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Colonial National Historic Park Shoreline Management Plan: Phase II York River Shoreline and Swanns Point, James River Shoreline

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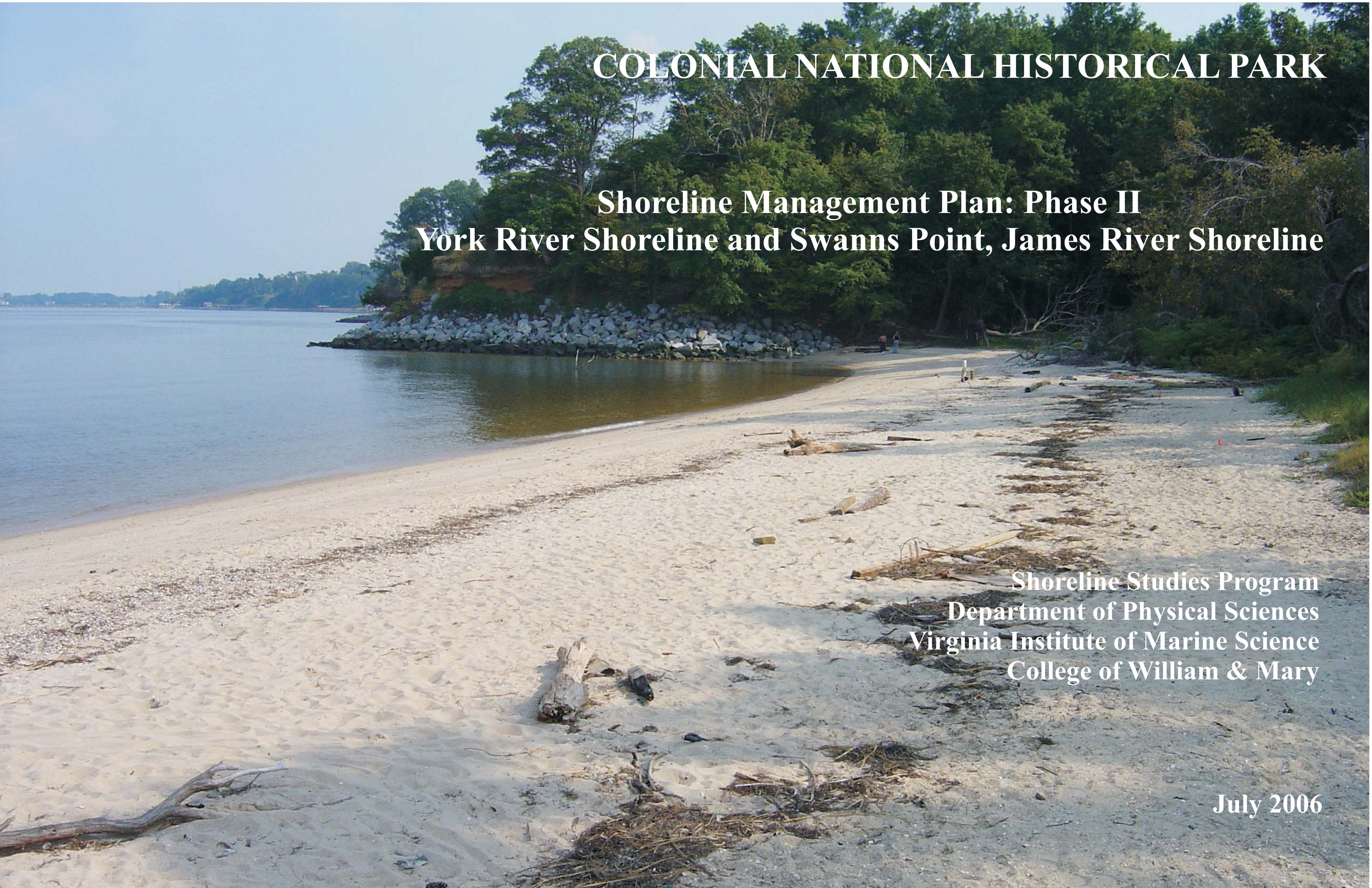

COLONIAL NATIONAL HISTORICAL PARK

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York River Shoreline and Swanns Point, James River Shoreline

Shoreline Studies Program
Department of Physical Sciences
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Final Report

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1 INTRODUCTION

1.1 Background and Purpose

This report presents a comprehensive shoreline management plan for Colonial National Historical Park (COLO) along its York River coast. In addition, COLO property at Swanns Point on the James River was addressed (Figure 1-1). The shoreline controlled by the U.S Naval Weapons Station on the York River is included in the overall reach analyses but not in the management plan recommendations. The plan addresses the mutual desires of state and federal agencies to improve water quality and enhance wetland habitat in Chesapeake Bay while preventing the loss of significant cultural and natural resources. Shoreline processes, past, present, and future, and the ways they relate to hydrodynamic forcing are a main component of this study.

Generally, the entire COLO shoreline on the James and York Rivers is subject to wind driven, wave forces that cause moderate to severe shoreline erosion. Numerous shoreline structures, such as stone revetments and seawalls, have been installed over the years to protect upland improvements from erosion; however, the unprotected shorelines continue to erode, and, under extreme storm conditions such as occurred in September 2003 during the passage of Hurricane Isabel, even protected shores were impacted. This study develops a management plan that puts the natural process of shoreline erosion into perspective as to potential long-term impacts to cultural and natural living and non-living resources. Specific goals of COLO will be incorporated into the analyses in order to produce a shoreline management plan.

1.2 COLO's Land Use Goals

Park Resource Management goals that pertain to this study include:

- Protect, enhance, interpret natural resources in a manner consistent with applicable policies and regulations while supporting cultural resource objectives.
- Develop an up-to-date inventory and data base of natural resources.
- Develop an active resource monitoring program.
- Cooperate with public agencies and with owners of property that adjoins the park to promote resource preservation and monitoring of land uses that could affect park management.
- Preserve, protect, and interpret cultural resources, museum collection, and natural processes/resources in their environment.
- Achieve better understanding of cultural and natural processes through research and monitoring to guide management activities and interpretation including ecological sound decision making; gather and evaluate information through research and monitoring in natural science, visitor use, archaeology, history, and land uses to guide decision making and management actions.
- To develop an up-to-date water resources inventory and database compatible with the park's GIS and database management systems.
- To manage floodplain and wetland resources in a manner that will protect their beneficial attributes and uses.

1.3 Components of the Shoreline Management Plan

1.3.1 Physical Assessment

The background information of regional geology and sea-level rise will be discussed in the context of shore erosion. The geologic underpinnings relative to shore morphology should be assessed since the geology of an area can cause shorelines to erode unevenly. Adjacent shore types, such as uplands and marsh and even unprotected shore segments that border protected shores, result in the development of different morphologic expressions along the shore. When developing a management plan to protect upland infrastructure, sea-level rise is an important long-term consideration. Projected sea-level rise rates tend to be higher than those of the recent past based on potential global warming. Recommended shoreline strategies should have the ability to be adjusted in order to address the impacts of sea-level rise over the long-term.

Understanding long-term change within the study area is important in assessing specific shoreline reaches. Upland features are assessed in terms of coincidence with areas of shoreline erosion and flooding to determine priority of action and what shoreline strategies should be employed. Shoreline morphology and erosion patterns are evaluated in order to determine the long-term shore response to hydrodynamic processes since beaches and shorelines tend to orient themselves into or parallel with the dominant direction of wave approach. The morphologic expressions are compared with the wave climate analysis to see if a correlation exists. Generally, beach and shoreline planforms will reflect the net impact of the impinging wave climate. When the wave-climate-analysis model agrees with the morphologic expression, then the impacts of proposed shoreline management strategies can be assessed more confidently.

Documentation of the existing condition of the upland bank, beach, intertidal and nearshore areas is essential to management of the shore zone. In addition to determining the type of shore and intertidal area (*i.e.* beach or marsh, sand or cobble), nearshore water depths and bottom stability must be assessed as well as the condition of the base of bank (BOB) and bank face. The bank face is an important factor in long-term shoreline management. The degree of instability and potential for future slumping must be weighted against threatened infrastructure and costs for shore/bank protection and structure relocation.

In order to quantify the general wave climate acting upon shorelines and assess the energy impacting the study shoreline, it is necessary to evaluate the local wind climate since wind-driven waves are the main forcing component in the study. Procedures developed by Sverdrup and Munk (1947) and Bretschneider (1966) are used to develop a general wind field evaluation from wind data collected at Norfolk between 1960 and 1990. In addition, increased water levels pose a threat to certain resources regardless of the wave conditions impacting the shoreline. For this reason, another component of the wave climate assessment was the determination of the frequency of storm surges and flooding. This assessment is based, in part, on long-term tidal data from the National Oceanic and Atmospheric Administration (NOAA) gauge at Gloucester Point. Analyses such as these are critical when determining the potential impact of the local wave climate and storm surge on the shoreline. Consideration of these impacts is an important element in the design of a shoreline management strategy particularly the dimensions of structural options.

1.3.2 Reach Assessment and Recommendations

When the previous analyses are completed, shore reach assessment can be performed. This assessment incorporates COLO's land use goals as well as existing shoreline conditions and their potential for change. The purpose of assessment is to determine the "immediate" need for any specific shoreline management strategy and how the strategies fit into the long-term plan.

A variety of shoreline management strategies may be recommended for each shore reach. The strategies may include any or combinations of the following:

1. Do nothing and/or move infrastructure
2. Defensive approach (stone revetments)
3. Offensive approach (stone sills with wetlands plantings, stone breakwaters and beach fill with wetlands planting)
4. Headland control (stone breakwaters strategically placed)

One or a combination of the above strategies may be appropriate for a given reach depending on the availability of funds and project goals. Phasing shoreline management strategies through time also is addressed because it is usually the more prudent and cost-effective approach. All strategies integrate upland management as part of the plan. Bank grading may be recommended in a few instances.

2 GEOLOGY, SEA-LEVEL CHANGE, and GEOMORPHOLOGY

2.1 Geologic Setting

The Colonial National Historical Park abuts the southwestern York River and its small tributaries generally between Queen and Wormley Creeks. The entire area is within the Coastal Plain province. The park is on the James-York Peninsula as the rivers approach Chesapeake Bay. The geology of the park along the York serves as a lesson in the regional geology with younger strata, primarily of Pleistocene age, overlying older Pleistocene and Tertiary beds which may be exposed in valley walls. Additionally the character of the strata displays the influence of the dominant feature of the underlying geology, the Chesapeake Bay Impact Crater which was formed approximately 35 million years ago.

About 35 million years ago, at the end of the middle Eocene, the generally horizontal strata in what today is the wide, southern portion of Chesapeake Bay, were disrupted by the impact of a substantial meteor or comet. The collision instantaneously created an impact crater (Figure 2-1) that is approximately 56 miles wide and at least 1.2 miles deep (Powars and Bruce, 1999). The center of the crater is approximately 20 miles east of Yorktown. The crater was (partially) back-filled extremely rapidly by what now is known as the Exmore beds or Exmore breccia. In subsequent periods of sedimentation, the strata over the crater were thicker than in surrounding areas since the sediments accumulated more rapidly in the basin and compaction of the breccia and differential compaction of the overly thick layers filling the crater. This compaction likely was the cause of tectonic adjustments that occurred in the region into the early Pliocene but had essentially ended by Bacons Castle time (Ramsey, 1992). The process, however, likely continues into the present as evidenced by the occurrence of weak earthquakes associated with the outer rim (Johnson *et al.*, 1998) and by small growth faults that approach the sediment surface under the York River within about 2 miles of Yorktown.

The Later Tertiary and Quaternary strata of the mid-Atlantic Coastal Plain were deposited in a series of major, glacially driven, marine transgressions. Figure 2-2 depicts the post-Miocene stratigraphy and Figure 2-3 is a portion of the regional geological map. The nature of the deposition has been that during high stands of sea level, marine processes cut into the shore, eroding older sediments and deposits them in the nearshore. This has resulted in a terrace-and-scarp geomorphology in which each terrace is the upper surface of stratum that has been reworked and exposed by a regressing sea and each scarp essentially marks the landward limit of a marine transgression. Figure 2-4 is an idealized geologic cross section characterizing the geomorphology and stratigraphy of the York-James Peninsula in the vicinity of Yorktown.

The Pliocene age Yorktown Formation is colloquially used as the "basement" in discussions of the local geology. According to Krantz (1990, 1991) it was formed between 4.0 (perhaps 4.8) million and 2.8 million years ago (Cronin *et al.*, 1984) during three transgressive episodes. The Yorktown was deposited as a shallow marine, barrier island, lagoonal/estuarine environment. Many of the fossils suggest a subtropical environment (Johnson and Ramsey, 1987) and, indeed, many sections of the Yorktown are richly fossiliferous with some sections containing numerous, well preserved, whole fossils, whereas others consist of dense, fragmented shell hash. Perhaps the best known outcrop of the Yorktown Formation is at Cornwallis Cave on the waterfront in the settlement of Yorktown. The cave is dug into a cross-bedded coquina of the Moore House member of the Yorktown Formation.

The early Pleistocene Windsor Formation, which outcrops in the bluffs overlooking Queen, King, and Felgates Creeks, unconformably overlies the Yorktown. The Windsor was deposited as sea level rose and eroded the Surry Scarp (Figure 2-4); it exemplifies some of the problems in identifying and correlating the regional strata. The Surry Scarp is a major geomorphic feature that extends fully across Virginia and North Carolina and has been mapped in South Carolina and Florida (Hobbs, 2004). The terrace immediately below the scarp is the Lackey Plain (Johnson, 1972; Hobbs, 2004). The Plain is the upper surface of the Windsor Formation. Because no diagnostic fossils have been found in the Windsor (Johnson and Berquist, 1989) and since it is comprised of sediments reworked from older strata, identification and correlation is difficult with the determination often being made on elevation and physical relationship with other strata.

The Ruthville Scarp (Johnson and Berquist, 1989) was cut during deposition of the Charles City formation and separates the older Lackey Plain from the Grove Plain. Charles City Formation (Johnson and Berquist, 1989), like the Windsor, has not yielded an datable fossils (Johnson and Ward, 1990) but is taken to have been deposited during the Middle Pleistocene.

The Lee Hall Scarp (Johnson, 1972) has just over 12 ft of relief; it is more a low rise that has been sufficiently cut by erosion in some areas as to be unrecognizable as it separates the Grove and Grafton Plains. The Chuckatuck Formation (Johnson and Berquist, 1989) underlies the Grafton Plain. According to Johnson and Berquist (1989), relative sea level reached about 60 ft above present during Chuckatuck time. As with the other Pleistocene sedimentary units, the Chuckatuck Formation was formed from sediments eroded from older strata and has not yielded any age-definitive fossils or fossil assemblages.

Along the York River, the Camp Peary Scarp (Johnson, 1972) separates the Grafton Plain from the Huntington Flat which is the upper surface of the Shirley Formation (Johnson and Berquist, 1989). According to Peebles (1984) and Johnson and Berquist (1989), the Shirley Formation contains fluvial, estuarine, marsh, shallow marine, and similar deposits. Based on dates (Cronin *et al.*, 1981; Mixon *et al.*, 1982) of correlative deposits along the Rappahannock River, Johnson and Berquist (1989) indicate that the Shirley Formation has a Late Middle Pleistocene age of about 185,000 years.

The Suffolk Scarp has been mapped for about 200 miles (300 km). Johnson (1972) considered it the most prominent scarp on the York James peninsula with 30 ft of rise as it separates the Huntington Flat from the Hornsbyville Flat and correlatives. These plains are the surface of the Shirley Formation and of the Sedgefield Member of the Tabb Formation, respectively (Johnson, 1976; Johnson and Berquist, 1989). The Big Bethel Scarp marks the lower edge of the Hornsbyville Flat and the upper limit of the Hampton Flat. The Mulberry Island Flat is lower than the Hampton but the two are not separated by a well defined scarp. The Hampton and Mulberry Island Flats likely are the surface expression of the Lynnhaven and Poquoson Members of the Tabb Formation and were deposited during the last above present stand of sea level, on the order of 100,000 years ago.

Most of the Pleistocene stratigraphic section is weakly cemented and poorly indurated. As a consequence, when exposed in steep faces, the sediments are easily eroded. From a shore change perspective, the more indurated beds are more erosion resistant. These outcrops form the headlands of what we call the Yorktown Bays. The bluffs along the York River portions of the Park are capped with Windsor Formation although older strata, especially the Yorktown Formation, are exposed in the valley cuts. The land surface in the immediate vicinity of Yorktown is the Chuckatuck Formation. Between Indian Field and King Creeks the Colonial Parkway sits atop the Huntington Flat, the surface of the Shirley Formation.

2.2 Sea-Level Change

Understanding the long-term change in sea level is an essential part of coastal planning. In particular, knowing the projected rate of change in water levels is essential for determining coastal hazards from storms and flooding risks. Tide gauges maintained by NOAA record water levels above a fixed point. These data have been used to determine rate of sea-level change for the past 50 years at Gloucester Point (Figure 2-5) and other locations in the region. The wavy lines are plots of average monthly mean sea level. A fair amount of 'scatter' exists from one month to the next but over several years the trend becomes clear. The three fitted lines represent the range in uncertainty of the trend. The tide gauge, located at VIMS, showed that sea level has been rising 1.3 ft/century (3.95 mm/yr) (NOAA, 2006a). This rate is slightly less than the overall rate for the Hampton Roads region as shown at the Sewells Point tide gauge on Hampton Roads which is 4.42 mm/year or 1.45 feet/century. The gauge at VIMS was destroyed in Hurricane Isabel in 2003 and has not been replaced. A new gauge has been installed downriver on the Coast Guard Pier in Yorktown.

The flooding risk is calculated by adding the short-term change in water level due to the storm (storm surge) to the everyday rise and fall of the astronomical tide. Seasonal variations in the mean sea level cycle over a two year period are also shown in Figure 2-5. These yearly variations in average sea level height each month impact the reach of storms and flooding risks. The months of August, September, and October have the highest heights; these months correspond to the highest risk of extratropical activity along the East Coast and Chesapeake Bay. Superimposed on the storm surge and astronomical tide, long-term sea level change can significantly increase the reach of storm waters (Boon, 2003).

For management purposes, the amount of yearly mean sea level rise relative to the land can be predicted for any future year by simply utilizing the linear trend for the region. Boon (2003) analyzed the rise in sea level within the context of Hurricane Isabel, which impacted the region on September 18, 2003, and the 'storm of the century" for Chesapeake Bay, the August 1933 hurricane. Tidewater residents who experienced the August 1933 hurricane have stated that the high water marks left by Hurricane Isabel approached, or may have exceeded, similar marks witnessed from the 1933 storm. Boon (2003) showed that the storm tides from both storms were very similar, the difference being about an inch and a half (4 cm). On the other hand, the 1933 storm produced a storm surge that was greater than Isabel's by slightly more than a foot. The 'equalizer' in this case is the difference in monthly mean water level for August 1933 and September 2003 – sea level has risen by 1.35 feet (41 cm) at Hampton Roads in the seventy years between these two storms.

2.3 Shore Geomorphology

Shoreline geomorphology refers to the shape a shoreline evolves from and to over time. The more exposed the shoreline is to an open fetch and the wind generated wave field, the greater the impinging wave energy. For the York River, geomorphology is the basis for reach discussions along a coast dominated by creeks that empty into the York River as well as the headlands that occur along the shore. When headlands, either natural or constructed, are located along a shore, the beach planform responds to impinging energy in the manner shown in Figure 2-6 as discussed in Sylvester (1970) and Sylvester and Hsu (1993). This method, known as the Static Equilibrium Bay (SEB) model, uses the net or dominant direction of wave approach to determine the beach or shoreline shape. Beaches and offsets of the upland bank can indicate the net movement of littoral sands since sediment transport is related to the impinging wave climate.

The Shoreline Studies Program at VIMS has many shoreline monitoring sites around Chesapeake Bay. Two of these sites are located on COLO property (Figure 2-7). In order to assess long-term shore morphology of similar sites for this project, we evaluated two shoreline projects that were monitored between 1986 and 1990 (Hardaway *et al.,* 1991) as well as for the first phase of this project (Hardaway *et al.*, 1999) and this most recent phase in 2003/2004. Both occur along the southern side of the York River. The Yorktown Bays are an example of naturally-formed pocket beaches with artificially-hardened headlands. They consist of three pocket beaches just downriver of the COLO picnic area near Cornwallis' Cave. These pocket beaches are "classic" spiral-shaped bays created by large headlands and represent an important element in shoreline management -- headland control. These three embayed beaches have attained a high degree of stability over the past 50 years. The largest bay was re-occupied and surveyed. Comparison with early surveys was done to assess about 8 years of wave action on the beach planform.

The Yorktown Bays have evolved into equilibrium embayments over the past fifty years. They are the empirical prototype of much of the research conducted by VIMS on the use of offshore breakwaters for shoreline erosion control (Hardaway *et al.*, 1989; Hardaway *et al.*, 1991; Hardaway and Gunn, 1991; Hardaway *et al.*, 1995; Suh and Hardaway, 1993; and Hardaway and Gunn, 1999). The headlands separating each bay beach are paleo-interfluves with banks approximately +80 ft above mean sea level that are composed of shelly marl from the Yorktown Formation (Figure 2-2 and Figure 2-4). The headlands were hardened with rock revetments in the early 1960s and reinforced in 1979 (Hardaway *et al.*, 1991).

The other site, called the National Park Service (NPS) breakwaters, consists of five broken concrete breakwaters just upriver from Yorktown Naval Weapons Station pier (Figure 2-7). These structures were designed by VIMS/DCR personnel, built in 1985 by personnel from COLO and the U.S. Army's Fort Eustis, and represent the practical use of offshore breakwaters for erosion control.

3 ASSESSING ENVIRONMENTAL FRAMEWORK

3.1 Physical Setting Assessment

3.1.1 Aerial Photo Rectification and Shoreline Change

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

Archived aerial photos from VIMS Shoreline Studies and Submerged Aquatic Vegetation (SAV) Programs were acquired. The years included 1937, 1953, 1960, 1963, 1968, 1973, 1978, 1994, and 2002. The 1994 imagery was already processed and mosaicked by the United States Geological Survey, while the 2002 imagery was processed and mosaicked by the Virginia Base Mapping Program. The aerials for the remaining flight lines were processed and 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 Quarter Quadrangles (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 are 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 such as corners of buildings or road intersections and stable natural landmarks such as easily recognized isolated trees. 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. The final format the shorelines are in shapefile format. One shapefile was produced for each year that was mosaicked. In areas where the shoreline was not clearly delineated on the aerial photography, the location was estimated based on the experience of the digitizer.

An Arcview extension was used to analyze shoreline rate of change. A shore parallel landward baseline is drawn, and the extension creates equally-spaced transects along the baseline and calculates distance from the baseline at that location to each year's shoreline. The extension determines the distance from the baseline to each digitized shoreline and provides the data to an attribute table. The attribute table is exported to a spreadsheet, and the distances are used to determine the rates of change.

This extension is useful on relatively straight shorelines. However, in areas that have unique shoreline morphology, such as creek mouths and spits, the data created from this extension may not provide an accurate representation of shoreline change and was manually checked for accuracy.

3.1.2 Shoreline Monitoring

VIMS established two monitoring sites along the York River shoreline as part of the *Chesapeake Bay Shoreline Study* (Hardaway *et al.*, 1991), a joint project among the U.S. Army Corps of Engineers (Corps), VIMS, and Department of Conservation and Recreation (DCR). These sites were monitored between 1987 and 1990 and were re-occupied for the first phase of COLO's shoreline management study along the James River.

Benchmarks were re-established for the rod and level survey of the site during the fall of 1997 and spring of 1998 as well as in 2003/2004 for this present project. The purpose of re-occupying these sites is to gain further data on the long-term performance of these shoreline strategies which protect the shoreline, allow a stable beach and intertidal zone to exist, and will not be a solid barrier between the upland and the river.

3.1.3 Upland Bank and Shore Zone Characteristics

The present shore structures and their conditions were field inventoried and marked on hardcopy base maps to assess the detail of the York River coast. These data were converted to shapefile format in GIS. Using the digital topographic lines, boundary, road and other base data provided by the Colonial Historical National Park, the field data was digitized from the base maps into ArcMap and attributed. The aerial photos from the Virginia Base Mapping Program were added to help check for correct location and other possible errors.

3.1.4 Nearshore Characteristics

The nearshore region within the project area varies in extent and bathymetry (Figure 3-1). The width and depth of the nearshore significantly impacts the wave climate acting on a coast. Along the York River shoreline, the nearshore "shelf" from the shoreline to about the -6 ft MLW isobath varies in width from a maximum of about 4,000 feet at the mouth of Kings Creek to almost adjacent to the shore where the York River narrows at the Rt. 17 Coleman Bridge. The nearshore widens downriver toward the Moore House.

Potential structures, such as sills and breakwaters, may be situated 50 ft to 100 ft from MLW. Along the York River, the nearshore bottom, which is important for structure stability, is generally hard due to underlying coarse material. Closer to the creek mouths, the nearshore region might vary from soft to hard.

Locally, marine resources of concern are primarily submerged aquatic vegetation (SAV) -- sea grasses which offer habitat to various fish species. These data were assessed by VIMS' SAV program. In general, they found no significant SAV exists in the nearshore along COLO's York River shoreline. However, a 0-10% patch of SAV occurs off Park Service property just upriver of the Yorktown Bays and a 10-40% patch off Moore House (VIMS, 2005). SAV is on the decline in the Lower York, down 33% to 242 hectacres (ha) in 2004 from 359 ha in 2003 (VIMS, 2004).

Anthropogenic impacts to the nearshore region have been minimal along COLO's shoreline. However, the U.S. Naval Weapons Station piers significantly impact waves and therefore the nearshore not only inside the piers but also on either side. In addition, at Yorktown four breakwaters have been constructed upriver of the Rt. 17 Coleman Bridge, a floating breakwater marina with revetment and five additional breakwaters downriver of the Bridge. These have impacted the nearshore region, but they also allow an opportunity to assess the stability of the nearshore and the influence structures have on it locally.

3.1.5 Energy

The wave climate is the overall wave energy that impacts the project shoreline averaged through time. The wave climate along any given shoreline is a function of fetch and nearshore bathymetry. Fetch is defined as the distance over water that wind can blow and generate waves and is determined by procedures outlined in U.S. Army Corps of Engineers (1984). Each section of COLO's shoreline has varying fetches which are shown in Table 1. The Reaches are shown in Figure 3-1. The more northward facing shoreline of Reach I has significant effective fetches to the northwest and north. Frequently during extratropical northeast storms, the winds will rotate to the northwest as the storm passes thereby impacting the shore from the opposite direction. Reaches II and III are relatively protected by the shore configuration; however, Reach IV is exposed to larger waves generated in Chesapeake Bay and coming through the mouth of the York River. Swanns Point is particularly exposed to the northwest and the east.

Data from Norfolk International Airport, summarized for the time period 1960-1990 in Table 2, show the long-term wind frequencies. The north component is dominant followed by the south, southwest, and northeast while the northwest is minor. Since southerly winds generate northerly traveling waves, they do not impact the COLO shoreline. The north winds dominate most of COLO's shoreline.

The wave climate varies alongshore as deep water waves are affected by the complex nearshore bathymetry. Modifications to the waves occur through the processes of shoaling, refraction, diffraction, and loss of wave energy by frictional dissipation by interaction with the bottom. Along Reach IV, the naturally deep York River Channel comes close to the shoreline allowing the wave energy to impact the shore zone with little modification.

Water levels effect the reach of the wave climate, and storms are a large part of the force of change along Chesapeake Bay's shorelines. Two types of storms can impact the shore: hurricanes and northeasters. During a hurricane, storm surges, which, theoretically, can exceed 16 feet on the open coast, and high winds can transport large amounts of sediments. Northeasters have weaker wind fields and generally have surges less than 7 feet. However, northeasters usually have longer durations which can span several tidal cycles significantly elevating water level during times of high tide. The largest rates of shore erosion occur during storms when the sediment transport system responds to storm surge level and to wind direction, intensity and duration. Table 3 shows the return frequency of storms and their associated water levels.

Simplified, wind-generated, wave growth formulas within the Automated Coastal Engineering System (Veri-Tech, 2001) were utilized as a wave hindcasting methodology to calculate wave information maps Bay-wide (Basco and Shin, 1993). Basco and Shin used the shallow-water formulations of ACES which account for fetch-limited, deep water forms, but not duration, to develop a local wave height from all fetch directions. Table 4 shows the calculated wave height and period within each of the Reaches discussed in the report. For the analysis, the winds speeds were restricted to a 50% exceedance probability level for any one year. This methodology is limited in that it does not consider nearshore wave transformation processes such as shoaling, refraction, and wave breaking processes in the surf zone. Therefore, the data calculated apply to the offshore region not at the shoreline. Water levels modeled were at mid-tide with a 2.5 ft storm surge.

Tides and tidal currents have an impact on wind/waves and sediment movement along the project shorelines. The mean tide range at Gloucester Point is 2.4 ft with a spring tide range of 2.7 ft (tidal epoch 1983-2001) (NOAA, 2006b). The mean tide range at Scotland just downriver from Swanns Point is 1.8 ft with a spring tide range of 2.2 ft (tidal epoch 1983-2001) (NOAA, 2006c).

Table 1. Calculated effective fetch of each reach discussed in the Management Plan.

	Effective Fetch (nmi)			
	Northwest	North	Northeast	East
Reach I	4.2	3.5	1.3	NA
Reach II & III	NA	1.7	1.0	1.2
Reach IV	NA	1.4	7.0	7.7
Swanns Point	3.9	1.9	1.2	2.7

Table 2. Summary of winds at Norfolk International Airport from 1960-1990.

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

*Number of occurrences ^Percent

Table 3. Frequency of stillwater levels.

Exceedance Frequency		Stillwater Level (feet MLW)
(Percent)	(Years)	U.S. COE (1989)
10	10	6.3
4*	25*	7.0*
2	50	7.8
1	100	8.5
0.2	500	10.3

**Interpolated*

Table 4. Wind wave hindcast modeled at the 50% exceedance probability level with a design wind speed of 35 mph (Basco and Shin, 1993).

	Wave Height* (ft)	Period ^(sec)
Reach I, II & III	4.0	3.9
Reach IV	5.0	4.5
Swanns Point	2.5	3.0

*Hmo=Spectral significant wave height ^Tp=Peak spectral period

3.2 Hurricane Isabel Impact Assessment

Hurricane Isabel made landfall along the southeast coast of North Carolina on September 18, 2003. At one time, the storm was a Category 5 on the Safir-Simpson scale. It had been downgraded to a Category 2 before it made landfall. By the time it impacted the Chesapeake Bay, it was a minimal Category 1. However, in addition to being in the "right-front" quadrant of the advancing hurricane, southeastern Virginia experienced east and east-southeast winds which have the greatest potential to transport water into Chesapeake Bay and its Virginia tributaries.

The extent of coastal flooding during a storm depends largely on both the background astronomical tide and the surge generated by the storm's high winds and low atmospheric pressure. Together, surge and astronomical tide combine to form a "storm tide." Storm-tide flooding is maximized when the storm surge and a rising tide reach their peak at the same time. As discussed earlier in the report, coastal flooding as a result of Hurricane Isabel matched that of the 1933 hurricane, widely known as the "storm of the century" for Chesapeake Bay.

Additional storm data were obtained by an Acoustic Doppler Current Profiler (ADCP) which was deployed in 28 ft of water offshore of VIMS at Gloucester Point. The instrument provided a quantitative record of the hurricane's impact on lower Chesapeake Bay. Data from the ADCP showed that Isabel created a 7-foot storm tide topped by 6-foot waves. At the height of the storm, wave crests were passing over the instrument once every 5 seconds, and the storm forced the entire flow of the York River upstream at a rate of 2 knots. Because Isabel was so large, its winds, waves, and surge effected the Bay for an abnormally long time. The ADCP data showed that storm conditions persisted in the Bay for nearly 12 hours and that wave-driven currents were strong enough to mobilize bottom sediments even at the instrument's depth, increasing water turbidity by a factor of two to three compared to fair-weather conditions (VIMS, 2003).

Around the Bay, similar impacts were recorded by tide gauges. However, the gauge at Gloucester Point across the river from Yorktown was destroyed during the storm before the peak water level was reached (Figure 3-2). This tide gauge stopped recording at 8.5 ft MLLW during the storm. Maximum measured stillwater level across the river at Yorktown was 8.6 ft MLLW with the trash line indicating the water plus waves was at 12.5 ft MLLW. That is a surge above the mean range (2.4 ft) of 6 ft with additional 4 ft waves. Weather data provided by instruments atop VIMS' Byrd Hall showed that maximum sustained winds on the campus reached 65 mph, with 90-mph gusts. The barometer bottomed out at 29.2 inches, with a rainfall accumulation of about 2.2 inches (VIMS, 2003).

The impact on the shoreline of such a significant event will be discussed through limited survey data and ground photography. The effect of Hurricane Isabel on breakwater systems around Chesapeake Bay, and Yorktown in particular, is discussed in Hardaway *et al.* (2005).

4 SHORELINE MANAGEMENT ELEMENTS

4.1 Objectives

The first step in developing a framework for shoreline management is establishing clear objectives toward which erosion control strategies can be directed. In developing this Shoreline Management Plan, the following objectives have been given consideration:

- Prevention of loss of land and protection upland improvements.
- Protection, maintenance, enhancement, and/or creation of wetlands habitat both vegetated and non-vegetated.
- Management of upland runoff and groundwater flow through the maintenance of vegetated wetland fringes.
- For a proposed shoreline strategy, addressing potential secondary impacts within the reach which may include impacts to downdrift shores through a reduction in the sand supply or the encroachment of structures onto subaqueous land and wetlands.
- Providing access to and/or creation of recreational opportunities such as beach areas.
- Proposed shoreline strategy should not interfere with historical interpretation.

These objectives must be assessed in the context of a shoreline reach. While all objectives should be considered, they will not carry equal weight. In fact, satisfaction of all objectives for any given reach is not likely as some may be mutually exclusive.

4.2 Protection Strategies

Four general shore protection strategies have been considered in the discussion of each shore reach within the study area. These strategies are discussed below.

No Action: Essentially, this strategy allows the natural processes of shoreline erosion and evolution to continue as they have for the past 15,000 years as part of the latest transgression.

Defensive Approach: The Defensive Approach refers to the use of shore protection structures that commonly are placed along the base of an eroding bank as a "last line of defense" against the erosive forces of wave action, storm surge, and currents. For the purposes of this study, stone revetments are the strategy employed.

Offensive Approach: The Offensive Approach to shoreline protection refers to structures that are built in the region of sand transport to address impinging waves before they reach upland areas. These structures traditionally have been groins, but over the past decade, the use of breakwaters has become an important element for shoreline protection. For this study, stone breakwaters and sills will be the strategies employed. Spurs are installed on breakwaters and sills to move the wave diffraction point further offshore to assist in attaining local equilibrium of the shore planform. The use of offensive structures requires a thorough understanding of littoral processes acting within a given shore reach.

Headland Control: Headland control is an innovative approach to shoreline erosion protection because it addresses long stretches of shoreline and can be phased over time. The basic premise is that by controlling existing points of land (*i.e.* headlands) or strategically creating new points of land, the shape of the adjacent embayments can be predicted. A thorough understanding of the littoral processes operating within the reach is necessary to create a stable planform. Headland control can utilize elements of the three previous strategies.

4.3 Coastal Structures

With about 8 miles of tidal shoreline within the study area, a variety of coastal structures can be employed as part of an overall erosion control strategy. The optimum plan will achieve a balance between long-term, predictable shore protection and cost. A brief description of each type of structure and its schematic diagram are provided in the following paragraphs and figures.

Revetments are shoreline armoring systems that protect the base of eroding upland banks and usually are built across a graded slope (Figure 4-1). The dimensions of the revetment are dependent on bank conditions and design parameters such as storm surge and wave height. These parameters also determine the size of the rock required for long-term structural integrity. Generally, two layers of armor stone are laid over a bedding stone layer with filter cloth between the earth subgrade and bedding layer.

Breakwaters and sills are "free standing" structures designed to reduce wave action by attenuation, refraction, and diffraction. A sill (Figure 4-2) has a lower crest, is closer to shore, and usually is more continuous than breakwaters. Sills are installed with beach fill to create a substrate for establishing a marsh fringe. Sills can be used in combination with breakwaters.

Attached or headland breakwaters usually require fill between the structures and the upland in order to acquire long-term shoreline erosion control (Figure 4-3) since they are constructed in areas that are subject to more energetic conditions. Headland breakwaters can be used to accentuate existing shore features and are the primary component for Headland Control. The dimensions of a breakwater system are dependent on the desired degree of protection and potential impacts on littoral processes.

The relationship among four specific headland breakwater system parameters were investigated by Hardaway *et al.* (1991) and Hardaway and Gunn (1991) for 35 breakwater embayments around Chesapeake Bay. Referring to Figure 4-4, these parameters include breakwater crest length, (L_B), gap between breakwaters (G_B), backshore beach width (B_m) and embayment indentation (M_b). The mid-bay backshore beach width and backshore elevation are important design parameters because they determine the size of the minimum protective beach zone in the headland breakwater system. This beach dimension often drives the bayward encroachment that is required for a particular shore protection design. Linear regression analyses were best for the relationship of M_b vs. G_B with a correlation coefficient of 0.892. The ratio of these two parameters is about 1:1.65 and can be used as a general guide in siting the breakwater system for preliminary analysis. Then, detailed bay shape using the SEB can be done. Stable relationships for M_b and G_B are not valid for transitional bay/breakwater segments that interface the main headland breakwater system with adjacent shores.

4.4 Reach Data

The discussion of COLO's shoreline is Reach- and Plate-based, both of which are shown on the index (Figure 4-5). Reaches are designated by Roman numerals and shown on Plates which are designated by regular numbers. Swanns Point on the James River is discreet and, as a result, is only shown by Plate 5. The historical ortho-rectified aerial photos for COLO's shoreline are shown on Plates in Appendix A. The shorelines digitized from the photos and the calculated rates of shoreline change are shown in Appendix A as well.

The existing conditions of the York River and Swanns Point shoreline as well as the proposed structures for the management plan are shown in Appendix B. Those graphics are not Plate-based. In fact, they show the shorezone at a larger scale so that conditions and structures can be readily identified. These graphics describe the shoreline as erosional, stable, or transitional as determined by field visits. Also shown are the proposed structures on an enlarged 2002 aerial photo.

A series of ground photos that are referenced in the following sections are shown in Appendix C. Most of these photos were taken post-Hurricane Isabel (13 October 2003) for the main section of COLO's shoreline on the York River. Additional photos used in report figures were taken at the Moore House on 5 March 2005. Swanns Point was photographed on 31 July 2003, pre-Hurricane Isabel.

5 REACH IA

5.1 Physical Setting

5.1.1 Reach Boundaries, Geology, and Shore Change

Reach IA (Plate 1, Appendix A) is a short shore segment on the east side of the Ringfield Picnic Area that extends from the mouth of King Creek to the mouth of Felgates Creek; it is about 2,000 feet (0.3 miles) long. It is bounded by the parkway on the south side and a marsh shore headland to the north. The long-term erosion rate (1937-2002) is -1.2 ft/yr (Appendix A, page A5). The underlying geology is the Shirley Formation.

5.1.2 Upland Characteristics, Shore Zone Conditions, and Storm Impacts

The southern two-thirds of the reach is actively eroding upland bank, vertically exposed with numerous fallen trees (Appendix C, page C1). Hurricane Isabel had a major impact on the reach that is not reflected in the shore change data. A narrow beach exists along this section of shoreline due to sand derived from the adjacent eroding bank. A few intermittent marsh fringes dot this shoreline section, but they are not wide enough at this time to provide wave attenuation. Toward the northern one-third of the reach, the upland bank turns west and the shoreline transitions to a broad marsh headland. The marsh edge exposed to the York River is erosional but less so than the adjacent eroding upland banks to the south.

The marsh shoreline and the parkway bridge abutments act as subtle headland features that give the whole reach a slightly curvilinear embayment planform. The nearshore region is shallow until encountering the natural channel to Felgates Creek. The reach is also sheltered in part from wave action by the long Penniman Spit. However, recent breaches along the spit are evidence of long-term decay. The spit will become smaller in the near future (10 years) and eventually will erode leaving much of the Park lands on King Creek exposed to open York River wind/wave climate.

5.1.3 Energy

Reach IA faces almost due east down and across the York River. It has a longest fetch to the east of about 4 nmi. Hurricane Isabel caused significant erosion including damage to the bridge embankment on the north side of the Colonial Parkway.

5.2 Management Recommendations

The general strategy is to fix the eroding bank at the bridge abutment on the Colonial Parkway. A low sill, which ends in spurs adjacent to the existing beach and severely eroding upland bank, is proposed along the eroding marsh shore (Appendix B, pages B1 and page B6).

No Action: Not Recommended

Defensive: The rock revetment along the bridge abutment under the Colonial Parkway should be heightened and extended along the graded bank on the north side of the parkway.
Installing a rock revetment along the eroding upland also is an option along with bank grading. A marsh toe revetment or sill could also be built along the eroding marsh shoreline for long-term protection.

Offensive: This could include a breakwater system or sill system along the eroding upland portion of the reach. Bank grading should also be considered under these scenarios but would not be essential.

Headland Control: Potentially an option by placing two large spur breakwaters, one on the upland/marsh transition and another toward the parkway's upland/marsh transitions to allow the adjacent upland to continue to erode toward equilibrium. Another breakwater or marsh toe revetment should be included along the marsh shore section to address impacts of the northern headland breakwater.

6 REACH I

6.1 Physical Setting

6.1.1 Reach Boundaries, Geology, and Shore Change

Reach I extends from Felgates Creek eastward to Indian Field Creek, a distance of about 1.7 miles. Shoreline change is depicted by two baselines on Plate 1 and Plate 2 (Appendix A). On Plate 1 for the first approximately 3,000 feet of shoreline, shore change has been slightly erosional with the exception of the area near the mouth of Felgates Creek which has accreted since 1937. Farther east on Plate 2, shore change varies at the position of low water (the digitized shoreline), but the bank has been stablized since 1960 by shore hardening. The underlying geology along this reach is the Shirley Formation.

6.1.2 Upland Characteristics, Shore Zone Conditions, and Storm Impacts

The upland bank along Reach I has been hardened with stone revetments since before 1960 to protect the Colonial Parkway from erosion. The bank face is fairly stable but Hurricane Isabel over topped the revetment which has crest elevations of +6.0 ft mean lower low water (MLLW) and created a wave cut scarp along the entire reach (Appendix C, page C2). Some minor slumping also occurred. Overall, the bank face remains stable along most of the reach but the base of bank was interpreted as transitional because of Isabel impacts (Appendix B, page B1). Vegetative growth along the base of the bank has masked most of the Isabel wave scarping.

The area near Felgates Creek has a low, marshy strand with intermittently eroding marsh fringe headlands and small pocket beaches (Figure 6-1A). The marsh strand protects the adjacent upland from erosion but also is eroding. Revetment overtopping and erosion of the grassed upland at the opposite end of the reach at Indian Field Creek is also evident (Figure 6-1B).

The 6 ft depth contour is about 3,900 feet offshore near Felgates Creek and gets closer toward Indian Field Creek where the 6 ft depth contour is only about 230 feet offshore.

6.1.3 Energy

Reach I is exposed to waves driven by winds from the northwest, north, and northeast. The western end of the reach is partially protected from northwest and north wind/waves by Penniman Spit which, as previously mentioned, is in state of erosive decay.

6.2 Management Recommendations

Reach I has been adequately protected with a stone revetment along most of its length but was overtopped during Isabel. This has not significantly impacted the stability of the bank face or threatened the parkway. However, another storm of that magnitude or greater might create more severe scarping with potential bank slumping. Also, the sand/marsh strand on the west end will continue to erode thereby reducing its ablility to attenuate wave action during severe storms (Appendix B, pages B1, B6, and B7).

No Action: A reasonable option at this time. Bank conditions should be assessed after severe storms. Also upland runoff may play a greater roll in bank erosion until vegetation is fully reestablished.

Defensive: The strategy of choice over the past 50 years yielding good service. The existing revetment is in good shape but could be more effective for the next 50 years if it was raised 2 feet or so. This would prevent wave scarping along the base of bank for Isabel type storms. In addition, the effective elevation of the revetment has decreased as sea level has risen approximately half a foot since the revetment was created.

Offensive: In the case of Reach I installing a sill along the low sand/marsh strand would not only enhance stability but would enhance beach and marsh fringe habitat.

Headland Control: The Reach I coast is not really conducive to this approach, mainly because of the extensive stone work. However, a long the beach area between an existing revetment and marsh headland may qualify.

7 REACH II

7.1 Physical Setting

7.1.1 Reach Boundaries, Geology, and Shore Change

Reach II extends from the mouth of Indian Field Creek eastward for about 1.4 miles to the west pier of the Yorktown Naval Weapons Station (YNWS). It starts on Plate 2 and carries over to Plate 3 (Appendix A). The underlying geology is the Shirley Formation, but the shoreline lies along a low terrace or plain of sandy and shelly fill that averages about 5 feet MLW along the river. Historically, from 1937 to 2002, the net shore change has been almost 0 (Appendix A, page A10). However, variability exists along much of the reach particularly at Sandy Point where a large spit feature grew over time. From 1937 to 1978, the spit called grew into the York River. After that, it became erosive.

7.1.2 *Upland Characteristics, Shore Zone Conditions, and Storm Impacts*

The low upland coast is hardened with a stone revetment near Indian Field Creek that extends downriver for about a 1,000 ft (Appendix B, page B2). This shoreline has intermittent marsh toe sills along much of its length. The areas without a sill are eroding marsh fringe headlands and beaches (Figure 7-1). The upland bank is stable where the marsh fringe has a sill or is wide enough to naturally attenuate moderate storm wave action. Otherwise the low bank is eroding and more recently from Hurricane Isabel impacts. Hurricane Isabel overtopped the entire shoreline uprooting trees and creating an obvious wrackline along the grassy terrace (Appendix C, page C4). The small broken concrete breakwaters (called the Parkway Breakwaters) are marginally protective and were overtopped by Isabel and the upland bank was significantly eroded (Appendix C, page C5).

At the location of the Parkway Breakwaters, the upland bank begins to increase in elevation. Downriver of the breakwaters, a sandy strand and intermittent marsh fringe occurs. It is wide enough to offer protection to the adjacent upland bank. The base of the bank has been denoted transitional with minor impacts from Isabel (Appendix B, page B2). This area is also partially protected by the long west pier at the YNWS which denotes the downriver boundary of Reach II.

The nearshore region is wider off Sandy Point as the 6 ft depth contour goes out about 400 ft. It draws back closer to the shoreline and is only about 260 ft offshore of the Parkway Breakwaters.

Approximately 5 kilometers along the parkway from Yorktown (also known as K5), the parkway comes very close to the York River (Figure 7-2). During Hurricane Isabel, the combination of storm surge and wave action severely eroded the upland banks, exposed the banks, and moved the top of the bank to within 6 ft of the road base. Emergency measures are being implemented using a stone revetment to secure the area (Figure 7-3).

7.1.3 Energy

Reach II is exposed to a wind/wave climate to the northwest, north, and northeast. The northwest wind waves tend to drive shoreline sediments downriver and constantly erode the marsh fringe. Frequent northeasters create wind/waves that approach the coast in a sub-parallel manner causing significant erosion and moving the sand in an onshore/offshore direction. The northwest winds frequently follow the passage of northeasters which impacts a recently stressed shoreline.

7.2 Long-Term Monitoring Data: Parkway Breakwaters

This site includes five, broken, concrete breakwaters that were constructed in 1985 just upriver from Yorktown Naval Weapons Station pier (Figure 2-7). The site, called the National Park Service (NPS) breakwaters, was surveyed before and after installation then two times per year until 1990. This site was re-occupied and surveyed in 1997, 1998 and post-Isabel in 2003.

The distance to the mean high water (MHW) line from the baseline is plotted for five surveys made at the NPS breakwater site (Figure 7-4). The downriver portion of the site had retreated between post-installation and 1998. However, the MHW line did not change much between 1998 and 2003 except in the middle of the site. Breakwaters 4 and 5 have become detached, and while breakwater 5 still slightly influences the wave climate at the site, breakwater 4 has become transparent to waves and does little to influence the shape of the shoreline. The bank also has eroded, particularly in response to storms when elevated water levels impact it directly. Hurricane Isabel caused severe erosion particularly above MHW. The NPS breakwaters are still adjusting, by upland erosion, into equilibrium embayments. The breakwaters are only 50 ft long and illustrate that the shorter breakwater units (shorter, relative to the impinging wave length) are less effective than longer structures in maintaining equilibrium embayments.

Figures 7-5 and 7-6 show the cross-section profiles of the NPS breakwaters through time. A great deal of erosion occurred along the entire beach profile between 1990 and 1997 even directly behind the breakwaters. However, between 1997 and 1998, much of the erosion occurred above +5 ft mean low water (MLW) indicating that elevated water levels allowed the waves to act directly on the bank. The upriver end of the site was relatively stable (P2) as the breakwater became fully attached; severe bank erosion occurred along much of the site likely due to Hurricane Isabel. After Isabel, breakwater 3 is detached (*i.e.* attached subaqueously). The downriver end of the site (P26) actually accreted on the bank and eroded at MHW between 1998 and 2003.

One interesting feature revealed by analysis of data obtained by Hardaway *et al.* (1991) at the NPS breakwater site is the difference between the beach and upland planforms. The tangential section of the embayed beach between breakwaters generally faces north-northwest and is controlled, in large part, by the northwest wind-generated wave climate. During a typical northeaster, the storm originally has winds blowing from the northeast and elevated water levels, but as the storm moves away from the area, the winds shift to the northwest leaving exposed shorelines orientated into this wind-wave condition. However, when water levels are elevated during northeast storms, the wave action is up against the bank, and the tangential section of the bank planform faces northeast in response to the major component of the storm's wind-generated wave climate.

Hurricane Isabel further eroded the upland bank. The structures have been at least partially successful over time but have been reduced in height by storm wave action.

7.3 Management Recommendations

No Action: This might be appropriate along most of Reach II except for K5 which requires attention before the next big storm. However, erosion and fragmentation of the unprotected marsh fringe will soon reduce the overall protection. Even now some sections of the upland behind the marshes eroded under storm conditions.

Defensive: Enhancing the revetment around the Parkway bridge at Indian Field Creek and building the revetment at K5 are necessary actions. K5 is designated critical.

Offensive: This approach here would be to build sills and spurs to accommodate the unprotected marsh fringe and beaches. Also, the existing broken concrete breakwaters need to be enhanced with an layer of armor stone that would not only improve their performance but their aesthetics as well (Appendix B, pages B7 and B8).

Headland Control: This concept is taking place inadvertently to some extent. Sandy Point is a headland, the intermittent sill and the Parkway Breakwaters are erosion resistant “hard points” while the adjacent land erodes toward static equilibrium.

8 REACH III

8.1 Physical Setting

8.1.1 Reach Boundaries, Geology, and Shore Change

Reach III extends from the east pier at the Yorktown Naval Weapons Station downriver about 1.3 miles to Yorktown Creek. It is shown in Plate 3 (Appendix A, pages A11-15). The underlying geology is the Shirley Formation with most of the reach being high bank except for several low drainages. Historic shore positions show areas of recession and advance with an overall average erosion rate of -0.4 ft/yr. Reach III is set within a curvilinear embayed coast the is defined by the Weapons Station pier and Stony Point on the upriver boundary and the Coleman Bridge and associated headland as the downriver boundary.

8.1.2 Upland Characteristics, Shore Zone Conditions, and Storm Impacts

Stony Point is a sandy feature associated with a low drainage. Sand has accreted and become heavily vegetated with a stable upland bank face. Proceeding downriver, the beach narrows and the base of bank becomes erosional to transitional (Appendix B, page B3). In a few areas, the bank face is actively eroding, particularly at K3 where the top of the bank is within 15 feet of the Parkway (Figure 8-1). Two areas of shore are hardened with revetments along this subreach. The nearshore is fairly consistent with about 130 ft to the six foot depth contour.

From K3 downriver, the shore is a relatively wide marsh and sand terrace that resides in a low drainage from Ballard Creek. The upland bank is stable here. The tidal creek outlet from Ballard Creek has helped create a significant ebb shoal or delta which is acting as a headland along this coast. It is acting in concert with the revetment headland just upriver of K3. Unfortunately for the area at K3, the embayed coast is stilling seeking equilibrium at that point, *i.e*. still eroding. From Ballards Creek, the upland draws back to the river and is hardened with a revetment most of the way downriver (Appendix B, page B3). The bank face is mostly stable here with two areas of exposed bank. The shore at K3 will be reveted (Figure 7-3).

Hurricane Isabel impacted the entirety of Reach III (Appendix C, pages C6 and C7). The upland banks eroded in several places, and revetments were overtopped scarping the bank in most cases causing or at least revealing significant vertical exposures. Once again, K3 was severely impacted. Also, the old concrete bulkheading in front of the old house (C7) was destroyed and impacted the undersized revetment along Water Street adjacent to Yorktown Creek. New revetments were installed in the spring of 2005.

8.1.3 Energy

The Reach III coast varies in exposure to wind and waves. The shoreline at Stoney Point faces approximately northeast and turns more northward toward the eastern section of Reach III. The western or upriver half of Reach III is somewhat protected from northwest wind/wave action whereas the eastern half is not. The entire reach is impacted by northeast to east wind/waves particularly during storms.

8.2 Management Recommendations

No Action: This is not an option for K3 but may be warranted in the near term for the remainder of the reach.

Defensive: Stone revetments and concrete seawalls were installed over the years to protect the high banks from wave attack. The concrete walls upriver of Yorktown Creek had severely deteriorated before Hurricane Isabel and were pretty much rendered useless afterwards. Recently, a large stone revetment was built along the lower section of Reach III. Like the revetments along Reach I, the existing revetments, although overtopped during Isabel, still provide good service but should be raised 2 feet to protect against larger storms. Also, revetments could be installed along the unprotected banks between Stoney Point and K3 thereby connecting the existing isolated structures to create a continuous stone wall.

Offensive: This approach here would to build a breakwater system rather than a stone revetment between Stoney Point and K3 (Appendix B, page B3). Although revetments are effective shore protection, they lack some of the habitat qualities of a breakwater system. However, there maybe security issues with the Navy by placing a beach adjacent to the Weapons Station.

Headland Control: Even with the impending construction of a revetment at K3, stability of the embayed beach along the Ballard Creek drainage will still be a question. A headland breakwater placed off the existing revetment headland just upriver from K3 would serve as a boundary structure to work in concert with the ebb shoal headland feature at Ballard Creek.

9 REACH IV

9.1 Physical Setting

9.1.1 Reach Boundaries, Geology, and Shore Change

Reach IV begins at the picnic area just downriver of Yorktown Beach and extends downriver about 1.4 miles to the Coast Guard Station (Appendix A). Included in this reach are several shore segments of private property. Historically, the shoreline has been relatively stable due, in part, to the erosion-resistant, semi-indurated Yorktown Formation stratigraphy and by intermittent shoreline hardening (Appendix A, page A20). One exception is the shoreline along the picnic area and the most upriver Yorktown Bay. The picnic area is a low bank coast that is protected by a stone revetment built in 1983. Prior to the installation of the revetment, the shore receded significantly from its 1937 position (station 3,500) until it was hardened. The overall long-term rate of shoreline change for this stretch of coast slightly erosional at -0.7 ft/yr.

The Yorktown Bays are formed by outcrops of the fossiliferrous marl facies of the Yorktown Formation. In 1937, a fairly continuos beach connected the picnic area to the Point of Rocks which was the main outcropping headland at that time (Appendix A, page A16). Over time, the beach began to recede, and two more outcrops became headlands with pocket beaches forming in between them. By 1960, the Yorktown Bays had formed and have remained relatively stable since mainly because the headlands were armored with rock over the years (Appendix A, page A17).

9.1.2 Upland Characteristics, Shore Zone Conditions, and Storm Impacts

The upland is a low bank along the picnic area (Figure 9-1). Historically, sand accreted in this area. However, it has been eroding for the last 50 years. The banks above the revetments of the Yorktown Bay headlands are vertically exposed (Appendix C, page C8). Downriver of the Point of Rocks, the old revetment was overtopped during Isabe. The banks incurred significant scarping and exist as vertically exposed cliffs above the base (Appendix C, page C9). The upper part of the bank face along the Redoubt 10 coast remains relatively stable.

The Moore House is at the downriver end of Reach IV and is the end of COLO property on the York River. The upland shore areas have 30 to 40-foot scarped cliffs with interspersed ravines. COLO requested an assessment of the shoreline at the Moore House by the U.S. Army Corps of Engineers and VIMS. The Corps provided a description of the reach based on a site visit on 3 March 2005 which is summarized here. The shore along this reach has existing shore protection structures including rubble-mound rock revetments (Figure 9-2A and 9-2B) and a low concrete (jersey-wall type) structure (Figure 9-2C). The rubblemound revetment, which protects the base of the 30-foot (mostly vertical) scarped shoreline, is slightly curvilinear following the shore alignment. The revetment appears to have been built in several phases with two types of stone (granite and gneiss). Two areas were protected by low-crested (damaged) concrete wall. Several of the private property owners have graded the scarped banks to more stable slopes (Figure 9-2D). The revetment has a variable crest width and elevation of approximately 6 ft above mean low water (MLW) in most areas. Closer to the western end the crest elevation drops to about 4 ft above MLW. Generally, the revetment provides sufficient protection to the base of the shoreline under normal conditions but only minimal protection during moderate storm events. Larger, rarer, coastal storms will continue to overtop the revetment and erode the scarp face.

Water depths are relatively shallow with shore parallel contours in the nearshore areas The nearshore is consistent over much of the upriver portion of the reach with the 6 ft contour about 100 ft offshore, the 12-ft contour 800 ft, and the 36 ft contour about 2,000 ft offshore. However, the pier at the Coast Guard station has influenced the nearshore such that the nearshore widens significantly, and the 6 ft depth contour is about 400 ft offshore at the pier.

9.1.3 Energy

Reach IV has the greatest exposure to the Chesapeake Bay wave climate. The full force of Hurricane Isabel drove across this coast flooding Yorktown, overtopping all the coastal protection structures, and scarping the high upland banks, particularly from Yorktown Bays downriver along the Moorehouse Reach.

9.2 Long-Term Monitoring Data: Yorktown Bays

The distance to mean high water (MHW) from the baseline is plotted for several surveys taken at the Yorktown Bay site (Figure 9-3). These distances describe the shape of the beach over time. In general, no net retreat of the shore was noted along the bay in the first ten years they were surveyed. Because the embayments are in a dynamic equilibrium, the sediment moves back and forth along the shore in response to waves. Analysis of earlier data (Hardaway *et al.*, 1991) showed that beach sand was shifted to the downriver side of the embayments during northeast storms. However, since 1997, the downriver, or tangential, section of the bays show a loss of material. The upriver section also had significant erosion between 1998 and 2004. Hurricane Isabel is likely the reason for the erosion.

Figure 9-4 shows the individual beach profile taken through time. Not only did significant erosion occur at MHW, a great deal of change occurred higher in the backshore indicating that much of the change is likely storm driven. While profile 4 had the least amount of change at MHW, profiles 5 and 6 appear to have had the least overall change.

9.3 Management Recommendations

No Action: While no action is an option for this reach, storms will still continue to impact the upland banks.

Defensive: Rebuilding the revetments along this reach is a good option. The U.S. Army Corps of Engineers have developed a plan for this reach.

Offensive: It is difficult to establish shore protection concepts along this reach due to multiple private property ownership and minimal COLO infrastructure

Headland Control: The option presently exists at the Yorktown Bays.

10 SWANNS POINT

10.1 Physical Setting

10.1.1 Reach Boundaries, Geology, and Shore Change

Swanns Point is located on the south side of the James River in Surry County, Virginia. It is COLO property that includes much of Mount Pleasant farm and has about 2 miles of shoreline. The bank geology is Yorktown Formation overlain by the Shirley Formation along the high banks and more recent Pliestocene sediments at and adjacent to Swanns Point. The cypress trees are Holocene features. The shoreline has generally receded over time and offsets are seen adjacent to erosion resistant headland usually created by clumps of cypress trees that lie along the low drainages (Appendix A). The long-term erosion rate (1937-2002) is about -1ft/yr in front of the "Manor House" (at 2000 on the baseline; Appendix A, page A24) which is the only infrastructure that may be threatened over time.

10.1.2 Upland Characteristics, Shore Zone Conditions, and Storm Impacts

At the COLO upriver boundary, the upland zone consists of 50 foot banks which continue past the Manor House downriver to a small drainage. The coast drops down to a low bank and drainage associated with Black Duck Gut around Swanns Point (Figure 10-1), then southward to the inlet into Black Duck Gut. The COLO boundary is about 800 feet south of the entrance to Black Duck Gut.

Shore conditions are recessional with a slow but steady loss of upland banks and low swamp coast. No shore control structures presently exist along this reach (Appendix B, page B5). The Manor House is approximately 200 feet from the top of the eroding bank so the threat is not immediate, but the erosional process will continue.

The nearshore is relatively shallow. Along the north-facing coast, the 6 ft contour is 300-500 feet offshore. Along the west facing shoreline, the 6 ft contour is 700-900 feet offshore.

10.1.3 Energy

Swanns Point has fetchs of 3.9 nmi, 1.9 nmi , 1.2 nmi, and 2.7 nmi to the northwest, north, northeast, and east along shore, respectively.

10.2 Management Recommendations

No Action: At this time, this approach may be most appropriate along the entire reach since no infrastructure or cultural resources are threatened.

Defensive: A revetment could be constructed along eroding shoreline.

Offensive: Breakwaters along eroding shoreline would provide habitat and effectively manage the shoreline.

Headland Control: Several geomorphic opportunities occur at designated offsets and spurs, breakwater and/or sills could be used to enhance them (Appendix B, page B10).

11 SUMMARY OF SHORELINE MANAGEMENT PLAN

The proposed structures are located in Appendix B. Table 11-1 details the approximate cost associated with each recommended structures for the reaches. Also shown is the type of work required and whether it's an existing site or a new site. Table 11-2 shows the total cost of the recommended structures.

Ongoing monitoring needs to be part of the long-range plan. After the phasing options are agreed upon, a reasonable cost-effective monitoring plan will be developed. Aerial photography supporting a shore change database will be the primary tool monitoring shoreline change. In addition, selected sites should be monitored through bank/beach profiling to document cross-sectional changes in the upland bank and beach profile.

Table 11-1. Structural cost estimate for COLO's York River Shoreline by reach.

Reach	Structure	Distance Alongshore (ft)	Rock (tons)	Sand (cy)	Shore Vegetation (# plants)	Work Type
1	S1A-1	700	2,310	1,400	4,200	Restoration
1	Bay1A-1	200		600	1,000	Restoration
1	S1A-2	600	1,980	1,200	3,600	Restoration
1	S1-1	650	2,145	1,300	3,900	Restoration
1	R1-1	1,000	3,000			Rehabilitation
	Total	**3,150**	**9,435**	**4,500**	**12,700**	
2	R2-1	1200	3,600			Rehabilitation
2	S2-1	850	2,805	1,700	5,100	Restoration
2	S2-2	200	660	400	1,200	Restoration
2	BW2-1	300	900	600	1,800	Rehabilitation
2	R2-2					K5 Site*
	Total	**2,550**	**7,965**	**2,700**	**8,100**	
3	BW3-1	2000	6,000	20,000	20,000	Restoration
	Spur3-1	150	1,200			Rehabilitation
	R3-1					K3 Site*
	R3-2					Completed
	Total	**2,150**	**7,200**	**20,000**	**20,000**	
4	R4-1	2,200	8,800			Rehabilitation
	Total	**2,200**	**8,800**			
Swann	BW-1	3,000	11,200	30,000	30,000	Restoration
Point	**Total**	**3,000**	**11,200**	**30,000**	**30,000**	

*Emergency repairs for the K3 and K5 sites are presently being designed by the U.S. Army Corps of Engineers, Norfolk District

Table 11-2. Structural cost estimate summary for COLO's York River Shoreline.

Reach	Distance Alongshore (ft)	Rock (tons)	Cost of Rock ($65/Ton)	Sand (cy)	Cost of Sand ($25/cy)	Shore Vegetation (# plants)	Cost of Plants ($1.5/plant)	Total Cost ($)
1	3,150	9,435	$613,275	4,500	$112,500	12,700	$19,050	$744,825
2	2,550	7,965	$517,725	2,700	$67,500	8,100	$12,150	$597,375
3	2,150	7,200	$468,000	20,000	$500,000	20,000	$30,000	$998,000
4	2,200	8,800	$572,000					$572,000
SP	3,000	11,200	$728,000	30,000	$750,000	30,000	$45,000	$1,523,000
						Total		$4,435,200
						Contingency (20%)		$887,040
						Grand Total		**$5,322,240**

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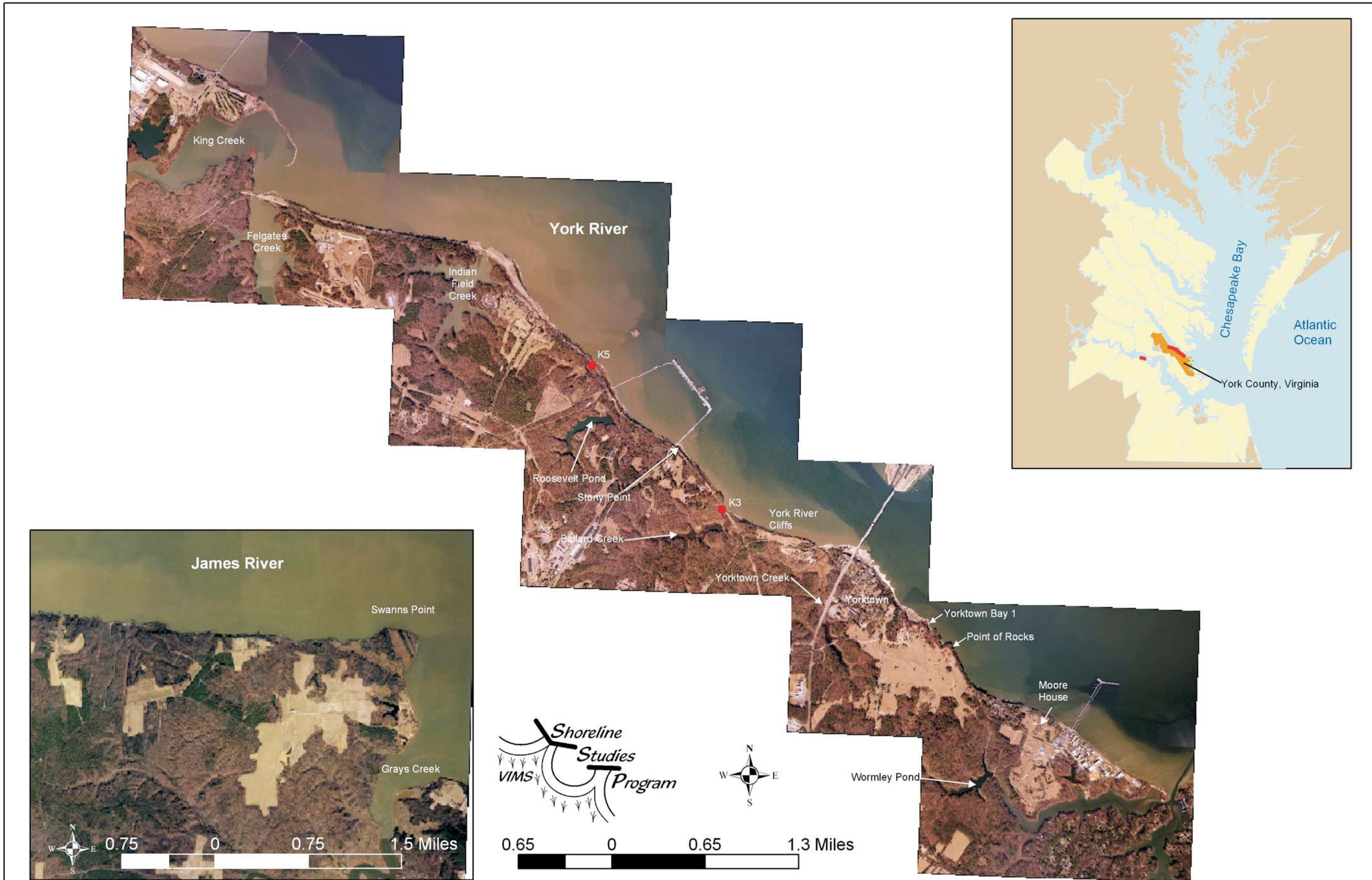


Figure 1-1. Location of the Colonial National Historical Park's York River shoreline and Swanns Point on the James River.

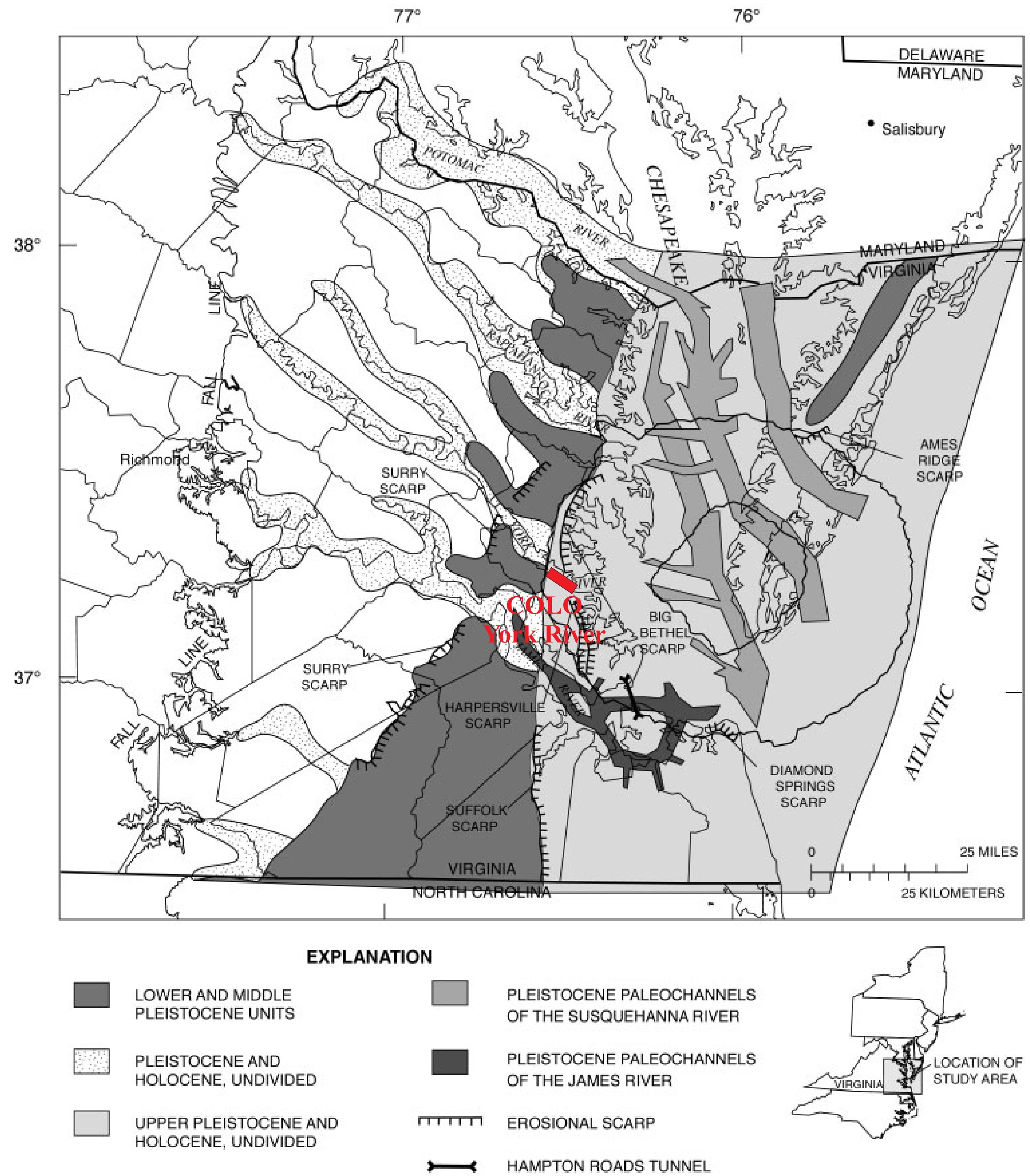


Figure 2-1. Generalized distribution of the post-impact, Quaternary, surficial stratigraphic units, including location of some major scarps and paleochannels (modified from Powars and Bruce, 1999).

Regional Stratigraphic Column

System	Series		Powars and Bruce (1999)			Mixon and others (1989)		
Quaternary	Holocene		Alluvium, swamp, beach			Coastal barriers, lagoons, alluvial, swamp, eolian		
Quaternary	Pleistocene	U	Tabb Formation				Tabb Fm.	Poquoson Mem.
Quaternary	Pleistocene	U	Tabb Formation				Tabb Fm.	Lynnhaven Mem.
Quaternary	Pleistocene	U	Tabb Formation				Tabb Fm.	Sedgefield Mem.
Quaternary	Pleistocene	M	Shirley Fm.			Shirley Fm.		
Quaternary	Pleistocene	M	Chuckatuck Fm.			Chuckatuck Fm.		
Quaternary	Pleistocene	L	Charles City Fm.			Charles City Fm.		
Quaternary	Pleistocene	L	Windsor Fm.			Windsor Fm.		
Tertiary	Pliocene	U	Bacons Castle Fm.			Moorings Unit		
Tertiary	Pliocene	U	Chesapeake Group	Yorktown Fm.	Moore House Mem.	Bacons Castle Fm.		
Tertiary	Pliocene	U	Chesapeake Group	Yorktown Fm.	Mogarts Beach Mem.	Chesapeake Group	Yorktown Fm.	
Tertiary	Pliocene	U	Chesapeake Group	Yorktown Fm.	Rushmere Mem.	Chesapeake Group	Yorktown Fm.	
Tertiary	Pliocene	L	Chesapeake Group	Yorktown Fm.	Sunken meadow Mem.	Chesapeake Group	Yorktown Fm.	
Tertiary	Miocene		Chesapeake Group	Eastover Fm.		Chesapeake Group	Eastover Fm.	

Figure 2-2. Regional stratigraphic column of formations and members.

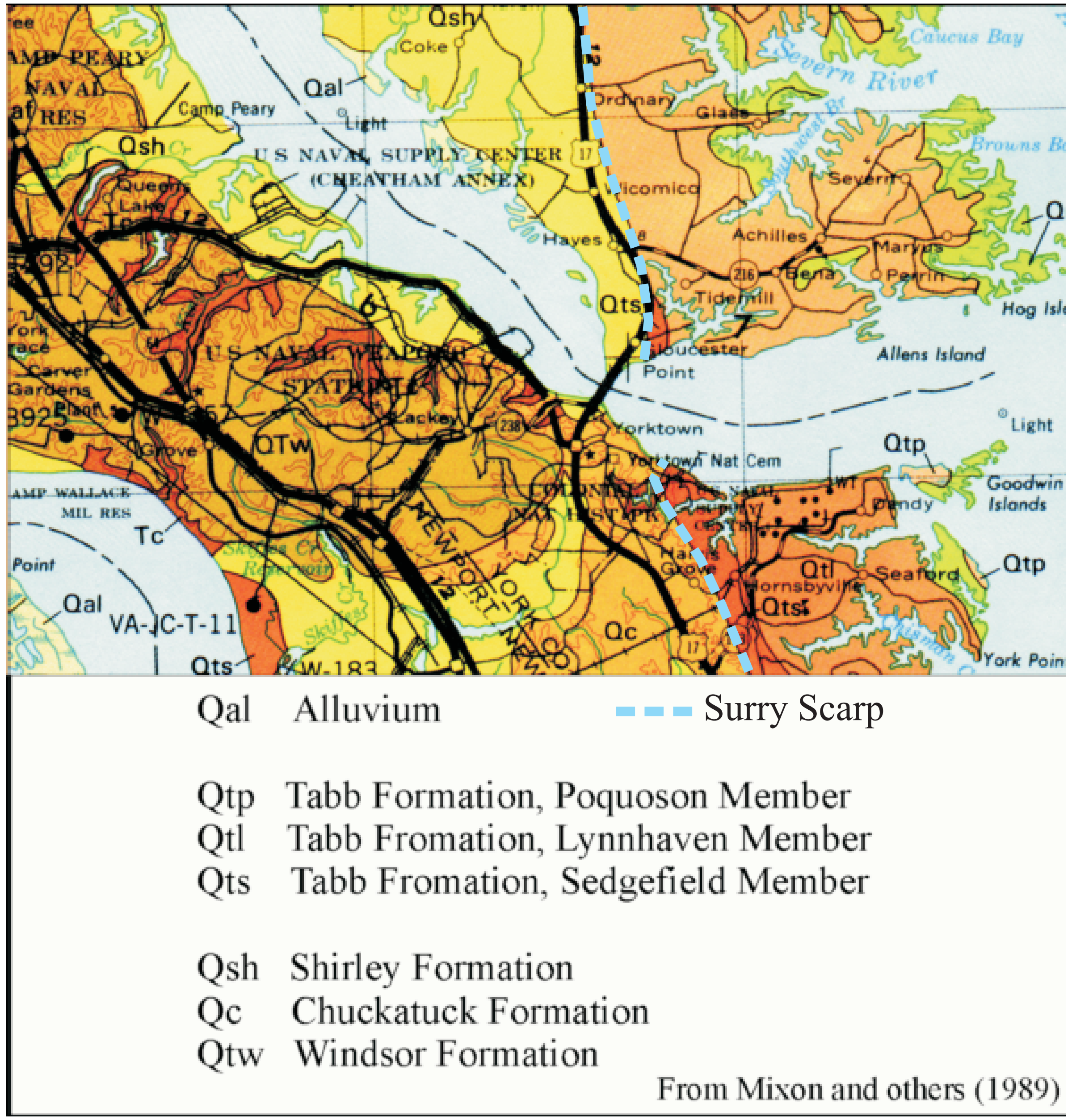


Figure 2-3. COLO’s York River shoreline geologic formations (from Mixon *et al.*, 1989).

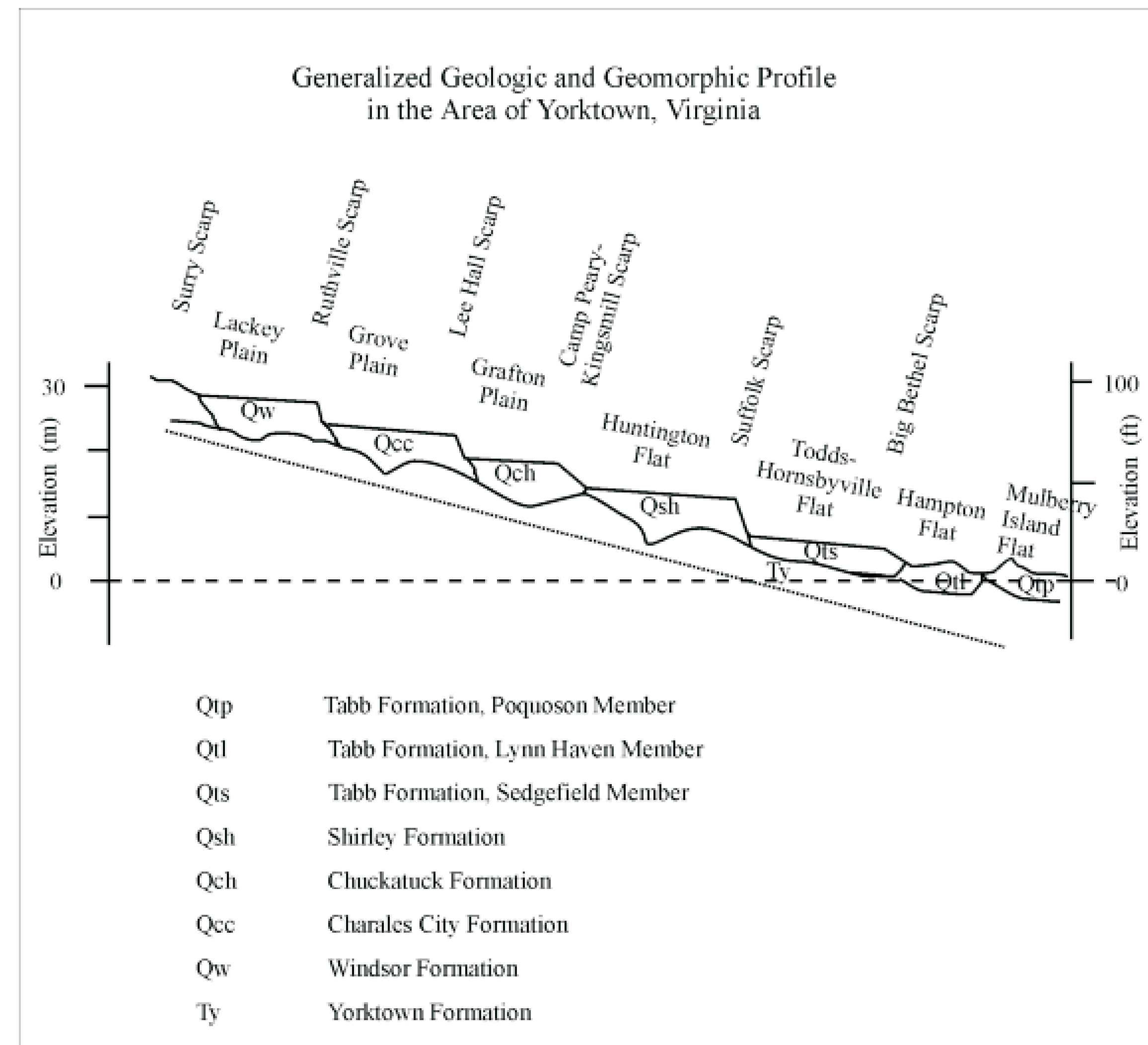
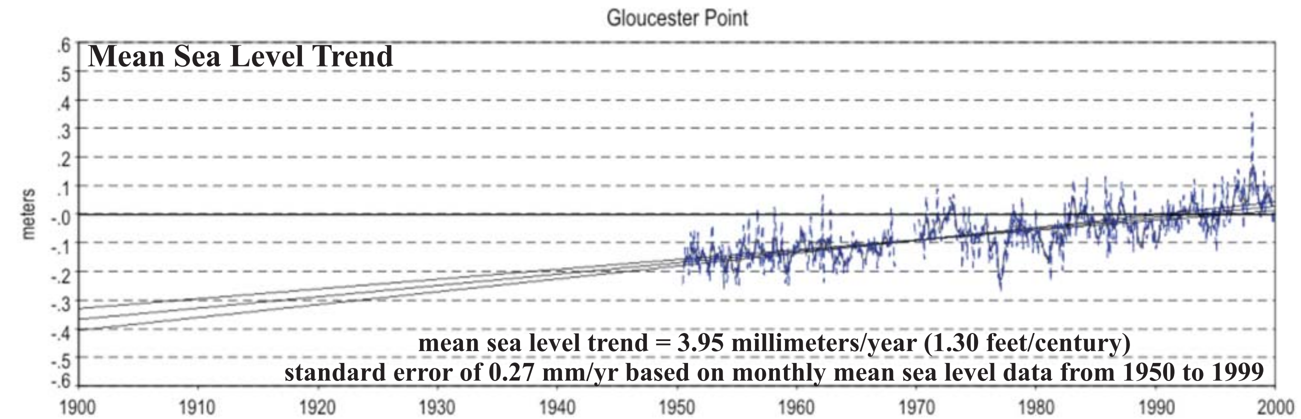
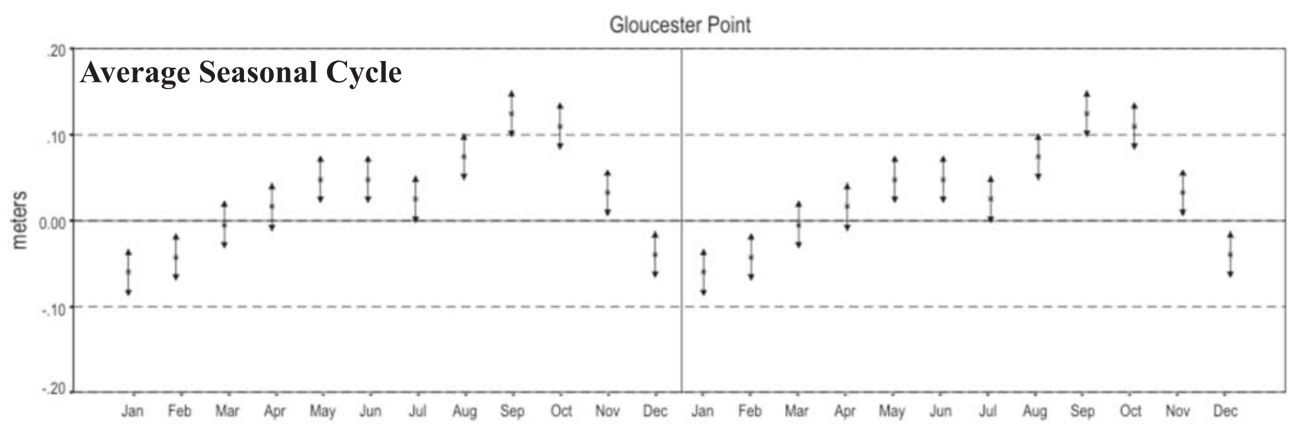


Figure 2-4. Generalized geologic and gemorphic profile in the area of Yorktown, Virgnia (modified from Johnson and Hobbs, 1990).



The plot shows the monthly mean sea level with the average seasonal cycle removed (dashed curve), a 5-month average (solid curve), and the linear trend with its 95% confidence interval which was obtained after accounting for the average seasonal cycle. For most stations, the plotted values are relative to the 1983-2001 mean sea level datum recently established by CO-OPS.



Average seasonal mean sea level cycle over a 2-year period with 95% confidence intervals. For most stations, the values are for the year 2000 relative to the 1983-2001 mean sea level datum recently established by CO-OPS.

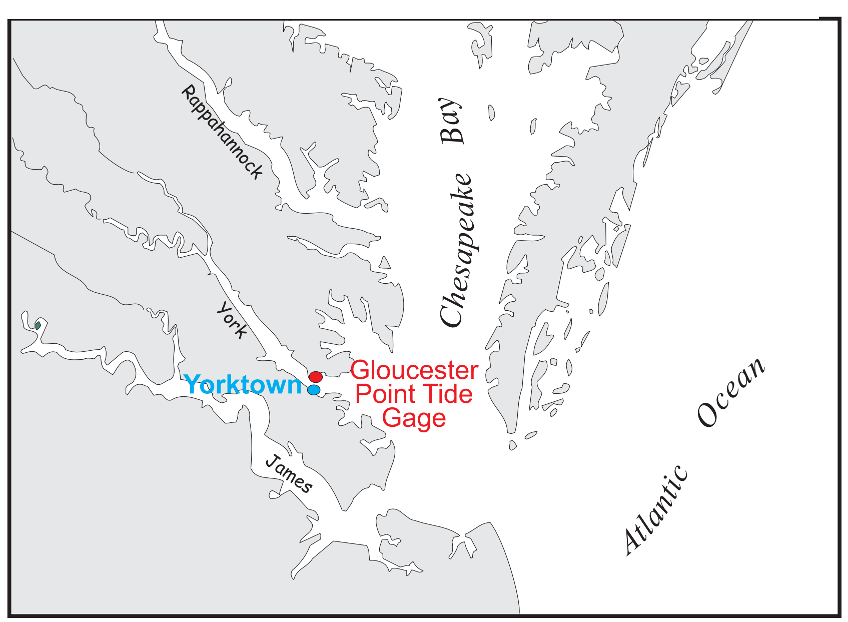


Figure 2-5. Mean sea-level trend and average tide seasonal cycle at the Gloucester Point, Virginia gauge. Http://www.co-ops.nos.noaa.gov/sltrends/sltrends_states.shtml?region=va

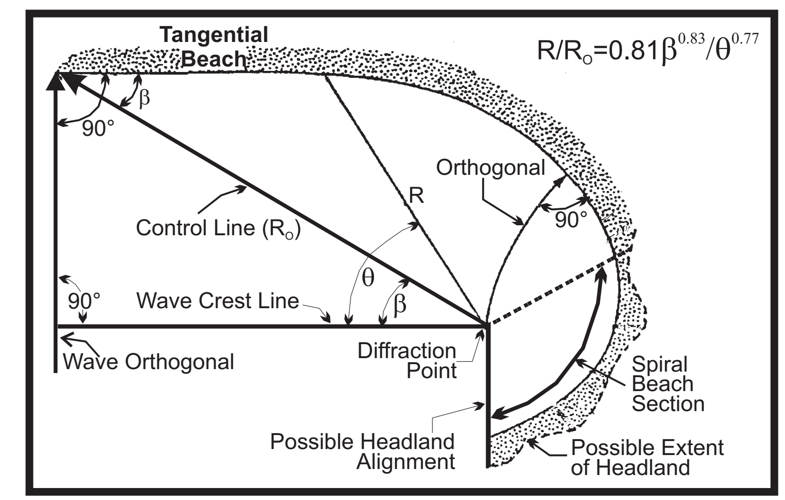


Figure 2-6. Parameters of the Static Equilibrium Bay (after Hsu *et al*., 1989).

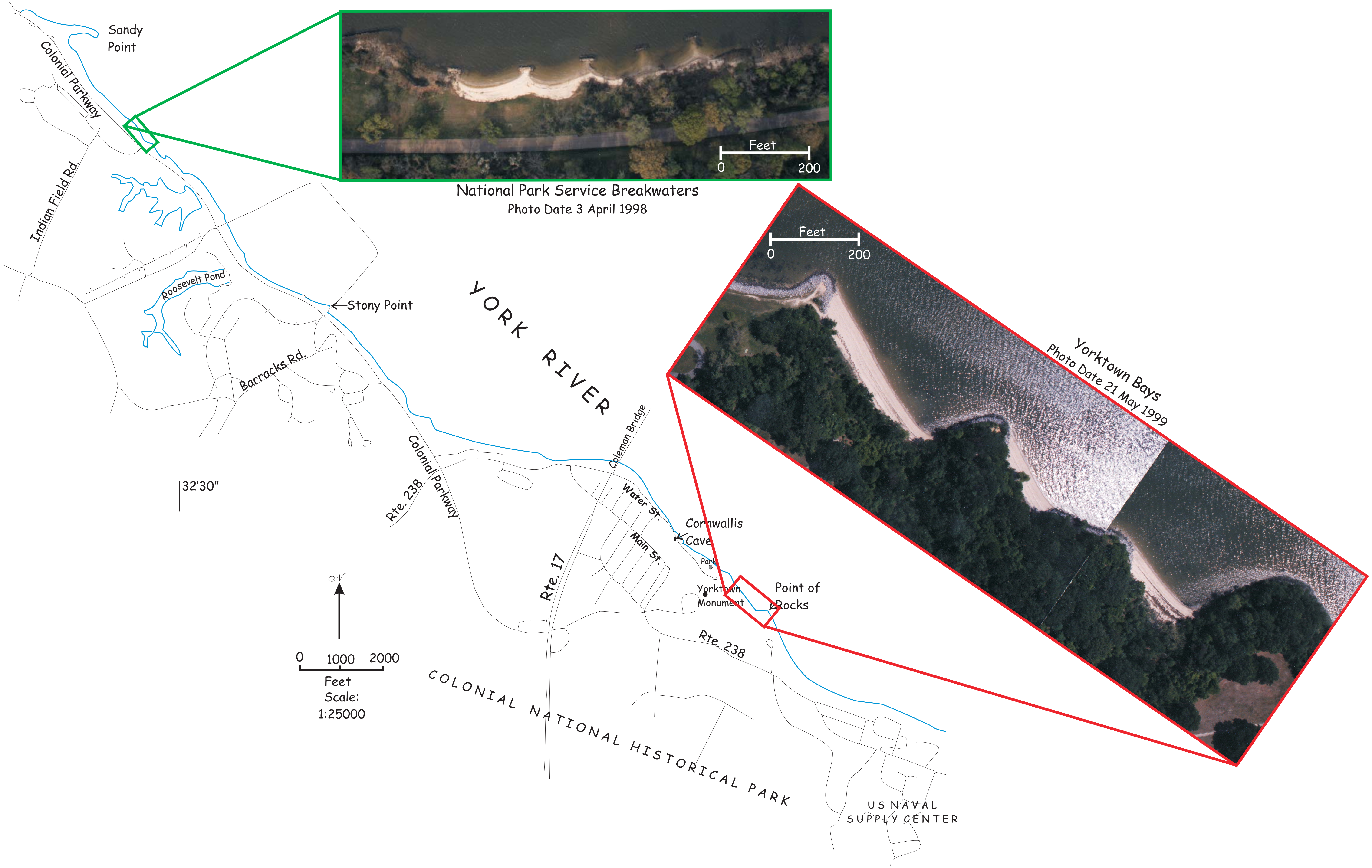


Figure 2-7. Location of embayed geomorphic monitoring sites on COLO property.

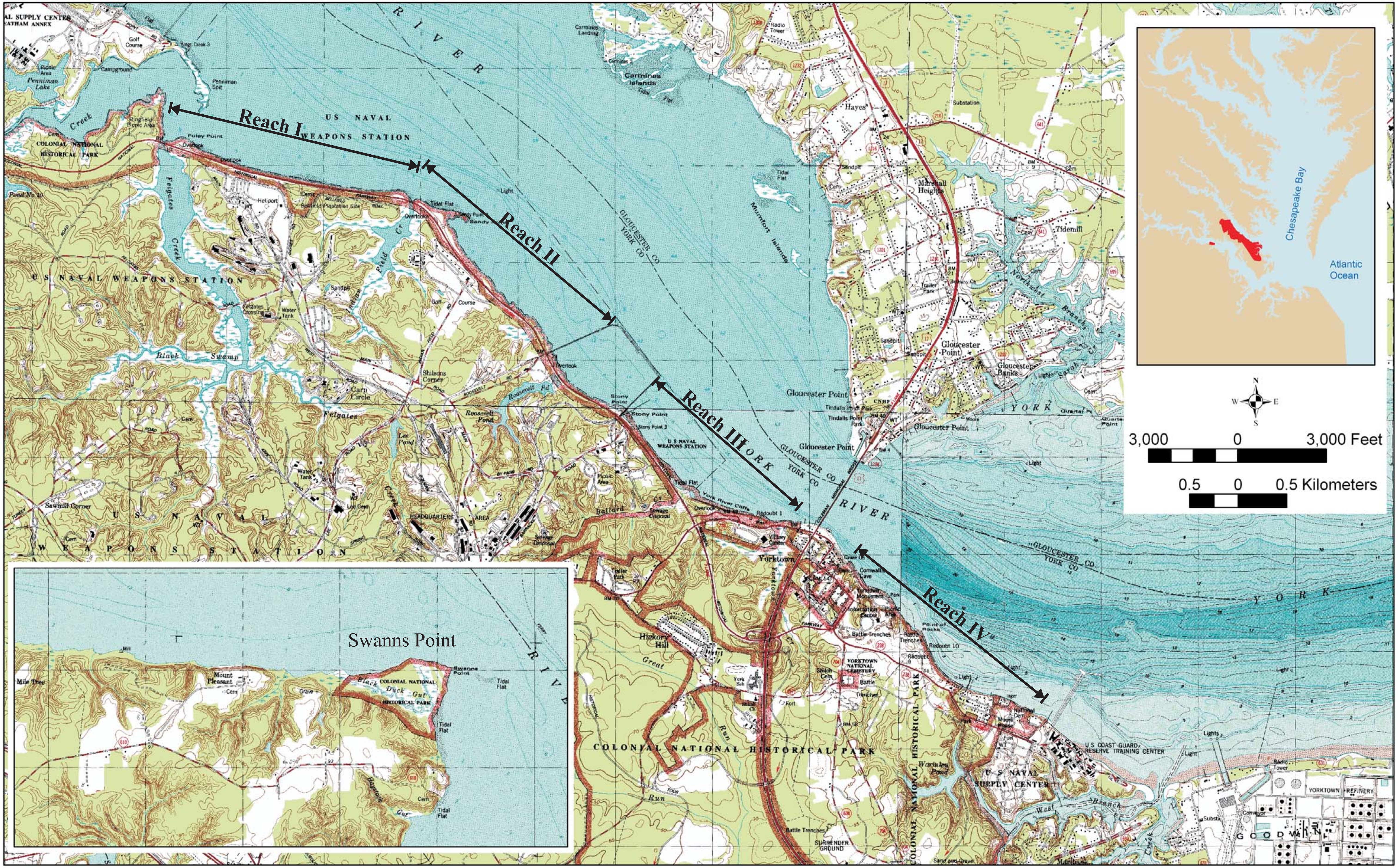
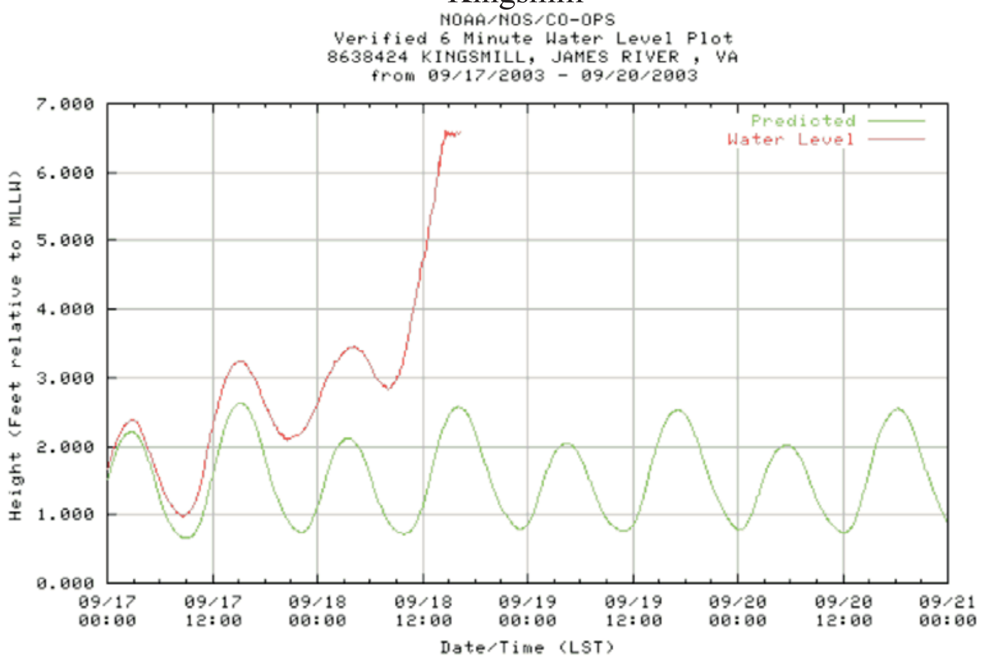
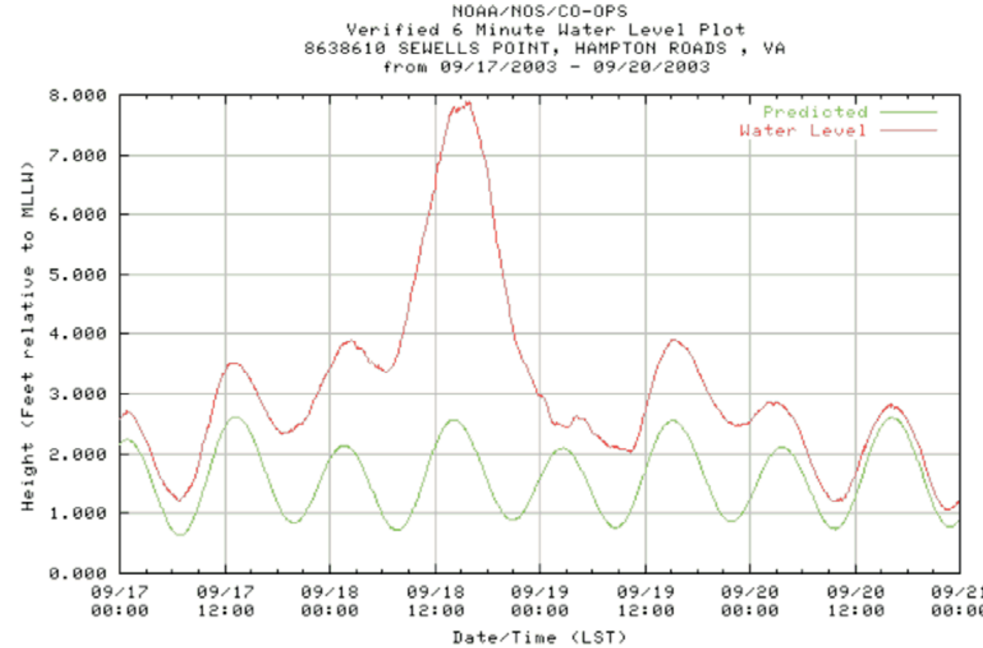


Figure 3-1 Location of reaches and bathymetry along COLO's York River shoreline and Swanns Point on the James River.

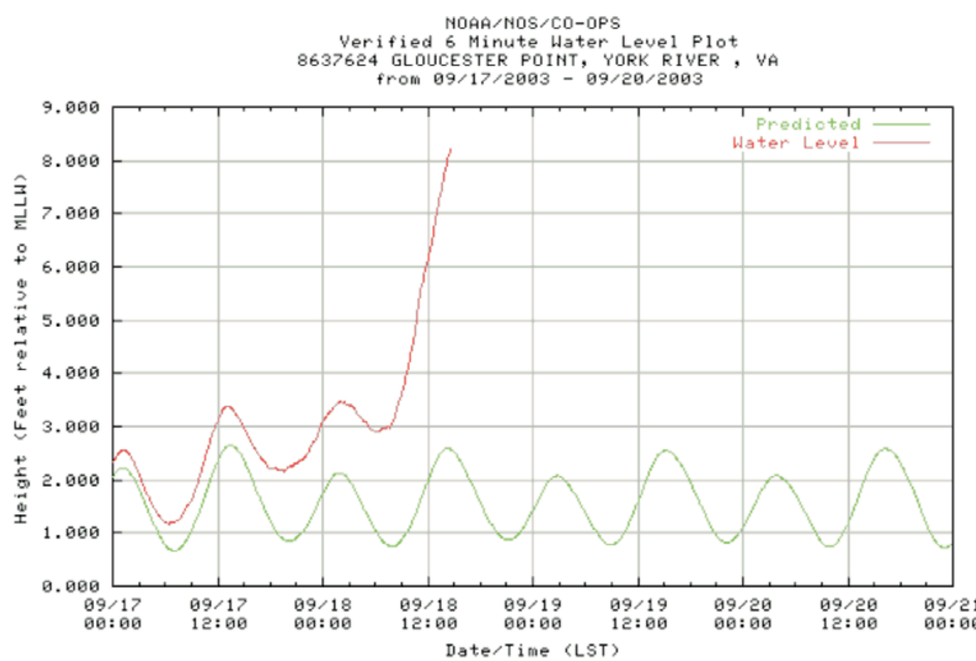
Kingsmill



Sewells Point



Gloucester Point



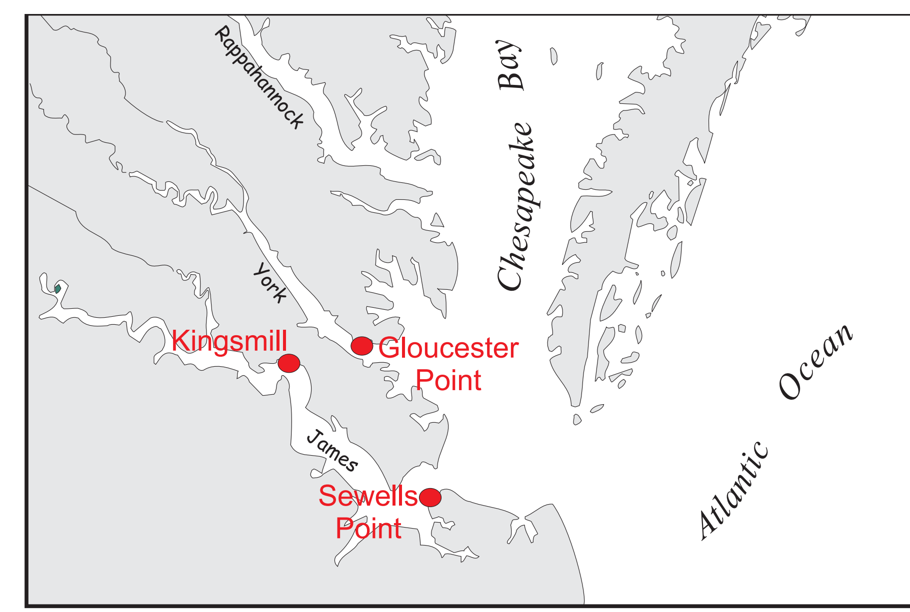


Figure 3-2. Verified water levels at tide gauges around Chesapeake Bay during Hurricane Isabel and approximate gauge location. From the NOAA website (http://www.co-ops.nos.noaa.gov/).

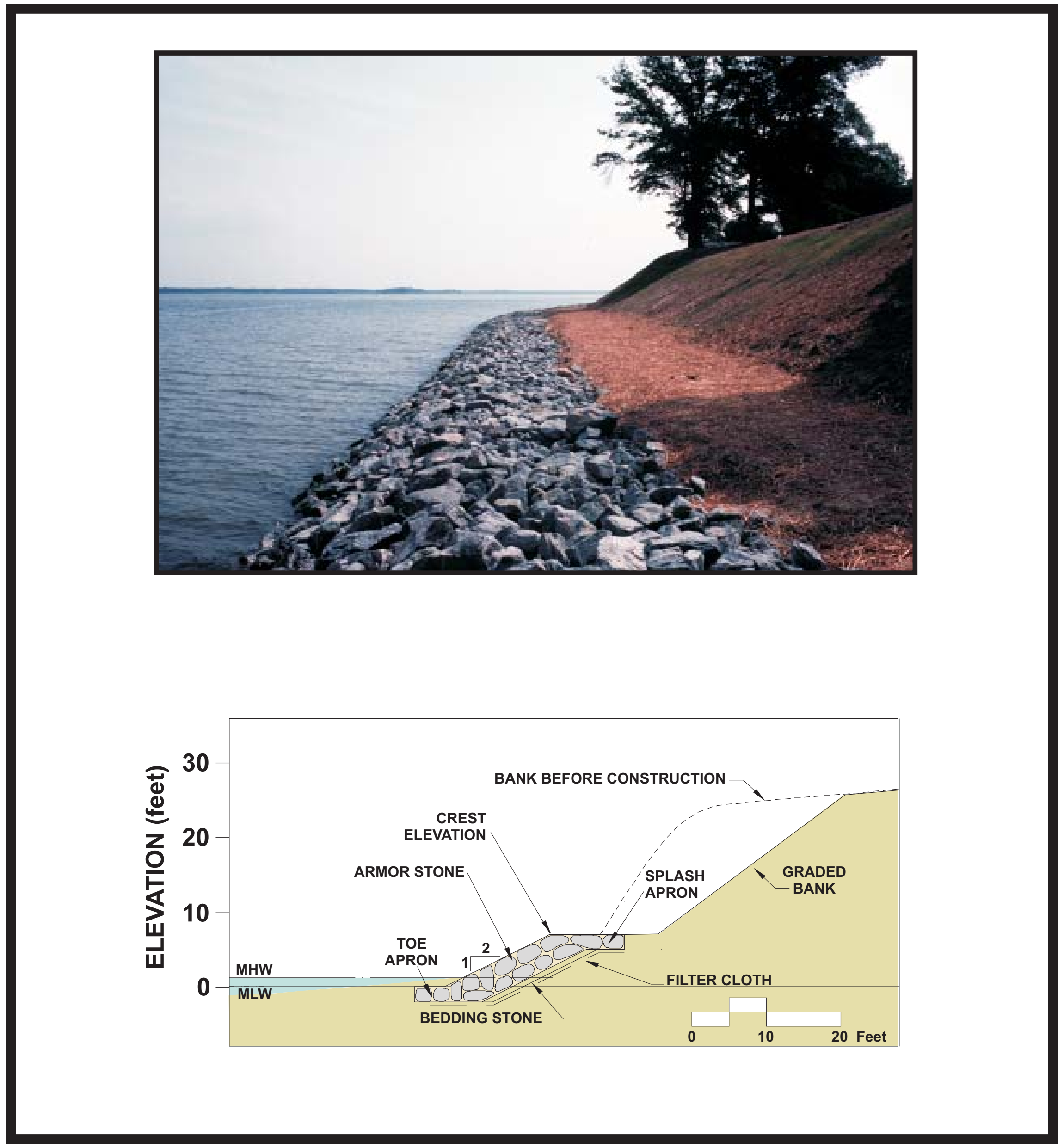


Figure 4-1. Stone revetment shortly after construction on the Potomac River, Virginia and cross-section of elements necessary for proper stone revetment design. Two layers of armor stone generally are lain over a bedding stone layer with filter cloth between the earth subgrade and bedding layer. Armor size is dependent on the design wave height which is determined from an analysis of wave climate for each project site (Hardaway and Byrne, 1999).

Figure 4-2. Stone sill along the St. Mary's River in Maryland and typical cross-section.

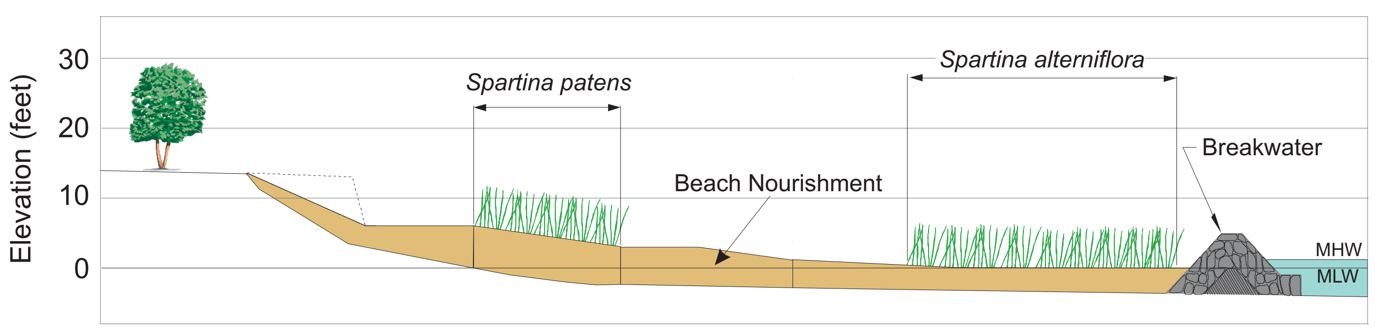


Figure 4-3. Breakwater system on Patuxent River in Calvert County, Maryland and a typical breakwater cross-section.

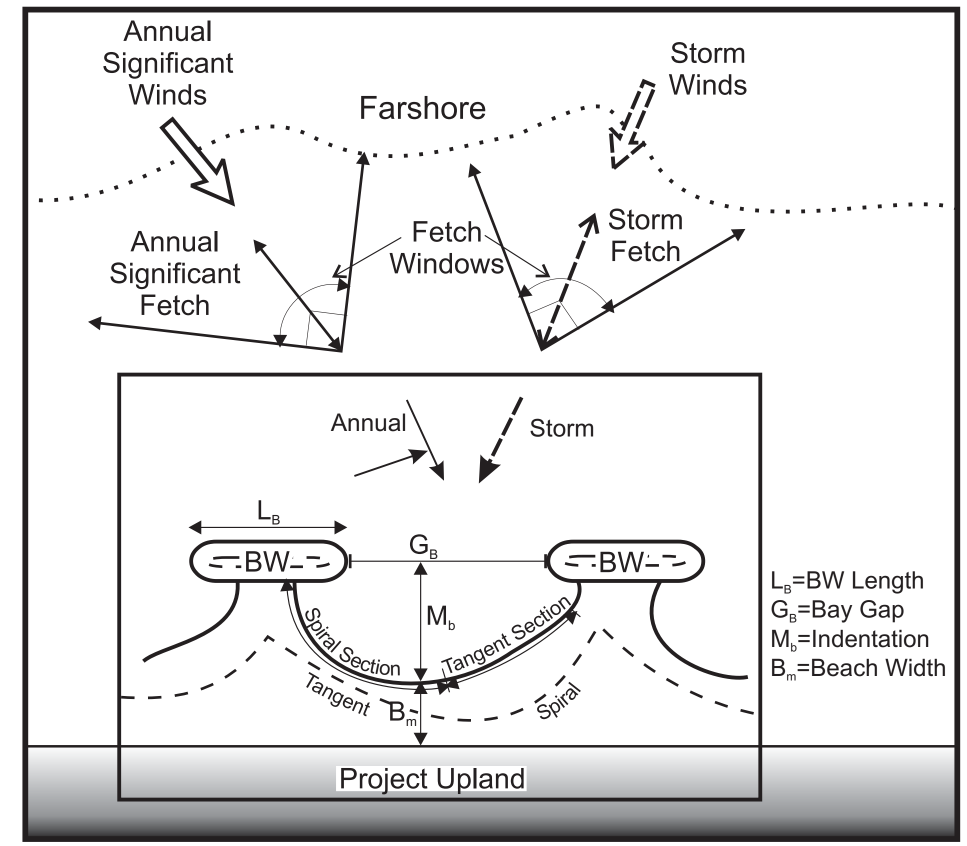


Figure 4-4. Parameters related to wind/wave generation and beach planform prediction.

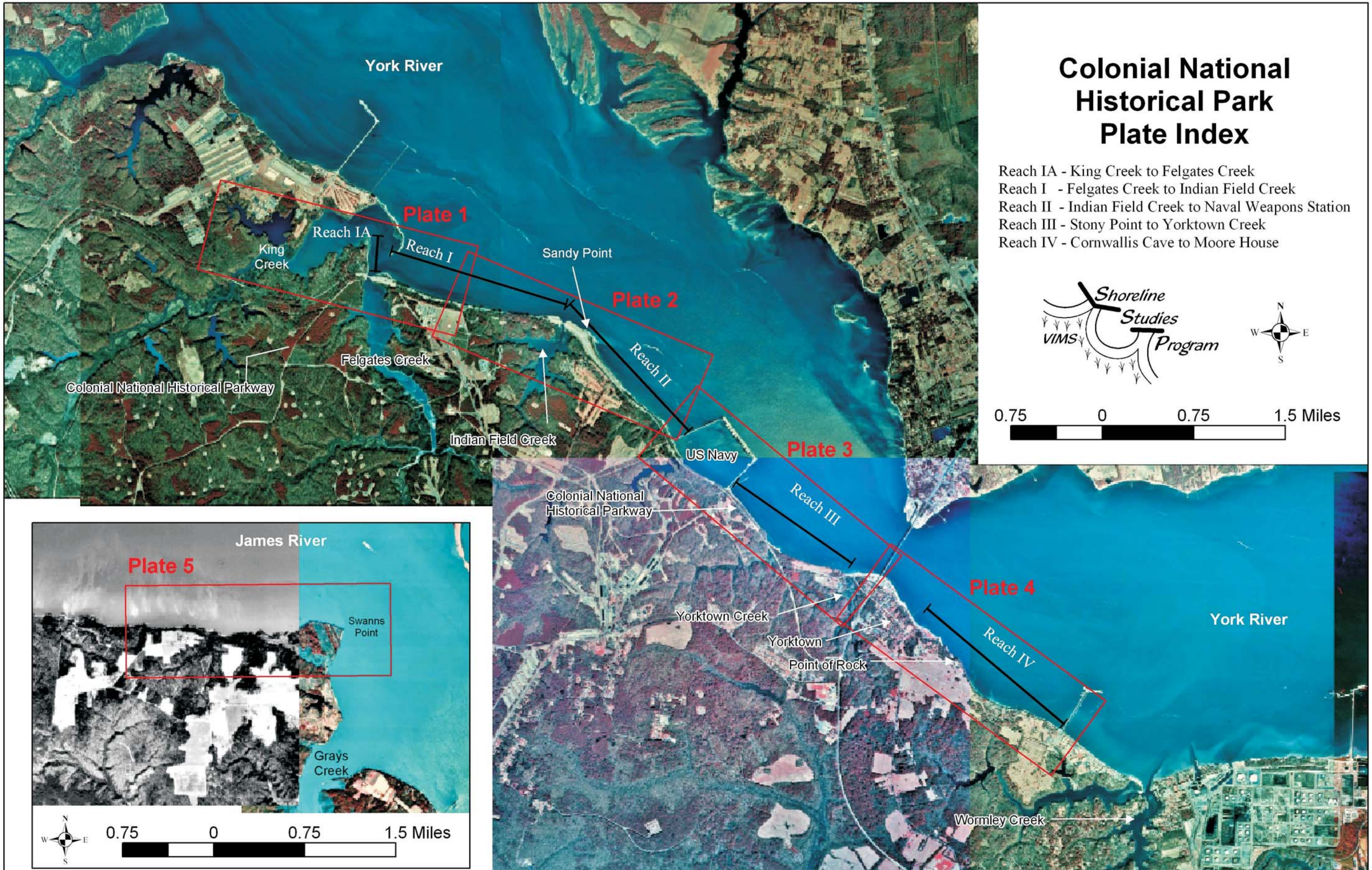


Figure 4-5. Plate and reach index for COLO's York River shoreline and Swanns Point on the James River.

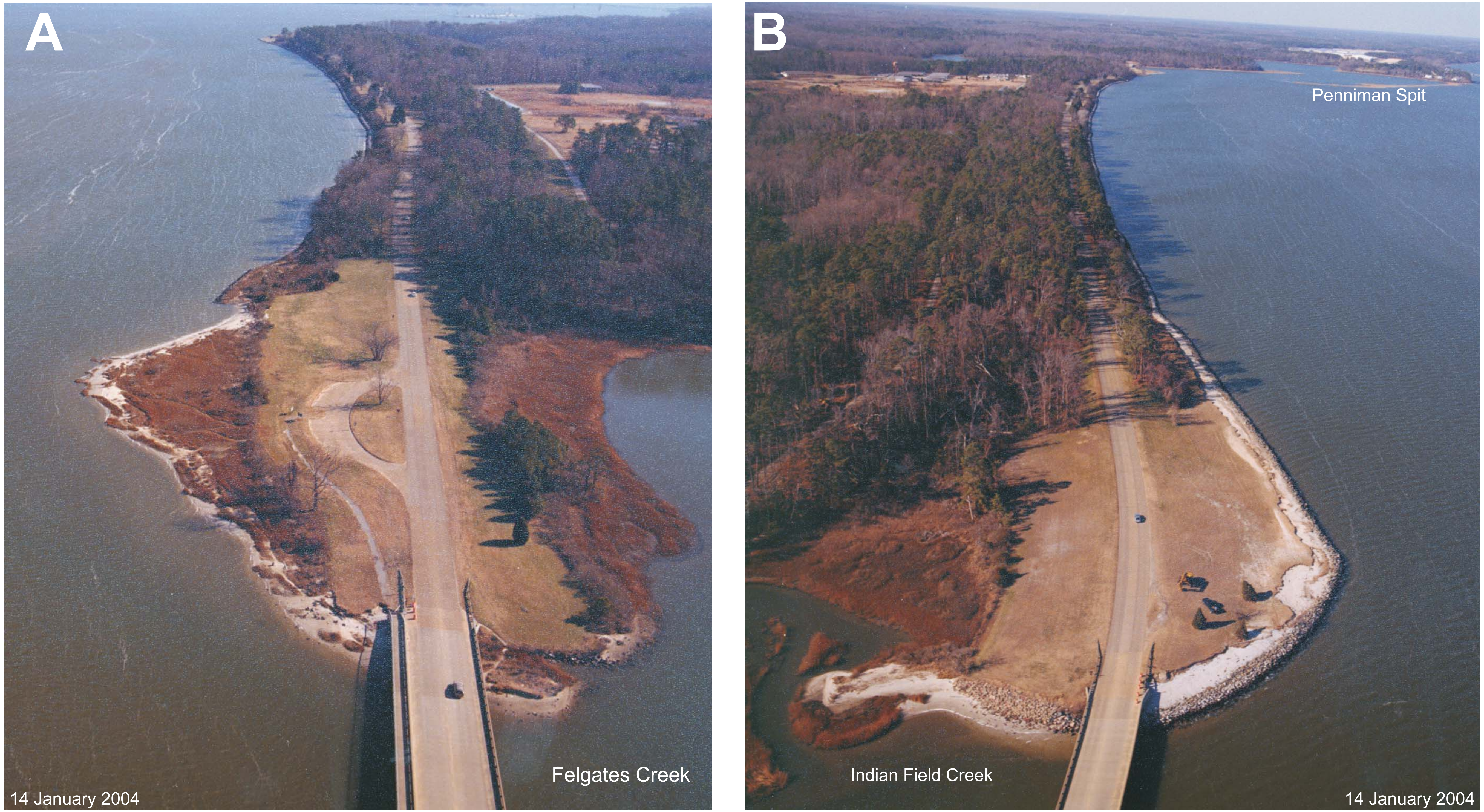


Figure 6-1. Aerial photos along Reach I of the COLO shoreline A) looking downriver from Felgates Creek and B) looking upriver toward Felgates Creek and Penniman Spit.

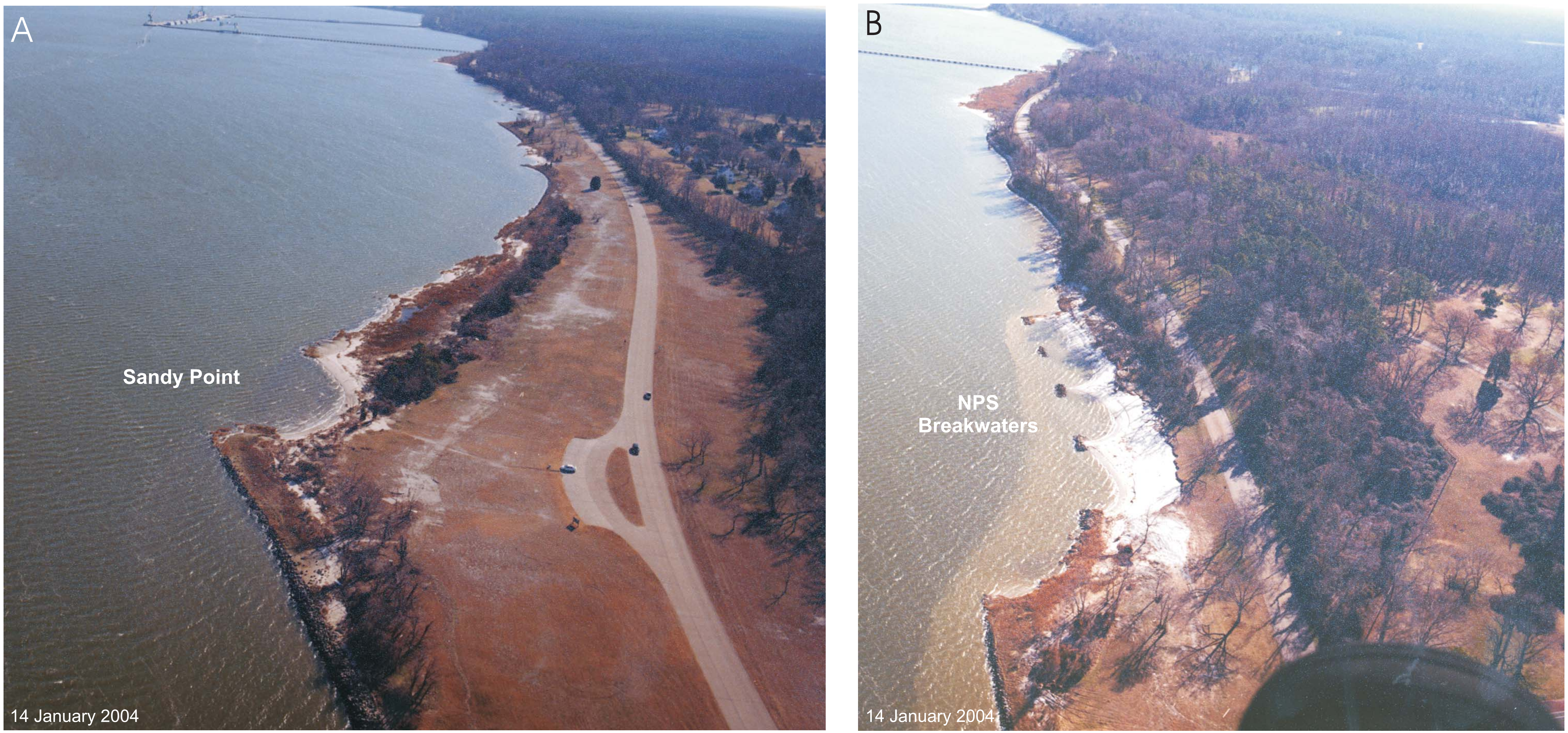


Figure 7-1. Aerial photos along Reach II of the COLO shoreline looking downriver A) toward the Naval Weapons Station Pier and B) showing the existing Parkway breakwaters.

Figure 7-2. Photos taken at K5 on 3 December 2005.

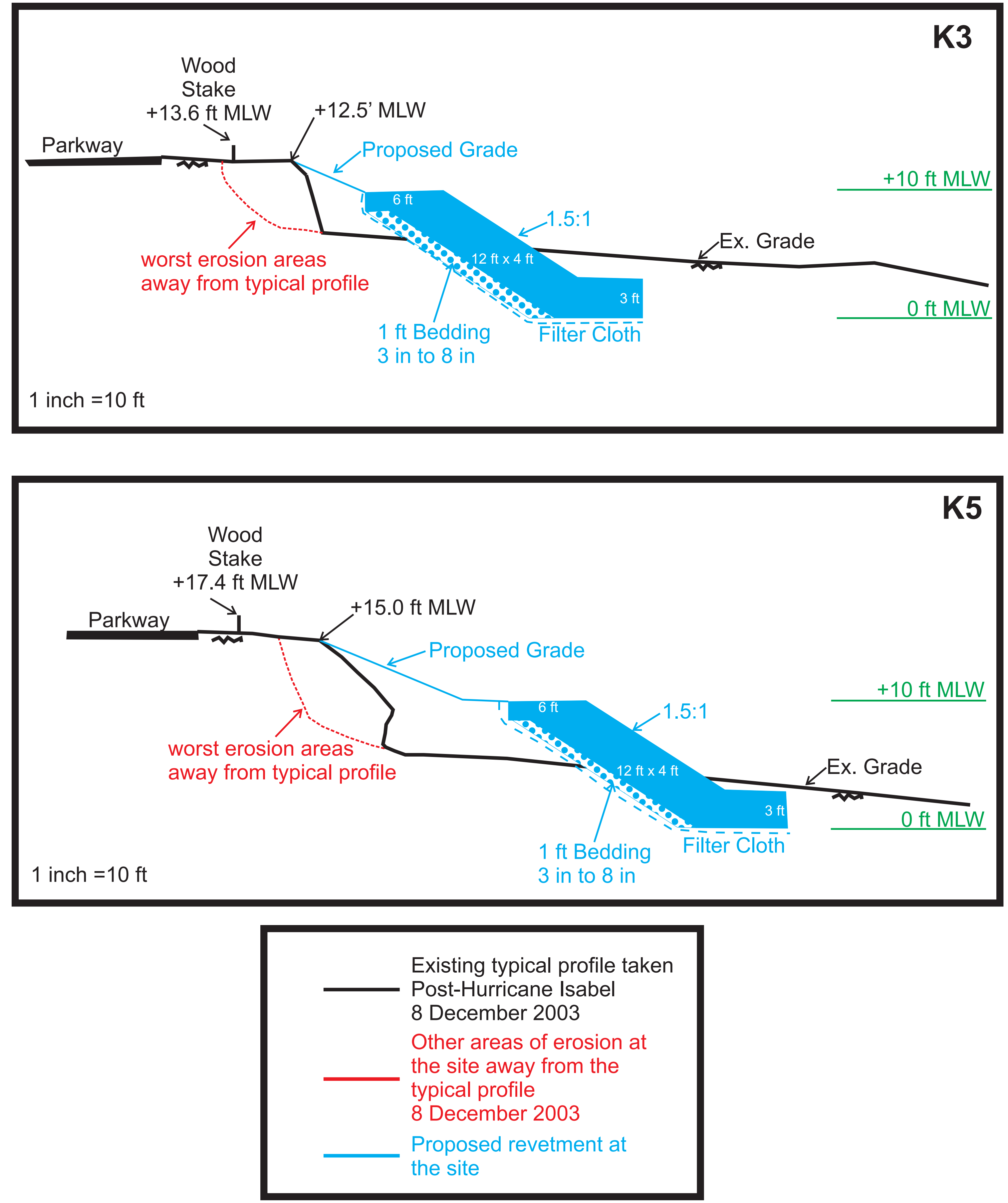


Figure 7-3. Typical profile taken after Hurricane Isabel and depiction of proposed revetment.

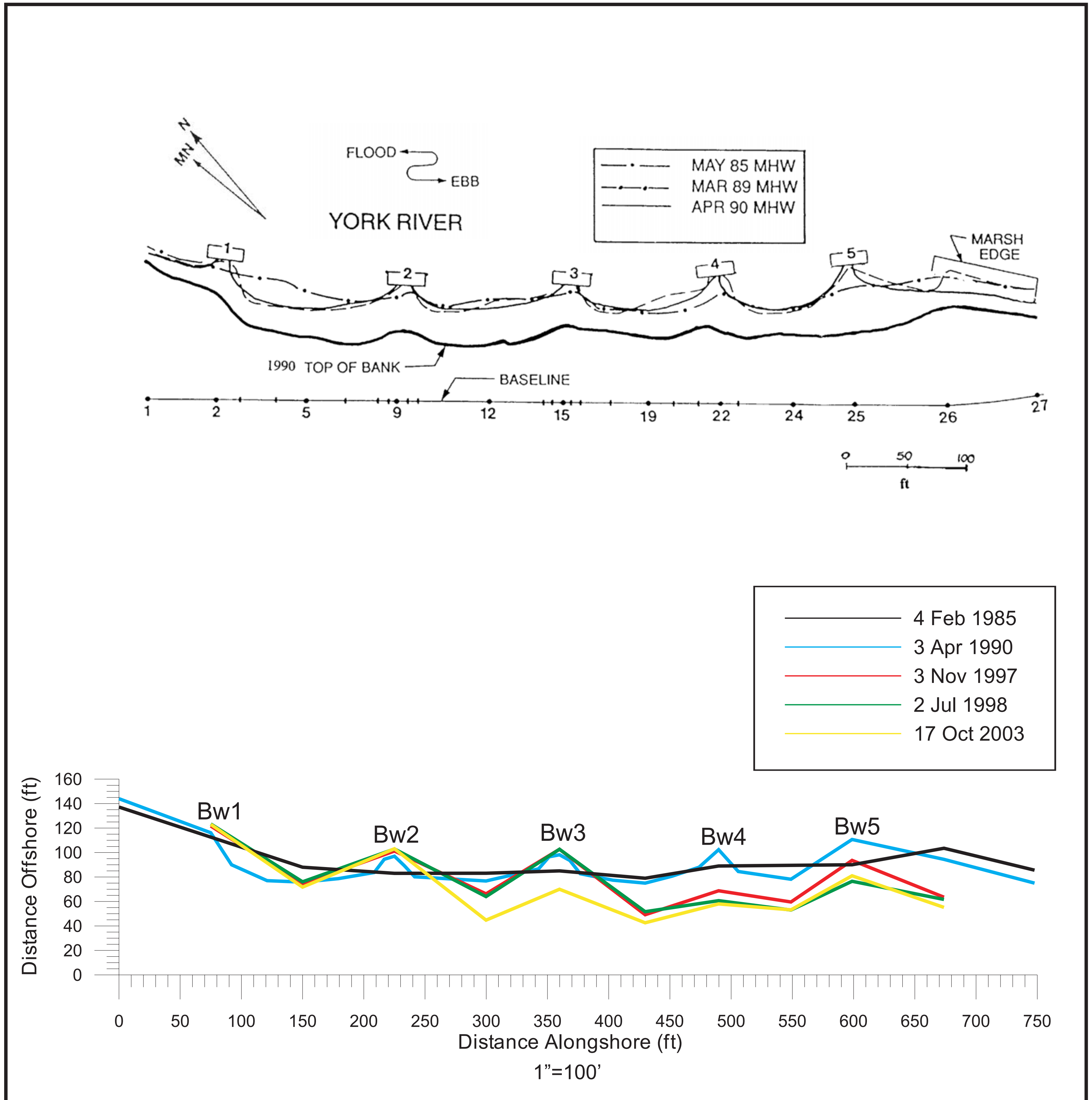


Figure 7-4. Distance to mean high water (+2.5 ft MLW) through time and the location of cross-sectional beach profiles at the Parkway Breakwaters.

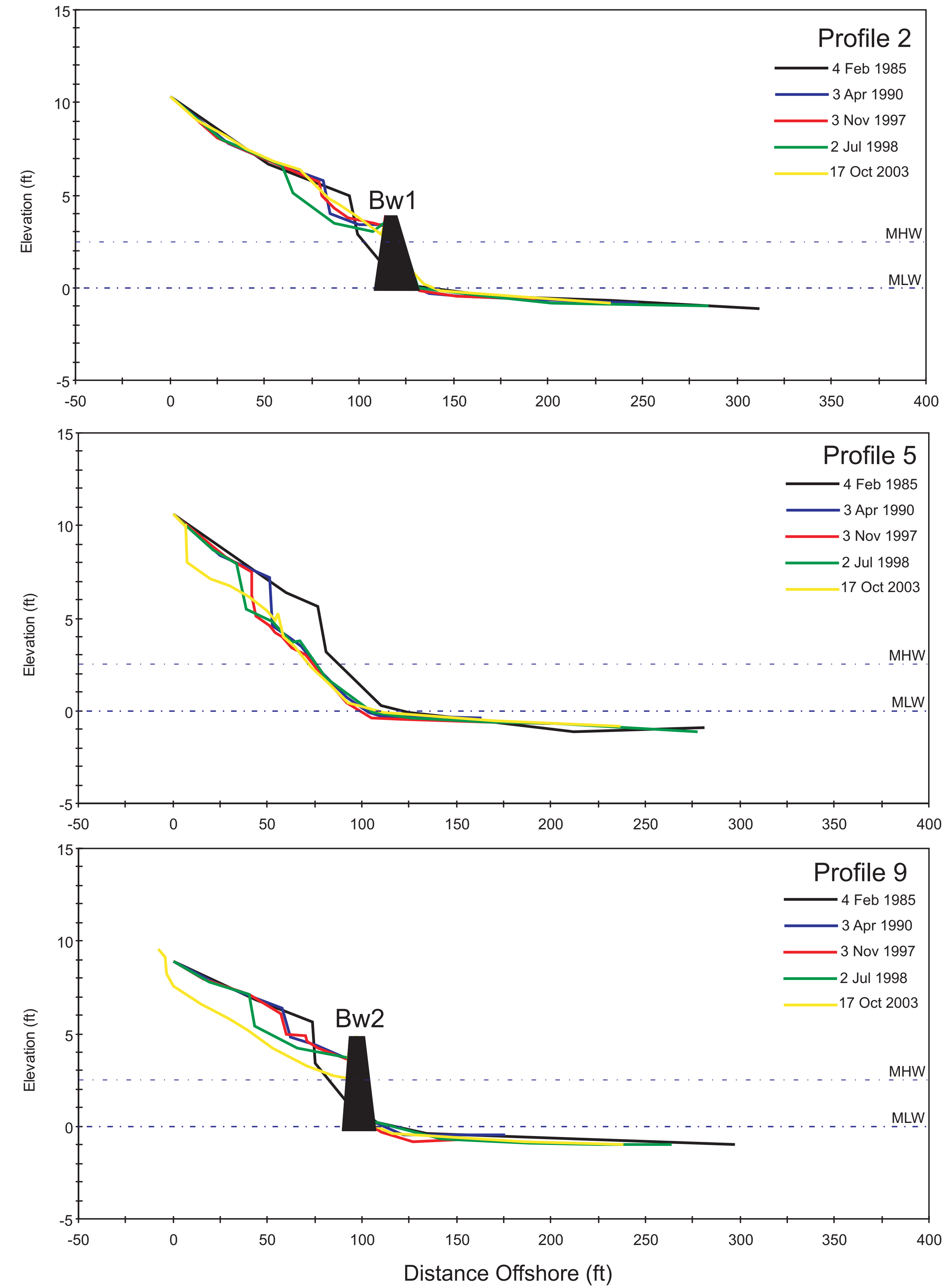


Figure 7-5. Cross-sectional profiles taken through time at Parkway breakwaters.

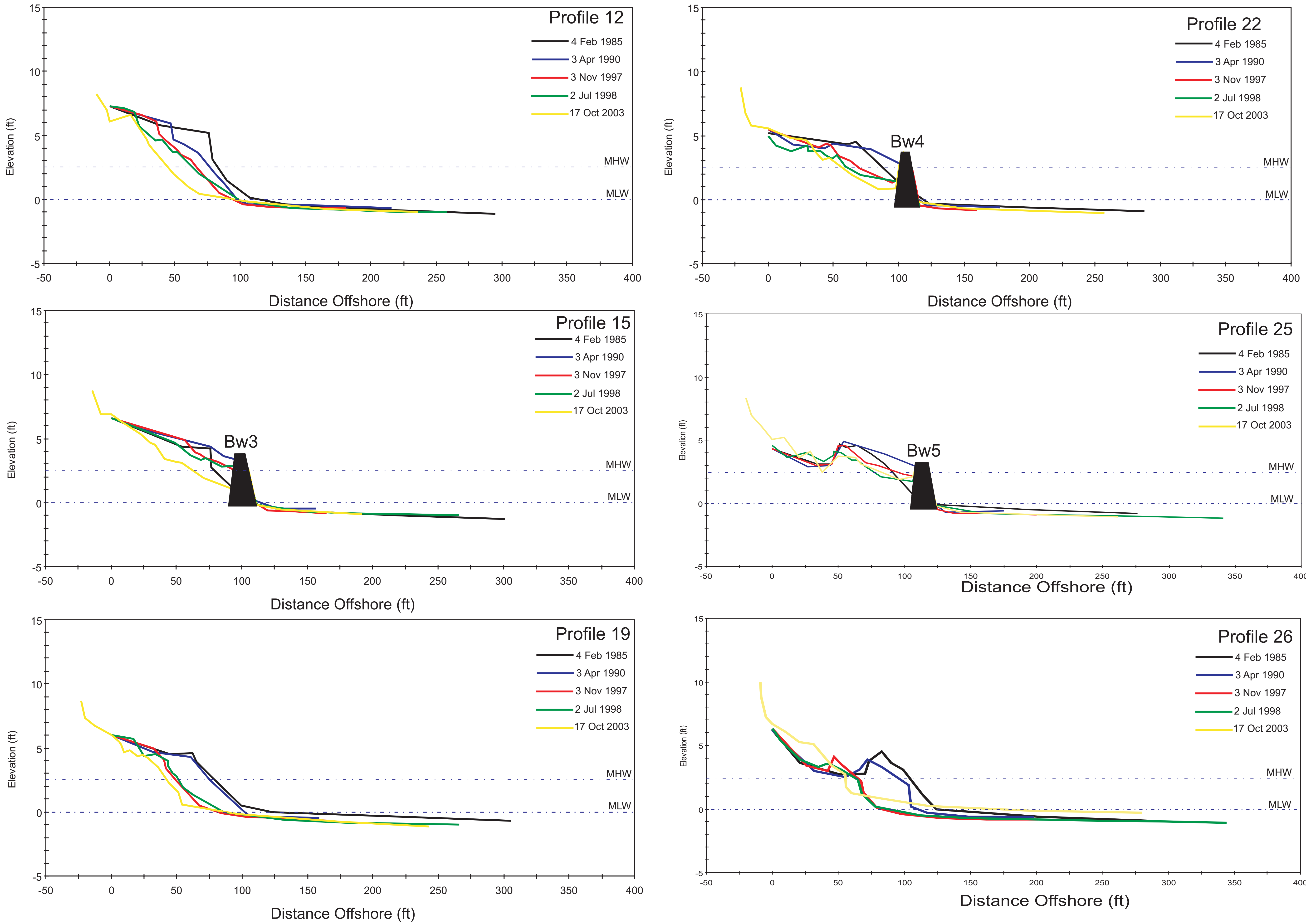


Figure 7-6. Cross-sectional profiles taken through time at Parkway breakwaters.

Figure 8-1. Ground photos taken at K3 almost three months after Hurricane Isabel.

Figure 9-1. Aerial photos along Reach IV of the COLO shoreline looking upriver toward Yorktown Beach and the Rt. 17 bridge showing A) the picnic area and B) Point of Rocks.

Figure 9-2. Ground photos showing the York River shoreline in the vicinity of the Moore House. Photos A and B show the rubble revetment and eroding shoreline; photo C shows the concrete structure; and D shows the grading of the shoreline on the private property near Moore House. Photos taken 3 March 2005.

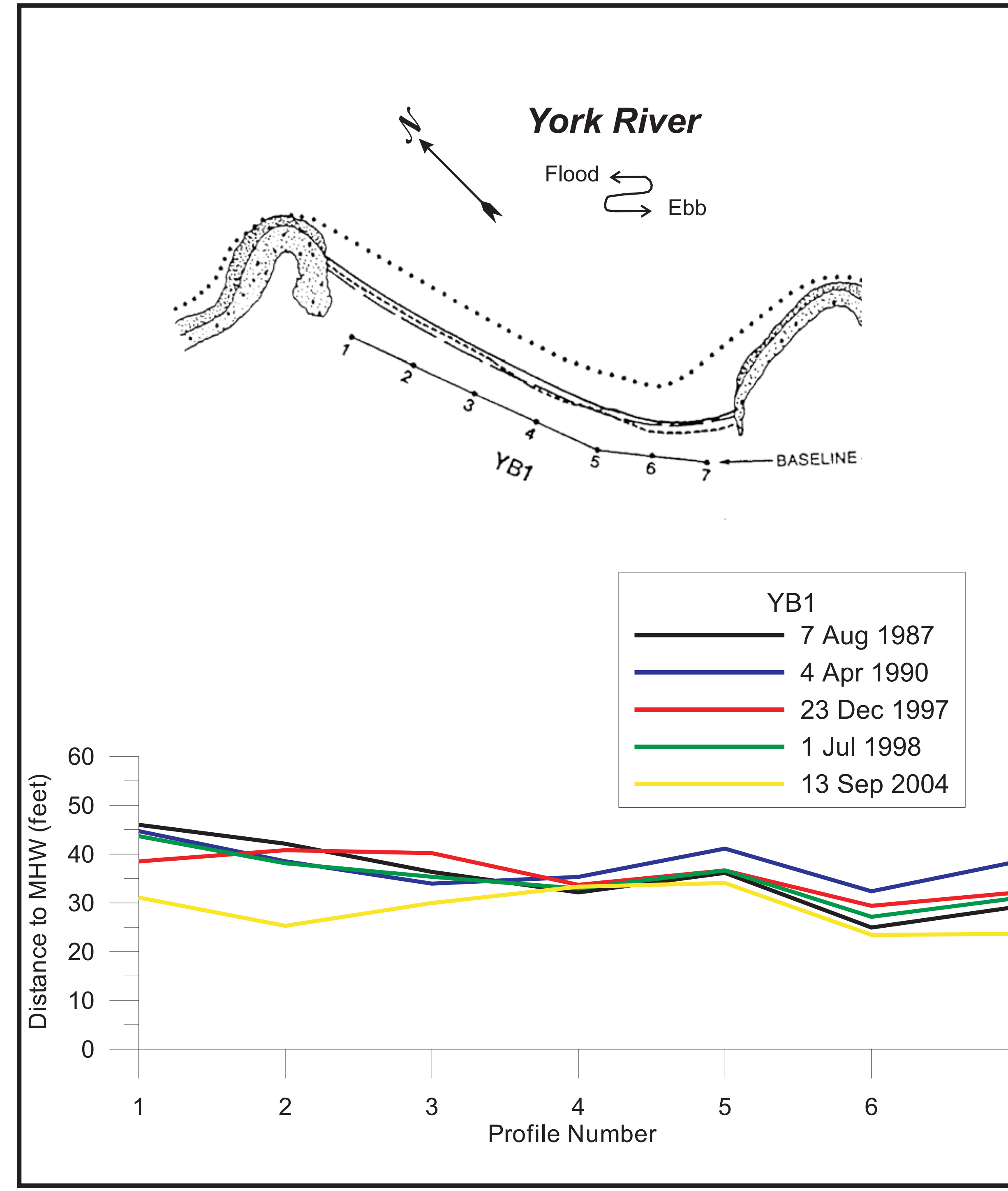


Figure 9-3. Distance to mean high water at Yorktown Bay 1.

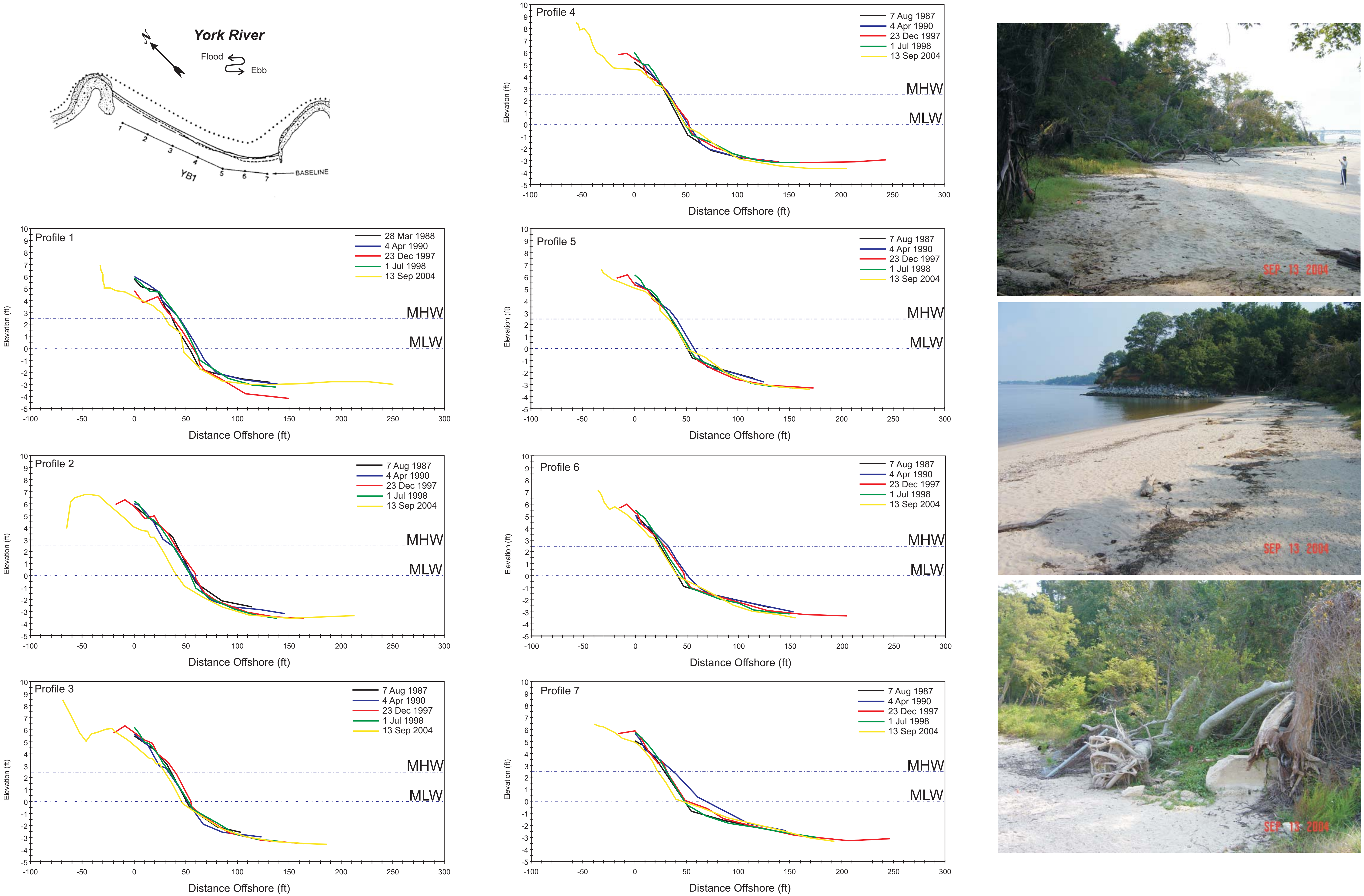
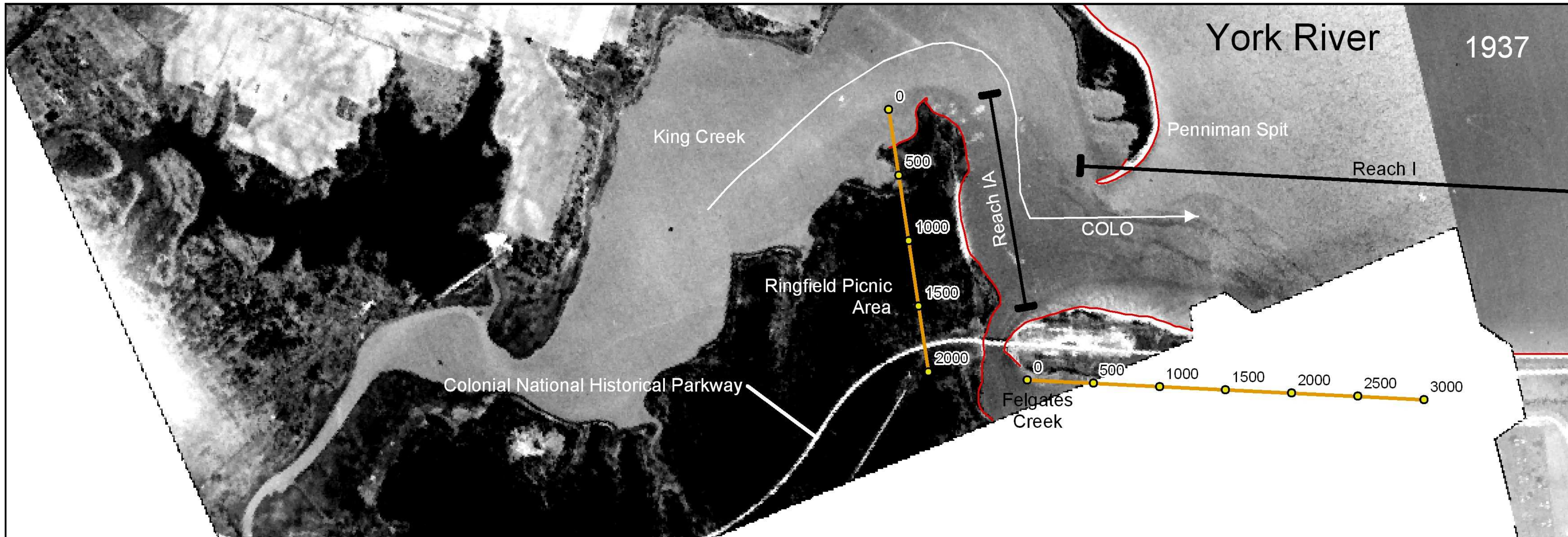


Figure 9-4. Individual beach profiles and ground photos taken at Yorktown Bay 1.

Figure 10-1. Aerial and ground photos of Swanns Point, COLO's property on the south side of the James River.

Appendix A

Ortho-rectified historical and recent aerial imagery



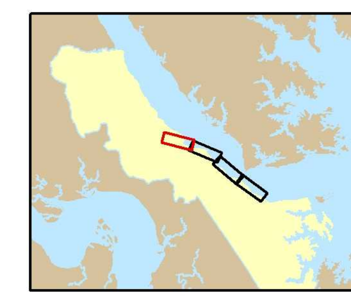
No Data Available

Colonial National Historical Park York River

Plate 1

Legend

- Transect Point
- Baseline
- 1937 Shoreline

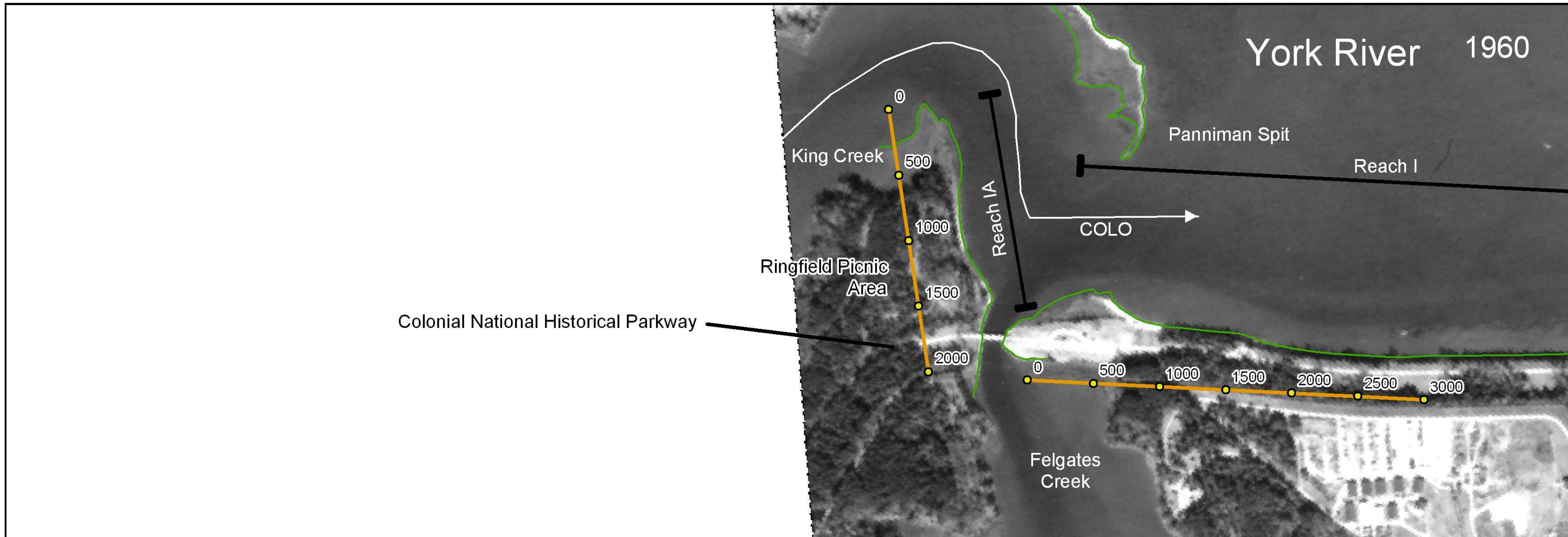


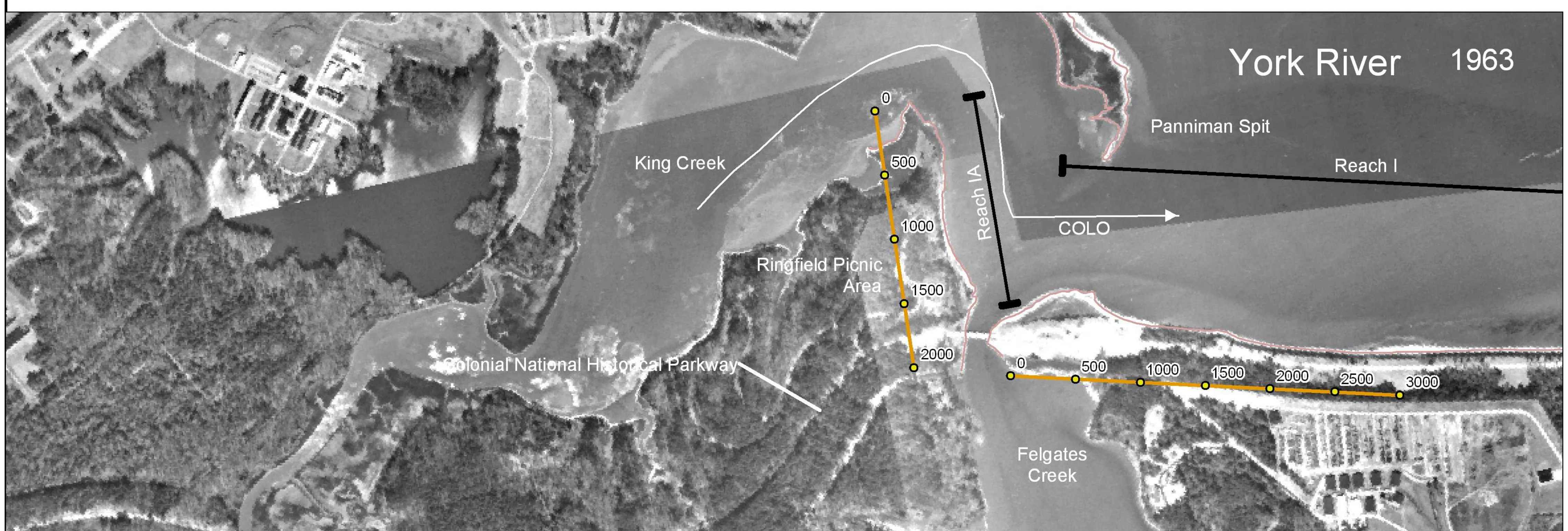
Shoreline Studies Program
VIMS

1,000 0 1,000 Feet

Colonial National Historical Park York River

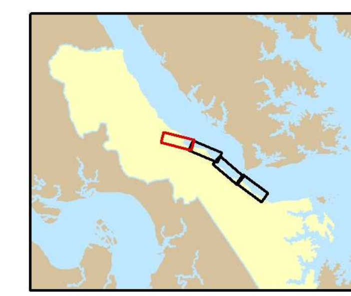
Plate 1





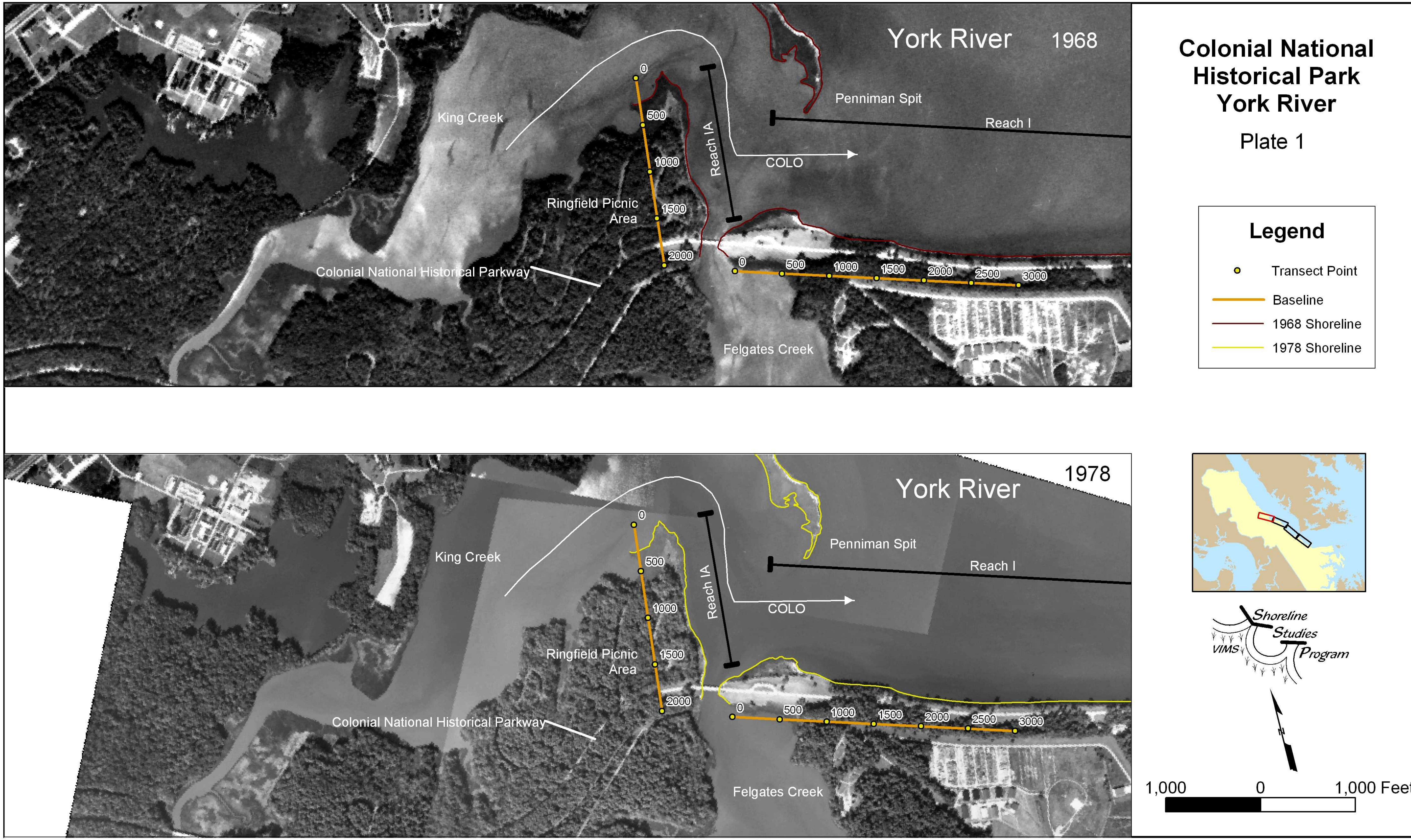
Legend

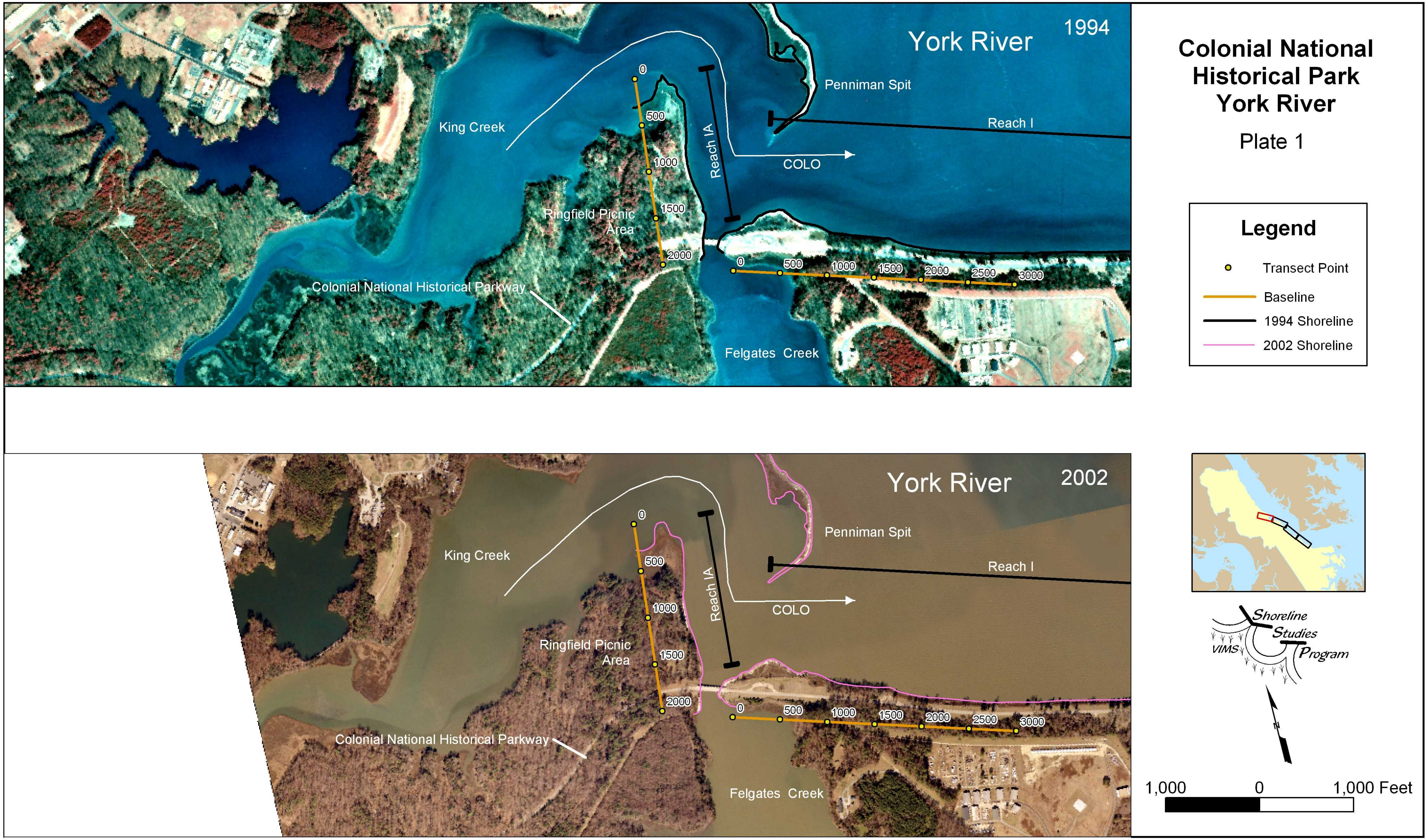
- Transect Point
- Baseline
- 1960 Shoreline
- 1963 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000 Feet

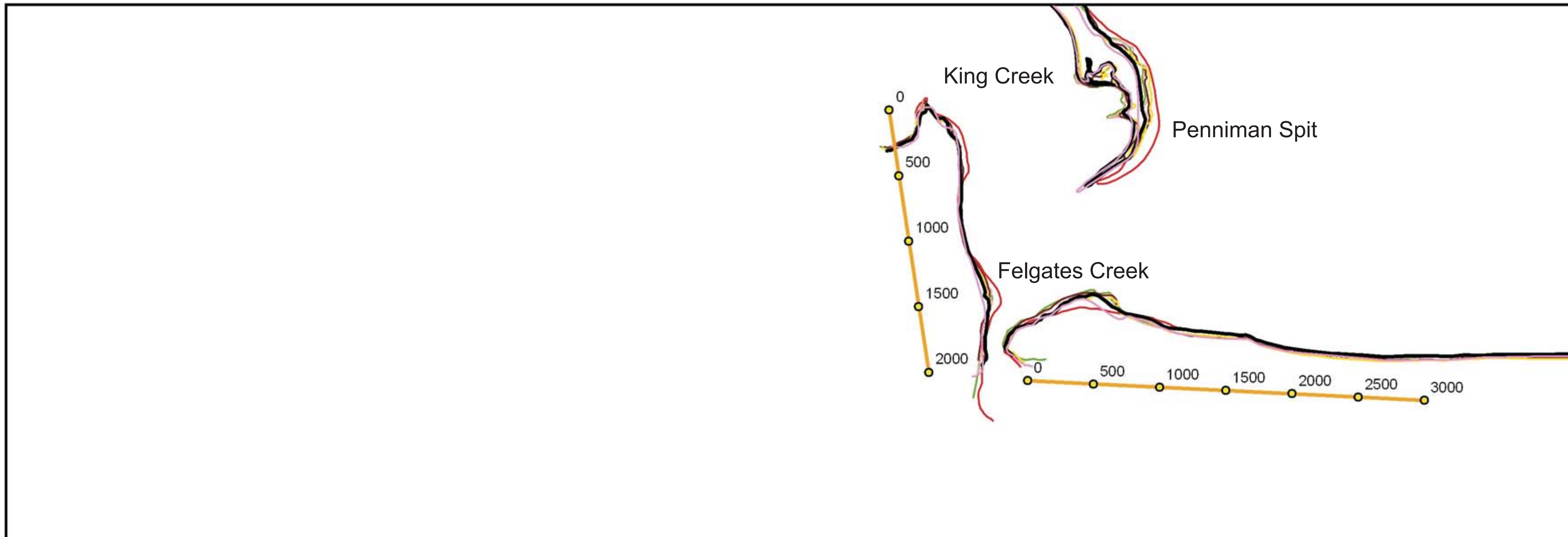

York River
1968
King Creek
Penniman Spit
Reach I
Reach IA
COLO
Ringfield Picnic Area
Colonial National Historical Parkway
Felgates Creek
0
500
1000
1500
2000
2500
3000
1978
Colonial National Historical Park
York River
Plate 1
Legend
Transect Point
Baseline
1968 Shoreline
1978 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet

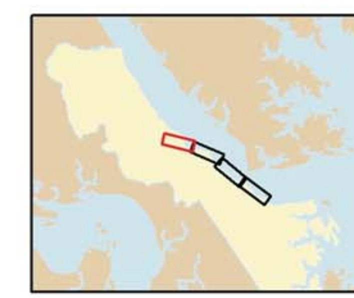


1994
York River
Penniman Spit
Reach I
Reach IA
COLO
King Creek
Ringfield Picnic Area
Colonial National Historical Parkway
Felgates Creek
0
500
1000
1500
2000
2500
3000
2002
York River
Penniman Spit
Reach I
Reach IA
COLO
King Creek
Ringfield Picnic Area
Colonial National Historical Parkway
Felgates Creek
Colonial National Historical Park
York River
Plate 1
Legend
Transect Point
Baseline
1994 Shoreline
2002 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet

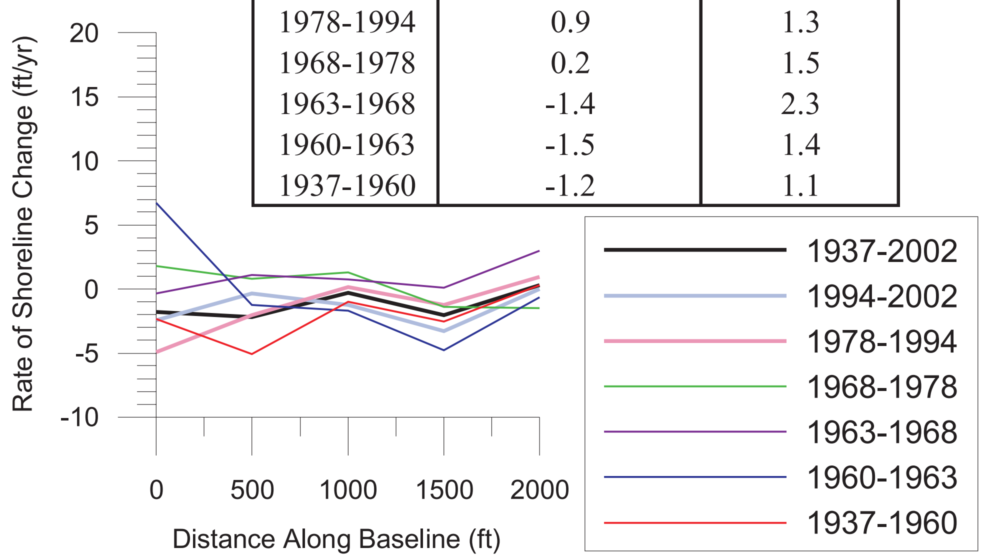
Colonial National Historical Park York River

Plate 1

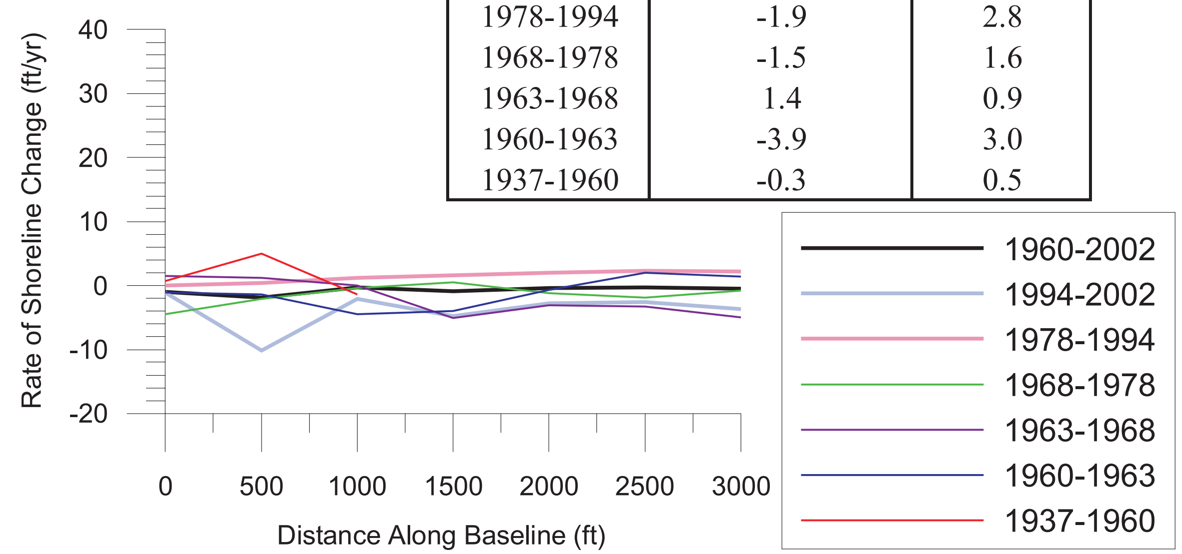


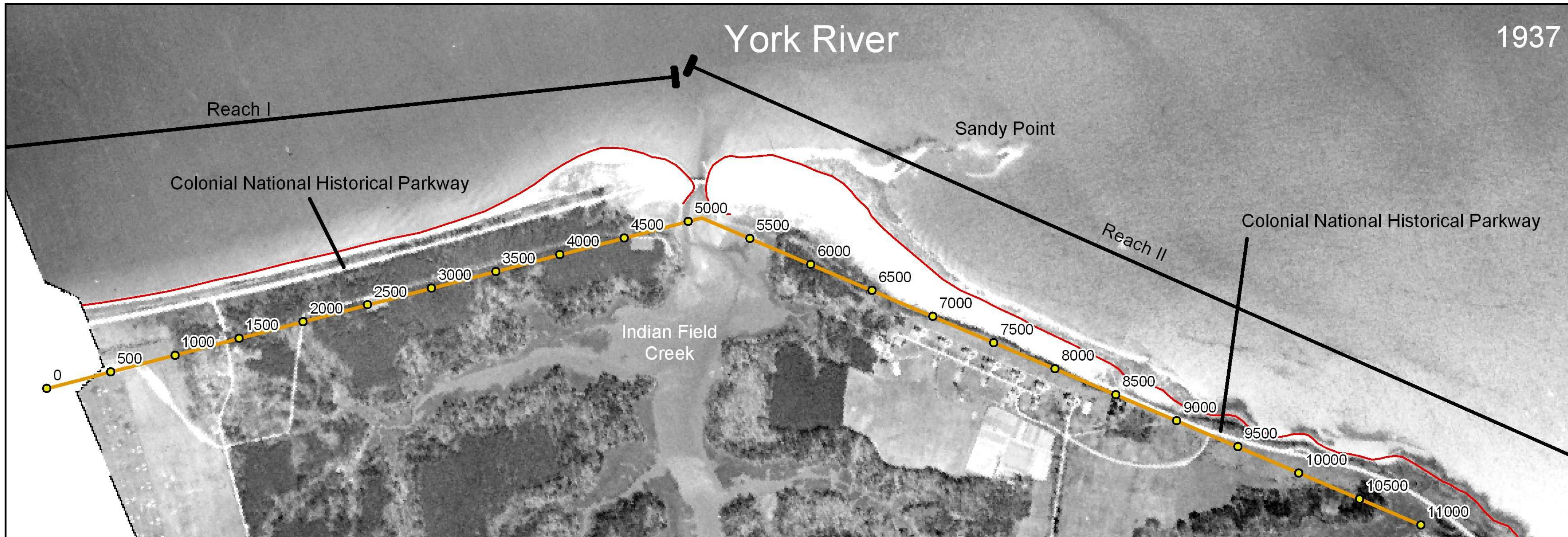


Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-2002	-2.1	2.0
1994-2002	-0.3	4.3
1978-1994	0.9	1.3
1968-1978	0.2	1.5
1963-1968	-1.4	2.3
1960-1963	-1.5	1.4
1937-1960	-1.2	1.1



Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1960-2002	-0.8	0.6
1994-2002	-1.2	2.4
1978-1994	-1.9	2.8
1968-1978	-1.5	1.6
1963-1968	1.4	0.9
1960-1963	-3.9	3.0
1937-1960	-0.3	0.5





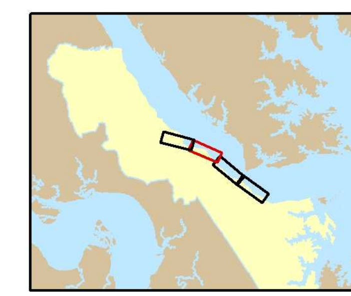
No Data Available

Colonial National Historical Park York River

Plate 2

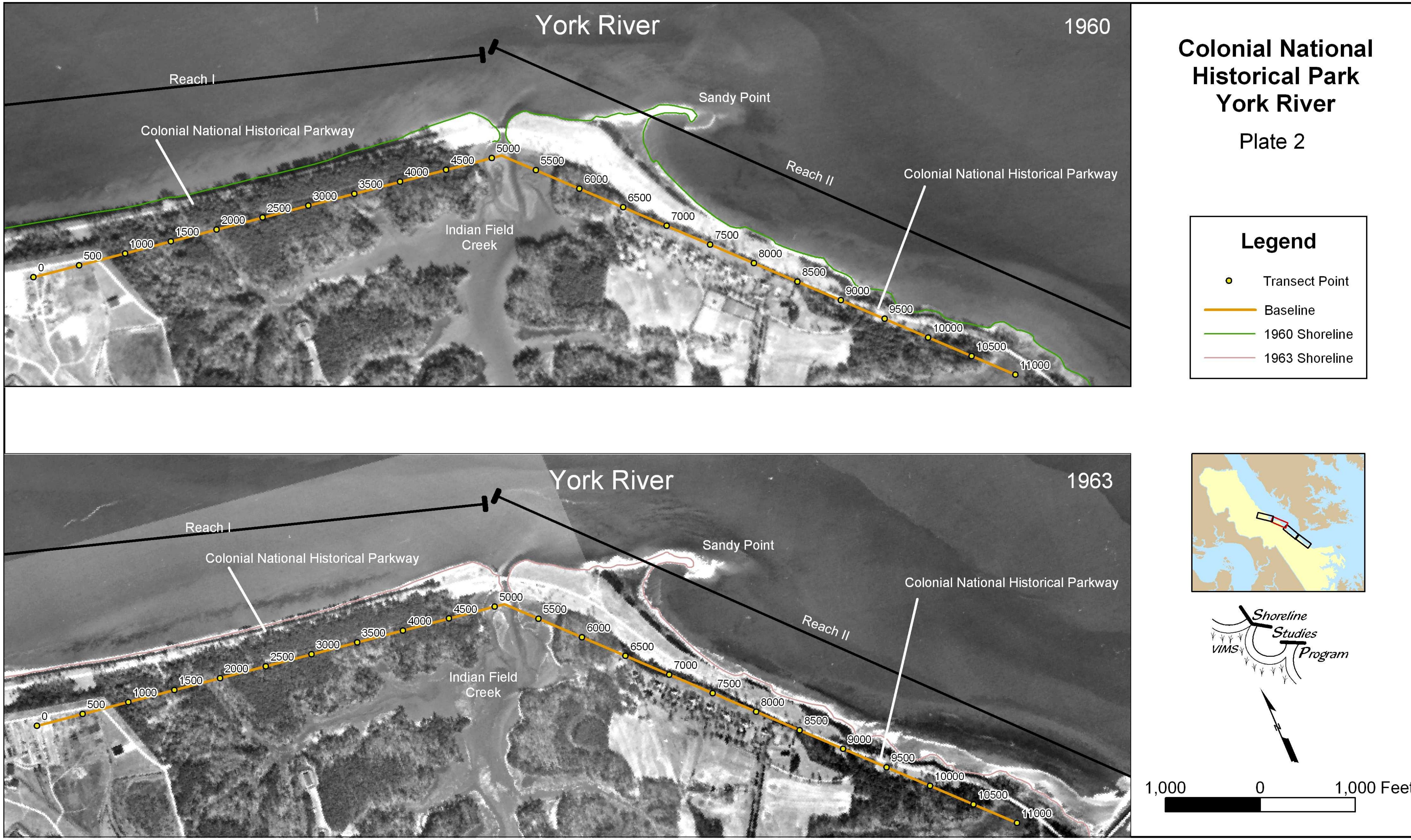
Legend

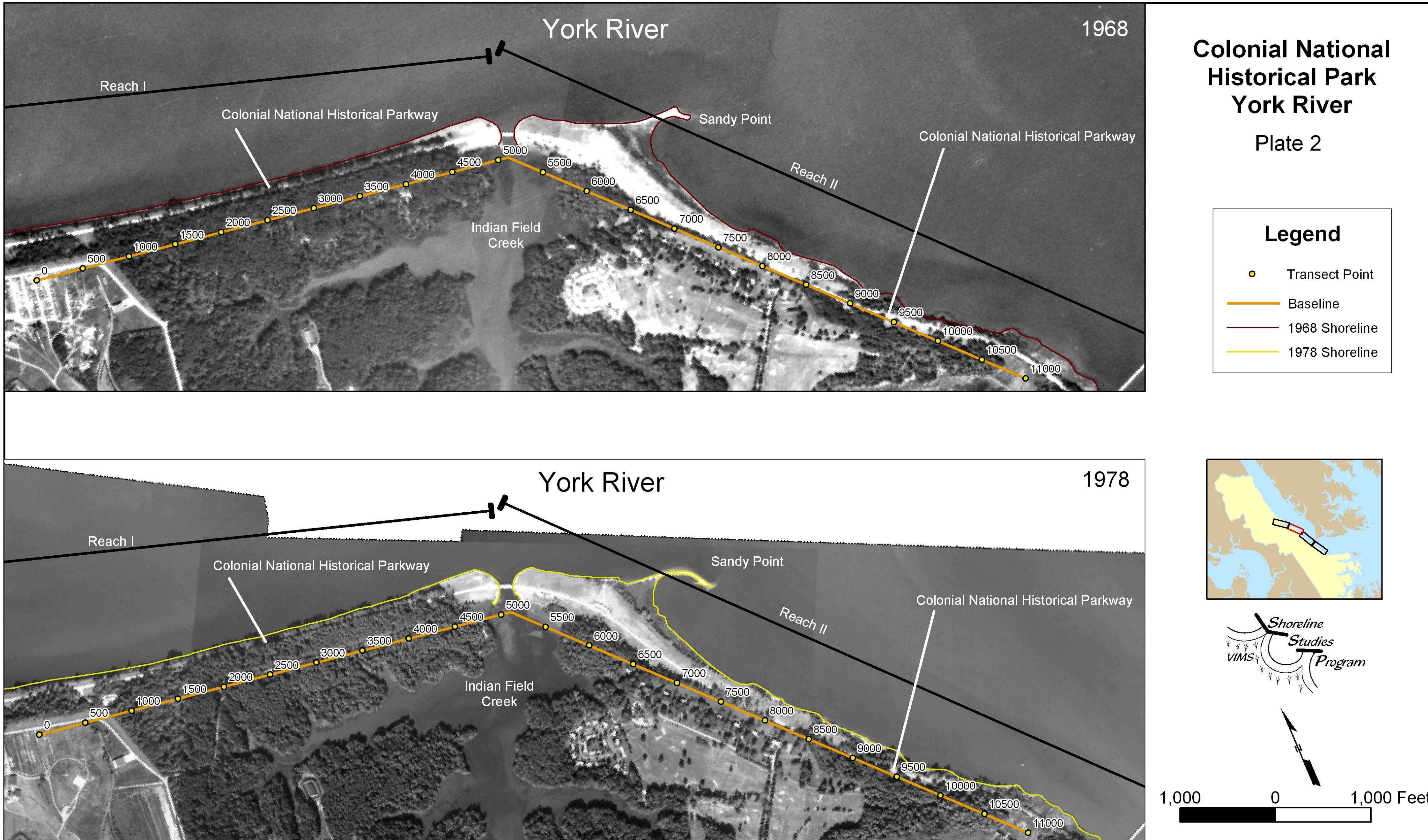
- Transect Point
- Baseline
- 1937 Shoreline

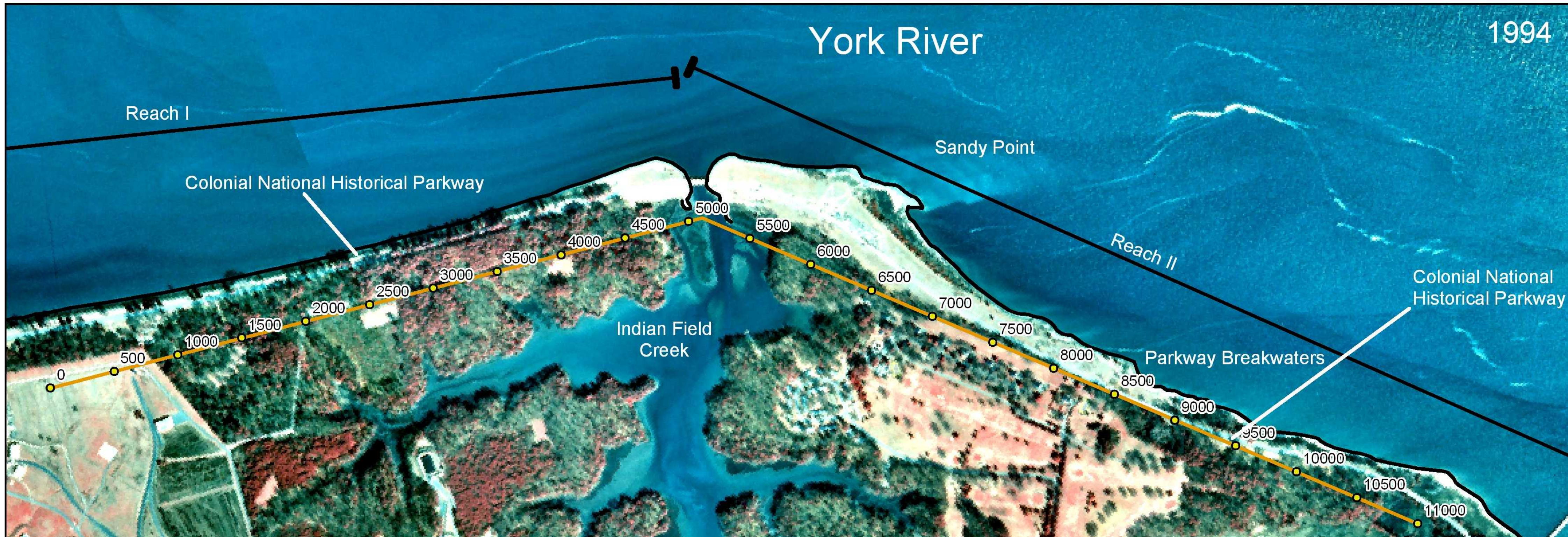


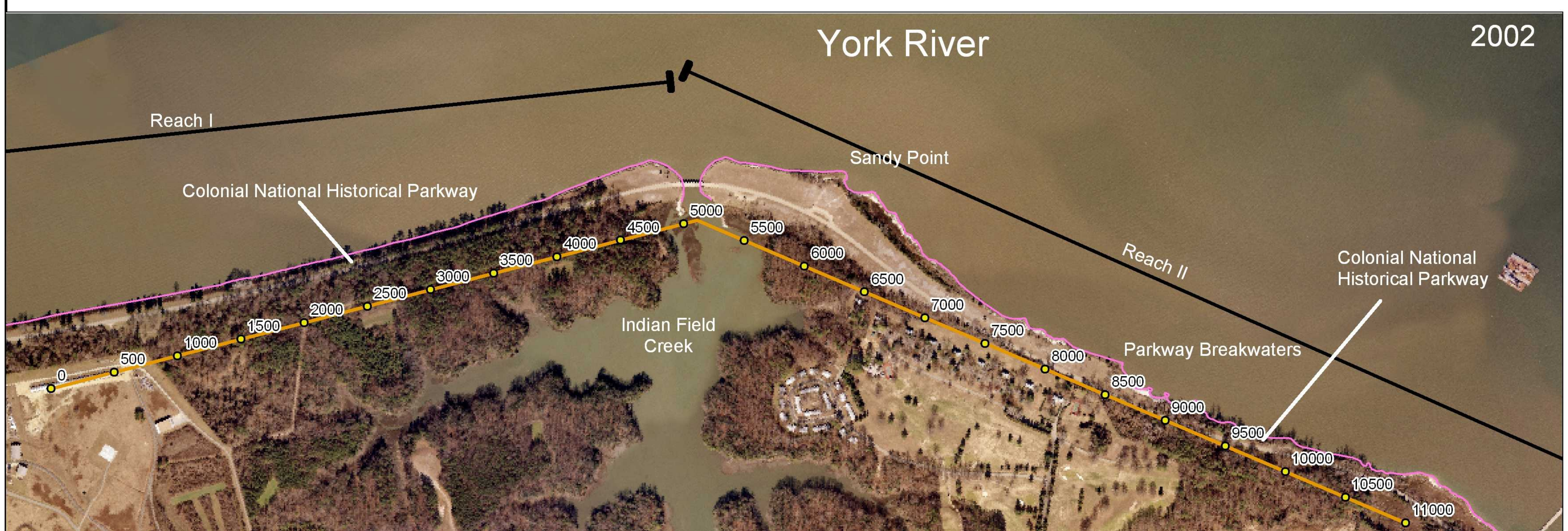
Shoreline Studies Program
VIMS

1,000 0 1,000 Feet


York River
1960
Reach I
Reach II
Sandy Point
Colonial National Historical Parkway
Colonial National Historical Parkway
Indian Field Creek
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
York River
1963
Reach I
Reach II
Sandy Point
Colonial National Historical Parkway
Colonial National Historical Parkway
Indian Field Creek
Colonial National Historical Park York River
Plate 2
Legend
Transect Point
Baseline
1960 Shoreline
1963 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet


Colonial National Historical Park
York River
Plate 2
York River
1968
Reach I
Reach II
Colonial National Historical Parkway
Sandy Point
Colonial National Historical Parkway
Indian Field Creek
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
York River
1978
Reach I
Reach II
Colonial National Historical Parkway
Sandy Point
Colonial National Historical Parkway
Indian Field Creek
Legend
Transect Point
Baseline
1968 Shoreline
1978 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet



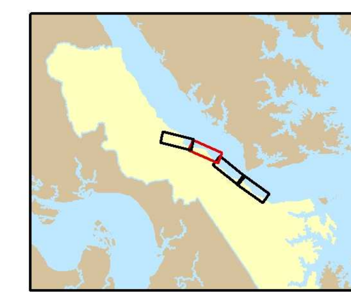


Colonial National Historical Park York River

Plate 2

Legend

- Transect Point
- Baseline
- 1994 Shoreline
- 2002 Shoreline

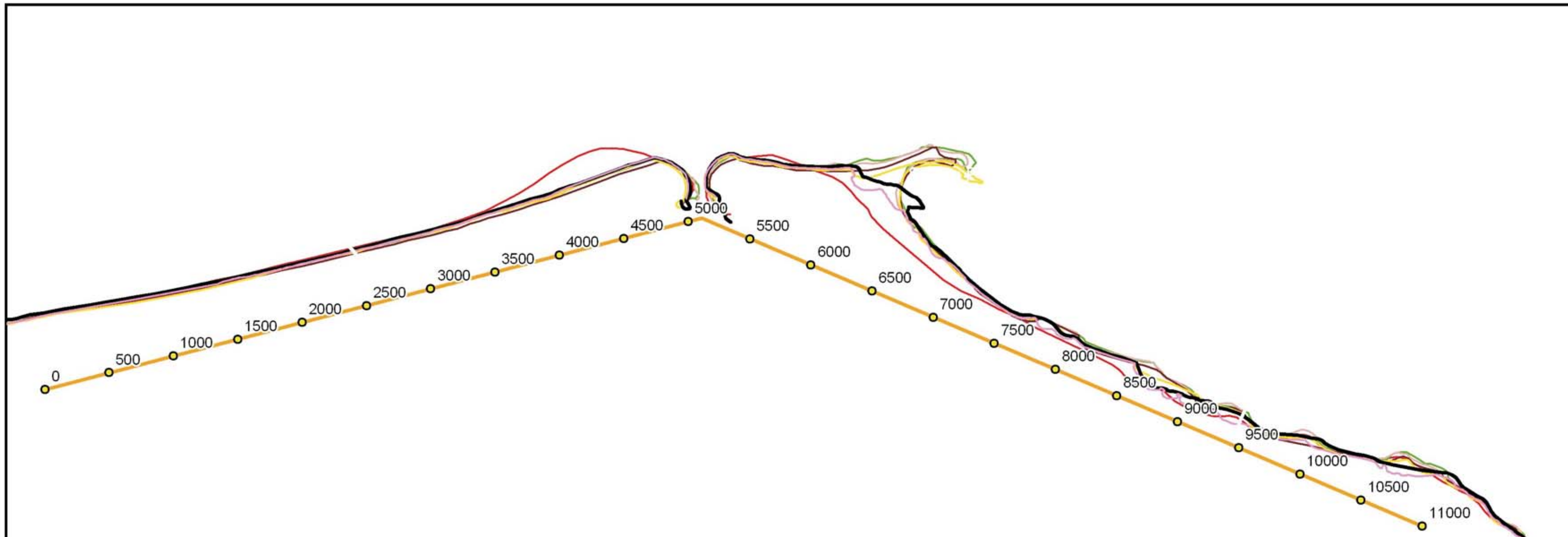


Shoreline Studies Program
VIMS

1,000 0 1,000 Feet

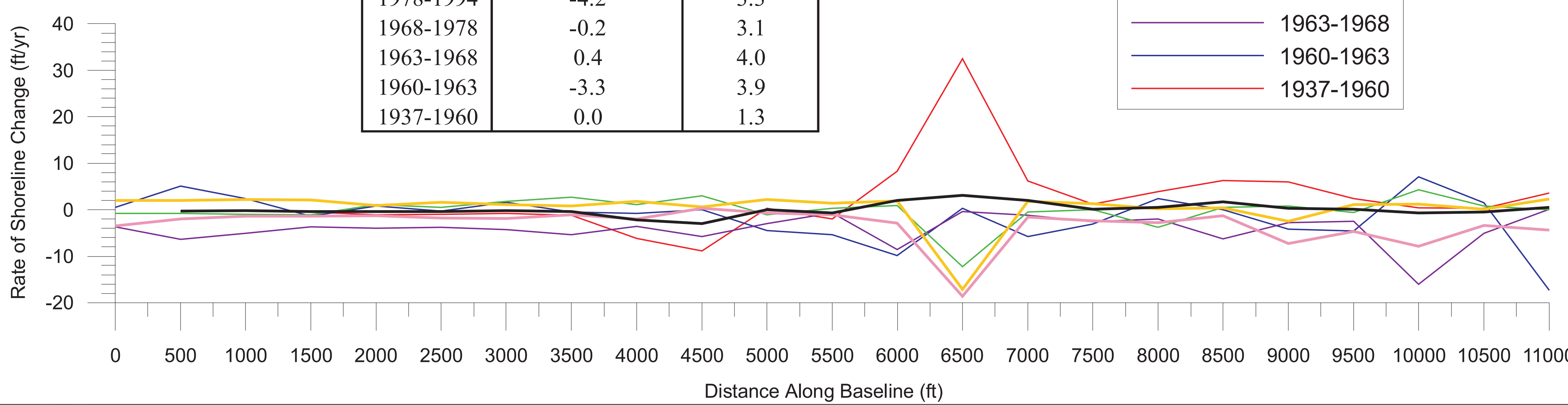
Colonial National Historical Park York River

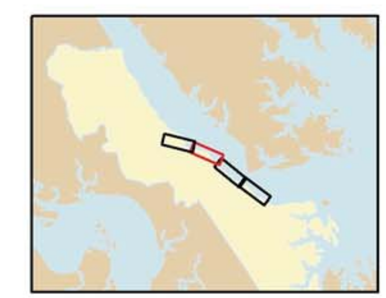
Plate 2



Legend

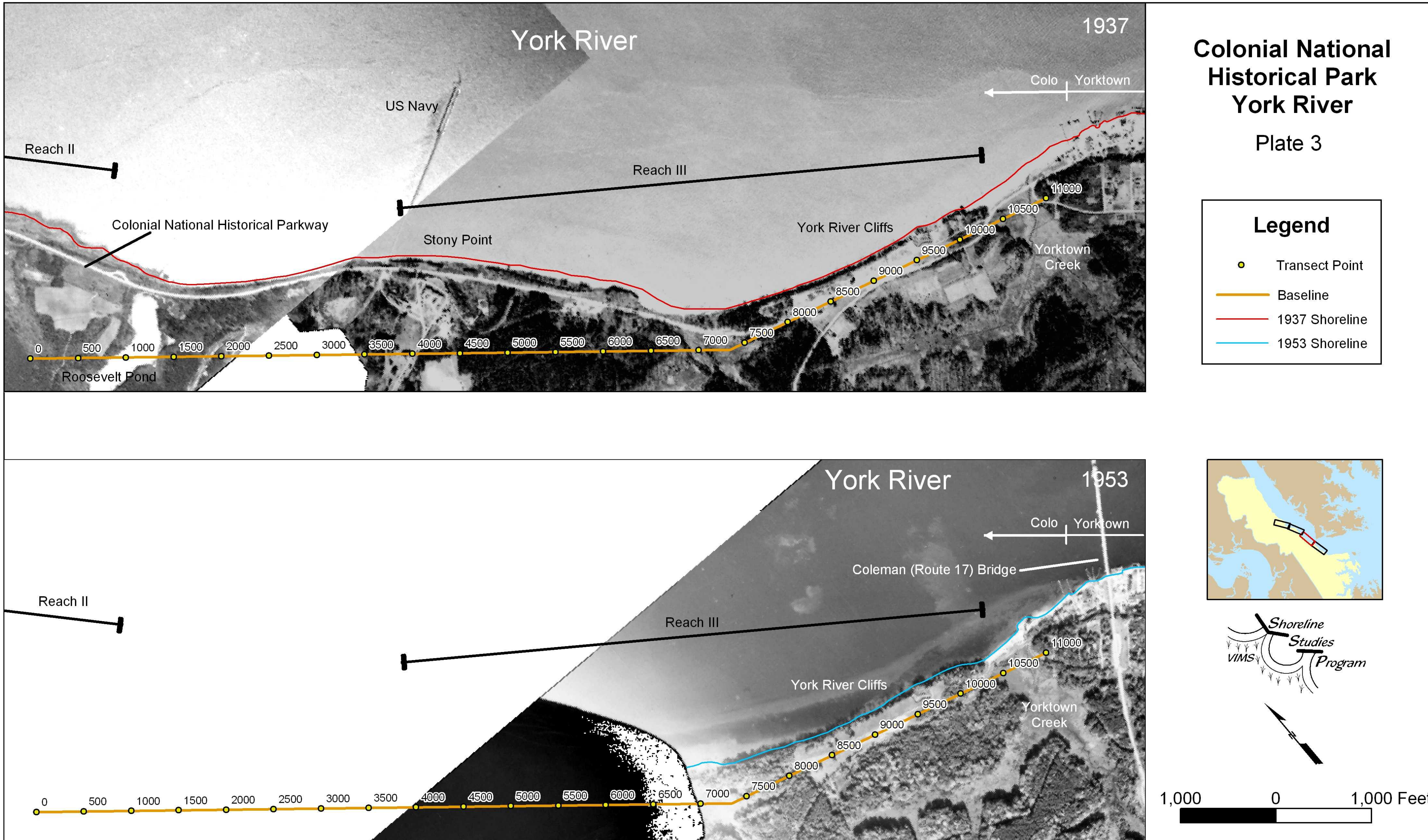
Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-2002	2.2	7.8
1994-2002	-1.6	5.1
1978-1994	-4.2	3.3
1968-1978	-0.2	3.1
1963-1968	0.4	4.0
1960-1963	-3.3	3.9
1937-1960	0.0	1.3

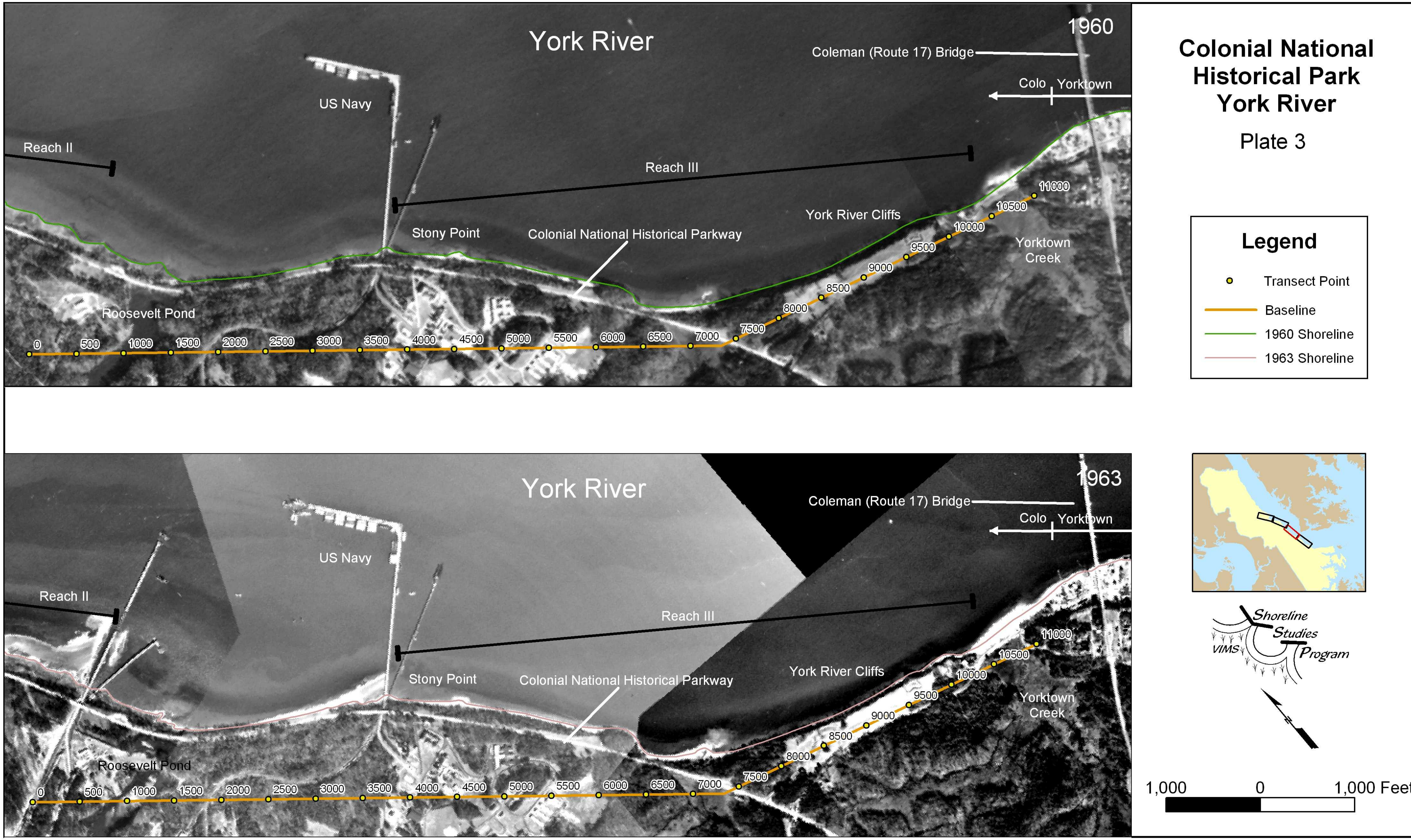




Shoreline Studies Program VIMS

1,000 0 1,000 Feet

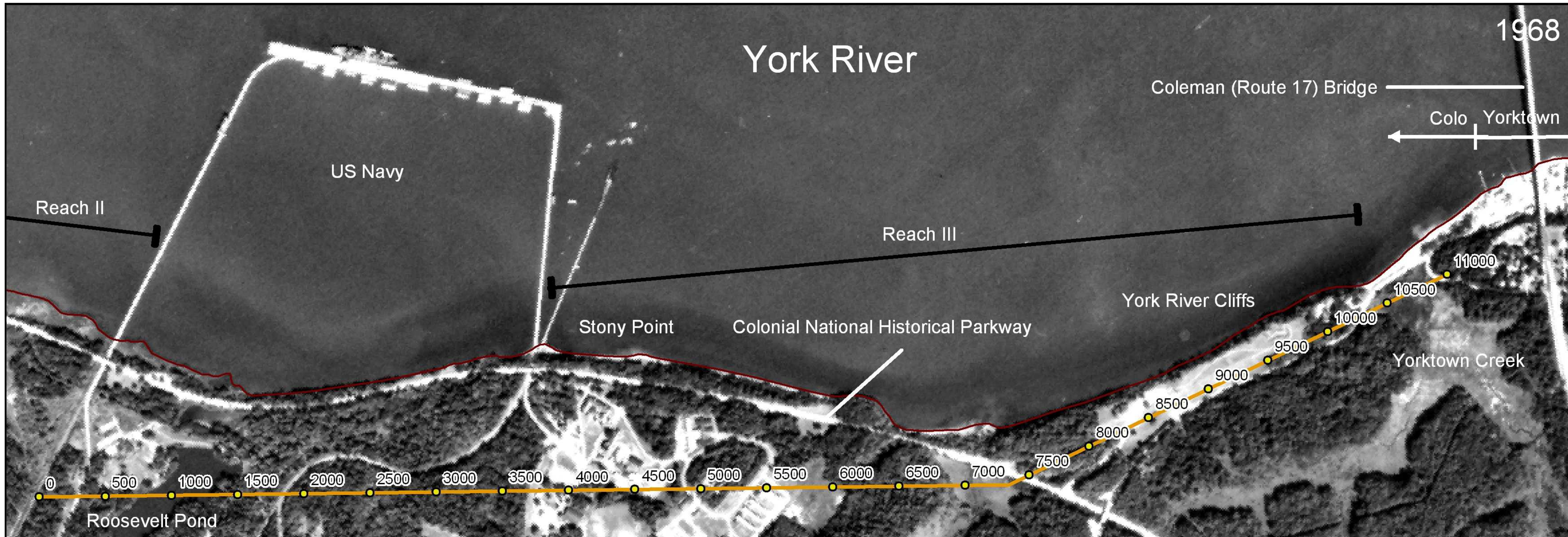

Colonial National Historical Park York River
Plate 3
1937
York River
US Navy
Colo
Yorktown
Reach II
Reach III
Colonial National Historical Parkway
Stony Point
York River Cliffs
Yorktown Creek
Roosevelt Pond
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10000 10500 11000
1953
York River
Colo
Yorktown
Coleman (Route 17) Bridge
Reach II
Reach III
York River Cliffs
Yorktown Creek
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10000 10500 11000
Legend
Transect Point
Baseline
1937 Shoreline
1953 Shoreline
Shoreline Studies Program
VIMS
1,000 0 1,000 Feet

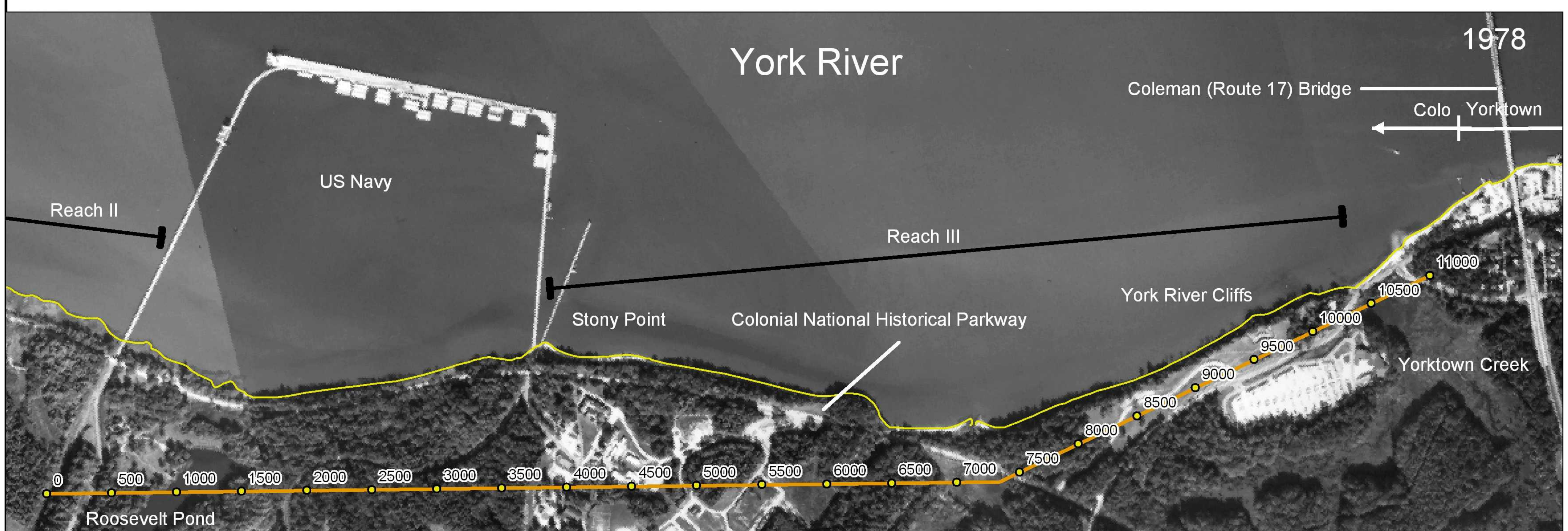


York River
1960
Coleman (Route 17) Bridge
Colo
Yorktown
US Navy
Reach II
Reach III
York River Cliffs
Stony Point
Colonial National Historical Parkway
Yorktown Creek
Roosevelt Pond
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
York River
1963
Colonial National Historical Park
York River
Plate 3
Legend
Transect Point
Baseline
1960 Shoreline
1963 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet

Colonial National Historical Park York River

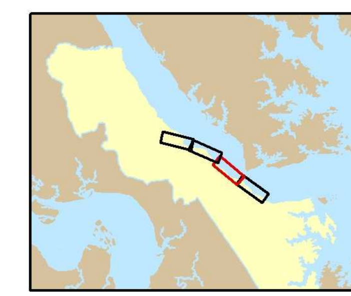
Plate 3





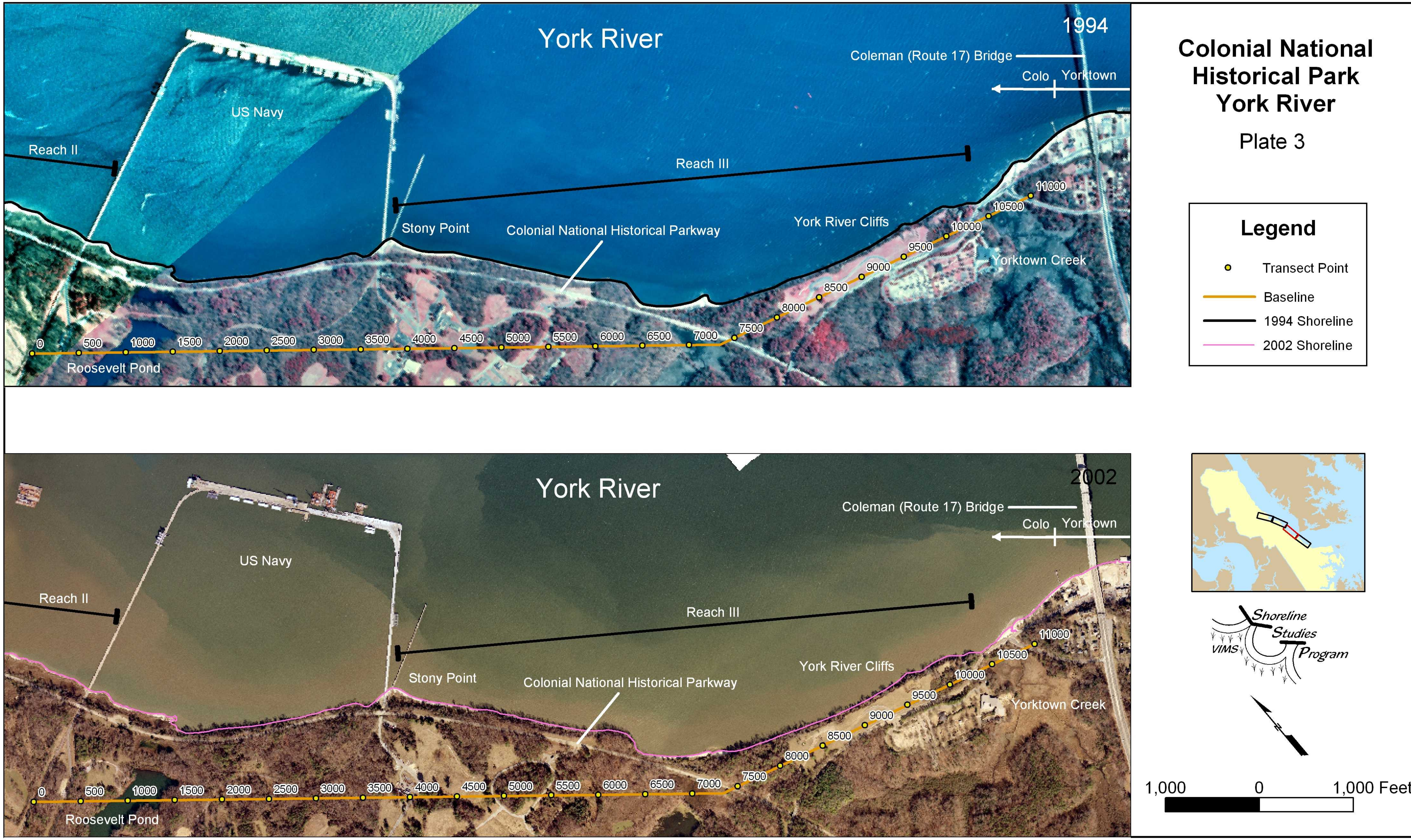
Legend

- Transect Point
- Baseline
- 1968 Shoreline
- 1978 Shoreline



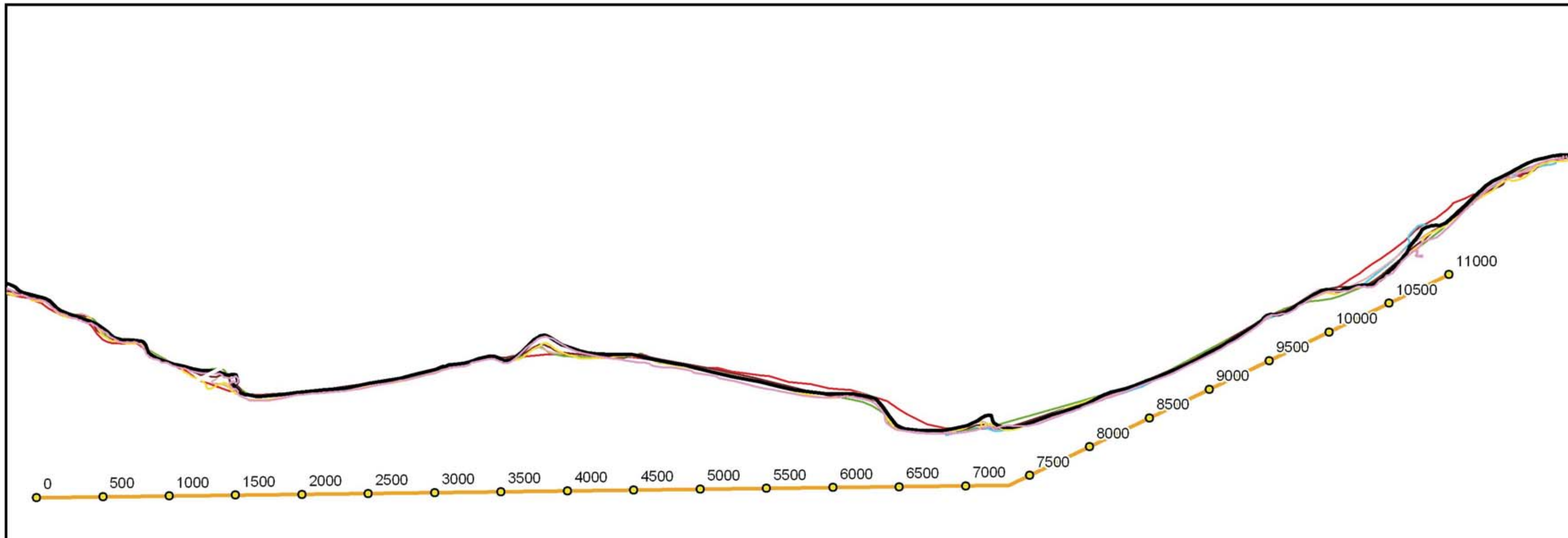
Shoreline Studies Program
VIMS

1,000 0 1,000 Feet


York River
1994
Coleman (Route 17) Bridge
Colo
Yorktown
US Navy
Reach II
Reach III
Stony Point
Colonial National Historical Parkway
York River Cliffs
Yorktown Creek
Roosevelt Pond
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
2002
Colonial National Historical Park York River
Plate 3
Legend
Transect Point
Baseline
1994 Shoreline
2002 Shoreline
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet

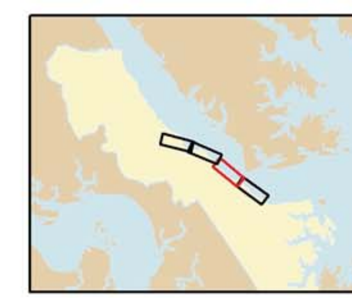
Colonial National Historical Park York River

Plate 3



Legend

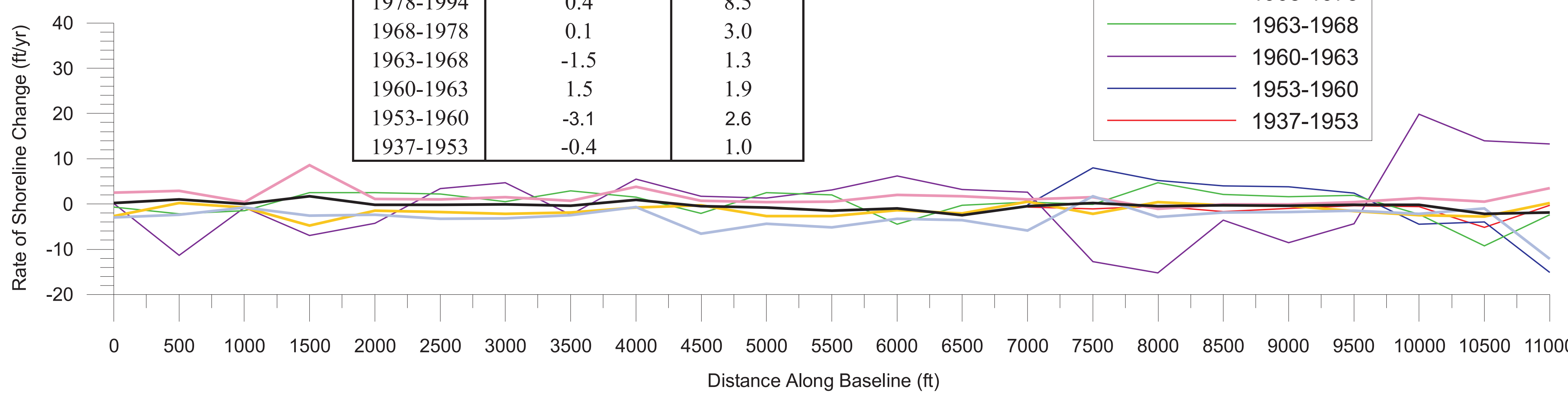
- Transect Point
- Baseline
- 2002 Shoreline
- 1994 Shoreline
- 1978 Shoreline
- 1968 Shoreline
- 1963 Shoreline
- 1960 Shoreline
- 1953 Shoreline
- 1937 Shoreline



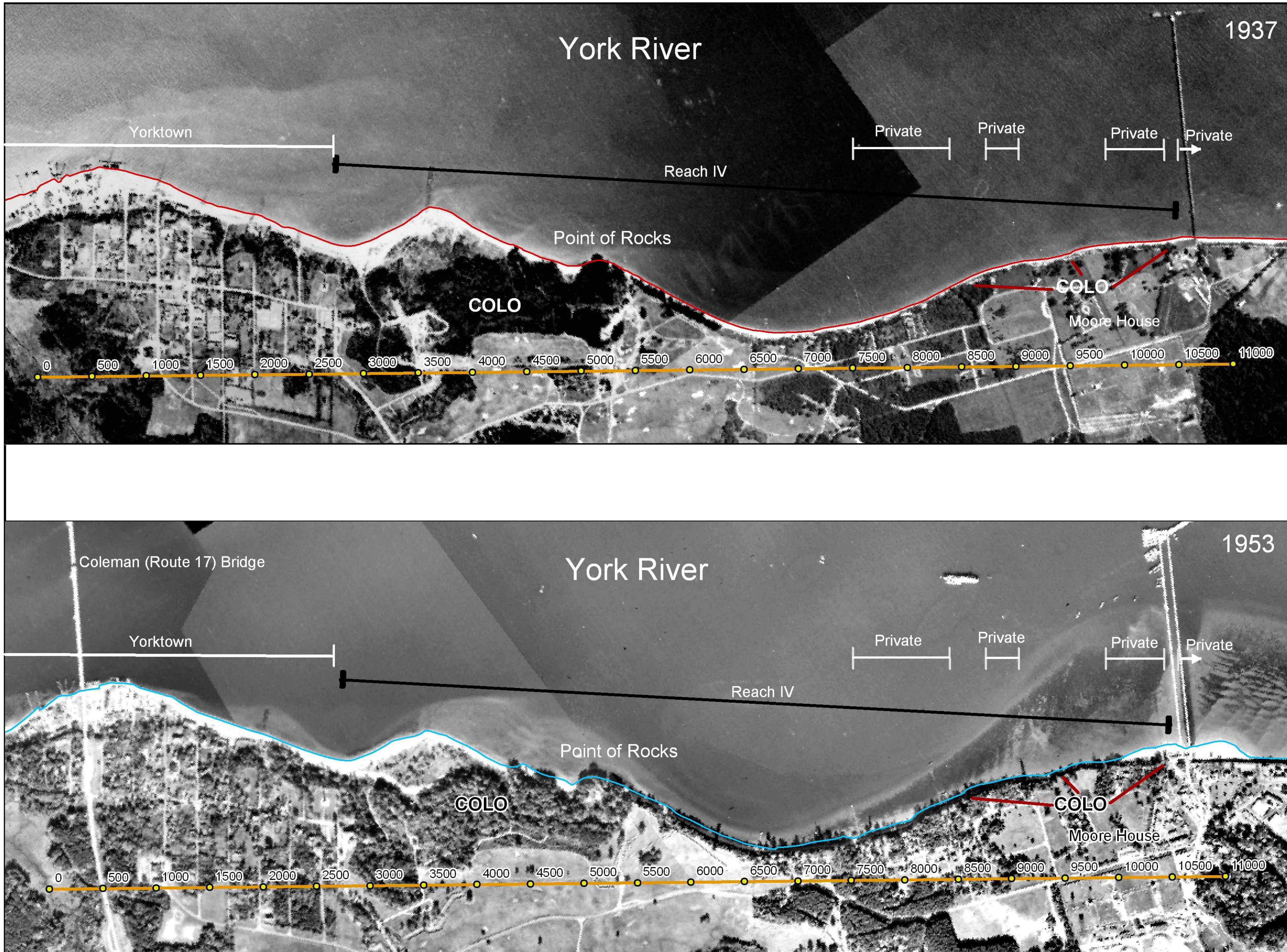
Shoreline Studies Program
VIMS

1,000 0 1,000 Feet

Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-2002	-1.3	1.5
1994-2002	0.0	7.0
1978-1994	0.4	8.5
1968-1978	0.1	3.0
1963-1968	-1.5	1.3
1960-1963	1.5	1.9
1953-1960	-3.1	2.6
1937-1953	-0.4	1.0



- **1937-2002**
- 1994-2002
- 1978-1994
- 1968-1978
- 1963-1968
- 1960-1963
- 1953-1960
- 1937-1953



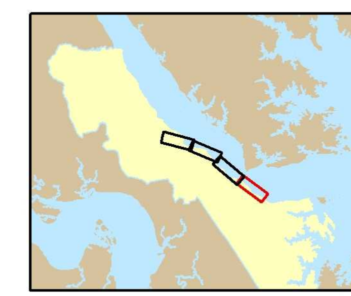
Colonial National Historical Park York River

Plate 4

Legend

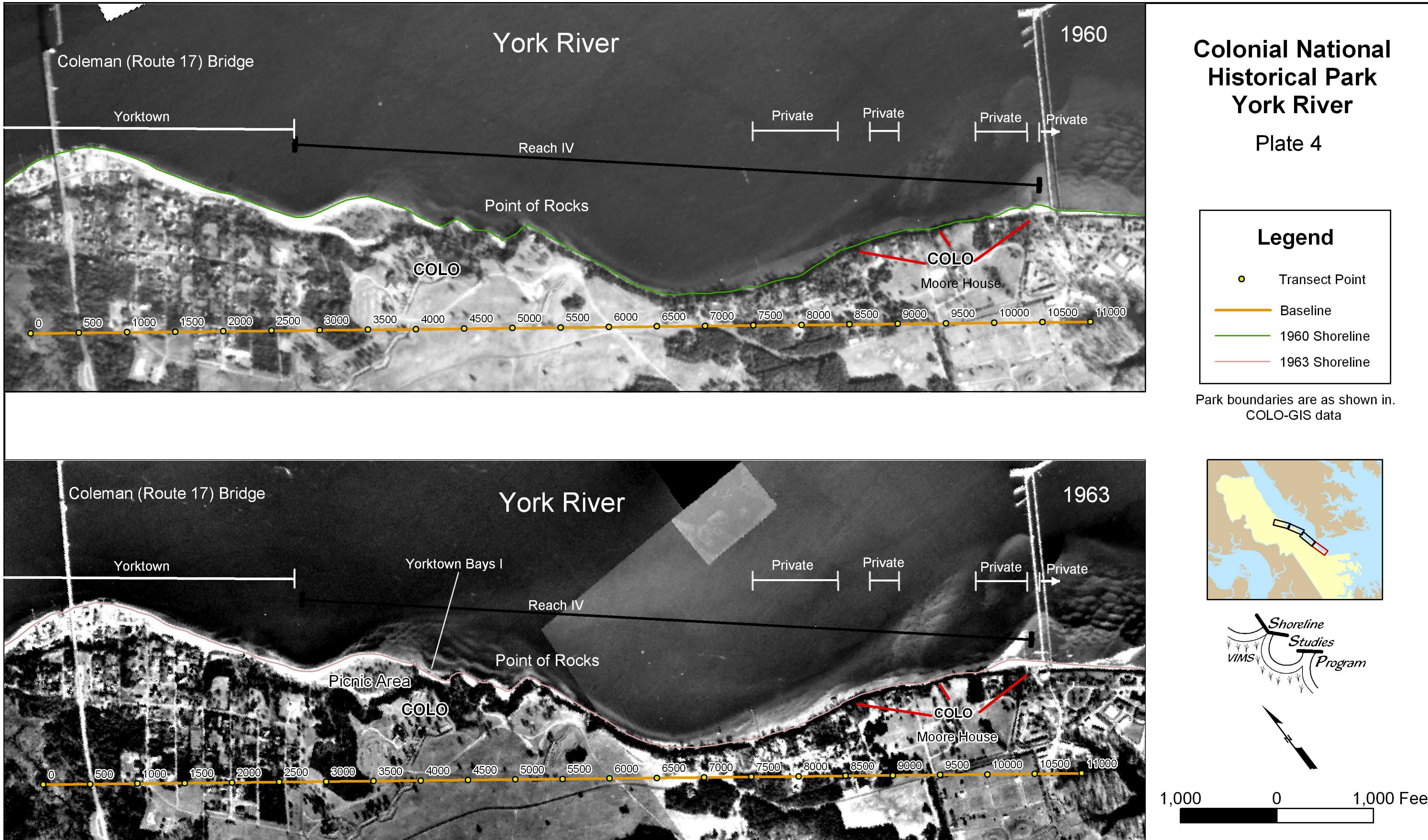
- Transect Point
- Baseline
- 1937 Shoreline
- 1953 Shoreline

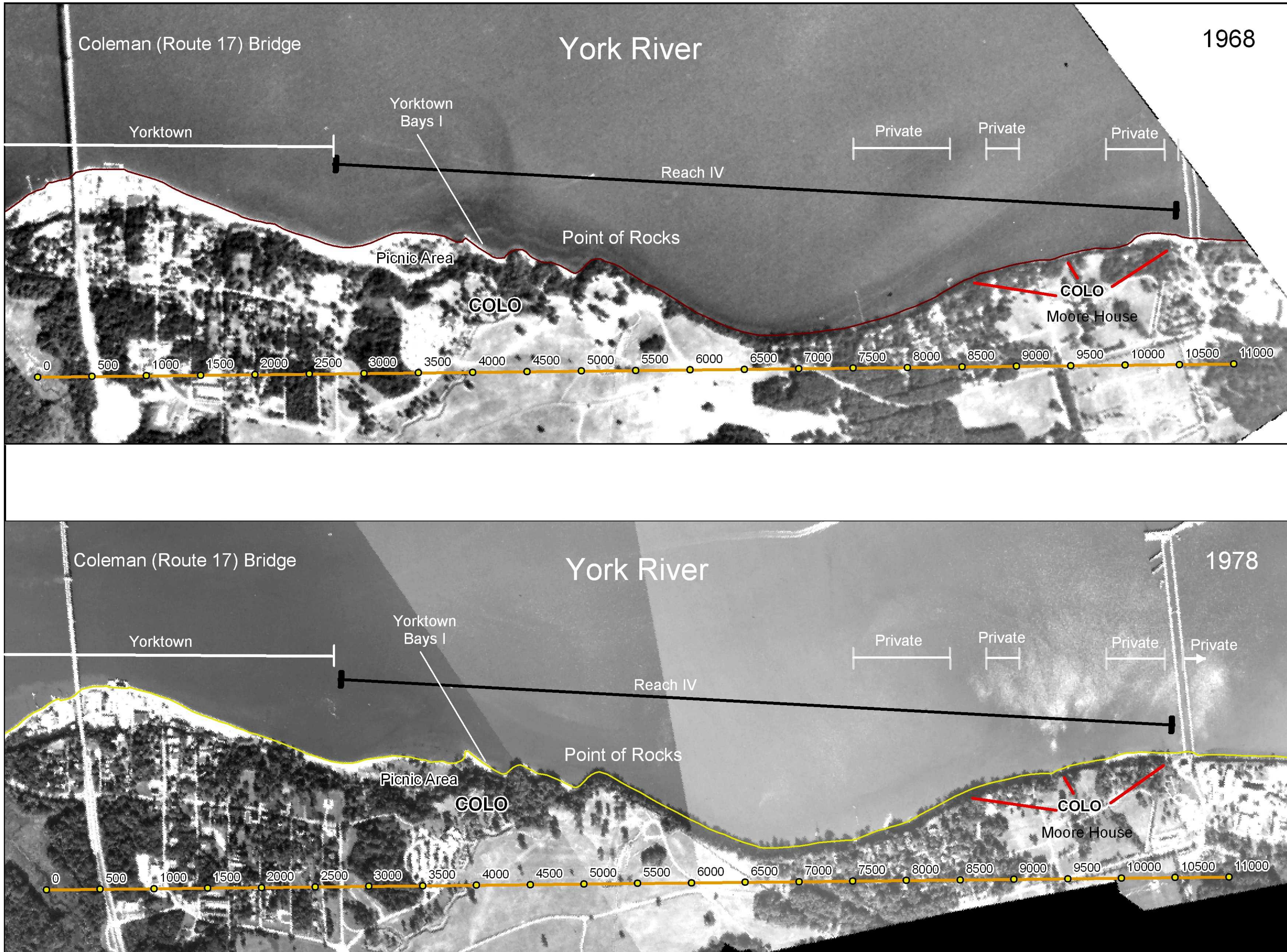
Park boundaries are as shown in. COLO-GIS data



Shoreline Studies Program VIMS

1,000 0 1,000 Feet


York River
1960
Coleman (Route 17) Bridge
Yorktown
Reach IV
Private
Private
Private
Private
Point of Rocks
COLO
COLO
Moore House
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
York River
1963
Coleman (Route 17) Bridge
Yorktown
Yorktown Bays I
Reach IV
Private
Private
Private
Private
Point of Rocks
Picnic Area
COLO
COLO
Moore House
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
Colonial National Historical Park York River
Plate 4
Legend
Transect Point
Baseline
1960 Shoreline
1963 Shoreline
Park boundaries are as shown in. COLO-GIS data
Shoreline Studies Program
VIMS
N
1,000
0
1,000 Feet



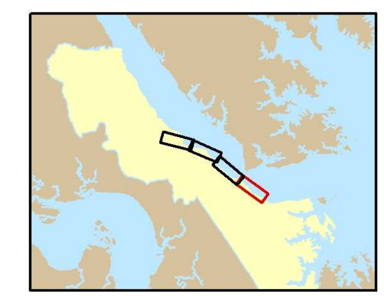
Colonial National Historical Park York River

Plate 4

Legend

- Transect Point
- Baseline
- 1968 Shoreline
- 1978 Shoreline

Park boundaries are as shown in. COLO-GIS data

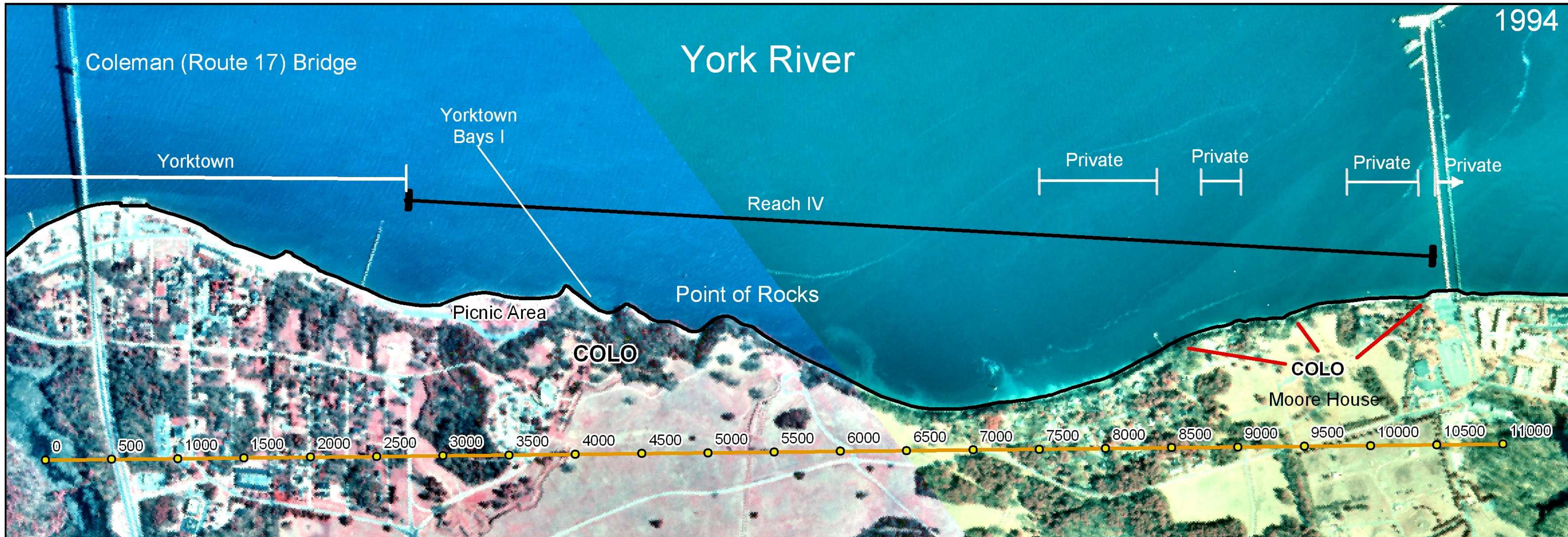


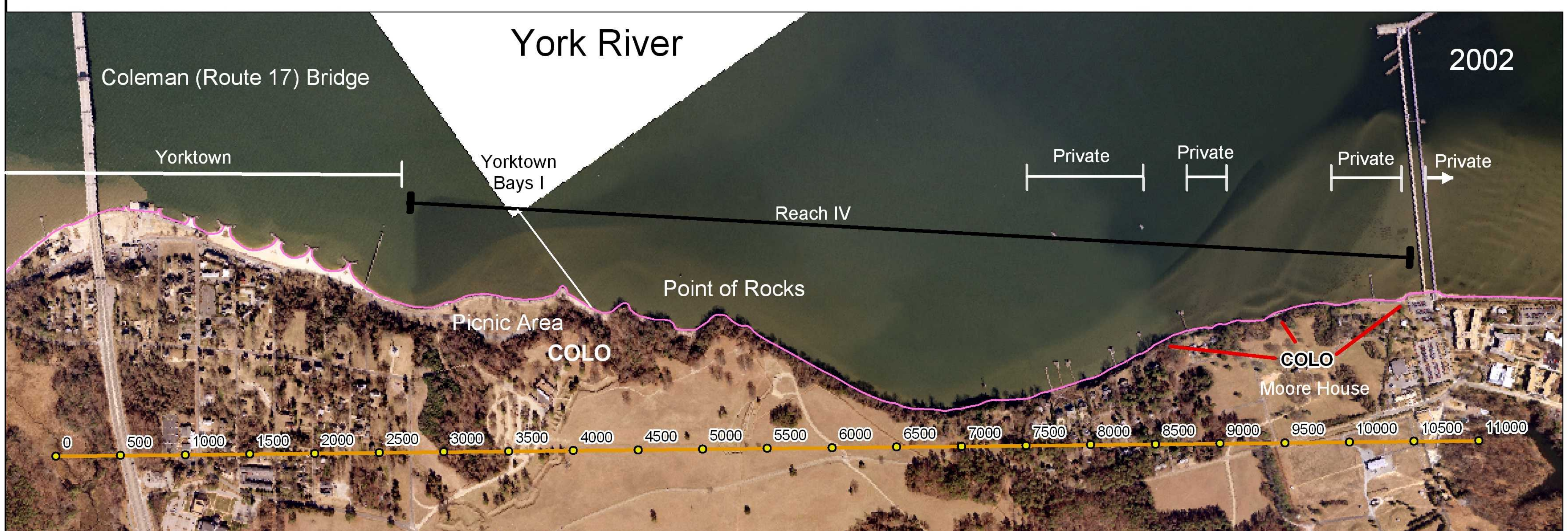
VIMS Shoreline Studies Program

1,000 0 1,000 Feet

Colonial National Historical Park York River

Plate 4

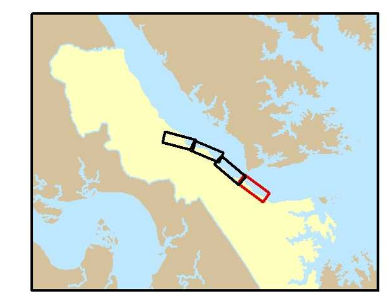




Legend

- Transect Point
- Baseline
- 1994 Shoreline
- 2002 Shoreline

Park boundaries are as shown in. COLO-GIS data

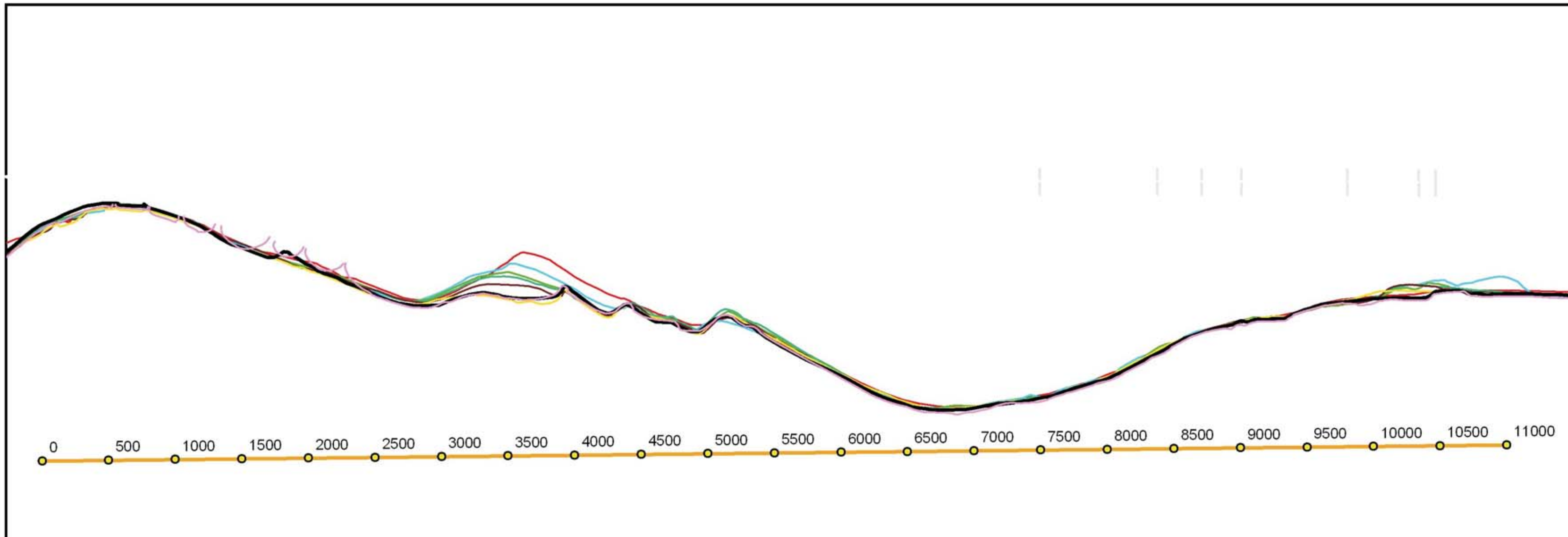


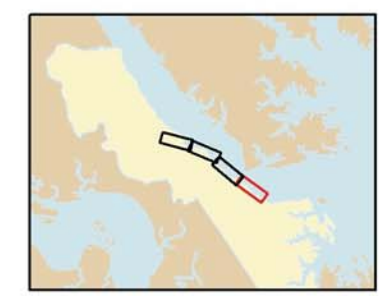
Shoreline Studies Program VIMS

1,000 0 1,000 Feet

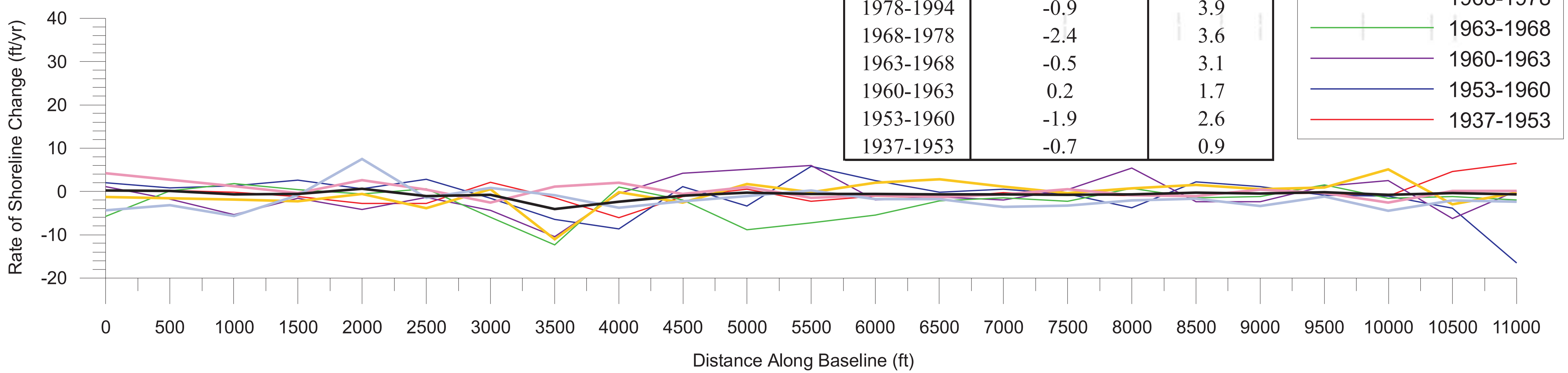
Colonial National Historical Park York River

Plate 4

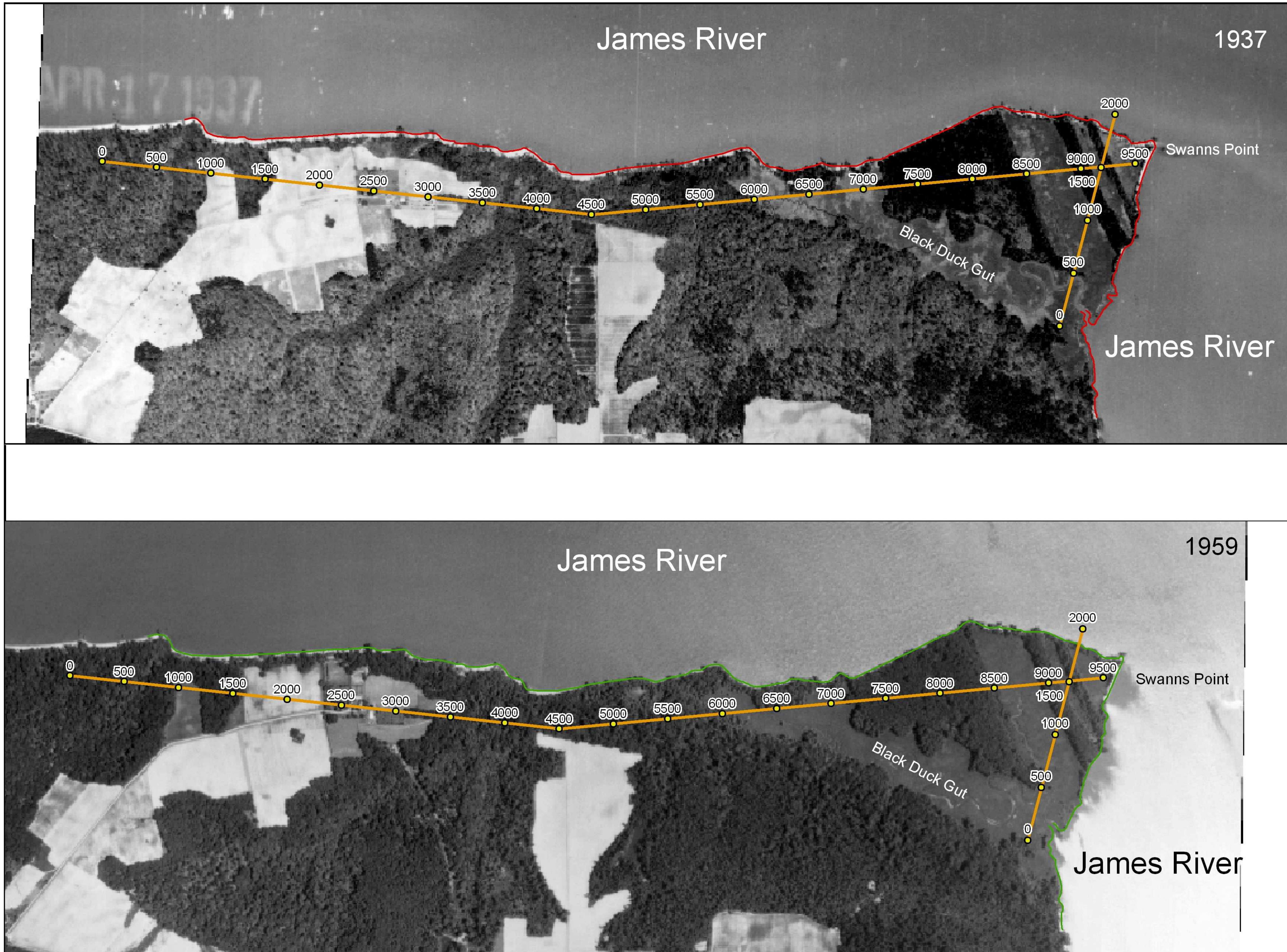




Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-2002	-0.4	2.4
1994-2002	-1.0	4.7
1978-1994	-0.9	3.9
1968-1978	-2.4	3.6
1963-1968	-0.5	3.1
1960-1963	0.2	1.7
1953-1960	-1.9	2.6
1937-1953	-0.7	0.9



Shoreline Studies Program VIMS

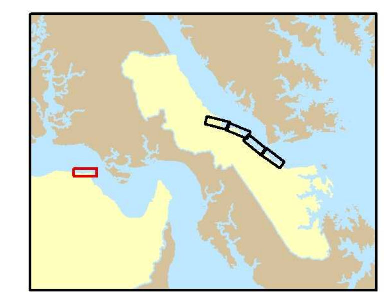


Colonial National Historical Park James River

Plate 5

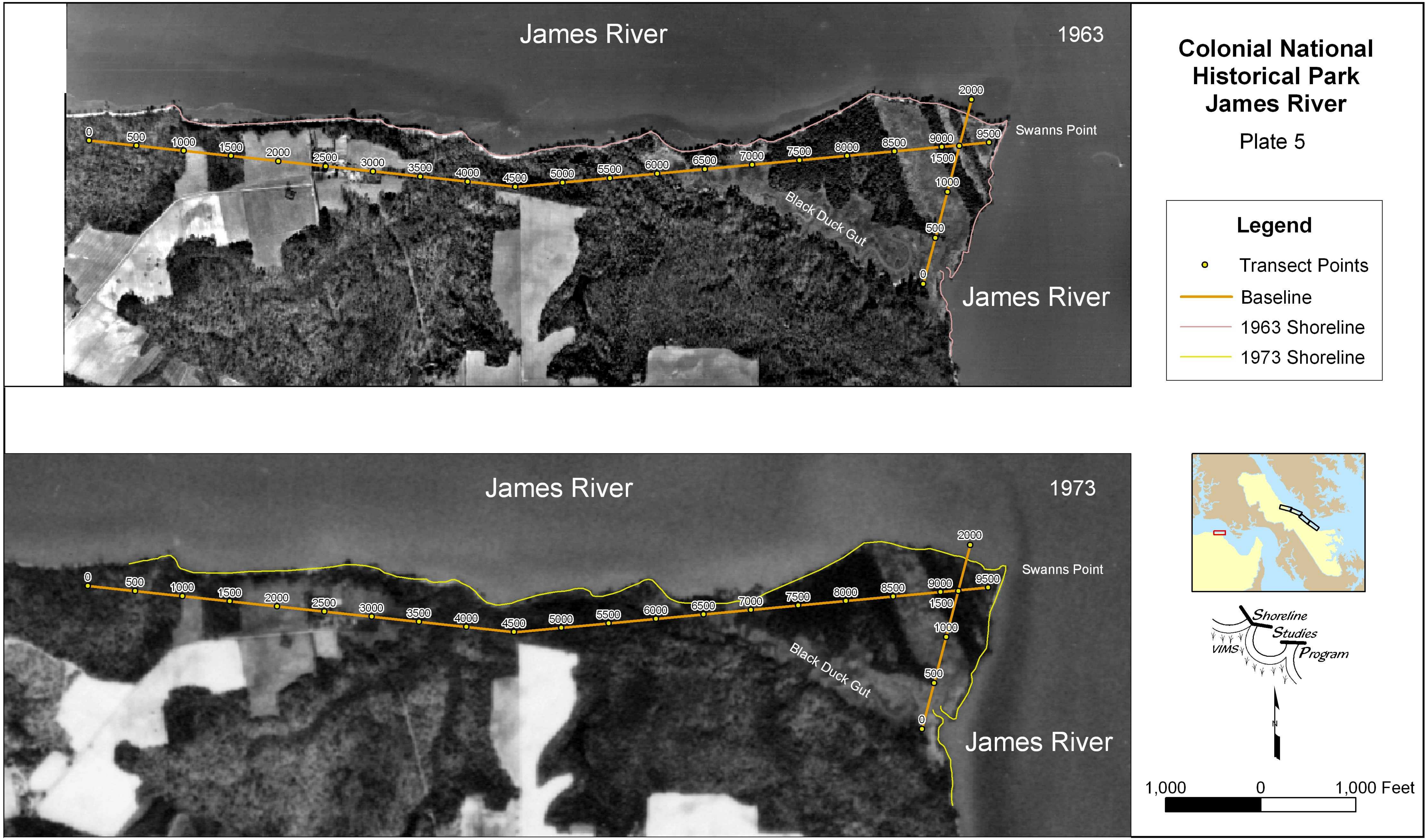
Legend

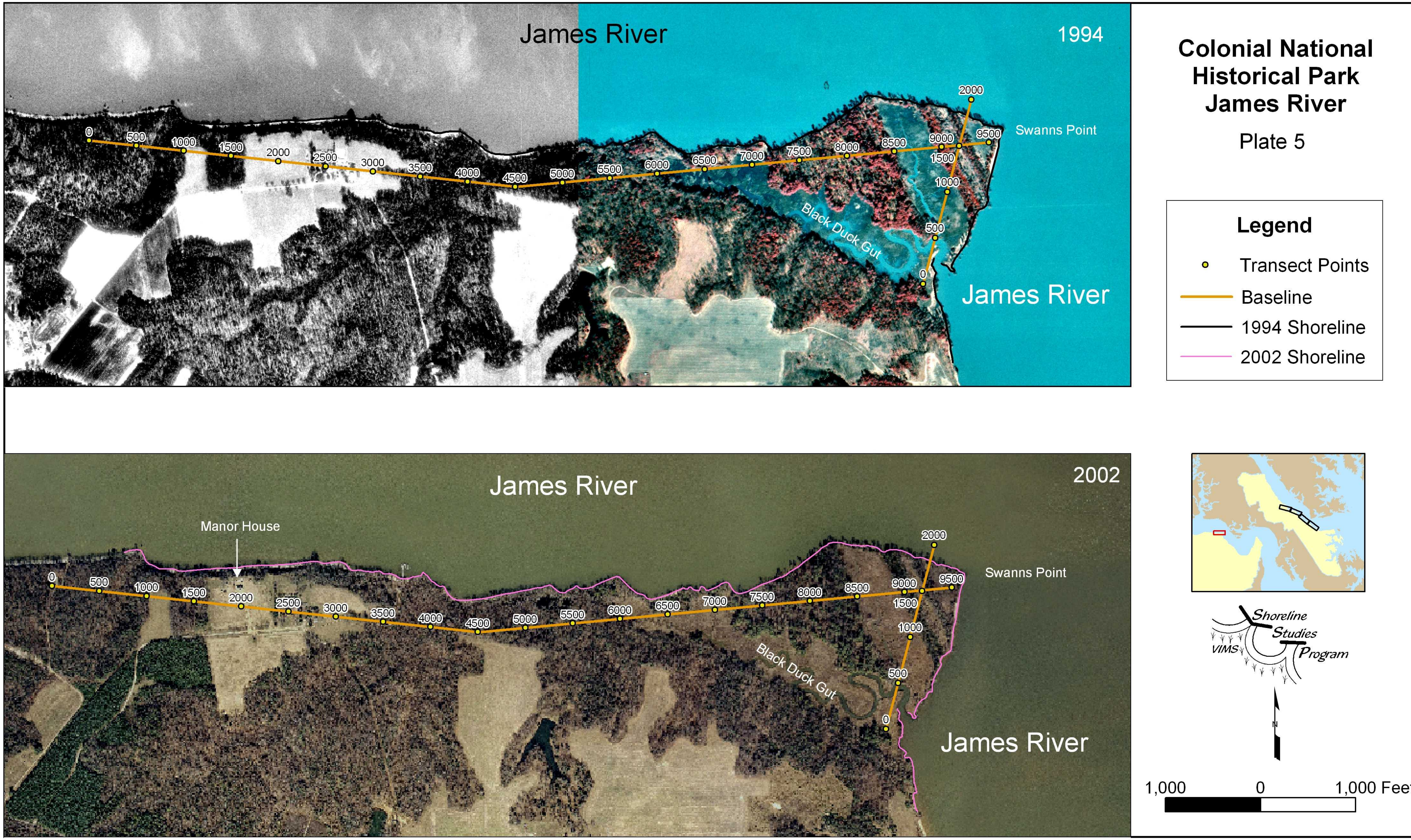
- Transect Points
- Baseline
- 1937 Shoreline
- 1959 Shoreline



Shoreline Studies Program
VIMS

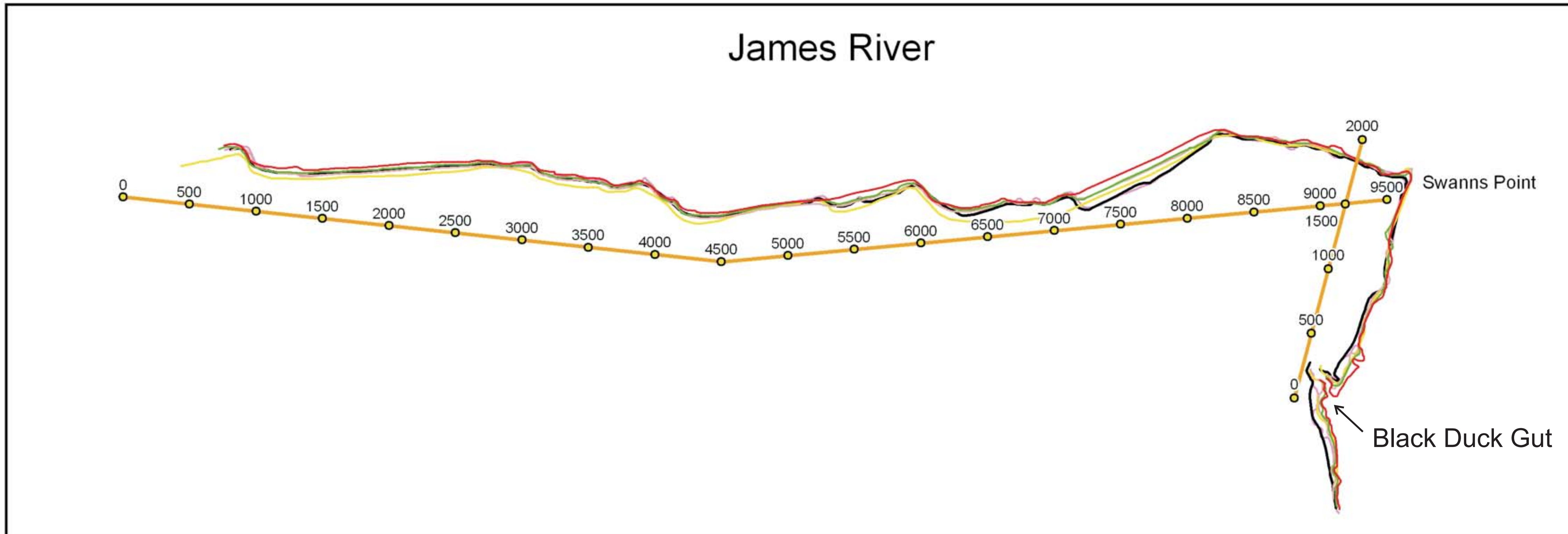
1,000 0 1,000 Feet


Colonial National Historical Park
James River
Plate 5
James River
1963
Swanns Point
Black Duck Gut
James River
James River
1973
Swanns Point
Black Duck Gut
James River
Legend
Transect Points
Baseline
1963 Shoreline
1973 Shoreline
Shoreline Studies Program
VIMS
1,000 0 1,000 Feet


Colonial National
Historical Park
James River
Plate 5
Legend
Transect Points
Baseline
1994 Shoreline
2002 Shoreline
1994
James River
Swanns Point
Black Duck Gut
James River
2002
James River
Manor House
Swanns Point
Black Duck Gut
James River
Shoreline Studies Program
VIMS
1,000
0
1,000 Feet

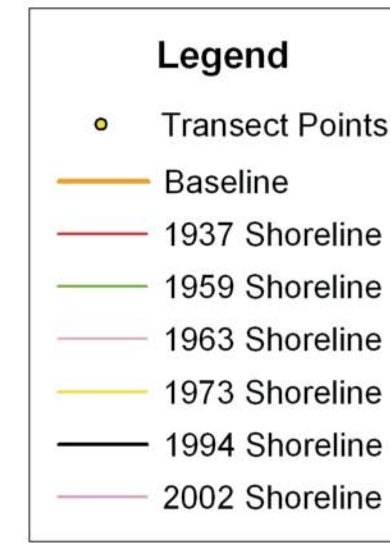
Colonial National Historical Park James River

Plate 5



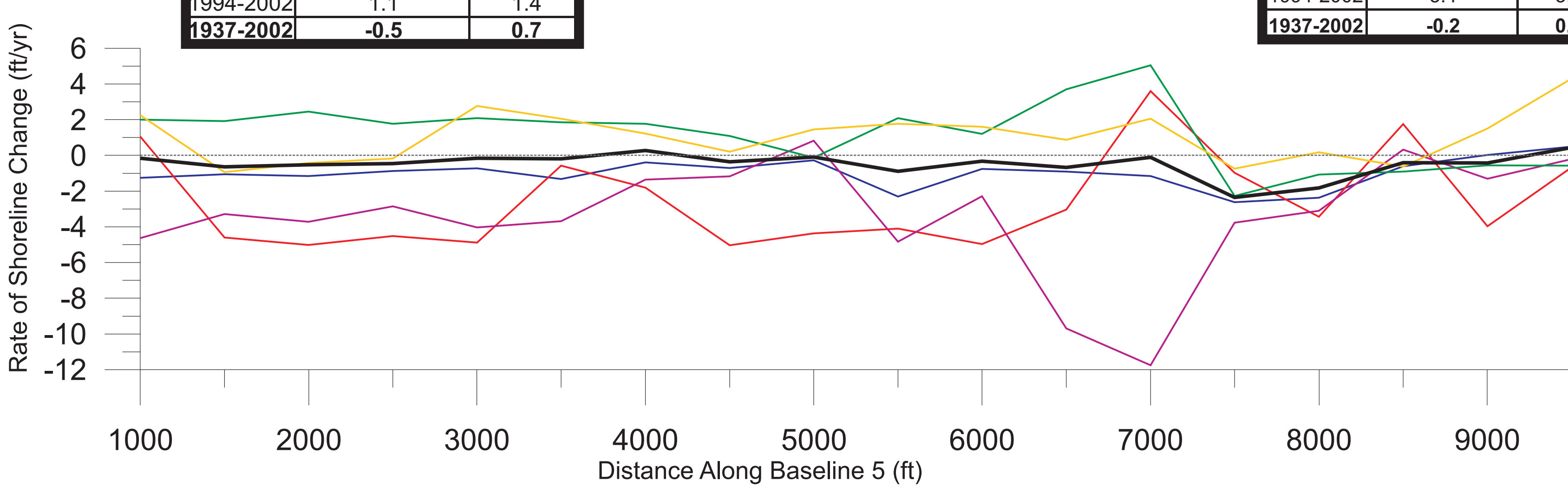
Legend

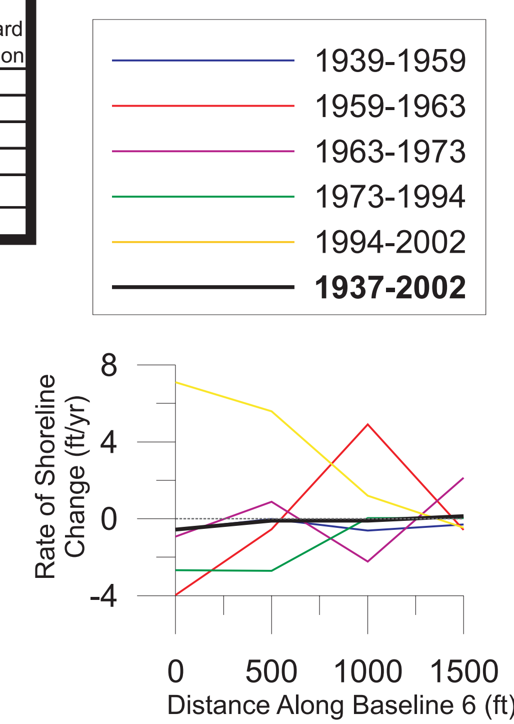
- Transect Points
- Baseline
- 1937 Shoreline
- 1959 Shoreline
- 1963 Shoreline
- 1973 Shoreline
- 1994 Shoreline
- 2002 Shoreline



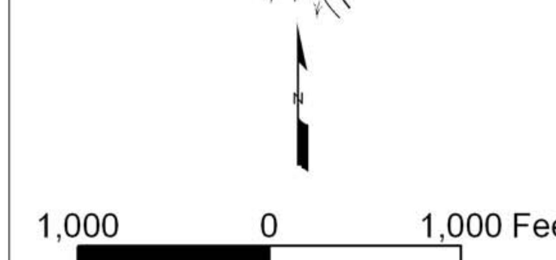
Baseline 5		
Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-59	-1.0	0.8
1959-63	-2.5	2.7
1963-73	-3.4	3.2
1973-94	1.2	1.8
1994-2002	1.1	1.4
1937-2002	**-0.5**	**0.7**

Baseline 6		
Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-59	-0.4	0.3
1959-63	0.0	3.7
1963-73	0.0	1.9
1973-94	-1.3	1.6
1994-2002	3.4	3.6
1937-2002	**-0.2**	**0.3**



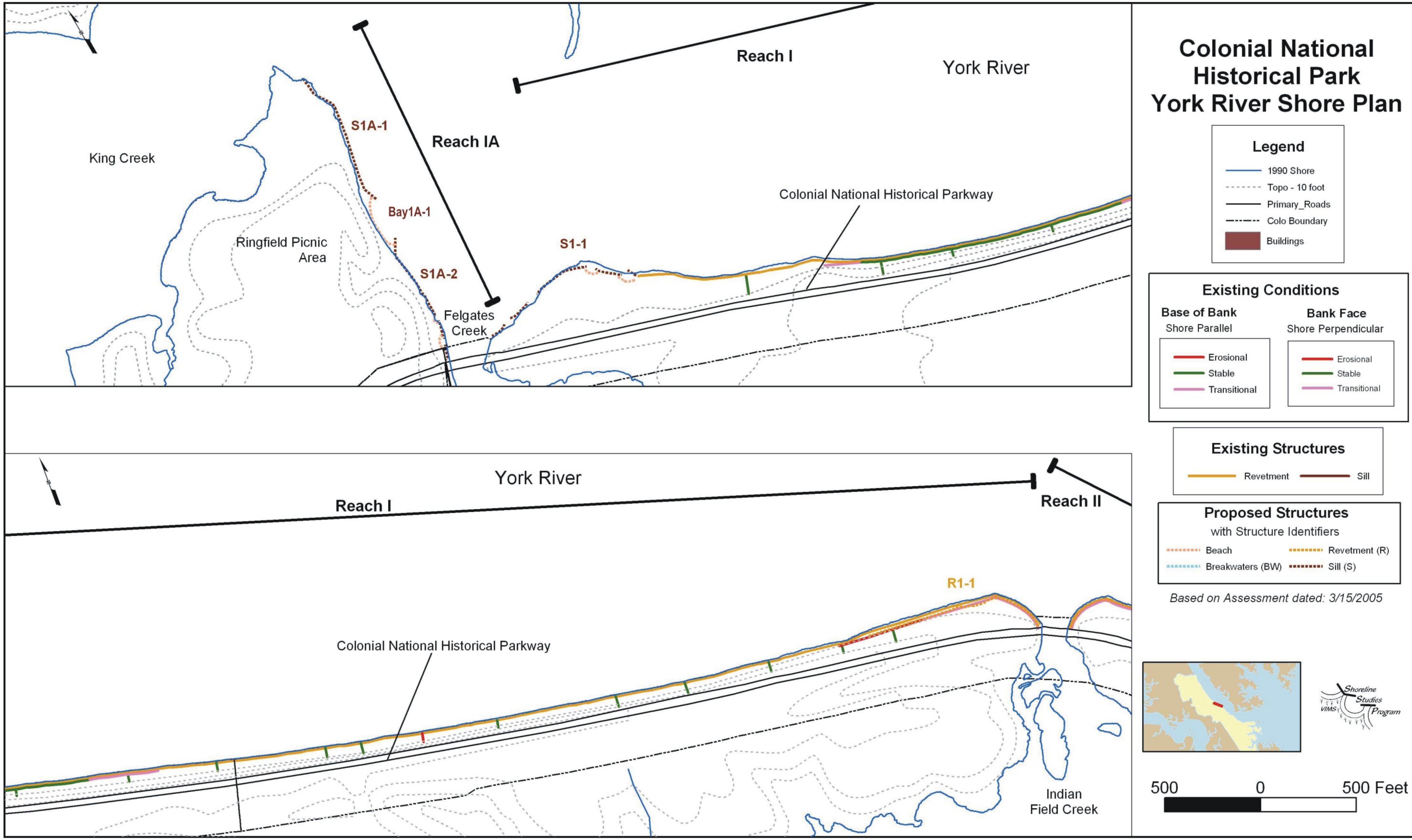


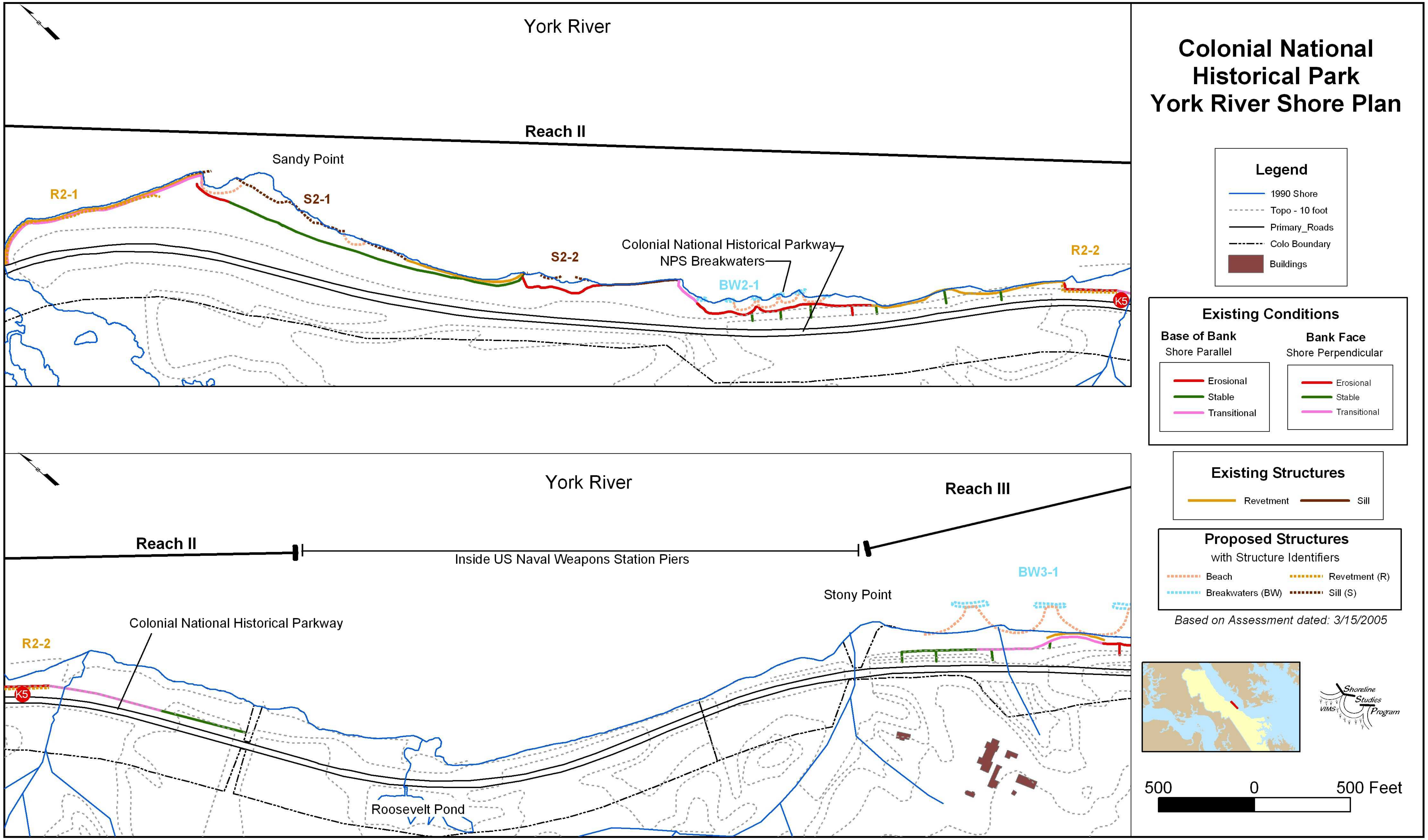
Shoreline Studies Program VIMS

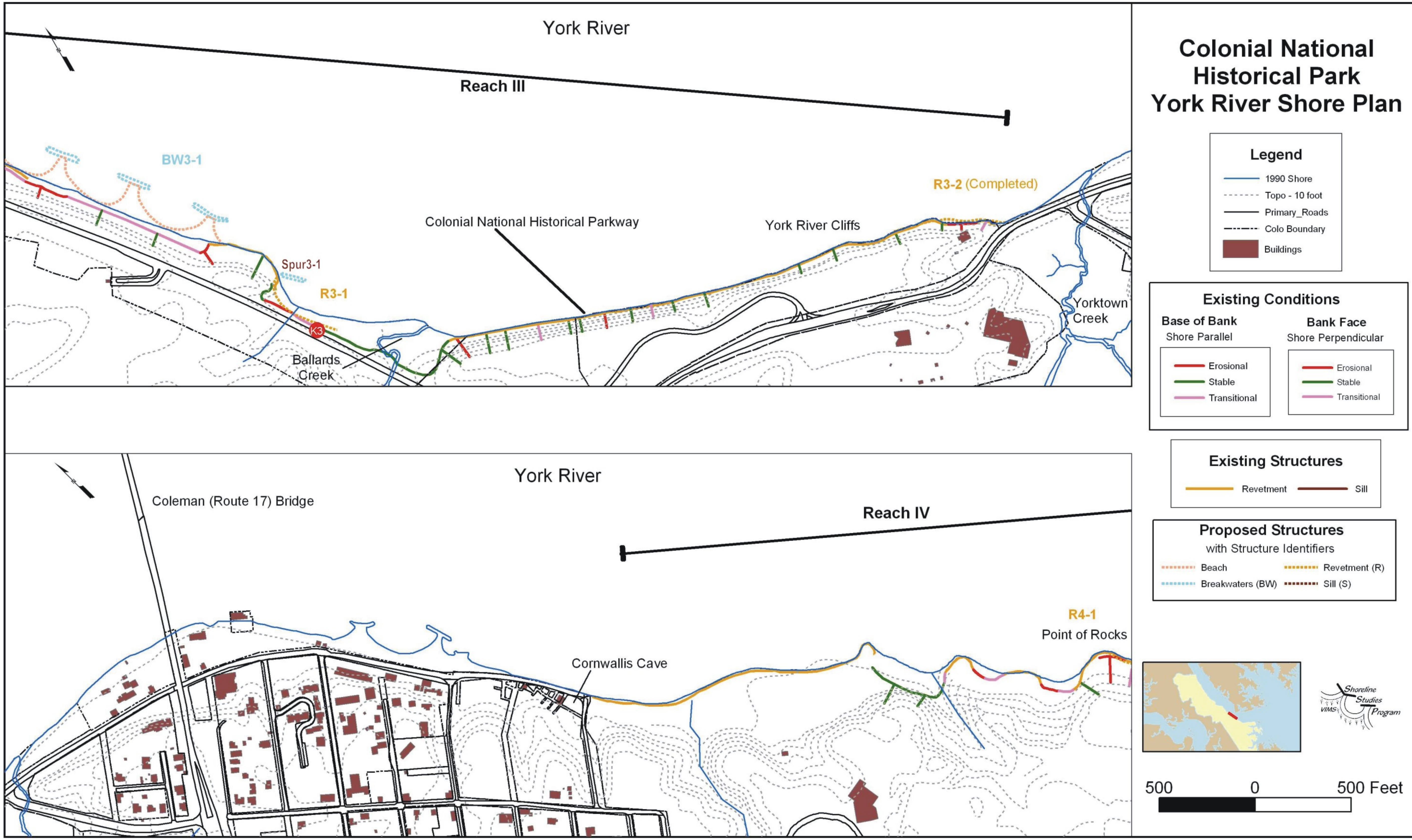


Appendix B

Shore Plan for Colonial National Historical Park's York River and Swanns Point

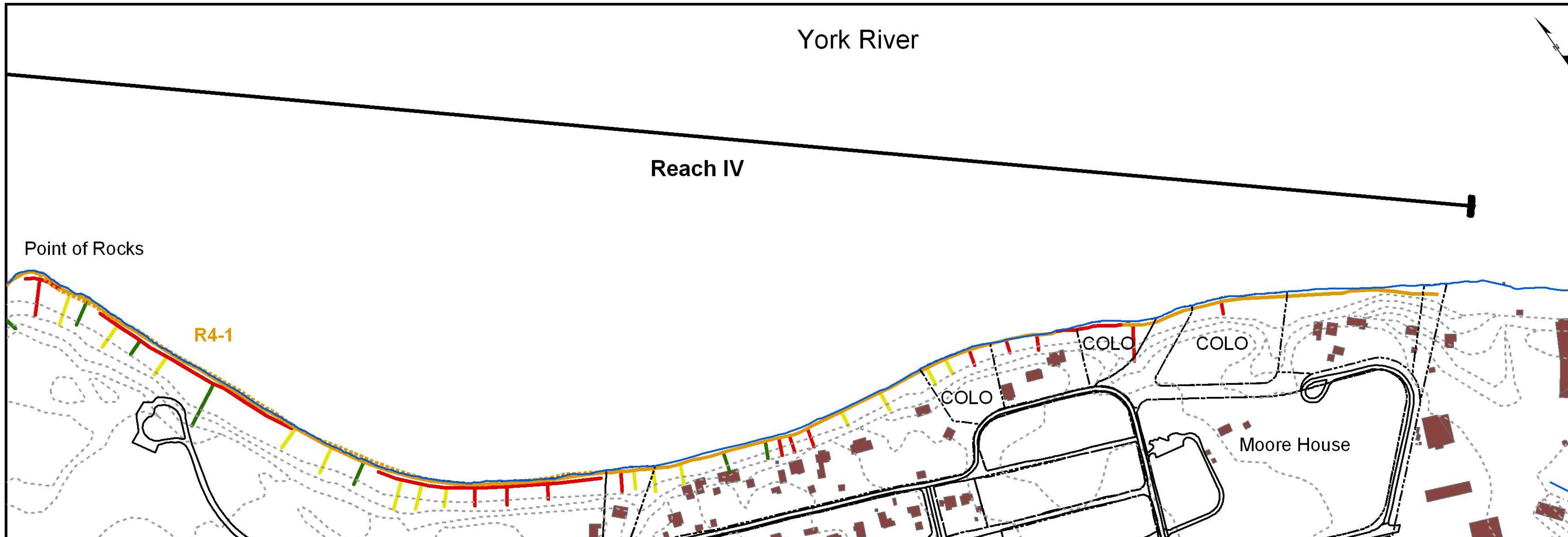

Colonial National Historical Park York River Shore Plan
Legend
1990 Shore
Topo - 10 foot
Primary_Roads
Colo Boundary
Buildings
Existing Conditions
Base of Bank
Shore Parallel
Erosional
Stable
Transitional
Bank Face
Shore Perpendicular
Erosional
Stable
Transitional
Existing Structures
Revetment
Sill
Proposed Structures
with Structure Identifiers
Beach
Revetment (R)
Breakwaters (BW)
Sill (S)
Based on Assessment dated: 3/15/2005
500 0 500 Feet
Shoreline Studies Program
VIMS
Reach I
York River
Reach IA
King Creek
S1A-1
Bay1A-1
S1A-2
Ringfield Picnic Area
Felgates Creek
S1-1
Colonial National Historical Parkway
York River
Reach I
Reach II
R1-1
Colonial National Historical Parkway
Indian Field Creek


Colonial National Historical Park
York River Shore Plan
York River
Reach II
Sandy Point
R2-1
S2-1
S2-2
Colonial National Historical Parkway
NPS Breakwaters
BW2-1
R2-2
K5
York River
Reach III
Reach II
Inside US Naval Weapons Station Piers
BW3-1
Stony Point
Colonial National Historical Parkway
R2-2
K5
Roosevelt Pond
Legend
1990 Shore
Topo - 10 foot
Primary_Roads
Colo Boundary
Buildings
Existing Conditions
Base of Bank
Shore Parallel
Erosional
Stable
Transitional
Bank Face
Shore Perpendicular
Erosional
Stable
Transitional
Existing Structures
Revetment
Sill
Proposed Structures
with Structure Identifiers
Beach
Revetment (R)
Breakwaters (BW)
Sill (S)
Based on Assessment dated: 3/15/2005
Shoreline Studies Program
VIMS
500
0
500 Feet



York River
Reach III
BW3-1
R3-2 (Completed)
Colonial National Historical Parkway
York River Cliffs
Spur3-1
R3-1
K3
Ballards Creek
Yorktown Creek
York River
Coleman (Route 17) Bridge
Reach IV
R4-1
Point of Rocks
Cornwallis Cave
Colonial National Historical Park York River Shore Plan
Legend
1990 Shore
Topo - 10 foot
Primary_Roads
Colo Boundary
Buildings
Existing Conditions
Base of Bank
Shore Parallel
Erosional
Stable
Transitional
Bank Face
Shore Perpendicular
Erosional
Stable
Transitional
Existing Structures
Revetment
Sill
Proposed Structures
with Structure Identifiers
Beach
Revetment (R)
Breakwaters (BW)
Sill (S)
Shoreline Studies Program
VIMS
500 0 500 Feet

Colonial National Historical Park York River Shore Plan



Legend
- 1990 Shore
- Topo - 10 foot
- Primary_Roads
- Colo Boundary
- Buildings

Existing Conditions

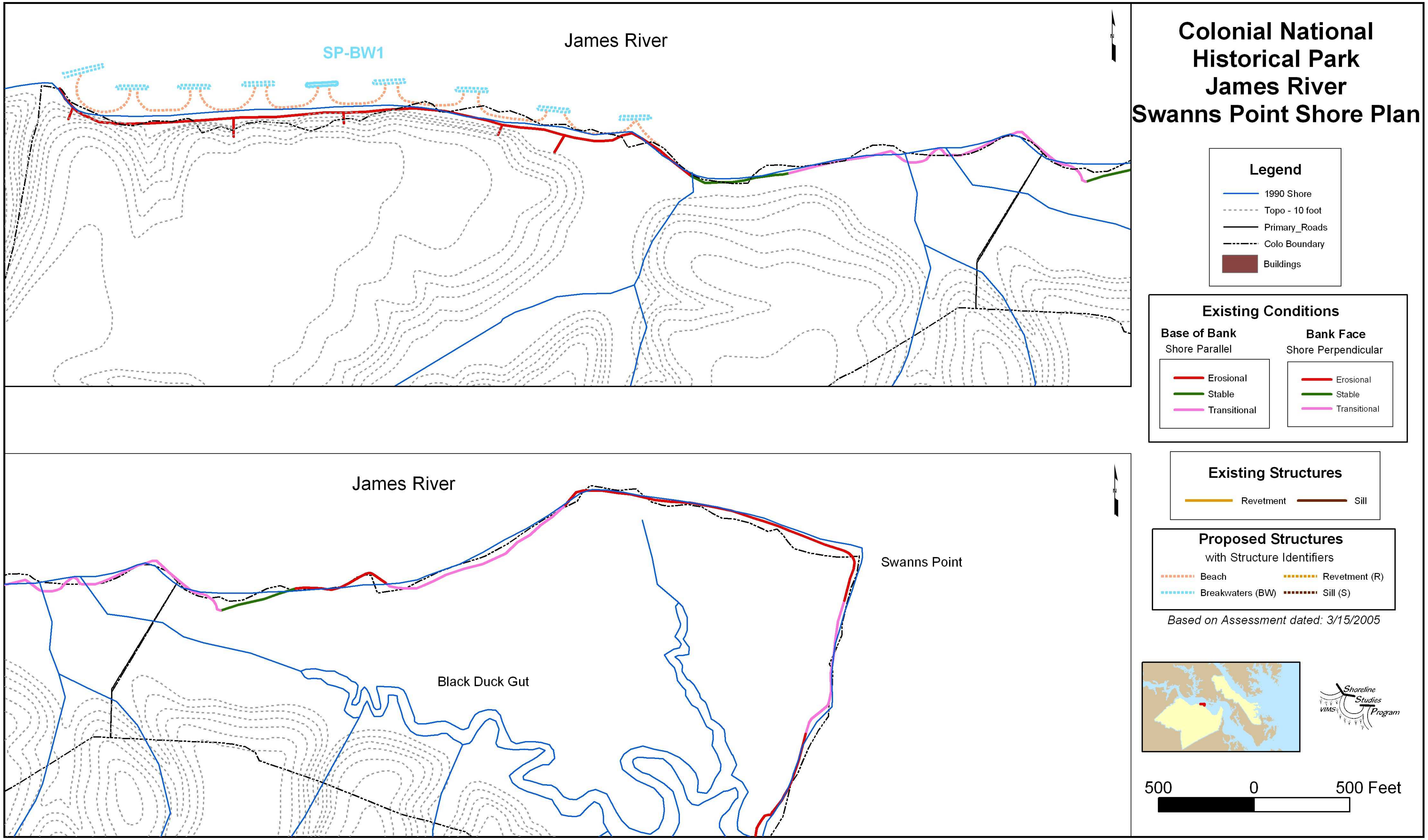
Base of Bank Shore Parallel	Bank Face Shore Perpendicular
Erosional	Erosional
Stable	Stable
Transitional	Transitional

Existing Structures
- Revetment
- Sill

Proposed Structures with Structure Identifiers
- Beach
- Revetment (R)
- Breakwaters (BW)
- Sill (S)

Based on Assessment dated: 3/15/2005

500 0 500 Feet


Colonial National
Historical Park
James River
Swanns Point Shore Plan
James River
SP-BW1
James River
Swanns Point
Black Duck Gut
Legend
1990 Shore
Topo - 10 foot
Primary_Roads
Colo Boundary
Buildings
Existing Conditions
Base of Bank
Shore Parallel
Erosional
Stable
Transitional
Bank Face
Shore Perpendicular
Erosional
Stable
Transitional
Existing Structures
Revetment
Sill
Proposed Structures
with Structure Identifiers
Beach
Revetment (R)
Breakwaters (BW)
Sill (S)
Based on Assessment dated: 3/15/2005
Shoreline Studies Program
VIMS
500
0
500 Feet

Colonial National Historical Park York River Shore Plan

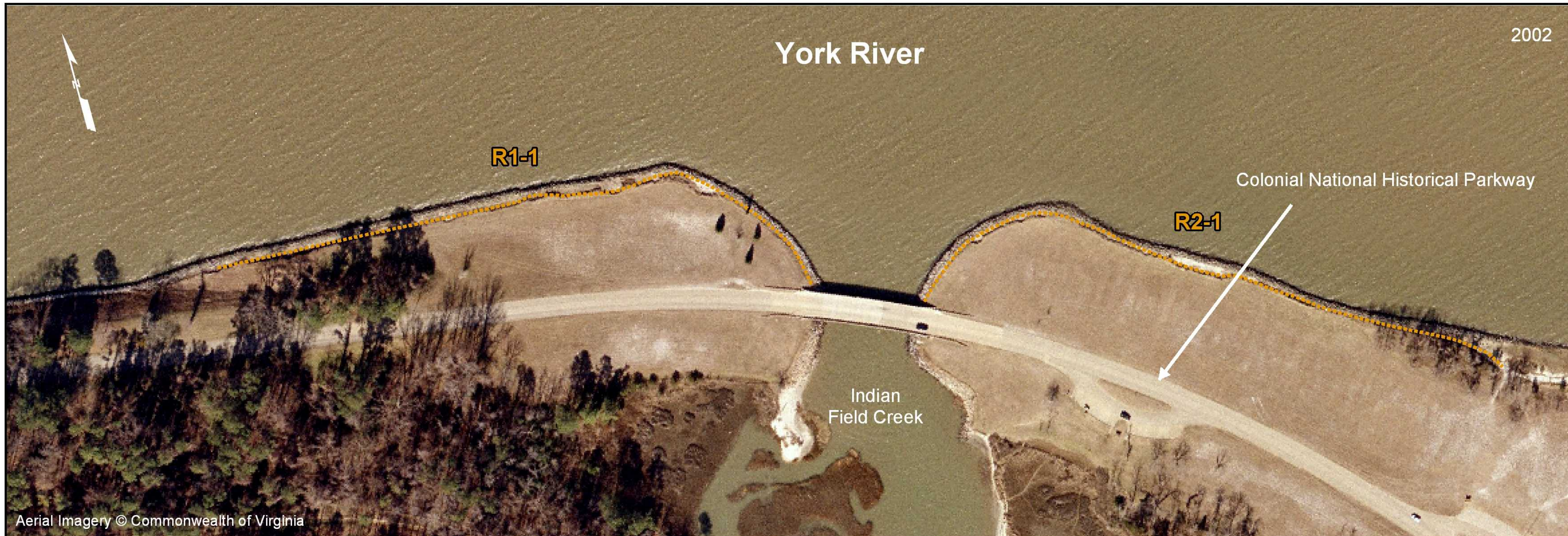
Proposed Structures

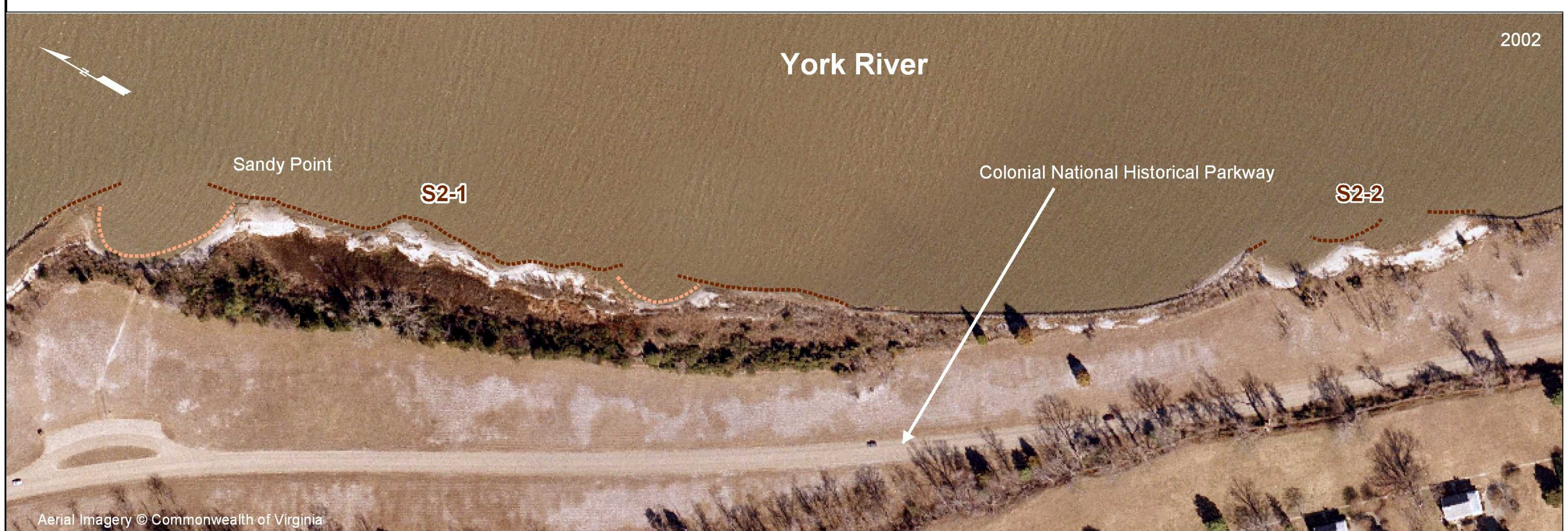
- Beach
- Breakwaters
- Revetment
- Sill

Shoreline Studies Program VIMS

200 0 200 Feet

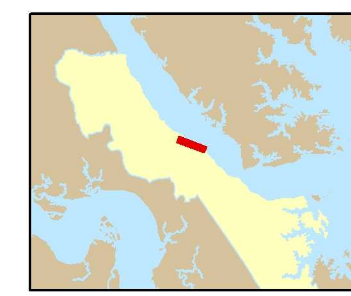
Colonial National Historical Park York River Shore Plan





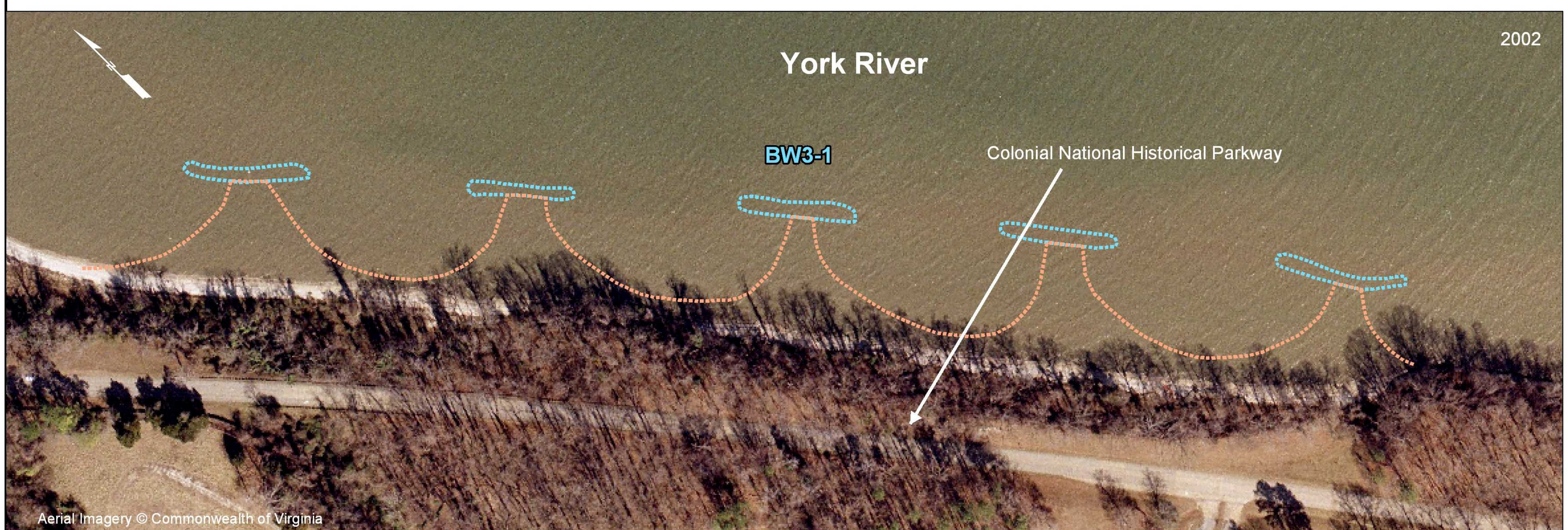
Proposed Structures

- Beach
- Breakwaters
- Revetment
- Sill

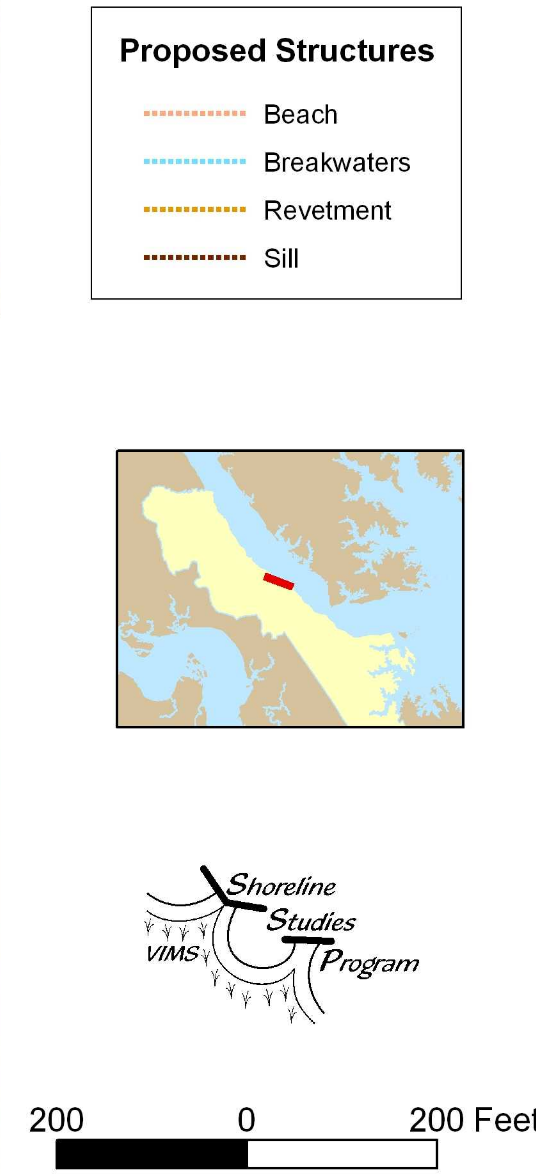


Shoreline Studies Program VIMS

200 0 200 Feet



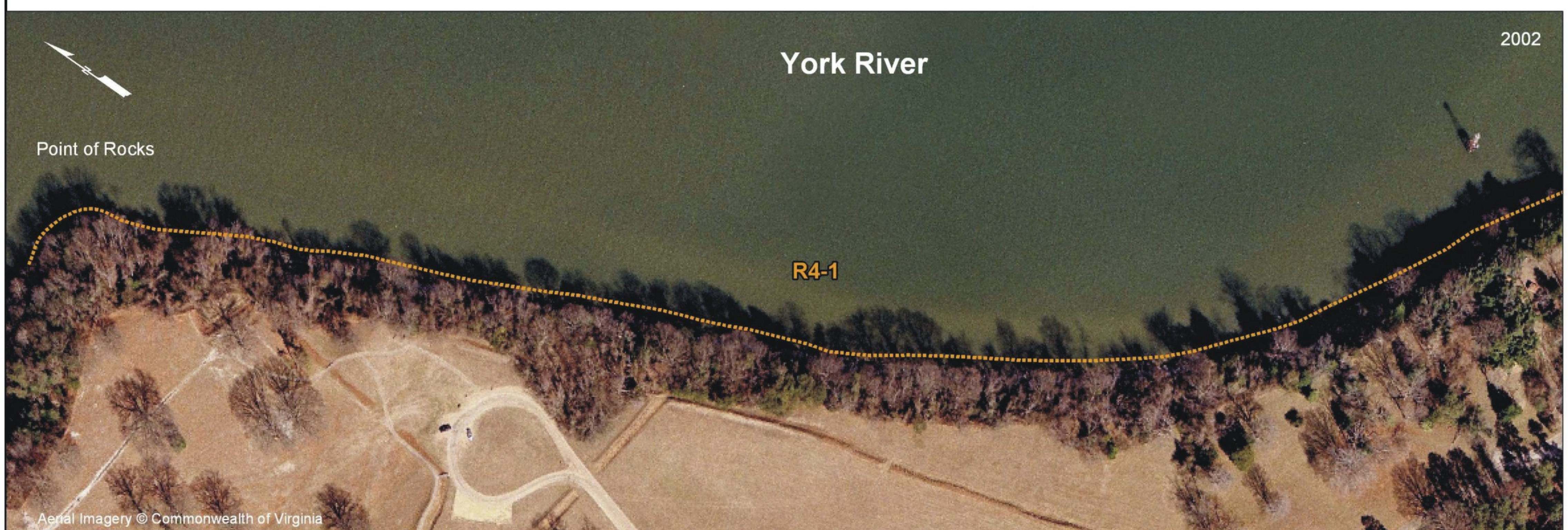
Colonial National Historical Park York River Shore Plan



Colonial National Historical Park York River Shore Plan

Proposed Structures

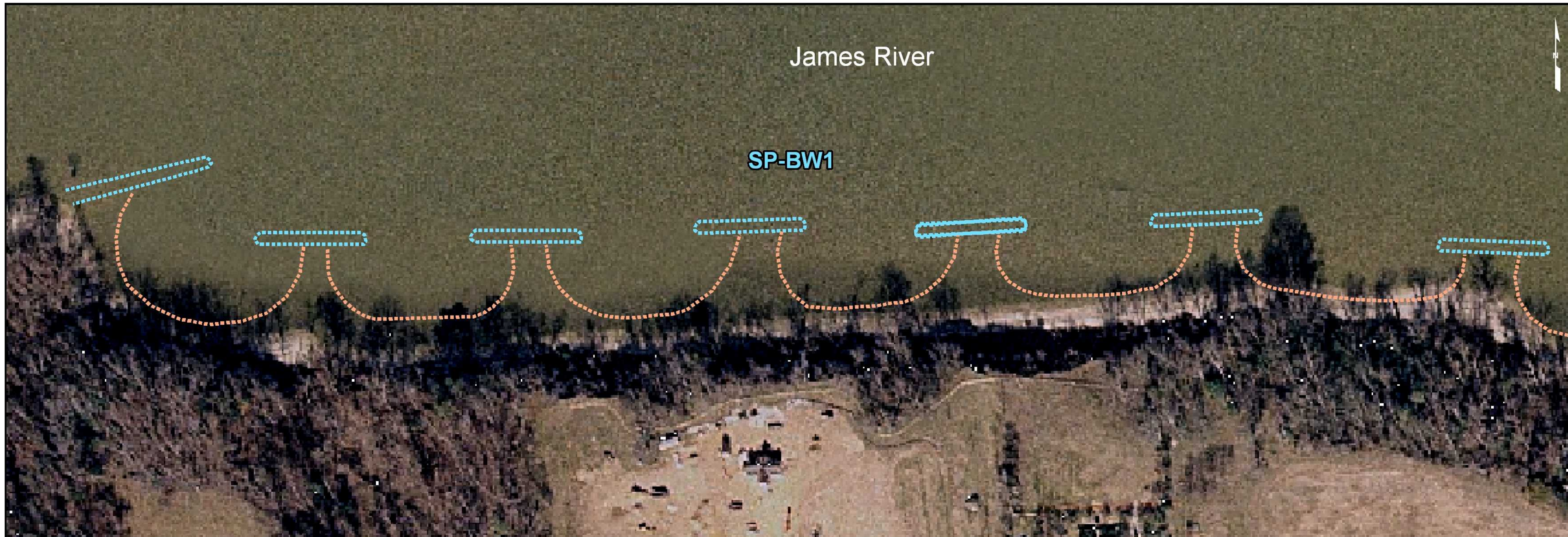
- Beach
- Breakwaters
- Revetment
- Sill

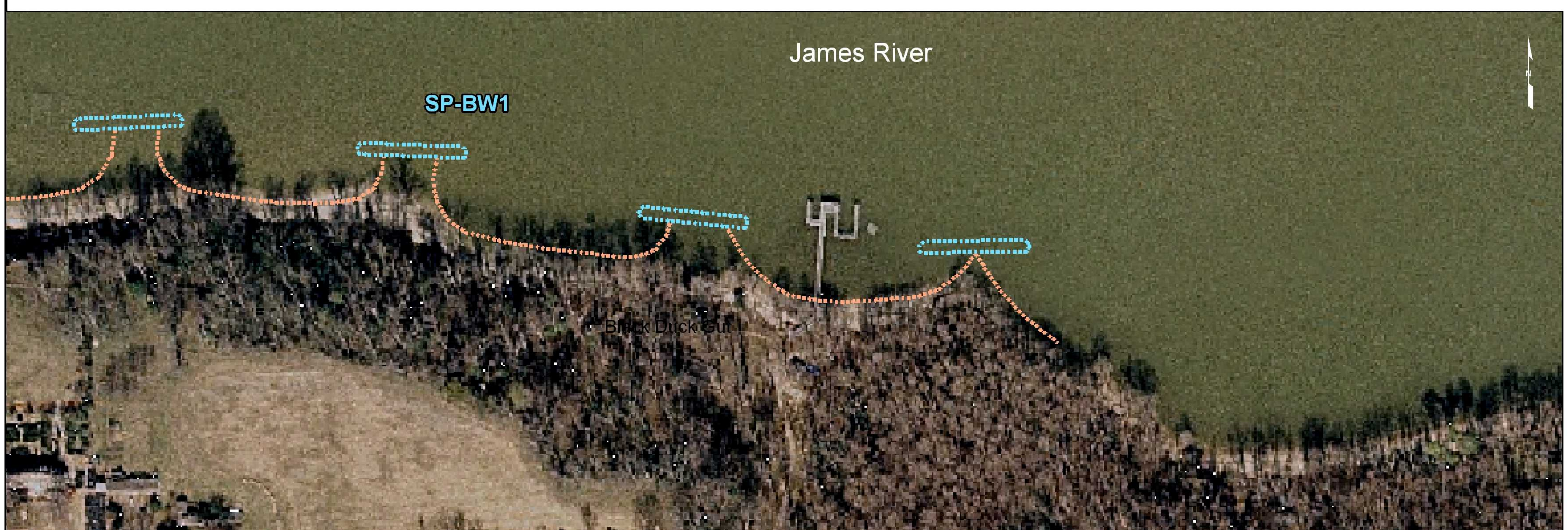


Shoreline Studies Program
VIMS

200 0 200 Feet

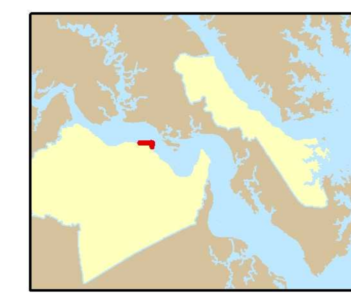
Colonial National Historical Park James River Swanns Point Shore Plan





Proposed Structures

- Beach
- Breakwaters
- Revetment
- Sill

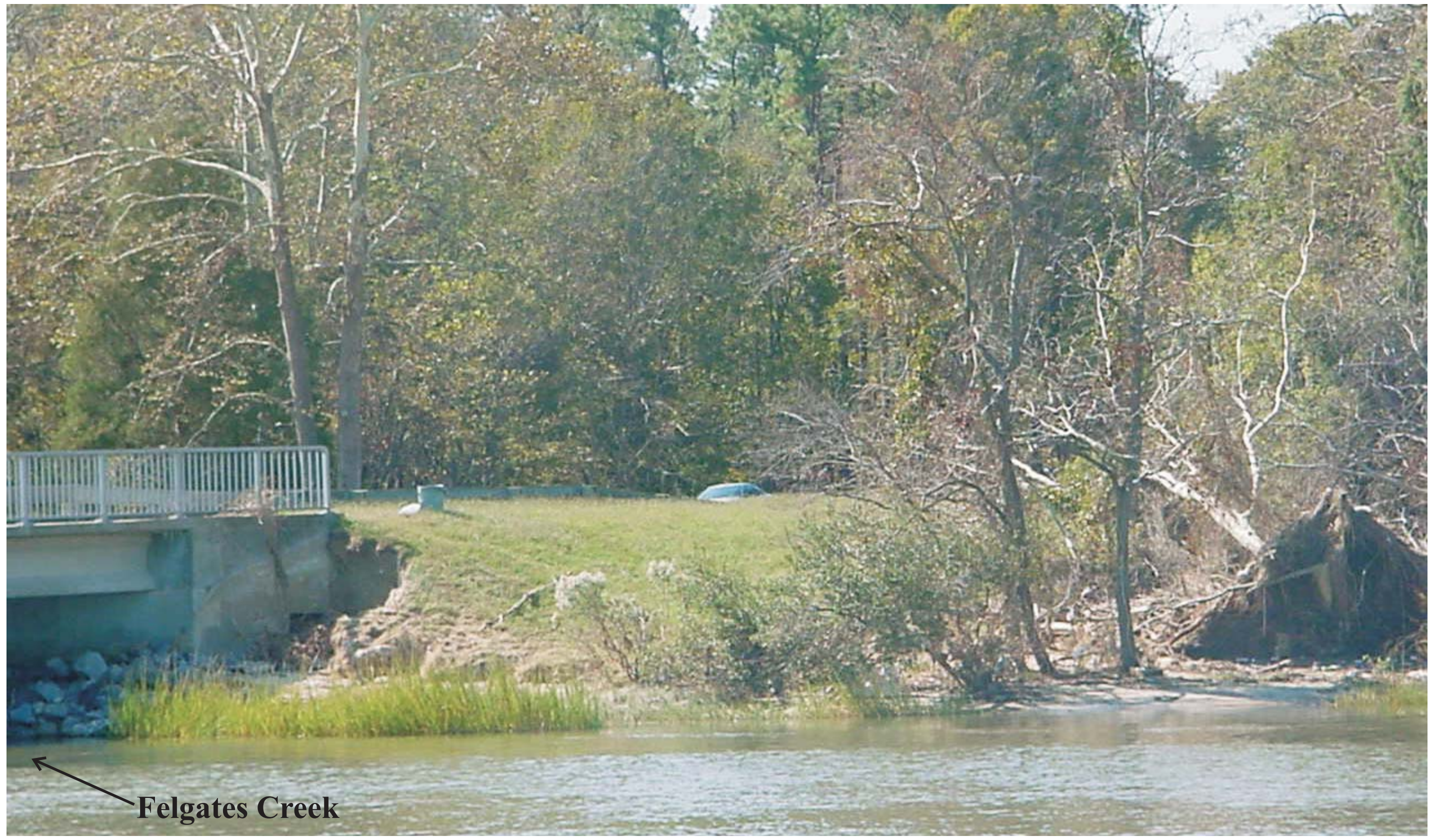


Shoreline Studies Program
VIMS

200 0 200 Feet

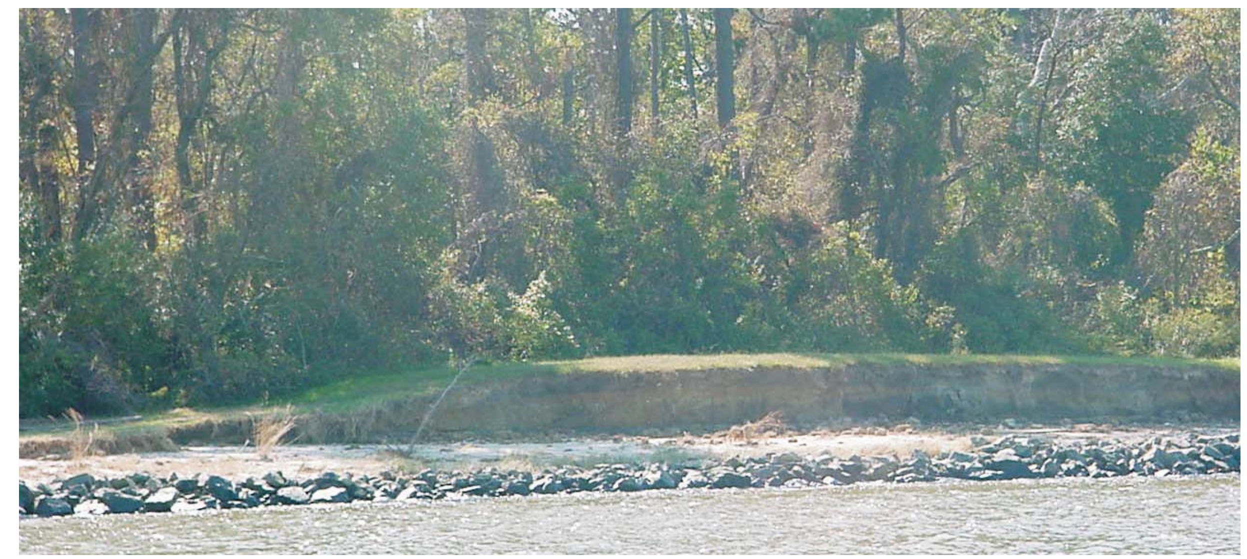
Appendix C

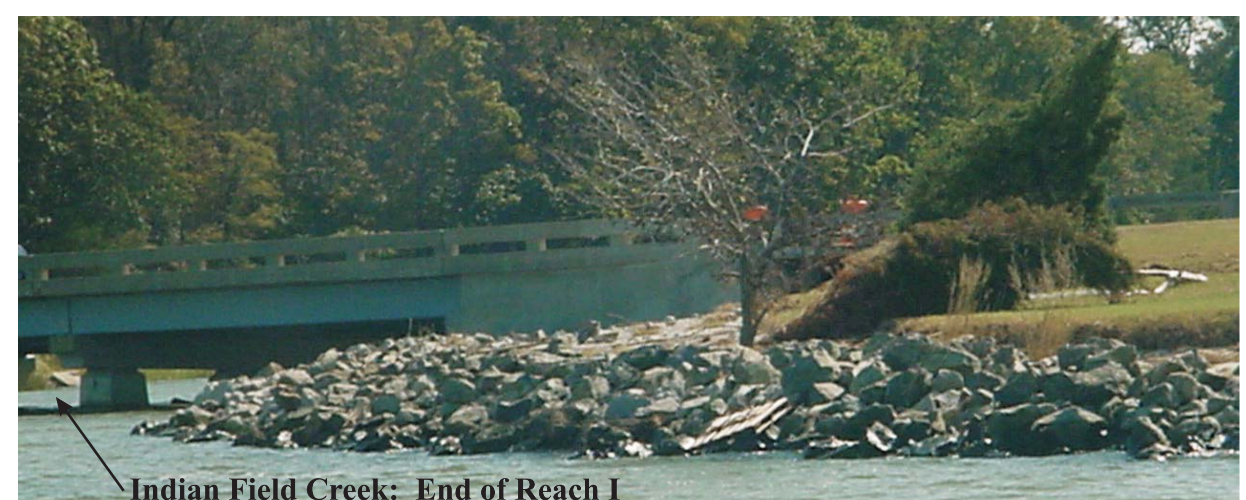
Ground photos of the COLO Shoreline primarily Post-Hurricane Isabel



REACH 1A Photos dated 13 Oct 2003, Post Hurricane Isabel.

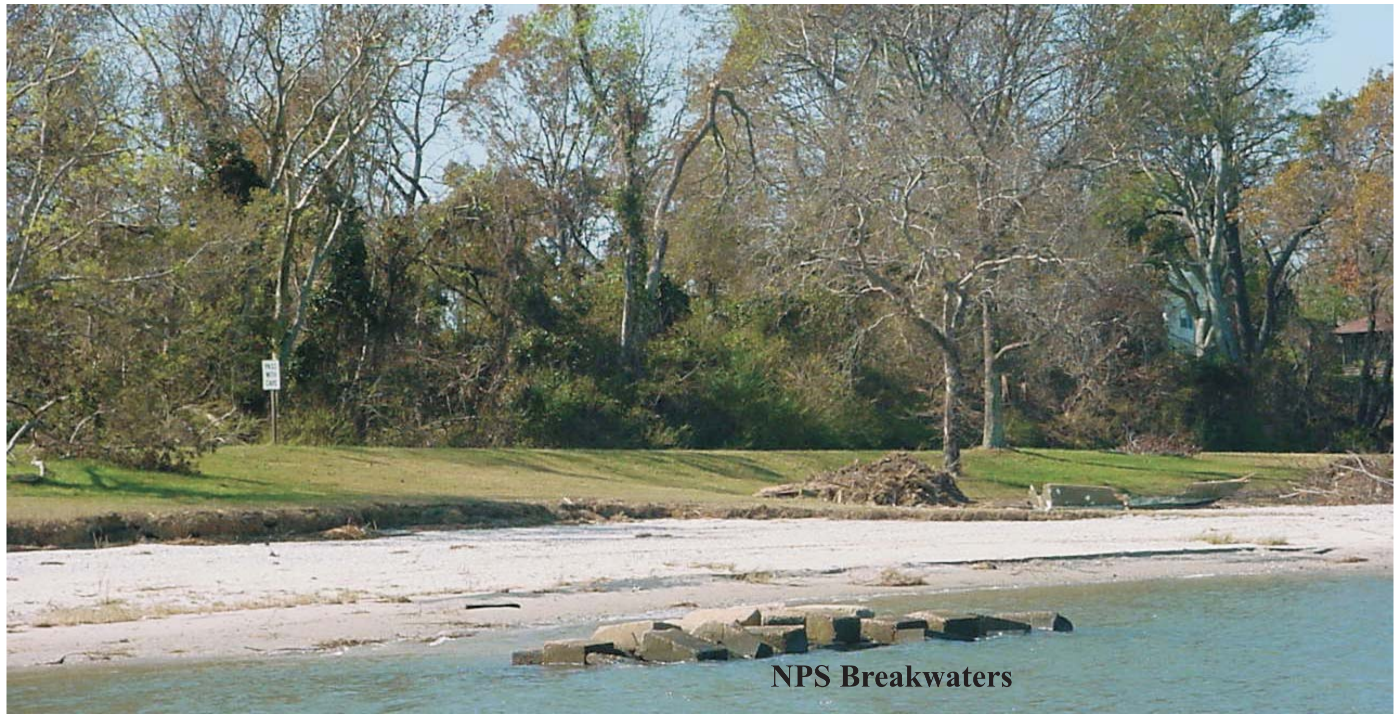
Heading west along Reach I; Photo date 13 Oct 2003





Heading west along Reach I; Photo date 13 Oct 2003

Heading west along REACH II; Photos dated 13 Oct 2003, Post Hurricane Isabel.

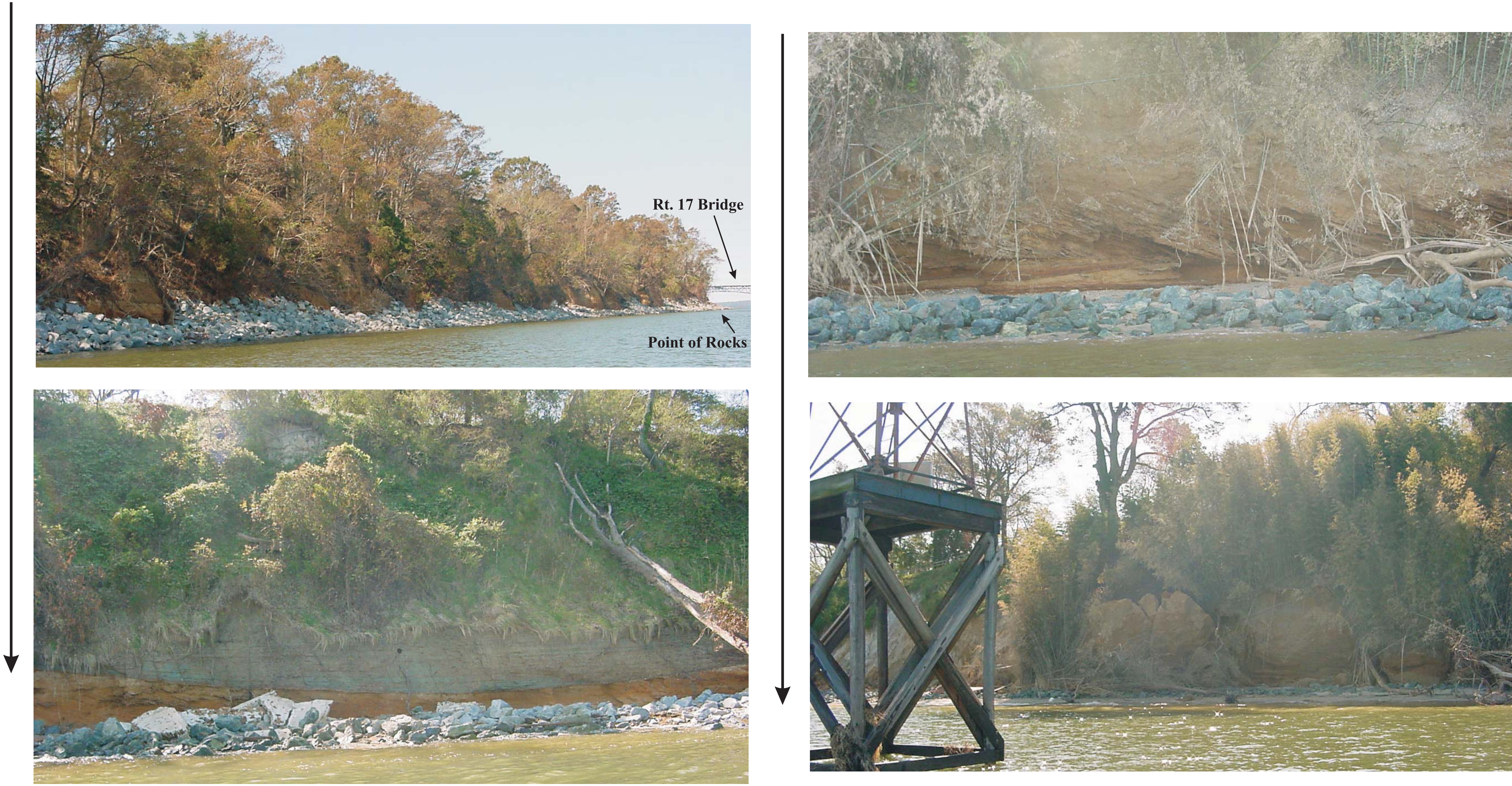


Heading west along REACH II; Photos dated 13 Oct 2003, Post Hurricane Isabel.

Heading east along Reach III; Photo date 13 Oct 2003; Post Hurricane Isabel

Heading east along Reach III; Photo date 13 Oct 2003; Post Hurricane Isabel

Heading east along Reach IV; Photo date 13 Oct 2003; Post Hurricane Isabel



Heading east along Reach IV; Photo date 13 Oct 2003; Post Hurricane Isabel