Attachment 2B

Supporting Technical Documents

Attachment 2B-1

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Design and performance of headland bays in Chesapeake Bay, USA

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ABSTRACT

The use of headland-breakwater systems along the shore of Chesapeake Bay began in the early 1980s. Properly designed and installed headland breakwaters with beach fill and wetlands plantings provide shore protection and create a “full” coastal profile of beach/backshore/dune which enhances habitat. They create a tertiary buffer for upland runoff and groundwater and provide access and recreation. The wetland grasses also create an erosion resistant turf. The coastal profile accommodates environmental permitting requirements of habitat enhancement for shore protection structures.

The Static Equilibrium Bay (SEB) model of Hsu and Sylvester has shown its utility in defining the pocket or embayed beach planform between headland breakwaters. Bay plots for varying wind/wave conditions and water levels define the limits of shoreline change. The embayed beach must be high and wide enough to offer protection, usually for the base of a graded upland bank, under design storm conditions. The embayed beach morphology should emulate nature; the existing beach profile should be assessed first in designing any headland-breakwater system. The design of the beach begins with establishing the minimum design beach width (B_m) and profile in the context of stable embayed beaches held by headland breakwaters. With B_m established, breakwater length (L_b), the breakwater gap (G_b) and the bay indentation distance (M_b) come into play depending on the wave environment. The empirically derived relationships between these parameters are offered as a *guide* for breakwater design along the sheltered coasts of Chesapeake Bay.

Constructing stable headland/embayed beaches for long-term shore protection can be done cost effectively. The procedures developed over the years to evaluate and design headland breakwaters have been, in retrospect, effective. These installations provide a database of successful headland-breakwater installations, some of which are over 20 years old. This database will continue to be used to verify and compare parameters for headland systems in the future as sites continue to mature.

1. Introduction

The Chesapeake Bay Estuarine System consists of a variety of shorelines that vary from low, upland banks and marshes to beaches and dunes to high bluffs. Erosion of these shorelines is significant when fetch exceeds a few kilometers and becomes severe when shorelines are exposed to fetches exceeding 16 km. Critical erosion, however, immediately threatens upland improvements and infrastructure no matter what the fetch. The use of headland breakwaters coupled with beach fill to create stable pocket or embayed beaches for shoreline management has become somewhat common place in Chesapeake Bay. Over the last 25 years, research and project installations have helped guide the way for widespread use of this technique (Hardaway and Gunn, 1991; 1999a, b; 2000; Hardaway et al., 1995; Hardaway and Byrne, 1999).

The use of headland-breakwater systems along the shore of Chesapeake Bay began in the early 1980s. Previously, shoreline erosion usually was addressed with bulkheads, groins, and stone revetments. These traditional strategies still are very much employed. These defensive means of shore protection may be effective in stopping erosion but they also “harden” the shoreline, often causing nearshore bottom scour and reducing intertidal, beach, backshore, and dune habitats. Groins can be effective if fill is added, but they tend to lose sand through time when placed along sand-limited shore reaches which are common in Chesapeake Bay.

Properly designed and installed headland breakwaters with beach fill and wetlands plantings provide shore protection and create a “full” coastal profile of beach/backshore/dune which enhances habitat. They create a tertiary buffer for upland runoff and groundwater and provide access and recreation. The wetland grasses also create an erosion resistant turf. The coastal profile accommodates environmental permitting requirements of habitat enhancement for shore protection structures.

2. Background research on design parameters

Wavelength is an important parameter in wave diffraction and refraction, both of which are important mechanisms in wave

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attenuation by breakwaters and bay beach configurations. Suh and Dalrymple (1987) demonstrated that when the gap between two diffraction points (*i.e.* the ends of adjacent breakwaters) becomes approximately twice the incident wave length or more, the shoreline behind each breakwater responds independently as if there is no interaction among breakwaters. This relationship might provide the response of the tangential section of the spiral bay or pocket beach as it orients itself into the dominant direction of wave approach.

Numerous studies, as documented in Chasten et al. (1993), show that as a breakwater is lengthened relative to its distance offshore, a tombolo becomes more likely to develop. A tombolo is an essential element in headland-breakwater systems. In Chesapeake Bay projects, the tombolo must be created with the addition of an appropriate fill material since natural supply of sand generally is limited in the nearshore. As breakwater length approaches double the design wave length, it can better hold a tombolo, particularly when the breakwater acts as a headland in a multiple breakwater unit system. The level of tombolo attachment may vary from attachment above high water to a low water connection.

Bodge (1998) offers the 1/3 rule for the relationship of breakwater gap (G_b) to bay indentation (M_b) which is the maximum offset of the embayed beach from a line connecting adjacent breakwaters (*i.e.* the 1/3 rule is M_b:G_b = 1:3). Bodge (2003) provides formulae to assist in developing this ratio and notes that it is a combination of the Static Equilibrium Bay (SEB) model and his research that defines mean low water (MLW) around the embayed coast.

The Coastal Engineering Manual (CEM, 2000) terms our minimum beach (B_m) (Fig. 1) width Ymin which is defined as the minimum horizontal distance of dry beach between the mean high water (MHW) shoreline and the landward boundary or base reference line. The MHW shoreline is employed because it is a common land/water boundary shoreline on maps, it is more readily identified from aerial photos, and is a more conservative, minimum width (and volume) for shore protection. Ymin is the minimum dry beach width required to protect the foredune, cliff, structure or vegetation behind the baseline for normal storm conditions. According to the CEM (2000), the beach does the work and its resilience and recovery are critical for long-term shore protection.

Hsu and Evans (1989) and Silvester and Hsu (1993, 1997) define *dynamic equilibrium* as sand transport through an embayed coast so long as the updrift supply of sand remains constant. If the sand supply is reduced over a reasonable length of time, the bay will become more indented or will recede in the curved portion. Should the supply cease altogether, the waterline will erode back to a limiting shape which is termed *static equilibrium*. For coasts with very predominate wave climate this becomes predictable and is the basis for the SEB formula. Varying wave conditions and sand supply are the norm in Chesapeake Bay and must be accounted for in the design process. The breakwater system at Cape Henry, Virginia at the confluence of Chesapeake Bay and Atlantic Ocean illustrates how an infusion of sand, from an adjacent beach nourishment project, takes the system from static to dynamic equilibrium (Fig. 2).

Over the years, a three step process has been developed (Hardaway et al., 1995; Hardaway and Gunn, 1999a; 1999b) for practical application of this research to systems in Chesapeake Bay. The steps are: (1) assess the wind/wave climate using the computer model SMB (Kiley, 1982) which creates significant wave heights and periods from the interaction of wind over a measured fetch, (2) calculate the nearshore/nearfield wave refraction using RCPWAVE, (Ebersole et al., 1986), and (3) plot beach shore planforms using Model SEB (Hsu et al., 1989a; 1989b; Hsu and Evans, 1989). Fig. 3A and B illustrates the parameters involved in this methodology. This process is a check against the shoreline evolution assessment. If agreement is found, then there is more confidence in the site evaluation.

3. Coastal setting

The shorelines around Chesapeake Bay occupy a variety of settings. The dendritic ancestral Susquehanna River drainage is being flooded by the present oceanic transgression. The coastal boundaries are being inundated at rates of about 30 cm per 100 years, but it is the coastal storms, northeasters and the occasional hurricanes, with associated high winds and water levels that erode shorelines and transport eroded material alongshore and offshore. The patterns and rates of erosion are dictated by the coastal setting such as whether the sites are on the open bay or up the rivers or whether a site is located on a headland, a straight reach, or within an embayment. Embayed coastal settings tend to retain more sand in the nearshore than those sited on erosive headlands.

The largest storm in the entire area in the last 70 years was Hurricane Isabel which impacted Chesapeake Bay on September 18, 2003 with record high storm surge and winds. Virtually all Chesapeake Bay

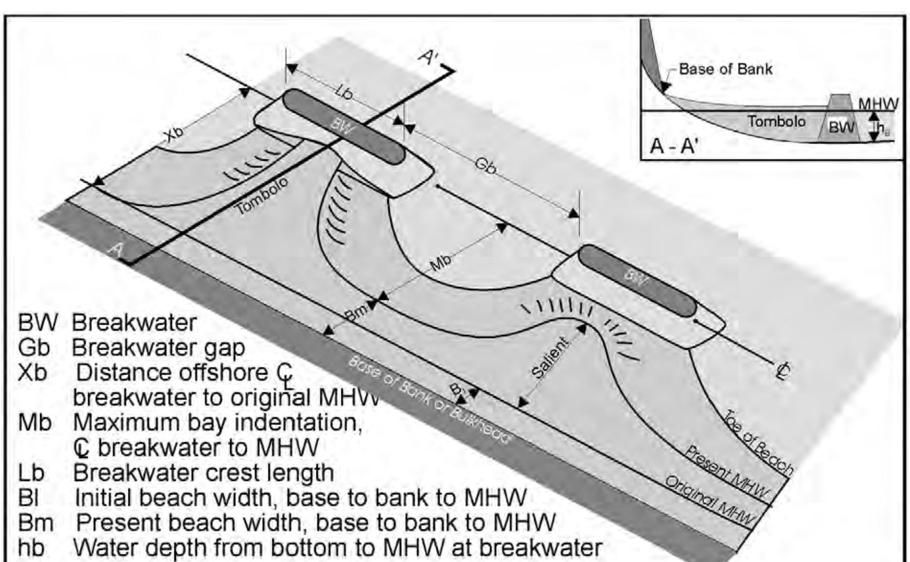

Fig. 1. Headland-breakwater system parameters.

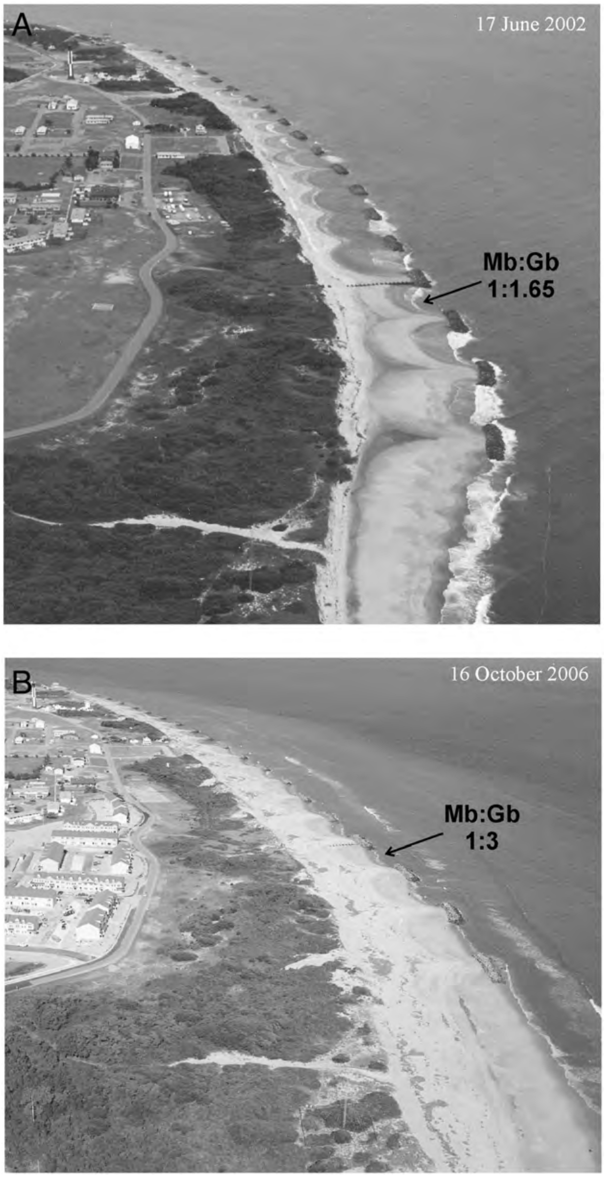

Fig. 2. Cape Henry breakwater installation showing dynamic equilibrium alongshore. M_b is the minimum beach width and G_b is the gap between adjacent breakwaters. As more sand becomes available to the system, the sight evolves to the 1/3 rule shown in B.

shorelines were affected. A Virginia Institute of Marine Science wave/current gauge in the York River showed the entire water column moving upriver at over 2.6 m/s during the height of the storm (VIMS, 2003). Peak wave height and period were 2 m and 5.1 s. Top wind speeds reached 144 km/h on a nearby anemometer. In lower Chesapeake Bay, tide gauges indicated a storm tide of +2.4 m mean lower low water (MLLW) which is about 1.5 m above normal. At Kingsmill on the James River (site #11) (Fig. 4), the tide gauge was destroyed during the storm. It stopped recording at +2 m MLLW, but surveyed trash lines and scarps at the site indicated that the maximum tide and wave level was 3.7 m above MLLW which is about 2.4 m above the mean range.

Those shorelines with open fetch to the north, northeast, east, southeast, and south were especially affected due to the rotation of Isabel's winds from north to south during her passage. Hundreds, if not thousands, of shore protection systems were damaged or destroyed. Many shorelines around the Bay which had no shore protection were eroded 3 to 9 m by storm surge and waves. Shore reaches with properly designed and constructed headland-breakwater systems incurred varying degrees of damage from none to several meters of cut at the adjacent base of the upland banks.

4. Design considerations

As with most shoreline protection projects, the local wave climate is the important hydrodynamic design element. In headland-breakwater design, the shape and performance of the embayed beach shore planform are critical in maintaining the minimum protective beach. The fetch and whether a site is exposed to a unidirectional or bimodal wind/wave field influence how the embayed beach responds to the annual and storm waves. A unidirectional wind/wave field indicates that the annual and frequent storms produce a wind/wave climate that approaches from roughly the same quadrant. Bimodal means that the annual and storm waves are from two different quadrants or that winds are from two different quadrants depending on the season.

Perhaps the most important parameters in headland-breakwater design are the width and elevation of the beach in the gaps of the breakwater system (*i.e.* minimum bay beach size). The beach must be high and wide enough to offer protection, usually for the base of a graded upland bank, under design storm conditions. Design storms are at least the 25-year event, and the breakwater itself should withstand the 100-year or greater storm. The beach morphology should emulate nature; the existing beach profile should be assessed first in designing any headland-breakwater system. The design of the beach begins with establishing the minimum design beach width (B_m) and profile in the context of stable embayed beaches held by headland breakwaters (Fig. 1). This will determine the amount of beach nourishment required. With B_m established, breakwater length (L_b), the breakwater gap (G_b) and the bay indentation distance (M_b) come into play depending on the wave environment. This paper discusses these and other minimum design parameters for shoreline protection by headland-breakwater/beach systems in fetch and depth limited settings like Chesapeake Bay.

Since the first headland-breakwater installation in 1985, the authors have attempted to address shore protection using bay beaches thereby reducing the amount of rock (*i.e.* breakwater length) per length of shoreline, accordingly. The 14 breakwater sites shown in Fig. 4 represent breakwater projects built in different coastal settings for shore protection and beach stability (Hardaway and Gunn, 2000). Stability of the bay beach is critical so that the need for future nourishment is minimized. However, rock costs for breakwater units also are significant, and it is a balance of these and project goals that make each site different.

The beach is the primary component of any given headland-breakwater system, and the source of material will dictate costs and, ultimately, the design. Sand that can be obtained directly from an adjacent sandy bank will cost significantly less than sand that has to be trucked in. All sites, except Aquia Landing, St. Catherine's Island, Carden, and Yorktown, had an eroding upland bank that the beach needed to protect from storm waves. The backshore was perched with a concrete barrier across a low shore at Aquia Landing. St. Catherine's Island and Carden were built to protect low spit features and required a backshore/dune to prevent overwash. Yorktown is a public beach with a low walkway landward of the edge of the beach.

Establishing vegetation zones within the headland-breakwater system is a critical design element since dune grasses can only survive above a stable berm along the open bay and broad rivers of the Chesapeake Bay estuarine system. Intertidal grasses must reside in sheltered regions. Beach berms occur on “natural” Chesapeake Bay beaches and typically are about 0.3 to 0.6 m above MHW. The more open the site, the higher the beach berm relative to MHW due, in part, to increased wave runup. Since a stable pocket beach is the goal of the headland-breakwater projects, it makes sense to build the beach berm into the project. Empirical evidence can be found on existing beaches, whether natural, man-induced (*i.e.* jetties) or man-made (*i.e.* groins or breakwaters). Protective beaches also may have a storm berm that

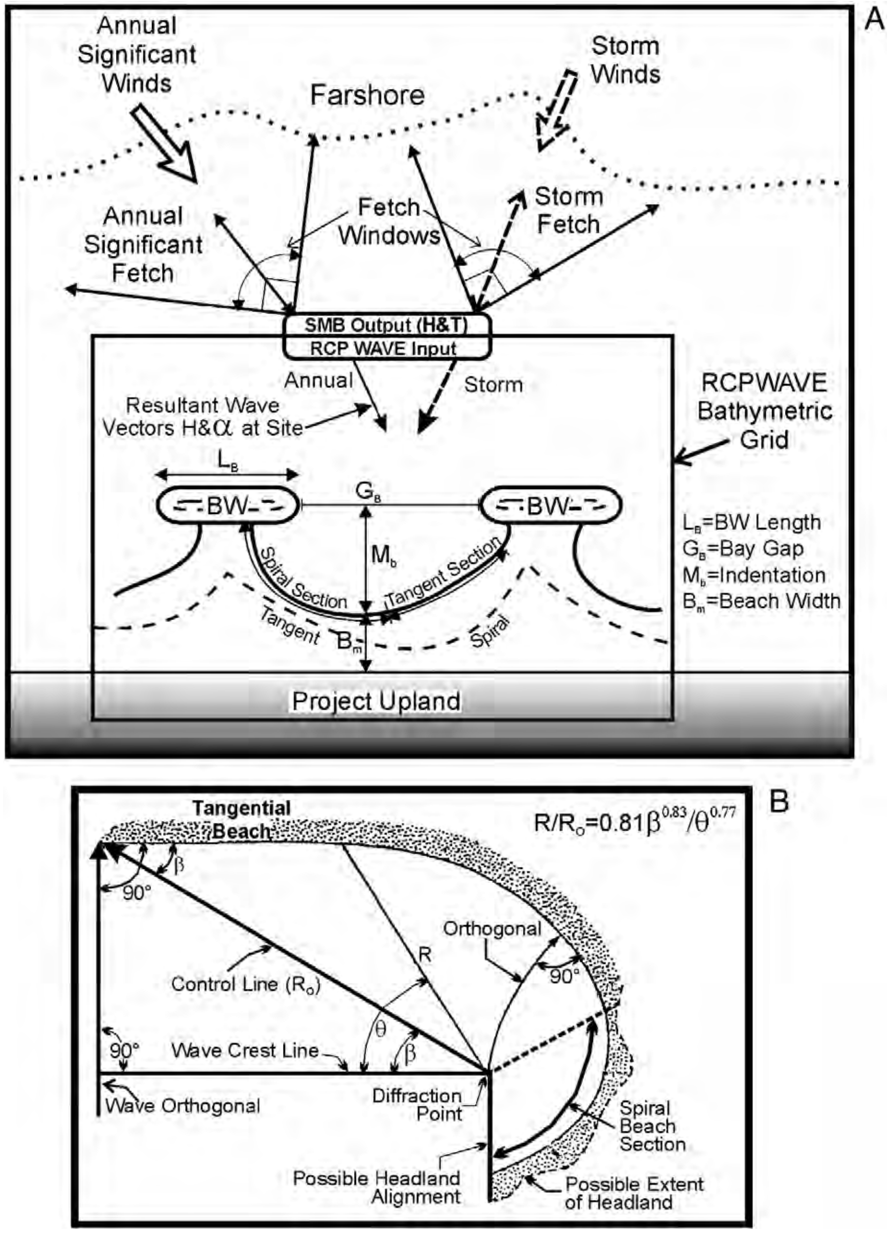

Fig. 3. Parameters related to A) wind/wave generation (SMB), nearshore wave refraction (RCPWAVE) and beach planform prediction, and B) specifically, the Static Equilibrium Bay model (after Hsu et al., 1989a,b).

is 0.3 to 0.6 m above the normal berm and 1.5 to 4.6 m landward. The berms also provide the planting zones for upper beach (*Spartina patens*) and dune grasses (*Ammophila*) (Fig. 5A and B). Often *Spartina alterniflora* can be established on the flanks of a tombolo in the lee of a breakwater unit between mean tide and spring high water.

An important consideration is how the system interfaces with adjacent shorelines. Headland breakwaters can have a significant impact on littoral processes, and those impacts need to be assessed early in the design process. Some methods range from placing shorter, low broad structures at the “downdrift” boundary to adding more fill as a feeder beach (Hardaway et al., 1993). Defining the downdrift shore is important because a bimodal wave climate may exist where storm wave conditions are different from the seasonal or annual wave field. The downdrift is more easily defined where there is a more unidirectional wave field. Bimodal and unidirectional conditions can be related to the shoreline setting or geomorphology and the location of the project on a coastal headland, embayment or a relatively straight shore (Hardaway and Gunn, 2000).

5. Equilibrium bays

The bay shoreline configuration or planform has been the topic of research for many years. The SEB model is the result of years of research by Hsu et al. (1989a,b), Hsu and Evans (1989) and Silvester and Hsu (1993, 1997) and by practical application by the present authors. In Chesapeake Bay, the waves are short, and the systems are scaled down. SEB was developed for open ocean coasts and relatively long bays between large headlands. Can the SEB be scaled down in such a manner? One must understand the goal of the project, how far off the breakwater units can or should be placed, how long the breakwater units should be, how wide the gaps should be, and, perhaps most importantly, how much beach fill is required.

The main component in SEB modeling is the position or the point of the extension of R_o, the control line (Fig. 3B). This and the tangential section of the bay are defined by the net direction of wave approach within the bay. R_o will shift with shifting wave direction, so whether a site is unidirectional or bidirectional is important. Fig. 6

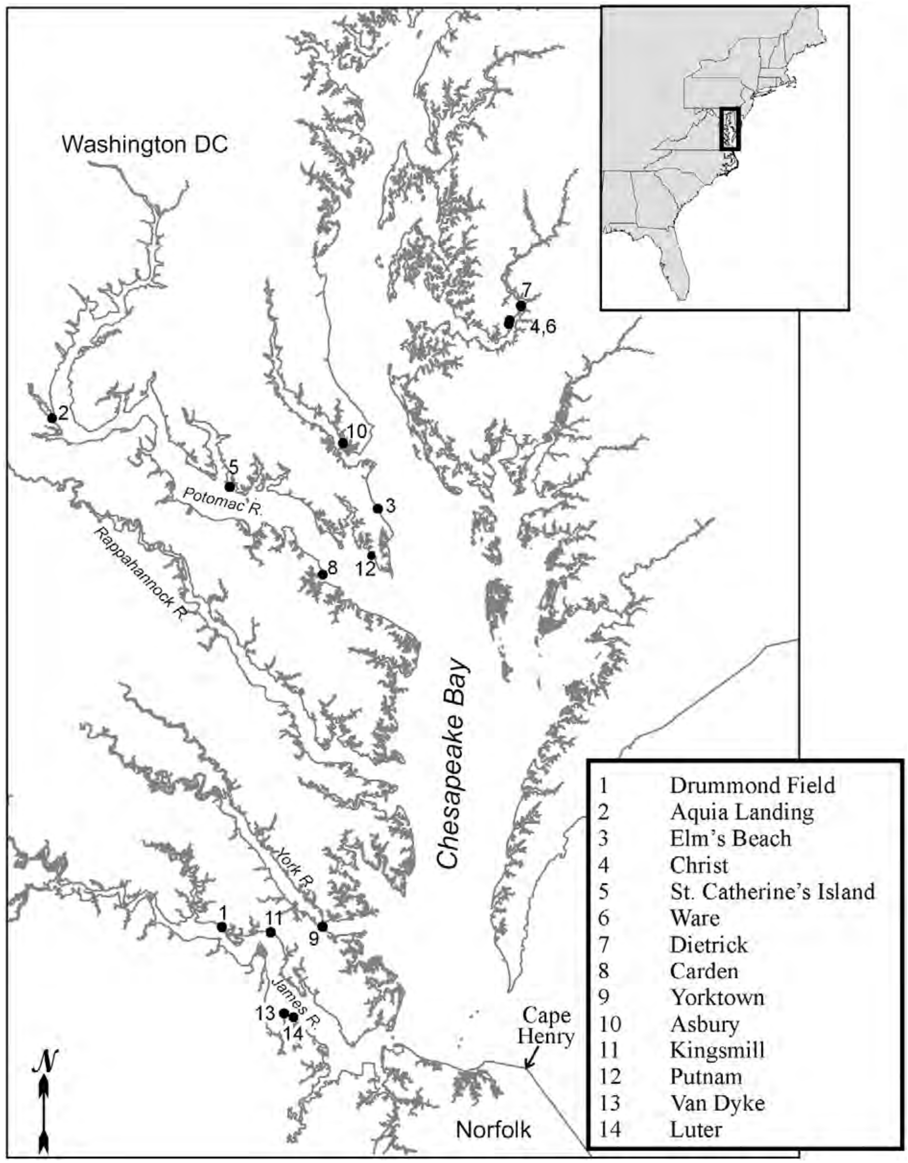

Fig. 4. Location of breakwater system installations.

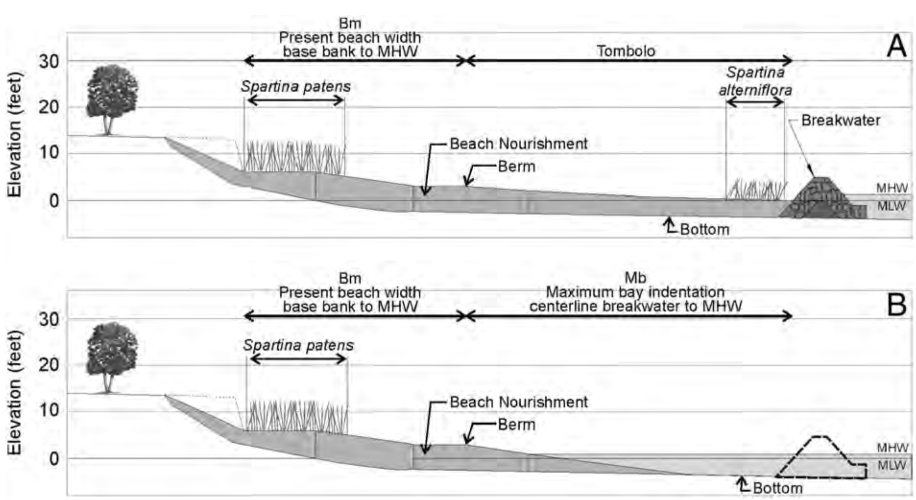

Fig. 5. Typical cross-section of A) Breakwater beach and B) Bay beach (from Hardaway and Gunn, 2000).

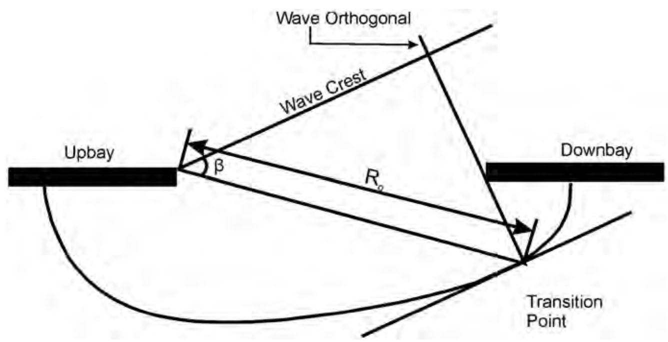

Fig. 6. Static Equilibrium Bay elements for protruding headlands (Silvester and Hsu, 1993).

shows how the wave orthogonal strikes the downdrift headland-breakwater unit and continues to a point on the bay beach shoreline that defines the terminus of R_o. This takes into account the downbay diffraction point which causes the shoreline to sit back in a small spiral. A shift in wave approach to the other quadrant would cause the small spiral to increase until it became the main spiral section of the crenulate embayment and a counter current effect would happen on the old upbay side as it became the new downbay side. This is why is it important to understand the geomorphic setting relative to the wave climate and to determine whether a site is unidirectional or bimodal or some variation therein. Also, one cannot connect breakwater units and call that R_o unless the site is in dynamic equilibrium because R_o must define the tangential section of the bay and, therefore, must be on the bay shore. The control line (R_o) can be plotted at different elevations to represent storm induced bay shapes. Typically we use the annual wave at MHW for the establishment of Ro.

The application to headland-breakwater design requires an embayment(s) to test or verify. When designing a headland-breakwater system one draws the embayments between headlands. Four bay planforms are shown in Fig. 7, and the wave orthogonal of interest is drawn in across the downbay unit and onto the shore, which for a typical or annual wave would be mean high water. The control line, R_o, is then drawn to that point from the upbay headland, β is determined, and the SEB formula applied. Table 4.2 from Silvester and Hsu (1993, 1997) can be used to get the various R values for each θ relative the associated wave crest line. One can also use the formula in Fig. 3B. In this way, the equilibrium plots allow the estimated shore planform to be "trued in".

Fig. 7 illustrates four bays drawn between two breakwater units that have different M_bs but the same wave approach. L_b and G_b also are constant. Applying the SEB formula shows how the equilibrium bay would reside against each bay "estimation". The ratios of bay indentation relative to breakwater gap (M_b:G_b) are shown as well. Bay R3 is drawn deep and might be the Kingsmill (Site 11) where a deep pocket is desired. R1 and R2 are more what we have come to see in Bay. R4 might occur where sand supplies are high (*i.e.* dynamic equilibrium). However, most bay sites need to reserve sand fill so the downdrift headland diffraction will tend to drive the shoreline back from the down bay diffraction point as seen in R1 and R2. R2 is a typical bay shape with an M_b:G_b of 1:1.65 (Hardaway and Gunn, 1991; 2000). The design beach width (B_m) will dictate bayward encroachment and embayment indentation. Some trial and error is involved. Site conditions and restrictions along with the level of protection desired will also fashion the final design.

6. Headland-breakwater performance analysis

Table 1 is a chronologic listing of selected headland-breakwater systems (Fig. 4) and their site parameters installed over the past 20 years (Hardaway and Gunn, 2000). Annual and storm wave lengths from wave climate analyses are shown. In general, as fetch increases so do the waves and wave length. The sites also are listed by wind/wave coastal settings, whether bimodal or unidirectional, in Tables 2 and 3, respectively. Site parameters of breakwater length (L_b), breakwater gap (G_b) and bay indentation (M_b) can be compared to each other by simple ratios that attempt to portray a complex system.

The project parameters (L_b), (G_b) and (M_b) (Tables 2 and 3) are averages for the project and include only those breakwaters and pocket beaches along the main trunk of the system. Interfacing breakwater units and beaches are unique to each site and comparisons would be invalid because the design beach width is not always

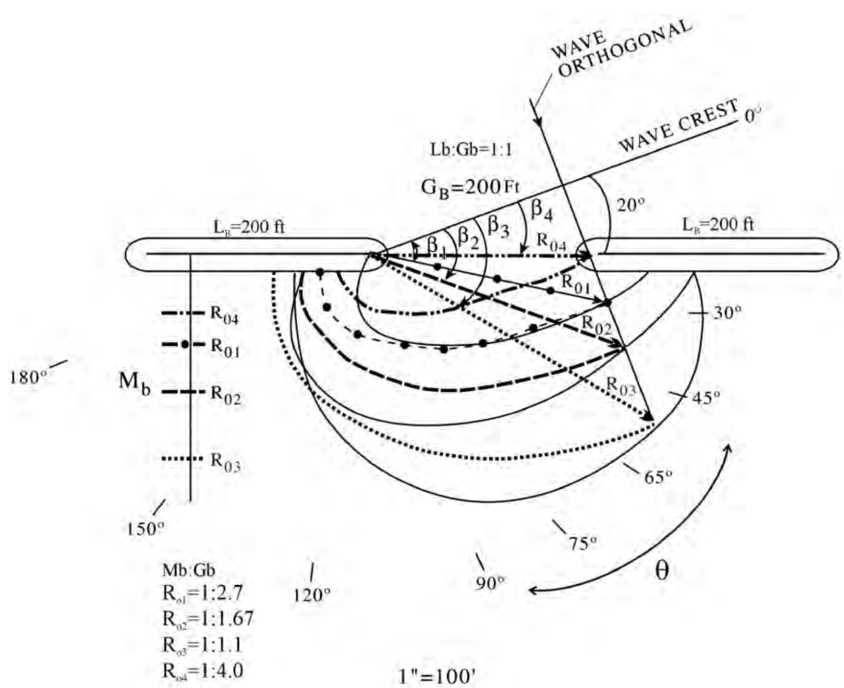

Fig. 7. Static Equilibrium embayment (dashed lines) determination for estimated shore planforms (solid lines).

Table 1
Chesapeake Bay headland-breakwater sites.

Site	Average fetch (km)	Date installed	Land use	Coast type	Wave Annual	Climate Storm
1. Drummond Field	6 to SW	Sep 1985	Residential	Embayed	$T=2.0$ $h=1.2$ $L=6.7$	$T=3.0$ sec. $h=1.8$ $L=12.8$
2. Aquia Landing	7 to E	Mar 1987	Public Beach	Headland	$T=2.0$ s $h=1.5$ $L=7.6$	$T=3.0$ s $h=2.1$ $L=13.7$
3. Elm's Beach	30 to NNE	Oct 1988	Public Beach	Straight	$T=2.5$ s $h=1.5$ $L=9.8$	$T=5.0$ s $h=2.1$ $L=22.9$
4. Christ	3 to NE	Jul 1988	Farm	Straight	$T=1.4$ s $h=0.9$ $L=4.3$	$T=2.0$ s $h=1.5$ $L=7.6$
5. St. Catherine's Island	7 to NW	Mar 1989	Spit	Headland	$T=2.0$ s $h=1.2$ $L=6.7$	$T=2.7$ s $h=1.8$ $L=11.3$
6. Ware	3 to E	Sep 1989	Residential	Embayment	$T=1.5$ s $h=0.9$ $L=4.6$	$T=2.5$ s $h=1.5$ $L=9.8$
7. Dietrick	3 to SE	Oct. 1989	Farm	Embayment	$T=1.6$ s $h=0.9$ $L=4.9$	$T=2.5$ s $h=1.5$ $L=9.8$
8. Carden	17 to NNE	Dec 1989	Spit	Headland	$T=2.0$ s $h=1.2$ $L=7.0$	$T=4.5$ s $h=1.8$ $L=18.9$
9. Yorktown	18 to NE	Sep 1994	Public Beach	Straight	$T=2.5$ s $h=1.5$ $L=9.8$	$T=4.0$ s $h=2.7$ $L=20.7$
10. Asbury	6 to NW	Dec 1995	Residential	Embayed	$T=2.0$ s $h=1.5$ $L=7.6$	$T=3.5$ s $h=2.1$ $L=15.9$
11. Kingsmill	11 to SW	Mar 1996	Residential	Embayment	$T=2.0$ s $h=1.5$ $L=7.6$	$T=3.5$ s $h=2.4$ $L=17.1$
12. Putnam	30 to SW	May 1997	Residential	Headland	$T=2.5$ s $h=0.9$ $L=7.6$	$T=4.5$ s $h=1.8$ $L=18.9$
13. Van Dyke	12 to N	Sep 1997	Residential	Headland	$T=2.0$ s $h=1.5$ $L=7.6$	$T=3.5$ s $h=2.4$ $L=17.1$
14. Luter	13 to NNE	May 1998	Farm	Straight	$T=2.0$ s $h=1.5$ $L=7.6$	$T=3.5$ s $h=2.4$ $L=15.9$

Shallow Water Wave Length ($L=(gh)^{½}\times T$) (From Hardaway and Gunn, 2000).
L = Wave length (meters).
h = Water depth (meters).
T = Wave period (seconds).

required. Therefore, each site is a "custom" fit within reasonable parameter relationships.

According to Hardaway and Gunn (2000) typically, breakwater systems with a bimodal wave exposure have a breakwater length to breakwater gap ratio (L_b:G_b) between 1:1.0 and 1:1.5. Van Dyke is such an example, located on a broad cape or coastal headland feature on the south shore of the James River, Isle of Wight County, Virginia (Fig. 8). When headland-breakwater systems are sited in more unidirectional settings, the L_b:G_b ratio can approach 1:1.5 to 1:2.0 particularly within embayed coastal settings that usually have an appreciable amount of natural littoral sands; for example Asbury on the Patuxent River in Calvert County, Maryland (Fig. 9). The average L_b:G_b ratios for bimodal sites are 1:1.2 whereas the average for unidirectional sites is 1:1.8.

Table 2
Chesapeake Bay beach headland-breakwater sites in bimodal wind/wave setting.

Site	Coast type	Average fetch (km)	Longest fetch (km)	L_b (m)	G_b (m)	M_b (m)	B_m (m)	L_b: G_b	M_b: G_b
6. Ware	Embayment	3 to E	4 to E	18.3	19.8	13.7	10.7	1:1	1:1.4
4. Christ	Straight	3 to NE	4 to SE	21.3	24.4	16.8	7.6	1:1.3	1:1.5
7. Dietrick	Embayment	3 to SE	4 to E	19.8	29.0	18.2	9.1	1:1.5	1:1.6
11. Kingsmill	Embayment	11 to SW	20 to S	53.3	64.0	51.8	21.3	1:1.2	1:1.2
13. Van Dyke	Headland	12 to N	22 to NNW	27.4	39.6	22.9	15.2	1:1.4	1:1.7
8. Carden	Headland	17 to NNE	43 to E	33.5	33.5	24.4	12.2	1:1.0	1:1.4
12. Putnam	Headland	30 to SW	68 to SE	33.5	42.7	42.7	18.3	1:1.3	1:1.0
3. Elm's Beach	Straight	30 to NNE	35 to SE	47.2	53.3	45.7	13.7	1:1.1	1:1.6
Average:								1:1.2	1:1.4

L_b = breakwater length (from Hardaway and Gunn, 2000).
G_b = breakwater gap.
M_b = minimum bay indentation.

Previous research by the authors has shown a relationship between the breakwater gap to pocket beach depth or indentation (G_b:M_b) ratio to be about 1:1.65 (Hardaway and Gunn, 1991). Further analysis shows that, for a unidirectional setting, the G_b:M_b ratio averages 1:1.9. For a bimodal wave climate, the average G_b:M_b ratio falls to 1:1.4.

The effectiveness of headland-breakwater sites was assessed after Hurricane Isabel (Hardaway et al., 2005) for four headland-breakwater sites: Aquia Landing, Yorktown, Kingsmill and Van Dyke. The surveys were performed as part of the Chesapeake Bay Breakwater Database and Monitoring under the U.S. Corps of Engineers Section 227 Program. Storm impacts varied at each site with the combination of storm surge and wave runup reaching +2.6 m, +3.1 m, +3.4 m, and +3.7 m MLW for Aquia Landing, Kingsmill, Van Dyke and Yorktown, respectively.

Aquia Landing and Yorktown, both public beaches, have low adjacent uplands that were readily flooded. Sand was carried into the adjacent roadways. Yorktown also had three restaurants and a hotel that were severely flooded. However, without the breakwater system damage would have been much worse since there would have been less wave attenuation and shoaling. After the storm, the sand was pushed back onto the beach and re-graded (Fig. 10). The rock structures at Aquia Landing suffered no damage and only a handful of armor stones on the Yorktown structures were turned up. These were one ton stones.

High graded banks occur along the upland coasts of Kingsmill (21 m) and Van Dyke (15 m) with significant housing on the top. The waves and storm surge attacked the base of each site's banks above the beach and backshore. Heavy established vegetation along the

Table 3
Chesapeake Bay headland-breakwater sites in unidirectional wind/wave setting.

Site	Coast type	Average fetch (km)	Longest fetch (km)	L_b (m)	G_b (m)	M_b (m)	B_m (m)	L_b:G_b	M_b:G_b
1. Drummond Field	Embayed	6 to SW	12 to S	27.4	54.9	22.9	9.1	1:2.0	1:2.4
10. Asbury	Embayed	6 to NW	13 to NW	33.5	57.9	36.6	21.3	1:1.8	1:1.7
5. St. Catherine's Island	Headland	7 to NW	15 to W	30.5	29.0	21.3	21.3	1:1*	1:1.4*
2. Aquia Landing	Headland	7 to E	9 to NE	33.5	48.8	19.8	18.3	1:1.5	1:2.5
14. Luter	Straight	13 to NNE	23 to NNW	29.0	48.8	30.5	15.2	1:1.7	1:1.6
9. Yorktown	Straight	18 to NE	43 to E	49.0	91.4	51.8	15.2	1:1.8	1:1.8
Average								1:1.8	1:1.9

* the use of dredge material required a more conservative design.
L_b = breakwater length (from Hardaway and Gunn, 2000).
G_b = breakwater gap.
M_b = minimum bay indentation.

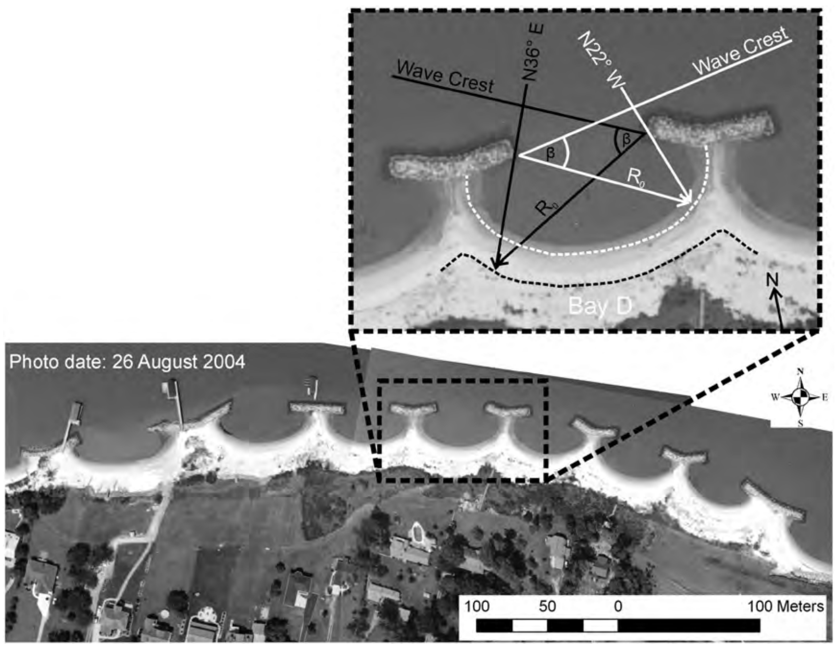

Fig. 8. Van Dyke shoreline showing the annual and storm wave direction and approximate shoreline resulting from that wave.

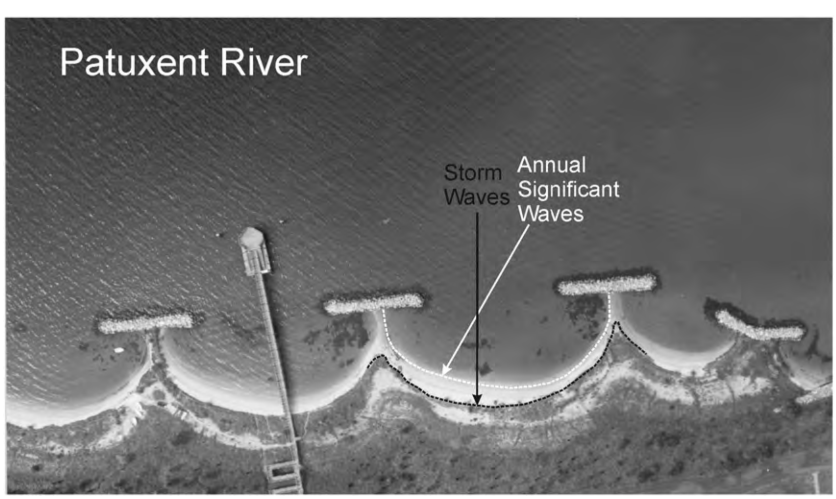

Fig. 9. Asbury project located in a coastal embayment with a unidirectional wind/wave climate demonstrating shore planforms resulting from annual and storm waves which approach from the same quadrant. Photo date: 20 Oct 2005.

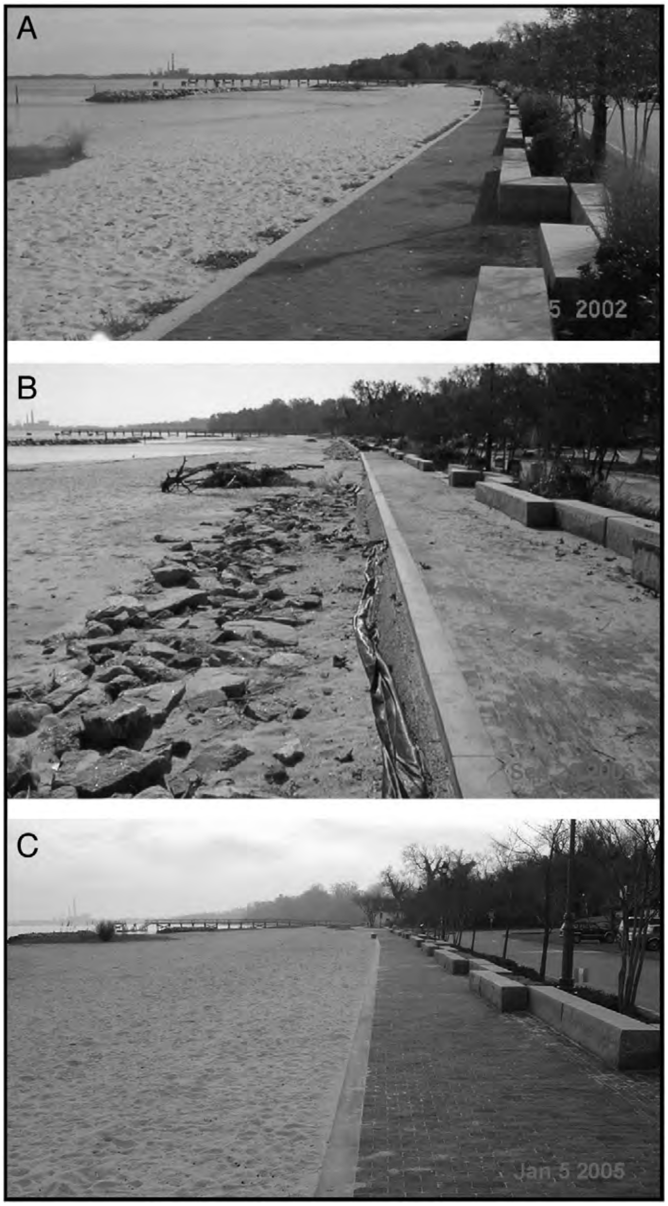

Fig. 10. View along the upriver portion of Water Street, Yorktown, Virginia (site #9), at the main recreational area A) before Hurricane Isabel, B) immediately after Isabel, and C) after the beach was repaired.

Kingsmill back base allowed only minor back scarping by wave action which was confined to the embayments. Van Dyke suffered significant bank erosion, particularly in the embayments and against the 2:1 graded bank face but this did not threaten the integrity of the bank slope. Areas along the Van Dyke site with graded banks at a 3:1 graded had little or no scarping. This supports the process by which a low broad stable beach planform is very effective at storm wave attenuation (Fig. 11). Fig. 11 also shows a 3:1 bank next to a stone revetment with a crest elevation at +2.4 m MLW.

7. Conclusions

The Static Equilibrium Bay (SEB) model of Hsu and Evans (1989) and Silvester and Hsu (1993; 1997) has shown its utility in defining the pocket or embayed beach planform between headland breakwaters. Bay plots for varying wind/wave conditions and water levels define the limits of shoreline change for each scenario, particularly conditions other than true unidirectional.

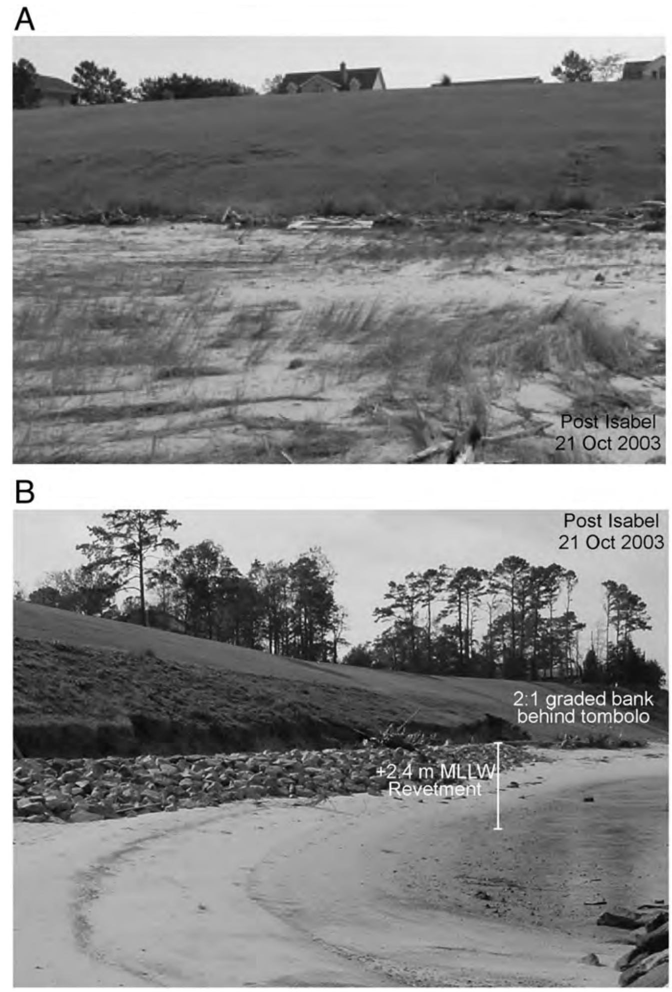

Fig. 11. Impact of Hurricane Isabel at Van Dyke including A) the upriver end where the bank is graded at 4:1, and B) at the downriver end of Van Dyke where the shore is protected by a revetment.

Generally, projects located in bimodal wind/wave settings should allow for what can be called omnidirectional wave attack at varying water levels. The breakwater gap (G_b) may have to be reduced relative to both breakwater length (L_b) and pocket beach indentation (M_b) so that major shifts in the beach planform will adjust within the embayment. On sites with a definite unidirectional wind/wave approach, the breakwater gap (G_b) can be opened relative to L_b and M_b. Some M_b:G_b ratios are as high as 1:2.5, and the tangential feature of the pocket beach does not change significantly alongshore. The sand volume, the protective beach, required to be placed in headland-breakwater systems is determined by the breakwater system dimensions that fall within the boundaries of the aforementioned parameter relationships (Hardaway and Gunn, 2000).

The parameter relationships are offered as a *guide* for breakwater design along fetch and depth limited shorelines like the Chesapeake Bay. These headland-breakwater systems have and continue to provide long-term shore protection, but they also create a stable coastal profile of beach, backshore, and low dunes that provide wetlands habitat and easy access to the waters of Chesapeake Bay. Constructing stable pocket beaches for long-term shore protection can be done cost effectively. The procedures used over the years to evaluate and design headland breakwaters have been, in retrospect, effective. These installations provide a database of successful headland-breakwater installations, some of which are over 20 years old. This database will continue to be used to verify and compare parameters for headland systems in the future as sites continue to mature.

References

Bodge, K.R., 1998. Beach fill stabilization with tune structures: experience in the southeastern USA and Caribbean. In: Allsop, N.H.W. (Ed.), Coastlines, Structures and Breakwaters. Thomas Telford, London, pp. 82–93.

Bodge, K.R., 2003. Design aspects of groins and jetties. Advances in Coastal Structure Design. ASCE.

CEM, 2000. Coastal Engineering Manual. Veritech, Inc., Vicksburg, MS, USA.

Chasten, M.A., Rosati, J.D., McCormick, J.W., 1993. Engineering design guidance for detached breakwaters as shoreline stabilization structures. Tech. Report CERC-93-19, U.S. Army Corps of Engineers, Waterways Experiment Station, MS.

Ebersole, B.A., Cialone, M.A., Prater, M.D., 1986. RCPWAVE—A linear wave propagation model for engineering use. Tech. Report CERC-86-4, U.S. Army Corps of Engineers, Waterways Experiment Station, MS.

Hardaway, Jr. C.S., Byrne, R.J., 1999. Shoreline management in Chesapeake Bay. Special report in Applied Marine Science and Ocean Engineering No. 356, Virginia Institute of Marine Science, College of William & Mary, VA, USA.

Hardaway Jr., C.S., Gunn, J.R., 1991. Headland breakwaters in the Chesapeake Bay. Proceedings Coastal Zone '91, ASCE 2, 1267–1281.

Hardaway Jr., C.S., Gunn, J.R., 1999a. Chesapeake Bay: design, installation, and early performance of four (4) new headland breakwater/composite systems. Beach Preservation Technology 1998. Florida Shore and Beach Preservation Assoc., pp. 1–18.

Hardaway Jr., C.S., Gunn, J.R., 1999b. Chesapeake Bay: design and early performance of three headland breakwater systems. Proceedings Coastal Sediments '99. ASCE, pp. 828–843.

Hardaway Jr., C.S., Gunn, J.R., 2000. Shoreline protection: design guidelines for pocket beaches in Chesapeake Bay, USA. Proceedings Carbonate Beaches.

Hardaway Jr., C.S., Gunn, J.R., Reynolds, R.N., 1993. Breakwater design in the Chesapeake Bay: dealing with the end effects. Coastal Engineering Considerations in Coastal Zone Management, Proceedings Coastal Zone '93. American Shore and Beach Preservation Association/ASCE, pp. 27–41.

Hardaway Jr., C.S., Gunn, J.R., Reynolds, R.N., 1995. Headland breakwater performance in Chesapeake Bay. Proceedings 1995 National Conference on Beach Preservation and Technology, St. Petersburg, FL, pp. 365–382.

Hardaway Jr., C.S., Milligan, D.A., Wilcox, C.A., Meneghini, L.M., Thomas, G.R., Comer, T.R., 2005. The Chesapeake Bay breakwater database project: Hurricane Isabel impacts to four breakwater systems. Virginia Institute of Marine Science, College of William & Mary, VA, USA.

Hsu, J.R.C., Evans, C., 1989. Parabolic bay shapes and applications. Proceedings Institution Civil Engineers, Part 2. Thomas Telford, London, 87, 557–570.

Hsu, J.R.C., Silvester, R., Xia, Y.M., 1989a. Generalities on static equilibrium bays. Coastal Engineering 12, 353–369.

Hsu, J.R.C., Silvester, R., Xia, Y.M., 1989b. Generalities on static equilibrium bays: new relationships. Journal of Waterway, Port, Coastal and Ocean Engineering, ASCE 115 (3), 285–298.

Kiley, K., 1982. A shallow water wind wave prediction program. Based on U.S. Army Corps of Engineers Program developed by CERC, Fort Belvoir, Virginia.

Silvester, R., Hsu, J.R.C., 1993. Coastal Stabilization: Innovative Concepts. Prentice-Hall, Englewood Cliffs, NJ. 578 pp.

Silvester, R., Hsu, J.R.C., 1997. Coastal Stabilization. World Scientific Publ. Co., Singapore. 578 pp. (Reprint of Silvester and Hsu, 1993).

Suh, K.D., Dalrymple, R.A., 1987. Offshore breakwaters in laboratory and field. Journal of Waterway, Port, Coastal and Ocean Engineering, ASCE 113 (2), 105–121.

VIMS, 2003. VIMS scientists quantify Isabel's impacts on the Bay. Press Release, Virginia Institute of Marine Science, College of William & Mary, VA, USA. http://www.vims.edu/newsmedia/press_release/isabel.html.

Attachment 2B-2

Relevant Presentation

"Living Shorelines" An Historical Perspective from Chesapeake Bay

Current Practices and how they got here

Living Shoreline Summit
2013

C. Scott Hardaway, Jr.
Geologist
Shoreline Studies Program
VIMS

Shoreline Studies Program
VIMS

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"Living Shorelines"

1970s Referred to as marsh fringe creation

1980s &1990s Non-structural approach, MD grant program and VA VEC project

1981 to 1987: VA Shoreline Erosion Advisory Service SEAS

Recent moniker: Living Shorelines (2006 by David Burke former head of MD Non-structural program)

Common goal: to apply marsh fringe and/or beach establishment to shore erosion control vs. hardening the coast.

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Shoreline Erosion

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SCS: Vegetation for Tidal Shoreline Stabilization - Innovation #1

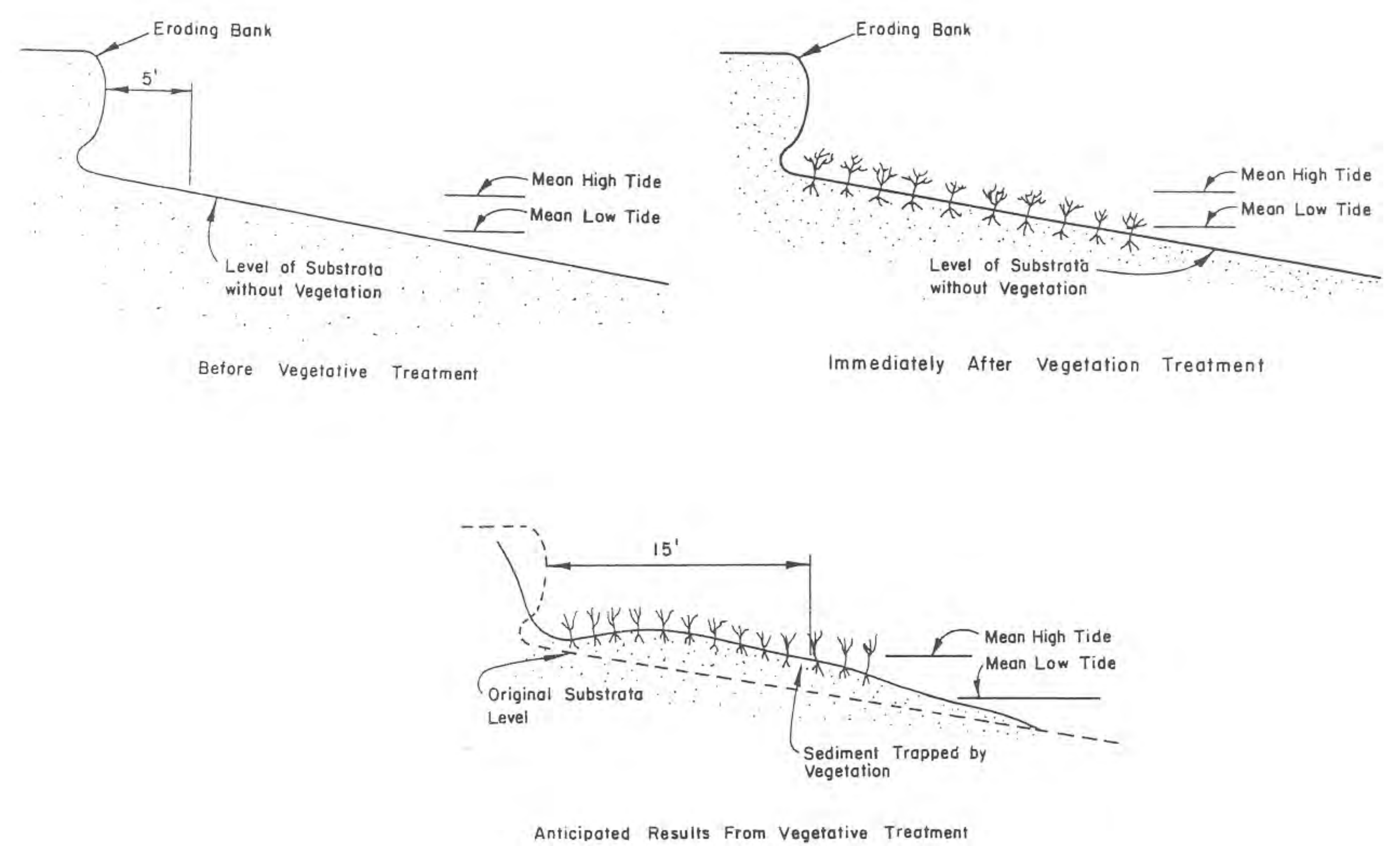

TABLE I VEGETATIVE TREATMENT POTENTIAL FOR ERODING TIDAL SHORELINES IN THE MID-ATLANTIC STATES

DIRECTION FOR USE

1. Evaluate each of the first four shoreline variables and match the site characteristics of the variable to the appropriate descriptive category.
2. Place the Vegetative Treatment Potential (VTP) assigned for each of the four variables in the right hand column.
3. Obtain the Cumulative Vegetative Treatment Potential for variables 1, 2, 3 & 4 by adding the VTP for each.
4. If it is 23 or more, the potential for the site to be stabilized with vegetation is very good and the rest of the table need not be used. If it is below 23, go to step 5.
5. Determine the VTP for shoreline variables 5 through 9 and obtain the cumulative VTP for variables 1-9.
6. Compare the cumulativ· VTP score with the Vegetative Treatment Potential Scale at the bottom of this page.

SHORELINE VARIABLES	DIRECTION FOR USE The Vegetative Treatment Potential (VTP) Is Located in Upper Left Hand of Each Category Box					VTP
1. Fetch: Average distance in miles of open water measured perpendicular to the shore and 45° either side of perpendicular to shore.	8 Less than 0.5 miles	7 0.5 thru 1.4 miles	4 1.5 thru 3.4 miles	2 3.5 thru 4.9 miles	0 over 5 miles see footnote 1/	
2. General shape of shore line for distance of 200 yards on each side of planting site.	8 Coves	3 Irregular shoreline	0 Headland or straight shoreline			
3. Shoreline orientation: General geographic direction the shoreline faces.	5 Any orientation less than one-half mile fetch	3 West to North	2 South to West	1 South to East	0 North to East	
4. Boat traffic: Proximity of site to recreational & commercial boat traffic	5 None	3 1-10 per week within 1/2 mi. of shore	2 More than 10 per week within 1/2 mi. of shore	1 1-10 per week within 100 yds. of shore	0 More than 10 per week within 100 yds. of shore	

Cumulative Vegetative Treatment Potential for Variables 1, 2, 3 & 4 ________

If this score is 23 or above, the potential for the site is very good and the rest of the table need not be used. If it is below 23, go to step 5 below.

					VTP
5. Width of Beach Above Mean High Tide in Feet	3 Greater than 10'	2 10' thru 7'	1 6' thru 3'	0 Less than 3'	
6. Potential width of 2/ Planting Area in Feet	3 More than 20'	2 20' thru 15'	1 14' thru 10'	Less than 10' Do Not Plant	
7. On Shore Gradient: % slope from MLW to toe of bank	6 Below 8%	3 8 thru 14%	1 15 thru 20%	0 over 20%	
8. Beach Vegetation	3 Vegetation below toe of slope	0 No vegetation below toe of slope			
9. Depth of sand at 3/ Mean High Tide in inches	3 More than 10"	2 10" thru 3"	0 Less than 3"		

Cumulative Vegetative Treatment Potential for Variables 1-9 ________

1/ Do not plant or see page 9 and figure 9 for possible exception.

2/ If tidal fluctuation is 2.5 feet or less, measure from MLW to toe of bank. If tidal fluctuation is over 2.5 feet, measure from MW to toe of bank. See page 7 for more information.

3/ Refers to depth of sand deposited by littoral drift over the substrata.

VEGETATIVE TREATMENT POTENTIAL SCALE

If the VTP is: Between	And	Potential of Site to be Stabilized with Vegetation
40	33	Good
32	24	Fair
23	16	Poor
below	16	Do Not Plant

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Early Research on Marsh Fringe Creation

1970s Knutson and Woodhouse, USCOE reports on marsh creation and wave studies

Broome and Seneca, NC coastal marshes

Ed Garbisch, MD

SCS Cape May Plant Materials Center

1980s Vegetative Erosion Control Project, VA VIMS and DCR (SEAS)

Same result: a fetch limited application

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Primary Limiting Parameters

- Fetch
- Shoreline orientation
- Shore geometry
- Nearshore bathymetry
- Boat wakes
- Sunlight (often over looked)

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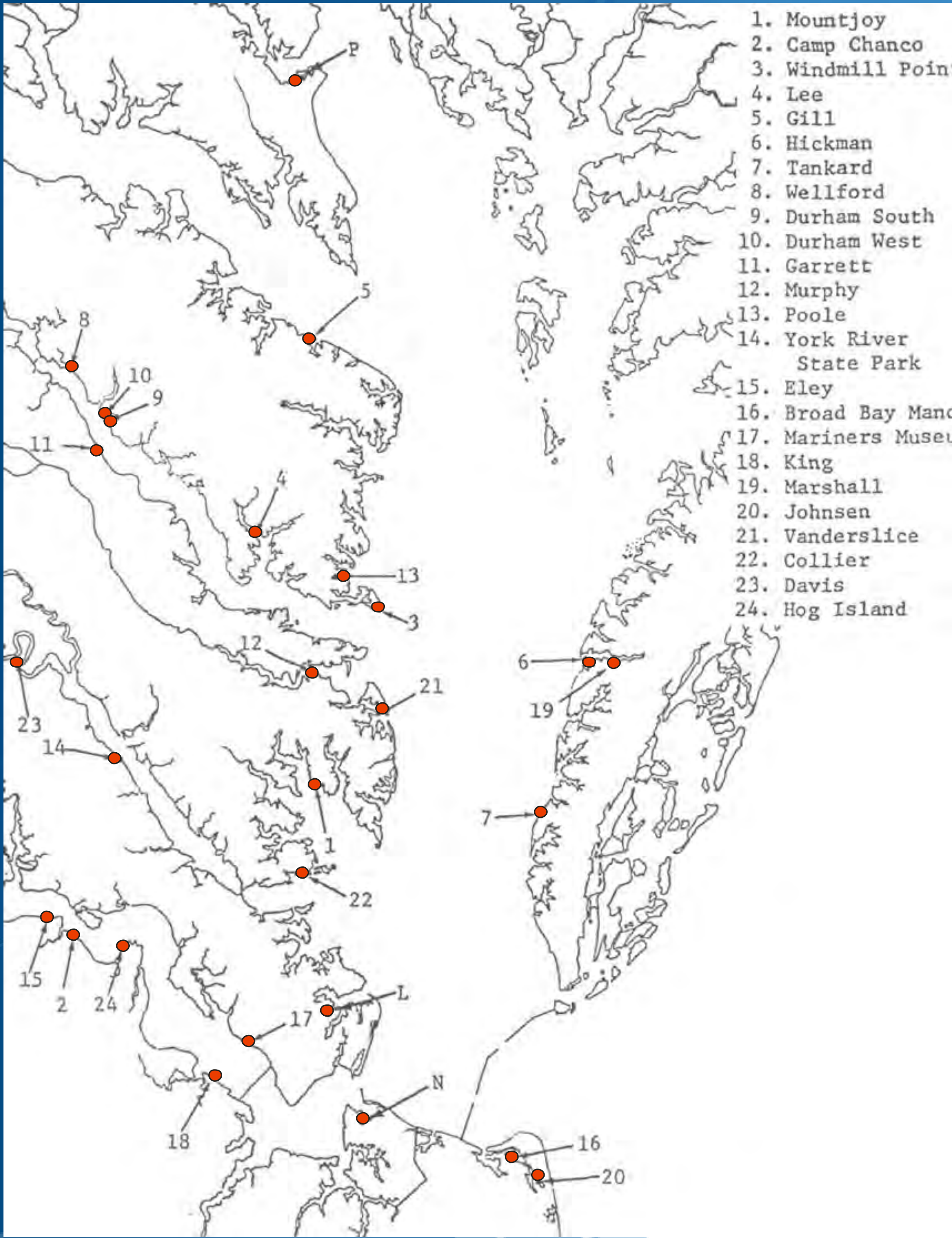

Vegetative Erosion Control Project VIMS and DCR 1981-1987

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Occahannock Creek VEC Site

Marsh planting along Occahannock Creek, Northampton County, Virginia.

Occahannock Creek marsh plantings after 1 year.

Occahannock Creek marsh planting after 10 years of growth.

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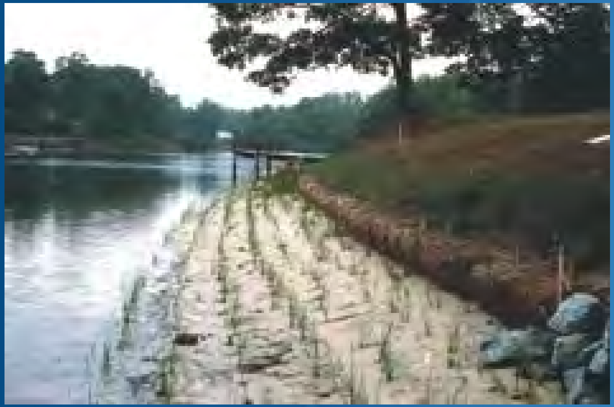
Poole VEC Site



Minor bank grading and temporary toe protection utilizing straw bales was used to protect the planted marsh fringe.

Since high water impinged upon the base of the bank, only the intertidal species (*Spartina alterniflora*) was utilized.

After one year.

After six years.

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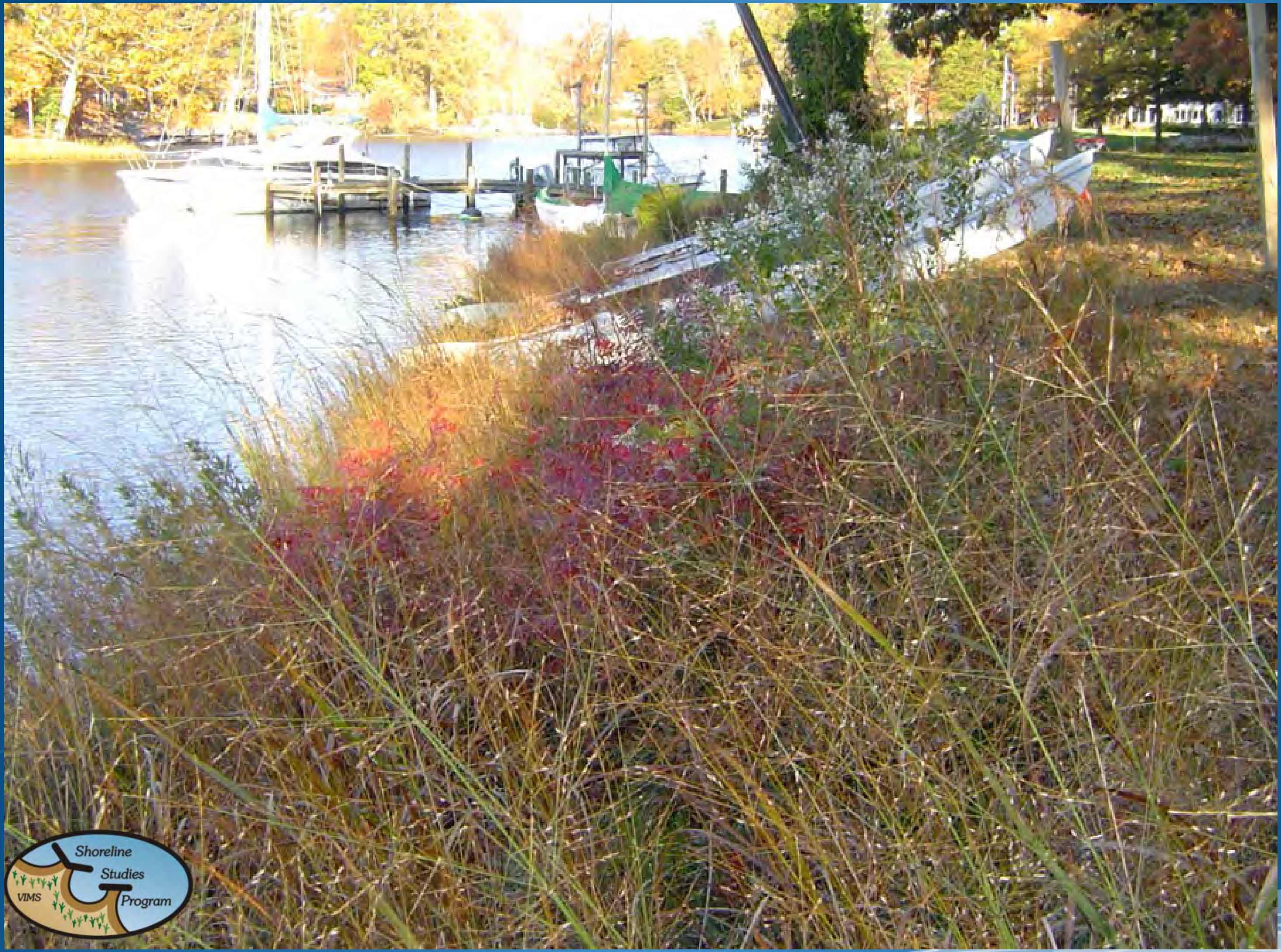
Poole VEC Site



24 years after construction

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Lee VEC Site

Shoreline Studies Program VIMS

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Lee VEC Site

25 years after construction

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VEC Project

- 24 sites planted in a variety of shore settings on existing substrate

- Success dependent of 1) fetch 2) shore geomorphology and 3) shore orientation

- Fetch:
    - <1.0 nm, high probability of success;
    - 1-5 nm, low probability, even with maintenance,
    - >5 nm, no probability of success.

- South facing shoreline have better chance.

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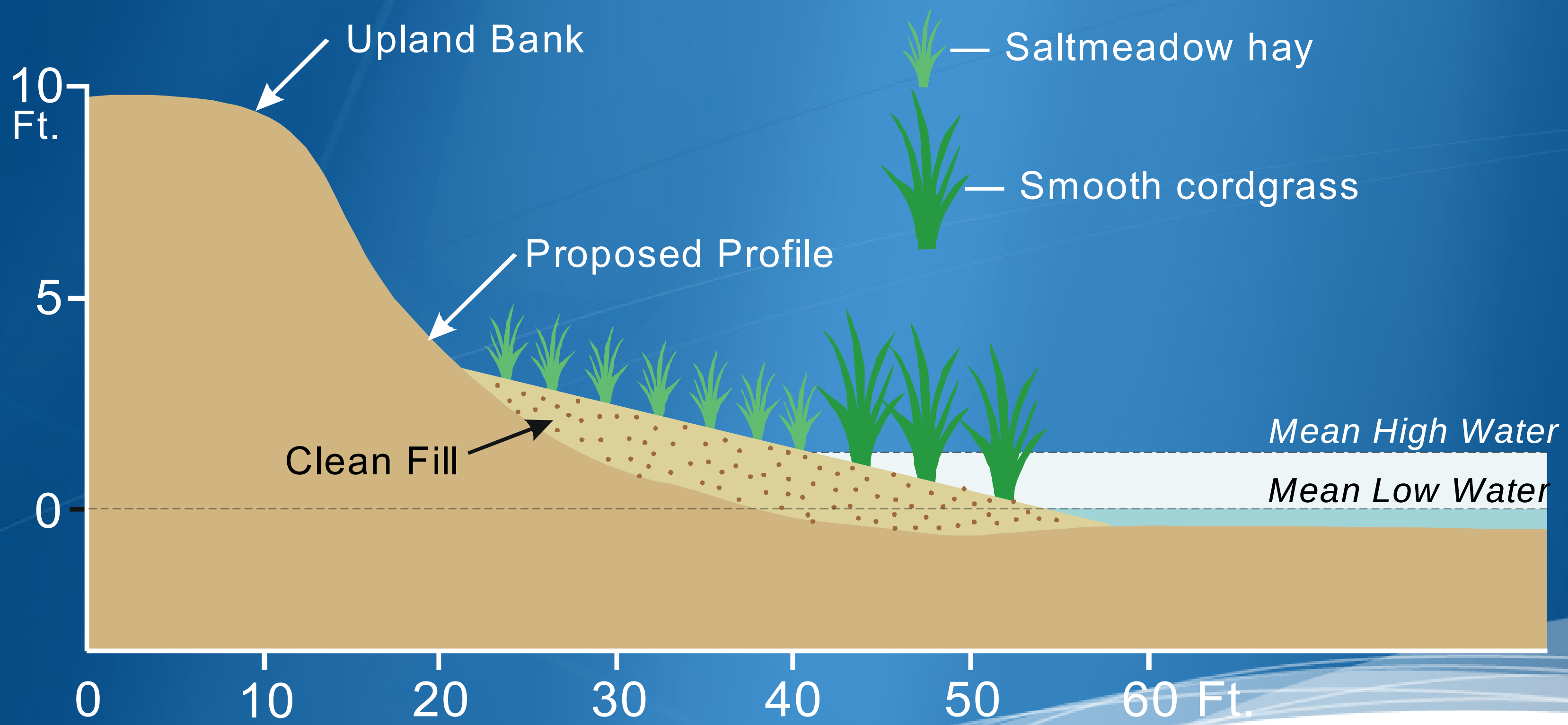
Management Strategies

This cross-section shows a proposed plan to stabilize a typical eroding shoreline using clean sand to create the appropriate planting area.



Maryland Non-Structural Program: Add sand and structures - Innovation #2

- Over 300 sites installed through grant program
- Program is still active.

RC&D: Dave Wilson and Jerry Walls

Maryland DNR: Lin Casanova, Dave Burke, Jordan Loran, Chris Zabawa, Kevin Smith

Current personnel: Kevin Smith, Tom Brower, Bhaskar Subramanian

Wye Island

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

Marsh grass plantings with sand fill and short, stone groins

3 months after installation

4 years after construction.

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Wye Island

28 years after construction

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South River

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Marsh Toe Revetment/Sill

East River
Mathews County, Virginia

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Jefferson Patterson Park & Museum

October 1986

Pre-project

December 1988

Jefferson Patterson Sill

16 years after construction

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Micro-topography

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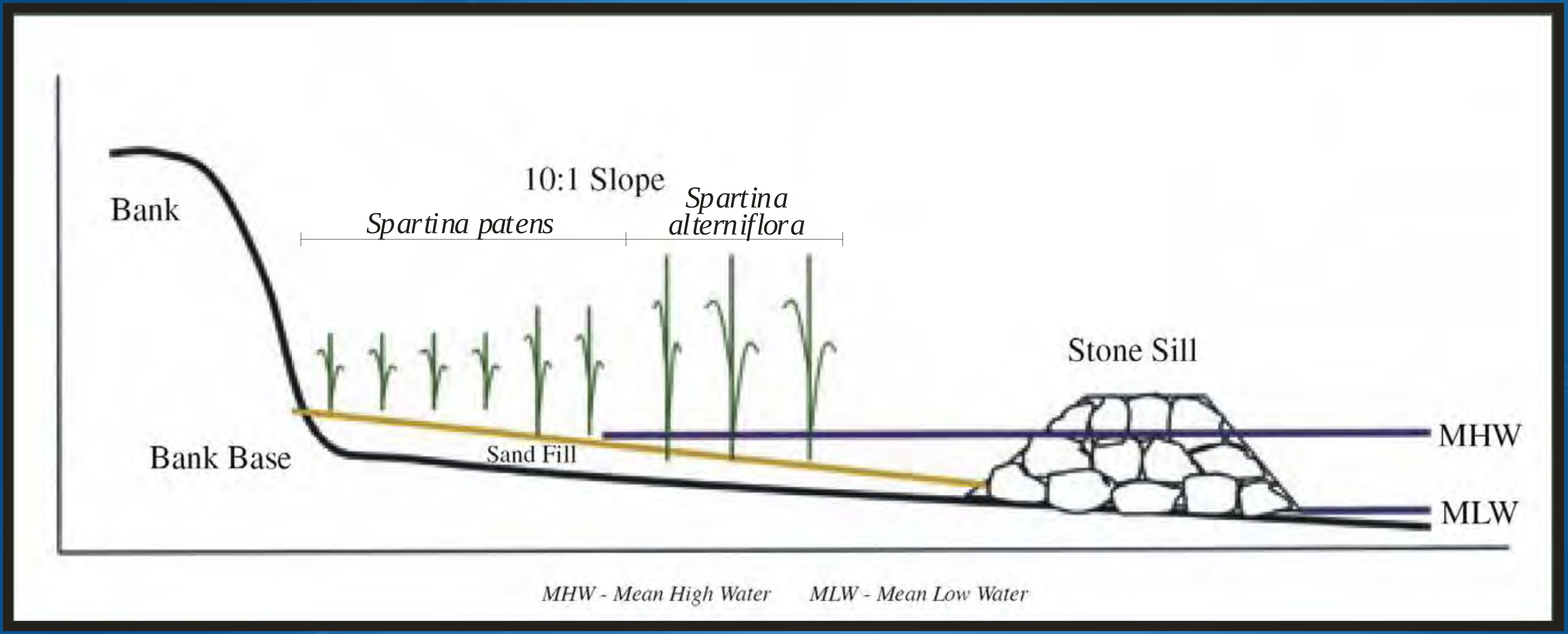

Profile of a typical marsh edge stabilization project used to prevent wetland edge loss.

(from Luscher and Hollingsworth, 2005)

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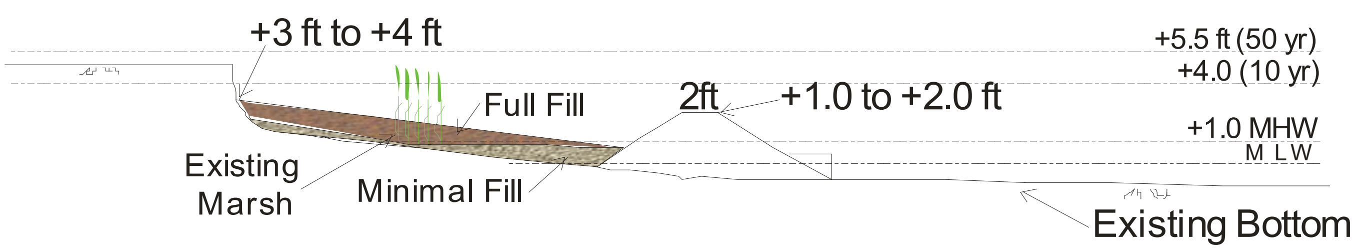
Typical Cross-sections for Living Shorelines

Low Sill/Low Bank

Existing Conditions

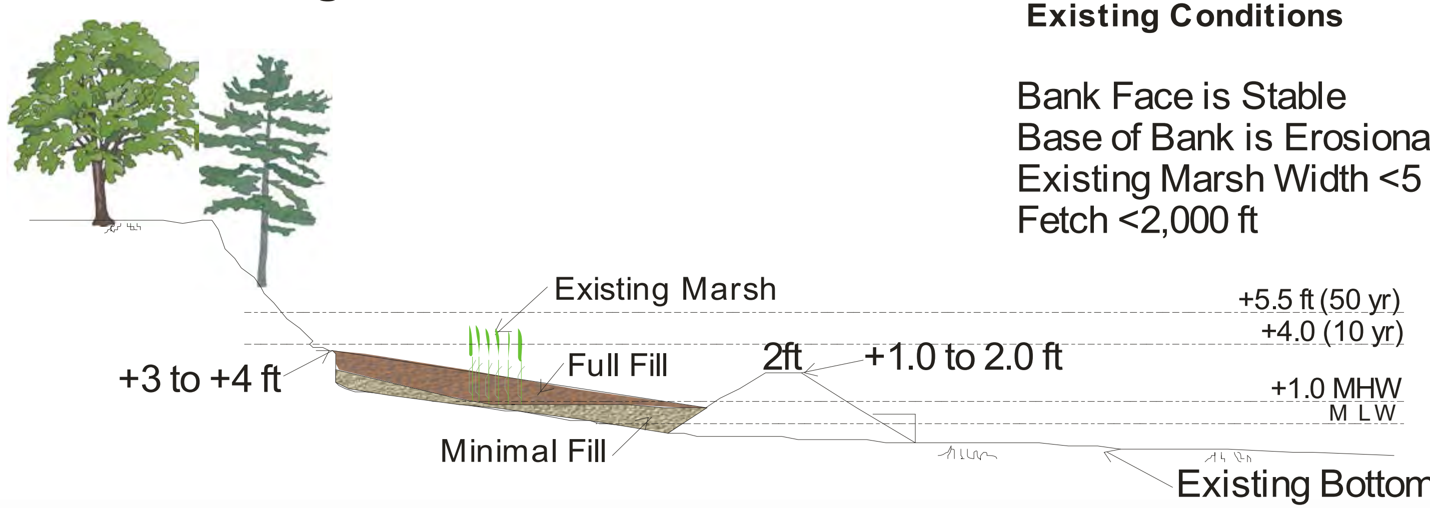
Bank Face is Erosional
Base of Bank is Erosional
Existing marsh <5ft



Low Sill/High Bank

Existing Conditions

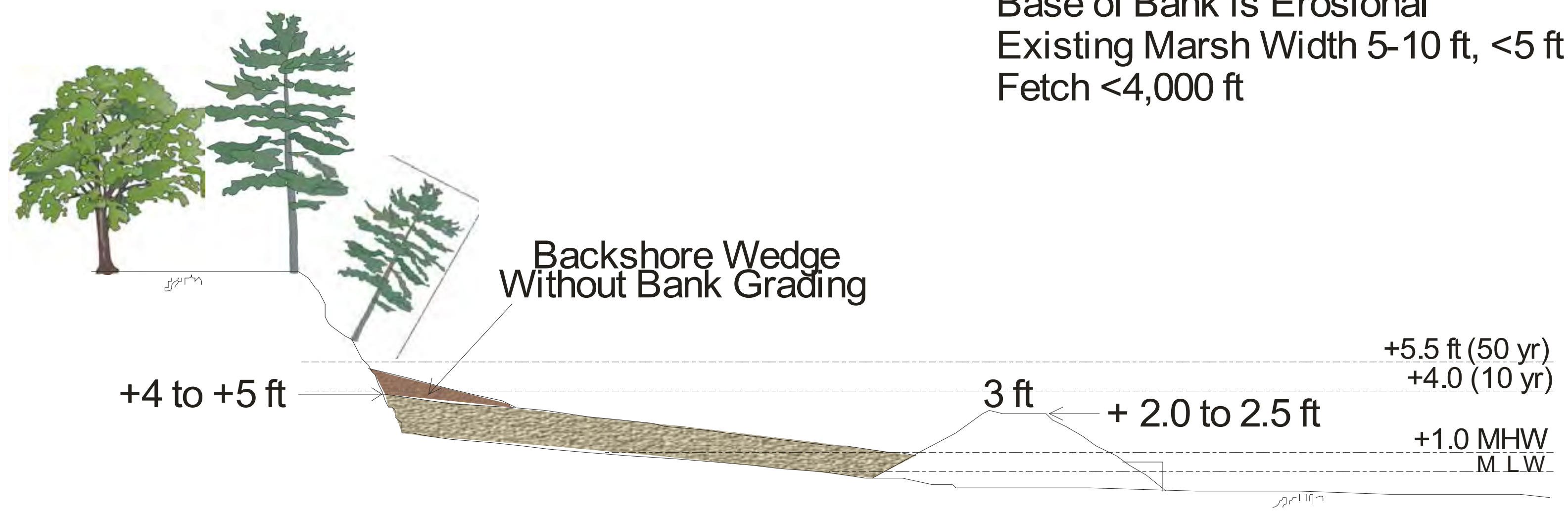
Bank Face is Stable
Base of Bank is Erosional
Existing Marsh Width <5 ft
Fetch <2,000 ft



Typical Cross-sections for Living Shorelines

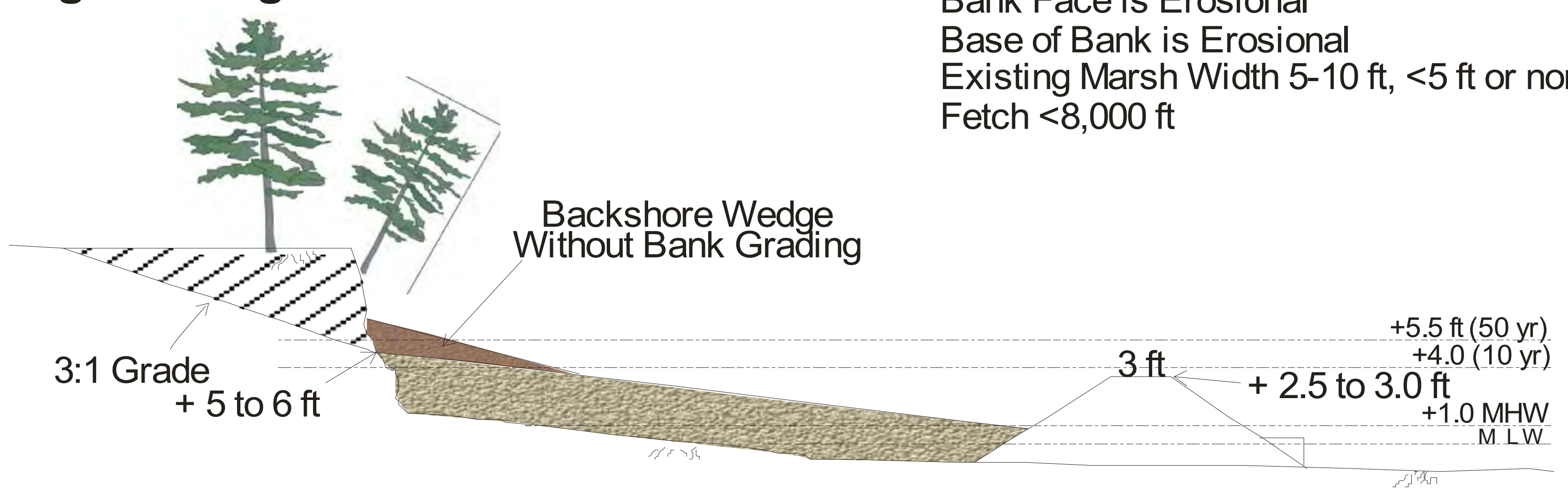
Medium Sill/High Bank

Bank Face is Transitional
Base of Bank is Erosional
Existing Marsh Width 5-10 ft, <5 ft or none
Fetch <4,000 ft



High Sill/High Bank

Bank Face is Erosional
Base of Bank is Erosional
Existing Marsh Width 5-10 ft, <5 ft or none
Fetch <8,000 ft



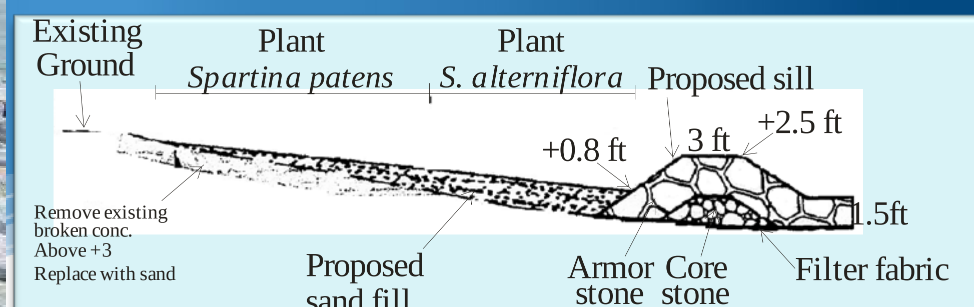
Webster Field Annex, Maryland
Sand fill with stone sills and marsh

before installation

after installation but before planting

after four years

the cross-section used for construction.



St. Mary's City Sill

August 2001

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St. Mary's City:
Sill with Window - Innovation #3

November 2006

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St. Mary's City

The sill at St. Mary's City at low tide depicting two of the access pathways including the sill windows and macro-pores in the sill.

(from Hardaway et al., 2008)

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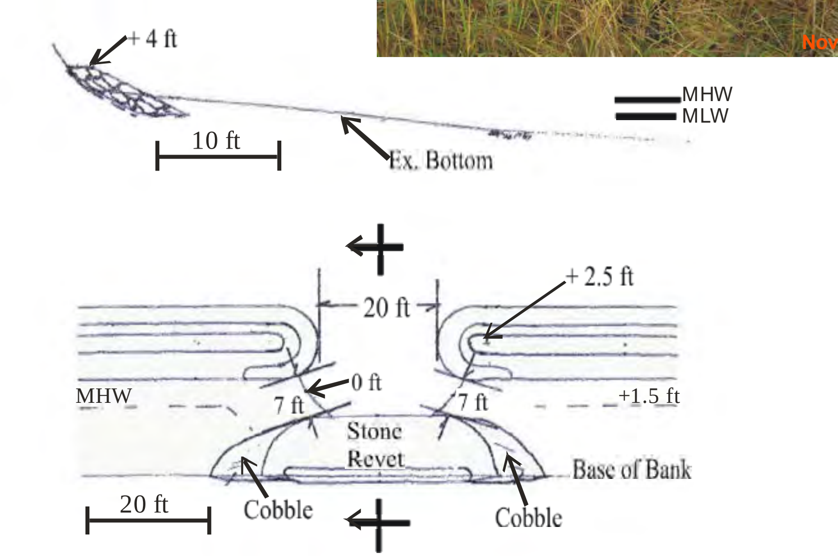
St. Mary's City

Post Construction, 2002

2006



Planform and cross-sectional design

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(From Hardaway et al., 2008)

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St. Mary's City
Cobble in window to reduce scour

November 2006

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Marsh Fringe Applications Lesson Learned

1) Plant existing substrate, provide sun at least 6 hours/day. (fetch < 0.5mi)

2) To provide more marsh width, add sand fill with minimal containment structures such as stone groins, coir logs, etc. (fetch 0.5 to 1.0 mile) Use stone for the long term. Maintain system.

3) For higher wave energy sites, use marsh toe revetments or stone sills, add sand and plant new marsh.

fetch 1.0 to 5.0 miles, > 5.0 miles-increase sill ht

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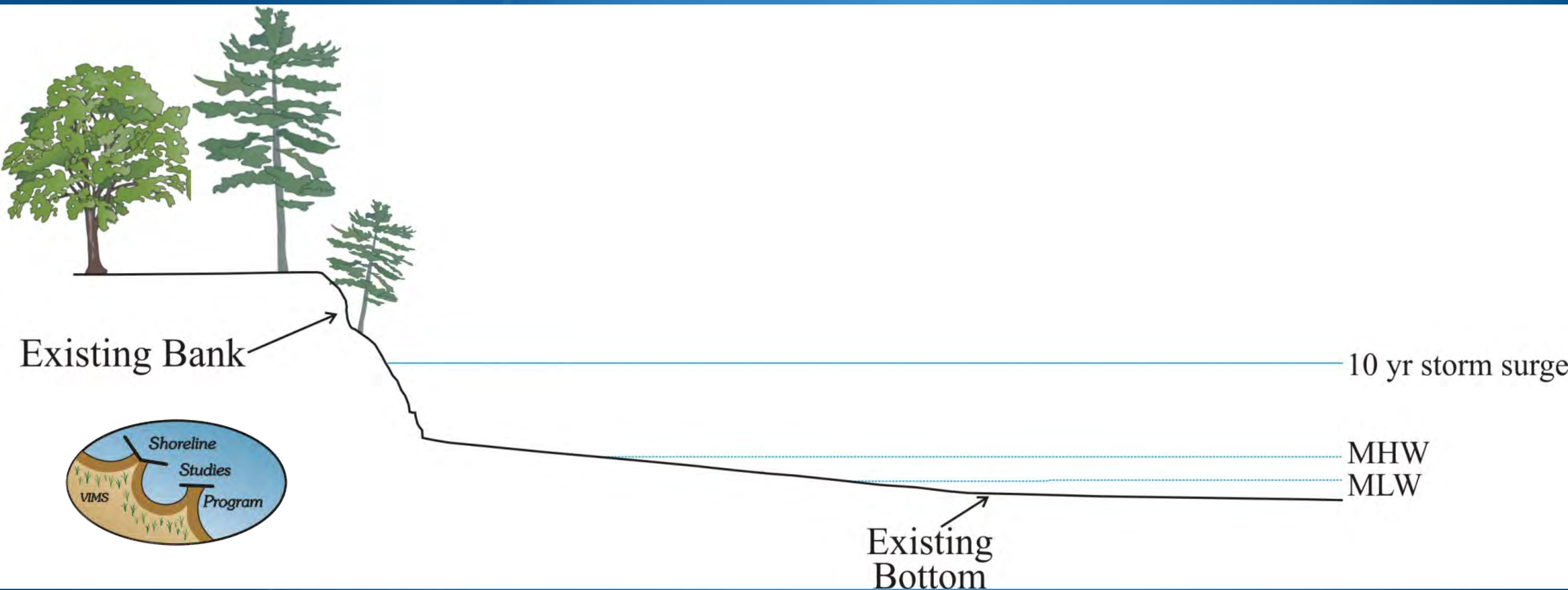
Marsh Fringe Applications



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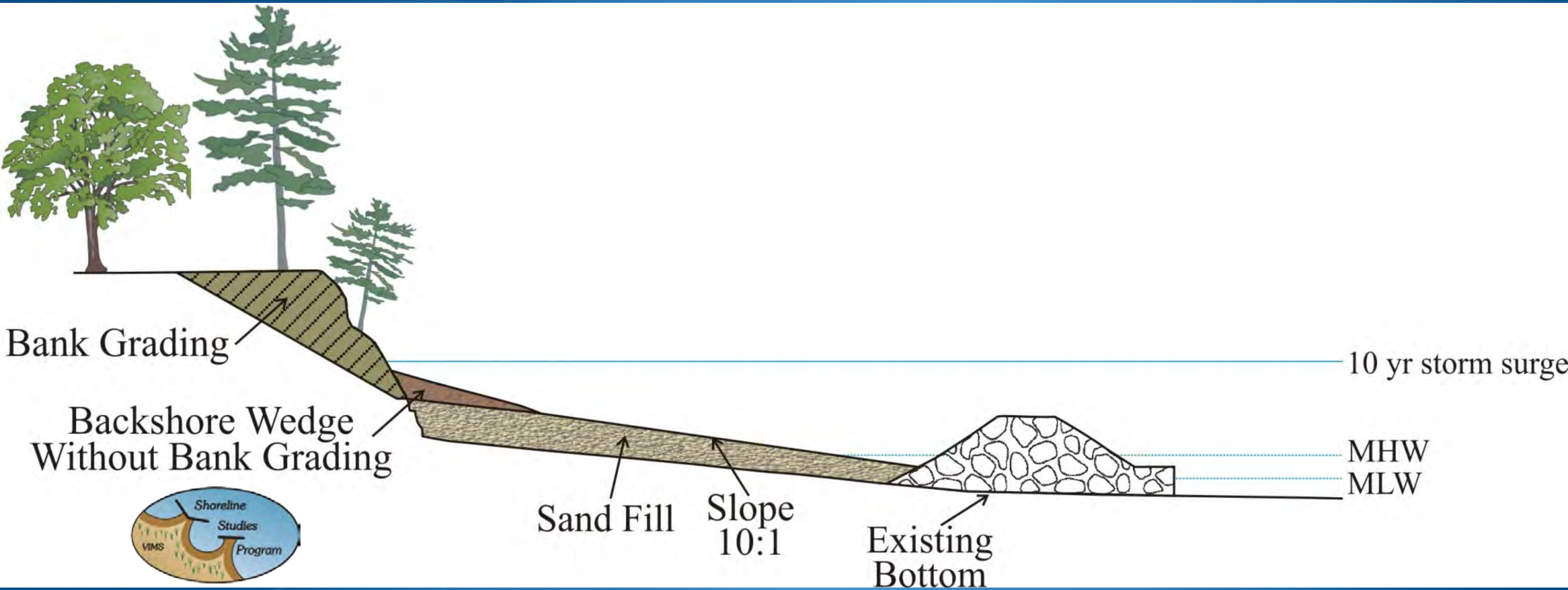
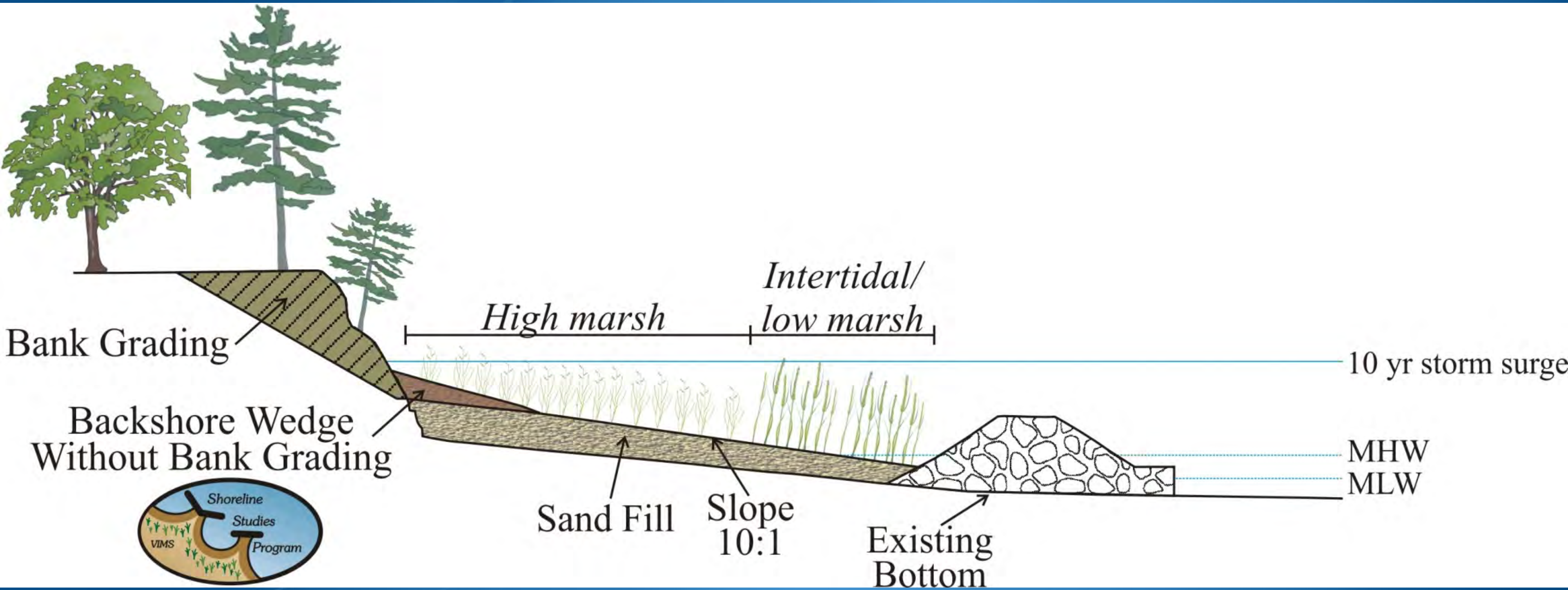
Marsh Fringe Applications



Marsh Fringe Applications



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Mathews County, Virginia

Sill with marsh and pocket beach.

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Mathews County, Virginia

Aerial view of entire project which included sills, pocket beach, and revetment to stabilize spit with historic mill.

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Beaches

- Naturally occurring beaches can provide shore protection if wide and high enough.
- Beach nourishment is a method used to maintain a protective beach.
- In Chesapeake Bay, ongoing beach nourishment projects are usually done in conjunction with some type of securing structure such as groins or breakwaters.
- The use of breakwaters on private property began in 1985.

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Chesapeake Bay Breakwaters Innovation BW #1

First system installed in 1985 by Coastal Design and Construction, Inc.

Drummond Field: James River
June 2005

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Drummond Field:
Beginning the Dream

Drummond Field: James River
1985

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Drummond Field:
Virginia's First Tombolo

Drummond Field: James River
1985

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Drummond Field

Drummond Field: James River
Feb 2004

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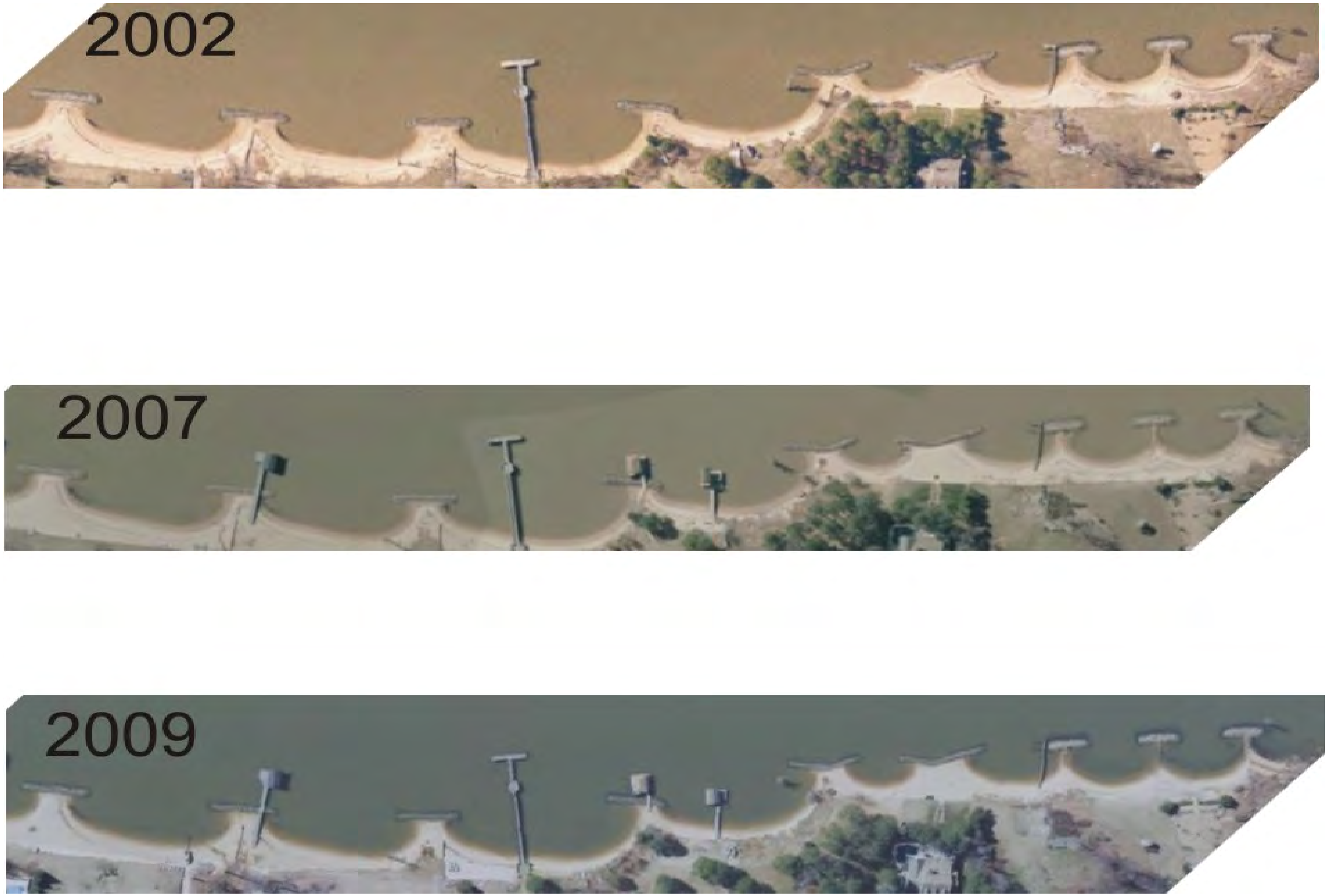
Drummond Field performance



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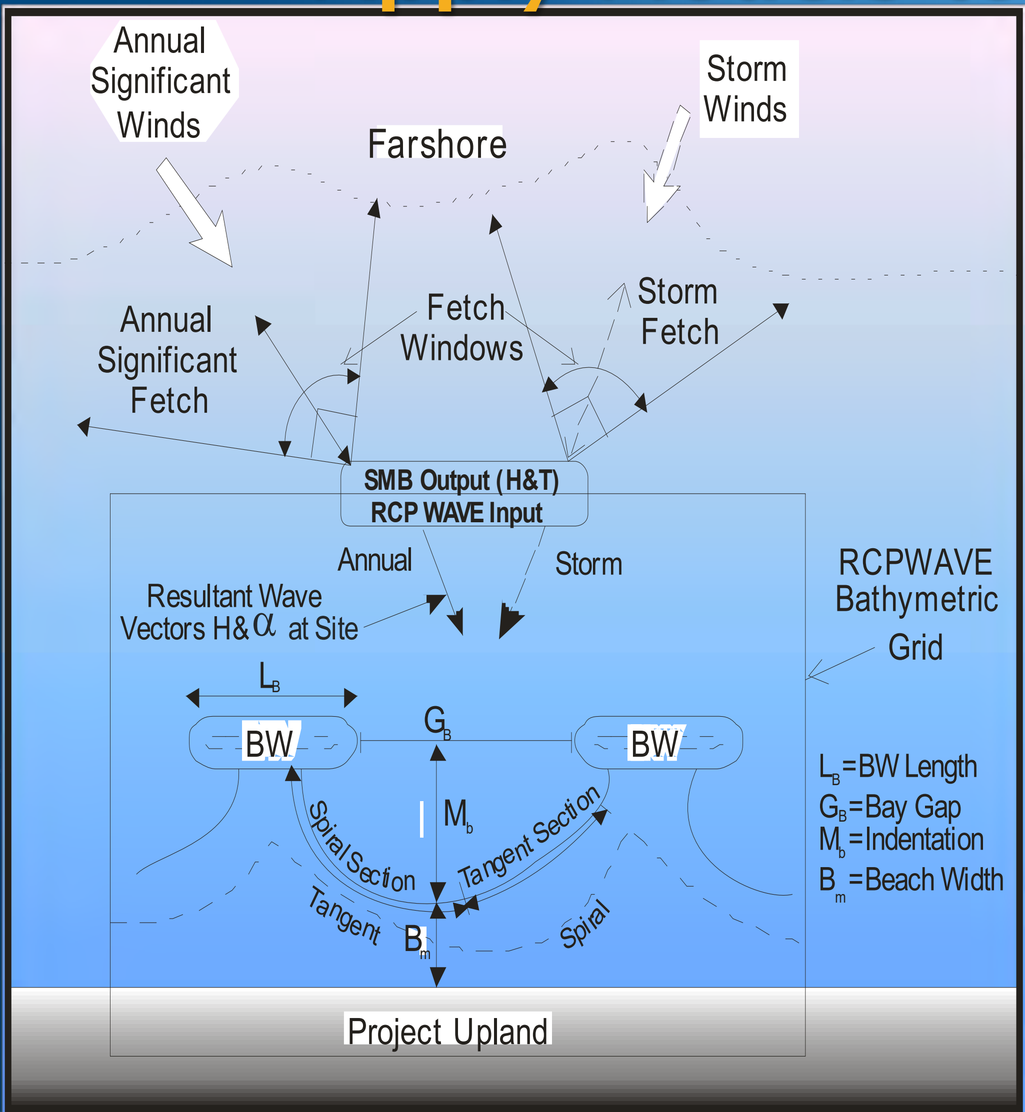
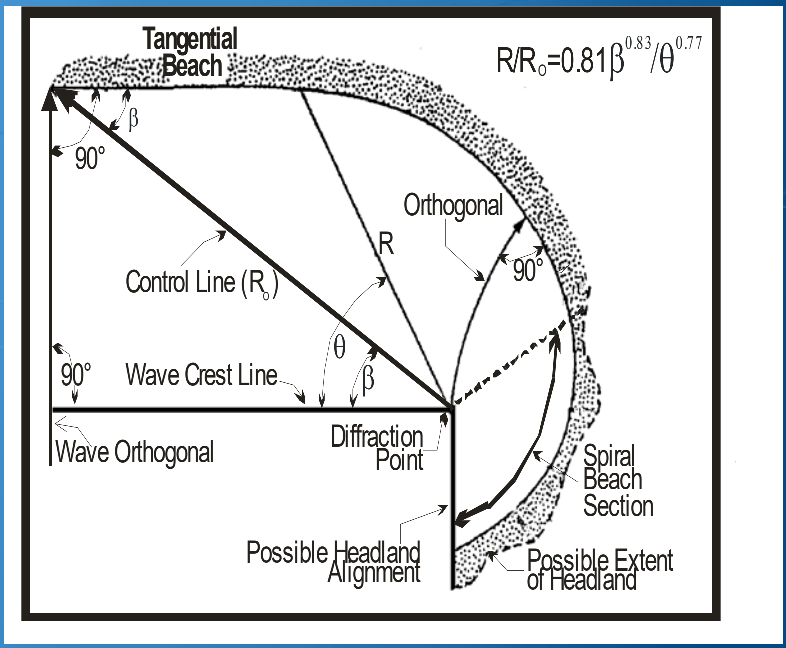
Chesapeake Bay Breakwaters Innovation BW #2 – Apply Models to BW Design





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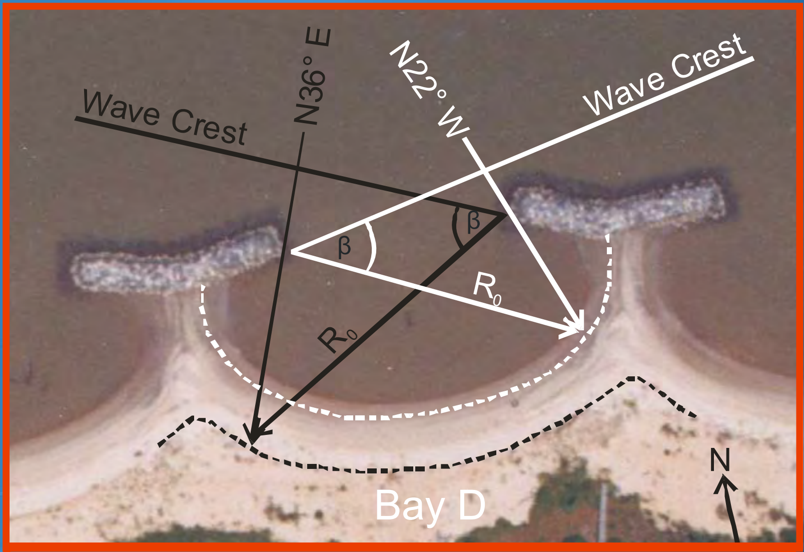
Van Dyke
James River



Shoreline Studies Program
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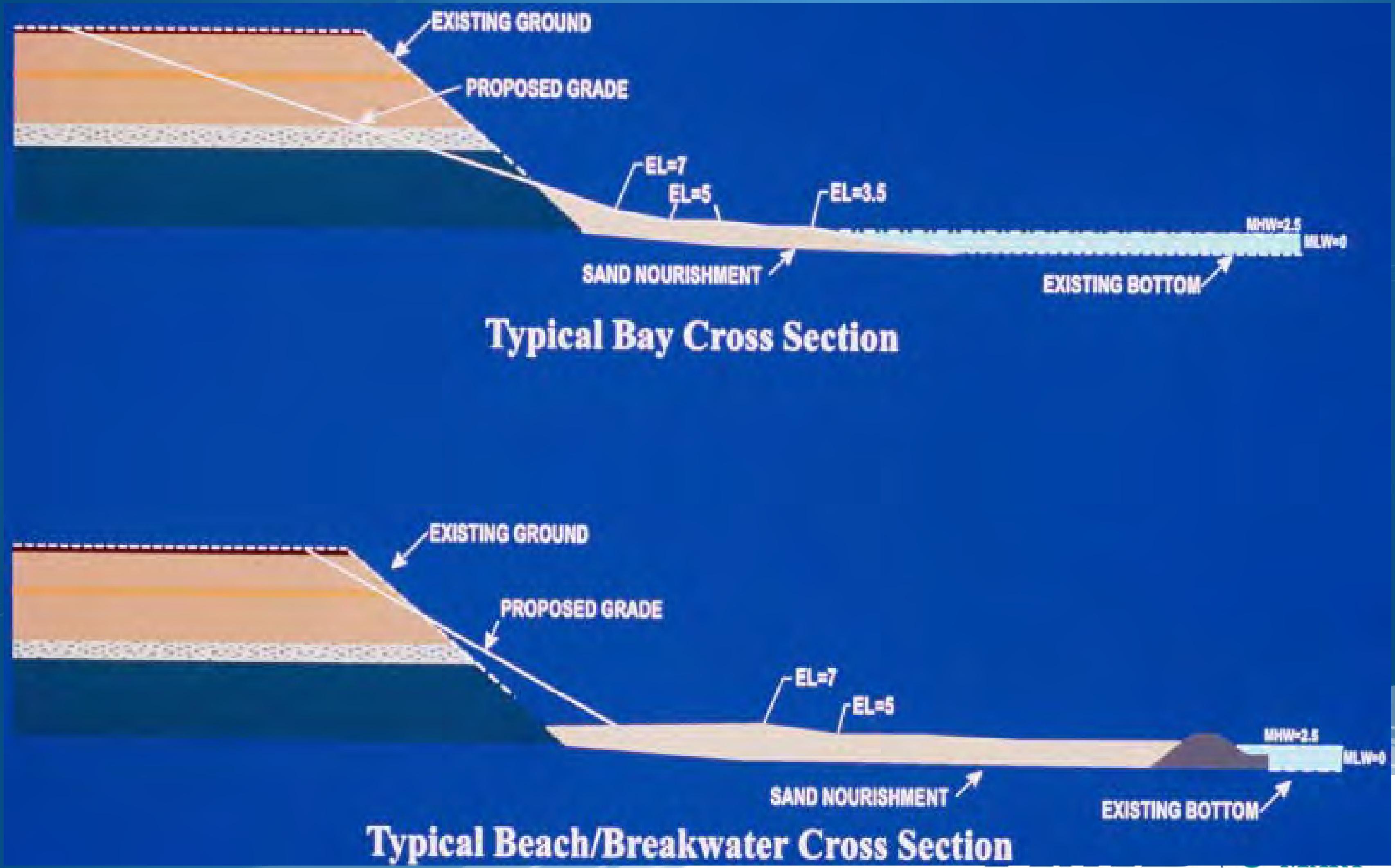
Shore Protection

Typical breakwater and bay cross-sections.



VIRGINIA INSTITUTE OF MARINE SCIENCE

Van Dyke: James River
After Construction

VIRGINIA INSTITUTE OF MARINE SCIENCE

Van Dyke: James River

Van Dyke: James River
August 2003

Figure 10. Non-rectified aerial photography of Van Dyke A) before installation and B) after installation.

VIMS | WILLIAM & MARY
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Chesapeake Bay Headland Breakwater Sites

VIMS | William & Mary
Virginia Institute of Marine Science

Luter: James River 2002

VIMS | WILLIAM & MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE

Luter: James River

Luter, Isle of Wright; James River
May 2004

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Virginia Institute of Marine Science

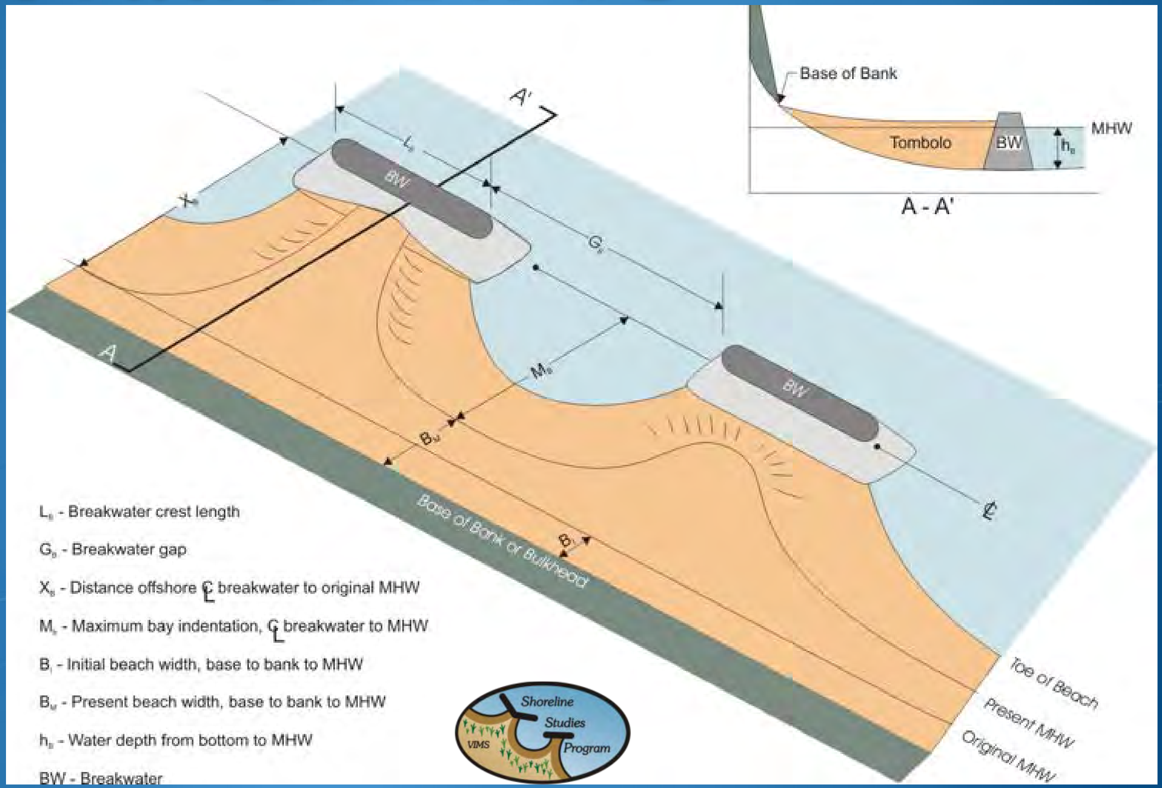
Luter: James River

Luter, Isle of Wright; James River
January 2010

Breakwater Design Guidelines: Innovation Bw #3

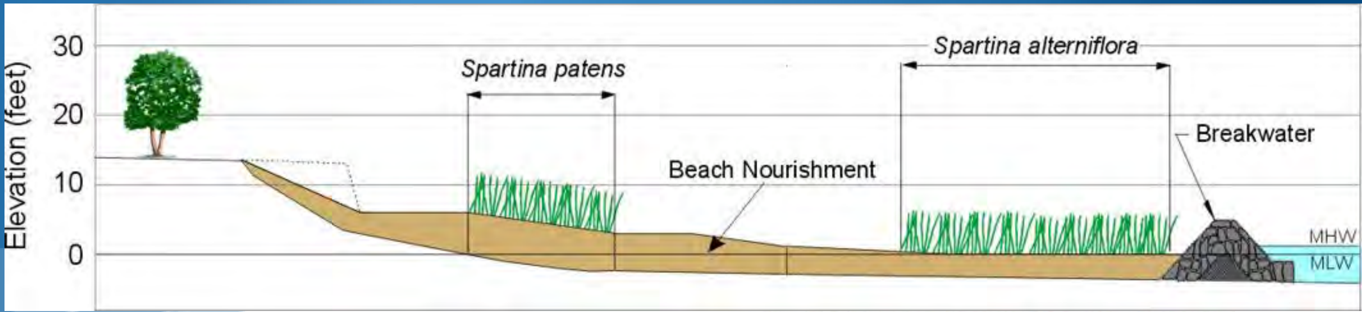
Maximum Bay Indentation : Gap Width

Mb:Gb
1:1.65



Crest Length : Gap Width

Lb:Gb
1:1.4



Yorktown: York River

Yorktown: York River

Yorktown: York River
April 2006

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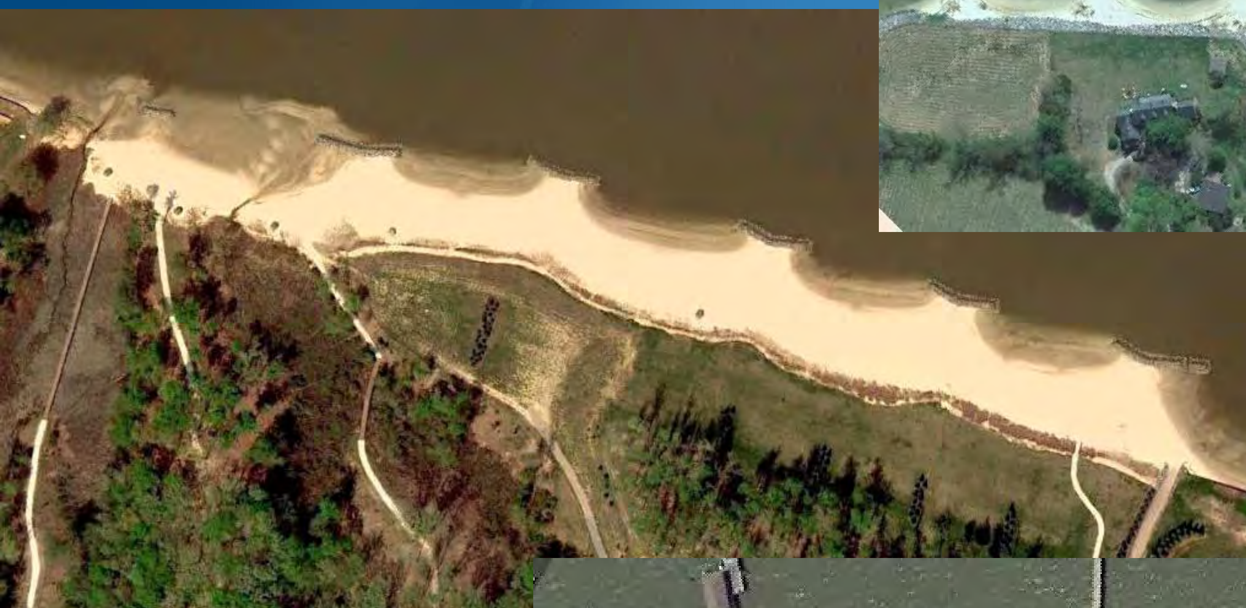
Other York River BW Sites

From Google Earth



Clarke: Eastern Shore

Minimize encroachment

Clarke: Eastern Shore

September 2013

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Summary: Marshes

- As fetch exposure increases so does the marsh width and elevation needed to attenuate wave action.

- At some point (> 0.5 nm fetch) a sill may be needed for long term marsh fringe stabilization.

- Marshes can provide long term protection if properly maintained.

- A large data base of marsh sites exists around the Bay along with various brochures and reports to support the Living Shoreline concept.

- This historical site data allows us to proclaim that shore erosion control can be achieved by creating ***Living Shorelines (i.e. marsh fringes).***

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Virginia Institute of Marine Science

Summary: Beaches

•Beaches are generally more suitable for greater fetch exposures > 1 nm.

•In Chesapeake Bay, maintaining a stable, wide protective beach requires:

- •some type of breakwater (s),
- •ongoing beach nourishment
- •or some combination.

•Best when applied to a shore reach.

THE END

Attachment 2B-3

Coastal Design, P.C. Qualifications

7. Brief Resume for Key Persons, Specialists, and Individual Consultants Anticipated for this Project

a. Name & Title:
C. Scott Hardaway, Jr., President, Coastline Design PC, Professional Geologist
(Glenn Gass, PE, Design Engineer)

.b. Project Assignment:
Coastal Projects: Develop Plans and Specifications for Shoreline Protection projects

c. Name of Firm with which associated:
Coastline Design, P.C.
P.O. Box 157, Achilles, Va. 23001

d. Years experience: With This Firm 25 With Other Firms 41

e. Education: Degree(s)/Year/Specialization
B.A. Geology, East Carolina University, 1973
M.S. Geology, East Carolina University, 1979

f. Active Registration: Year First Registered/Discipline
Professional Geologist, North Carolina , since 1985
Professional Geologist, Virginia, since 1984

g. Other Experience and Qualifications relevant to the proposed project:
Mr. Hardaway is a licensed geologist and President of Coastline Design, P.C. which was founded in 1995. He has more than 40 years of experience in research and analysis of shoreline erosion processes and development of shoreline protection strategies in Chesapeake Bay working for the Virginia Institute of Marine Science. Mr. Hardaway has developed empirical relationships for shoreline parameters in the Chesapeake Bay for breakwater and sill systems and has been involved in the design and implementation of more than 80 shore protection systems (breakwaters and sills, aka Living Shorelines). Coastline Design PC has designed more than 40 projects including each project listed below

Mr. Gass has been construction manager on all Indian Head and Smith Island shoreline projects and serves as Design Engineer for the firm. Licensed Profession Engineer PE, MD #14544.

C. Scott Hardaway, Jr.
1995-2005: Vice-chairman of the ASCE committee on Shore Protection Standards.
2006: Served on National Academy of Science's "Committee on Mitigating Shore Erosion on Sheltered Coasts".

Swan Point Development, Charles Co, MD. Completed in spring of 2012, this project consists of a series of 13 breakwater units, sills, beach nourishment and wetland/dune plantings along about 4,000 feet of shoreline on the Potomac River. Project costs approx. $ 4million and created over 11 acres of beach , dune and wetland habitat.

Indian Head Naval Base, Charles County, MD: Coastline Design, P.C. designed Phase 0 (completed, 2008 at a cost of about $4 million) and Phase 1 (completed 2010 at about $4 million) and Phase 2 ($7 million) completed 2012. All phases include approx. 3.0 miles (25.4 acres) of Living Shorelines consisting of breakwaters, stone sills, beach fill and wetlands plantings.

The Navy Recreation Center at Solomons, Calvert County, MD. A $3.0 million breakwater system that utilized adjacent sandy bank material to create stable pocket beach planforms in the lee of a series of 12 breakwaters and spurs. Marsh and dune vegetation was established in the lee of each breakwater and across the backshore respectively. Several of these beaches are currently used for recreational activities including swimming, volleyball and launching small boats. The project was completed in 1999 and covers more than 4,000 feet of shoreline on the Patuxent River.

Jefferson/Patterson Park and Museum. Calvert County, MD. This project covers more than one mile of estuarine shoreline on the Patuxent River and consists of a series of breakwaters, sills, beach nourishment and marsh creation. Significant archeological resources in the eroding bank required the project be designed around those resources. This is an example of a several Living Shoreline elements including, marsh sills, pocket beaches and windows. The project was completed in 1999 at a cost of $1.3 million. Hurricane Isabel caused only minor bank scarping even though the system was completely submerged. Hurricane Isabel was arguably a 100 year event.

Patuxent River Naval Air Station, Fuel Pier, St. Mary's County, MD The project consists of a system of 5 headland breakwaters with beach sands obtained from the adjacent 60-foot sandy upland banks to create a series of stable pocket beaches. Dune and marsh vegetation was planted to help support the tombolos and backshore regions. There is a bimodal wave climate of 4 miles to the northwest and over 12 miles to the northeast. The project was installed in 2001 and spans approximately 2,200 feet of shoreline at a total cost of $900,000. The site survived a direct hit from Hurricane Isabel with no detectible impact.

Patuxent Naval Air Station; Websters Field, St. Mary's County MD. This project includes about 3,000 ft of shoreline on the St. Mary's River and consists of series of revetments, **sills** and breakwaters that incorporate broken concrete alongshore into the structures as core and bedding material. About 0.5 acres of tidal wetlands habitat is created along with shore protection that preserves some of the most significant archaeological resources in Maryland. The installed project cost was about $730,000 and took a direct hit from Isabel with no damage. This project received a Coastal America

Award in the Coastal Partnership division in 2004 and is a good example of Living Shoreline application.

Patuxent NAS, Theodolite Tracking Stations, St.Mary's Co.,MD. This project, installed in 2010, included the design of stone revetments around and adjacent to each tracking station for long term shore protection. The projects were impacted but not affected by Hurricane Irene.

Patuxent Naval Air Station, Gate 4, St. Mary's County, MD Gate 4 was a shoreline segment including part of the West Basin seawall and part eroding bank and beach coast. Large breakwaters and spurs with beach fill and wetlands plants were placed along 1,500 feet of eroding shore, the site of the new O Club. The project costs were about $1.7 million along about 1,800 feet of shoreline. It was completed in 2005 and received a Coastal America award in 2006.

Smith Island, Maryland. Martin NWR for National Fish and Wildlife Service. This Living shore protection project along about 20,000 feet of coast involved construction of 30 headland breakwaters with wetlands plantings. This is a Headland Control Project where the shoreline between strategically placed headland breakwaters is allowed to erode to an equilibrium shore planform. Installed in 2015 at cost of $6.9 million.

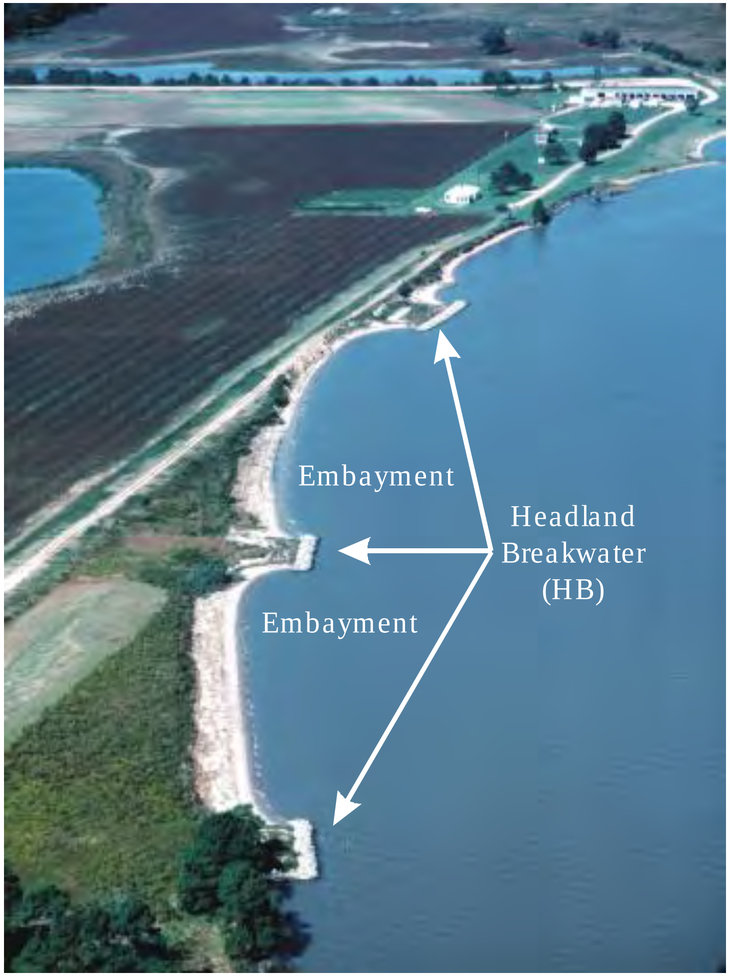
Smith Island, Maryland. Rhodes Pt Living Shoreline Project, Somerset County, MD. Similar to Martin NWR this project coves about 1 mile of shoreline with 20 headland breakwaters. Project cost of $3.8 million installed in 2016. All Smith Island construction is done by and from water.

Coastline Design PC Projects: Examples of Headland Control, Headland Breakwaters and sills

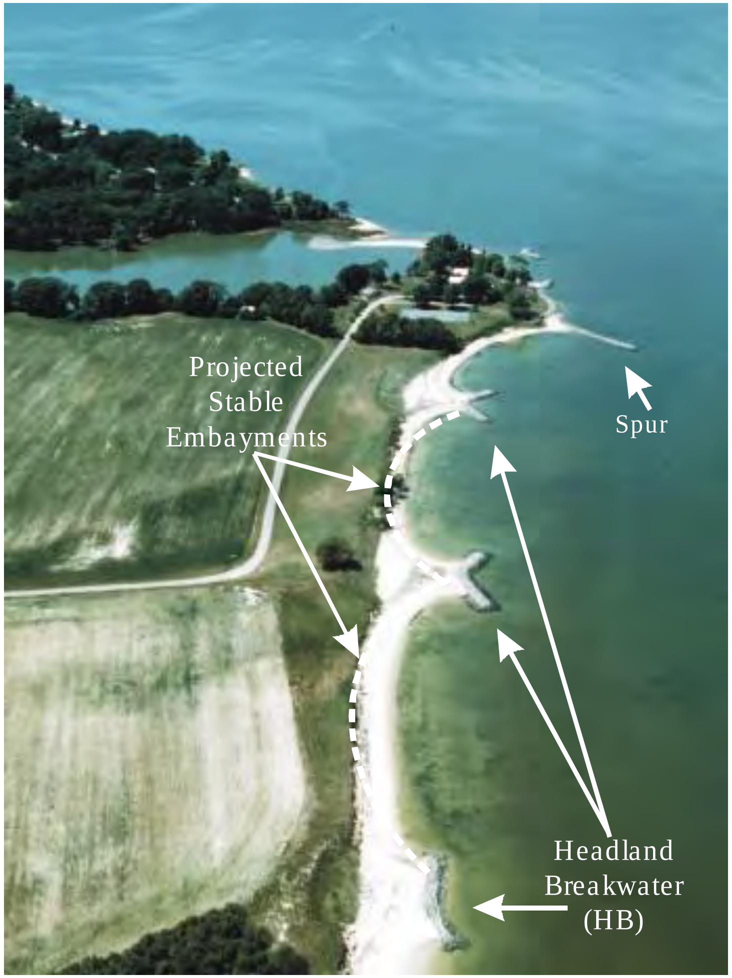
Headland Control

- Hog Island Headlands, James River, Isle of Wight County, VA. Designed by C. Scott Hardaway, for VA DCR. Project Length = 2,500 ft.
- St. Inigoes, St.Mary's River and Potomac River (fetch = 8 miles to SE) , St. Mary's County, MD. Project Design by Coastline Design PC. Project Length = 5,000 ft. Project costs : $1.0 million.
- Newtown Neck, Potomac River (fetch = > 40 miles to SE), St. Mary's County MD. Design by Coastline Design PC. Project Length = 4 miles, 6,500 feet on open river exposure.
- Jamestown Island, James River (fetch 9 miles to W), James City County, VA. Conceptual Design by C. Scott Hardaway, Jr. Final Design by U.S. Army Corps of Engineers, Norfolk. Project Length = 8,000 ft. Project cost: $3.0 million
- Smith Island: Martin Is. NWR, Coastline Design PC. This is a Living Shoreline project in the truest sense: Addresses the 3.3 acre annual loss of valuable estuarine ecosystem; establishes over 8 acres of wetland and dune habitat along 20,000 feet of shoreline. Project costs: $6.9 million
- Smith Island: Rhodes Point Project goals to maintain, restore and protect estuarine habitat as well as provide long term shore protection for the Community of Rhodes Point. Another Living Shoreline design in the truest sense: Addresses the 1.5 acre annual loss of valuable estuarine ecosystem; establishes over 5 acres of wetland and dune habitat along 1 mile of shoreline. Project Costs: $3.7 million. Coastline Design PC

Placing widely spaced breakwaters and allowing adjacent embankments to erode and evolve into equilibrium embayments can be a cost-effective method of reach management, as seen at Hog Island Wildlife Management Area, James River, Virginia. Installed 1989



Headland control system in Westmoreland County, Virginia, Potomac River, installed 1998.



Headland Control

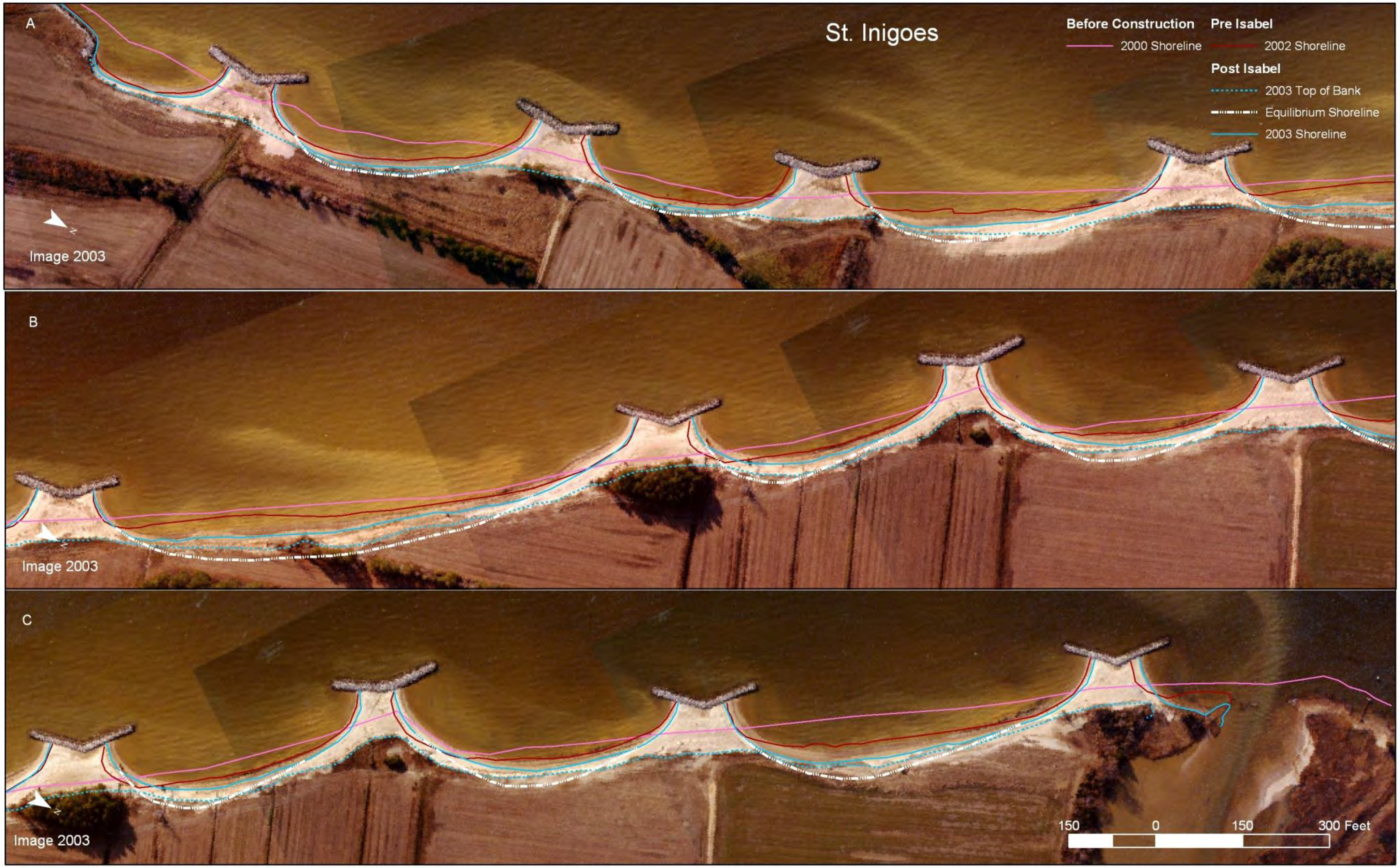
St. Inigoes, St. Mary's River: installed 2002

For Corporation of Catholic Churches, now a Maryland State Park

11 November 2006

26 September 2006

St. Inigoes Shore Change



Installed 2006

Newtown Neck

Google Earth Imagery date October 26, 2013

NTS

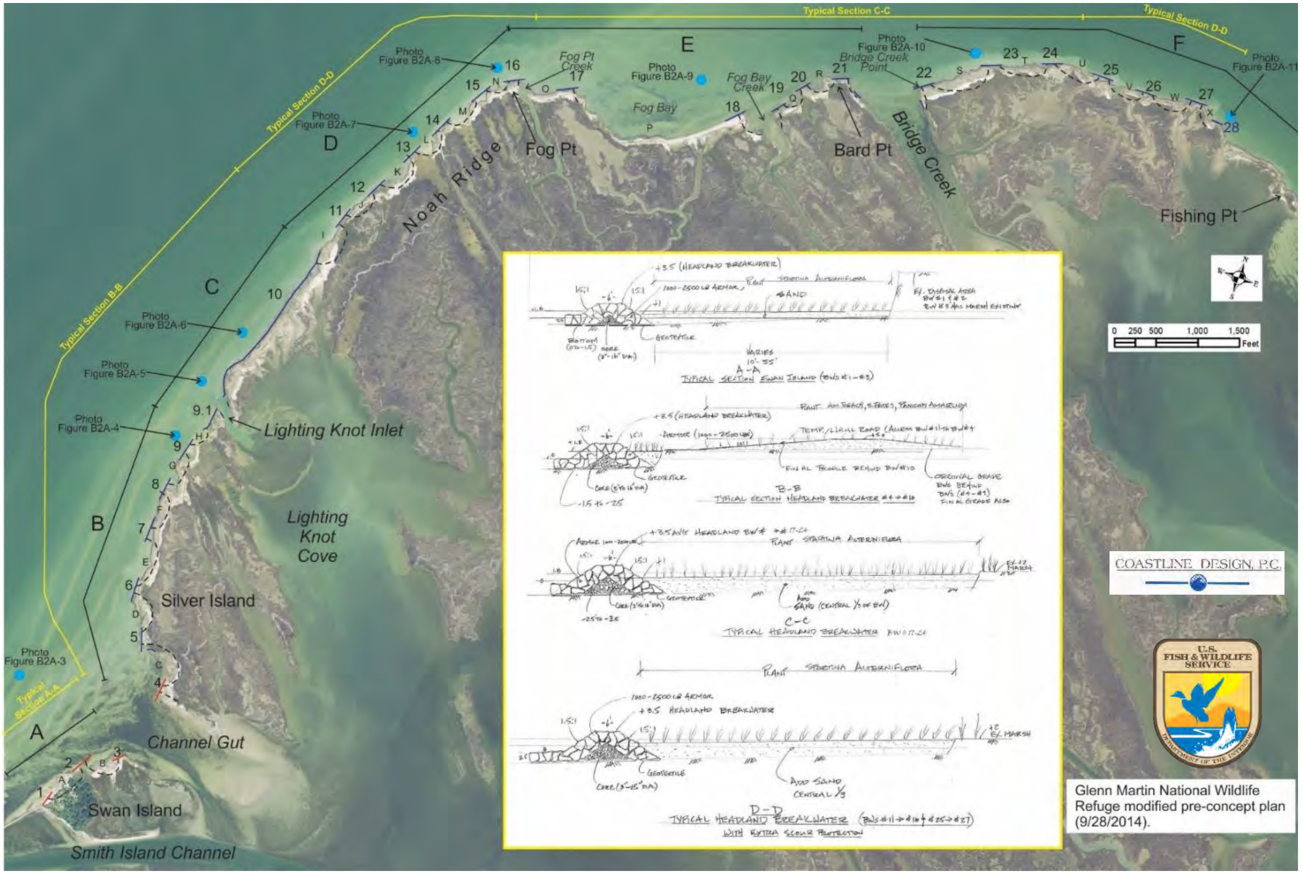
Jamestown Island
James River

National Park Service
Installed 2004

Headland control by maintaining archaeological Rich upland ridges and allowing adjacent marsh Shorelines to evolve

Google Earth Imagery date June 21, 2011

Smith Island – Martin NWR
Living Shoreline Project



Smith Island – Martin NWR
Reaches B through F

Rhodes Point: Living Shoreline Protection Project -2016

Design

The proposed plan extends along about 8,000 feet of Bay coast. It includes 18 headland breakwaters 180 to 300 feet in length and a 400 foot structure at the southern mouth of Sheep Pen Gut.

Breakwaters # 16-19 I control the coast north of Sheep Pen Gut.

Creates about 2.2 acres of low marsh and 3.6 acres of high marsh.


13
10
9
8
7
6


Rhodes Point : 10.19.19 Low marsh behind headland BW

Chesapeake Bay Headland Breakwaters/sills: Coastline Design PC

- Swan Point, Potomac River (fetch = 15 miles to SE), Charles County, MD, Designed by Coastline Design PC.

- Indian Head Naval Base, Charles County, Md. Designed by Coastline Design PC. Project length = 3 phases over 3.0 miles. Project cost about $15 million

- Pax River NAS Fuel Pier, Mouth of Patuxent River, (long fetch to NE over 12 miles) St. Mary's County, MD. Designed by Coastline Design, PC.

- Pax River NAS Gate 4, Mouth of Patuxent River, (long fetch to NE over 12 miles) St. Mary's County, MD. Designed by Coastline Design, PC.. Project length = 1,500 ft.

- Pax River NAS, Solomons Annex, Patuxent River (Long fetch to NW of over 14 miles), Calvert County, MD. Designed by Coastline Design PC. Constructed by Coastal Design and Construction, Inc. Project length = 4,000 ft.

- Elms' Beach, Chesapeake Bay, (fetches to N and SE over 30 miles) St. Mary's County, MD. Designed by Coastine Design PC and Constructed by Coastal Design and Construction, Inc. Project length = 1,000 ft.

- Jefferson Patterson Park and Museum, Patuxent River, (fetch = 6.5 miles to W), Calvert County, Va. Designed by Coastline Design, PC.. Project Length = 5,500 ft.

- Strott/Jacobsen sill system ,Chesapeake Bay (fetch = 15.5. miles to ENE), Anne Arundel Co, MD. Designed by Coastline Design.

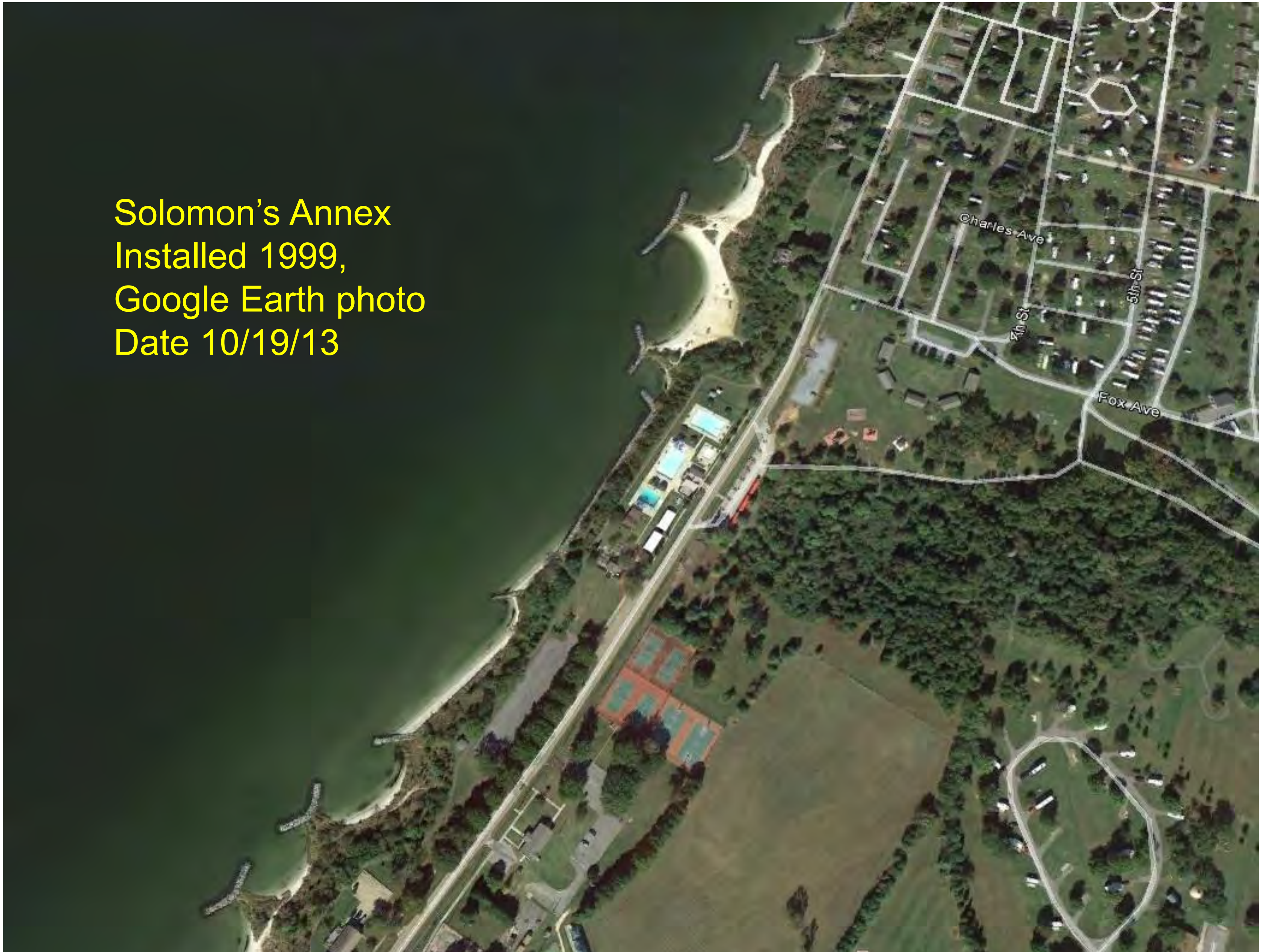
- Patuxent River NAS: Webster Field sill system, St. Mary's River, St. Mary's County MD,(Fetch = 8.0 miles to S).

The Villages at Swan Point, Site 4 Photo 3/27/12,Post-construction, pre-planting

Swan Point 9/11/13: establishing wetlands vegetation

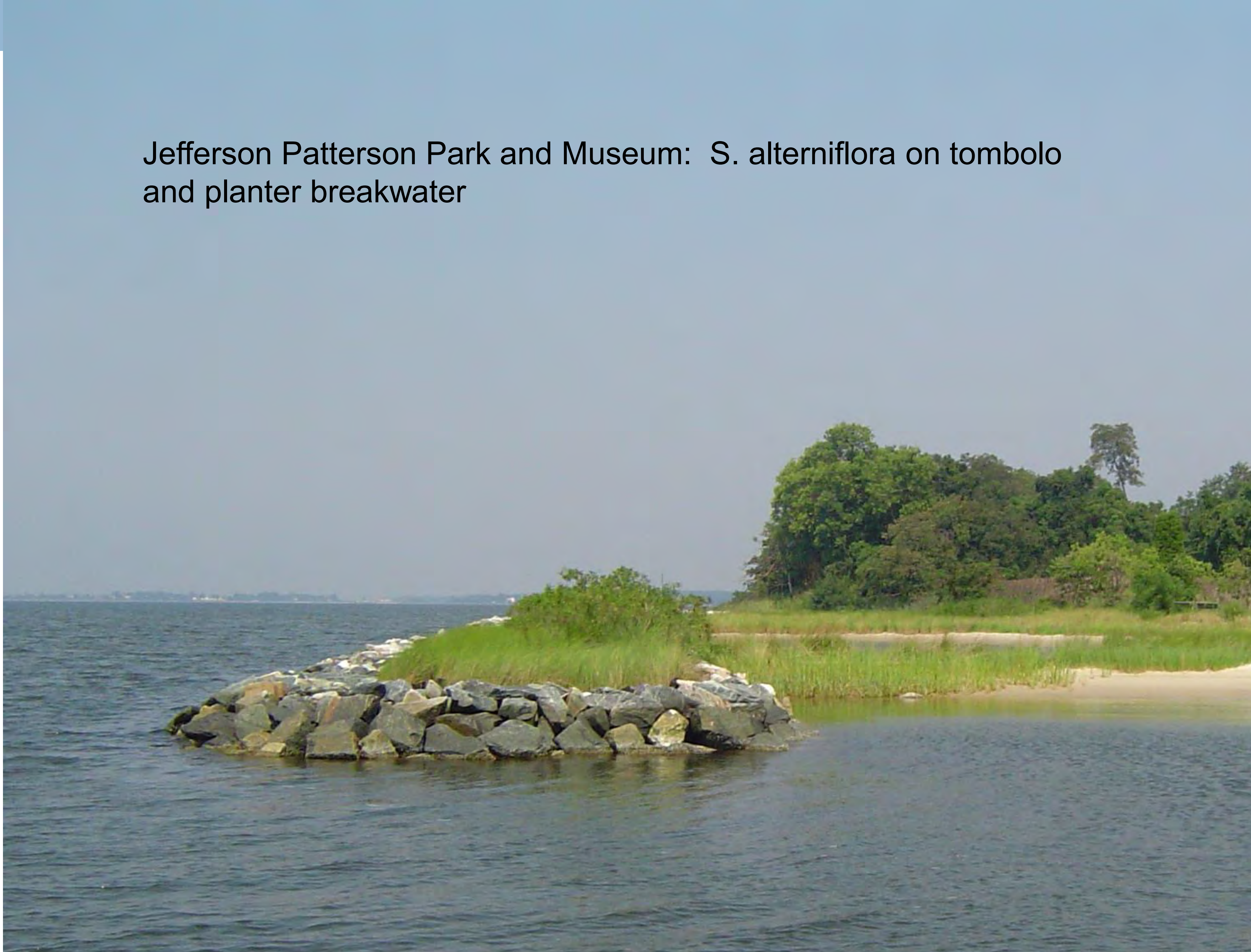
Indian Head Naval Base: Charles County, MD

Indian Head Naval Base: Charles County, MD, sill system


Solomon's Annex
Installed 1999,
Google Earth photo
Date 10/19/13
Charles Ave
5th St
7th St
Fox Ave

7/26/12

Jefferson Patterson Park and Museum Installed 1999   For MD Dept of Planning



Jefferson Patterson Park and Museum: S. alterniflora on tombolo and planter breakwater

Patuxent River NAS Fuel Pier

For US Navy

Installed 1999

Patuxent River NAS Gate 4

For US Navy

Elm's Beach

For St. Mary's County, MD Parks Department

Strott/Jacobsen: Installed January 2012

For Maryland Department of Natural Resources

Strott/Jacobsen October 1013

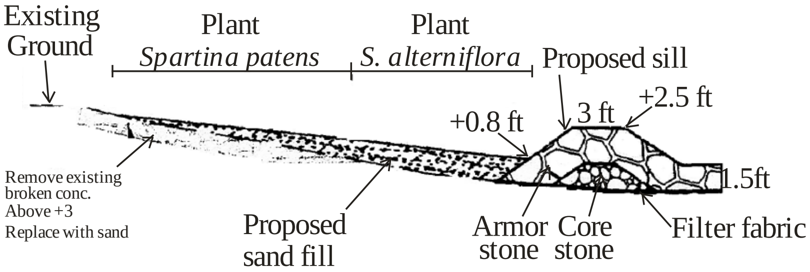
Webster Field Annex, US Navy installed April 2003

Sand fill with stone sills and marsh plantings at Webster Field Annex, St. Mary's County, Maryland

before installation

after installation but before planting

after four years



the cross-section used for construction.

Webster Field: 2014

November 2014

Attachment 2B-4

Coastal Design, P.C. Proposal

COASTLINE DESIGN, P.C.
P.O. BOX 157
ACHILLES, VA. 23001

Proposal
to develop a Shoreline Management Plan

for

Neeld Estate Citizens Association (NECA)

Plum Point, Calvert County, Maryland
May 24, 2021

1.0 Introduction and Statement of Problem

Plum Point is located along the Chesapeake Bay in Calvert County, MD (Figure 1). The Plum Point and adjacent shorelines have gone through significant shoreline change over the years (Figure 2). The NECA shoreline extends from the south jetty (adjacent to the entrance inlet into Breezy Point marina) southward about 1,200 feet to approximately to the end of Bay Parkway. This project shoreline has evolved over the years from having a relatively wide beach 25 years ago to a narrow beach to no beach at all by 2020 resulting in extensive bulkheading and further beach width reduction.

With community concerns about the ongoing and chronic beach loss, an onsite meeting with the Shoreline Committee headed by Jon Norris was held on May 21, 2021. The result of the meeting was for Coastline Design PC to develop a proposal and Scope of Work for shoreline management along the NECA shoreline. The purpose of this proposal is to develop a plan to restore and maintain a protective and stable beach system using a combination of headland breakwater and sand nourishment as well as the potential use of dredge material from the adjacent channel. The impacts of sea level rise (SLR) and Coastal Resiliency will also be addressed.

2.0 Site Setting

The Plum Point coast is oriented roughly north south and a straight line fetch to the NNE of about 50 miles and a fetch to the ESE of about 75miles. This impacts the impinging wind wave climate from strong NE storms with elevated storm surge will transport littoral (shorezone) sands southward. The longer wave period but less frequent SE wind driven waves will move sand north. The Maryland Department of Natural Resources (DNR) data base reports the net littoral drift (sand movement) favors the SE but every NE storm can “counter act” that effect, at least temporarily.

In 1993 there was a wide beach from Bay Parkway northward about 800 feet where the beach narrowed almost up to the existing homes for the last 400 feet. (Figure 3). In 2007 the beach width varies from 40 -50 ft from the homes to the shoreline (Figure 4). In 2010, the north half homes began installing a bulkhead beginning with the fender pilings as seen in Figure 5. The finished bulkhead in 2012 extended from the south channel jetty about 600 feet southward along the coast except for a 35 foot opening to the beach at the end of Ridge Avenue (Figure 6). There was still a beach in front of the bulkhead. By 2020 the beach continued to narrow along shoreline with only a low tide beach along the bulkhead (Figure 7). The project shoreline today is experiencing southward migrating bank erosion and property owners have installed sand bags to abate the problem (Figure 8 and 9).

The tide range at Plum Point is 1.4 feet. According to FEMA (2014), the storm surge levels for the 10 yr, 50 yr and 100 yr storm events are 4.1 ft, 4.5 ft and 4.7 ft above mean low water (MLW). For planning purposes, we should us the 50 yr. water level. Also, according to MD DNR, a 1.3 foot rise in sea level by 2050 can be expected which we will address in the plan.

3.0 Recommendation

If the current erosional trend continues the sand bagged portion may become hardened with the remaining coast following suit. To re-establish a wide, protective and stable beach front along the project shoreline, a series of headland breakwaters with sand nourishment and dune grass plantings is recommended (Figure 10). This might be similar in size and scope as the headland breakwater system along the Breezy Point Marina shoreline. However, the NECA project will be a balance between the effects of the existing hardened and non-hardened shoreline segments, level of protection and costs. Phasing scenarios will also be provided. Project costs per linear foot of shoreline may range from $1,000 to $1,300 per foot. These are not atypical for Bay front shoreline projects and will be dependent on the site survey. Water depths along with design lengths, widths and elevations of the structures and sand nourishment will determine quantities of rock and sand required.

4.0 Costs

In order to address the project goals Coastline Design, PC proposes the following:

Task 1: Site Survey and site assessment: $9,050

Survey will be in Maryland State Plane horizontal coordinate system with vertical control relative to mean low water (MLW). The nearshore stability will be assessed with a combination of short cores, augers and probes.

Task 2: Preliminary Shoreline Plan (CAD) and cost estimate: 7,400

The plan will include a site presentation and input from the shoreline committee.

Task 3: Pre-final plans and specifications.

Prepare Joint Permit application (JPA) for submission and act as agent: 8,750*

This phase will include a pre-application site visit with MDE and the Corps

Task 4: Prepare final plans, specifications, *construction bid form*, cost estimate and acquire local permits, including Critical Areas and Erosion And Sediment Control. (The plans, specifications and bid form constitute the construction bid package.) **7,125**

Task 5: Permit Fees (if applicable) 2,000

Travel 406

Total **$34,731**

*If the project is not considered a Living Shoreline there maybe a $1,500 permit fee. Local permit fees maybe as much as $500. Therefore, and additional **$2000** should be budgeted for these.

A tentative timeline follows from a Notice to Proceed:

Task 1: 45 days
Task 2: 30 days
Task 3: 270 days (permit process includes MDE, BPW and Corps). Permits include:

Maryland Dept of Environment (MDE): Water Quality Certification
Maryland Board of Public Works (BPW): Wetlands License
U.S. Army Corps of Engineers (Corps): Department of the Army Permit

Task 4: 45 days after receipt of state and federal permits from Task 3.

Invoicing will be done by percentage of each task performed as agreed upon by:

C. Scott Hardaway, Jr.
President
Coastline Design PC

Jon Norris
Chairman NECA Shoreline Committee

If requested Coastline Design PC will assist on the construction phase.

Task 6: Construction Management, includes weekly project inspection during construction: $20,000

Task 7: Perform an as-built survey and report $4,500

References

FEMA, 2014. Calvert County Maryland, Flood Insurance Study.

Maryland DNR, 2017. Littoral Drift Maps. GIS online database.

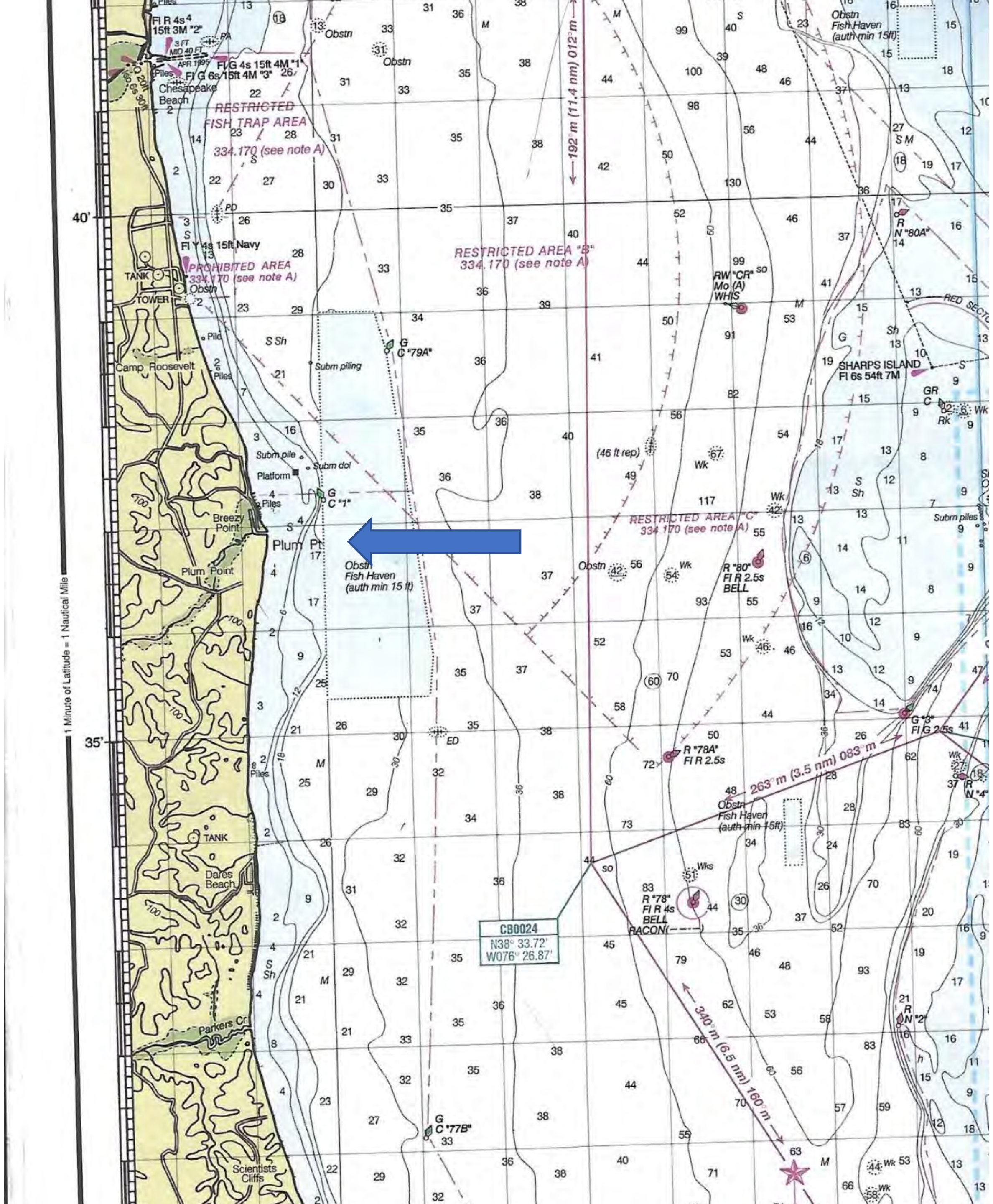


Figure 1: Plum Point and adjacent Bathymetry.

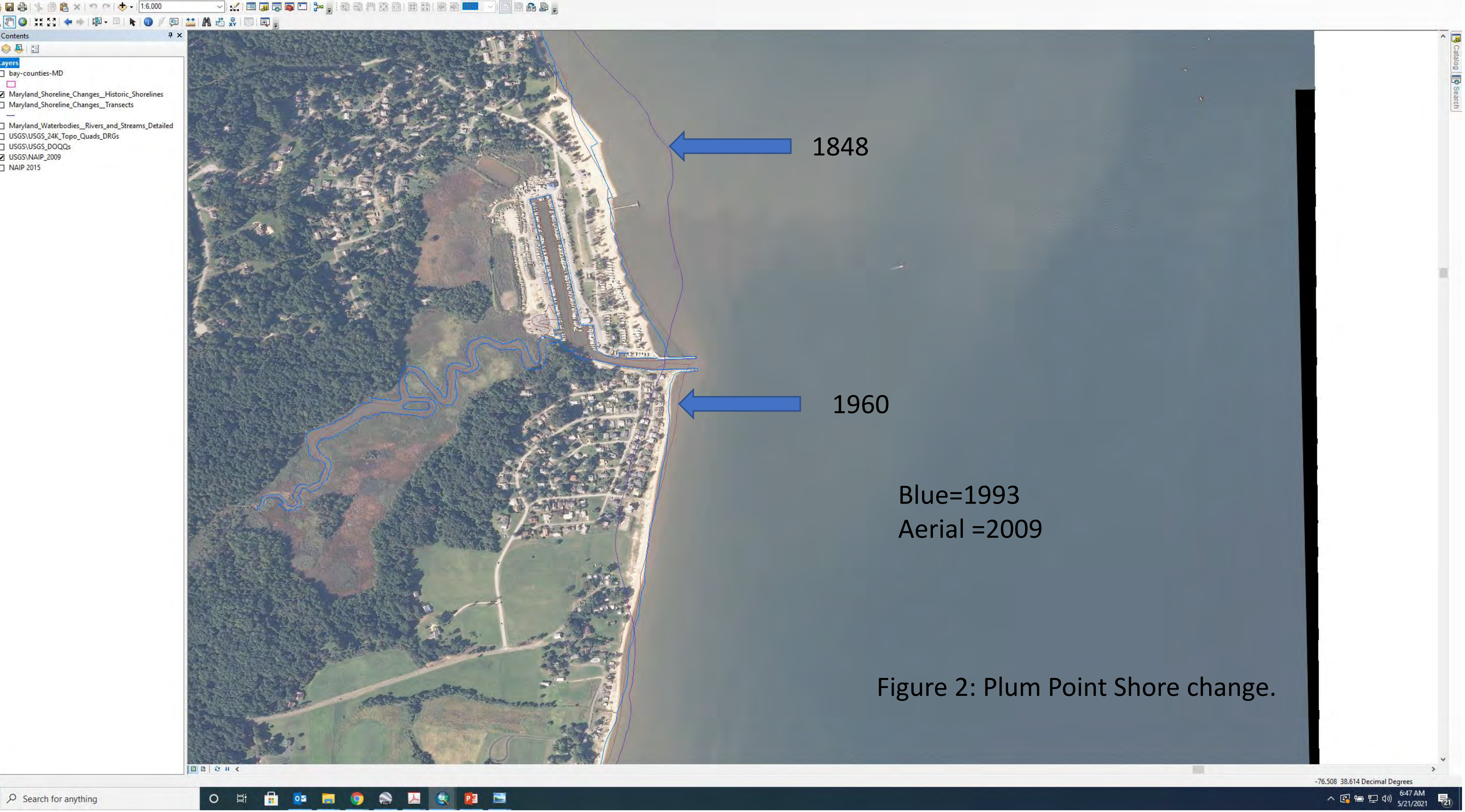


Figure 2: Plum Point Shore change.

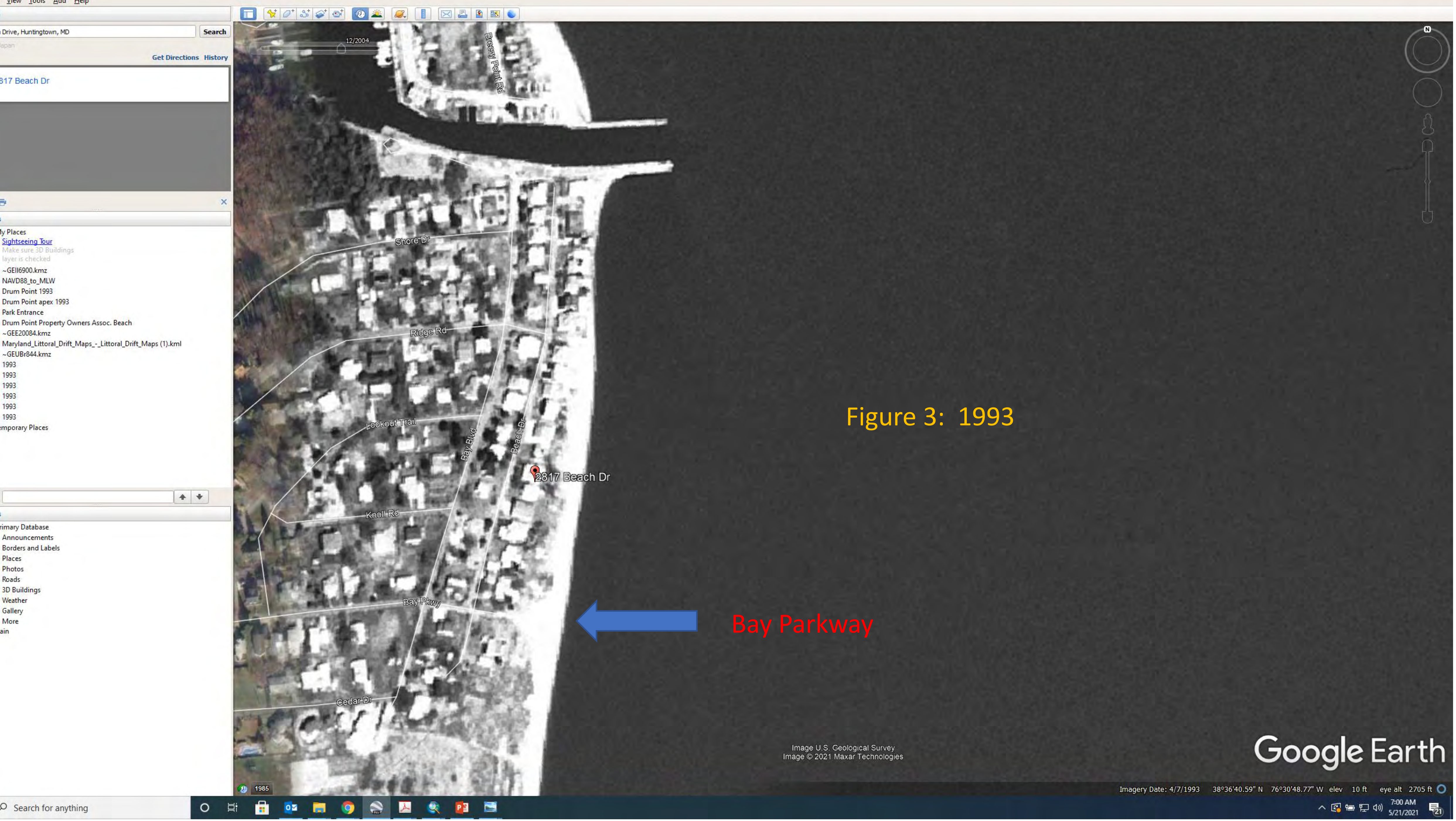


Figure 3: 1993

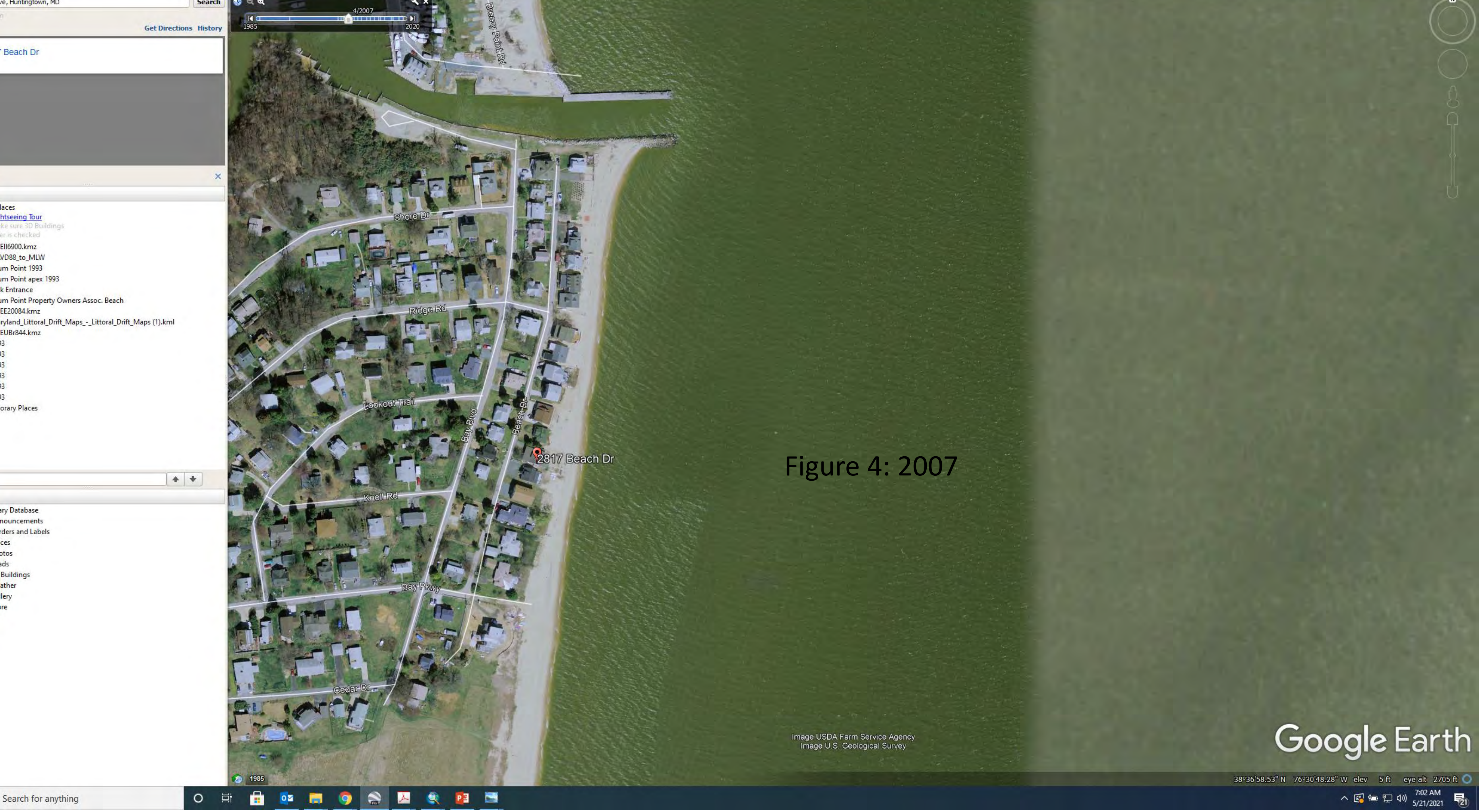


Figure 4: 2007

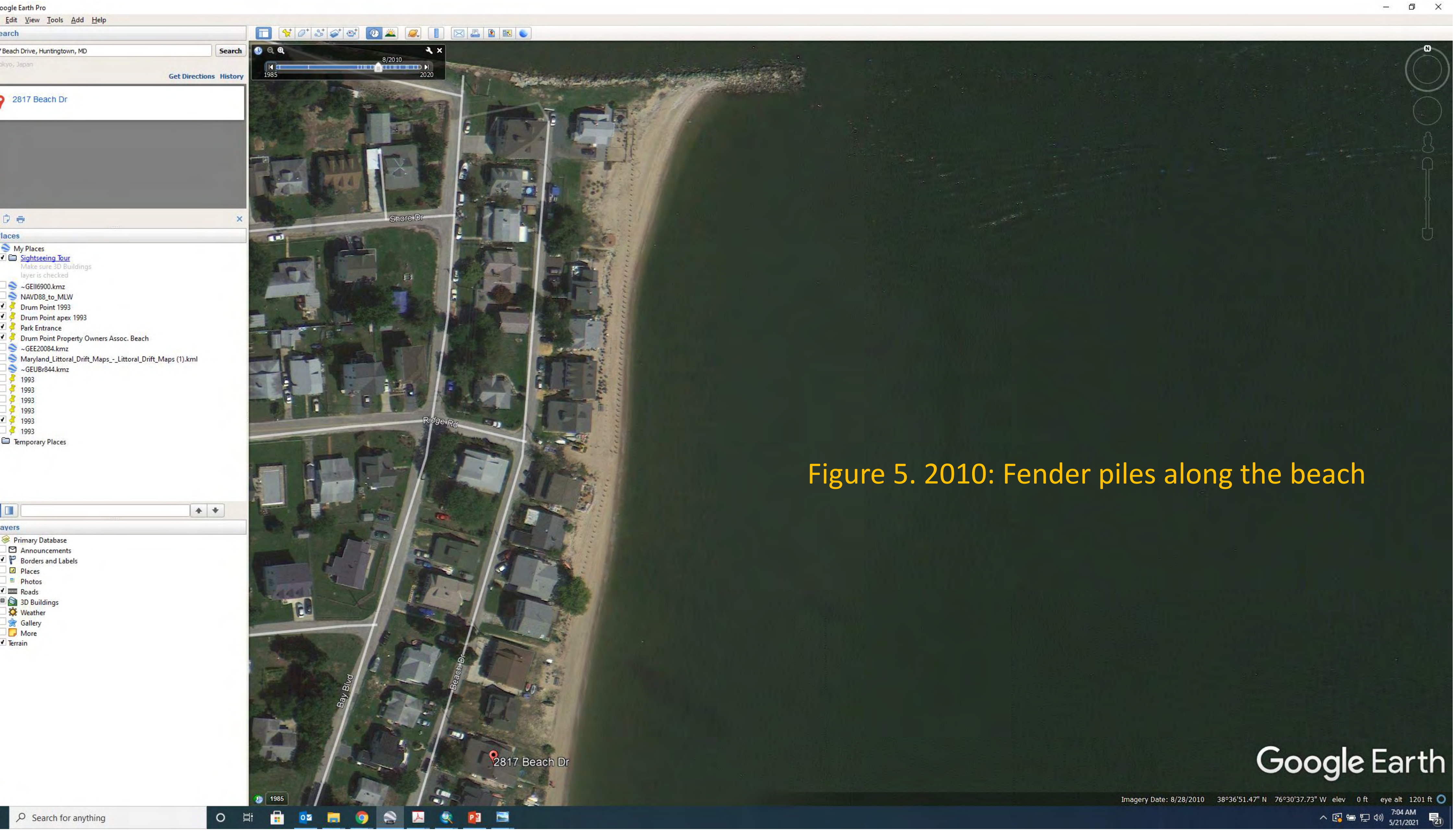


Figure 5. 2010: Fender piles along the beach

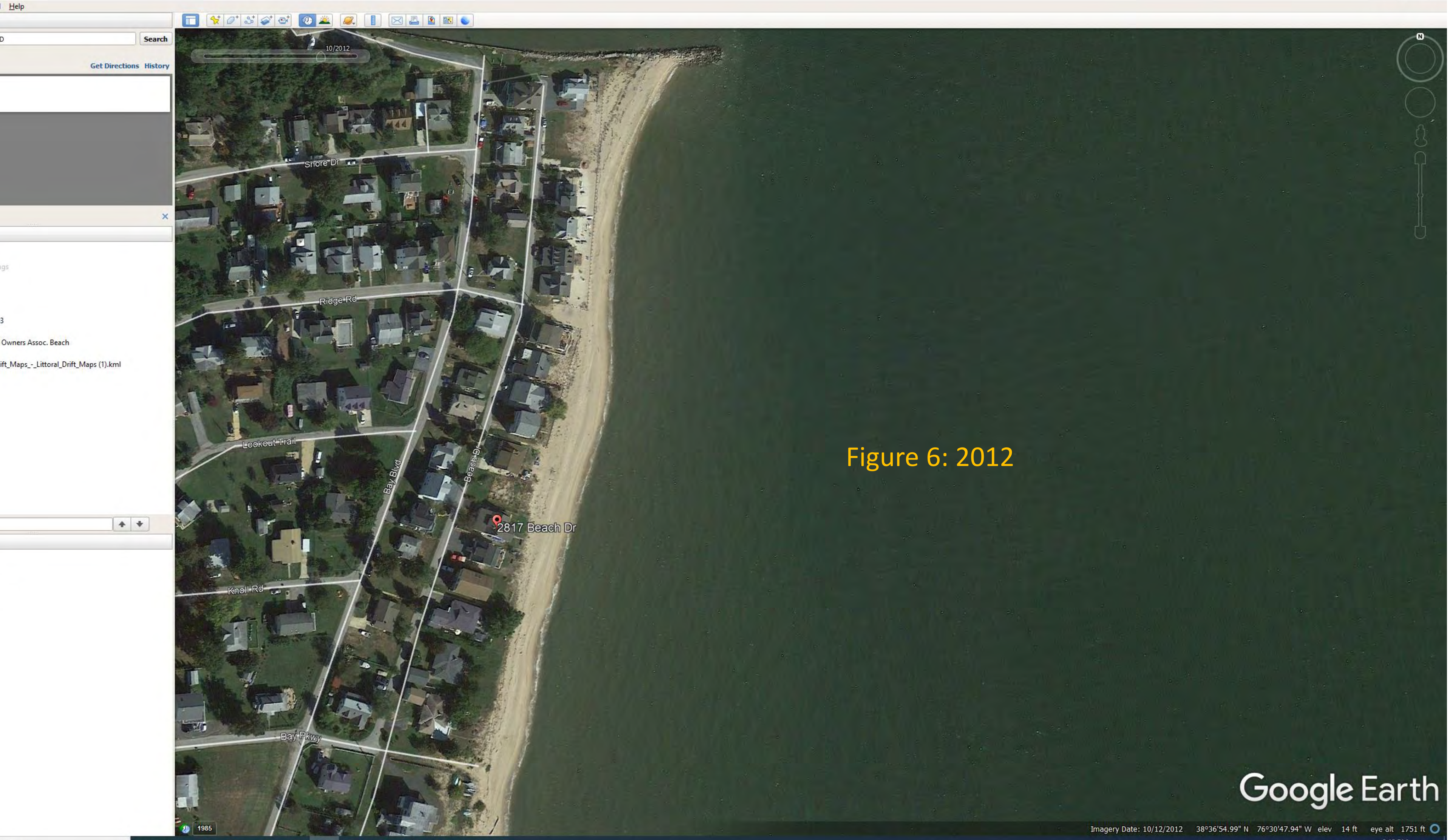


Figure 6: 2012

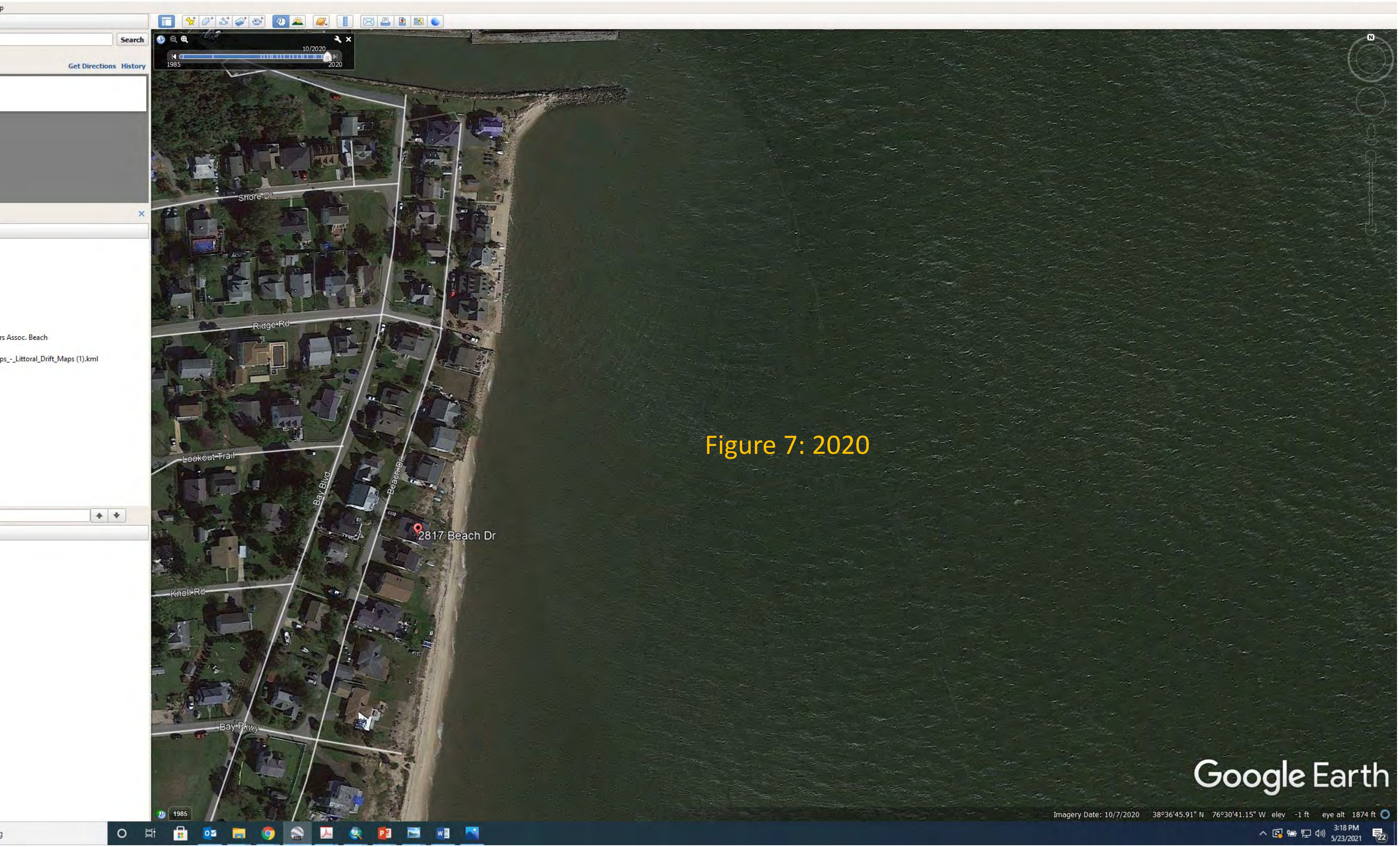


Figure 7: 2020

Figure 8: Looking north from the meeting house shore. Beach meeting took place on May 21, 2021.

Figure 9: Looking south from the meeting house shore. Beach meeting took place on May 21, 2021

Figure 10: Plum Point Concept sketch with a 100 ft spur and 3-200 ft headland breakwaters with sand nourishment .
Dune grass will be planted along the backshore and behind each structure. Maybe opportunity for low marsh too in lee of breakwater units.