Eastern Shore of Virginia RC&D
Shoreline Erosion Control
Final Report
National Fish and Wildlife Foundation
Project Number: 2006-0100-017

1. Summary of Accomplishments

The goal of this project was to provide an array of informational resources to assist waterfront landowners with determining whether their shoreline erosion can be prevented or controlled by vegetative or non-structural approaches that are protective of water quality and benthic habitat. The Eastern Shore RC&D Council contracted with the Virginia Institute of Marine Science (VIMS) to prepare a *Shoreline Erosion Assessment and Living Shoreline Options Report* in order to assist landowners on the Creek with determining appropriate shoreline stabilization techniques for their properties. The VIMS report details shoreline management solutions and maps specific living shoreline strategies for each section of eroding shoreline on Occohannock Creek. Once completed, the VIMS report was disseminated in a landowner workshop for residents on Occohannock Creek and in a joint work session with the Accomack and Northampton County Wetlands Boards. In addition, the ESRC&D, in conjunction with the Maryland Eastern Shore RC&D's shoreline program, assisted six landowners requesting technical assistance on shoreline stabilization. During the project period, The Nature Conservancy was implementing a living shoreline project that provides a publicly accessible demonstration site in the town of Oyster, Virginia. With input from TNC and the Maryland RC&D, a list of consultants with experience in shoreline restoration was developed to add to the available resources promoting "living shoreline" techniques.

2. Introduction

The permanent alteration of shoreline is occurring piecemeal throughout the Chesapeake Bay, parcel by parcel, with permits and variances issued by dozens of local governments. Traditionally these alterations take the form of bulkheads and revetments to provide erosion control and flood protection, and in many cases the vital ecological functions at the water/land margin are lost in the process. The goal of RC&D's Erosion Control Project is to promote the replacement of "hardened" shoreline protection where more habitat preserving measures would work. The project set forth to educate and demonstrate "bioengineered" alternatives where erosion control can have less environmental impact; where vital wetlands functions such as nutrient cycling and sediment removal can take place; and, where the shallow benthic ecosystem remains intact.

The strategies of the Shoreline Erosion Control project included the following five elements:

1) Library of resources to assist waterfront landowners determine if their shoreline erosion can be prevented or controlled by vegetative or non-structural approaches that are protective of water quality.
2) A list of marine contractors, shoreline engineers, soft-shoreline designers and consultants available to work on the Eastern Shore.
3) An assessment of all shoreline along Occohannock Creek to determine the suitability of different stabilization techniques for particular reaches.
4) Twenty days of onsite technical assistance for waterfront landowners planning to install shoreline stabilization features, with four intensive consultations for contiguous property owners experiencing severe erosion and who want to employ alternatives to bulk heading.
5) Design one soft shoreline demonstration project to be installed on public property which receives high level of visitation.

3 / 4 Methods and Results

3 /4 -1 Resource Library

Compilation was expected at the end of the project; however, the project coordinator retired before this deliverable was completed to the extent described in the grant proposal. There was a several-month gap before a new coordinator could assist with assessing completion and preparing a final grant report. Several excellent resource material s were compiled during the grant cycle and these are posted on the current Eastern Shore RC&D website, www.esrcd.org under *Projects*. Plans to create a more complete web-based resource library will be realized by December 2010 (beyond the scope of the grant project).

3 /4 -2 List of Contractors and Consultants available to work on the Eastern Shore

Contractor and Consultant Lists developed for the project were distributed in outreach efforts, including workshops with Occohannock Creek landowners, joint session of the County Wetlands Boards, and to individual landowners seeking technical assistance. These are also available in the RC&D office at the Accomac USDA Service Center and they are posted on the www.esrcd.org website.

These lists are attached to this report on pages 8-9. These contractors have been approved for work under the Maryland RC&D Living Shorelines program. Additional Virginia contractors were added to updated lists currently posted in the office and on the website.

3 /4 -3 An assessment of all shoreline along Occohannock Creek to determine the suitability of different stabilization techniques for particular reaches.

A *Shoreline Erosion Assessment and Living Shoreline Options Report* was completed under contract with the Virginia Institute of Marine Science. The *Report* provides a valuable resource for waterfront landowners on the Eastern Shore and specifically on Occohannock Creek. It discusses previous research on "living shorelines"; develops management considerations and strategies; collects specific data affecting Occohannock Creek bank conditions; and characterizes the existing shoreline in terms of management options for all shoreline segments of the creek.

A landowner workshop was held on July 31, 2008 to present a draft version of the report and discuss shoreline alternatives with Scott Hardaway, the principal author, and with Mike Vanlandingham from the Virginia Shoreline Erosion Advisory Service. There were 25 participants from the community as listed in the attendance roster attached on page 11. The mailing notice for the event was distributed to 139 landowners with waterfront tracts on Occohannock Creek. The full report and maps were provided to participants and a summary PowerPoint presentation was given at the workshop and is attached in pages 12-24. This is also the presentation that was given to the two County Wetlands Boards.

A survey of participants was taken for follow-up after the workshop that included 1) disseminating the report with technical appendices and map; 2) requesting services of the Virginia Shoreline Erosion Advisor; and, 3) requesting services of the Eastern Shore Forester about tree species for individual properties.

Since the *Shoreline Option Report* is also a valuable tool for local decision-makers, the RC&D hosted a joint work session on June 3, 2008 with the Accomack County and Northampton

County Wetlands Boards to present the study's findings. Scott Hardaway from VIMS presented the summary PowerPoint and facilitated a discussion of additions that would be made to the final report. The *Occohannock Creek Shoreline Erosion Assessment and Living Shoreline Options Report* was finalized in October 2008. The full report (without appendices) is attached in pages 27-84. The full report with appendices will be submitted the hard copy grant report. The full report including appendices is also available on the www.esrcd.org and the www.vims.edu websites. On March 5, 2009, Scott Hardaway presented "living shoreline" concepts in a lecture program for the Shore community at the Palace Theater in Cape Charles, VA. This program was titled "Design and Performance of Headland Breakwater Systems for Protection of Shoreline in High Energy Environments."

3 /4 -4 Twenty days of onsite technical assistance for waterfront landowners planning to install shoreline stabilization features, with four intensive consultations for contiguous property owners experiencing severe erosion and who want to employ alternatives to bulk heading.

On September 29, 2007 the RC&D announced the availability of technical advice for shoreline protection in a notice in the Eastern Shore News (Press Release attached on page 80). From that solicitation, the RC&D, worked with the Maryland Eastern Shore RC&D staff and local landowners to develop conceptual designs for their properties. These intensive consultations resulted in the preparation of the six landowner reports that attached in pages 81-109. Appendices that were included with each report are provided only with the first report.

3 /4 -5 Design one soft shoreline demonstration project to be installed on public property which receives high level of visitation.

The final component of the project involved the installation of a "living shoreline" demonstration on a publicly accessible site. The RC&D identified the shoreline in Oyster Harbor as an excellent demonstration area. The Nature Conservancy (TNC) had begun work on the site by removing an old bulkhead. As part of this project, funds were to be assigned to the planning and design phase. During the project period, however, TNC designed and installed the shoreline treatments using other Federal and Foundation grant funds, making the RC&D contribution redundant. Additionally the non-Federal component of the project was used by TNC to match Chesapeake Bay Trust, NFWF, and NOAA funding that TNC obtained for implementation. The

Oyster "Living Shoreline" has been completed and serves as a model for alternative "bioengineered" solutions. Photos of the project are included in pages 115-119.

5. Results

Lessons learned and transferability: Without doubt, there is high interest in treating shoreline erosion with techniques that protect ecological values at the water's edge. Prior to the project, the RC&D hosted two sessions of a shoreline erosion seminar with 102 persons attending. In direct recruitment during the project period, five landowners requested technical assistance to develop design concepts for their shorelines and to implement "living shoreline" techniques where appropriate. An additional 25 landowners on Occohannock Creek participated in the workshop that disseminated the VIMS shoreline options study for their waterfront. Despite the high interest, however, there is a large gap between the concept and implementation. This gap exists for a number of reasons. This project helped bridge some, but not all, of the impediments to construction. Specifically, the project elevated the understanding within the Shore community that more ecological options for shoreline erosion control are available. It also provided sound resource materials that are now freely accessible.

Ongoing obstacles to implementation include the lack of contractors on the Eastern Shore of Virginia that have experience installing "bioengineered" shorelines. With more variables involved in determining the design for any given situation - compared to hardened shoreline techniques, local contractors need to work with consulting designers/engineers and gain a better understanding of the design criteria and site variables. There appears to be more numerous "living shoreline" installations in Maryland where resources have supported this development; and consequently, supporting resources (consultants, contractors, plant nurseries, site guidelines, etc) are more readily available. At the present time the RC&D website is posting a list of Contractors and Plant Suppliers that can assist landowners. This list will be updated and expanded with input from conservation partners who are working with various contractors on shoreline projects. The website also directs landowners to the Maryland RC&D "Shorelines Program" where technical assistance is available for a nominal fee.

Although outreach to the County Wetlands Boards was a project component, more can be done to assist local landowners and decision-makers. One goal should be to increase site visits to the installation of the "living shoreline" at Oyster by The Nature Conservancy, which is the first publicly accessible demonstration site. It is anticipated that additional demonstration sites will also help illustrate what can be achieved in various site situations. Lastly, a locally focused guide should be provided at the planning and zoning offices where landowners first inquire about permits and options. Ideally this publication would include general specifications, regionally encountered variables such as tide ranges and exposure, cost guidelines, where to see demonstration installations, where technical assistance is available, and possible funding assistance through grant and incentive programs.

Dissemination:

A landowner workshop was held on July 31, 2008 to present a draft version of the Occohannock Creek Shoreline Assessment and Management Options Report. Scott Hardaway, the principal author from VIMS, and with Mike Vanlandingham from the Virginia Shoreline Erosion Advisory Service provided the program. There were 25 participants from the community from a mailing of 125 landowners identified by Accomack and Northampton Counties.

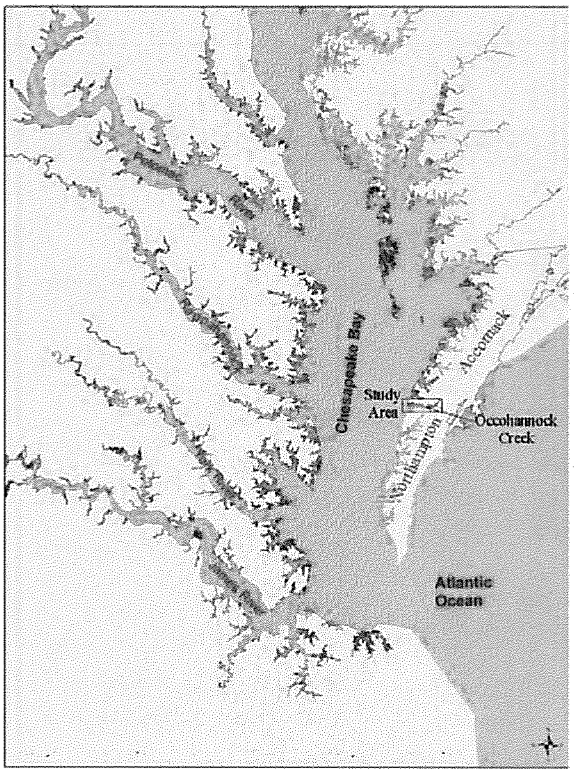
A joint meeting with the Accomack and Northampton County Wetlands Boards was held on June 3, 2008 to present the findings of the Occohannock Creek Report and to discuss the value of the draft report and how to make it more useful to decision-makers as well as the landowners. Scott Hardaway from VIMS and Marian Huber with RC&D facilitated the discussion among attendees.

A lecture program by Scott Hardaway was given on March 5, 2009 to discuss the project. There were an estimated 35 in attendance.

Products from the grant project are included in following pages:

- Contractors, Designers and Plant Suppliers Lists were developed in conjunction with the Maryland Eastern Shore RC&D Living Shoreline Program. This is posted on the www.esrcd.org website, supplied as an attachment to the preliminary shoreline reports prepared for five landowners, and distributed at the landowner workshop on July 31, 2008.
- VIMS *Occohannock Creek Shoreline Erosion Assessment and Living Shoreline Options Report*
- In conjunction with Maryland Eastern Shore RC&D Shore *Preliminary Shoreline Reports* for landowners Mayers, Myers, Weaver, Gemmel and Leaks

The project has fostered ongoing cooperation with the Maryland Eastern Shore RC&D and their shore erosion staff. This staff is now available for site consultation with Virginia landowners for a nominal fee. They will provide site specific preliminary shoreline reports. If interested, landowners can continue to work with this staff through the design, permitting and implementation phases of a shore erosion project.



Location of Occohannock Creek within the Chesapeake Bay estuarine system.

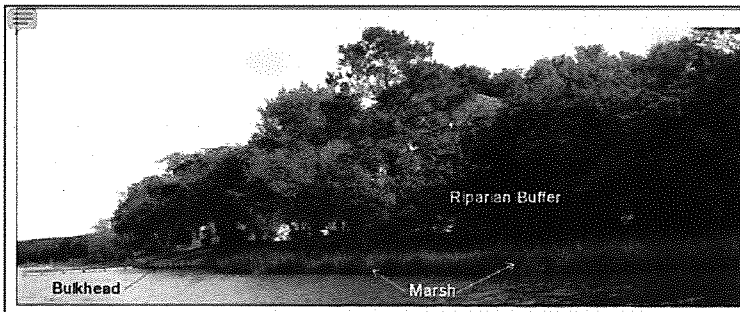
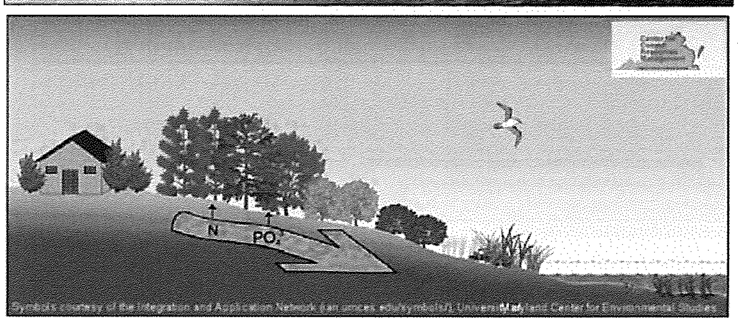


Photo taken along Occohannock Creek depicting aspects of the coastal profile.

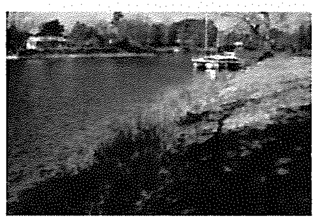


	Upland Landuse	Riparian Landuse	Banks	Intertidal Zone	Subaqueous Lands
(+)	Trees, shrubs, tall grass	Trees, shrubs, tall grass	Vegetated, Stable	Marshes, Phragmites	Seagrass (SAV)
			Partial vegetation	Coastal Sand Dunes	Oyster Reefs
	Agriculture	Residential, Agriculture	Undercut	Riprap, Bulkheads	Aquaculture
(-)	Residential, Commercial	Industrial	Bare, Unstable	Boat ramps	Marinas

An integrated shoreview of a water quality model that shows the relative contribution of different landscape elements to water quality and habitat, from positive (diverse habitat opportunities and improved water quality) to negative (few habitat opportunities and reduced water quality).

Management Strategies

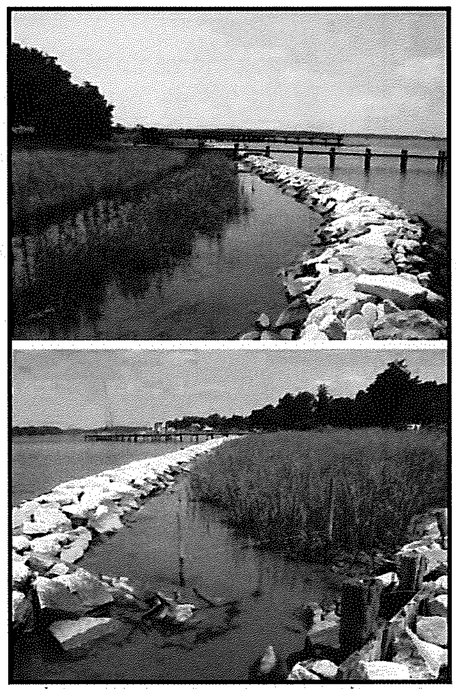
Minor bank grading and temporary toe protection utilizing straw bales was used first then *Spartina alterniflora* was planted to establish a marsh fringe.



At this site, high water impinged upon the base of the bank. Therefore, only the intertidal species (*Spartina alterniflora*) was utilized. This photo shows the site one year after planting.

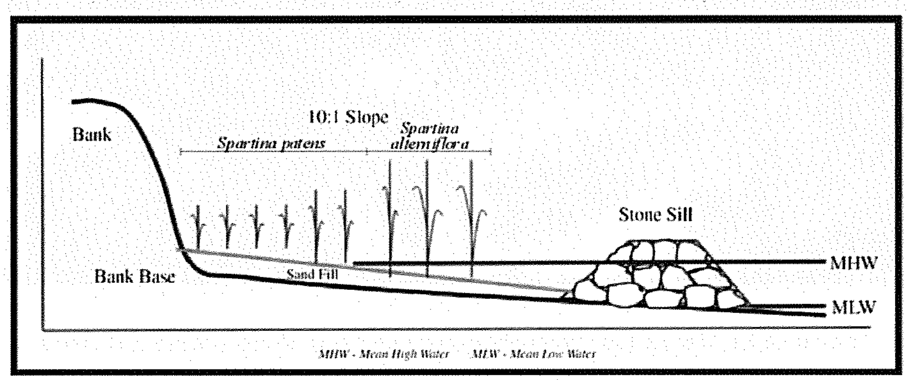
The established marsh fringe and vegetative upland slope are shown here after six years.

Management Strategies



The Poster Child for Successful Marsh Projects. Photos taken at a community marsh in Anne Arundel County.This site received the highest overall marsh ranking and embodies many of the factors deemed essential to a successful project.

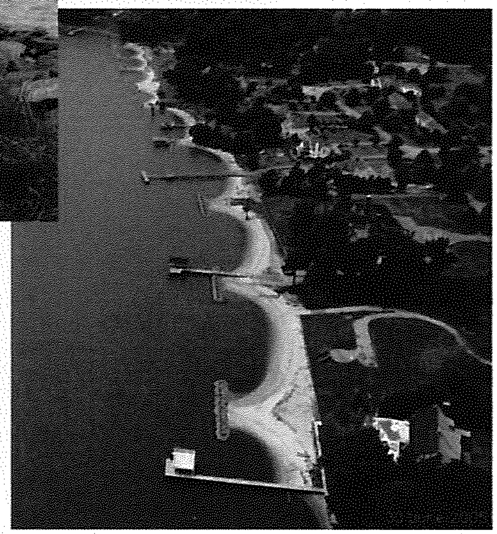
(from Bosch et al., 2006)



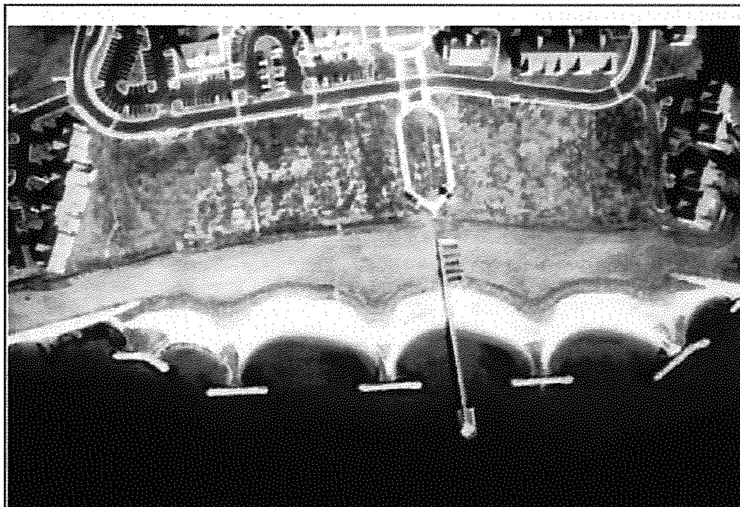
Profile of a typical marsh edge stabilization project used to prevent wetland edge loss.

(from Luscher and Hollingsworth, 2005)

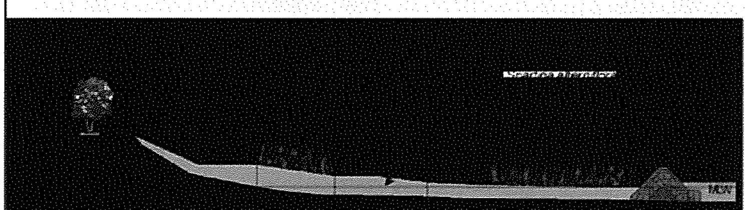
A sill at Webster Field in St. Mary's County, Maryland.



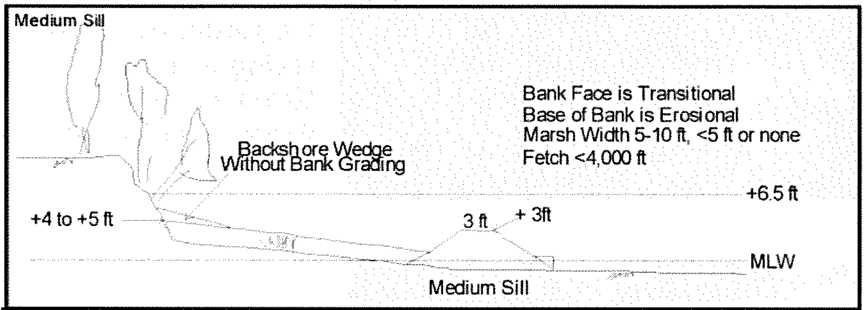
A breakwater system on the James River, Virginia.

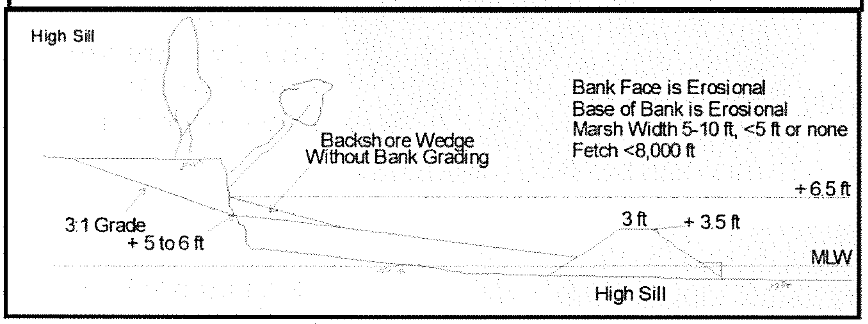


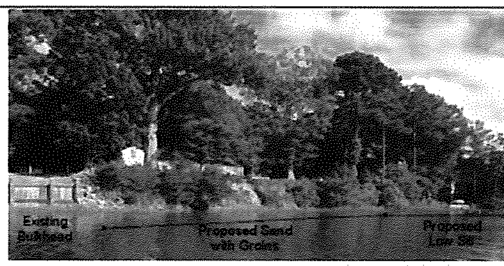
Breakwater system on Patuxent River in Calvert County, MD



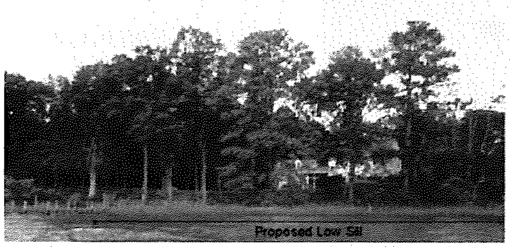
Typical Breakwater Cross-section







On Tawes Creek
facing west to southwest
Erosive bank face
Erosive base of bank
with existing marsh fringe



Pons Point
facing southeast
Transitional bank face
erosive base of bank
with existing marsh fringe

Occohannock Creek
facing southeast
Transitional bank face
transitional base of bank
with existing marsh fringe

Catergory	Type	Number of Structures	Length (miles)	% of Total Shore Length
Recommended	Breakwaters	2	0.34	1.1%
Structures	Marsh Man in small creeks	43	15.57	50.6%
	Low Sill	52	4.29	13.9%
	Medium Sill	11	0.73	2.4%
	High Sill	1	0.04	0.1%
	Sand and Groins	3	0.35	1.1%
	Marsh Man on open creek		7.29	23.7%
		Total	**28.60**	**93.0%**
Marsh Width	>15		3.91	12.7%
	10-15		3.66	11.9%
	5-10		14.52	47.2%
	<5		4.45	14.5%
Base of Bank	Erosional		4.01	13.0%
	Transitional		1.64	5.3%
	Stable		22.39	72.8%
Bank Slope	Erosional		2.57	8.4%
	Transitional		1.59	5.2%
	Stable		24.18	78.6%
Bank Graded	Yes		1.12	3.7%
Trim Trees	Yes		16.42	53.4%

Type	Amount of Rock (Tons/ft)	Estimated Cost ($65-$75/Ton)	Amount of Sand (cubic yards/ft)	Estimated Cost ($25-$35/cy)	Total Estimated Cost ($/linear ft)
Low Bank Low Sill Full Fill	1.7	$110-$127	1	$25-$35	$135-$162 plus plants
High Bank Low Sill Full Fill	1.7	$110-$137	1	$25-$35	$135-$162 plus plants
Medium Sill	2	$130-$150	2	$50-$70	$180-$220 plus plants
High Sill	3	$195-$225	3.8	$95-$133	$290-$358 plus plants

Occohannock Creek Shoreline Erosion Assessment and Living Shorelines Options Report

The following report is available with complete appendices on the Eastern Shore Resource Conservation and Development Council website – www.esrcd.org -
and on the Virginia Institute of Marine Science website – www.vims.edu.

OCCOHANNOCK CREEK
Shoreline Erosion Assessment and Living Shoreline Options Report

Virginia Institute of Marine Science
College of William & Mary
Gloucester Point, Virginia

October 2008

Landowner's Summary

This summary of the "Occohannock Creek Shoreline Erosion Assessment and Living Shoreline Options" report was provided by the Resource Conservation and Development Council to landowners at an informational meeting at the conclusion of the project.

1. Why was this shoreline erosion assessment performed?

Occohannock Creek is one of the most beautiful Creeks on the Eastern Shore Bayside. It is about 6 miles long from the confluence of Chesapeake Bay to its upper reaches, where the Creek narrows to about 100 feet or less. There are 31 miles total miles of shoreline. The northern side of the Creek is largely in Accomack County, while land on the southern side is in Northampton County. Overall, the Creek shoreline is fairly stable and erosion is minor by Bay standards, averaging between 0 and 1 feet per year. Erosion is more likely to occur near the mouth of the Creek and the Bay which has longer fetch exposures and higher wave energy than the eastern or tributary areas.

This study provides information to Occohannock Creek property owners to help them assess their shoreline stability and their options if erosion is a problem. In the past, shoreline erosion control options were typically limited to rip-rap, groins, or bulkheads. These hard structures often destroyed marsh and other habitat and may not have provided the protection desired. Other methods of erosion control now exist that have been used in a variety of conditions and evaluated for their durability and performance. The alternative techniques incorporate vegetation and are referred to as Living Shoreline designs. Conditions on Occohannock Creek make it a very good place to use Living Shoreline techniques to stabilize areas that are losing land or fringe marsh. All segments of Occohannock Creek can achieve some benefit by planting new marsh grasses or enhancing those already present to improve habitat, trap sediment, and reduce the erosive force of waves.

The specific design varies depending on the level of wave energy, which is usually a function of fetch (distance to nearest shore) and size of boat wakes. Shorelines in low energy environments may be stabilized entirely with vegetation, while increasing levels of wave energy require additional structural protection. Hybrid designs incorporate low stone structures called sills to protect the exposed edge of a marsh and may require sand fill and planting of additional marsh. In higher energy areas, offshore stone breakwaters constructed in segments can help retain fill sand or trap sand already moving along the shore.

In May of 2005, the Eastern Shore Resource Conservation and Development (RC&D) Council conducted two informational sessions on Living Shorelines. They were well attended and generated a lot of interest. Because there are a limited number of companies with experience designing Living Shorelines, RC&D contracted with Virginia Institute of Marine Science to perform a study and develop a report with conceptual design recommendations for sixteen segments of Occohannock Creek. Occohannock Creek was chosen for this demonstration shoreline assessment because increasing productive marsh and reducing shoreline erosion here will benefit the environment and the residents of both counties.

is probably active erosion. If there is no undercutting at the base of the bank, and the bank face is fully vegetated, then both are likely stable. These two extremes are readily identified. It is intermediate or transitional cases that are harder to determine. Generally, along the main stem of Occohannock Creek, the wider the marsh/beach fringe, the more stable the upland bank. Narrow (<5 ft) marshes or beaches have less ability to absorb wave energy than wide (>15 ft) marshes or beaches. Some action to manage the shoreline is recommended where the banks are actively eroding and the marsh or beach fringes are narrow.

3. Shorezone Management Considerations

Wherever it is possible to preserve a continuous connection between the vegetation of the upland, the marshes, and the aquatic vegetation, high quality ecosystem can be maintained which benefits the fish, crabs, and wildlife that make waterfront living desirable. Occohannock Creek has a high percentage of natural or unhardened shoreline. Along most of its shoreline, Occohannock Creek has little or no erosion and no action is needed. Most of the areas with serious erosion have already been riprapped or bulkheaded. A number of landowners have taken steps to maintain their marsh and understand the importance of controlling overland flow and trees at the edge of unstable banks. A large scale Living Shoreline project has even been created on the Creek.

Trees grow along much of the shoreline, above the elevation of tidal wetlands. Some parcels have woodlands or riparian forests. Trees and shrubs act as riparian buffers to trap and filter sediments, nutrients, and chemicals from surface runoff and shallow groundwater. Their roots can stabilize a Creek bank and microbes in organic forest soils convert nitrate, especially from agricultural land, into nitrogen gas through denitrification. However, tree roots exposed by an eroding bank can accelerate land loss if the tree falls and takes part of the bank with it. Trees that shade marsh grasses can kill them.

Managing trees and shoreline vegetation to stabilize an exposed and eroding bank face may require trimming, removal, or other measures to obtain a grade slope that will be more stable. Tree work, bank grading, and planting with the appropriate vegetation is best done with assistance from experts who can plan, permit and/or perform the job. To find out what permits are required, check with local planning departments and wetlands boards.

4. Shoreline Management Measures

The first thing a landowner should do before taking any action is to observe what is happening to their shoreline and their neighbors' shoreline. If possible, take measurements and photographs spanning the season when storms are more likely to occur. Note the type, location and density of vegetation, its orientation to the sun, and particularly the hours of sunlight reaching marsh grasses. Observations at low and high tide, from the shore or from a boat offshore, can be helpful. Look at historic photographs of your property, available in this report. This information will be helpful in understanding the shoreline process on a specific property, deciding if you have a problem that requires action, and working with consultants or contractors if erosion must be addressed. If a shoreline needs stabilization, consider how to incorporate the principles of Living Shoreline design into the project.

The shoreline specific management recommendations for Occohannock Creek are shown on a series of maps in Plates 1 through 16, Appendix C of this report. Generally, only structural recommendations are shown. Where no recommendation is shown and no structure presently exists, it is understood that the recommendation is Marsh/Buffer Management.

The sill systems recommended for Occohannock Creek varied in size depending on the level of protection desired and the height of the upland bank. Based on a wave climate assessment, the level of the 2 year, 10 year and 50 year storm surges are 4.2 feet, 6.5 feet and 8.5 feet, respectively. This becomes an issue on the more exposed sections of Occohannock Creek when fetch exposures exceed 2,000 feet. For Occohannock Creek, the design level of protection should be at least the 10 year water level which is about +6.5 feet MLW.

Here are more specific guidelines for applying Living Shoreline techniques along Occohannock Creek. Maintenance is always required. Marsh grasses and even sand may need to be replaced after storm events.

- **Marsh Management**: Appropriate in very fetch limited creeks (F=<1,000 feet) but may work in more open shores where the existing marsh fringe is narrow or absent and the base of bank is exposed. Considerations: Watch year to year as the erosion rate may be minimal; trim overhanging tree limbs; and plant bare areas of existing intertidal substrate, usually *Spartina alterniflora.*

- **Add sand with structures**: As fetch exposures increase beyond about 1,000 feet, the intertidal marsh width may not be sufficient to attenuate wave action. In these cases, the addition of sand can increase the intertidal substrate as well as the backshore region. The simple addition of sand is usually not enough and a sand retaining structure such as short groins or a low sill will be required. Any addition of fill, sand or rock beyond mean high water will require a permit.

- **Stone sills**: The general cross-section (Figure 5) shows the sand for the wetlands substrate is on about a 10:1 slope from the base of the bank to the back of the sill. The elevation of the intersection of the fill at the bank and the sill will determine, in part, the dimensions of the sill system. The size of the sill systems recommended are related to what is threatened, residential vs agricultural or wooded.

- **Breakwater System**: Although single breakwaters can be used, two or more are recommended to address several hundred feet of coast. Breakwaters can also have varying levels of protection where increased dimensions generally correspond to increased increased fetch exposure and where a beach/dune shoreline is desired.

Four typical cross-sections are shown in Figure 16. The condition of the bank, fetch, and landuse were used to assign a sill size to a given reach. With both high and low banks in Occohannock Creek, three sill systems are given for the higher banks and one typical cross-section is depicted for the low bank situation. High banks offer a "backstop" to the sand

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Appendix A. Existing Shore Conditions Maps
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Cover Photo: Occohannock Creek shoreline, 2 October 2007 by Shoreline Studies Program, VIMS

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Table 9. Approximate costs of each structure type per linear foot of shoreline. These numbers generally are valid in 2008. Later time frames will need updated costs 28

Bosch *et al.* (2006) ranked the marshes as very successful, successful, moderately successful, or unsuccessful according to three factors: vegetation, wildlife, and erosion. Of the 80 sites visited, 14 sites, or 18%, received an unsuccessful ranking. Twenty one marshes (26%) a moderately successful ranking. Thirty one sites (38%) earned a successful rating. Finally, 14 projects (18%) scored a rating of very successful.

After the sites were ranked, the sites were evaluated in relation to their fetch and the presence of sills. The only relationship observed for overall marsh ranking was only marginally significant reduction of rank with increasing longest shore fetch for sites with sills. Because no significant relationships were observed for wildlife or erosion rankings, the pattern observed for marsh rank is likely due to the decrease in vegetation rank with increasing fetch for sites with sills. However, there is considerable variation in rank, with sites with low and high fetch having both low and high rankings, independently of the presence or absence of sills (Bosch *et al.*, 2006).

In order to determine the marshes general characteristics, Bosch *et al.* (2006) evaluated the site rankings for low or high ranked projects. Low-ranked sites tended to have little or no vegetation, were poorly constructed or designed, or were built directly adjacent to eroding cliffs. High-ranked sites tended to have established marsh vegetation and preventing erosion. High-ranked sites tended to be wider and longer than lower-ranked sites. The study did not find that fetch vs. sills were a strong determinant of whether a site was ranked as high or low.

More specifically, low-ranked sites tended to have low vegetation cover (<30%) while high-ranked sites had high cover (>70%). Additionally, low-ranked sites tended to have only high or low marsh, but not both, while high-ranked sites generally had an equitable distribution of high and low marsh. Hurricane Isabel negatively impacted some of the low-ranked sites. High-ranked sites also tended to have higher plant diversity, but some of these had bare patches, Phragmites australis, or experienced herbivory of plantings (Bosch *et al.*, 2006).

Low-ranked sites had low numbers of organisms observed or collected in dip nets, and either had no access for wildlife or little or no wildlife habitat. Highly-ranked sites, on the other hand, generally supported abundant and diverse wildlife based on observation or dip-netting. However, some of these sites provided good terrestrial or aquatic habitat, but not both. Organisms observed or reported included waterfowl, fish, crabs, snakes, turtles, snails, frogs, fish, and miscellaneous aquatic invertebrates. Clearly these observations show that constructed wetland sites can provide valuable habitat for aquatic and terrestrial organisms (Bosch *et al.*, 2006).

Lower ranked sites tended to exhibit erosion or clearly offered little protection from erosion, particularly due to a lack of established vegetation. Highly-ranked sites appeared to be stable or accreting sediment from incoming waves (*i.e.* not from an adjacent eroding cliff, as was observed in some cases). Vegetation again appeared to be important in reducing or stabilizing against erosion (Bosch *et al.*, 2006).

- *Independently stabilized cliff.* In properties with high cliffs, the marsh will not prevent the top of the cliff from eroding due to run off. This erosion may ultimately bury the marsh with eroded sediments. The cliff should be stabilized with either a re-grading and upland plant stabilization or a structural solution such as a retaining wall or ground mesh to hold back erosion. With the cliff stabilized, the marsh can then be used to prevent undercutting at the base of the cliff.
- *Proper grading and sill placement.* When the site is not properly graded and the sill is placed too close to the shore, there is danger of "sillvetment" formation, where the sill becomes a revetment as the marsh and sediment builds up behind the rock wall. Additionally, the low marsh should extend to the lowest tide line. If the sill is placed too close to the mean high water line, then the marsh will trap sediment without flushing, and will ultimately accrete to the point where the marsh doesn't flood during high tide and the low marsh does not get enough water. Then, the sill turns into a revetment and the marsh turns into an upland/high marsh region. If possible, the sill should be placed about one meter from plantings.
- *Proper maintenance.* As with any shoreline erosion control project, a certain amount of maintenance is necessary to keep the project working effectively and to sustain it in the long term. Three main things need to be done for marsh projects: keep the marsh clear of debris; refrain from the use of chemical lawn treatments; and keep marsh free of unwanted, alien plant and animal invaders. Dead vegetation from the year before can accumulate in such density that it buries new growth and can kill off marsh grasses. This problem is especially pressing in *Spartina patens* high marshes. It is important to ensure that new plant growth is not choked off by last year's die-off or any debris that washes onto the shore. Chemical lawn treatments can kill *Spartina alterniflora.* Even neighboring use can be damaging to the marsh plants. It is very important to refrain from using chemical lawn treatments that can run off into the marsh. It is important to note that chemical treatments can and should be used on individual undesirable plants, such as Phragmites australis. It is very important to keep the marsh free of unwanted alien invaders-both flora and fauna. *Polygonum perfaliatum* (mile-a-minute weed), *Cuscuta gronovii* (dodder), and *Phragmites australis* can take over man-made marshes and render them inhospitable to desired plants and wildlife. It is important to make sure that the marsh is kept free of these invasive flora; for example, by using specific applications (use hypodermic to prevent poisoning of *Spartina*) of Roundup® or Rodeo® to kill *Phragmites australis.* Unwanted fauna such as Mute swans or Canada geese can be kept from the marsh with the use of geese fencing. This is especially important while grasses are young and have not taken root.

Based on their research, Bosch *et al.* (2006) portrayed the traits consistent with healthy marsh creation projects on the Chesapeake Bay many of which are embodied in the sill shown in Figure 2. A severely eroding cliff bank is independently stabilized. The marsh plants are planted in a 50/50 *Spartina patens* to *Spartina alterniflora* ratio corresponding to a 50/50 split between high and low marsh. The marsh is free of shade and gets mostly full sun. It is planted in proper filling with a 10:1 gradient. Mean high water line falls between the high and low marsh plantings. A three foot space between the low marsh and the sill will break wave action but not trap all sediment, prevent wildlife access or proper flushing.

allow marine fauna ingress and egress, the local wave climate also comes in as well. The result was twofold: 1) during storms, the waves could impact the upland bank which the sill was designed to protect, and 2) the waves would create a "beach" berm around the perimeter of the opening thereby closing the marsh fringe off and reducing access to the adjacent marsh. In fact, sill openings will create small pocket beaches which are important estuarine habitat themselves. These factors have been addressed by numerous creative opening designs including varying the opening or gap, offset on side to the other, turning the sills offshore to create small spurs, using cobble instead of sand in adjacent to the openings, and others. The effectiveness of each window design type was analyzed.

The sill site has evolved over the past five years to a be a viable system for shore protection and habitat creation (Hardaway *et al.*, 2007). Variations in landscape due to increases and decreases in elevation only serve to diversify site vegetation communities. The site has been impacted by several high water events that significantly exceeded the design elevations. This has caused only minor bank scarping, mostly within some of the window areas with no evidence of bank failure. Overall, the 2002 sill installation has performed well as a shore protection system, enduring Hurricane Isabel (September 2003) and Tropical Storm Ernesto (September 2006) with minimal base of bank scarping. Although the water levels were well up on the upland bank during these storms, only modest wave action impacted it due to relatively short fetch distances and sheltering from the main storm winds

The type of window with a backshore revetment, appears to be the best of the gap types installed at St. Mary's in terms of maintaining tidal flow across and adjacent to the opening and providing for protection of the bank in the midbay region (Figure 3). The inclusion of cobble and gravel enhanced shore protection and allowed much less berming around the bay perimeter than those windows with the standard sand fill requirement (Hardaway *et al.*, 2007).

The flushing model (Unstructured, Tidal, Residual Intertidal, and Mudflat model (UnTRIM)) for these types of systems showed that more windows allow for better flushing if there is no interchange through the sills. The seepage model allows for significant exchange between the river and silled marsh. The reality is that water moves through the rock void and that the porosity of the rock is as important, if not more important, than the window opening. Oversized stone may even be preferred (Hardaway *et al.*, 2007).

The ecological services provided by a stone sill system is significant, especially from a fisheries perspective. Access to the fringe marsh behind the sill (Figure 4) occurs through three pathways: 1) the sill windows, 2) macro-pores in the sill, and 3) overtopping by tidal waters. Results indicate that marsh minnows reside within the filled pore spaces of the St. Mary's sill during low water and move with rising water into the intertidal marsh region. Aggregating within the sill structure during low water conditions may serve as a behavioral adaptation to minimize predation risk. Having some part of the sill below mean low water may be an important design component for sills (Hardaway *et al.*, 2007).

coastal landscape. Natural landuse helps stabilize the bank reducing erosion and sediment introduction into the waterway and provides native or unaltered habitat for terrestrial and avian species and generally has a high diversity whereas agricultural land has reduced availability of suitable habitat for a wide variety of creatures. Developed landuse may result in reduced available habitat and increased human disturbance.

In the intertidal zone, beaches interact with dunes and serve as habitat of animals and plants living on or in the sand (Figure 6). Dunes themselves are a transitional area between marine and terrestrial habitats providing essential habitat and are protective barriers from flooding and erosion resulting in decreased sediment and nutrient input. Marshes provide habitat for both aquatic and terrestrial animals and reduce erosion by intercepting run-off, filtering groundwater, and holding sediment in place. Bulkheads, boat ramps may stabilize the shore reducing sediment input, but they have an adverse impact on habitat because they displace native environments and interrupt the marine-terrestrial interface (CCRM, 2007).

In the subaqueous zone, submerged aquatic vegetation (SAV) and oyster reefs are becoming increasingly rare in Chesapeake Bay and the surrounding watersheds (Figure 6). They are important components of the coastal ecosystem for a wide variety of estuarine species (CCRM, 2007). They also have limited capabilities to dampen waves and stabilize nearhsore sediments and may help reduce excess nutrients. Breakwaters, sills, and jetties provide attachment surfaces for aquatic animals, but they are not native habitats since they cover the existing bottom. They also stabilize the shoreline reducing sediment input. Marinas have an adverse impact on habitat because they cover subaqueous bottom and increase shading and introduce pollutants associated with boating.

1.4 Shoreline Management Strategies

In developing the Living Shoreline options for effective shoreline management, the following objectives have been given consideration:

- Prevention of loss of land and protection of upland improvements.
- Protection, maintenance, enhancement, and/or creation of wetlands habitat both vegetated and non-vegetated.
- Management of upland runoff and groundwater flow through the maintenance of riparian and vegetated wetland fringes.
- For a proposed shoreline strategy, address potential secondary impacts within the reach which may include impacts to downdrift shores through a reduction in the sand supply or the encroachment of structures onto subaqueous land and wetlands.
- Providing access to and/or creation of recreational opportunities such as beach areas.
- Align costs with goals.

These objectives must be assessed in the context of a shoreline reach. While all objectives should be considered, they will not carry equal weight. In fact, satisfaction of all objectives for any given reach is not likely as some may be mutually exclusive.

2 Methods and Plan Development

2.1 Shoreline Condition Survey

2.1.1 Introduction

The Comprehensive Coastal Inventory Program (CCI) has developed a set of protocols for describing shoreline conditions along Virginia's tidal shoreline. The assessment approach uses state of the art Global Positioning Systems (GPS), and Geographic Information Systems (GIS) to collect, analyze, and display shoreline conditions. These protocols and techniques have been developed over several years, incorporating suggestions and data needs conveyed by state agency and local government professionals (Berman and Hershner, 1999).

Three separate activities embody the development of a Shoreline Inventory: data collection, data processing and analysis, and map generation. Data collection follows a three tiered shoreline assessment approach described below. Data are portrayed on maps in Appendix A.

2.1.2 Three Tiered Shoreline Assessment

The data inventory developed for the Shoreline Inventory is based on a three-tiered shoreline assessment approach. This assessment characterizes conditions in the shorezone, which extends from a narrow portion of the riparian zone seaward to the shoreline. This assessment approach was developed to use observations that could be made from a moving boat. To that end, the survey is a collection of descriptive measurements that characterize conditions. GPS units log location of conditions observed from a boat. No other field measurements are performed.

The three tiered shoreline assessment approach divides the shorezone into three regions: 1) the immediate riparian zone, evaluated for land use; 2) the bank, evaluated for height, stability, cover, and natural protection; and 3) the shoreline, describing the presence of shoreline structures for shore protection and recreational purposes. Each tier is described in detail below.

Riparian Land Use: Land use adjacent to the bank is classified into one of ten categories (Table 1). The categories provide a simple assessment of land use, and give rise to land management practices that can be anticipated. GPS is used to measure the linear extent along shore where the practice is observed. The width of this zone is not measured. Riparian forest buffers are considered the primary land use if the buffer width equals or exceeds 30 feet. This width is calculated from digital imagery as part of the quality control in data processing.

Table 3. Tier 3 - Shoreline Features.

Feature	Feature Type	Comments
Control Structures		
riprap	L	
bulkhead	L	
breakwaters	L	first and last of a series is surveyed
groinfield	L	first and last of a series is surveyed
jetty	P	
debris	L	can include tires, rubble, tubes, etc.
unconventional	L	composed of non-traditional materials
marsh toe revetment	L	placed in front of an eroding marsh
Recreational Structures		
pier/wharf	P	includes private and public
boat ramp	P	distinguishes private vs. public landings
boat house	P	all covered structures, assumes a pier
marina	L	includes piers, bulkheads, wharfs

2.1.3 Data Collection/Survey Techniques

Data collection was performed in June 2007 from a small, shoal draft vessel, navigating at slow speeds parallel to the shoreline. To the extent possible, surveys take place on a rising tide, allowing the boat to be as close to shore as possible. Data is logged using the handheld Trimble GeoExplorer III, GeoExplorer XT, or GeoExplorer XH GPS unit. GeoExplorers are accurate to within 4 inches of true position with extended observations and differential correction. Without post processing, these units can achieve accuracies around 3 ft (1 meter). Both static and kinematic data collection is performed. Kinematic data collection is a collection technique where data is collected continuously along a pathway (in this case along the waterway). GPS units are programmed to collect information at a rate sufficient to compute a position anywhere along the course. The shoreline data is collected at a rate of one observation every five seconds. Land use, bank condition, and linear shoreline structures are collected using this technique.

Static surveys pin-point fixed locations that occur at very short intervals. The boat actually stops to collect these data, and the boat operator must hold the boat against tidal current, and surface wind waves. Static surveys log 6 GPS observations at a rate of one observation per second at the fixed station. The GPS receiver uses an averaging technique to compute one position based on the 6 static observations. Static surveys are used to position point features like piers, boat ramps, and boathouses.

2.2 General Wave Climate Analysis

The wave climate is the overall wave energy that impacts the project shoreline averaged through time. The wave climate along any given shoreline is a function of fetch and nearshore bathymetry. Fetch is defined as the distance over water that wind can blow and generate waves and was determined for 22 fetch locations. The individual reach locations are shown in Figure 11. The 2002 image mosaic from Virginia Base Mapping Program and its corresponding shoreline were used to determine the starting point of each fetch location, while a bay wide shoreline from NOAA and a 30 meter bathymetric DEM from NOAA were used to establish the end shoreline locations.

The shoreline and fetch centerline shapefiles and the DEM information were input to an AML program running in ArcInfo Workstation which produced two sets of 6 additional vectors for each fetch location. The additional vector lines were spaced at 6 degree intervals on either side of the original centerline, starting at the same point as the corresponding centerlines and extending to the opposite shoreline. At each of the 22 sites, the NOAA bathymetric DEM was used to compute the average depth along the resulting 15 vector lines. The average depth and distance to the opposite shore were exported into a separate dbf table for each of the 22 locations. The average depth of the entire fetch window was calculated as well. Each section of Occohannock Creek's shoreline has varying fetches which are shown in Table 4. Generally, fetches decrease up the creek.

While wave climate is fetch limited, select storm wave conditions can be portrayed along each subreach using the wind/ wave growth program developed as part of the ACES (Veritech, Inc., 2008) modeling package. ACES predicts wave height and period based on input fetch and wind conditions. Three storm scenarios were modeled: 1) a two year event with 25 mph sustained winds and a 4.2 ft MLW surge, 2) a ten year event with 35 mph sustained winds and a 6.5 ft MLW surge, and 3) a 50 year event with a 55 mph sustained wind and an 8.2 ft MLW surge. The wind direction was assumed to come from the direction of the longest fetch. Surge levels were added onto the average depth of the fetch window.

Data from Norfolk International Airport, summarized for the time period 1960-1990 in Table 5, show the long-term wind frequencies. The north component is dominant followed by the south, southwest, and northeast while the west and northwest components are minor. Westerly winds can generate storm waves that travel through the mouth of the creek. However, shoaling on the sand shoals will greatly reduce Bay-generated waves. The other parts of the Creek have only local winds generated due to limited fetches and relatively shallow depths.

2.3 Shoreline Change Assessment

Historical aerial imagery was digitized in order to portray shoreline evolution since 1938 to the present. Understanding the long-term shoreline change is critical to assessing shoreline reaches in Chesapeake Bay. The method for this assessment involves digitizing historic shorelines into a database. Available aerial photos were orthorectified and the shoreline digitized. The years included 1904 (map), 1938, 1949, 1953, 1979, 1994, 2002, and 2006. The 1994 imagery was already processed and mosaicked by the United States Geological Survey, while the 2002 imagery was processed and mosaicked by the Virginia Base Mapping Program. The aerials for the remaining flight lines were processed and mosaicked by the VIMS Shoreline Study Program.

The images were scanned as tiffs at 600 dpi and converted to ERDAS IMAGINE (.img) format. They were orthorectified to a reference mosaic, the 1994 Digital Orthophoto Quarter Quadrangles (DOQQ) from USGS. The original DOQQs were in MrSid format but were converted into .img format as well. ERDAS Orthobase image processing software was used to orthographically correct the individual flightlines using a bundle block solution. Camera lens calibration data was matched to the image location of fiducial points to define the interior camera model. Control points from 1994 USGS DOQQ images provide the exterior control, which is enhanced by a large number of image-matching tie points produced automatically by the software. A minimum of four ground control points are used per image, allowing two points per overlap area. The exterior and interior models were combined with a 30-meter resolution digital elevation model (DEM) from the USGS National Elevation Dataset (NED) to produce an orthophoto for each aerial photograph. The orthophotographs that cover each USGS 7.5 minute quadrangle area were adjusted to approximately uniform brightness and contrast and were mosaicked together using the ERDAS Imagine mosaic tool to produce a one-meter resolution mosaic also in an .img format.

To maintain an accurate match with the reference images, it was necessary to distribute the control points evenly. This can be challenging in areas with little development. Good examples of control points are permanent features such as manmade features such as corners of buildings or road intersections and stable natural landmarks such as easily recognized isolated trees. The maximum root mean square (RMS) error allowed is 3 for each block.

Once the aerial photos were orthorectified and mosaicked, the shorelines were digitized in ArcMap with the mosaics in the background to help delineate and locate the shoreline. The edge of marshes and the toe of the narrow beaches are documented along the creek. These features generally can indicate the MLW position but can be very difficult to see due to tree cover. This was particularly the case in the smaller creeks. Tree cover and photo quality combine to make this very difficult in terms of characterizing the shore. The final format the shorelines are in shapefile format. One shapefile was produced for each year that was mosaicked. In areas where the shoreline was not clearly delineated on the aerial photography, the location was estimated based on the experience of the digitizer.

SAV - VIMS, Submerged Aquatic Vegetation Program

The 2006 Chesapeake Bay SAV Coverage was mapped from 1:24,000 black and white aerial photography. Each area of SAV was interpreted on-screen from the rectified photography and classified into one of four density classes by the percentage of cover. The final 2006 SAV beds are stored as ArcInfo GIS coverages. http://www.vims.edu/bio/sav/

2.5 Shoreline Strategy Development

Living Shoreline strategies were recommended for each section of eroding coast. The initial recommendation was done by boat in October and December 2007 using similar procedures to the shoreline condition survey. A handheld GPS unit, the GeoExplorer XH, was used to store the recommended structures in the field. The data were downloaded, processed as raw data and in GIS to create the management recommendations. Once the data were compiled and evaluated, adjustments to the recommendations were made based on other collected data.

The Occohannock Creek watershed drains westward from head waters to Chesapeake Bay. The underlying geology is upper Pleistocene Formations including Kent and Nassawaddox (Figure 12). At the contact between these two formations, a scarp exists. Here the land drops from about +25 feet to about +10 feet going from east to west. This is reflected in the upland or fastland bank heights along the creek's shoreline

The shorelines along Occohannock Creek are a variety of low to medium height fastland banks between 5 to 25 feet high with intermittent marsh fringes and sandy backshores. The landuse of these upland areas include forested, agricultural and residential properties with one marina and one public landing. The key parameters measured during the field assessment include marsh/beach width, condition of the base of the bank, and condition of the bank face. The condition of the front edge of marsh also was assessed but not included in the final analysis.

The fringing marsh/beach along Occohannock Creek has varying histories as to how they were formed and influenced by littoral processes. It suffices to say that narrow marsh/beach features (<5 ft) will have less wave attenuation capabilities that wide marsh/beach features (>15 ft). We have included intermediate categories as well, 5-10 ft and 10-15 ft. The state of the upland bank on the land side of the marsh/beach fringe is determined largely by the marsh/beach width along with the site's orientation, fetch, and hydrodynamic elements.

The upland banks have two components that were assessed, the base of bank (BOB) and the bank face. The stability of the BOB is usually the first indicator of shore erosion. The bank face is the second. Vertically exposed bank face and exposed BOB are signs of active erosion. A stable bank face and BOB are indicated by no undercutting at BOB and a fully vegetated bank face. These two extremes are readily identified but the intermediate or transitional cases are a bit more subjective (Figure 13).

Generally, along the main stem of Occohannock Creek, the wider the marsh/beach fringe, the more stable the upland bank. The narrower marsh/beach fringes tend to occur in front of erosional banks and are usually the shore reaches where a proactive management strategy is recommended.

3.2 General Wave Climate Analysis

The results of the wave climate analysis are shown in Table 6. As expected the reaches, facing out of the mouth of the creek have larger potential wave energies impacting the shore due to exposure from waves from Chesapeake Bay (N1, S1, N3). All other shore reaches have average fetch exposures less than 5,000 ft except N8 which has an 11,000 ft effective fetch. Reach N8 is about 14,000 ft from the mouth of Occohannock Creek, but it is oriented such that it has a long fetch to the west. This results in a potential increase in wind/wave energy. Basically, the less the fetch exposure, the less the wave energy potential. Conversely, the higher the water levels, the higher the wave energy potential. Shore reaches up the smaller creeks were not assessed. This analysis is meant to provide landowners with the potential wave energies relative to the frequency of storm events so that shoreline management strategies and the level of protection they afford can be assessed.

along the main stem of the Creek are shown in Appendix B. The average rate of change for most of Occohannock Creek is between 0 and -1 feet per year.

3.4 Assessment of Existing Marine Resources

Figures 14 and 15 show the existing marine resource databases available for Occohannock Creek. Areas of SAV as well public oyster grounds and private oyster leases are shown. In addition, the risk levels associated with oyster aquaculture in the Creek are also shown. In Figure15, the risks associated with clam aquaculture are shown.

3.5 Living Shoreline Strategies and Recommendations

In order to apply management strategies to the Occohannock Creek shorelines, it was necessary to establish some assumptions and boundaries regarding the cause and severity of erosion, what is threatened, and level of protection that will be provided. Generally, the shorelines along the main trunk of the creek were the focus of the plan because of greater fetch exposures and measurable historic shore change. As one proceeds into the small creeks, the erosion is much less. Shorelines up these smaller sub-watersheds might have an exposed base of bank, but the erosion is more a perception than land loss. Nevertheless, perception can move a property owner to action. The recommendations are offered accordingly although many situations might not seem to warrant protection in that the erosion is not really severe. However, it is impossible to anticipate what present day and/or future waterfront property landowners might desire.

3.5.1 Strategies

Do-Nothing:

The do-nothing option should be considered first. Many areas of the Occohannock Creek watershed have no erosion problems. Even areas with minimal erosion, the scale is so small that doing nothing may not significantly affect the stability of the shoreline.

Marsh/Buffer Management:

This requires the landowner to maintain and enhance an existing marsh fringe by planting more plants, removing smothering wrack material and/or providing adequate sunlight. The latter can be done by prudent limbing of trees and NOT the whole sale stripping of the riparian buffer and grading the bank. Marsh management applies to all the Occohannock Creek shorelines but particularly up the smaller creeks where wave forces are small. In these regions, marsh maintenance can be very effective. Generally, no permits are required as long as no fill is going into wetlands or onto state-owned bottom.

If the property has a stable bank and bank face, it is usually because of an existing marsh fringe that is wide enough to offer shore protection. However, many of the marsh fringes along the main stem of Occohannock Creek are themselves erosional and may with time be reduced in width and gradually (or suddenly) be rendered ineffective for shore the same approach except the "back stop" effect is limited to the height of the bank. Bank grading is recommended where needed, usually with the high sill since it generally has a greater fetch exposure. Examples of the types of shoreline where recommendations are shown in Figures 17 and 18.

Bank condition indicators for sills include in descending order where #1 is most severe:
1. Eroding Base of Bank, Eroding Bank Face
2. Eroding Base of Bank, Transition Bank Face
3. Eroding Base of Bank, Stable Bank Face
4. Transitional Base of Bank, Transitional Bank Face
5. Transitional Base of Bank, Stable Bank Face

Landuse condition indicators for sills include in descending order:
1. Residential
2. Lawn
3. Agricultural land
4. Woodland

As shown in Table 7, the low sill option was most recommended sill type around Occohannock Creek, with 52 segments. At these sites, an existing but narrow fringe marsh usually existed, but it needed some level of enhancement. The upland was generally either agricultural or wooded. Residential properties in lower energy realms and or low banks also qualified for low sill systems.

Eleven medium sill systems were recommended some of which were intermittently included within a low sill system or addressed high eroding banks. Only one high sill system was recommended between low sills at structure #25 where there was a high eroding bank on residential property. Individual shore segment management recommendations are shown in Table 8. Table 9 includes the breakdown of costs associated with building the various types of structures recommended in this report. These numbers include unit costs and per linear feet of shoreline costs. These numbers were calculated in 2008. Costs will vary in later time frames and may need to be updated. They do provide a ballpark number on which homeowners may make decisions regarding a system's cost.

Two breakwater systems are recommended. One along an eroding upland bank with an existing groin field and another along the west coast of Morley's Wharf. A typical breakwater system for this type of coastal setting is shown in Figure 18 with 60 foot breakwater units, 60 feet offshore with 60 foot gaps.

Three sand with groin segments were recommended, one up Shields Cove with a narrow intertidal width that needs enhancement.

Table 8. Individual shoreline recommendations for Occohannock Creek.

Structure Number	Structure Type	Bank Slope	Bank of Base	Marsh Width	Bank Grading	Erosion Categories
1	Low Sill	Stable	Erosional	<5	No	0 to -1
2	Low Sill	Stable	Erosional	<5	No	0 to -1
3	Low Sill	Erosional	Erosional	<5	No	Not Calculated
4	Low Sill	Stable	Transitional	5-10	No	Not Calculated
5	Low Sill	Transitional	Transitional	<5	No	Not Calculated
6A	Sand and	Erosional	Erosional	<5	No	0 to -1
6B	Low Sill	Erosional	Erosional	<5	No	-1 to -3
6B	Low Sill	Erosional	Erosional	5-10	No	0 to -1
6B	Low Sill	Transitional	Transitional	<5	No	0 to -1
7	Low Sill	Stable	Erosional	<5	No	0 to -1
8	Low Sill	Erosional	Erosional	5-10	No	0 to -1
9A	Low Sill	Erosional	Erosional	5-10	Yes	0 to -1
9B	Medium Sill	Erosional	Erosional	5-10	Yes	0 to -1
9C	Low Sill	Erosional	Erosional	5-10	Yes	0 to -1
9D	Medium Sill	Erosional	Erosional	5-10	Yes	0 to -1
9E	Low Sill	Erosional	Erosional	5-10	Yes	0 to -1
10	Low Sill	Transitional	Erosional	5-10	No	0 to -1
11	Low Sill	Transitional to Erosional	Transitional to Erosional	5-10	No	0 to -1
12	Low Sill	Transitional	Transitional	5-10	No	0 to -1
13	Low Sill	Transitional	Transitional	5-10	No	0 to -1
14	Low Sill	Erosional	Erosional	<5	No	0 to -1
15	Medium Sill	Erosional	Erosional	<5	Yes	0 to -1
16	Low Sill	Transitional	Transitional	5-10	No	0 to -1
17	Breakwater	Erosional	Erosional	<5	Yes	0 to -1
18	Low Sill	Transitional	Transitional	5-10	No	0 to -1
19	Low Sill	Transitional	Erosional	5-10	No	0 to -1
20	Low Sill	Transitional	Erosional	<5	No	0 to -1
21	Low Sill	Transitional	Transitional	<5	No	0 to -1
22	Low Sill	Transitional	Transitional	<5	No	0 to -1
23	Low Sill	Transitional to Erosional	Erosional	<5	No	0 to -1
24	Sand and	Stable	Erosional	<5	No	Not Calculated
25A	Low Sill	Stable	Erosional	<5	No	0 to -1
25B	High Sill	Erosional	Erosional	<5	Yes	0 to -1
25C	Low Sill	Erosional	Erosional	<5	Yes	0 to -1
26	Low Sill	Stable	Erosional	<5	No	0 to -1
27	Low Sill	Transitional	Erosional	<5	No	0 to -1
28	Medium Sill	Transitional	Erosional	<5	No	0 to -1
29	Low Sill	Stable	Erosional	<5	No	0 to -1
30	Low Sill	Stable	Transitional	<5	No	0 to -1
31	Low Sill	Stable	Transitional	5-10	No	0 to -1
32	Sand and	Stable	Erosional	<5	No	0 to -1
33	Low Sill	Transitional	Transitional	<5	No	-1 to -3
34	Low Sill	Erosional	Erosional	<5	No	-1 to -3
35	Low Sill	Erosional	Erosional	<5	No	-1 to -3
36	Low Sill	Transitional to Stable	Erosional	5-10	No	-1 to -3
37	Low Sill	Stable	Transitional	5-10	No	0 to -1
38A	Low Sill	Transitional	Transitional	<5	No	0 to 5
38B	Breakwater	Transitional	Transitional	<5	No	0 to -1
39	Medium Sill	Erosional	Erosional	<5	No	0 to -1

4 Conclusions

Understanding the dimensions of the shore reach and those factors which influence it puts the problem into context for property owners. A primary goal of this project was to provide information and documentation on shoreline strategies that can be applied along Occohannock Creek as well as their limitations and consequences. The overarching theme of the shoreline erosion assessment is to provide an environmental edge along the Creek, particularly through marsh and beach creation and buffer management. The recommendations are meant to offer alternatives to shoreline hardening along Occohannock Creek and are shown at a conceptual level.

Many of the sites chosen for recommendations along the main stem of Occohannock Creek have a marsh fringe that is presently too narrow to offer shore protection. By enhancing the marsh with a sill and some fill, one can not only provide an increased level of protection but also provide wetland habitat. These strategies generally are acceptable to the local, state and federal permitting agencies. In fact, these Living Shorelines methods are encouraged in many localities Bay wide. However, encroachment onto state bottom with sand fill and structures and modification to the riparian buffer must be minimized. Reducing the impacts to these elements but attaining adequate shore protection requires a detailed evaluation of each site.

Except for a few areas, most of the shore change is minor by Bay standards. Landowners, especially those new to waterfront living may view an exposed bank as a problem that must be fixed. It is the landowner's prerogative to do so and hopefully this document will help in the decision making process and provide local wetlands boards and planners a guide to shoreline development.

The management approaches and strategies recommended are intended to be informational for landowners and managers. Generally, the recommended strategies are the minimum needed for effective erosion control. Other types of approaches can and will work. This report presents the data necessary for those making decisions and designing systems to develop a project that meets their goals, expectations, and cost. Final design will require a site survey and geotechnical investigations as well as fitting the project more closely to the coastal geomorphology.

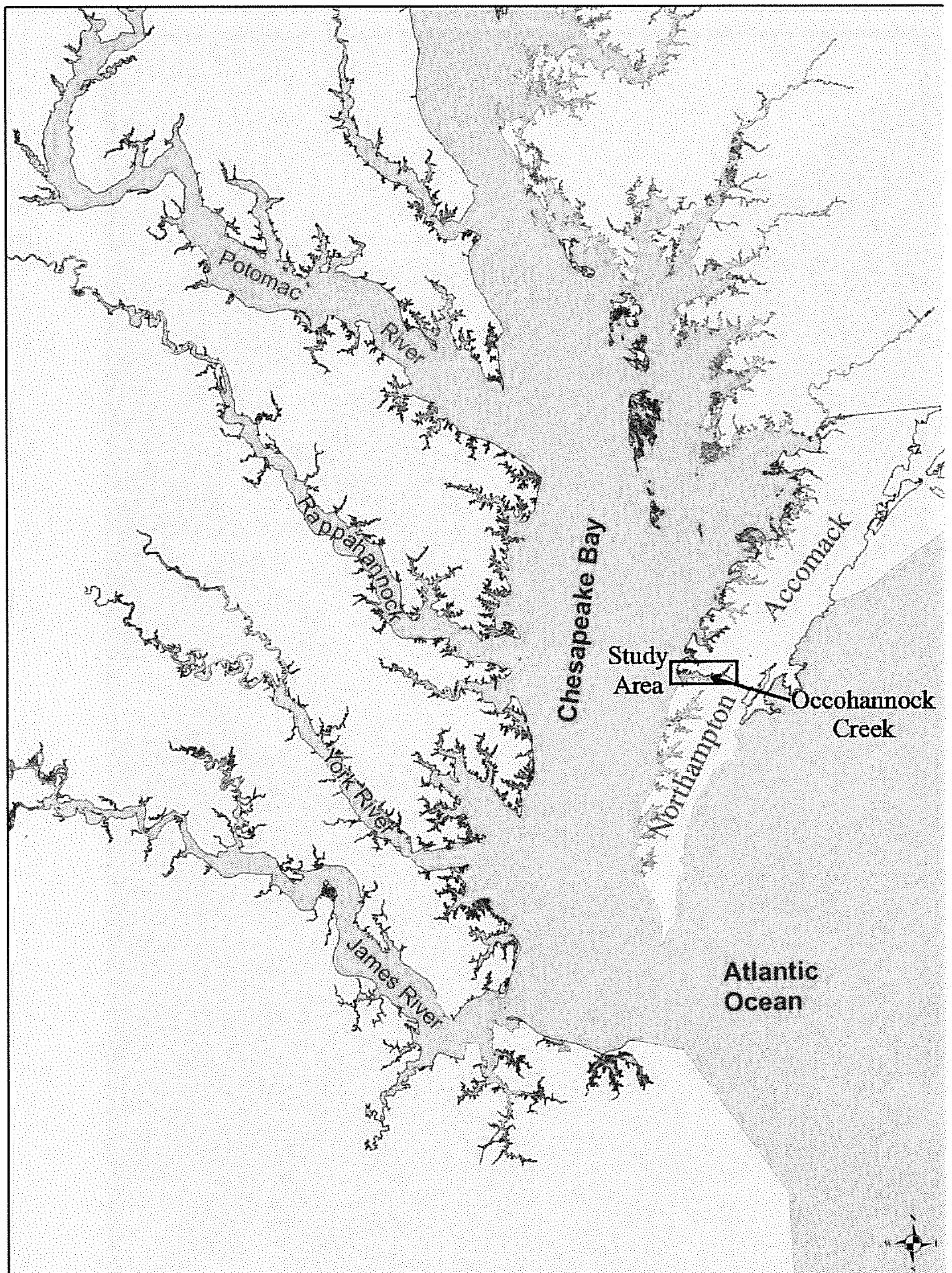


Figure 1. Location of Occohannock Creek within the Chesapeake Bay estuarine system.

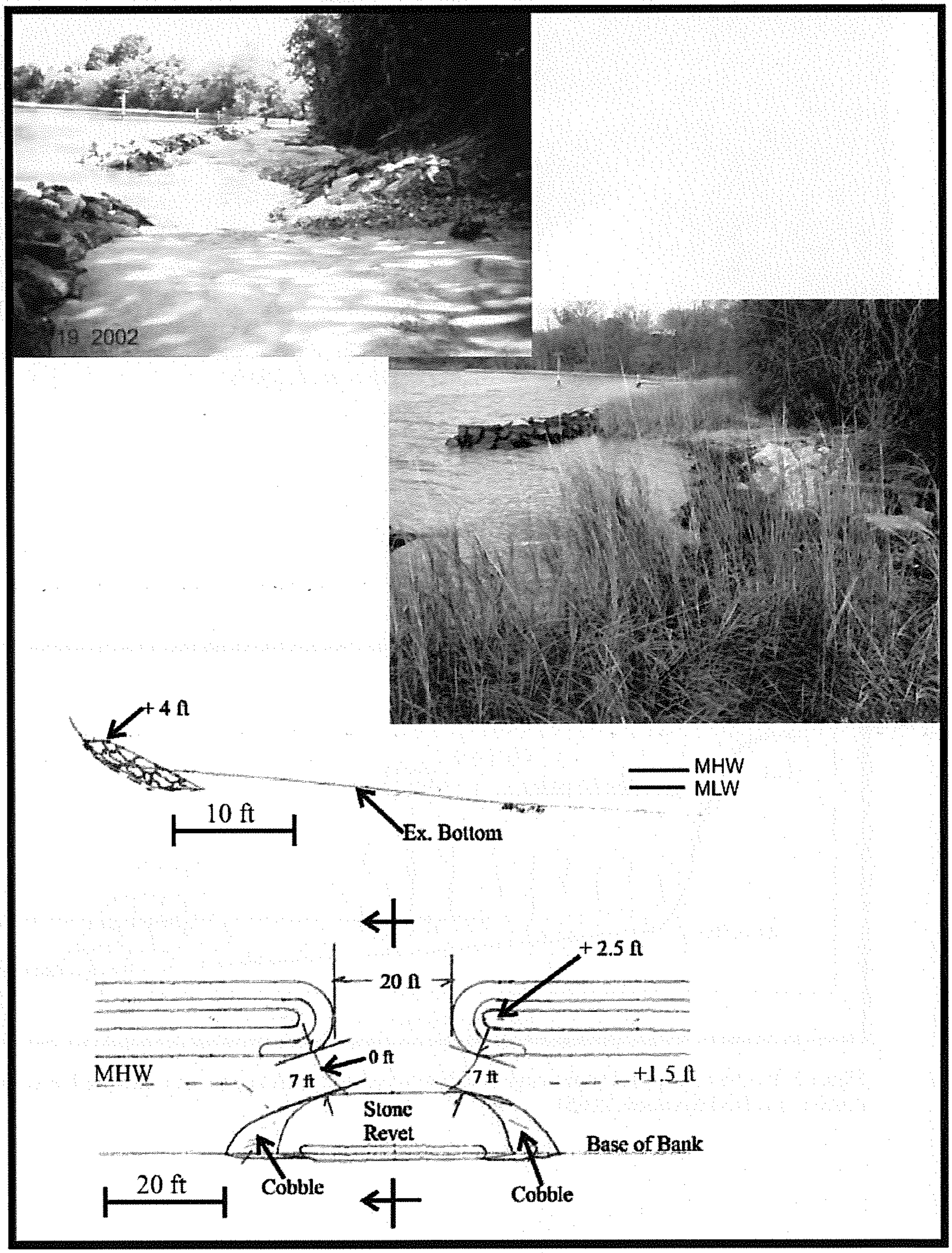
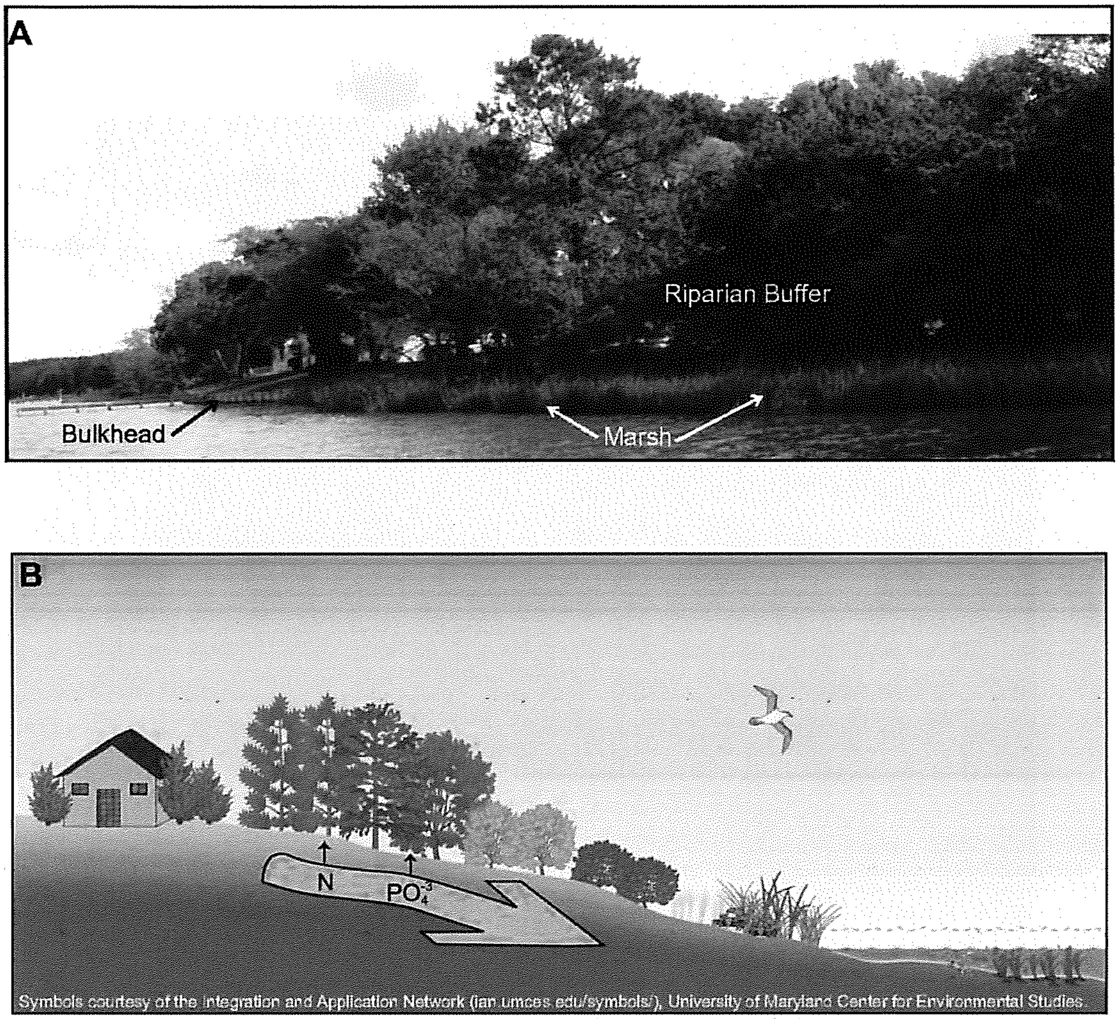


Figure 3. Photos showing a window in the Historic St. Mary's City sill post construction in 2002 and in 2006. The window 9 has a stone revetment along the backshore shown in the planform and cross-sectional design (From Hardaway *et al.*, 2008). 33



	Upland Landuse	Riparian Landuse	Banks	Intertidal Zone	Subaqueous Lands
(+)	Trees, shrubs, tall grass	Trees, shrubs, tall grass	Vegetated, Stable	Marshes, Phragmites	Seagrass (SAV)
			Partial vegetation	Coastal Sand Dunes	Oyster Reefs
	Agriculture	Residential, Agriculture	Undercut	Riprap, Bulkheads	Aquaculture
(-)	Residential, Commerial	Industrial	Bare, Unstable	Boat ramps	Marinas

Figure 6. A) Photo taken along Occohannock Creek depicting aspects of the coastal profile, and B) an integrated shoreview of a water quality model that shows the relative contribution of different landscape elements to water quality and habitat, from positive (diverse habitat opportunities and improved water quality) to negative (few habitat opportunities and reduced water quality). B is reprinted courtesy of VIMS Center for Coastal Resources Management.

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Pre-project shoreline on Wye Island, Kent County, Maryland (1988).

Marsh grass plantings with sand fill and short, stone groins 3 months after installation on Wye Island, Kent County.

Wye Island project four years after construction.

Figure 8. Photos showing a marsh construction project at Wye Island, Maryland before and after installation and after four years (Hardaway and Byrne, 1999).

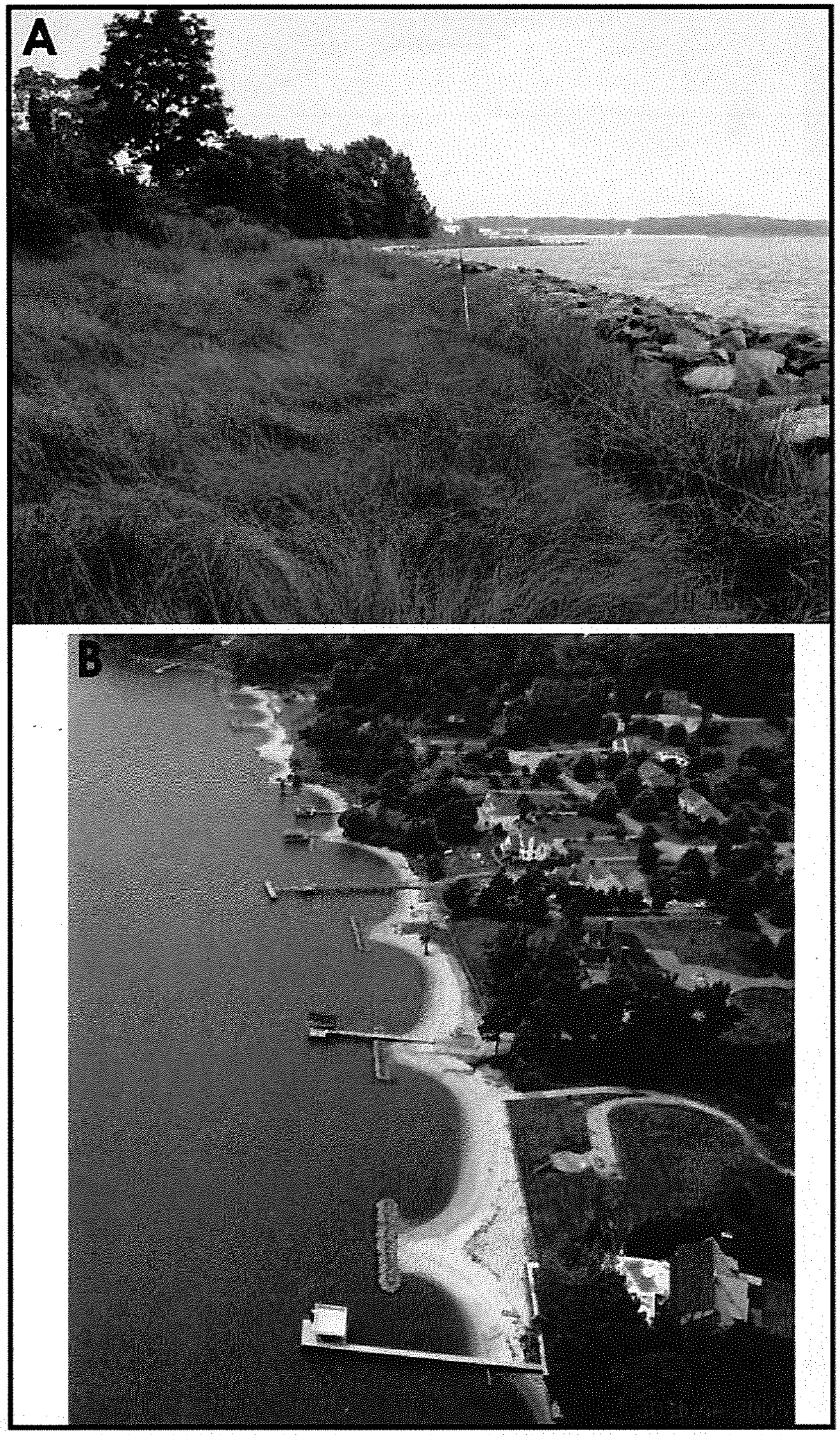


Figure 10. Photo of A) a sill project at Webster Field in St. Mary's County, Maryland and B) a breakwater system on the James River, Virginia.

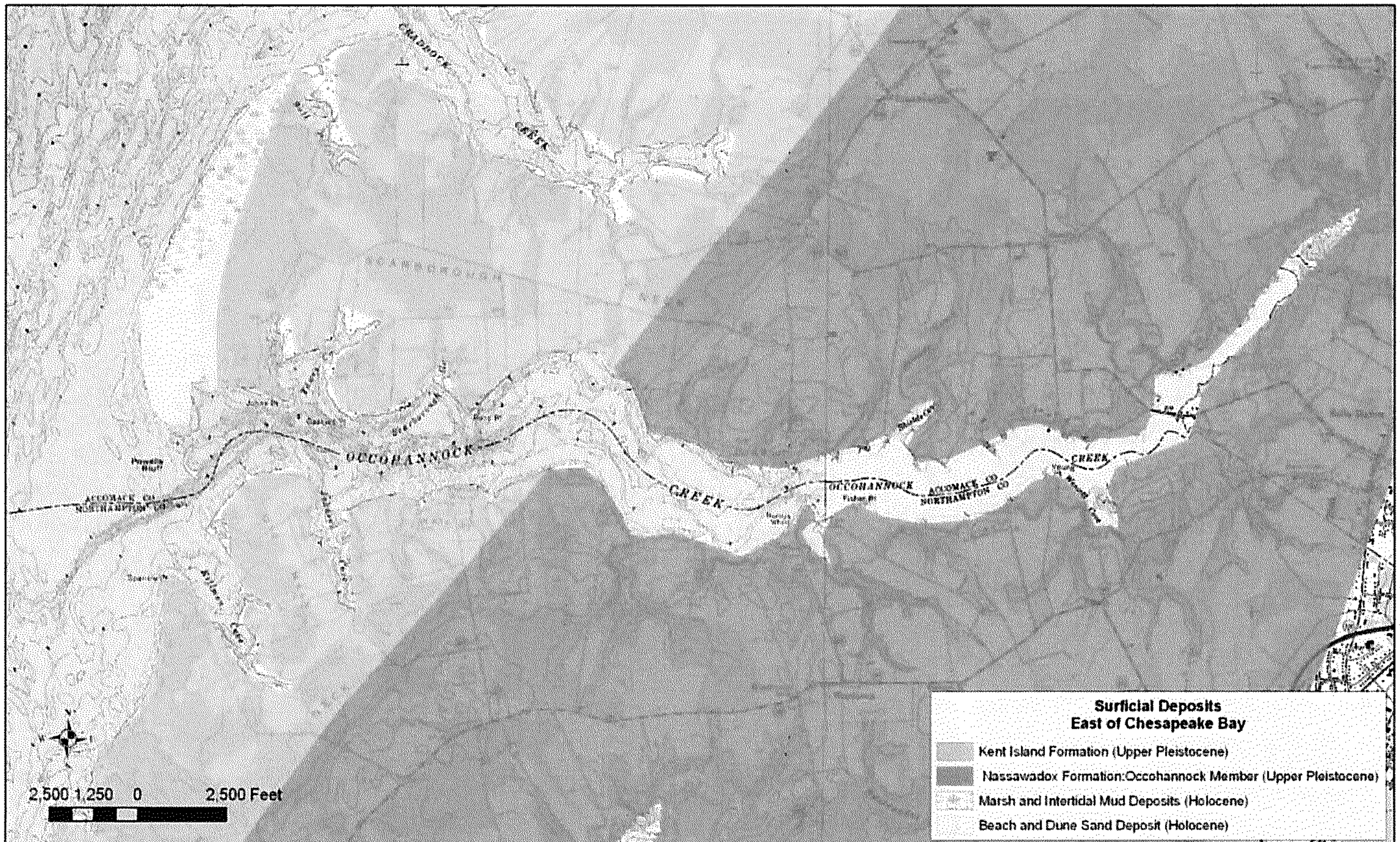


Figure 12. Geology of the region surrounding Occohannock Creek. Base map is a US Geological Survey topographic map of the area.

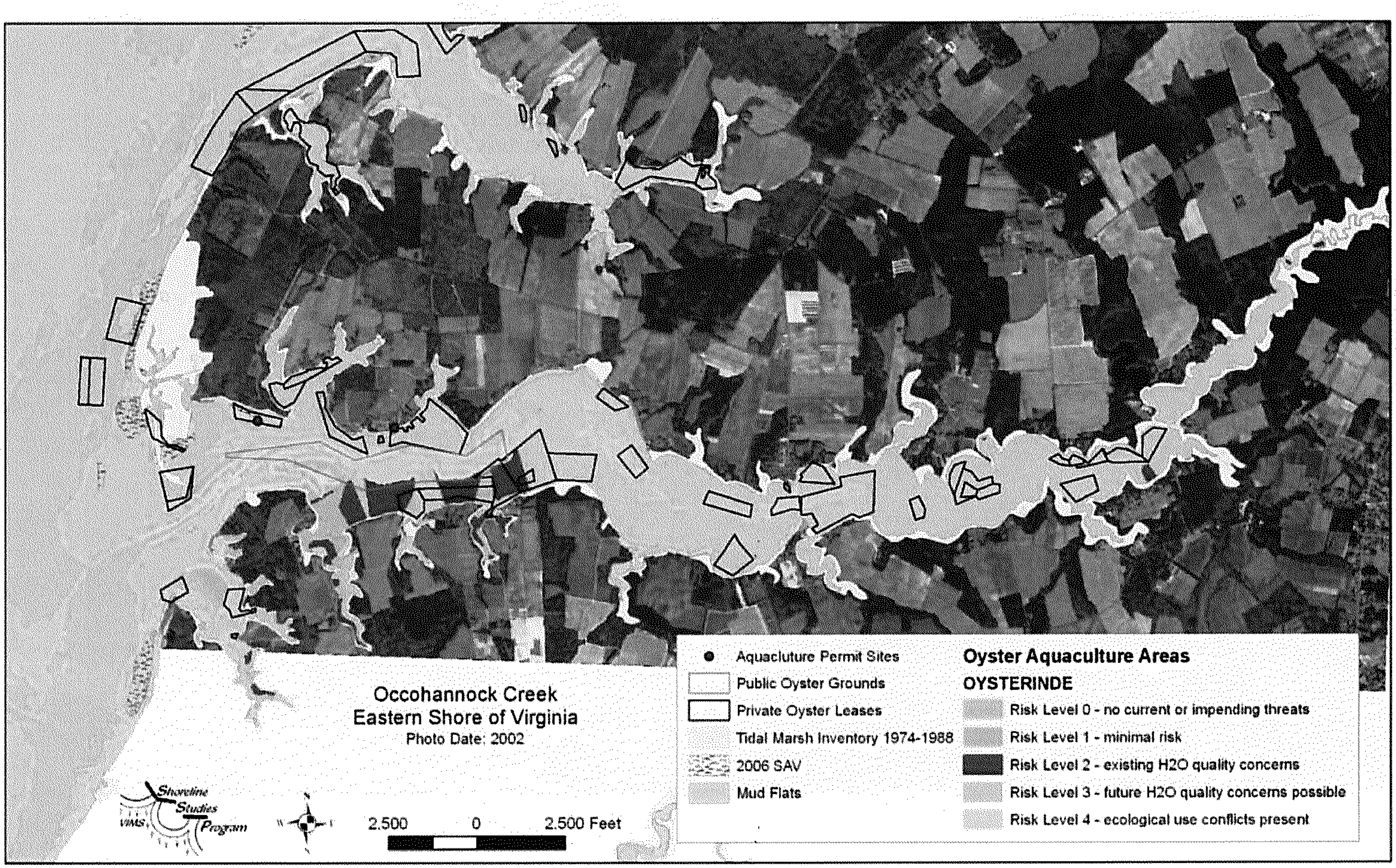


Figure 14. Existing marine resources including SAV and oyster aquaculture risk areas are shown for Occohannock Creek. The data comes from existing databases available on the VIMS website.

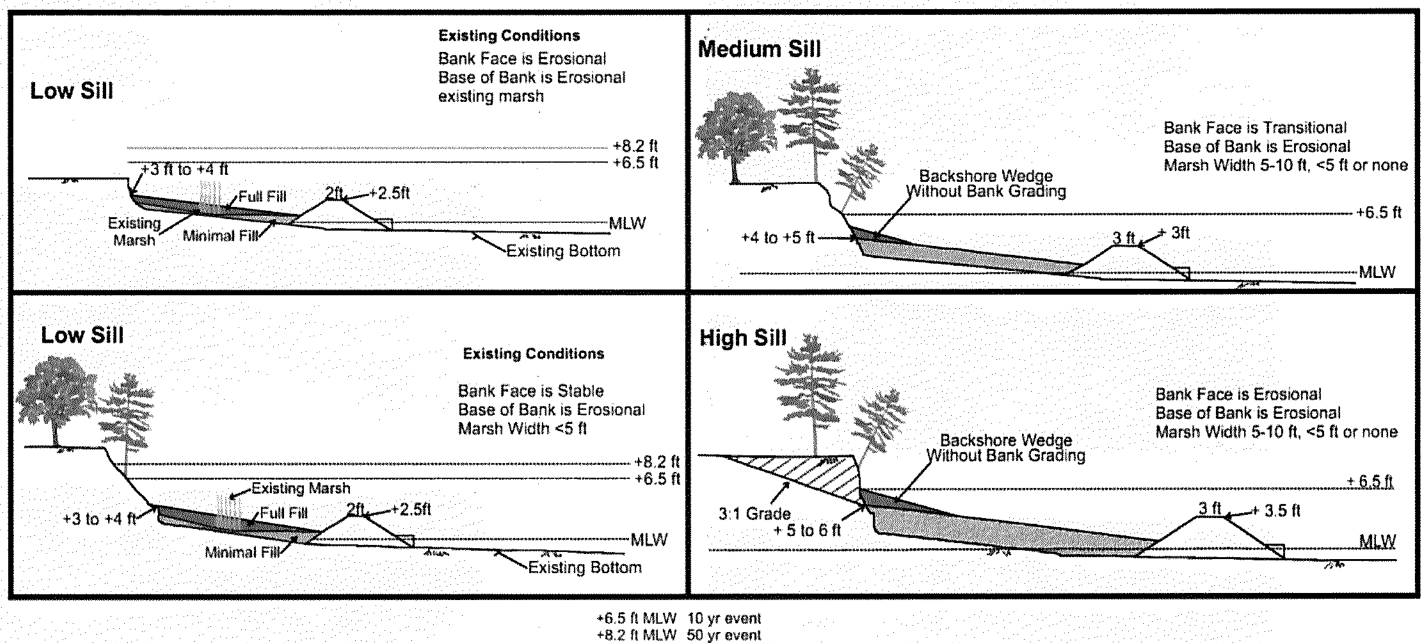


Figure 16. Cross-sections of sill types proposed for the Occohannock Creek shoreline.

Figure 18. Photo of Knott in Kent County, Maryland on the Chester River showing an example of breakwaters that would be suitable for Occohannock Creek.

FOR IMMEDIATE RELEASE

Contact: Marian Huber
Coordinator, Eastern Shore Resource
787-2786

USDA- NRCS
22545 Center Parkway
Accomac, VA 23301-1330

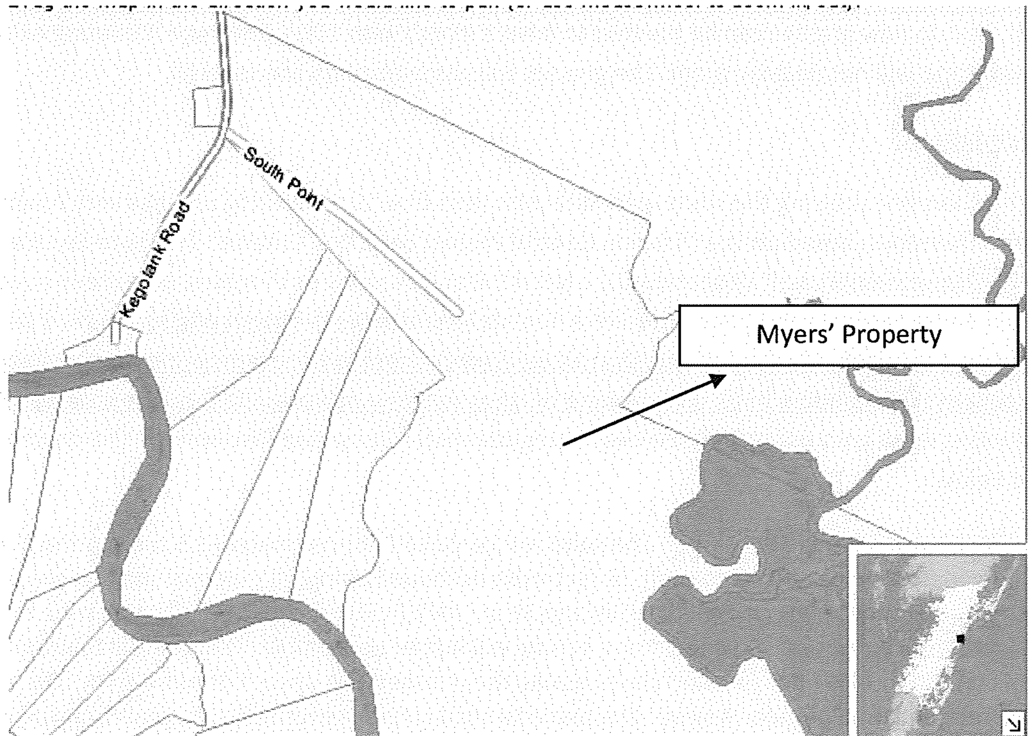
Free Technical Advice for Homeowners with Shoreline Erosion

If you live on the water and have been wondering if your shoreline is going to take a beating this winter, you can get some free advice about ways to protect it. ES Resource Conservation and Development will send a shoreline erosion specialist to your property to give you suggestions on how to protect your land and habitat along the shore.

Although the RC&D is trying to promote the use of Living Shorelines techniques through this service, the recommendations offered will reflect the reality of your site. Shoreline exposed to a long fetch of deep water will not be a candidate for protection with vegetation alone. There are some medium energy situations where hybrid designs of stone and vegetation perform well. In protected areas with limited boat wakes, vegetative techniques can often work alone. During a visit to your property, the RC&D technical advisor can determine what types of designs will work on your shore line.

This service is being offered through a partnership between Maryland and Virginia Eastern Shore RC&D Councils. Maryland's RC&D has designed and installed over 60 Living Shoreline projects and documented their performance over a number of years. They give landowners independent and professional advice and do not sell any products for shoreline stabilization. The design recommendation they provide can be given to several contractors for bids. Taking advantage of this service does not obligate you to construct a specific project. Landowners often evaluate erosion over several years before deciding on a course of action

RC&D Chair Ruth Boettcher noted that a National Fish and Wildlife Foundation made it possible for Council to promote the use of Living Shorelines in appropriate situations. "This is National RC&D week and all over the Country 370 Councils like ours are busy doing projects that solve local problems and enhance the environment and rural economies."



The site has a sandy beach suitable for planting marsh plants, but additional sand needs to be placed to widen the marsh fringe with other species. Areas devoid of grasses within the existing marsh need to be

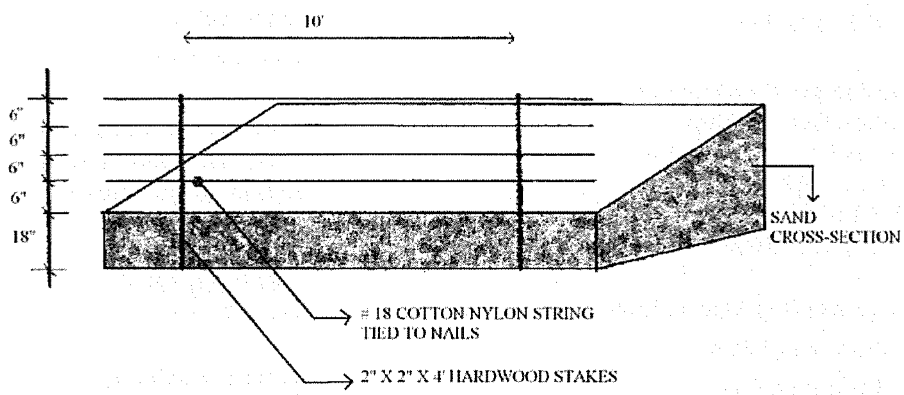
- Give a proposal to stabilize the problem.
- Give an estimated cost to do the work.

Contractors with experience in living shorelines and marine stone works will be considered. Equipment access to the shoreline need to be by the path of least resistance, that is, with the least amount of potential damage to lawns, bushes, trees, structures, etc. Contractors will put the access back, after the completion of the project, in at least as good/better condition as found. There appears to be no over the bank flow from the yard, downspout, etc.

Disclaimer: The recommendations made by RC&D maybe different from that of the Contractor. Since the contractor will guarantee the project for at least one year, the property owner may accept the contractors' recommendation because of the associated guarantee.

APPENDIX- 2

Sketch for Goose Exclusion Fence



NOT TO SCALE

DESIGNERS' LIST*

Environmental Quality Resources, Inc.
Attention Jennifer Connolly
P. O. Box 227
Trappe, MD 21673
(410) 476-3458
CELL (301) 370-7704

Angler Environmental (In-House Design)
Attention Matt Carrier
12801 Randolph Ridge Lane, Suite 102
Manassas, VA 21019
(703) 393-4844
FAX (703) 393-2934

Bayland Consultants & Designers, Inc.
Attention Sepehr Baharlou
1321 Mercedes Drive, Suite C
Hanover, MD 21076
(410) 694-9401
FAX (410) 694-9405
sbaharlou@baylandinc.com

Herr Landscape Architecture and Environmental Design
Attention Debbie Herr
402 Talbot Avenue
Cambridge, MD 21613
(410) 228-4533

The Permit Coordinators, Inc.
Attention Scott Meilke
260 Moreau Lane
Severna Park, MD 21146
CELL (410) 703-8533
FAX (410) 421-9161

Shoreline Designs
Attention Wes Matthews
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Edgewater, MD 21037
(443) 336-0978

Andrews Miller and Associates
Attention Gary Williams
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(410) 228-7117

Coastal Design & Construction, Inc. **
Attention Jim Gunn
P. O. Box 650, 6364 Allmondsville Rd.
Gloucester, VA 23061
(804) 693-4158
FAX (804) 693-0064

Lane Engineering, Inc.
Attention William Stagg
117 Bay Street
Easton, MD 21601
(410) 822-8003
Fax: (410) 822-2024

KCI Technologies, Inc.
Attention Christopher R. Eaton
3105 Lorena Avenue
Baltimore, MD 21230
(410) 644-8921
Fax: (410) 644-5888
E-mail: ceaton@kci.com

Sustainable Science
Attention Albert McCullough
410 S 2nd St
Denton, MD 21629
(410) 820-9464*

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* These contractors have been approved for work under the Maryland RC&D Living Shorelines program. Virginia contractors will be added as they qualify under this program.

** Typically performs large-scale projects.

EASTERN SHORE OF VIRGINIA RESOURCE CONSERVATION AND DEVELOPMENT (RC&D) COUNCIL

Report of the Initial Site Visit of Mrs. Nancy Weaver's Shoreline

30461 Kusian Cove Rd
Painter, VA 23420

37°37'28.39"N 75°50'24.37"W (Location)

Description of the Site:

A site visit was made to Mrs. Nancy Weaver's property in December 2007, by Marian Huber (RC&D, VA), Jerry Walls and Bhaskaran Subramanian (RC&D, MD). The property is situated on a calm cove (Kusian Cove), and has minimal boat traffic. The bank is 4-5 feet high and composed of sandy silt material. It is vegetated with trees, shrubs, and grasses. The depth of the water offshore, at high tide, in the middle of the cove is 3 feet.

Recommendations:

The shoreline is facing the north-east direction (less than ½ mile fetch) and has very minimal boat traffic. Therefore, based on the "Erosion Control Project Selection Criteria" in "Shore Erosion Control: The Natural Approach" (*Appendix-1)*, a fetch 1.0 or less miles of a shoreline on a creek or cove fall into the low energy column and hence require a non-structural project- **marsh edging** coupled with **filling sand on the beach, planting of marsh grasses- *Spartina alterniflora* (smooth cordgrass) and *Spartina patens* (saltmeadow hay), and pruning of trees to allow more sunlight to the grasses** *(Please check prevailing local laws about tree removal and replacement- Please see Disclaimer)*. The problems caused by the upland areas could be managed by **building a 12- inch berm, optional grading of the bank, and building rock swales** to channel the water down the slope. The process involved in the living shorelines project is explained below:

4. Place clean sand fill on a 10:1 slope. The sand will be placed approximately 2.5 feet up the 4-foot high bank resulting in sand placement 25 feet wide outbound. Sand fill material shall be medium to coarse grained sandy soils classified as SW and SP in "ANSI/ASTM D-2487-69, Classification of Soils for Engineering Purposes". Crushed stone or slag will not be acceptable. The sand fill material must contain less than 10% fines (clay and silt) passing the number 100 sieve, not more than 10% by weight retained on a number 4 sieve. The material shall consist of rounded or semi-rounded grains with a medium diameter of 0.6mm (±0.25 mm). No frozen material, trash, roots, or other organic material will be permitted in the fill.

Fence will be installed just inside the sills to prevent the geese from gaining access to the young, tender plants.

Contractor Bids:

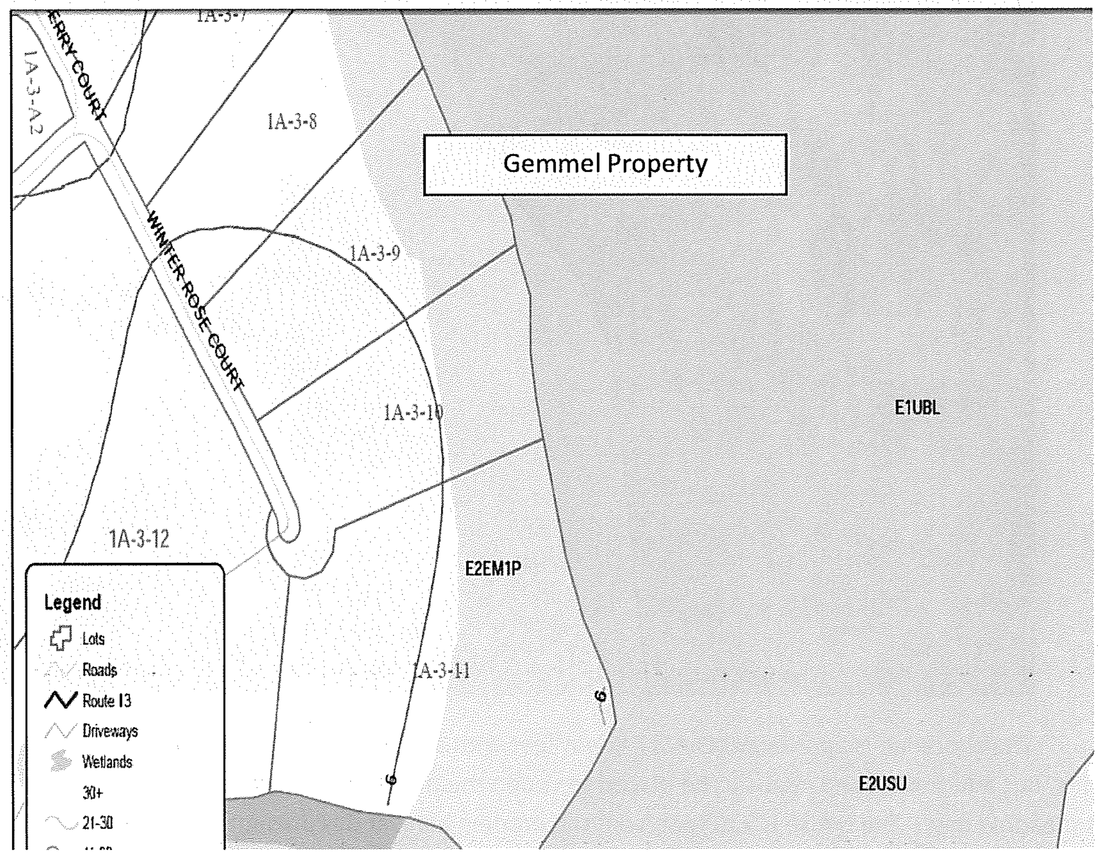
RC&D recommends that the landowner contact at least 2 or 3 contractors on the attached list (*Appendix-3*) to:

- Give a proposal to stabilize the problem.
- Give an estimated cost to do the work.

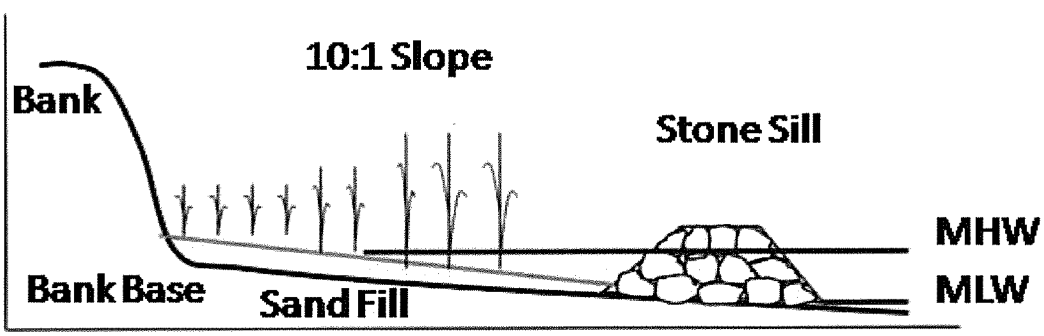
Contractors with experience in living shorelines and marine stone works will be considered. Equipment access to the shoreline needs to be by the path of least resistance, that is, with the least amount of potential damage to lawns, bushes, trees, structures, etc. Contractors will put the access back, after the completion of the project, in at least as good or better condition found.

Disclaimer: The recommendations made by RC&D maybe different from that of the Contractor. Since the contractor will guarantee the project for at least one year, the property owner may accept the contractors' recommendation because of the associated guarantee.

was classified by reddish clay material. A narrow fringe of *Spartina alterniflora* (smooth cordgrass) exists in front of the eroding bank, but not enough marsh is available to stop erosion of the bank.



8. Sand will not remain in place with a northeast fetch of 2.1 miles. Therefore, a low profile sill will need to be constructed at 25 feet out from the bank. The sill, see attached sketch, will have a 2-foot wide top, 2:1 outside slope, 2:1 landward slope, and be 6 inches above MHT. Tiebacks on both property lines will connect the sill to the bank to prevent tidal action and boat wakes from attaching, eroding the bank from the ends.



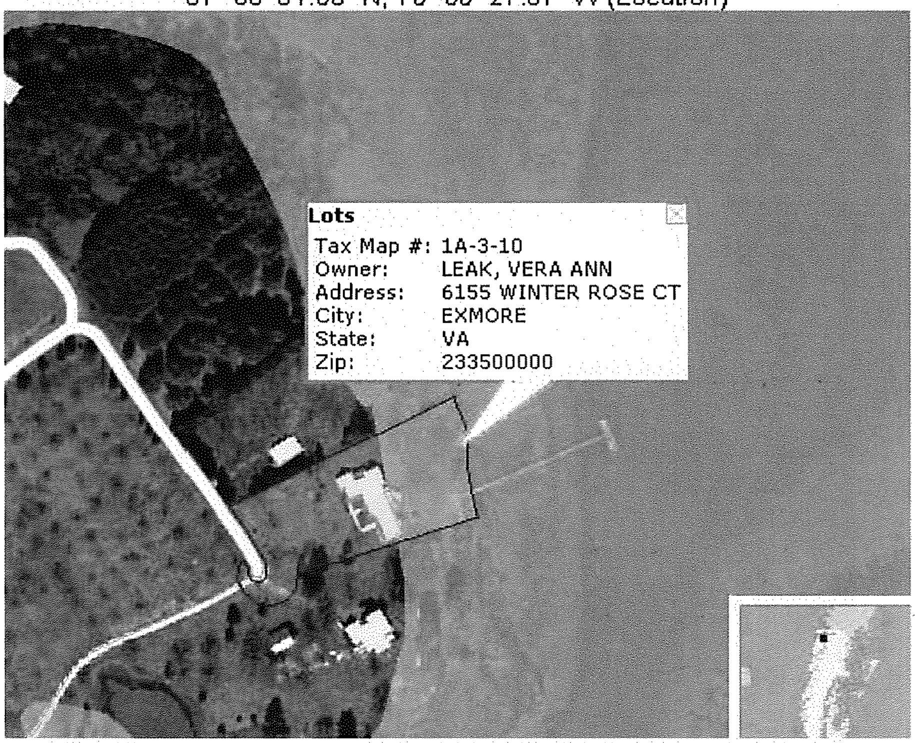
9. The new sand fill will be planted from:

EASTERN SHORE OF VIRGINIA RESOURCE CONSERVATION AND DEVELOPMENT (RC&D) COUNCIL

Report of the Initial Site Visit of Mrs. Vera Leak's Shoreline

6155 Winter Rose Path
Exmore, VA 23350-3655
(757) 442-3098

37° 33' 01.56" N; 75° 55' 27.87" W (Location)



Description of the Site:

A site visit was made to Ms. Vera Leak's property in December 2007, by Marian Huber (RC&D, VA) and Jerry Walls (RC&D, MD). The property had a 4-foot high eroding bank with overhanging trees. The bank was classified by reddish clay material with portions of the shoreline undercuting and slumping. A narrow fringe of *Spartina alterniflora* (smooth cordgrass) and *Spartina patens* (saltmeadow hay) exists in front of the eroding bank, but not enough marsh is available to stop erosion of the bank.

The shoreline is approximately 218 linear feet with a sandy beach (about 6 feet wide at high tide) suitable for planting marsh plants, but additional sand needs to be placed to widen the marsh fringe with more *Spartina* species. Sand needs to be added to the narrow existing sandy beach to create an area for planting marsh grasses approximately 25 ft wide. Areas devoid of grasses within the existing marsh need to be filled with sand so new grasses can be planted to have a marsh with 100% coverage. Covering existing grasses with sand will not destroy them. The grasses will come through the sand fill. The nearest structure is nearly 64 feet from the eroding bank and needs to be protected at the earliest.

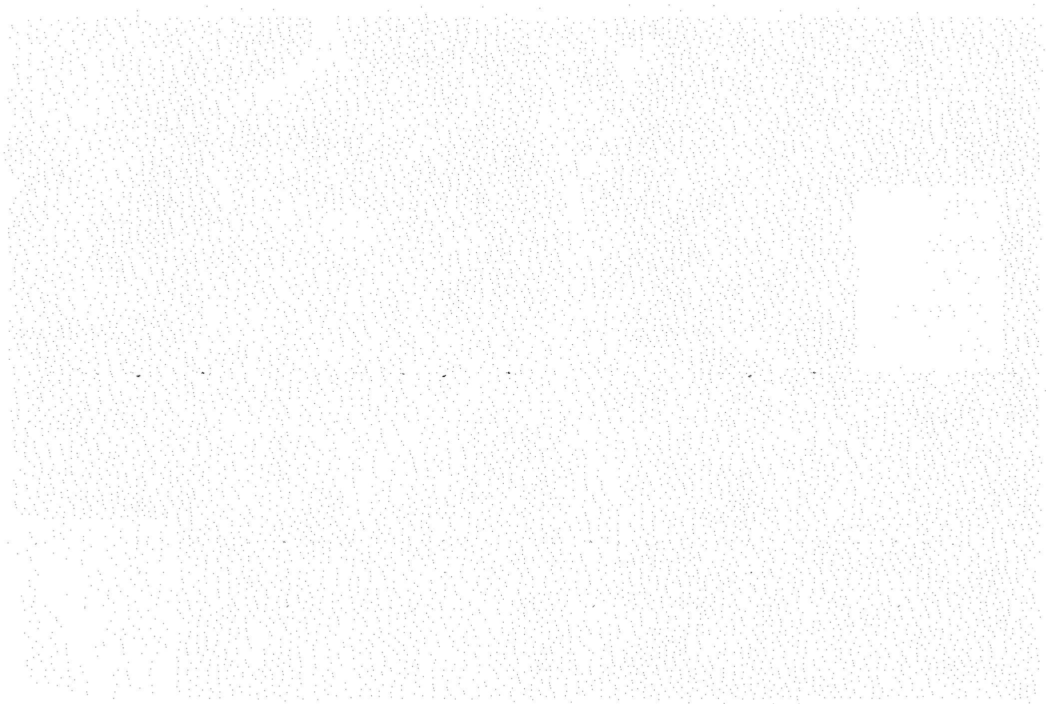
Recommendations:

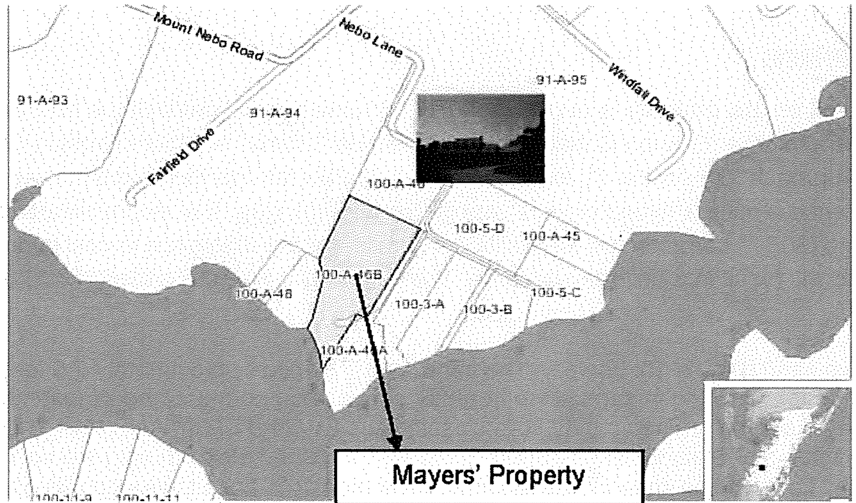
The fetch on this property is north-easterly (2.0 miles). Therefore, based on the "Erosion Control Project Selection Criteria" in "Shore Erosion Control: The Natural Approach" (*Appendix-1*), a fetch 2.0 or more miles of a shoreline on a major tributary fall into the medium energy column and hence require a hybrid project- **marsh fringe with sills**. The following is how the project would be constructed:

1. Place clean sand fill on a 10:1 slope. The sand will be placed approximately 2.5 feet up the 4-foot high bank resulting in sand placement 25 feet wide outbound. Sand fill material shall be medium to coarse grained sandy soils classified as SW and SP in "ANSI/ASTM D-2487-69, Classification of Soils for Engineering Purposes". Crushed stone or slag will not be acceptable. The sand fill material must contain less than 10% fines (silt and clay) passing the number 100 sieve, not more than 10% by weight retained on a number 4 sieve. The material shall consist of rounded or semi-rounded grains with a medium diameter of 0.6mm (±0.25 mm). No frozen material, trash, roots, or other organic material will be permitted in the fill.

put the access back, after the completion of the project, in good or better condition than found. There appears to be no over the bank flow from the yard, downspout, etc.

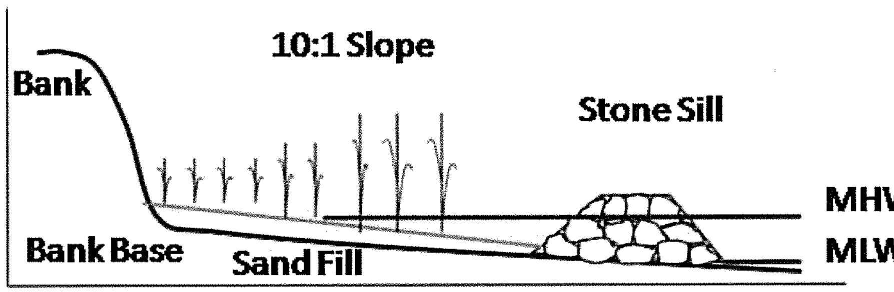
Disclaimer: The recommendations made by RC&D maybe different from that of the Contractor. Since the contractor will guarantee the project for at least one year, the property owner may accept the contractors' recommendation because of the associated guarantee.





The shoreline is approximately 300 linear feet, while only about 200 ft need to be protected as erosion is more severe in this section. Sand needs to be added to the narrow existing sandy beach to create an area for planting marsh grasses approximately 25 ft wide. Areas devoid of grasses within the existing marsh need to be filled with sand so new grasses can be planted to have a marsh with 100% coverage. Covering existing grasses with sand will not destroy them. The grasses will come through the sand fill. The nearest structure (porch/deck of the house) is about 18 ft from the top of the slumping bank and needs to be protected as soon as possible.

the sill to the bank to prevent tidal action and boat wakes from attaching, eroding the bank from the ends.



3. The new sand fill will be planted from:
   - High tide line to the mid-tide (sill) with *Spartina alterniflora* (smooth cordgrass) on 18-inch centers. One ounce of Osmocote® six-month slow release rate (19-6-4) will be used for each plant. Plants will be placed 3-4 inches deep in the hole over the peat pot it was grown in (peat pots usually 1 ¾-inch by 1 ¾-inch).
   - The area from the high tide line to the base of the bank will be planted with *Spartina patens* (saltmeadow hay) on 18-inch centers. One ounce of Osmocote, six month slow release rate will be used. Also the little remaining bank that has not been covered with sand will be planted with saltmeadow hay or switchgrass (*Panicum virgatum*). (*Note: Switch grass can grow 3-4 feet high and may not want to be used if it obstructs view of the water from the house.*)
4. Install goose fence as per attached sketch (*Appendix-2*). Without the goose fence, geese and ducks will destroy the young plants, and a healthy tidal marsh will not be successful. Goose fence specifications:
   - 2" × 2" × 4' stakes
   - #18 cotton/nylon string
   - roofing nails (1 pound)

   Fence will be installed just inside the sills to prevent the geese from gaining access to the young, tender plants.

Contractor Bids:

RC&D recommends that the landowner contact at least 2 or 3 contractors on the attached list (*Appendix-3*) to:

- Give a proposal to stabilize the problem.
- Give an estimated cost to do the work.

Contractors with experience in living shorelines and marine stone works will be considered. Equipment access to the shoreline needs to be by the path of least resistance, that is, with the least amount of potential damage to lawns, bushes, trees, structures, etc. Contractors will put the access back, after the completion of the project, in at least as good or better condition than found. There appears to be no over the bank flow from the yard, downspout, etc.

Photos of Oyster Living Shoreline in progress.