACE, 2000), and the disposal or placement alternative selected should maximize the net economic development and national environmental restoration benefits (USEPA and USACE, 2007b). Thus, even if a beneficial use alternative does not meet the Federal Standard on a cost basis, it may receive federal funding support. Additionally, a beneficial use project may serve more than one purpose, such as navigation and flood control. Considering the benefits of the placement or disposal options when multiple purposes are considered jointly may result in different outcomes than when each purpose is considered individually (USEPA and USACE, 2007b).

If a beneficial use alternative is selected, and that beneficial use is the Federal Standard of base plan option or part of it, the costs of the beneficial use are considered to be part of the navigational purpose of the project and therefore are shared with the non-federal sponsor as shown in Table 2 (USEPA and USACE, 2007b). On the other hand, if the beneficial use is not the Federal Standard option, the costs for the beneficial use option are divided into two categories for the purpose of determining the federal and non-federal allocations. The costs assigned to the navigational purpose of the project (i.e., the amount it would have cost to implement the Federal Standard option) are shared with the non-federal sponsor as in Table 2. Then, the remaining costs, known as the "incremental costs," are allocated depending on the type of beneficial use. (USEPA and USACE, 2007b).

Table 2. Distribution of costs for the "navigation purpose" of a dredging project (USEPA and USACE, 2007b).

New Navigation Projects			
For the portion of the project with depth:	The non-federal share is:	Paid during construction	Paid over 30 years*
<20 ft.	20%	10%	10%
20 ft. < depth < 45 ft.	35%	25%	10%
>45 ft.	60%	50%	10%
Operation and Maintenance of Existing Navigation Projects			
1. Operation and Maintenance Dredging: Federal share is 100% (except for harbors >45 ft., where the non-federal share is 50% of the costs beyond those which would be incurred for a project with a depth of 45 ft. or less			
2. Constructing land based and aquatic disposal facilities: same as for new navigation projects			
3. Operating and maintaining land-based and aquatic disposal facilities: Federal share is 100%			

There are four acts which determine the cost sharing for beneficial use projects:

- Improvement of the Quality of the Environment (Section 1135 of Water Resources Developmental Act (WRDA) 1986 as amended by Section 202 of WRDA 1992 and Section 204 of WRDA 1996);
- Protection, Restoration, or Creation of Aquatic and Related Habitats (Section 204 of WRDA 1992 as amended by Section 207 of WRDA 1996 and Section 209 of WRDA 1999);
- Placement of Dredged Materials on Beaches (Section 145 of WRDA 1976 as amended by Section 933 of WRDA 1986, Section 207 of WRDA 1992 and Section 217 of WRDA 1999); and
- Achieving Environmental Benefits (Section 207 of WRDA 1996).

The Protection, Restoration or Creation of Aquatic and Related Habitats is the most commonly used authority for funding beneficial uses of maintenance dredging both because of this specific focus and because it is appropriated programmatically. The costs are shared on a 75% federal and 25% non-federal basis (USEPA and USACE, 2007b).

6 State and Federal Agency Experiences

In line with our goal of exploring best practices in the field, we conducted personal interviews with eleven sets of practitioners affiliated with the US Army Corps of Engineers (USACE), the US Environmental Protection Agency (USEPA), The National Oceanic and Atmospheric Administration National Marine Fisheries Division (NOAA NMFS) and the US Fish and Wildlife Service (USFWS) as well as state agencies, including the New Jersey Department of Environmental Protection (NJDEP), the Rhode Island Coastal Resources Management Council (RI CRMC) and the Connecticut Department of Energy and Environmental Protection (CTDEEP). A summary of our key discoveries is presented below.

6.1 Wetland Creation versus Restoration

At both the federal and state level, a legal definition that distinguishes a wetland creation versus a restoration site is typically broad or generally lacking. However, the consensus of the interviews defines wetland restoration as a project occurring where wetland conditions are present and have degraded over time, or had previously existed. Wetland creation occurs where wetlands had not previously existed. Various agencies utilize different relevant statutes to guide their practice of implementing beneficial use of dredged material. Wetland restoration projects that utilize dredged material are being undertaken across different regions extending from the North Atlantic to Gulf of Mexico. Beneficial use of dredged material for wetland creation is permitted and does occur on occasion, albeit there has not been a policy to routinely explore such project needs. Restoring eroded or lost wetland in an area with a historically or currently identified need remains a priority.

6.2 Useful Tools for Site Evaluation

Commonly adopted approaches to identify a wetland restoration or creation site involve the examination of historical maps (dating as far back as 100-200 years), aerial photos, ground photos, site visits, soil analysis, forensic soil interpretation (to determine the historic conditions), review of site-use permit documents and computer evaluation models. The USACE also uses cost analysis tools to evaluate policy and required processes, in addition to ecological functional assessment models currently in use and under further development. At both the state and federal level, the key question about site evaluation for beneficial use of dredged material pertains to whether the need for a project covers a specific area or region. This is because a wetland restoration or creation project involving dredged material reuse may serve the purposes of habitat creation, restoration, or enhancement, in addition to the establishment of living shorelines for the purpose of erosion control, among others. Thus, defining or prioritizing the expected and longevity of project outcomes for the purposes of optimizing the lasting environmental benefits is necessary, due to the high cost nature of these projects.

6.3 Sea-Level Rise

USFWS notes that sea-level rise has brought frequent occurrence of ponding water on tidal marshes to cause marsh degradation. In practice, USACE (Region 1), applies *ER 1100-2-8162*, "*Incorporating Sea Level Changes in Civil Works Programs*" under the *Corps Planning Program* – to assess the effects of sea level rise on project alternatives – including consideration for the effects of historic, medium and high sea-level rise scenarios. In addition, under the directives of the *Preparedness and Resilience Policy Statement* and *ER 1110-2-8160* "*Policy for Referencing Project Elevation Grades to Nationwide Vertical Datums*," USACE also utilizes tools such as the USACE sea-level rise calculator to analyze the outcomes of regulatory permit decisions.

NOAA NMFS (Marine Fisheries Service and Restoration Center) typically evaluates the impact of sea-level rise on tidal wetlands creation and restoration projects when considering relevant project proposals. In particular, the *2007 Restoration Planning Document*, developed by NOAA NMFS, plans for the scenarios of sea-level rise 50 years into the future. As the speed of sea-level rise has hastened, estimating the elevation height for restoration sites to prevent the conversion of low marsh into mudflats has become a challenge. If sites are built at too high of an elevation, then invasive *Phragmites* may grow on the restored site, and if they are too low, then they are vulnerable to sea-level rise. USEPA Region 1 considers the creation of low marsh more beneficial for preserving fish habitat, more efficient at tidal exchanges, and for nutrient-load maintenance. USEPA is also concerned with the challenge of balancing marsh restoration levels to be resilient to sea-level rise while not allowing for conditions that would increase *Phragmites* infestation. USEPA Region 2 maintains that it is necessary to balance the current site restoration height against the projected site conditions, due to future sea-level rise.

From the perspective of project planning and implementation, federal and state agencies may have slightly different views and strategies, due to the former's responsibility in broad-scope policy making and the latter's policy adaptation to create local site-specific outcomes. For example, CTDEEP generally develops shoreline protection plans by considering a three-foot sea-level rise in 100 years, even though no specific standard is applied for sea-level rise adaption in wetland restoration or creation projects. CTDEEP encourages high marsh elevations in wetland restoration or creation projects to increase wetland resilience – and adaptation to sea-level rise – which may transform high marsh to low marsh over time. The application of thin-layer deposition for adaptation to longer-term resilience is also preferred. For the NJDEP, the degree of accretion is used to determine restoration elevations. With consensus among state and federal agencies and the science community, RI CRMC identifies sea-level rise as the main driver of marsh loss and a key factor in planning shoreline and wetland projects that aim to prepare for or mitigate the impacts of climate change.

6.4 Wetland Restoration or Creation for Flood and Erosion Control

According to USACE Region 2, Section 1184 of the *2016 Water Infrastructure for Improvements to the Nation Act* requires that nature-based features and projects be considered for flood and erosion control. However, no tools have been developed to evaluate flood and erosion control measures to enforce this law. USACE Region 1 also indicates that its *Civil Works Policy* permits the use of dredge material for hurricane and storm damage reduction projects. Likewise, while the NOAA NMFS considers living shorelines as measures for flood and erosion control, it does not identify wetland restoration in the same way. Instead, wetland restoration is evaluated for degradation and restoration design features to prevent future marsh loss. For wetland creation projects, however, flood and erosion control benefits are the focus for evaluation. NOAA NMFS does not have a specific policy on implementing flood or erosion control through wetland restoration or creation. It nonetheless recommends that developing wetlands in a wide area – which extends to miles in width (e.g., projects in New Jersey and the Gulf of Mexico) – may present a good opportunity for deriving flood control benefits. NOAA NMFS also suggests that care needs to be taken when converting upland to a wetland, as inappropriate elevations can help create marshes with invasive *Phragmite*s.

USFWS points out that Rhode Island has limited opportunities for marsh migration, due to the challenges created by location of roads, houses, private property, and the like. Hence, increasing marsh elevations has been permitted to protect these structures and land-mass to achieve flood and erosion control objectives. Per USEPA (Region 2), flood and erosion control benefits can be considered as part of a wetland restoration project. In particular, dredged material can be used to construct levees; for example, Louisiana and Gulf restoration projects are driven by flood and erosion control and storm surge. USEPA (Region 1) also indicates that flood control and erosion benefits can complicate projects aimed at addressing the impact of sea-level rise, as these projects may not adopt mitigation strategies that derive beneficial use of wetlands. Again, no dedicated policy for guiding the creation or restoration of wetlands primarily for flood or erosion control goals exists. There are, however, policies that favor the use of coir logs and biodegradable materials – over hard structures such as rocks or stones – to prevent the erosion of dredged material used in wetland projects.

At the state level, CTDEEP considers flood and erosion control benefits as inherent to wetland restoration projects. For the purposes of creating Living Shorelines, wetland restoration or creation projects may include flood or erosion control goals. According to "Connecticut Statute *22a-109c*, "*shoreline flood and erosion control structure*" means "*any structure or effect of which is to control flooding or erosion from tidal, coastal or navigable waters*." Connecticut Statute *22a-92(c) (2)(e)* further states, "*reasonable mitigation measures and techniques*" can include "*upland migration of on-site tidal wetlands, replenishment of the littoral system and public beaches with suitable sediment at a frequency and rate equivalent to the sediment removed from the site as a result of the proposed structural solution*." For Connecticut, the permitting is different for the stand-alone wetland creation/restoration projects and the more complex living shoreline projects. Similarly, the RI CRMC explicitly identifies wetland projects with having flood and erosion control benefits, per the discussion of functions and values of shoreline features within its regulatory programs. Rhode Island's policy on shoreline protection generally favors non-structural approaches without specifically referring to wetlands or living shorelines. Currently, Rhode Island is working on refining the relevant policy language.

6.5 Stakeholder Engagement

Stakeholder engagement activities appear to differ in their approach and substance across the various projects discussed herein, which have yielded varying degrees of success or failure. For example, lack of communication led to a failure in collaboration between the Town, state government and funding agencies for the Rumney Marsh project. According to USEPA (Region 1), this project received its permit in 1996 – for the purposes of restoring a freshwater *Phragmites*-dominated marsh back into a salt marsh – was funded by USEPA, USFWS and NRCS. When construction of the project began, the Town cancelled the project, due to an unsuccessful partnership between the local, state and federal parties involved. This project later was undertaken at the State level, targeting a set of outcomes different from the approved plan. USEPA (Region 2) also observes that when seeking public support, wetland creation projects are much more complex than wetland restoration projects.

Another example of failed stakeholder engagement can be illustrated by the Brownhill Salt Marsh project, which involved removing upland to create a salt marsh and filling in the frequently migrating inlet of the marsh area. According to the NOAA Restoration Center, the project is not yet executed due to a lack of public support, even though the feasibility study was completed in 2009. Despite repeated attempts to inform and educate the property owners, the public believes that the proposed plan may adversely affect their property, families, quality of life and recreational opportunities. It should be noted that when involved in stakeholder engagement, NOAA NMFS typically provides technical support, expertise and policy review. The NOAA NMFS and Office for Coastal Management Division both provide engagement programs for local/state stakeholders.

The Ninigret Project in Rhode Island, led by the RI CRMC similarly exemplifies the need for achieving a coherent set of expectations for project implementation across stakeholders, including the Town, the State and relevant federal agencies. This on-going project now focuses on restoring wetlands by reusing dredged material from a breachway channel to slow sediment deposition in the Ninigret Pond (which can also support the adjacent recreational boating activities). Though this project was ultimately successful and brought the Town, the State and local partners together, early communication missteps experienced by all parties concerned helped identified the key lessons learned as follows. Battling climate change skepticism and denial related to sea-level rise is a significant challenge. Hence, constant communication and hosting site visits as well as providing on-site marsh assessment demonstrations is a valuable approach. Face-to-face communication with different stakeholders to enable real-time feedback and interaction is most effective, when coupled with offering the Town the autonomy to make non-technical decisions.

As for the "success" stories, the Jamaica Bay Marsh Islands project may serve as a good example. Specifically, USACE (Region 2) actively engaged the stakeholders about the project prior to the development of the *Comprehensive Habitat Restoration Plan* in 2009 – to address concerns and skepticism about potential contamination in the dredged materials – used for wetland creation with new or unproven methods. As the public prefers 100% clean sediment in wetland projects, honesty and openness in communicating about sediment evaluation and data sharing is key to successful stakeholder engagement. Another lesson learned by USACE (Region 1) suggests that initial responses from the relevant stakeholders on wetland creation and restoration activities tend to be tepid. Hence, follow-up outreach that provides continuing education about the beneficial project goals is essential.

These lessons were also observed by USFWS, when it was invited to present a wetland restoration project by the Narrow River Preservation Association – which also organized volunteers for the planting project on the restoration sites – along with Save the Bay and other non-profit groups. While The Nature Conservancy also held community-based talks and restoration-site tours, University of Rhode Island bused pupils to the site for science education via its *SMILE* program. CTDEEP took up a local-interest driven project through connecting with the local legislators, when a dam went under water and sandy shoals were exposed during low tides in the Town of Darien. Through holding night meetings in the community to maximize participation of all stakeholders in the mitigation project, the project became a success. The NJDEP experience with stakeholder engagement likewise suggests that early and frequent outreach tend to achieve greater community support.

Taken together, successful stakeholder engagement entails developing and implementing a coordinated communication strategy between collaborators and advocates across the local, state and/or federal constituents. This strategy should allay the misapprehensions, concerns and fears – as well as share the cost-benefit analyses – associated with the proposed project at the individual and community level. Frequent and candid communication can facilitate direct feedback and interaction between all stakeholders to help build good will, trust and support.

7 A Public Health Perspective

This section looks at public health considerations associated with projects designed to create or restore coastal lands' ability to capture and hold water using dredged materials, including expanded discussions on *Coastal Resilience and Wave Attenuation* (Section 7.2) and *Surface Runoff and Drainage* (Section 7.3). Over the last decade, communities in the United States experienced severe storm events that brought significant flooding, some with record breaking amounts of water and some with storm surges that moved water to farther inland locations and higher up in buildings (Blake and Zelinsky, 2018; NOAA, 2016; NOAA, 2018). Actions that would make the coast more resilient to storm events, such as increasing marsh capacity and/or building islands, have clear benefit in reducing consequences from future storms. The ecological benefit from the increased ability of salt marsh to hold water and buffer physical impacts is straightforward (Elmer et al., 2013) and is further discussed in Sections 7.2 (*Coastal Resilience and Wave Attenuation*) and 7.3 (*Surface Runoff and Drainage*). However, the outcomes to communities of well-intended environmental improvements, including those that build resilient coasts, are complicated. The solution to public health threats that arise from the hazards of these storms [immediate safety concerns; disease from exposures to contaminated water; injuries and illness associated with infrastructure breaches (including power loss); and the health and economic impacts from short and long term displacement (Lane et al., 2013; USGCRP, 2016)] is multi- dimensional. Bringing a public health point-of-view to the discussion early on in the planning process for coastal improvements gives voice to the community and can serve to identify broader considerations that are easily overlooked (IOM, 2015). This perspective may identify and even support companion activities that will prevent illnesses (or the risk of illness) both in individuals and communities, an underpinning of public health science.

What do we mean by "public health" in the context of this project? The World Health Organization (WHO) has a broad statement on public health that sets prevention of illness as a major underpinning of "the art and science of preventing disease, prolonging life and promoting health through the organized efforts of society" (Acheson, 1988). The current dictionary definition speaks more to the means of achieving that goal and introduces community engagement- "*the art and science dealing with the protection and improvement of community health by organized community effort and including preventive medicine and sanitary and social science*" (Merriam Webster, 2018). With a focus on coastal engineering to build marshes and/or islands, it is also helpful to look at an expanded definition that defines place. The Centers for Disease Control and Prevention introduces that place matters- "*Public health is the science of protecting and improving the health of people and their communities. [...] as small as a local neighborhood, or as big as an entire country or region of the world*" (CDC Foundation, 2018). Considering these definitions, public health and community welfare are common-sense factors to consider in planning environmental improvements such as creating coastal structures with dredged materials.

Another, not insignificant viewpoint on the strength of integrating public health considerations into coastal recovery lies in the possibility that successful ecological improvements can contribute to reducing health disparities. The Intergovernmental Panel on Climate Change (IPCC) in its 2012 report, "*Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation,*" points out that adaptive measures can address some of the needs in groups with health vulnerabilities. The authors note that current development and post-disaster recovery efforts often overlook "*local development visions*" that would serve to reduce social inequity (IPCC, 2012). Involving the community that is most directly affected by disasters such as severe floods has potential to improve the health and economic status and achieve an "*optimally health community*" (IOM, 2015).

A public health viewpoint is a critical element in the broadest sense to truly rebuild the coast with resiliency. This means taking actions, that (1) support health and well-being in the community and

(2) reduce the risks to workers involved in construction and future response, when restoring and creating marshes and islands to ensure the physical resiliency of coasts.

7.1 Public Health in Current Coastal Planning Approaches.

A number of federal agency programs and reports focus on threats to coastline resources and some discuss the use of reclaimed dredged materials in re-building coastal integrity. Interested agencies include the US Fish and Wildlife Service, the US Environmental Protection Agency (EPA), the Federal Emergency Management Agency (FEMA), and the US Army Corps of Engineers (USACE). These oversight initiatives identify public health benefits and discuss methods for incorporating a public health perspective.

For example, the USACE " *Final Programmatic Environmental Impact Statement for Long Island Sound Connecticut, New York and Rhode Island and Dredged Material Management Plan*" (USACE, 2015) discusses many topics-from toxicity testing and limitations on the appropriate use of dredged materials to the involvement of community members in overall decision-making. The Fish and Wildlife Service's "*Status and Trends of Wetlands in the Long Island Sound Area 130-Year Assessment*" raises ecological and human health concern over the historical loss of marsh lands when discussing utility of flood protection, carbon sequestration, and other actions that promote overall resilience. The report calls for public engagement to address "loss of ecosystem services which has social and economic implications for people" (Basso et al., 2015). The USEPA and USACE report, "*Identifying, Planning, and Financing Beneficial Use Projects Using Dredged Material: Beneficial Use Planning Manual*" (USEPA and USACE, 2007b) states that involvement of stakeholders improves the "quality of decisions" and provides a corollary fact sheet with a How- To-Involve guidance (USEPA and USACE, 2007a). Much earlier on, the USEPA published guidance on principles of wetland restoration that, while primarily focused on establishing a list of technical issues to consider, directed wetland restoration initiatives to utilize community perspectives and values in restoration design so to support positive societal change (USEPA, 2000). The online and more recently authored FEMA Recovery Management Toolkit includes engagement and planning guidance to address specific public health concerns - housing, medical care, water and air quality/safety (FEMA, 2017a). This toolkit provides links to a wide range of resources including the Health Resources and Services Administration, an agency of the US Department of Health and Human Services charged with establishing programs to improve health care and delivery (FEMA, 2017a).

While the primary focus of these federal reports and guidance materials is on environmental improvement and ecological impact, they all, as noted above, touch on human health impacts from proposed actions, and some suggest steps to bring about community involvement. But in many planning efforts, public health and human welfare considerations are brought in, if at all, as secondary topics, often addressed independently of the proposed action, late in the process. A review of the planning effort for salt marsh restoration in Rhode Island after Hurricane Sandy (Wigand et al., 2017) and of a survey of community priorities around dredged material use in Long Island Sound (Collier et al., 2014) provide insights into additional benefits accrued when community public health is considered early in planning activities.

Wigand's Rhode Island example discussed facilitation and involvement of an array of stakeholders in planning activities designed to sustain the ecology of the coast and identified the advantage this effort had to secure needed approvals (Wigand et al., 2017). While stakeholder input to decision-making was stressed in this example, the opportunity to look at public health values was left unfulfilled. An argument based on housing pressure in the populated study area was used to establish the need for flood abatement, but consideration of mitigating housing needs and/or other health or social impacts was largely missing in the development of the plan. In contrast a collaborative decision-making model presented around dredged material use for Long Island Sound included not only consideration of environmental change and ecological impact, but also human welfare and economics (Collier et al. 2014). The process described in the model employs participatory research methods and takes into account human welfare criteria. By exploring priorities among a broad set of stakeholders, economic considerations emerged as a common priority for participants to rally around in the plan. In this way, the planning effort, that integrated health, social and economic considerations with other project factors, became the mesh that linked individual viewpoints. This approach could have utility for other coast rebuilding efforts.

7.1.1 Public health opportunities and threats from using dredged materials.

Dredging is a requirement of marine commerce. Using dredged materials to rebuild coastal structures provides an attractive way to dispose of the material. Coastal improvements also have additional attributes. The community benefits from flood protection and potential economic development (for more details, see Section 7.2, *Coastal Resilience and Wave Attenuation*), and individuals may benefit from enhanced recreation (USEPA and USACE, 2007c), as discussed further in Section 7.5, *Benefits & Public Health – Recreational Value of Marshes*. The wetlands and/or coastal islands created become habitats with ecological value (see Section 2.1, *Marsh Ecosystem Services*, and the associated appendix, ***Appendix A – Ecosystem Services of Tidal Marshes***). Poplar Island in Chesapeake Bay is one example where dredged materials were used in its restoration, and the re-constructed resource brought significant ecological and social value. Almost gone in 1990, Poplar Island today has secure wetlands and is a vibrant marine habitat for a variety of birds, and other animal and vegetation species. The restoration has become a valued historical resource to Maryland. In other cases where dredged materials were used to develop brownfields, economic development had been fostered. (Great Lakes Commission, 2010).

However, some components of dredged materials/ocean sediments may pose risk to the health and well-being of those who come in contact. For example, beachgoers complained about sediment odors, and skin, eye and respiratory irritation associated with dredged materials that were used to reconstruct beach dunes on the New Jersey coast after Hurricane Sandy (Plumlee et al., 2016). This illustrates why it is important in planning to consider how the coastal structure, whether marsh, dune, island or something else, would be used and what exposures would likely be associated with people using the resource. Because contaminants may move into water, air and land, human exposure assessment goes beyond the immediate use. Contaminants, even in treated sediments, may include significant levels of heavy metals - arsenic, lead, cadmium and others - and a variety of polycyclic aromatic hydrocarbons. Health risk assessment would explore toxicity and exposure potential, and help determine appropriate use of specific dredged materials (Perrodin et al., 2014).

There are other risks. Coastal development, especially marsh and wetland construction, provides habitat for an array of animal life including insects, some of which can be vectors for human disease. Vectors such as ticks and mosquitoes are a means for transmitting illness to humans, both by introducing the disease agent directly from an animal carrier, and/or by transmitting infection from one human to another. Successful vector management requires habitat management strategies and maintenance of wetlands (Little, 2013). The proper wetland design and maintenance plan minimizes threats. Consequently, habitat management strategies that recognize the health threat from vectors are important considerations in wetland and island design to improve coastal integrity. In addition, overall approaches to vector control can anticipate community concerns over pesticide use that may arise. More details on this topic are provided in Section 7.4, *Mosquitoes and Other Perceived Pests*.

7.1.2 The public health opportunity

Resources will continue to be marshalled to mitigate severe weather's impact. When coastlines are sustained and protected against severe weather, there is less threat to housing from flooding. By mitigating the impact from storm severity, interruptions to medical care access and damage to infrastructure would likely be reduced and benefits would accrue from less disruption to power and fewer contamination events from failed sewer systems (see Section 7.2 *Coastal Resilience and Wave Attenuation*). Recreational opportunities for individuals from increased access and new structures on the coast contribute to physical and mental health improvement (see Section 7.5, *Benefits & Public Health – Recreational Value of Marshes*). All of this is important, but the potential to improve public health and welfare is profoundly broader. Initiatives to rebuild coastal structures could foster healthier, more resilient communities, beyond improving the integrity of coastal structures.

To improve public health, communities can transform in a host of ways. The Institute of Medicine (IOM) convened an expert committee to explore the process for preparing and responding to disasters with an eye to utilizing the resources to "*advance the long-term health, resilience, and sustainability of a community and its residents. Pursuit of this under realized social goal begins with a vision of a healthy, resilient, and sustainable community and requires a recovery approach that incorporates health considerations into every step of the planning process, informed by an assessment of community health and vulnerability*" (IOM, 2015). While the IOM report acknowledges that current rebuilding efforts designed to maintain critical infrastructure add important resiliency, the report goes further and advocates for community engagement to enhance overall health and welfare. The panel suggests that recovery resources from FEMA and other public and private sources can be utilized in ways that raise population health status. The report defines a process around four stages- "*visioning, assessment, planning and implementation*", to use in both pre- and post- disaster planning. The community roles detailed in the IOM document are: to make decisions around resources and priorities that acknowledge health and welfare opportunities, to identify workforce opportunities, to disseminate information, and (importantly) to develop community health assessments. The second part of the IOM report is a manual for a "*health improvement plan."* The report details criteria and methods on how to integrate a range of health and welfare topics (public health, health care, behavioral health, social services, place-based recovery, and healthy housing) into post disaster actions fostering community recovery.

7.1.3 Conclusion and criteria/checklist

Severe weather challenges coasts and wetlands. Using dredged materials to improve coastal integrity is environmentally sound and part of a response to rebuilding coastal structures after severe weather. Federal policies and other technical materials provide guidance to determine and minimize health risks from exposure to harmful constituents of the dredged material, and from vector populations that may result from new habitats (see Section 7.4, *Mosquitoes and Other Perceived Pests*). Stakeholder involvement is an important element to the success of these projects, encouraged and required for both planning and implementation phases (USEPA and USACE, 2007b; Collier et al., 2014; IOM, 2015). The Federal Emergency Management Agency's guidance materials for state and local governments in preparing for disasters emphasize robust community engagement (FEMA, 2014, 2016, 2017).

Recognizing and incorporating health considerations into plans and actions have far-reaching benefits for the community's future welfare. The Institute of Medicine (IOM) guidance document, "*Healthy, Resilient, and Sustainable Communities after Disasters: Strategies, Opportunities, and Planning for Recovery*", recommends a framework with an emphasis on "co-benefits" and community involvement (IOM, 2015). Many actions can be implemented to realize the community engagement envisioned by the IOM panel.

This section concludes with a brief list of suggested actions to consider when planning for, building and implementing environmental-focused improvements to coasts, including some adapted from the IOM (2015) report. Attention to the items on this list will leverage resources to support public health while fulfilling project goals:

a. Engage a wide array of stakeholders and community members in "healthy community visioning" to identify concerns and opportunities associated with proposed action
b. Employ openness/ transparency in information gathering and reporting
c. Assess health and exposure risks
d. Integrate public health impacts into planning decisions
e. Include habitat management and vector control over the long term in maintenance plans for the coastal structures
f. Incorporate place-based strategies for the impacted community that are intentionally designed to support public health and welfare such has:

i. A multi-faceted team with members from the affected communities in all planning efforts to address housing, community development, environmental management, occupational safety and public health
ii. Healthy housing improvement
iii. Infrastructure development to active life styles – trails, bike paths, sidewalks, parks
iv. Improved access to “critical goods (healthy food), community services (medical care) and amenities (libraries, schools, recreational/physical fitness facilities)”.
v. Employment expansion for the community
vi. Health recovery actions
vii. Occupational health and safety training as needed for workers
viii. Systematically monitoring health indicators in the community during and after construction

7.2 Coastal Resilience and Wave Attenuation

Tidal salt marshes, whether natural or restored, can provide critical protection to coastal communities by substantially attenuating wave heights and therefore wave energy, reducing storm surge levels and durations, and mitigating coastal erosion (Bridges et al., 2015; Gedan et al., 2011; Shepard et al., 2011, 2012; Sutton-Grier et al., 2015). Although there is increasing understanding of the performance of the ecosystems services and coastal protection provided by salt marshes, the number of factors affecting their performance, as well as the variation within each factor, has hindered our ability to predict the success of a living shoreline for a particular location based on its performance at different locations (Bridges et al., 2015). Additionally, the effect of vegetation on surge elevations and wave height has only be studied in low energy conditions, thus the feasibility of relying on tidal marshes to provide coastal protection during storm conditions is not well-understood (Anderson et al., 2011; NRC, 2014). More in depth information can be found in ***Appendix G – Coastal Resilience and Wave Attenuation***.

7.2.1 Wave Attenuation

Tidal marsh restoration and creation have been shown to mitigate coastal erosion in low wave energy conditions. Marsh vegetation extensive root systems help to maintain the existing soil, thus reducing sediment transport while plant stems attenuate wave energy (CCRM, 2010). The ability of marsh vegetation to attenuate wave energy has been well-documented in field and laboratory studies using real and artificial vegetation (e.g., Knutson et al. 1982; Kobayashi et al., 1993; NRC, 2014; Tschirky et al., 2000). The majority of these studies have been performed in small to medium wave heights; presumably since salt marshes are most likely to be exposed to low wave heights conditions (Shepard et al., 2011).

Most wave attenuation has been shown to occur in the first few meters of the seaward edge of a marsh, for gradual and abrupt marsh edges (Shepard et al., 2011). Knutson et al. (1982) observed in their study of wave dampening in two tidal marshes of closely packed, tall stems of cordgrass (*Spartina alterniflora*) that on average more than 50% of small amplitude wave energy (wave heights of 0.15 - 0.18 m) was dissipated in the first 2.5 m of marsh, and 100% was dissipated in 30 m. Other researchers (Brampton, 1992; Möller and Spencer, 2002) found similar results through physical modeling and field testing. Therefore, it is misleading to calculate the average rate of attenuation across the marsh width (Gedan et al., 2011) since it has been shown that over 40% of incoming wave energy is dissipated with in the first

10 m of the marsh seaward edge. Thus, even a narrow fringe marsh is effective in attenuating wave energy (Gedan et al., 2011; Möller and Spencer, 2002,). However, at high wave energy sites, an abrupt edge reduces the wave heights, but leads to near continuous erosion of the marsh face, which is obviously an unsustainable condition that will cause narrowing of the marsh width over time (Möller and Spencer, 2002). Marsh edge protection, in addition to containing placed material on restored wetlands can provide protection against erosive wave action on marsh edges.

The ability of vegetation to attenuate wave energy is affected by vegetation characteristics (e.g. stem height, stiffness, buoyancy and density, marsh width [Möller, 2006; Sheng et al., 2012; Shepard et al., 2011]), and wave conditions (e.g., incident wave height, period and direction), as well as water depth and tidal amplitude (Augustin et al., 2009). In addition, many vegetation characteristics are modified with wave action (e.g., stems bend, relative stem height, orientation [Anderson et al., 2011]) and through seasonal and spatial variations in vegetation height, foliage and coverage (Möller and Spencer, 2002). Although understanding of the effectiveness of marsh plants to attenuate wave heights is critical in evaluating their ability to provide coastal protection, the variety of tidal marsh plants and the complexity in quantifying vegetative characteristics in the field makes it difficult to determine the effect of marsh vegetation on wave attenuation (Bradley and Houser, 2009; Mendez and Losada, 2004; Möller and Spencer, 2002; Tschirky et al., 2000). Despite these complexities, it is generally accepted that wave attenuation is increased with marsh width, stem density, and decreased water depth (Anderson et al., 2011). However, no clear correlation of wave attenuation with wave height has been determined. The relationship between wave attenuation and wave period also remains poorly understood.

The composition of salt marsh vegetation varies widely due to spatial and temporal changes, competition between, as well as competition between individual plants of the same and different species. Salt marshes may be composed primarily of one species (e.g. invasive phragmites) or a more diverse community of vegetation. Given the complexities of evaluating wave attenuation through one species of marsh vegetation, it is unsurprising that there have been few studies evaluating diverse marsh communities. Nor are numerical models similar to those for evaluating the performance of hard structures for coastal defense available for predicting the performance of marsh vegetation (Arkema et al., 2013; NRC, 2014). Yet evaluation of the effect of marsh vegetation at reducing wave height is critical for predicting the performance of vegetation for shoreline protection (Anderson et al., 2011).

7.2.2 Shoreline Stabilization

Numerous studies have discussed the ability of marsh vegetation to stabilize shorelines by reducing sediment transport, increasing marsh elevation and producing biomass (NRC, 2014). As with attenuation in marshes, the capability of marsh vegetation to trap sediment is dependent on a number of factors: sediment supply, tidal range (which governs the duration of inundation), marsh elevation, and vegetation characteristics such as density, height and biomass production (Shepard et al., 2011). Processes that help maintain or increase marsh surface elevation such as sediment deposition and root production affect marsh surface elevation and contribute to shoreline stability (Shepard et al., 2011). Gedan et al. (2011) in concluded that coastal vegetation protects shorelines from erosion and wave damage by reducing flow velocities and increasing sediment deposition and soil cohesion.

7.2.3 Storms: Surge and Waves

The effectiveness of tidal wetlands to provide coastal protection during storms is of particular importance yet their performance capabilities during storm conditions are poorly understood (Gittman et al., 2014; Pinsky et al., 2013). Extreme weather events (such as Hurricanes Irene and Sandy) and projected sea level rise has led to increased interest in the vegetation to attenuate coastal flooding and wave action. It has long been accepted that salt marshes have the potential to slow and absorb flooding from storm surges by reducing flood peaks and durations through storage and drainage of flood waters, however, their effectiveness is difficult to determine (Augustin et al., 2009; Shepard et al., 2011; Wamsley et al., 2010). Studying the effect of Hurricane Irene on shore erosion in North Carolina, Gittman et al. (2014) determined that although vegetation density was reduced by the hurricane, marshes had recovered to pre-storm conditions. They concluded marshes, with and without sills, are more durable and provide better protection from storm-induced erosion in Category 1 hurricane conditions as compared to bulkheads. Möller et al. (2014) found that 60% of the wave attenuation during storm events is due to vegetation and that even when waves were sufficiently large to damage plant stems, the vegetation prevented soil erosion (Sutton-Grier et al., 2015).

Marsh characteristics, variations in coastal geology, bathymetry and exposure, and storm specific parameters such as duration, intensity, size and track all affect the attenuation of waves and flooding (Gedan et al., 2011; Resio and Westerink, 2008; Sheng et al., 2012). After 50 years of study, we still do not understand storm surge and wave attenuation in tidal wetlands well enough to develop models suitable for coastal planning of marsh protective services (Shepard et al., 2011). The limited observations reported in the literature are insufficient to evaluate the importance of different types and composition of marsh vegetation, and storm and site characterizes on the drag coefficient and Reynolds stresses (Sheng et al., 2012).

The ability of vegetation to attenuate short-period waves has been studied through field and laboratory experiments (NRC, 2014); however, the effects of longer period storm waves may not scale linearly and so the observations from short-period waves are not necessarily applicable (Feagin et al., 2010). Longer period storm waves increase the water level over a longer period of time and with greater force on the vegetation than short waves. Thus the plants are more likely to bend with the flow, reducing the drag coefficient and wave attenuation (Bradley and Houser, 2009; Pinsky et al., 2013). The decrease in drag coefficient in turbulent flows is critical because storm conditions are highly turbulent. Failure to account for this can over-estimate wave attenuation in storms by approximately 20 – 1600%, thus to protect coastal communities, marshes may need to be larger than thought previously (Pinsky et al., 2013).

One of the difficulties in assessing the effectiveness of living shorelines for storm protection is the variability in storm characteristics. Vegetation is more effective protection during fast moving storms. In slow moving storms, surge will have more time to increase, sometimes building over through multiple tidal cycles as in Hurricane Sandy (Sutton-Grier et al., 2015). Waves are attenuated more in emergent vegetation where the height of the plant exceeds the water depth than in conditions where the top of the plant is submerged and thus does not affect the top of the water column where wave orbital velocities are greatest (Anderson et al., 2011). Additionally, the increased water depth from storm surge will cause waves to break further inland, causing an abrupt marsh edge to move landward (Feagin et al., 2009).

Despite the complexity of storm effects on storm surge and wave attenuation, field and modeling observations show that salt marshes can provide shoreline protection during storms (Möller et al., 2014; Shepard et al., 2011;). During and immediately following a storm, marshes may experience a decrease in plant density and marsh elevation, but as the marsh recovers from the storm deposition of suspended sediments can increase marsh elevation (Shepard et al., 2011).

7.2.4 Sea Level Rise

Coastal communities are becoming increasingly interested in the capability of tidal wetlands and living shorelines approaches to provide natural protection from sea level rise (SLR). Natural salt marshes exist in low lying areas that will be the first to experience the effects of SLR, yet salt marsh migration is limited by coastal development so researchers have investigated the ability of salt marshes to maintain their surface elevation relative to sea level rise (Morris et al., 2002; Shepard et al., 2011). The long term stability of a marsh is dependent upon the sea level, primary plant production and sediment accumulation which regulate the marsh elevation relative to mean sea level (Morris et al., 2002). Natural marshes exposed to large variations in tidal range and marshes with high sediment concentrations will be best able to adapt to large increases in SLR (Kirwan et al., 2010; Morris et al., 2002;). Morris et al. (2002) developed a model that suggests a marsh ecosystem will be stable against sea level rise when the marsh elevation exceeds the optimal level for primary production and unstable when the marsh elevation is less than optimal. The optimal range varies regionally, dependent upon tidal range, vegetation, salinity, nutrient loading, and climate (Morris et al., 2002). Beneficial use of dredged material is an opportunity to increase the marsh elevation to increase its stability in response to sea level rise.

Further details on the effects of wetlands vegetation on wave attenuation and storm surge is provided in ***Appendix G – Coastal Resilience and Wave Attenuation.***

7.3 Surface Runoff and Drainage

One of the ecosystem services often attributed to wetlands is their ability to regulate or modulate the hydrologic cycle, reducing the impact of flooding by storing water and providing water to aquifers in times of drought (Millenium Ecosystem Assessment, 2005). In an urban setting, wetlands have the potential to store or convey surface runoff. In addition to acting as a sponge to excess quantities of water, marshes also act as a filter, removing some of the nutrients and toxins carried in surface runoff before it reaches coastal waters (Craft, 2016b). The question pertinent to this report is, how much of a service will a coastal wetland provide to an urban landscape in Connecticut, in terms of surface runoff and drainage management?

Much is known about the impact of inland (freshwater) wetlands on the hydrologic cycle. In short, floodplain wetlands and headwater wetlands are known to impact flood water in different ways (Bullock and Acreman, 2003 - review of 169 studies conducted between 1930 and 2002). Floodplain wetlands reduce the impact of larger quantities of water during floods by absorbing water, acting as a sponge. In contrast, headwater wetlands, those located at the source of a river, serve to increase river flow during flood events and decrease river flow during drought; headwater wetlands are typically fully saturated, thus any additional rain entering the wetland is rapidly transmitted to the river.

Many papers, reports, and books acknowledge the benefits of marshes for flood protection, though we know relatively little about the ***capacity*** of coastal (saltwater) wetlands to absorb excess water. For coastal marshes, excess water may originate from either storm surge that has overtopped shoreline protections (natural or man-made) to reach inland areas or flooding due to surface runoff and rising river levels. A comprehensive literature review evaluating the impact of salt marshes on floodwater attenuation identified four studies which evaluated the effect of salt marshes on flooding (Shepard, et al., 2011). These four studies consistently noted that natural salt marshes drain floodwater more efficiently than altered salt marshes (As reviewed by Shepard, et al., 2011: Bolduc and, Afton, 2004; Brody, et al., 2007; Meeder, 1987; Swenson and Turner, 1987). The marshes absorb water and efficiently move water in a sheet flow towards the ocean (Shepard, et al., 2011). While we cannot identify the capacity of marshes, evidence indicates coastal marshes contribute to the removal of excess water generated during storm events (Craft, 2016; Millenium Ecosystem Assessment, 2005; Shepard, et al., 2011).

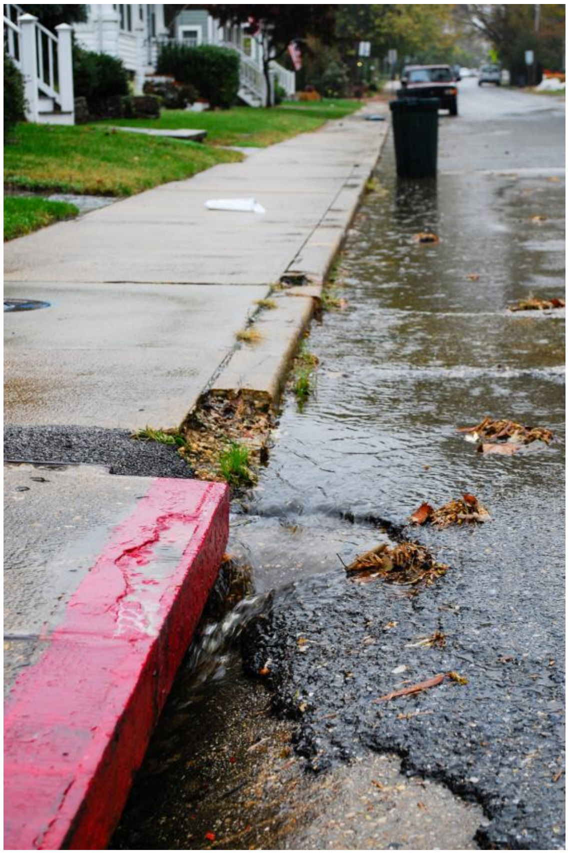


Photo credit: Stormwater Runoff by Chesapeake Bay Program (CC BY-NC 2.0). https://www.flickr.com/photos/29388462@N06/25321487171

Raccoon at Stanley Park by Márcio Cabral de Moura, https://www.flickr.com /photos/ mcdemoura/15315572792, (CC BY-NC-ND 2.0)

Though we cannot easily quantify the capacity of coastal marshes to store excess water in terms of volume or dollar amount saved in damages, overall, an estimated $23.2 billion per year in storm protection is provided by coastal wetlands in the U.S. with a loss of 1 ha of wetlands corresponding to an increase of $33,000 in storm damages (Costanza et al., 2008; Sutton-Grier et al., 2015). As one feature of a hybrid living shoreline including natural and man-made features, coastal marshes contribute to the mitigation of stormwater impacts on local communities (Sutton-Grier et al., 2015; Van den Belt et al., 2013). Inclusion of coastal floodplains as a flood control feature in the green redesign of urban areas such as Bridgeport, CT and New York City points to the growing recognition of these natural features as important contributors to developing a resilient coastal community (WB unabridged and Yale ARCADIS, 2014; Zhao et al., 2014).

7.4 Mosquitoes and Other Perceived Pests

The presence of animals, including mosquitoes with the potential to carry disease, are one aspect of concern for some stakeholders when considering the installation of a living shoreline. Fears over the adverse impacts can be exacerbated by anecdotal evidence and sensationalized stories. While comprehensive research addressing the specific impacts of urban living shorelines on nuisance animal encounters is lacking, the research conducted to date clearly indicates the negative effects are outweighed by the positive impacts of increasing green and blue spaces in an urban setting. The evidence presented in ***Appendix H - Mosquitoes and Other Perceived Pests***, leans towards indicating no notable increase in negative impacts over the preexisting conditions associated with urban wildlife; in other words, the negative interactions people may have with animals (including mosquitoes) in a living shoreline habitat are the same negative interactions they are already having with wildlife in the parks and alleys of their city – the living shoreline should not bring an additional hazard into play. The scientific literature provides a number of reviews of negative impacts of green and blue spaces on urban dwellers, but these interactions are typically in low-latitude and low-income cities, places where extreme poverty results in sanitation issues, making green spaces toxic to residents (Barua et al., 2013; Douglas, 2012). In developed countries and in temperate latitudes, the disservices exist but are greatly offset by the benefits gained by increasing the resident's exposure to a natural environment (Elmqvist et al., 2015; Lyytimäki and, Sipilä, 2009; Lyytimäki et al., 2008; Tzoulas et al., 2007).

7.5 Benefits & Public Health – Recreational Value of Marshes

Traditional recreational uses of living shorelines include activities similar to natural wooded or vegetated parklands with water features,
including:

- running and walking
- birding
- nature observation
- relaxation
- boating and kayaking
- wading
- fishing and crabbing

Installation of walking paths and board walks facilitate access to these natural environments while educational displays increase awareness of the ecosystem services provided by the natural environment

Photo credit: Aquatic Restoration by June Marie (CC BY-SA 2.0).
https://www.flickr.com/photos/jms2/8212879715

and by the installation of living shorelines to communities.

The average value of recreational services provided by natural spaces in urban settings is estimated at $2,684 per acre per year[2] with a range of $905 to $4,462 per acre per year (Elmqvist, et al., 2015). This recent review of the benefits of restoring ecosystem services in urban settings noted a number of additional benefits not accounted for in the monetary estimate, including increased social cohesion and trust provided by a place for people to gather (Elmqvist, et al., 2015; Kaźmierczak, 2013; Maas, et al., 2009), greater human well-being, and a "sharpened sense of place and space," – values the authors collectively identify as a sense of identity (Elmqvist, et al., 2015). As noted by Elmvqvist and colleagues (2015), access to natural spaces has been correlated with greater overall longevity (Takano, et al., 2002), faster recovery from surgeries (Ulrich, 1984), reduced stress (Korpela, Ylén, 2007; White, et al., 2013), improved mental health (Alcock, et al., 2014), and a general self-perception of better health (Maas, et al., 2006; van den Berg, et al., 2010); all of these factors contribute to greater well-being in populations with exposure to beneficial natural environments in urban settings.

8 The Future of Beneficial Use in CT Marshes– What's Possible?

Despite remaining technical challenges of implementing beneficial use (BU) generally, it has promise for the CT coast. The population and built infrastructure density of the CT shoreline is high, and the possibility of allowing shoreline retreat is unrealistic in many locations. There is mixed evidence that CT marshes are retreating landward even in locations where upland slope should allow (e.g., Barn Island). Recognizing these realities further justifies augmenting either local sediment supply, direct application of sediment to existing marshes, or converting suitable areas of subtidal habitat in to intertidal marsh using dredge material.

A total of 36 million cubic yards of sediment suitable for BU is expected to be dredged from CT over the next 30 years (USACE, 2015). Beneficial use evaluation is required for each dredging project whereby, "*…each proposed dredging project will be evaluated to determine whether there are practicable, environmentally preferable alternatives to open-water disposal. … If environmentally preferable, practicable disposal alternatives exist, open-water disposal will not be allowed."* Although several beaches in CT were identified as potential BU recipients in the 2015 DMMP, no existing marshes in CT were identified. The USACE however proposed the development of three new marsh creation sites that were included in cost evaluations in the DMMP.

8.1 New Marsh Creation

Marsh creation lies at the opposite end of the spatial scale from living shorelines. The scope of marsh creation projects can be quite large. They can be implemented as extensions or modifications of

[2] All dollar values have been adjusted to US$2017 using the US Bureau of Labor Statistics CPI Inflation Calculator.

existing coastal landforms as is being done in Barataria, LA, or consist of wholesale engineering of new islands from scratch as is being done in Poplar Island, MD, and Portersville, AL. Site selection and evaluation of wave energy are critically important. Construction methodologies vary depending on whether new construction or additive application is being done. Regardless of the approach, these projects are large undertakings that require significant capital investment. In addition to funding constraints, they are contingent on appropriate bathymetry of the subtidal environment, particularly when constructing islands from scratch. These bathymetric constraints are likely to be significant along the CT shoreline where limited shoals are available as suitable sites. Such shoals also have the potential for possessing significant existing benthic resources that would be replaced by the dredge island and resulting marsh. Marsh island building does however provide a strong option for wave attenuation and creation of important and dwindling marsh habitat. Moreover, and unlike offshore deep water dredge disposal, this approach retains some sediment within the local supply. This is essential for the sustainability of other natural marshes in the vicinity (Clough et al., 2014; Kirwan and Megonigal, 2013; Morris et al., 2002). Recent work from NC suggests that importance of local erosion processes to support marsh accretion (Currin, 2013) This connectivity between marshes and sediment supplied by local erosion/sediment transport, highlights the nuances of building shoreline resilience by using marsh buffers within a broader shoreline protection scheme.

Past examples to build new marsh islands are limited. The potential benefit in terms of shoreline protection and optimizing ecosystem services however is high. The drawbacks however are significant. Cost is large as are the challenges of public buy-in and regulatory approval. More importantly, the approach involves conversion of subtidal habitat into intertidal habitat. In order move these projects further, there has to be room within the regulatory framework to consider the cost/benefits of trading subtidal habitat for intertidal marsh habitat and shoreline protection, and other extant ecological services provided by marshes. Given the pros and cons, and potential benefits, some pilot scale new marsh creations seems warranted in CT, perhaps in the form of extension of existing land forms or backfilling on the lee-side of points of land.

Three potential marsh creation sites were proposed by the USACE in the 2015 LIS They are located in the Norwalk Outer Harbor Islands, West Haven, and Little Narragansett Bay. The Norwalk Outer Harbor Islands would be an enlargement of a confined disposal facility (CDF) site proposed for that location. The other two sites are Sandy Point in Little Narragansett Bay on the Rhode Island/Connecticut border, and Sandy Point in New Haven Harbor at West Haven. Both would involve filling areas in the lee of an existing barrier spit or island to create substrate for salt marsh development. The two Sandy Point sites are shown in Figures 4-15 and 4-16 from the DMMP, with capacities provided in Table 4-13. Any of these three sites would make a suitable pilot or demonstration project for habitat restoration and enhancement in partnership with the USACE. The Aquatic Ecosystem Restoration: Section 206 of the Water Resources Development Act (WRDA) as amended in 1996 authorizes USACE to carry out projects for aquatic ecosystem restoration and protection if the project will improve environmental quality, is in the public interest, and is cost-effective. Feasibility studies are cost-shared 50/50 with the non-Federal sponsor after the first $100,000. The cost of design and implementation of these modifications are shared on a 65 percent Federal and 35 percent non-Federal basis up to $10 million. These proposed marsh creation sites are large enough that they represent a significant addition of marsh habitat in areas where marsh has been lost. Further their scale serves as a carbon, nitrogen, and phosphorous repository that has economic value within carbon and nutrient trading schemes.

There are likely other existing marshes and other sites suitable for marsh creation in CT using dredged sediment. A comprehensive elevation survey of CT marshes would be a key step to identifying existing marshes that are not accreting at a pace on par with sea level rise and could benefit from BU. Similarly, a combined review of nearshore bathymetry, shoreline geomorphology, and wave analysis would be useful for identifying other potential locations suitable for marsh creation. Finally, the science advisory resources available through the LISS Technical Advisory Committee and Citizens Advisory Committee, the CT Academy of Science and Engineering, DEEP, NOAA, and private sector should be leveraged to evaluate feasibility and cost, of alternative sites/uses of dredged sediment for adaptive marsh management.

Table 3. Area and capacity of marsh creation sites proposed in the 2015 LIS DMMP, Table 4-13.

Table 4-13 - Additional Marsh Creation Sites Considered

Site Name	State	Municipality	Area (Acres)	Fill Capacity (CY)
Norwalk Outer Harbor Islands	CT	Norwalk	78	930,000
Sandy Point at Little Narragansett Bay	RI	Westerly	65	500,000
Sandy Point at New Haven Harbor	CT	West Haven	70	1,100,000

Figure 5. Two marsh creation locations proposed in the LIS 2015 DMMP – Figs 4-16, 4-15

8.2 Floating Marshes

Another, shoreline protection option for specific circumstances, although not BU, is floating marsh. These structures represent an alternative small scale approach for limited wave buffering and habitat augmentation. Floating marshes are engineered structures that have natural analogs most notably the 'tremblante' in the Gulf of Mexico, and some freshwater reed communities that occur in numerous settings in the Middle East. These free floating wetlands are anchored to the substrate but roots but are not tightly knitted to an underlying sediment bed. Consequently the vegetative mat is free to undulate with wave action and dampen energy. There is no evidence that these types of marshes were ever present in CT and the possibility of establishing 'naturally occurring floating marshes' along the CT shoreline is doubtful. Engineered versions of floating marshes, however, have been implemented to provide wave buffering and nutrient control in some coastal and lake settings. Some examples include Lake Rotorua NZ, Baltimore, MD Inner Harbor, Puget Sound, and soon to be Jamaica Bay, NY. These systems consist of floating cells that are planted with wetland plants that are flexibly linked together and anchored to the bottom. Because they do not rest on the bottom, there is minimized impact to the benthic ecological resources, provided there is no eelgrass to be shaded, and thus likely avoid some of the regulatory hurdles associated with conversion of subtidal habitat to marsh habitat.

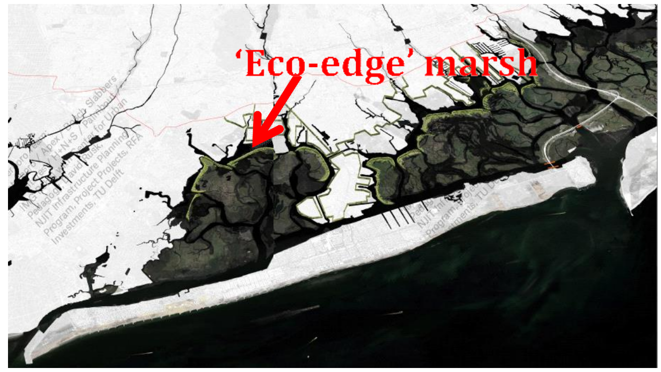
Floating wetlands supply ecological services such as habitat for bird species, as well as nutrient removal through plant uptake. They can be particularly useful in urban settings for improving water quality. Because they do not inundate regularly, as do intertidal marshes, the ecological benefits to fin and shellfish is unclear, although the seasonal export of plant biomass would be expected to help to fuel local foodwebs. These systems efficiently dissipate wave energy from low amplitude short period waves typically generated from wind over relatively small fetches. Therefore their use in partially sheltered environments is most appropriate. In these settings they provide a good barrier to slow moderate but persistent erosion. One such example is Lake Rotorua, NZ where floating marsh cells were installed along an erosive shoreline as a means to stem shoreline retreat adjacent to important cultural resources. This shoreline is positioned downwind of a 5km fetch and regularly receives in 1-2 ft waves. Installation occurred in 2014 and the floating marsh is presently considered mature and heavily used by several bird species. The efficacy of floating marshes for wave dampening and their structural sustainability in larger storm driven waves remains uncertain. They are not recommended for high wave, high erosion areas. Additionally periodic maintenance of anchoring systems should occur. Even when they are placed in appropriate areas of low to moderate wave energy, infrequent high wave events associated with tropical or extra-tropical (Nor'easters) storms have the potential to dislodge these structures and create potential hazards to navigation or nearby infrastructure. The level of risk for this occurring is not known. Floating wetlands are soon to be deployed as part of the ongoing Jamaica Bay marsh restoration project. Their performance in this more challenging setting will be assessed over the next few years. Nevertheless, these types of systems constitute another tool in the toolbox to provide some shoreline resilience. Because they are floating, they do not need to 'keep pace with sea level rise' as do natural, constructed marshes, or marshes that have been purposely augmented with sediment (i.e. TLP). In CT, deployment of floating marshes might be best considered on small scales. Such settings might include proximity to town docks, boat ramps, marinas, or adjacent to shoreline natural (parks) or cultural resources.

Figure 6. Generalized floating marsh schematic and deployment of interconnected marsh cells in Kauri Park, NZ.

Marsh Restoration and Enhancement as a Wave and Storm Surge Barrier

Living with the Bay – Coastal Marsh Restoration
A Rebuild by Design Competition Project

Interboro Team, 2014



The in-bay “eco-edge” meant to protect against storm surge and waves for upland areas. Image from Living with the Bay Design Team (Interboro Team, 2014).

This proposed project was designed as part of an innovative design competition in the Sandy-impacted area, called Rebuild by Design (Interboro Team, 2014). The design area focused on Nassau County on Long Island. This area was heavily impacted during Sandy from storm surge, but it has also long suffered from flood risk and environmental degradation from storm water runoff and wastewater overflows (Georgetown Climate Center, 2016). The initial Rebuild by Design proposal developed by the design team called for the creation of an “eco-edge” using the restoration of marshes and the creation of wooded marsh islands with additional elevation to provide protection from waves, storm surge and to improve the resiliency of the marsh system to future sea level rise. Hydrodynamic modeling using a scenario where the marsh islands would be raised to 12 feet above mean sea level showed the islands could reduce wave run up and reduce flooding landward of the marshes by 1 foot. However, the modelers noted that water could flow around the sides of the marshes, making it difficult to determine how effective the strategy would be (Interboro Team, 2014).

Once $125 million in funds were awarded from the Rebuild by Design competition, this marsh restoration and protection strategy was narrowed to the Town of Hempstead and evaluated against other proposed projects under the Living with the Bay concept to decide how to use the limited funding provided (GOSR, 2017). The coastal marsh restoration project scored the highest of all of the proposed projects with significant benefits to habitat restoration and water quality as well as social resiliency for improved quality of life and educational opportunities.

Project Cost

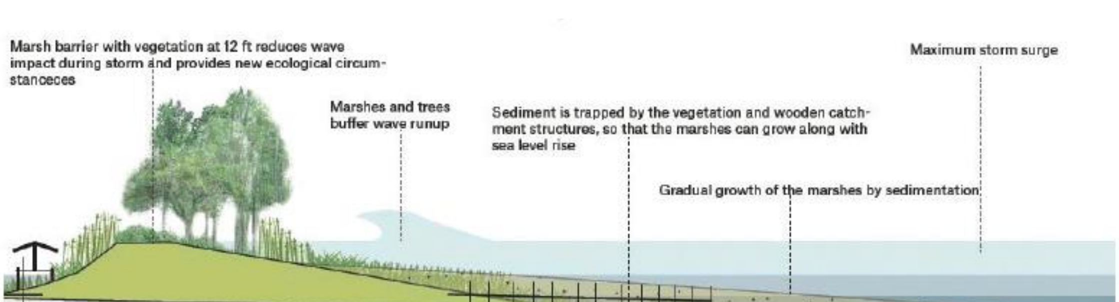
The project cost was estimated at $30.8 million with a 100-year storm level of protection and a 50-year project life. (GOSR, 2017)

Project Components

The project description includes marsh erosion protection, elevated marsh heights for resilience to sea level rise, connecting high elevation areas in the bay to form a barrier to waves and storm surge as well as upland protection strategies. (GOSR, 2017)

Policy Barriers

The restoration and creation of wetlands and living shorelines will have to comply with the NYS DEC Tidal Wetlands Act’s requirement that fill in wetlands is considered “presumptively incompatible” and the activities will have to demonstrate that they preserve, protect, and enhance tidal wetlands. (Georgetown Climate Center, 2016)



A profile of the conceptual in-bay protection strategy (Georgetown Climate Center. 2016).

9 Lessons Learned

Cammen (1976) determined marsh restoration/creation success depended on five factors:

1) Similar elevations for the restored/created marsh using dredged material to natural marsh in vicinity;
2) Similarity of the dredged material with natural marsh sediment particle size;
3) The natural sedimentation rate in the vicinity of the restored/created marsh;
4) The proximity of the dredge site to natural marsh;
5) The relative maturity of the natural marsh faunal community.

Since Cammen's paper was published in 1976, dredged material has been used successfully for marsh restoration/creation projects with a resulting increase in the lessons learned for the beneficial use of dredged materials.

9.1 Planning Observations

Beneficial use of dredged material for marsh restoration/creation projects have demonstrated that development of successful, implementable projects have been led by local interests responding to a need (Collins et al., 2015). A team should be formed consisting of technical, social and economic experts as well as local and community groups capable of identifying and understanding local concerns. Regulators and landowners should be involved early in the project to bring all interested parties to a common cause (Mohan et al., 2007). The team should be engaged often to identify and address issues as they occur (Chaffee and Frisell , 2017; Yepsen et al., 2017); Collins et al. (2015) recommends monthly meetings as an overall team with sub-committees meeting weekly. The project team should establish the project goals, objectives and performance criteria as discussed in sections on site selection criteria and design criteria. If dredging will be an ongoing concern or the volume of dredged material is likely to exceed the requirements of a particular marsh restoration/creation, a regional beneficial use plan should be developed to provide detailed habitat restoration/creation alternatives and goals, and to support engineering and material placement options (Collins et al., 2015). As-built and post-construction project goals should be clearly documented to evaluate the project's success (Yepsen et al., 2017).

9.2 Assessment of Suitability for Marsh Restoration and Creation

When evaluating the dredging project requirements and assessing the suitability of the dredged material for beneficial use, and the suitability of the marsh restoration/creation site alternatives, it is essential to conduct site visits (Chaffee and Frisell, 2017), not only in the planning and design stages but also during the construction phase to ensure that design and construction issues are addressed promptly and accurately. Site surveys, sediment characteristics analysis and consolidation estimates are essential for successful design and implementation of a marsh restoration/creation project (Collins et al., 2015). The impacts of the project on the proposed site should be documented and if possible, future impacts should be anticipated (Chaffee and Frisell, 2017).

9.3 Design

A successful marsh restoration/creation project must have physical and biological attributes that mimic a natural marsh. The physical attributes include:

- Hydrology (Collins et al., 2015);
- Elevation using bio-benchmarks and reference marsh surface elevation (Collins et al., 2015; Pecchioli 2015);
- Undulating marsh surface condition (Collins et al., 2015);
- Mixture of vegetated edge and open water areas to allow free tidal exchange and full circulation through tidal channels and tributaries (Collins et al., 2015);
- Sufficient habitat that meet the proposed vegetation and wildlife species criteria (Collins et al., 2015).

The required biological attributes include:

- Intertidal marsh habitat for birds, fish and other aquatic and wildlife species typically found in natural marshes;
- Biological function similar to existing natural marshes;
- Enhance habitat heterogeneity to increase biodiversity (Collins et al., 2015).

Of these, arguably the most important is the final marsh elevation since errors in the design or constructed marsh elevation will lead to failure to meet the project objectives (Mohan et al. 2007; Yepsen 2017). Not only will the design vegetation fail to become established and appropriate wildlife species habitat not develop when the constructed marsh elevation exceeds the design or reference elevation, failure to develop a system of tidal channels can extend the time it takes for the constructed marsh to achieve functional equivalency to the reference natural marsh and could prevent the development of the desired marsh functions (Winfield et al., 1997). Therefore, implementing a system that allows the marsh to evolve naturally, maintaining tidal flushing and reducing the need for containment, is the preferred option (Mitsch and Wilson, 1996; Yepsen, 2017).

Additional lessons learned in the design phase include:

- Plan for extensive data collection including detailed site surveys to support project design (Chaffee and Frisell, 2017; Pecchioli 2015);
- Plan and budget for adaptive management changes to avoid adverse impacts (Chaffee and Frisell, 2017);
- Manage stakeholder expectations for design and outcomes (Chaffee and Frisell, 2017).

Coordinating a marsh restoration/creation project with maintenance dredging schedules and locations is challenging. To reduce design and construction obstacles and increase the likelihood of project success:

- Be responsive to bidder feedback and open to issuing addenda to ensure proposed project is constructible (Chaffee and Frisell, 2017);
- Consider the distance that sediments can be pumped from the dredge site and the distance from the marsh edge that sediment can be pumped onto the marsh (Yepsen et al., 2017);

- Chaffee and Frisell (2017) recommend a single contractor for dredging and in-marsh work, although others have suggested that may result in a project elevation more likely to meet dredging disposal needs than marsh restoration/creation requirements;
- For larger marsh projects, constructed as a series of wetland cells, the cell should be optimized for the volume of dredge material. Larger cells decrease construction costs and reduce the volume of material need to construct containment dikes; however, larger wetland cells are more difficult to manage in terms of consolidation of the dredged material and the complexity of the hydraulics (Mohan et al., 2007).

Finally,

- The planting schedule should ensure that the dredged material has undergone most of its consolidation and settlement prior to the time of planting;
- Pilot demonstration projects are useful in obtaining site specific conditions, increasing public support and field testing new techniques and assumptions (Mohan et al., 2007).

9.4 Construction Considerations

- Criteria and objectives should be followed as closely as possible through construction, initial development, and some period of follow-up (long-term) monitoring by data collection and site evaluation (Landin et al., 1989); however, immediate and long-term adaptive management measures are critical (Chaffee and Frisell, 2017; Pecchioli, 2015).
- Need to be prepared to make decisions in the field about project design and target elevations so frequent construction oversight is necessary (Chaffee and Frisell, 2017; Collins et al., 2015).
- Site variables must be taken into account and allowance made for margin of errors since correct elevation of the site after consolidation and settling is absolutely critical (Landin et al., 1989). If a site is allowed to evolve naturally over time, it may develop into an alternative but functional habitat. Development of a contingency plan recognizes that this should not necessarily be considered a project failure without assessment of the habitat attribute (Landin et al., 1989).

9.5 Monitoring

- Monitoring is critical to evaluate project success or failure (Collins et al., 2015; Landin et al., 1989; Pecchioli, 2015). Allowing a marsh to develop naturally is a long-term process, and natural disturbances should be anticipated in monitoring and evaluation of project success.
- Regular, periodic site visits should include repeatable, qualitative observations, such as fixed photographic locations, condition of containment, marsh elevation, vegetation and animal species assessments) (Yepsen et al., 2017).
- Individual species are vital to ecosystem function. These critical species should be identified and monitored and their function in the habitat incorporated into the site management (Collins et al., 2015).
- Because marsh development takes time, it is important to find funding to monitor for more than three years after construction; five to ten years of monitoring is preferable to allow for

corrective actions and provide lessons learned for future marsh development projects (Pecchioli, 2015; Yepsen et al., 2017).

- Marsh elevations should be measured during construction, after consolidation and settling, and for at least three to five years post construction (Pecchioli, 2015).
- Continued local communication and financial support is critical to the success of beneficial use of dredged material for marsh restoration and creation (Collins et al., 2015).

9.6 Public Support for Marsh Restoration/Creation in Connecticut

There numerous motivations to build new marsh islands, restore old marsh, augment existing marshes with low elevation via BU. And there are several but not insurmountable technical challenges. Much has been learned on the technical side from the large and small marsh creation projects in the Gulf of Mexico, Seal Beach, CA, and along the East Coast. While there is a high degree of commonality among technical challenges between regional projects (all have to deal with waves, and the right grain size, and quantifying "success", etc.), potential social impediments are likely more regionalized. A restoration project in Louisiana is likely to have different types and levels of public buy-in, than say Long Island Sound or Jamaica Bay. And different justifications for marsh projects are likely to get different levels of traction in different places. A region with a stronger ties to wetland resources, for example through hunting and fishing (commercial and recreational) has a much different social connection to that resource than a region where shoreline modification and more urban lifestyles have diminished social connections to wetland resources for over a century. First – dredge has negative connotations in marine urban settings. Second, siting restoration projects along the CT coast will almost certainly require close juxtaposition to higher population density than seen in other regions, although Jamaica Bay can provide a lens through which to view this issue. Third – while there are birders in CT who value wetland habitat, the shoreline in CT is largely 'worked' and valued in a more mercantile / industrial way than in other regions, and less so from a natural resource perspective. CT has the potential for the social challenges to be the rate limiting step for whether or not marsh creation, particularly with use of dredged material could be implemented in a large program-scale way. There is certainly the need for such projects. There is certainly the expertise to address the physical science and engineering complexity. But whether there is a will to implement adaptive marsh management approaches is contingent on how well public acceptance can be garnered. Until that happens, the likelihood of these kinds of projects being large enough to be a reasonable dredge disposal alternative is unknown.

One example for engaging stakeholders can be seen in the LSU Coastal Sustainability Studio (http://css.lsu.edu/) which provides and interesting focal point through which to engage the public. The Studio's mission is to "*bring together academic disciplines that typically conduct research separately—such as designers, scientists, planners, and engineers—to intensively study and respond to critical issues of coastal settlement, restoration, flood protection, and economic development*. *Through its integrated design and systems thinking approach, programs, and projects, the CSS builds university capacity and transdisciplinary teams that work to develop strategies that address coastal problems*" This approach provides a valuable model, but expectations should be tempered by the reality that LIS is not Louisiana and one model may not fit all. LIS is highly modified, industrial, and there has a limited legacy of public use of wetland habitat in the past century. An insightful assessment of the complicated and evolving relationship between humans and marshes in the CT urban setting can be found in David Casagrandes "The Full Circle: A Historical Context for Urban Salt Marsh Restoration". Restoring the connection between the public and the value of coastal wetlands, may be of equal importance as restoring the wetlands themselves.

10 Conclusions

The question of whether using dredged material for marsh restoration/creation is a win-win situation is undetermined. Many questions remain unanswered (Winfield et al., 1997; Yepsen et al., 2017):

- Are there long-term negative impacts of such projects?
- Are there really cost savings by combining projects?
- Is this a once and done solution or will we need to place sediment on the marsh repeatedly over time?

But the question of greatest interest to researchers and project planners seems to be how long does it take for the marsh to be enhanced and can functional equivalency even be attained?

Although marshes constructed from dredged material develop some of the same physical and biological attributes as nearby natural marshes, data does not show that the constructed marshes provide all the functions of natural marshes. Limited data has even shown that dredged material marshes provide habitat for a different community of birds than natural marshes (Streever, 2000).

Only by continued efforts in designing, creating and monitoring beneficial use of dredged material will the answers to these questions be resolved.

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