Designing Living Shorelines for Sea Level Rise in Virginia:

A Resource for Practitioners

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Cover photo by Yuzhu Zheng of the Elizabeth River Project's headquarters, the "Pru & Louis Ryan Resilience Lab." The Ryan Resilience Lab's living shoreline is a model for sea level rise adaptation. Designed to help facilitate wetlands migration landward as water rises, the shoreline design prioritizes a wider high marsh, inviting the wetlands into the property. When sea level rise begins to overtake the property, posing a safety threat to the building, the Elizabeth River Project will remove the structures and allow the re-naturalization of the land. This future land conversion is mandated by the legal agreement placed on the property by the Coastal Virginia Conservancy. This first in the nation "rolling conservation easement" was designed by Wetlands Watch in partnership with the Virginia Institute of Marine Science and many others.

View the digital guide with links to resources.

Scan the QR code or visit wetlandswatch.org/designing-living-shorelines-for-sea-level-rise

Photo by VHB

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Introduction

"The extent to which living shorelines can mimic the resiliency of natural marshes and oyster reefs will depend on their setting, design and the type of human maintenance provided. Truly resilient projects will require engineers and ecologists to work together to describe the dynamics of shoreline processes under sea level rise and translate this understanding into living shoreline design."
Mitchell, Molly and Bilkovic, Donna M., Embracing dynamic design for climate-resilient living shorelines (2019). *Journal of Applied Ecology*, 56, 1099.

Overview

Coastal Virginia experiences the highest rate of relative sea level rise on the east coast and as a result, its shorelines are already experiencing dramatic change. Property owners are experiencing land loss, saltwater intrusion, eroding banks and shorelines, drowning wetlands, and frequent flooding events. In coastal Virginia, wetlands are drowning in place due to sea level rise rates outpacing the natural vertical accretion rates of marshes. The Virginia Coastal Resilience Master Plan predicts a loss of 89% of existing tidal wetlands and 51% of existing nontidal wetlands by 2080, if wetland migration does not occur.

The Language of the Legislation:

The Commission shall permit only living shoreline approaches to shoreline management unless the best available science shows that such approaches are not suitable. If the best available science shows that a living shoreline approach is not suitable, the Commission shall require the applicant to incorporate, to the maximum extent possible, elements of living shoreline approaches into permitted projects. (28.2-1301)

The Commission shall preserve and prevent the despoliation and destruction of wetlands while accommodating necessary economic development in a manner consistent with wetlands preservation and any standards set by the Commonwealth in addition to those identified in § 28.2-1308 to ensure protection of shorelines and sensitive coastal habitats from sea level rise and coastal hazards, including guidelines and minimum standards promulgated by the Commission pursuant to subsection C. (28.2-104.1)

Virginia is a low-water state, meaning waterfront property owners own to the mean low water line, while the state owns the bottom lands and water extending beyond mean low water. The Virginia General Assembly passed legislation in 2020, amending the section of Code referred to as the Virginia Wetlands Act, to reduce the impacts of shoreline erosion and wetlands loss by requiring property owners to use living shorelines as the state's default erosion control method. In addition to this default mandate, the law requires the update of standards and guidelines to ensure the "protection of shorelines and sensitive coastal habitats from sea level rise and coastal hazards." (Code of VA § 28.2-104.1) The Virginia Wetlands Act Guidelines stipulate that "all shoreline alterations should, 1) be designed and constructed to mitigate coastal hazards including storm-level hydrological energy that may reasonably be expected over the useful life of the project, and 2) be functionally resilient and structurally designed to endure the impacts of sea level rise." The Guidelines discuss requirements for what types of data should be considered and used to inform the design of living shorelines that are adaptive to sea level rise and coastal hazards, but there are no specific directions or examples of how to best accomplish adaptive design in variable site conditions.

Living shorelines are permitted through a regulatory process that starts with submitting a Joint Permit Application (JPA) to the Virginia Marine Resources Commission (VMRC). However, the JPA does not explicitly require an explanation of how a living shoreline is designed to mitigate coastal hazards and withstand the impacts of sea level rise to meet these standards. Wetlands Watch, with funding from the Virginia Coastal Zone Management Program, gathered a Work Group of living shoreline practitioners from Virginia's coastal zone to develop a resource document that explores how to design and provides examples of adaptive living shorelines - those that mitigate coastal hazards and endure the impacts of sea level rise. The Work Group met four years after the new climate change requirements were passed (2020) and three years after the new standards' effective date (2021). The project deliverable, this document, is a resource living shoreline practitioners can use to help design and implement adaptive living shorelines. This was accomplished by compiling a list of case studies to showcase various design approaches and adaptive strategies used in existing living shoreline projects, and by developing a list of best design practices based on the knowledge gained from implementing these projects.

Role and Value of Living Shorelines

The 2020 amendment to the law strengthened an existing preference for living shorelines, mandating their use for shoreline stabilization, unless best available science indicates a living shoreline is not suitable. More information about best available science can be found on page 101 and a list of site conditions that create particularly challenging conditions for implementing a living shoreline can be found on page 7.

The primary purpose of a living shoreline is to provide shoreline erosion control. A living shoreline provides this control through planted or established marsh vegetation, often in combination with a structural element such as a nearshore sill or breakwater. If a sill is used, it provides the initial reduction in wave energy. As water comes onto the shore, the salt marsh vegetation attenuates the remaining wave energy and slows flow rates, while the roots stabilize sediment. **Though sometimes referred to as flood control measures, living shorelines do not prevent flooding by stopping water from encroaching on a property. Rather, living shorelines lessen the impact of waves and tidal flow by reducing energy. This wave attenuation can result in the reduction of property damage during storm events.** The level of wave attenuation is related directly to marsh width, sill size and sufficient backshore elevation; wider marshes provide higher levels of wave attenuation. Living shorelines that include wide marshes and higher backshore elevations or large sills to attenuate waves may offer the most protection against the impacts of coastal hazards and sea level rise, but this increased level of protection comes with greater costs. Property owners may not be able to afford this increased level of protection, therefore designing a living shoreline to adapt to increased future impacts for an extremely long period of time may be cost prohibitive particularly in key, residential settings.

Living shorelines provide an array of valuable functions, or multi-benefits, beyond erosion control and wave attenuation. The wetlands created by living shorelines offer habitat for diverse wildlife, such as birds, crabs, oysters, snails, algae, and microorganisms. The fish and shellfish that depend on wetlands for food or habitat constitute more than 75% of commercial and 90% of recreational harvests (EPA). Living shorelines also improve water quality by trapping sediments, absorbing nutrients, and removing toxicants. Resulting from these water quality benefits, living shorelines enhance recreational opportunities for fishing, hunting, and low impact water sports. Living shorelines provide aesthetics to a community, preserve parcel size, and prevent unsightly erosion, each of which can improve property values. They can trap and store carbon, mitigating the impacts of climate change. Living shorelines that include marsh creation provide an incremental gain in the extent of tidal marsh off-setting some historic and future losses and can create opportunities for marsh migration in certain settings. Finally, living shorelines maintain the connection between land and water, thereby allowing natural coastal processes to persist.

Purpose and Scope

Purpose

The purpose of this resource is to help design and construction professionals design and install living shorelines that can adapt to and recover from coastal hazards, such as sea level rise, coastal storms, and erosion, thereby protecting and conserving critical shoreline ecosystems. The 2020 amendment to the Virginia Wetlands Act section of state law requires this new standard. While the 2021 update to the Wetlands Act Guidelines references the data required to include in the permitting process, the Guidelines do not offer specific examples of living shorelines that are adaptive to coastal hazards and sea level rise. This resource seeks to fill this gap with a compiled list of design practices for adaptive living shorelines and case studies of permitted adaptive shoreline projects. The aim of this resource is to offer general information and is not intended to be prescriptive, as designing living shorelines is site-specific and site-dependent.

Scope

This resource was written for living shoreline practitioners, such as ecologists, engineers (coastal, geotechnical, structural) and landscape architects, although other stakeholders with less direct experience in living shoreline design and installation may find the information useful. Given this range in readership, this resource offers brief explanations of technical concepts, while providing links to additional references. It is beyond the scope of this document to define what strategies constitute a living shoreline; that determination is made by regulators and lawmakers. Case studies may include both traditional living shorelines and alternative proprietary shoreline erosion control strategies and materials.

This resource:

- Explains the amendments to Virginia law - referred to as the (Tidal) Wetlands Act, and subsequent updates to the Guidelines, as related to new living shoreline design standards for sea level rise and coastal hazards.
- Clarifies the required data for designing and permitting erosion control practices on the shoreline, while including sources of information.
- Compiles criteria for designing living shorelines, in various site conditions, that protect natural resources from the impacts of sea level rise and coastal hazards.
- Includes 26 case studies of living shorelines and erosion control practices in Virginia that demonstrate adaptive design approaches implemented on various site conditions, fulfilling the mandate to protect shorelines and coastal habitats from sea level rise and coastal hazards.

This resource does not:

- Include an exhaustive list of data, and how to access the data, that is required to design a living shoreline; the data is limited to that included in the Guidelines as required for the new sea level rise/coastal hazards standards.
- Include an exhaustive list of design criteria to install adaptive living shorelines; the criteria included represent the current science and technologies, and the perspectives of Living Shoreline Design Work Group members.
- Include an exhaustive list of case studies and may exclude projects that were designed to be adaptive to sea level rise.

Foundational Living Shoreline Information

The following references are invaluable for building a solid foundation in living shorelines. Authored by leading experts, they are essential additions to any living shoreline professional's library.

- Living Shorelines 101 Video
- Living Shorelines 101 Brochure
- Living Shorelines: The Science and Management of Nature-Based Coastal Protection
- Embracing dynamic design for climate-resilient living shorelines
- Evaluation: Management, Policy, Science, and Engineering of Nonstructural Erosion Control in the Chesapeake Bay: Evaluation of Living Shoreline Techniques (2006)
- Design: Management, Policy, Science, and Engineering of Nonstructural Erosion Control in the Chesapeake Bay: Living Shoreline Design (2006)
- Tools & Decision Making: Management, Policy, Science, and Engineering of Nonstructural Erosion Control in the Chesapeake Bay: Tools and Decision-Making - Facilitating and Encouraging Living Shoreline Implementation (2006)
- Adapt Virginia Comprehensive Viewer
- VMRC Guidelines
- VIMS Shoreline Management Handbook
- VIMS Shoreline Change Web Viewer
- VIMS Living Shoreline Design Guidelines for Shore Protection in Virginia's Estuarine Environments (2021)
- James River Quality Improvement Planner

Photo by Elizabeth Ronston

Additional work that supports the importance and role of living shorelines:

- Guthrie, A.G., Bilkovic, D.M., Mitchell, M., Chambers, R., Thompson, J.S. and Isdell, R.E., 2022. Ecological equivalency of living shorelines and natural marshes for fish and crustacean communities. Ecological Engineering, 176, p.106511. https://doi.org/10.1016/j.ecoleng.2021.106511
- Isdell, R.E., Bilkovic, D.M., Guthrie, A.G., Mitchell, M.M., Chambers, R.M., Leu, M. and Hershner, C., 2021. Living shorelines achieve functional equivalence to natural fringe marshes across multiple ecological metrics. PeerJ, 9, p.e11815. https://doi.org/10.7717/peerj.11815
- Bilkovic, D.M. and Mitchell, M.M., 2017. Designing living shoreline salt marsh ecosystems to promote coastal resilience. In Living Shorelines (pp. 293-316). CRC Press. https://www.taylorfrancis.com/chapters/edit/10.1201/9781315151465-19/designing-living-shoreline-salt-marsh-ecosystems-promote-coastal-resilience-donna-marie-bilkovic-molly-mitchell
- Scheld, A.M., Bilkovic, D.M., Stafford, S., Powers, K., Musick, S. and Guthrie, A.G., 2024. Valuing shoreline habitats for recreational fishing. Ocean & Coastal Management, 253, p.107150. https://doi.org/10.1016/j.ocecoaman.2024.107150
- Bilkovic, D.M., Isdell, R.E., Stanhope, D., Angstadt, K.T., Havens, K.J. and Chambers, R.M., 2021. Nursery habitat use by juvenile blue crabs in created and natural fringing marshes. Ecological Engineering, 170, p.106333. https://doi.org/10.1016/j.ecoleng.2021.106333
- Chambers, R.M., Gorsky, A.L., Isdell, R.E., Mitchell, M.M. and Bilkovic, D.M., 2021. Comparison of nutrient accrual in constructed living shoreline and natural fringing marshes. Ocean & Coastal Management, 199, p.105401. https://doi.org/10.1016/j.ocecoaman.2020.105401
- Leu, M., Isdell, R.E., Galvin III, R.M., Rapp, A.J., Mason, S.D., Bilkovic, D.M. and Chambers, R.M., 2023. Comparable use of tidal living shorelines and natural-fringe marshes by herons and shorebirds. Ecosphere, 14(11), p.e4683.
- Bilkovic, D.M., R.E. Isdell, A.G. Guthrie, M.M. Mitchell, and Chambers R.M., 2021. Ribbed mussel *Geukensia demissa* population response to living shoreline design and ecosystem development. Ecosphere 12(3), p.e03402. https://doi.org/10.1002/ecs2.3402
- Smith, C.S., Puckett, B., Gittman, R.K., and Peterson, C.H., 2018. Living shorelines enhanced the resilience of saltmarshes to Hurricane Matthew (2016). Ecological Applications, 28(4), p.871. https://doi.org/10.1002/eap.1722
- Smith, C.S., Gittman, R.K., Neylan, I.P., Scyphers, S.B., Morton, J.P., Fodrie, F.J., Grabowski, J.H. and Peterson, C.H., 2017. Hurricane damage along natural and hardened estuarine shorelines: using homeowner experiences to promote nature-based coastal protection. Marine Policy, 81, p.350. https://doi.org/10.1016/j.marpol.2017.04.013


Photo by Elizabeth Ronston

Definitions

To provide consistency with existing legislation and official guidance, definitions have been taken directly from the Wetlands Act "(A)" and the Guidelines "(G)" promulgated by the VMRC, wherever possible. Definitions for terms not defined in those documents have been derived from technical sources including the Virginia Institute of Marine Science (VIMS) and the National Oceanic and Atmospheric Administration (NOAA).

Adaptation: Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects. (G)

Adaptive Management: An intentional approach to making decisions and adjustments in response to new information and changes in context. (ADS (USAID))

Breakwater: A structure usually built of rock positioned a short distance from the shore. The purpose is to deflect the force of incoming waves to protect a shoreline. (G)

Coastal Hazard: Generally, physical phenomena that expose a coastal area to the risk of property damage, and environmental degradation. (Peron Naturaliste Partnership)

Ecosystem Services: Components of nature, directly enjoyed, consumed, or used to yield human well-being. (G)

Fetch: The distance along open water over which wind blows. For any given shore, there may be several fetch distances depending on predominant wind directions, but there is generally one fetch which is longest for any given shoreline exposure. (G)

Global Sea Level Rise: The rate of change of average sea levels in the world's ocean, primarily caused globally by added water from melting ice sheets and glaciers, and the expansion of seawater as it warms. (Adapted from VIMS Sea-Level Rise: what's to know? | Virginia Institute of Marine Science)

Groin: A rigid, vertical structure extending perpendicular to shore to trap transporting sand or other material down a shoreline. (G)

Living Shoreline: A shoreline management practice that provides erosion control and water quality benefits; protects, restores, or enhances natural shoreline habitat; and maintains coastal processes through the strategic placement of plants, stone, sand fill, and other structural and organic materials. When practicable, a living shoreline may enhance coastal resilience and attenuation of wave energy and storm surge. § 28.2-104.1 (A)

> **Other structural and organic materials** means materials or features that provide added protection or stability for the natural shoreline habitat components of a living shoreline that attenuate wave energy and do not interfere with natural coastal processes or the natural continuity of the land-water interface. "Other structural and organic materials" may be composed of a variety of natural or man-made materials, including rock, concrete, wood fiber, oyster shells, and geotextiles; however, structural features shall be free from contaminants and shall be adequately secured to prevent full or partial dislodging or detachment due to wave action or other natural forces. (A) § 28.2-104.1

Monitor: Monitoring is the systematic observation and recording of current and changing conditions. (EPA)

Multi-Benefit: Conservation efforts designed to simultaneously benefit local communities of people, enhance ecological function, and improve habitat quality for fish and wildlife. (Gardali, Thomas & Dybala, Kristen & Seavy, Nathaniel. (2021). Multiple-Benefit Conservation defined. Conservation Science and Practice. 3. 10.1111/csp2.420.) *More commonly referred to as co-benefits.*

Persistence (of marsh): Where the marsh continues to exist in place through natural processes or human assistance, especially past a usual, expected, or normal time (Modified Miriam Websters)

Relative Sea Level Rise: Relative sea level rise refers to the change in sea level relative to the elevation of the land, which includes global sea level rise, land subsidence and changes in ocean circulation (Titus et al. 2010). In Coastal Virginia, additional factors that affect relative sea level rise rates include the slowing of the Gulf Stream and land subsidence. (Adapted from VIMS Sea-Level Rise: what's to know? | Virginia Institute of Marine Science)

Resilience: The capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, health, the economy, and the environment. (G)

Sill: An erosion protection measure that combines elements of both revetments and offshore breakwaters. Sills are usually built of stone *or other materials*, low in profile and built close to shore. (G) *Work Group contribution in italics.*

Slope: The degree of deviation of a surface from the horizontal measured as a numeric ratio, percentage or in degrees. When expressed as ratio, the first number is the horizontal distance and the second is the vertical distance. (G)

Shoreline Flora: The plants or plant life present in areas where water bodies meet the land. (VIMS Resource)

Shoreline Fauna: The animals or animal life that live in areas where water bodies meet the land. (VIMS Resource)

Storm Surge: The resulting temporary rise in sea level due to large waves and low atmospheric pressure created during storms. (G)

Useful Life: The average amount of time in years that the project is estimated to function when installed properly and routine maintenance is practiced. (G) Shoreline alterations that are generally proposed to address coastal resiliency and control active erosion should ensure that the stabilizing objectives address the most erosive conditions predictable to the project site. (G: General Criteria, D)

Design Considerations For Sea Level Rise and Coastal Hazards

When considering a potential site for a living shoreline, it's important to understand specific shoreline characteristics. These include fetch, offshore depths, bottom substrate type, nearshore and offshore morphology, backshore elevation, orientation, tide range, erosion rates, and other variables. Detailed guidance on these aspects can be found in the [VIMS Living Shoreline Design Guidelines for Shore Protection in Virginia's Estuarine Environment 2021 manual](#).

This section explains how existing site conditions can affect the implementation of an adaptive strategy in the final design. It also provides design strategies from case studies that have overcome these challenges, explores useful life and how it can be determined, and reviews some maintenance strategies that should be considered.

General Considerations

While living shorelines are the required approach under Virginia law, when suitable, to managing shoreline erosion in Virginia, certain sites will present conditions that are not compatible with a living shoreline, or a site may have features that constrain the useful life of a living shoreline. When evaluating a site for a living shoreline solution, suitability and feasibility must first be determined.

The following data should be considered:

- Shoreline change/erosion rate
- Tide range
- Wave energy/fetch exposure
- Sea level rise projections
- Storm surge and flooding
- Marsh migration
- Existing natural resources
- Existing infrastructure
- Bank height/slope
- Slope stability
- Current shoreline vegetative conditions
- Nearshore bathymetry
- Bottom substrate type/bearing capacity
- Soil/sediment characterization

Sites that are specifically challenging for living shorelines are ones that demonstrate:

- Extremely high banks, unless the bank slopes are reduced and vegetated as part of the living shoreline
- Deep nearshore water depths
- Connection to a residential canal system
- Close proximity to a navigation channel
- Result in negative environmental impacts
- Limited construction access, by land or water
- Soft nearshore bottom substrates that may not support the weight of a sill (when sills are necessary for protection of the shoreline)
- North facing exposure, which limits sunlight availability for shoreline vegetation

- Historical and cultural assets and lands.
- Developed lands - former commercial, industrial, and landfill properties that have real or perceived environmental constraints.

While these site characteristics can complicate implementation of a living shoreline, they do not automatically exclude living shorelines as appropriate shoreline stabilization strategies. A complete site evaluation is necessary to determine the most suitable strategy for the site.

Useful Life

The Guidelines defines *useful life of a project* as "the average amount of time in years that the project is estimated to function when installed properly and routine maintenance is practiced." The Guidelines further state that "[s]horeline alterations that are generally proposed to address coastal resiliency and control active erosion should ensure that the stabilizing objectives address the most erosive conditions predictable to the project site," (Tidal Wetlands Guidelines: General Criteria, Section D) but does not specify a standard number of years for which projects should be designed to function. Determining a useful life for a project does not effectively assign an end date to the project's life span, but can be used to define how protective the design needs to be against the impacts of sea level rise and storm events today and in the future. The useful life of any individual living shoreline project should be determined based on a number of factors that will vary from project to project.

Site specific conditions: Each potential living shoreline site's conditions will factor into how long the project can continue to function as designed. Characteristics that are relevant are detailed later in this section.

Property owner goals: At the forefront of this decision are the goals the property owner has for their shoreline. In addition to erosion control, property owners may desire to create habitat for wildlife, water access for recreation, replicate projects their neighbors have installed, or preserve the marsh in its present location. As with any shoreline project, guidance from shoreline professionals and/or advisory services can help inform property owner decisions to develop a living shoreline that will provide the greatest amount of protection for the longest period of time, while considering the owner's goals and budget. Property owners should be made fully aware of the present and long-term implications of how their shoreline will respond to storm events and sea level rise and understand the tradeoffs involved in planning for short vs. long-term protection.

Type and availability of funding: Living shorelines funded by grants, cost-share programs, or public funds may not fully align with the goals of the property owner. In many cases, the multi-benefits of living shorelines, rather than their erosion control and wave attenuation functions, are primary drivers in providing funding for shoreline restoration and funders may require that the living shoreline be designed to provide these functions for a specified period of time.

Projected impacts of sea level rise: The Guidelines specify that sea level rise projections should come from a model or forecast that uses the 2017 (or more recent update) National Oceanographic and Atmospheric Administration's (NOAA) Intermediate-High scenario projection curve. Using these projections, practitioners can determine the future vertical positions of Mean Low Water (MLW), Mean Tide Level (MTL), and Mean High Water (MHW) at various time intervals to predict how long the created or restored shoreline will be able to survive at its current elevations.

Potential for marsh migration or persistence: Once an evaluation of sea level rise impacts is complete, a site can be evaluated to determine the potential for marsh migration or the interventions necessary over time to allow the marsh to persist in place. Several factors influence migration potential and will be discussed later in this document. When considering migration or persistence as part of useful life determination, sites that offer favorable conditions for vertical and landward marsh migration to occur may realize the full range of benefits provided by the living shoreline for a longer period of time.

Proximity to upland structures/development: One factor in determining the potential for marsh migration is to evaluate how close the built environment is to the shore. Structures (e.g., houses, garages, sheds, pools, patios, etc.) and infrastructure (water wells, septic systems, waste and water pipes, etc.) placed close to the shore can also constrain design options (e.g. grading of bank), which may impact the useful life of the project.

Impact of mature vegetation: Upland and adjacent trees, shrubs, and herbaceous plants should be identified and evaluated for their long-term impacts on living shorelines. Mature plants can shade and compete with shoreline plantings, affecting their growth and health over several decades.

Storm surge: Most commonly used to dictate the level of protection needed to prevent erosion at a site, storm surge also plays a role in determining useful life. Sea level rise must be considered when evaluating future storm surge elevations to accurately determine how long a specific living shoreline design can provide the level of protection needed. Minimally, living shoreline designs should provide protection for a 10-year storm event. It may not be feasible that all living shorelines be designed to withstand the extreme erosive forces experienced during 100- or 500-year storms (FEMA's 1-percent-annual-chance flood & 0.2-percent-annual-chance flood) due to the associated cost, feasibility, and constructability concerns involved.

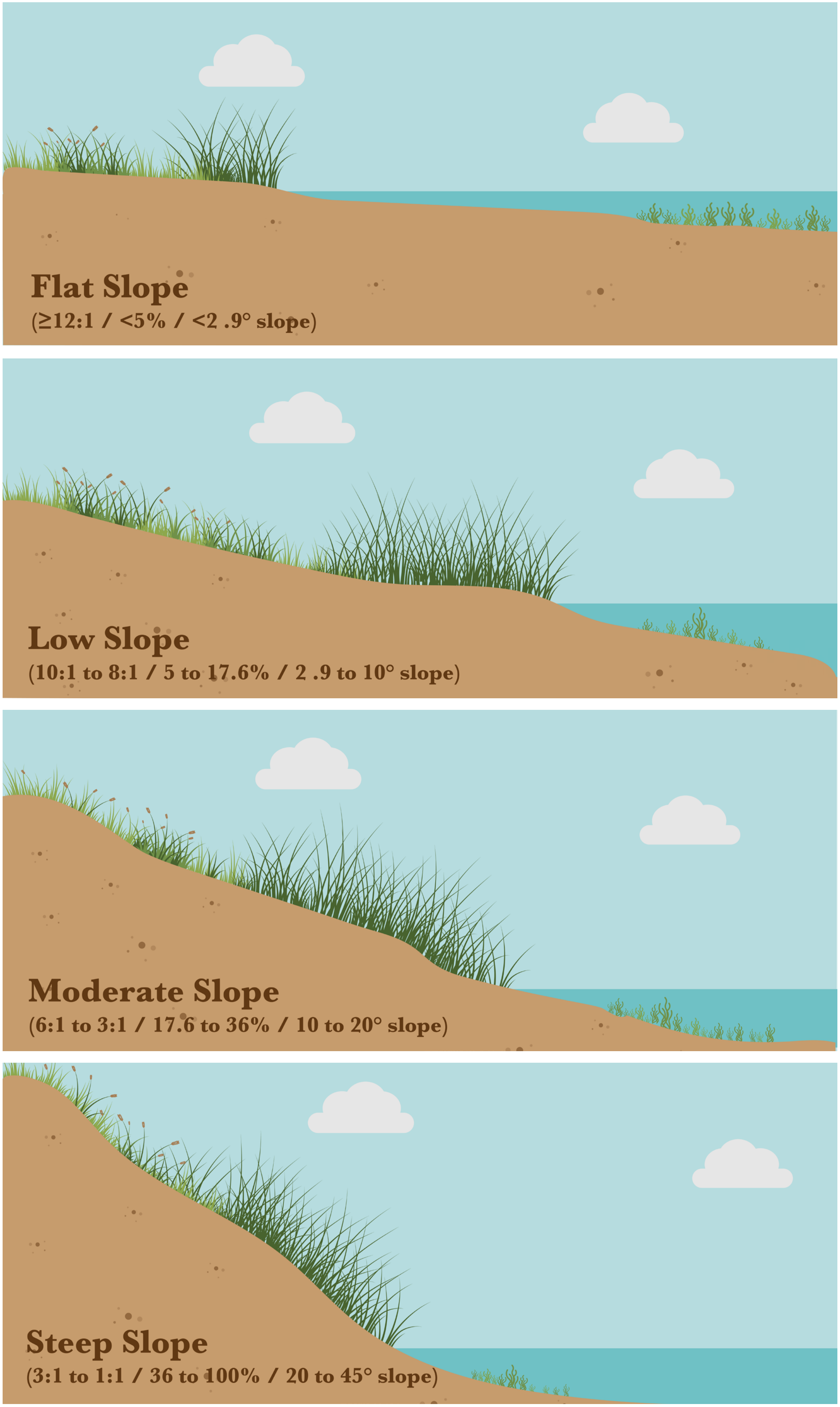
Compliance with permitting requirements: Ultimately, construction of a living shoreline design must be permitted by local, state, and federal regulatory agencies. Permits will specify any restrictions or limitations on individual design elements of a living shoreline.

Slope

The shoreline's slope is a critical factor in determining whether wetland flora and fauna can migrate landward. Landward, upslope migration helps protect wetlands and sensitive coastal habitats from the impacts of sea level rise. Slope is a strong indicator of erodibility and stability of the shoreline and bank. Living shoreline designs should endeavor to create the most gradual, and therefore stable, slope possible for a particular site. Creating a gradual slope from the water's edge to the top of the bank creates the most favorable conditions for marsh migration. However, the slope that can be achieved will be determined by existing site conditions and limitations. While the recommended slope for the shore is 10:1 (Hardaway et. al., 2021), other research suggests that wetlands migration and stability may occur at slightly steeper slopes on the backshore and bank. Slopes can be classified as Flat (<5% / <2 .9 degrees slope), Low Slope (5-17.6% / 2.9 -10 degree slope), Moderate Slope (17.6% - 36% / 10-20 degree slope), Steep Slope (36-100% / 20 to 45 degree slope) and Very Steep Slope (>45 degrees) (see Figure 1 below). These categories are based on literature (Molino et al., 2021), and the ShoreWatch App developed by the Center for Coastal Resource Management at VIMS.

Slope is also a factor for wave attenuation during storm events. Gradual slopes allow waves to travel up the shoreline and the friction of the water movement decreases wave energy before it impacts the bank. Steep slopes allow waves to reach the base of the bank, which may then erode more quickly and more dramatically, increasing the potential risk to property, particularly when structures are in close proximity to the shoreline.

Figure 1. Shoreline slope classifications for flat, low, moderate, and steep slopes. Very steep slopes (>45 degrees) are not depicted in this figure.



Bank Height

Six basic shoreline types in the Chesapeake Bay have previously been classified (Shoreline Management in Chesapeake Bay). These six types were grouped into high- and low-bank categories, where a high bank is described as having an elevation 10 ft or higher above mean low water and low banks are those with an upland elevation less than 10 ft above mean low water. A later study classified bank heights as low (< 3ft), moderate (3 - 6ft), and high (> 6ft) (Bilkovic, Mitchell, La Peyre, Toft, 2017). These more recent shoreline categories are used in this document and associated case studies to discuss bank heights most often associated with living shorelines that exhibit potential for marsh migration. Generally, the level of protection necessary increases with bank height.

Low banks offer the least resistance to the upward migration of marsh plants. A low-bank site may require sand fill to raise shore elevations to support the establishment of marsh vegetation and in the backshore to establish a gradual tie-in to the bank. Grading low banks is not usually necessary to achieve a stable slope.

Moderate banks may benefit from some grading to achieve the most stable slope on the site. Sand fill may not provide sufficient elevation to create a continuous slope to the top of the bank. If the bank is vertical, it will erode upon wave impact and impede marsh migration landward and will require more adaptive support to help the wetlands persist in place.

High banks are the most challenging to grade to a continuous stable slope from shoreline to top of bank. There may not be enough space to grade landward without impacting upland vegetation or structures, or property owners may not want to grade into the upland a sufficient distance for a living shoreline to be installed. Cost is also a consideration when extensive grading is proposed. However, high vertical banks will prevent marsh migration. Where banks cannot be stabilized in high energy areas, by grading, terracing, or vegetation, erosional forces will continue to impact the bank face.

Wave Energy

Determining the wave energy that a shoreline will experience requires consideration of multiple factors, including fetch, shoreline orientation, nearshore depth, boat wake, and shoreline morphology. Fetch is the primary indicator of the amount of wave energy a shoreline will experience, but this energy can be increased or reduced by other site characteristics. Fetch is classified as very low (< 0.5 mile), low (0.5 to 1 mile), medium (1 - 5 miles), high (5 - 15 miles), and very high (> 15 miles) (Hardaway et al. 2021). Another factor in determining wave energy of a site is shoreline orientation, and its relation to the dominant fetches and wind directions. In coastal Virginia, the most frequent winds impact north, northeast, south, and southwest facing shorelines, while the strongest winds come from the north and northeast (Hardaway, et. al., 2021). Wind pattern information is based on historic data and patterns may shift in response to other climate change impacts. Shallow nearshore depths and/or the presence of sand bars can reduce wave energy as it approaches the shore. The more expansive the nearshore shallows, the further offshore waves will break. Conversely, deep water nearshore allows the full energy of the waves to reach the shoreline. Lastly, shoreline morphology influences how directly wave energy can impact the shore. Shorelines that are protected by natural features, such as marsh or coves, are less likely to receive the full energy of waves, while headlands and straight stretches of shoreline are more likely to experience the full impacts of wave energy. As sea level rises in the future, nearshore depths will concurrently increase, thereby increasing wave energy (Barnes, et. al., 2024).

Sediment

Bottom sediment can vary from firm to soft, and this will determine how much weight can be supported for living shoreline elements included offshore (i.e., sills and breakwaters). It may seem intuitive to build larger sills that will protect shorelines for a longer period of time, but soft sediments may not support the additional weight and heavy sills will sink in such conditions. A quick field test can be done to determine the stability of the bottom substrate by having a 200-lb person stand on the substrate with their feet together, covering about 1 ft^2, and then gently hopping in place. If the person doesn't sink, it indicates that the bottom is stable enough to support a sill. If the bottom is too soft to support the person, settling of sill materials can sometimes be mitigated by placing sand and/or geotextile fabric under the sill, or by designing to a higher crest elevation that allows for a degree of settlement.

Other Considerations

The following is a list of additional considerations for designing an adaptive living shoreline:

- Whether there are endangered species, submerged aquatic vegetation, customary land uses, or cultural/historical assets on the property that would limit the ability to design a living shoreline adaptive to sea level rise and coastal hazards
- Select native plant species for the low/high marshes and upland buffers: The Virginia Native Plant Guide and ERP Planting Guide are helpful resources.


Photo by Sue Mangan Photography

Design Strategies

The strategies outlined in this section are intended to assist practitioners in choosing the appropriate stabilization solution for their particular site. Site-specific conditions and constraints will dictate which strategies are the most suitable. The strategies are divided into sections related to sea level rise and coastal hazards for organizational purposes, but a combination of strategies may be needed to achieve a project's goals. Where appropriate, specific case studies illustrating these strategies are noted. Finally, adaptive management and maintenance are discussed at the end of this section. Managing the shoreline after the initial establishment of marsh vegetation is not required, but property owners and shoreline practitioners may implement management strategies that will extend the useful life of their project.

Designing for Sea Level Rise

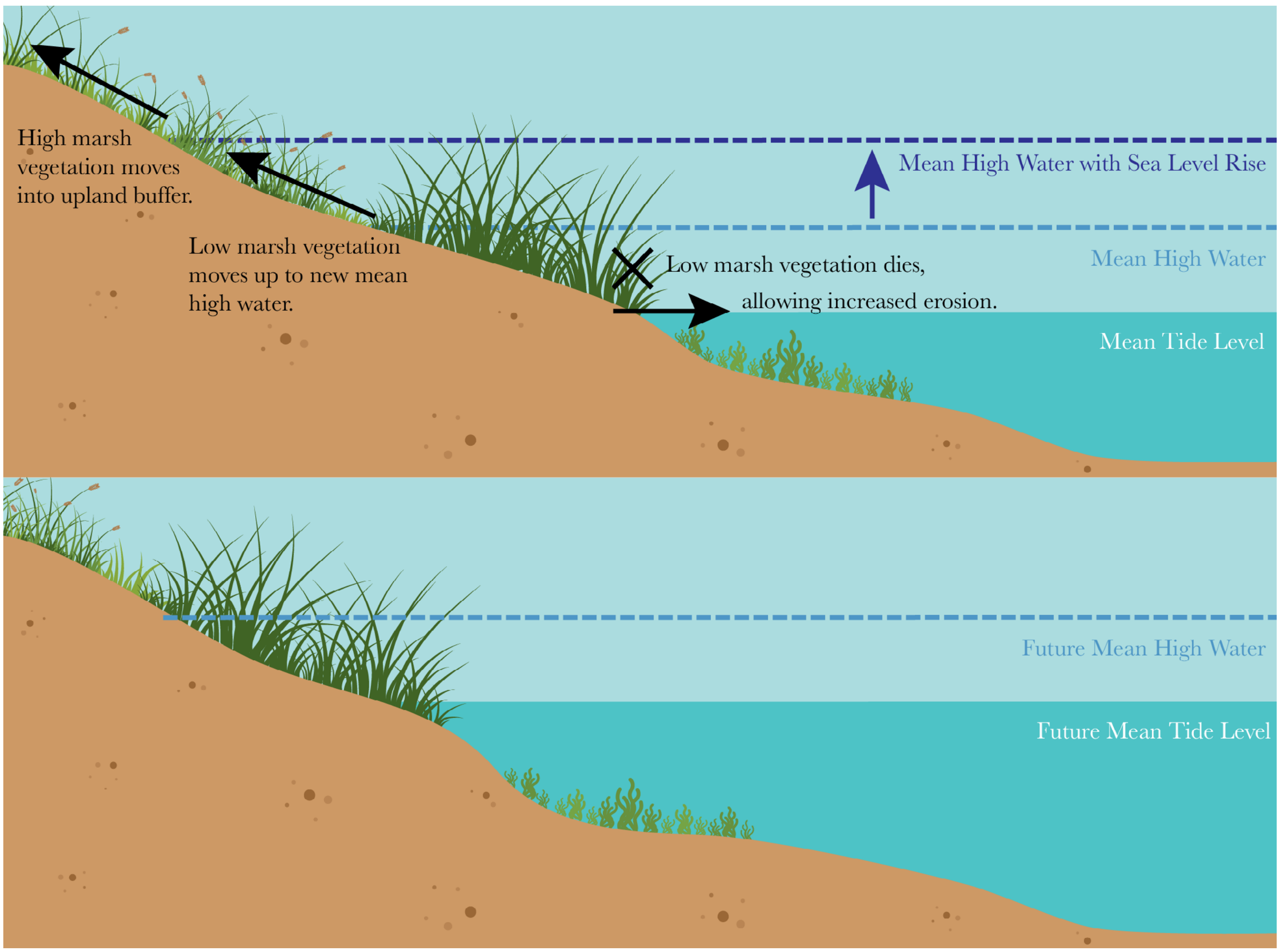
Living shorelines create, enhance or preserve marshlands to mitigate wave energy impacts, capture sediment, and prevent erosion. The migration or assisted persistence of the existing marsh in response to sea level rise will prolong these benefits and increase the return on investment realized by property owners and other project funders. In addition to their primary function of shore protection, living shorelines, when designed appropriately and where conditions are favorable, will provide a natural pathway for marshes to migrate to the upland as water levels rise. To migrate landward, wetlands will compete with development, infrastructure, and human intervention. Houses, businesses, roads, and other infrastructure located near shorelines will impede the landward migration of marshes, however, it is rarely feasible to relocate these structures. The potential for future shoreline changes should be discussed with property owners, with qualified design professionals educating on the long-term implications of sea level rise. Where wetlands migration is not possible or prioritized, the assisted persistence of wetlands can help protect properties against the impacts of sea level rise and coastal hazards.

In their natural setting and where gradual slopes are present, tidal marshes and their adjacent upland buffers respond to sea level rise in a number of ways, somewhat like a domino effect (Figure 2). As sea level rises, the low marsh zone, from mean tide level to mean high water, begins to deteriorate because of increased periods of inundation. This causes the vegetation at the channelward edge of the low marsh to die. This loss of vegetation and root system destabilizes the sediments and allows them to be easily eroded away. While this is happening, the increased level of inundation is also impacting the high marsh zone located above mean high water. Sea level rise is essentially raising the elevation of mean high water. The high marsh vegetation is not adapted to this increased frequency and duration of flooding, which stresses it and causes it to die back. This allows the low marsh vegetation, that is adapted to the new hydrologic regime, to migrate landward and replace the high marsh. This migration process, in turn, also affects the adjacent upland buffer. With increased periods of inundation and increased soil salinity, the upland buffer vegetation cannot adapt and begins to die back. This allows the adjacent high marsh to migrate landward replacing the affected upland buffer. And so it goes, the dynamic process of landscape transition in response to sea level rise.

Low marsh grasses generally occur between mean tide level (MTL) and spring high water (SHW) and are regularly flooded, while high marsh species appear landward of MHW and are flooded irregularly. As sea level rises, many of the areas where low marsh grasses are growing today are expected to be persistently under water in the future and therefore unsuitable for habitation by low marsh species. Understanding the future potential location of high and low marsh habitat, and either providing a pathway for these species to migrate landward or ensuring through maintenance and adaptive management that the species can persist in place, is critical when designing living shorelines that adapt to sea level rise.

The following design strategies should be considered when developing a living shoreline project that will adapt to sea level rise. Not all strategies will be appropriate for all sites and practitioners should evaluate all site-specific conditions when determining the appropriate living shoreline design for a particular site. The data needed for consideration is detailed in the Data and Tools section of this resource.

Figure 2. The process of marsh migration and the resulting profile.



Strategy: Create stable slopes that promote marsh migration

Methods:

- Create low, gradual slopes from the shore to the upland. Consider how sea level rise projections will affect the future vertical positions of MLW, MTL, and MHW and correct the slope as much as possible up to 1.5x Mean Tidal Range (MTR). Current regulations do not allow placement of fill material on the shore that results in the conversion of jurisdictional wetlands to uplands. Where banks are high and/or there is not sufficient horizontal space to grade banks to a 10:1 slope, consider whether a continuous slope of 8:1 or 6:1 may be achievable. Low, flat marshes in front of high vertical banks or bulkheads are unlikely to migrate past these barriers. Creating a slope that will increase the likelihood of marsh grasses migrating landward is preferable, even if the slope is steeper.
- Marsh sill structures may need to be placed channelward of MLW to gain the space necessary to achieve a low, gradual slope from shore to upland.

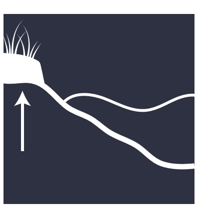
Case Studies: Newport Crescent; Sarah Creek; Linnet Lane; Money Point: Phase 1; Island Road; Hermitage; Free School Creek; Port Haywood; East River; Ryan Resilience Lab; Killman Cove; Captain Sinclair; Black Marsh Farm; Poplar Grove; Occohannock On The Bay

Strategy: Design planting zones to plan for migration

Methods:

- Consider marsh migration and shifts in vegetation types when determining the low and high marsh planting zones. The Ryan Resilience Lab case study details this approach to planned loss of low marsh area and emphasizes creation of a wide high marsh zone. The total width of the combined low and high marsh zones provides the space for wave attenuation, while recognizing that the low marsh zone will only remain as marsh for a relatively short term as sea level continues to rise. The high marsh supplies a migration corridor for low marsh species to move into over time, while the vegetated upland buffer is planned as the future high marsh zone.

Case Studies: Newport Crescent; Linnet Lane; Island Road; Townsend Place; Knitting Mill Creek; Free School Creek; East River; Ryan Resilience Lab; Werowocomoco; Berkeley Plantation; Jamestown Beach



Strategy: Elevate marsh to persist in place

Methods:

- Increase the elevation of the marsh to the greatest extent possible, while still allowing regular flooding of the low marsh.
- Where marsh migration is not possible or preferred, maintain the elevation of marsh over time, through the manual addition of sediment and wetlands species.

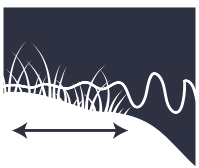
Case Studies: Sarah Creek; Little Creek; Poquoson River; Port Haywood; Ryan Resilience Lab; Werowocomoco; Nassawadox Creek; Berkeley Plantation

Designing for Coastal Hazards

Protecting shorelines and banks from erosion due to wave energy is a primary function of living shorelines. As previously discussed, wave energy is determined by a combination of factors and dictates the type and size of materials and structures needed to protect the shore and upland. Living shorelines do not prevent tidal flooding from storm events, but can lessen the impacts of flooding by reducing the wave energy before it reaches the bank and upland, thereby helping to preserve the marsh and adjacent upland property.

Hardened shoreline structures, such as bulkheads and revetments, reflect wave energy, which can lead to scour at the base of the structure, impacts to neighboring properties, and scour behind the structures. Unlike hardened structures, living shorelines are considered resilient practices because of their ability to recover following storm events.

The following design strategies should be considered when developing a living shoreline project that will persist in the face of coastal hazards and adapt to future environmental conditions. Not all strategies will be appropriate for all sites and practitioners should evaluate all site-specific conditions when determining the appropriate living shoreline design for a particular site.

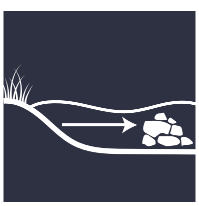


Strategy: Increase marsh width to enhance wave attenuation

Methods:

- Create as wide (distance from mean low water to the top of the bank) a marsh as possible. This provides more space for wave attenuation to occur.
- Establish dense stands of marsh grasses with initial plantings installed at 12" to 18" on center spacing, maximum. Fertilize with slow-release fertilizer at planting (Priest, 2017), particularly when planting directly in sand fill.

Case Studies: Sarah Creek; Hoffler Creek; Little Creek; Poquoson River; Hermitage; Milford Haven; Port Haywood; Ryan Resilience Lab; Killman Cove; Captain Sinclair; False Cape State Park; Werowocomoco; Nassawadox Creek; Jamestown Beach



Strategy: Place sills channelward of MLW to increase width and longevity of the intertidal zone

Methods:

- If feasible and permittable, it may be advantageous to place the sill channelward of MLW and backfill with sand to decrease nearshore depths in the short term, thus resulting in shallower depths in the future. Placing the sill as far from the bank as possible maximizes the space between where waves break and the bank.

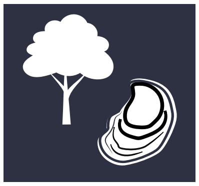
Case Studies: Money Point: Phase 1; Hermitage; Ryan Resilience Lab

Strategy: Design robust sills or breakwaters to reduce future anticipated storm energy

Methods:

- Design and build to be as protective for the most severe current and future conditions possible, as budget, regulations, and site conditions allow.
- Where sediments can support the weight, increase the material size used in constructing sills. Heavier material is less likely to be displaced by wave action.

Case Studies: Island Road; Free School Creek; East River; Ryan Resilience Lab; Killman Cove; False Cape State Park; Werowocomoco; Nassawadox Creek; Berkeley Plantation; Jamestown Beach; Occohannock on the Bay



Strategy: Use multiple nature-based solutions to reduce erosion

Methods:

- If site conditions are favorable for oyster recruitment, consider oyster structures, or constructing sills out of materials that maximize oyster survivability. As a living component that will respond to changing water levels, oysters may migrate vertically and landward if appropriate substrate is available, or they may accrete on structures fast enough to keep pace with sea level rise.
- Restore the upland buffer to provide additional protection to upland structures. Buffers will dissipate wave energy in the same manner as marshes, and restoring the buffer extends this mechanism in the upland.

Case Studies: Newport Crescent; Sarah Creek; Linnet Lane; Money Point Phase 1; Island Road; Townsend Place; Hoffler Creek; Poquoson River; Milford Haven; Port Haywood; East River; Killman Cove; Poplar Grove

Strategy: Stabilize slopes to reduce erosion from wave energy

Methods:

- Manage the bank slope to lessen storm impacts. Where bank height exceeds the elevation of sand fill and grading is not an option, consider terracing of the bank to reduce the slope. VIMS recommends minimally a 3:1 bank slope. (Hardaway, et. al., 2021).
- Establish or maintain vegetation on the bank to attenuate wave and runoff energy and help hold soils in place.

Case Studies: Little Creek; Poquoson River; Knitting Mill Creek; Milford Haven; Captain Sinclair; Poplar Grove; Werowocomoco; Nassawadox Creek; Berkeley Plantation; Occohannock On The Bay

Other Considerations

Shorelines are dynamic systems that change over time, however, the function and benefits of living shorelines can be prolonged by performing routine maintenance and monitoring for long-term adaptive management. Virginia does not require monitoring beyond the initial establishment period of the marsh, except in specific case-by-case circumstances. Periodic monitoring of a living shoreline will identify when routine maintenance or adaptive management may be necessary. The VIMS ShoreWatch app may be a good resource to catalog and monitor long term change. Maintenance tasks may include replanting marsh grasses, removing wrack lines, and managing overhanging tree limbs that may shade out marsh plantings. Adaptive management strategies to help the wetlands persist in place and evolve at a pace equal with sea level rise and coastal hazard frequencies may include adding sand/sediment fill, adding plants, and increasing sill heights. If future water levels will require fill beyond the current jurisdictional boundaries to maintain a gradual slope, adaptive management strategies should be considered. Additionally, managing stormwater runoff from the upland over time is critical to protect against the erosion of the shoreline, which could weaken the effectiveness of the living shoreline. Changes in waterfront use, whether upstream or downstream, such as adding a new marina or fishing pier, can impact a living shoreline site by increasing wave action and turbidity. The practitioner is advised that some of these recommended activities may require additional future regulatory approval.

Case Studies

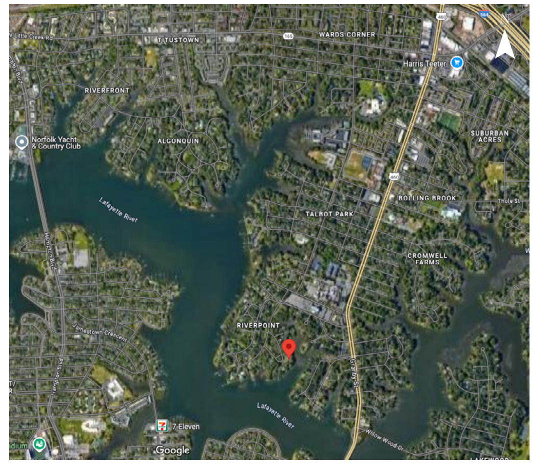
The case studies provided here do not represent a Work Group endorsement of any specific living shoreline or erosion control approach. These examples are provided to offer an idea of how these strategies can be employed in the field to protect natural shoreline resources from the impacts of sea level rise and coastal hazards. Case studies have been formatted to be as consistent as possible. If available, complete permit applications and other supporting documentation for each case study is linked in the Appendix. Case studies are organized according to the level of protection needed for each site.

1. Newport Crescent
2. Sarah Creek
3. Linnet Lane
4. Money Point: Phase 1
5. Island Road
6. Townsend Place
7. Hoffler Creek
8. Little Creek
9. Poquoson River
10. Hermitage
11. Knitting Mill Creek
12. Free School Creek
13. Milford Haven
14. Port Haywood
15. East River
16. Ryan Resilience Lab
17. Killman Cove
18. Captain Sinclair
19. Black Marsh Farm
20. Poplar Grove
21. False Cape State Park
22. Werowocomoco
23. Nassawadox Creek
24. Berkeley Plantation
25. Jamestown Beach
26. Occohannock On The Bay

Photo by Karen Duhring/VIMS

Newport Crescent

Location	Norfolk
Waterway	Lafayette River
Permit	Living Shoreline General Permit, Group 2
Year Built	2023
Key Partners	Chesapeake Bay Foundation & Elizabeth River Project
Major Storms	N/A



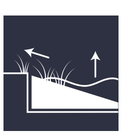
Project Description:

A 123-linear foot (1,048 square feet) living shoreline project. Prior to the installation of the living shoreline sill, the dilapidated wooden bulkhead needed to be removed. Also, since the top layer of the existing rubble sill had live oysters, we moved them two feet channelward to create a base for loose oyster shells. The project involved installing 123 linear feet of 16-inch coir logs secured with 80 five-foot wood stakes, crossed at the top and tied with twine. We then placed 200 bushels of loose recycled oyster shells channelward of the coir logs, followed by backfilling with 184 cubic yards of Vulcan's white sand. We varied the sand elevations based on the type of vegetation being planted in specific areas. For elevation, we used *Iva frutescens* as the biological indicator for *Juncus roemerianus* and *Spartina patens*. We also utilized the small existing patch of *Spartina alterniflora* as the biological indicator for itself. After two tidal cycles, we planted 300 *Spartina alterniflora* plugs, 162 *Spartina patens* plugs, and 373 *Juncus roemerianus* plugs.

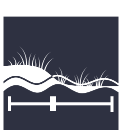
In the spring of 2024, 700 square feet of the mowed lawn was converted into a vegetated buffer, including Marsh Mallow, Northern Sea Oats, Pink Muhly Grass, Seaside Tansey (Sea Oxide), Little Bluestem, and Blue Wild Indigo.

The shoreline project was completed over the span of two weeks, and the buffer was completed in two days. All work was done via volunteer labor.

Adaptive Strategies:



Create stable slopes that promote marsh migration



Design planting zones to plan for migration

Use multiple nature-based solutions to reduce erosion

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Coir logs & loose oyster shell			
Year Constructed	New (2023)			
Fetch	Very low (<0.5 mi)			
Exposure	Low			
Shore Orientation	SE/E			
Erosion Rate	Low (-1 to -2 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Silt			
SAV Present	No			
Shore Length	123 linear ft			
Shore Morphology	Headland			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Tide Range	2.6 to 2.8 ft			
Sill Height	16 in			
Mean Low Water	-0.5 ft			
Mean High Water	2.8 ft			
Upper Limits Tidal Wetland	11.75 ft (*Iva frutescens*)			
Storm Surge	10 yr: 5.5 ft	50 yr: 6.9 ft	100 yr: 7.5 ft	
Expected Sea Level Rise (+MHW)	2020: 1.02 ft	2040: 1.87 ft	2060: 3.06 ft	2080: 4.57 ft
Proximity of Upland Structures	36.81 ft			
Adjacent Shoreline(s)	Defended bulkhead and riprap			

Site Condition	Pre-Construction	Post-Construction
Slope	Steep (3:1)	Low (10:1)
Bank Height	Low	Low (+/- 2 ft)
Low Marsh	Transitional (148 ft^2)	Stable (372 ft^2 of *Juncus roemerianus* and 461 ft^2 of *Spartina alterniflora*)
High Marsh	Transitional (449 ft^2)	Stable (1,607 ft^2)
Buffer Condition	Vegetated (mowed lawn)	Vegetated (native wetland grasses and perennial flowers)
Shore Width	Narrow (7.5 ft)	Wide (19 ft)

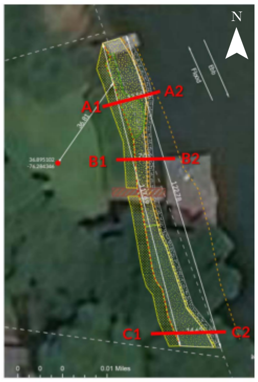
Useful Life Factors:

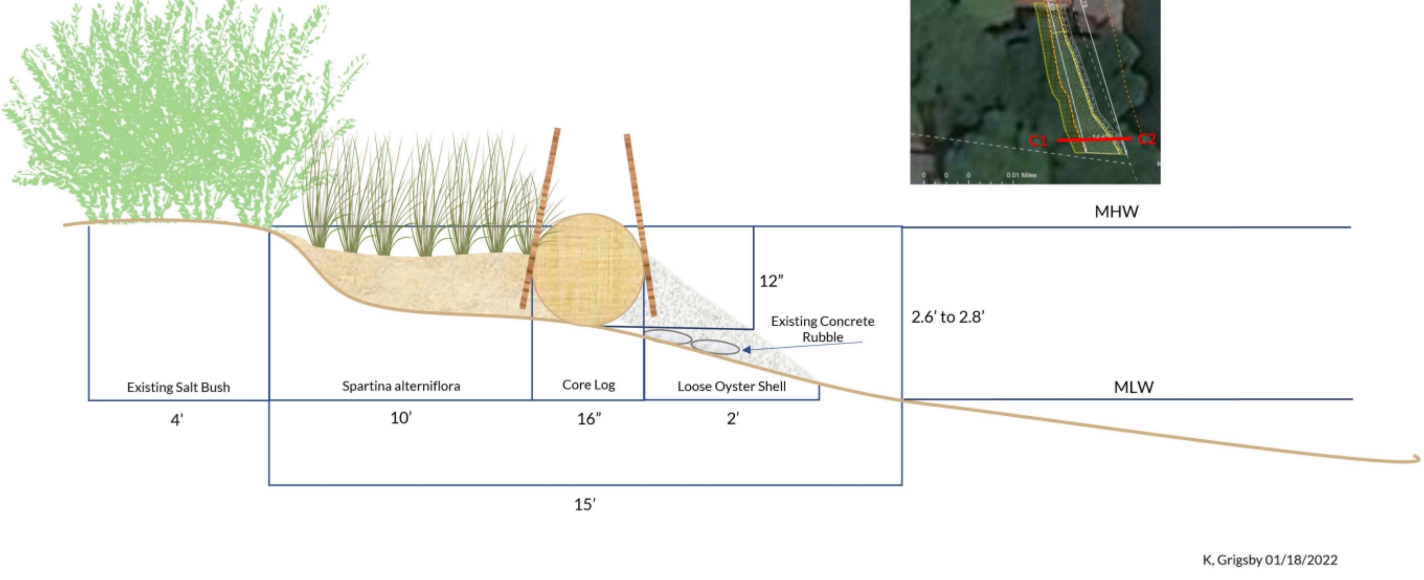
Chesapeake Bay Foundation and Elizabeth River Project have established a maintenance agreement with the homeowner to ensure the project functions as intended for 10 years after installation.

Site Challenges:

Challenge: A dilapidated wooden bulkhead and dock needed to be removed without excessive damage or disturbance to the site, and shoreline stabilization needed to be added.
Solution: Hand tools like a saw and sledgehammer were used for careful and controlled removal, minimizing site disturbance. 74 linear feet of 16-inch coir logs were installed and anchored after bulkhead removal. Sand backfilling and 462 *Spartina alterniflora* were planted to establish a new wetland buffer.

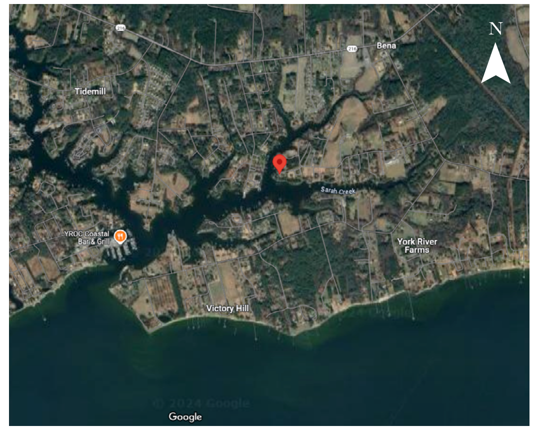
Challenge: Live Oak shading out a portion of the project.
Solution: Plant *Juncus roemerianus*





Sarah Creek

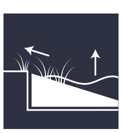
Location	Hayes
Waterway	Sarah Creek
Permit	Living Shoreline General Permit, Group 2
Year Built	2022
Key Partners	Knee Deep Shoreline Consulting
Major Storms	N/A



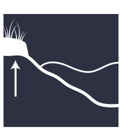
Project Description:

A 270-linear-foot oyster shell bag sill is proposed 20 feet channelward of an eroding low bank, with 128 cubic yards of coarse sandy fill placed landward to raise the marsh substrate and support a wider vegetated marsh fringe. The shell bags, measuring 18” long x 8” wide x 6” high, will be stacked four layers high with staggered joints for structural integrity, creating a 24” high structure aligned landward of mean low water. The sand will be placed at mid-tide elevation at the sill and slope landward, not exceeding 1.5 times the tide range above mean low water. Existing *Spartina alterniflora* will grow through the sand where suitable, and additional *Spartina alterniflora* will be transplanted landward of the sill, with *Spartina patens* planted between mean high water and the existing bank.

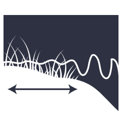
Adaptive Strategies:



Create stable slopes that promote marsh migration



Elevate marsh to persist in place



Increase marsh width to enhance wave attenuation

Use multiple nature-based solutions to reduce erosion

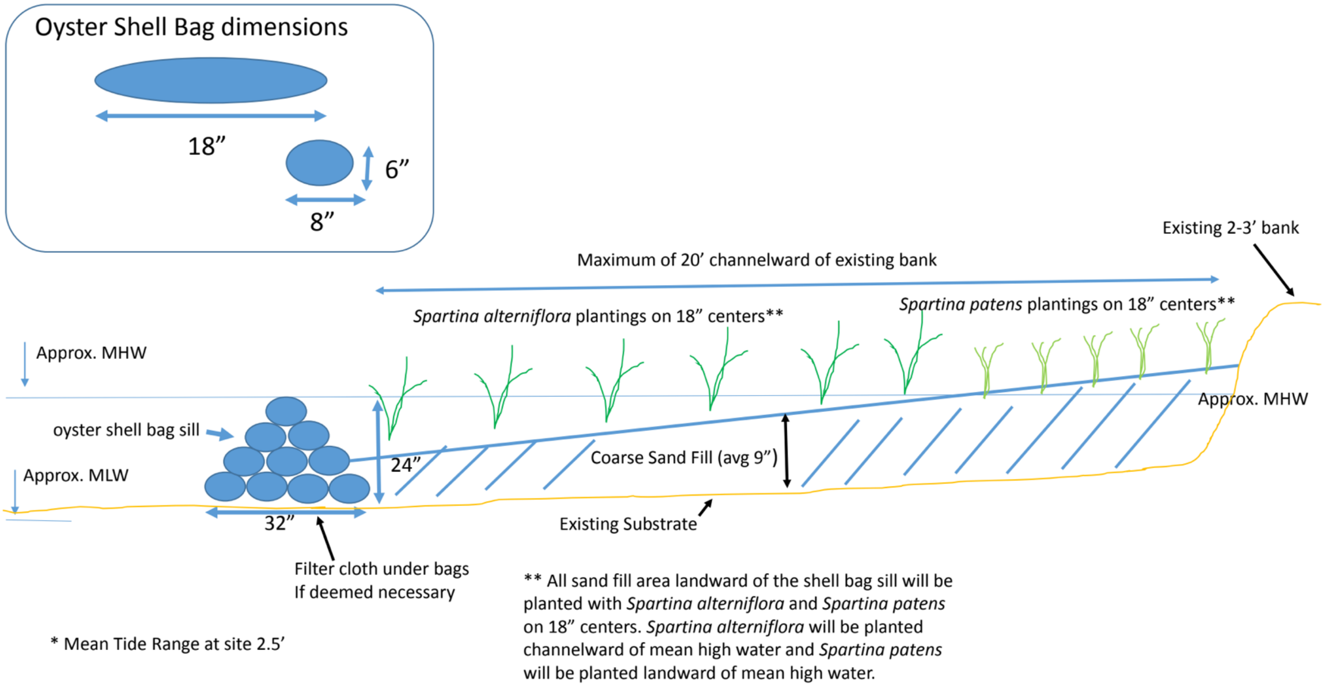
Site Parameters

Wetlands Type	Saltwater			
Sill Type	Oyster shell bags			
Year Constructed	New (2022)			
Fetch	Low (<1 mi)			
Exposure	Low			
Shore Orientation	S/SW			
Erosion Rate	Very low (0 to -1 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Firm			
SAV Present	No			
Shore Length	270 linear ft			
Shore Morphology	Headland			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.5 ft			
Upper Limits Tidal Wetland	20 ft			
Storm Surge	10 yr: 6.19 ft	50 yr: 7.36 ft	100 yr: 7.85 ft	
Expected Sea Level Rise (+MHW)	2020: 1.24 ft	2040: 2.09 ft	2060: 3.28 ft	2080: 4.79 ft
Proximity of Upland Structures	House, ~150 ft from shoreline			
Adjacent Shoreline(s)	Undefended			

Site Condition	Pre-Construction	Post-Construction
Slope	Low	Low
Bank Height	Low	Low
Low Marsh	Eroded	Stable
High Marsh	Eroded	Stable
Buffer Condition	Vegetated	Vegetated
Shore Width	Wide	Wide

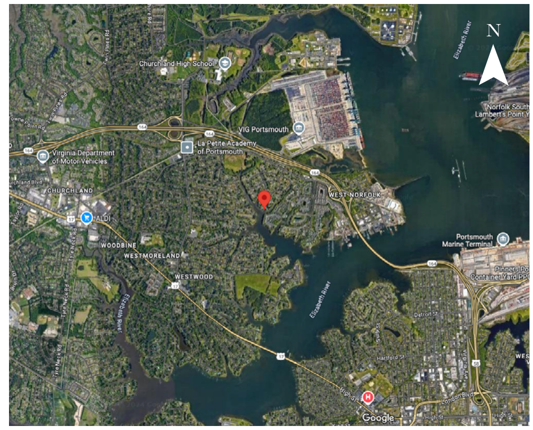
Useful Life Factors:

Large vegetated buffer and gradual slopes promote landward migration of the marsh. Structures positioned approximately 150' from shore and will not impede migration.



Linnet Lane

Location	Portsmouth
Waterway	Elizabeth River - Western Branch
Permit	Living Shoreline General Permit, Group 2
Year Built	2023
Key Partners	Chesapeake Bay Foundation & Elizabeth River Project
Major Storms	N/A



Project Description:

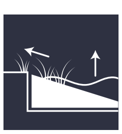
A 718-foot living shoreline project that added 2,967 square feet of native tidal wetland vegetation and 2,521 square feet of oyster reef habitat to the property. To address soft sediment conditions, a base layer of sand (roughly 100 cubic yards) was required to minimize subsidence of the sill structures. This sand layer, along with geotextile filter cloth, was placed before the sill structures, using volunteer labor via wheelbarrow.

The oyster castles, totaling 2,400, were used for the sill structure in areas with the highest erosion rates. These were arranged in three 100 ft sections and two 49 ft sections, with a 5-foot gap between each section. The oyster castles were placed on a diagonal, three castles high (18 inches tall). Additionally, 10-footx16-inch coir logs (28 logs total) were positioned on either side of the oyster castles. A wedge (1 foot tall and 2.5 feet long) of loose oyster shells (2,000 bushels) was placed on the channelward side of the oyster castles and coir logs, and Natrx Basalt Oyster Shell Bags (100 bags) were successfully tested on the project.

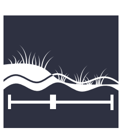
After the sill structures were installed, backfilling was done, using 300 cubic yards of Vulcan White Sand to the elevation where the *Spartina alterniflora* was currently growing. The sand was placed via EQR's Sand Thrower. Following the backfill, 3,000 *Spartina alterniflora* plugs were planted (1 foot on center).

In October of 2023, a 1,607 sq feet high marsh was planted with salt tolerant species: Persimmon, Sweetbay Magnolia, Southern Wax Myrtle, Bayberry, Swamprose Mallow, Saltbush, *Spartina patens*, and Seaside Goldenrod.

Adaptive Strategies:



Create stable slopes that promote marsh migration



Design planting zones to plan for migration

Use multiple nature-based solutions to reduce erosion

Site Parameters

Wetlands Type	Saltwater			
Sill Type	Natrx basalt shells bags, oyster castles, loose oyster shell & coir logs			
Year Constructed	New (2023)			
Fetch	Very low (<0.5 mi)			
Exposure	Low			
Shore Orientation	S/SW			
Erosion Rate	Very low (0 to -1 ft/yr)			
Bank Composition	Soft sediment conditions			
Nearshore Sediment	Soft sediment conditions			
SAV Present	No			
Shore Length	718 linear ft			
Shore Morphology	Headland			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Tide Range	2.6 to 2.8 ft			
Mean Low Water	-0.0 ft			
Mean High Water	2.8 ft			
Upper Limits Tidal Wetland	>3.2 ft			
Storm Surge	10 yr: 7.5 ft	50 yr: 9.1 ft	100 yr: 9.8 ft	
Expected Sea Level Rise (+MHW)	2020: 0.14 ft	2040: 0.99 ft	2060: 2.18 ft	2080: 3.69 ft
Proximity of Upland Structures	House, 124.24 ft from shoreline			
Adjacent Shoreline(s)	Undefended wetlands/tidal flats			

Site Condition	Pre-Construction	Post-Construction
Slope	Low (10:1 to 6:1)	Low (10:1 to 6:1)
Bank Height	Low (<3 ft)	Low (2.8 ft)
Low Marsh	Transitional	Stable (2,967 ft^2)
High Marsh	Transitional	Stable
Buffer Condition	Vegetated	Vegetated (1,607.3 ft^2)
Shore Width	Wide (>8 ft)	Wide (15 ft)

Useful Life Factors:

Chesapeake Bay Foundation (CBF) and Elizabeth River Project (ERP) have established a maintenance agreement with the homeowner to ensure the project functions as intended for 10 years after installation.

Site Challenges:

Challenge: The soft sediment conditions may have led to subsidence of the sill structures.
Solution: A base layer of sand, along with geotextile filter cloth, will be placed before the installation of the oyster castles sill structures to ensure minimal subsidence.

Challenge: Although volunteers and CBF staff moved 100 tons of Vulcan's "White Concrete Sand" via wheelbarrows to create the sand base layer for the oyster castles, it would have taken several more months to move the additional 300 tons needed for backfilling. CBF and ERP were worried about the damage to the existing wetlands if large equipment was used and Lily Creek was too narrow for a barge to access.
Solution: CBF and ERP hired Environmental Quality Resources (EQR) to test their "Sand Thrower" equipment. This equipment was able to move 200 tons of sand in just two days. It works by utilizing a hopper mechanism that can shoot the sand onto the shoreline with an accuracy of up to 100 feet within a five-foot range. This machinery allowed us to stay out of the wetlands, while saving time and money.

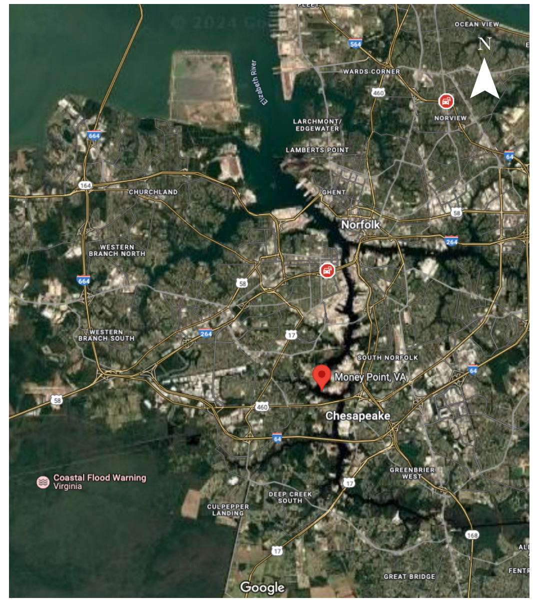
Challenge: Undercutting at the base of oyster castles could lead to the structures tipping into the channel.
Solution: To prevent this from occurring, we positioned the oyster castles diagonally to help disperse the energy from boat wakes. Additionally, we placed a wedge of loose oyster shells at the base of the channelward side of the oyster castles to protect the base from wave energy. This wedge serves to dissipate the wave energy up and over the oyster castle, rather than undercutting at the base. Furthermore, it provides extra intertidal habitat and adds to the aesthetic appeal.

Challenge: In certain areas, the backshore had a four-foot incline next to a shell driveway around 80 feet from the average low water mark. At the same time the shoreline was being installed, the homeowner was also demolishing and replacing a pier. A 16-yard dumpster was placed on the shell driveway to dispose of old pier materials near one of the steepest parts of the backshore. About a week after the shoreline construction, there was heavy rainfall, leading to stormwater runoff from the higher ground hitting the 16-yard dumpster. As the water flowed around the dumpster, it created a channel. This led to sand washing over the oyster castles where the channel met the shoreline.
Solution: Installing silt fencing at the base of the four-foot incline, placing loose oyster shells in the gaps between oyster castles, and planting a buffer between the backshore incline and the shoreline.

Photos by Sue Mangan

Money Point: Phase 1

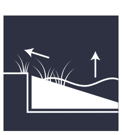
Location	Chesapeake
Waterway	Elizabeth River
Permit	VMRC Subaqueous Permit
Year Built	2009
Key Partners	Elizabeth River Project, Kinder Morgan, AECOM & Bay Environmental, Inc., NOAA Restoration Center
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021), Isaias (8/4/2020), Nestor (10/20/2019), Michael (10/12/2018), Matthew (10/9/2016), Sandy (10/29/2012) & Irene (8/28/2011)



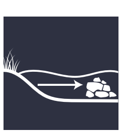
Project Description:

The Money Point area of the Elizabeth River has some of the highest concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) due to historical releases in the 1960s and 1970s, leading to reduced biodiversity and increased rates of liver cancer, lesions, deformities, and cataracts in bottom-dwelling fish. This project aims to remove or contain the contaminated sediment by dredging a 61,630 square yard area to extract approximately 82,197 cubic yards of sediment. The dredged material will be managed through various methods, including bucket dredging, hydraulic pumping, stabilization, and transport to an off-site disposal facility in Charles City County. A 12-inch thick sand layer will be placed over the southern portion of the site to isolate remaining contaminants, followed by the construction of a 10,720 square yard marsh and a 12,000 square yard oyster reef to restore the area.

Adaptive Strategies:



Create stable slopes that promote marsh migration



Place sills channelward of MLW to increase width and longevity of the intertidal zone

Use multiple nature-based solutions to reduce erosion

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	Older (2009)			
Fetch	Low (0.5 to 1 mi)			
Exposure	Low			
Shore Orientation	W/NW			
Erosion Rate	Low (0 to -1 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Firm			
SAV Present	No			
Shore Length	446 linear ft			
Shore Morphology	Pocket			
Nearshore Morphology	Tidal flats			
Datum	NAVD88			
Mean Low Water	-1.70 ft			
Mean High Water	1.27 ft			
Upper Limits Tidal Wetland	Varies			
Storm Surge	10 yr: 5.7 ft	50 yr: 7.2 ft	100 yr: 7.9 ft	
Expected Sea Level Rise (+MHW)	2020: 0.38 ft	2040: 1.23 ft	2060: 2.42 ft	2080: 3.93 ft
Proximity of Upland Structures	>1,000 ft			
Adjacent Shoreline(s)	Defended (industrial)			

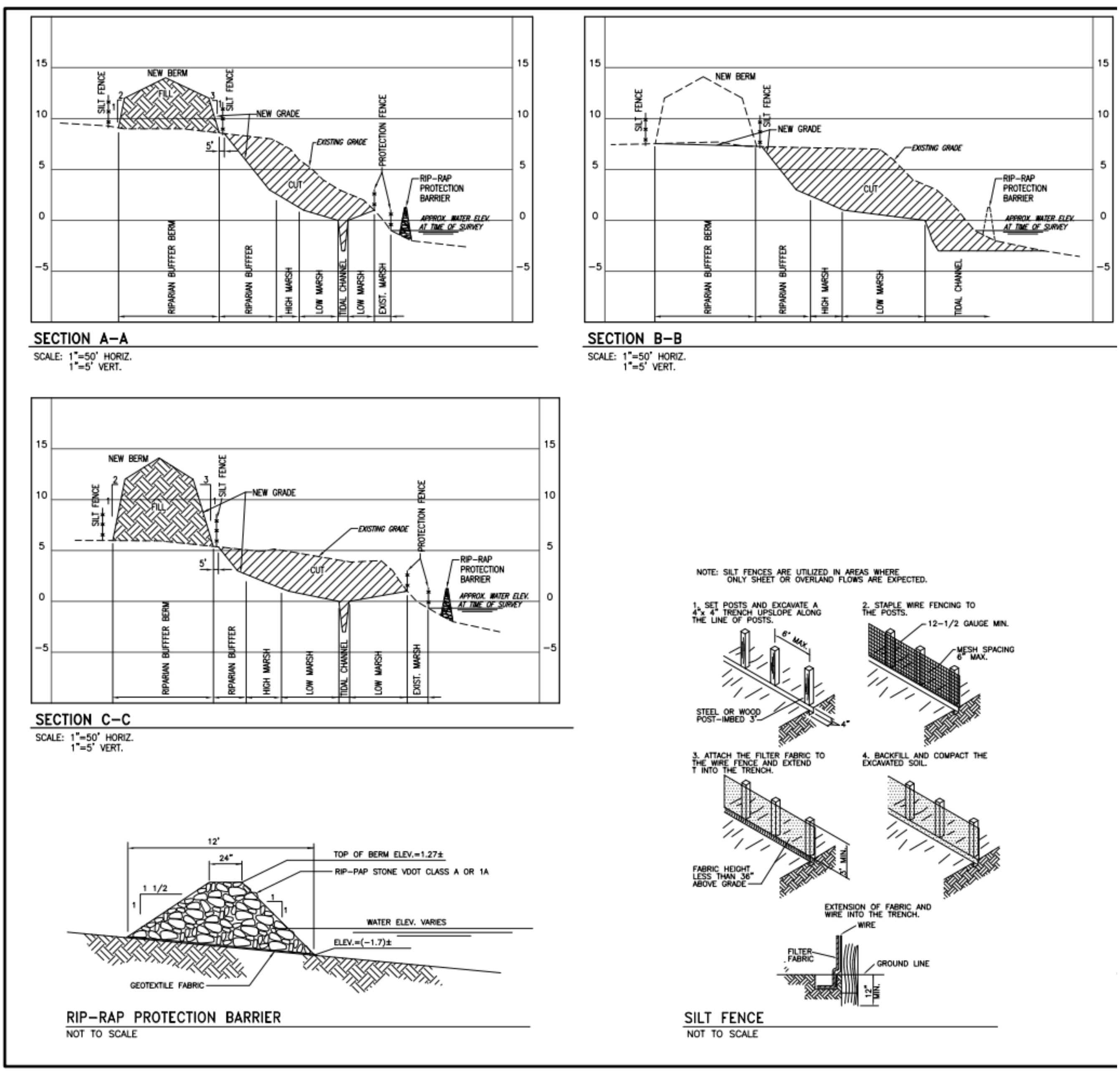
Site Condition	Pre-Construction	Post-Construction
Slope	Low	Moderate (5:1 berm)
Bank Height	Moderate	High (~10 ft)
Low Marsh	Eroded	Stable (-0.26 to -1.27 (NAVD88))
High Marsh	Eroded	Stable (1.27 to 2.6 (NAVD88))
Buffer Condition	Non-vegetated	Vegetated (2.60 ft to match existing grade)
Shore Width	Wide	Wide (>70 ft)

Useful Life Factors:

Slopes were graded and stabilized and will allow for marsh migration to the upland. A large existing vegetated buffer provides space for vegetation to shift landward. Structures are positioned away from the shoreline and should not impede migration.

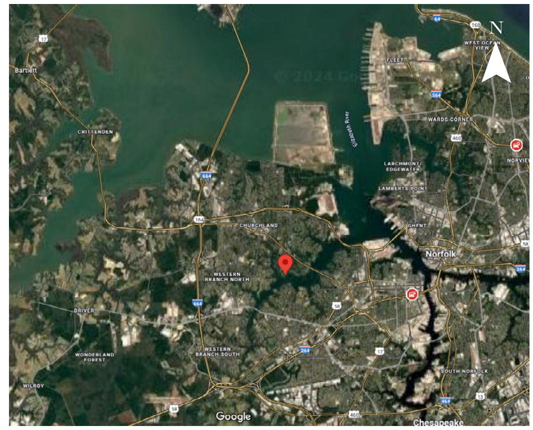
Site Challenges:

Challenge: Contamination from legacy sediment.
Solution: Clean up effort in phase 1 and phase 2; living sand cap allowed for removal of toxic sediment, capping with clean sand and planting with native wetlands.



Island Road

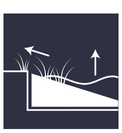
Location	Portsmouth
Waterway	Elizabeth River - Western Branch
Permit	Living Shoreline General Permit, Group 2
Year Built	2021
Key Partners	Elizabeth River Project
Major Storms	N/A



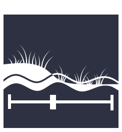
Project Description:

The primary purpose of the project is to protect the existing natural shoreline from erosion through the installation of a living shoreline. The secondary purpose of the project is to restore native wetlands and riparian buffer habitat to the Western Branch Elizabeth River. The project consists of 316 linear feet of living shoreline to include 1,400 sq ft of *Spartina alterniflora* planting, 316 linear feet of oyster castle sill, and 1.500 sq ft of buffer restoration through grading and planting native buffer species along the Western Branch of the Elizabeth River in Portsmouth.

Adaptive Strategies:



Create stable slopes that promote marsh migration



Design planting zones to plan for migration

Design robust sills or breakwaters to reduce future anticipated storm energy

Use multiple nature-based solutions to reduce erosion

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Oyster castles			
Year Constructed	New (2021)			
Fetch	Low (0.5 to 1 mi)			
Exposure	Moderate			
Shore Orientation	SE			
Erosion Rate	Very low (0 to -1 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Firm			
SAV Present	No			
Shore Length	316 linear ft			
Shore Morphology	Irregular			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.70 ft			
Upper Limits Tidal Wetland	4.05 ft			
Storm Surge	10 yr: 5.9 ft	50 yr: 7.5 ft	100 yr: 8.2 ft	
Expected Sea Level Rise (+MHW)	2020: 2.33 ft	2040: 3.18 ft	2060: 4.37 ft	2080: 5.86 ft
Proximity of Upland Structures	Pool, ~147 ft from shoreline			
Adjacent Shoreline(s)	Varies across shoreline (undefended, defended, riprap sill)			

Site Condition	Pre-Construction	Post-Construction
Slope	Steep (2:1)	Moderate (4:1)
Bank Height	High (8 ft)	High (~9 ft)
Low Marsh	Eroded (mudflat)	Stable (1,400 ft^2 vegetated wetlands)
High Marsh	Transitional	Stable
Buffer Condition	Vegetated (turf conversion)	Vegetated (1,500 ft^2 native buffer)
Shore Width	Wide	Wide (10 ft)

Useful Life Factors:

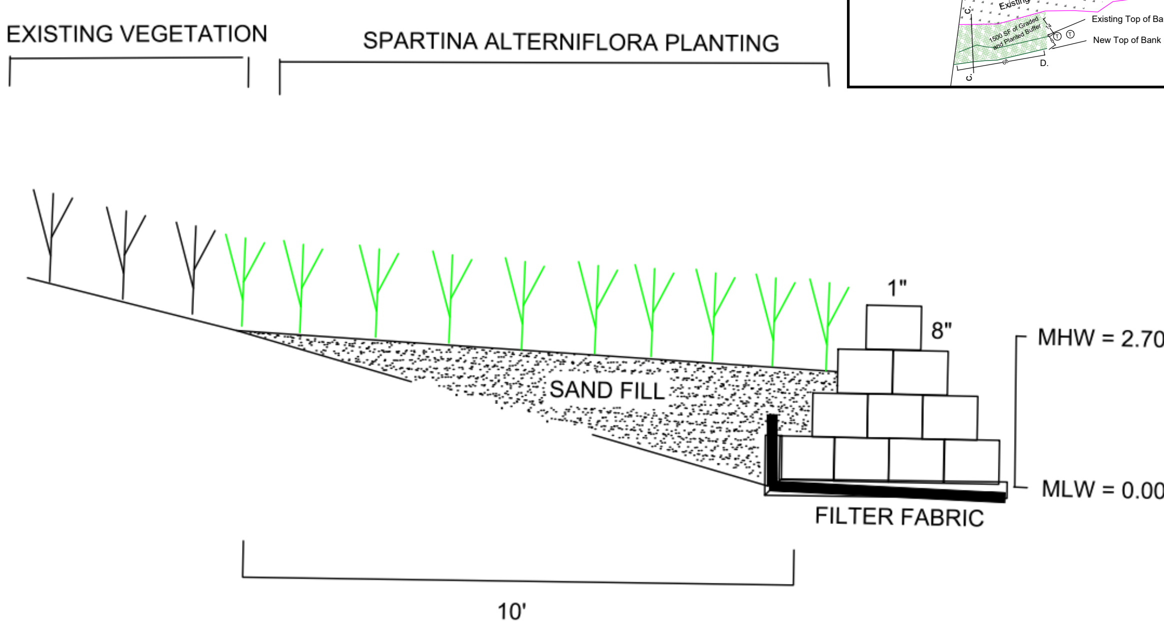
The living shoreline was designed to adapt to sea level rise along the property, with planned landward migration of the wetlands over time. Due to the existing bank height and the home being set far back from the shoreline, the property is generally safe from sea level rise impacts, but the larger fetch and south facing wetland exposes the shoreline to higher waves, winds, and storm damage potential. The project was designed with connection from low marsh to the upland buffer as the key priority. The riparian buffer was designed with a large interspecies planting along the high marsh zone located above MHW. This will allow the marsh to continue to migrate inland, continue to stabilize the soil, and adapt to sea level rise.

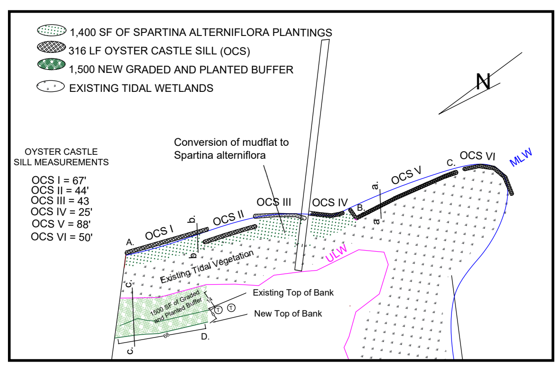
Site Challenges:

Challenge: Bank erosion along the parcel was variable, with the Southern end having moderate erosion along the tidal wetlands. The northernmost end had extreme undercutting along the base of the bank by wave and water action.
Solution: Grading was necessary for the higher bank to be cut and filled for best access to the site and proper elevation for wetlands.

Challenge: Existing tree root exposure and severe soil loss, therefore trees needed removal for grading.
Solution: Elizabeth River Project's solution was to create an extensive riparian buffer to hold the newly-graded bank with native salt tolerant species.

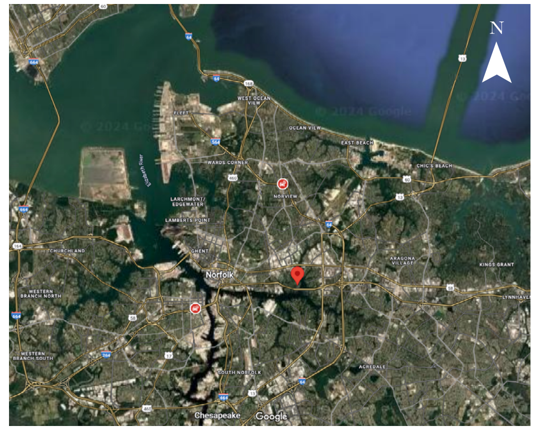
Challenge: Invasive phragmites were taking over parts of the existing marsh.
Solution: A phragmites control plan in the project design and permitting and oversaw contractors for eradication using manual and chemical controls.





Townsend Place

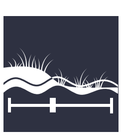
Location	Norfolk
Waterway	Elizabeth River - Eastern Branch
Permit	Living Shoreline General Permit, Group 2
Year Built	2023
Key Partners	Elizabeth River Project
Major Storms	N/A



Project Description:

The Elizabeth River Project installed a living shoreline to re-establish native wetlands, reduce nutrient runoff, and assist with wetlands migration under sea level rise conditions. Two large fallen trees and existing shoreline rubble were removed and replaced with native wetland plants. To prevent future erosion, the project used a 15-ft Oyster Castle Sill stacked three high at the southwest end to tie into the bank. Loose recycled oyster shells were placed seaward of the coir logs, and the area behind was backfilled with clean sand and planted with *Spartina alterniflora*. This 1,800 square ft low marsh area was complemented by a 1,200 square ft high marsh zone with *Spartina patens* and salt bushes. The project created a 3,000 square ft tidal marsh to filter storm-water pollution, provide wildlife habitat, and protect the shoreline from erosion.

Adaptive Strategies:



Design planting zones to plan for migration

Use multiple nature-based solutions to reduce erosion

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Oyster castles			
Year Constructed	New (2023)			
Fetch	Very low (<0.5 mi)			
Exposure	Low			
Shore Orientation	S/SW			
Erosion Rate	Medium (-2 to -5 ft/yr)			
Bank Composition	Urban fill			
Nearshore Sediment	Sand, urban fill			
SAV Present	No			
Shore Length	121 linear ft			
Shore Morphology	Pocket/straight			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.99 ft			
Upper Limits Tidal Wetland	2.99 ft			
Storm Surge	10 yr: 5.7 ft	50 yr: 7.2 ft	100 yr: 7.9 ft	
Expected Sea Level Rise (+MHW)	2020: 0.32 ft	2040: 1.17 ft	2060: 2.36 ft	2080: 3.87 ft
Proximity of Upland Structures	30 ft			
Adjacent Shoreline(s)	Defended			

Site Condition	Pre-Construction	Post-Construction
Slope	Low (7:1)	Low (10:1)
Bank Height	Moderate (3 ft)	High (~9 ft)
Low Marsh	Eroded (very little/none)	Stable (1,800 ft^2)
High Marsh	Eroded (very little/none)	Stable (1,200 ft^2)
Buffer Condition	Non-vegetated (poor, rubble, dead/dying trees))	Vegetated (healthy, no mow restriction)
Shore Width	Wide (~5-10 ft)	Wide (15 ft)

Useful Life Factors:

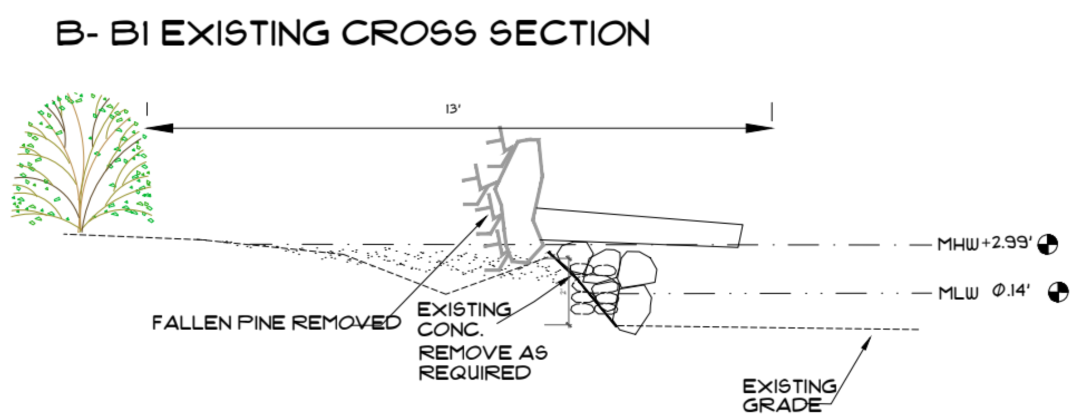
The living shoreline was designed to adapt to sea level rise along the south of the property, with planned landward migration of the wetlands over time. The structure is only 30 feet from the shoreline. Wind waves and boat-generated waves marginally impact the location of the shoreline. The erosion conditions are attributed to high storm water levels, resulting in tree and land loss. A gradual bank slope was created that will allow for both low and high marsh plantings. This project includes a no mow zone included in the design, to allow the high marsh to establish behind the low marsh. This no mow zone allows for the natural transgression of the shoreline, as sea levels rise.

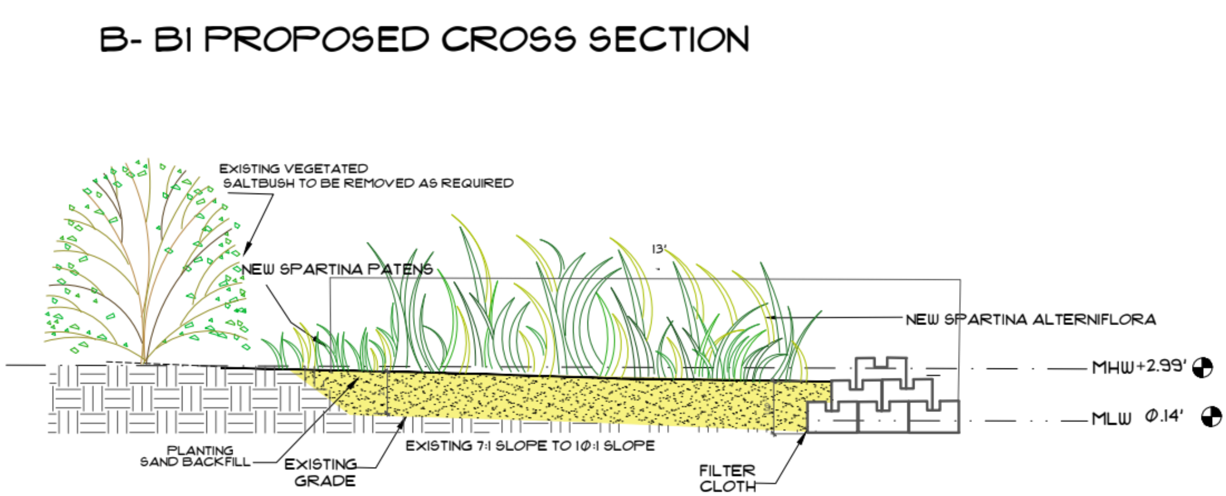
Site Challenges:

Challenge: The first challenge was navigating the sill design and creating a coir logs natural sill. However, a closer look at the neighboring property had *Spartina alterniflora* (biological benchmark) much higher than anticipated.
Solution: We changed the sill to oyster castles to establish a higher elevation for the *Spartina alterniflora*. Incorrect elevation of the planted area can cause widespread failure if it's too low.

Challenge: The second challenge was the large Pine trees that had fallen into the channel. Removal was costly, as well as finding the correct timing for the removal due to protection restrictions for the Northern Long-eared Bat. The protected species limit the time of year that trees can be removed due to the time of roosting.
Solution: We solved the timing by having the trees removed during colder months.

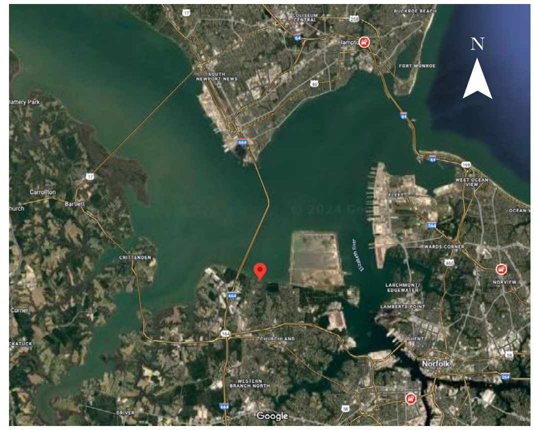
Challenge: The cost of removing large rubble is always a challenge.
Solution: We resolved this with labor from staff and volunteers.





Hoffler Creek

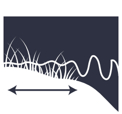
Location	Suffolk
Waterway	Hoffler Creek
Permit	Wetlands Board Permit
Year Built	2023
Key Partners	James River Association, Natrx
Major Storms	N/A



Project Description:

A shoreline covering two parcels where Hoffler Creek enters the James River is experiencing erosion. A living shoreline consisting of NATRX exoforms (oyster structures), coir logs, sandfill, and native marsh plantings is proposed to alleviate current erosion and to prevent future erosion. Large NATRX exoforms will be placed at the mid-tide line on the north side of the property, with three sections of sill covering 232 linear feet. Small NATRX exoforms will be placed at the mid-tide line continuing 222 linear on the east side of the adjacent property, continuing south to the other adjacent property. Total sill impact area is 1,365 sq ft. 3,311 sq ft of unvegetated mudflat will be covered with coarse, clean sandfill and planted with native marsh grass, *Spartina alterniflora*. The primary purpose of this project is to stop erosion and further loss of the properties. The secondary purpose is to create habitat for native wildlife.

Adaptive Strategies:



Increase marsh width to enhance wave attenuation

Use multiple nature-based solutions to reduce erosion

Site Parameters

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Natrx			
Year Constructed	New (2023)			
Fetch	Very high (>15 mi)			
Exposure	High			
Shore Orientation	E/NE			
Erosion Rate	Medium (-2 to -5 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Firm			
SAV Present	No			
Shore Length	455 linear ft			
Shore Morphology	Headland			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.8 ft			
Upper Limits Tidal Wetland	15 ft			
Storm Surge	10 yr: 7.4 ft	50 yr: 9 ft	100 yr: 9.6 ft	
Expected Sea Level Rise (+MHW)	2020: 1.17 ft	2040: 2.02 ft	2060: 3.21 ft	2080: 4.72 ft
Proximity of Upland Structures	Houses, pool, patios, 35-40 ft from high marsh at 11 ft elevation			
Adjacent Shoreline(s)	Defended, revetments			

Site Condition	Pre-Construction	Post-Construction
Slope	Flat (12:1 transitioning to variable bank heights)	Low (10:1 transitioning to variable bank heights)
Bank Height	Moderate (2-5 ft)	Moderate (2-5 ft)
Low Marsh	Eroded	Stable
High Marsh	Eroded	Stable
Buffer Condition	Non-vegetated	Vegetated
Shore Width	Wide	Wide (10 ft)

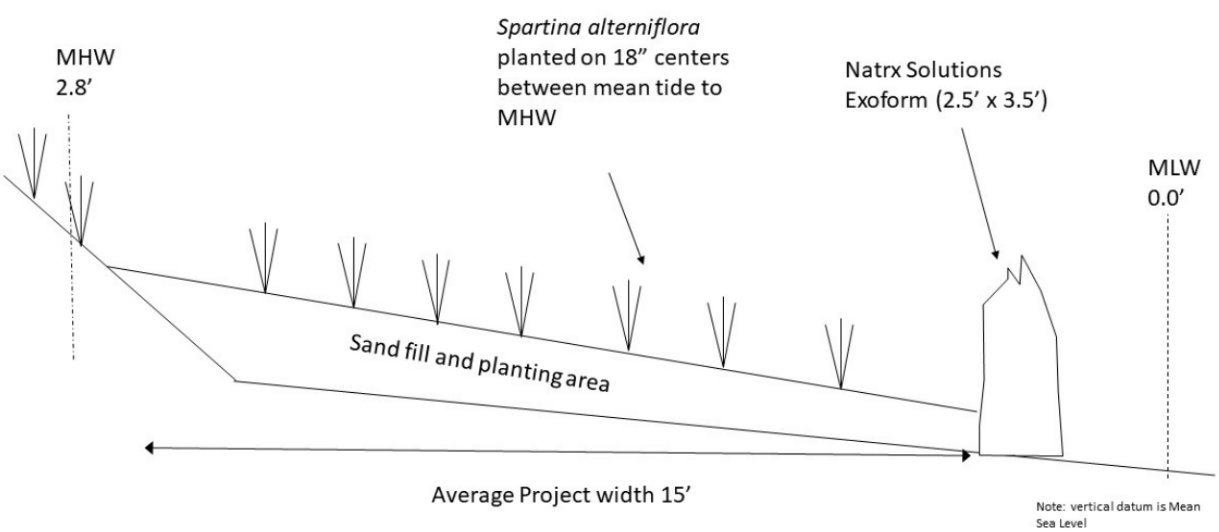
Useful Life Factors:

Sand fill created stable slopes to tie into the bank face, increasing potential for upland migration of marsh zones.

Site Challenges:

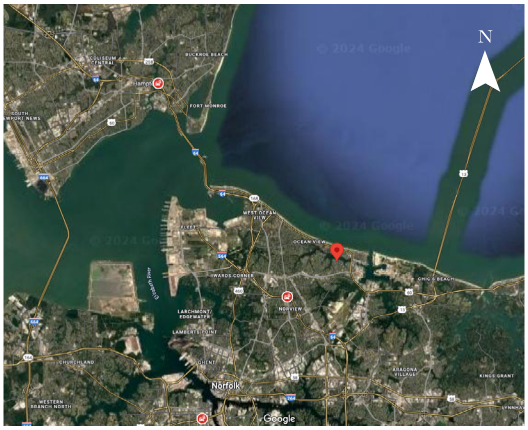
Challenge: Restricted site access for equipment

Challenge: High fetch and wave energy



Little Creek

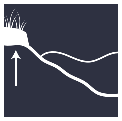
Location	Norfolk
Waterway	Little Creek
Permit	Wetlands Board Permit
Year Built	2018
Key Partners	ReadyReef
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021), Isaias (8/4/2020), Nestor (10/20/2019)



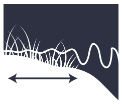
Project Description:

The project involves removal of an existing dilapidated bulkhead and replacement with a new living shoreline utilizing a flexamat (concrete mat) with integrated wetland plantings suitable for site conditions. The wetlands have grown through the flexamat structure, giving the appearance of a naturally vegetated living shoreline.

Adaptive Strategies:



Elevate marsh to persist in place



Increase marsh width to enhance wave attenuation

Stabilize slopes to reduce erosion from wave energy

Site Parameters

Wetlands Type	Saltwater			
Sill Type	N/A			
Year Constructed	Recent (2018)			
Fetch	Very low (<0.5 mi)			
Exposure	Low			
Shore Orientation	N			
Erosion Rate	Low (-1 to -2 ft/yr)			
Bank Composition	Bulkhead			
Wave Climate	Low/boat wake			
SAV Present	No			
Shore Length	142 linear ft			
Shore Morphology	Straight			
Nearshore Morphology	Tidal flats			
Datum	NAVD88			
Mean Low Water	-1.68 ft			
Mean High Water	1.04 ft			
Upper Limits Tidal Wetland	2.44 ft			
Storm Surge	10 yr: 6.8 ft	50 yr: 8.2 ft	100 yr: 8.8 ft	
Expected Sea Level Rise (+MHW)	2020: 3.78 ft	2040: 4.63 ft	2060: 5.82 ft	2080: 7.33 ft
Proximity of Upland Structures	House, 160 ft			
Adjacent Shoreline(s)	Defended			

Site Condition	Pre-Construction	Post-Construction
Slope	Bulkhead	Low
Bank Height	Moderate (3-6 ft)	Moderate
Low Marsh	Eroded (None)	Stable
High Marsh	None	Stable
Buffer Condition	Non-vegetated	Non-vegetated
Shore Width	Narrow	Wide (13 ft)

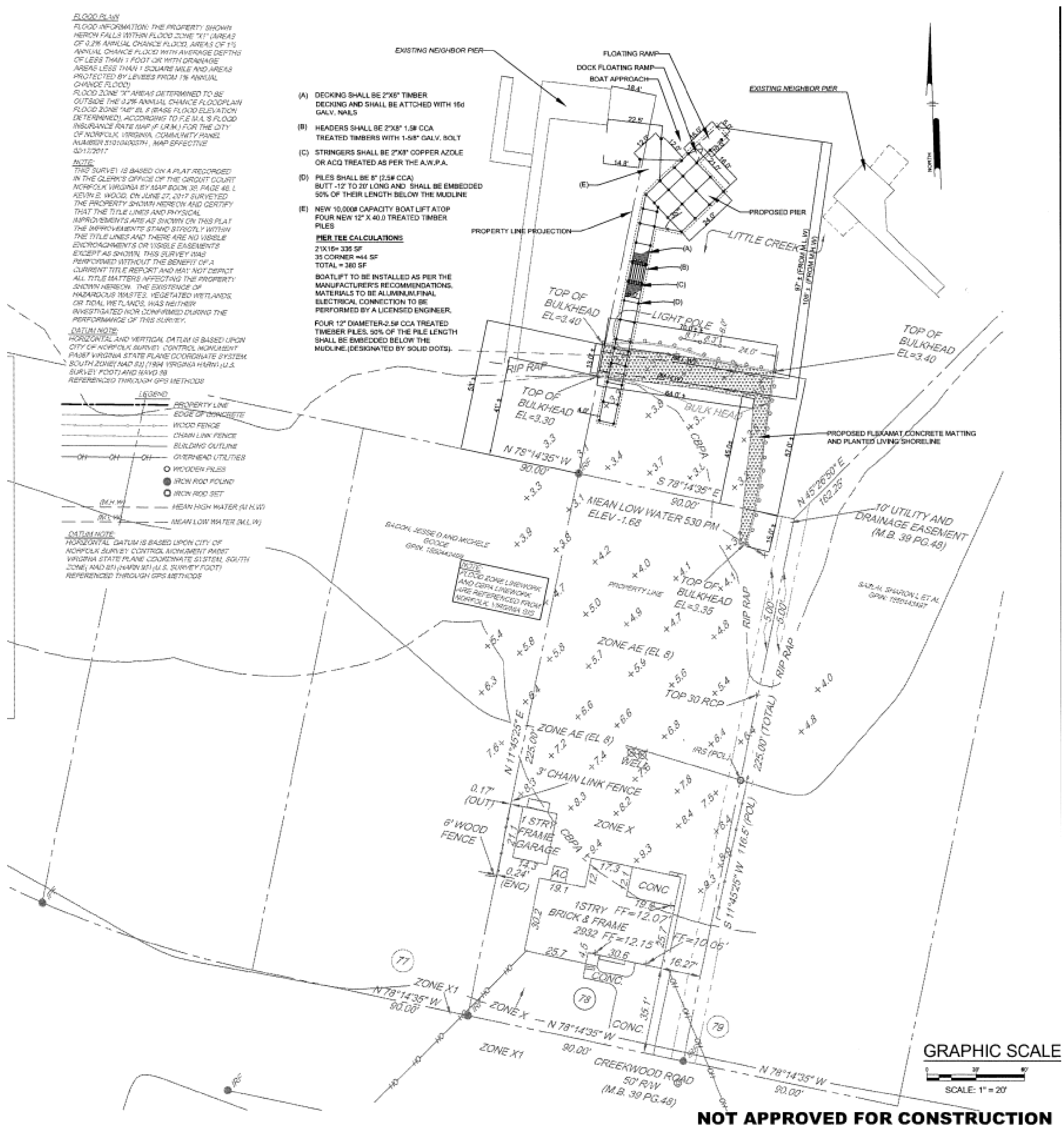
Useful Life Factors:

This project involved removing a bulkhead on two sides of the property. One side was replaced with riprap and the other replaced with flexamat and wetlands vegetation. The structure is located 160 feet from the shoreline, suggesting that the proximity of the structure was not a factor in limiting the useful life of the project.

Site Challenges:

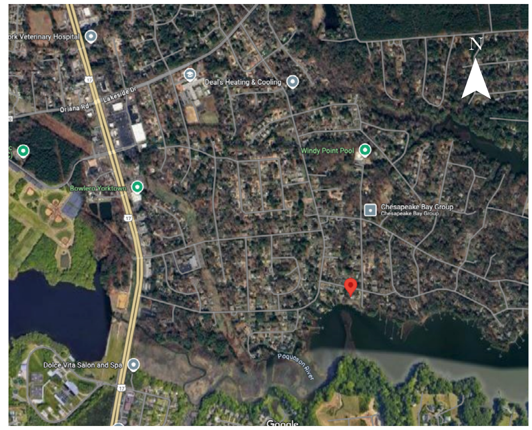
Challenge: Prior to the project, there was significant scour behind the bulkhead of the property, due to erosive forces, such as boat wake and sea level rise.

Solution: The combination of riprap on the creek side of the property and flexamat on the river side of the property stabilized the shorelines, reducing the negative impact of the erosive forces.



Poquoson River

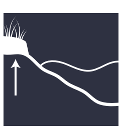
Location	York
Waterway	Poquoson River
Permit	Wetlands Board Permit
Year Built	2019
Key Partners	ReadyReef
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021), Isaias (8/4/2020)



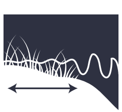
Project Description:

The primary purpose of the project is to protect the property from erosion caused by boat wakes and relative sea level rise. The secondary purposes of the project are to establish an oyster community reef to provide marine habitat along with oysters and mussels to help clean the water, restore an active width of *Spartina* grasses along the whole shoreline, and provide an upward path for grasses.

Adaptive Strategies:



Elevate marsh to persist in place



Increase marsh width to enhance wave attenuation

Stabilize slopes to reduce erosion from wave energy

Use multiple nature-based solutions to reduce erosion

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	ReadyReef			
Year Constructed	Recent (2019)			
Fetch	Low (0.5 to 1 mi)			
Exposure	Low			
Shore Orientation	S			
Erosion Rate	Very low (0 to -1 ft/yr)			
Bank Composition	Clay			
Nearshore Sediment	Sand			
SAV Present	No			
Shore Length	97 linear ft			
Shore Morphology	Creek			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0			
Mean High Water	Unknown			
Storm Surge	10 yr: 6.3ft	50 yr: 7.4 ft	100 yr: 7.9 ft	
Expected Sea Level Rise (+MHW)	2020: 1.03 ft	2040: 1.72 ft	2060: 2.58 ft	2080: 3.63 ft
Proximity of Upland Structures	~110 ft			
Adjacent Shoreline(s)	Undefended (brush)			

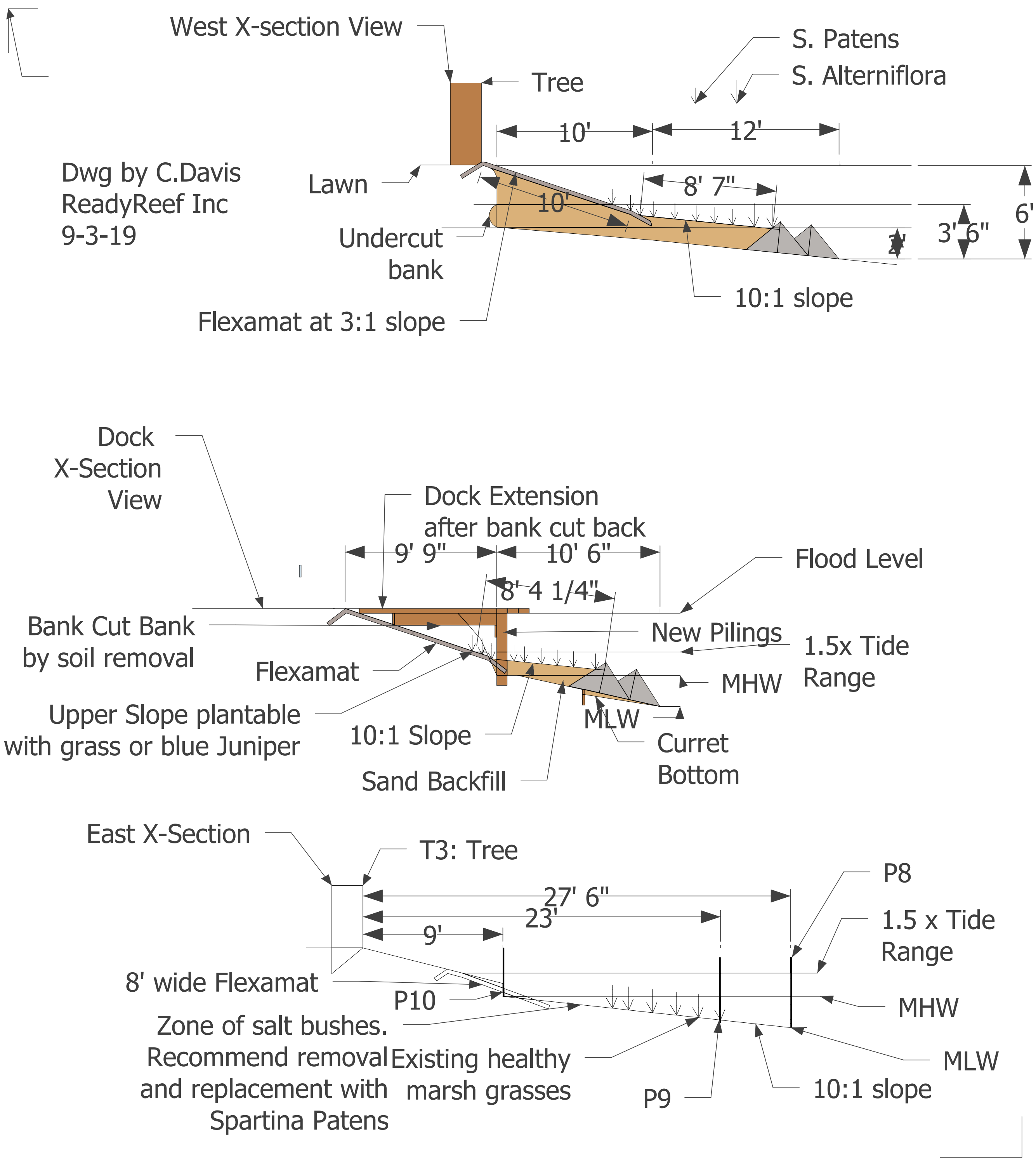
Site Condition	Pre-Construction	Post-Construction
Slope	Steep (3:1)	Steep (3:1)
Bank Height	Moderate	Moderate
Low Marsh	Eroded/None	Stable (10:1)
High Marsh	Transitional	Stable (3:1)
Buffer Condition	Vegetated (shrubs, wetlands)	Vegetated
Shore Width	Wide	Wide

Useful Life Factors:

Increased potential for marsh migration and protection against wave energy from boat wakes.

Site Challenges:

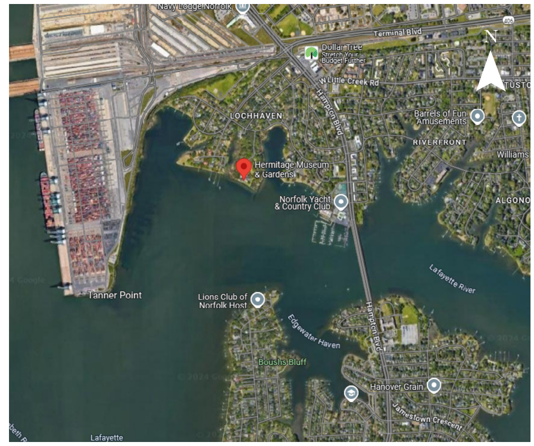
Challenge: Erosion from boat wakes created scour on the shoreline.
Solution: Grading and flexamat were used to stabilize the shoreline conditions.



Received by VMRC on September 5, 2019 /blh

Hermitage

Location	Norfolk
Waterway	Lafayette River
Permit	VMRC Subaqueous Permit
Year Built	2019
Key Partners	Brown & Caldwell, City of Norfolk, Lochhaven Civic League, Ward 1, Superward 6
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021)



Project Description:

This project will provide 1,681 linear feet of shoreline restoration and 1.04 acres of wetland creation/ restoration. The restoration plan for this site includes removing existing concrete along the shoreline and reusing the debris in a sill in order to create tidal wetlands for protection of the adjacent shoreline, specifically some of the eroding banks where existing riparian trees are at risk of falling into the river.

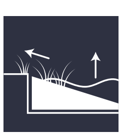
In general, the sill is proposed to be channelward of the mean low water (MLW) elevation to construct adequate slopes for a stable marsh. Due to the proximity of road and utility infrastructure, there is no opportunity to grade the banks landward to place the sill landward of the MLW elevation.

The shoreline condition along the west side of the Lafayette River cove is actively eroding, threatening walking paths, riparian vegetation, open water tidal marsh inlets, and some building infrastructure on the Hermitage Museum property. To limit further impact to these features the sill will also be located channelward of the MLW elevation to provide adequate slopes for stable marshes.

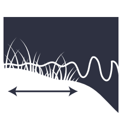
The stormwater outfalls will be incorporated into the restoration work by using a submerged outfall protection design. This design allows for adequate drainage from the existing storm drains while providing water quality treatment through settling and filtering through the restored wetland marsh.

The marsh wetland areas will include clean sand and will be planted with both saltmeadow hay (*Spartina patens*) and saltmarsh cordgrass (*Spartina alterniflora*). Additional native vegetation will be installed along the bank and riparian zone to provide further protection and stabilization to the bank.

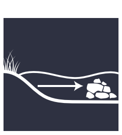
Adaptive Strategies:



Create stable slopes that promote marsh migration



Increase marsh width to enhance wave attenuation



Place sills channelward of MLW to increase width and longevity of the intertidal zone

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	Recent (2019)			
Fetch	Medium (1 to 5 mi)			
Exposure	Moderate			
Shore Orientation	S/E			
Erosion Rate	Very low accretion (+1 to 0 ft/yr)			
Bank Composition	Sand			
SAV Present	No			
Shore Length	1680 linear ft			
Shore Morphology	Pocket			
Nearshore Morphology	Tidal flats			
Datum	NAVD88			
Mean Low Water	-1.47 ft			
Mean High Water	1.2 ft			
Upper Limits Tidal Wetland	2.5 ft			
Storm Surge	10 yr: 7.1 ft	50 yr: 8.5 ft	100 yr: 9.2 ft	
Expected Sea Level Rise (+MHW)	2020: 3.29 ft	2040: 3.98 ft	2060: 4.84 ft	2080: 5.89 ft
Proximity of Upland Structures	60 ft			
Adjacent Shoreline(s)	Defended			

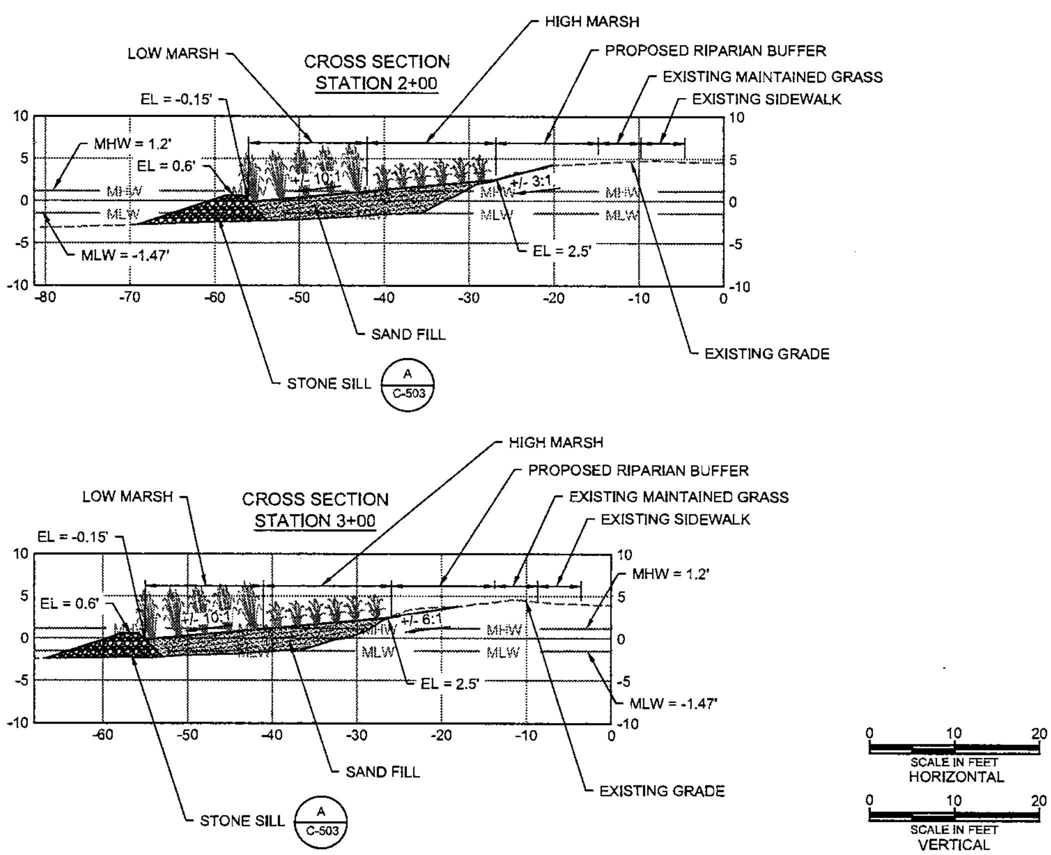
Site Condition	Pre-Construction	Post-Construction
Slope	Moderate and Low	Low
Bank Height	Moderate	Moderate
Low Marsh	Transitional	Stable
High Marsh	Transitional	Stable
Buffer Condition	Vegetated	Vegetated
Shore Width	Wide	Wide

Useful Life Factors:

The presence of significant historical resources and infrastructure will limit the ability of the marsh to migrate landward. The property has a small vegetated buffer that will allow for minimal migration. Adaptive management of marsh elevation could extend the useful life by allowing the marsh to persist in place over time.

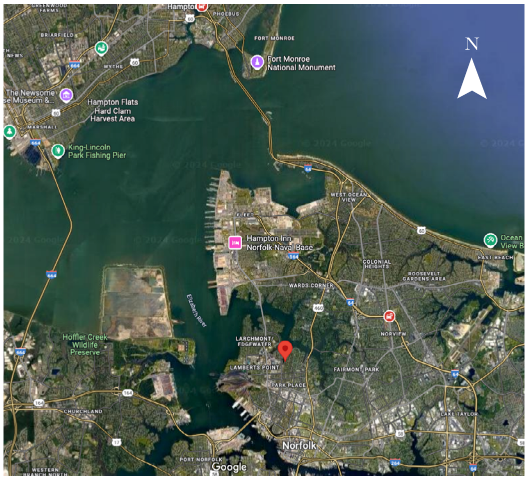
Site Challenges:

Challenge: Several stormwater outfalls were present in the North Shore portion of the project.
Solution: These were addressed by incorporating a submerged outfall protection design.



Knitting Mill Creek

Location	Norfolk
Waterway	Knitting Mill Creek
Permit	VMRC Subaqueous Permit
Year Built	2018
Key Partners	City of Norfolk, Wetland Design and Restoration, Moffat Nichol
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021), Isaias (8/4/2020), Nestor (10/20/2019), Michael (10/12/2018), Matthew (10/9/2016)



Project Description:

The purpose of the project is to improve the eroding shoreline. This will be accomplished by removing the remaining pieces of derelict timber bulkhead and constructing a section of bulkhead to stabilize an improved outfall pipe, sections of revetment, and a section of living shoreline.

Photos by VMRC

Adaptive Strategies:

Create stable slopes that promote marsh migration

Stabilize slopes to reduce erosion from wave energy

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	Recent (2018)			
Fetch	Very low (<0.5 miles)			
Exposure	Low			
Shore Orientation	NW			
Erosion Rate	Very low (0 to -1 ft/yr)			
Bank Composition	Urban fill			
Nearshore Sediment	Silt, sand, urban fill (altavista-urban land complex)			
SAV Present	No			
Shore Length	350 ft			
Shore Morphology	Straight			
Nearshore Morphology	Tidal flats			
Datum	NAVD88			
Mean Low Water	-1.72ft			
Mean High Water	0.95ft			
Upper Limits Tidal Wetland	2.6 ft			
Storm Surge	10 yr: 5.5 ft	50 yr: 6.8 ft	100 yr: 7.5 ft	
Expected Sea Level Rise (+MHW)	2020: 2.0 ft	2040: 2.85 ft	2060: 4.04 ft	2080: 5.55 ft
Proximity of Upland Structures	Mayflower Rd, ~20 ft			
Adjacent Shoreline(s)	Bulkhead, revetment			

Site Condition	Pre-Construction	Post-Construction
Slope	Low (2-6%)	Low (10:1)
Bank Height	Low	Moderate (3.4 ft)
Low Marsh	None	Stable (6.5 feet)
High Marsh	None	Stable (13 feet)
Buffer Condition	Non-vegetated (grass)	Vegetated (grass/walking path)
Shore Width	Narrow	Wide (24 ft)

Useful Life Factors:

The project's proximity to upland structures, the public road and a neighborhood walking trail adjacent to the living shoreline, hindered the ability to expand the low and high marsh beyond predetermined maximum widths. The proximity to the public road and walking path also impacts the potential for significant marsh migration, although persistence of marsh could be achieved through an adaptive management plan.

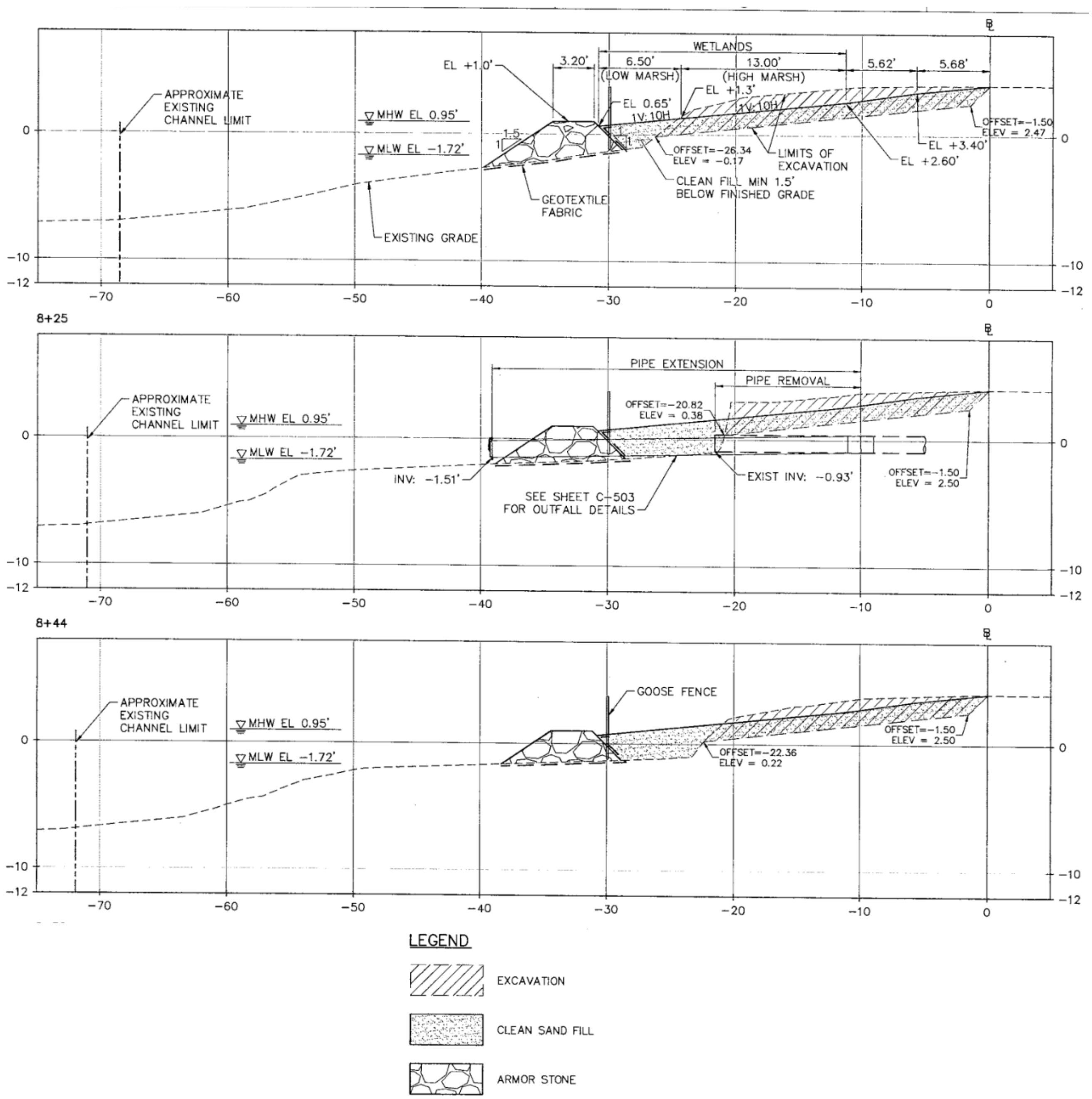
Site Challenges:

Challenge: An adjacent federal channel made permitting along certain parts of the shoreline challenging.

Challenge: Existing timber piles along the shoreline.

Challenge: Urban conditions impacted site access and size of the project.

Challenge: Urban shoreline conditions (rubble, concrete) needed removal for shoreline stabilization.



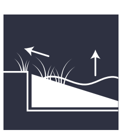
Free School Creek

Location	Gloucester
Waterway	Free School Creek
Permit	VMRC Subaqueous Permit
Year Built	2014
Key Partners	Gloucester County, VDOT, VIMS, NOAA Restoration Center, Chris Clifford, Wetland Design and Restoration
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021), Isaias (8/4/2020), Nestor (10/20/2019), Michael (10/12/2018), Matthew (10/9/2016)

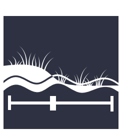
Project Description:

A living shoreline project at John's Point Boat Landing that will protect 300 linear feet of shoreline and utilize a breakwater to create approx. 5,250 sq ft of wetlands.

Adaptive Strategies:



Create stable slopes that promote marsh migration



Design planting zones to plan for migration

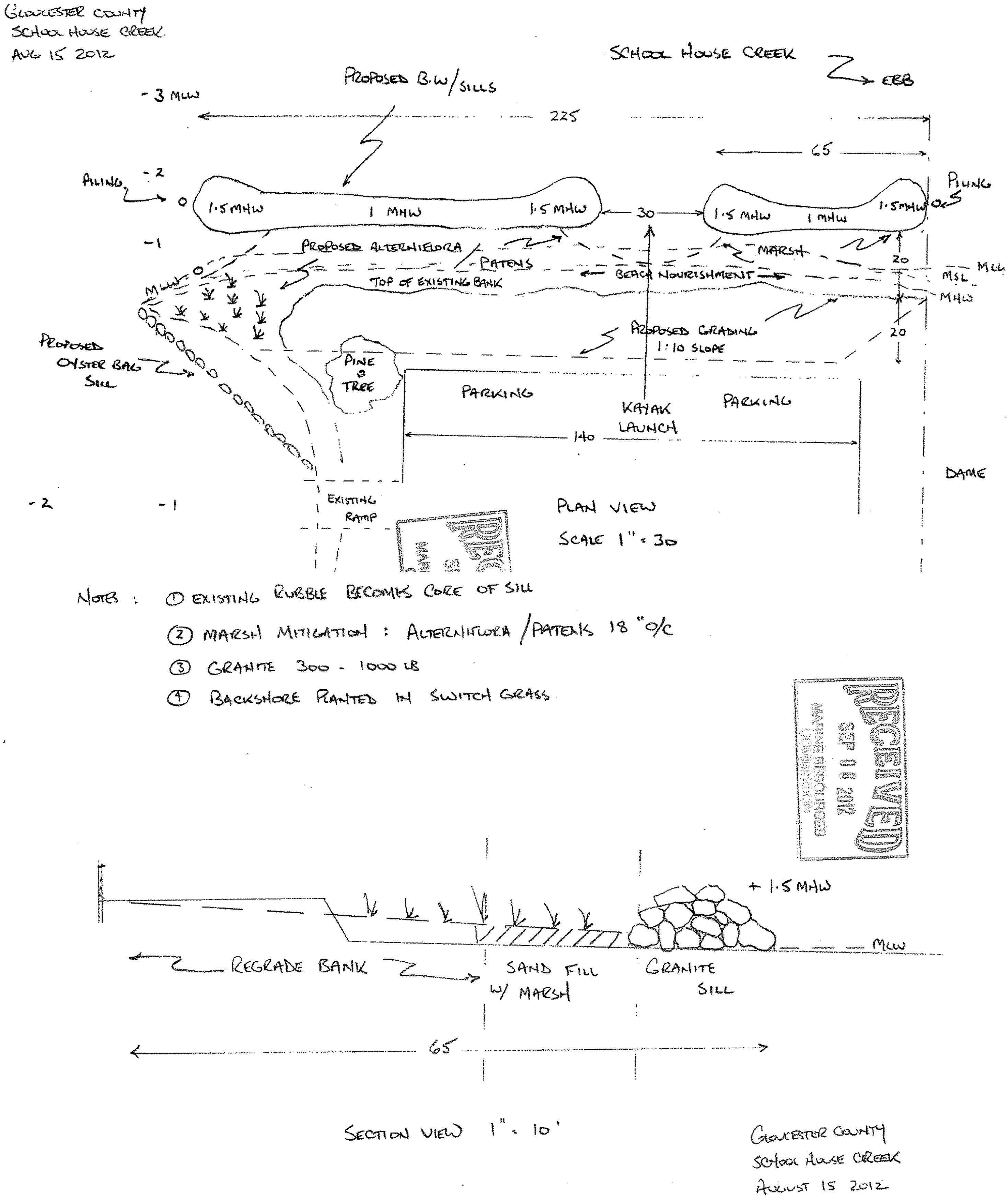
Design robust sills or breakwaters to reduce future anticipated storm energy

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	Recent (2014)			
Fetch	Medium(1 to 5 mi)			
Exposure	Moderate			
Shore Orientation	S			
Erosion Rate	Medium (-2 to -5 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Firm			
SAV Present	No			
Shore Length	265 ft			
Shore Morphology	Headland			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.3 ft			
Upper Limits Tidal Wetland	20 ft			
Storm Surge	10 yr: 6.17 ft	50 yr: 7.2 ft	100 yr: 7.65 ft	
Expected Sea Level Rise (+MHW)	2020: 2.97 ft	2040: 3.82 ft	2060: 5.01 ft	2080: 6.52 ft
Proximity of Upland Structures	Gravel road, ~ 65 ft			
Adjacent Shoreline(s)	Undefended			

Site Condition	Pre-Construction	Post-Construction
Slope	Flat	Low (10:1)
Bank Height	Low	Low
Low Marsh	Eroded	Stable
High Marsh	Eroded	Stable
Buffer Condition	Non-vegetated	Vegetated
Shore Width	Narrow	Wide

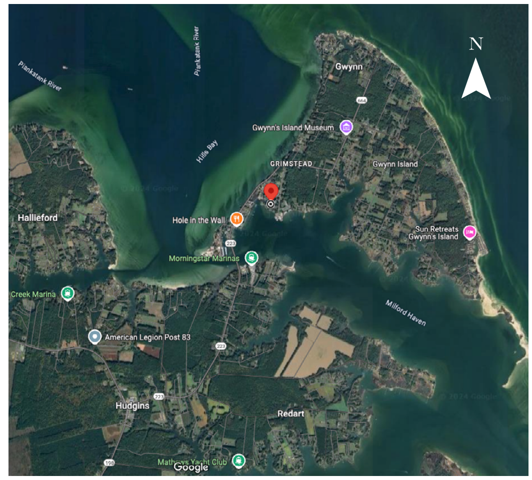
Useful Life Factors:

Vegetated buffer and favorable slope will allow for marsh migration. Upland is undeveloped except for a gravel parking area and will not impede landward shifts in vegetation. Monitoring data since construction has shown expansion of the marsh to approximately 6,661 sq ft.



Milford Haven

Location	Hudgins
Waterway	Milford Haven
Permit	Wetlands Board Permit
Year Built	2021
Key Partners	ReadyReef
Major Storms	N/A

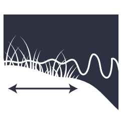


Project Description:

The primary purpose of the project is to prevent erosion from sea level rise and the secondary purpose is to enhance habitat through oyster habitat and wetlands grasses. The project placed 144 ft of 1 ft high Ready Reefs as a sill, backfilled with clean sand on a 10:1 slope, and planted with 1240 sq ft *Sporobolus alterniflorus* along the eroding shoreline. All of this work was above MLW. The reefline will extend 18 sq feet seaward of MLW. Additionally, Envirolok bags will be stacked up close to the bank for erosion control, extending up to the lawn edge for a total of 195 linear feet of bank. *Sporobolus pumilus* will be planted in the 471 sq ft of bag face.

Adaptive Strategies:

Use multiple nature-based solutions to reduce erosion



Increase marsh width to enhance wave attenuation

Stabilize slopes to reduce erosion from wave energy

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	ReadyReef/Envirolok			
Year Constructed	New (2021)			
Fetch	Very low (<0.5 mi)			
Exposure	Low			
Shore Orientation	NW			
Erosion Rate	Very low (0 to -1 ft/yr)			
SAV Present	No			
Shore Length	144 ft ReadyReef; 195 ft Envirolok			
Shore Morphology	Straight			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	1.2 ft			
Upper Limits Tidal Wetland	4 ft			
Storm Surge	10 yr: 3.6 ft	50 yr: 4.6 ft	100 yr: 4.9 ft	
Expected Sea Level Rise (+MHW)	2020: 1.57 ft	2040: 2.42 ft	2060: 3.61 ft	2080: 5.12 ft
Proximity of Upland Structures	House, ~ 40 ft			
Adjacent Shoreline(s)	Undefended			

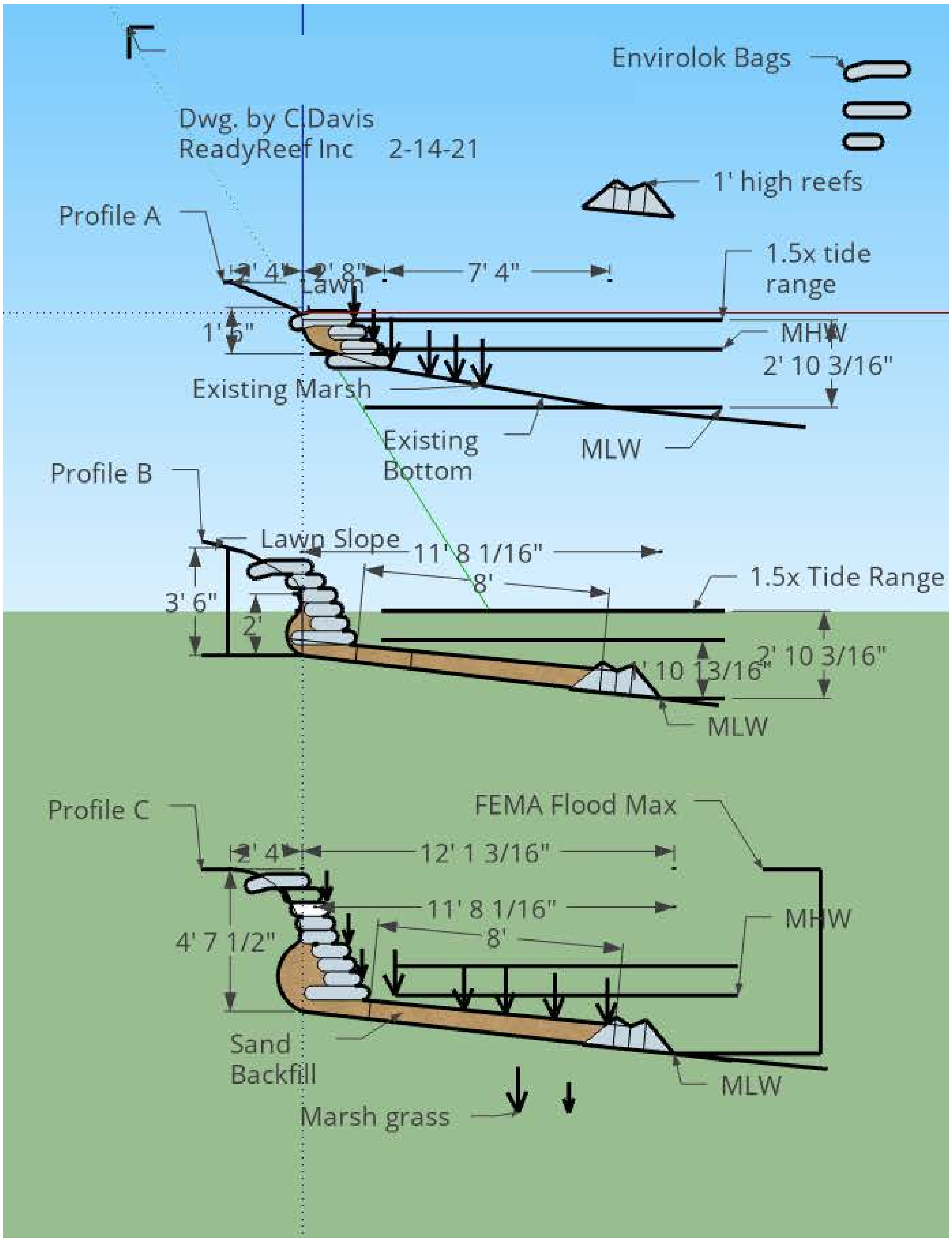
Site Condition	Pre-Construction	Post-Construction
Slope	Moderate	Moderate
Bank Height	Moderate (4.5 ft)	Moderate (4.5 ft)
Low Marsh	Eroded	Stable (1296 sq ft, 8 ft wide)
High Marsh	Transitional	Stable (471 sq ft)
Buffer Condition	Vegetated (lawn)	Vegetated
Shore Width	Wide	Wide

Useful Life Factors:

Erosion from sea level rise scoured the shoreline. The project could allow for migration, but it is unclear whether migration or persistence could occur on the site given the moderate bank height, moderate slope, and receptiveness of the Envirolok bags.

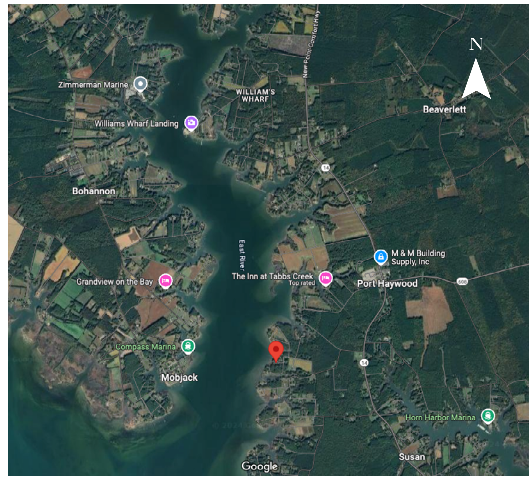
Site Challenges:

Challenge: Proximity to the structure and bank height: bank grading was not possible.



Port Haywood

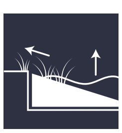
Location	Port Haywood
Waterway	East River
Permit	Wetlands Board Permit
Year Built	2018
Key Partners	ReadyReef
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021)



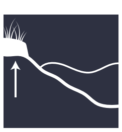
Project Description:

A failing timber bulkhead along the shoreline and around an excavated boat basin was removed and replaced with sand fill, planted salt marsh, and ReadyReef oyster structures. An existing low marsh and natural oysters were incorporated into the design based on advice and encouragement from Tidewater Oyster Gardeners Association (TOGA) and members with living shorelines. Oyster productivity was present at time of construction because the property owner started oyster gardening from the pier in 2007 with no prior oyster strike on the bulkheads or marsh. Five foot bulkhead elevation lift for low marsh migration was removed and replaced with gently sloped low and high marsh into upland. Salt marsh area impacted by the boat basin and concrete boat ramp was restored.

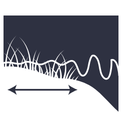
Adaptive Strategies:



Create stable slopes that promote marsh migration



Elevate marsh to persist in place



Increase marsh width to enhance wave attenuation

Use multiple nature-based solutions to reduce erosion

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	ReadyReef			
Year Constructed	Recent (2018)			
Fetch	Medium (1 to 5 mi)			
Exposure	Moderate			
Shore Orientation	NW			
Erosion Rate	Very low (0 to -1 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Firm			
SAV Present	Yes			
Shore Length	126 linear ft			
Shore Morphology	Straight			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.3 ft			
Upper Limits Tidal Wetland	8 ft			
Storm Surge	10 yr: 5.8 ft	50 yr: 6.7 ft	100 yr: 7.1 ft	
Expected Sea Level Rise (+MHW)	2020: 1.61ft	2040: 2.46 ft	2060: 3.65 ft	2080: 5.16 ft
Proximity of Upland Structures	House and shed, 110.5 ft			
Adjacent Shoreline(s)	Varies across shoreline (undefended to the north; revetment to the south			

Site Condition	Pre-Construction	Post-Construction
Slope	Bulkhead	Low (10:1 to 6:1)
Bank Height	High (>6 ft)	Moderate
Low Marsh	Transitional	Stable (17 ft)
High Marsh	Eroded	Stable (11 ft)
Buffer Condition	Vegetated	Vegetated
Shore Width	Narrow	Wide (28 ft)

Useful Life Factors:

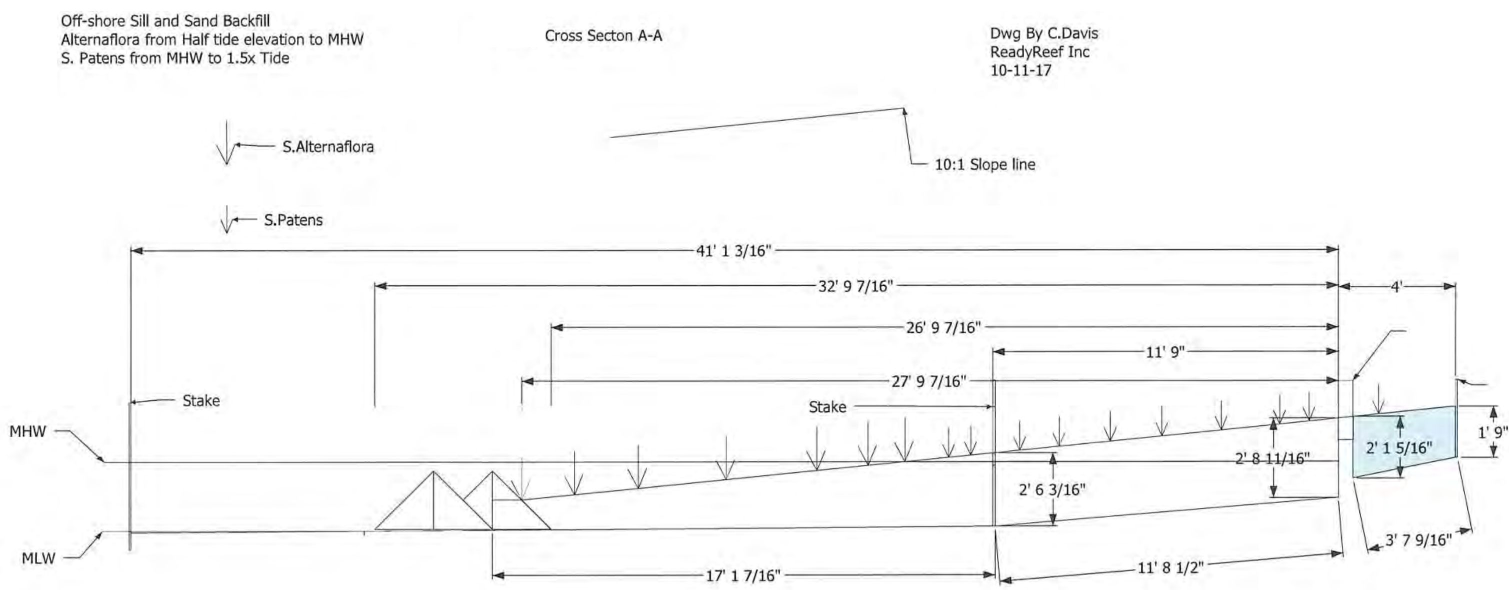
Vegetated buffer and favorable slope provide opportunity for marsh migration.

Site Challenges and Solutions:

Challenge: Existing bulkhead and excavated boat basin with concrete boat ramp partially demolished and covered with sand.

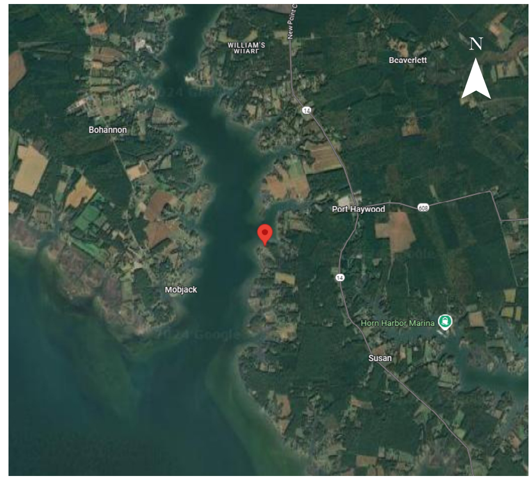
Challenge: Restricted construction access (unpaved, narrow driveway & very shallow nearshore with SAV) required use of construction mats and driveway repairs-restoration.

Challenge: Large pine trees limited bank grading.
Solution: Stormwater runoff addressed with additional materials (coir blankets, plastic edging) and new channel diversion.



East River

Location	Mathews
Waterway	East River
Permit	Wetlands Board Permit
Year Built	2023
Key Partners	Shoreline Structures, LLC, Middle Peninsula PDC, VIMS-Shoreline Studies Program, Natrx
Major Storms	N/A



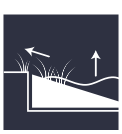
Project Description:

The living shoreline project is designed to protect the upland and rebuild the marsh that has eroded over time, resulting in large mudflats. This property has 3 reaches: 1) an extensive marsh shoreline along the north coast; 2) an eroding upland and marsh between 2 existing revetments (installed by previous owners) on the NW coast; and 3) eroding upland and marsh adjacent to an existing revetment on the SW coast. The NW and SW shorelines have become extensive marshes. Along the NW coast, some areas are eroding at up to -2ft/yr. The nearshore is very shallow along the property with MLW some distance offshore. The 2015-2019 composite coverage map from VIMS shows that SAV comes in close to the shoreline above MLW. To avoid impacts to this intertidal SAV, the Natrx structures were placed closer to shore. To protect the existing marsh and upland, 5 rock sills were constructed along the shoreline with sand fill and marsh planting, including *Spartina alterniflora* and *S. patens*.

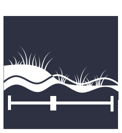
Approximately 10,190 sq ft of wetlands was created/restored along about 570 ft of shoreline. The rocks and Natrx concrete modules provide additional habitat for oysters and other shellfish. Cobble fill was used in an embayment on the NW coast to prevent erosion of the fill from a drainage ditch. The project was designed to interface with the existing marsh, so the existing marsh was not impacted. Along the eroding marshes on the N and SW coasts, Natrx concrete oyster modules were placed along the marsh shoreline. About 150 of these 17 inch wide and 33 inch long concrete structures were placed along 408 ft of shoreline at 0.5 MLW. Oysters are expected to attach to these structures, forming a reef over time.

Adaptive Strategies:

Use multiple nature-based solutions to reduce erosion



Create stable slopes that promote marsh migration



Design planting zones to plan for migration

Design robust sills or breakwaters to reduce future anticipated storm energy

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Natrx Exoforms			
Year Constructed	New (2023)			
Fetch	Medium (1 to 5 mi)			
Exposure	Moderate to high			
Shore Orientation	N/NW/NE			
Erosion Rate	Low (-1 to -2 ft/yr)			
Bank Composition	Peat			
Nearshore Sediment	Firm			
SAV Present	Yes			
Shore Length	570 linear ft			
Shore Morphology	Headland			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.5 ft			
Upper Limits Tidal Wetland	2.5-3.5 ft			
Storm Surge	10 yr: 5.9 ft	50 yr: 6.7 ft	100 yr: 7.2 ft	
Expected Sea Level Rise (+MHW)	2020: 1.45 ft	2040: 2.3 ft	2060: 3.49 ft	2080: 5.0 ft
Proximity of Upland Structures	House, ~230 ft; driveway, 70 ft			
Adjacent Shoreline(s)	Defended by revetments and bulkhead			

Site Condition	Pre-Construction	Post-Construction
Slope	Moderate (variable; 10:1 to 2:1)	Moderate (variable, 10:1 to 4:1)
Bank Height	Low (2-3)	Low (2-3)
Low Marsh	Eroded/None	Stable (10,190 sq ft)
High Marsh	Transitional (2,420 sq ft)	Stable
Buffer Condition	Non-vegetated (Sparse tree canopy/lawn))	Vegetated
Shore Width	Wide	Wide

Useful Life Factors:

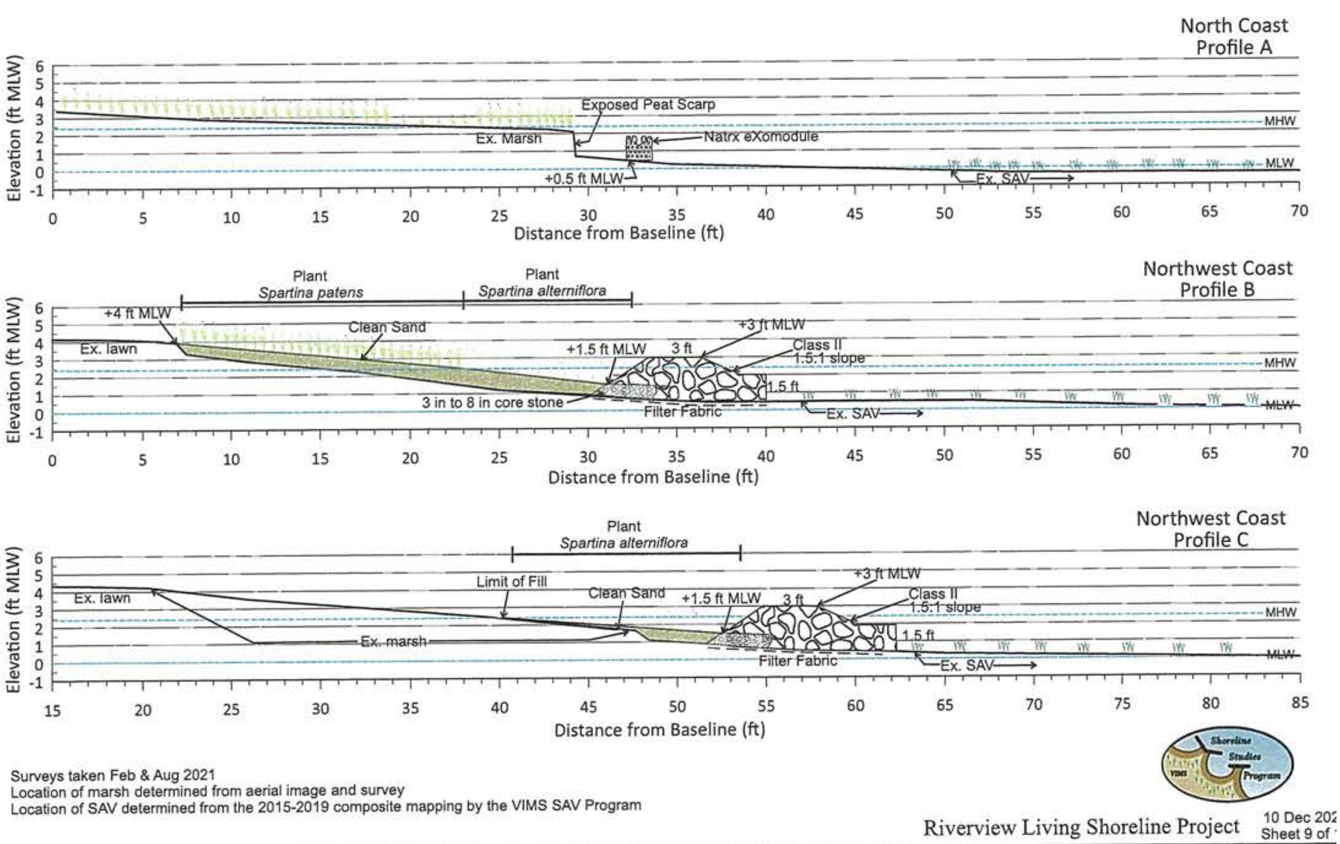
Wetlands species were not present on two of the three reaches of this property. The site was improved significantly through the restoration of marsh, stabilization of the shorelines, and creation of a buffer to ensure health of existing and newly created marsh.

Site Challenges:

Challenge: Proximity of stormwater infrastructure created runoff on the site, particularly from a drainage ditch.

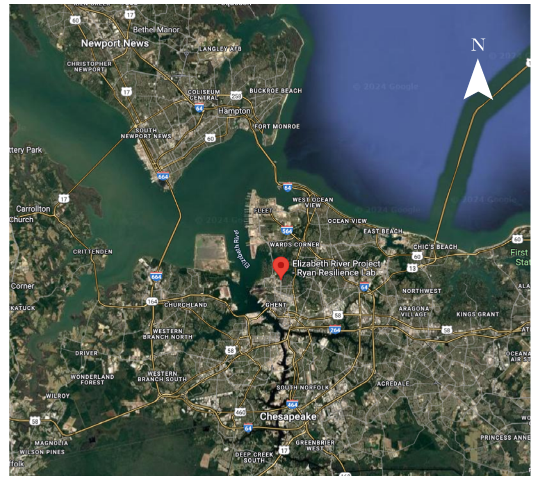
Challenge: Presence of intertidal SAV limited the amount of lower marsh created in the project, because the sill had to be designed closer to the shoreline.

Challenge: Existing revetment on a portion of the shoreline.



Ryan Resilience Lab

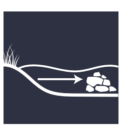
Location	Norfolk
Waterway	Knitting Mill Creek
Permit	State: VMRC Subaqueous Permit & CBPA Approved WQIA Federal ACE: Boardwalk, dock, and pier were permitted under ACE Regional Permit-18; living shoreline permitted under Regional Permit-19
Year Built	2023
Key Partners	Elizabeth River Project; Stromberg, Garrigan & Associates
Major Storms	N/A



Project Description:

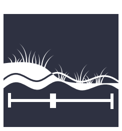
The project, known as the Ryan Resilience Lab, is located along Knitting Mill Creek. The existing dock structure and bulkhead was demolished and replaced with a living shoreline that extends around the entire shoreline of the property. The project also included the construction of a new floating dock and boardwalk/observation platform over the living shoreline area. The living shoreline project is designed to allow wetlands to migrate landward onto the site, unobstructed and at pace with sea level rise. When water levels reach a specific elevation on the site, all impervious surfaces will be removed from the site, allowing the wetlands and water to fully overtake the property.

Adaptive Strategies:

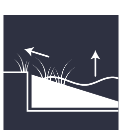


Place sills channelward of MLW to increase width and longevity of the intertidal zone

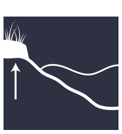
Design robust sills or breakwaters to reduce future anticipated storm energy



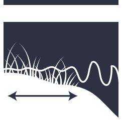
Design planting zones to plan for migration



Create stable slopes that promote marsh migration



Elevate marsh to persist in place



Increase marsh width to enhance wave attenuation

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	New (2023)			
Fetch	Very low (<0.5 mi)			
Exposure	Low			
Shore Orientation	E			
Erosion Rate	High (-5 to -10 ft/yr)			
Bank Composition	Urban fill over soft sediment and clay			
Nearshore Sediment	Soft sediment and clay			
SAV Present	No			
Shore Length	310 linear ft			
Shore Morphology	Straight			
Nearshore Morphology	Tidal flats			
Datum	NAVD88			
Mean Low Water	-1.7 ft			
Mean High Water	1.1 ft			
Upper Limits Tidal Wetland	2.5 ft			
Storm Surge	10 yr: 5.5 ft	50 yr: 6.8 ft	100 yr: 7.5 ft	
Expected Sea Level Rise (+MHW)	10 yr: 1.7 ft	20 yr: 2.16 ft	50 yr: 4.07 ft	80 yr: 6.70 ft
Proximity of Upland Structures	Building deck, ~130 linear ft			
Existing Shoreline Structures	Bulkhead			
Adjacent Shoreline(s)	Varies across shoreline (undefended park/defended bulkhead)			

Site Condition	Pre-Construction	Post-Construction
Slope	Bulkhead structure	Low (10:1/8:1)
Bank Height	Moderate (3.4-4.5 ft)	High (6.5-7.5 ft)
Low Marsh	Eroded/None	Stable (2,600 sq ft)
High Marsh	Eroded/None	Stable (9,700 sq ft)
Buffer Condition	Non-vegetated (parking lot)	Vegetated (14,000 sq ft vegetative buffer)
Shore Width	Narrow	Wide (20-22 ft)
Sill Height	N/A	2.1 (subsidence) - 2.6 ft

Low marsh zone:
Dis-investment in low marsh zone for planned loss and landward migration of low marsh plant species. Low Marsh "Toe" of living shoreline slope steepened to 8:1 slope to truncate the low marsh cross section to 9' wide (original design called for a 9' to 24' wide low marsh zone). Low marsh zone was planted with 100% *Spartina alterniflora* monoculture to act as a near-term landward migration datum observation.

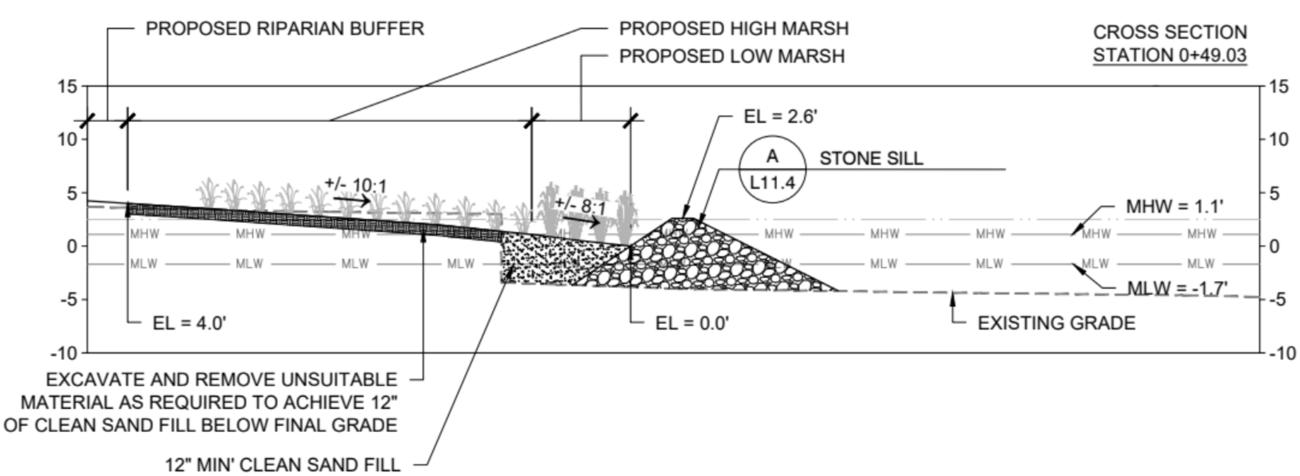
High marsh zone:
Enlargement of high-marsh zone up slope to elevation +4.0' for planned landward migration of low-marsh and high-marsh wetland above the current upper limits of +2.5. High marsh zone was planted with 100% *Spartina patens* monoculture to act as a near-term up slope/gradient landward migration datum observation. Upper limits of high marsh zone (+3.5 to +4.0) are interplanted with riparian buffer shrub species to assist with near-term stabilization and to accommodate near-term planned loss of high marsh species until SLR occurs.

Rock armament:
Adaptive plans are in place to elevate the rock sill armament from +2.5' to +4.0' as SLR occurs, and shoreline wetlands migrate landward.

Long-term planning:
Along with the rolling conservation easement, ERP plans to perform milestone evaluations of living shoreline migration and if required the development of retrofit adaptation plans for the wetland migration should unforeseen conditions impact further migration or long-term viability of the living shoreline wetland. Additionally, thin layer placement of sediment in the living shoreline has occurred as a pilot effort (2024), to help the wetlands elevation keep pace with sea level rise. If successful, this practice will continue to occur over time.

Useful Life Factors:
The living shoreline was designed to meet 2017 NOAA SLR intermediate high curve projections for the desired and planned life cycle of the Elizabeth River Project's Ryan Resilience Lab building of 50 years. See adaptive strategies for the planned landward migration of the living shoreline.

Site Challenges:
Challenge: Subaqueous condition of soft sediment and clay presented a challenge during construction due to settlement of sill.
Solution: Rock sill armament installation timeline extended and installation still ongoing. More sand needed than anticipated.



Killman Cove

Location	Exmore
Waterway	Killman Cove
Permit	VMRC Subaqueous Permit, Wetlands Board Permit
Year Built	2023
Key Partners	CRM, LLC
Major Storms	N/A

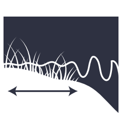
Project Description:

The project proposes constructing a 620-ft marsh sill in front of an existing marsh scarp and oyster rock trip structure to address significant erosion caused by vast fetches, particularly on the northwest to northeast shorelines, which are exposed to the mouth of Occohannock Creek and the Chesapeake Bay. The project includes nourishing three cove areas with approximately 60 cubic yds of material, followed by planting primarily *Spartina alterniflora* at 1.5-ft intervals after the material settles. A buffer permit and mitigation are required, and mats will be used on the marsh and in the buffer. The project aims to enhance the existing oyster rock sill to better protect the marsh from increasing wave heights, with a monitoring period of three years targeting an 80% vegetation survival rate. The rocks will support oyster growth, and the planted coves will form a living shoreline.

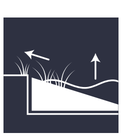
Adaptive Strategies:

Design robust sills or breakwaters to reduce future anticipated storm energy

Use multiple nature-based solutions to reduce erosion



Increase marsh width to enhance wave attenuation



Create stable slopes that promote marsh migration

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	New (2023)			
Fetch	High (5 to 15 mi)			
Exposure	High			
Shore Orientation	N/NW			
Erosion Rate	Very low (0 to -1 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Firm			
SAV Present	Yes			
Shore Length	620 ft			
Shore Morphology	Headland			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.0 ft			
Upper Limits Tidal Wetland	6 ft			
Storm Surge	10 yr: 4.3 ft	50 yr: 4.8 ft	100 yr: 5.2 ft	
Expected Sea Level Rise (+MHW)	2020: 0.13 ft	2040: 0.98 ft	2060: 2.17 ft	2080: 3.68 ft
Proximity of Upland Structures	House, 70 ft			
Adjacent Shoreline(s)	Undefended			

Site Condition	Pre-Construction	Post-Construction
Slope	Low	Low
Bank Height	Low (1-2 ft)	Low (1-2 ft)
Low Marsh	Transitional	Stable (1,400 sq ft added)
High Marsh	Transitional	Stable
Buffer Condition	Vegetated	Vegetated
Shore Width	Wide	Wide

Useful Life Factors:

This site presents a large, vegetated buffer and favorable slopes that will provide space and a path for marsh migration. Adaptive management of the woody buffer plants may be needed as planting zones shift.

Site Challenges:

Challenge: SAV present

Challenge: Access through the established buffer

PROJECT NOTES:

SILL CONSTRUCTION / FILL & PANT

1 – SILLS & GROIN CONSTRUCTION: CLASS I, II STONE, FILTER CLOTH,

2 – NOURISHMENT BEHIND THE NEW MARSH SILL: < 10% PASSING THRU A #100 SIEVE; PLANTS: S. ALTERNIFLORA, SPACING: 1.5' O.C.; SPRING PLANTING; 3 YR MONITORING PERIOD, FALL REPORTING; TO ACHIEVE 80% SURVIVAL RATE.

3 – MATS WILL BE USED WHEN TRAVERSING THE RPA IN ORDER TO ACCESS THE MORE NORTHERN REACHES OF THE SHORELINE.

4 – MATS WILL BE USED ANY TIME EQUIPMENT MUST BE ON THE MARSH OR IN THE SENSITIVE EMBAYMENTS.

5 – WORK MAY BE DONE FROM THE MARSH USING EQUIPMENT MATS

6 – NOURISHMENT WILL BE PLACED BEHIND THE NEW SILLS IN THE EMBAYMENTS ONLY, & ALLOWED TO STABILIZE BEFORE PLANTING.

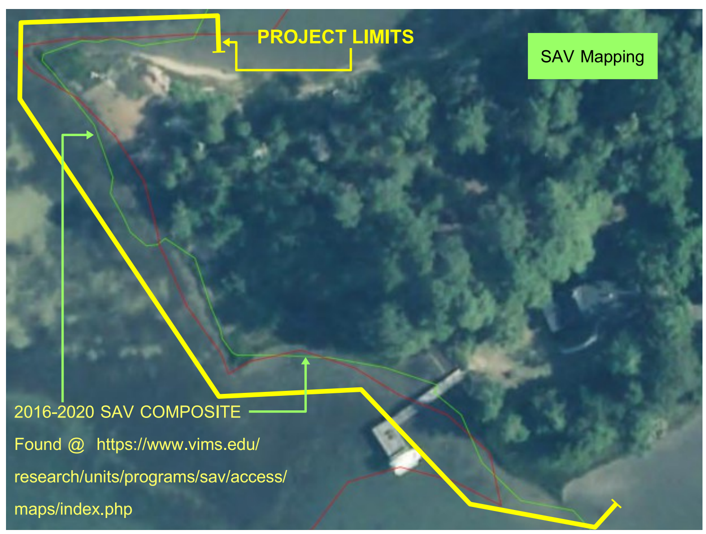
5 – THE MATERIALS STAGING AREA(20'x20') WILL BE IN THE BUFFER AS THERE ARE NO OTHER VIABLE, COST EFFECTIVE OPTIONS, DUE TO LOT CONFIGURATION. A 20'X20' AREA FOR STAGED STONE & MATTED EQUIPMENT TRACKS.

7 – SOME TREES IN THE RPA WILL NEED TO BE LIMBER FOR ACCESS TO THE MORE NORTHERN REACHES OF THE SHORELINE. NO TREES IN THE BUFFER NEED REMOVAL. IF THIS CONDITION CHANGES, IT IS THE RESPONSIBILITY OF THE PROPERTY OWNER OR CONTRACTOR TO NOTIFY THE COUNTY & ALTER THE WQIA ACCORDINGLY.

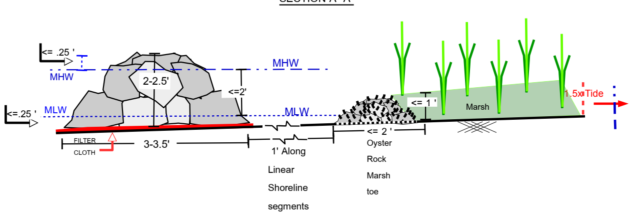
8 – THE BUFFER WILL BE PLANTED, POST CONSTRUCTION, AS PER THE BUFFER MANUAL REGULATION. WQIA WILL BE SUBMITTED POST-JPA.

9 - THIS AGENT IS NOT RESPONSIBLE FOR THE CONDUCT & OR WORKMANSHIP OF OTHER CONTRACTORS. THIS IS NOT A CRM,llc DESIGNED PROJECT.

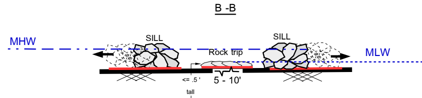
10 - IF DEVIATION FROM APPROVED PROJECT PLANS IS NECESSARY, PROJECT MODIFICATIONS MAY NECESSITATE ADDITIONAL AGENCIES REVIEW & PERMITTING.



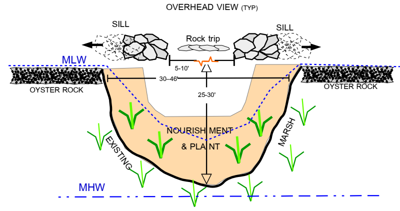
PROPOSED
OFF-SET SILL DESIGN
SECTION A -A



GAP DETAILS
B -B



GAP DETAILS
C -C
OVERHEAD VIEW (TYP)

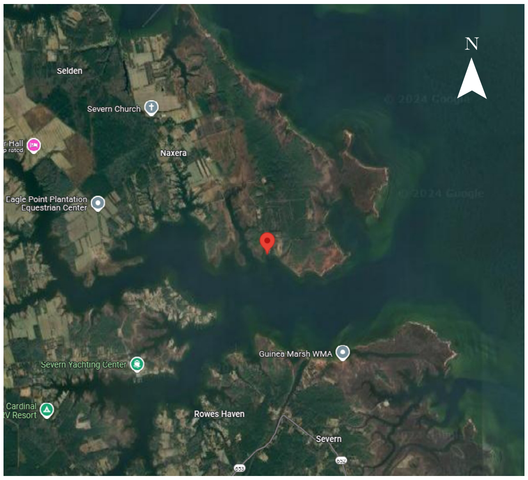


Project drawings are in color on 8.5" x 14" paper. Best viewed electronically for greater detail

	Project Details Sill Construction / Fill / Plant Killmon Cove Northampton County TM# 1A-1-A	SUBMIT DATE: 11/10/22 REVISION DATE: Pg 3 of 3 By: CRM,llc: 757 442 5640	SCALES VARY Coastal Resource Management

Captain Sinclair

Location	Gloucester
Waterway	Severn River
Permit	VMRC Subaqueous Permit
Year Built	2015
Key Partners	MPPAA, VIMS, Wetland Design and Restoration
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021), Isaias (8/4/2020), Nestor (10/20/2019), Michael (10/12/2018), Matthew (10/9/2016)



Project Description:

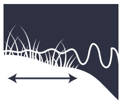
Marsh edge erosion was stabilized with stone sills, sand fill and planted salt marsh that tied into the natural marsh. This is a public demonstration project.

The MPPDC partnered with the Shoreline Studies Program at VIMS and received a NFWF Small Watershed grant in order to accomplish the Shoreline Management Plan for the property as well as develop a living shoreline demonstration site and educational outreach program.

Photos by VMRC

Adaptive Strategies:

Create stable slopes that promote marsh migration



Increase marsh width to enhance wave attenuation

Stabilize slopes to reduce erosion from wave energy

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	Recent (2015)			
Fetch	Medium (1 to 5 mi)			
Exposure	Moderate			
Shore Orientation	S/SE			
Erosion Rate	Very low (0 to -1 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Sand			
SAV Present	Yes			
Shore Length	350 linear ft			
Shore Morphology	Irregular			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.4 ft			
Upper Limits Tidal Wetland	2.5 ft at mouth of Severn River (tidal range)			
Storm Surge	10 yr: 4.69 ft	50 yr: 5.75 ft	100 yr: 6.22 ft	
Expected Sea Level Rise (+MHW)	2020: 0.04 ft	2040: 0.89 ft	2060: 2.08 ft	2080: 3.59 ft
Proximity of Upland Structures	Abandoned elevated pool, ~60 ft; abandoned house, ~100 ft			
Adjacent Shoreline(s)	Undefended marsh			

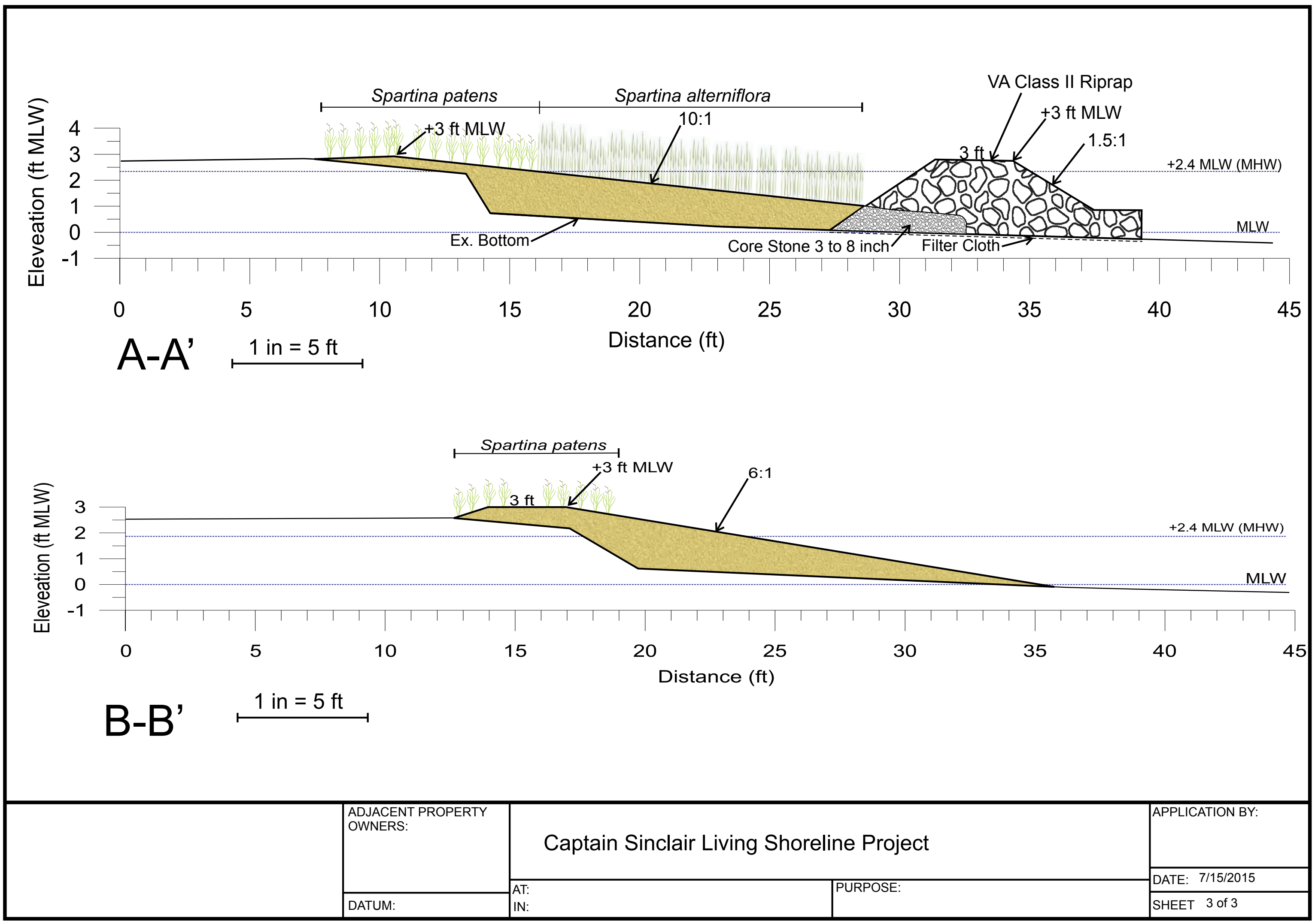
Site Condition	Pre-Construction	Post-Construction
Slope	Low (10:1 to 6:1)	Low (10:1 to 6:1)
Bank Height	Low	Low (3 ft)
Low Marsh	Eroded	Stable (10:1)
High Marsh	Transitional	Stable (6:1)
Buffer Condition	Vegetated (Highly eroded 0.6 ft/yr)	Vegetated
Shore Width	Wide	Wide

Useful Life Factors:

Erosion rates due to sea level rise (~.5 ft per year) will impact wetlands survival. Proximity to structures and development is less of a factor, although in some portions of the property, the main structure is ~60 ft from the shoreline.

Site Challenges:

Challenge: Construction equipment had to cross a wide marsh to repair the dock.



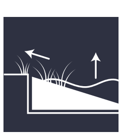
Black Marsh Farm

Location	Caroline
Waterway	Rappahannock
Permit	Living Shoreline General Permit, Group 2
Year Built	2022
Key Partners	Friends of the Rappahannock, Bayshore Design, LLC
Major Storms	N/A

Project Description:

The project constructed a living shoreline treatment to include a 420 ft rip-rap sill with 60 cubic yds of beach nourishment and 1,500 sq ft wetlands vegetation plantings.

Adaptive Strategies:



Create stable slopes that promote marsh migration

Site Parameters				
Wetlands Type	Freshwater			
Sill Type	Stone			
Year Constructed	New (2024)			
Fetch	Very low (<0.5 mi)			
Exposure	Low			
Shore Orientation	S			
Erosion Rate	Very low accretion (+1 to 0 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Sand/silt			
SAV Present	No			
Shore Length	~390 linear ft			
Shore Morphology	Pocket			
Nearshore Morphology	Bars			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.3 ft			
Upper Limits Tidal Wetland	18-24 feet MLW			
Storm Surge	10 yr: N/A	50 yr: N/A	100 yr: N/A	
Expected Sea Level Rise (+MHW)	2020: 1.02 ft	2040: 1.87 ft	2060: 3.06 ft	2080: 4.57 ft
Proximity of Upland Structures	Farmhouse, ~175 ft			
Adjacent Shoreline(s)	Forest			

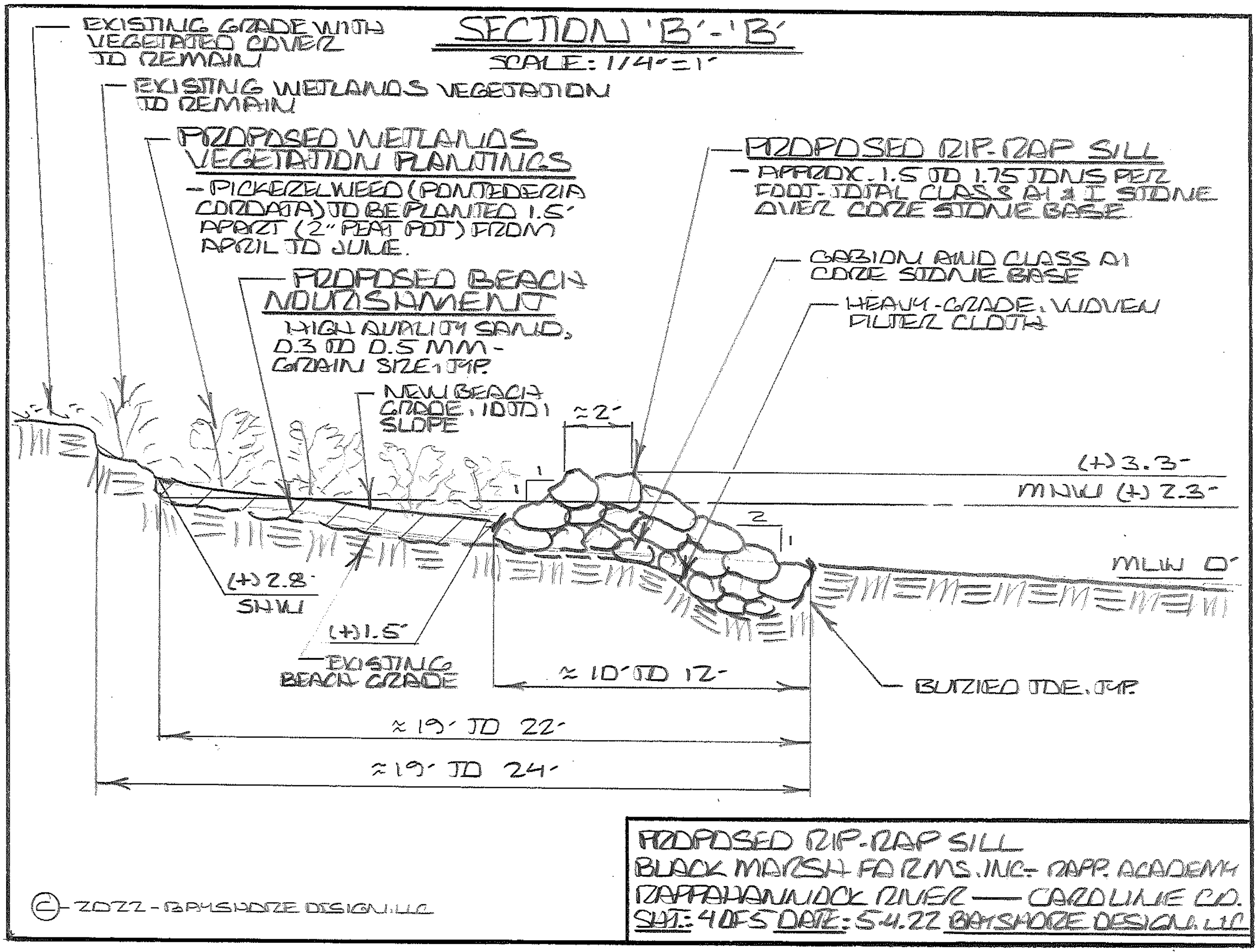
Site Condition	Pre-Construction	Post-Construction
Slope	Low (10:1 to 6:1)	Low (10:1 to 6:1)
Bank Height	Moderate (~3.3 ft)	Moderate (~3.3 ft)
Low Marsh	Eroded	Stable
High Marsh	Transitional	Stable
Buffer Condition	Vegetated	Vegetated
Shore Width	Wide	Wide (18-24 ft)

Useful Life Factors:

The vegetated buffer provides space for vegetation to shift landward and the slopes are favorable for migration. Structures are positioned away from the shore. Relatively low bank heights are not likely to impede migration.

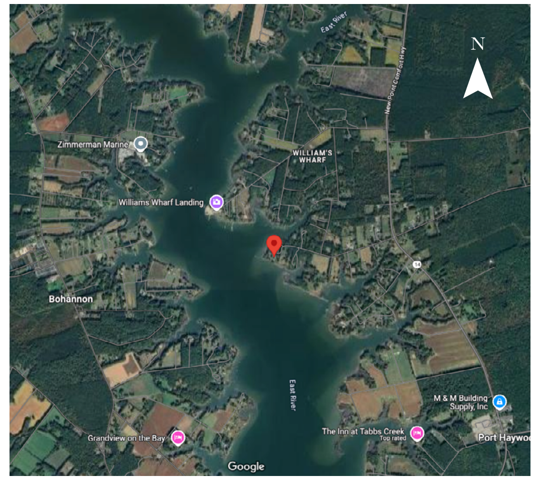
Site Challenges:

Challenge: This project on the Rappahannock River is in a freshwater system. Typical elevations for tidal salt marshes are not relevant to planting zone placement and require the use of freshwater plant species not typically used in salt water environments.



Poplar Grove

Location	Mathews
Waterway	East River
Permit	VMRC Subaqueous Permit
Year Built	2003
Key Partners	VIMS, Coastal Design & Construction
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021), Isaias (8/4/2020), Nestor (10/20/2019), Michael (10/12/2018), Matthew (10/9/2016), Sandy (10/29/2012), Irene (8/28/2011)

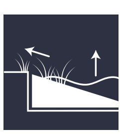


Project Description:

The sill was designed as a low wide sill with an elevation at +3 ft MLW and crest width of 4 ft which was needed for the proposed armor stone required to address the long, southern fetch. The sand fill was placed on a 10:1 slope beginning near the top of the low bank and extending to the back of the sill at about MTL. This provided for a maximum planting zone of 12 ft of *Spartina alterniflora* and 16 ft of *Spartina patens*. Approximately 20,000 sq ft of vegetated wetlands was created.

“The project was installed in 2003 and took about two months to complete. The site has experienced numerous storm events beginning with Hurricane Isabel and the Veteran’s Day Northeaster. Water levels during the Veteran’s Day Northeaster were more than 4 ft higher than a normal high tide. Storm waves essentially rolled over the project area and were effectively attenuated with no signs of bank scarping. A slight offset has developed at the beach between the sill and the small breakwater but that was expected and appears to have reached a state of shore planform equilibrium. The most recent Google Earth imagery (November 2015) shows a stable system that has changed little since construction.” - VIMS

Adaptive Strategies:



Create stable slopes that promote marsh migration

Use multiple nature-based strategies to reduce erosion

Stabilize slopes to reduce erosion from wave energy

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	Older (2003)			
Fetch	Very high (>15 mi)			
Exposure	Moderate			
Shore Orientation	S			
Erosion Rate	Very low (0 to -1 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Firm			
SAV Present	No			
Shore Length	1,500 linear ft			
Shore Morphology	Irregular (straight and pocket)			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.7 ft			
Storm Surge	10 yr: 4.3 ft	50 yr: 5.2 ft	100 yr: 5.7ft	
Expected Sea Level Rise (+MHW)	2020: 1.15 ft	2040: 1.84 ft	2060: 2.70 ft	2080: 3.19 ft
Proximity of Upland Structures	30 ft			
Adjacent Shoreline(s)	Undefended			

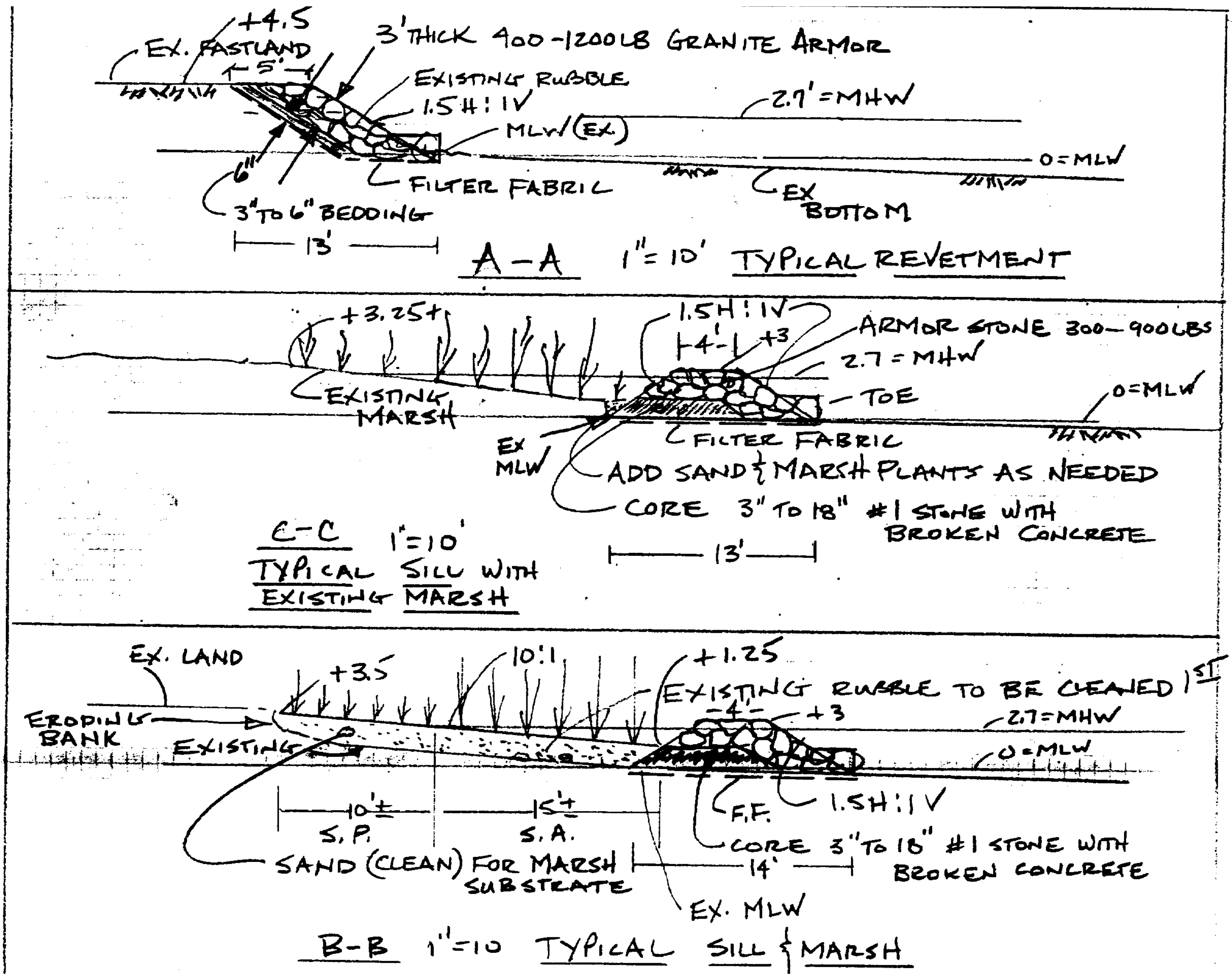
Site Condition	Pre-Construction	Post-Construction
Slope	Low	Low
Bank Height	Moderate	Moderate
Low Marsh	Eroded	Stable
High Marsh	Eroded	Stable
Buffer Condition	Vegetated	Vegetated
Shore Width	Wide	Wide

Useful Life Factors:

The site features space in the buffer for migration to occur and the shore slope will promote migration. Upland structures are situated back from the bank and will not impede migration.

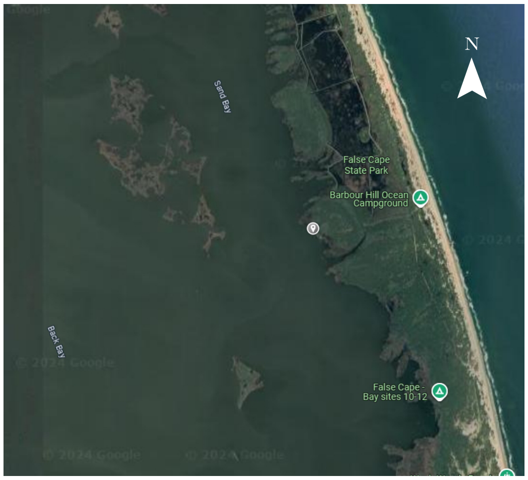
Site Challenges:

Challenge: Previous erosion control strategies failed to protect the shoreline, including broken concrete and a failing bulkhead.
Solution: Existing concrete rubble and debris were present on the shore. This material was repurposed as bedding and core for the sill structures.



False Cape State Park

Location	Virginia Beach
Waterway	Back Bay
Permit	VMRC Subaqueous Permit
Year Built	2016
Key Partners	US FWS, City of Virginia Beach, AECOM-design, Wetland Design and Restoration-design assistance and planting
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021), Isaias (8/4/2020), Nestor (10/20/2019)



Project Description:

Three projects at Barbours Hill, Spratts Cove, and the Education Center with the primary purpose being to stabilize eroding sections of shoreline through the use of living shoreline techniques for protection of public infrastructure and assets. Two sites include the installation of class 1 rock sills (approx. 12 ft wide, 3 ft high), sand fill, and native coastal/buffer plantings. The remaining site, a primary access road, involves raising the elevation of the roadway to avoid overtopping, and replacement of a failed culvert pipe. The secondary purpose is achieving the goals of the park to protect and provide natural resources by reducing sedimentation to Back Bay, improving water quality and habitat for aquatic animal and plant species, and promoting establishment and presence of submerged aquatic vegetation.

Photos by VMRC

Adaptive Strategies:

Design robust sills or breakwaters to reduce future anticipated storm energy

Increase marsh width to enhance wave attenuation

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	Recent (2016)			
Fetch	High (5 to 15 mi)			
Exposure	Moderate			
Shore Orientation	W			
Erosion Rate	Very low (0 to -1 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Firm			
SAV Present	No			
Shore Length	347 linear ft			
Shore Morphology	Irregular			
Nearshore Morphology	Tidal flats			
Datum	NAVD88			
Mean Low Water	-1.3 ft			
Mean High Water	1.5 ft			
Upper Limits Tidal Wetland	Varies			
Storm Surge	10 yr: 5.2 ft	50 yr: 6.6 ft	100 yr: 7.0 ft	
Expected Sea Level Rise (+MHW)	2020: 1.23 ft	2040: 2.08 ft	2060: 3.27 ft	2080: 4.78 ft
Proximity of Upland Structures	Road, ~3 ft			
Adjacent Shoreline(s)	Undefended marsh (state park/back bay refuge)			

Site Condition	Pre-Construction	Post-Construction
Slope	Low (10:1 to 6:1)	Low and flat (15:1)
Bank Height	Low	Low (1.75-2.90 ft)
Low Marsh	Transitional	Stable
High Marsh	Transitional	Stable
Buffer Condition	Vegetated	Vegetated
Shore Width	Narrow	Wide

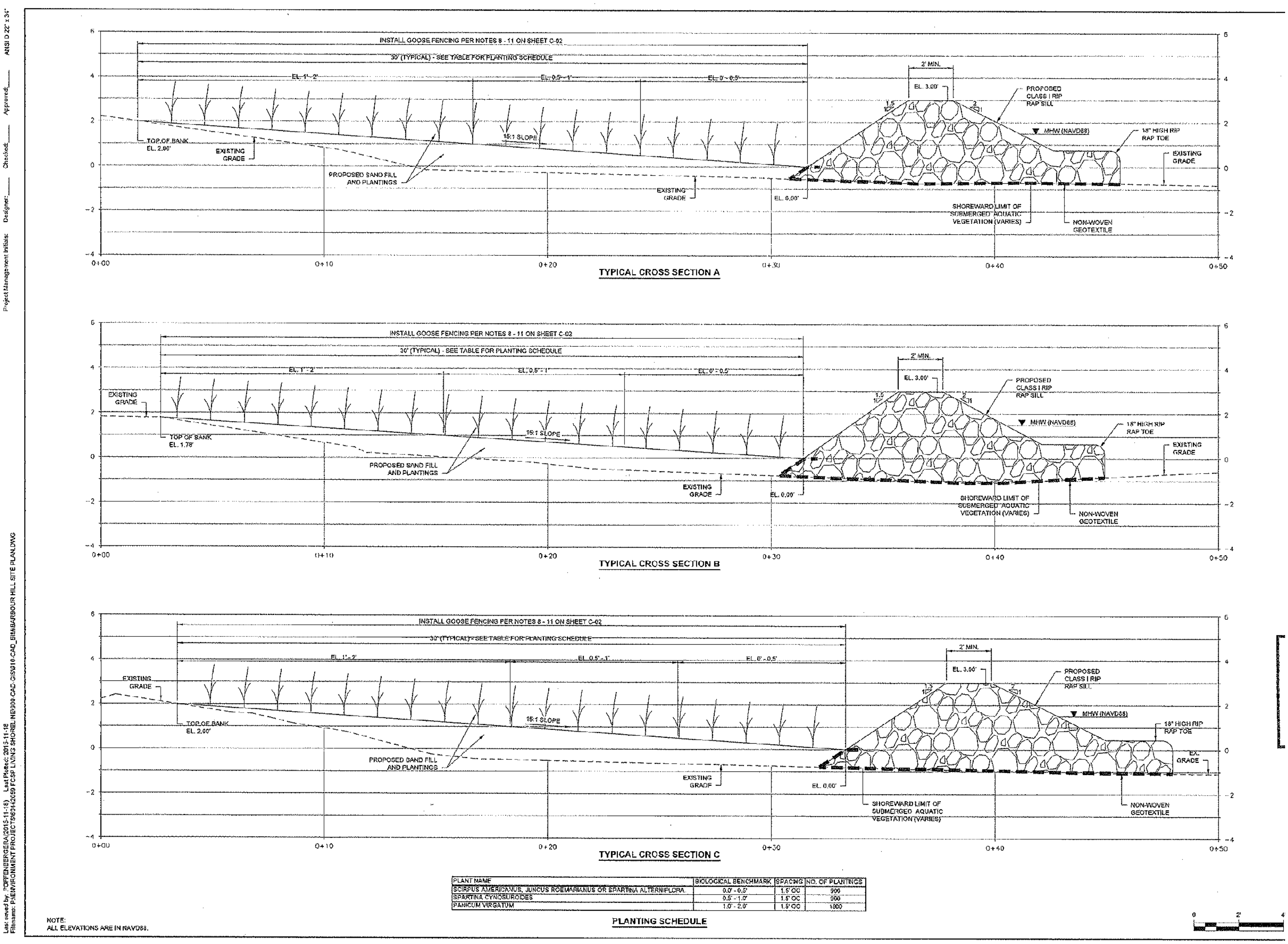
Useful Life Factors:

Along the Spratts Cove reach, maintaining the existing access roadway will restrict upland marsh migration. In other project areas, an upland buffer will provide space for migration. Low, stable slopes provide a pathway for the marsh to move inland.

Site Challenges:

Challenge: SAV present at and below MLW across Barbour's Hill section of the project.
Solution: Sills were designed to avoid as much encroachment as practical.

Challenge: A failed culvert and water control structure along the north end of the Spratt's Cove access road required redesign to increase capacity.



PLANT NAME	BIOLOGICAL BENCHMARK	SPACING	NO. OF PLANTINGS
SCIRPUS AMERICANUS, JUNCUS ROEMARIANUS OR SPARTINA ALTERNIFLORA	0.0' - 0.5'	1.5' OC	900
SPARTINA CYNOSUROIDES	0.5' - 1.0'	1.5' OC	900
PANICUM VIRGATUM	1.0' - 2.0'	1.5' OC	1800

PLANTING SCHEDULE

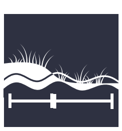
Werowocomoco

Location	Gloucester
Waterway	York River
Permit	VMRC Subaqueous Permit
Year Built	2019
Key Partners	National Park Service, VIMS, Coastal Design and Construction, Wetland Design and Restoration
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021)

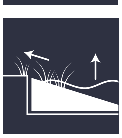
Project Description:

This project added 340 linear ft of living shoreline to an existing sill system to protect valuable archaeological resources. Tied into Phase 1 660+ linear feet constructed in 2001 (VMRC 2001-0072). The project created 5,700 sq ft of low marsh and 8,800 sq ft of high marsh.

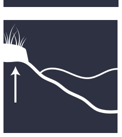
Adaptive Strategies:



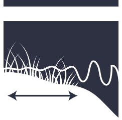
Design planting zones to plan for migration



Create stable slopes that promote marsh migration



Elevate marsh to persist in place



Increase marsh width to enhance wave attenuation

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	Recent (2019)			
Fetch	Medium (1 to 5 mi)			
Exposure	High/moderate			
Shore Orientation	W/SW			
Erosion Rate	Low (-1 to -2 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Firm			
SAV Present	No			
Shore Length	340 ft			
Shore Morphology	Straight			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	2.8 ft			
Upper Limits Tidal Wetland	5 ft MLW			
Storm Surge	10 yr: 4.74 ft	50 yr: 5.87 ft	100 yr: 6.32 ft	
Expected Sea Level Rise (+MHW)	2020: 0.55 ft	2040: 1.58 ft	2060: 2.94 ft	2080: 4.63 ft
Proximity of Upland Structures	286 ft			
Adjacent Shoreline(s)	Undefended			

Site Condition	Pre-Construction	Post-Construction
Slope	Low	Flat (12:1)
Bank Height	High (21 ft MLW)	High (21 ft MLW))
Low Marsh	Eroded	Stable (18 ft)
High Marsh	Transitional	Stable (27 ft)
Buffer Condition	Vegetated	Vegetated
Shore Width	Wide	Wide (~60 ft)

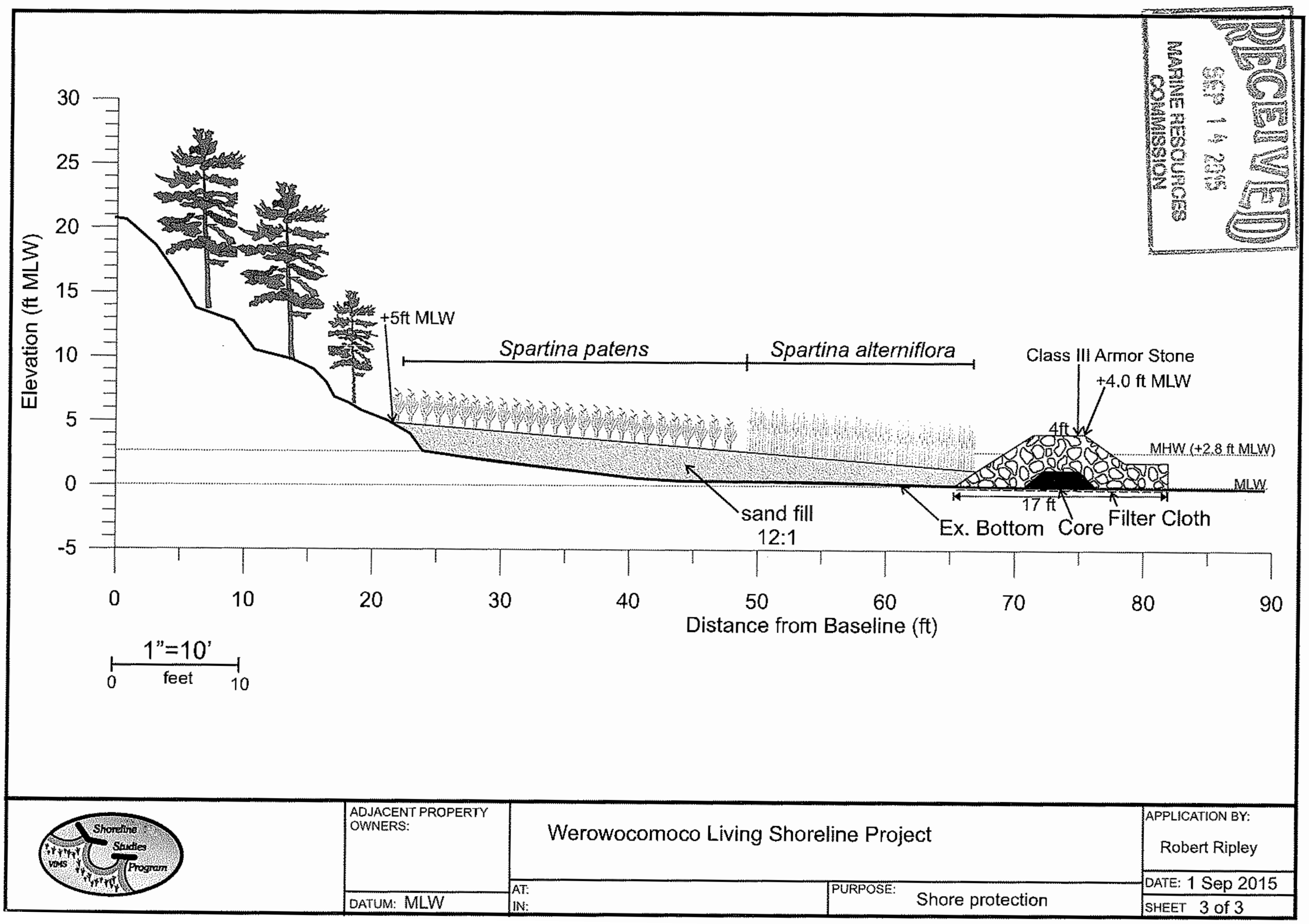
Useful Life Factors:

A high bank (+21 ft MLW) will impede upland marsh migration as sea level rises. Adaptive management and maintenance of incremental sand fill and plantings will assist the marsh's persistence in place over time. Creation of a wide low and high marsh zone, approximately 45' combined, provides space for the low marsh zone to shift landward in response to sea level rise if adaptive management and maintenance does not take place.

Site Challenges:

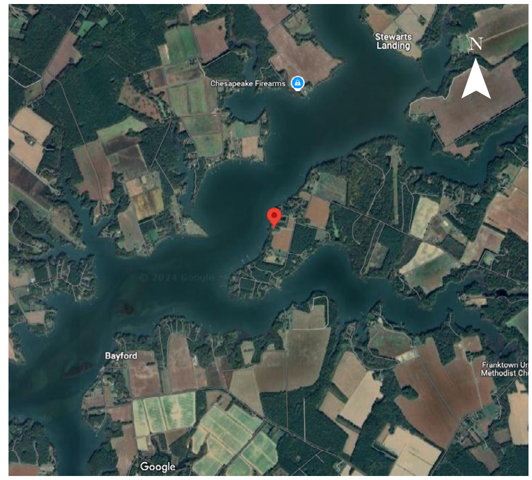
Challenge: Known archeological resources restricted the ability to grade the bank. Active erosion of approximately 1.5 ft/yr was exposing artifacts as the bank receded.

Solution: Sand fill was used to create low and high marsh planting zones and tie in to the existing bank at +5 ft MLW, protecting the bank face from the full force of wave impacts.



Nassawadox Creek

Location	Northampton
Waterway	Nassawadox Creek
Permit	VMRC Subaqueous Permit, Wetlands Board Permit
Year Built	2022
Major Storms	N/A

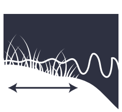


Project Description:

The project involved installing armor stone sills backed by sand marsh and backshore planting terraces, integrating existing vegetated wetlands by feathering sand fill into the current vegetation, and largely avoiding submerged lands with stone sills running along the MLW line. Reach I features four armor stone sills totaling 896 ft, with sand terraces planted with 15,927 square ft of *Spartina alterniflora* and 10,844 square ft of *Spartina patens*, and a 60-ft stone revetment. Reach II has two armor stone sills totaling 498 ft, with sand terraces planted with 9,299 square ft of *Spartina alterniflora* and 7,184 square ft of *Spartina patens*. The primary goal was to stabilize the shoreline and enhance existing vegetation, while the secondary goal is to create a broad marsh fringe to dissipate wave energy. No clearing or bank grading was proposed.

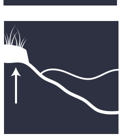
Adaptive Strategies:

Design robust sills or breakwaters to reduce future anticipated storm energy



Increase marsh width to enhance wave attenuation

Stabilize slopes to reduce erosion from wave energy



Elevate marsh to persist in place

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	New (2022)			
Fetch	Low (0.5-1 mi)			
Exposure	Moderate			
Shore Orientation	W/NW			
Erosion Rate	Very low (0 to -1 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	N/A			
SAV Present	No			
Shore Length	1,420 ft			
Shore Morphology	Irregular			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	1.8 ft			
Upper Limits Tidal Wetland	4 ft			
Storm Surge	10 yr: 4.6 ft	50 yr: 5.4 ft	100 yr: 5.9 ft	
Expected Sea Level Rise (+MHW)	2020: 3.89 ft	2040: 4.74 ft	2060: 6.4 ft	2080: 7.91 ft
Proximity of Upland Structures	~135 feet			
Adjacent Shoreline(s)	Mostly defended			

Site Condition	Pre-Construction	Post-Construction
Slope	Steep (3:1 to 1:1)	Low (10:1)
Bank Height	Low	High (~6-12 ft)
Low Marsh	Transitional	Stable; (15,927 sq ft - Reach I; 9,299 sq ft - Reach II)
High Marsh	Eroded/None	Stable; (10,844 sq ft - Reach I; 7,184 sq ft - Reach II)
Buffer Condition	Vegetated	Vegetated (Defended with rock sills, vegetated low and high marsh in planting terraces)
Shore Width	Narrow	Wide (~30-40 ft)

Useful Life Factors:

Property owners' goals to protect the shoreline from erosive forces, while integrating as much wetlands planting as possible.
Steep bank heights will impact the life of the project, but the use of stone to attenuate wave impacts will extend the lifespan of the project.

Site Challenges:

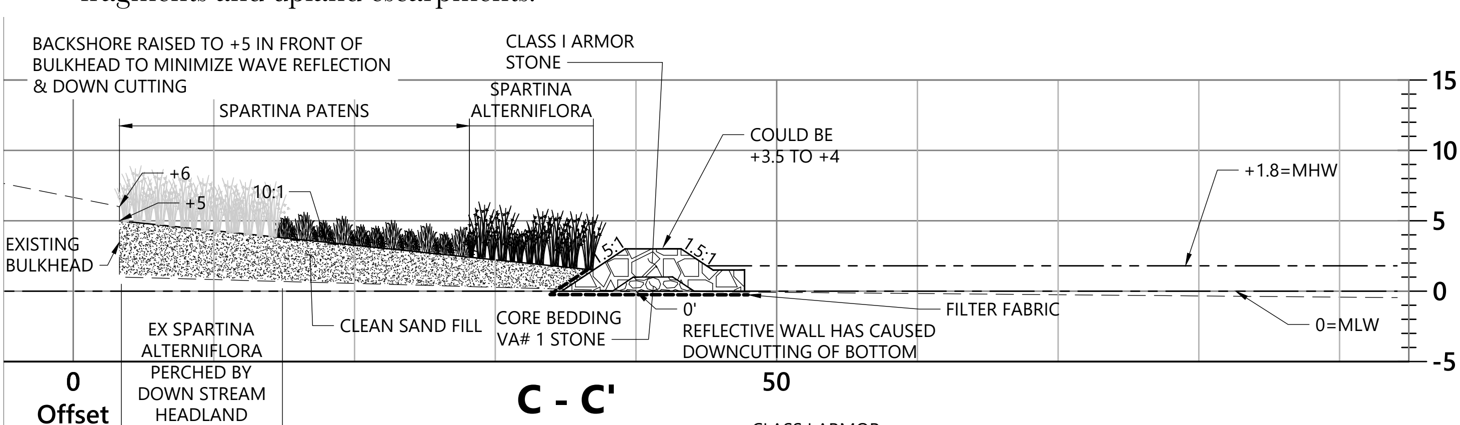
Challenge: The shoreline, consisting of fragmented marsh and upland escarpment, experiences significant erosion during high water storm events.
Solution: Installation of armor stone sills backed by sand marsh and backshore planting terraces to stabilize the shoreline and protect against erosion by dissipating wave energy.

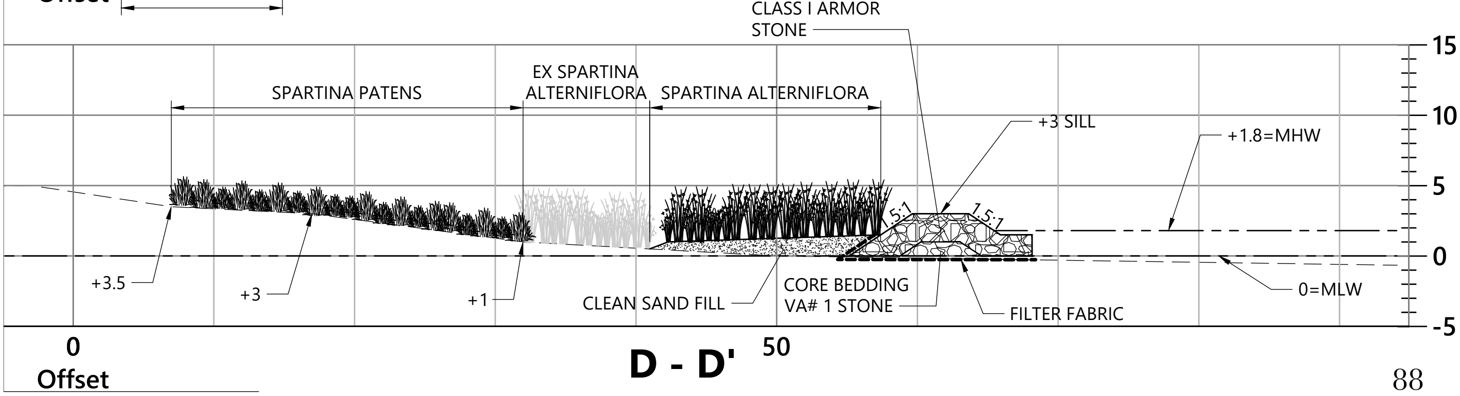
Challenge: State regulations require that a living shoreline approach be considered where possible, and this site must comply with these regulations.
Solution: The project design includes low sills and sand planting terraces that create a marsh fringe to dissipate wave energy, complying with state regulations for nature-based solutions.

Challenge: Avoiding damage to existing vegetated wetlands (*Spartina alterniflora* and *Spartina patens*) while implementing the project.
Solution: The project incorporates the existing vegetated wetlands by feathering sand fill into the existing vegetation - enhancing rather than disturbing these areas.

Challenge: The project must avoid clearing and bank grading to preserve the natural landscape.
Solution: No clearing or bank grading is proposed, maintaining the integrity of the existing landscape and reducing environmental impact.

Challenge: Providing long-term stability to the shoreline and enhancing existing vegetation at the lower limits of its preferred growth.
Solution: Establishing a broad marsh fringe to dissipate wave energy, stabilize the shoreline, and enhance vegetation through careful placement and integration of sand planting terraces with existing marsh fragments and upland escarpments.





Berkeley Plantation

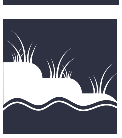
Location	Charles City County
Waterway	James River
Permit	VMRC Subaqueous Permit
Year Built	2024
Key Partners	VHB, JRA, USACE, DCR-SEAS, Colonial District SWCD
Major Storms	N/A

Project Description:

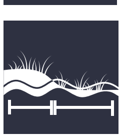
The project proposes shoreline improvements along 1,500 linear ft of shoreline on the James River at Harrisons Point in Charles City County, Virginia. The project, initiated by the James River Association, Colonial Soil and Water Conservation District, and the Virginia Department of Conservation and Recreation – Shoreline Erosion Advisory Service, aims to implement resilient practices along tidal shorelines through the Virginia Agricultural BMP Cost-Share Program. The plan involves installing armor stone sills, sand marsh, and backshore planting terraces to create a resilient shoreline that accommodates sea level rise and protects adjacent uplands and cultural resources. An archaeological investigation by the James River Institute of Archaeology led to modifications in the plan to avoid disturbing upland soils and archaeological sites. Construction includes one breakwater and two sills with sand planting terraces, resulting in the creation of 43,594 sq ft of vegetated wetlands and additional backshore habitat, with measures to protect threatened and endangered species and heritage resources.

Adaptive Strategies:

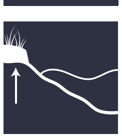
Design robust sills or breakwaters to reduce future anticipated storm energy



Stabilize slopes to reduce erosion from wave energy



Design plating zones to plan for migration



Elevate marsh to persist in place

Site Parameters				
Wetlands Type	Tidal Saltwater			
Sill Type	Stone			
Year Constructed	New (2024)			
Fetch	High (5 to 15 mi)			
Exposure	Moderate			
Shore Orientation	SW			
Erosion Rate	Low (-1 to -2 ft/yr)			
Bank Composition	Sandy loam, clayey sand, sand			
Nearshore Sediment	Sand			
SAV Present	No			
Shore Length	1,500 linear ft			
Shore Morphology	Straight/headland			
Nearshore Morphology	Tidal flats			
Datum	NAVD88			
Mean Low Water	0.0 ft			
Mean High Water	2.2 ft			
Upper Limits Tidal Wetland	2.2 ft			
Storm Surge	10 yr: 7.2 ft	50 yr: 8.6	100 yr: 8.9	
Expected Sea Level Rise (+MHW)	2020: 2.62 ft	2040: 3.47 ft	2060: 4.66 ft	2080: 6.17 ft
Proximity of Upland Structures	477 ft			
Adjacent Shoreline(s)	Undefended			

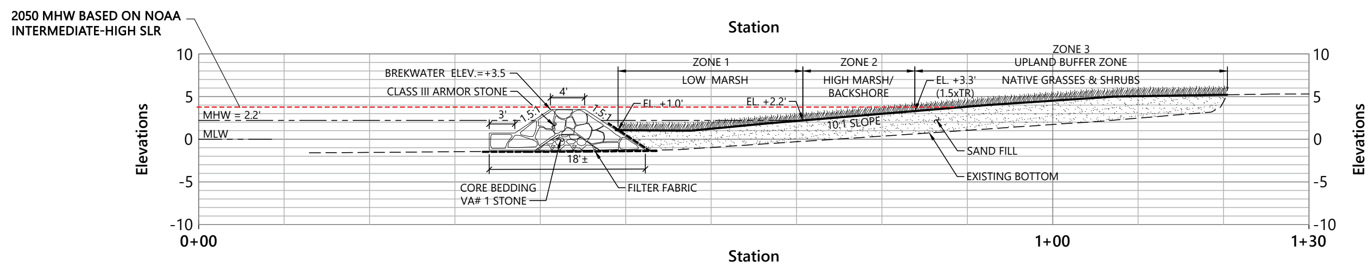
Site Condition	Pre-Construction	Post-Construction
Slope	Steep (3:1 to 1:1)	Low (10:1)
Bank Height	Low	High (~6-12 ft)
Low Marsh	Transitional	Stable (28,265 sq ft)
High Marsh	Eroded/None	Stable (11,565 sq ft)
Buffer Condition	Vegetated	Vegetated (Defended with rock sills, and vegetated low and high marsh)
Shore Width	Narrow	Wide (varies ~100 ft)

Useful Life Factors:

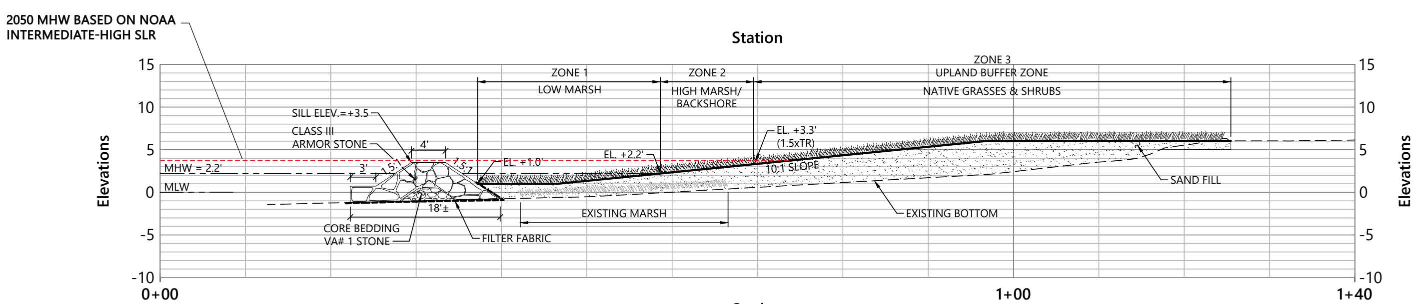
Low marsh, high marsh, and upland buffer planting zones, along with favorable slopes, will promote upland migration of the marsh. Sill and breakwater heights were designed to the predicted 2050 MHW based on NOAA's Intermediate High Sea Level Rise Curves.

Site Challenges and Solutions:

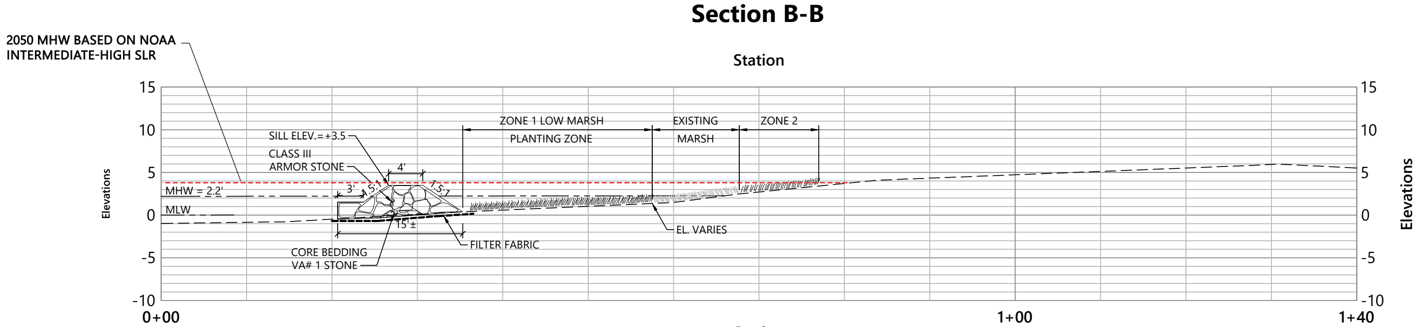
Challenge: The Berkeley Plantation shoreline is most exposed to wind events from the southwest and west, but also experiences ship/boat wakes from the nearby channel. The central headland along the project exhibits an erosional scarp, while the upstream and downstream reaches are more stable with gradual sloping backshores. An onsite investigation of archaeological resources was conducted in April 2022 by the James River Institute of Archaeology (JRIA). Initial conceptual shoreline plans included regrading portions of the eroded bank slope landward and transitioning the living shoreline into the proposed graded areas. However, JRIA's investigations yielded cultural materials at 30 of their 51 shovel test sites. *Solution:* The proposed plan was modified to eliminate grading and thereby avoid disturbance of upland soils. The proposed sills and sand fill were shifted slightly offshore to avoid disturbing Site 44CC0459 that is now recorded in the Virginia Cultural Resource Information System (V-CRIS). JRIA concluded that this site be considered eligible for listing in the National Register of Historic Places. In order to avoid disturbing site 44CC0459 during construction of the shoreline project, access will be gained along the existing farm road that leads to Harrison's Point. All staging and stockpiling of material will be done upon timber matting placed over geofabric to avoid disturbing the underlying soils during construction. The actual construction area is located within the intertidal zone and nearshore that have migrated landward over time so the potential for adverse effects to archaeological resources is not likely within the living shoreline footprint.



Section A-A



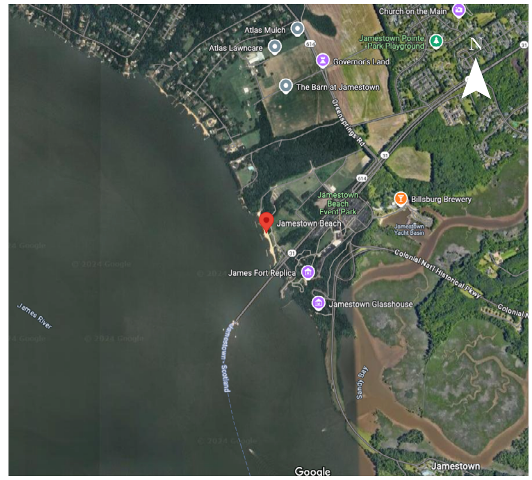
Section B-B



Section C-C

Jamestown Beach

Location	James City County
Waterway	James River
Permit	VMRC Subaqueous Permit
Years Built	2011, 2012, 2014
Key Partners	James City County, VHB, NOAA Restoration Center
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021), Isaias (8/4/2020), Nestor (10/20/2019), Michael (10/12/2018), Matthew (10/9/2016)

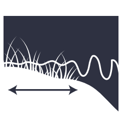


Project Description:

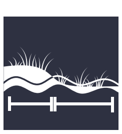
This project is a three part living shoreline restoration. Part 1 included using Class III stone breakwater and 3,500 square ft of *Spartina patens* for property owned by James City County. Part 2 stabilized 450 linear ft of shoreline along the James River on property owned by James City County. The primary purpose of Part 3 of the project was to finish stabilizing the remaining section of unprotected, eroding shoreline through the use of living shoreline techniques. This included the installation of a single breakwater, rock spur, sand fill, and select coastal/buffer plantings. The secondary purpose of the project was to provide public access to the water.

Adaptive Strategies:

Design robust sills or breakwaters to reduce future anticipated storm energy



Increase marsh width to enhance wave attenuation



Design plating zones to plan for migration

Site Parameters	
Wetlands Type	Tidal saltwater
Sill Type	Stone
Year Constructed	Older (2011)
Fetch	High (5 to 15 mi)
Exposure	High
Shore Orientation	SW
Erosion Rate	Low (-1 to -2 ft/yr)
Bank Composition	Sand
Nearshore Sediment	Firm
SAV Present	No
Shore Length	400 linear ft
Shore Morphology	Straight
Nearshore Morphology	Tidal flats
Datum	MLW
Mean Low Water	0.0 ft
Mean High Water	1.9 ft
Upper Limits Tidal Wetland	Varies
Storm Surge	10 yr: 6.7 ft; 50 yr: 7.8 ft; 100 yr: 8.2 ft
Expected Sea Level Rise (+MHW)	2020: 2.21 ft; 2040: 3.06 ft; 2060: 4.25 ft; 2080: 5.76 ft
Proximity of Upland Structures	House, ~700 ft
Adjacent Shoreline(s)	Defended w/ breakwaters

Site Condition	Pre-Construction	Post-Construction
Slope	Low (12:1)	Low (10:1)
Bank Height	High (16.0 MLW)	Moderate (4 ft)
Low Marsh	N/A	N/A
High Marsh	Transitional	Stable (9,200 sq ft)
Buffer Condition	Vegetated	Vegetated
Shore Width	Wide	Wide
Breakwater height	N/A	+5 MLW

Useful Life Factors:

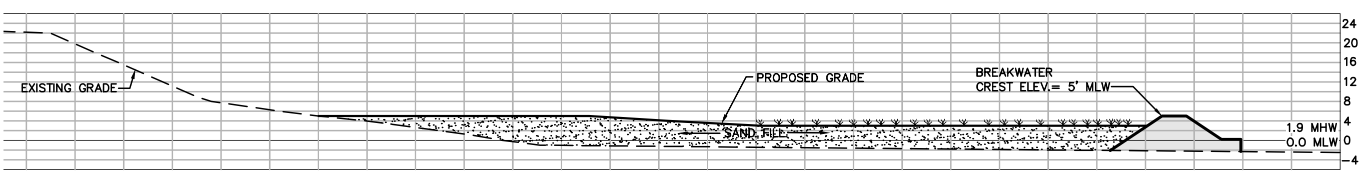
Property owner goals played a factor, as the projected needed to allow for recreational use of the beach. Proximity to upland development was also a factor, as the Colonial Parkway is on the other side of the beach, which will affect the life of the project. Storm surge and wave energy are considerable factors in this project, as the site is exposed to high fetch.

Site Challenges:

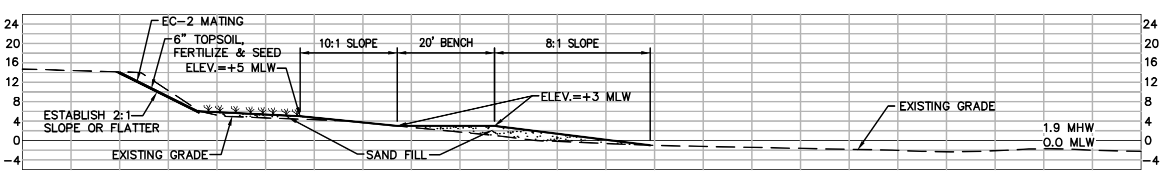
Challenge: Upland runoff - Stormwater outfall pipe.

Challenge: Extensive erosion from high fetch, which was addressed through the use of high breakwaters.

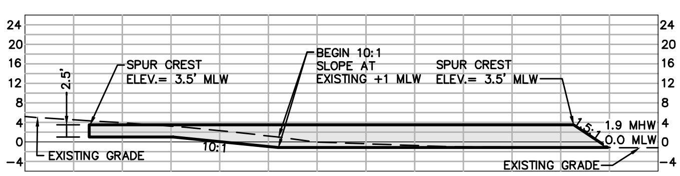
Challenge: The site is used for swimming, so creating a beach for recreational access was a priority.



SECTION A-A



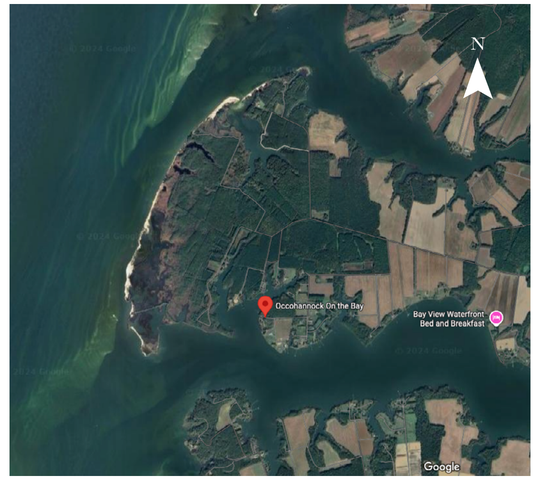
SECTION B-B



SECTION C-C

Occohannock on the Bay

Location	Accomack County
Waterway	Occohannock Creek
Permit	VMRC Subaqueous Permit
Years Built	2013
Key Partners	ES District UMC, Occohannock on the Bay Camp and Retreat Center, VIMS, NOAA Restoration Center, The Nature Conservancy
Major Storms	Elsa (7/9/2021), Claudette (6/21/2021), Isaias (8/4/2020), Nestor (10/20/2019), Michael (10/12/2018), Matthew (10/9/2016)

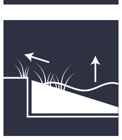


Project Description:

Living shoreline project with 6,900 sq ft of low marsh and 9,120 sq ft of high marsh and 3 distinct treatment sections:
1) Approx 405 ft of cobble sill to protect and enhance the existing high marsh fringe which was actively eroding along the water's edge. This marsh is partially protecting the adjacent upland from moderate storm waves. Portions of the low upland bank were eroding as the fringe became narrower.
2) Approx 185 ft of stone revetment to protect actively eroding upland and access path.
3) Approx 480 ft of stone sill consisting of sill units.

Adaptive Strategies:

Design robust sills or breakwaters to reduce future anticipated storm energy



Create stable slopes that promote marsh migration (in certain places along the shoreline)

Stabilize slopes to reduce erosion from wave energy

Site Parameters				
Wetlands Type	Saltwater			
Sill Type	Stone			
Year Constructed	Older (2013)			
Fetch	High (5 to 15 mi)			
Exposure	Moderate			
Shore Orientation	SW			
Erosion Rate	Low accretion (+2 to +1 ft/yr)			
Bank Composition	Sand			
Nearshore Sediment	Sand			
SAV Present	Yes			
Shore Length	1050 linear ft			
Shore Morphology	Headland			
Nearshore Morphology	Tidal flats			
Datum	MLW			
Mean Low Water	0.0 ft			
Mean High Water	1.7 ft			
Upper Limits Tidal Wetland	4.4 ft			
Storm Surge	10 yr: 4.3 ft	50 yr: 5.1 ft	100 yr: 5.6 ft	
Expected Sea Level Rise (+MHW)	2020: 0.17 ft	2040: 1.02ft	2060: 2.21 ft	2080: 3.72 ft
Proximity of Upland Structures	Building, 165 ft			
Adjacent Shoreline(s)	Various (defended and undefended)			

Site Condition	Pre-Construction	Post-Construction
Slope	Steep	Steep
Bank Height	High	High (Various; 5-12 ft, MLLW, +9, 120 sq ft)
Low Marsh	Eroded	Stable (+1.7 ft MLLW, +6,900 sq ft)
High Marsh	Transitional	Stable (+4.4 ft MLLW
Buffer Condition	Vegetated	Vegetated
Shore Width	Wide	Wide

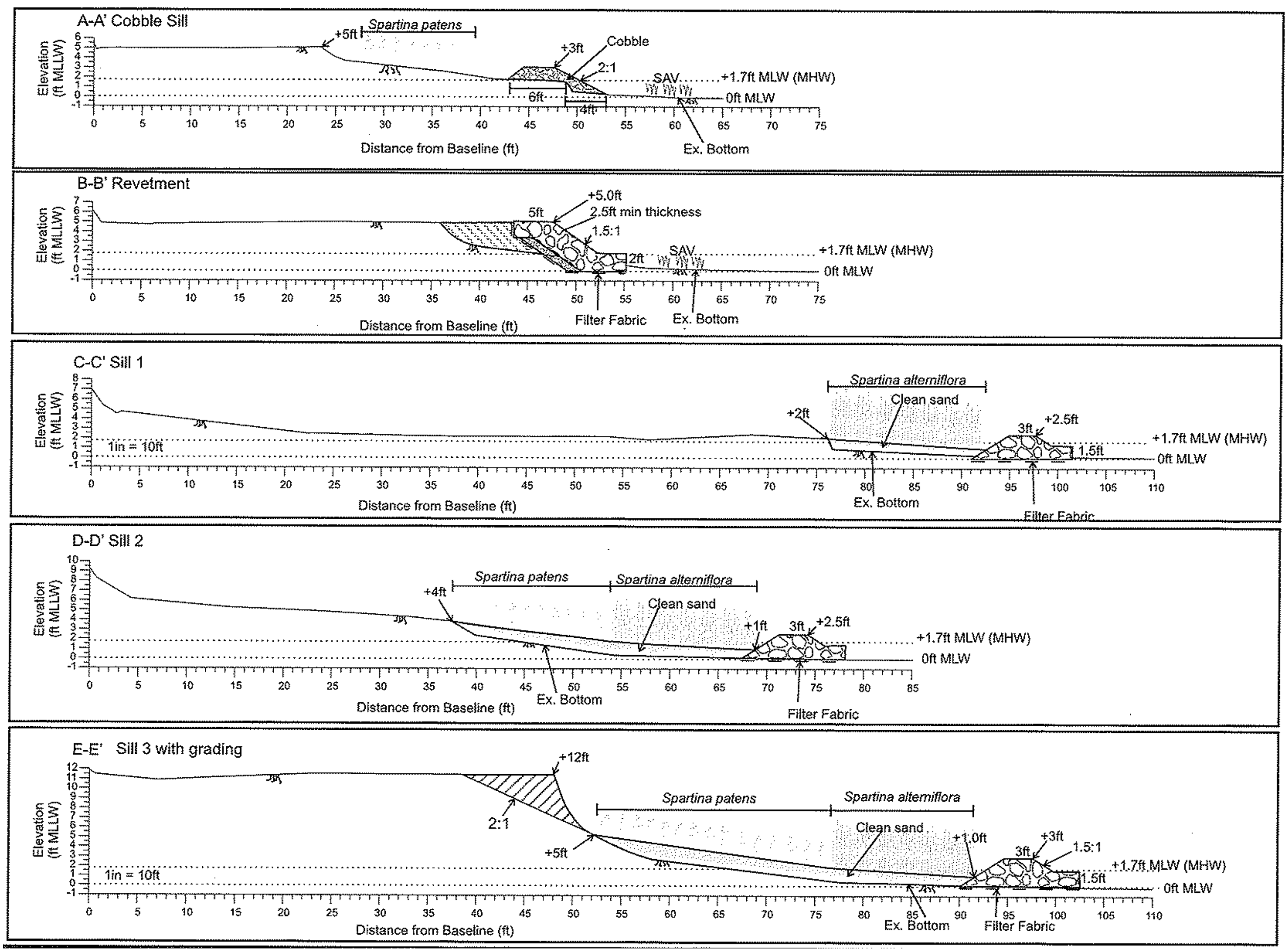
Useful Life Factors:

The site has an intact buffer that will provide space for future marsh migration if managed to allow marsh grass establishment. Structures in the upland are located 165 ft from the shoreline and will not impede migration. The sill was constructed at +3 ft MLW. Sea level rise at this location is predicted to be +2.21 ft in 2060.

Site Challenges:

Challenge: Existing SAV beds are within a few feet of MLW, disallowing encroachment into the nearshore.

Challenge: Three subreaches of shoreline required separate site assessment and stabilization strategies.



Data and Tools

Virginia Shoreline management law and guidelines require two things: 1) Using living shorelines as the default erosion control structure, unless best available science indicates a living shoreline is not suitable and 2) Living shorelines must protect shorelines and sensitive coastal habitats from the impacts of sea level rise and coastal hazards. The updates to the Wetlands Act and the corresponding Guidelines do not include comprehensive directions for accomplishing either of these considerations. There is no singular location or reference document from which a designer or installer could collect the required data to ensure compliance with the new law. This resource highlights what data the Guidelines indicate are needed to design living shorelines and what tools and resources are available to locate the data.

The tools below provide guidance on their use, but for more specific information, consult the Chesapeake Bay Landscape Professional Certification Living Shoreline Site Conditions Tool Guide ("CBLP Living Shoreline Data Guide"). For general information on many data requirements listed below, consult the 2017 report, "Living Shoreline Design Guidelines for Shore Protection in Virginia's Estuarine Environment" (Hardaway, Milligan, Duhring, Wilcox).

Data	Source	Notes
Bank composition	Google Earth; VIMS Google Earth Plug-In Tools	
Bank height	VIMS Adapt VA Viewer; VIMS Shoreline Management Model	
Boat wakes	VIMS Shoreline Inventory, onsite observations, NOAA Nautical Chart Viewer, Defining boat wake impacts on shoreline stability toward management and policy solutions, marinetraffic.com	
Depth offshore	Google Earth; NOAA Nautical Chart Viewer	
Design wave determination	VDOT Significant Wave Height Prediction Curves	
Erosion rate	VIMS Shoreline Change Viewer	
Existing and projected bathymetric elevations	Google Earth; NOAA Bathymetric Data Viewer	CBLP Living Shoreline Data Guide
Fastland bank condition	Google Earth & VIMS Google Earth Plug-In Tools; VIMS Adapt VA Viewer	Design wave is used when assessing sites with an average fetch of 1 mile or greater; CBLP Living Shoreline Data Guide
Fetch	Google Earth; VIMS Google Earth Plug-In Tools	Ranges presented in very low erosion to very high erosion; CBLP Living Shoreline Data Guide

Data	Source	Notes
Nearshore morphology	Google Earth; VIMS Google Earth Plug-In Tools; NOAA Nautical Chart Viewer	To calculate projected elevations, add sea level rise to existing elevations
Nearshore stability	*Field verification required*	Fastland bank height is measured from mean high water (MHW) to the top of the bank
Oyster leases	VMRC Chesapeake Bay Online Map (private oyster lease map)	CBLP Living Shoreline Data Guide
Sea Level Rise: NOAA Intermediate High Scenario (2017 data and higher)	Adapt VA Viewer (2017 NOAA data); NOAA SLR Viewer (2017/2022 NOAA data) detailed site data is only available where "Scenario Location" icons are nearby	CBLP Living Shoreline Data Guide
Shoreline morphology	Google Earth & VIMS Google Earth Plug-In Tools	CBLP Living Shoreline Data Guide
Shoreline orientation	Google Earth & VIMS Google Earth Plug-In Tools	CBLP Living Shoreline Data Guide
Storm event water levels (10-year storm)	FEMA Flood Insurance Study (FIS) for locality	Water levels in NAVD88 - Google Earth & VIMS Google Earth Plug-In Tools: Convert NAVD88 elevations to mean low water; CBLP Living Shoreline Data Guide; Storm chart included in appendix
Storm-level hydrological energy	Adapt VA Viewer(SLOSH Data from 2022)	Storm chart included in appendix
Storm surge frequency	NOAA Storm Event Database	
Submerged aquatic vegetation (SAV)	VIMS Interactive SAV Map; SAV Conflicts Viewer	
Tide range	Google Earth & VIMS Google Earth Plug-In Tools; NOAA Tides & Currents	CBLP Living Shoreline Data Guide
Upland use/proximity to infrastructure/cover	Google Earth & VIMS Google Earth Plug-In Tools; VIMS Adapt VA Viewer	Google Earth & VIMS Google Earth Plug-In Tools: Convert NAVD88 elevations to mean low water; CBLP Living Shoreline Data Guide
Width and elevation of backshore region	Google Earth & VIMS Google Earth Plug-In Tools	Marsh Migration Corridor Envelope

The Guidelines indicate that different data is required depending on the type of erosion control structure being permitted: General Permits 1 or 2, Non-General Permits, and all shoreline alterations.

The following is a list of the data requirements included in the Guidelines for each type of permit (emphasis added).

Living Shoreline: General Permits (Groups 1 & 2)

Proposed uses or development of tidal wetlands must allow, to the maximum extent possible when considering existing structures and infrastructure (including but not limited to roads, houses, and outbuildings), and natural impediments (including but not limited to steep banks and bluffs), the landward migration of existing vegetation over the useful life of the project, using the **2017 NOAA Intermediate-High scenario projection curve** outlined in Section III-D of these Guidelines or, in the future, any updated projection based on the best available science and selected through the Coastal Master Plan process; measurements of **fetch, depth offshore,shoreline morphology, shoreline orientation, nearshore morphology, oyster leases, submerged aquatic vegetation, tide range, storm surge frequency, erosion rate, design wave determination, and sea level rise.**

Living Shoreline: Non-General Permits

Square footage of existing and resulting tidal wetland types, existing and proposed grade elevations and slope, mean high, mean low and the **10-year storm event water levels** as calculated by NOAA and the Federal Emergency Management Agency (FEMA), **existing and projected bathymetric elevations** to the minus 1-foot mean low water elevation and the current shoreline condition of adjacent properties to include any existing treatments. Additional consideration of shoreline variables shall also be given to **fetch exposure, fastland bank condition, bank height, bank composition, nearshore stability, upland use/proximity to infrastructure/cover, width and elevation of backshore region, and boat wakes.**

All Shoreline Alterations

Be designed and constructed to mitigate coastal hazards including **storm-level hydrological energy** that may reasonably be expected over the useful life of the project; be functionally resilient and **structurally designed to endure the impacts of sea level rise using the 2017 NOAA Intermediate-High scenario projection curve** or, in the future, any updated projection based on the best available science and selected through the Coastal Master Plan process.

Best Available Science

The Wetlands Act directs the Virginia Marine Resources Commission to "permit only living shoreline approaches to shoreline management unless the best available science shows that such approaches are not suitable." It clarifies that "[i]f the best available science shows that a living shoreline approach is not suitable, the Commission shall require the applicant to incorporate, to the maximum extent possible, elements of living shoreline approaches into permitted projects." (VA Code § 28.2-104.1) Neither the Act nor the Guidelines include a definition or additional information about "best available science," however, the Guidelines includes several instances of how best available science should be determined. On page 6 and 7, the Guidelines advise that "[w]hen considering the suitability of a living shoreline design or treatment, the Commission or the local wetlands board shall look to the *Virginia Institute of Marine Science Office of Research and Advisory Services* in instances in which there is a question as to what constitutes the "best available science." On page 14, the Guidelines explain that "[h]abitat Engineers within *VMRC's Habitat Management Division* provide an experienced conduit through which the best available science and the suitability of a site for a living shoreline can be relayed to an applicant." The Guidelines indicate that "[t]he Virginia Institute of Marine Science (VIMS) is designated as the Commonwealth's science advisor on coastal and marine natural resource-related issues. As such, ***VIMS will be the arbiter in situations in which the best available science is in question***." (page 14) One may assume the reference to VIMS on page 14 refers to the VIMS Office of Research and Advisory Services referenced on page 7, although the Guidelines do not confirm this assumption.

Photo by Karen Duhring/VIMS

Appendix

Case Study Permit Documents

1. Newport Crescent: Application, VMRC Report, StoryMap
2. Sarah Creek: JPA Application, VMRC Report, Relevant Report on Nearby Conditions
3. Linnet Lane: JPA Application, VMRC Report, StoryMap ("Berner Shoreline"), Photos
4. Money Point: Phase 1: JPA Application, Site Plans, VMRC Report
5. Island Road: JPA Application, VMRC Report
6. Townsend Place: JPA Application, Permit Drawings, VMRC Report
7. Hoffler Creek: JPA Application, VMRC Report
8. Little Creek: JPA Application, VMRC Report, Photos
9. Poquoson River: JPA Application, VMRC Report, Photos
10. Hermitage: JPA Application, VMRC Report
11. Knitting Mill Creek: JPA Application, VMRC Report, Permit Drawings
12. Free School Creek: JPA Application, VMRC Report
13. Milford Haven: JPA Application, VMRC Report, Photos
14. Port Haywood: JPA Application, VMRC Report
15. East River: JPA Application, VMRC Report
16. Ryan Resilience Lab: JPA Application, VMRC Report
17. Killman Cove: JPA Application, VMRC Report
18. Captain Sinclair: JPA Application, VMRC Report
19. Black Marsh Farm: JPA Application, VMRC Report
20. Poplar Grove: VIMS historic permit record
21. False Cape State Park: JPA Application, VMRC Report
22. Werowocomoco: JPA Application, VMRC Report
23. Nassawadox Creek: JPA Application, VMRC Report
24. Berkeley Plantation: JPA Application, VMRC Report
25. Jamestown Beach: JPA Application I, JPA Application II, JPA Application III
26. Occohannock On The Bay: JPA Application, VMRC Report, Additional Resources from VIMS

Historical Storm Record

Storm	Category	Max Wind Speed (kt)	Water Level (+MHHW)			
			Kiptopeke	Sewell's Point	Yorktown USCG	Windmill Point
Elsa (7/9/2021)	Tropical Storm	45	.54	.40	1.10	1.05
Claudette (6/21/2021)	Tropical Storm	40	.88	.70	.80	.81
Isaias (8/4/2020)	Tropical Storm	60	.49	.60	.74	.94
Nestor (10/20/2019)	Tropical Storm	40	1.17	1.16	1.47	1.77
Michael (10/12/2018)	Tropical Storm	60	1.84	1.91	1.87	2.63
Matthew (10/9/2016)	Hurricane - Cat 1	70	2.01	2.97	2.16	1.36
Sandy (10/29/2012)	Hurricane - Cat 2	85	3.86	4.04	3.43	3.02
Irene (8/28/2011)	Hurricane - Cat 1	65	.35	4.80	4.02	3.36
Isabel (9/16/2003)	Hurricane - Cat 2	82	3.58	5.13	N/A	N/A (gauge damaged)

Stone Size

Classes of riprap stone based on weight per VDOT specifications
Class AI: 25-75 pounds, > 10% weighing more than 75 lbs, "man-sized"
Class 1: 50-150 pounds, 60% weighing more than 100 lbs
Class 2: 150-500 pounds, 50% weighing more than 300 lbs
Class 3: 500-1,500 pounds, 50% weighing more than 900 lbs
Type 1: 1,500-4,000 pounds, average weight 2,000 lbs
Type 2: 6,000 - 20,000 pounds, average weight 8,000 lbs

Living Shoreline Design Work Group Members and Advisors

* member of the technical review committee

Work Group Members

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- Jeff Watkins, Shoreline Structures, LLC
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Work Group Meetings

- November 30, 2023 - Virginia Beach
- December 21, 2023 - Virtual Follow Up
- February 29, 2024 - Williamsburg
- April 8, 2024 - Virtual Follow Up
- May 30, 2024 - Hampton
- June 6, 2024 - Virtual Follow Up
- July 23, 2024 - Virtual Meeting
- August 1, 2024 - Virtual Follow Up

Photo by Wetlands Watch