2006

# Dune Evolution Westmoreland County, Virginia Potomac River Shoreline

C. Scott Hardaway Jr.
*Virginia Institute of Marine Science*

Donna A. Milligan
*Virginia Institute of Marine Science*

Lyle M. Varnell
*Virginia Institute of Marine Science*

Christine Wilcox
*Virginia Institute of Marine Science*

George R. Thomas
*Virginia Institute of Marine Science*

*See next page for additional authors*

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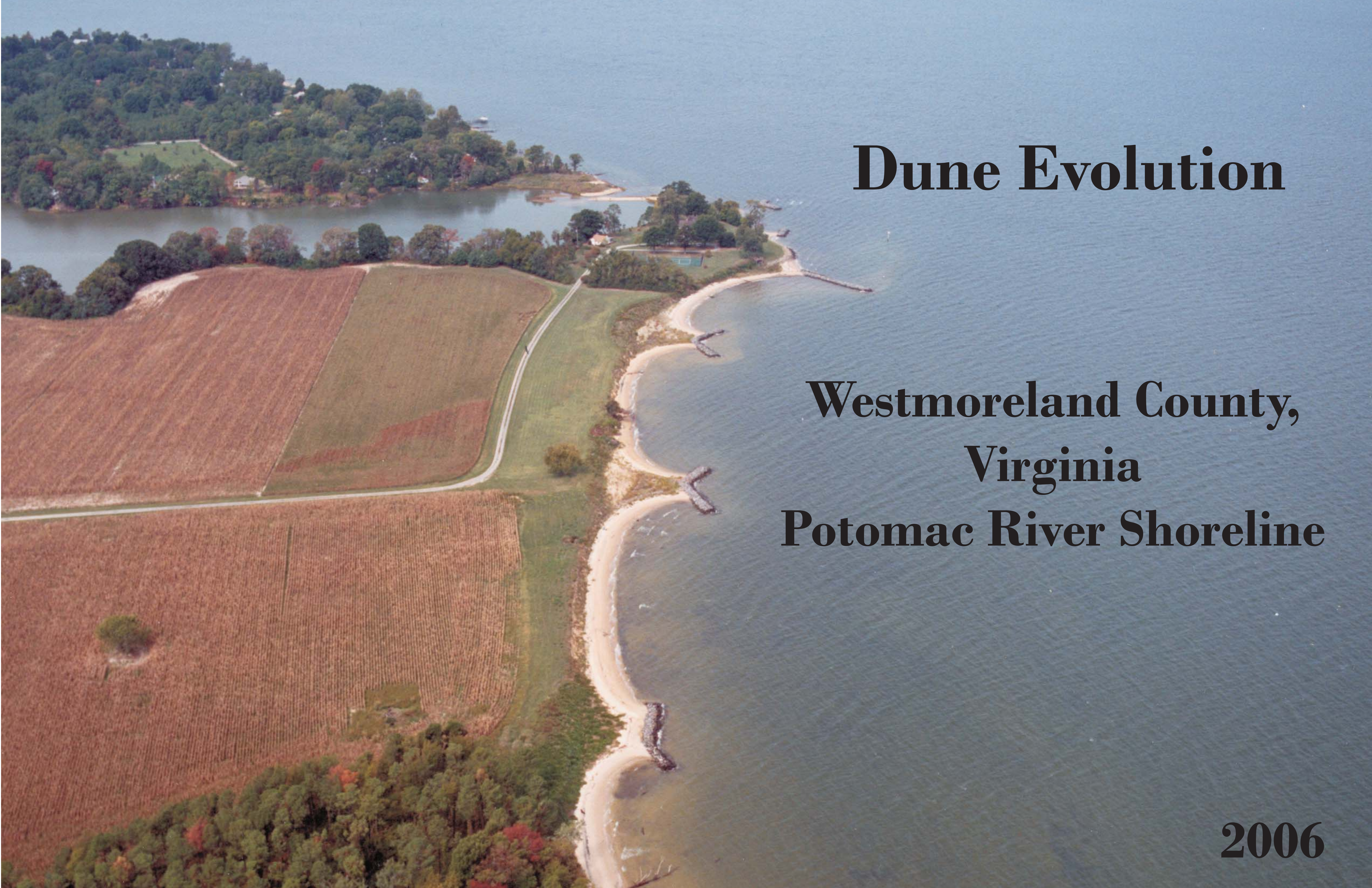

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C. Scott Hardaway, Jr. [1]
Donna A. Milligan [1]
Lyle M. Varnell [2]
Christine Wilcox [1]
George R. Thomas [1]
Kevin P. O'Brien[1]

Shoreline Studies Program [1]
Department of Physical Sciences
and
Office of Research and Advisory Services[2]

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


**2006**


This project was funded by the Virginia Department of Environmental Quality's Coastal Resources Management Program through Grants NA17OZ2355, NA17OZ1142,and NA04NOS4190060 of the National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management, under the Coastal Zone Management Act of 1972, as amended.

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**Cover Photo:** Photograph of site WM18, the Murphy headland breakwater system on the Potomac River. Photo taken by Shoreline Studies Program on 25 September 2002.

# 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 dunes on Potomac River shores of Westmoreland (Figure 1) have 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 where dunes occur 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 Dune Evolution report is to be able to determine how dunes and beaches along the coast of Westmoreland 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 2002, Hardaway *et al*. characterized dunes in several non-jurisdictional localities including Westmoreland. That report detailed the location and nature of the jurisdictional primary dunes along the River shore of Westmoreland, 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 2001. 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 Potomac River of Westmoreland County extends from the county line with Northumberland at the Yeocomico River upriver to Rosier Creek and the border with King George County (Figure 3). This includes about 40 miles of tidal shoreline along the Potomac River. Historic shore erosion rates vary from 0 ft/yr to over 4 ft/yr along the Potomac River shoreline (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 Potomac River coast of Westmoreland is undifferentiated Lynnhaven and Poquoson Members in the lower section of the county to Nomini Bay. Along a short section of the Potomac river, the older Tertiary Chesapeake Group outcrops with high banks (Figure 4). The Quaternary Sedgefield Member occurs farther upriver. The younger Quaternary geology is generally lower in elevation than the older Tertiary formations. The Atlantic Ocean has come and gone numerous times over the Virginia coastal plain over the past million years or so creating these various geologic formations. The effect has been to rework older deposits into beach and lagoonal deposits at 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. Parts of Westmoreland's littoral system is sand rich from erosion over time of the sandy, sometimes high, upland banks and the nearshore substrate.

Sea level is continuing to rise in Chesapeake Bay. 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/). Lewisetta on the Potomac River in neighboring Northumberland County rose 4.85 mm/yr or 1.59 ft/century. Increased water levels directly effect 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 (~0.5 in), 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.

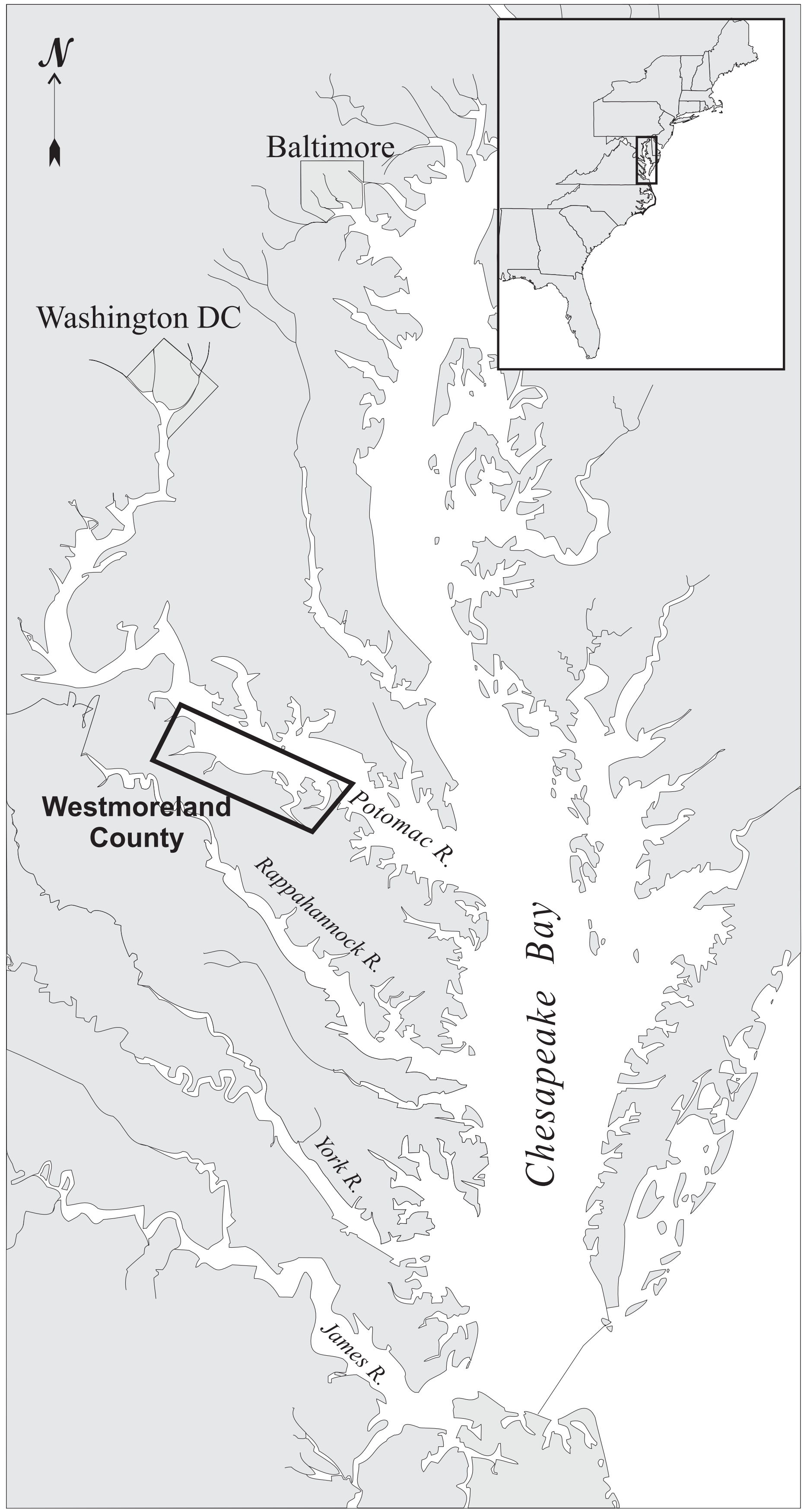



Figure 1. Location of Westmoreland County within the Chesapeake Bay estuarine system.

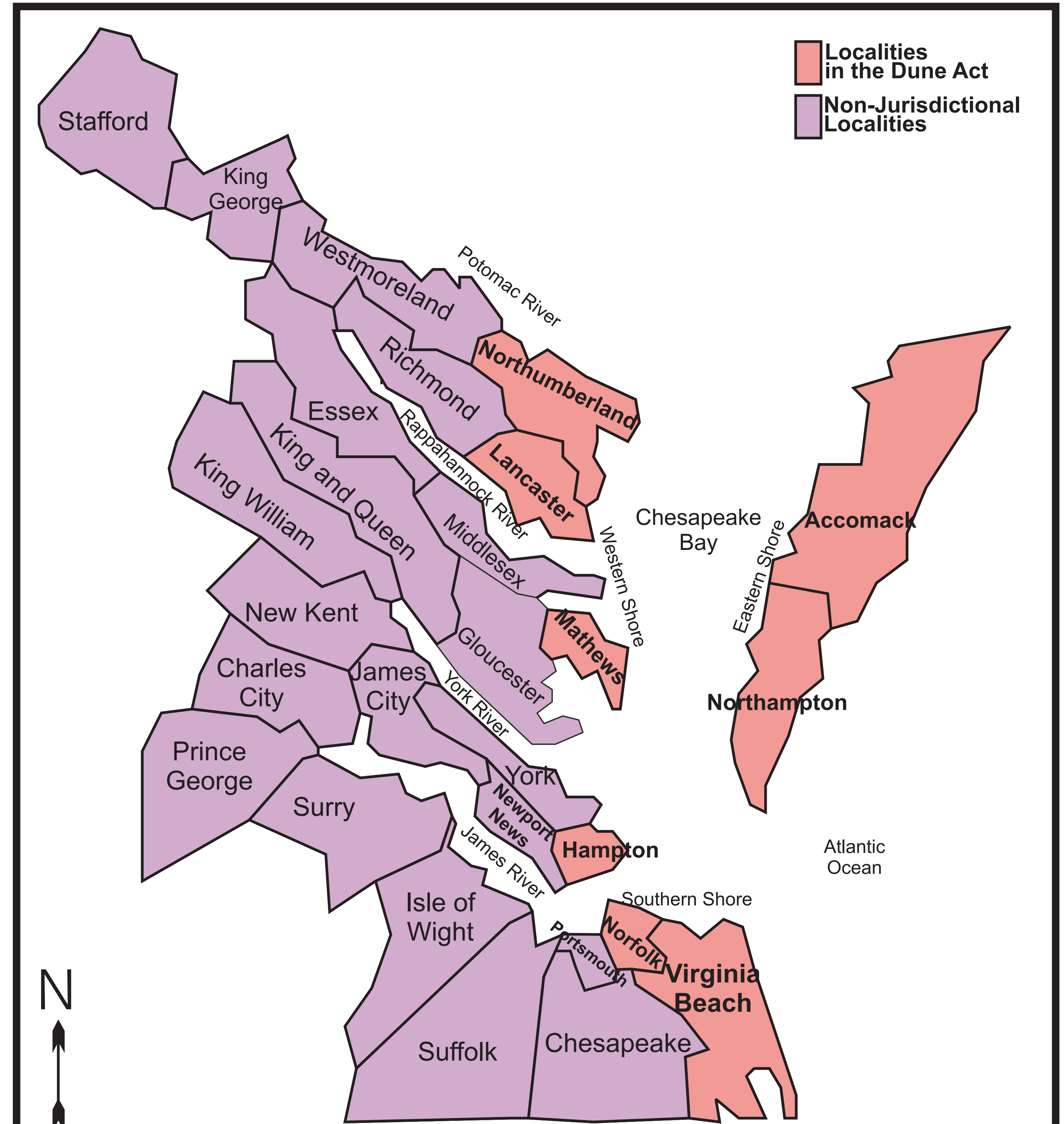



Figure 2. Location of localities in the Dune Act with jurisdictional and non-jurisdictional localities noted.

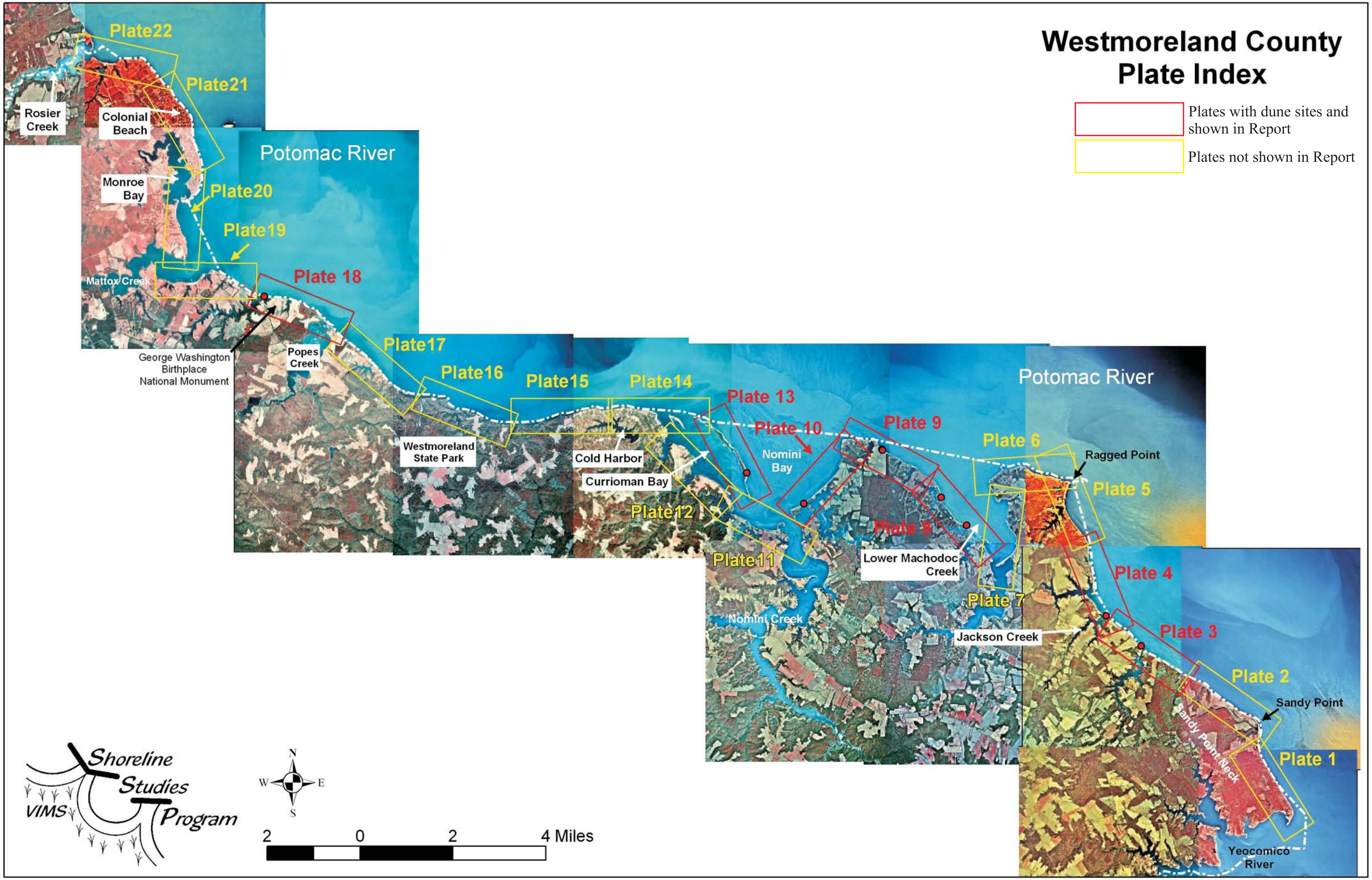
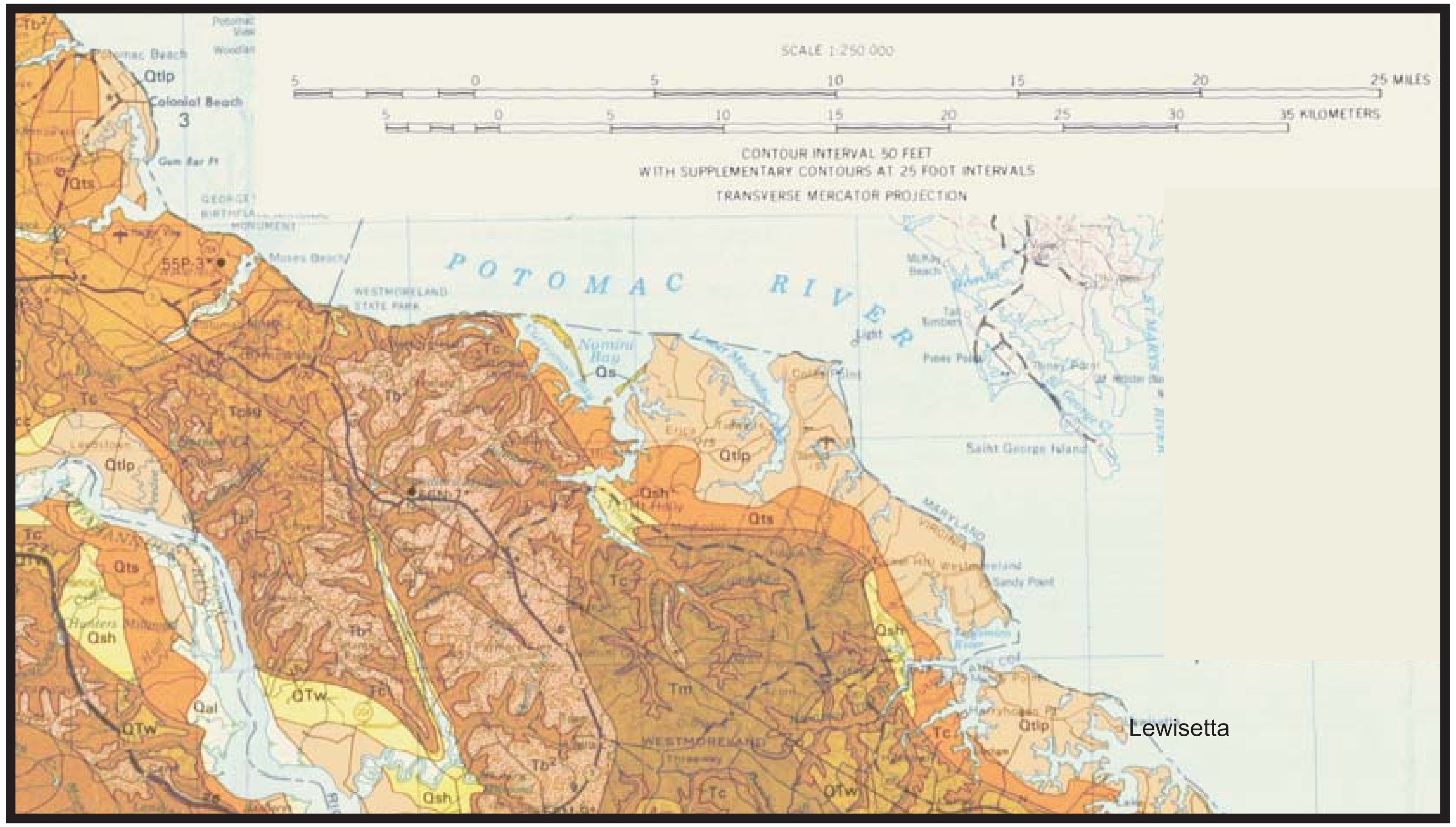



Figure 3. Westmoreland plate index.




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.

Qtlp **Lynnhaven and Poquoson Members, undifferentiated.**

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.

QTw **Windsor Formation (lower Pleistocene or upper Pliocene) -** Gray and yellow to reddish-brown sand, gravel, silt, and clay. Constitutes surficial deposits if extensive plain (alt. 85-95 ft) seaward of Surry scarp and coeval, fluvial-estuarine terrace west of scarp. Fining-upward sequence beneath plain consists of basal pebbly sand grading upward into crossbedded, quartzose sand and massive, clayey silt and silty clay; lower and upper parts of sequence were deposited, respectively, in shallow-marine or open-bay and restricted-bay or lagoonal environments. In terraces west of Surry scarp, fluvial-estuarine deposit comprise Muddy, coarse, trough-crossbedded sand and gravel grading upward to sandy silt and clay. Unit is 0-40 ft thick.

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.

Tc **Chesapeake Group (upper Pliocene to lower Miocene) -** Fine to coarse, quartzose sand, silt, and clay; variably shelly and diatomaceous, deposited mainly in shallow, inner- and middle-shelf waters. Ages of units based in studies of foraminiferal, nannofossil, diatom, and molluscan assemblages in Virginia and adjacent states (Andrews, 1988; Gibson, 1983; Gibson and others, 1980; Poag, 1989; Ward and Blackwelder, 1980; Ward and Krafft, 1984), Includes the following formations (see also sheet 2, figure 1), from youngest to oldest; Chowan River Formation (upper Pliocene), Yorktown Formation (lower upper and lower Pliocene), Eastover Formation (upper Miocene), St. Mary's Formation (upper and

Tm **Moorings unit of Oaks and Coch (1973) (upper Pliocene) -** White, light-gray, and grayish-yellow quartzose sand and gray to grayish-brown clayed silt and silty clay. Constitutes discontinuous linear body along and just west of Surry scrap; depositional. Surfaces range in altitude from 130 ft along slightly higher, ridge-like topography at scarp to about 110 ft west of scarp. Eastern facies of unit is unfossiliferous, massive to cross-laminated, moderately well-sorted, fine sand.

$Tb^1$ $Tb^2$ **Bacons Castle Formation (upper Pliocene) -** Gray, yellowish-orange, and reddish-brown sand, gravel, silt, and clay; Constitutes surficial deposits of high plain extending from Richmond, VA., Eastward to Surry Scrap. Unit is subdivided into two members: Tb^1 and Tb^2. Tb^2 predominantly thin-bedded and laminated clayey silt and silty fine sand. TB^2 is characterized by flaser, wavy, and lenticular bedding and rare to common clay-lined burrows including *Ophiomorpha nodosa.* Unit is 0-70 ft thick.

Tpsg **Pliocene sand and Gravel -** Interbedded yellowish-orange to reddish-brown gravelly sand, sandy gravel, and fine to coarse sand, poorly to well-sorted, crossbedded in part, includes less amounts of clay and silt in thin to medium beds. Commonly caps drainage divides (alt. 250-170ft ) in northwestern part of Coastal Plain. Lower part of unit, showing flaser and lenticular bedding and contain rare to abundant *Ophiomorpha nodosa,* represents deposition in marginal-marine environment and is in part, a nearshore equivalent of the more downslip, marine facies of the Yorktown Formation. The more fluvial-deltaic sediments that prograded eastward across the shelf during a regressive phase of the Yorktown. Thickness is 0-50ft.

Figure 4. Geologic map of Westmoreland County (from Mixon *et al*., 1989).

B. Hydrodynamic Setting

Mean tide range along the upper Potomac River coast of Westmoreland is about 1.2 ft (1983-2001 Tidal Epoch at Lewisetta). Spring tide range is 1.5 ft. The wind/wave climate impacting the Westmoreland shore is defined by fetch exposures to the northwest, north, northeast, and east along Potomac River. Wind data from Quantico Marine Corps Base upriver reflect the frequency and speeds of wind occurrences from 1973 to 2001 (Table 1) which characterize the locally-generated Bay waves.

Northeasters are particularly significant in terms of the impacts of storm surge and waves on beach and dune erosion. Hurricanes, depending on their proximity and path can also have an impact to the Virginia 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 erosion and dune scarping were significant but areas with wide beaches offered more protection to the adjacent dunes.

Table 1. Summary wind conditions at Quantico Marine Corps Base from 1973-2001.

| | | WIND DIRECTION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Wind Speed (mph)** | **Mid Range (mph)** | **North** | **North east** | **East** | **South east** | **South** | **South west** | **West** | **North west** | **Total** |
| **< 5** | 3 | 5703*<br>3.21[+] | 3330<br>1.87 | 3868<br>2.18 | 4792<br>2.70 | 12257<br>6.90 | 4291<br>2.42 | 7070<br>3.98 | 15437<br>8.69 | 56748<br>31.95 |
| **5-11** | 8 | 17454<br>9.82 | 10087<br>5.68 | 6504<br>3.66 | 8117<br>4.57 | 22593<br>12.72 | 8515<br>4.79 | 13391<br>7.54 | 18453<br>10.39 | 105114<br>59.17 |
| **11-21** | 16 | 3698<br>2.08 | 1460<br>0.82 | 386<br>0.22 | 517<br>0.29 | 2030<br>1.14 | 1156<br>0.65 | 1129<br>0.64 | 4601<br>2.59 | 14977<br>8.43 |
| **21-31** | 26 | 165<br>0.09 | 64<br>0.04 | 34<br>0.02 | 21<br>0.01 | 60<br>0.03 | 64<br>0.04 | 102<br>0.06 | 274<br>0.15 | 784<br>0.44 |
| **31-41** | 36 | 7<br>0 | 1<br>0 | 2<br>0 | 0<br>0 | 1<br>0 | 1<br>0 | 7<br>0 | 7<br>0 | 26<br>0.01 |
| **41-50** | 46 | 0<br>0 | 0<br>0 | 0<br>0 | 0<br>0 | 1<br>0 | 0<br>0 | 0<br>0 | 0<br>0 | 1<br>0 |
| **>50** | | 1<br>0 | 3<br>0 | 3<br>0 | 3<br>0 | 4<br>0 | 0<br>0 | 7<br>0 | 5<br>0 | 26<br>0.01 |
| **Total** | | 27028<br>15.20 | 14945<br>8.41 | 10797<br>6.08 | 13450<br>7.57 | 36946<br>20.79 | 14027<br>7.9 | 21706<br>12.22 | 38777<br>21.82 | 177676<br>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 Westmoreland. Some of the photographs were available in fully geographically referenced (georeferenced) digital form, but most were scanned and orthorectified for this project.

Aerial photos from VIMS Shoreline Studies as well as from United States Geological Survey (USGS) archives were acquired. The years used for the shoreline change analysis included 1937, 1969, 1987, 1994, and 2002. Color aerials were obtained for 1994 and 2002. The 1994 imagery was processed and mosaicked by USGS, while the imagery from 2002 was acquired from the Virginia Base Mapping Program (VBMP). 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 Westmoreland's coast, an approximation to mean low water (MLW) was digitized. This is approximately the edge of the marsh or the "toe" of the beach. 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 Westmoreland 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.

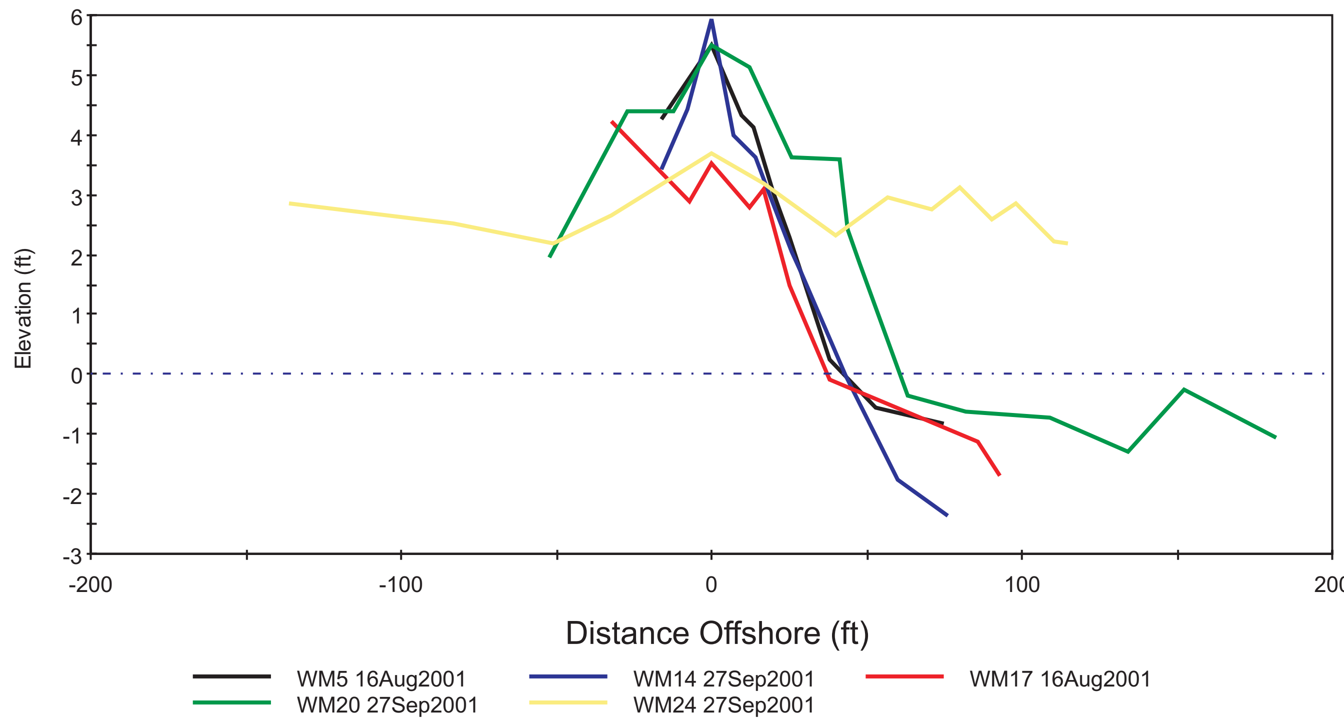



Figure 5. Variability of dune and beach profiles in Westmoreland County.

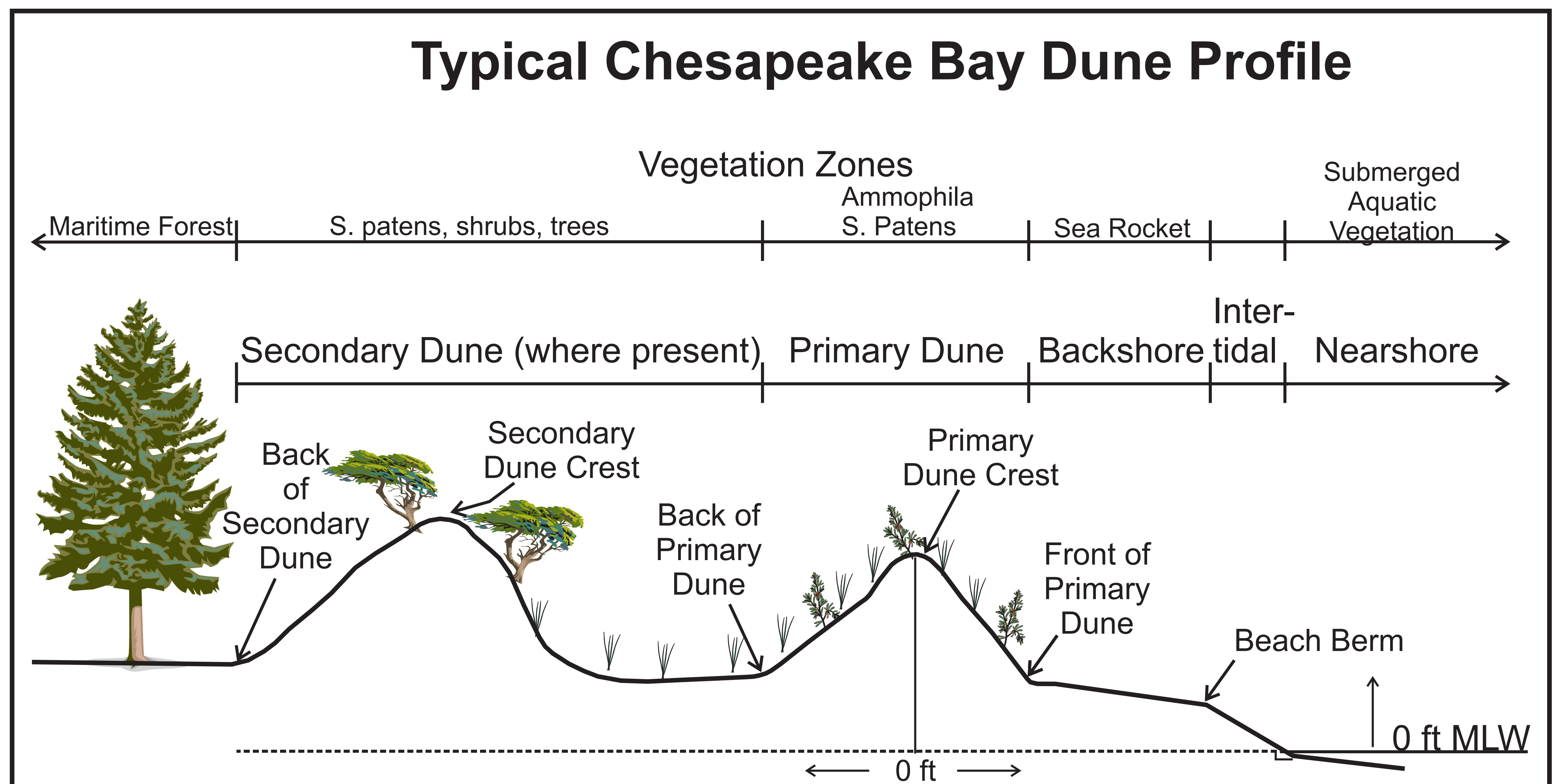



Figure 6. Typical profile of a Chesapeake Bay dune system (from Hardaway *et al.*, 2001).

# IV. RESULTS and DISCUSSION of NEAR FUTURE TRENDS OF DUNE SITES

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 Westmoreland can be found in Hardaway *et al.* (2001) and Hardaway *et al.* (2002). Only those Plates that have dune sites are shown in Appendix A.

The shoreline trends are delineated 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.**

Westmoreland County's Potomac River coast extends from the Yeocomico River northward to Rosier Creek just upriver of the Town of Colonial Beach. Twenty-two plates subdivide the shore along the Potomac River but only 7 plates have dune sites. These are plates 3, 4, 8, 9, 10, 13, and 18; only these plates shall be discussed in this section. Plate 3 has one dune site, WM5, that is located on the upriver side of the north jetty at Bonum Creek. It has evolved primarily due to the jetty trapping littoral sands. Shore change along Plate 3 has been quite variable over time with a net rate of -1.9 ft/yr. Site WM5 appears to be stable for the near term.

Site WM6 is the only dune site on Plate 4 and it lies at the mouth of Jackson Creek. The site was a spit feature in 1937 and appears to have gained backshore vegetation by 1969. Aerial imagery in 1987 shows a dredged channel and dredge material deposition on the downriver side of Jackson Creek. Site WM6 further evolved on the river side of that deposition. The short length of shoreline measured on Plate 4 includes the shoreline on either side of Jackson Creek and shows a net recession rate of -2.2 ft/yr. Since WM6 is backed by sandy dredge material against a maintained channel, it should be relatively stable.

Plate 8 goes from Glebe Point to Cabin Point along Lower Machodoc Creek and has three dune sites, WM14 and WM15/16. Site WM14 is an erosional remnant of a longer, more extensive beach and spit as seen in 1937 imagery. The Glebe Point spit has been reduced to almost no shore at all in 2002. WM14 marks the mainland attachment position of the spit. Site WM14 has had a history of erosion and that trend will most likely continue until it disappears.

The inlet to Cabin Point Creek was moved upriver by dredging a new channel in the late 1980s and can be seen in 1994 imagery. Site WM15/16 evolved in the groinfield upriver that was installed when the channel was created. The shoreline has become relatively stable due to the groins; however the source of sand to the reach has been cut off by extensive bulkheading upriver. The site may experience reduced sand supply with consequent reduction in beach width and dune erosion.

Sites WM18A and WM18B, on Plate 9, exists because of the offshore headland breakwater installed in 1995. The site evolved on the attached tombolo. The headland breakwaters allow the adjacent banks to erode into an equilibrium planform. This site may grow with time as more sand enters the embayments from the eroding sandy banks as well as from onshore deposition. Overall, the net long-term erosion on the Plate 9 coast is -1.8 ft/yr.

Plate 10 had one dune site as well, WM20. It is part of a long, stable curvilinear embayment formed, in part, by a long jetty at the mouth of Nomini Creek. The net shoreline change rate is -0.6 but the embayed coast from 4,000 to 11,000 is closer to +0.5 ft/yr. This is a very stable coast, and WM20 should remain in existence as long as the jetty is maintained.

Plate 13 has one dune site, WM24, that has evolved as the south spit on Hollis Marsh has grown and decayed over time. Hollis Marsh island has diminished in size, in length, as well as breadth over time. Site WM24 was in its present position by 1987, increased in length, then retreated slightly by 2002. It is stable for now, but further breakup of Holly Marsh will impact its fate. Shore change patterns show erosion of the Hollis Marsh Island coast with accretion then erosion of the southern spit. The net rate of change for the island is -5.9 ft/yr.

Plate 18 has dune site WM28 which lies in a slightly curved, embayed coast at George Washington's Birthplace National Monument. A narrow beach and possibly a dune can be seen in 1937 imagery. A small un-named creek inlet also can be seen which has an associated ebb shoal that has helped maintain a beach and dune on its landward flanks. In fact, that area has a net (1937-2002) accretion rate of +0.3 ft/yr. However, the shoal and beaches have been reduced over time, and this trend appears to be continuing.


Figure 7. Ground photos of select Westmoreland dune sites.

## VI. SUMMARY

Shoreline change rates are based on aerial imagery taken at a particular point in time. For those plates shown in the report, the rate of change was calculated every 500 ft. The mean or average rate for each plate is shown in Table 2 for five 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 standard deviations are close to the average rate of change indicating that the shore change rates were relatively consistent for that time period. Overall rates of change were relatively small with the exception of Plate 13 which depicts Hollis Marsh Island separating Currioman Bay from the Potomac River. This section of shore has been highly erosive since 1937, and the negative shore change rate has been increasing ever since. Plates 8, 10,and 18 had the lowest overall rates of change. However, for Plates 8 and 10, the standard deviation is much larger than the average rate of change indicating that the overall rate is probably not indicative of the change which occurred on this section of shore. 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.

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 Westmoreland County.

| | Plate 3 | | Plate 4 | | Plate 8 | | Plate 9 | | Plate 10 | | Plate 13 | | Plate 18 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Imagery Dates** | **Rate of Change (ft/yr)** | **Std. Dev.** | **Rate of Change (ft/yr)** | **Std. Dev.** | **Rate of Change (ft/yr)** | **Std. Dev.** | **Rate of Change (ft/yr)** | **Std. Dev.** | **Rate of Change (ft/yr)** | **Std. Dev.** | **Rate of Change (ft/yr)** | **Std. Dev.** | **Rate of Change (ft/yr)** | **Std. Dev.** |
| 1937-1969 | -1.4 | 1.1 | -1.3 | 1.1 | -0.4 | 2.4 | -1.8 | 0.8 | -1.1 | 2.9 | -4.9 | 5.4 | 0.3 | 1.5 |
| 1969-1987 | -2.8 | 1.9 | -3.4 | 2.5 | 1.1 | 3.5 | -1.0 | 2.5 | 0.1 | 1.6 | -5.4 | 9.2 | -0.4 | 0.9 |
| 1987-1994 | -2.6 | 2.5 | -2.5 | 2.0 | -3.0 | 3.8 | -1.4 | 2.3 | 0.4 | 1.3 | -6.4 | 8.1 | -2.8 | 1.4 |
| 1994-2002 | -1.3 | 1.9 | -2.1 | 2.2 | -2.7 | 3.6 | -3.6 | 3.6 | -0.9 | 1.4 | -10.4 | 14.5 | -4.1 | 1.5 |
| **1937-2002** | **-1.9** | **1.0** | **-2.2** | **1.0** | **-0.7** | **1.8** | **-1.8** | **1.2** | **-0.6** | **1.5** | **-5.9** | **6.4** | **-0.6** | **0.9** |

## VII. REFERENCES

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**Acknowledgments**

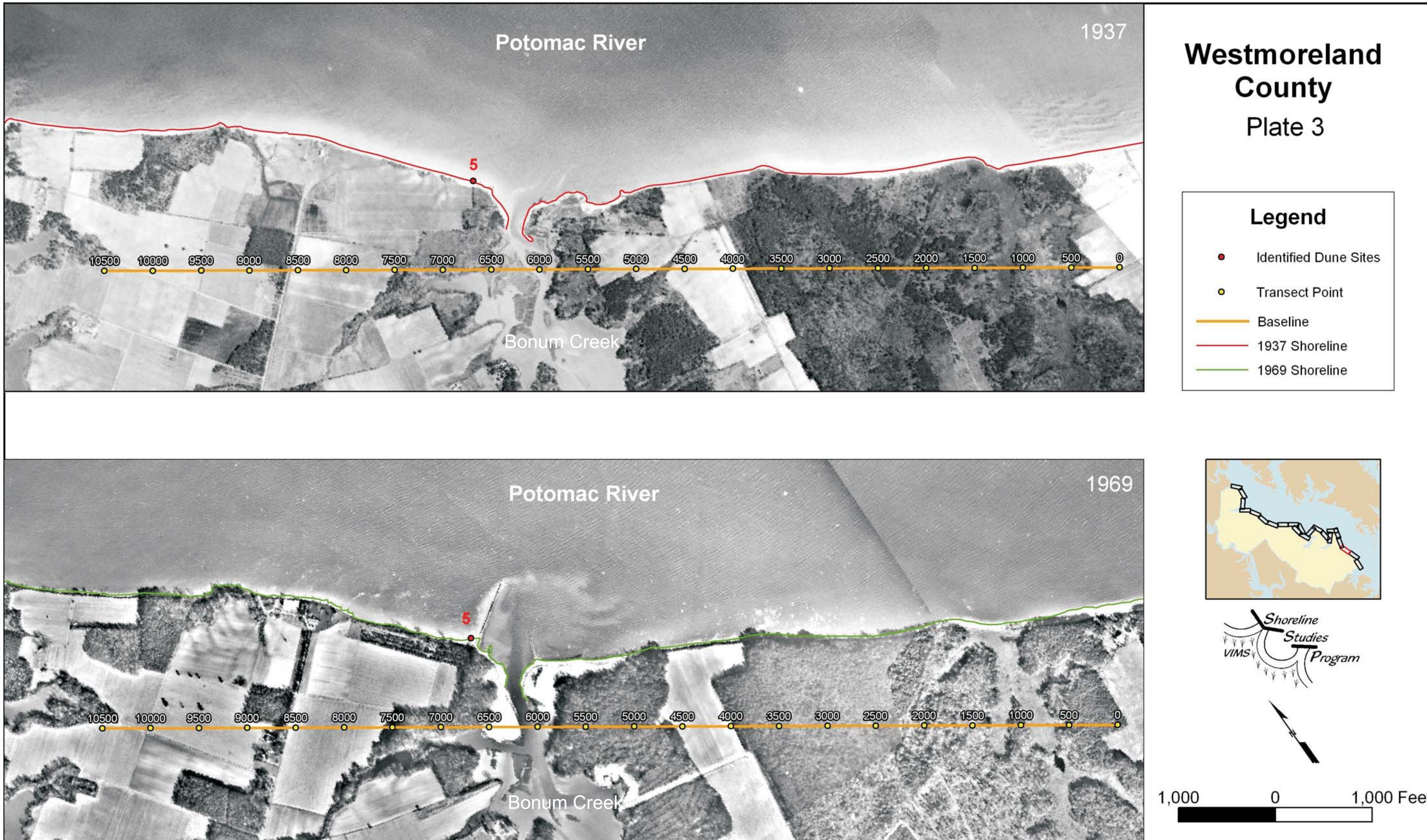
The authors would like to thank the personnel in VIMS' Publications Center, particularly Susan Stein, Ruth Hershner, and Sylvia Motley, for their work in printing and compiling the final report.

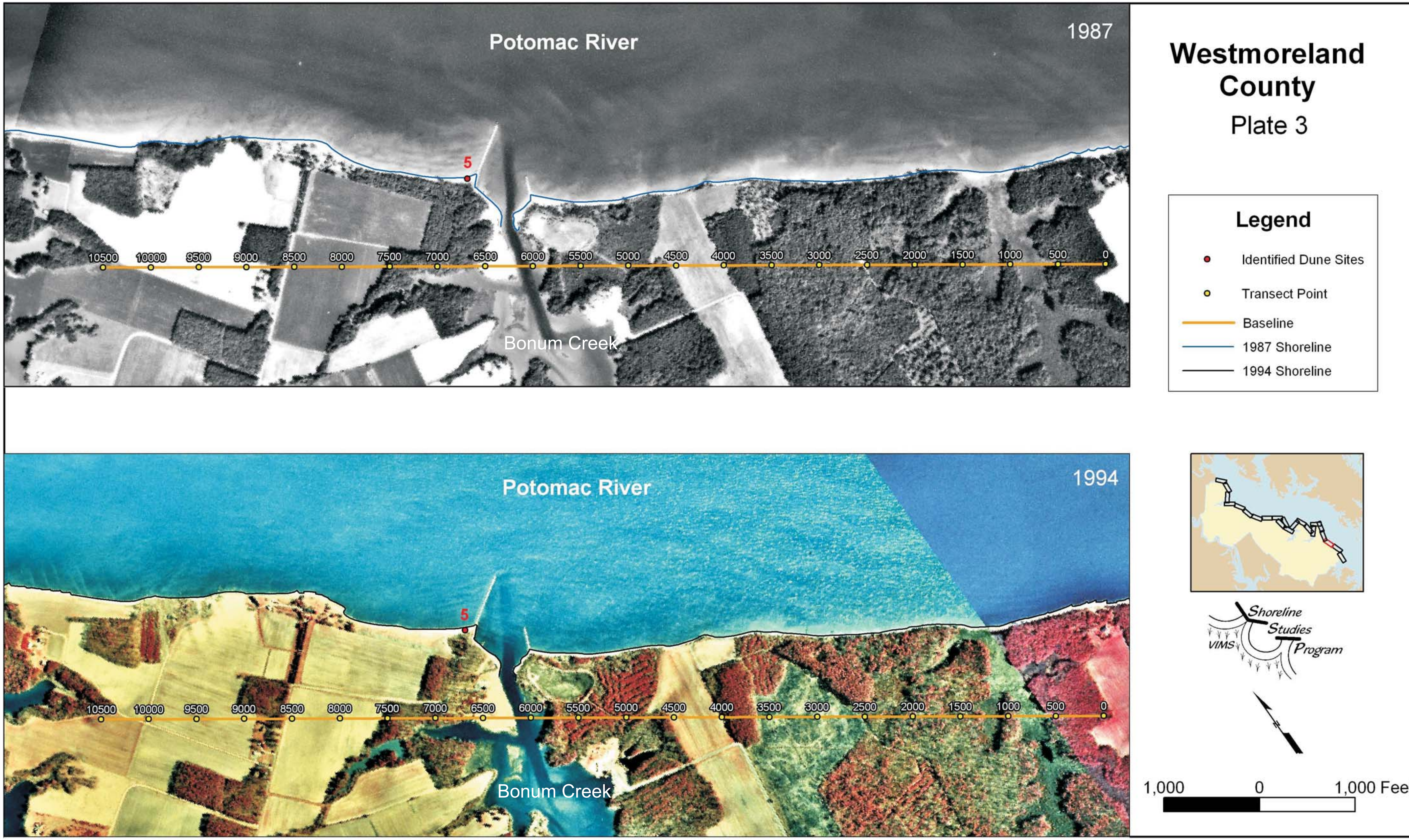
## APPENDIX A

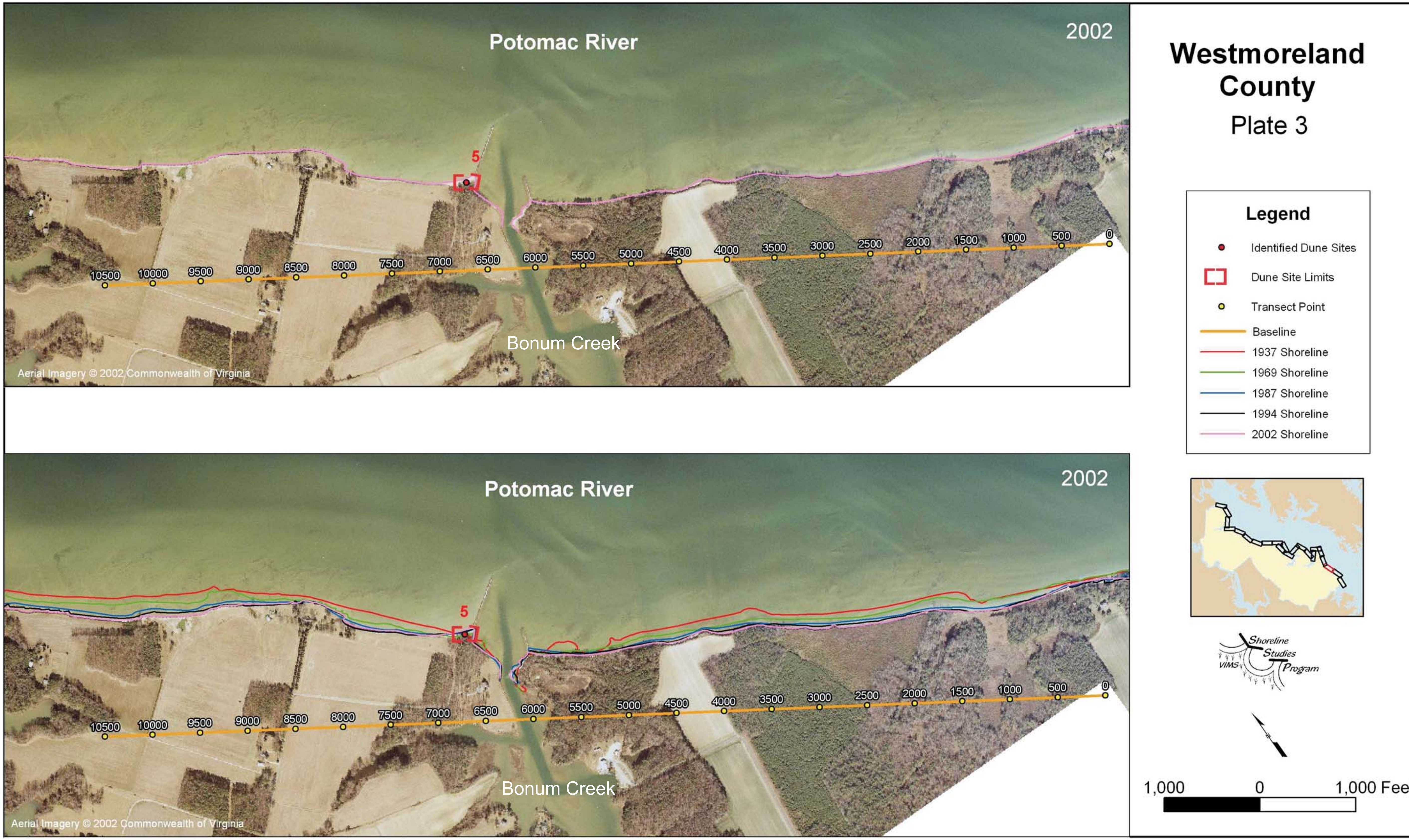
For each Plate shown on Figure 3, Appendix A contains orthorectified aerial photography flown in 1937, 1969, 1987, 1994, and 2002.
Also shown are the digitized shorelines, identified dune sites, and an arbitrarily created baseline.
A plot shows only the relative locations of the shorelines while another 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.**

**Plate 3** **Plate 4** **Plate 8**
**Plate 9** **Plate 10**
**Plate 13** **Plate 18**

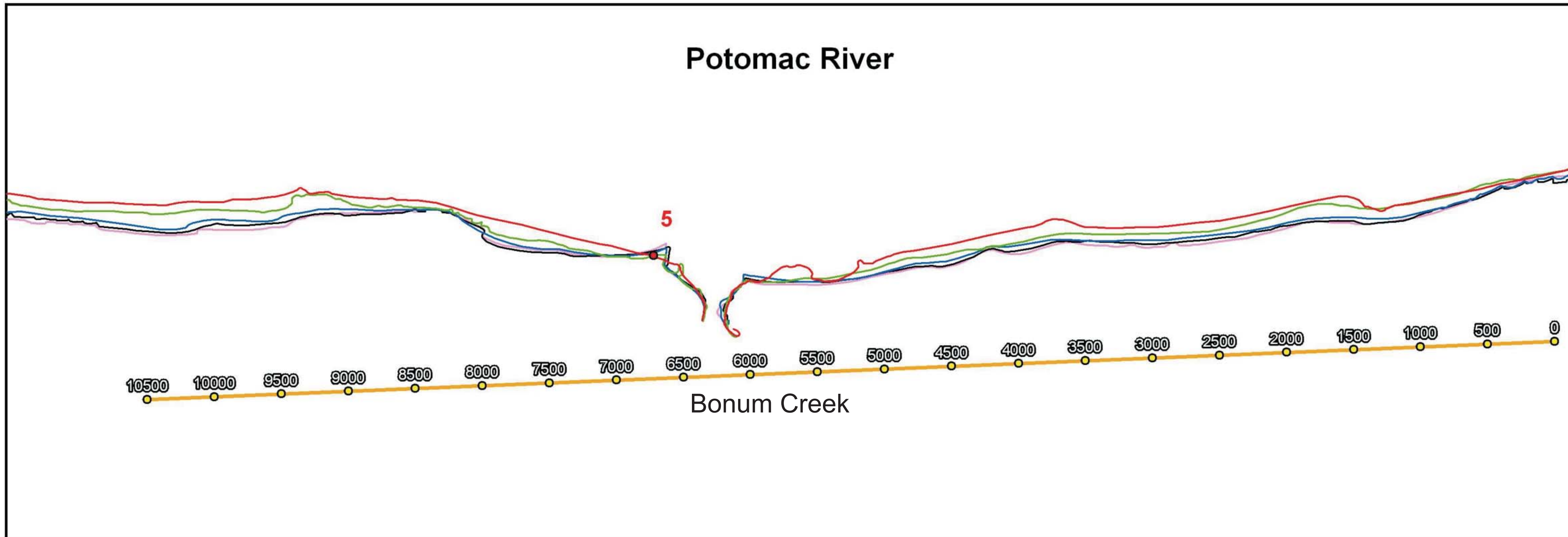

Westmoreland County
Plate 3
Legend
Identified Dune Sites
Transect Point
Baseline
1937 Shoreline
1969 Shoreline
Potomac River
1937
5
10500 10000 9500 9000 8500 8000 7500 7000 6500 6000 5500 5000 4500 4000 3500 3000 2500 2000 1500 1000 500 0
Bonum Creek
Potomac River
1969
5
10500 10000 9500 9000 8500 8000 7500 7000 6500 6000 5500 5000 4500 4000 3500 3000 2500 2000 1500 1000 500 0
Bonum Creek
Shoreline Studies Program
VIMS
1,000 0 1,000 Feet


Potomac River
1987
5
10500 10000 9500 9000 8500 8000 7500 7000 6500 6000 5500 5000 4500 4000 3500 3000 2500 2000 1500 1000 500 0
Bonum Creek
Potomac River
1994
5
10500 10000 9500 9000 8500 8000 7500 7000 6500 6000 5500 5000 4500 4000 3500 3000 2500 2000 1500 1000 500 0
Bonum Creek
Westmoreland County
Plate 3
Legend
Identified Dune Sites
Transect Point
Baseline
1987 Shoreline
1994 Shoreline
Shoreline Studies Program
VIMS
1,000 0 1,000 Feet


Potomac River
2002
Bonum Creek
Aerial Imagery © 2002 Commonwealth of Virginia
5
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Potomac River
2002
Bonum Creek
Aerial Imagery © 2002 Commonwealth of Virginia
Westmoreland County
Plate 3
Legend
Identified Dune Sites
Dune Site Limits
Transect Point
Baseline
1937 Shoreline
1969 Shoreline
1987 Shoreline
1994 Shoreline
2002 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet

# Westmoreland County

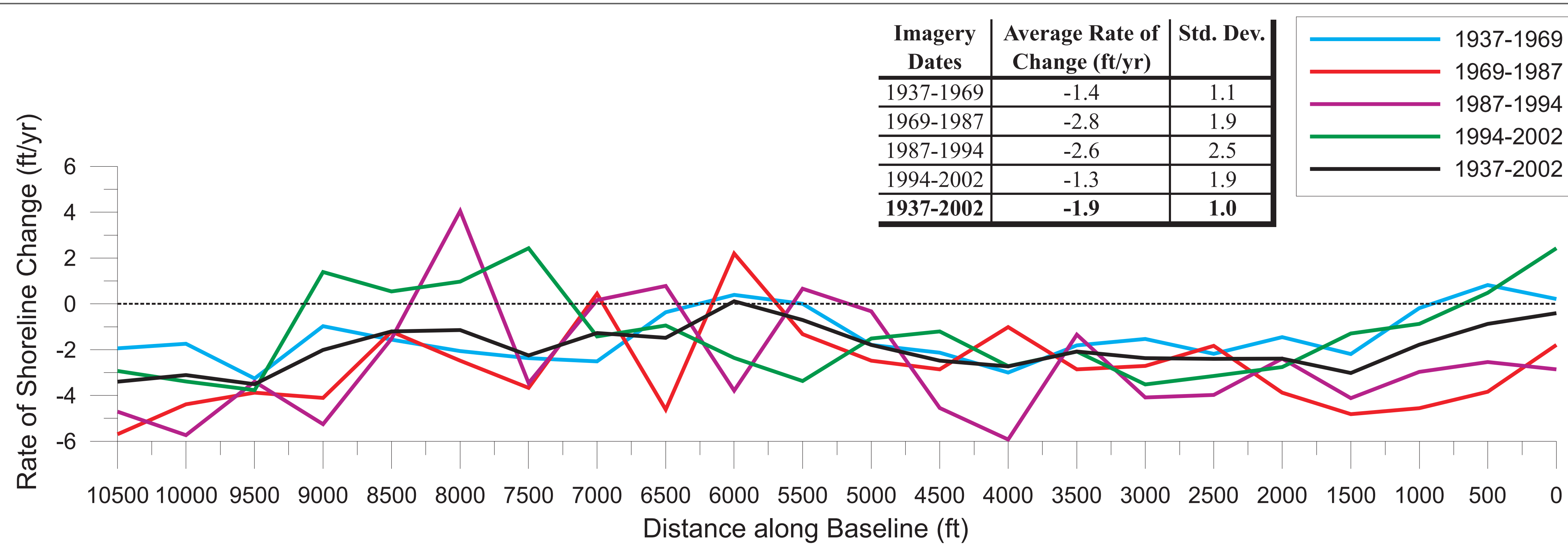
Plate 3

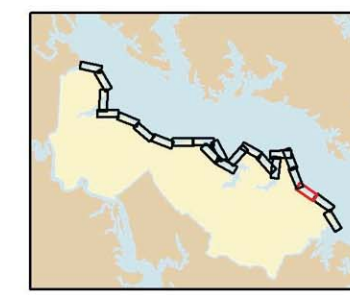



## Legend

- Identified Dune Sites
- Transect Point
- Baseline
- 1937 Shoreline
- 1969 Shoreline
- 1987 Shoreline
- 1994 Shoreline
- 2002 Shoreline

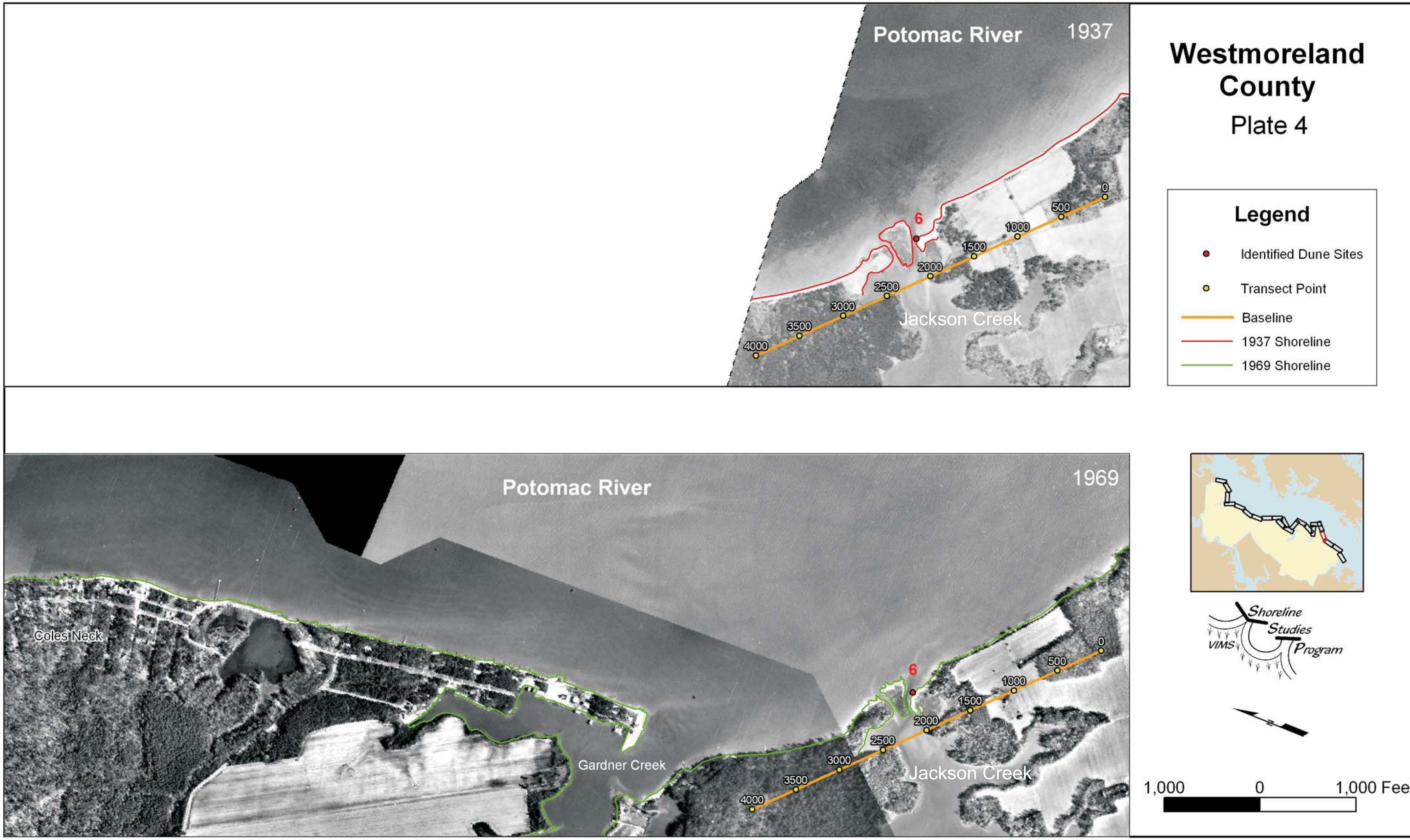
| Imagery Dates | Average Rate of Change (ft/yr) | Std. Dev. |
|---|---|---|
| 1937-1969 | -1.4 | 1.1 |
| 1969-1987 | -2.8 | 1.9 |
| 1987-1994 | -2.6 | 2.5 |
| 1994-2002 | -1.3 | 1.9 |
| **1937-2002** | **-1.9** | **1.0** |



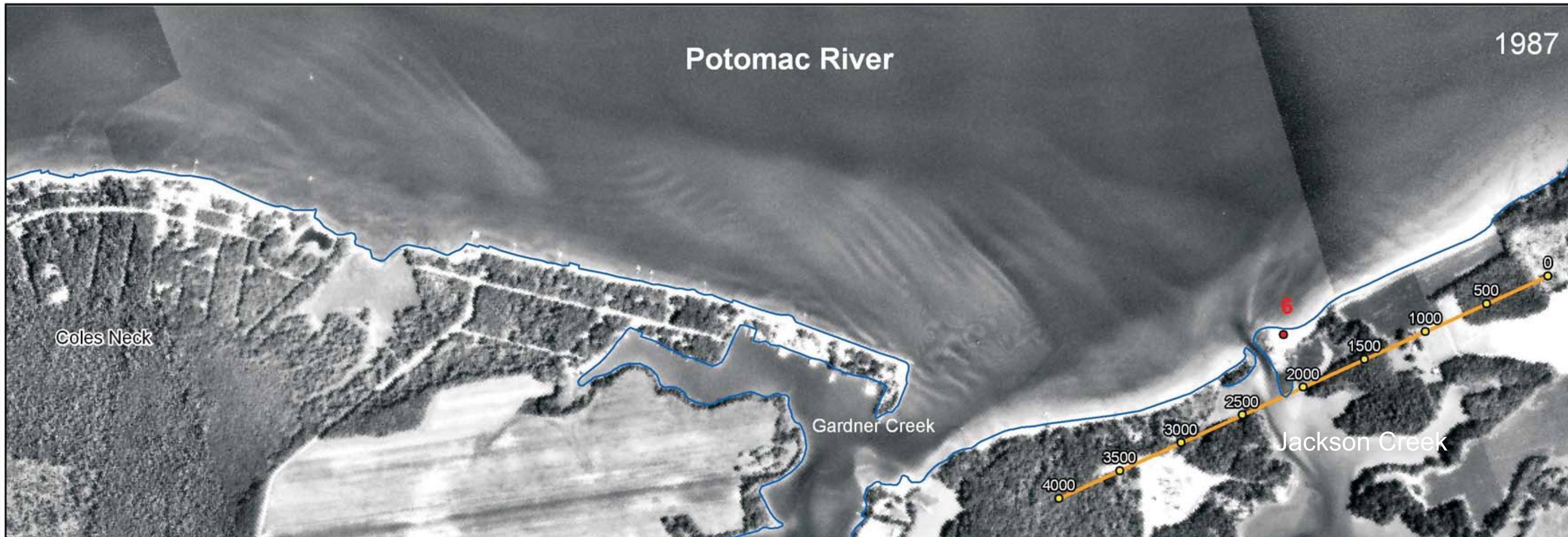
Shoreline Studies Program VIMS

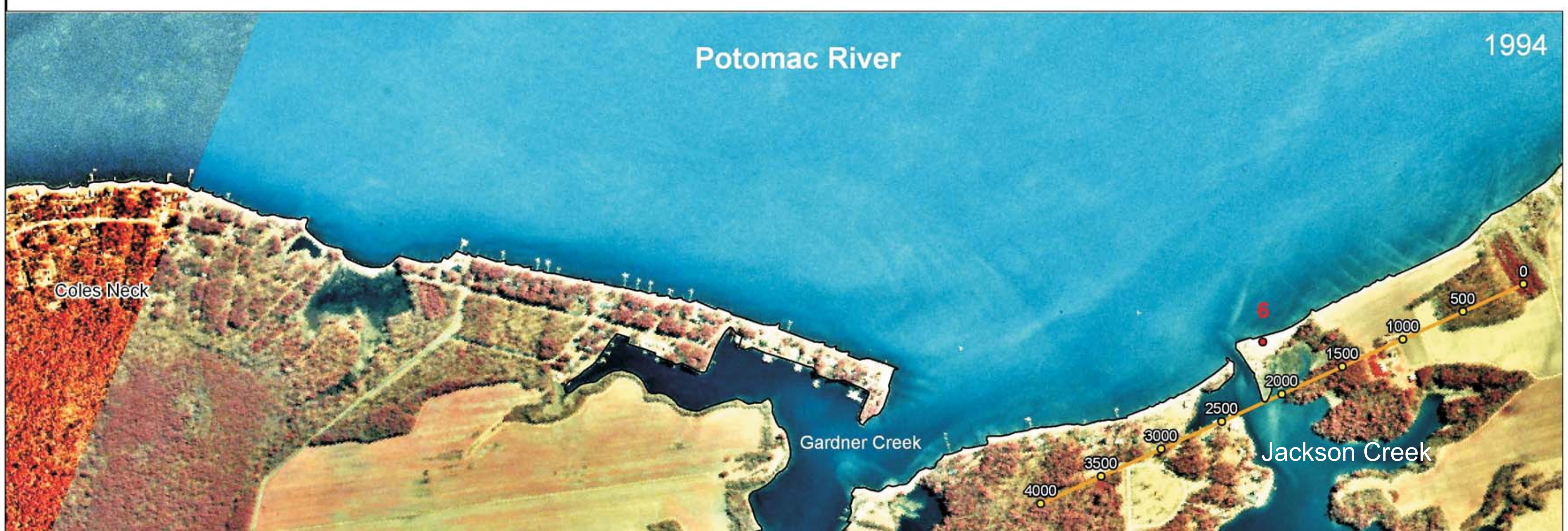
1,000 0 1,000 Feet


Westmoreland County
Plate 4
Legend
Identified Dune Sites
Transect Point
Baseline
1937 Shoreline
1969 Shoreline
Potomac River
1937
Jackson Creek
6
0
500
1000
1500
2000
2500
3000
3500
4000
Potomac River
1969
Coles Neck
Gardner Creek
Jackson Creek
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet

# Westmoreland County

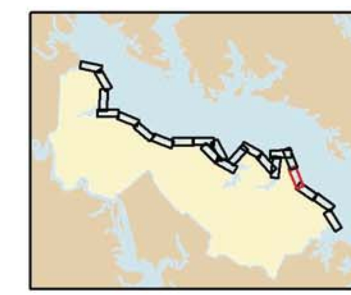
Plate 4



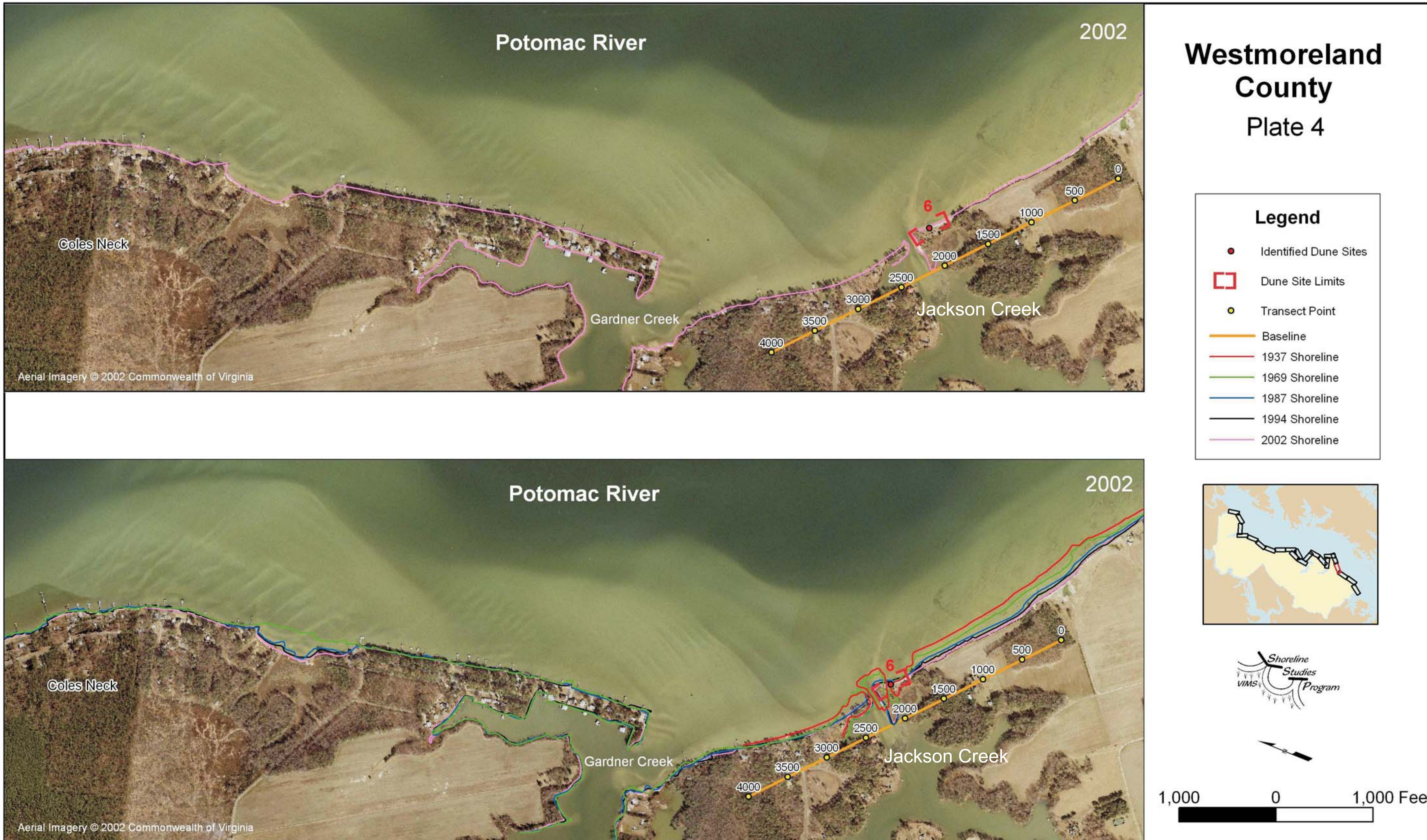

**Legend**

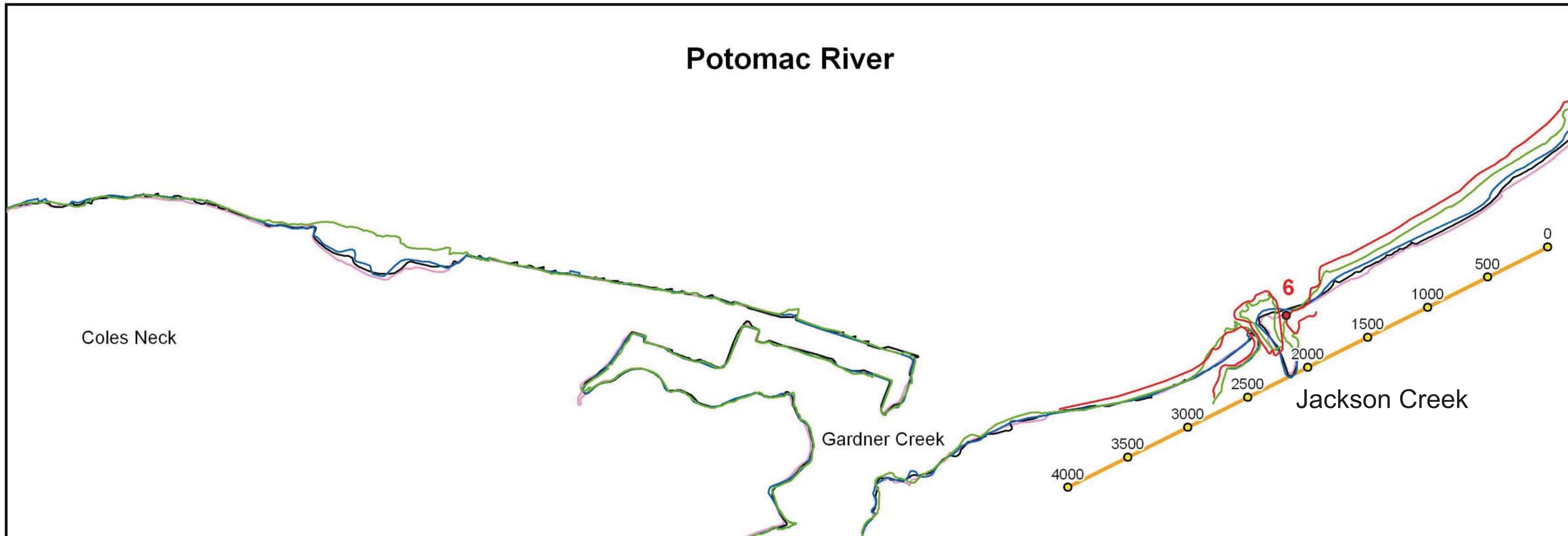
- Identified Dune Sites
- Transect Point
- Baseline
- 1987 Shoreline
- 1994 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000 Feet


Westmoreland County
Plate 4
Potomac River
2002
Coles Neck
Gardner Creek
Jackson Creek
6
0
500
1000
1500
2000
2500
3000
3500
4000
Aerial Imagery © 2002 Commonwealth of Virginia
Potomac River
2002
Coles Neck
Gardner Creek
Jackson Creek
6
0
500
1000
1500
2000
2500
3000
3500
4000
Aerial Imagery © 2002 Commonwealth of Virginia
Legend
Identified Dune Sites
Dune Site Limits
Transect Point
Baseline
1937 Shoreline
1969 Shoreline
1987 Shoreline
1994 Shoreline
2002 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet

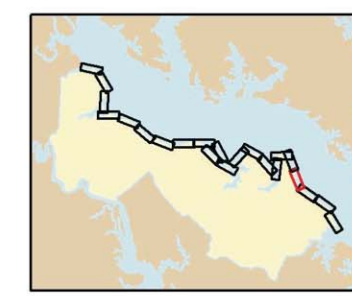



# Westmoreland County

## Plate 4

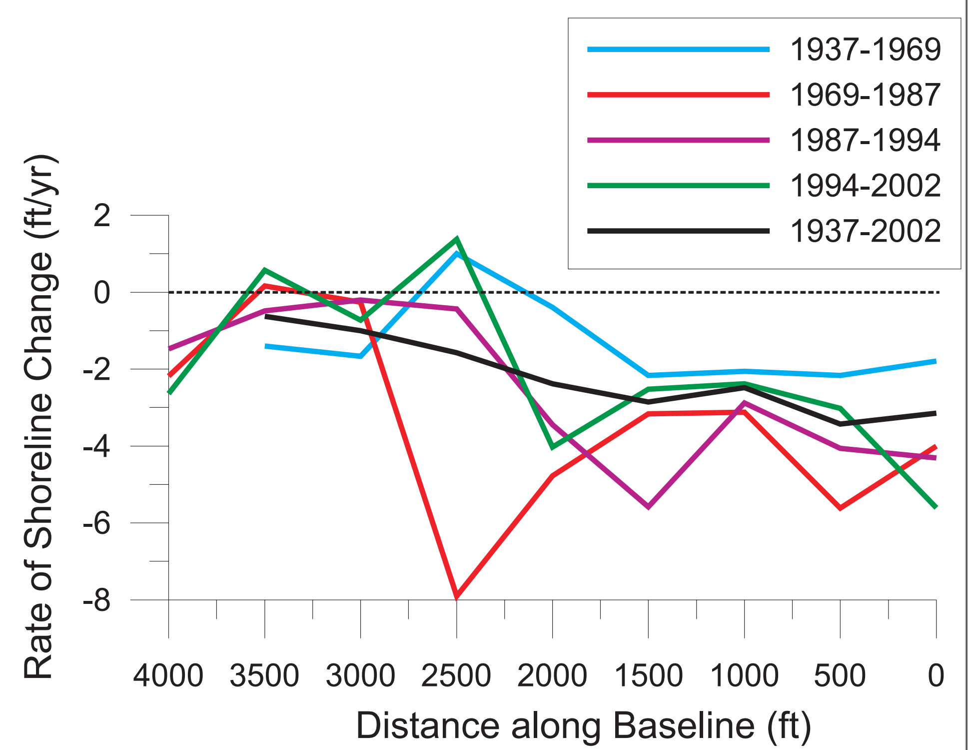
### Legend

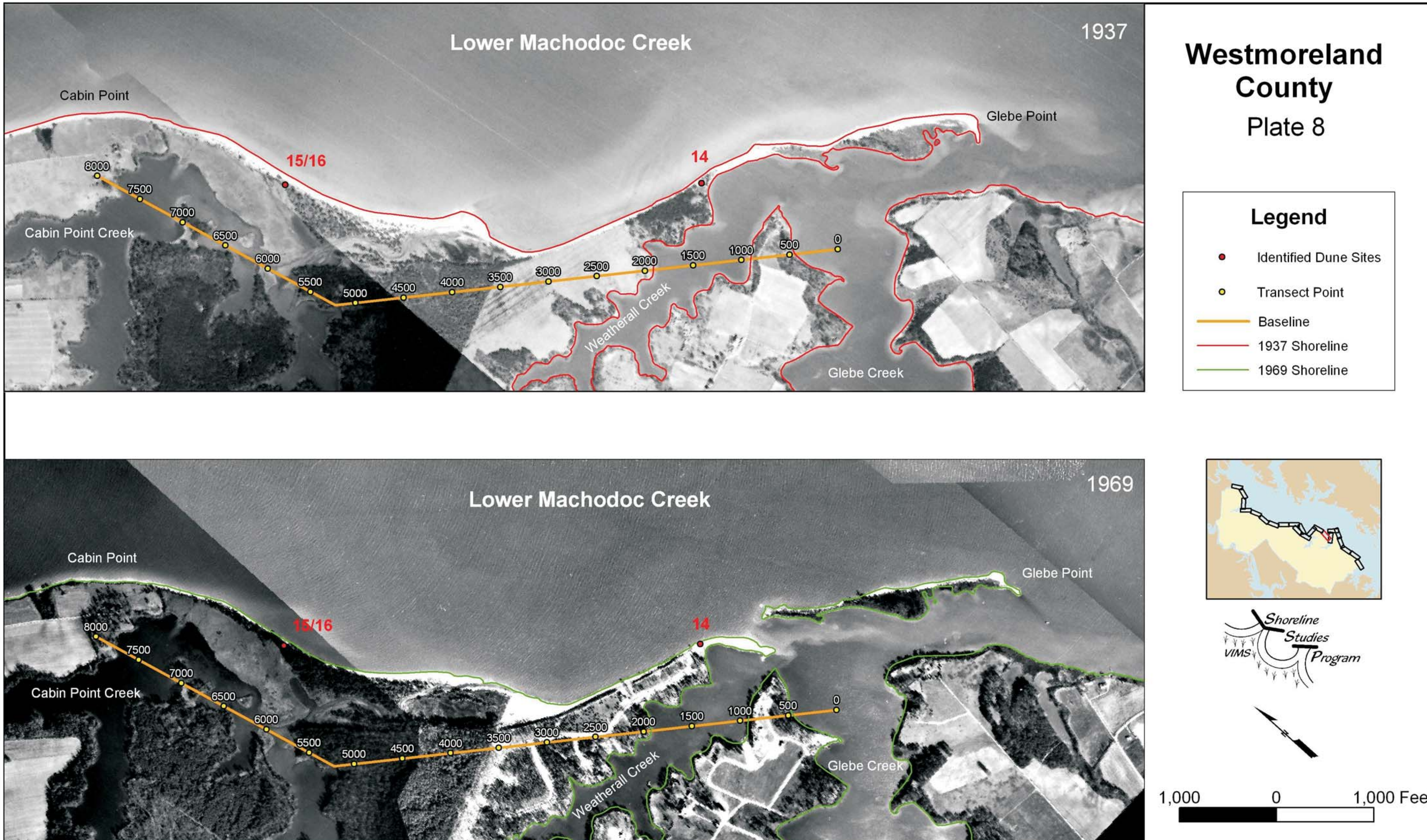
- Identified Dune Sites
- Transect Point
- Baseline
- 1937 Shoreline
- 1969 Shoreline
- 1987 Shoreline
- 1994 Shoreline
- 2002 Shoreline

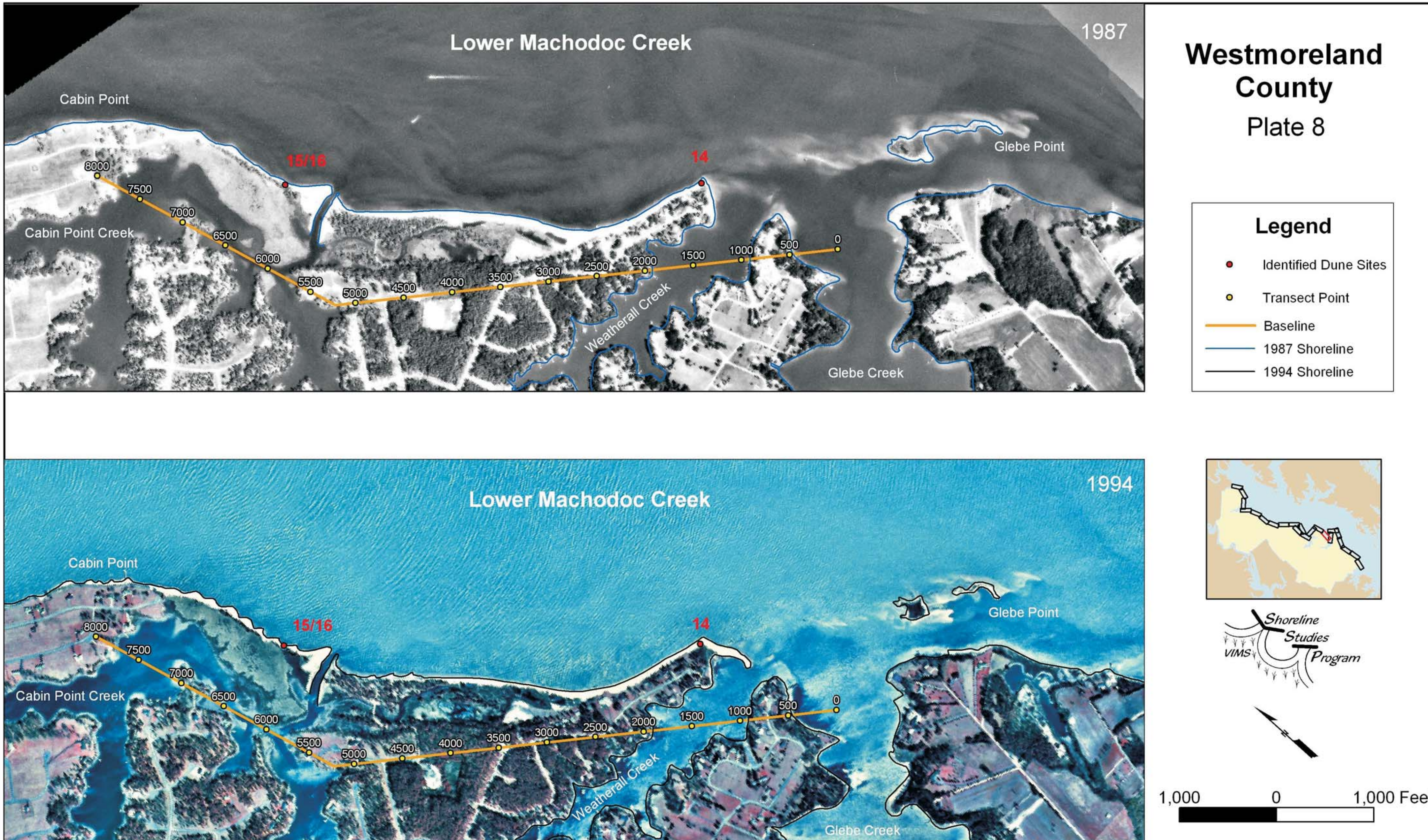


1,000 0 1,000 Feet

| Imagery Dates | Average Rate of Change (ft/yr) | Std. Dev. |
|---|---|---|
| 1937-1969 | -1.3 | 1.1 |
| 1969-1987 | -3.4 | 2.5 |
| 1987-1994 | -2.5 | 2.0 |
| 1994-2002 | -2.1 | 2.2 |
| **1937-2002** | **-2.2** | **1.0** |




Westmoreland County
Plate 8
1937
Lower Machodoc Creek
Cabin Point
Glebe Point
15/16
14
Cabin Point Creek
Weatherall Creek
Glebe Creek
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1969
Lower Machodoc Creek
Cabin Point
Glebe Point
15/16
14
Cabin Point Creek
Weatherall Creek
Glebe Creek
Legend
Identified Dune Sites
Transect Point
Baseline
1937 Shoreline
1969 Shoreline
VIMS
Shoreline Studies Program
1,000
0
1,000 Feet

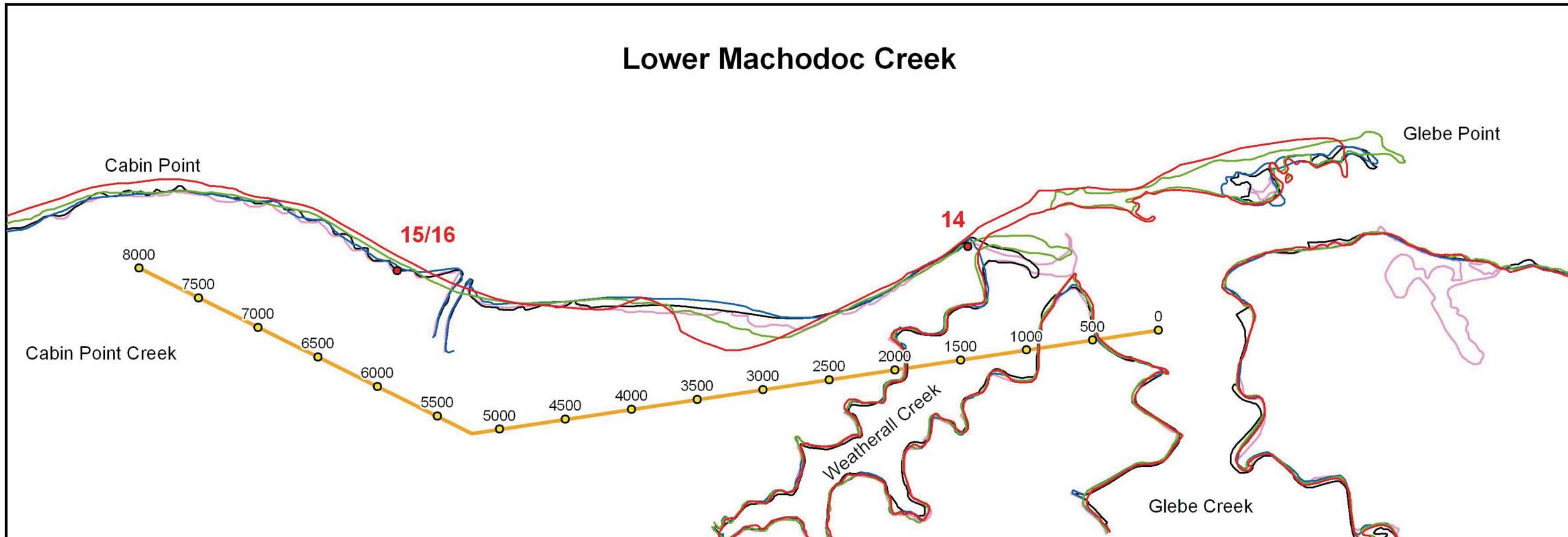

Westmoreland County
Plate 8
Lower Machodoc Creek
1987
Cabin Point
Cabin Point Creek
Glebe Point
Weatherall Creek
Glebe Creek
15/16
14
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1994
Legend
Identified Dune Sites
Transect Point
Baseline
1987 Shoreline
1994 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet


Westmoreland County
Plate 8
2002
Lower Machodoc Creek
Cabin Point
Glebe Point
15/16
14
Cabin Point Creek
Weatherall Creek
Glebe Creek
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Aerial Imagery © 2002 Commonwealth of Virginia
1994
Lower Machodoc Creek
Cabin Point
Glebe Point
15/16
14
Cabin Point Creek
Weatherall Creek
Glebe Creek
Aerial Imagery © 2002 Commonwealth of Virginia
Legend
Identified Dune Sites
Dune Site Limits
Transect Point
Baseline
1937 Shoreline
1969 Shoreline
1987 Shoreline
1994 Shoreline
2002 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet

# Westmoreland County

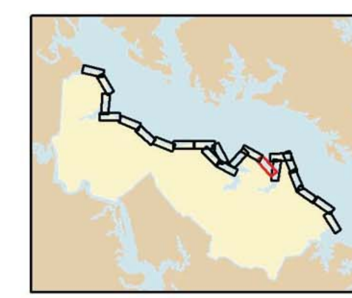
Plate 8

## Lower Machodoc Creek



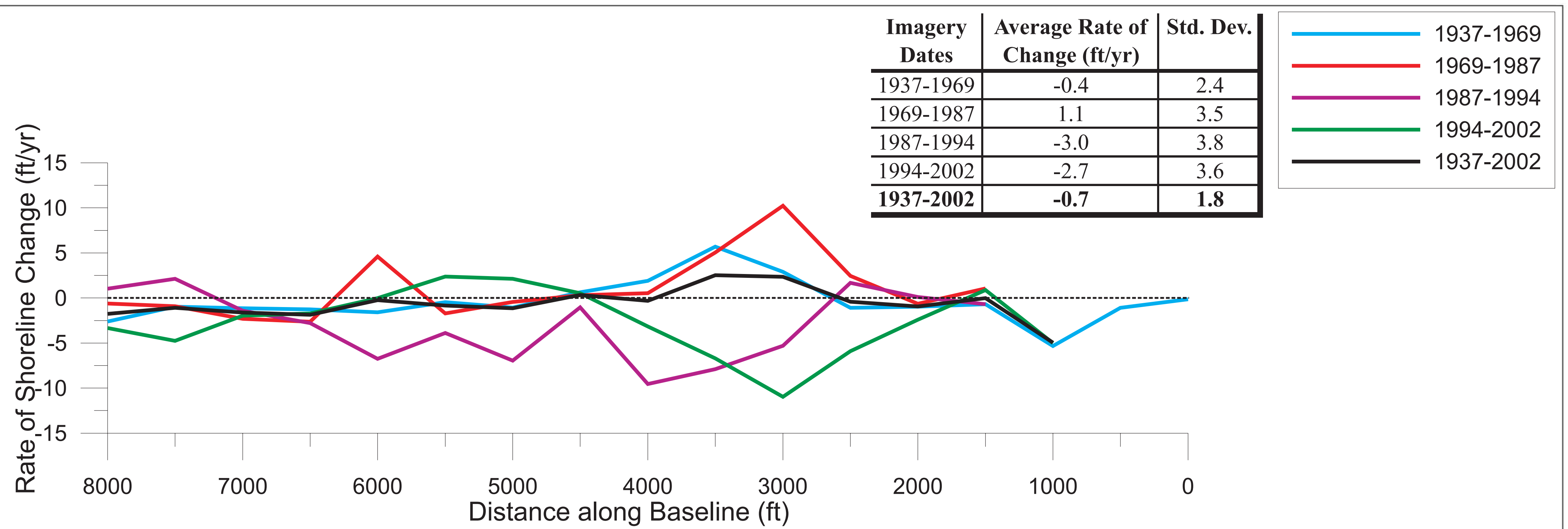

**Legend**

- Identified Dune Sites
- Transect Point
- Baseline
- 1937 Shoreline
- 1969 Shoreline
- 1987 Shoreline
- 1994 Shoreline
- 2002 Shoreline



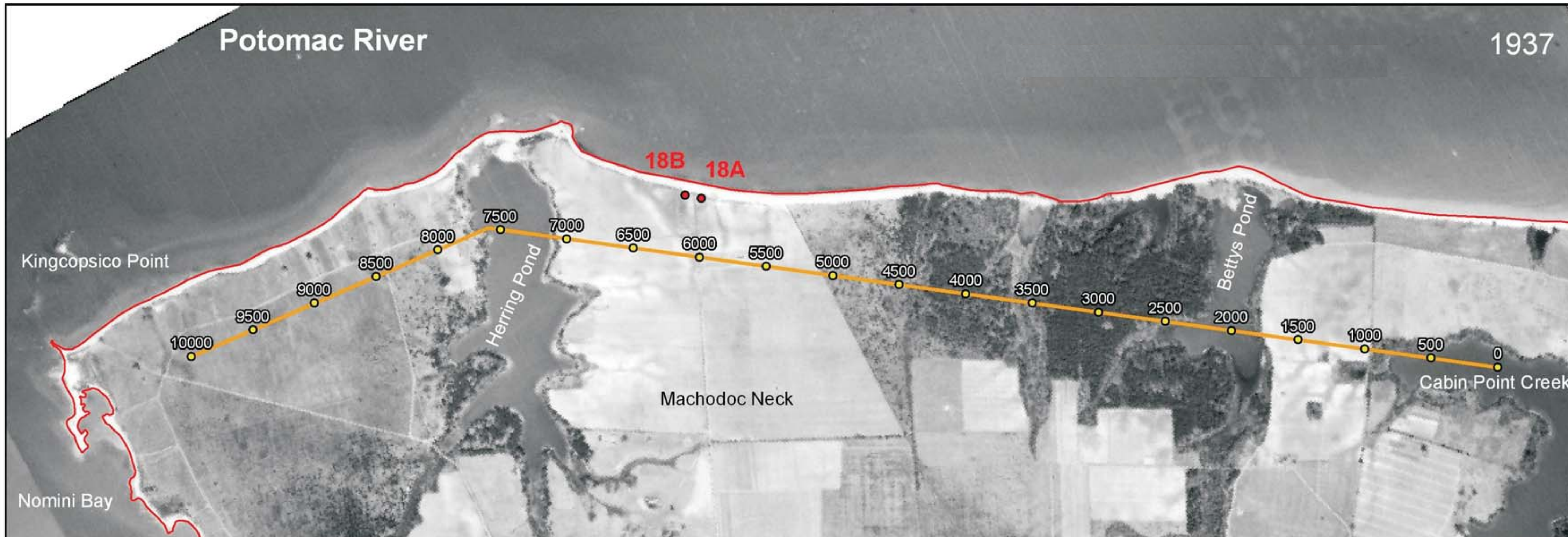
1,000 0 1,000 Feet

| Imagery Dates | Average Rate of Change (ft/yr) | Std. Dev. |
|---|---|---|
| 1937-1969 | -0.4 | 2.4 |
| 1969-1987 | 1.1 | 3.5 |
| 1987-1994 | -3.0 | 3.8 |
| 1994-2002 | -2.7 | 3.6 |
| **1937-2002** | **-0.7** | **1.8** |



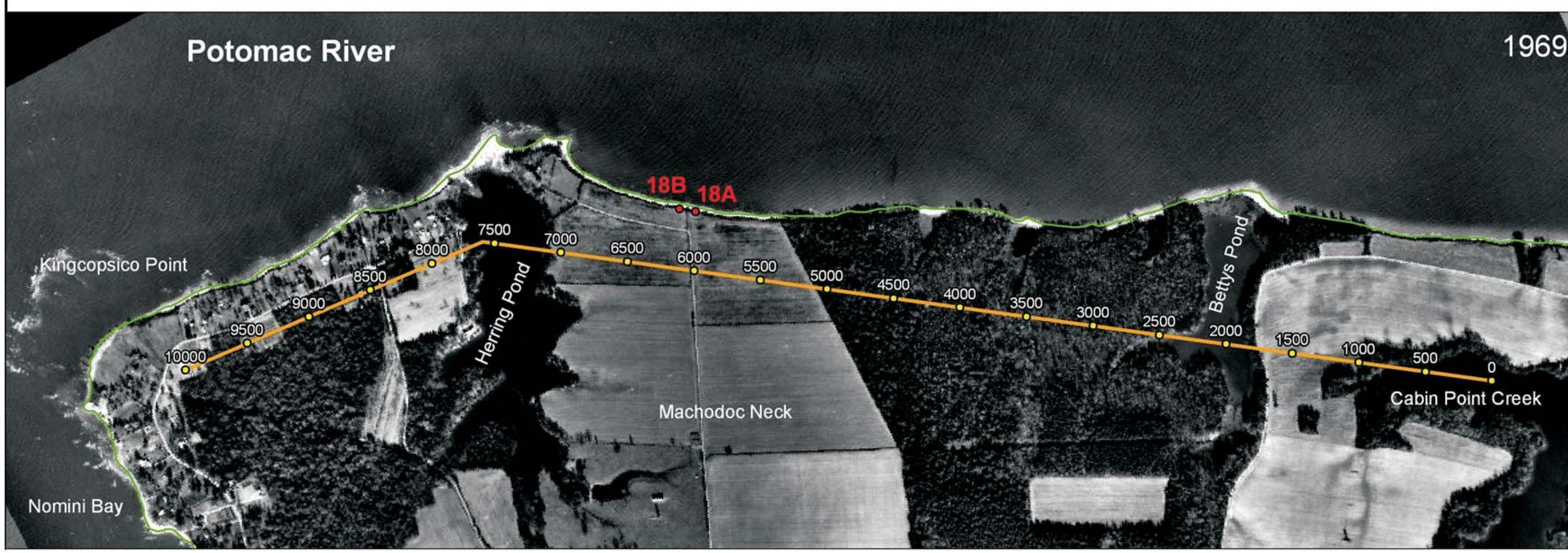
# Westmoreland County

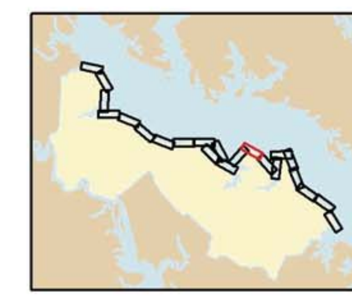
## Plate 9




### Legend

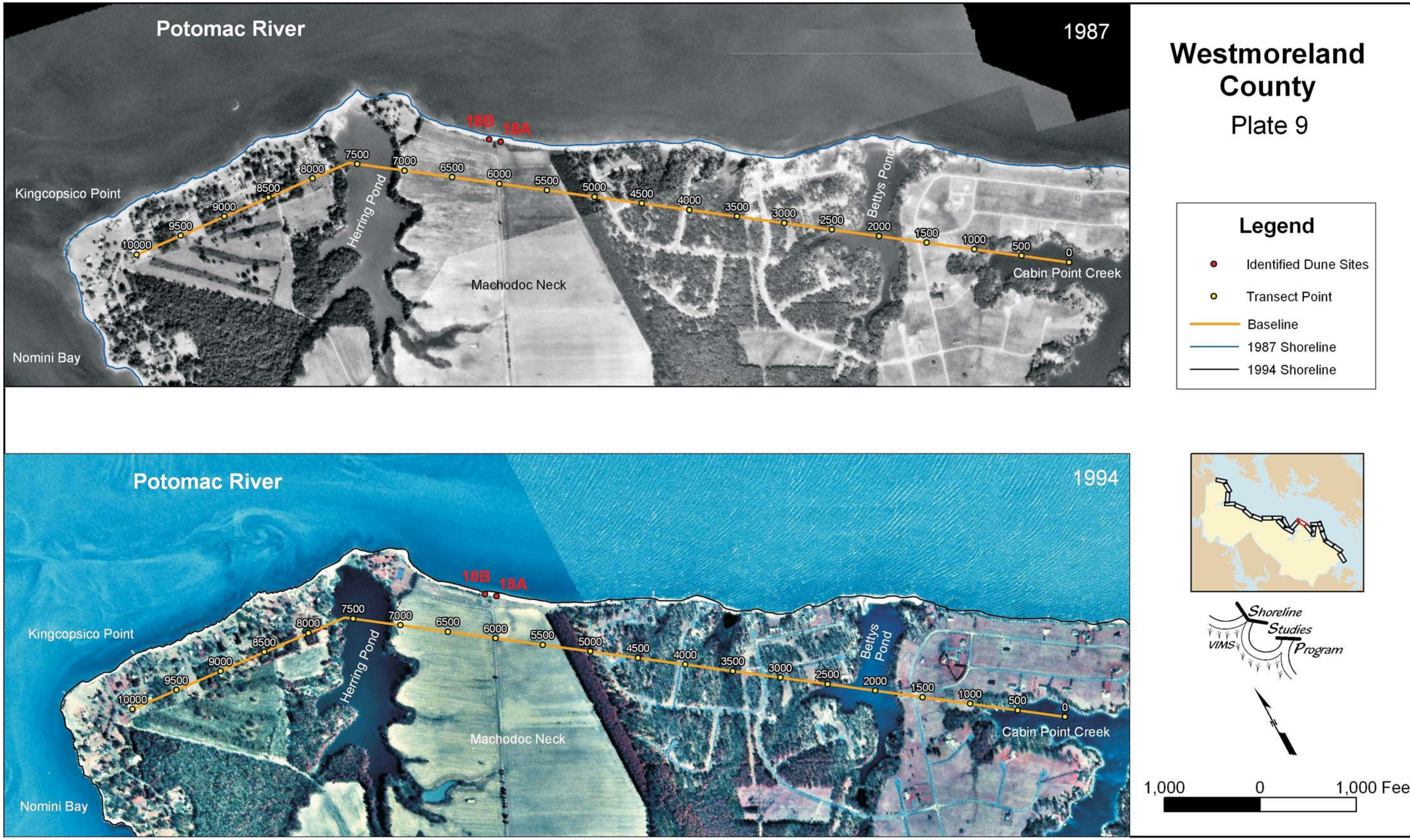
- Identified Dune Sites
- Transect Point
- Baseline
- 1937 Shoreline
- 1969 Shoreline



Shoreline Studies Program
VIMS

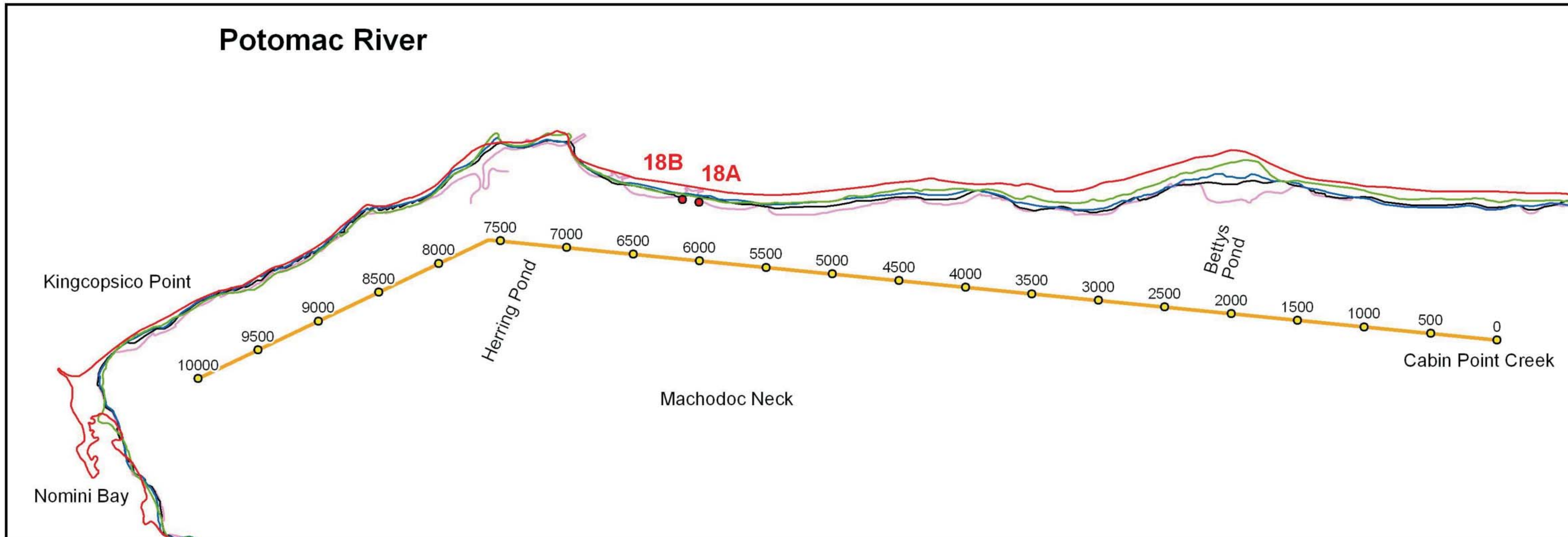
1,000 0 1,000 Feet


Potomac River
1987
18B
18A
Kingcopsico Point
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Herring Pond
Bettys Pond
Machodoc Neck
Cabin Point Creek
Nomini Bay
Potomac River
1994
Westmoreland County
Plate 9
Legend
Identified Dune Sites
Transect Point
Baseline
1987 Shoreline
1994 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet


Westmoreland County
Plate 9
Potomac River
2002
18B
18A
Kingcopsico Point
Herring Pond
Machodoc Neck
Bettys Pond
Cabin Point Creek
Nomini Bay
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Aerial Imagery © 2002 Commonwealth of Virginia
Legend
Identified Dune Sites
Dune Site Limits
Transect Point
Baseline
1937 Shoreline
1969 Shoreline
1987 Shoreline
1994 Shoreline
2002 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet

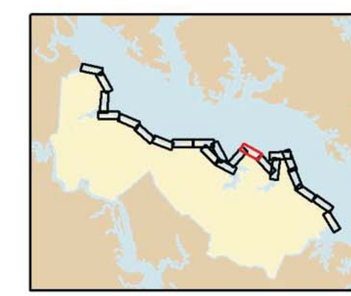
# Westmoreland County

Plate 9

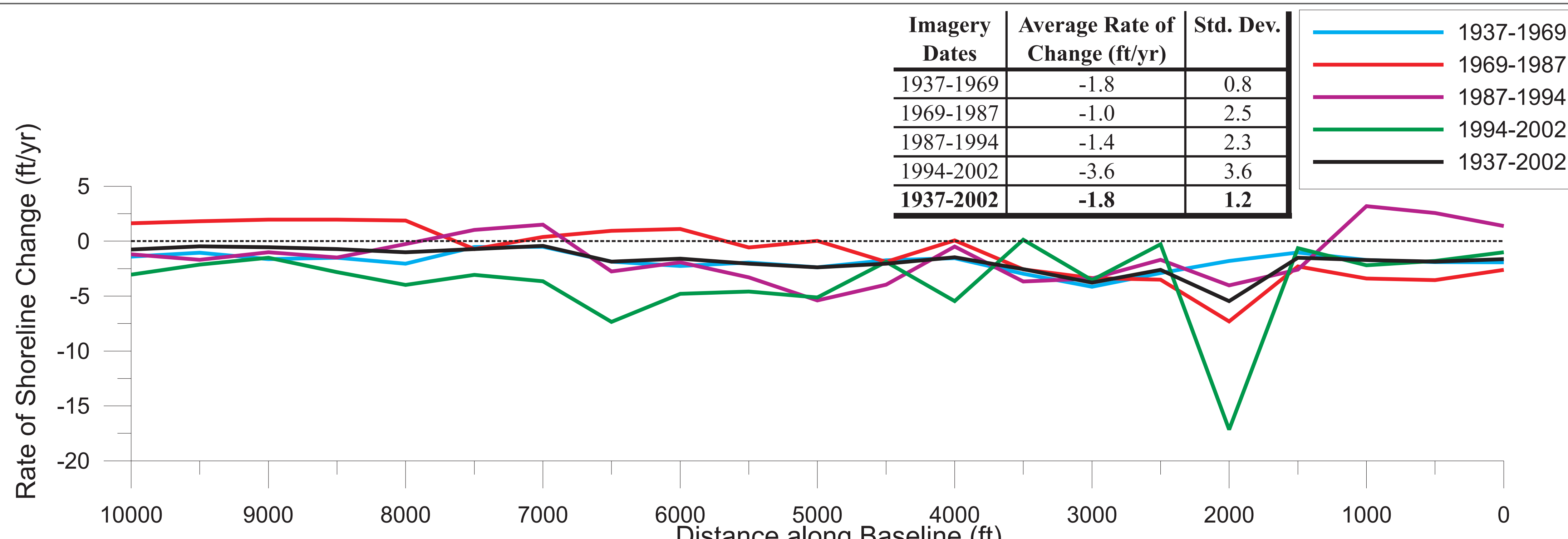



## Legend

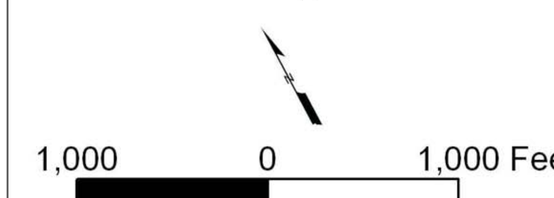
- Identified Dune Sites
- Transect Point
- Baseline
- 1937 Shoreline
- 1969 Shoreline
- 1987 Shoreline
- 1994 Shoreline
- 2002 Shoreline



| Imagery Dates | Average Rate of Change (ft/yr) | Std. Dev. |
|---|---|---|
| 1937-1969 | -1.8 | 0.8 |
| 1969-1987 | -1.0 | 2.5 |
| 1987-1994 | -1.4 | 2.3 |
| 1994-2002 | -3.6 | 3.6 |
| **1937-2002** | **-1.8** | **1.2** |

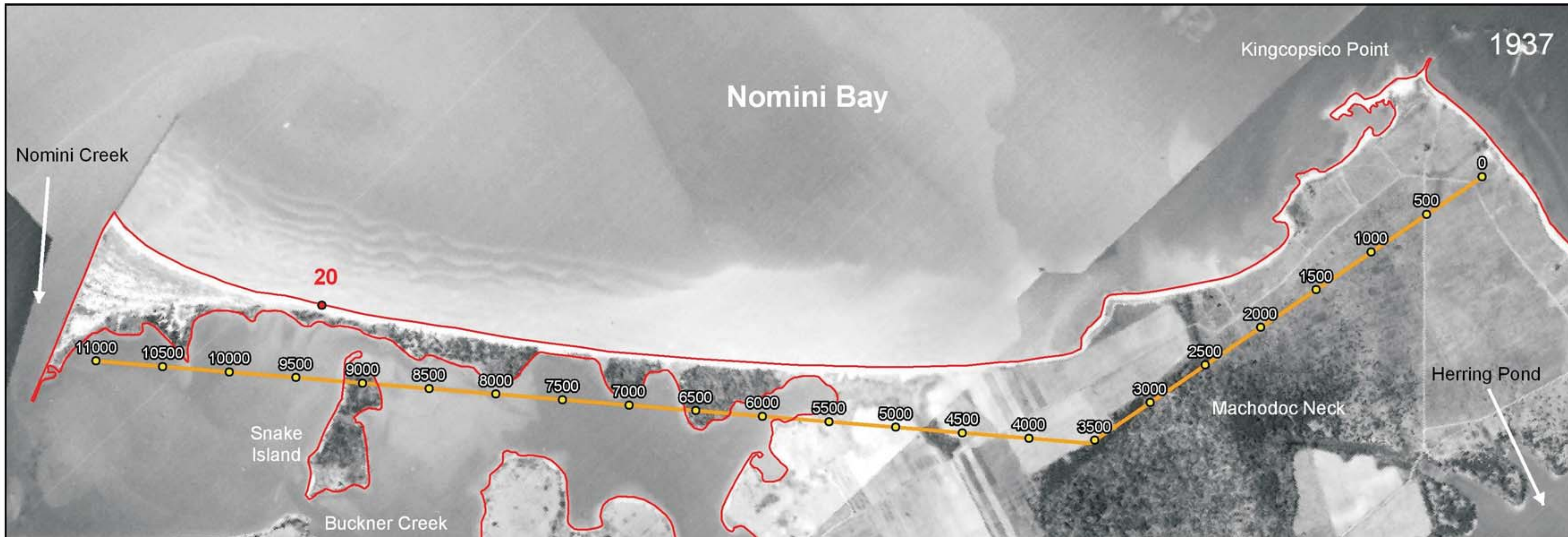



Shoreline Studies Program VIMS



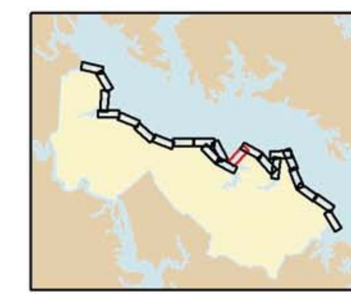
# Westmoreland County

Plate 10



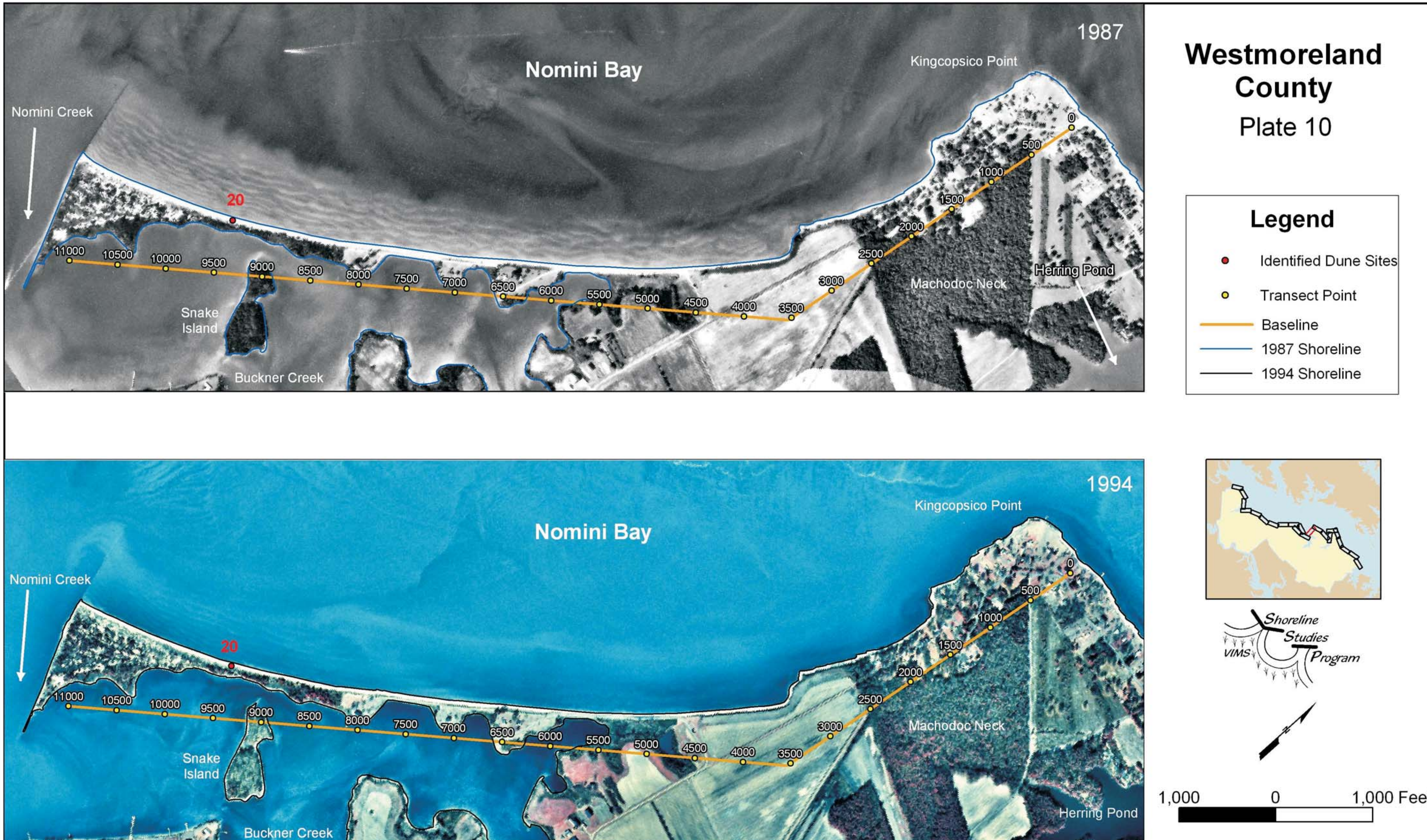

## Legend

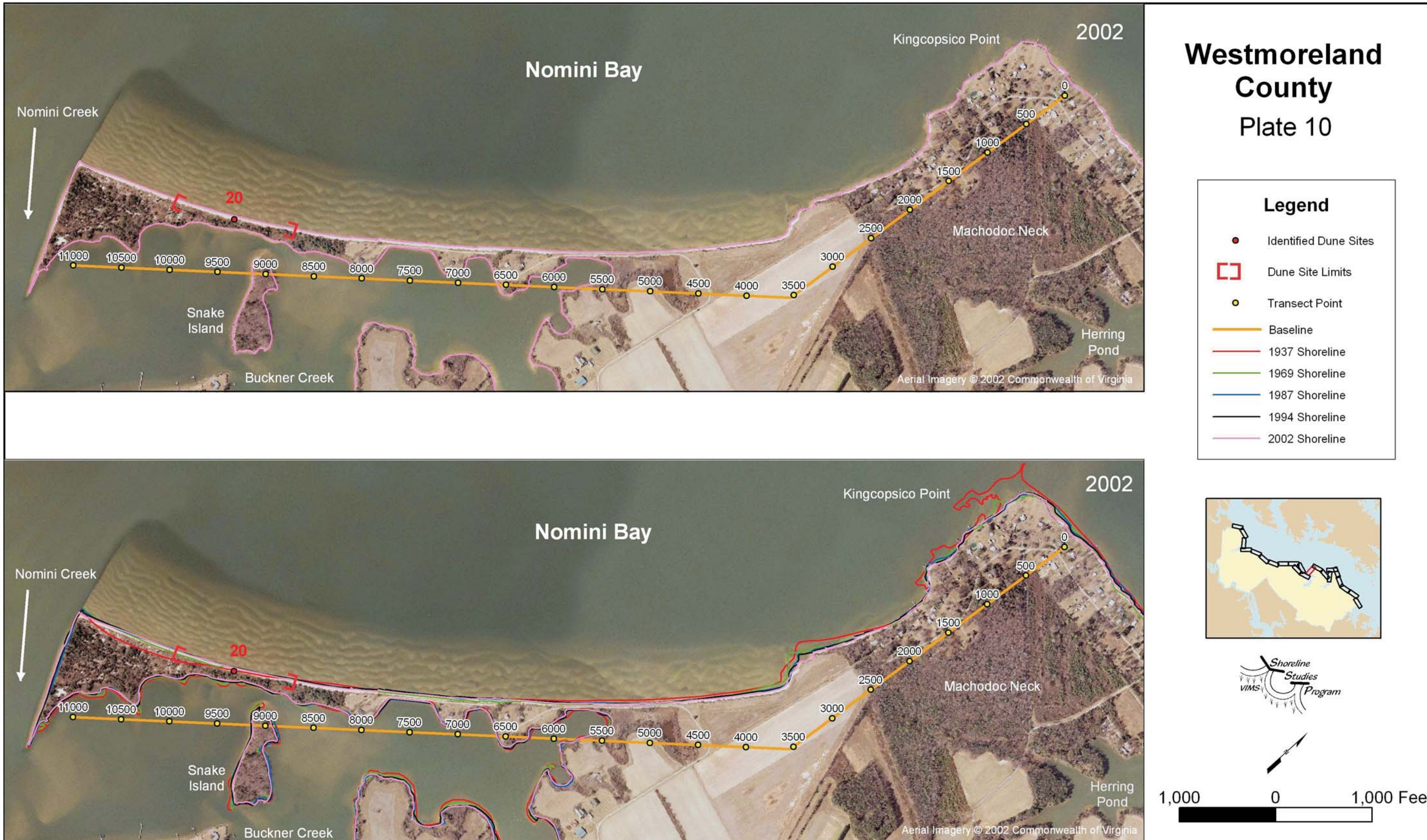
- Identified Dune Sites
- Transect Point
- Baseline
- 1937 Shoreline
- 1969 Shoreline

Shoreline Studies Program VIMS

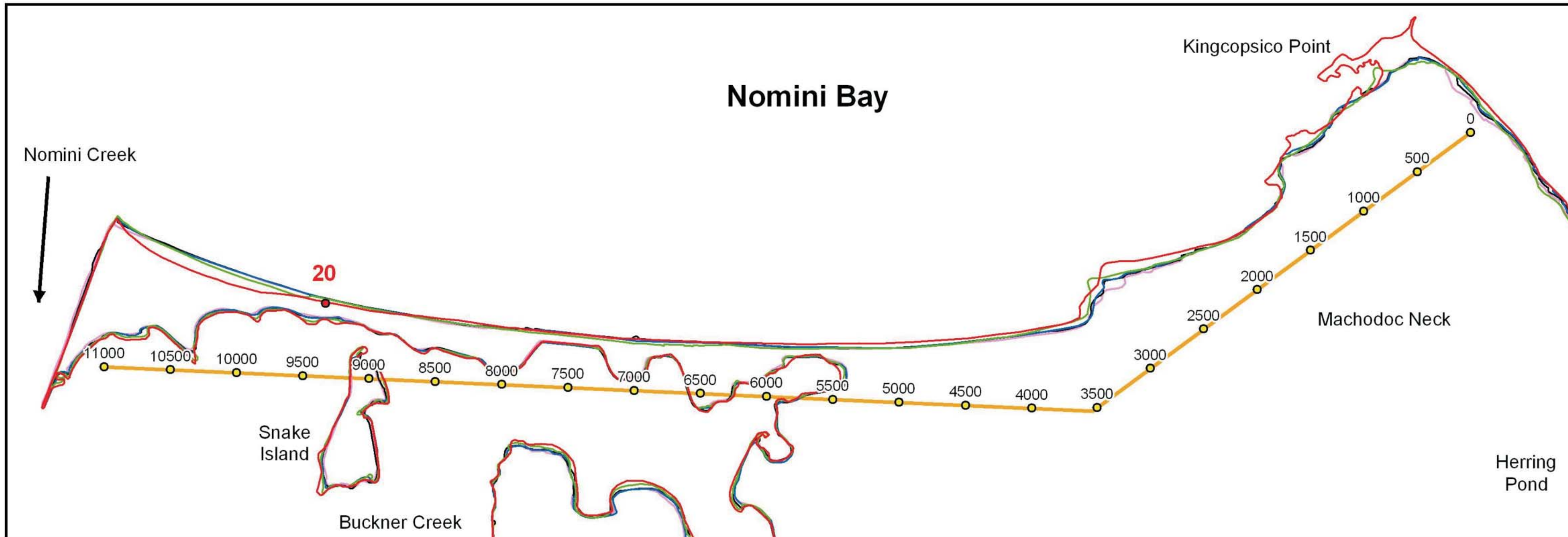
1,000 0 1,000 Feet


Westmoreland County
Plate 10
Legend
Identified Dune Sites
Transect Point
Baseline
1987 Shoreline
1994 Shoreline
1987
Nomini Bay
Kingcopsico Point
Nomini Creek
Snake Island
Buckner Creek
Machodoc Neck
Herring Pond
20
1994
Shoreline Studies Program
VIMS
1,000 0 1,000 Feet


Westmoreland County
Plate 10
2002
Nomini Bay
Kingcopsico Point
Nomini Creek
20
Machodoc Neck
Snake Island
Buckner Creek
Herring Pond
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
Aerial Imagery © 2002 Commonwealth of Virginia
2002
Nomini Bay
Kingcopsico Point
Nomini Creek
20
Machodoc Neck
Snake Island
Buckner Creek
Herring Pond
Aerial Imagery © 2002 Commonwealth of Virginia
Legend
Identified Dune Sites
Dune Site Limits
Transect Point
Baseline
1937 Shoreline
1969 Shoreline
1987 Shoreline
1994 Shoreline
2002 Shoreline
VIMS Shoreline Studies Program
1,000
0
1,000 Feet

# Westmoreland County

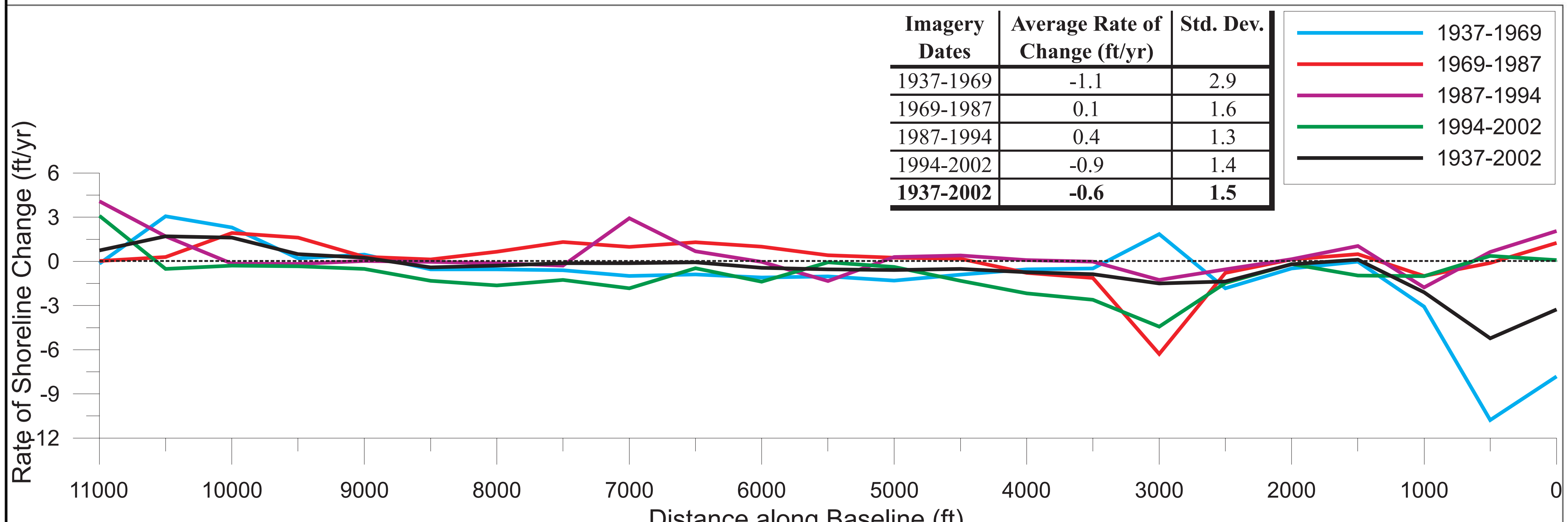
Plate 10

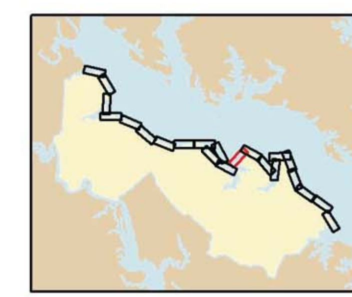



## Legend



| Imagery Dates | Average Rate of Change (ft/yr) | Std. Dev. |
|---|---|---|
| 1937-1969 | -1.1 | 2.9 |
| 1969-1987 | 0.1 | 1.6 |
| 1987-1994 | 0.4 | 1.3 |
| 1994-2002 | -0.9 | 1.4 |
| **1937-2002** | **-0.6** | **1.5** |



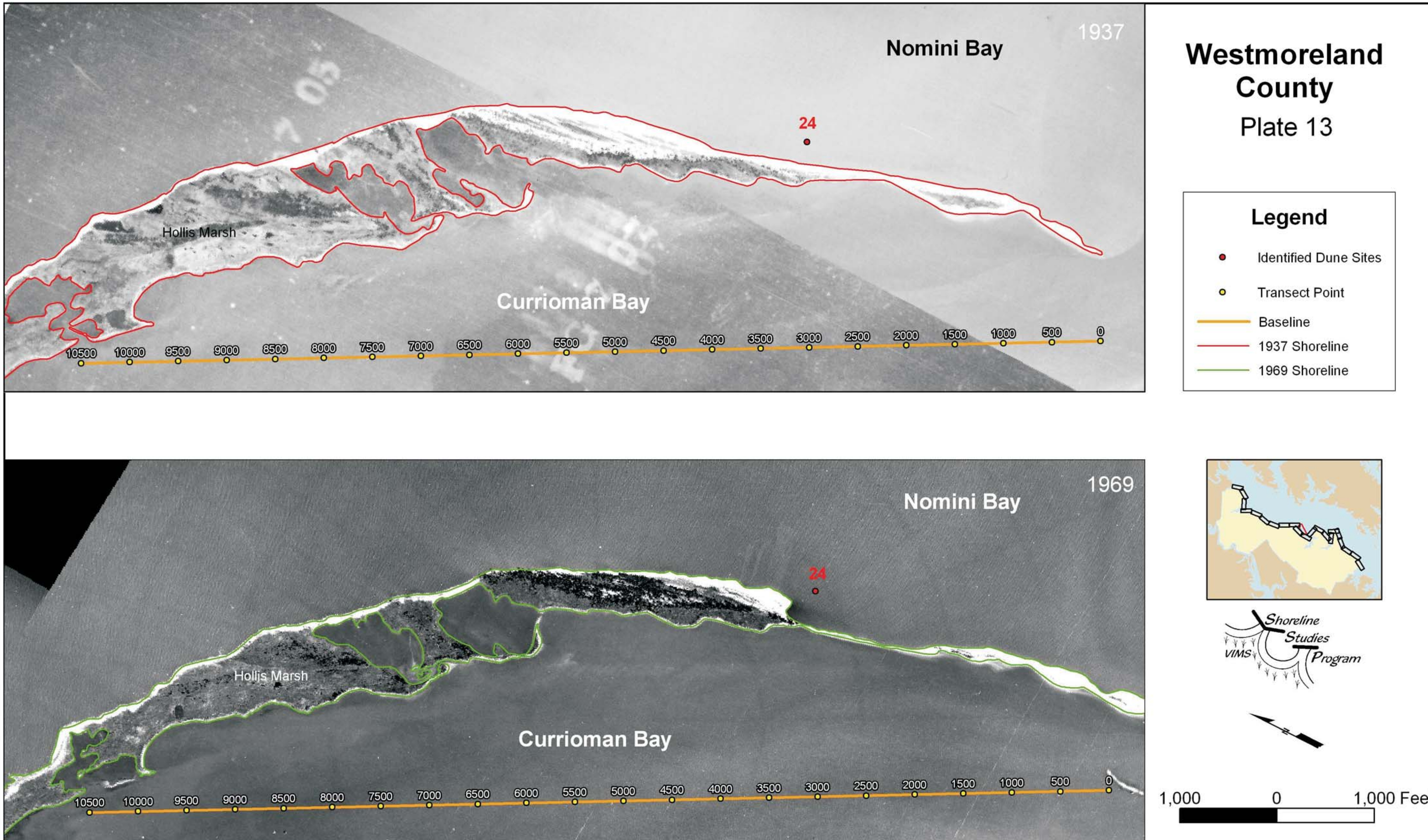



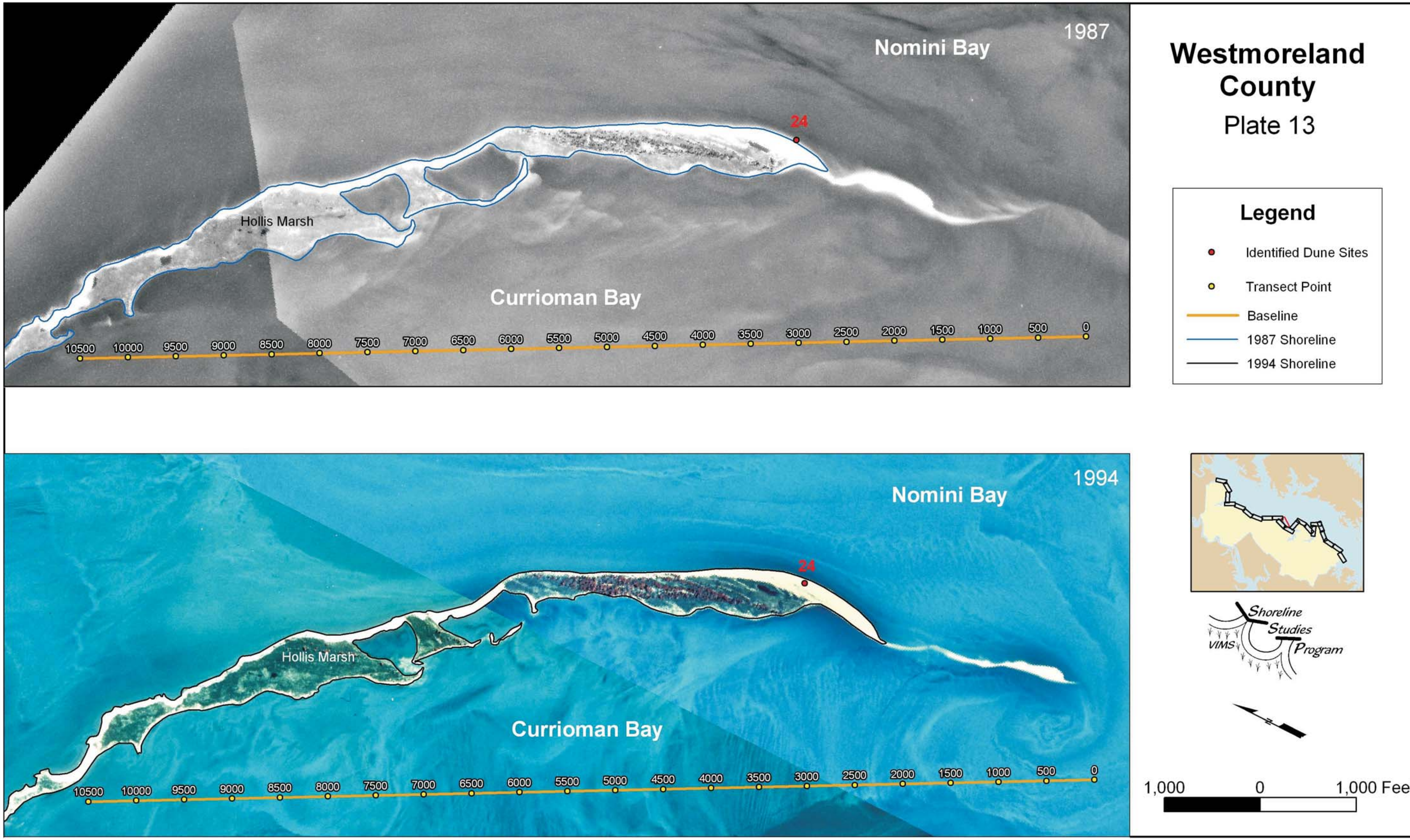
Shoreline Studies Program
VIMS

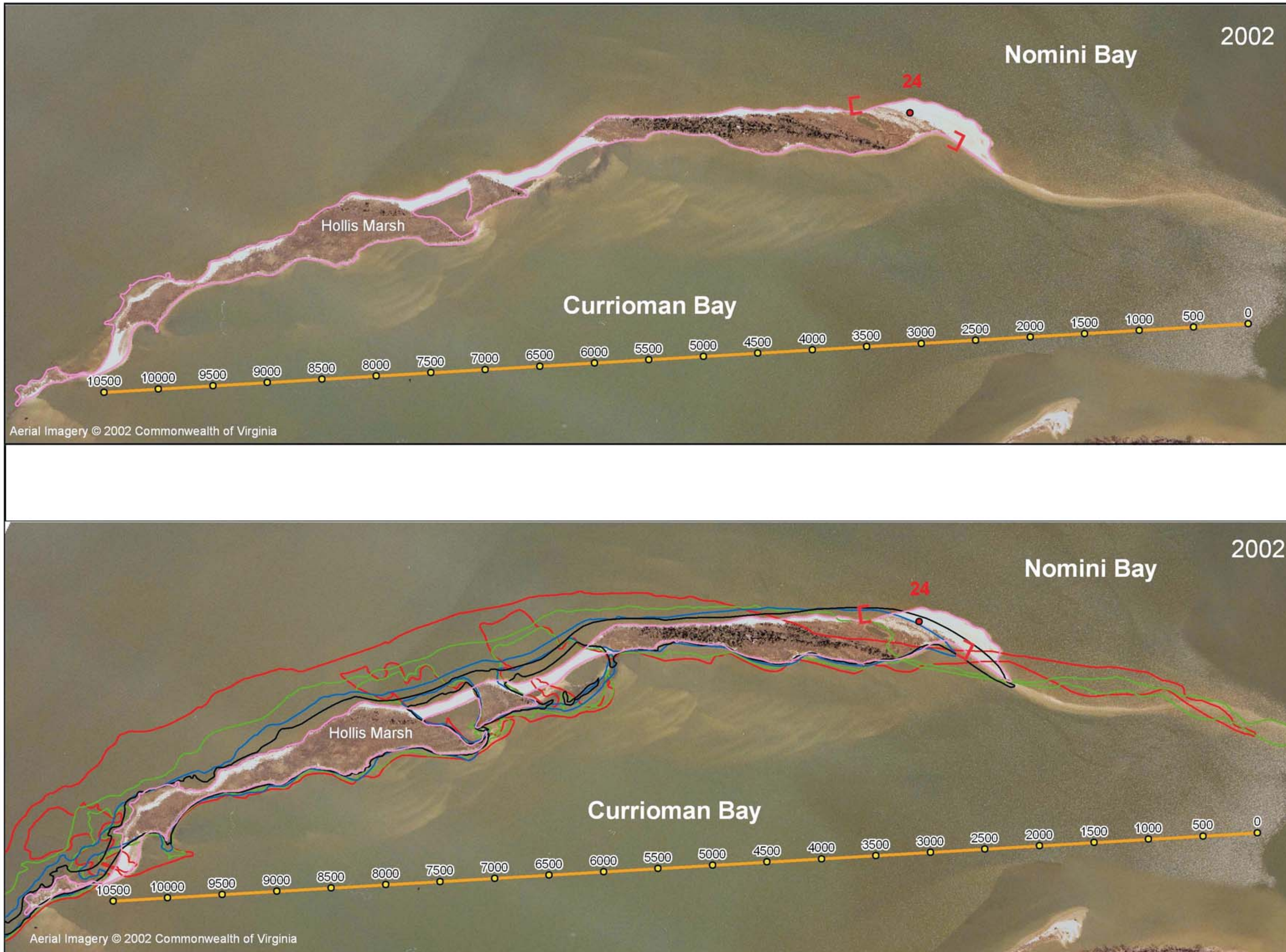
1,000 0 1,000 Feet

# Westmoreland County

Plate 13

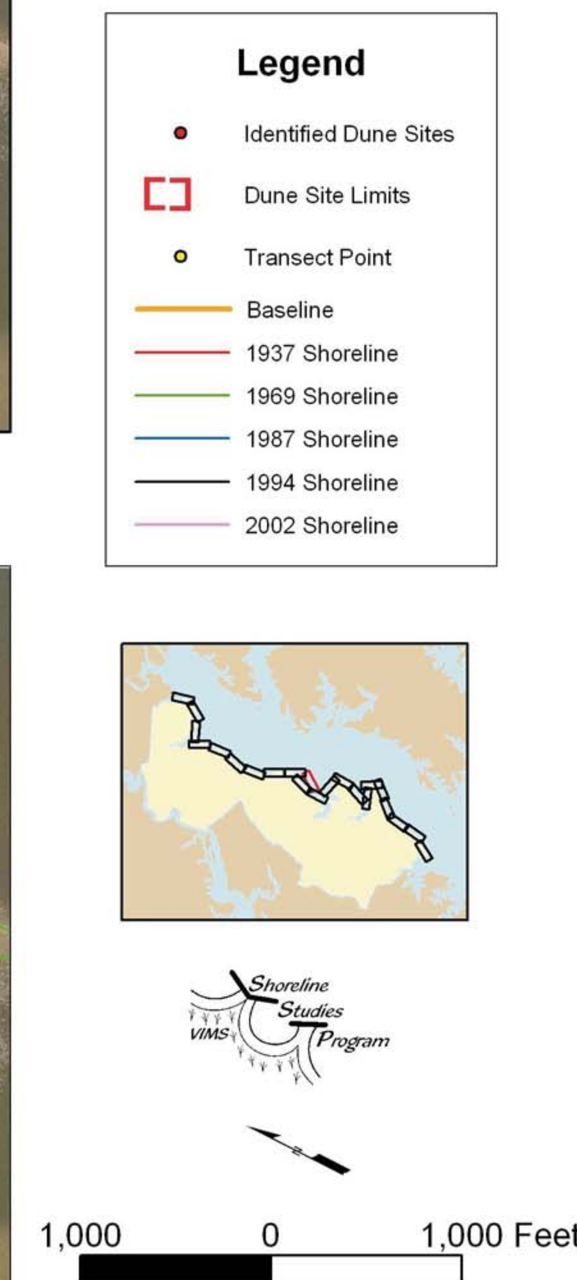



Westmoreland County
Plate 13
1987
Nomini Bay
Currioman Bay
Hollis Marsh
24
10500 10000 9500 9000 8500 8000 7500 7000 6500 6000 5500 5000 4500 4000 3500 3000 2500 2000 1500 1000 500 0
1994
Nomini Bay
Currioman Bay
Hollis Marsh
24
10500 10000 9500 9000 8500 8000 7500 7000 6500 6000 5500 5000 4500 4000 3500 3000 2500 2000 1500 1000 500 0
Legend
Identified Dune Sites
Transect Point
Baseline
1987 Shoreline
1994 Shoreline
Shoreline Studies Program
VIMS
1,000 0 1,000 Feet



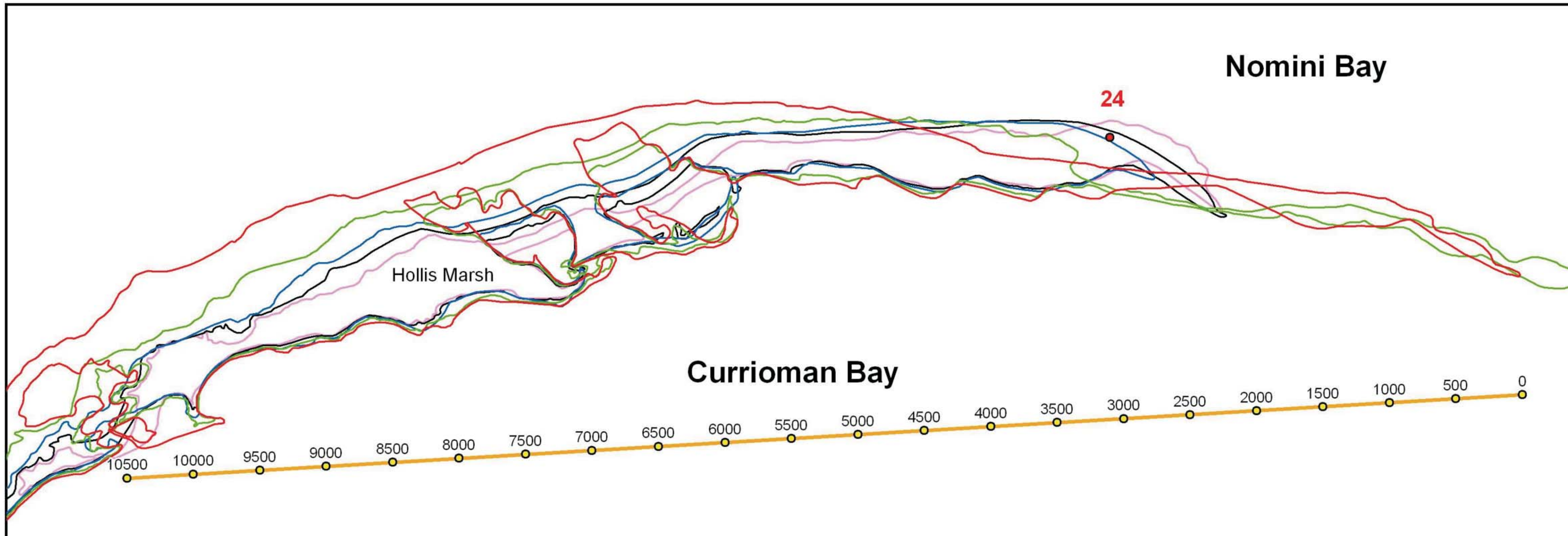

# Westmoreland County

## Plate 13



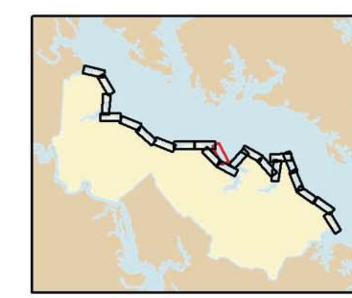
# Westmoreland County

Plate 13




## Legend

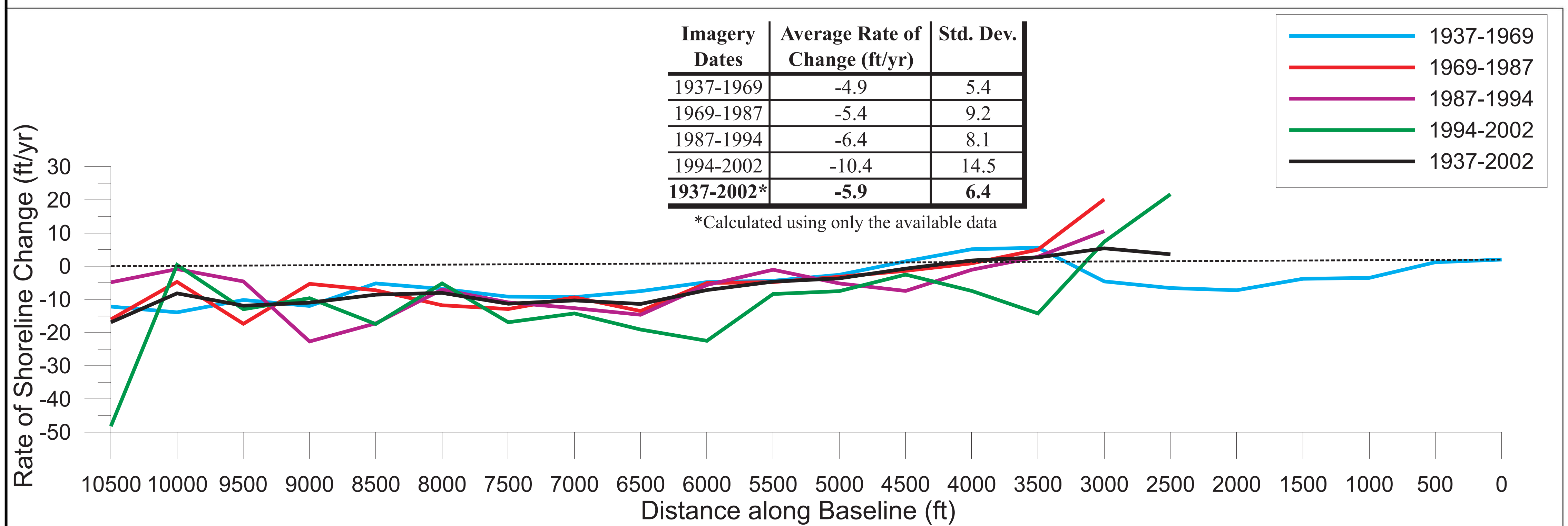
- Identified Dune Sites
- Transect Point
- Baseline
- 1937 Shoreline
- 1969 Shoreline
- 1987 Shoreline
- 1994 Shoreline
- 2002 Shoreline



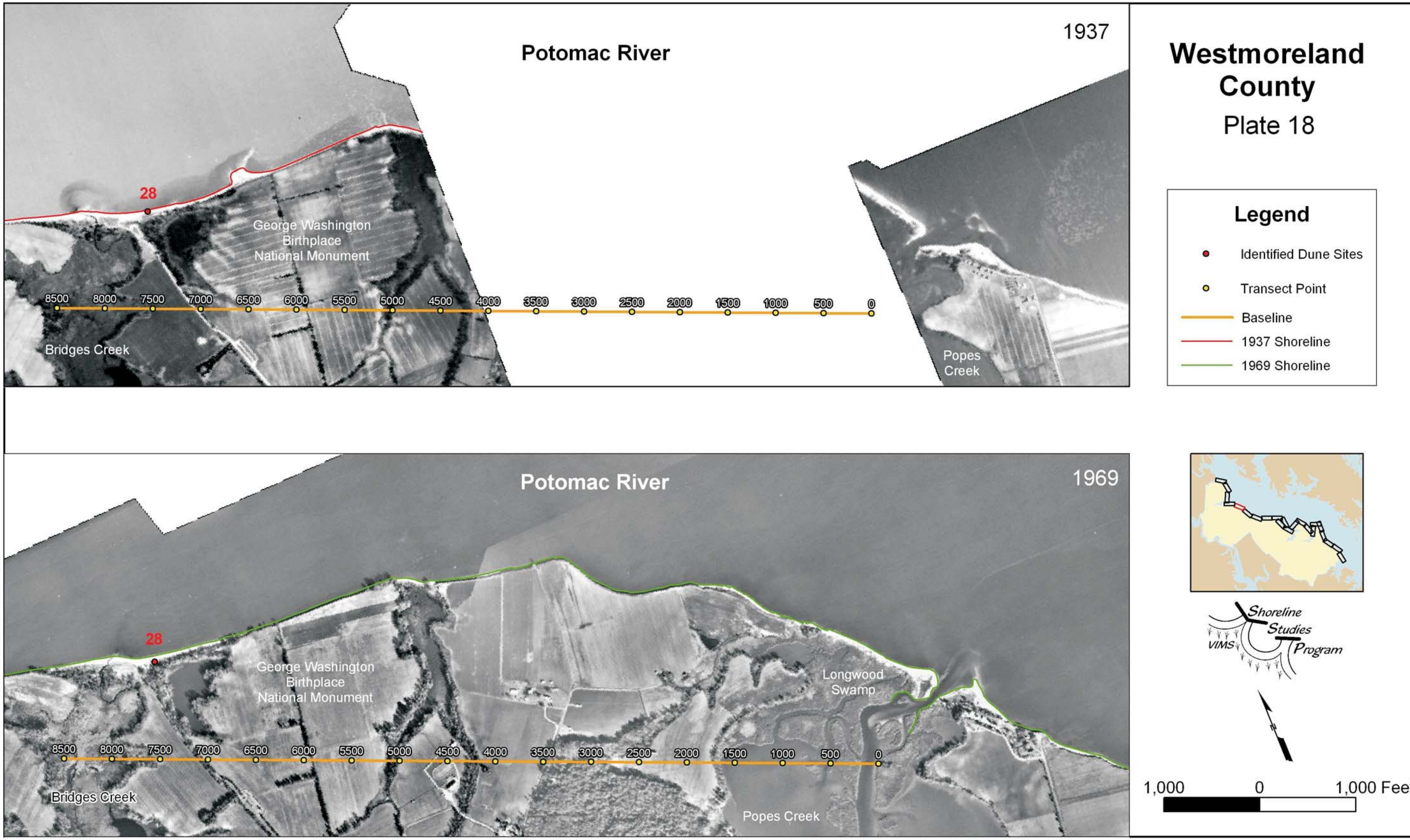
1,000 0 1,000 Feet

| Imagery Dates | Average Rate of Change (ft/yr) | Std. Dev. |
|---|---|---|
| 1937-1969 | -4.9 | 5.4 |
| 1969-1987 | -5.4 | 9.2 |
| 1987-1994 | -6.4 | 8.1 |
| 1994-2002 | -10.4 | 14.5 |
| **1937-2002*** | **-5.9** | **6.4** |

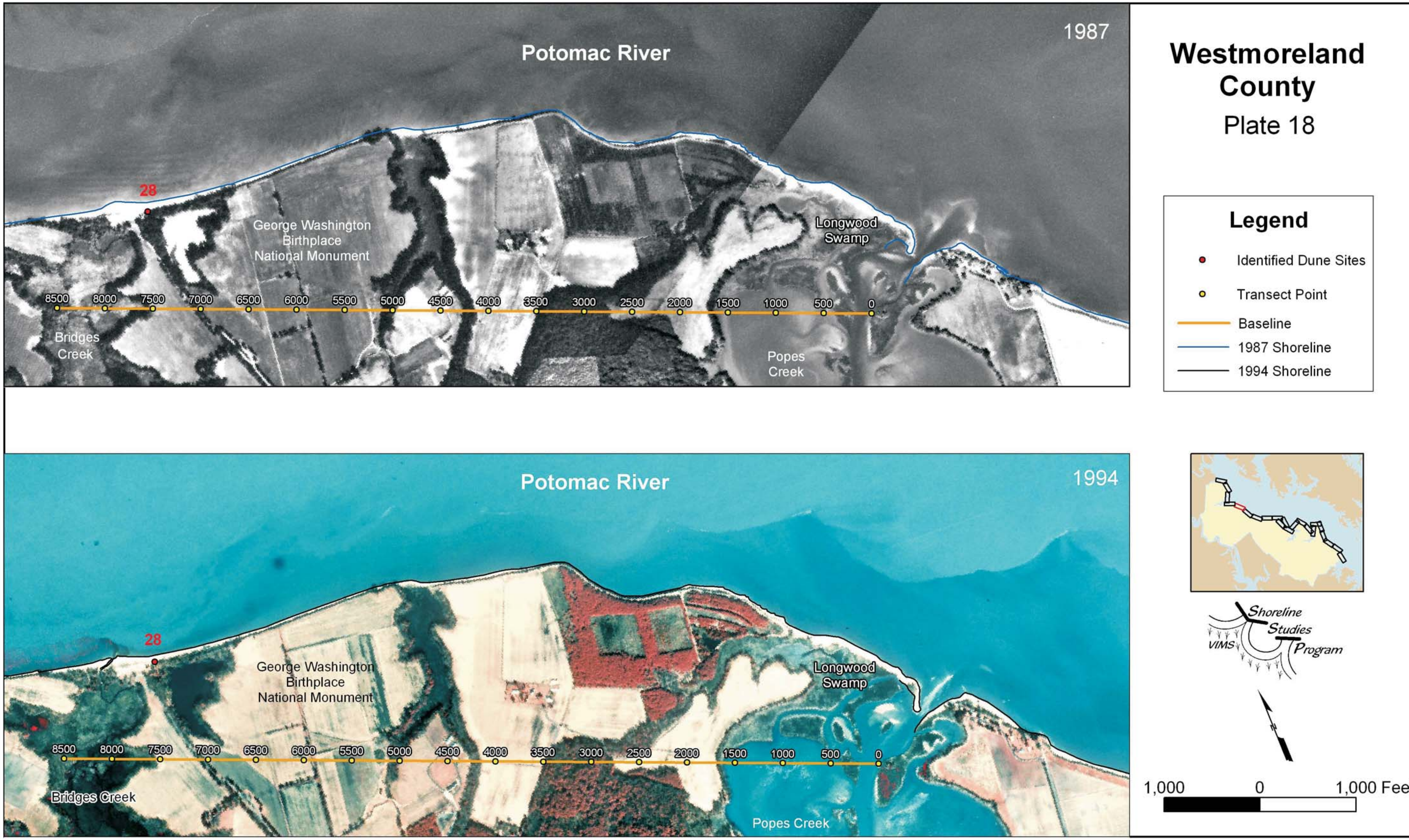
*Calculated using only the available data




Shoreline Studies Program VIMS



Westmoreland County
Plate 18
1937
Potomac River
28
George Washington Birthplace National Monument
Bridges Creek
Popes Creek
8500 8000 7500 7000 6500 6000 5500 5000 4500 4000 3500 3000 2500 2000 1500 1000 500 0
1969
Potomac River
28
George Washington Birthplace National Monument
Longwood Swamp
Bridges Creek
Popes Creek
8500 8000 7500 7000 6500 6000 5500 5000 4500 4000 3500 3000 2500 2000 1500 1000 500 0
Legend
Identified Dune Sites
Transect Point
Baseline
1937 Shoreline
1969 Shoreline
Shoreline Studies Program
VIMS
1,000 0 1,000 Feet


Westmoreland County
Plate 18
1987
Potomac River
28
George Washington Birthplace National Monument
Longwood Swamp
Bridges Creek
Popes Creek
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1994
Potomac River
28
George Washington Birthplace National Monument
Longwood Swamp
Bridges Creek
Popes Creek
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Legend
Identified Dune Sites
Transect Point
Baseline
1987 Shoreline
1994 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet

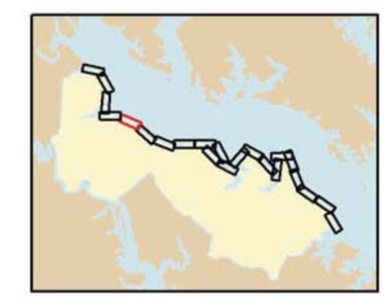


# Westmoreland County

## Plate 18

### Legend

- Identified Dune Sites
- Dune Site Limits
- Transect Point
- Baseline
- 1937 Shoreline
- 1969 Shoreline
- 1987 Shoreline
- 1994 Shoreline
- 2002 Shoreline

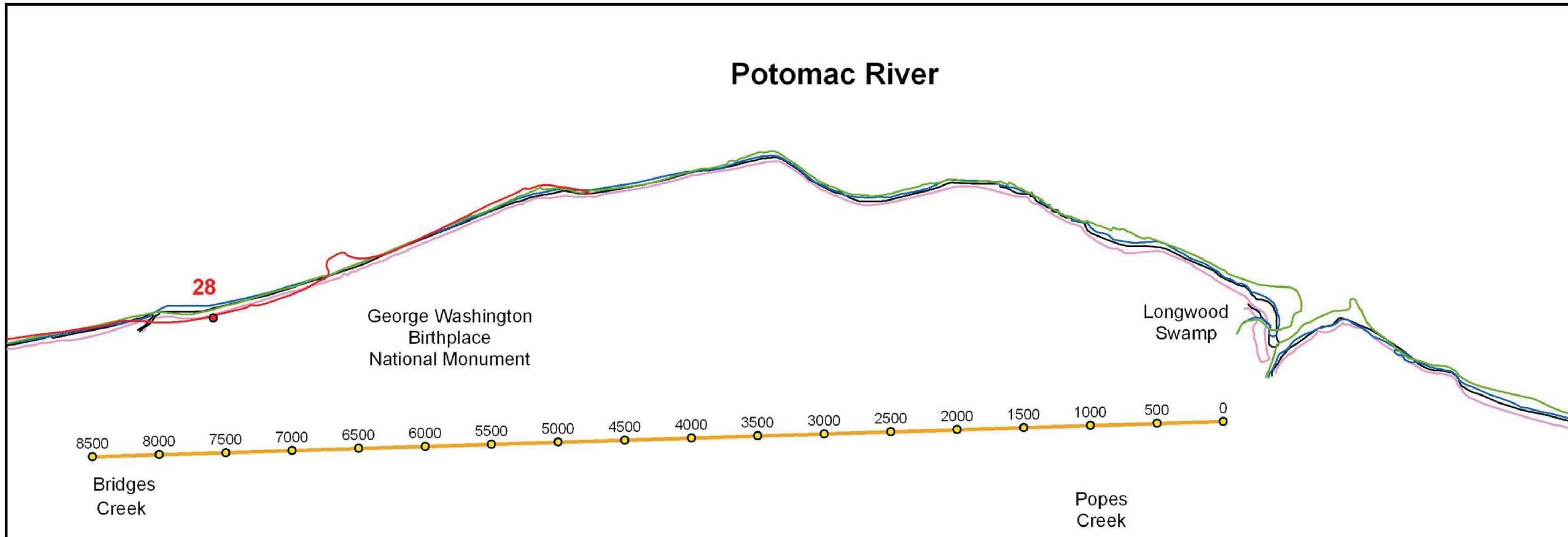


VIMS Shoreline Studies Program

1,000 0 1,000 Feet

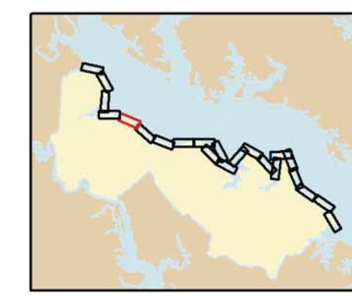
# Westmoreland County

## Plate 18




**Legend**

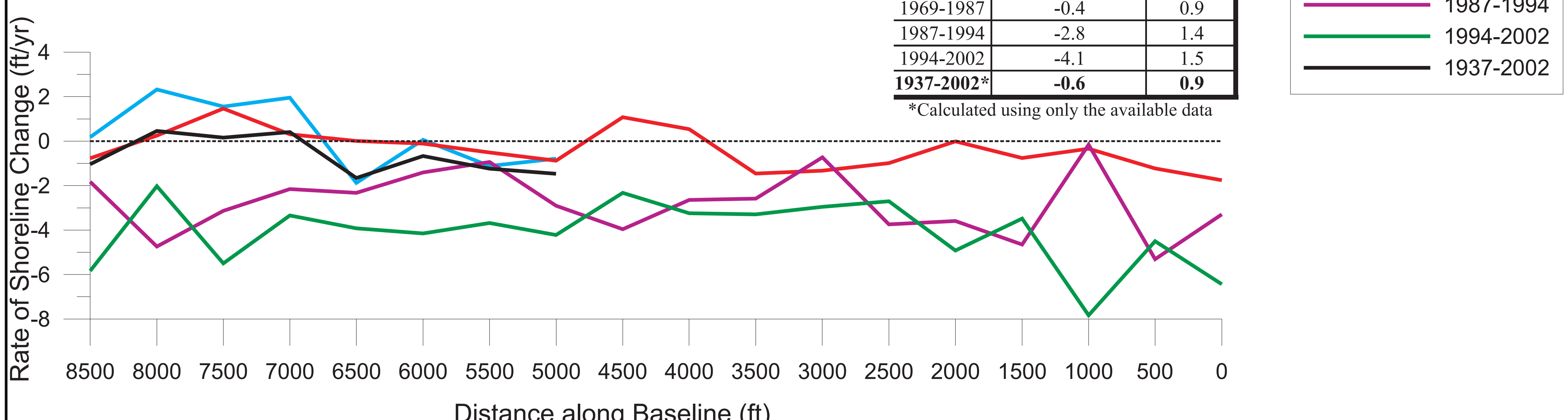
- Identified Dune Sites
- Transect Point
- Baseline
- 1937 Shoreline
- 1969 Shoreline
- 1987 Shoreline
- 1994 Shoreline
- 2002 Shoreline



1,000 0 1,000 Feet

| Imagery Dates | Average Rate of Change (ft/yr) | Std. Dev. |
|---|---|---|
| 1937-1969 | 0.3 | 1.5 |
| 1969-1987 | -0.4 | 0.9 |
| 1987-1994 | -2.8 | 1.4 |
| 1994-2002 | -4.1 | 1.5 |
| **1937-2002*** | **-0.6** | **0.9** |

*Calculated using only the available data



# APPENDIX B

The data shown in the following tables were primarily collected as part of the Chesapeake Bay Dune Systems: Monitoring Year One report and presented in Hardaway *et al.* (2002). 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 Systems: Monitoring Year One (Hardaway *et al.*, 2002).
Site characteristics may now be different due to natural or man-influenced shoreline change.

Identified dune sites in Westmoreland County as of date of site visit.

| Dune Site No. | Location^ Easting (feet) | Northing (feet) | Date Visted | Dune Shore Length (feet) | Primary Dune Site? | Secondary Dune Site? | *Public Ownership? |
|---|---|---|---|---|---|---|---|
| 5 | 2551770 | 647818 | 16-Aug-2001 | 170 | Yes | | |
| 6 | 2547691 | 651065 | 16-Aug-2001 | 320 | Yes | Yes | |
| 14 | 2531440 | 660758 | 27-Sep-2001 | 400 | Yes | | |
| 15/16 | 2528489 | 663735 | 29-Nov-2001 | 800 | Yes | | |
| 18a | 2521524 | 669004 | 29-Nov-2001 | 90 | Yes | | |
| 18b | 2521524 | 669004 | 29-Nov-2001 | 90 | Yes | | |
| 22 | 2512881 | 662546 | 29-Nov-2001 | 1200 | Yes | | |
| 24 | 2506253 | 665760 | 29-Nov-2001 | 1000 | Yes | | |
| 28 | 2450953 | 683746 | 27-Sep-2001 | 200 | Yes | | Yes |
| Total | | | | 4270 | | | |

*Public ownership includes governmental entities including local, state, and federal; otherwise ownership is by the private individual.
^Location is in Virginia State Plane South, NAD 1927

Dune site measurements in Westmoreland County as of date of site visit.

| | Site No. | Dune Shore Length (Feet) | Primary Dune: Crest Elev (ft MLW) | Primary Dune: Distance from Crest Landward to Back Base (Feet) | Primary Dune: Distance from Crest To MLW (Feet) | Secondary Dune: Juris-diction | Secondary Dune: Crest Elev (ft MLW) | Secondary Dune: Distance From Primary Crest Landward to Profile end (Feet) | Secondary Dune: Distance From 2ndCrest landward (Feet) | Secondary Dune: Distance From 2nd Crest seaward to 1st back base (Feet) |
|---|---|---|---|---|---|---|---|---|---|---|
| WM | 5 | 170 | 4.27 | 16 | 42.7 | | | | | |
| WM | 6 | 320 | 5.06 | 28 | 44.1 | Y | 4.67 | 90 | 23 | 34 |
| WM | 14 | 400 | 5.94 | 16 | 42.9 | | | | | |
| WM | 15/16 | 800 | 5.83 | 35 | 64.9 | | | | | |
| WM | 18a | 90 | 3.54 | 7 | 83.6 | | | | | |
| WM | 18b | 90 | 5.78 | 29 | 66.9 | | | | | |
| WM | 22 | 1200 | 5.51 | 52 | 60.5 | | | | | |
| WM | 24 | 1000 | 3.69 | 51 | | | | | | |
| WM | 28 | 200 | 5.02 | 4.5 | 56.8 | | | | | |

These data were collected as part of the Chesapeake Bay Dune Systems: Monitoring Year One (Hardaway *et al.*, 2002).
Site characteristics may now be different due to natural or man-influenced shoreline change.

Dune site parameters in Westmoreland County as of date of site visit.

| | Site No. | Type | Dune Site Parameters: Fetch Exposure A | Shoreline Direction of Face B | Nearshore Gradient C | | Morphologic Setting D | Relative Stability E | Underlying Substrate F | Structure or Fill G |
|---|---|---|---|---|---|---|---|---|---|---|
| WM | 5 | Man Inf | Riverine | North | Steep | No Bars | Isolated, Linear | Stable | Marsh/CB | Jetty |
| WM | 6 | Man Inf | Riverine | Northeast | Steep | No Bars | Isolated, Linear | Stable | Marsh/CB | Groin |
| WM | 14 | Man Inf | Riverine | Northeast | Medium | No Bars | Creek Mouth Barrier/ Spit | Erosional | Marsh/CB | Groin |
| WM | 15/16 | Man Inf | Riverine | Northeast | Medium | No Bars | Creek Mouth Barrier/ Spit | Stable | Marsh/CB | Groin, Jetty |
| WM | 18a | Man Inf | Riverine | East | Steep | No Bars | Isolated, Linear | Stable | Upland | BW |
| WM | 18b | Man Inf | Riverine | Northwest | Steep | No Bars | Isolated, Linear | Stable | Upland | BW |
| WM | 22 | Man Inf | Riverine | Northwest | Medium | No Bars | Creek Mouth Barrier/ Spit | Stable | Marsh/CB | Jetty |
| WM | 24 | Man Inf | Riverine | East | Medium | No Bars | Creek Mouth Barrier/ Spit | Erosional | Marsh/CB | |
| WM | 28 | Natural | Riverine | North | Steep | No Bars | Isolated, Linear | Stable | Upland | |

Long-term, recent stability and future predictions of shore erosion and accretion rates for dune sites in Westmoreland County.

| Site | No. | Long-Term Stability 1937-2002 | Recent Stability 1994-2002 | Near Future Prediction |
|---|---|---|---|---|
| WM | 5 | Accretionary | Stable | Stable |
| WM | 6 | Stable | Stable | Stable |
| WM | 14 | Erosional | Erosional | Erosional |
| WM | 15/16 | Erosional | Stable | Erosional |
| WM | 18 | Erosional | Stable | Stable |
| WM | 20 | Accretionary | Erosional | Stable |
| WM | 24 | Accretionary | Accretionary | Stable* |
| WM | 28 | Stable | Erosional | Erosional |

*Will eventually erode