Shoreline Evolution
Chesapeake Bay and Piankatank River Shorelines
Mathews County, Virginia

Shoreline Studies Program
VIMS

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The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies or DEQ.

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Cover Photo: Photographs of Festival Beach in Mathews County showing the evolution of the shoreline. Photos taken by Shoreline Studies Program on 5 December 2000 and 1 September 2005.

I. INTRODUCTION

A. General Information

Shoreline evolution is the change in shore position through time. In fact, it is the material resistance of the coastal geologic underpinnings against the impinging hydrodynamic (and aerodynamic) forces. Along the shores of Chesapeake Bay, it is a process-response system. The processes at work include winds, waves, tides and currents, which shape and modify coastlines by eroding, transporting and depositing sediments. The shore line is commonly plotted and measured to provide a rate of change but it is as important to understand the geomorphic patterns of change. Shore analysis provides the basis to know how a particular coast has changed through time and how it might proceed in the future.

The purpose of this report is to document how the Bay shore of Mathews (Figure 1) has evolved since 1937. Aerial imagery was taken for most of the Bay region beginning that year, and it is this imagery that allows one to assess the geomorphic nature of shore change. Aerial imagery shows how the coast has changed, how beaches, dunes, bars, and spits have grown or decayed, how barriers have breached, how inlets have changed course, and how one shore type has displaced another or has not changed at all. Shore change is a natural process but, quite often, the impacts of man through shore hardening or inlet stabilization come to dominate a given shore reach. Most of the change in shore positions will be quantified in this report. Others, particularly very irregular coasts, around inlets, and other complicated areas will be subject to interpretation.

B. Chesapeake Bay Dunes

The primary reason for developing this Shoreline Evolution report is to be able to determine how dunes and beaches along the Bay coast of Mathews have and will evolve through time. The premise is that, in order to determine future trends of these important shore features, one must understand how they got to their present state. Beaches and dunes are protected by the Coastal Primary Sand Dune Protection Act of 1980 (Act)[1]. Research by Hardaway *et al.* (2001) located, classified and enumerated jurisdictional dunes and dune fields within the eight localities listed in the Act. These include the counties of Accomack, Lancaster, Mathews, Northampton and Northumberland and the cities of Hampton, Norfolk and Virginia Beach (Figure 2). Only Chesapeake Bay and river sites were considered in that study.

In 2003, Hardaway *et al*. created the Mathews County Dune Inventory. That report detailed the location and nature of the jurisdictional primary dunes along the Bay shore of Mathews County and those results appear in Appendix B. For this study, the positions of the dune sites are presented using the latest imagery in order to see how the sites sit in the context of past shoreline positions. The dune location information has not been field verified since the original visits in 2000. This information is not intended to be used for jurisdictional determinations regarding dunes.

[1]The General Assembly of Virginia enacted the Coastal Primary Sand Dune Protection Act (the Dune Act) in 1980. The Dune Act was originally codified in § 62.1-13.21 to -13.28. The Dune Act is now recodified as Coastal Primary Sand Dunes and Beaches in § 28.2-1400 to -1420.

II. SHORE SETTING

A. Physical Setting

The Bay shoreline of the Mathews extends from New Point Comfort to Gwynn's Island into Hills Bay. This includes about 11.6 nautical miles (nm) of tidal shoreline along the Bay side and approximately 5.7 nm miles along the Hill's Bay side from Cherry Point to Iron Point. Another 2.2 nm of shoreline occurs from Iron Point to Cobb's Creek along the Piankatank River where 2 small dune sites reside. The shorelines along Chesapeake Bay are mostly low sandy banks and marsh. Historic shore change rates vary from 0 ft/yr to over 8 ft/yr for both shore recession and shore advance along the Bay coast (Byrne and Anderson, 1978).

The coastal geomorphology of the County is a function of the underlying geology and the hydrodynamic forces operating across the land/water interface, the shoreline. The Chesapeake Bay coast of Mathews County varies from Holocene marsh along the southern coast to Holocene beach sands on Gwynn's Island (Figure 3). Both sediment types overlie the Lynnhaven Member of the Tabb Formation (Late Pleistocene). The Atlantic Ocean has come and gone numerous times over the Virginia coastal plain over the past million years or so. The effect has been to rework older deposits into beach and lagoonal deposits at the time of the transgressions.

The last low stand found the ocean coast about 60 miles to the east when sea level about 300 feet lower than today and the coastal plain was broad and low. The current estuarine system was a meandering series of rivers working their way to the coast. About 15,000 years ago, sea level began to rise and the coastal plain watersheds began to flood. Shorelines began to recede. The slow rise in sea level is one of two primary long-term processes which cause the shoreline to recede; the other is wave action, particularly during storms. As shorelines recede or erode the bank material provides the sands for the offshore bars, beaches and dunes.

Sea level is continuing to rise in the Tidewater Region. Tide data collected at Sewells Point in Norfolk show that sea level has risen 4.42 mm/yr (0.17 inches/yr) or 1.45 ft/century (http://www.co-ops.nos.noaa.gov/). This directly effects the reach of storms and their impact on shorelines. Anecdotal evidence of storm surge during Hurricane Isabel, which impacted North Carolina and Virginia on September 18, 2003, put it on par with the storm surge from the "storm of the century" which impacted the lower Chesapeake Bay in August 1933. Boon (2003) showed that even though the tides during the storms were very similar, the difference being only 4 cm or about an inch and a half, the amount of surge was different. The 1933 storm produced a storm surge that was greater than Isabel's by slightly more than a foot. However, analysis of the mean water levels for the months of both August 1933 and September 2003 showed that sea level has risen by 41 cm (1.35 ft) at Hampton Roads in the seventy years between these two storms (Boon, 2003). This is the approximate time span between our earliest aerial imagery (1937) and our most recent (2002), which means the impact of sea level rise to shore change is significant. The beaches, dunes, and nearshore sand bars try to keep pace with the rising sea levels.

Nine shore reaches are described along the coast of Mathews County (Figure 4). Reaches I thru V are on the open Bay, Reach VI, VII, and VIII are along Hills Bay and Reach IX is on the Piankatank River. The Bay reaches are divided by tidal creeks and inlets that have opened over time and segmented the coast. The littoral system is sand limited due to erosion of mostly marsh shores over time. The sand beaches and dunes lie along a low, often marshy coast that is subject to overwashing during storms. The long-term erosion of Gwynn's Island has been a major source of sands to the littoral system but shore hardening has limited this input. Bank erosion along Hill's Bay has also been a sand source over time which has helped create small beaches and dunes and an extensive nearshore sand bar field.

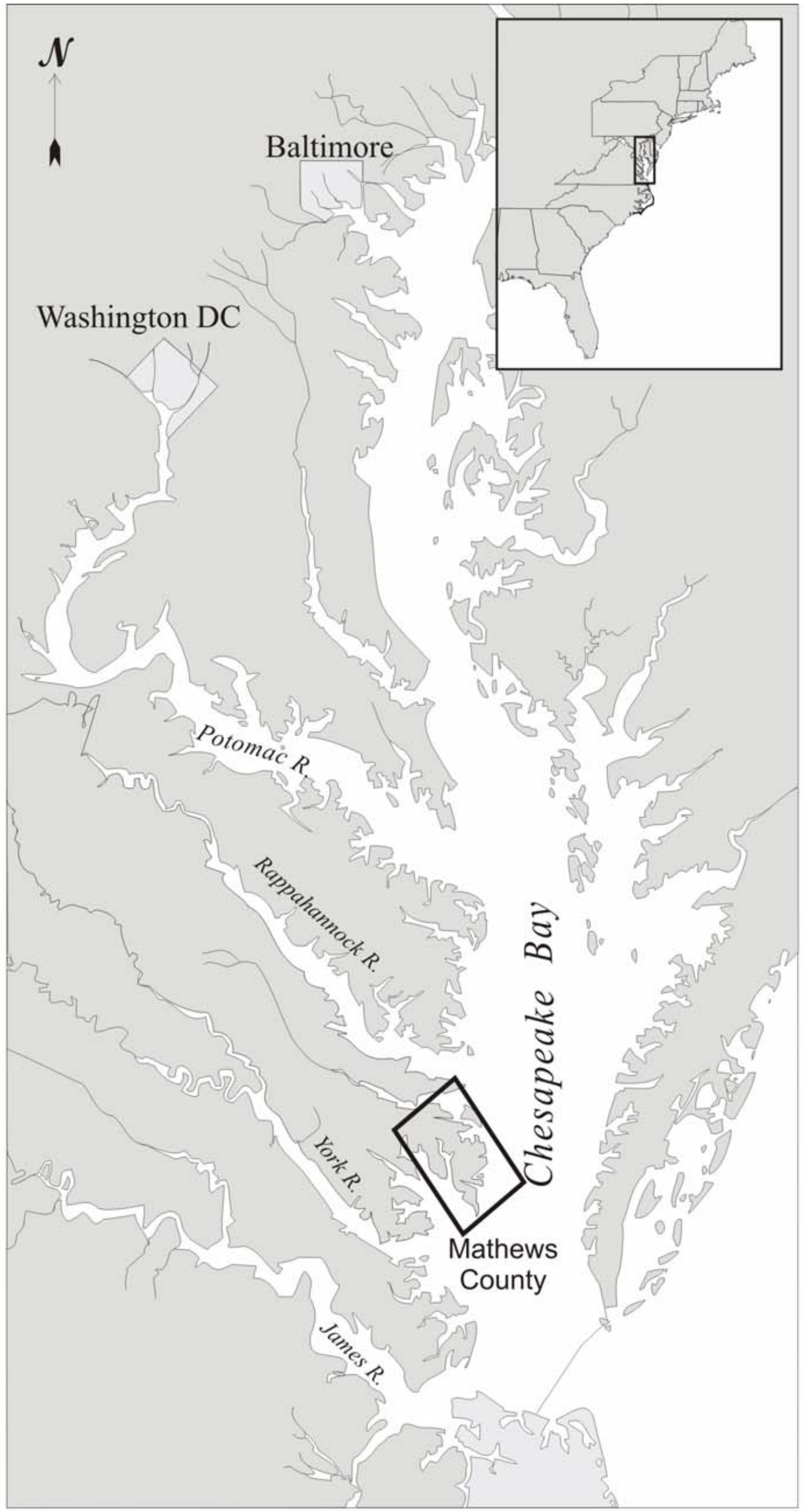

Figure 1. Location of Mathews County within the Chesapeake Bay estuarine system.

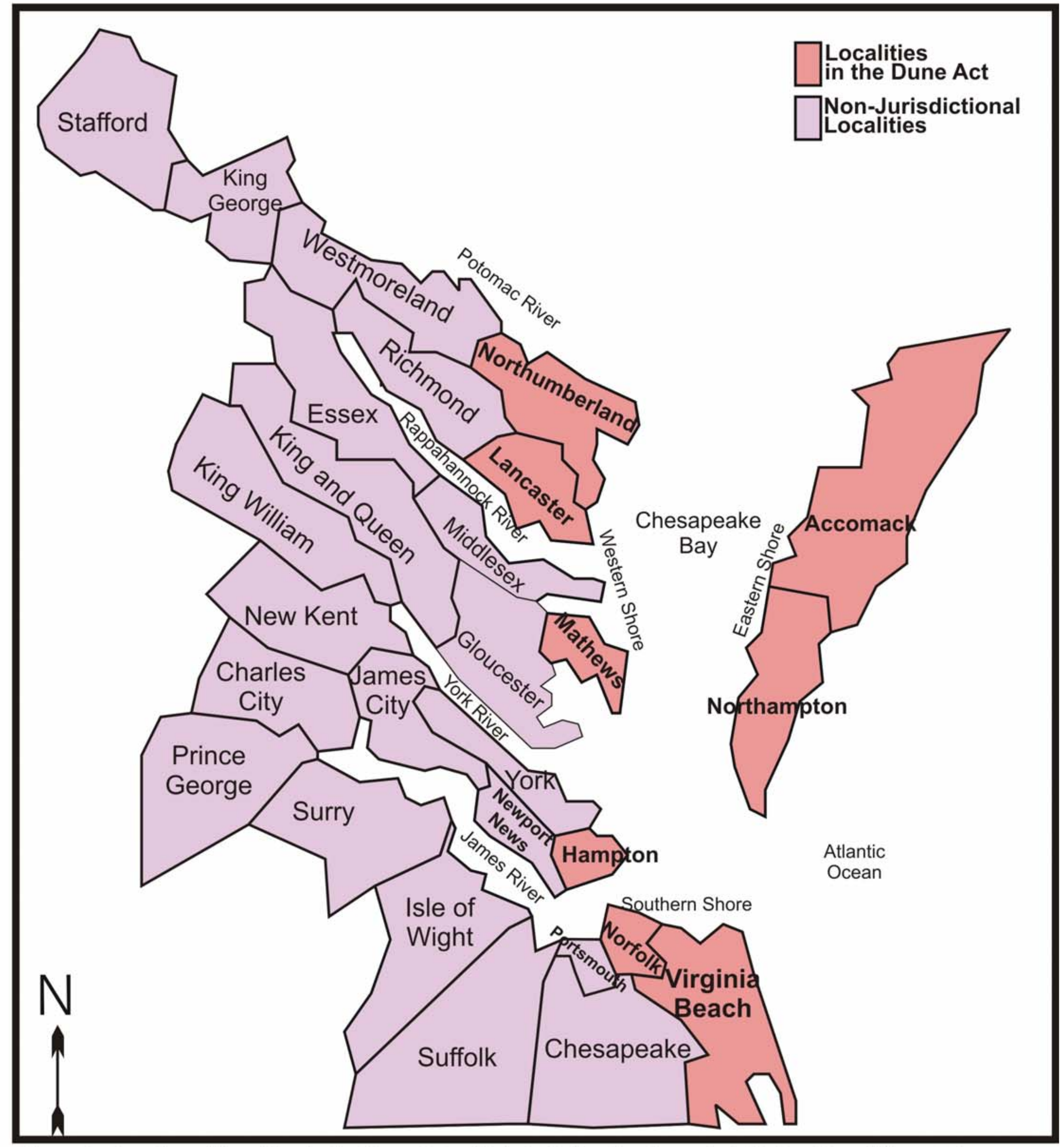

Figure 2. Location of localities in the Dune Act with jurisdictional and non-jurisdictional localities noted.

Qs	**Holocene Sand** - Pale gray to light-yellowish gray, fine to coarse, poorly sorted to well sorted, shelly in part; contains angular to rounded fragments and whole valves of mollusks. Comprises deposits of coastal barrier islands and narrow beach-dune ridges bordering brackish-water marshes of Chesapeake Bay. As much as 40 ft in thickness.
Qm	**Holocene Soft Mud** - Medium to dark-gray, and peat, grayish brown. Comprises sediment of marshes in coastal areas and Chesapeake Bay. Thickness is 0-10 ft.
Qsh	**Shirley Formation (middle Pleistocene)** - Light-to dark-gray and brown sand, gravel, silt, clay, and peat. Constitutes surficial deposits of riverine terraces and relict baymouth barriers and bay-floor plains (alt. 35-45 ft) inset below depositional surfaces of the Chuckatuck Formation (Johnson and Peebles, 1984). Upper part of unit is truncated on the east by the Suffolk and Harpersville scarps; locally, lower part extends east of scarps. Fluvial-estuarine facies comprises (1) a lower pebble to boulder sand overlain by (2) fine to coarse sand interbedded with peat and clayey silt rich in organic material, including in situ tree stumps and leaves and seeds of cypress, oak, and hickory, which grades upward to (3) medium- to thick-bedded, clayey and sandy silt and silty clay. Marginal-marine facies in lower James River and lowermost Rappahannock River areas is silty fine sand and sandy silt containing *Crassostrea virginica*, *Mulinia*, *Noetia*, *Mercenaria*, and other mollusks. *Astrangia* from lower Rappahannock River area has yielded a uranium-series age of 184,000 +/- 20,000 years B.P. (Mixon and other, 1982). Thickness is 0-80 ft.
Qtlp	**Lynnhaven and Poquoson Members, undifferentiated**.
Qts	**Sedgefield Member** - Pebbly to bouldery, clayey sand and fine to medium, shelly sand grading upward to sandy and clayey silt; locally, channel fill at base of unit includes as much as 50 ft of fine to coarse, crossbedded sand and clayey silt and peat containing in situ tree stumps. Sandy bay facies commonly contains Crassostrea biostromes, Mercenaria, Anadara, Polynices, Ensis, and other mollusks. Specimes of the coral Astrangia have yielded estimated uranium-series ages averaging 71,000 +/- 7,000 yrs B.P. (Mixon and others, 1982). Unit constitutes surficial deposit of river- and coast-parallel plains (alt. 20-30 ft) bounded on landward side by Suffolk and Harpersville scarps. Thickness is 0-50 ft.

Figure 3. Geologic map of Mathews County (from Mixon *et al*., 1989).

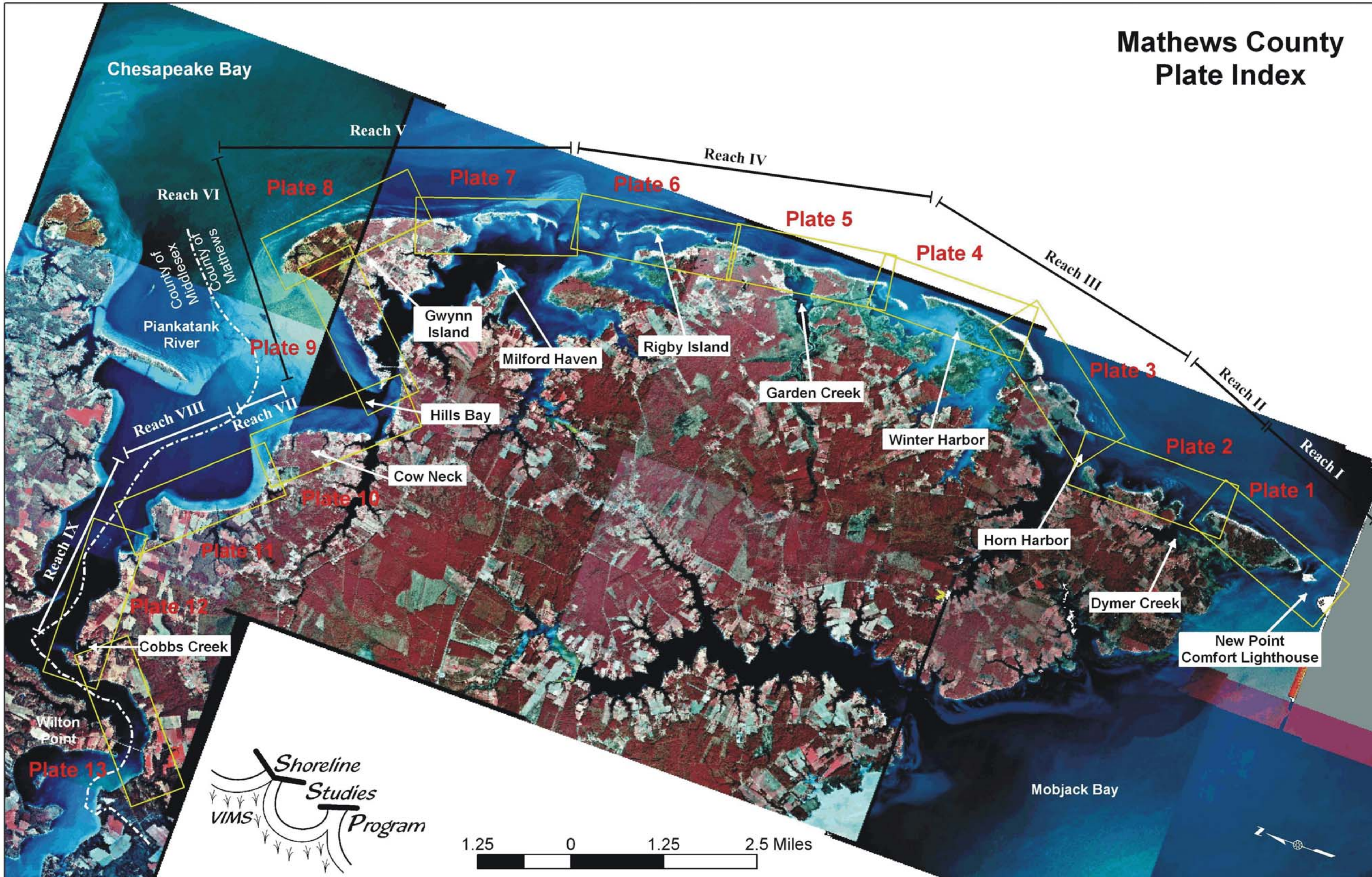

Figure 4. Index of shoreline plates.

B. Hydrodynamic Setting

Mean tide range along the Bay coast of Mathews County varies from 2.4 ft at New Point to 1.4 ft at Cherry Point. The wind/wave climate impacting the Bay coast is defined by large fetch exposures to the northeast, east and southeast across Chesapeake Bay. Wind data from Norfolk International Airport reflect the frequency and speeds of wind occurrences from 1960 to 1990 (Table 1). Northeasters can be particularly significant in terms of the impacts of storm surge and waves on beach and dune erosion. Hills Bay is more fetch-limited with the major exposure to the northeast out of the mouth of the Piankatank River and across Chesapeake Bay.

Hurricanes, depending on their proximity and path can also have an impact to the Mathews County Bay coast. On September 18, 2003, Hurricane Isabel passed through the Virginia coastal plain. The main damaging winds began from the north and shifted to the east then south. Beach and dune erosion at sites like Bavon (Plate 1) were significant but the existing dunes offered protection to the adjacent cottages. Storm surge and wave action combined to create wrack lines measuring up to 8 ft above MLW.

Table 1. Summary wind conditions at Norfolk International Airport from 1960-1990.

		WIND DIRECTION								
Wind Speed (mph)	**Mid Range (mph)**	**South**	**South west**	**West**	**North west**	**North**	**North east**	**East**	**South east**	**Total**
< 5	3	5497* 2.12[+]	3316 1.28	2156 0.83	1221 0.47	35748 13.78	2050 0.79	3611 1.39	2995 1.15	56594 21.81
5-11	8	21083 8.13	15229 5.87	9260 3.57	6432 2.48	11019 4.25	13139 5.06	9957 3.84	9195 3.54	95314 36.74
11-21	16	14790 5.70	17834 6.87	10966 4.23	8404 3.24	21816 8.41	16736 6.45	5720 2.20	4306 1.66	100572 38.77
21-31	26	594 0.23	994 0.38	896 0.35	751 0.29	1941 0.75	1103 0.43	148 0.06	60 0.02	6487 2.5
31-41	36	25 0.01	73 0.03	46 0.02	25 0.01	162 0.06	101 0.04	10 0.00	8 0.00	450 0.17
41-51	46	0 0.00	0 0.00	0 0.00	1 0.00	4 0.00	4 0.00	1 0.00	0 0.00	10 0.00
Total		41989 16.19	37446 14.43	23324 8.99	16834 6.49	70690 27.25	33133 12.77	19447 7.50	16564 6.38	259427 100.00

*Number of occurrences [+]Percent

III. METHODS

A. Photo Rectification and Shoreline Digitizing

Recent and historic aerial photography was used to estimate, observe, and analyze past shoreline positions and trends involving shore evolution for Mathews County. Some of the photographs were available in fully geographically referenced (ortho-referenced) digital form, but most were scanned and orthorectified for this project.

Aerial photos from VIMS Shoreline Studies and Submerged Aquatic Vegetation (SAV) Programs, as well as from United States Geological Survey (USGS) archives were acquired. The years used for the shoreline change analysis included 1937, 1953, 1968, 1982,1 994, and 2002. Color aerials were obtained for 1982 and 1994. The 1994 imagery was processed and mosaicked by USGS, while the imagery from 2002 was mosaicked by the Submerged Aquatic Vegetation Program. The aerial photography for the remaining years were mosaicked by the VIMS Shoreline Study Program.

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

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

Once the aerial photos were orthorectified and mosaicked, the shorelines were digitized in ArcMap with the mosaics in the background to help delineate and locate the shoreline. For Mathews' coast, an approximation to mean high water (MHW) was digitized. This often was defined as the "wetted perimeter" on the beach sand as the last high water location. In areas where the shoreline was not clearly delineated on the aerial photography, the location was estimated based on the experience of the digitizer. Digitizing the shoreline brings in, perhaps, the greatest amount of potential error because of the problems of image clarity and definition of shore features. A series of Mathews dune site profiles are displayed in Figure 5 which shows beach/dune variability. Figure 6 shows the relationship of MHW, MLW and beach/dune system components.

B. Rate of Change Analysis

A custom Arcview extension called "shoreline" was used to analyze shoreline rate of change. A straight, approximately shore parallel baseline is drawn landward of the shoreline. The extension creates equally-spaced transects along the baseline and calculates distance from the baseline at that location to each year's shoreline. The output from the extension are perpendicular transects of a length and interval specified by the user. The extension provides the transect number, the distance from beginning baseline to each transect, and the distance from the baseline to each digitized shoreline in an attribute table. The attribute table is exported to a spreadsheet, and the distances of the digitized shoreline from the baseline are used to determine the rates of change. The rates of change are summarized as mean or average rates and standard deviations for each Plate.

It is very important to note that this extension is only useful on relatively straight shorelines. In areas that have unique shoreline morphology, such as creek mouths and spits, the data collected by this extension may not provide an accurate representation of true shoreline change. The shore change data was manually checked for accuracy. However, where the shoreline and baseline are not parallel, the rates may not give a true indication of the rate of shoreline change.

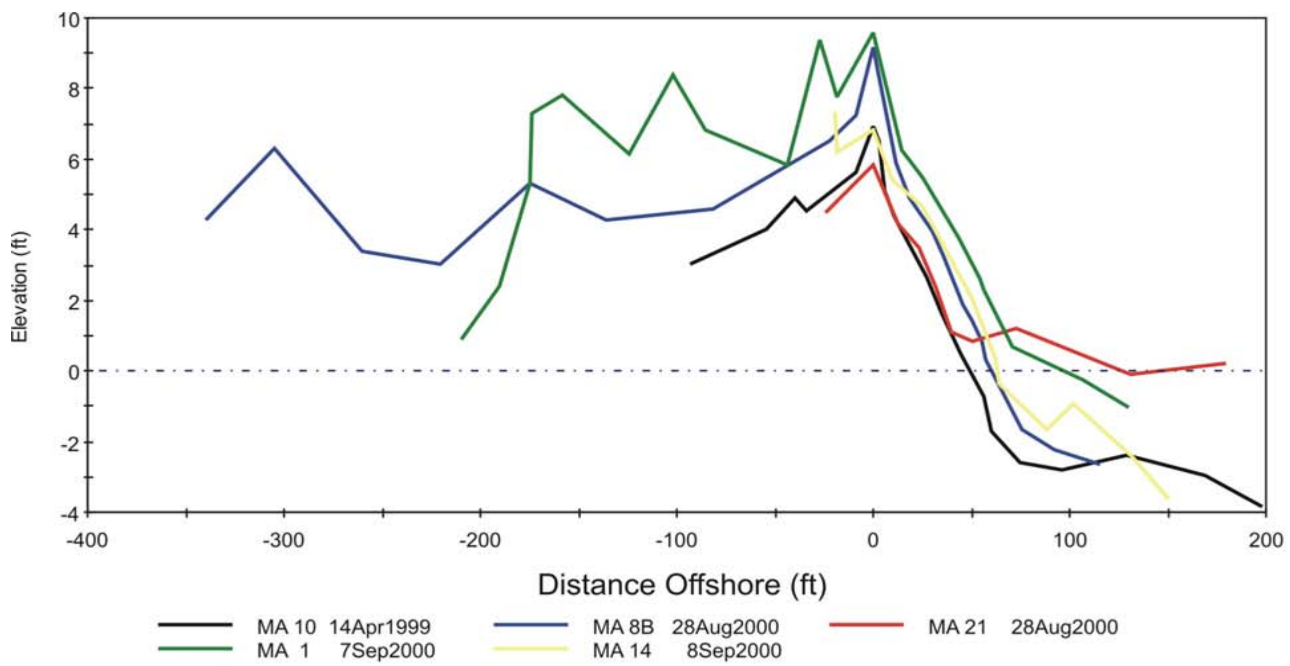

Figure 5. Variability of dune and beach profiles in the Mathews County.

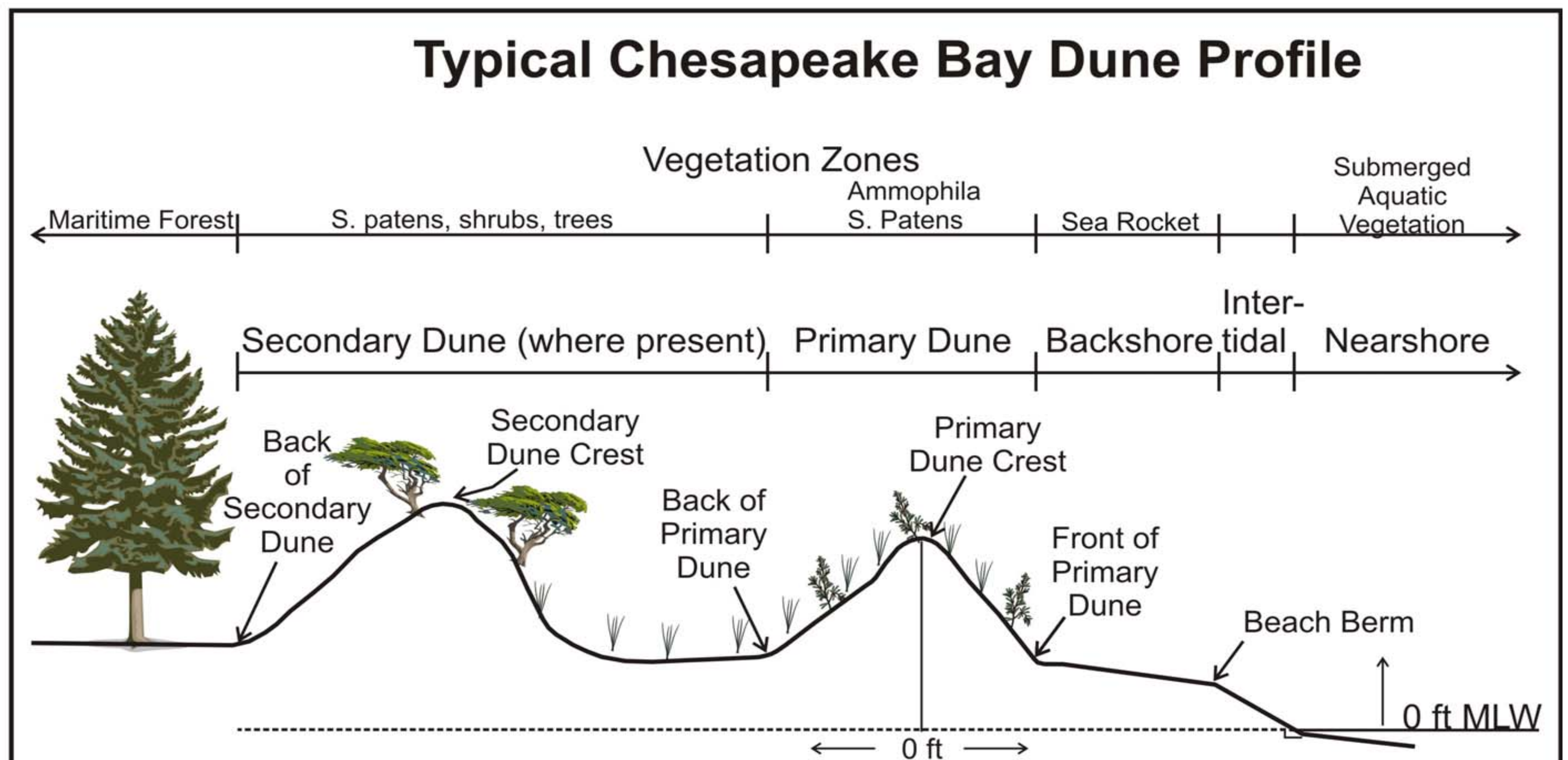

Figure 6. Typical profile of a Chesapeake Bay dune system (from Hardaway *et al.*, 2001).

IV. RESULTS

The Plates referenced in the following sections are in Appendix A. Dune locations are shown on all photo dates for reference only. Dune sites and lengths are positioned accurately on the 2002 photo. Because of changes in coastal morphology, the actual dune site might not have existed earlier. Site information tables are in Appendix B. More detailed information about Chesapeake Bay dunes and individual dune sites in Mathews County can be found in Hardaway *et al.* (2001) and Hardaway *et al.* (2003). Since much of the dune data were collected several years ago and the beach and dune systems may have changed, this report is intended as a resource for coastal zone managers and homeowners; it is not intended for use in determining legal jurisdictional limits.

A. Reach I

Reach I lies within Plate 1 and extends from New Point to Dyer Creek. Dune sites in Reach I are denoted MA1, MA2 and MA3. As seen in the shoreline change summary of Plate 1, the southern most part of Mathews County has had dramatic shifts in shore position. The dune sites MA1 and MA2 are positioned in areas that were water in 1937. The sand has subsequently shifted into its current position by wave and current forces operating at this confluence of Mobjack Bay and Chesapeake Bay. New Point Comfort Lighthouse, completed in 1805, became an island in the 1850s when Deep Creek breached. The island has since receded leaving the lighthouse completely stranded in Chesapeake Bay. The shore reach at MA3 has been more stable over the years, and the coast has evolved to a semi-equilibrium shore form. Hardening of the point at the north end of Reach I has helped maintain headland control and thereby shore stability on that end of the reach.

The long term shore change rate (1937-2002) of the mainland, where the baseline is drawn, shows an erosional trend from station 0 to about station 4750. The trend is slightly accretional from station 4750 to station 6750, but then is very erosional at the end of the reach where the point seen in 1937 imagery is completely eroded. Overall, the long-term rate of change for this reach is -5.5 ft/yr. Extreme fluctuations in shore change are seen at each end of the reach where wave and current dynamics interact and significantly influence alongshore sand movement.

B. Reach II

Reach II lies within Plate 2 and extends from Dyer Creek on the south to Horn Harbor on the north. The coast is very convoluted marsh so the baseline method of shore change assessment is limited to a narrow neck of land where dune site MA 4 occurs. An abundance of SAV, tidal flats and nearshore sand bars exist along this reach. A pocket beach existed at about station 500 until about 1953 when the small bay was used intermittently for dredged material disposal from the navigation channel into Horn Harbor. This resulted in the formation of MA4. Overall, this reach is relatively stable with a net change of -0.5 ft/yr between 1937 and 2002.

C. Reach III

Reach III includes Plates 3 and 4 and extends from Horn Harbor to the opening into Winter Harbor. The breach into Winter Harbor was closed by a sandy barrier up until about 1980 when it was breached (Plate 4). The opening has gotten wider with time and interrupted sand transport along the reach. One dune site, MA8, occurs within Reach III. MA8 has two distinct sub-sections due to the change in direction of shoreline face. Much of this dune site has been and is currently used as a dredge disposal area for the Winter Harbor Navigation Channel which is south of the breach into Winter Harbor.

Shoreline configuration along Plate 3 is generally irregular, making shore change assessments using the baseline method difficult. The one short baseline behind MA8A shows a net advance between 1937 and 2002 due, in part, to the area being used for dredge material disposal, but it also appears to be a natural accretionary feature as well. The remainder of the Reach III coast along Plate 4 is dominated by the barrier breach into Winter Harbor. The adjacent shoreline to the south has experienced significant long-term erosion from station 1500 to station 6500. Erosion in this area may have been exacerbated because of the breach. However, a beach fill project performed between 1994 and 2002 increased the shore position significantly and caused the long-term trend to become positive in that area.

D. Reach IV

The bay shorelines along Plates 5 and 6 make up Reach IV which include dunes sites MA9, MA10 and MA11 all of which reside on Plate 5. The present positions of each dune site, MA9, MA10 and MA11, were 400 feet, 200 feet and 500 feet, respectively, from the shoreline in 1937. The shoreline was once more continuous and has eroded to its present position. It appears that the Winter Harbor breach impacted this reach of coast as much as the Plate 4 shoreline. Rather than having a constant lateral coast for beach sands to move along, the breach opened and broke that continuum and sand was lost to the breach and consequently the littoral system. This is evidenced, in part, by increased erosion rates on adjacent coasts after the breach.

Additionally, two man-made features have broken the continuity of the old beach system. These include the Garden Creek jetties and the small cottage community know as Bethel Beach. The Garden Creek jetties were installed on either side of a man-made channel prior to 1937 in order to provide a more direct entrance into Garden Creek. They interrupted the alongshore transport, accumulating sand on the north side and causing scour and local erosion on the south side. The jetties have been maintained periodically since then, and the area exists as a headland feature. This offset trend continued with the development of Bethel Beach community as a series of groins were installed to maintain a beach. The shore positions illustrate this trend as it also has developed a downdrift offset. The long-term trend is highly erosional at rate of -6.0 ft/yr for the Plate 5 coast.

The influence of the Winter Harbor breach probably diminishes northward by the Garden Creek jetties and into Plate 6. However, another barrier decay and breach occurred to the north at White's Creek and Rigby Island which once again, broke up a once more continuos barrier beach system. The result is an average long-term rate of over 10 -ft/yr.

E. Reach V

Reach V extends from the "Hole in the Wall" to Cherry Point on the north end of Gwynn's Island and includes Plates 7 and 8 and dune sites MA12, MA13, MA14, MA15, and MA16. Sites MA12 and MA13 are fairly recent features having developed after 1982 and the breach at Hull Creek. Sites MA14, MA15, and MA16 are located along the main upland shore of Gwynn's Island and occur as erosional remnants of a once more extensive beach system.

The Hills Creek breach occurred around 1980 and separated the southern spit connection with the Gwynn's Island mainland. The subsequently formed island began to deteriorate in earnest but elongated as well allowing MA 12 to develop. After the breach, sand poured through and accumulated on the Gwynn's Island mainland where MA 13 developed. Dune site MA12 is probably an ephemeral feature whereas MA13 appears to be a more stable pocket beach configuration. Severe erosion is the long-term trend along the Plate 7 coast.

The Plate 8 coast consists of mostly the Gwynn's Island mainland. Erosion is the long-term trend especially on the north end. Recent rates, since 1982, are very low due, in part, to the installation of groins and bulkheads. These structures effectively removed a source of sand from bank erosion from the littoral system and may have led to or accelerated the Hills Creek breach. The isolated dune sites along Gwynn's Island appear relatively stable at this time.

F. Reach VI

Reach VI extends from Cherry Point along Hills Bay to Narrow Point and Milford Haven, the northwest coast of Gwynn's Island. It is on Plate 9 and includes dune site MA 18. One interesting feature of this shore reach is the large sand protuberance seen in the 1937 imagery between about station 7,500 and 8,500. This is sandy material dredged from the adjacent navigational channel into Milford Haven. This sand "slug" migrated back toward the channel where much of it was trapped by a subsequently placed jetty. With time, that area accreted and became today's dune site, MA18.

Shore change along most of this reach is slightly erosional to stable except for fluctuations south of station 7000 associated dredge disposal and jetty. Much of the shore has been hardened with bulkheads, groins and riprap from 0 to 8000 as development proceeded long the coast even before 1937. The shallow nearshore and extensive sand bar system have perhaps provided the foundation for the expansion of SAV beds in that region.

G. Reach VII

Reach VII is included in Plate 10 and extends from the Milford Haven navigation channel to Queens Creek and then to Burton Point. No dune sites occur along this reach at this time, but historically a thin beach and possibly some small and or isolated dunes did occur. Shore change patterns are irregular much like the coast along the measured baseline, but the net change is an erosional trend.

H. Reach VIII

Reach VIII is included in Plate 11 and extends from Burton Point around Godfrey Bay to Iron Point. The reach includes dune sites MA19, MA20 and MA21. The shoreline occurs as a long curvilinear embayment along Godfrey Bay. The western half of MA 19 is a public beach/landing in Godfrey Bay which has a low accreting dune against a high upland bank. The old dune areas to the east and west have been modified by bank grading and mowing. The coast has been relatively stable over the years with the isolated dune sites being remnants of what appears to have been a more continous beach in 1937. At that time dunal aerial signatures appear adjacent to Chapel Creek. This creek had jetties installed in 1980 which defined the channel and bounded MA20 and MA21 on either side. Due to the curvilinear nature of the shoreline, change rates were not determined for this reach.

I. Reach IX

Reach IX extends from Iron Point up the Piankatank River to Cobbs Creek and includes dune sites MA23 and MA24 (Plate 12). These sites are small isolated dunes that appear in the same position over time since 1937. The overall shoreline has changed little over the 65 years of aerial records although rates of change were not calculated to quantify this due to the irregular nature of the shore. The shoreline farther up the Piankatank River in Mathews County shown on Plate 13 had little change and no dune sites.

V. DISCUSSION: NEAR FUTURE TRENDS OF DUNE SITES

The following discussion is a delineation of shoreline trends based on past performance. Ongoing shore development, shore stabilization and/or beach fill, and storms will have local impacts on the near term. “Near Future” is quite subjective and only implies a reasonable expectation for a given shore reach to continue on its historic course for the next 10 to 20 years. In addition, the basis for the predictions are the shorelines digitized on geo-rectified aerial photography which have an error associated with them (see Methods, Section III). Each site’s long-term and recent stability as well as a near future prediction are shown in a table in Appendix B. **This data is intended as a resource for coastal zone managers and homeowners; it is not intended for use in determining legal jurisdictional limits.**

Dune site MA1 is occurs on an eroding island that is constantly changing and is currently beginning to weld to the mainland so it will continue to erode and evolve into MA2 (Figure 7). Dune site MA2 is relatively stable but subject to constant change so its future is subject to the next big storm. MA3 lies in a curvilinearly embayed shoreline and should be relatively stable over time especially with the residents maintaining their sand fencing after major storm events.

Dune site MA 4 is the product of the disposal of dredge material (Figure 8). It is currently stable and should remain so due to its pocket beach morphology and intermittent sand disposal. Dune site MA8 is the longest dune field in Mathews County (Figure 8). It lies in an accretionary sedimentary environment and because of occasional dredge disposal along its shores, it should be stable for the near term.

Dune site MA9 lies near the Winter Harbor breach and is subject to washover and landward advance. It will not maintain its current position. Dune site MA10 sits within the Bethel Beach cottage community and should be relatively stable for the near future (Figure 8). Dune site MA11 resides against the Garden Creek jetties and should be stable as long as the jetties remain intact (Figure 8). However, the shoreline is receding slightly at the location. Increased shore erosion will threaten the dune.

Dune site MA12 is an ephemeral feature that has been reduced by about ½ since the site visit in 2000 (Figure 8) as shown on the 2002 photo for Plate 7. MA 13 has evolved into a relatively stable pocket beach setting. In fact, the shore accreted between 1994 and 2002. However, the shore just north of the pocket had significant erosion during the same time period. The three dune sites along mainland Gwynn’s Island (MA14, MA15, and MA16) reside in groin fields in relatively stable situations (Figure 8).

Dune site MA18 is an accreting beach and dune that has evolved in response to a combination bulkhead/jetty that was installed as part of the Gwynn’s Island Marina and restaurant/motel complex (Figure 8). Presently, it is relatively stable. The location of sites MA19, MA20, and MA21 within the curvilinear embayment of Godfrey Bay as well as the relative abundance of sand in the system makes the shorelines and therefore the dunes relatively stable (Figure 8). In particular, MA20 and MA21 are associated with channel jetties which interrupt the flow of sand allowing it to accumulate. Farther upriver, dune sites MA23 and MA24 are in fairly protected riverine environments lending to long-term stability (Figure 8).

Figure 7. Photos of Mathews County’s shoreline showing dune sites MA1, MA2 and MA3.

Figure 8. Photos of Mathews County's shoreline showing selected dune sites between MA 4 and MA 23.

VI. SUMMARY

Shoreline change rates are based on aerial imagery taken at a particular point in time. We have attempted to portray the same shoreline feature for each date along the coast of Mathews County. Every 500 feet along each baseline on each plate, the rate of change was calculated. The mean or average rate for each plate is shown in Table 2 for six time periods with the long-term rate determined between 1937 and 2002. The total average and standard deviation (Std Dev) for the entire data set of individual rates is also given. The standard deviation shows the relative spread of values about the mean or average. Larger standard deviation values relative to the mean indicates a wider scatter of erosion rates about the mean while lower standard deviation values indicates erosion rates are concentrated near the mean (*i.e.* all the rates calculated for the entire plate were similar).

The largest variability in mean shore change rates and standard deviations were recorded for the shoreline on Plate 1. For instance, between 1968 and 1982, the standard deviation is over double the average rate of change indicating that the overall rate is probably not indicative of the change which occurred on this section of shore. However, not all of the dates for this section of shore had mean shore change rates with large standard deviations. For the period between 1937 and 2002, the mean shore change rate and the standard deviation were the same, indicating that the shore change rates were relatively consistent for that time period.

When short time frames are used to determine rates of shoreline change, shore alterations may seem amplified. The rates based on short-time frames can modify the overall net rates of change. Hopefully, the shore change patterns shown in this report along with the aerial imagery will indicate how the coast will evolve based on past trends and can be used to provide the basis for appropriate shoreline management plans and strategies. Dunes and beaches are a valuable resource that should be either maintained, enhanced or created in order to abate shoreline erosion and provide sandy habitat.

Table 2. Summary shoreline rates of change and their standard deviation for Mathews County.

Plate No.	Mean Shore Change 1937-1953 (ft/yr)	Std Dev (ft/yr)	Mean Shore Change 1953-1968 (ft/yr)	Std Dev (ft/yr)	Mean Shore Change 1968-1982 (ft/yr)	Std Dev (ft/yr)	Mean Shore Change 1982-1994 (ft/yr)	Std Dev (ft/yr)	Mean Shore Change 1994-2002 (ft/yr)	Std Dev (ft/yr)	Mean Shore Change 1937-2002 (ft/yr)	Std Dev (ft/yr)
Plate 1	-16.0	17.0	3.1	13.8	-5.9	16.9	-2.3	5.2	-0.1	10.3	-5.5	4.7
Plate 2	-0.9	5.3	0.5	2.0	-2.2	1.9	0.7	4.0	-0.7	0.4	-0.5	2.0
Plate 3	5.2	3.9	6.9	2.8	1.7	5.7	-0.3	5.4	0.0	5.9	2.9	2.0
Plate 4	-1.9	3.0	-0.8	5.2	-6.0	3.8	-11.5	6.6	-5.7	16.2	-4.8	4.4
Plate 5	-2.6	5.0	-6.8	3.5	-6.4	3.5	-8.9	3.7	-7.5	5.1	-6.0	2.0
Plate 6	-8.5	6.1	-11.3	2.6	-8.2	6.6	-15.8	11.7	-10.0	5.0	-10.4	3.3
Plate 7	-3.6	3.6	-6.5	3.3	-2.9	19.5	-10.8	11.2	-7.0	16.8	-6.3	3.1
Plate 8	-3.2	2.6	-4.1	3.4	-1.2	2.1	-0.1	1.2	-0.4	2.1	-2.1	1.2
Plate 9	-1.9	5.9	-1.6	3.1	0.8	3.7	-0.6	1.5	0.4	1.7	-0.7	1.9
Plate 10	-2.6	1.4	0.5	1.4	-2.5	3.1	-0.9	3.5	-2.8	2.2	-1.8	1.0
Total^	-4.4	8.5	-3.0	7.2	-3.7	9.4	-5.8	8.6	-3.7	9.2	-4.0	4.3

^Calculated using all available data

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APPENDIX A

For each Plate shown on Figure 4 (Page 4), Appendix A contains orthorectified aerial photography flown in 1937, 1968, 1982, 1994, and 2002. Also shown are the digitized shorelines, identified dune sites, and an arbitrarily created baseline. A plot shows only the relative locations of the shorelines while another one depicts the rate of shore change between dates. A summary of the average Plate rate of change in ft/yr as well as the standard deviation for each rate is also shown.

This data is intended as a resource for coastal zone managers and homeowners; it is not intended for use in determining legal jurisdictional limits.

APPENDIX B

The data shown in the following tables were primarily collected as part of the Chesapeake Bay Dune: Evolution and Status report and presented in Hardaway *et al.* (2001) and Hardaway *et al.* (2003). Individual site characteristics may now be different due to natural or man-induced shoreline change.

An additional table presents the results of this analysis and describes each dune site's relative long-term, recent, and near-future predicted stability. This data results from the position of the digitized shorelines which have an error associated with them (see Methods, Section III).

Since much of the dune data were collected several years ago and the beach and dune systems may have changed, this report is intended as a resource for coastal zone managers and homeowners; it is not intended for use in determining legal jurisdictional limits.

These data were collected as part of the Chesapeake Bay Dune: Evolution and Status Report
(Hardaway *et al.*, 2001). Site characteristics may now be different due to natural or man-induced shoreline change.

Identified dune site information for Mathews County as of 2000.

Dune Site No.	Location^ Easting (Feet)	Northing (Feet)	Date Visited	Dune Shore Length (Feet)	Primary Dune Site?	Secondary Dune Site?	*Public Ownership?
1	2,645,910	362,500	8/7/2000	630	Yes		
2	2,646,620	363,300	8/7/2000	1,600	Yes	Yes	
3	2,647,500	368,050	4/14/1999	4,290	Yes	Yes	
4	2,647,100	374,900	4/14/1999	500	Yes		
8A’	2,654,100	387,100	8/28/2000	3,150	Yes	Yes	
8B’			8/28/2000	3,050	Yes	Yes	
9	2,653,780	399,100	4/14/1999	225	Yes		
10	2,653,440	401,900	4/14/1999	485	Yes		
11	2,652,950	404,800	4/14/1999	515	Yes		
12	2,649,180	422,450	8/28/2000	1,540	Yes		
13	2,646,340	427,600	9/8/2000	450	Yes	Yes	
14	2,644,980	431,900	9/8/2000	460	Yes		
15	2,643,340	435,300	9/8/2000	65	Yes		
16	2,640,680	437,720	9/8/2000	105	Yes		
18	2,633,820	428,300	9/8/2000	525	Yes		
19	2,622,400	433,780	9/8/2000	250	Yes		Yes&Private
20	2,621,180	435,550	8/28/2000	315	Yes		
21	2,620,940	435,900	8/28/2000	430	Yes		
23	2,615,720	440,840	8/28/2000	250	Yes		
Total				18,835			

Dune site measurements for Mathews County as of 2000.

Mathews		Dune Site Measurements								
							Secondary Dunes			
	Site No.	Dune Shore Length (feet)	Crest Elev (ftMLW)	Extent from Crest landward (Feet)	Extent from Crest To MLW (Feet)	Juris-diction	Crest Elev (ftMLW)	LandXtnt From PrimCrest (Feet)	2ndCrest landward (Feet)	2ndCrest BackBase PrimDune (Feet)
MA	1	630	9.6	44	98	Yes	8.4	56	73	
MA	2	1,600	10.2	12	370	Yes	8.0	180	155	13
MA	3	4,290	10.0	8.5	65	Yes	8.4	98	20	69.5
MA	4	500	6.9	8	239					
MA	8A	3,150	6.9	64	68	Yes	8.0	224	71	89
MA	8B	3,050	9.2	82	60	Yes	6.3	340	35	223
MA	9	225	4.5	15	56					
MA	10	485	6.9	9	50					
MA	11	515	6.3	8	62					
MA	12	1,540	7.2	45	96					
MA	13	450	8.0	13	97	Yes	5.7	44	13	18
MA	14	460	6.8	18	63					
MA	15*	65								
MA	16*	105								
MA	18	525	6.1	64	62					
MA	19	250	4.5	10	58					
MA	20	315	5.2	26	43					
MA	21	430	5.8	24	126					
MA	23	250	3.5	31	36					

*Not profiled

*Public ownership includes governmental entities including local, state, and federal;
otherwise ownership is by private parties.
^Location is in Virginia State Plane South, NAD 1927.
‘One site with variable alongshore dune conditions.

These data were collected as part of the Chesapeake Bay Dune: Evolution and Status Report
(Hardaway *et al.*, 2001). Site characteristics may now be different due to natural or man-induced shoreline change.

Dune site parameters in Mathews County as of 2000. Site characteristics may now be different due to natural or man-induced shoreline change.

Mathews			Dune Site Parameters							
	Site No.	Type	Fetch Exposure A	Shoreline Direction of Face B	Nearshore Gradient C		Morphologic Setting D	Relative Stability E	Underlying Substrate F	Structure or Fill G
MA	1	Natural	Open Bay	East	Medium	Bars	Dune Field, linear	Erosional	Marsh/CB	
MA	2	Natural	Open Bay	Southeast	Medium	Bars	Dune Field, salient	Stable	Marsh/CB	
MA	3	Man-Inf	Open Bay	East	Shallow	Bars	Dune Field, linear	Stable	Upland	
MA	4	Man-Inf	Open Bay	Northeast	Medium	Bars	Isolated, bay	Stable	Upland	Beach fill
MA	8A	Man-Inf	Open Bay	Southeast	Medium	No Bars	Ck Mouth	Accretion	Marsh/CB	
MA	8B	Man-Inf	Open Bay	East	Medium	No Bars	Ck Mouth	Accretion	Marsh/CB	
MA	9	Natural	Open Bay	East	Medium	No Bars	Isolated, pocket	Erosional	Marsh/CB	
MA	10	Man-Inf	Open Bay	East	Medium	No Bars	Isolated, linear	Stable	Upland	Groin
MA	11	Man-Inf	Open Bay	East	Shallow	No Bars	Dune Field, linear	Erosional	Marsh/CB	Jetty
MA	12	Natural	Open Bay	East	Medium	Bars	Ck Mouth	Erosional	Marsh/CB	
MA	13	Man-Inf	Open Bay	Northeast	Medium	Bars	Isolated, pocket	Erosional	Upland	Groin
MA	14	Man-Inf	Open Bay	Northeast	Medium	Bars	Isolated, linear	Stable	Upland	Groin
MA	15	Man-Inf	Open Bay	Northeast	Medium	Bars	Isolated, linear	Stable	Upland	Revet/BH
MA	16	Man-Inf	Open Bay	Northeast	Medium	Bars	Isolated, pocket	Stable	Upland	Groin
MA	18	Man-Inf	Riv-Bay	North	Steep	No Bars	Dune Field, linear	Stable	Upland	Jetty
MA	19	Natural	Riv-Bay	Northeast	Steep	Bars	Isolated, linear	Stable	Upland	
MA	20	Man-Inf	Riv-Bay	Northeast	Steep	Bars	Isolated, linear	Stable	Marsh/CB	Jetty Beach Fill
MA	21	Man-Inf	Riv-Bay	Northeast	Steep	Bars	Isolated, linear	Stable	Upland	Jetty
MA	23	Natural	Riverine	East	Steep	No Bars	Isolated, linear	Stable	Upland	

Long term, recent stability, and future predictions of sediment erosion and accretion rates for dune sites in the Mathews County.

Site No.	Long-Term Stability 1937-2002	Recent Stability 1994-2002	Near Future Prediction
1	Erosional	Erosional	Erosional
2	Accretionary	Accretionary	Stable
3	Erosional	Stable	Stable
4	Accretionary	Erosional	Stable
8A	Accretionary	Accretionary	Stable
8B	Accretionary	Accretionary	Accretionary
9	Erosional	Erosional	Erosional
10	Erosional	Stable	Stable
11	Erosional	Erosional	Erosional
12	Erosional	Erosional	Erosional
13	Erosional	Accretionary	Accretionary
14	Erosional	Erosional	Stable
15	Stable	Stable	Stable
16	Erosional	Stable	Stable
18	Accretionary	Stable	Stable
19	Stable	Stable	Stable
20	Stable	Stable	Stable
21	Stable	Stable	Stable
23	Accretionary	Erosional	Stable
24	Erosional	Stable	Stable