CHAPTER 5: COASTAL EROSION

INTRODUCTION

Standing on the pristine beach of Cobb Island in Northampton County, one would never know that the now-tranquil barrier island was a bustling recreational center in its prime where a harpist once entertained guests in the island's grand resort hotel (Figure 4.1: Advertisement for Cobb's Island Hotel).

Figure 1: Advertisement for Cobb Island Hotel

The Cobb's Island Hotel might have been lost in a single storm, but the setup came over the course of a couple of decades as the hotel went from being 500 yards from the surf to within 50', according to authors of "A Short History of the Virginia Barrier Islands" (Barnes and Truitt, 1997). Erosion from a series of late century storms had made the hotel easy pickings for a nor'easter-hurricane double-punch in 1897.

Over the course of the subsequent 100 years, Tangier Island would see more than half of its land mass recede into the Chesapeake Bay, but officials are working to make sure that Cobb Island's history is not Tangier Island's future. The Town received a commitment from the Commonwealth and the Corps of Engineers in 2012 to build a seawall and jetty to protect the Town harbor.

There are other factors that differentiate Cobb and Tangier Islands. For example, the conditions and energy to which they are subjected are vastly different. Cobb Island is part of a long chain of barrier islands subjected to a constant barrage of plunging ocean waves breaking onto the beach, while Tangier Island is within the Chesapeake Bay where wave energy is less intense and erosion is augmented primarily by sea-level rise and subsidence.

Erosion itself can be described in simplistic terms as energy moving sediment. It can happen so incrementally that it goes almost unnoticed in the short-term, and is best measured in years, or so dramatically that what was there one day is gone the next. Although erosion is a natural coastal process, it becomes problematic when it threatens lives or property, and with sea-level rise, it is doing so with greater frequency.

On a peninsula, water and waves come to mind as primary drivers of erosion, but wind is also a powerful sculptor of land. The rate of erosion is also greatly influenced by underlying geology, and sometimes by man-made interventions in those natural processes - like the seawall and jetty proposed for Tangier. Those interventions can also have negative effects, like accelerating erosion in other locations, or destruction of natural bottom in front of the structure from reflected wave energy.

FEMA's Coastal Construction Manual describes these ways in which erosion can threaten coastal buildings:

- Destroying dunes or other natural protective features,
- Destroying erosion control devices,
- Lowering ground elevations,

- Undermining shallow foundations, and reducing penetration depth of pile foundations,
- Transporting beach and dune sediments landward, where they can bury roads, buildings and marshes,
- Breaching low-lying coastal barrier islands exposing structures on the mainland to increased flood and wave effects, and
- Eroding coastal bluffs that provide support to buildings outside the floodplain itself.

This chapter succinctly reviews the forces at work that cause erosion, how erosion changes the coastline and adjacent landforms over time, and erosion control measures that have attempted to redirect - at least temporarily - water's capacity to reshape land.

While the section does look at changes to portions of the Eastern Shore landscape over time, risk assessment is not found in this chapter, but can be found in each of the locality chapters, beginning with Chapter 8.

NATURAL FORCES AND CONDITIONS

CAUSES OF EROSION

Large tropical and extratropical storms are associated with three of the major causes of erosion: Water, wind, and waves. A list of major storms affecting the region can be found the Chapter 1: Hazards on the Shore.

WATER

Water moving over land surfaces picks up and transports sediment. Surface erosion by water will depend on the volume of water, the speed at which it is moving, the surface characteristics (vegetative cover, permeability, sediment grain size), and its slope (EPA, water.epa.gov). Coastal floods identified in the previous chapter can be sources of coastal erosion as they pick up and move large quantities of water-borne sediment to be deposited elsewhere. Erosion from water can degrade coastal bluffs and tidal marshes, causing them to slump into adjacent water bodies.

Localized scour - the removal of sediment from around a fixed structure - can result from water moving at high velocity. Scour can undermine slabs or other at-grade foundations, causing them to fail, or expose other structural elements (FEMA Coastal Construction Manual, 2011).

Regardless of the source, sediment transported by water is left somewhere, and even experienced boaters have been caught in spring on shoals that were not there the previous fall. Shoaling in some stretches of the Virginia Inside Passage, once a continuous seaside water passage buffered from the sea by the mainland to the west and the barrier islands to the east, has now rendered sections impassable, and others passable only at high tide.

WIND

Anyone who has been stung by sand carried in a gust on the beach has felt directly the effects of sediment being transported by wind. Exposed soil is susceptible to wind erosion, and in coastal areas, sandy areas are prevalent. The same wind that shifts sand on the beach can lower ground elevations around coastal buildings, exposing those built in velocity zones to higher-than-anticipated forces, and exposing buildings that were not built to withstand velocity flows to those hazards. Like water, wind can also scour sand from around structural supports (FEMA Coastal Construction Manual, 2011).

Wind also contributes to wave height – another erosional force - through the interaction of three factors: wind speed, duration, and fetch - the distance over water that wind blows in a single direction. Slow wind speed will produce small waves, regardless of duration and fetch. Strong winds lasting only a few minutes will not produce large waves, and strong winds over a long period, but over a short fetch, will not result in large waves. All three factors must be present (NOAA, oceanservice.noaa.gov).

WAVES

Away from shore, waves do not have much forward motion, but as they approach the shore, friction with the ocean bottom gives the top of the waves forward momentum, causing the waves to break. The mass of forward-moving water breaking into the shore gives waves their erosive power (Hyndman and Hyndman, 2011).

With perpendicular or near-perpendicular waves, sand is pushed onto the beach by breaking waves, and pulled back as the wave washed back into the ocean. Sometimes waves break at angles, pushing sand on shore at an angle, but as the water is pulled back into the ocean, it is pulled back in perpendicularly, which nudges sand along the coastline through a process known as longshore drift, and this drift generally moves sand southward along the Atlantic coast of the Eastern Shore (Hyndman and Hyndman, 2011).

This pattern moves sediment grain-by-grain to build long stretches of beach, a pattern that is repeated, within zones, along the entire Atlantic coastline, taking from one area of the zone through erosion, and depositing in another through accretion.

The general pattern of transport in the Eastern Shore area is southward along the Atlantic Coastline into the Chesapeake, and southward within the bay to the lower Chesapeake where it is deposited either in the bay or tributaries of lower bay rivers (USACE, 2015) (Figure 2).

Figure 2: Net sediment transport pathways for Chesapeake Bay and Atlantic area off the Virginia Coast. Source: "North Atlantic Coast Comprehensive Study Report" USACE, 2015

EROSION AND UNDERLYING GEOLOGY

The rate of erosion of a given area is largely dependent on its underlying geology. Figure 3 is taken from the USACE North Atlantic Comprehensive Study, mandated to examine coastal risk following Hurricane Sandy. The figure depicts the mid- and northern Atlantic's coastal geology, with the Chesapeake Bay side of the Eastern Shore characterized as "drowned river valley" and the ocean side as "barrier coast."

Drowned river valley coastlines are commonly characterized by low banks, marshes, and beaches fronting the mainland. Bayside dunes are extant in both counties, with 4.9 miles of dune shoreline in Accomack County and 10.2 miles of dune shoreline in Northampton County, including those reaching 20'-50' at Savage Neck Dunes Natural Area Preserve. In addition to the dunes, natural resiliency features include submerged aquatic vegetation beds, oyster reefs, tidal marsh beds, and tidal creeks. Primary drivers of erosion are wave action, wave height, and wind strength and direction, which can direct water into normally dry shore areas.

Atlantic barrier coastlines consist of long and narrow barrier islands, with beach on the seaward side and one or

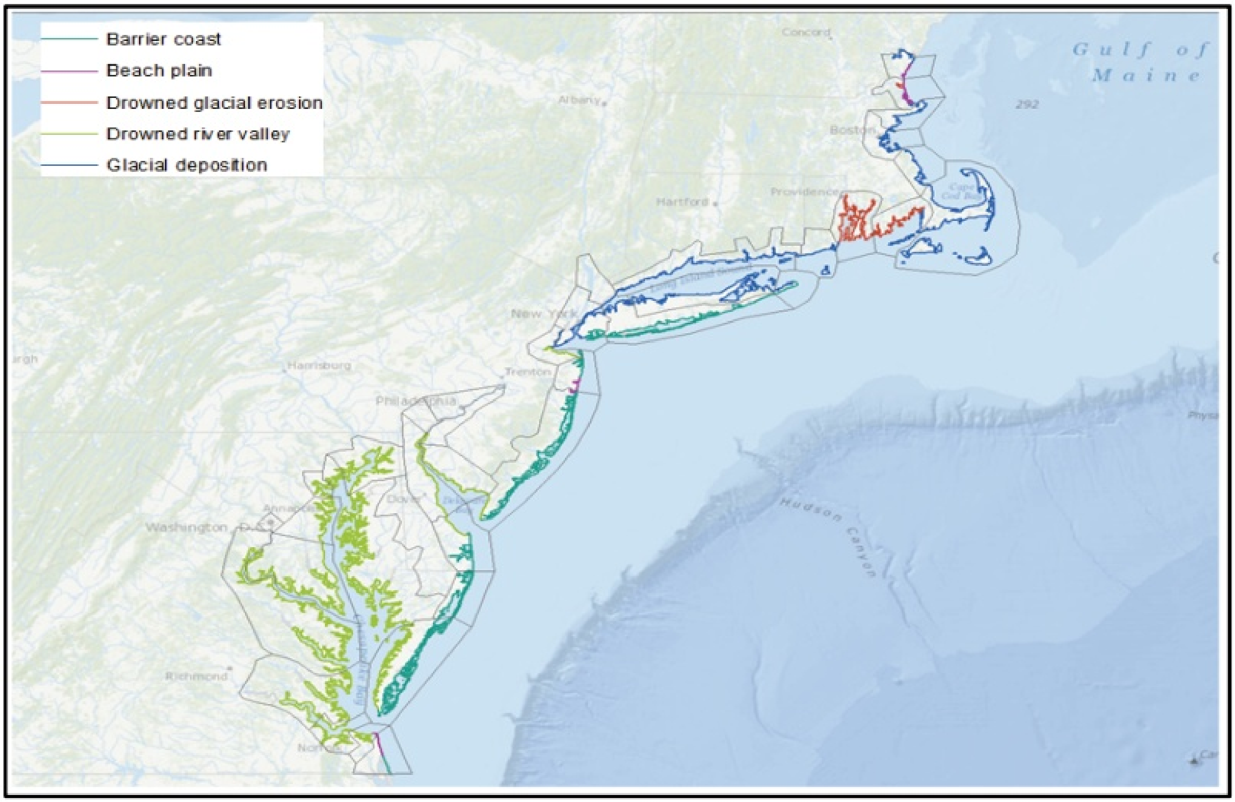

Figure 3: Atlantic Coastal Geology. Source: "North Atlantic Coast Comprehensive Study Report" USACE, 2015.

more bays on the land-facing side that support complex tidal marsh systems. Natural resiliency features include beaches, washover fans, extensive tidal marshes with tidal flats and tidal creeks, mollusk reefs, and submerged aquatic vegetation beds.

The Eastern Shore's seaside includes the longest expanse of coastal wilderness remaining on the Atlantic seaboard and is comprised of thousands of acres of pristine tidal marshes, vast tidal mudflats, shallow lagoons, and navigable tidal channels that support thriving seafood and recreational tourism industries. This unique environment carries the designation of World Biosphere Reserve from United Nations Educational, Scientific and Cultural Organization.

Biodiversity of the barrier island ecosystem may be globally recognized, but it is only one benefit the island chain affords. Barrier islands take the brunt of ocean energy, protecting the habitats and structures behind them. This makes barrier islands important in times of hurricanes, tropical storms and destructive nor'easters. The low wave energy environments allow for thousands of acres of tidal marshes to thrive in the coastal bays behind the islands, increasing their flood mitigation benefits.

Governor, USACE announce funding for Tangier Island jetty

U.S. Army Corps of Engineers Press Release, Norfolk, Nov. 21, 2012

TANGIER ISLAND - Gov. Bob McDonnell and Col. Paul Olsen of the U.S. Army Corps of Engineers traveled today to Tangier Island in the Chesapeake Bay to announce they have signed an agreement to build a long-awaited seawall and jetty to protect the Island's endangered harbor. The project will involve both state and federal funding.

"This is fantastic news," Gov. McDonnell said. "The harbor is the economic heart of Tangier Island, and the center of a significant commercial fishing industry worth millions to Virginia's economy."

The purpose is to protect the channel to the only harbor on the island, and shield the harbor itself from direct wave impact and from damage caused by sheets of ice pushed into the inner channel and harbor. The project also will reduce erosion of the shoreline and sediment flow into the navigation channel.

The cost of the project is currently estimated at $4.2 million, of which the federal government will ultimately pay approximately $3.2 million. The state's share would be $950,000 over the next five years.

Sediment in this environment is moved by both longshore drift, which requires an adequate supply of sediment and "rollover," where high tides erode sand from the ocean side of the island and carry it toward the center or back side of the island (Figures 4 and 5). In addition to wave action, another factor of barrier island erosion is the interruption of the supply of sand by up-stream interventions such as jetties or groins. Storms are unable to remobilize this trapped sediment, and downstream islands become starved for nourishment and erode (USACE, 2015).

Sections of the barrier islands are changing rapidly, with segments of islands disappearing and moving into the back barrier channels and marshes. This is especially true for areas adjacent to active inlets and this phenomenon can be observed in Figure 4. The home that is the subject of the photos no longer exists. The owners saw its fate as inevitable, and burned it rather than have it fall into the sea.

Tidal marshes are also subject to erosion. Some of the worst erosion occurs when winds pick up during mid-tide or from wake generated by motorized vessels. During low tide, the water is not high enough for waves to lap against the land edge, and during high tide, it is buried. However, at mid-tide the water is pushed against the marsh edge and wears away at the edge, (Art Schwarzchild, University of Virginia Long-Term Ecological Research-Anheuser Busch Coastal Research Center, Comments made during March 4, 2015 meeting).

SEA-LEVEL RISE AND EROSION

Sea-level rise threatens both seaside and bayside marshes, which afford the mainland with protection from both floods and erosion. As sea-level rises, barrier islands will respond by migrating landward, disintegrating if sediment supply is insufficient, or drowning in place (Moore, List, et al., 2011).

Changes to vegetation can also occur, as seen on Assateague Island, where a 2012 study concluded that the "ghost forests" - stands of dead and dying loblolly pines - are succumbing to salt water intrusion caused by a combination of sea-level rise and barrier island processes. Vegetation serves as a stabilizing force for shorelines and loss of vegetation increases a shoreline's vulnerability to erosion.

With changes in inundation, habitat types shift, changing, for example, from irregularly-flooded marshes to regularly-flooded marshes, and eventually to mud flats or open water. This change in habitat type is not only detrimental to the wildlife that reside there, but also increases coastal exposure to wind and wave action, most often leading to increases in erosion rates.

Figure 5: Changes to the southern end of Cedar Island, 2006-2014. Source: Gordon Campbell, At Altitude Photograph. Copyright protected, used with permission.

Because the Eastern Shore barrier islands are largely in their natural states and without erosion control mechanisms, the process of rollover is readily observed. In Figure 5, images of a section of Assateague Island, taken before and after Hurricane Sandy, illustrate how waves washing over the island carried sand toward the mainland. This phenomenon provides critical width for islands and establishes a back-barrier platform which the island can continue to roll onto, thereby increasing the long-term viability of the island.

Figure 4: Aerial photographs of a section of Assateague Island before and after Hurricane Sandy. Photo Credit: USGS

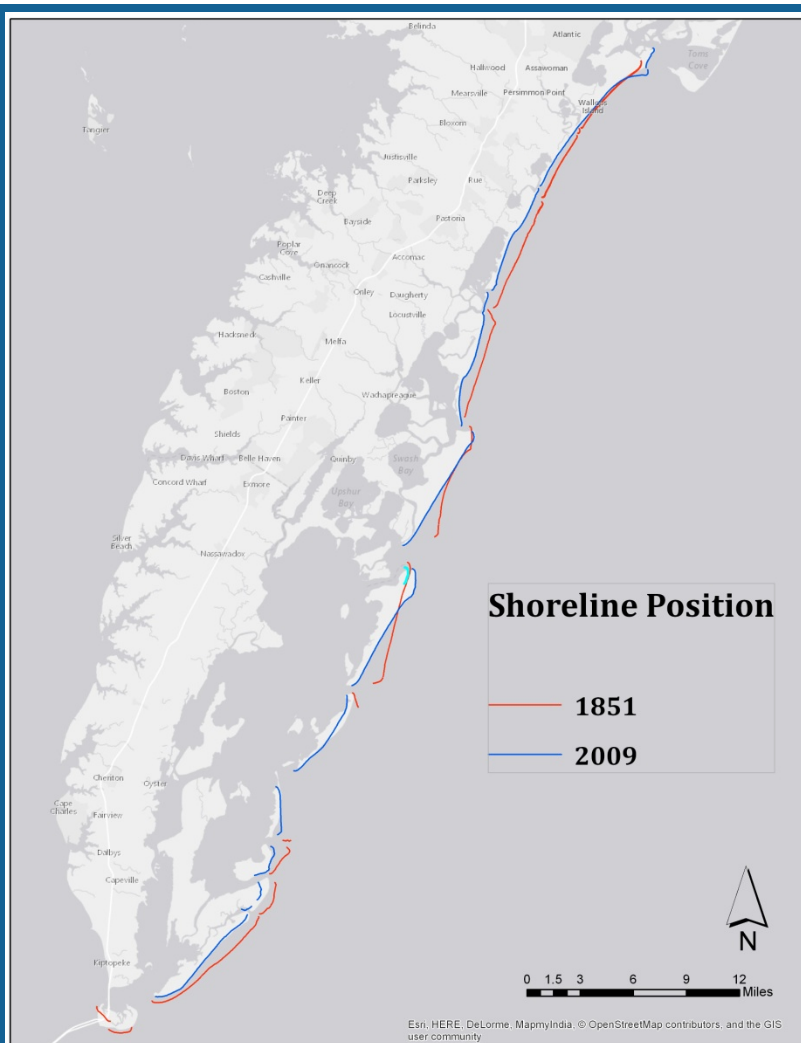

Figure 6: Historically mapped shorelines from Chincoteague Inlet to Fishermans Island as digitized by Dr. Michael Fenster and students at Randolph-Macon College.

HUMAN SYSTEMS

When natural processes threaten lives and investments, it is commonplace to look for ways to redirect nature's course or lessen its impacts. To slow coastal erosion and stabilize shorelines, structural interventions such as groins, jetties, and seawalls, are often employed, or soft interventions may be used, such as living shorelines or beach nourishment. These erosion control responses must be considered and selected based on conditions of the particular location and surrounding environs. Measures that are employed on the Eastern Shore are described in the following sections. A complete listing, along with benefits, impacts, and costs, can be found in Appendix C of the North Atlantic Coast Comprehensive Study.

HUMAN INTERVENTIONS

GROINS AND JETTIES

Groins and jetties are engineered structures placed perpendicular to the shoreline to interrupt longshore drift. Both kinds of structures extend out into the water, but jetties are generally used to protect inlets and harbor entrances (Figure 7), while groins can be used to protect any stretch of shoreline.

Because groins and jetties interrupt the natural drift of sand, sediment tends to build, or accrete, on the up-drift side of the structures, but they accelerate erosion on the immediate down-drift side because the area is robbed of the natural sediment it would have received from longshore drift. (Barnard, Thomas, VIMS Self-Taught Education Unit, Coastal Shoreline Defense Structures).

Figure 7: Jetty at Cape Charles Harbor. Photo Credit: Jay Diem, Eastern Shore News. Used with permission.

PARALLEL STRUCTURES – SEAWALLS, BULKHEADS, AND REVETMENTS

Seawalls are built parallel to shorelines to inhibit erosion by intercepting waves. They are designed with sufficient height and heft to prevent being overrun by storm surge or undermined by powerful waves.

The down-side to seawalls is up-front costs – they average $36 million per mile - and they can be undermined by scour, causing wall failure. (Reuters, "Water's Edge: The Crisis of Rising Sea Levels, September 4, 2014) Seawalls can also obstruct scenic views and negatively impact wildlife (USACE, 2015).

Bulkheads, also built parallel to shorelines, are meant to keep land from eroding into the sea. They can be anchored or cantilevered sheet piles, or gravity structures; but they, too, can be undermined by scour.

Both seawalls and bulkheads can have detrimental effects on neighboring shorelines and nearshore environments. When these structures work as designed, they protect the property where they are installed, but the deflected wave energy has to go somewhere. Neighboring properties and the near-shore environment in front of parallel shoreline protection structure usually receive the brunt of that energy, which creates not only scour conditions for the structure, but scours the ocean bottom of marine life (Barnard, Thomas, VIMS Self-Taught Education Unit, Coastal Shoreline Defense Structures).

Figure 9 shows the locations of all type of shoreline erosion control structures for the northern two-thirds of Northampton County, including bulkheads. As increasing numbers of property owners install these structures, and with lifespans of 20-25 years, long-term financial commitments will be needed to maintain them (Barnard, Thomas, VIMS Self-Taught Education Unit, Coastal Shoreline Defense Structures).

Figure 8: Revetment at the beach of Wallops Flight Facility. Photo Credit: NASA

REVETMENTS

Revetments are hardening or reinforcement of a surface exposed to waves or strong currents to prevent erosion. Typical construction consists of a filter layer overlain with stone or concrete (Figure 8). Revetments can be used alone or in combination with other structures. For example, a seawall can be capped with a revetment.

Revetments tend to reflect less wave energy because they are more sloped, but are still subject to the same erosion impacts as other parallel structures. Accessibility to the shoreline can be a drawback of using revetments (USACE, 2015).

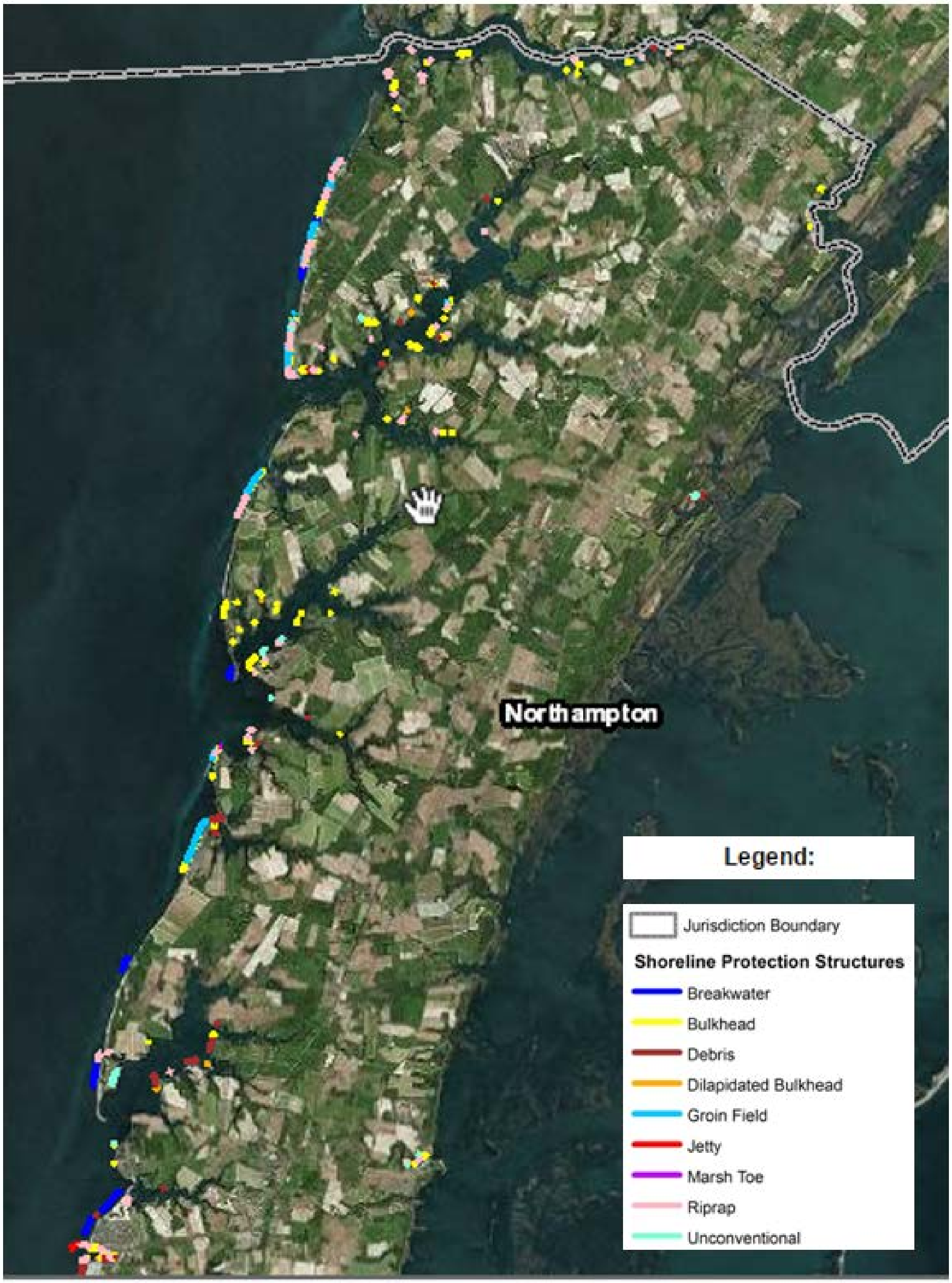

Figure 9: Northampton County Shoreline Protection Structures. Source: VIMS Center for Coastal Resource Management

BEACH NOURISHMENT

The placement of sand on an eroded beach is known as beach nourishment. It can be used alone as a beach restoration tool or in combination with other tactics, such as breakwaters. Beach nourishment does not change the rate at which erosion is occurring, and in fact, can accelerate erosion under certain conditions (USACE, 2015).

Beach nourishment is not a long-term fix; once it is selected as a solution, it requires periodic renourishment, typically every four to five years on average, or following major storms. NASA found it had good news and bad news to report about its recently completed beach protection project at the Wallops Flight Facility in the aftermath of Hurricane Sandy in 2012. The $43 million investment in a revetment and beach nourishment – completed three months before the storm - had worked to protect $1.2 billion in state and federal space program-related assets and launch infrastructure. The bad news was that another $11 million would be needed to replace 650,000 cubic yards of sand taken from the beach by the storm (Figure 10).

Figure 10: Beach Erosion at Wallops Flight Facility. Left: The completed beach nourishment project at WFF in August 2012. Right: The same stretch of beach is extensively eroded less than three months later, following Hurricane Sandy. Photo Credit: NASA

INTERVENTIONS ON BARRIER ISLANDS

In their natural states, conventional wisdom holds that barrier islands are best left to manage themselves. Such conventional wisdom may offer little consolation to communities like Wachapreague and Chincoteague, which are closely watching the year-by-year changes to Cedar Island and Assateague Island – barrier islands that have long afforded storm protection to their communities.

The USACE North Atlantic Coast Comprehensive Study acknowledges that some barrier islands may require management and intervention if the islands are to continue to provide such protections, and in fact, the USACE did intervene at the Assateague Island National Seashore.

The USACE has begun a sediment management plan, but communities like Wachapreague would like to do more to engage state and federal agencies to develop management plans where erosion threatens the island system that protects lives or natural resources.

Figure 12: Locations of Manually-Constructed Oyster Reefs in Waters off Virginia's Eastern Shore. Source: VCZMP

Figure 11: Oyster Reef under Construction Photo Credit: © Bowdoin Lusk/ The Nature Conservancy. Used with permission.

BREAKWATERS

Offshore structures placed parallel to the shoreline to soften the impact of waves are called breakwaters. Because wave energy is slowed by the structures, sand and sediment may settle in the area behind the breakwater, which can form an inviting environment for the growth of marsh grasses, an added protection against future erosion. The downside of breakwaters is that they can disrupt supply of sand to down-drift beaches (USACE, 2015).

Oyster reefs can serve as natural breakwaters and, once established, continue to grow vertically over time with sea-level rise, improving their ability to resist storms and mitigate erosion. Figure 11 shows the locations of oyster reefs that have been installed for long-term water quality and coastal resilience benefits, and Figure 12 is a photograph of an oyster reef under construction. Since oyster reefs are limited in elevation by the depth of the water column at a normal high tide, they provide excellent protection from relatively smaller waves and storm surge events; however, they can only provide minimal protection from wave action riding atop that is above average high tides or storm surge.

LIVING SHORELINES

One approach that is being employed in low wave-energy areas on the Eastern Shore is the construction of living shorelines. These shorelines re-establish the natural vegetative, nutrient, and slope characteristics of healthy shorelines so that they naturally dissipate wave energy. Figure 13 provides a cross-section of a typical living shoreline.

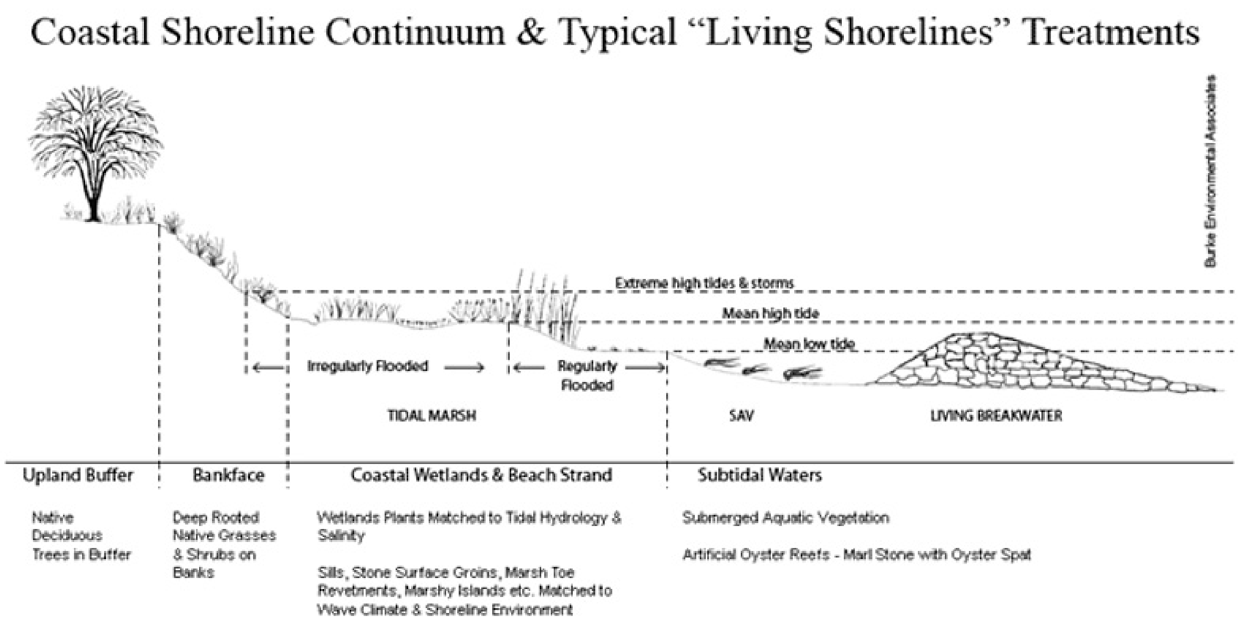

Figure 13: Typical Living Shoreline Cross-Section. Source: Burke Environmental Associates, http://www.habitat.noaa.gov/restoration/techniques/lsimplementation.html/

Large-scale living shorelines have been established in Oyster and at Camp Occohannock. In both locations, large granite rocks were brought in and piled parallel to the shore. Sand was added between the rock barriers and the shoreline to create salt marshes sloping upward to meet the previous shore edges. Marsh grasses were planted to stabilize the newly created areas between the open waters and the uplands.

Figure 14 shows the construction of the living shoreline in Oyster in 2009, and in July 2012 with marsh grasses fully established.

Figure 14: Living Shoreline in Oyster, Virginia. Left: October, 2009 - Construction. Right: July, 2012 - Fully Established. Photo Credit: Jay Diem, Eastern Shore News.

EROSION PREVENTION LAWS AND PROGRAMS

COASTAL ZONE MANAGEMENT ACT

The federal Coastal Zone Management Act (CZMA) of 1972 put into statute the recognition of the "national interest in the effective management, beneficial use, protection, and development of the coastal zone."

The CZMA established three national programs, the National Coastal Zone Management Program, the National Estuarine Research Reserve System, and the Coastal and Estuarine Land Conservation Program (CELCP). The National Coastal Zone Management Program aims to balance competing land and water issues through state and territorial coastal management programs, the reserves serve as field laboratories that provide a greater understanding of estuaries and how humans impact them, and the CELCP provides matching funds to state and local governments to purchase threatened coastal and estuarine lands or obtain conservation easements.

The CZMA connects with coastal erosion prevention through its many programs, including Coastal Zone Enhancement Grants, technical assistance grants, and research.

VIRGINIA COASTAL ZONE MANAGEMENT PROGRAM

The Coastal Zone Management Program, established through Executive Order, administers enforceable laws, regulations and policies that protect coastal resources and foster sustainable development. Those that are relevant to protecting against coastal erosion are shown below.

WETLANDS MANAGEMENT

The tidal wetlands program is administered by the Marine Resources Commission under Code of Virginia § 28.2-1301 thru § 28.2-1320. It is intended to preserve and protect tidal, and accommodate economic development in a manner consistent with wetlands preservation. Oversight is provided by the Virginia Marine Resources Commission and local wetlands boards.

The Virginia Water Protection Permit Program is administered by the Department of Environmental Quality (DEQ) and includes protection of tidal and non-tidal wetlands. This program is authorized by the Code of Virginia § 62.1-44.15.5 and the Water Quality Certification requirements of Section 401 of the Clean Water Act of 1972.

DUNES AND BEACHES MANAGEMENT

Dune protection is carried out pursuant to the Coastal Primary Sand Dune Protection Act and is intended to prevent destruction or alteration of primary dunes. This program is administered by the Marine Resources Commission (Code of Virginia § 28.2-1400 thru 28.2-1420).

COASTAL LANDS MANAGEMENT

*Coast*al Lands Management is a state-local cooperative program administered by DEQ's Water Division and 84 localities that regulates activities in Chesapeake Bay Resource Management Areas and Resource Protection Areas in Tidewater, Virginia established pursuant to the Chesapeake Bay Preservation Act (Virginia Code §§ 62.1-44.15:67 through 62.1-44.15:79) and Chesapeake Bay Preservation Area Designation and Management Regulations (Virginia Administrative Code 9 VAC 25-830-10 et seq.).

EROSION AND SEDIMENT CONTROL

Three state laws apply to land disturbance activities in Virginia: the Stormwater Management Act, Erosion and Sediment Control Law, and the Chesapeake Bay Preservation Act. For more information on these three laws, see "Storm Water Flooding Prevention Laws and Programs" in the Storm Water chapter.