

FINAL REPORT--CHESAPEAKE BAY TRUST

An Ecosystem Approach to Living Shoreline Project Design

a. Names of individuals providing the services

Investigators

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Partners

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b. Project Summary relative to deliverables and scope of work

[Note: Figures are in Appendix 1, Tables in Appendix 2.]

Preface

Due to the information generated by this project funded by the Chesapeake Bay Trust (CBT), we were successful in competing for two subsequent grants, one for \$40,000 from the Chesapeake Research Consortium (CRC) and a second for \$1,000,000 from the Department of Defense's Readiness and Environmental Protection Integration (REPI) Challenge Grant program. In addition, we submitted an additional proposal for \$140,000 to the Chesapeake Bay Cooperative Ecosystem Studies Unit. All three of these are to conduct shoreline and habitat restoration at the Naval Weapons Station Yorktown as part of a comprehensive restoration program that also involves the shoreline of the National Park Service's Colonial National Historical Park.

Objective 1: Develop a shovel-ready living shoreline restoration plan and monitoring protocols.

Under Deliverable 1 we discuss the biological elements of the living shoreline design relative to oyster population enhancement. The physical design is discussed in subsequent Deliverables.

Deliverable 1. Literature review of living shoreline design applications effective for oyster population enhancement

This task involved a review of the effectiveness of living shoreline restoration designs that incorporate alternative oyster reef substrates. The review emphasized the placement of and assessment of the performance of living shorelines constructed with the goal to maximize oyster production and ecosystem benefits over time, and was comprised of three elements. First, we determined whether we could conduct a formal meta-analysis or a limited review based on the time and effort necessary to conduct a formal meta-analysis. As explained below, the funding under this grant could not cover the time required for a formal meta-analysis, only a limited review. However, we estimated the time necessary for a formal meta-analysis in order to acquire funding to complete the meta-analysis. Fortunately, we now have some funding under the CRC grant to initiate the meta-analysis and are doing so. Second, we reviewed requirements for placement of living shoreline oyster reefs to produce self-sustaining, productive oyster populations and their attendant ecosystem benefits. Third, we reviewed and recommended protocols for reliable assessment of the performance of living shoreline oyster reefs.

Note: If we are able to secure some additional funding to cover the time required for the meta-analysis, we will provide a report to CBT as an addendum to this report. The addendum report will acknowledge CBT, CRC and other funding agencies.

(i) Requirements for a meta-analysis of living shoreline restoration designs that also aim to enhance oyster populations

Formal conduct of a meta-analysis will require adherence to the PRISMA standard for meta-analysis reporting (Moher et al., 2009). A PRISMA checklist will be followed as shown in the table below.

The steps involved in a PRISMA search involve (i) records identified through database searching and additional records identified through other sources, (ii) screening of Titles and Abstracts to eliminate records that do not meet meta-analysis criteria, (iii) screening of full text to eliminate additional records that do not meet meta-analysis criteria, and (iv) analysis of remaining records to extract data and information for the meta-analysis. Two of the PIs (Lipcius and Seitz) have experience with meta-analysis methods, and have estimates of the time needed to go through the PRISMA search steps (i-iv) above.

Part of step (i) was completed and we don't include it in the estimates of time commitment. Step (ii) takes on average 2 h per 500 Abstracts and requires two individuals to review the Abstracts independently. When agreement is not reached by the two individuals, estimated at 30% of the Abstracts, then the two individuals discuss their decisions and revise the selected records accordingly. This step takes about 1 h per 20 Abstracts. If the two individuals disagree after discussion, then a third individual makes the deciding choice. On average 15% of records require a third individual at 2 h per 500 Abstracts. We performed a Google Scholar search using the search string: ["living shoreline" AND oyster], which yielded 676 references. Step (ii) in the search thus would require an estimated $(676/500) \times 2 = 27$ h per individual. Assuming that 30% of Abstracts require discussion, this step is estimated at $676 \times 0.3 = 203$ Abstracts at 1 h per 20 Abstracts,

resulting in 10 h for both individuals. Then 15% of the Abstracts require a third individual ($676 * 0.15 = 101$ Abstracts), which at 2 h per 500 Abstracts is 0.4 h. Hence, the total time for step (ii) is estimated at $(27 * 2) + (10 * 2) + 0.4 =$ about 74 h. Step (iii) takes about twice as much time as step (ii), which if about 50% of the Abstracts remain after step (ii) would require an additional 37 h. Collectively, steps (ii) and (iii) would take about 111 h.

All three staff under Lipcius and Seitz were funded at 40 h each, which was required to conduct the field sampling and lab processing. Lipcius and Seitz had about 24 h left after the field sampling, which is insufficient to conduct even steps (ii) and (iii). Consequently, a limited review was undertaken rather than a meta-analysis. Step (iv) takes much more time, approximately 0.4-0.5 h per Abstract. If 20% (135) of the Abstracts remained for step (iv), an additional $135 * 0.4$ or $0.5 = 54-68$ h would be required. Adding time for analysis and report preparation at 120 h, the complete meta-analysis is estimated to need $111 + 54-68 + 80 = 285-299$ h for completion.

Section/Topic	#	Checklist item
TITLE		
Title	1	Identify the report as a systematic review, meta-analysis, or both.
ABSTRACT		
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria; participants; and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.
INTRODUCTION		
Rationale	3	Describe the rationale for the review in the context of what is already known.
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).
METHODS		
Protocol & registration	5	Indicate if a review protocol exists. If and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).
Data collection	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.
RESULTS		
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.
Risk of bias in studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.
Risk of bias by studies	22	Present results of any assessment of risk of bias across studies (see item 15).
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see item 16]).
DISCUSSION		
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.
FUNDING		
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.
From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed.1000097. For more information: www.prisma-statement.org .		

(ii) Requirements for placement and performance assessment of living shoreline oyster reefs

To conduct a limited review, we focused on recent publications, some of which were reviews. The following publications were consulted:

- Baggett, L.P. et al. 2015. Guidelines for evaluating performance of oyster habitat restoration. *Restor. Ecol.* 23:737–45.
- Bilkovic et al. 2017. *Living Shorelines: The Science and Management of Nature-Based Coastal Protection*. Taylor & Francis.
- Bilkovic, D.M and M.M. Mitchell. 2017. Designing living shoreline salt marsh ecosystems to promote coastal resilience. In: Bilkovic et al. (2017).
- Boyer, K. et al. 2017. San Francisco Bay living shorelines, Restoring eelgrass and Olympia oysters for habitat and shore protection. In: Bilkovic et al. (2017).
- Browne, M.A. and M.G. Chapman. 2017. The ecological impacts of reengineering artificial shorelines, The state of the science. In: Bilkovic et al. (2017).
- Chowdhury, M.S.N. et al. 2020. Do oyster breakwater reefs facilitate benthic and fish fauna in a dynamic subtropical environment? *Ecol. Eng.* 142:105635.
- Cordell, J.R. 2017. Benches, beaches, and bumps, How habitat monitoring and experimental science can inform urban seawall design. In: Bilkovic et al. (2017).
- Currin, C.A. et al. 2017. Response of salt marshes to wave energy provides guidance for successful living shoreline implementation. In: Bilkovic et al. (2017).
- Currin, C.A. 2019. Living shorelines for coastal resilience. In: Perillo et al. (2019).
- Davis, J. 2017. Gaps in knowledge, Information we still need to know about living shoreline erosion control. In: Bilkovic et al. (2017).
- Du Bois, K.R. 2017. Overcoming barriers to living shoreline use and success, Lessons learned from Southeastern Virginia’s coastal plain. In: Bilkovic et al. (2017).
- Hall, S.G. 2017. Growing living shorelines and ecological services via coastal bioengineering. In: Bilkovic et al. (2017).
- Heck, K.L. Jr. 2017. Ecosystem services provided by shoreline reefs in the Gulf of Mexico, An experimental assessment using live oysters. In: Bilkovic et al. (2017).
- Hernandez, A.B. et al. 2018. Restoring the eastern oyster: how much progress has been made in 53 years? *Front. Ecol. Env.* 16:463-471.
- La Peyre, M.K. et al. 2017. Comparison of oyster populations, shoreline protection service, and site characteristics at seven created fringing reefs in Louisiana, Key parameters and responses to consider. In: Bilkovic et al. (2017).
- Lipcius, R.N., R.P. Burke, D.N. McCulloch, S.J. Schreiber, D.M. Schulte, R.D. Seitz and J. Shen. 2015. Overcoming restoration paradigms: value of the historical record and metapopulation dynamics in native oyster restoration. *Front. Mar. Sci.* 2:65, doi: 10.3389/fmars.2015.00065.
- Lipcius, R.N. and R.P. Burke. 2018. Successful recruitment, survival and long-term persistence of eastern oyster and hooked mussel on a subtidal, artificial restoration reef system in Chesapeake Bay. *PLoS ONE* 13(10): e0204329. <https://doi.org/10.1371/journal.pone.0204329>.
- Lipcius, R.N. et al. 2019. Modeling quantitative value of habitats for marine and estuarine populations. *Front. Mar. Sci.* 6:DOI=10.3389/fmars.2019.00280.

- Liversage, K. 2020. An example of multi-habitat restoration: Conceptual assessment of benefits from merging shellfish-reef and boulder-reef restorations. *Ecol. Eng.* 143:105659.
- Morris, R.L. et al. 2019. The application of oyster reefs in shoreline protection: Are we over-engineering for an ecosystem engineer? *J. Appl. Ecol.* 56:1703-1711.
- Perillo, G.M.E. et al. 2019. *Coastal Wetlands, Second Edition: An Integrated Ecosystem Approach*. Elsevier.
- Peterson, M.S. 2017. Species richness and functional feeding group patterns in small, patchy, natural and constructed intertidal fringe oyster reefs. In: Bilkovic et al. (2017).
- Priest, W.I. III. 2017. Practical living shorelines, Tailored to fit in Chesapeake Bay. In: Bilkovic et al. (2017).
- Ridge, J.T. 2017. Evidence of exceptional oyster-reef resilience to fluctuations in sea level. *Ecol. Evol.* 7:10409-10420.
- Schulte, D.M. et al. 2018. Gear and survey efficiency of patent tongs for oyster populations on restoration reefs. *PLoS ONE* 13(5):e0196725.
- Seitz, R.D. et al. 2019. Production and vertical distribution of invertebrates on riprap shorelines in Chesapeake Bay: a novel rocky intertidal habitat. *Est. Coast. Shelf Sci.* 228:106357, URL=<https://doi.org/10.1016/j.ecss.2019.106357>.
- Smith, C.S. et al. 2020. Coming to terms with living shorelines: a scoping review of novel restoration strategies for shoreline protection. *Front. Mar. Sci.* doi: 10.3389/fmars.2020.00434.
- Theuerkauf, S.J. and R.N. Lipcius. 2016. Quantitative validation of a habitat suitability index for oyster restoration. *Front. Mar. Sci.* 3:64, doi: 10.3389/fmars.2016.00064.
- Theuerkauf, S.J. et al. 2015. Settlement, growth and survival of eastern oysters on alternative reef substrates. *J. Shellfish Res.* 34:241-250.
- Walters, L. et al. 2017. Lessons learned from living shoreline stabilization in popular tourist areas, Boat wakes, volunteer support, and protecting historic structures. In: Bilkovic et al. (2017).
- Wiberg, P.L. et al. 2019. Wave attenuation by oyster reefs in shallow coastal bays. *Estuar. Coasts.* 42:331-347.

From these publications, we developed the following guidelines for optimal placement of living shorelines to maximize performance as an alternative oyster reef and the ecosystem benefits derived from the oyster population. We recognize that these guidelines may not be feasible for all projects due to limited funding or personnel; use of even subsets of these can foster success.

Search for and utilize historical information on the past occurrence of oyster reefs at the proposed location — This information may be in the grey literature or archival document some of which may be hidden in archival documents. Such documents may be instrumental in better defining areas suitable for oyster reefs.

Conduct a pre-construction oyster population survey — Assessment of the current state of the oyster population can inform the likelihood of success. For instance, when evaluating areas for oyster restoration as part of a living shoreline, we census existing shoreline structures such as riprap or breakwaters for the presence or absence of oysters.

Conduct a pre-construction bottom survey — Such a survey will aid in identifying suitable bottom for the living shoreline oyster reefs, and can be accomplished through simple means such as by taking bottom samples at low tide or by more advanced methods such as core samples for gravimetric analysis. These data can also inform development of a Habitat Suitability Index (HSI) model.

Assess habitat quality and environmental conditions to develop an HSI model — Information on physical variables such as salinity, temperature, dissolved oxygen and water-column sediment concentration, can be integrated into an HSI model to determine if they are satisfactory for oyster survival, reproduction and growth. Note that an HSI model should be calibrated and validated for the specific area under consideration, if possible. The use of a general, uncalibrated and unvalidated HSI is inadvisable, as it can lead to costly failures.

Use the latitudinal gradient in Chesapeake Bay to determine the optimal combination of intertidal and shallow subtidal living shorelines — Due to the latitudinal gradient in Chesapeake Bay, water temperatures decrease upbay. Consequently, intertidal shoreline reefs are less likely to succeed in the upper bay. From our experience, intertidal shoreline reefs perform well south of the Great Wicomico River and poorly north of it. The Great Wicomico River appears to be in the transition zone where intertidal oysters can exist, but are killed in mass mortality events during extreme winter freezes.

To minimize the deleterious future effects of climate change and sea-level rise use a ‘bet-hedging’ strategy — Construction of different types of living shoreline reefs or in multiple sites over a larger geographic area will confer a degree of resistance and resilience to climate change.

Assess metapopulation connectivity with calibrated, high-resolution hydrodynamic models — Information from these models can be used to define sites that are likely to receive larvae or provide larval subsidies to the broader metapopulation.

When feasible, utilize demographic models and field experiments to assess the role of non-linear processes — Living shoreline reef features such as height in the water column may not affect oyster survival and growth linearly, but as threshold responses, such as the ‘sweet spot’ between Mean Low Water and Mean High Water for oysters in the lower bay.

Define optimal living shoreline reef design and scale for the specific system — For example, in areas of moderate to high siltation, high-relief reefs may ameliorate physical stress whereas low-relief reefs are likely to degrade.

Monitor the performance of living shoreline reefs over a prolonged time period, no less than 3 years post construction — From the literature and our own experiments, 3 years is the minimum amount of time needed to determine if a living shoreline will succeed or fail as an oyster reef. In many cases, larval settlement and juvenile abundance will be high in the first one or two years and subsequently fail. Conversely, in other situations larval settlement and juvenile abundance have been low, but then increase significantly in year three.

Monitor the performance of living shoreline reefs by using size-specific oyster abundance, biomass and age structure — Successful oyster reefs should have high abundance, high biomass, and multiple year classes (>2 year classes). For instance, the Chesapeake Bay Fisheries Goal Implementation Team recommends a restoration success threshold of 15 oysters per m², 15 g dry weight per m², and the presence of 2 or more year classes, and a target of 50 oysters per m², 50 g dry weight per m², and the presence of 2 or more year classes. We are adding a third year class to the metrics because in our experience and that of oyster restoration ecologists in the Gulf of Mexico, a restoration oyster reef can fail in the third year even after having two year classes in the second year after construction.

Monitor the performance of living shoreline reefs by using a reliable experimental design with random or stratified random sampling and adequate sample sizes to generate accurate and precise oyster population estimates — From the literature it is not uncommon for oyster population estimates to be biased (= inaccurate) and imprecise. Inaccurate population estimates can originate from non-random sampling and imprecision from low sample sizes. These problems can lead to either faulty conclusions or an inability to differentiate population estimates statistically over time or space. We are completing a manuscript/report that will provide clear guidelines for accurate and precise sampling of oyster reefs, including those of living shorelines, and will provide the report to CBT as an addendum.

Manage adaptively — Be prepared to alter living shoreline reefs as environmental conditions change and living shoreline reefs develop. In many instances it is possible to rehabilitate or reinforce living shoreline reefs to ensure successful performance. ecological outcomes is limited and alterations to restoration plans will almost assuredly be necessary.

If possible, design living shorelines as an experiment — Many living shorelines are constructed without different experimental treatments, whether due to specific goals or limitations, and if they succeed or fail one cannot determine which environmental or biotic factors drove success or failure. The science of living shorelines is in its developmental phase, and any experimental designs that generate information on why living shorelines succeed or fail will advance the science of living shorelines.

Consider the living shoreline in an ecosystem context — A living shoreline is not an independent entity. Rather it is part of a larger ecosystem, whether with adjacent seagrass beds, mangroves or salt marshes. The living shoreline's success may be determined by the ecosystem or it can have an impact, good or bad, on the ecosystem. For example, in our experience some living shoreline oyster reefs constructed in polluted habitats have performed very well, but in others the oyster reefs have been decimated by toxic pollutants two years after initial success. Due to the complexity of this issue, we cannot offer specific recommendations, except to discuss living shoreline plans with ecologists familiar with the ecosystem before expending money and effort to construct living shoreline oyster reefs.

Deliverable 2. Description of chosen site and rationale for methodology based on physical characteristics of site

To develop a shovel-ready living/hybrid shoreline plan required by the RFP, the following

criteria were met:

1. The living shoreline design **used structures that have been proven to succeed in marsh/shoreline protection under high-energy conditions** such as sill reefs serving as hybrid living shorelines (Hardaway et al., 2017) and other robust structures. Smaller, low-profile structures were used in creeks or low-energy areas.
2. The design **used structures that have been proven to succeed in oyster restoration and placed in locations benefitting York River oyster restoration**. Proven elements included sill reefs (Burke, 2010; Hardaway et al., 2017), and for low-energy habitats, alternative oyster reef substrates (Burke, 2010; Theuerkauf et al., 2017; Lipcius & Burke, 2018) such as refurbished derelict crab traps (Fodrie & Lindquist, 2015; Kingsley-Smith & Stone, 2015). Our location was chosen as Penniman Spit, as part of Naval Weapons Station Yorktown. The Virginia Interagency Oyster Team coordinated by NOAA and US Army Corps of Engineers has designated the suitable area of the York River for oyster restoration from Heron Point (upriver of York River mouth and Guinea Marshes) upriver to Clay Bank on the north shore, and the Goodwin Islands upriver to York River State Park on the south shore. These boundaries are consistent with our hydrodynamic models indicating that oyster reefs must be upriver of the York River mouth and downriver of York River State Park to assure larval connectivity between oyster populations in the river.
3. The plan **involved public landowners** (e.g., Department of Defense, National Park Service). The York River provided opportunities to collaborate with major public landowners interested in enhancing their shorelines using living shorelines that integrates natural features, including marsh grass and oyster reefs, and alternative reef structures such as derelict crab pots. In particular, two key public landowners that we have involved are the Department of Defense (DoD), specifically Department of the Navy, Naval Weapons Station Yorktown (NWSY) and National Park Service (NPS), who have authority and mandates to protect the shorelines bordering their facilities. We have established partnerships with these entities (see Partners above) to design a hybrid living shoreline at a key ecological site along the NWSY and NPS where the shoreline has been eroding significantly, causing major loss of marsh and shallow-water habitat—Penniman Spit on the south shore of the York River (Fig. 1).
4. The design **included elements that enhance the ecosystem**, especially those addressing **CBP outcomes for blue crab, fish habitat, oyster, wetlands (i.e., salt marshes), and climate resiliency**. We integrated all of the above into the design plan, except for seagrass (SAV) because the science on interactions between oyster reefs and seagrass reflects a knowledge gap (see Davis, 2017 for other examples), and due to the negative effects observed on the West coast (where eelgrass was degraded in the presence of the alternative oyster reefs due to sedimentation and burial; Boyer et al., 2017).
5. The design will **be resilient to climate change**, such as sill reefs which can be constructed to allow for sea level rise, and can be adapted to future augmentation, such as by addition of substrate (Hardaway et al., 2017).
6. The plan will **be transferable to other York River sites and in the Bay**.
7. The plan **involved a project advisory team with experience in living (hybrid) shoreline applications**. Our PIs and Advisors have extensive knowledge and experience with living shoreline applications.
8. The plan is designed to **serve as a demonstration project visible to the general public**.

We based our hybrid living shoreline design plan on that by Hardaway et al., (2014; see below -

“Physical design considerations”), which was revised to include the ecosystem-based design considerations listed above. The proposed hybrid living shoreline (HLS) is an oyster reef sill and adjacent alternative oyster reefs that will (i) be resilient to climate change, (ii) stimulate recovery and expansion of a salt marsh community, (iii) augment oyster restoration efforts in the York River, (iv) create shallow-water habitat through a lagoon for juvenile crabs and fish, (v) protect an ecosystem behind the spit that will be destroyed if the shoreline is not protected, and (vi) serve as a demonstration project easily visible to the public along the Colonial Parkway of the NPS.

(i) Physical design considerations – insight from previous projects

Hundreds of sill and breakwater sites occur around Chesapeake Bay in a variety of settings and have been installed at different times over the past 40 years. Though the design and construction of these systems that utilize rock, sand, and plants has changed over time, the basics of creating a stable marsh or pocket beaches for shore protection remains an effective method of shore protection (Hardaway et al., 1991; Hardaway et al., 2005; Hardaway & Gunn, 2010; Hardaway et al., 2007; Hardaway et al., 2009; Hardaway et al., 2018; Hardaway et al., 2019; Milligan et al., 2011; Milligan et al., 2016A; Milligan et al., 2016B; Milligan et al., 2019).

Of the many site characteristics necessary for design, fetch exposure typically drives design of shore protection systems. Effective shore protection must be sized correctly for its environment both in width of the system and height of the structures. For medium energy shorelines, sills should be placed far enough offshore to provide a 12-m-wide (low bank) to 21-m-wide (high bank) marsh fringe (Hardaway and Byrne, 1999) so that waves are attenuated during storms. During extreme events when water levels exceed 1 m above mean high water, some wave action may penetrate the system. For this reason, a sill height of at least 0.3 m above mean high water (MHW) should be installed, and armor stone may be Class II (fetch < 3 km) to Class III (fetch up to 5 km) (Hardaway et al., 2017). Sills on high energy sites need to be very robust as impinging wave heights can exceed 1 m and maintaining a vegetative fringe can be difficult. Therefore, sill heights should be at least 0.6 m above MHW, and the minimum size for armor stone should be Class III (Hardaway et al., 2017).

Breakwaters are large rock structures placed strategically offshore to maintain stable pocket beaches between the structures. The beaches provide most of the protection, so beach nourishment should be included as part of the strategy and periodic beach re-nourishment may be needed. Hardaway and Byrne (1999) suggest that breakwater systems in medium energy environments should cover at least 61 m of shoreline because individual breakwater units should have crest lengths of 18-46 m with crest heights of .6-1 m above MHW. Minimum mid-bay beach width should be 11-14 m above MHW. On high energy coasts, the mid-bay beach widths should be 14-20 m especially along high bank shorelines. Crest lengths should be 27-61 m. Armor stone of Class III (230 kg) is a minimum, but up to Type I (680-1800 kg) may be required especially where a deep near shore exists (Hardaway et al., 2017).

Part of the design process for shoreline protection in Chesapeake Bay is to assess the performance of previously installed projects. Several vegetated breakwater projects occur nearby on the York River at the Virginia Institute of Marine Science (VIMS) and the US Coast Guard

Station at Wormley Creek (Fig. 2). The breakwaters at VIMS were installed in 2010 and have experienced several large storms including Hurricane Irene in 2011. This system includes four breakwaters that range in length from 27-43 m with crest elevations of +1.5 m mean low water (MLW) located 21-30 m offshore (Fig. 3). The system also includes a 32 m spur with crest elevations of about 2 m MLW to interface with the downdrift Gloucester Point Public beach and reduce impacts. Prior to installation, the VIMS shoreline had a revetment and narrow beach along most of its shoreline, and the upland was eroded during storms (Hardaway et al., 2019). After 10 years, the wide beaches are heavily vegetated and submerged aquatic vegetation (SAV) has come into the embayments increasing habitat along with shore protection.

The breakwaters at the US Coast Guard Station are located at the entrance to Wormley Creek. In 1963, a relatively large, heavily vegetated spit occurred across the mouth of Wormley Creek (Fig. 4a). However, the area where the spit was attached to the upland was becoming narrow. To protect the spit and the creek from potential impacts if a breach occurred, the US Army Corps of Engineers designed four detached breakwaters and an attached sill that was installed in 1993. The breakwaters were 14-24 m long and were placed 21-31 m offshore (Hardaway et al., 2020). However, an insufficient amount of fill material was placed behind the structures during construction, so erosion of the spit continued. Over time, the sand fill has “separated” from breakwaters, and the spit attachment narrowed considerably by 2007 (Fig. 4). Low marsh had colonized small shoals behind each structure, but by this time, three of the four breakwaters are detached from the shoreline. Sand is being lost across the spit and into creek as evidenced by the sand bulge between breakwaters 2 and 3. By 2013, only a small spit remnant existed (Fig. 5). The spit had completely disintegrated by 2017 (Fig. 4). The sill component of the shore protection system has functioned well through time. It has maintained the marsh behind the structure. However, the loss of sand behind breakwater 4 has allowed waves to impact the marsh at the north end of the structure. It is eroding and could eventually be flanked causing the marsh island to erode from the backside.

The shore protection at Wormley Creek failed for several reasons including an insufficient amount of sand fill volume was placed at the site during construction. Detached systems rely on sediment accretion behind the structure in a tombolo or salient to provide shore protection. However, one reason erosion occurs at a site is because sand is lacking in the sediment transport system. This is the case at Wormley Creek; without sufficient sand volume, the backshore and upland are still impacted by waves and continue to erode. In addition, the breakwaters themselves are a little too short for the open fetch exposure. Design guidance indicates that the ratio of structure length to distance offshore should be about 1.5 or greater for tombolo development (Chasten et al., 1993). The Wormley Creek structures had a ratio of 0.8 to 1. In other words, structures need to be longer or closer to shore for a tombolo to be maintained. A last reason for the failure is the lack of maintenance at the site. If monitoring had occurred, the continued erosion at the site could have been remediated before the spit attachment was completely lost.

(ii) Current design plans

Our plan incorporates all NOAA (NOAA, 2015, 2017) and VIMS (Hardaway et al., 2017) guidelines including: (i) **site analysis**, (ii) **pre-construction monitoring**, (iii) **permit approval**

and legal compliance, (iv) site preparation, (v) installation, and (vi) post-construction monitoring.

Historically, Penniman Spit has existed for more than 160 years and was once more substantial than it is today (Fig. 6). The north and northeast facing spit provides protection to the mouths of King Creek and Felgates Creek as well as to the National Park Service (NPS) land along the Colonial Parkway. In 1937, the spit extended across the mouth of King Creek for over 915 m and was over 137 m at its widest part (Fig. 7). Between 1937 and 1994, the spit stayed relatively the same length but narrowed by almost 30 m in the area that ultimately breached (Milligan et al., 2010). By 2007, only a small strip of sand joined the west peninsula and east island of Penniman Spit. By 2011, the spit had narrowed in some areas by over 61 m since 1937 and breached in the center (Fig. 7) (Hardaway et al., 2020). Recently, the breached area is completely subaqueous with depths ranging from 0.3-0.5 m MLW. The marsh on the western peninsula is presently only about 24 m wide and only 18 m wide on the eastern island. The spit encompassed 6 ha in 1937 but now is only 0.8 ha, having lost 86% of its area.

Penniman Spit is the result shore erosion upriver. As the sandy upland banks erode, the material is transported downriver and feeds the spit. However, many of the shorelines updrift of the spit have been hardened in response to ongoing shore and bank erosion effectively reducing the amount of sand available to the long-shore transport system. Now that the spit has breached, spit decay will continue to accelerate because what sand is available will not cross the breach to feed the end of the spit.

The geomorphology varies between the remnants of Penniman Spit. The western peninsula still has the expected morphology of a large marsh spit. A higher vegetated high marsh (*Spartina patens*) berm surrounds a low interior marsh (Fig. 8). The low marsh (*Spartina alterniflora*) on the York River side of the peninsula is eroding and occurs only as a narrow band with scarps and peat outcrops. The peninsula is narrowing and likely will breach in the future. The eastern island is rapidly disappearing. It only has remnant marsh, sand and mud flats, and overwash areas (Fig. 9).

Augers sampled material in the nearshore on the York River side of the Spit indicate that in some areas the subbottom is sandy and overlays a layer of clay. The sand is fine to coarse. In other areas, the clay layer is exposed. The King Creek side of the Spit is steeper and muddier than the York River side. No SAV exists at the site.

The longest fetch to the East is 7.5 km; to the Northeast, it is 4.5 km; and to the North, it is 5 km. The mean tide range at Penniman Spit is 0.8 m (2.5 ft) and the rate of sea-level rise is 4.86 mm/yr (+/- .35 mm/yr) at Yorktown (NOAA, 2020). Starting wave conditions for the 100-year event include the significant wave height at 1.3 m and the peak wave period at 3.7 seconds. Starting still water elevations are 2.0 m, 2.3 m, 2.5 m, 2.9 m MLW (6.5 ft, 7.7 ft, 8.2 ft, 9.6 ft MLW) for the 10-year, 50-year, 100-year, and 500-year events, respectively (FEMA, 2015).

If the existing spit is not stabilized and it continues to erode, the dynamics at the mouths of both King Creek and Felgates Creek may change. Once the spit has been reduced, it will no longer provide protection to the shorelines behind it. Erosion could increase significantly behind it,

particularly at the exposed Colonial Parkway shoreline near the bridge across Felgates Creek. This shoreline presently is protected from the northwest, north, and northeast by Penniman Spit. During extratropical northeast storms, the winds, and therefore the waves, rotate around to the north and northwest as the storm moves through an area. Presently, the spit protects the interior King Creek shoreline from waves from the northeast, and once the spit is gone, waves will be able to reach far into King Creek and effect shoreline that presently is only impacted during large storms.

Deliverable 3. Design/construction document with scale and scope of restoration, engineering requirements of sufficient detail to carry out construction activities, and materials list with estimated quantities

Hardaway and his group (VIMS Shoreline Studies Program) have over 30 years of experience in developing design, construction, engineering, and materials plans for living shoreline projects (Hardaway et al., 2017). The preliminary plans for the living shoreline restoration plan have been revised in coordination with other team members, partners, and the advisors (See attached plan set “Penniman Spit Living Shoreline & Oyster Restoration Project”). Comments from partners were incorporated into the final plan along with the final cost estimate, including existing conditions as well as proposed plan sheets. Final plan drawings and specifications are available in digital format. Data have been created in GIS with appropriate metadata.

The living shoreline project is designed to protect and rebuild the sandy marsh spit known as Penniman Spit. The rock sill and breakwaters are appropriate for this section of shoreline due to its large fetch exposure on the York River. Recent coastal resiliency studies revisited sill sites that have been in place varying amounts of time, from 2-20 years, and found that the rock structures have performed very well for their intended purposes of shore protection and habitat enhancement (Hardaway et al., 2018; Hardaway et al., 2019). The spit was surveyed for elevation in October and December 2019 using a Trimble real-time kinematic global positioning system and a Trimble robotic total station to determine the elevations within the system. The marsh is relatively low with the highest elevation of +1.5 m MLW (+5 ft MLW) occurring on the upper marsh berm on the western peninsula (See attached plan set “Penniman Spit Living Shoreline & Oyster Restoration Project”). The nearshore on the York River side is shallow with depths of about -0.5 m MLW (-1.5 ft MLW) at about 24 m from MLW.

The project consists of 5 rock sills, 1 rock breakwater, and 2 rock spurs, along with sand fill and marsh plantings including *Spartina alterniflora* and *Spartina patens* (See attached plan set). Approximately 75 oyster castles will be stacked in a 2 m square configuration channelward of and immediately adjacent to the rock structures. Also, approximately 190 upcycled 0.6 m square crab pots will be coated in concrete and placed on the backside of the spit at MLW. The Five rock sills are proposed to be: Sill 1 is 61 m (200 ft) long and attaches to an existing revetment that occurs along the mainland at NWSY; Sill 2 is 167 m (548 ft) long. These two structures protect the western peninsula and comprise Reach A. Sill 3 is 88.1 m (289 ft) long, Sill 4 is 73.2 m (240 ft) long, and Sill 5 is 125 m (410 ft) long. These structures protection the eastern island and comprise Reach C. Two spurs and a breakwater are proposed for the center of the spit that has eroded completely away. Spur 1 is 22.6 m (74 ft) long, Spur 2 is 19.8 m (65 ft) long, and Breakwater 1 is 48.8 m (160 ft) long. These structures comprise Reach B. Gaps between the

structures are narrow, less than 6 m (20 ft) to reduce the impact of waves in the new marsh. The rock structures will cover about 0.8 ha (1 acre) of subaqueous bottom. Sand will be placed landward of the structures over about 1.2 ha (3 acres) and planted with *Spartina alterniflora* and *Spartina patens*. Each species will be planted on a 0.5 m by 0.5 m grid spacing with 0.5 oz of slow release fertilizer per plant. Sand should be allowed to equilibrate for about two weeks before planting occurs. Survival of 80% of the planting is required for one year.

Approximately 1.2 ha (3 acres) of wetlands will be created/restored along about 600 m of shoreline, and the rocks, oyster castles, and concrete crab pots will provide additional habitat for oysters and other shellfish. No tree clearing or grading will occur.

The most likely way to construct this project will be by water. A barge port will be established on the creek side of Penniman Spit. This will allow light-loaded barges to deliver rock and sand to the project site. Larger material barges will bring rock and sand up the York River where they will be moored offshore on Coast Guard approved moorings. A machine barge with excavator will unload material onto smaller light load barges that will be moved by small tugs into King Creek and up to the barge port. Another excavator will transfer material to site trucks on the port barge which will take sand to the project shoreline. A sand path will be established to transfer material along the project shore to build the rock structures. Final sand grades will be established and planted in wetlands vegetation.

Construction oversight is an important component of the plan. Oversight is required to make sure the materials used are as described in the specification. The construction manager also is responsible for being on site regularly to make sure safety protocol is being adhered to and that the environment is being protected as per the design. They have a working knowledge of living shorelines and construction procedures to ensure that the system is being built as specified throughout the process not just at the end.

The total estimated cost for the Living Shoreline project is shown in Table 1. The cost for materials includes both the cost of the rock and sand and the cost of installation by the contractor. The marsh grasses can be planted by volunteers hosted by the Navy to reduce costs and increase awareness. Site work includes mobilization/demobilization costs such as creation of barge port, silt fencing, creation of a stockpile, safety requirements, returning the project site to pre-installation status, etc. and is necessary for construction projects. Some phasing of this project can occur. Reach A can be constructed without Reaches B and C. The structures in Reach A will protect the western peninsula which will continue to provide some protection to the creeks behind the spit. Reach B only makes sense as connector between the two sections of the spit. Though Reach C could be built without Reach B, barge access maybe more difficult because it's relatively more shallow on the lee side.

Hardaway et al. (2018 & 2019) indicated that rock sills and breakwaters can be an adaptive management strategy for shore protection in the face of sea-level rise. When needed, the addition of sand and rock can raise the shore protection system to maintain effectiveness as sea-level rise impacts shore habitats and the upland. Conditions along the spit are different than when the conceptual design was created five years ago. The original conceptual design from the York County Shoreline Management Plan (Hardaway et al., 2014) was modified to reflect existing

environments so that the shoreline and habitat restoration is more resilient to coastal conditions and sea-level rise. In addition, ecosystem-based changes included oyster reef base to enhance oyster habitat.

Recent studies in NC (Fodrie & Lindquist, 2015) and SC (Kingsley-Smith & Stone, 2015) indicate that refurbished derelict crab traps coated in concrete (Fig. 10) serve as oyster reefs (Fig. 11). We have partnered with a blue crab processor (Carino's Seafood, J. Carino, owner) who crabs and processes the blue crab catch from crabbers in the York River. He noted that crabbers crush degraded crab traps, and throw them into the river channel as derelict traps rather than using space on their boats to transport them to disposal sites. He indicated that crabbers would readily return degraded traps if paid ~\$1 per pot. Mr. Carino will stockpile the crabbers' derelict traps, which we will purchase for ~\$1 each for use as oyster reefs. We also have commitments from crabbers and processors in the Rappahannock (D. Jenkins) and Poquoson (T. Farrington) Rivers who will stockpile crabbers' traps from their rivers. Consequently, our HLS plan has the additional benefit of removing derelict crab traps from the ecosystem.

A Tidewater Joint Permit Application (See attached JPA) was developed to calculate the habitat changes and create the permit drawings.

Deliverable 4. Monitoring protocol with timeline of pre-construction monitoring, implementation, and post-construction monitoring.

(i) Physical structure maintenance and monitoring

As was shown by the Wormley Creek project analysis, maintenance and monitoring are important components when trying to determine if the Living Shoreline is functioning as effective shore protection. Maintenance typically includes removing wrack, vegetation debris, and flotsam and jetsam. Unwanted vegetation should also be removed from the planted marsh. Unwanted vegetation can be species that move into the marsh, particularly trees, that will eventually shade it out as well as invasive species like *Phragmites australis*. If bare spots occur in the marsh, replanting should occur. Some sand may be lost during storms and should be replaced to maintain the design elevations.

When creating a monitoring plan, the metrics to document include sand retention, movement and elevation variability, tidal inundation which ensures that the wetland vegetation is being regularly inundated, a visual inspection, and evaluate the success of the plantings. Over a pre-determined period are the metrics improving? staying the same? or deteriorating? To ascertain the metrics of the system and sand retention after construction topographic surveys should be performed pre-construction, as-built, and over a pre-determined longer-term. Monitoring after one year allows for the near-term changes to be determined. This is especially important because the sand fill will adjust and can affect survival of the plants. After a year, topographic surveys can be less frequent. However, visual surveys, whether on the ground through photography or in the air with satellite or drone imagery can be more frequent. Vegetation is an integral part of the living shoreline design and should be monitored with meter square plots over time. The monitoring results will provide information for remedial actions to maintain the stability and effectiveness of the shore protection system.

(ii) Living resource monitoring

To evaluate biological responses of the estuarine community and epibenthic predators to living shoreline construction, we conducted baseline sampling in a Before-After Control-Impact (BACI) experimental design, which is the gold standard for impact studies (Underwood, 2009). Our survey constituted “Before” sampling. At three parts on the HLS site (Penniman Back, Penniman Front, Inshore and Penniman Front Offshore or Mainland) and at two control sites (Indian Field Creek, Carter’s Creek) we took 8 benthic samples with and 4 - 11 seines, which is a sufficient number to detect differences in estuarine fauna to ecosystem alterations (Seitz et al. 2018) (Fig. 12). At each site and replicate location, we collected benthos and epibenthic predators. For benthic samples, we used a suction apparatus (with sediment sieved on a 3-mm mesh), and used a 10-cm-diameter hand-held core (sieved on a 500 μ m mesh). Benthic suctions were immediately put on ice, transported to VIMS, and frozen for later sorting. Benthic cores were preserved in normalin and stained with Rose Bengal. Benthic were sorted twice, organisms were identified to lowest possible taxa, and enumerated. Organisms were dried 70 °C for 48 h and then combusted in a muffle furnace for 4 h at 550 °C to obtain ash-free dry weights (AFDW). For predator (crabs and fish) sampling, we used a beach seine (15.25-m long and 1.2-m deep with a mesh of 0.64 cm). Seining involved sweeping roughly a quarter-circle quadrant by fixing one pole on the shore and taking the other pole off the shore at a 90° angle stretching the net, then dragging the offshore pole in an arch to the shore. This sampling was conducted in the shallow areas adjacent to the shoreline. Immediately after retrieval of the net, all fish and crabs were placed into ambient water-filled totes. Fish were identified to species and the first 30 individuals of each fish species were measured millimeter to fork length. Crabs were enumerated, sexed, and width was measured to nearest one-tenth of millimeter.

Density, diversity, and biomass of benthos, oysters, mussels, blue crabs, and fish were compared among habitats with differing shorelines using Analysis of Covariance (General Linear Models) statistical models, with AIC model comparisons, and community structure analyzed using multivariate analyses and routines in PRIMER v. 7 (Clarke & Gorley, 2015). We also measured water temperature, salinity, dissolved oxygen (DO), turbidity, water depth, sediment grain size, and sedimentary carbon. These physical measurements will aid in determining mechanisms underlying any changes in estuarine organisms and predators that could be detected in a future project assessing the effects of the living shoreline 'After' its construction. By conducting a through 'Before' sampling at the project site and at nearby controls, organismal responses after HLS construction can be statistically compared between Control and HLS (Impact) sites. Data from this project serves as the baseline (Before) for analyses after construction (After) in the BACI design.

(iii) Baseline data

Samples were collected from September 10 to October 1, 2019, individual collection dates, location, number, and type of samples are listed in Table 2. Water temperature ranged from 24.5 – 30.8 (°C), salinity from 18.0 – 20.0, and all sites had normoxic dissolved oxygen levels.

For 3-mm benthic suctions, in total, 1162 individuals and 28 species were collected in 40

samples. Densities ranged from 92 individuals at Carter's Creek to 375 individuals at Indian Field (Fig. 13a). The Baltic clam, *Limecola balthica*, the clam worm, *Alitta succinea*, the stout razor clam, *Tagelus plebeius*, and capitellid worms were the most dominant species across all sites contributing to 61.7% to 81.8% of all individuals (Table 3). Biomass ranged from 1.6 g/m² at Carter's Creek to 17.9 g/m² at Penniman Back (Fig 13b). Benthic biomass was dominated by *T. plebeius*, *L. balthica*, and polychaete worms contributed to 78.6 % to 97.5% of all the biomass (Table 4). Species richness was highest at Indian Field (9.1) and lowest at Carter's Creek (3.9) (Fig. 13c). Similarly, diversity (H' loge) was highest at Indian Field (1.529) and lowest at Carter's Creek (1.022) (Fig. 13d). Evenness was lowest at Indian Field (0.693) and highest at Carter's Creek (0.863) (Fig. 13e). Differences in community composition between sites are shown by Canonical analysis of principal coordinates (CAP) with vector lines indicating which species are contributing to differences among sites (Fig. 14).

In total, 451 individuals and 26 species were collected in the 500 μ m cores. Densities ranged from 400.9 individuals at Carter's Creek to 1757.7 individuals at Indian Field (Fig. 15a). Polychaetes largely dominated the cores with Capitellids, *Alitta succinea*, Spionids, *Spiochaetopterus oculatus*, and *Leitoscoloplos* spp. being the most common types consisting 72.3% to 82.9% of the individuals (Table 5).

Biomass ranged from 0.15 g/m² at Carter's Creek to 4.7 g/m² at Indian Field (Fig. 15b). Biomass was dominated by polychaetes, *L. balthica*, phoronids, and *Molgula manhattensis* (Table 6). Species richness was highest at Penniman Back and Indian Field (4.5) and lowest at Carter's Creek (2.0) (Fig. 15c). Diversity was lowest at Carter's Creek (0.548) and highest at Penniman Back (1.169) (Fig. 15d). Evenness ranged from 0.780 at Penniman offshore to 0.893 at Carter's Creek (Fig. 15e).

In total, 4374 individuals and 20 species were collected in 45 seines across the sites. Abundance ranged from 19.5 individuals at Penniman Main to 174.7 individuals at Carter's Creek (Fig. 16a). The Atlantic silverside, *Menidia menidia*, the blue crab, *Callinectes sapidus*, striped killifish, *Fundulus majalis*, the white shrimp, *Neohaustorius schmitz*, mummichugs, *Fundulus heteroclitus*, and bay anchovy, *Anchoa mitchilli* consisted of 80.1% to 96.7% of individuals (Table 7). Species richness ranged from 1.2 to 6.7 species with the lowest at Penniman Main and highest at Carter's Creek (Fig. 16b). Diversity was lowest at Penniman Front (0.771) and highest at Penniman Back (1.22) (Fig. 16c). Evenness was lowest at Carter's Creek (0.532) and highest at Penniman Main (0.781) (Fig. 16d). Differences in community composition among sites are shown by Canonical analysis of principal coordinates (CAP) with vector lines indicating which species are contributing to differences among sites (Fig. 17).

Deliverable 5. Key partner recommendations and feedback

Besides the meetings specified in the RFP, we had planning meetings/Zoom calls with the Partners and Advisors listed above, as well as with the individuals selected for the project advisory team, for their feedback.

Deliverable 6. Budget and potential funding sources

As noted in the Preface, the PI and co-PIs have successfully competed for two grants and have a third grant proposal submitted.

Deliverable 7. Potential ecological and physical outcomes of restoration

The PI and co-PIs have published over 100 scientific documents on the ecological and physical impacts of ecosystem alteration, and along with the results of monitoring described earlier, will be able to quantify ecological and physical impacts comprehensively using results in future publications. We have conducted the “before” sampling and will plan to conduct the “After” sampling (for use in a Before-After Control-Impact design) after the living shoreline is built. The differences in “Before” and “After” metrics of living resources will demonstrate the ecological outcomes of the restoration.

Deliverable 8. Recommendations for future maintenance/adaptive management

This task is incorporated into ***Deliverables 1 and 2*** through reviews of the various documents and scientific publications dealing with guidelines and best practices for living shorelines, and gaining insight from previous projects. An additional meta-analysis to be performed with additional funding is planned.

Deliverable 9. Plan for permitting application process based on site selection

Hardaway and his group have been generating permit applications for numerous locations throughout Chesapeake Bay for over 35 years, and generated one as part of this project (See Attached JPA).

Objective 2: Explain how results of this work will be transferable to comparable locations.

Environmental conditions at the Penniman Spit site are representative of eroding shorelines along the York River and other locations in Chesapeake Bay, particularly for shorelines managed by NPS, DoD, and the Chesapeake Bay National Estuarine Reserve System. As such, the results of this plan can be used for locations throughout the York River and Chesapeake Bay where shoreline erosion is a significant problem. Additional funding will allow further outreach on applicability of this work.

Objective 3: Provide guidance for future restoration projects within Chesapeake Bay and beyond.

The project design plan will not only provide details for the specific shovel-ready site, but also be applicable for suitable sites in Chesapeake Bay as well as other locations in the Mid-Atlantic, Southeast Atlantic, and Gulf of Mexico. The plan includes site details, justification, and scientific basis for restoration projects involving combined oyster reef, hybrid/living shorelines, and salt marsh restoration resilient to climate change (See Attached “Penniman Spit Living Shoreline & Oyster Restoration Project” document).

Objective 4: Include project designs eligible for grants such as NFWF Coastal Resilience Funding.

The Preface lists the grants received including the REPI Challenge grant which is being administered by NFWF.

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Appendix #1 - Figures



Figure 1. Shore change at Penniman Spit on the York River (Milligan et al., 2010; Milligan et al., 2018).

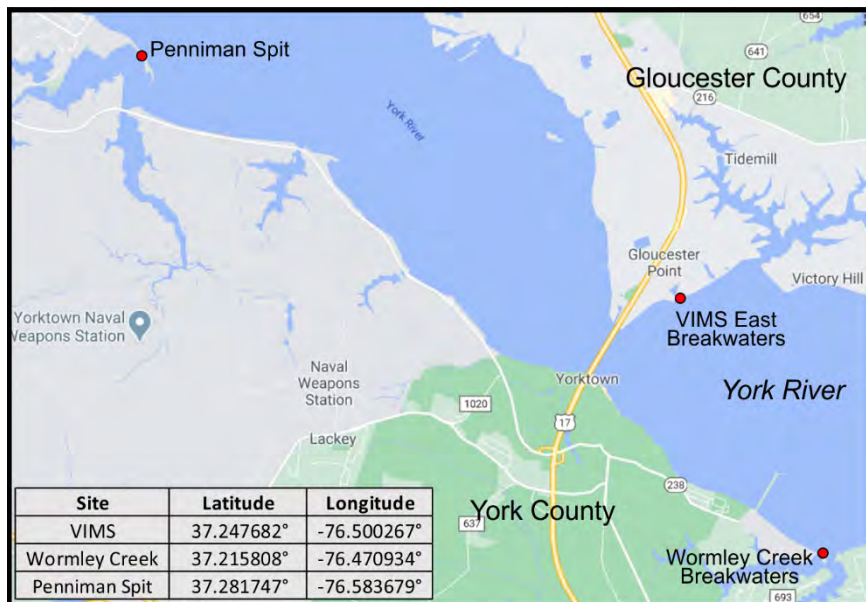


Figure 2. Location of Penniman Spit, Wormley Creek Breakwaters, and the VIMS East Breakwaters on the York River in Virginia.

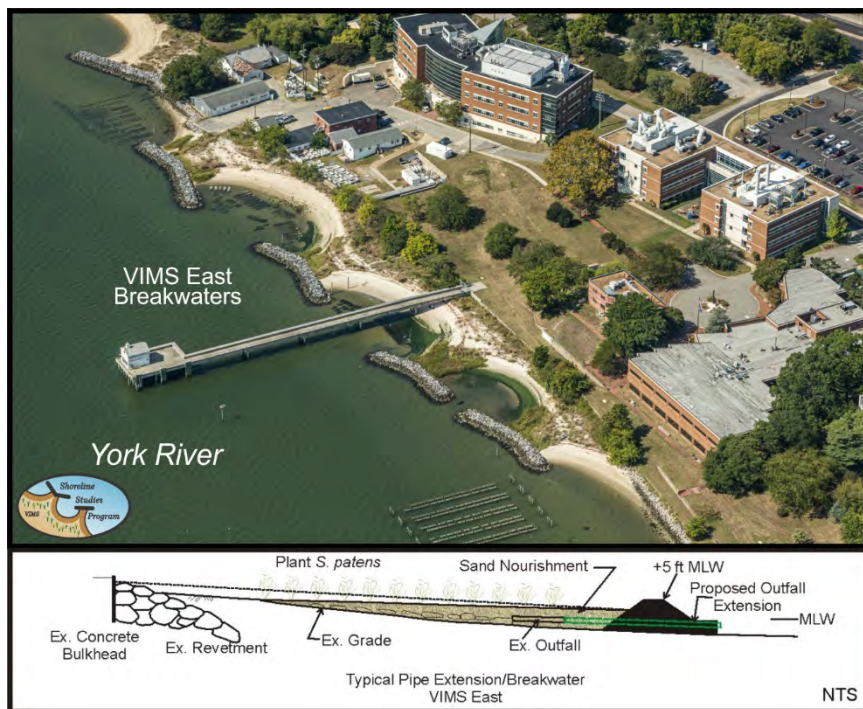


Figure 3. Aerial image of the VIMS East breakwaters taken on 23 Sep 2019. The system was installed in 2010 and has remained stable over the last nine years. The backshore has become heavily vegetated. Also shown is the typical cross-section that was developed for the conceptual design of the system. The breakwaters were built at +5 ft MLW because this is a high energy environment.

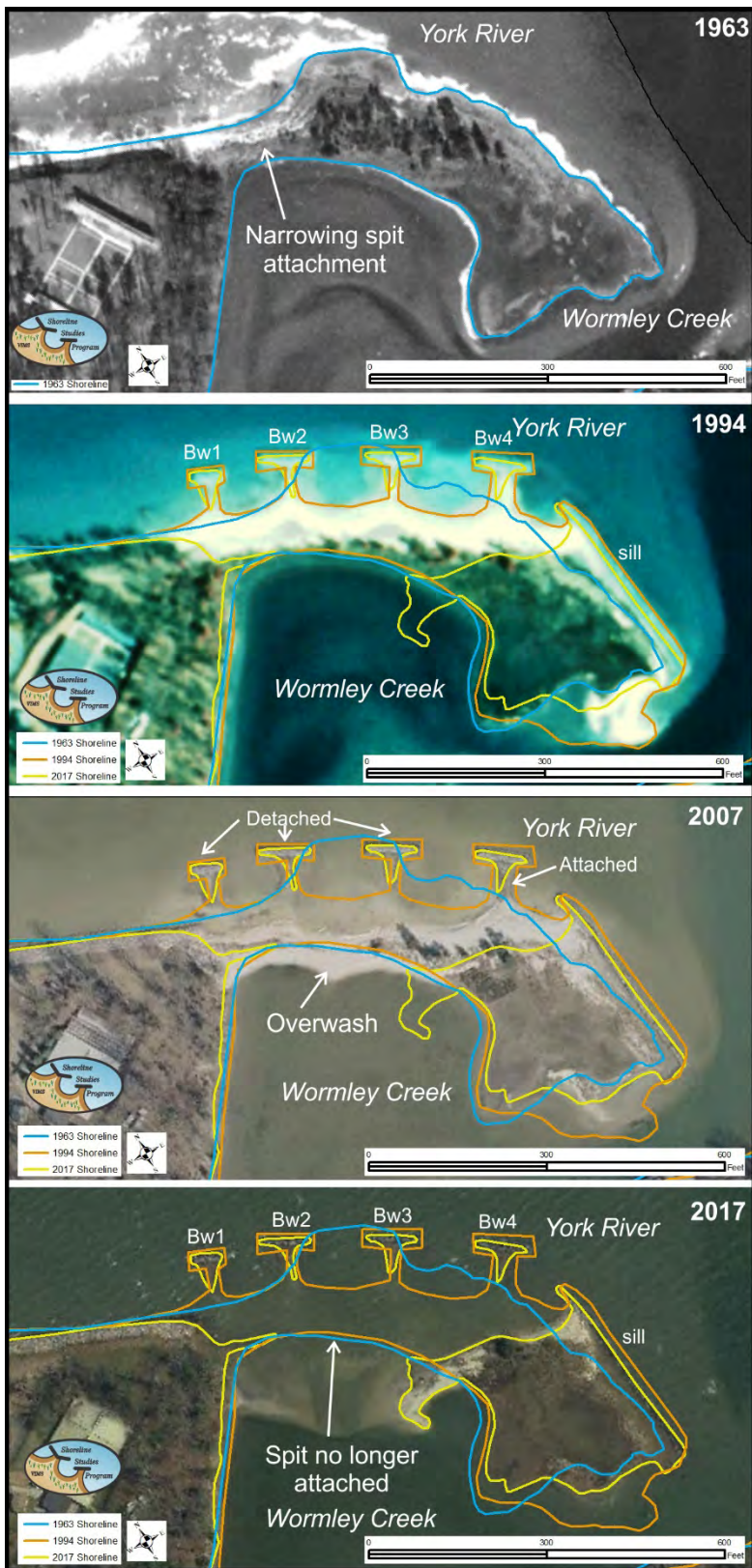


Figure 4. Shoreline change through time at Wormley Creek breakwaters on the York River. In 1963, a large spit occurs across Wormley Creek, but the attachment is becoming narrow. In 1994, the newly constructed system was only attached by a salient behind the structures. Over time, the salient deteriorated and the system became completely detached. The narrow section of attachment became a washover and eventually became no longer attached (from Hardaway et al., 2020).



Figure 5. Photo of Wormley Creek breakwaters in 2013 showing that the spit attachment was

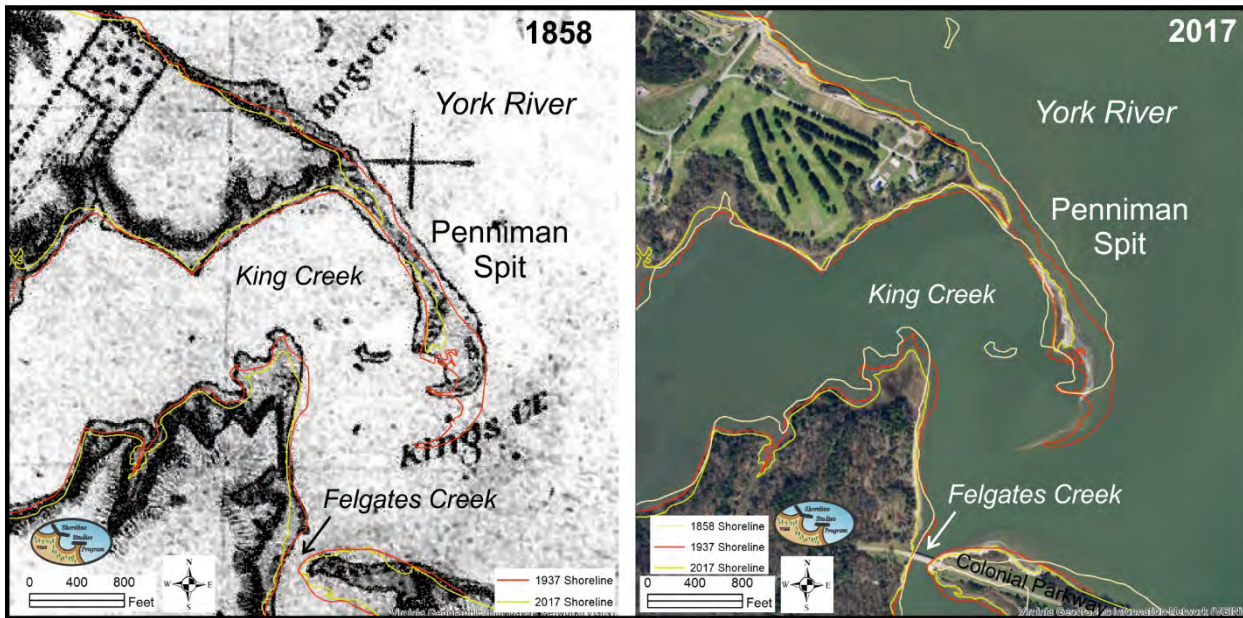


Figure 6. Long-term change at Penniman Spit. In 1858, the spit was much larger than it is today. Also, over time, the shorelines in King Creek and along the Colonial Parkway have eroded likely as the spit disintegrated (Hardaway et al., 2020).

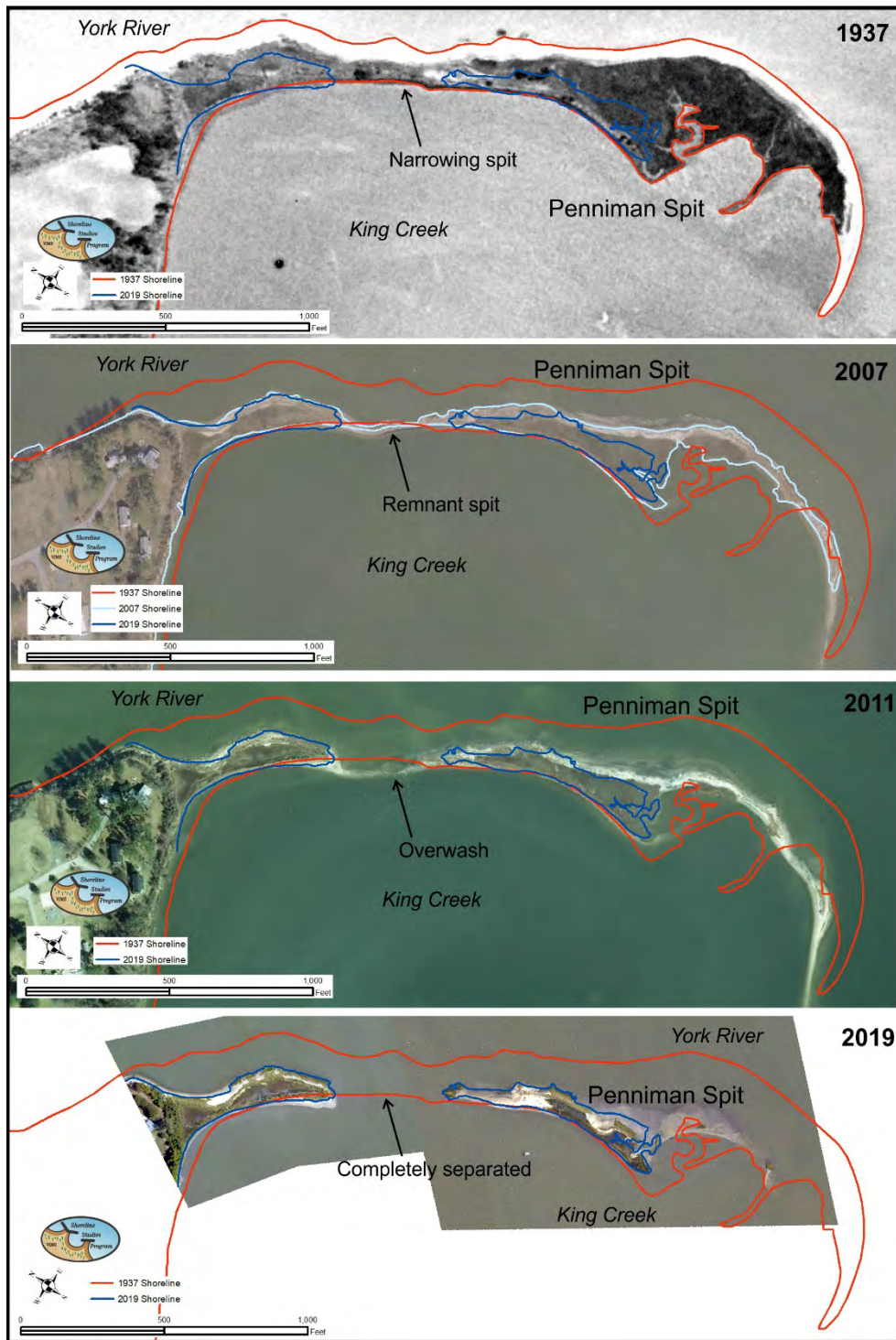


Figure 7. Closer view of shoreline change at Penniman Spit over time. The spit was wider on both ends in 1937 and narrower in the center. By 2007, the center part only had a remnant of the spit and the ends were both very reduced in size. The spit had completely breached by 2011 and in 2019, the breached section is 1-2 ft deep (Hardaway et al., 2020).



Figure 8. Aerial and ground photo showing the morphology of Penniman Spit's western peninsula.



Figure 9. Aerial and ground photos showing the morphology of Penniman Spit's eastern island.



Figure 10. Refurbished derelict crab trap coated in concrete.



Figure 11. Concrete coated crab trap colonized by oysters.

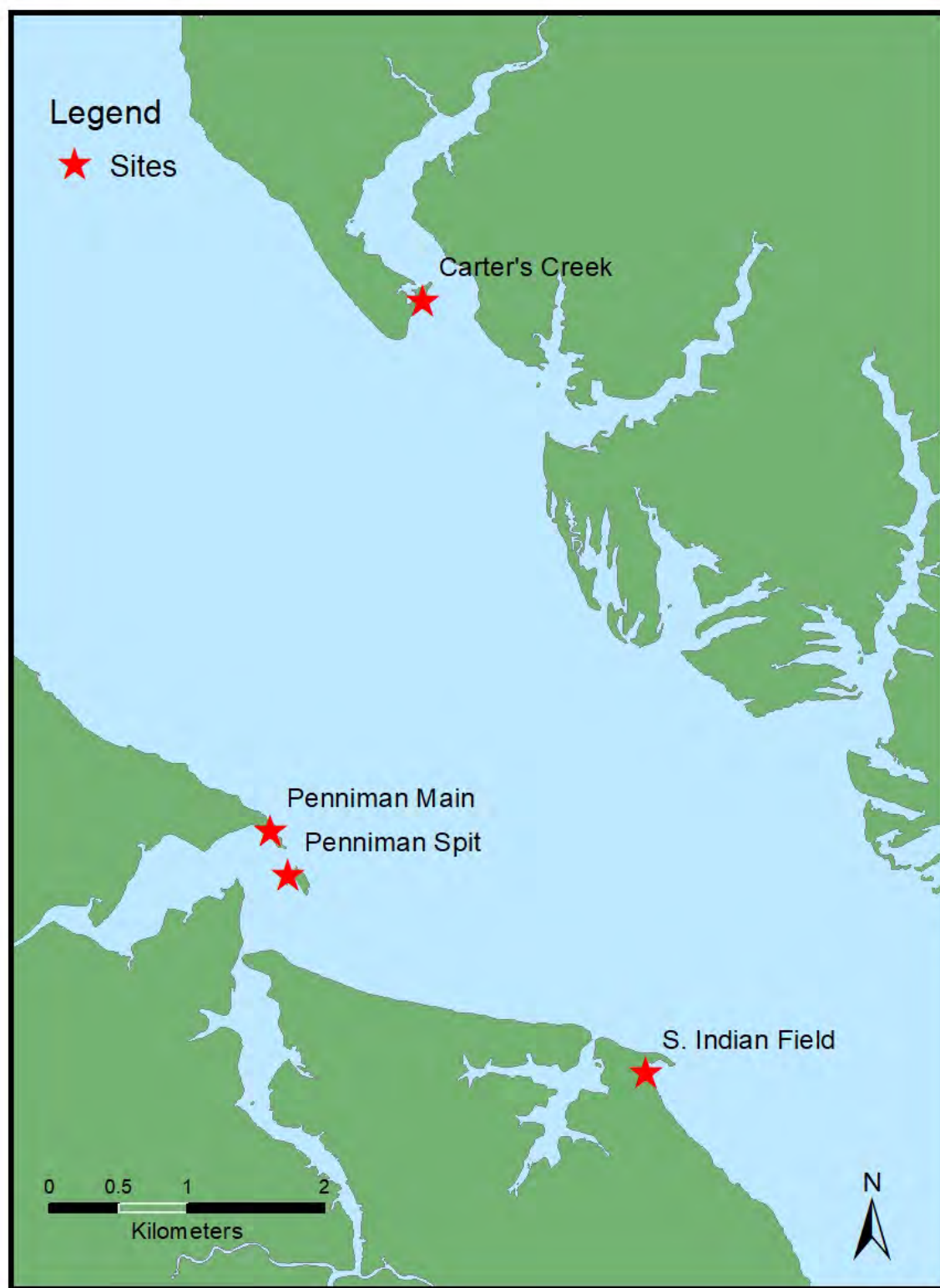


Figure 12. Sites for baseline “before” sampling.

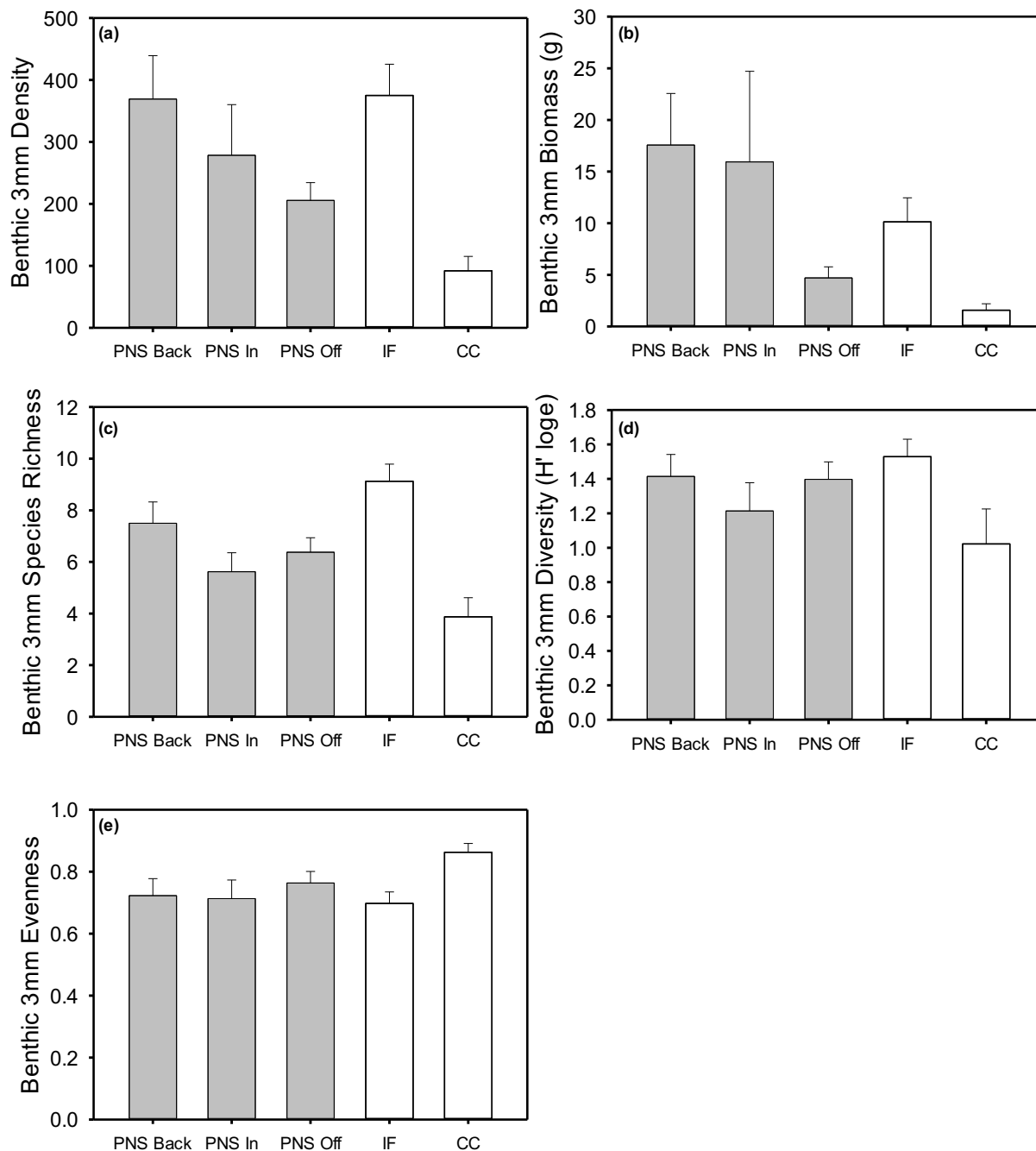


Figure 13. 3-mm benthic suction density, biomass, species richness, diversity, evenness (\pm standard error) by site. PNS Back = Penniman Spit Back, PNS in = Penniman Spit inshore, PNS Off = Penniman Spit offshore, IF = S. of Indian Field, and CC = Carter's Creek. Grey = Impact sites, White bars = Control sites.

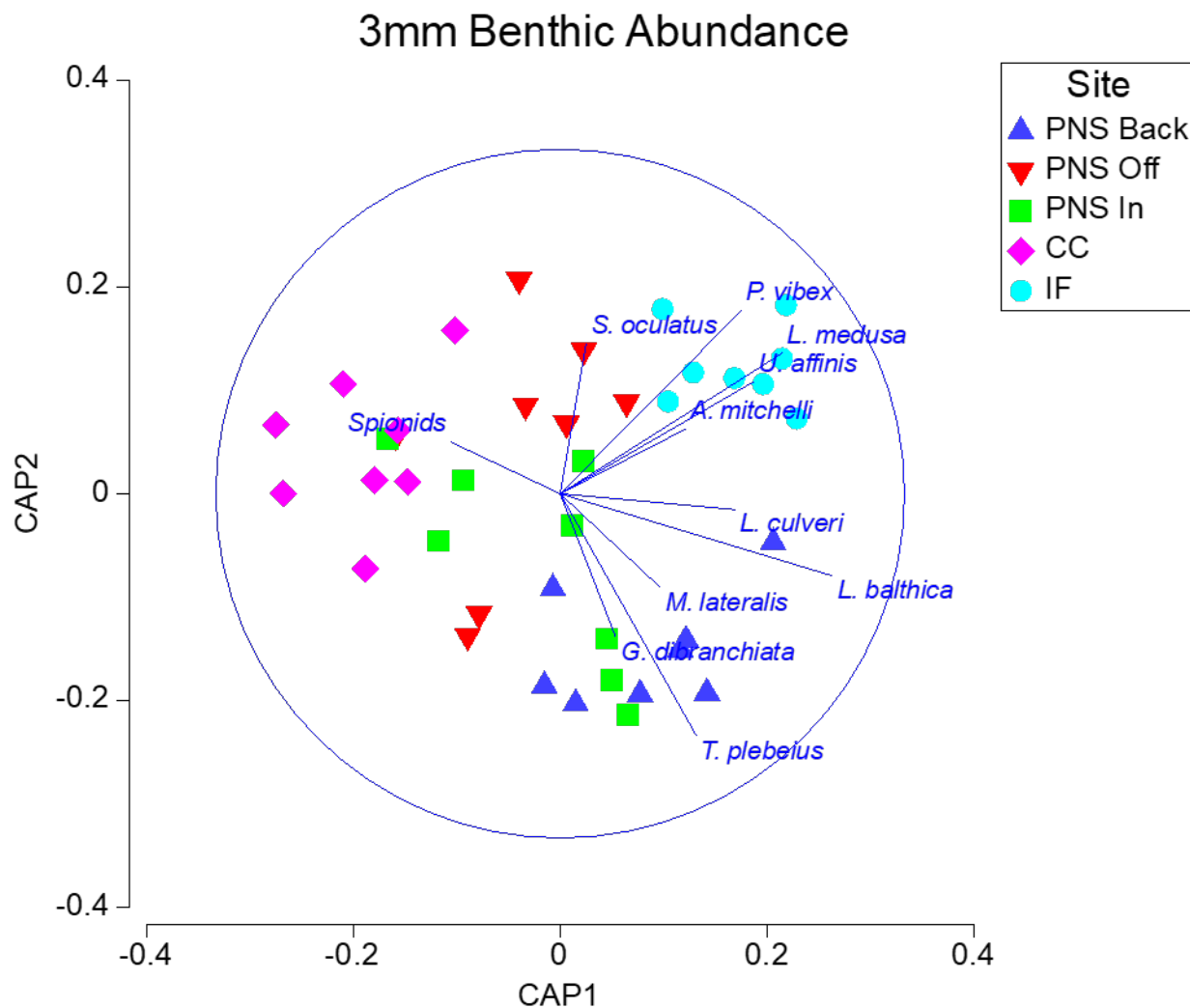


Figure 14. Canonical analysis of principal coordinates (CAP) 3-mm benthic abundance (square-root transformed, Bray-Curtis similarity resemblance) data with vector overlay of species having a Spearman rank correlation >0.35 . PNS Back = Penniman Spit Back, PNS in = Penniman Spit inshore, PNS Off = Penniman Spit offshore, IF = S. of Indian Field, and CC = Carter's Creek.

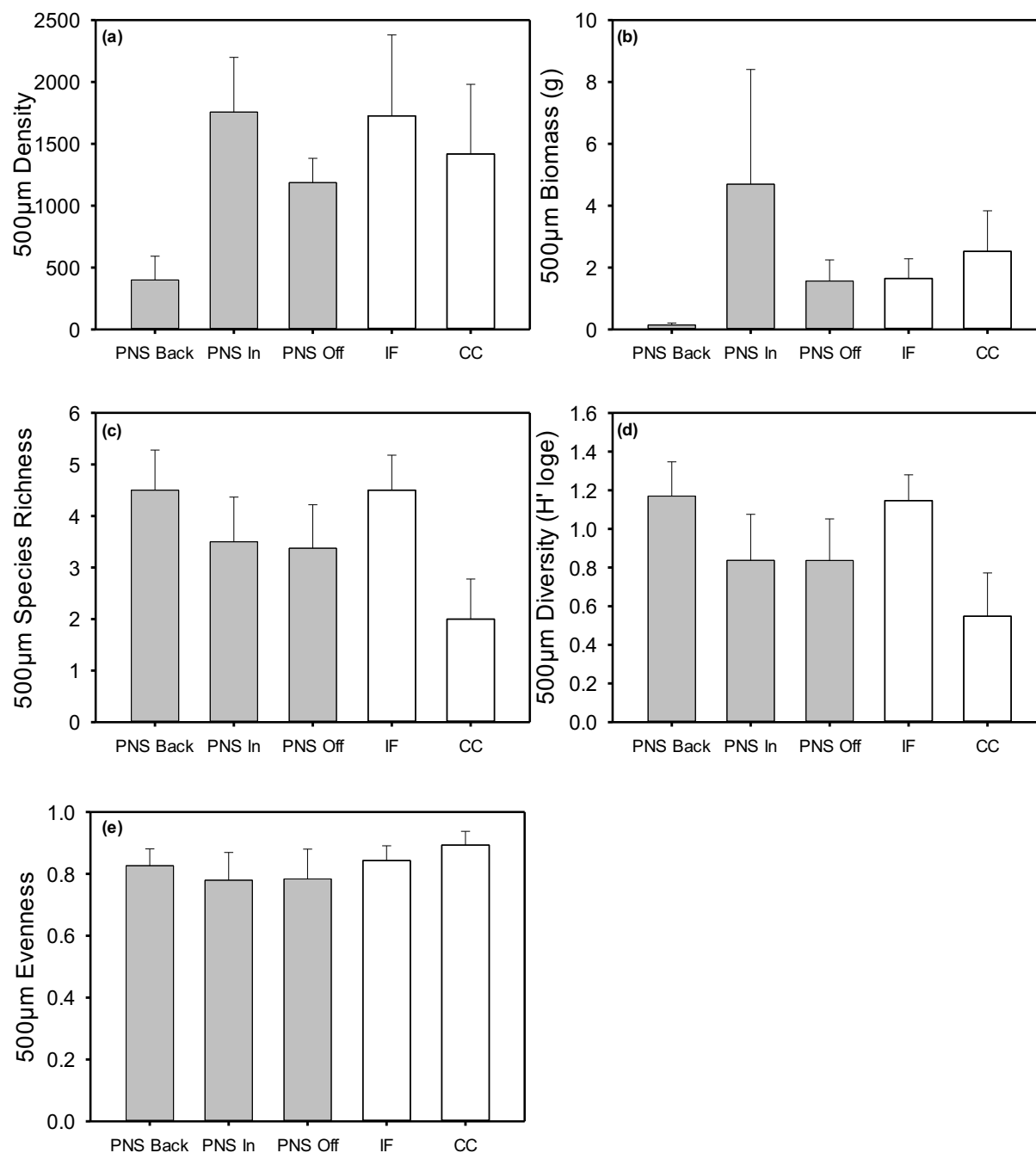


Figure 15. 500 μ m benthic suction density, biomass, species richness, diversity, evenness (\pm standard error) by site. PNS Back = Penniman Spit Back, PNS in = Penniman Spit inshore, PNS Off = Penniman Spit offshore, IF = S. of Indian Field, and CC = Carter's Creek. Grey = Impact sites, White bars = Control sites.

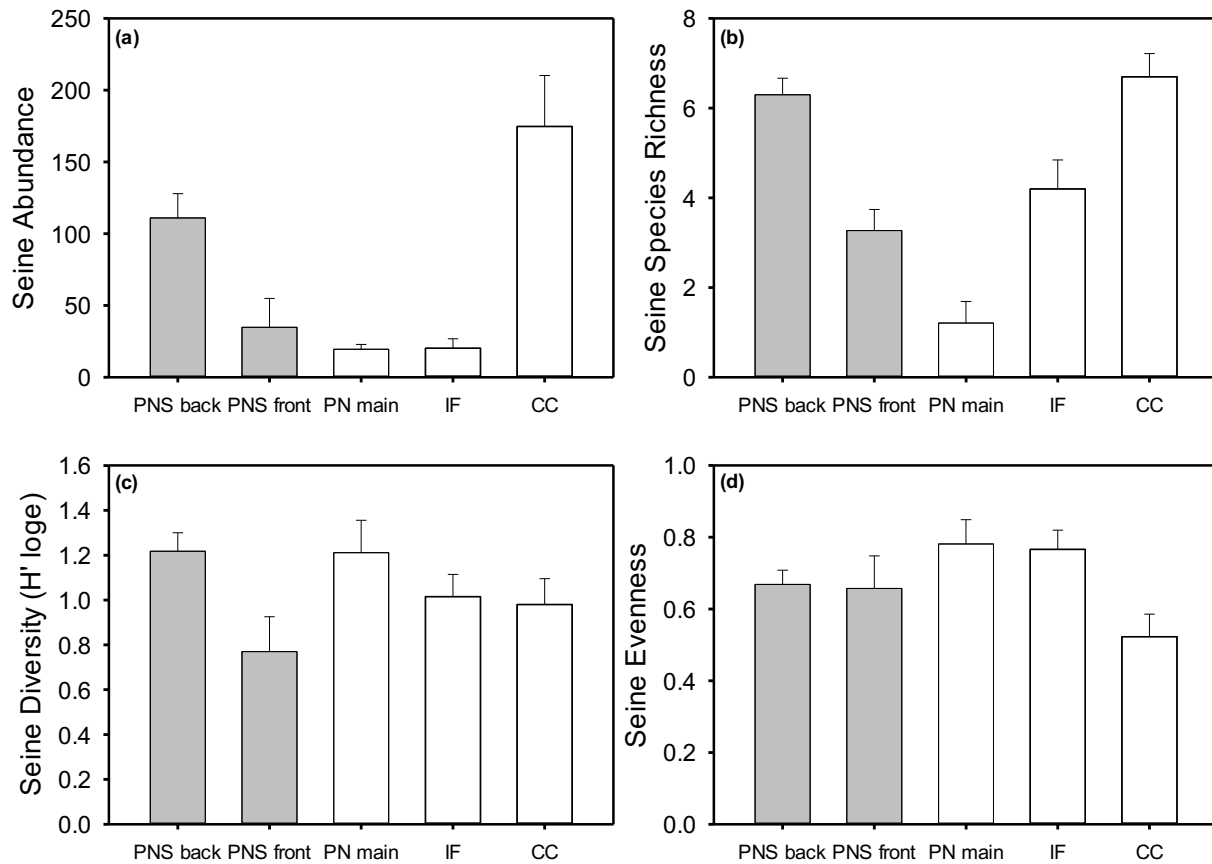


Figure 16. Seine abundance, species richness, diversity, evenness (\pm standard error) by site. PNS Back = Penniman Spit Back, PNS front = Penniman Spit front, PN Main= Penniman Main, IF = S. of Indian Field, and CC = Carter's Creek. Grey = Impact sites (but include PN main), White bars = Control sites (except not PN main).

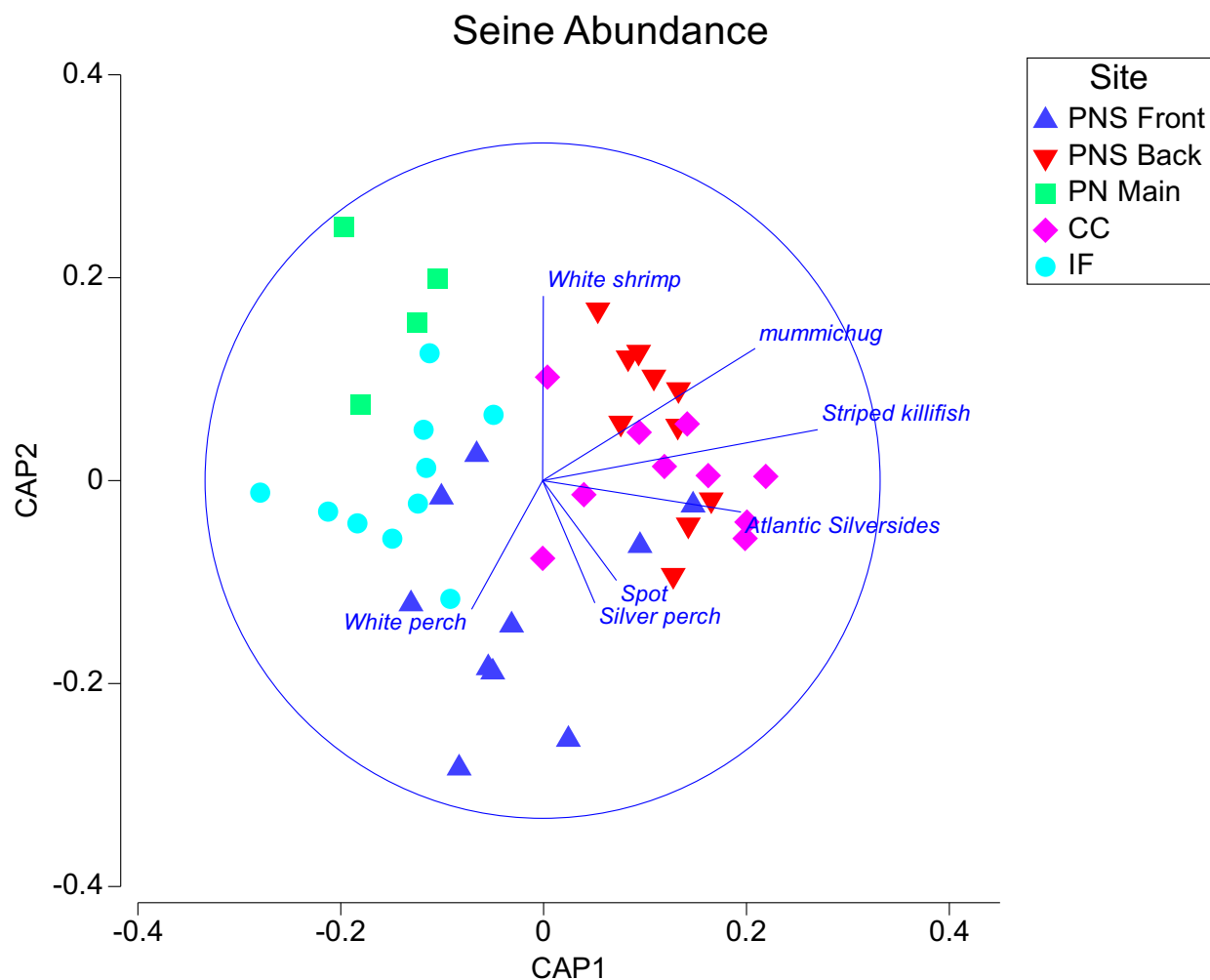


Figure 17. Canonical *analysis* of principal coordinates (CAP) seine abundance (square-root transformed, Bray-Curtis similarity resemblance) data with vector overlay of species having a Spearman rank correlation >0.35 . PNS Back = Penniman Spit Back, PNS front = Penniman Spit front, PNS Main = Penniman Main, IF = S. of Indian Field, and CC = Carter's Creek.

Appendix 2: Tables

Table 1. Calculated cost for the Living Shoreline project at Penniman Spit. The cost estimate does not include the oyster restoration components.

Material	Amount	Cost/unit	Total Cost
Rock (tons)	8,824	110	\$970,640
Sand (cy)	17,244	75	\$1,293,300
Plants (per plant)	52,327	1	\$52,327
<i>Subtotal</i>			<i>\$2,316,267</i>
Site work, mob & demob			
(17%)			\$393,765
Site Design (10%)			\$271,003
Total			\$2,981,036

Table 2. Sampling sites, number of samples, type (control/impact), temperature, D.O., and salinity.

Site	N	Type	Date	Temp (°C)	D.O. (mg/L)	Salinity (ppt)
Seine						
Penniman Front	11	impact	Sept. 10 & 11, 2019	27.5	6.6	18.3
Penniman Back	10	impact	Sept. 10 & 11, 2019	27.9	7.7	18.4
Penniman Main	4	control	Sept. 12, 2019	30.8	8.7	18.0
Carter's Creek	10	control	Sept. 24, 2019	26.0	7.2	18.5
S. of Inidan Field	10	control	Sept. 25, 2019	24.5	7.1	18.5
Benthic						
Penniman Back	8	impact	Sept. 16, 2019	28.3	7.3	18.0
Penniman Inshore	8	impact	Sept. 20, 2019	24.9	7.4	18.0
Penniman Offshore	8	impact	Sept. 20, 2019	24.9	7.4	18.0
Carter's Creek	8	control	Oct. 1, 2019	25.6	7.2	20.0
S. of Inidan Field	8	control	Oct. 1, 2019	25.5	6.9	19.9

Table 3. Benthic (3 mm) mean percent abundance from each location. Ordered by highest percent species across sites.

Species	Taxa	Penniman back	Penniman inshore	Penniman offshore	Indian Field	Carter's Creek
<i>Limecola balthica</i>	Bivalvia	47.37	33.39	26.05	44.87	8.17
<i>Alitta succinea</i>	Polychaeta	6.00	31.47	26.27	20.20	30.48
<i>Tagelus plebeius</i>	Bivalvia	22.67	13.38	8.78	2.96	8.90
Capitellids	Polychaeta	5.74	3.18	6.43	4.37	14.17
Phoronids	Phorinida	3.14	2.37	15.35	1.00	4.03
Spionids	Polychaeta	0.00	1.92	0.00	0.21	22.42
<i>Mulinia lateralis</i>	Bivalvia	3.00	2.75	4.98	1.70	4.09
<i>Laeonereis culveri</i>	Polychaeta	3.54	1.07	2.38	4.06	0.00
<i>Lomia medusa</i>	Polychaeta	0.68	0.00	0.00	8.84	0.96
Nemerteans	Nemertea	1.51	2.30	0.74	1.91	1.92
<i>Phrontis vibex</i>	Gastropoda	0.31	0.33	3.97	3.36	0.00
<i>Upogebia affinis</i>	Crustacea	0.79	1.25	0.00	3.48	0.00
<i>Spiochaetopterus oculatus</i>	Polychaeta	0.00	0.00	1.24	1.49	1.82
<i>Gemma gemma</i>	Bivalvia	0.93	0.74	0.00	0.76	1.47
<i>Glycera dibranchiata</i>	Polychaeta	2.47	0.00	1.35	0.00	0.00
<i>Leitoscoloplos spp.</i>	Polychaeta	0.20	1.07	0.00	0.00	1.56
<i>Molgula manhattensis</i>	Ascidacea	0.96	1.25	0.00	0.00	0.00
<i>Petricolaria pholadiformis</i>	Bivalvia	0.00	1.62	0.00	0.00	0.00
<i>Crepidula plana</i>	Gastropoda	0.00	0.00	1.25	0.00	0.00
Sabellids	Polychaeta	0.00	1.25	0.00	0.00	0.00
<i>Diopatra cuprea</i>	Polychaeta	0.00	0.00	0.71	0.00	0.00
<i>Owenia fusiformis</i>	Polychaeta	0.20	0.00	0.50	0.00	0.00
Un. Amphipod	Crustacea	0.48	0.00	0.00	0.00	0.00
<i>Ameritella mitchelli</i>	Polychaeta	0.00	0.00	0.00	0.40	0.00
<i>Ischadium recurvum</i>	Bivalvia	0.00	0.00	0.00	0.38	0.00
<i>Geukensia demissa</i>	Bivalvia	0.00	0.33	0.00	0.00	0.00
<i>Pectinaria gouldii</i>	Polychaeta	0.00	0.33	0.00	0.00	0.00

Table 4. Benthic (3 mm) mean percent biomass from each location. Ordered by highest percent species across sites.

Species	Taxa	Penniman back	Penniman inshore	Penniman offshore	Indian Field	Carter's Creek
<i>Tagelus plebeius</i>	Bivalvia	70.07	52.14	46.55	36.49	41.19
<i>Limecola balthica</i>	Bivalvia	21.64	27.77	25.52	39.37	14.88
Polychaetes	Polychaeta	5.76	2.25	6.52	14.22	34.48
<i>Phrontis vibex</i>	Gastropoda	0.20	2.16	15.04	5.08	0.00
<i>Petricolaria pholadiformis</i>	Bivalvia	0.00	13.85	0.00	0.00	0.00
Nemerteans	Nemertea	0.31	0.93	0.88	0.32	6.89
Phoronids	Phorinida	0.52	0.13	4.25	0.13	1.21
<i>Mulinia lateralis</i>	Bivalvia	0.52	0.56	1.11	0.95	1.08
<i>Upogebia affinis</i>	Crustacea	0.64	0.04	0.00	3.27	0.00
<i>Gemma gemma</i>	Bivalvia	0.04	0.02	0.00	0.01	0.28
<i>Molgula manhattensis</i>	Ascidiacea	0.30	0.00	0.00	0.00	0.00
<i>Geukensia demissa</i>	Bivalvia	0.00	0.17	0.00	0.00	0.00
<i>Crepidula plana</i>	Gastropoda	0.00	0.00	0.14	0.00	0.00
<i>Ameritella mitchelli</i>	Bivalvia	0.00	0.00	0.00	0.12	0.00
<i>Ischadium recurvum</i>	Bivalvia	0.00	0.00	0.00	0.04	0.00

Table 5. Benthic (500 µm core) mean percent abundance from each location. Ordered by highest percent species across sites.

Species	Taxa	Penniman back	Penniman inshore	Penniman offshore	Indian Field	Carter's Creek
Capitellids	Polychaeta	50.42	20.25	47.98	29.83	19.87
<i>Alitta succinea</i>	Polychaeta	16.4	33.37	18.85	24.86	38.54
Spionids	Polychaeta	8.87	14.47	2.08	10.59	10.77
<i>Spiochaetopterus oculatus</i>	Polychaeta	9.14	12.47	4.12	0.48	0
<i>Leitoscoloplos</i> spp.	Polychaeta	0	0	0	6.91	13.74
<i>Glycinde solitaria</i>	Polychaeta	3.04	2.54	1.85	5.14	5
<i>Limecola balthica</i>	Bivalvia	4.32	3.55	5.53	3.56	0
Phoronids	Phorinida	1.79	1.59	6.2	0	5
<i>Molgula manhattensis</i>	Ascidacea	0	1.79	6.48	1.72	1.54
<i>Nehaustorius</i> sp.	Crustacea	0	0	0	6.25	0
Nemerteans	Nemertea	2.44	1.59	0	0	1.54
<i>Lomia medusa</i>	Polychaeta	0	2.89	0.93	1.72	0
<i>Phrontis vibex</i>	Gastropoda	0	0	0	4.41	0
<i>Geukensia demissa</i>	Bivalvia	0	0	0	0	4
Un. Anemones	Anthozoa	0	1.79	0	1.92	0
<i>Owenia fusiformis</i>	Polychaeta	0	0	3.7	0	0
<i>Eteone heteropoda</i>	Polychaeta	0	0	2.27	0	0
<i>Gemma gemma</i>	Bivalvia	0	0	0	1.87	0
Ephyridae larva	Insecta	1.79	0	0	0	0
<i>Leptocheirus plumulosus</i>	Crustacea	0	1.59	0	0	0
<i>Amygdalum papyrium</i>	Bivalvia	0	1.34	0	0	0
<i>Mulinia lateralis</i>	Bivalvia	1.14	0	0	0	0
<i>Ameritella mitchelli</i>	Polychaeta	0	0	0	0.74	0
<i>Tagelus plebeius</i>	Bivalvia	0.66	0	0	0	0
<i>Demonax microphthalmus</i>	Polychaeta	0	0.45	0	0	0
<i>Pectinaria gouldii</i>	Polychaeta	0	0.35	0	0	0

Table 6. Benthic (500 μm) mean percent biomass from each location. Ordered by highest percent species across sites.

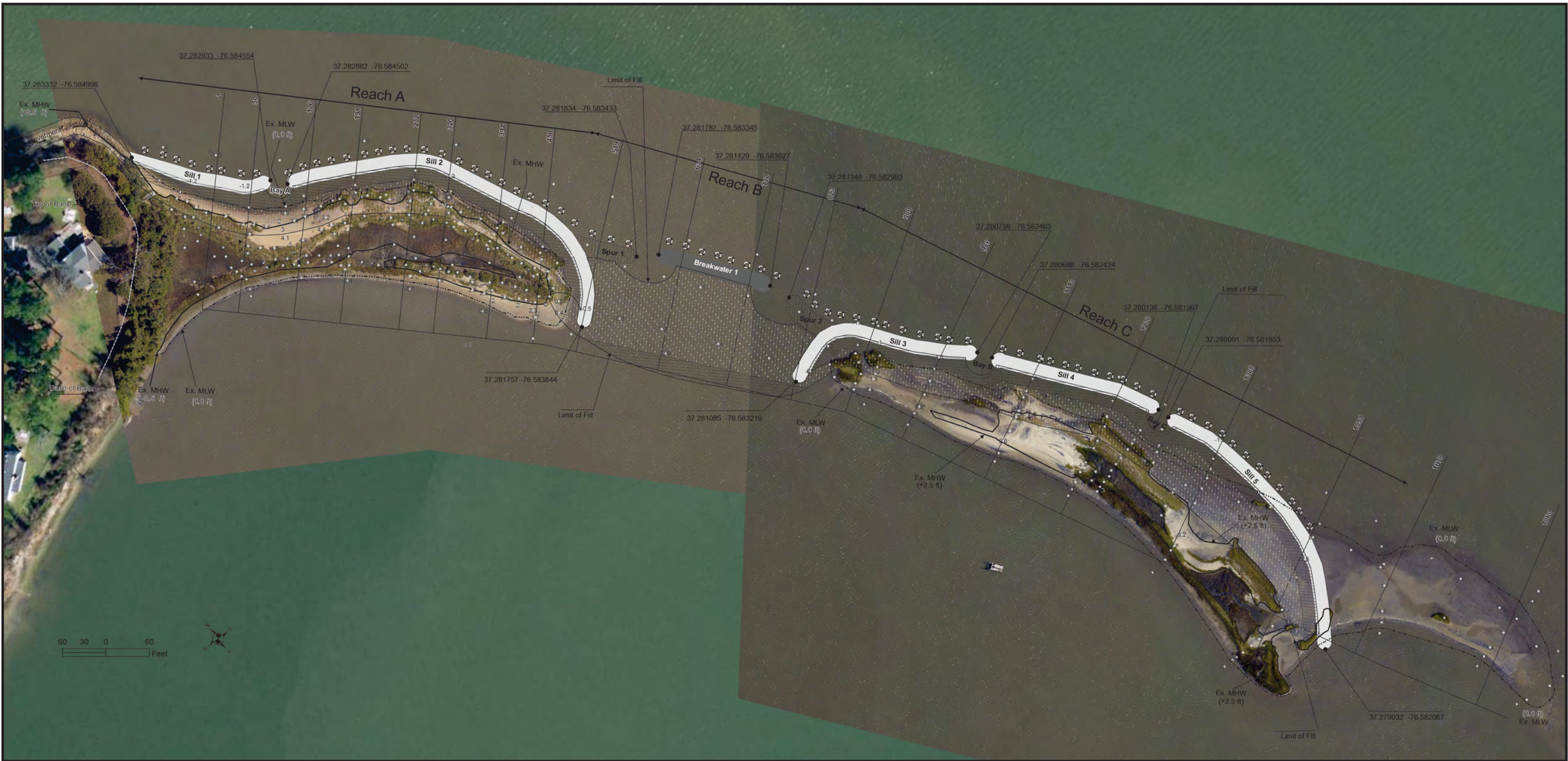
Species	Taxa	Penniman back	Penniman inshore	Penniman offshore	Indian Field	Carter's Creek
<i>Polychaetes</i>	Polychaeta	56.54	58	38.75	72.13	70.01
<i>Limecola balthica</i>	Bivalvia	16	25.07	37.94	10.65	0
Phoronids	Phoronida	0	0	13.21	0	11.11
<i>Molgula manhattensis</i>	Ascidacea	0	4.1	10.11	1.96	6.87
<i>Nemerteans</i>	Nemertea	10.31	8.44	0	0	0
<i>Phrontis vibex</i>	Gastropoda	0	0	0	12.27	0
<i>Geukensia demissa</i>	Bivalvia	0	0	0	0	12
<i>Mulinia lateralis</i>	Bivalvia	8.86	0	0	0	0
<i>Tagelus plebeius</i>	Bivalvia	8.28	0	0	0	0
<i>Gemma gemma</i>	Bivalvia	0	0	0	2.97	0
<i>Amygdalum papyrium</i>	Bivalvia	0	2.81	0	0	0
Un. Anemones	Anthozoa	0	1.58	0	0	0
<i>Ameritella mitchelli</i>	Bivalvia	0	0	0	0.03	0

Table 7. Seine mean percent abundance from each location. Ordered by highest percent species across sites.

Species	Common Name	Penniman Back	Penniman Front	Penniman Main	Indian Field	Carter's Creek
<i>Menidia menidia</i>	Atlantic silverside	14.81	32.67	4.09	15.43	53.65
<i>Callinectes sapidus</i>	Blue Crabs	11.75	17.7	21.52	43.77	2.57
<i>Fundulus majalis</i>	Striped killifish	34.1	9.85	0	1.57	24.02
<i>Neohaustorius schmitz</i>	White shrimp	7.46	5.63	48.13	1.36	0.65
<i>Fundulus heteroclitus</i>	Mummichug	19.63	0.66	8.28	13.52	14.46
<i>Anchoa mitchilli</i>	Bay Anchovy	8.94	13.81	8.73	6.58	0.39
<i>Bairdiella chrysoura</i>	Silver perch	0.26	11.02	0	0	0.41
<i>Menticirrhus saxatilis</i>	Northern kingfish	0.56	1.98	4.55	1.82	0.65
<i>Micropogonius undulatus</i>	Croaker	1.15	0	0.96	4.71	2.58
<i>Morone americana</i>	White perch	0	3.38	2.27	1.67	0
<i>Syngnathus spp.</i>	Pipefish	0.31	1.11	1.47	1.67	0.25
<i>Chaetodipterus faber</i>	Spade fish	0.06	0	0	3.47	0
<i>Symphurus plagiusa</i>	Tongue fish	0.68	1.67	0	0	0
<i>Gobiosoma bosc</i>	Naked goby	0.11	0.04	0	2.07	0
<i>Gobiesox strumosus</i>	Skilletfish	0	0	0	1.54	0.2
<i>Leiostomus xanthurus</i>	Spot	0.17	0.48	0	0	0
<i>Hippocampus erectus</i>	Seahorse	0	0	0	0.56	0
Xanthidae	mud crabs	0	0	0	0.27	0.17
<i>Archosargus probatocephalus</i>	Sheepshead	0	0	0	0	0
<i>Cynoscion nebulosus</i>	Speckled trout	0	0	0	0	0

Penniman Spit

Living Shoreline and Oyster Restoration Project



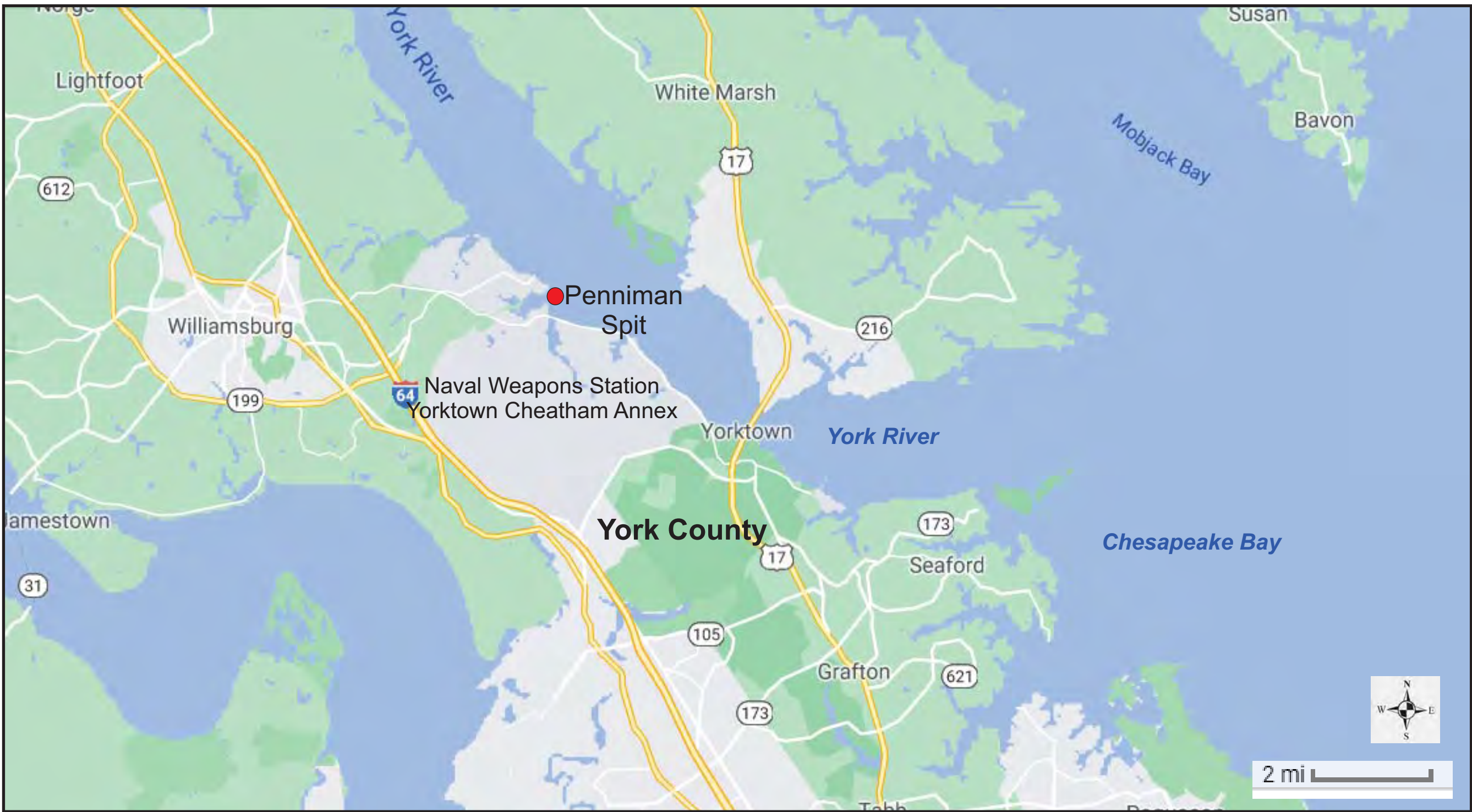
GENERAL NOTES

1. Mean tide range is 2.5 ft (1983-2001)
2. Horizontal control was established by Real Time Kinematic Global Positioning System (RTK-GPS) and is shown in UTM, zone 18, NAD83, ift.
3. Vertical control is MLW. MLW (1983-2001) was determined to be 1.5 ft below NAVD88 at Penniman Spit.
4. Topographic data obtained on 29 Oct 2019 using RTK-GPS.
5. All dimensions and coordinates are given in feet.
6. Plans were created in Esri ArcGIS.

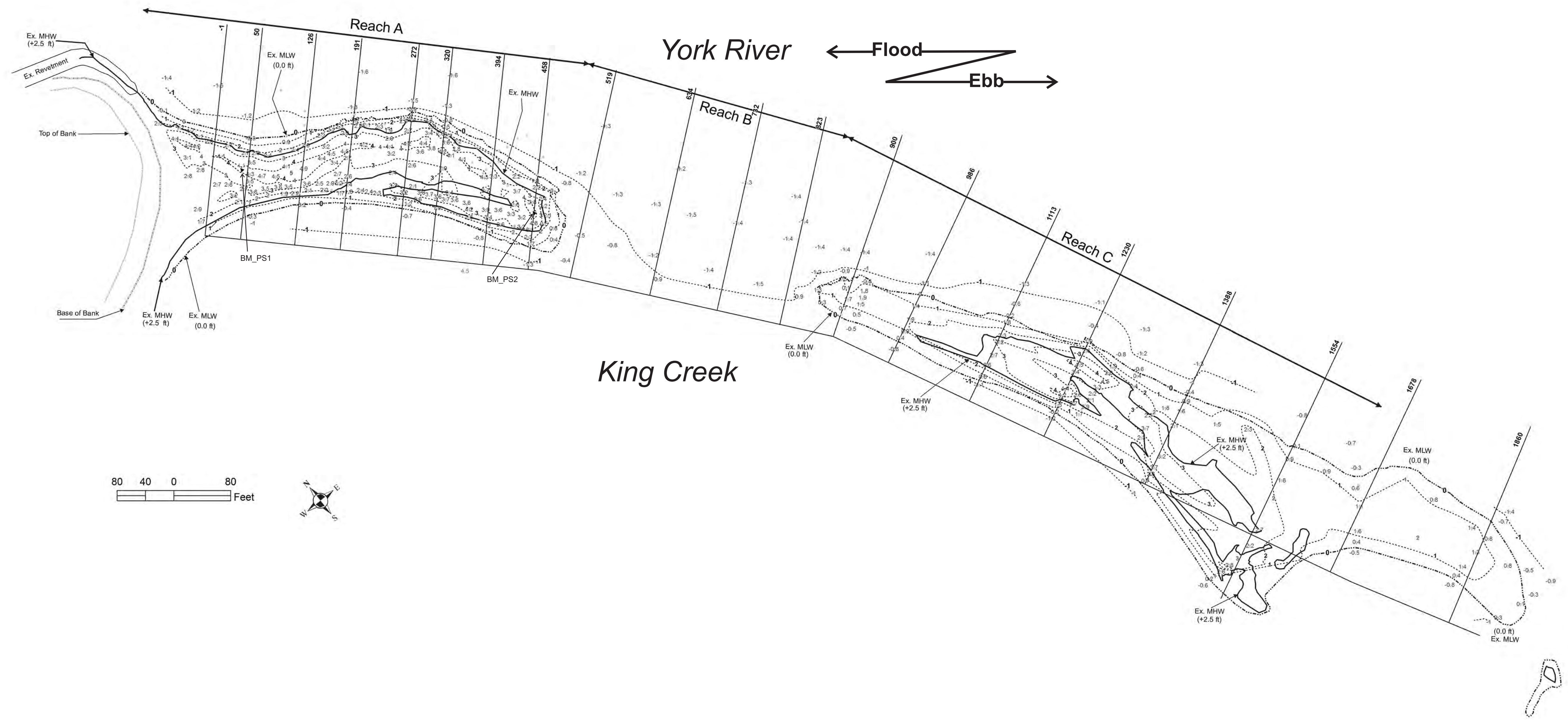
CONSTRUCTION SCHEDULE FOR SEDIMENT AND EROSION CONTROL

1. Contractor is to notify NWSY of the date construction is to begin at least 14 days prior to the date.
2. Install silt fences, erosion and sediment control measures and turbidity curtain, as needed (3 days).
3. Remove all debris interfering with shoreline construction as construction proceeds (continuous).
4. Structure installation (120 days).
 1. Install stone sills.
 2. Place sand as a vegetative terrace.
 3. Plant vegetative planting terrace as specified
5. Stabilize and seed all upland disturbed areas as specified
6. Remove turbidity curtain (2 days).
7. After establishment of vegetative cover on site, remove silt fence and other erosion and sediment control measures.

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Sheet 1	Cover Sheet
Sheet 2	Existing Conditions
Sheet 3	Proposed Plan
Sheet 4	Structure Locations
Sheet 5	Cross-sections
Sheet 6	Erosion and Sediment Control

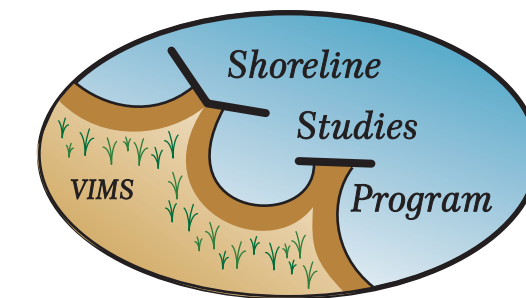


Project Title	Penniman Spit Living Shoreline & Oyster Restoration Project
Issued for	Final Draft Plan
Drawing Title	Cover Sheet
Date	25 August 2020
Scale	
Sheet	1 of 6



Existing Conditions

- Survey Points (ft MLW)
Survey Date: 29 Oct 2019
- ▲ Benchmark
- Existing MLW
- Existing MHW
- Contours
- Base of Bank
- Top of Bank
- Existing Revetment
- ↔ Reach Lines
- Profiles
- Baseline



Penniman Spit
Living Shoreline & Oyster
Restoration Project

Existing Conditions

● Survey Points (ft MLW)
Survey Date: 29 Oct 2019

▲ Benchmark

----- Existing MLW

— Existing MHW

== Base of Bank

--- Top of Bank

— Existing Revetment

↔ Reach Lines

— Profiles

— Baseline

Proposed Plan

Rock Sill

Breakwater

Spur

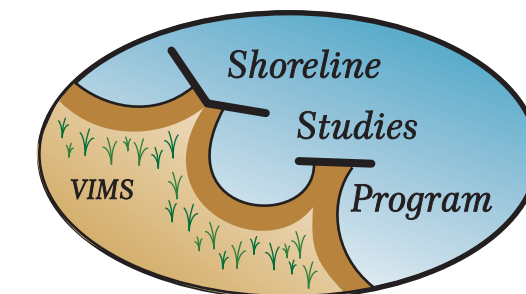
Spartina alterniflora

Spartina patens

Limit of Sand Fill

Oyster Castles

Concreted Crab Pots
Locations are approximate



Project Title

Penniman Spit
Living Shoreline & Oyster
Restoration Project

Issued for

Final Draft Plan

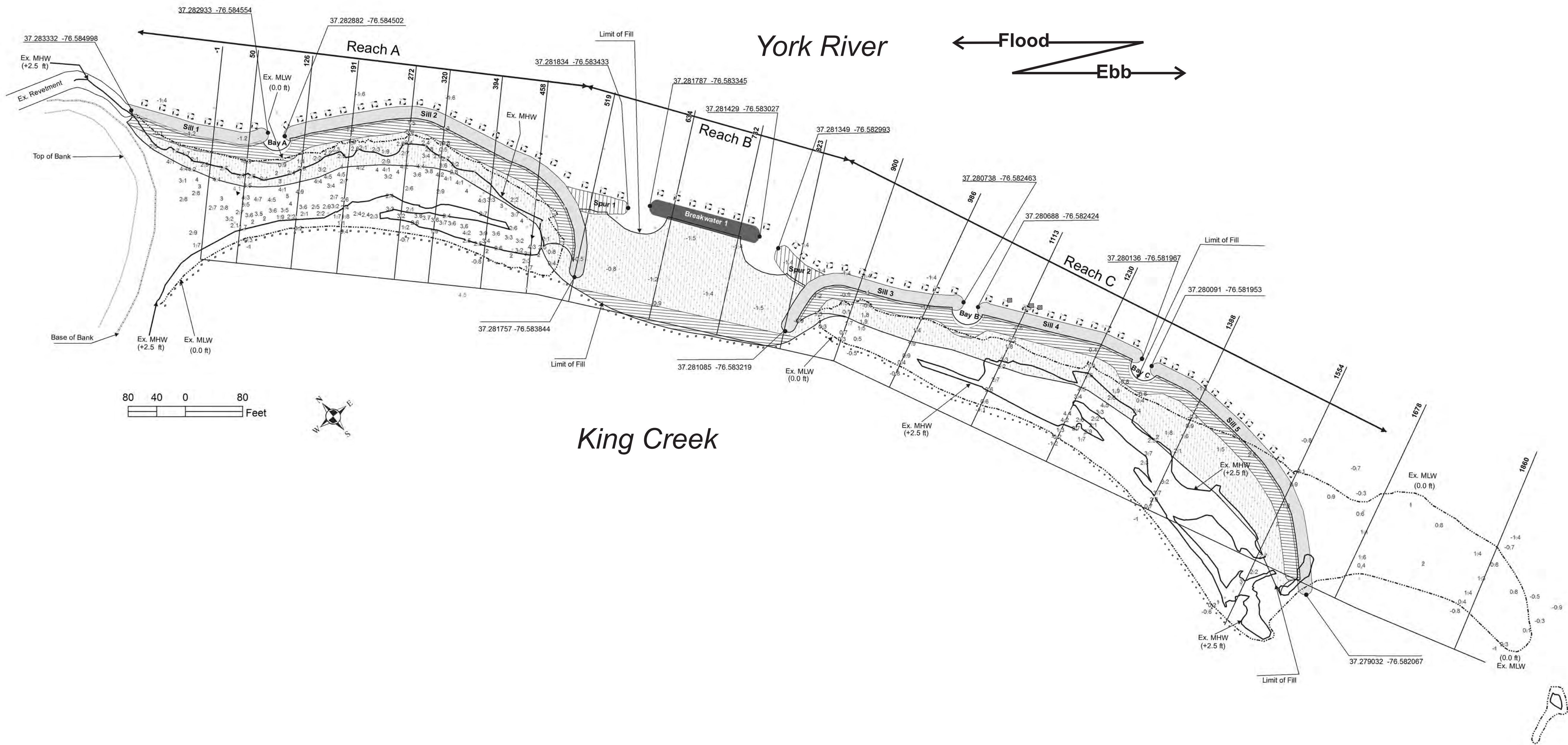
Drawing Title

Proposed Plan

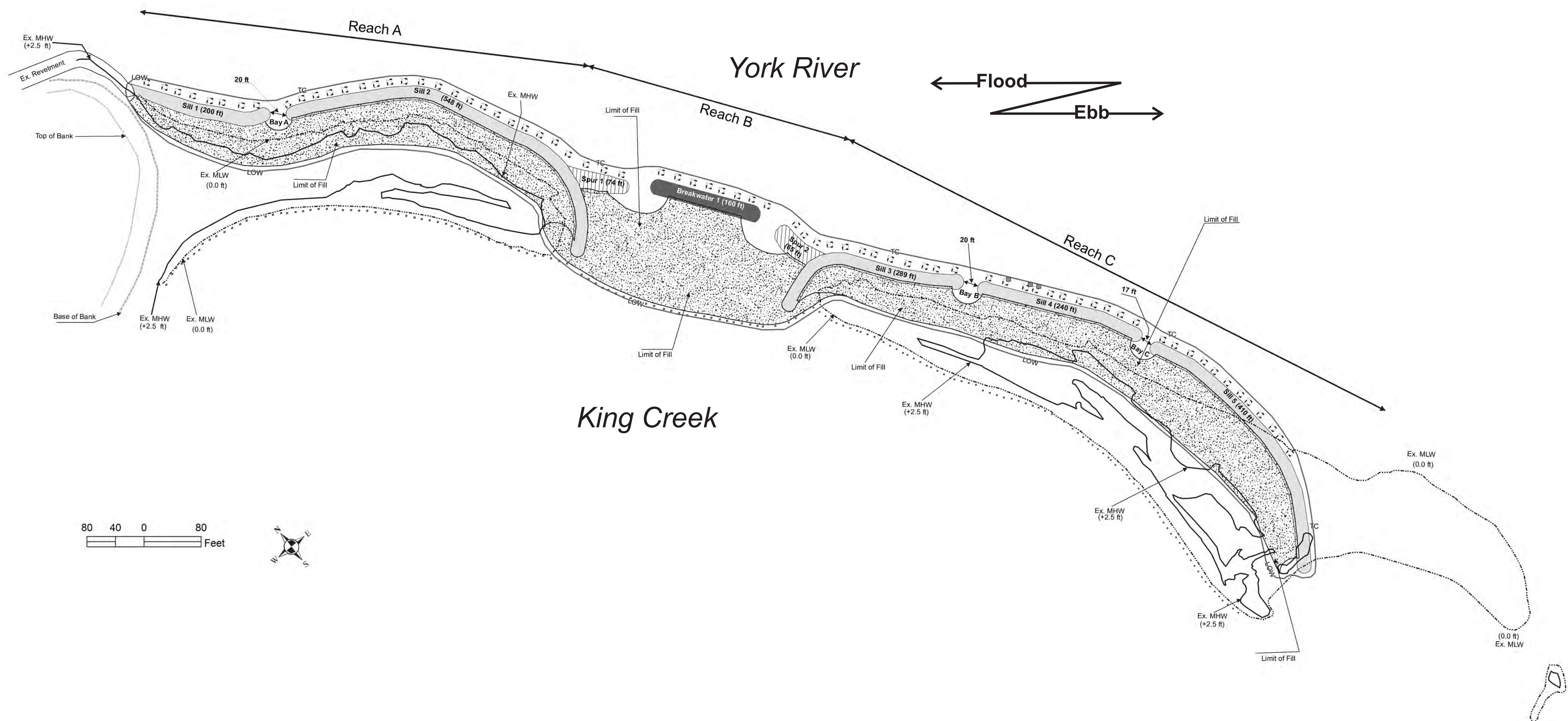
Date
25 August 2020

Scale
1"=80'

Sheet
3 of 6



Penniman Spit
Living Shoreline & Oyster
Restoration Project



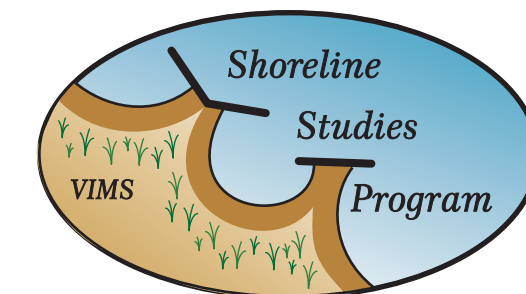
Existing Conditions

- Existing MLW
- Existing MHW
- Base of Bank
- Top of Bank
- Existing Revetment
- Reach Lines

Proposed Plan

- Rock Sill
- Breakwater
- Spur
- Spartina alterniflora
- Spartina patens
- Limit of Sand Fill
- Oyster Castles
- Concreted Crab Pots
Locations are approximate

- LOW- Limit of Construction Work
- TC- Turbidity Curtain



Project Title

Penniman Spit
Living Shoreline & Oyster
Restoration Project

Issued for

Final Draft Plan

Drawing Title

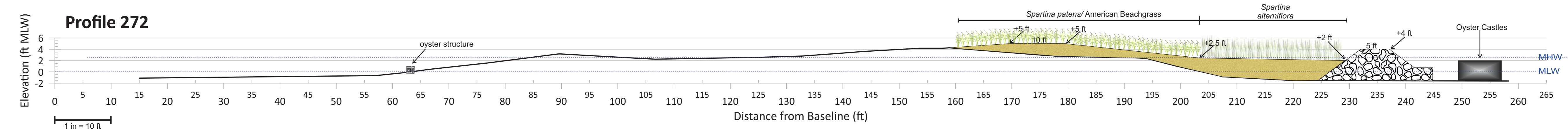
Structure Locations

Date
25 August 2020

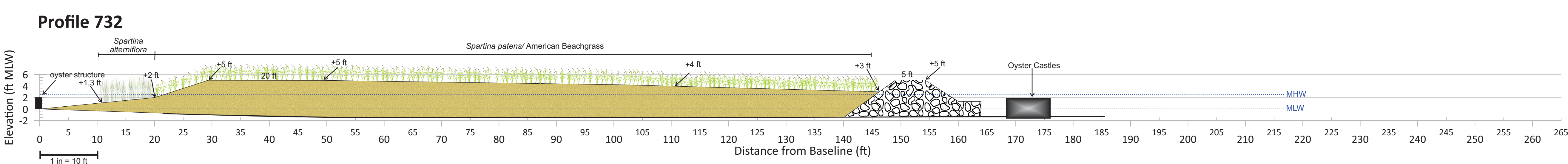
Scale
1"=80'

Sheet
4 of 6

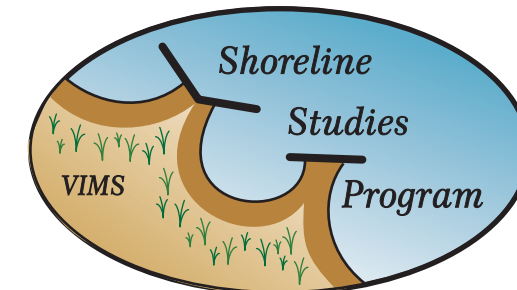
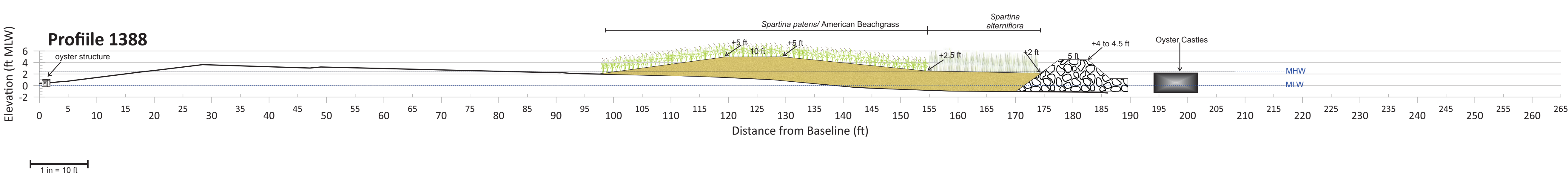
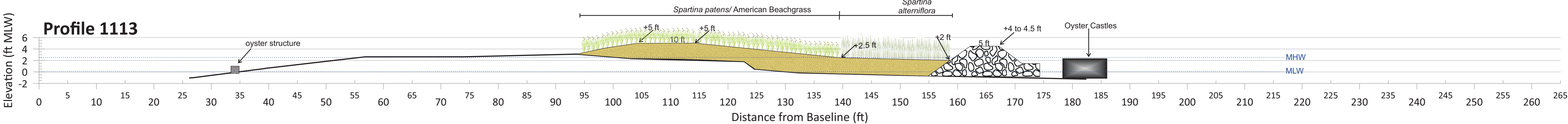
Reach A Typical Cross-Section



Reach B Typical Cross-Sections for the gap



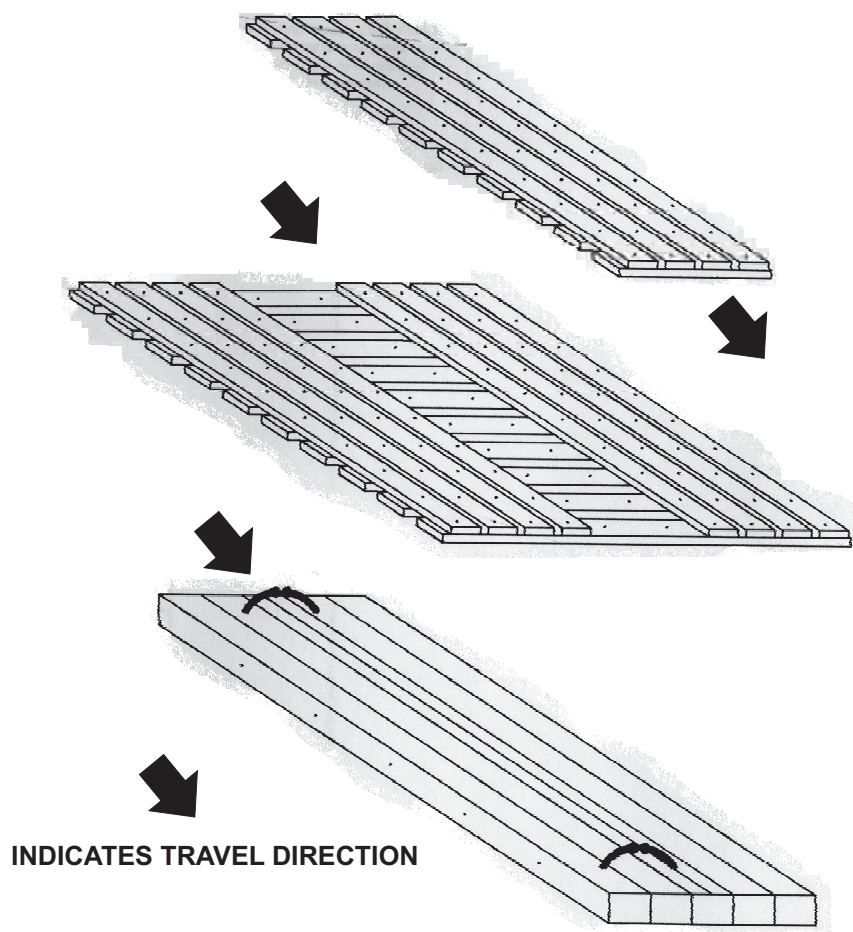
Reach C Typical Cross-Sections



Project Title	
Penniman Spit Living Shoreline & Oyster Restoration Project	
Issued for	
Final Draft Plan	
Drawing Title	
Typical Cross-sections	
Date	Scale
25 August 2020	1"=10'
Sheet	
5 of 6	

Virginia Erosion and Sediment Control Notes (VAESCH)

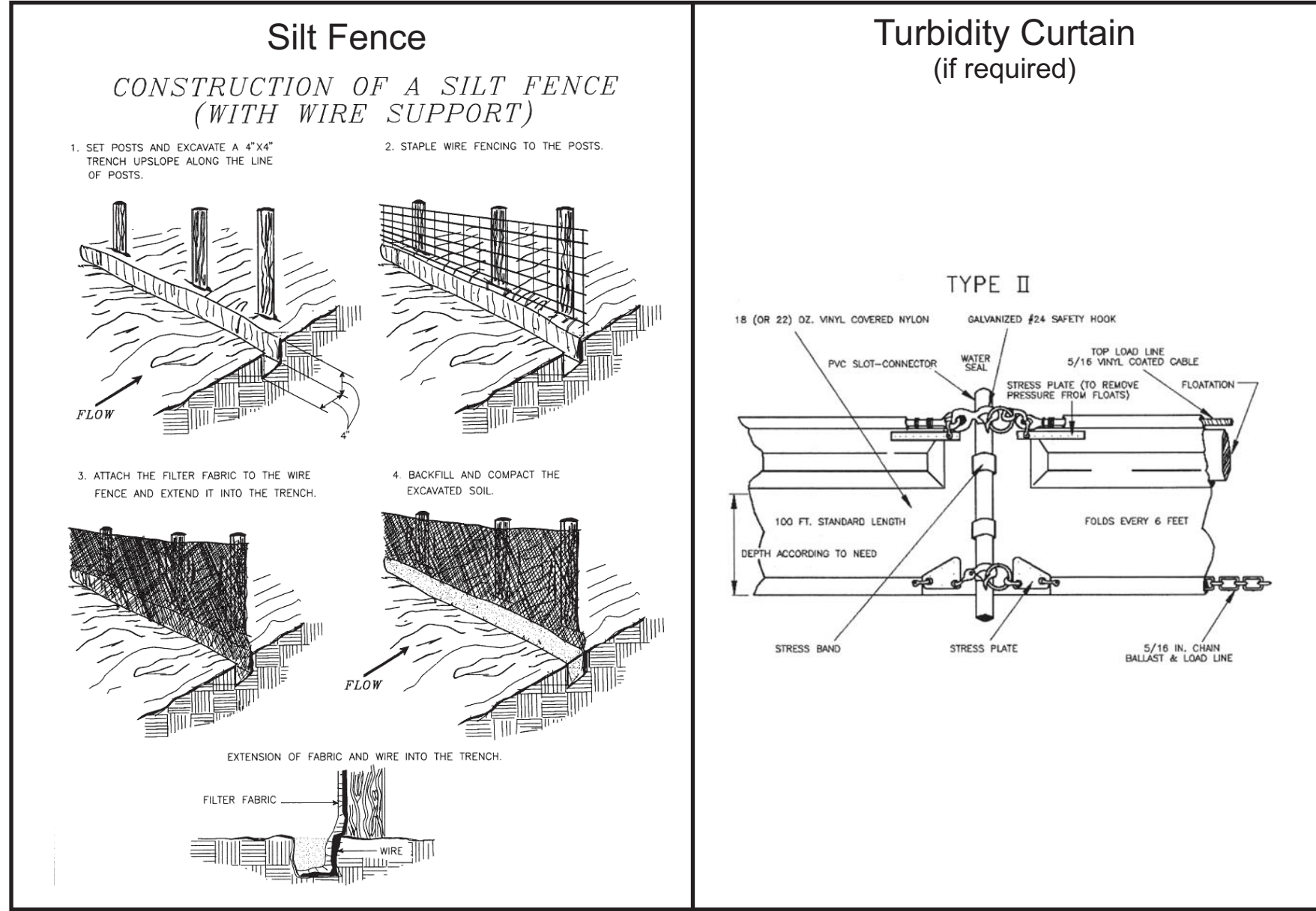
- ES-1: Unless otherwise indicated, all vegetative and structural erosion and sediment control practices will be constructed and maintained according minimum standard and specifications of the Virginia erosion and sediment control handbook and the Virginia erosion and sediment control regulations (9VAC25-840)
- ES-2: NWSY must be notified one week prior to the pre-construction conference, one week prior to the commencement of the land disturbing activity and one week prior to the final inspection. The name of the responsible land disturber must be provided to the plan-approving authority prior to actual engagement in land-disturbing activity shown on the approved site plan. If the name is not provided prior to engaging in the land-disturbing activity, the plan's approval will be revoked.
- ES-3: All erosion and sediment control measures are to be placed prior to or as the first step in clearing.
- ES-4: A copy of the approved erosion and sediment control plan and the Virginia erosion and sediment control handbook shall be maintained on the site at all times.
- ES-5: Prior to commencing land disturbing activities in areas other than indicated on these plans (including, but not limited to, off-site borrow or water areas), the contractor shall submit a supplementary erosion control plan to the owner for review and approval by the plan approving authority.
- ES-6: The contractor is responsible for installation of any additional erosion control measures necessary to prevent erosion and sedimentation as determined by the plan approving authority.
- ES-7: The contractor shall inspect all erosion control measures at least weekly and immediately after each runoff-producing rainfall event. Any necessary repairs or cleanup to maintain the effectiveness of the erosion control devices shall be made immediately.
- ES-8: The contractor is responsible for the daily removal of sediment that has been transported onto a paved or public road surface.
- ES-9: The contractor shall be responsible for preventing surface and air movement of dust from exposed soils which may present health hazards, traffic safety problems, or harm animal or plant life.
- ES-10: All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization or after the temporary measures are no longer needed, unless otherwise authorized by the local program. Trapped sediment and disturbed soil areas resulting from the disposition measures shall be permanently stabilized to prevent further erosion and sedimentation.



LOGGING MAT:

- Definition:
A logging mat is a portable fabrication usually of boards or timbers held together by bolts or cable to provide temporary protection of a forest harvest entrance or haul road.
- Purpose:
This practice protects the surface soil structure from excessive compaction and rutting.
- Conditions where practice applies:
This practice applies to any part of the forest harvest access system where rutting could be an erosion or water handling problem. It is often used as a substitute for stone or other stabilization materials at the entrance of a forest harvest site and isolated wet areas on haul roads or skid trails. They are also used to access shoreline construction sites.

- Specifications:
- Mats shall be placed end to end to form a continuous span for the entire length of the area to be protected.
 - Mats can be used as substitute for or in conjunction with stone, gravel, wood chips, culverts, and other stabilizing material at the entrance to the harvest site.
 - Mats shall be inspected frequently and maintained or replaced as necessary to ensure their proper function.



Project Title	
Penniman Spit Living Shoreline & Oyster Restoration Project	
Issued for	
Final Draft Plan	
Drawing Title	
Sediment & Erosion Control	
Date	Scale
25 August 2020	
Sheet	
6 of 6	

Regulatory Agency Contact Information



Virginia Marine Resources Commission (VMRC)

Habitat Management Division
380 Fenwick Road, Building 96
Fort Monroe, VA 23651

Phone: (757) 247-2200, Fax: (757) 247-8062

Website: <http://www.mrc.virginia.gov/hmac/hmoverview.shtm>



United States Army Corps of Engineers (USACE)

Norfolk District

803 Front Street, ATTN: CENAO-WR-R
Norfolk, Virginia 23510-1011

Phone: (757) 201-7652, Fax: (757) 201-7678

Website: <http://www.nao.usace.army.mil/Missions/Regulatory.aspx>



Virginia Department of Environmental Quality (DEQ)

Virginia Water Protection Permit

Program

Post Office Box 1105
Richmond, Virginia 23218

Phone: (804) 698-4000

Website: <http://www.deq.virginia.gov/>



LOCAL WETLANDS BOARD (LWB) CONTACT INFORMATION:

Links to LWB information on the Web can be found at

http://ccrm.vims.edu/permits_web/guidance/local_wetlands_boards.html

In addition, the phone numbers listed below can be used to contact the LWB. Please be advised that these phone numbers are subject to change at any time.

Accomack County (757) 787-5721, Cape Charles (757) 331-3259, Charles City County (804) 829-9296, Chesapeake (757) 382-6248, Colonial Heights (804) 520-9275, Essex County (804) 443-4951, Fairfax County (703) 324-1364, Fredericksburg (540) 372-1179, Gloucester County (804) 693-2744, Hampton (757) 727-6140, Hopewell (804) 541-2267, Isle of Wight County (757) 365-6211, James City County (757) 253-6673, King and Queen County (804) 769-4978, King George County (540) 775-7111, King William County (804) 769-4927, Lancaster County (804) 462-5220, Mathews County (804) 725-5025, Middlesex County (804) 758-0500, New Kent County (804) 966-9690, Newport News (757) 247-8437, Norfolk (757) 664-4368, Northampton County (757) 678-0442, Northumberland County (804) 580-8910, Poquoson (757) 868-3040, Portsmouth (757) 393-8836, Prince William County (703) 792-6984, Richmond County (804) 333-3415, Stafford County (540) 658-8668, Suffolk (757) 923-3650, Virginia Beach (757) 427-8246, Westmoreland County (804) 493-0120, West Point (804) 843-3330, Williamsburg (757) 220-6130, York County (757) 890-3538

Tidewater Joint Permit Application (JPA) For Projects Involving Tidal Waters, Tidal Wetlands and/or Dunes and Beaches in Virginia

This application may be used for most commercial and noncommercial projects involving **tidal waters, tidal wetlands and/or dunes and beaches in Virginia** which require review and/or authorization by Local Wetlands Boards (LWB), the Virginia Marine Resources Commission (VMRC), the Department of Environmental Quality (DEQ), and/or the U. S. Army Corps of Engineers (USACE). This application can be used for:

- **Access-related activities**, including piers, boathouses, boat ramps (without associated dredging or excavation*), moorings, marinas.
- **Shoreline stabilization projects** including living shorelines, riprap revetments, marsh toe stabilization, bulkheads, breakwaters, beach nourishment, groins, and jetties. It is the policy of the Commonwealth that living shorelines are the preferred alternative for stabilizing tidal shorelines (Va. Code § 28.2-104.1).
- **Crossings** over or under tidal waters and wetlands including bridges and utility lines (water, sewer, electric).
- **Aquaculture structures**, including cages and floats except “oyster gardening”**

***Note:** for all dredging, excavation, or surface water withdrawal projects you **MUST** use the Standard JPA form; for noncommercial, riparian shellfish aquaculture projects (i.e., “oyster gardening”) you must use the abbreviated JPA found at https://mrc.virginia.gov/forms/2019/VGP3_Aquaculture_form_2019.pdf or call VMRC for a form.

The DEQ and the USACE use this form to determine whether projects qualify for certain General, Regional, and/or Nationwide permits. If your project does not qualify for these permits and you need a DEQ Virginia Water Protection permit or an individual USACE permit, you must submit the Standard Joint Permit application form. You can find this application at <http://www.nao.usace.army.mil/Missions/Regulatory/JPA.aspx>. Please note that some health departments and local agencies, such as local building officials and erosion and sediment control authorities, do not use the Joint Permit Application process or forms and may have different informational requirements. The applicant is responsible for contacting these agencies for information regarding those permitting requirements.

HOW TO APPLY

Submit one (1) completed copy of the Tidewater JPA to VMRC:

1. If by mail or courier, use the VMRC address provided on page 1.
2. If by electronic mail, address the package to: JPA.permits@mrc.virginia.gov. The application must be provided in the .pdf format and should not exceed 10 MB. If larger than 10 MB you may provide a file transfer protocol (ftp) site for download purposes.

The Tidewater JPA should include the following:

1. **Part 1** – General Information
2. **Part 2** – Signatures
3. **Part 3** - Appendices (A, B, C, and/or D as applicable to your project)
4. **Part 4** – Project Drawings.

The drawings shall include the following for **ALL** projects:

- Vicinity Map (USGS topographic map, road map or similar showing project location)
- Plan View Drawing (overhead, to scale or with dimensions clearly marked)
- Section View Drawing (side-view, to scale or with dimensions clearly marked)

Sample drawings are included at the end of Part 4 of this application to show examples of the information needed to consider your application complete and allow for the timely processing.

When completing this form, use the legal name of the applicant, agent, and/or property owner. For DEQ application purposes, *legal name* means the full legal name of an individual, business, or other organization. For an individual, the legal name is the first name, middle initial, last name, and suffix. For an entity authorized to do business in Virginia, the legal name is the exact name set forth in the entity's articles of incorporation, organization or trust, or formation agreement, as applicable. Also provide the name registered with the State Corporation Commission, if required to register. DEQ issues a permit or grants coverage to the so-named individual or business, who becomes the 'permittee'. Correspondence from some agencies, including permits, authorizations, and/or coverage, may be provided via electronic mail. If the applicant and/or agent wishes to receive their permit via electronic mail, please remember to include an e-mail address at the requested place in the application.

In order for projects requiring LWB authorization to be considered complete (Virginia Code § 28.2-1302); "The permit application shall include the following: the name and address of the applicant; a detailed description of the proposed activities; a map, drawn to an appropriate and uniform scale, showing the area of wetlands directly affected, the location of the proposed work thereon, the area of existing and proposed fill and excavation, the location, width, depth and length of any proposed channel and disposal area, and the location of all existing and proposed structures, sewage collection and treatment facilities, utility installations, roadways, and other related appurtenances of facilities, including those on the adjacent uplands; a description of the type of equipment to be used and the means of access to the activity site; the names and addresses of record of adjacent land and known claimants of water rights in or adjacent to the wetland of whom the applicant has notice; an estimate of cost; the primary purpose of the project; and secondary purpose of the proposed project; a complete description of measures to be taken during and after alteration to reduce detrimental offsite effects; the completion date of the proposed work, project, or structure; and such additional materials and documentation as the wetlands board may require."

You may include signed Adjacent Property Owner (APO) Acknowledgement Forms found at the end of this Short Form. You must provide these addresses in Part 1 whether or not you use the APO forms. VMRC will request comments from APOs for projects that require permits for encroachment over state-owned submerged lands. VMRC or your local wetlands board must notify all APO's of public hearings required for all proposals involving tidal wetlands and dunes/beaches that are not authorized by statute. This information will not be used by DEQ to meet the requirements of notifying riparian land owners.

Regional Permit 17 (RP-17), authorizes the installation and/or construction of open-pile piers, mooring structures/devices, fender piles, covered boathouses/boatslips, boatlifts, osprey pilings/platforms, accessory pier structures, and certain devices associated with shellfish gardening, for private use, subject to strict compliance with all conditions and limitations further set out in the RP-17 enclosure located at <http://www.nao.usace.army.mil/Missions/Regulatory/RBregional/>. In addition to the information required in this JPA, prospective permittees seeking authorization under RP-17 must complete and submit the 'Regional Permit 17 Checklist' with their JPA. A copy of the 'Regional Permit 17 Checklist' is found on pages 13 and 14 of this application package. If the prospective permittee answers "yes" (or "N/A", where applicable) to all of the questions on the 'Regional Permit 17 Checklist', the permittee is in compliance with RP-17 and will not receive any other written authorization from the Corps but may not proceed with construction until they have obtained all necessary state and local permits. ***Note: If the prospective permittee answers "no" to any of the questions on the 'Regional Permit 17 Checklist' then their proposed structure(s) does not meet the terms and conditions of RP-17 and written authorization from the Corps is required before commencement of any work.***

Note: Land disturbance (grading, filling, etc.) or removal of vegetation associated with projects located in Chesapeake Bay Preservation Areas will require approval from local governments. Certain localities utilize this application during their Bay Act review. Part 5 of this application is included to provide assistance for the applicant to comply with Bay Act /or Erosion and Sediment Control requirements concurrent with this application.

WHAT HAPPENS NEXT

Upon receipt of an application, VMRC will assign a permit application number to the JPA and will then distribute a copy of the application and any original plan copies submitted to the other regulatory agencies that are involved in the JPA process. All agencies will conduct separate but concurrent reviews of your project. Please be aware that each agency must issue a separate permit (or a notification that no permit is required). Note that in some cases, DEQ may be taking an action on behalf of the USACE, such as when the State Program General Permit (SPGP) applies. Make sure that you have received all necessary authorizations, or documentation that no permit is required, from each agency prior to beginning the proposed work.

During the JPA review process, site inspections may be necessary to evaluate a proposed project. Failure to allow an authorized representative of a regulatory agency to enter the property, or to take photographs of conditions at the project site, may result in either the withdrawal or denial of your permit application.

For certain federal and state permit applications, a public notice is published in a newspaper having circulation in the project area, is mailed to adjacent and/or riparian property owners, and/or is posted on the agency's web page. The public may comment on the project during a designated comment period, if applicable, which varies depending upon the type of permit being applied for and the issuing agency. In certain circumstances, the project may be heard by a governing board, such as a Local Wetlands Board, the State Water Control Board, or VMRC in cases where a locality does not have a wetlands board and with certain subaqueous cases. You may be responsible for bearing the costs for advertisement of public notices.

Public hearings that are held by VMRC occur at their regularly scheduled monthly commission meetings under the following situations: Protested applications for VMRC permits which cannot be resolved; projects costing over \$500,000 involving encroachment over state-owned subaqueous land; and all projects affecting tidal wetlands and dunes/beaches in localities without a LWB. All interested parties will be officially notified regarding the date and time of the hearing and Commission meeting procedures. The Commission will usually make a decision on the project at the meeting unless a decision for continuance is made. If a proposed project is approved, a permit or similar agency correspondence is sent to the applicant. In some cases, notarized signatures, as well as processing fees and royalties, are required before the permit is validated. If the project is denied, the applicant will be notified in writing.

PERMIT APPLICATION OR OTHER FEES

Do not send any fees with the JPA. VMRC is not responsible for accounting for fees required by other agencies. Please consult agency websites or contact agencies directly for current fee information and submittal instructions.

- ❖ **USACE:** Permit application fees are required for USACE Individual (Standard) permits. A USACE project manager will contact you regarding the proper fee and submittal requirements.

- ❖ DEQ: Permit application fees required for Virginia Water Protection permits – while detailed in 9VAC25-20 – are conveyed to the applicant by the applicable DEQ office (<http://www.deq.virginia.gov/Locations.aspx>). Complete the Permit Application Fee Form and submit it per the instructions to the address listed on the form. Instructions for submitting any other fees will be provided to the applicant by DEQ staff.
- ❖ VMRC: An application fee of \$300 may be required for projects impacting tidal wetlands, beaches and/or dunes when VMRC acts as the LWB. VMRC will notify the applicant in writing if the fee is required. Permit fees involving subaqueous lands are \$25.00 for projects costing \$10,000 or less and \$100 for projects costing more than \$10,000. Royalties may also be required for some projects. The proper permit fee and any required royalty is paid at the time of permit issuance by VMRC. VMRC staff will send the permittee a letter notifying him/her of the proper permit fees and submittal requirements.
- ❖ LWB: Permit fees vary by locality. Contact the LWB for your project area or their website for fee information and submittal requirements. Contact information for LWBs may be found at http://ccrm.vims.edu/permits_web/guidance/local_wetlands_boards.html.

FOR AGENCY USE ONLY	
	Notes: <hr/> JPA #

APPLICANTS

Part 1 – General Information

PLEASE PRINT OR TYPE ALL ANSWERS: If a question does not apply to your project, please print N/A (not applicable) in the space provided. If additional space is needed, attach 8-1/2 x 11 inch sheets of paper.

<i>Check all that apply</i>				
Pre-Construction Notification (PCN) <input type="checkbox"/> NWP # _____ <i>(For Nationwide Permits ONLY - No DEQ-VWP permit writer will be assigned)</i>	Regional Permit 17 (RP-17) <input type="checkbox"/>			
County or City in which the project is located: _____ Waterway at project site: _____				
<i>PREVIOUS ACTIONS RELATED TO THE PROPOSED WORK (Include all federal, state, and local pre application coordination, site visits, previous permits, or applications whether issued, withdrawn, or denied)</i>				
Historical information for past permit submittals can be found online with VMRC - https://webapps.mrc.virginia.gov/public/habitat/ - or VIMS - http://ccrm.vims.edu/perms/newpermits.html				
Agency	Action / Activity	Permit/Project number, including any non-reporting Nationwide permits previously used (e.g., NWP 13)	Date of Action	If denied, give reason for denial

Part 1 - General Information (continued)

1. Applicant's legal name* and complete mailing address: Contact Information:

Home (____)_____

Work (____)_____

Fax (____)_____

Cell (____)_____

e-mail _____

State Corporation Commission Name and ID Number (if applicable) _____

2. Property owner(s) legal name* and complete address, if different from applicant: Contact Information:

Home (____)_____

Work (____)_____

Fax (____)_____

Cell (____)_____

e-mail _____

State Corporation Commission Name and ID Number (if applicable) _____

3. Authorized agent name* and complete mailing address (if applicable):

Contact Information:

Home (____)_____

Work (____)_____

Fax (____)_____

Cell (____)_____

e-mail _____

State Corporation Commission Name and ID Number (if applicable) _____

*** If multiple applicants, property owners, and/or agents, each must be listed and each must sign the applicant signature page.**

4. Provide a detailed description of the project in the space below, including the type of project, its dimensions, materials, and method of construction. Be sure to include how the construction site will be accessed and whether tree clearing and/or grading will be required, including the total acreage. If the project requires pilings, please be sure to include the total number, type (e.g. wood, steel, etc), diameter, and method of installation (e.g. hammer, vibratory, jetted, etc). If additional space is needed, provide a separate sheet of paper with the project description.

Part 1 - General Information (continued)

5. Have you obtained a contractor for the project? ____ Yes* ____ No. *If your answer is "Yes" complete the remainder of this question and submit the Applicant's and Contractor's Acknowledgment Form (enclosed)

Contractor's name* and complete mailing address:

Contact Information:

Home (____) _____

Work (____) _____

Fax (____) _____

Cell (____) _____

email _____

State Corporation Commission Name and ID Number (if applicable) _____

*** If multiple contractors, each must be listed and each must sign the applicant signature page.**

6. List the name, address and telephone number of the newspaper having general circulation in the area of the project. Failure to complete this question may delay local and State processing.

Name and complete mailing address:

Telephone number

(____) _____

7. Give the following project location information:

Street Address (911 address if available) _____

Lot/Block/Parcel# _____

Subdivision _____

City / County _____ ZIP Code _____

Latitude and Longitude at Center Point of Project Site (Decimal Degrees):

_____ / - _____ (Example: 36.41600/-76.30733)

If the project is located in a rural area, please provide driving directions giving distances from the best and nearest visible landmarks or major intersections. *Note: if the project is in an undeveloped subdivision or property, clearly stake and identify property lines and location of the proposed project. A supplemental map showing how the property is to be subdivided should also be provided.*

8. What are the *primary and secondary purposes of and the need for* the project? For example, the primary purpose may be "to protect property from erosion due to boat wakes" and the secondary purpose may be "to provide safer access to a pier."

Part 1 - General Information (continued)

9. Proposed use (check one):
 ___ Single user (private, non-commercial, residential)
 ___ Multi-user (community, commercial, industrial, government)
10. Describe alternatives considered and the measures that will be taken to avoid and minimize impacts, to the maximum extent practicable, to wetlands, surface waters, submerged lands, and buffer areas associated with any disturbance (clearing, grading, excavating) during and after project construction. *Please be advised that unavoidable losses of tidal wetlands and/or aquatic resources may require compensatory mitigation.*
11. Is this application being submitted for after-the-fact authorization for work which has already begun or been completed? ___Yes ___No. If yes, be sure to clearly depict the portions of the project which are already complete in the project drawings.
12. Approximate cost of the entire project (materials, labor, etc.): \$_____
Approximate cost of that portion of the project that is channelward of mean low water:
\$_____
13. Completion date of the proposed work: _____-
14. Adjacent Property Owner Information: List the name and complete **mailing address**, including zip code, of each adjacent property owner to the project. (NOTE: If you own the adjacent lot, provide the requested information for the first adjacent parcel beyond your property line.) Failure to provide this information may result in a delay in the processing of your application by VMRC.

Part 2 - Signatures

1. Applicants and property owners (if different from applicant).

NOTE: REQUIRED FOR ALL PROJECTS

PRIVACY ACT STATEMENT: The Department of the Army permit program is authorized by Section 10 of the Rivers and Harbors Act of 1899, Section 404 of the Clean Water Act, and Section 103 of the Marine Protection Research and Sanctuaries Act of 1972. These laws require that individuals obtain permits that authorize structures and work in or affecting navigable waters of the United States, the discharge of dredged or fill material into waters of the United States, and the transportation of dredged material for the purpose of dumping it into ocean waters prior to undertaking the activity. Information provided in the Joint Permit Application will be used in the permit review process and is a matter of public record once the application is filed. Disclosure of the requested information is voluntary, but it may not be possible to evaluate the permit application or to issue a permit if the information requested is not provided.

CERTIFICATION: I am hereby applying for all permits typically issued by the DEQ, VMRC, USACE, and/or Local Wetlands Boards for the activities I have described herein. I agree to allow the duly authorized representatives of any regulatory or advisory agency to enter upon the premises of the project site at reasonable times to inspect and photograph site conditions, both in reviewing a proposal to issue a permit and after permit issuance to determine compliance with the permit.

In addition, I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Applicant's Legal Name (printed/typed)

(Use if more than one applicant)

Applicant's Signature

(Use if more than one applicant)

Date

Property Owner's Legal Name (printed/typed)
(If different from Applicant)

(Use if more than one owner)

Property Owner's Signature

(Use if more than one owner)

Date

Part 2 – Signatures (continued)

2. Applicants having agents (if applicable)

CERTIFICATION OF AUTHORIZATION

I (we), _____, hereby certify that I (we) have authorized _____
(Applicant's legal name(s)) (Agent's name(s))

to act on my behalf and take all actions necessary to the processing, issuance and acceptance of this permit and any and all standard and special conditions attached.

We hereby certify that the information submitted in this application is true and accurate to the best of our knowledge.

(Agent's Signature)

(Use if more than one agent)

(Date)

(Applicant's Signature)

(Use if more than one applicant)

(Date)

3. Applicant's having contractors (if applicable)

CONTRACTOR ACKNOWLEDGEMENT

I (we), _____, have contracted _____
(Applicant's legal name(s)) (Contractor's name(s))
to perform the work described in this Joint Permit Application, signed and dated _____.

We will read and abide by all conditions set forth in all Federal, State and Local permits as required for this project. We understand that failure to follow the conditions of the permits may constitute a violation of applicable Federal, state and local statutes and that we will be liable for any civil and/or criminal penalties imposed by these statutes. In addition, we agree to make available a copy of any permit to any regulatory representative visiting the project to ensure permit compliance. If we fail to provide the applicable permit upon request, we understand that the representative will have the option of stopping our operation until it has been determined that we have a properly signed and executed permit and are in full compliance with all terms and conditions.

Contractor's name or name of firm

Contractor's or firms address

Contractor's signature and title

Contractor's License Number

Applicant's signature

(use if more than one applicant)

Date

Part 2 – Signatures (continued)

ADJACENT PROPERTY OWNER'S ACKNOWLEDGEMENT FORM

I (we), _____, own land next to (across the water
(Print adjacent/nearby property owner's name)

from/on the same cove as) the land of _____.
(Print applicant's name(s))

I have reviewed the applicant's project drawings dated _____
(Date)

to be submitted for all necessary federal, state and local permits.

I HAVE NO COMMENT _____ ABOUT THE PROJECT.

I DO NOT OBJECT _____ TO THE PROJECT.

I OBJECT _____ TO THE PROJECT.

The applicant has agreed to contact me for additional comments if the proposal changes prior to construction of the project.

(Before signing this form be sure you have checked the appropriate option above).

Adjacent/nearby property owner's signature(s)

Date

Note: If you object to the proposal, the reason(s) you oppose the project must be submitted in writing to VMRC. An objection will not necessarily result in denial of the project; however, valid complaints will be given full consideration during the permit review process.

Part 2 – Signatures (continued)

ADJACENT PROPERTY OWNER'S ACKNOWLEDGEMENT FORM

I (we), _____, own land next to (across the water
(Print adjacent/nearby property owner's name)

from/on the same cove as) the land of _____.
(Print applicant's name(s))

I have reviewed the applicant's project drawings dated _____.
(Date)

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I HAVE NO COMMENT _____ ABOUT THE PROJECT.

I DO NOT OBJECT _____ TO THE PROJECT.

I OBJECT _____ TO THE PROJECT.

The applicant has agreed to contact me for additional comments if the proposal changes prior to construction of the project.

(Before signing this form, be sure you have checked the appropriate option above).

Adjacent/nearby property owner's signature(s)

Date

Note: If you object to the proposal, the reason(s) you oppose the project must be submitted in writing to VMRC. An objection will not necessarily result in denial of the project; however, valid complaints will be given full consideration during the permit review process.

Part 3 – Appendices (continued)

Appendix B: Projects for Shoreline Stabilization in tidal wetlands, tidal waters and dunes/beaches including riprap revetments and associated backfill, marsh toe stabilization, bulkheads and associated backfill, breakwaters, beach nourishment, groins, jetties, and living shoreline projects. Answer all questions that apply. Please provide any reports provided from the Shoreline Erosion Advisory Service or VIMS.

NOTE: It is the policy of the Commonwealth that living shorelines are the preferred alternative for stabilizing tidal shorelines (Va. Code § 28.2-104.1). **Information on non-structural, vegetative alternatives (i.e., Living Shoreline) for shoreline stabilization is available at http://ccrm.vims.edu/coastal_zone/living_shorelines/index.html.**

1. Describe each **revetment, bulkhead, marsh toe, breakwater, groin, jetty, other structure, or living shoreline project** separately in the space below. Include the overall length in linear feet, the amount of impacts in acres, and volume of associated backfill below mean high water and/or ordinary high water in cubic yards, as applicable:

2. What is the maximum encroachment channelward of mean high water? _____ feet.
Channelward of mean low water? _____ feet.
Channelward of the back edge of the dune or beach? _____ feet.

3. Please calculate the square footage of encroachment over:

- Vegetated wetlands _____ square feet
- Non-vegetated wetlands _____ square feet
- Subaqueous bottom _____ square feet
- Dune and/or beach _____ square feet

4. For bulkheads, is any part of the project maintenance or replacement of a previously authorized, currently serviceable, existing structure? ____ Yes ____ No.

If yes, will the construction of the new bulkhead be no further than two (2) feet channelward of the existing bulkhead? ____ Yes ____ No.

If no, please provide an explanation for the purpose and need for the additional encroachment.

Part 3 – Appendices (continued)

5. Describe the type of construction and **all** materials to be used, including source of backfill material, if applicable (e.g., vinyl sheet-pile bulkhead, timber stringers and butt piles, 100% sand backfill from upland source; broken concrete core material with Class II quarry stone armor over filter cloth).

NOTE: Drawings must include construction details, including dimensions, design and all materials, including fittings if used.

6. If using stone, broken concrete, etc. for your structure(s), what is the average weight of the:

Core (inner layer) material _____ pounds per stone Class size _____

Armor (outer layer) material _____ pounds per stone Class size _____

7. For **beach nourishment**, including that associated with breakwaters, groins or other structures, provide the following:

- Volume of material _____ cubic yards channelward of mean low water
- _____ cubic yards landward of mean low water
- _____ cubic yards channelward of mean high water
- _____ cubic yards landward of mean high water

- Area to be covered _____ square feet channelward of mean low water
 _____ square feet landward of mean low water
 _____ cubic yards channelward of mean high water
 _____ cubic yards landward of mean high water

- Source of material, composition (e.g. 90% sand, 10% clay):_____
- Method of transportation and placement:

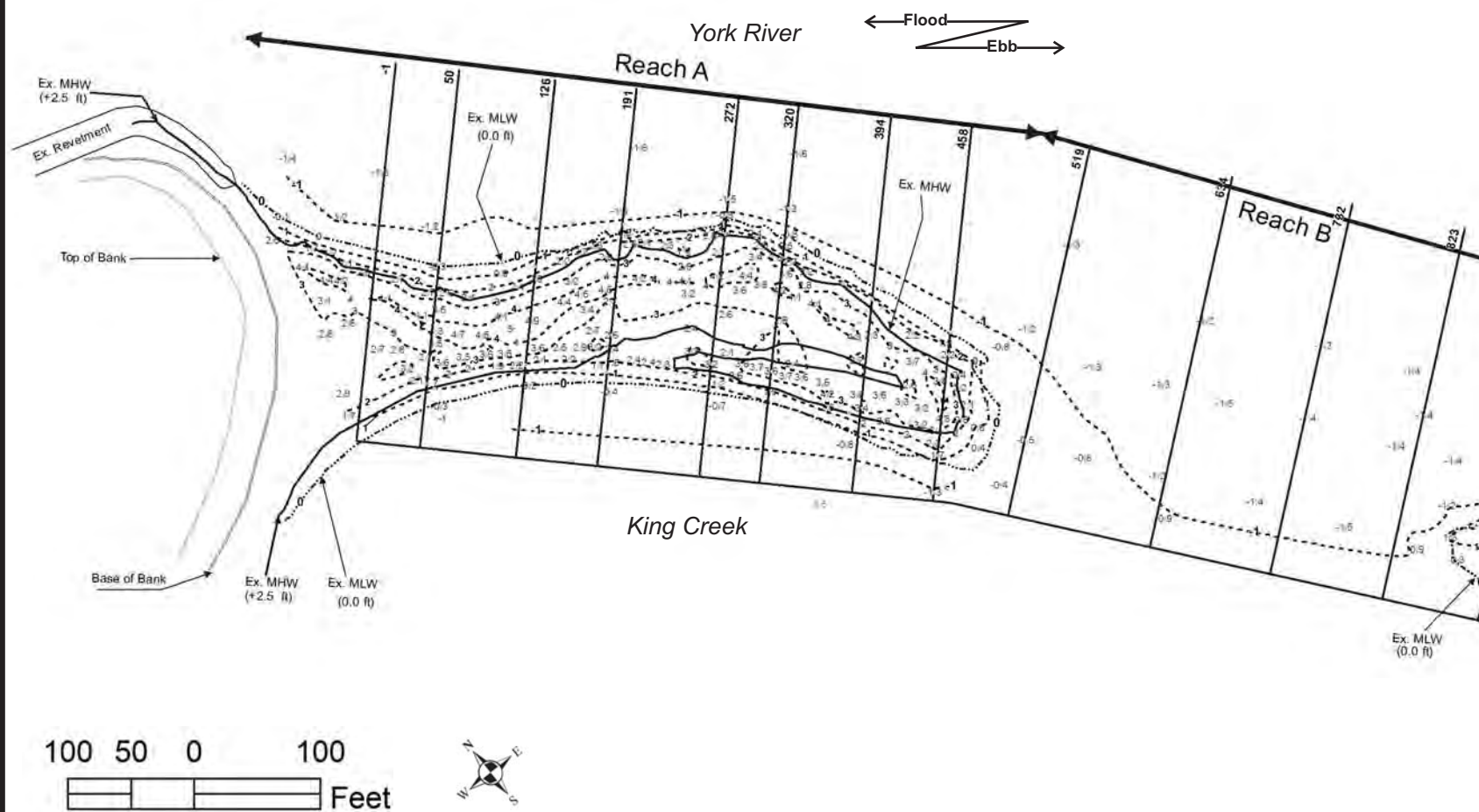
- Describe any proposed vegetative stabilization measures to be used, including planting schedule, spacing, monitoring, etc. Additional guidance is available at <http://www.vims.edu/about/search/index.php?q=planting+guidelines>:

Existing Conditions

- ▲ Benchmark
- Existing MLW
- Existing MHW
- Contours
- Base of Bank
- Top of Bank
- Existing Revetment
- ↔ Reach Lines
- Profiles
- Baseline



Project Title	
Penniman Spit Living Shoreline & Oyster Restoration Project	
Issued for	
Final Draft Plan	
Drawing Title	
Existing Conditions	
Date	Scale
25 August 2020	
Sheet	



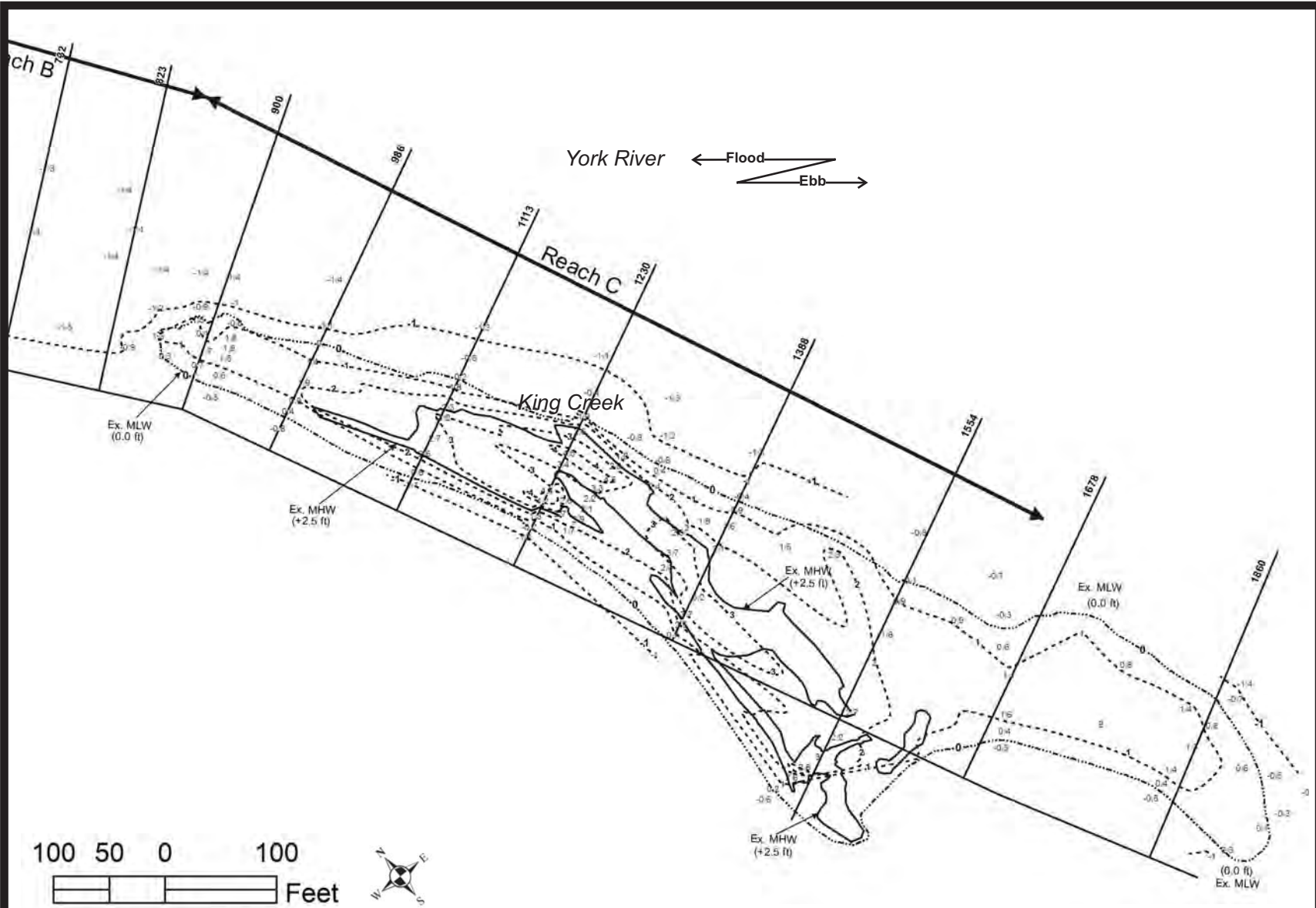
Penniman Spit Living Shoreline & Oyster Restoration Project

Existing Conditions

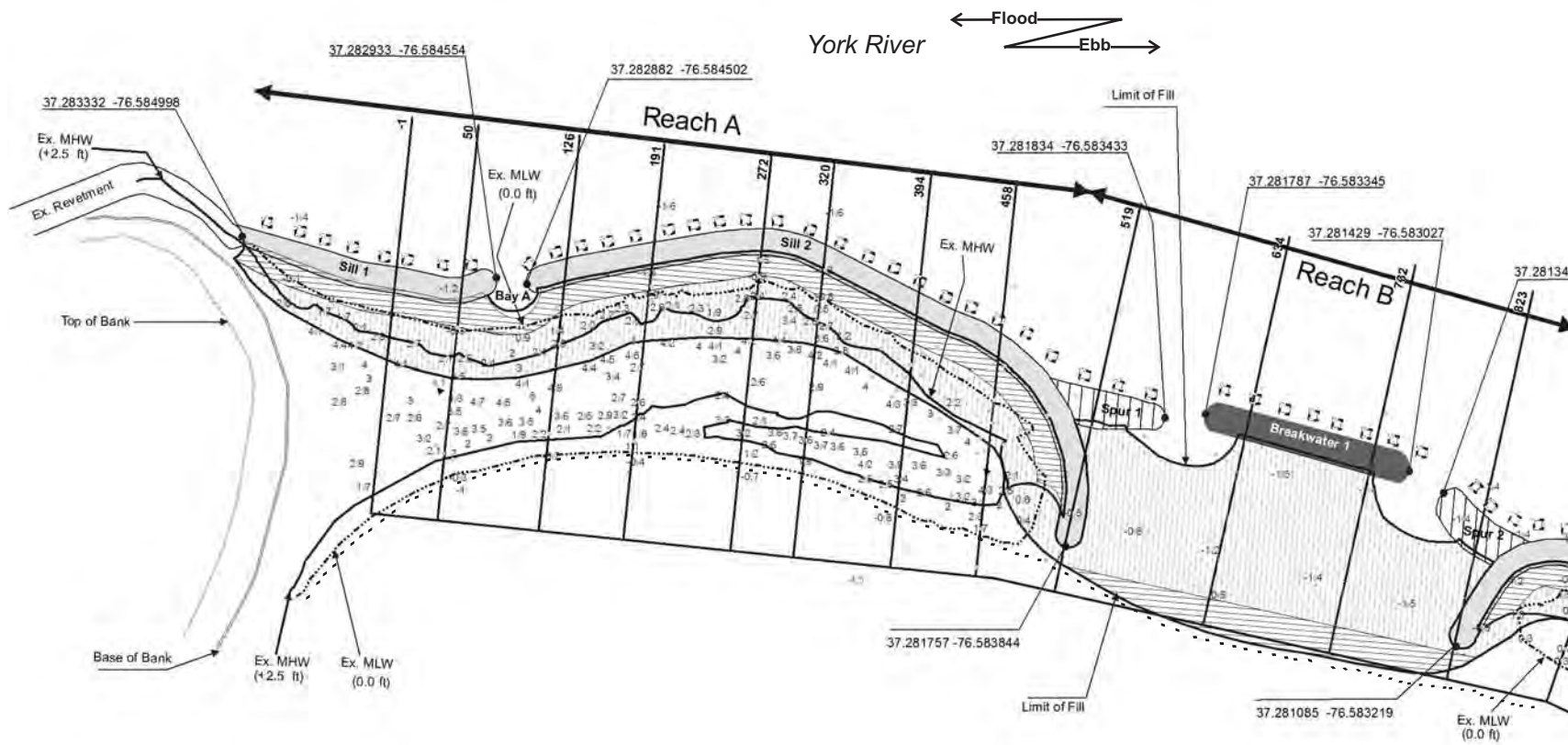
- Survey Points (ft MLW)
Survey Date: 29 Oct 2019
- ▲ Benchmark
- Existing MLW
- Existing MHW
- Contours
- Base of Bank
- Top of Bank
- Existing Revetment
- ↔ Reach Lines
- Profiles
- Baseline



Project Title	
Penniman Spit Living Shoreline & Oyster Restoration Project	
Issued for	
Final Draft Plan	
Drawing Title	
Existing Conditions	
Date	Scale
25 August 2020	
Sheet	



Penniman Spit Living Shoreline & Oyster

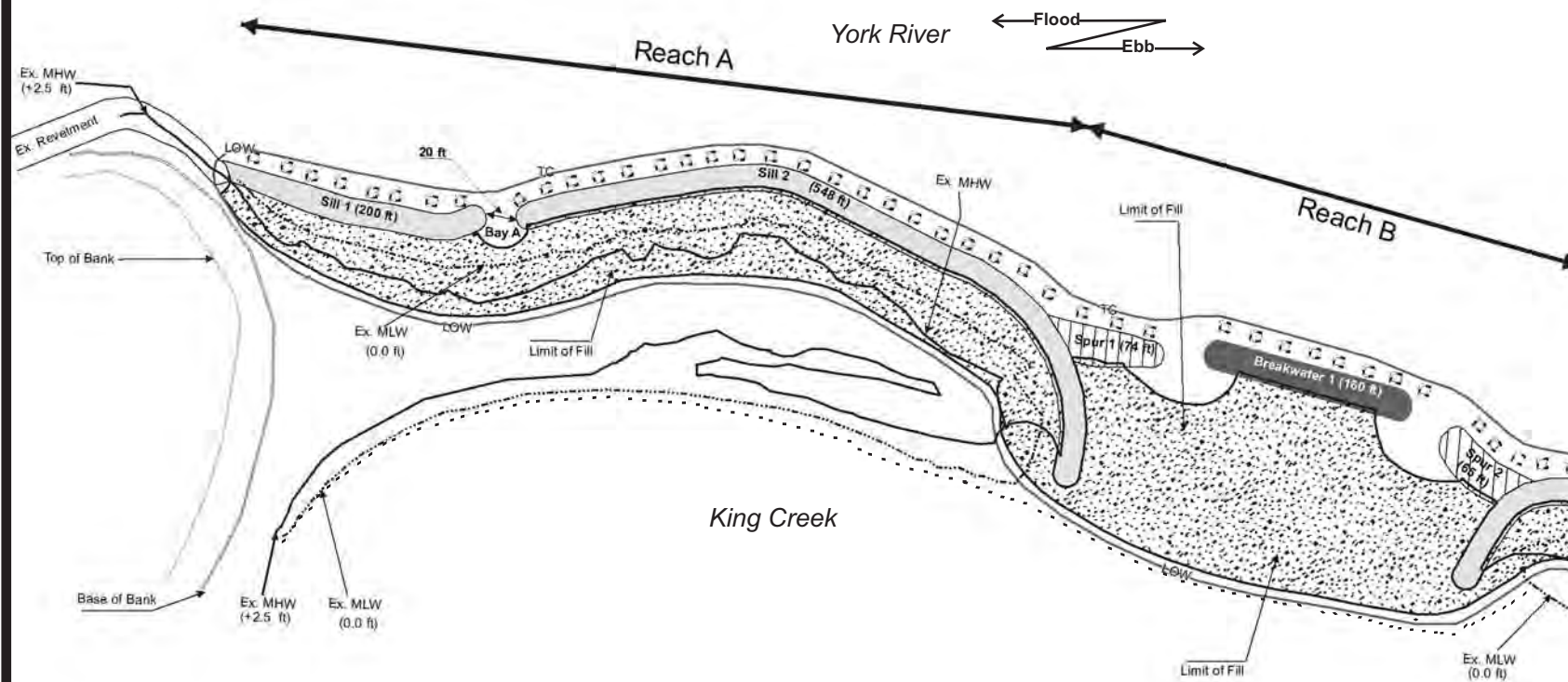


- Existing Conditions**
- Survey Points (ft MLW)
Survey Date: 29 Oct 2019
 - ▲ Benchmark
 - Existing MLW
 - Existing MHW
 - Base of Bank
 - Top of Bank
 - Existing Revetment
 - Reach Lines
 - Profiles
 - Baseline
- Proposed Plan**
- Rock Sill
 - Breakwater
 - Spur
 - Spartina alterniflora
 - Spartina patens
 - Limit of Sand Fill
 - Oyster Castles
 - Concreted Crab Pots
Locations are approximate



Project Title	
Penniman Spit Living Shoreline & Oyster Restoration Project	
Drawing Title	
Final Draft Plan	
Drawing Title	
Proposed Plan	
Date	Scale
25 August 2020	
Sheet	

Penniman Spit Living Shoreline & Oyster



Existing Conditions

- Existing MLW
- Existing MHW
- Base of Bank
- Top of Bank
- Existing Revetment
- Reach Lines

Proposed Plan

- Rock Sill
- Breakwater
- Spur
- Spartina alterniflora
- Spartina patens
- Limit of Sand Fill
- Oyster Castles
- Concreted Crab Pots
- Limit of Construction Work
- Turbidity Curtain



Project Title
Penniman Spit
Living Shoreline & Oyster
Restoration Project

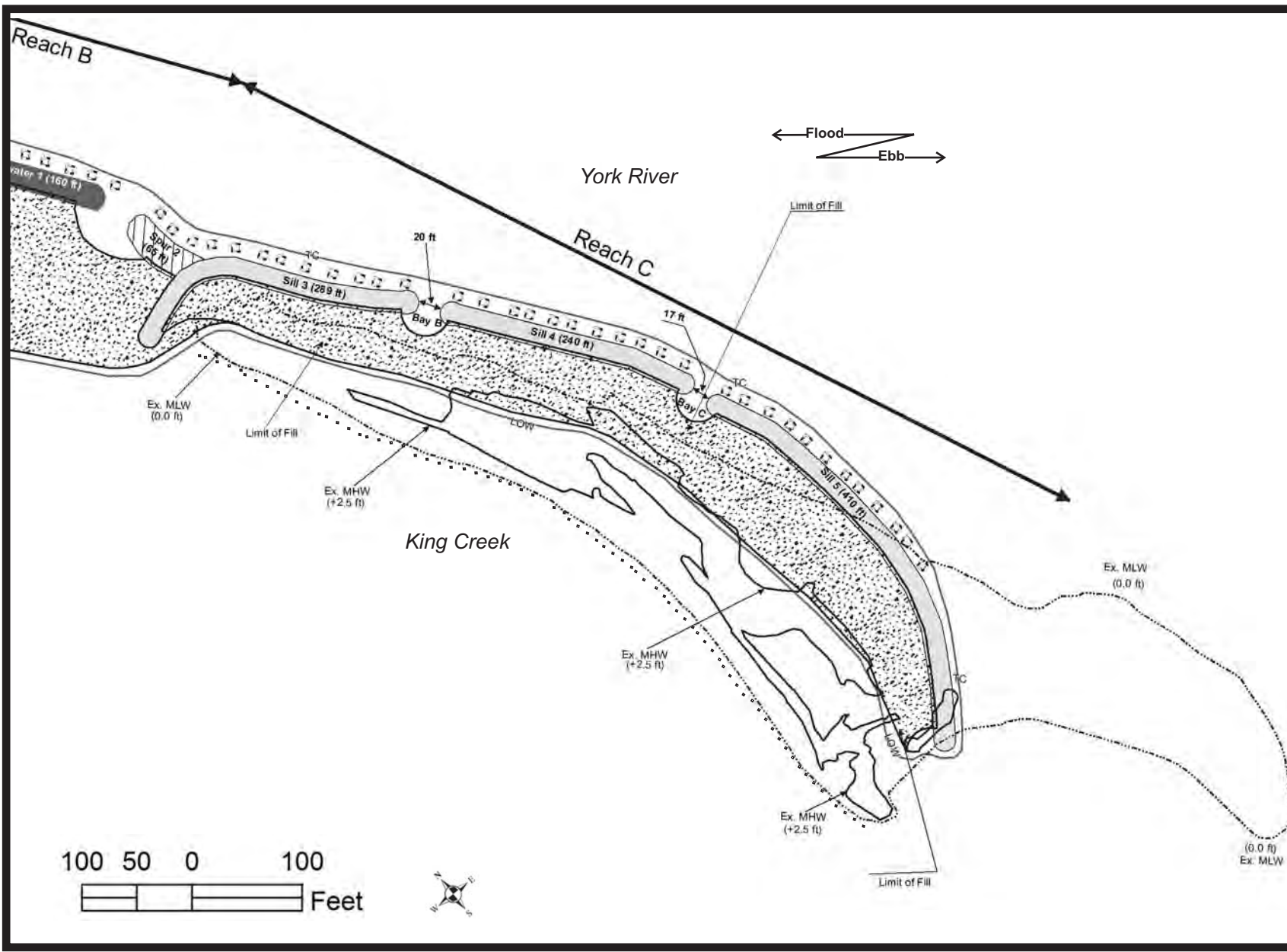
Issued for
Final Draft Plan

Drawing Title
Measurement Sheet

Date
25 August 2020

Scale

Sheet
4 of 5



Penniman Spit Living Shoreline & Oyster

- Existing Conditions
- Existing MLW
 - Existing MHW
 - Base of Bank
 - Top of Bank
 - Existing Revetment
 - Reach Lines

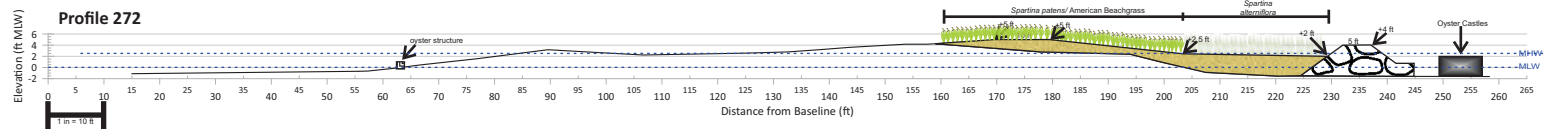
- Proposed Plan
- Rock Sill
 - Breakwater
 - Spur
 - Spartina alterniflora
 - Spartina patens
 - Limit of Sand Fill
 - Oyster Castles
 - Concreted Crab Pots

LOW—Limit of Construction Work
TC—Turbidity Curtain

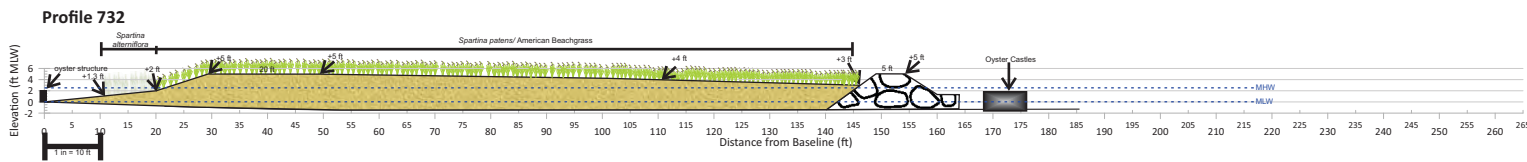


Project Title	
Penniman Spit Living Shoreline & Oyster Restoration Project	
Issued for	
Final Draft Plan	
Drawing Title	
Measurement Sheet	
Date	Scale
25 August 2020	
Sheet	
4 of 5	

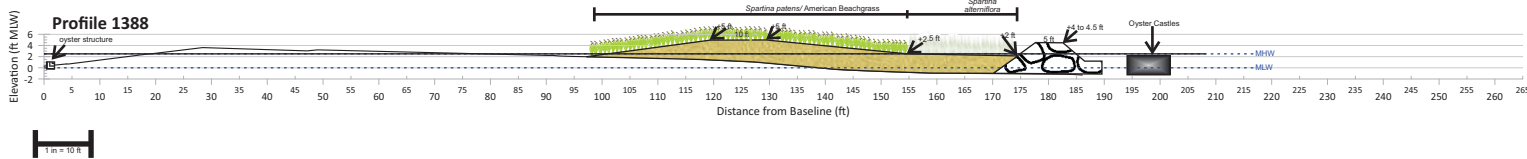
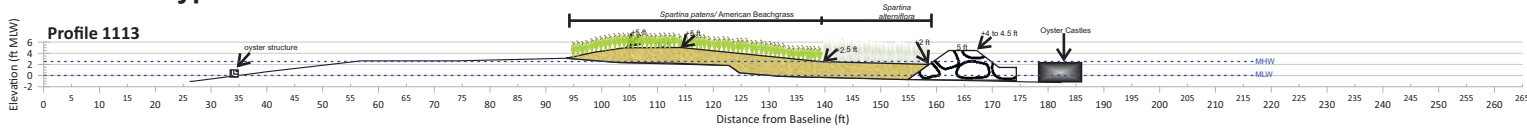
Reach A Typical Cross-Section



Reach B Typical Cross-Sections for the gap



Reach C Typical Cross-Sections



Penniman Spit Construction of Oyster Castle Living Shorelines and Used Blue Crab Traps

The following table provides estimates of the costs associated with purchase and deployment of **7,200 oyster castles and 950 refurbished used crab traps** at Naval Weapons Station Yorktown (NWSY). Note that the numbers of oyster castles and crab traps to be deployed have been increased significantly from the numbers in the CBT report due to revised estimates for the REPI Challenge Program grant.

Item	Unit Cost	Number of Units	Total Cost
Oyster Castle	\$5.50		
Oyster Castle Cube (72 oyster castles)	\$396	100 cubes	\$39,600
Freight to NWSY (20 cubes per day)	\$1,400 per day	5 days (5 days for 100 cubes)	\$7,000
Specialty Barge at NWSY	\$1,100 per day	6 days	\$6,600
VIMS vessel for deployment	\$150 per day	18 days	\$2,700
Labor*	\$720 per day	18 days	\$12,960
Subtotal for Oyster Castles			\$68,860
Used Crab Trap purchase (5 per unit)	\$5.00 per set of 5 traps	190 sets	\$950
Freight	\$120 per day	5 days	\$600
Trap Preparation (refurbishment & concrete coating)	\$720 per day	9 days	\$6,480
VIMS vessel for deployment	\$150 per day	5 days	\$750
Labor*	\$720 per day	5 days	\$12,960
Subtotal for Crab Traps			\$21,740
Total			\$90,600**

* Depending on the level of volunteer assistance (e.g., Navy sailors/marines), labor could be higher or lower. In this category we have only included labor costs for 2 VIMS staff, which without volunteer assistance would rise to 4-5 staff or could be only 1 staff member with extra volunteer assistance.

** The total does not include indirect costs.