Living Shoreline Professionals Advanced Training

August 24 & 31, 2017

Hosted by
Virginia Institute of Marine Science
College of William & Mary

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LIVING SHORELINE PROFESSIONALS ADVANCED TRAINING AUGUST 2017

Part 3

DESIGN GUIDELINES FOR MARSH SILLS & OFFSHORE BREAKWATERS

This project was funded by the Virginia Coastal Zone Management Program at the Department of Environmental Quality through Grant #NA16NOS4190171 of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, under the Coastal Zone Management Act of 1972, as amended. The views expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Department of Commerce, NOAA, or any of its subagencies.

Virginia Coastal Plain Geology

The underlying geology of a site is important because it determines such things as bank height, sediment type, and resistance to erosion.

From Mixon et al., 2005

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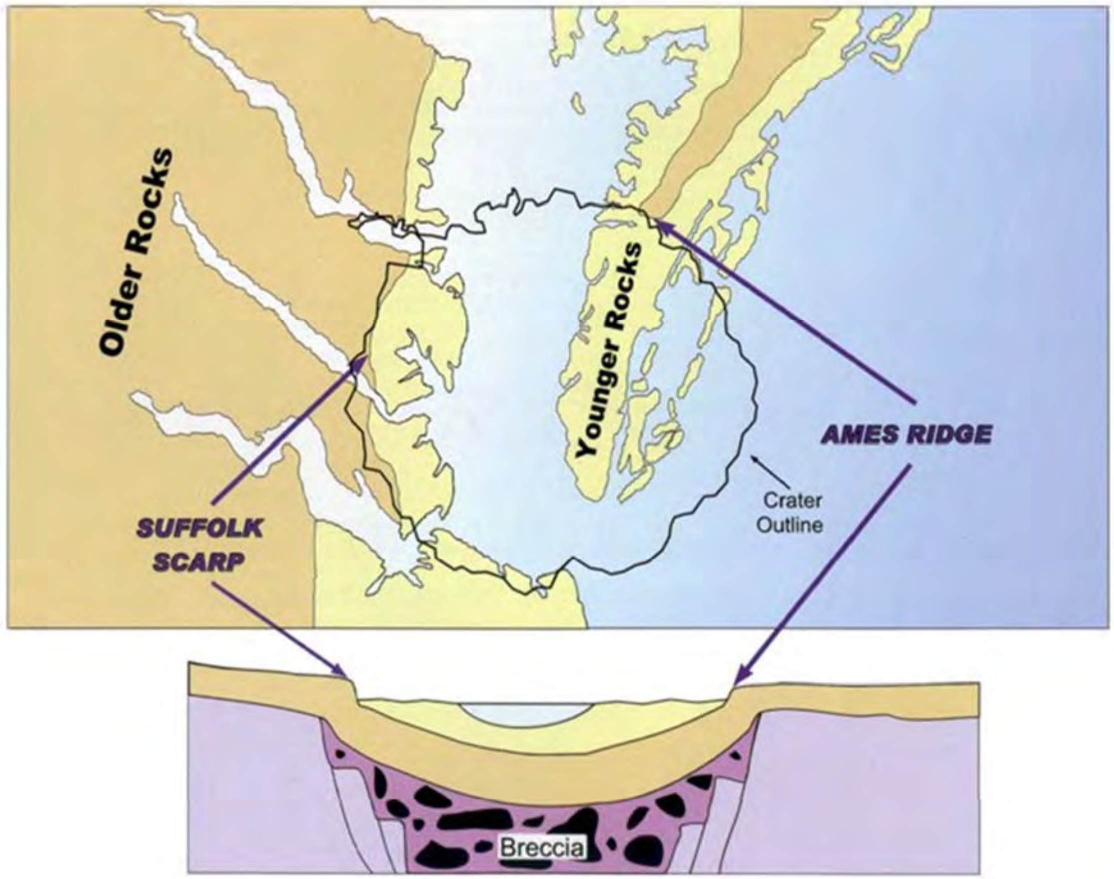
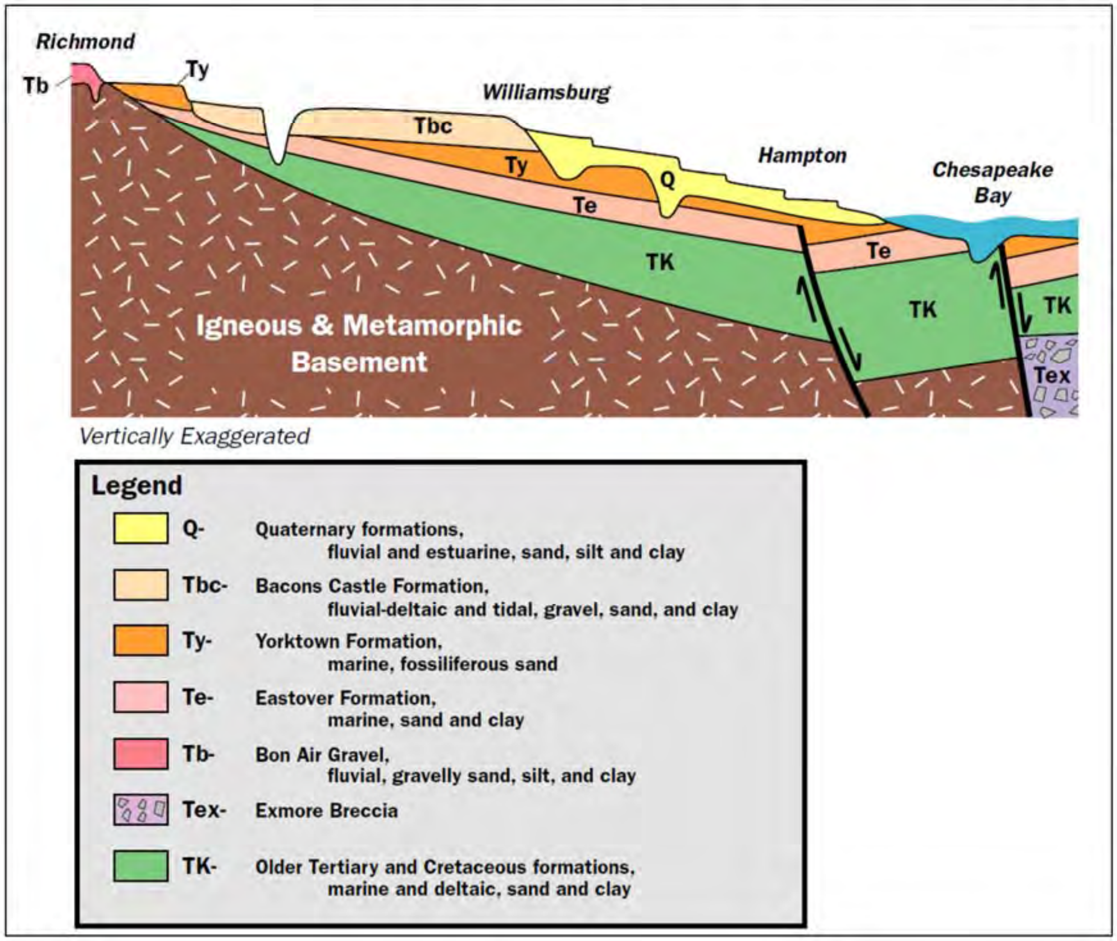
Mixon, R. B., C. R. Berquist, Jr., W. L. Newell, G. H. Johnson, D. S. Powars, J. S. Schindler, E. K. Rader, 1989. Geological map and generalized cross sections of the coastal plain and adjacent parts of the Piedmont, Virginia. USGS IMAP: 2033. As modified in digital form by United States Geological Survey, 2005.

Chesapeake Bay Crater



In lower Chesapeake Bay, the meteor impact crater 35 million years ago still affects the bay today through land subsidence, river diversion, disruption of coastal aquifers, ground instability, and location of Chesapeake Bay (https://pubs.usgs.gov/fs/fs49-98/).

Coastal Plain Stratigraphy



Much of Chesapeake Bay was incised after the Yorktown marine transgression (Ty)

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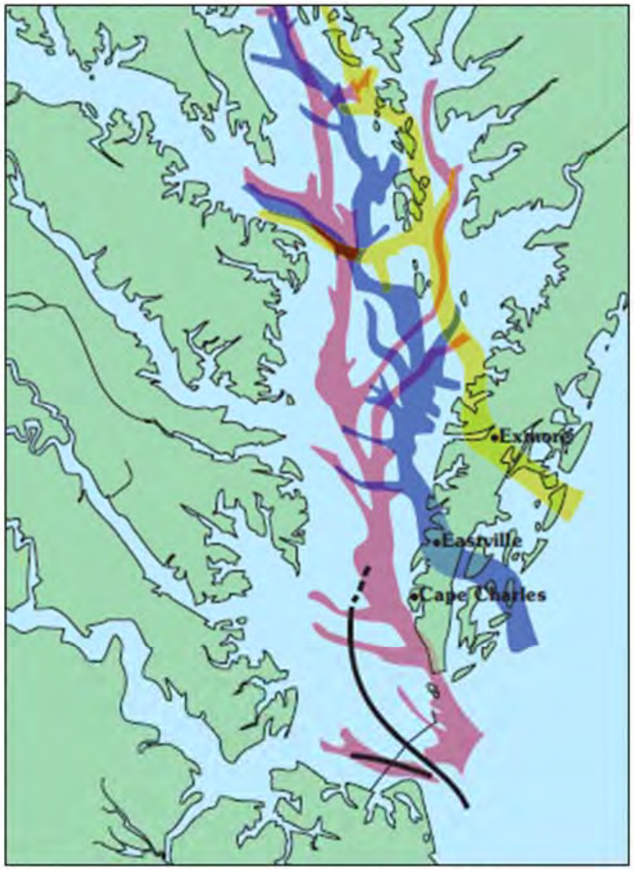
http://historicrivers.org/docs-links/geology/geology_va_coastal_plane.pdf

Ancient Drainage Channels



Coleman et al., 1990

The growth of the Eastern Shore through time has moved the Chesapeake Bay drainage channel farther south.

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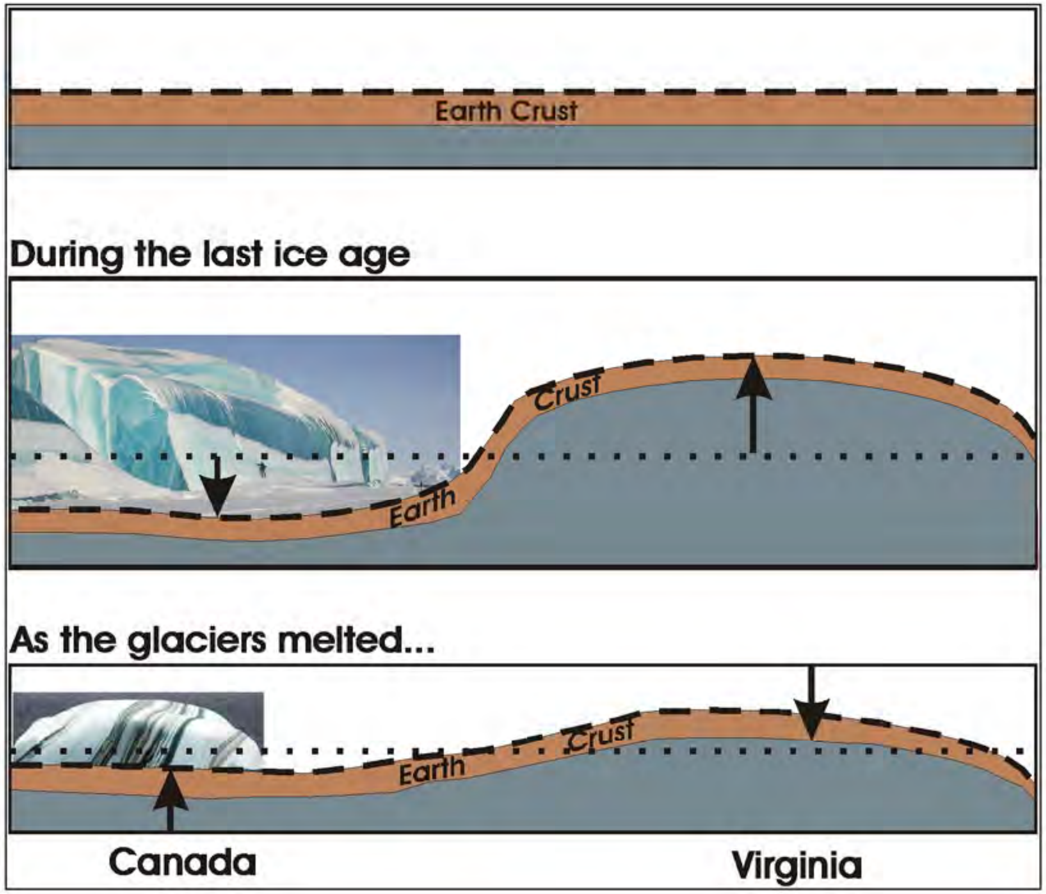
Coleman, S.M., J.P. Halka, C.H. Hobbs, III, R.B. Mixon, and D.S. Foster, 1990. Ancient channels of the Susquehanna River beneath Chesapeake and the Delmarva Peninsula. Geological Society of America Bulletin, v. 102, p. 1268-1279.

The land is sinking…



Glacial rebound in northern US/Canada causing local subsidence

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During the last ice age, the weight of the glaciers in the far north (Canada and Northern US) deformed the crust pushing it down. As a result, the land farther south (Virginia) was pushed higher. As the glaciers melted in the far north, the crust became less deformed and began to rise back to its original position. Farther south, the crust is subsiding. This leads to local sea level rise as the land falls relative to the water.

Project Sea Level Rise

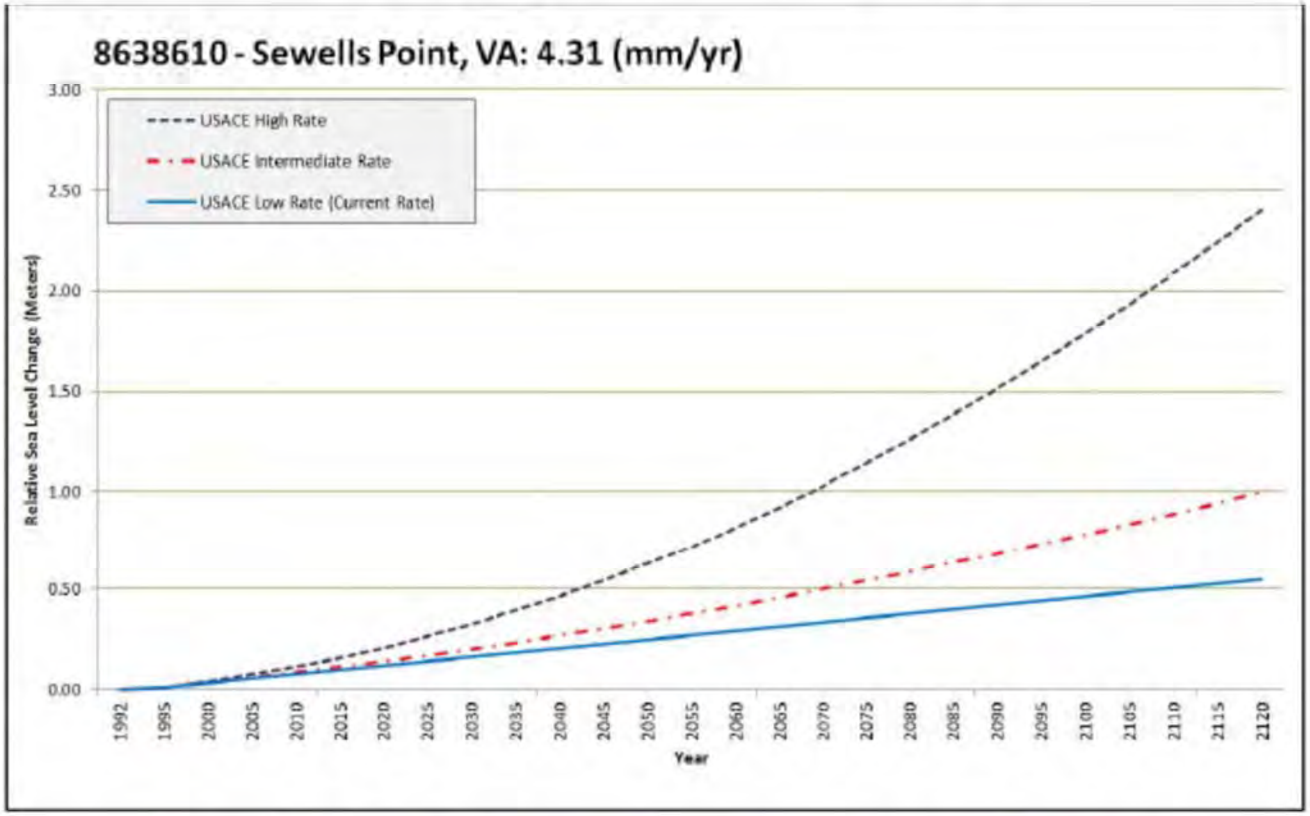
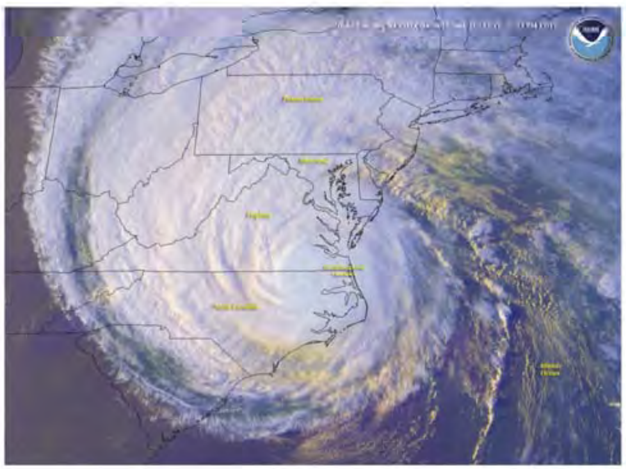
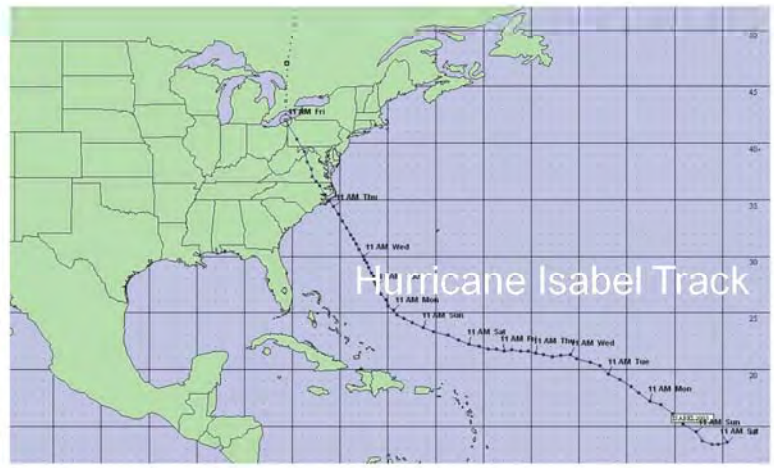


Figure 10: Projected Sea Level Rise, Sewell's Point Station (1992 – 2120)

Storms

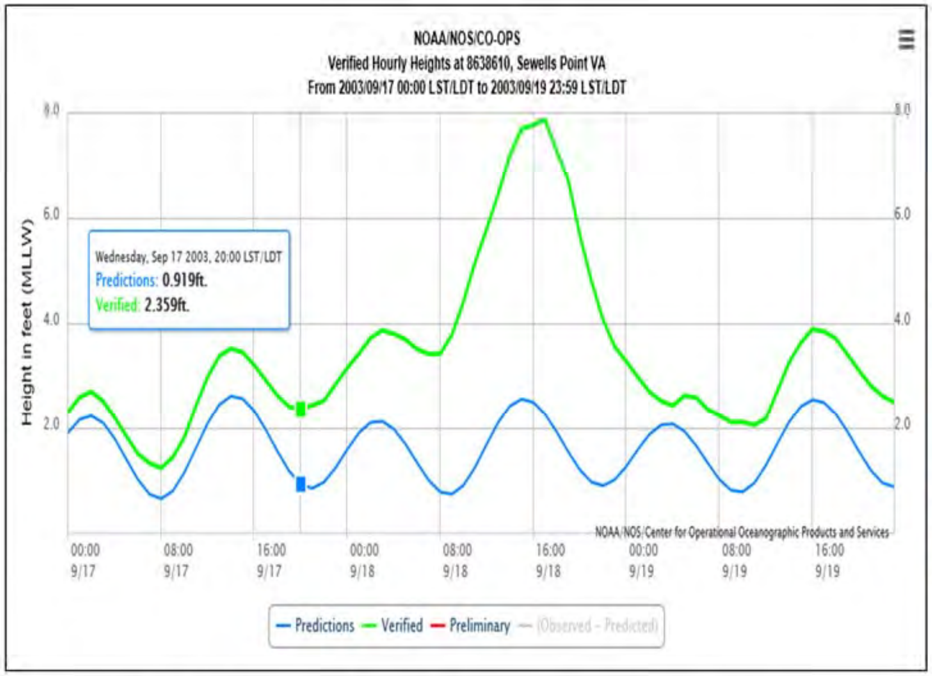
Storms can severely impact a site. Wind, waves, and storm surge must be accounted for in the design.





In 2003, Hurricane Isabel impacted the Chesapeake Bay, it was a minimal Category 1. However, in addition to being in the “right front” quadrant of the advancing hurricane, southeastern Virginia experienced east and east south east winds which have the greatest potential to transport water into Chesapeake Bay and its Virginia tributaries. Since then, several other storms, including Hurricane Sandy have impacted shorelines in Chesapeake Bay.

Storm Surge
Sewell's Point: Isabel



NOAA Tides and Currents Website

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The historic maximum water elevation likely to impact a site can be used to determine the level of protection needed.
tidesandcurrents.noaa.gov

Shoreline Evolution

Broad marshes in foreground give way to fringing marshes downstream where there is greater fetch exposure. At the transition point (T), shoreline processes go from tidally dominated to wave dominated (Ware River, Virginia).

Understanding how a shoreline is evolving through time is an important design element.

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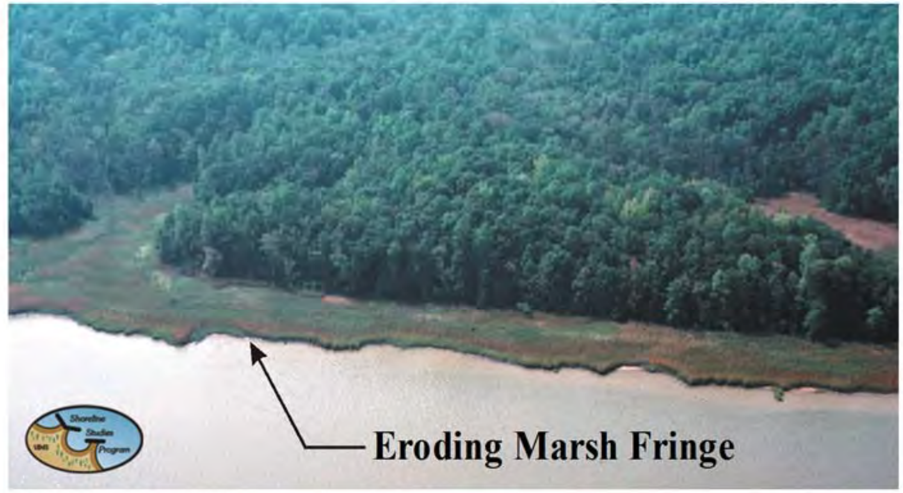
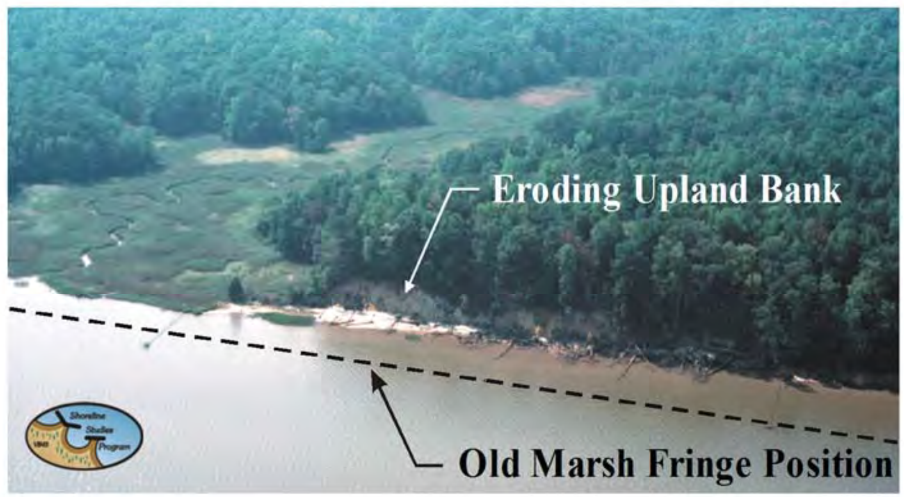
Hardaway, Jr., C.S. & Byrne, R.J. (1999). Shoreline Management in Chesapeake Bay. Special Report in Applied Marine Science and Ocean Engineering Number 356. Gloucester Point, VA: Virginia Institute of Marine Science. http://web.vims.edu/physical/research/shoreline/docs/ShorelineErosionInCBay.pdf

Shoreline Evolution

This marsh fringe along the York River in James City County, Virginia is eroding on the water side, but it is wide enough to protect the upland region from wave attack.



York River shoreline with fringe marsh absent due to erosion. The upland banks are directly exposed to the force of the waves. The result is eroding upland banks.



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Shoreline Evolution

Exposed and eroding upland banks along the Rappahannock River, Virginia. Note: Basal clay acts as a groundwater perch causing the upper layer of sand to slump.

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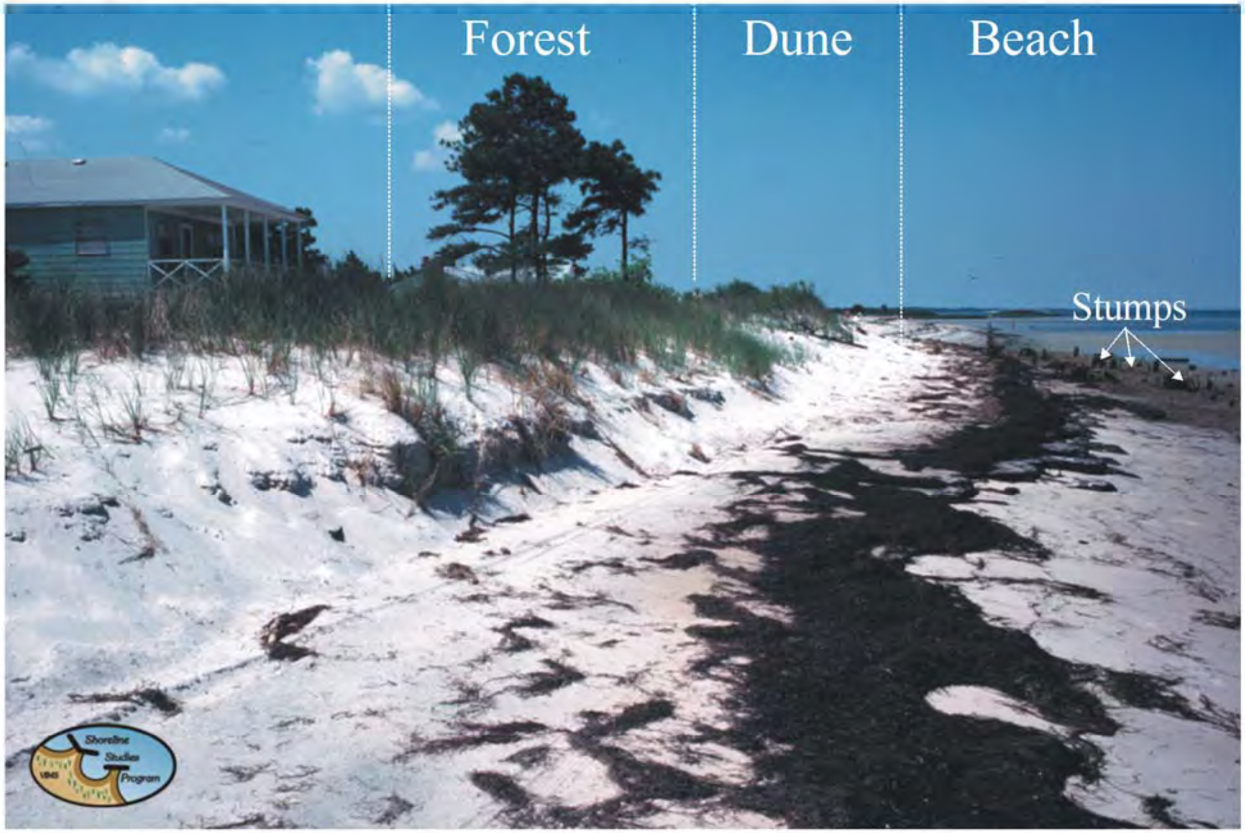
Hardaway, Jr., C.S. & Byrne, R.J. (1999). Shoreline Management in Chesapeake Bay. Special Report in Applied Marine Science and Ocean Engineering Number 356. Gloucester Point, VA: Virginia Institute of Marine Science. http://web.vims.edu/physical/research/shoreline/docs/ShorelineErosionInCBay.pdf

Shoreline Evolution

Dune and beach system along the Chesapeake Bay, Mathews County, Virginia. Old stumps in the nearshore area are evidence of landward migration of dune and beach systems.



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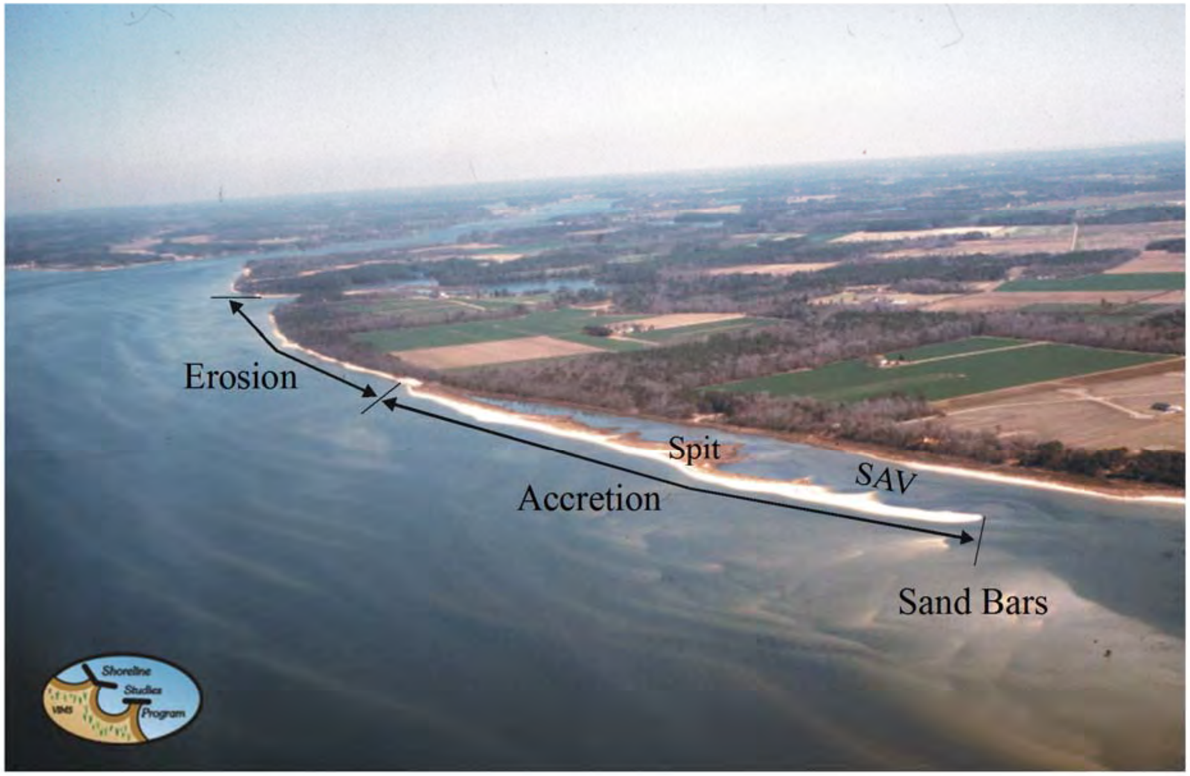
Shoreline Evolution

Erosion of sandy upland banks along the Eastern Shore provides significant sediment to create spits and offshore sand bars that protect the "mainland" from wave attack in addition to providing a haven for submerged aquatic vegetation.



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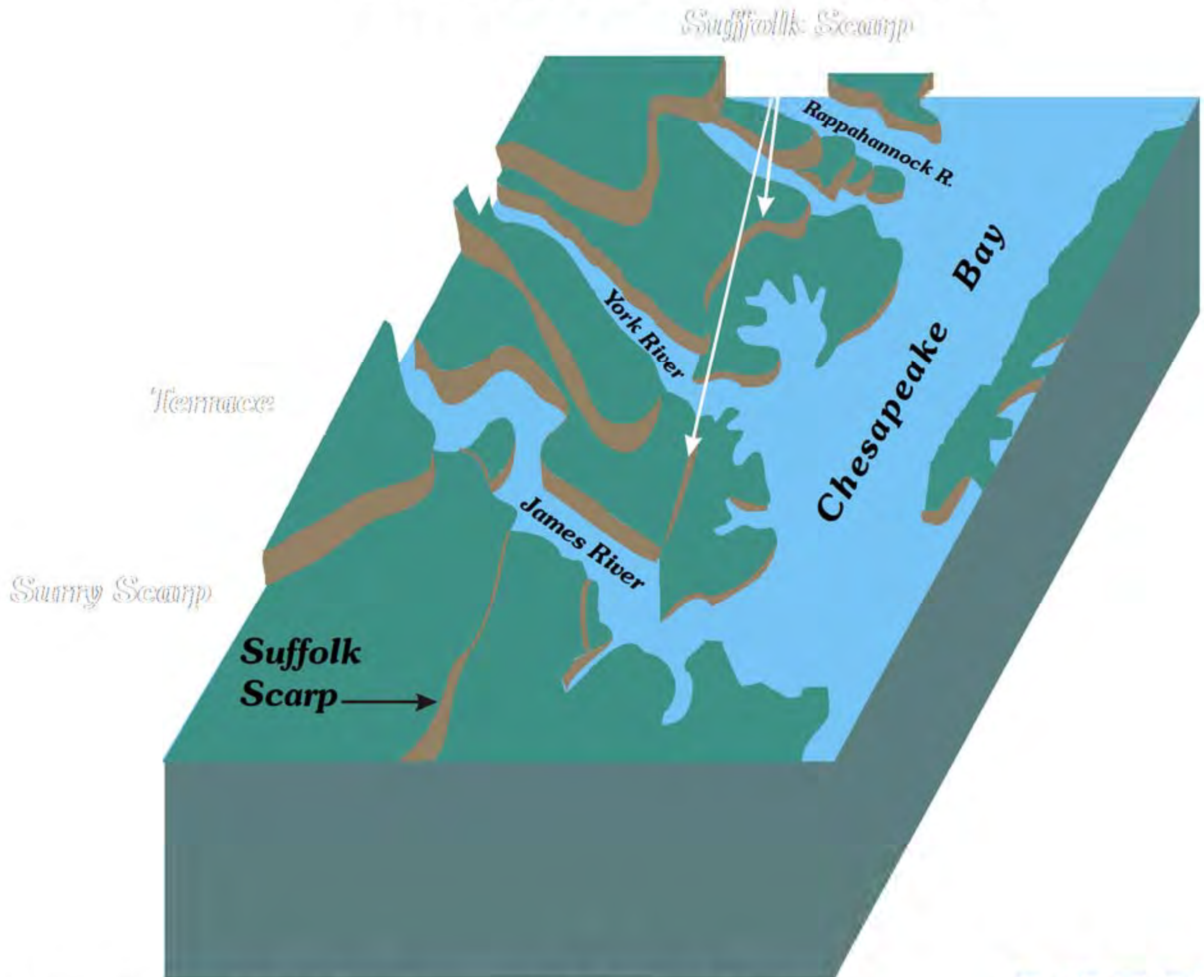
Shoreline Evolution



Modified from Peebles (1984) for Hardaway & Byrne (1999)

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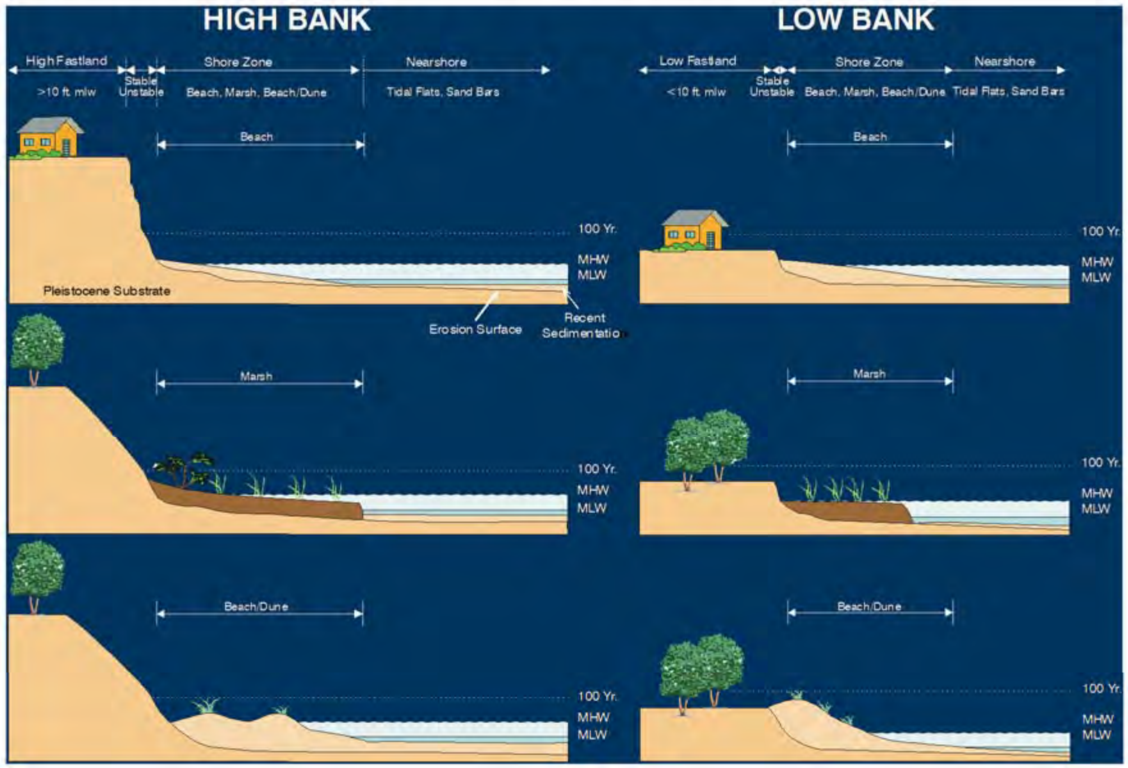
Peebles, P.C. (1984). Late Cenozoic landforms, stratigraphy, and history of sea level oscillations in southeastern Virginia and northeastern North Carolina (PhD Thesis). Williamsburg, VA: College of William & Mary.
Hardaway, Jr., C.S. & Byrne, R.J. (1999). Shoreline Management in Chesapeake Bay. Special Report in Applied Marine Science and Ocean Engineering Number 356. Gloucester Point, VA: Virginia Institute of Marine Science. http://web.vims.edu/physical/research/shoreline/docs/ShorelineErosionInCBay.pdf

Shoreline Erosion

Six typical shoreline profiles around Chesapeake Bay. The stability of the bank face is dependent upon the width and type of shore zone features. Wide beaches/dunes and marsh zones can offer significant wave protection even during storms.



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Hardaway, Jr., C.S. & Byrne, R.J. (1999). Shoreline Management in Chesapeake Bay. Special Report in Applied Marine Science and Ocean Engineering Number 356. Gloucester Point, VA: Virginia Institute of Marine Science. http://web.vims.edu/physical/research/shoreline/docs/ShorelineErosionInCBay.pdf

Shoreline Erosion

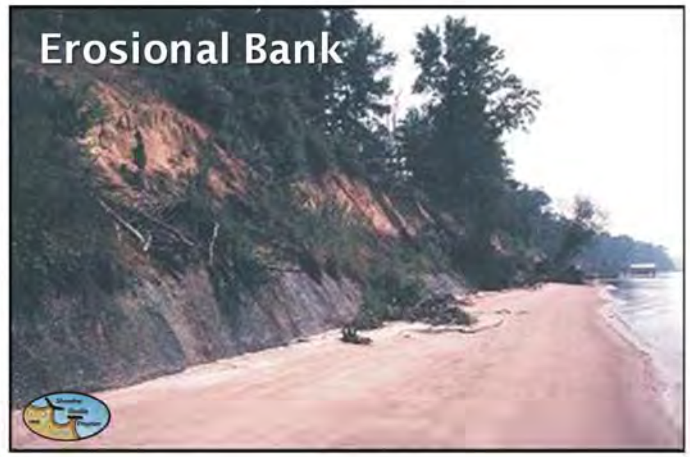
Photos indicating different conditions for low banks. A stable bank has a wide marsh and vegetated bank.

The erosional bank has no marsh and a scarped bank. The transitional bank does not have an actively eroding bank, but the narrow fringe marsh in front is eroding. The bank may be impacted under storm conditions. Once the marsh is entirely gone, it will be come an erosional bank.

Hardaway, Jr., C.S., Milligan, D.A., Hobbs, III, C.H., Wilcox, O'Brien, K.P., & Varnell, L.M. (2010). Mathews County Shoreline Management Plan. Gloucester Point, VA: Virginia Institute of Marine Science. https://publish.wm.edu/reports/178/

Shoreline Erosion

Photos indicating different conditions for higher banks. A stable bank has a marsh and vegetated bank.



The erosional bank has a beach created primarily from material eroded from the bank. The transitional bank may be undercut with little or no marsh present. The marsh fringe is entirely gone, it will be come an erosional bank.

Hardaway, Jr., C.S., Milligan, D.A., Hobbs, III, C.H., Wilcox, O'Brien, K.P., & Varnell, L.M. (2010). Mathews County Shoreline Management Plan. Gloucester Point, VA: Virginia Institute of Marine Science. https://publish.wm.edu/reports/178/

Primary Design Elements

- Fetch
- Shoreline orientation
- Shore Morphology
- Bank Height-condition-Composition
- Shoreline Erosion Rate
- Nearshore morphology/stability
- SAV
- Tide range
- Storm Surge Frequency
- Boat wakes
- Sunlight (often over looked)

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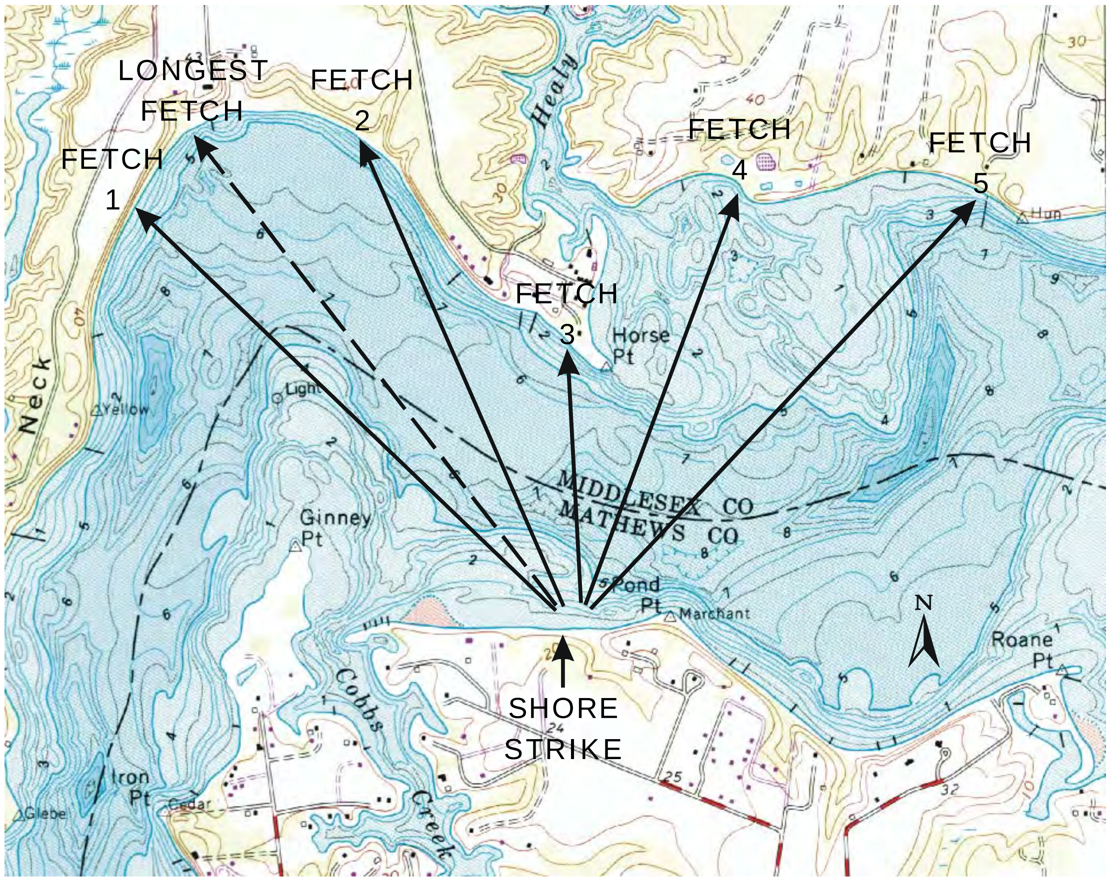
Reach Assessment

Measured parameters include average fetch (AF=(F1+F2+F3+F4+F5)/5) and longest fetch. Also shown is shore strike from which the wind/wave window for fetch and shore orientation are established (after Hardaway *et al*., 1999). Shore orientation in this case is about due north.



Fetch is defined as the distance over which wind can blow to generate waves. This average distance can be used to approximate the amount of energy impacting a shoreline.

Wave Energy

Wave Energy in Chesapeake Bay relative to average fetch:

Low energy : < 1.0 mile

Medium energy : 1.0 to 5.0 miles

High energy: 5.0 to 10.0 miles

Very High energy: > 10.0 miles

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Shore Morphology

Shore morphology is an important consideration in shore protection design because certain shore types, such as pocket or embayed, provide protection themselves. Open, straight shorelines tend to receive the full impact of waves, and irregular shorelines can break up the wave crests along its length, reducing impacts. Also, little sand may be transported around a major headland, creek mouth, tidal inlet, or major change in orientation.

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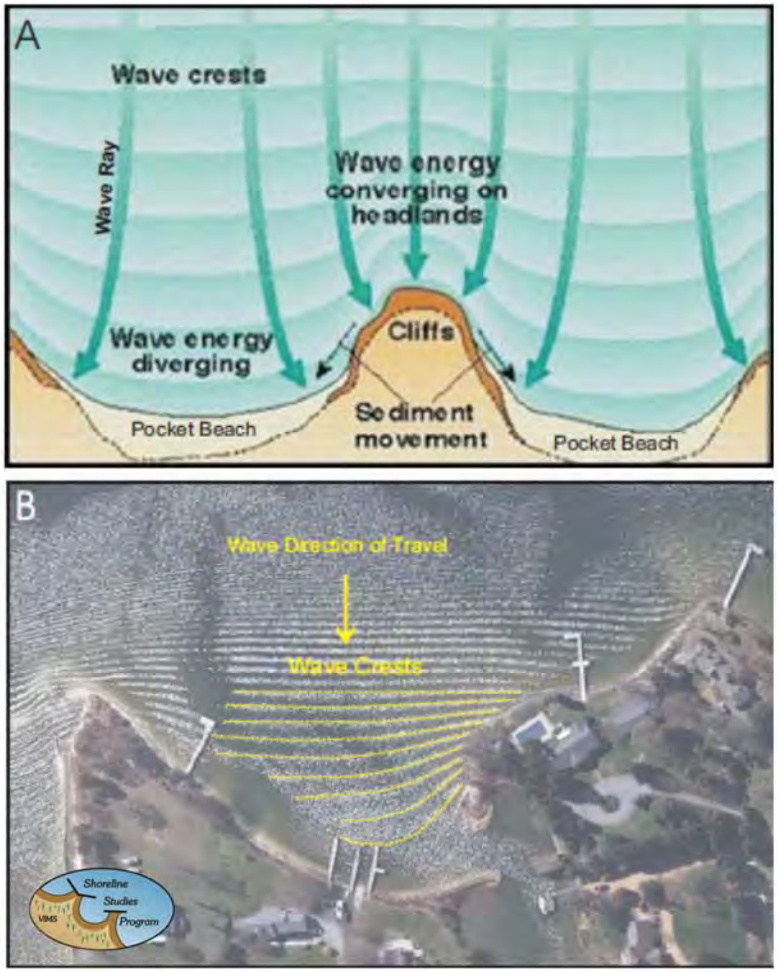
Hardaway, Jr., C.S., Milligan, D.A., & Duhring, K. (2017). Living shoreline design guidelines for shore protection in Virginia's estuarine environment (SCRAMSOE #463). Gloucester Point, VA: Virginia Institute of Marine Science. https://doi.org/10.21220/V5CF1N



Hardaway et al., 2017

Shore Attenuation

Headlands tend to converge wave energy such that they may be exposed to higher waves while pocket beaches and embayments tend to diverge waves so that their energy is somewhat dissipated before they impact the shoreline.

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Hardaway et al., 2017

Nearshore Morphology and Stability

Top: Sand bars north of the channel will attenuate waves while the shoreline adjacent to the channel has no bars and will feel the full effect of the waves impacting the shoreline.

Bottom: SAV and sand bars in the nearshore will attenuate waves.

Sand flats indicated sand is available to the overall system and generally mean that the bottom is stable enough to hold a structure.

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Wind Data Summary

Number of Occurrences									
(mph)	S	SW	W	NW	N	NE	E	SE	Total
0-5	6072	5452	7272	7364	36097	2879	3833	3618	72587
5-10	40130	32463	28302	26169	27514	26834	22295	20215	223922
10-20	25990	33523	18711	17884	34078	31018	13132	9523	183859
20-30	1924	3740	2161	2496	4569	3969	811	351	20021
30-40	46	112	79	49	168	287	51	18	810
40-90	0	1	2	2	14	20	9	1	49
Total	74162	75292	56527	53965	102440	65007	40131	33726	501250
Percent of Occurrences									
(mph)	S	SW	W	NW	N	NE	E	SE	Total
0-5	1.2	1.1	1.5	1.5	7.2	0.6	0.8	0.7	14.5
5-10	8.0	6.5	5.6	5.2	5.5	5.4	4.4	4.0	44.7
10-20	5.2	6.7	3.7	3.6	6.8	6.2	2.6	1.9	36.7
20-30	0.4	0.7	0.4	0.5	0.9	0.8	0.2	0.1	4.0
30-40	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2
40-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14.8	15.0	11.3	10.8	20.4	13.0	8.0	6.7	100.0

Norfolk 1948-2010

Created by VIMS, Shoreline Studies Program

Location	Annual Chance (feet MLLW)			
	10%	2%	1%	0.2%
Chesapeake Bay – Entire Shoreline	5.5	7	7.8	9.8

10 year, 50 year, 100 year, and 500 year storm predicted flood levels relative to MLLW (1983-2001) for Gloucester County's Chesapeake Bay Shoreline

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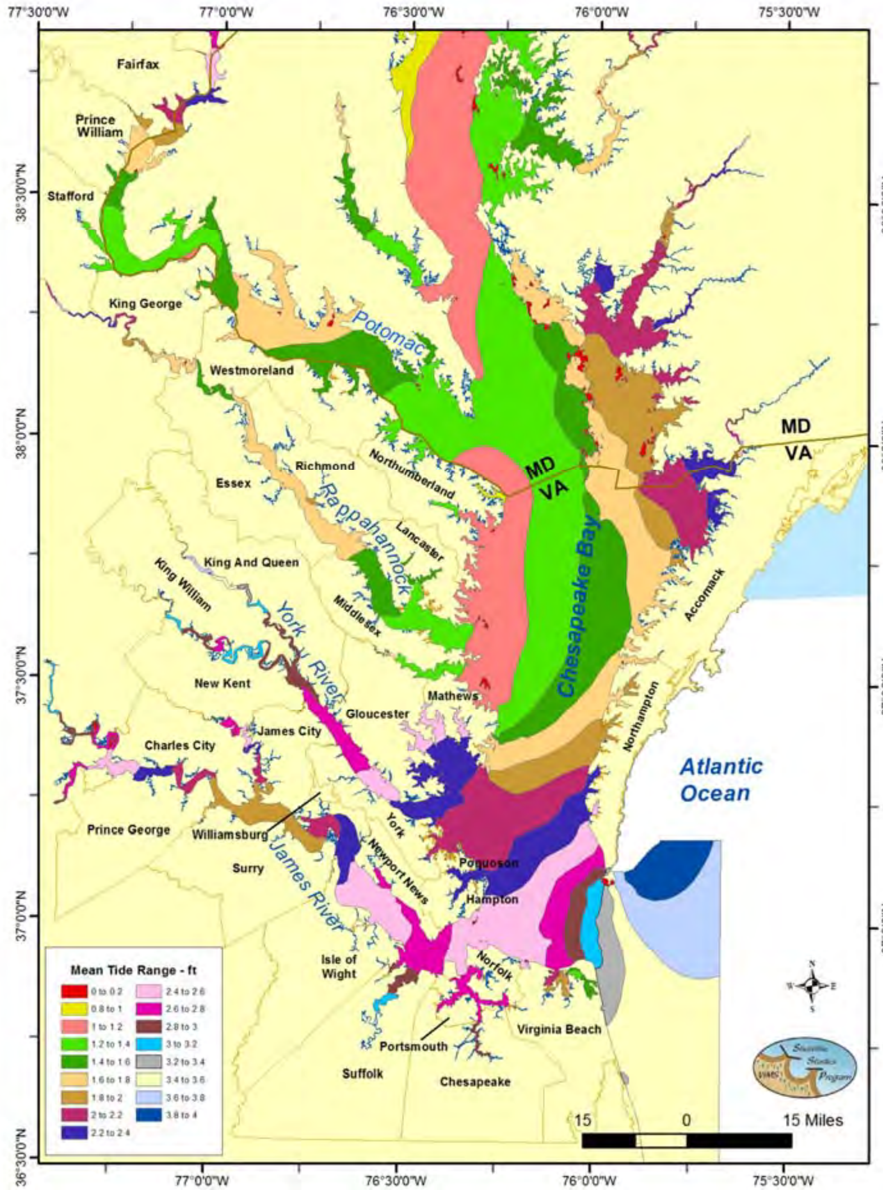
Source: Gloucester County Flood Insurance Report, FEMA (2010). Converted from NAVD88 using NOAA's online program VDATUM.

Tide Range



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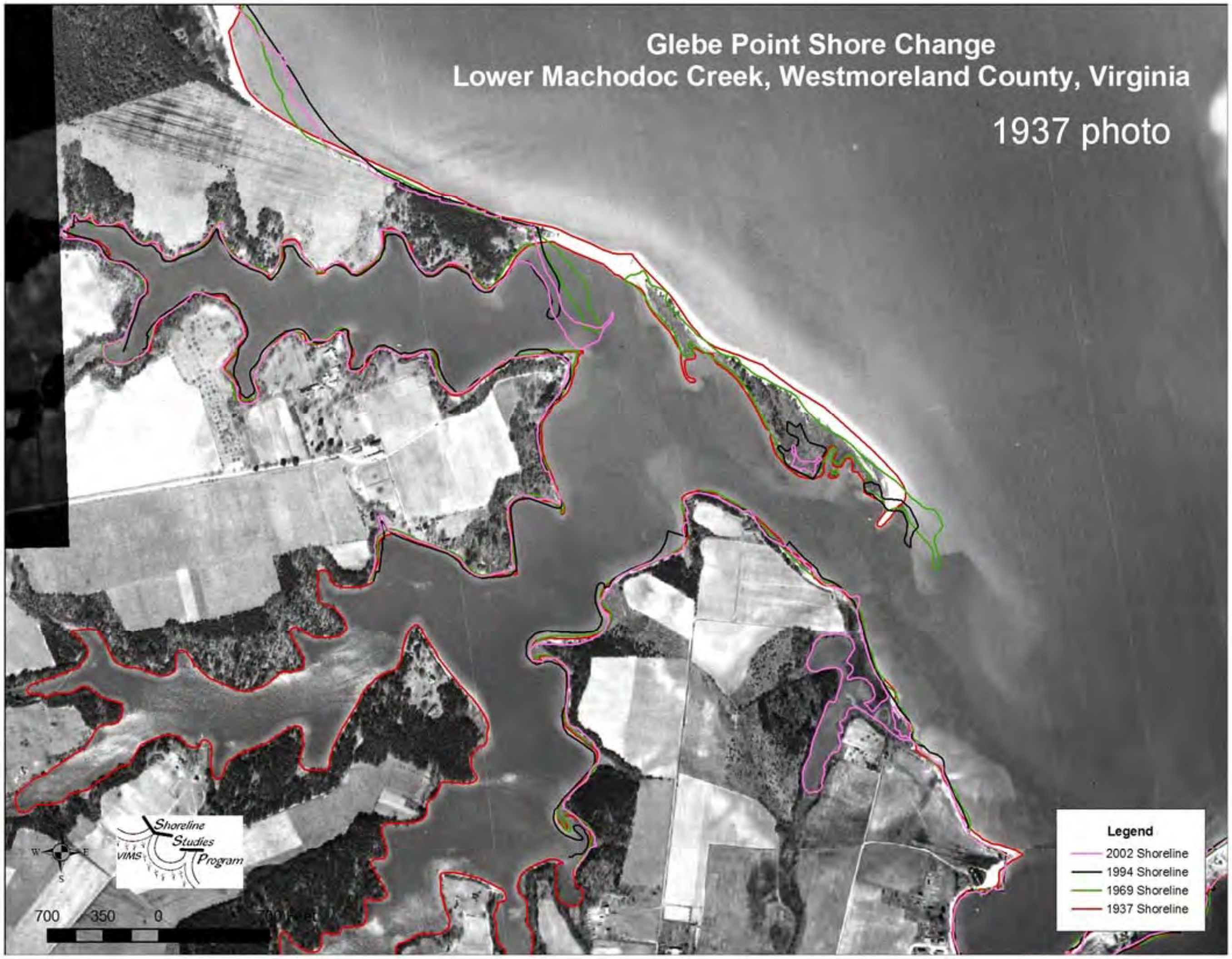
Mean tide ranges in Chesapeake Bay. Tide range polygons interpolated by Shoreline Studies Program personnel in ArcGIS from data points obtained from NOAA Tides & Currents online. A Google Earth map is available at www.vims.edu/research/departments/physical/programs/ssp/shoreline_management/living_shorelines/class_info



Shoreline evolution at Glebe Point in Westmoreland County, Virginia.
Milligan, Donna A., Christine Wilcox, C. Scott Hardaway, Jr, and Mary C. Cox, 2012. Shoreline Evolution: Westmoreland County, Virginia, Potomac River and Rappahannock River Shorelines. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA. https://publish.wm.edu/reports/384/

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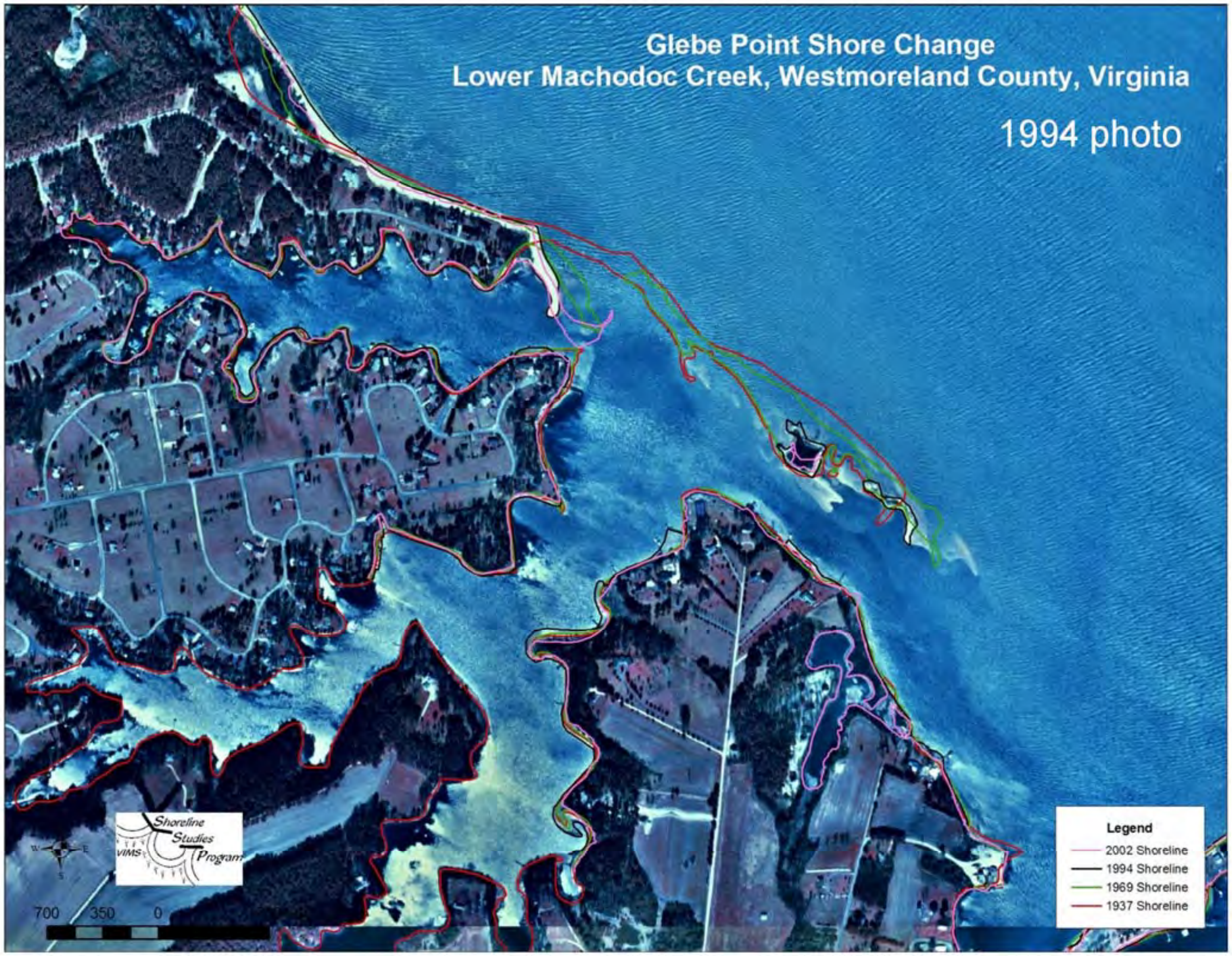

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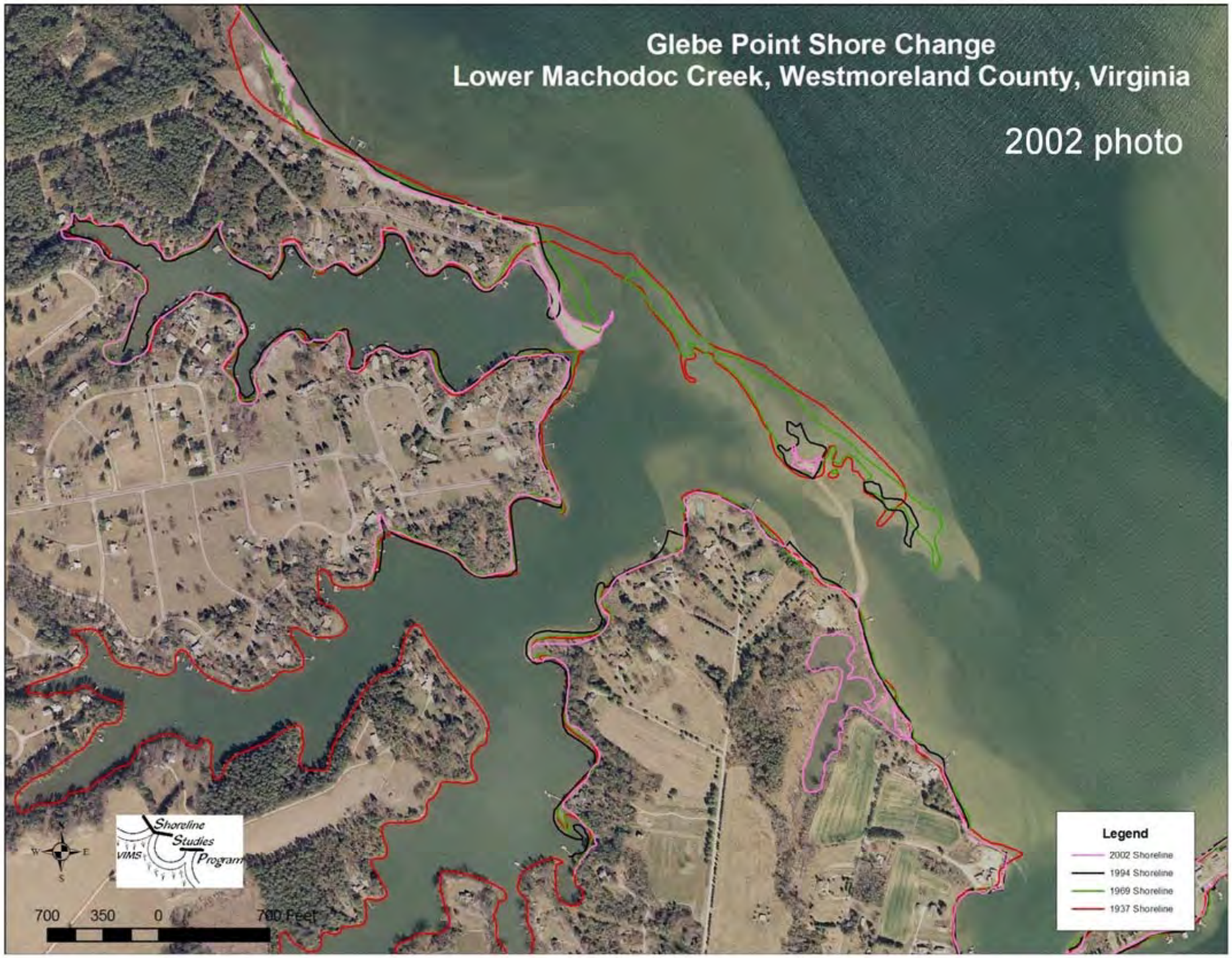

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Marsh Sill

Stone structure placed near MLW

Backfilled with sand and planted with tidal wetland vegetation

- Stone
- Sand
- Plants

All 3 elements usually required for sustainable design

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Marsh Toe Revetment

Sill placed next to an existing wide marsh.

Maintain desirable marsh ecosystem services.

Natural accretion depends on local sediment supply.

Can also spot fill and plant to fill in non-vegetated areas

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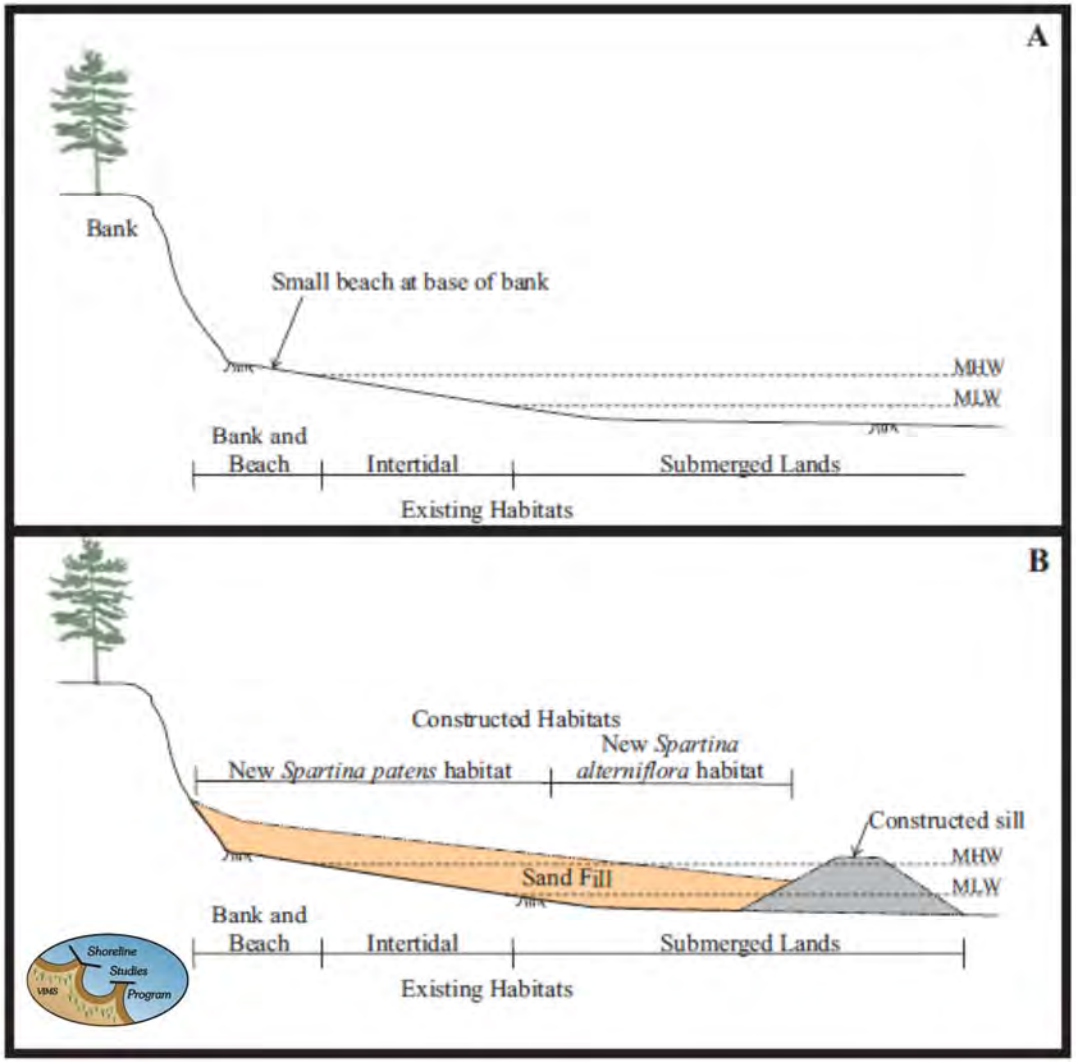
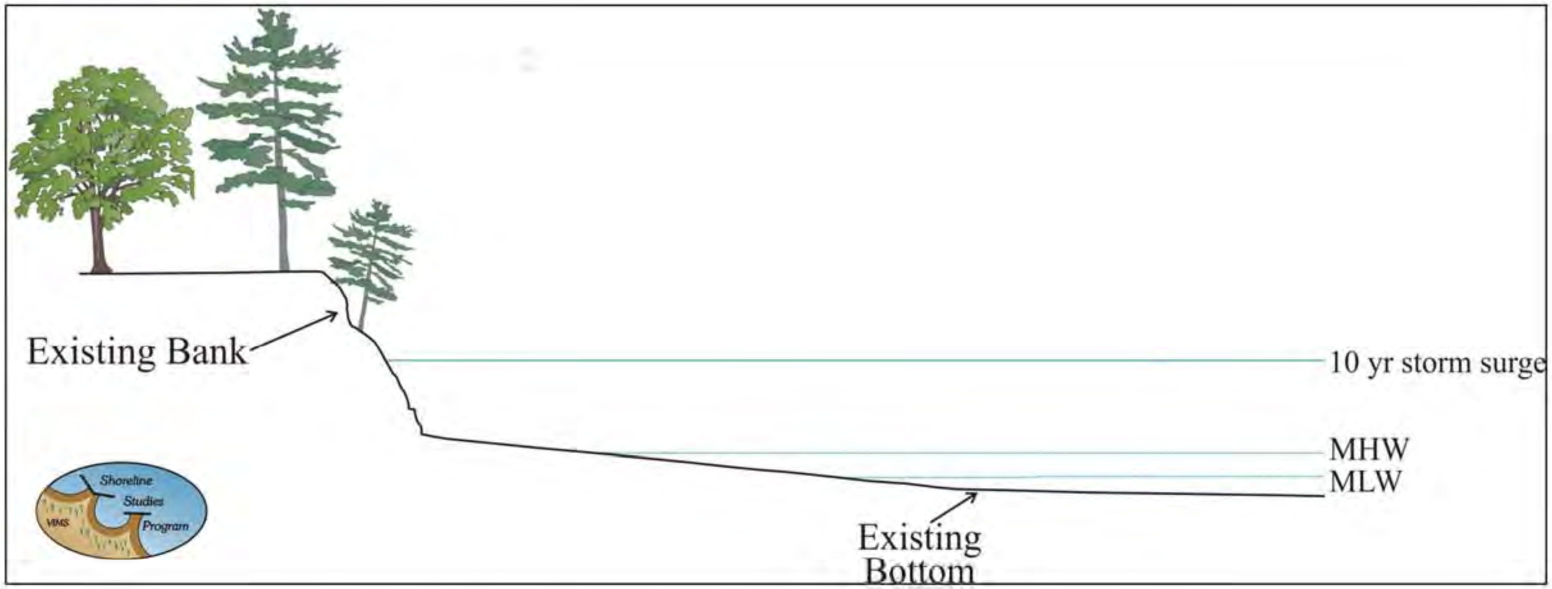
Photo by Karen Duhring



A typical eroding shoreline and bank.

Typical design of marsh sill with beach nourishment.

Marsh Fringe Applications



Steps in the design process: Existing Conditions

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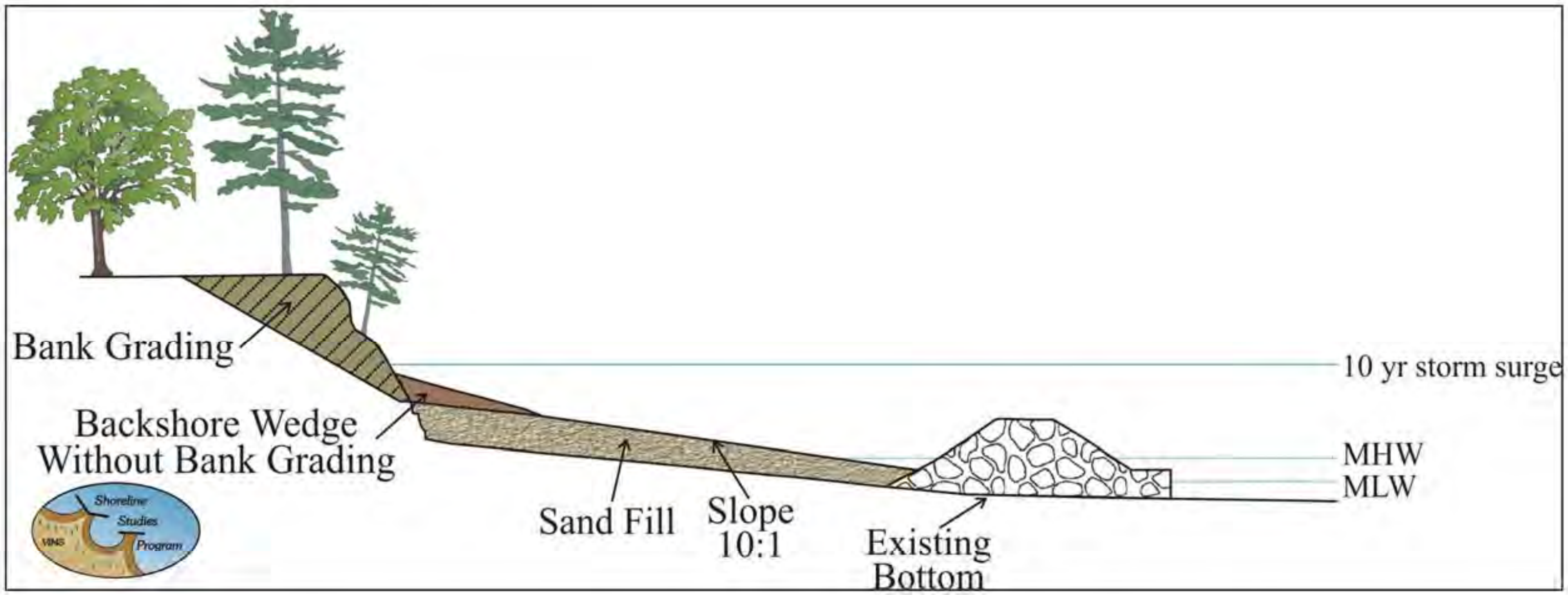
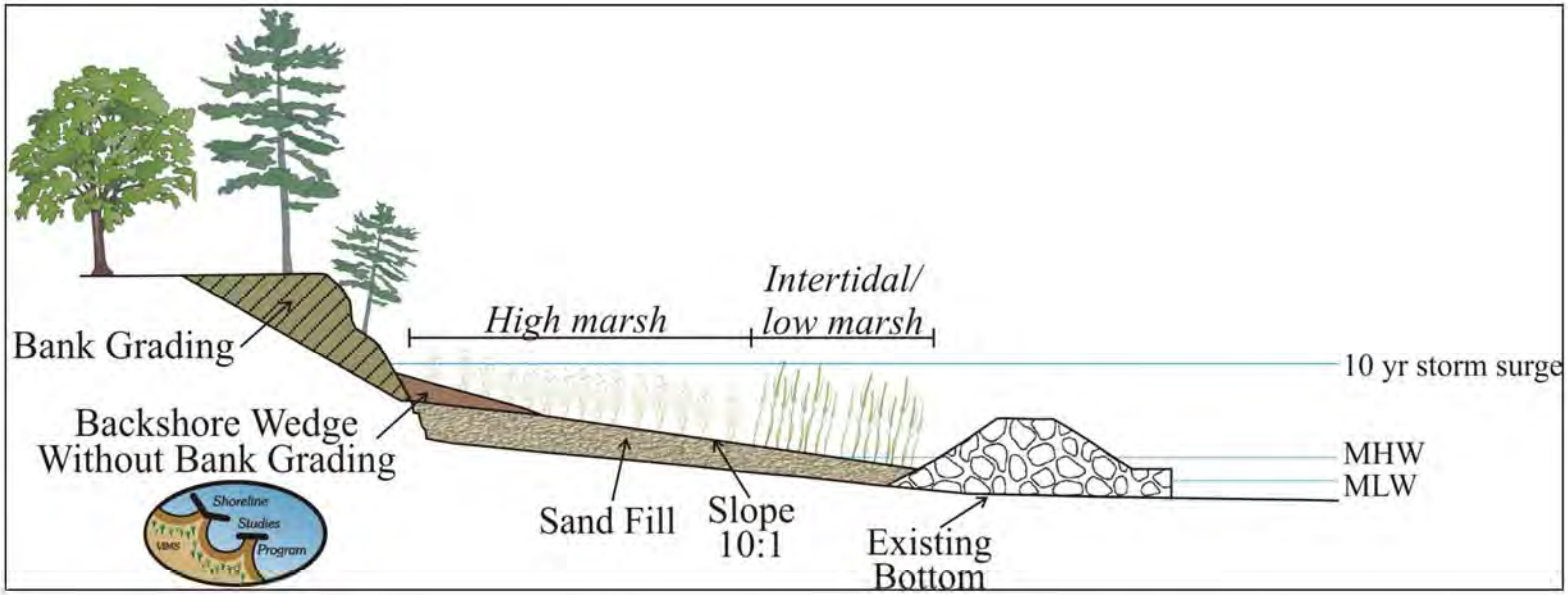
Marsh Fringe Applications



Steps in the design process: Design structure, sand fill, and bank grading (if needed).

Marsh Fringe Applications



Steps in the design process: Planning high and low marsh based on elevations of sand fill.

Hull Springs Farm
Sill and Revetment

Description

- Grant-funded public demonstration site
- Design process 2005-2008, build 2008
- Large historic oak tree at top of bank
- Bank erosion during design period, modification to include revetment
- 2 different tidal openings
- Low energy with long fetch to NE over one mile
- HIGH and Low Bank

Lessons Learned

- Level of protection needed underestimated
- Unstable bank disguised by dense vegetation cover
- Just one tree can limit options

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Hull Springs Farm Existing Conditions Before Project

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Hull Springs Farm

Fetch

Historic tree that was threatened by erosion and needed to be preserved.

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Hull Springs Farm

Longwood University's Hull Springs Farm on Glebe Creek.

Top: Before the shoreline project, the bank is eroding in front of the Manor House.

Bottom: After the project, the shore zone was widened with sand behind the sills.

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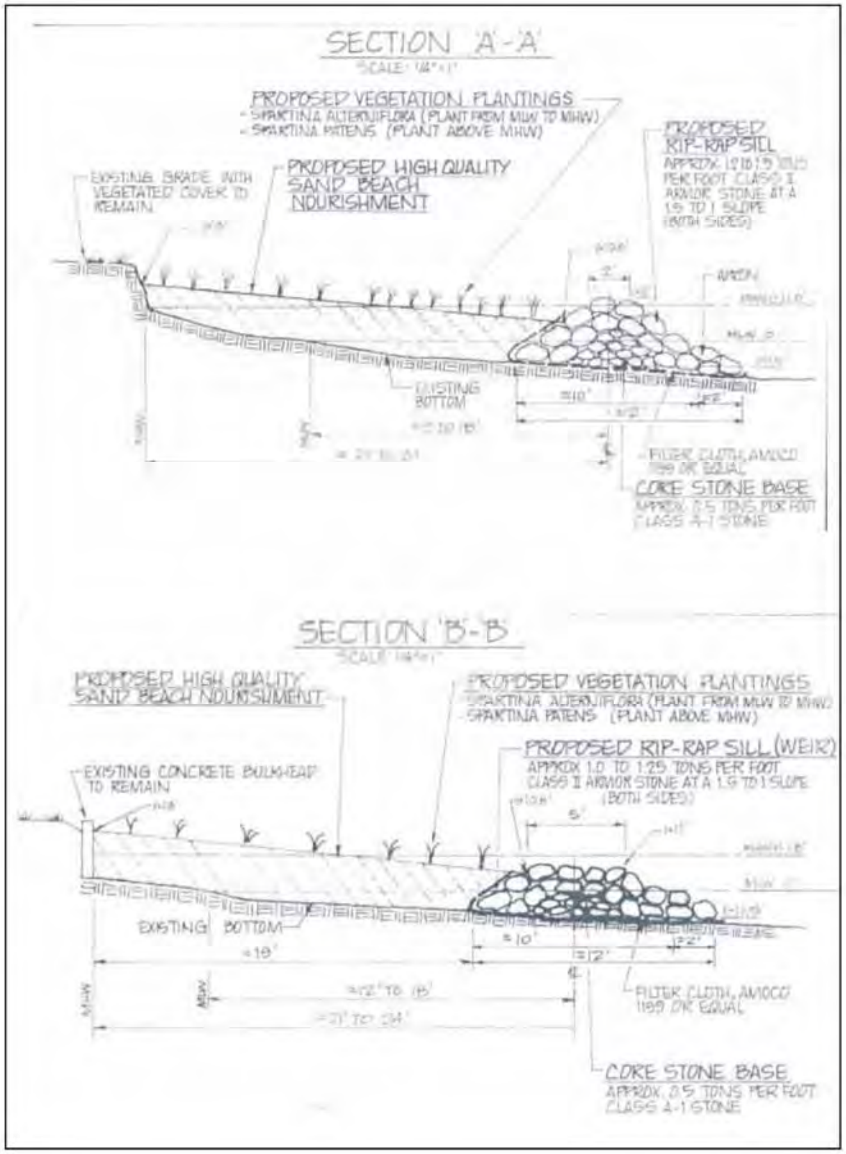
Hardaway, Jr. C.S., D.A. Milligan and K. Duhring, 2010. **Living Shoreline Design Guidelines for Shore Protection in Virginia's Estuarine Environments**. Special Report in Applied Marine Science and Ocean Engineering #421. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Va. https://publish.wm.edu/reports/559/



Typical cross-sections for sill built at Hull Springs Farm.

Permit drawings by Bayshore Design, LLC.

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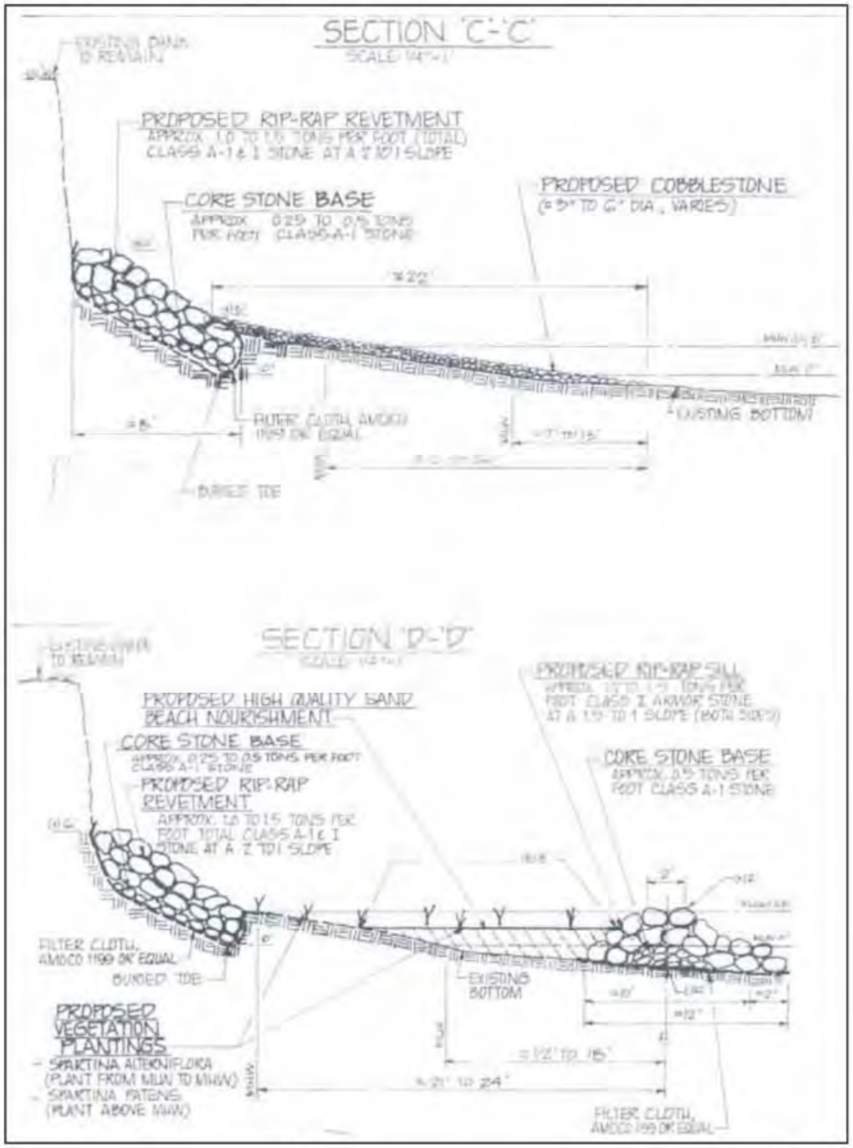

Typical cross-sections for sill built at Hull Springs Farm.

Permit drawings by Bayshore Design, LLC.

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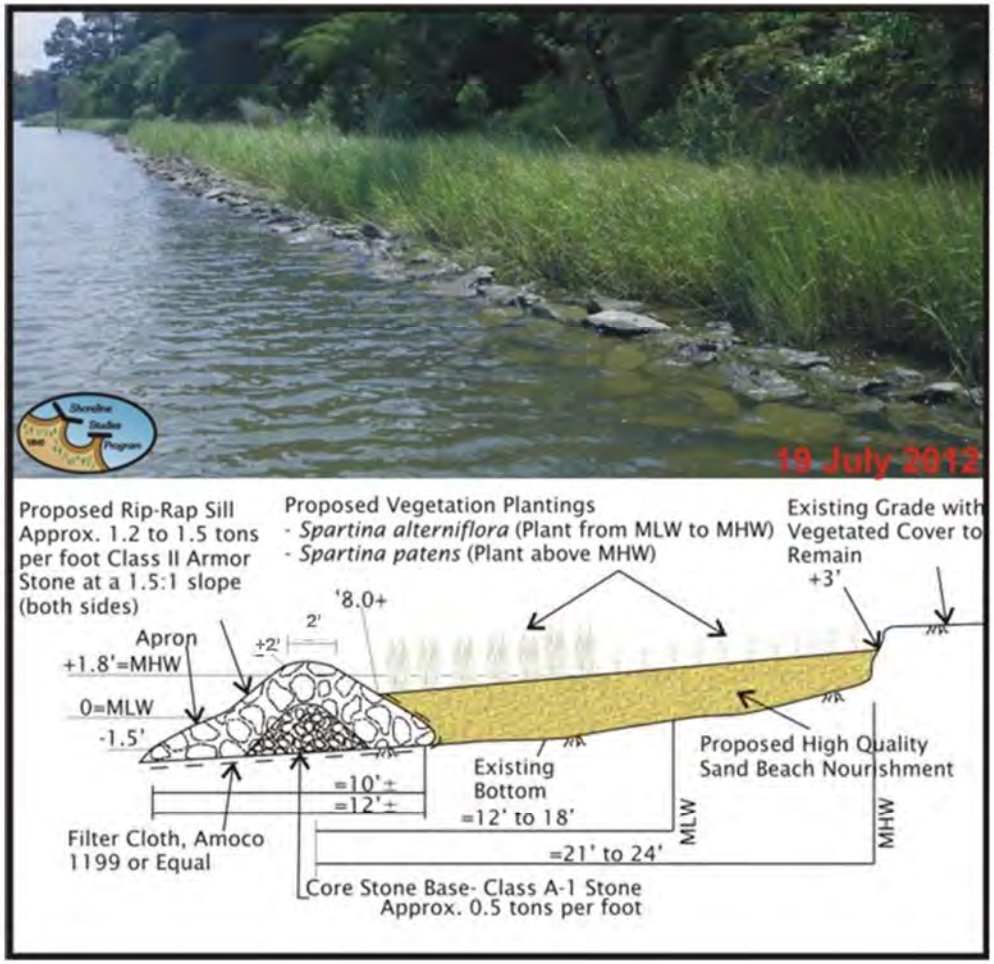
Hull Springs Farm
Sill & Revetment

Aug
2008

June
2009

Post construction (pre-planting) and after 1 year.

Structural Design Considerations



Longwood University's Hull Springs Farm four years after construction and the cross-section used for construction

Hull Springs Farm
Sill & Revetment

April
2010

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Two years after construction, the marsh grass is filling although some bare spots occurred. Also shown is the revetment that was built along the backshore for complete protection of the bank (Top Left) and the cobble window that was built in the system (Bottom).

Hull Springs Farm
After 7 Years

The marsh behind the sill has filled in over the 7 years post-project (Top). The backshore is being colonized by other types of vegetation (Bottom).

Foxx: Sturgeon Creek

Description

- Constructed in 2005
- 250 ft project
- Longest fetch to ENE 1,500ft
- High sandy bank transitions to low spit
- Bank grading provided sand to project
- LOW energy

Lessons Learned

- Site has withstood several significant storms
- Marsh established quickly.
- No signs of bank scarping

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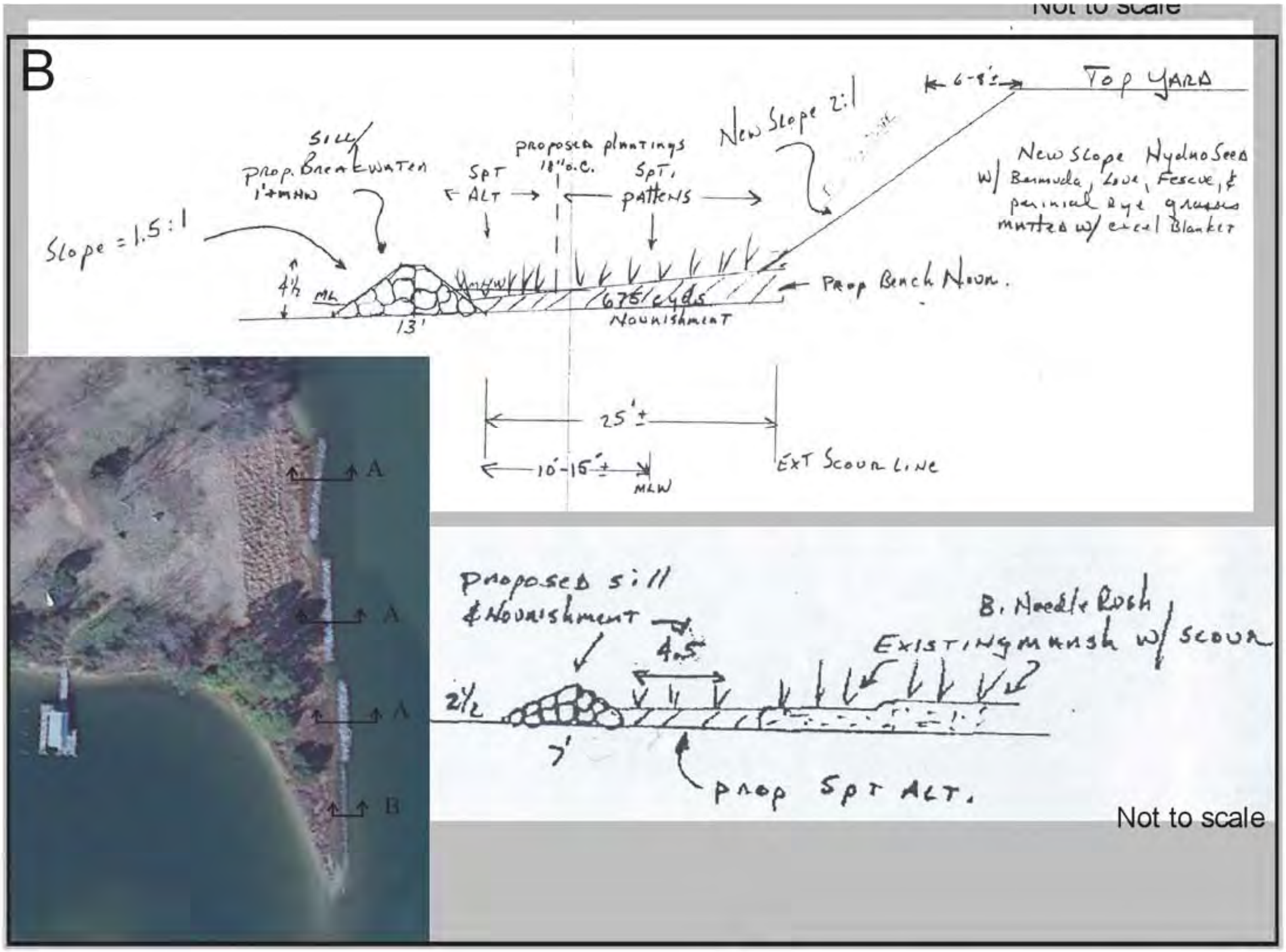
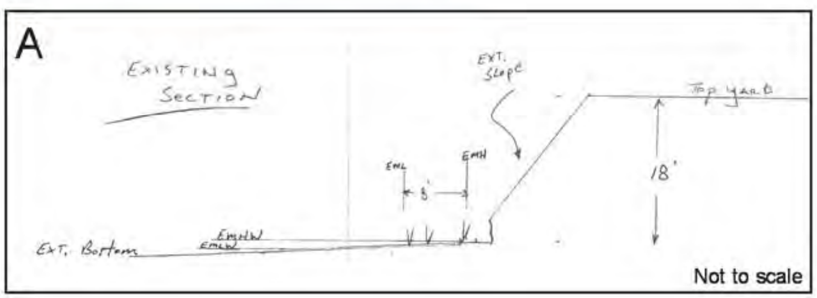
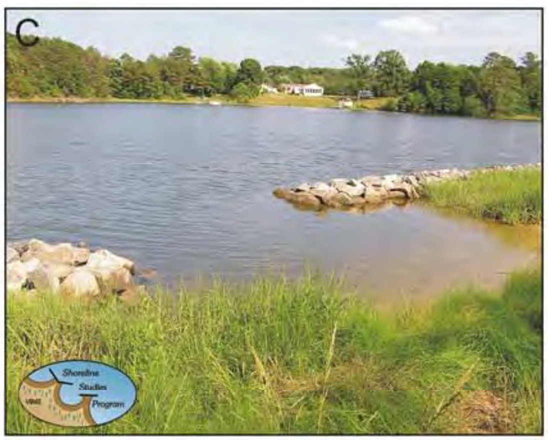




Permit Drawings, Riverworks, Inc.

FOXX: Sturgeon Creek



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