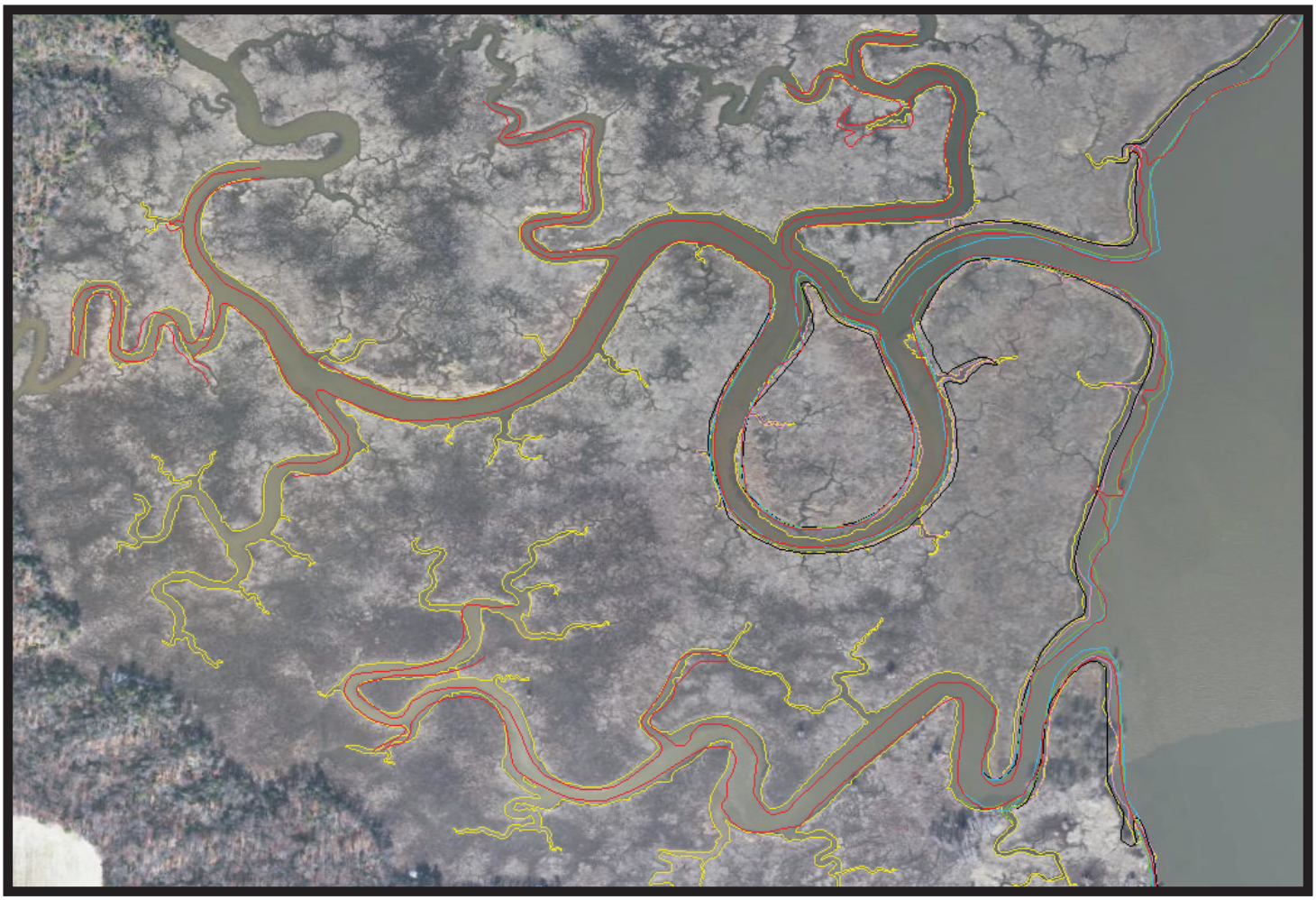
Shoreline Evolution: Charles City County, Virginia

James River and Chickahominy River Shorelines



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

February 2014

Shoreline Evolution: Charles City County, Virginia James River and Chickahominy River Shorelines

Data Summary Report

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February 2014

Table of Contents

1 Introduction.....1

2 Methods
2.1 Photo Rectification and Shoreline Digitizing.....2
2.2 Rate of Change Analysis.....3

3 Results and Summary.....7

4 Summary.....7

5 References.....8

Appendix A. End Point Rate of Shoreline Change Maps

Appendix B. Historical Photo and Digitized Shoreline Maps

List of Figures

Figure 1. Location of Charles City County in the Chesapeake Bay estuarine system.....1

Figure 2. Recent Bing Maps photos of Charles City County showing the difficulties in digitizing the shoreline even on the most recent photos. A: Cypress trees growing in the water obscure the shoreline. B: Trees on an upland bank overhang the shoreline making difficult to delineate. C: Low marsh shoreline, particularly inner creeks do not have a clear representation of where the toe of the marsh peat is.....4

Figure 3. Plate index for Charles City County shorelines.....6

List of Tables

Table 1. Average end point rates of shoreline change in feet per year along sections of Northampton County's coast. Chesapeake Bay sections are shown in bold.....7

1 Introduction

Charles City County is situated along the upper reaches of the James River (Figure 1). Because the County's shoreline is continually changing, determining where the shoreline was in the past, how far and how fast it is moving, and what factors drive shoreline change will help define where the shoreline will be going in the future. These rates and patterns of shore change along Chesapeake Bay's estuarine shores will differ through time as winds, waves, tides and currents shape and modify coastlines by eroding, transporting and depositing sediments.

The purpose of this report is to document how the shore zone of Charles City County has evolved since 1937. Aerial imagery was taken for most of the Bay region beginning that year and can be used to assess the geomorphic nature of shore change. Aerial photos show how the coast has changed, how beaches, dunes, bars, and spits have grown or decayed, how barriers have breached, how inlets have changed course, and how one shore type has displaced another or has not changed at all. Shore change is a natural process but, quite often, the impacts of man, through shore hardening or inlet stabilization, come to dominate a given shore reach. In addition to documenting historical shorelines, the change in shore positions along the larger creeks in Charles City County will be quantified in this report. The shorelines of very irregular coasts, small creeks and around inlets, and other complicated areas will be shown but not quantified.

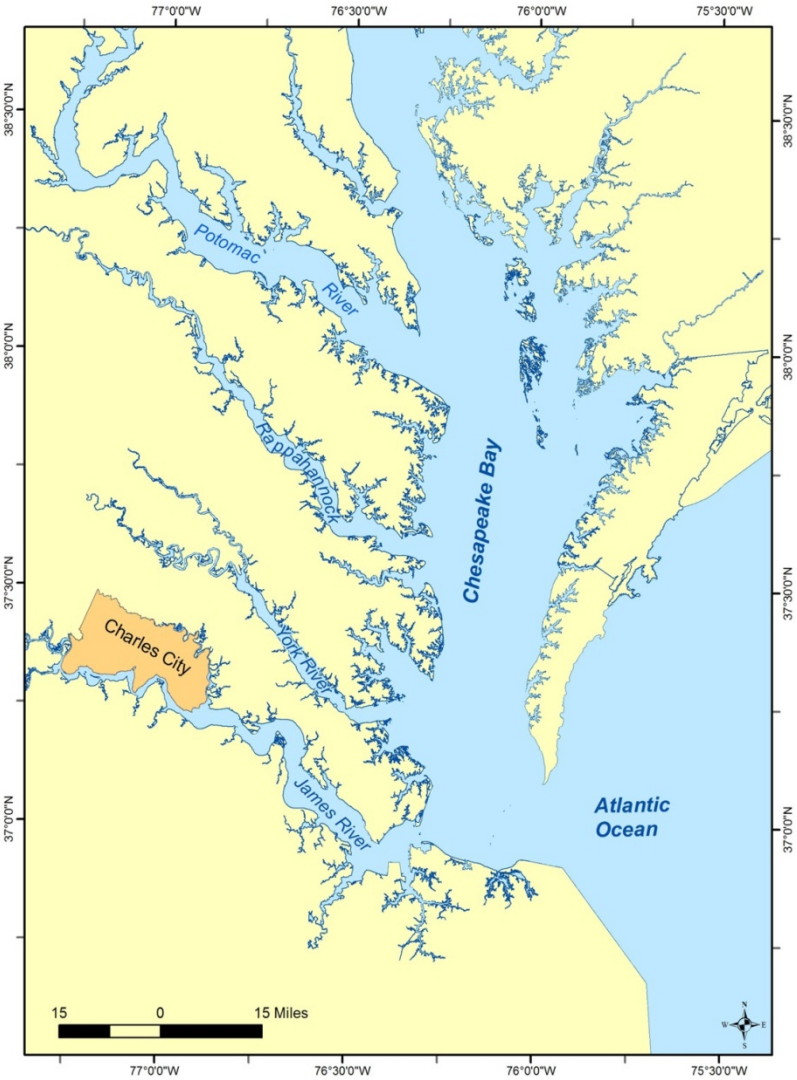

Figure 1. Location of Charles City County in the Chesapeake Bay estuarine system.

2 Methods

2.1 Photo Rectification and Shoreline Digitizing

An analysis of aerial photographs provides the historical data necessary to understand the suite of processes that work to alter a shoreline. Images of the Charles City County Shoreline from 1937, 1953, 1968, 1994, 2002, and 2009 were used in the analysis. The 1994, 2002 and 2009 images were available from other sources. The 1994 imagery was orthorectified by the U.S. Geological Survey (USGS) and the 2002 and 2009 imagery was orthorectified by the Virginia Base Mapping Program (VBMP). The 1937, 1953 and 1968 photos are part of the VIMS Shoreline Studies Program archives. The historical aerial images used to analyze the entire County shoreline were not always flown on the same day. The exact dates that the 1994 images were flown could not be ascertained; however, the dates for the other years are as follows:
1937 – March 30, April 7 and 12;
1953 –October 13 and 17 and December 3;
1968 – January 18;
2002 – February 16, 18, 19, 22, and 24;
2009 – February 1, 5, 13, 20, 21, and March 9.

The 1937, 1953 and 1968 images were scanned as tiffs at 600 dpi and converted to ERDAS IMAGINE (.img) format. These aerial photographs were orthographically corrected to produce a seamless series of aerial mosaics following a set of standard operating procedures. The 1994 Digital Orthophoto Quarter Quadrangles (DOQQ) from USGS were used as the reference images. The 1994 photos are used rather than higher quality, more recent aerials because of the difficulty in finding control points that match the earliest 1937 images.

ERDAS Orthobase image processing software was used to orthographically correct the individual flight lines using a bundle block solution. Camera lens calibration data were 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. The exterior and interior models were combined with a digital elevation model (DEM) from the USGS National Elevation Dataset to produce an orthophoto for each aerial photograph. The orthophotographs 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 .img format. To maintain an accurate match with the reference images, it is necessary to distribute the control points evenly, when possible. This can be challenging in areas given the lack of ground features and poor photo quality on the earliest photos. Good examples of control points were manmade features such as road

intersections and stable natural landmarks such as ponds and creeks that have not changed much over time. The base of tall features such as buildings, poles, or trees can be used, but the base can be obscured by other features or shadows making these locations difficult to use accurately. Many areas of the County were particularly difficult to rectify, either due to the lack of development when compared to the reference images or due to no development in the historical and the reference images.

Once the aerial photos were orthorectified and mosaicked, the shorelines were digitized in ArcMap with the mosaics in the background. The morphologic toe of the beach or edge of marsh was used to approximate low water. High water limit of runup can be difficult to determine on some shorelines due to narrow or non-existent beaches against upland banks or vegetated cover. The feature digitized is noted in the shoreline attributes for the 2009 photos. Two hundred nine miles of shoreline were digitized from the 2009 photos. However, not all tidal shoreline was digitized inside very small creeks and marshes. Poor quality photos in some areas made rectifying and digitizing images difficult. Environmental conditions along the shoreline made it difficult to delineate the shoreline even on the latest photos in some areas as well (Figure 2). It was difficult to tell the difference between marsh and tidal flats in some areas. In addition, trees exist along many sections of the Charles City shoreline. These trees can obscure the true shoreline because they can grow in the water and their branches cover the shoreline. In areas where the shoreline was not clearly identifiable on the aerial photography, the location was estimated based on the experience of the digitizer. The displayed shorelines are in shapefile format. One shapefile was produced for each year that was mosaicked.

Horizontal positional accuracy is based upon orthorectification of scanned aerial photography against the USGS digital orthothophoto quadrangles. For vertical control, the USGS 30m DEM data was used. The 1994 USGS reference images were developed in accordance with National Map Accuracy Standards (NMAS) for Spatial Data Accuracy at the 1:12,000 scale. The 2002 and 2009 Virginia Base Mapping Program's orthophotography were developed in accordance with the National Standard for Spatial Data Accuracy (NSSDA). Horizontal root mean square error (RMSE) for historical mosaics was held to less than 20 ft.

2.2 Rate of Change Analysis

AMBUR (Analyzing Moving Boundaries Using R) is a suite of tools that are used to better analyze and understand historic shoreline changes. These tools use the free, open-source R software environment and can be customized to perform not only advanced statistics but also geospatial and geostatistical functions. The AMBUR package provides tools for investigating diverse

shoreline types through: multiple shoreline settings, improved transect casting methods, and detailed analysis and output. The package allows import and export of geospatial data in ESRI shapefile format, which is compatible with most commercial and open-source GIS software. The "baseline and transect" method is the primary technique used to quantify distances and rates of shoreline movement, and to detect classification changes across time.

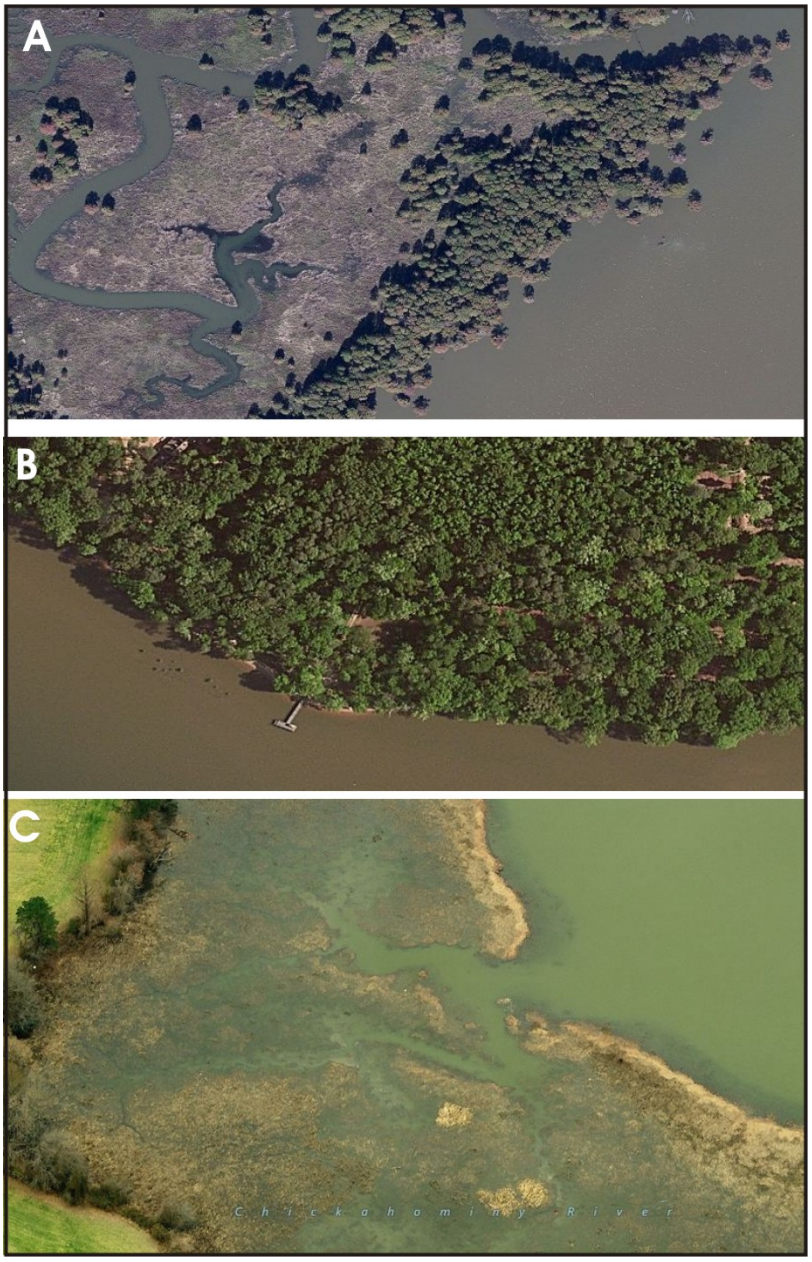

Figure 2. Recent Bing Maps photos of Charles City County showing the difficulties in digitizing the shoreline even on the most recent photos. A: Cypress trees growing in the water obscure the shoreline. B: Trees on an upland bank overhang the shoreline making difficult to delineate. C: Low marsh shoreline, particularly inner creeks do not have a clear representation of where the toe of the marsh peat is.

Eighty four miles of baselines and 12,900 transects about 30 feet apart were created for Charles City County. Baselines were digitized slightly seaward of the 1937 shoreline and encompassed most of the County's coast. The baselines may not include very small creeks and areas that have unique shoreline morphology such as creek mouths and spits.

The End Point Rate (EPR) is calculated by determining the distance between the oldest and most recent shoreline in the data and dividing it by the number of years between them. This method provides an accurate net rate of change over the long term and is relatively easy to apply to most shorelines since it only requires two dates. This method does not use the intervening shorelines so it may not account for changes in accretion or erosion rates that may occur through time. However, Milligan *et al.* (2010a, 2010b, 2010c, 2010d) found that in several localities within the bay, EPR is a reliable indicator of shore change even when intermediate dates exist.

Using methodology reported in Morton *et al.* (2004) and National Spatial Data Infrastructure (1998), estimates of error in orthorectification, control source, DEM and digitizing were combined to provide an estimate of total maximum shoreline position error. The data sets that were orthorectified (1937, 1953, and 1968) have an estimated total maximum shoreline position error of 20.0 ft, while the total maximum shoreline error for the three existing datasets are estimated at 18.3 ft for USGS and 10.2 ft for VBMP. The maximum annualized error for the shoreline data is $\pm$0.7 ft/yr. The smaller rivers and creeks are more prone to error due to their lack of good control points for photo rectification, narrower shore features, tree and ground cover and overall smaller rates of change. These areas are digitized but due to the higher potential for error, rates of change analysis are not calculated. Many areas of Charles City County have shore change rates that fall within the calculated error. Some of the areas that show very low accretion can be due to errors within the method as described above.

The Charles City County shoreline was divided into 15 plates (Figure 3) in order to display the shoreline data. In Appendix A, the 2009 image is shown with only the 1937 and 2009 shorelines and the calculated EPR of change. In Appendix B, one photo date and the associated shoreline is shown on each. These include the photos taken in 1937, 1953, 1968, 1994, 2002 and 2009. The shorelines are summarized on the 2009 image.

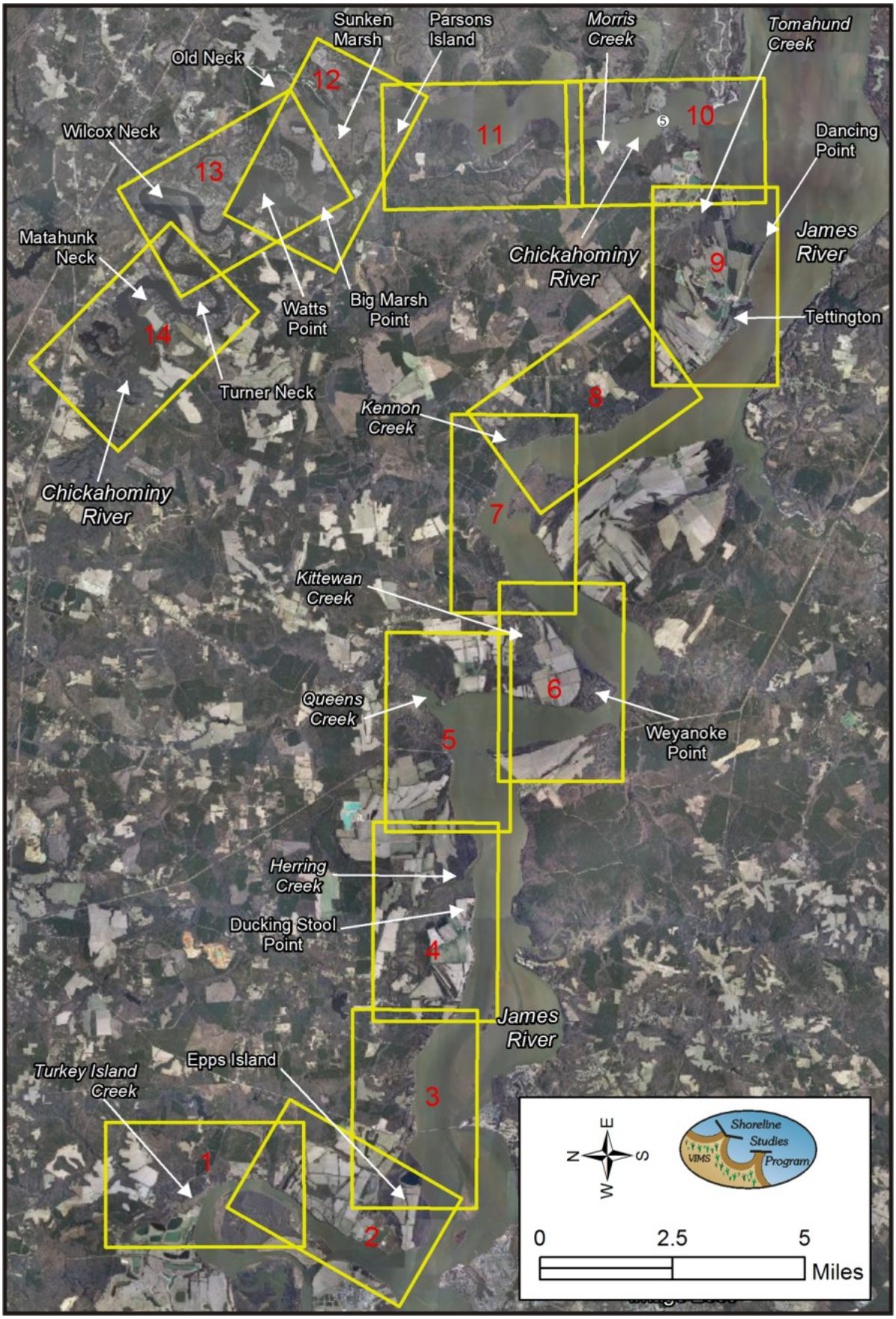

Figure 3. Plate index for Charles City County shorelines.

3 Results and Discussion

Most of the river and creek shoreline in Charles City County is experiencing very low erosion (<1 ft/yr). Table 1 shows the average EPR of change for sections of the County based on the digitized shorelines. Those sites that are on the open river, face downriver, and/or occur on a point of land tend to have higher rates of change. In addition, many areas of the shoreline consists of high wooded banks. When trees on the bank fall, it can exacerbate instability of the high bank. Even though wave action is limited due to small fetches, during storms, waves can directly impact the base of bank causing the entire bank to slump. This can deposit enough material to offset the erosion.

Several areas are noteworthy. Along the James River at Epps Island (Plate 2), the marsh was dredged between 1953 and 1968, and the material placed in the nearshore. The offshore island area has grown since then. On Plate 9, placement of structures in the offshore have resulted in a positive shoreline change. Several areas indicate that marsh has been lost due to sea level rise rather than erosion. Plate 10 shows an area inside the Chickahominy River at the mouth of Morris Creek where marsh has disappeared between 1968 and 1994. A large area of marsh disappeared from Eagle Bottom (Plate 11) during the same time frame. In addition, many of the small tidal creeks have gotten wider through time and is particularly noticeable on Plate 14.

Table 2. Average end point rates of shoreline change in feet per year along sections of Charles City County's coast.

Reach Name	Plate Number	Avg EPR (ft/yr)	Category
James River Turkey Island Creek to Epps Island*	1 and 2	-0.1	Very Low Erosion
James River Epps Island to Herring Creek	3 and 4	-0.3	Very Low Erosion
Herring Creek	4	-0.4	Very Low Erosion
James River Herring Creek to Queens Creek	4 and 5	-0.5	Very Low Erosion
Queens Creek	5	-0.3	Very Low Erosion
James River Queens Creek to Kennon Creek	5-7	-0.4	Very Low Erosion
James River Kennon Creek to Tomahund Creek	7-10	-0.1	Very Low Erosion
Chickahominy River	10-14	-0.6	Very Low Erosion

*excludes dredged area

4 Summary

The rates of change shown in Table 1 are averaged across large sections of shoreline and may not be indicative of rates at specific sites within the reach. Some areas of the County, where the shoreline change rates are categorized as accretion, have structures along the shoreline which results in a positive long-

term rate of change due to the structures themselves. Some of the areas with very low accretion, particularly in the smaller creeks and rivers, may be the result of errors within photo rectification and digitizing wooded shorelines.

5 References

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Morton, R.A., T.L. Miller, and L.J. Moore, 2004. National Assessment of Shoreline Change: Part 1 Historical Shoreline Change and Associated Coastal Land Loss along the U.S. Gulf of Mexico. U.S. Department of the Interior, U.S. GeologicalSurvey Open-File Report 2004-1043, 45 p.

National Spatial Data Infrastructure, 1998. Geospatial Positional Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy. Subcommittee for Base Cartographic Data. Federal Geographic Data Committee. Reston, VA.

Appendix A

End Point Rate of Shoreline Change Maps

Note: The location labels on the plates come from U.S. Geological Survey topographic maps, Google Earth, and other map sources and may not be accurate for the historical or even more recent images. They are for reference only.

Plate 1 Plate 2 Plate 3

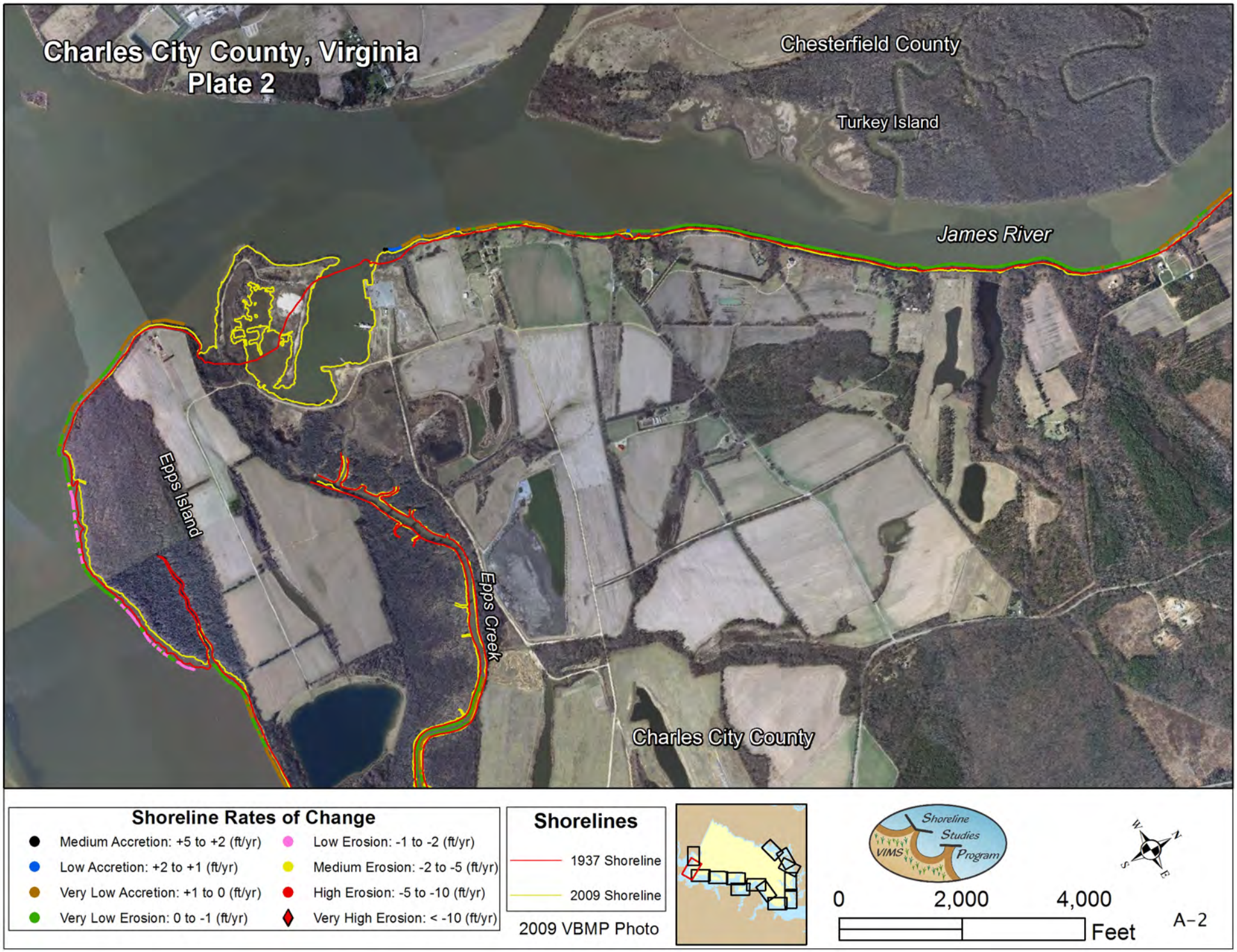
Plate 4 Plate 5 Plate 6

Plate 7 Plate 8 Plate 9

Plate 10 Plate 11 Plate 12

Plate 13 Plate 14

Charles City County, Virginia
Plate 1
Chesterfield County
Henrico County
Turkey Island
Presque Isle Swamp
Turkey Island Creek
James River
Charles City County
Shoreline Rates of Change
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -10 (ft/yr)
Shorelines
1937 Shoreline
2009 Shoreline
2009 VBMP Photo
Shoreline Studies Program
VIMS
N
W
E
S
0
2,000
4,000
Feet
A-1


Charles City County, Virginia
Plate 2
Chesterfield County
Turkey Island
James River
Epps Island
Epps Creek
Charles City County
Shoreline Rates of Change
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -10 (ft/yr)
Shorelines
1937 Shoreline
2009 Shoreline
2009 VBMP Photo
Shoreline Studies Program
VIMS
0
2,000
4,000
Feet
A-2

Shoreline Rates of Change

- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion: +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: < -10 (ft/yr)

Shorelines

- 1937 Shoreline
- 2009 Shoreline

2009 VBMP Photo

Shoreline Studies Program VIMS

0 2,000 4,000 Feet

N W E S

Charles City County, Virginia
Plate 4
Herring Creek
Ducking Stool Point
Bucklers Point
James River
Shoreline Rates of Change
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -10 (ft/yr)
Shorelines
1937 Shoreline
2009 Shoreline
2009 VBMP Photo
Shoreline Studies Program
VIMS
0
2,000
4,000
Feet
N
W
E
S
A-4

Shoreline Rates of Change

- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion: +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: < -10 (ft/yr)

Shorelines

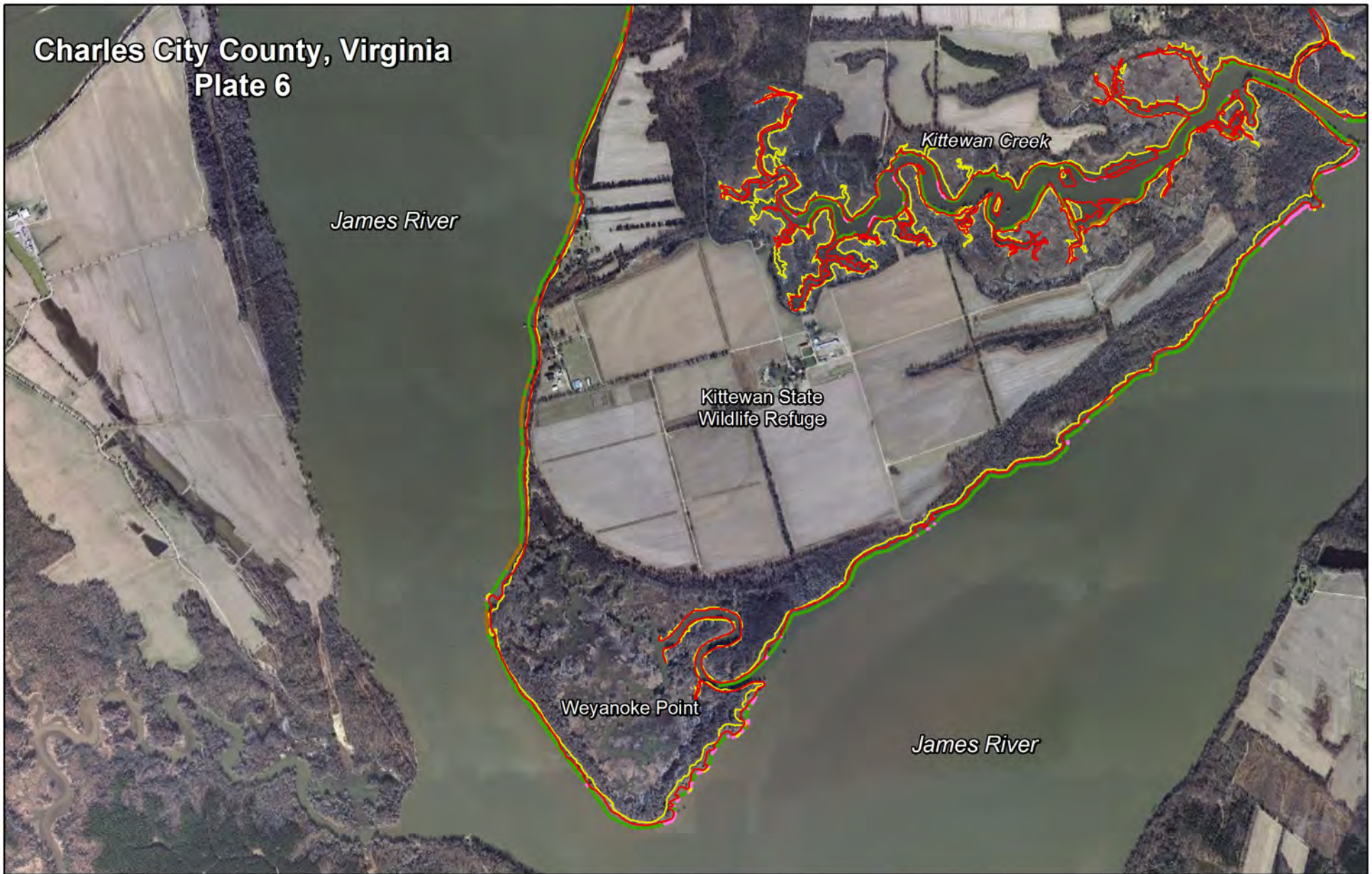
- 1937 Shoreline
- 2009 Shoreline

2009 VBMP Photo

Shoreline Studies Program VIMS

0 2,000 4,000 Feet

N W E S



Shoreline Rates of Change

- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion: +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: < -10 (ft/yr)

Shorelines

- 1937 Shoreline
- 2009 Shoreline

2009 VBMP Photo

Shoreline Studies Program VIMS

0 2,000 4,000 Feet

N W E S

Shoreline Rates of Change

- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion: +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: < -10 (ft/yr)

Shorelines

- 1937 Shoreline
- 2009 Shoreline

2009 VBMP Photo

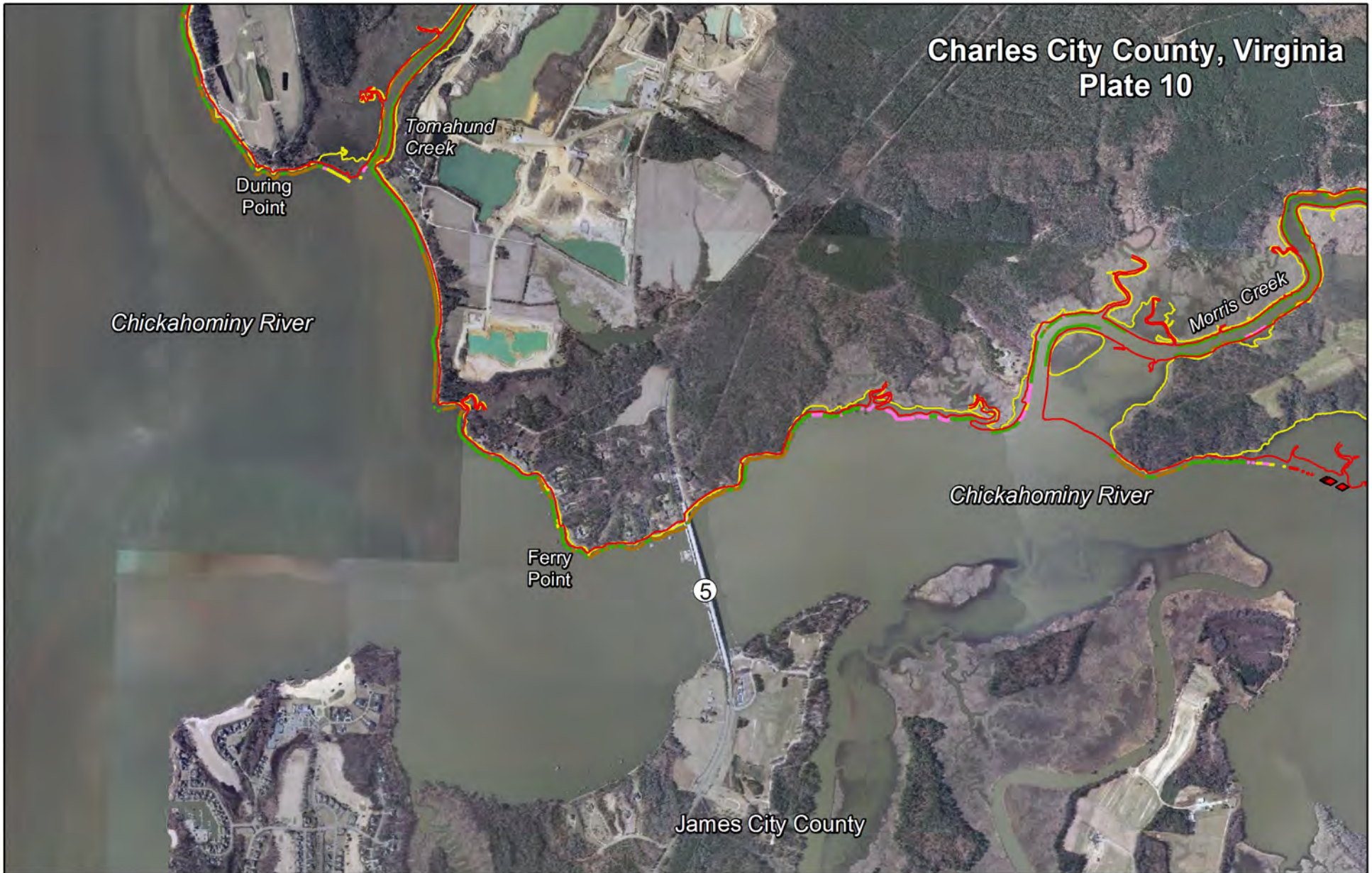
Shoreline Studies Program VIMS

0 2,000 4,000 Feet

N W E S

Charles City County, Virginia
Plate 8
Kennon Creek
Bachelor Point
Kennon March
James River
Trees Point
Prince George County
Shoreline Rates of Change
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -10 (ft/yr)
Shorelines
1937 Shoreline
2009 Shoreline
2009 VBMP Photo
Shoreline Studies Program
VIMS
0
2,000
4,000
Feet
N
E
S
W

Charles City County, Virginia
Plate 9
Tomahund Creek
Tettington
Chickahominy River
Sandy Point
James River
Dancing Point
Shoreline Rates of Change
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -10 (ft/yr)
Shorelines
1937 Shoreline
2009 Shoreline
2009 VBMP Photo
Shoreline Studies Program
VIMS
0
2,000
4,000
Feet
N
W
E
S



Shoreline Rates of Change

- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion: +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: < -10 (ft/yr)

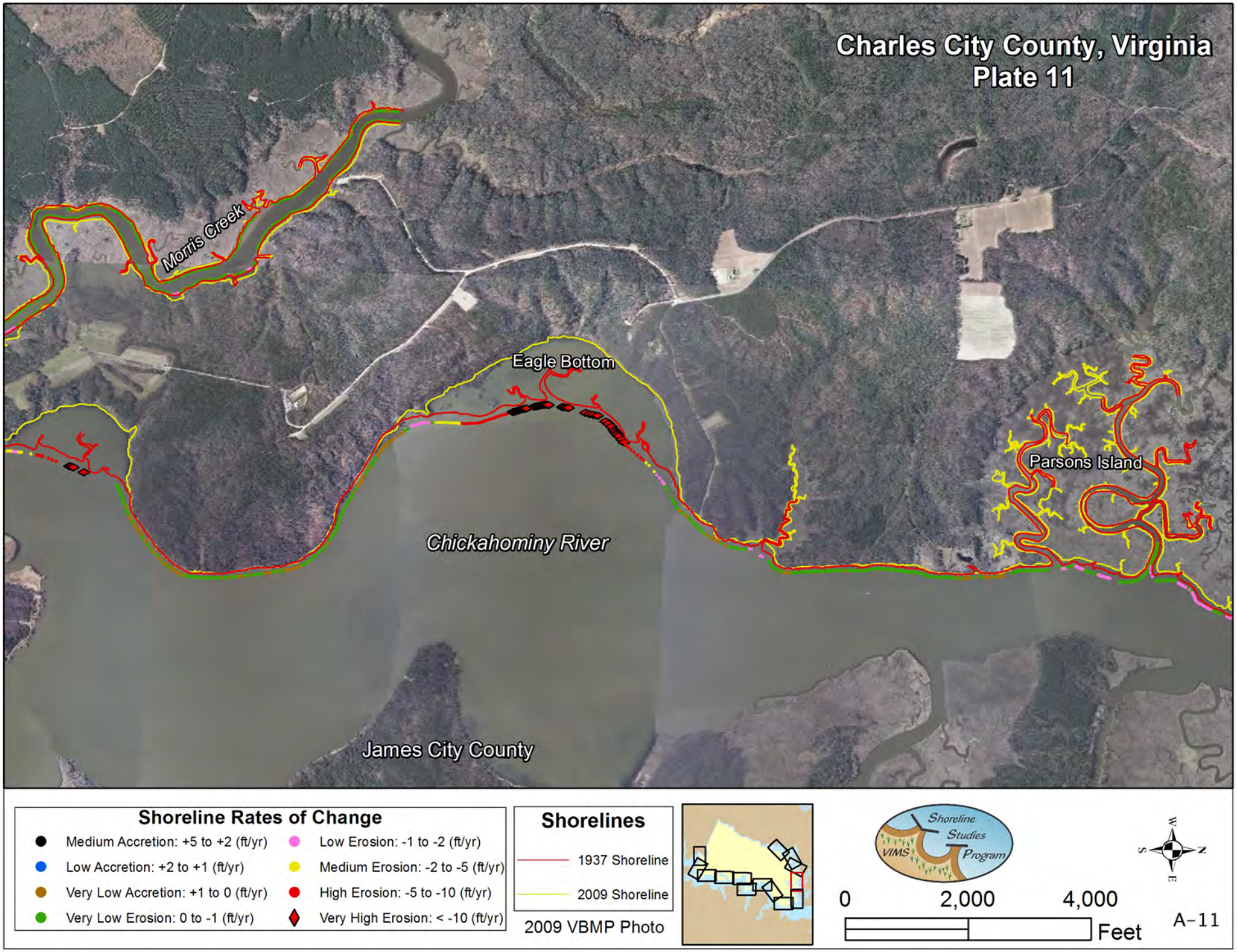
Shorelines

- 1937 Shoreline
- 2009 Shoreline

2009 VBMP Photo

Shoreline Studies Program VIMS

0 2,000 4,000 Feet


Charles City County, Virginia
Plate 11
Morris Creek
Eagle Bottom
Parsons Island
Chickahominy River
James City County
Shoreline Rates of Change
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -10 (ft/yr)
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2009 Shoreline
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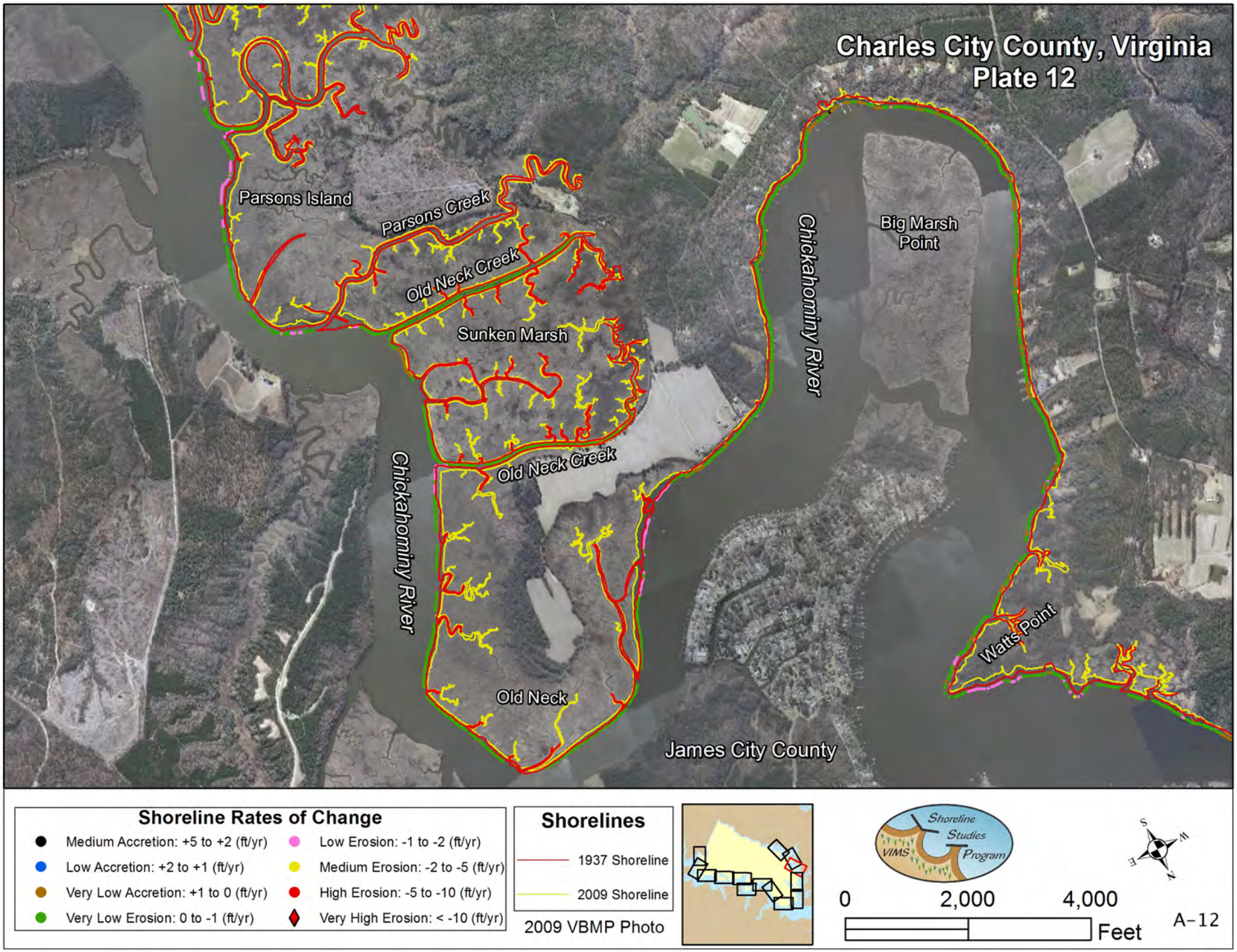
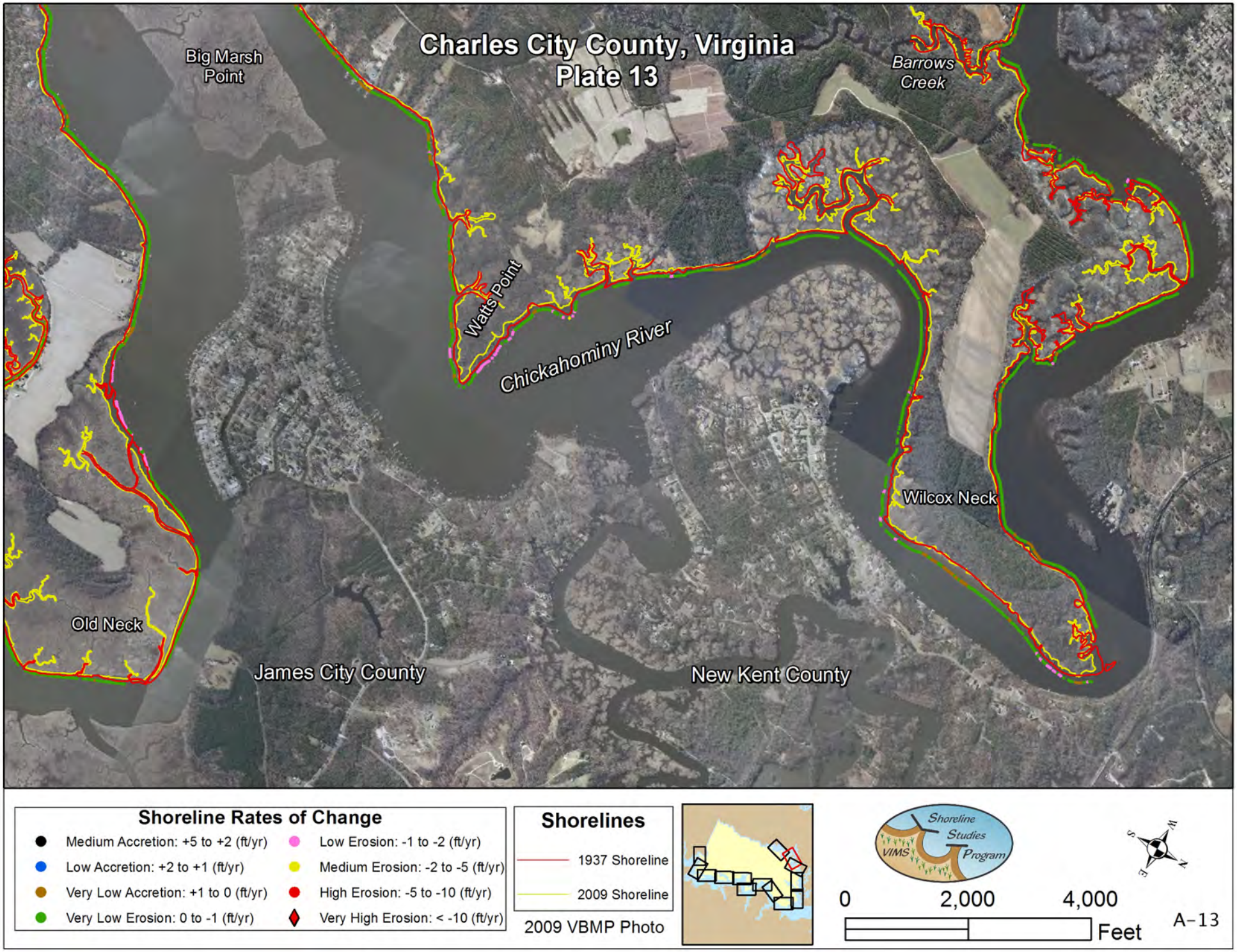
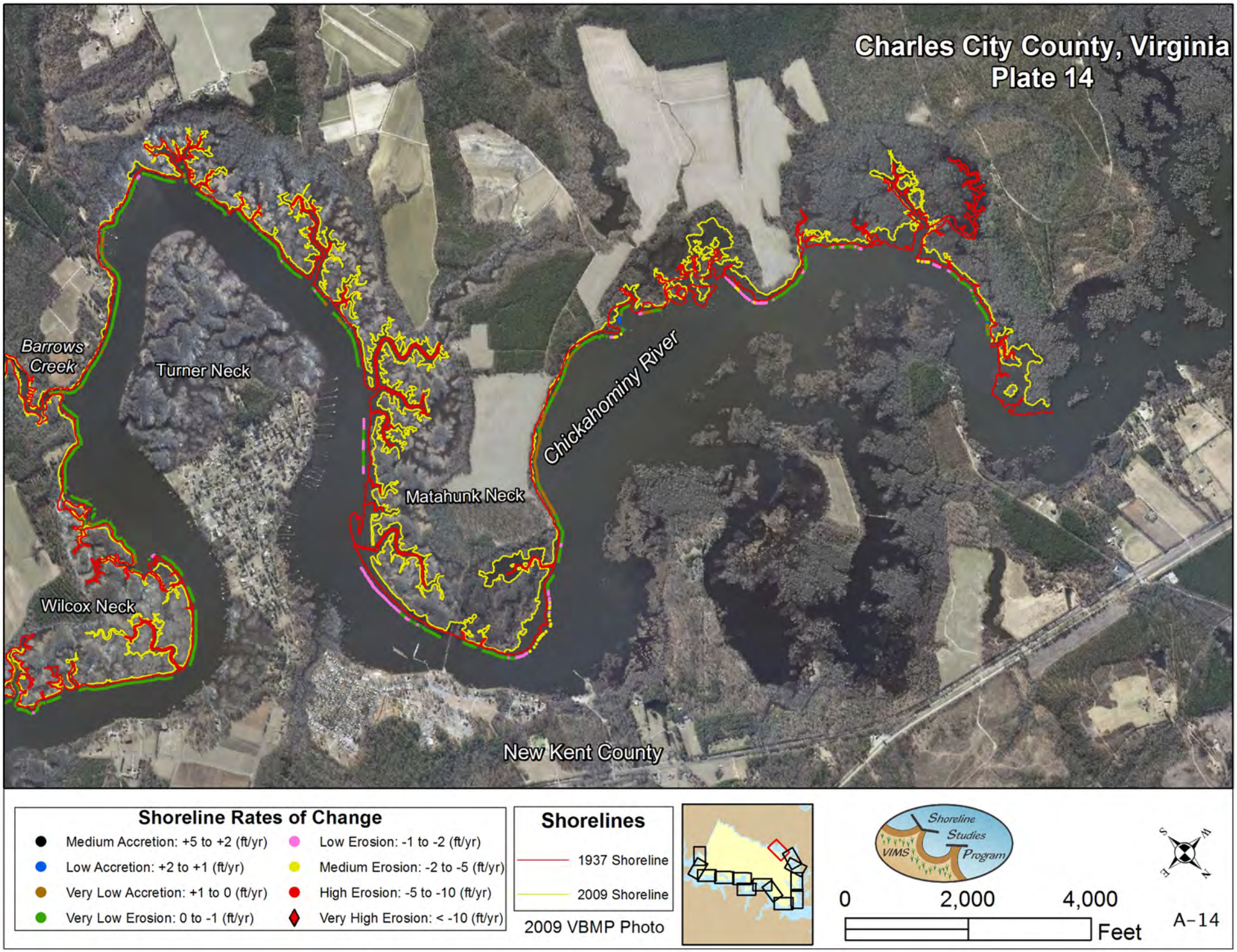
2,000
4,000
Feet
A-11


Charles City County, Virginia
Plate 12
Parsons Island
Parsons Creek
Old Neck Creek
Sunken Marsh
Old Neck Creek
Chickahominy River
Chickahominy River
Big Marsh Point
Watts Point
Old Neck
James City County
Shoreline Rates of Change
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -10 (ft/yr)
Shorelines
1937 Shoreline
2009 Shoreline
2009 VBMP Photo
Shoreline Studies Program
VIMS
0
2,000
4,000
Feet
A-12


Charles City County, Virginia
Plate 13
Big Marsh Point
Barrows Creek
Watts Point
Chickahominy River
Wilcox Neck
Old Neck
James City County
New Kent County
Shoreline Rates of Change
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -10 (ft/yr)
Shorelines
1937 Shoreline
2009 Shoreline
2009 VBMP Photo
Shoreline Studies Program
VIMS
0
2,000
4,000
Feet
A-13


Charles City County, Virginia
Plate 14
Barrows Creek
Turner Neck
Chickahominy River
Matahunk Neck
Wilcox Neck
New Kent County
Shoreline Rates of Change
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -10 (ft/yr)
Shorelines
1937 Shoreline
2009 Shoreline
2009 VBMP Photo
Shoreline Studies Program
VIMS
0
2,000
4,000
Feet
A-14

Appendix B

Historical Photo and Digitized Shoreline Maps

Note: The location labels on the plates come from U.S. Geological Survey topographic maps, Google Earth, and other map sources and may not be accurate for the historical or even more recent images. They are for reference only.

Plate 1 Plate 2 Plate 3

Plate 4 Plate 5 Plate 6

Plate 7 Plate 8 Plate 9

Plate 10 Plate 11 Plate 12

Plate 13 Plate 14

Legend

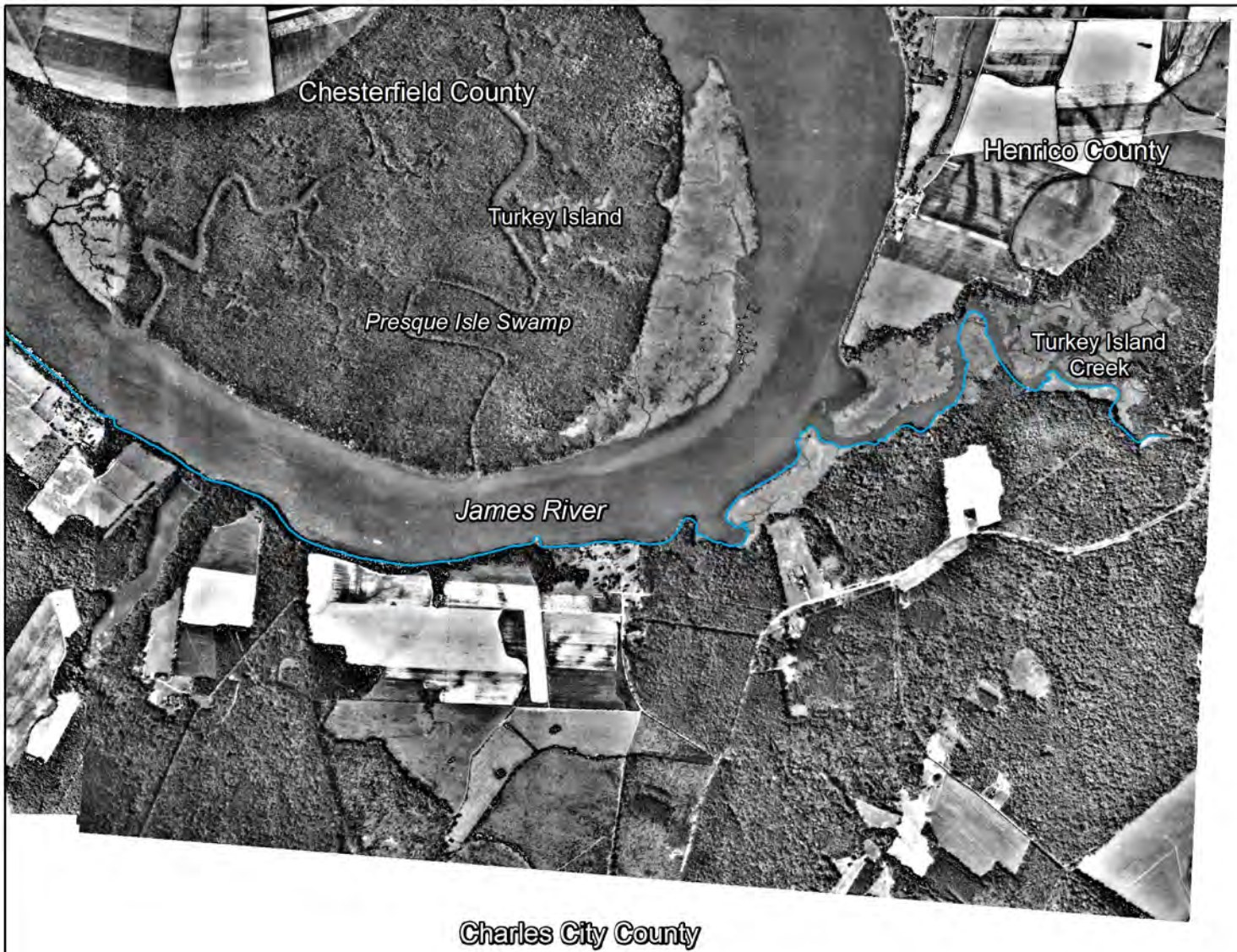
Shoreline1937

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 1

Photo Date: 1937

Shoreline Studies Program VIMS



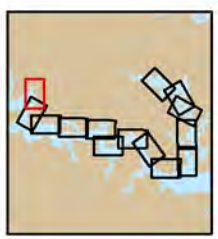
Legend

Shoreline 1953

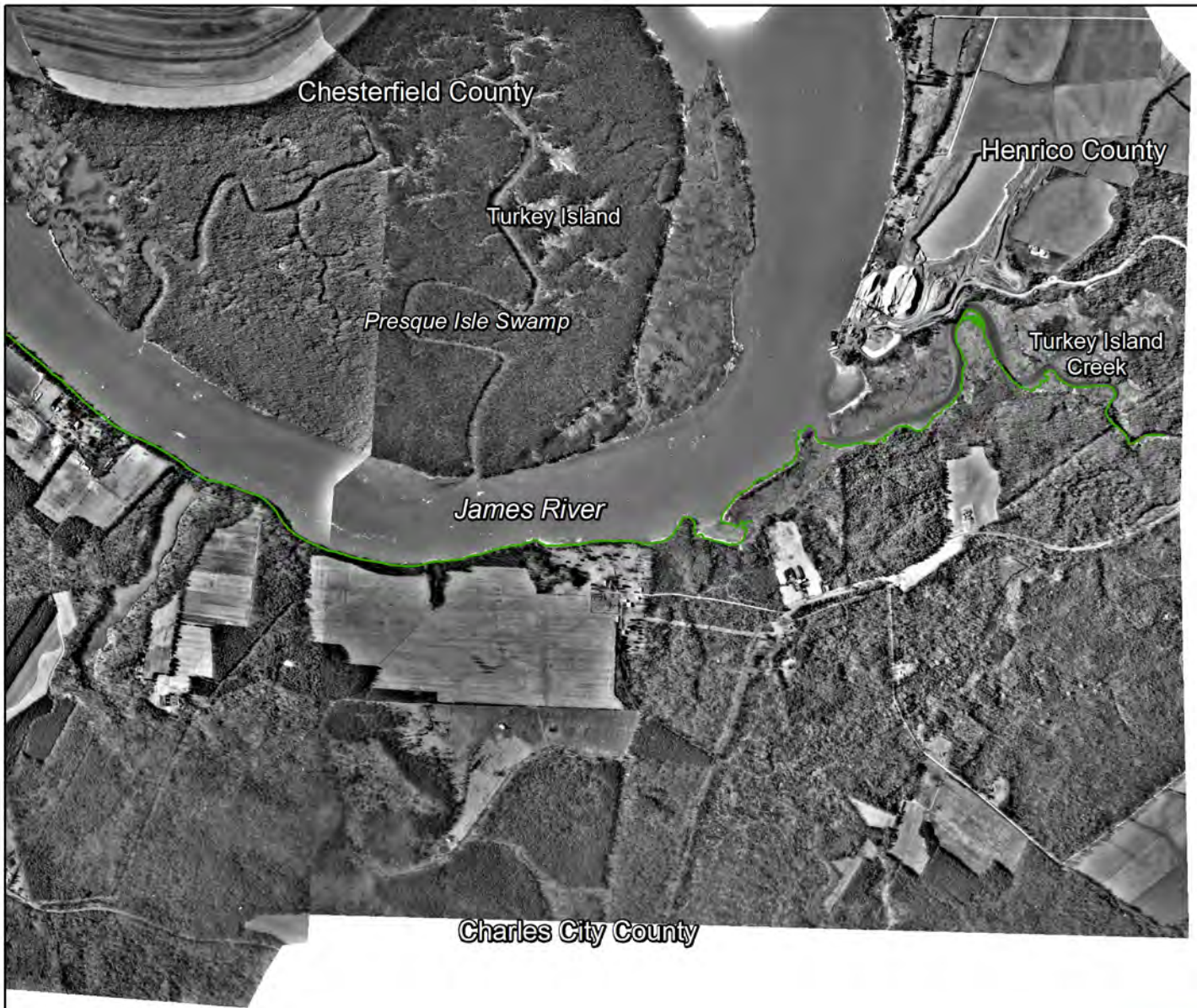
0 2,000 4,000 Feet

Charles City County, Virginia
Plate 1

Photo Date: 1953



Shoreline Studies Program VIMS



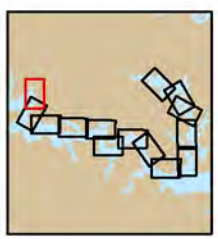
Legend

Shoreline 1968

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 1

Photo Date: 1968



Shoreline Studies Program VIMS

Legend

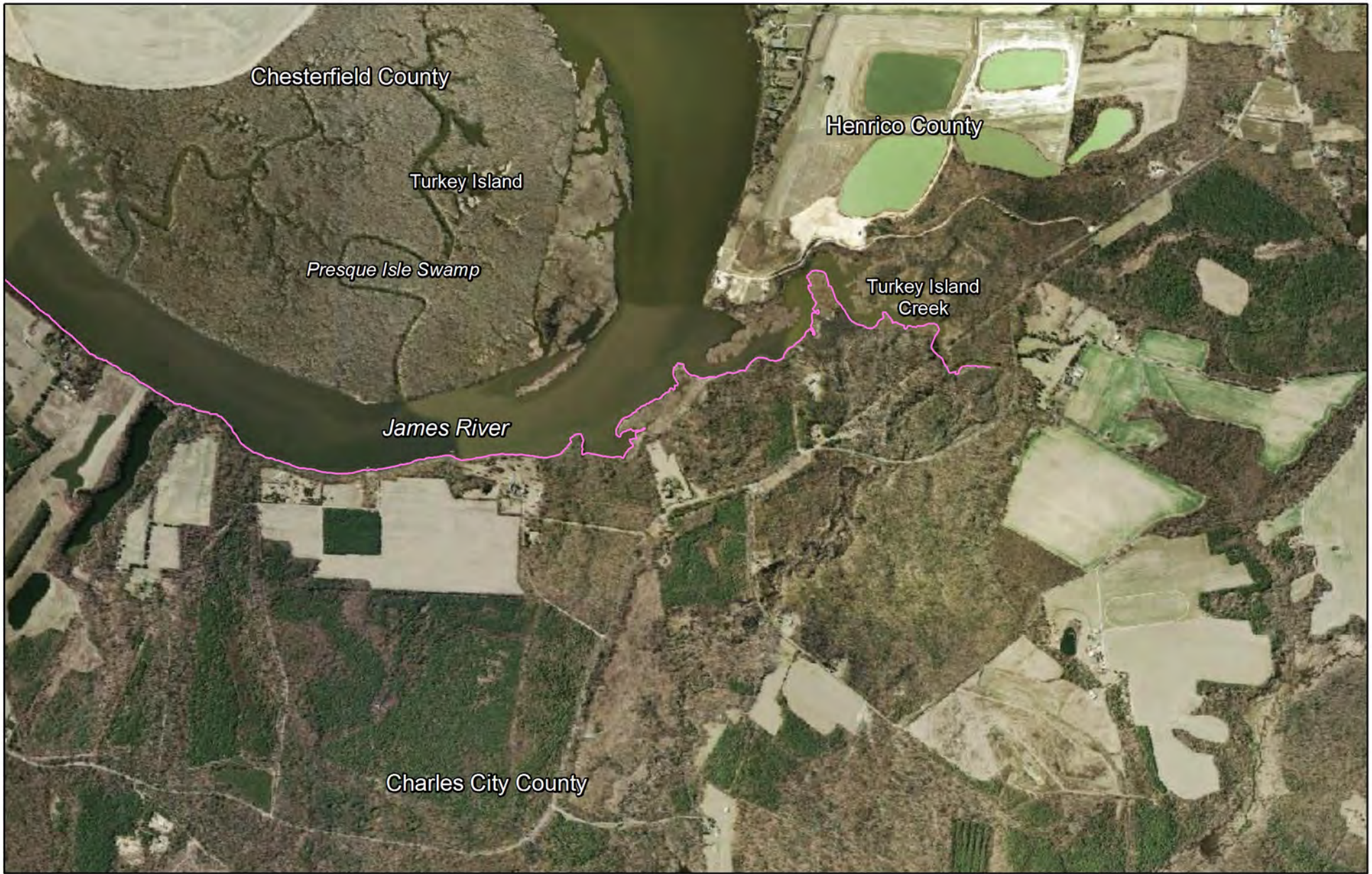
Shoreline 1994

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 1

Photo Date: 1994

Shoreline Studies Program VIMS



Legend

Shoreline 2002

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 1

Photo Date: 2002

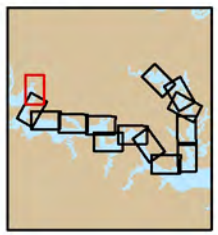
Shoreline Studies Program VIMS

Legend

- Shoreline 1937
- Shoreline 1994
- Shoreline 1953
- Shoreline 2002
- Shoreline 1968
- Shoreline 2009

Charles City County, Virginia
Plate 1

0 2,000 4,000 Feet



Shoreline Studies Program VIMS

Legend

Shoreline1937

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 2

Photo Date: 1937

Shoreline Studies Program VIMS

Legend

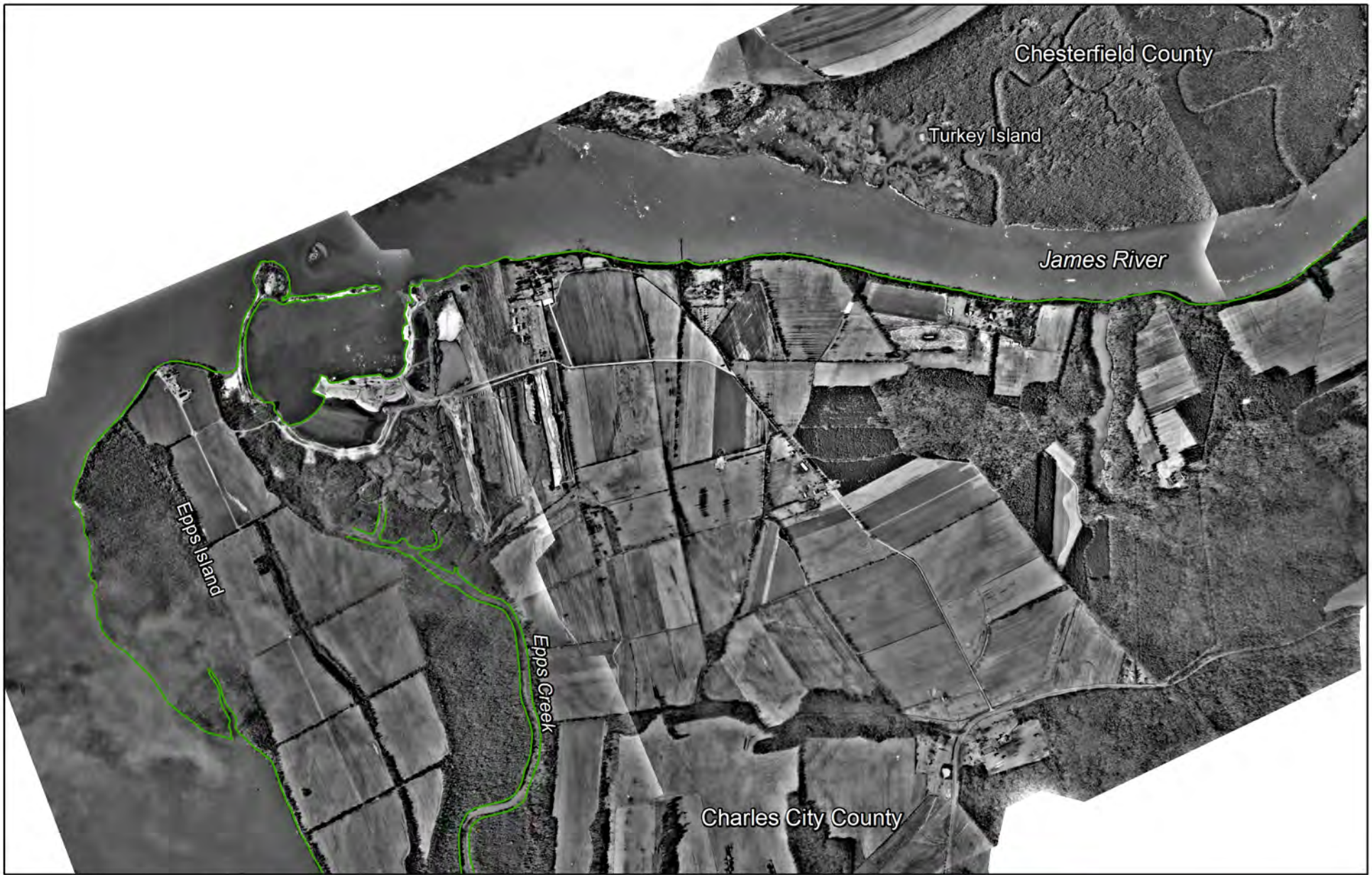
Shoreline 1953

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 2

Photo Date: 1953

Shoreline Studies Program VIMS



Legend

Shoreline 1968

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 2

Photo Date: 1968

Shoreline Studies Program VIMS

Legend

Shoreline 1994

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 2

Photo Date: 1994

Shoreline Studies Program VIMS

Legend

Shoreline 2002

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 2

Photo Date: 2002

Shoreline Studies Program VIMS

Legend

- Shoreline 1937
- Shoreline 1953
- Shoreline 1968
- Shoreline 1994
- Shoreline 2002
- Shoreline 2009

Charles City County, Virginia
Plate 2

0 2,000 4,000 Feet

Shoreline Studies Program VIMS

Legend

Shoreline1937

N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 3

Photo Date: 1937

Shoreline Studies Program VIMS

Legend

Shoreline 1953

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 3

Photo Date: 1953

Shoreline Studies Program VIMS

Legend

Shoreline 1968

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 3

Photo Date: 1968

Shoreline Studies Program VIMS

Legend

Shoreline 1994

N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 3

Photo Date: 1994

Shoreline Studies Program VIMS

Legend

Shoreline 2002

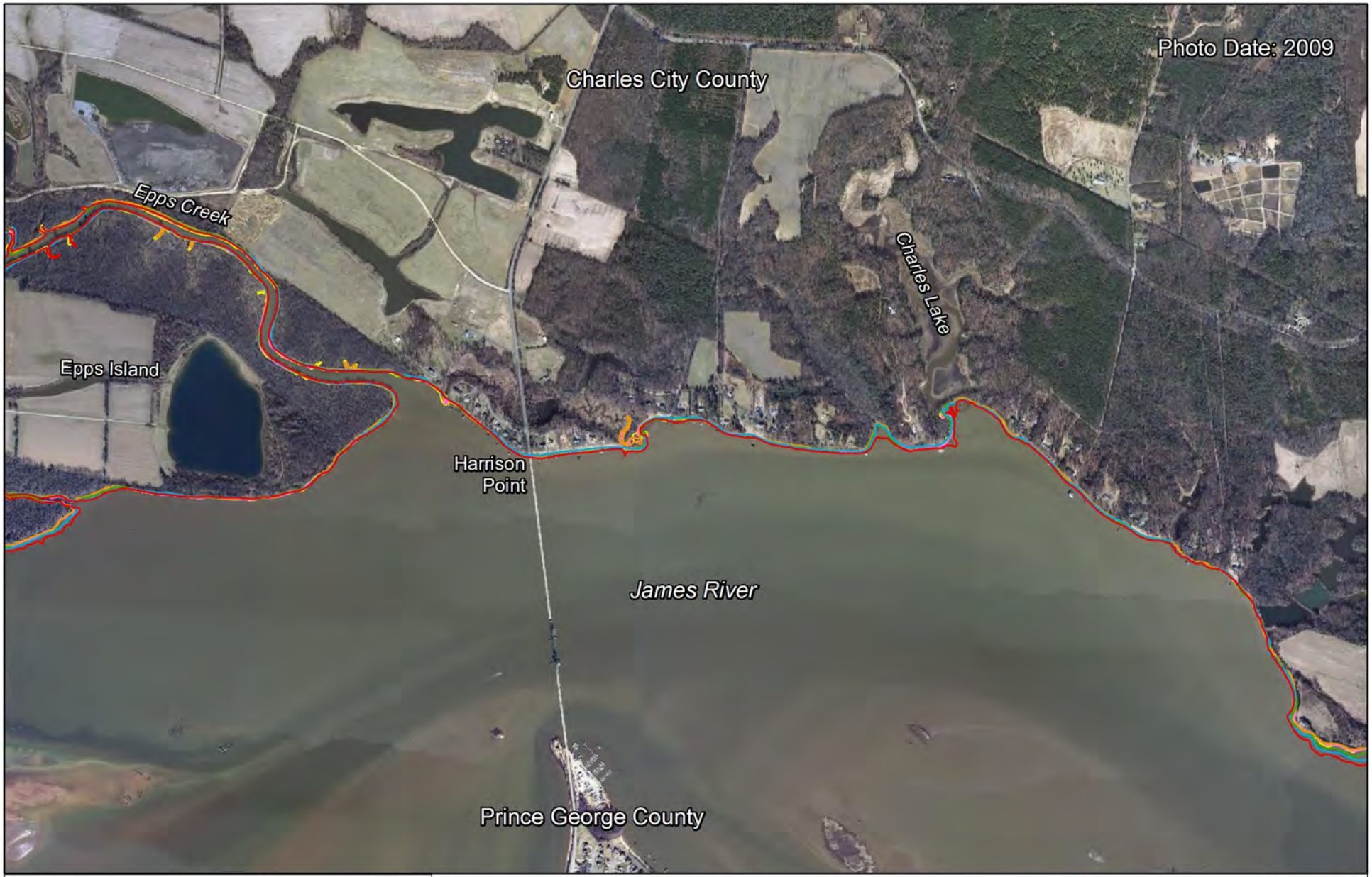
N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 3

Photo Date: 2002

Shoreline Studies Program VIMS



Legend

- Shoreline1937
- Shoreline 1953
- Shoreline 1968
- Shoreline 1994
- Shoreline 2002
- Shoreline 2009

Charles City County, Virginia
Plate 3

0 2,000 4,000 Feet

N W E S

Shoreline Studies Program VIMS

Legend

Shoreline1937

N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 4

Photo Date: 1937

Shoreline Studies Program VIMS

Legend

Shoreline 1953

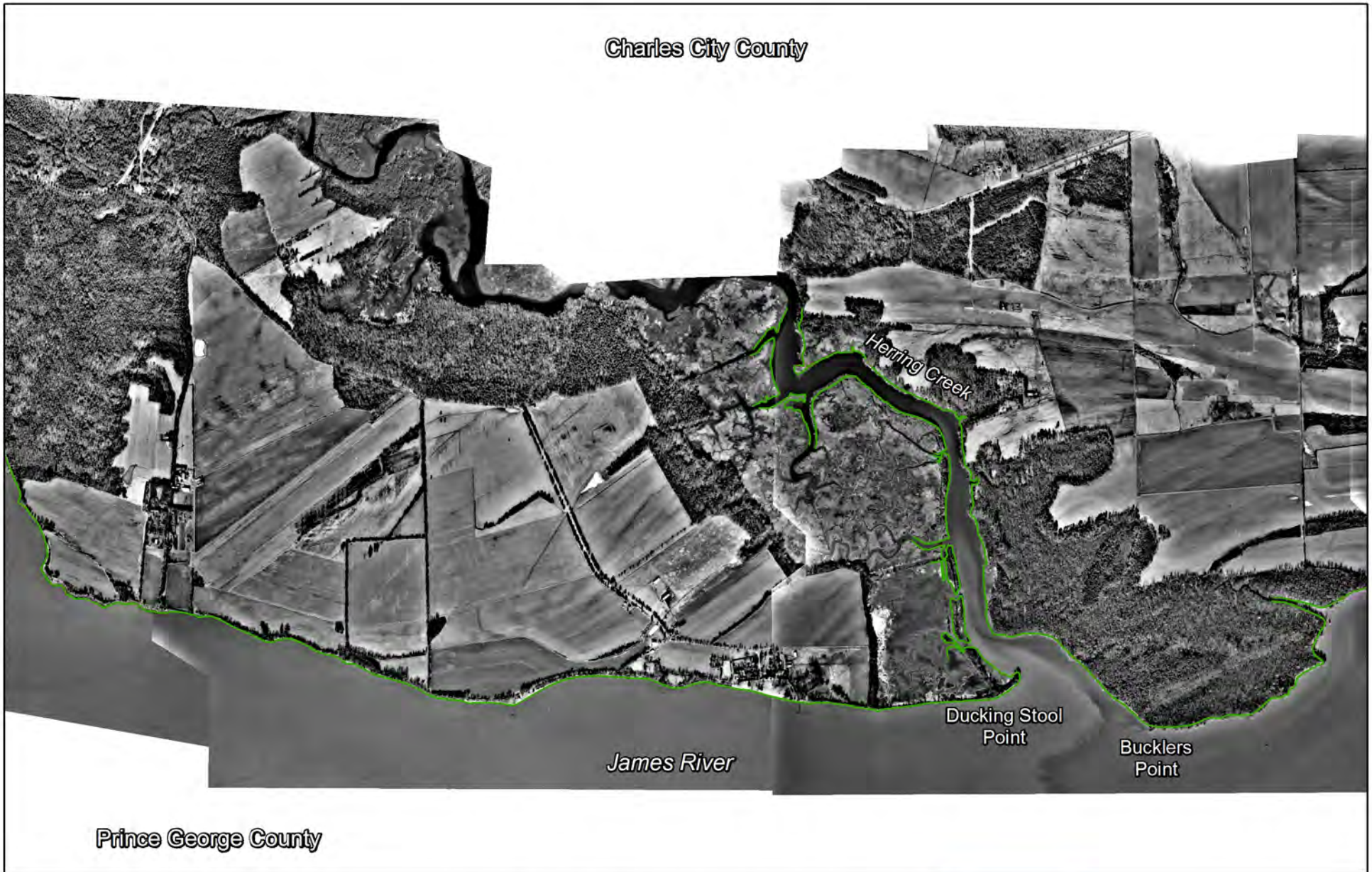
N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 4

Photo Date: 1953

Shoreline Studies Program VIMS



Legend

Shoreline 1968

N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 4

Photo Date: 1968

Shoreline Studies Program VIMS

Legend

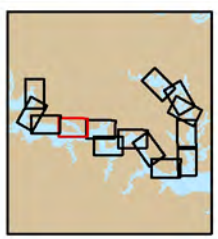
Shoreline 1994

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 4

Photo Date: 1994



Shoreline Studies Program VIMS

Legend

Shoreline 2002

0 2,000 4,000 Feet

N W E S

Charles City County, Virginia
Plate 4

Photo Date: 2002

Shoreline Studies Program VIMS

Legend

- Shoreline 1937
- Shoreline 1953
- Shoreline 1968
- Shoreline 1994
- Shoreline 2002
- Shoreline 2009

Charles City County, Virginia
Plate 4

0 2,000 4,000 Feet

N W E S

Shoreline Studies Program VIMS

Legend

Shoreline1937

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 5

Photo Date: 1937

Shoreline Studies Program VIMS

Legend

Shoreline 1953

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 5

Photo Date: 1953

Shoreline Studies Program VIMS

Legend

Shoreline 1968

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 5

Photo Date: 1968

Shoreline Studies Program
VIMS

Legend

Shoreline 1994

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 5

Photo Date: 1994

Shoreline Studies Program
VIMS

Legend

Shoreline 2002

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 5

Photo Date: 2002

Shoreline Studies Program
VIMS

Legend

- Shoreline 1937
- Shoreline 1953
- Shoreline 1968
- Shoreline 1994
- Shoreline 2002
- Shoreline 2009

Charles City County, Virginia
Plate 5

0 2,000 4,000 Feet

N W E S

Shoreline Studies Program VIMS

Legend

Shoreline1937

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 6

Photo Date: 1937

Shoreline Studies Program VIMS

Legend

Shoreline 1953

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 6

Photo Date: 1953

Shoreline Studies Program VIMS

Legend

Shoreline 1968

N
W E
S

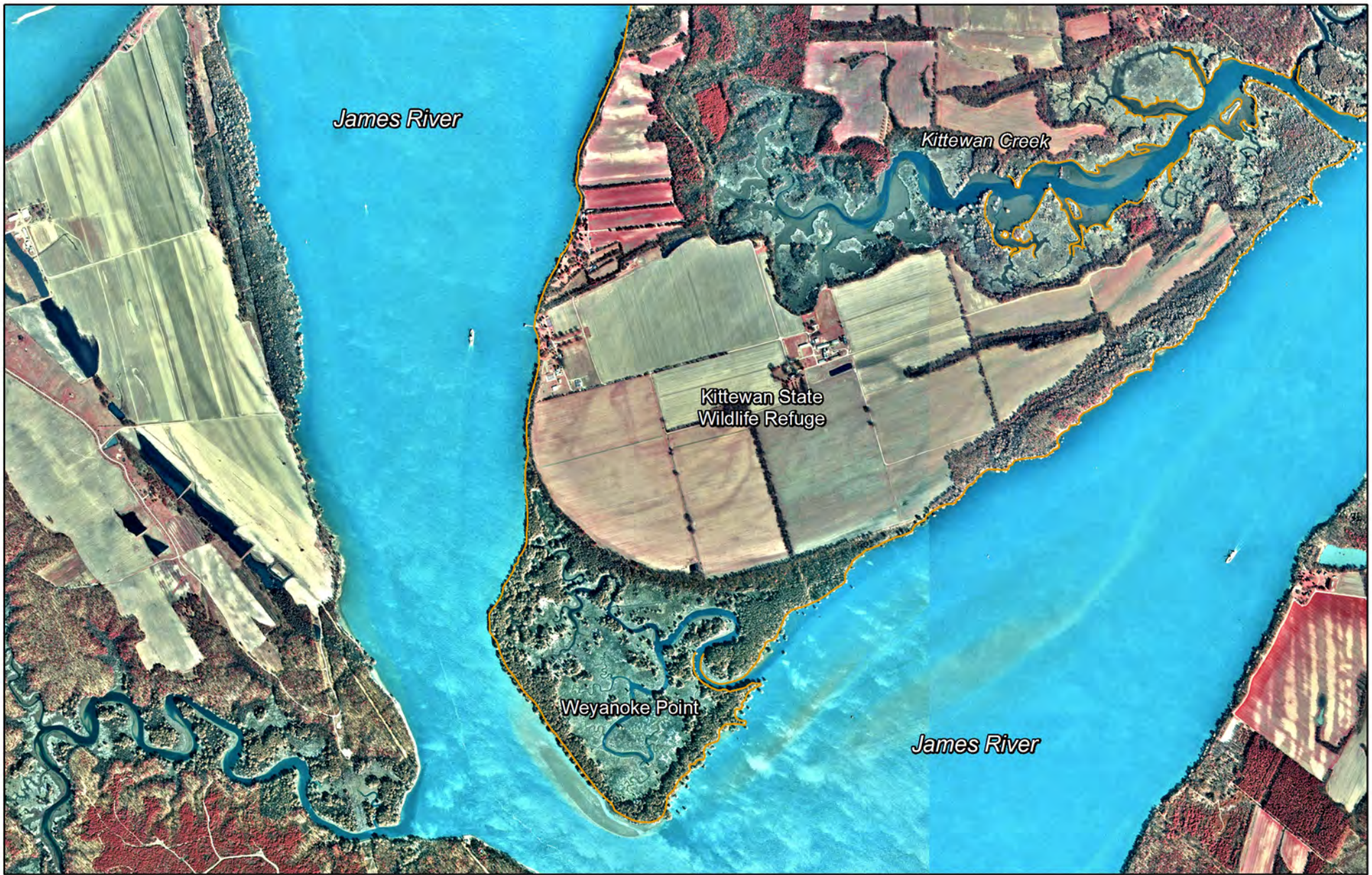
0 2,000 4,000

Feet

Charles City County, Virginia
Plate 6

Photo Date: 1968

Shoreline Studies Program
VIMS



Legend

Shoreline 1994

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 6

Photo Date: 1994

Shoreline Studies Program
VIMS

Legend

Shoreline 2002

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 6

Photo Date: 2002

Shoreline Studies Program VIMS

Legend

- Shoreline 1937
- Shoreline 1953
- Shoreline 1968
- Shoreline 1994
- Shoreline 2002
- Shoreline 2009

Charles City County, Virginia
Plate 6

0 2,000 4,000 Feet

N W E S

Shoreline Studies Program VIMS

Legend

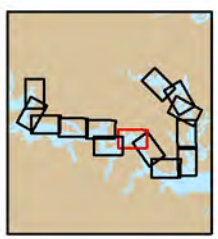
Shoreline1937

N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 7

Photo Date: 1937



Shoreline Studies Program VIMS

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Shoreline 1953

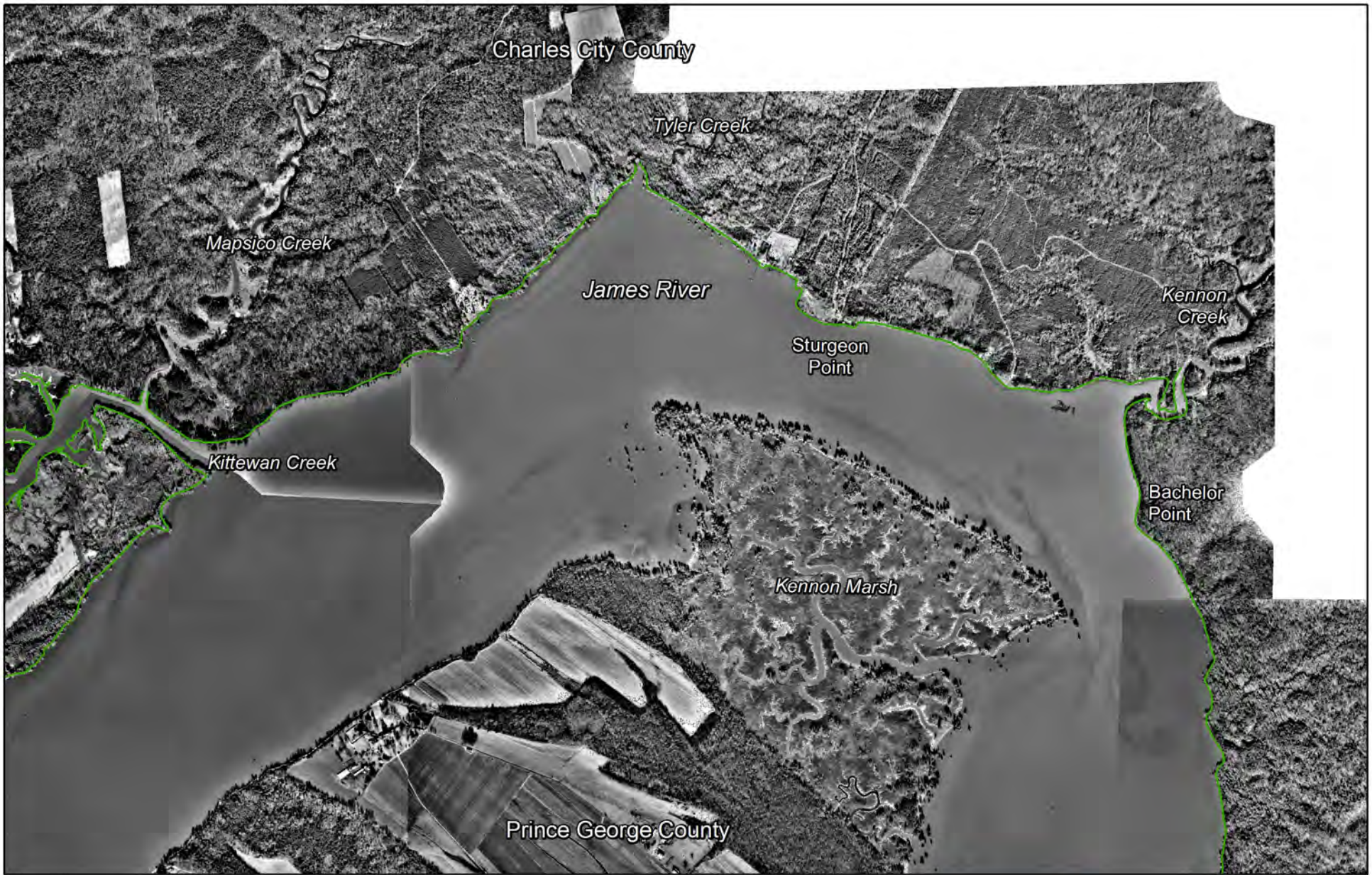
N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 7

Photo Date: 1953

Shoreline Studies Program VIMS



Legend

Shoreline 1968

N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 7

Photo Date: 1968

Shoreline Studies Program VIMS

Legend

Shoreline 1994

N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 7

Photo Date: 1994

Shoreline Studies Program VIMS

Legend

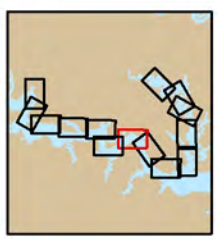
Shoreline 2002

N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 7

Photo Date: 2002



Shoreline Studies Program VIMS

Legend

- Shoreline 1937
- Shoreline 1953
- Shoreline 1968
- Shoreline 1994
- Shoreline 2002
- Shoreline 2009

Charles City County, Virginia
Plate 7

0 2,000 4,000 Feet

N W E S

Shoreline Studies Program VIMS

Legend

Shoreline1937

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 8

Photo Date: 1937

Shoreline Studies Program VIMS

Legend

Shoreline 1953

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 8

Photo Date: 1953

Shoreline Studies Program VIMS

Legend

Shoreline 1968

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 8

Photo Date: 1968

Shoreline Studies Program VIMS

Legend

Shoreline 1994

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 8

Photo Date: 1994

Shoreline Studies Program VIMS

Legend

Shoreline 2002

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 8

Photo Date: 2002

Shoreline Studies Program VIMS

Legend

- Shoreline 1937
- Shoreline 1953
- Shoreline 1968
- Shoreline 1994
- Shoreline 2002
- Shoreline 2009

Charles City County, Virginia
Plate 8

0 2,000 4,000 Feet

Shoreline Studies Program VIMS

Legend

Shoreline1937

N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 9

Photo Date: 1937

Shoreline Studies Program VIMS

Legend

Shoreline1953

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 9

Photo Date: 1953

Shoreline Studies Program VIMS

Legend

Shoreline 1968

N
W E
S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 9

Photo Date: 1968

Shoreline Studies Program VIMS

Legend

Shoreline 1994

N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 9

Photo Date: 1994

Shoreline Studies Program VIMS

Legend

Shoreline 2002

N W E S

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 9

Photo Date: 2002

Shoreline Studies Program VIMS

Legend

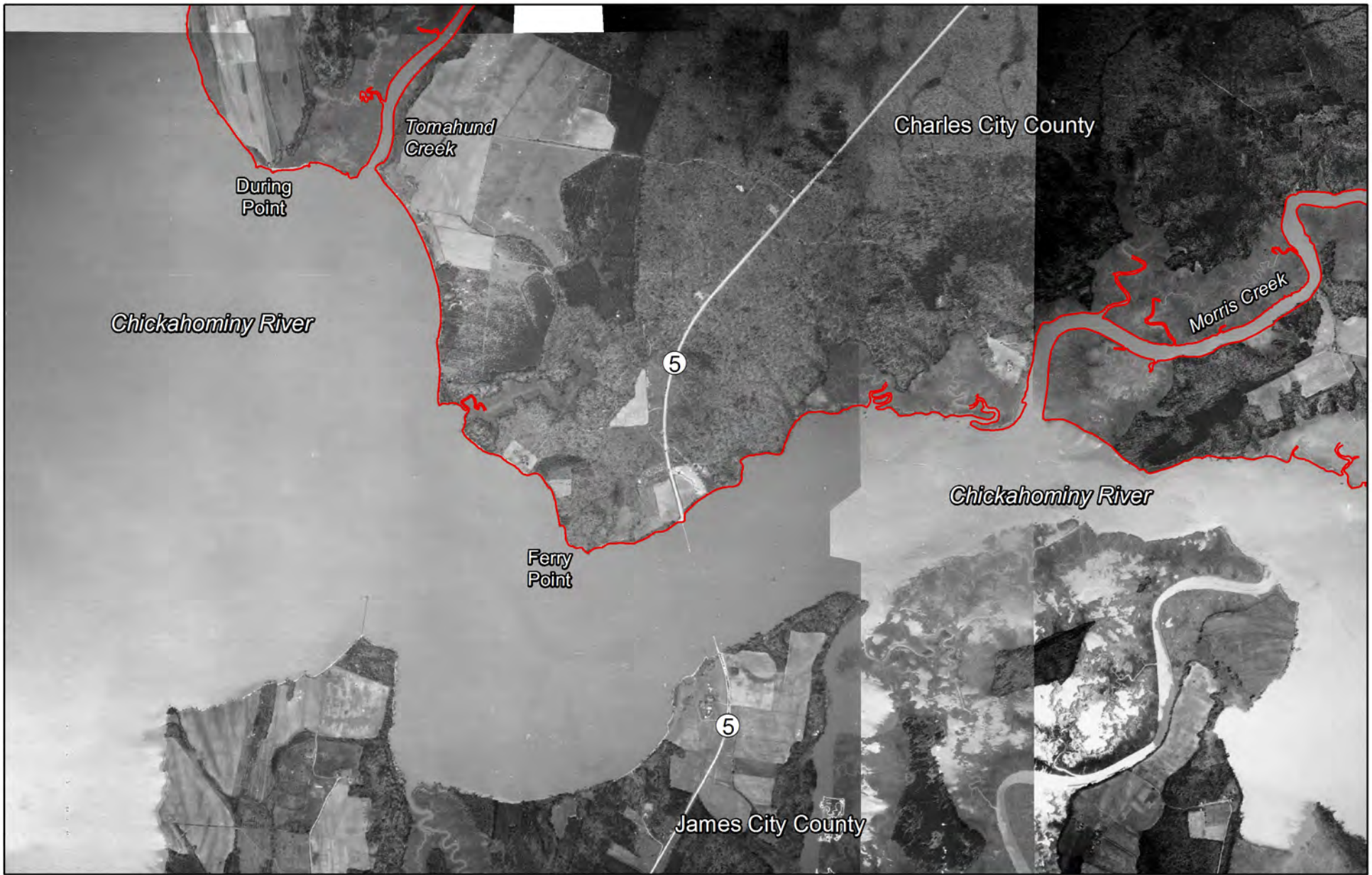
- Shoreline 1937
- Shoreline 1994
- Shoreline1953
- Shoreline 2002
- Shoreline 1968
- Shoreline 2009

Charles City County, Virginia
Plate 9

0 2,000 4,000 Feet

N W E S

Shoreline Studies Program VIMS



Legend

Shoreline1937

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 10

Photo Date: 1937

Shoreline Studies Program VIMS

Legend

Shoreline 1953

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 10

Photo Date: 1953

Shoreline Studies Program VIMS

Legend

Shoreline 1968

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 10

Photo Date: 1968

Shoreline Studies Program VIMS

Legend

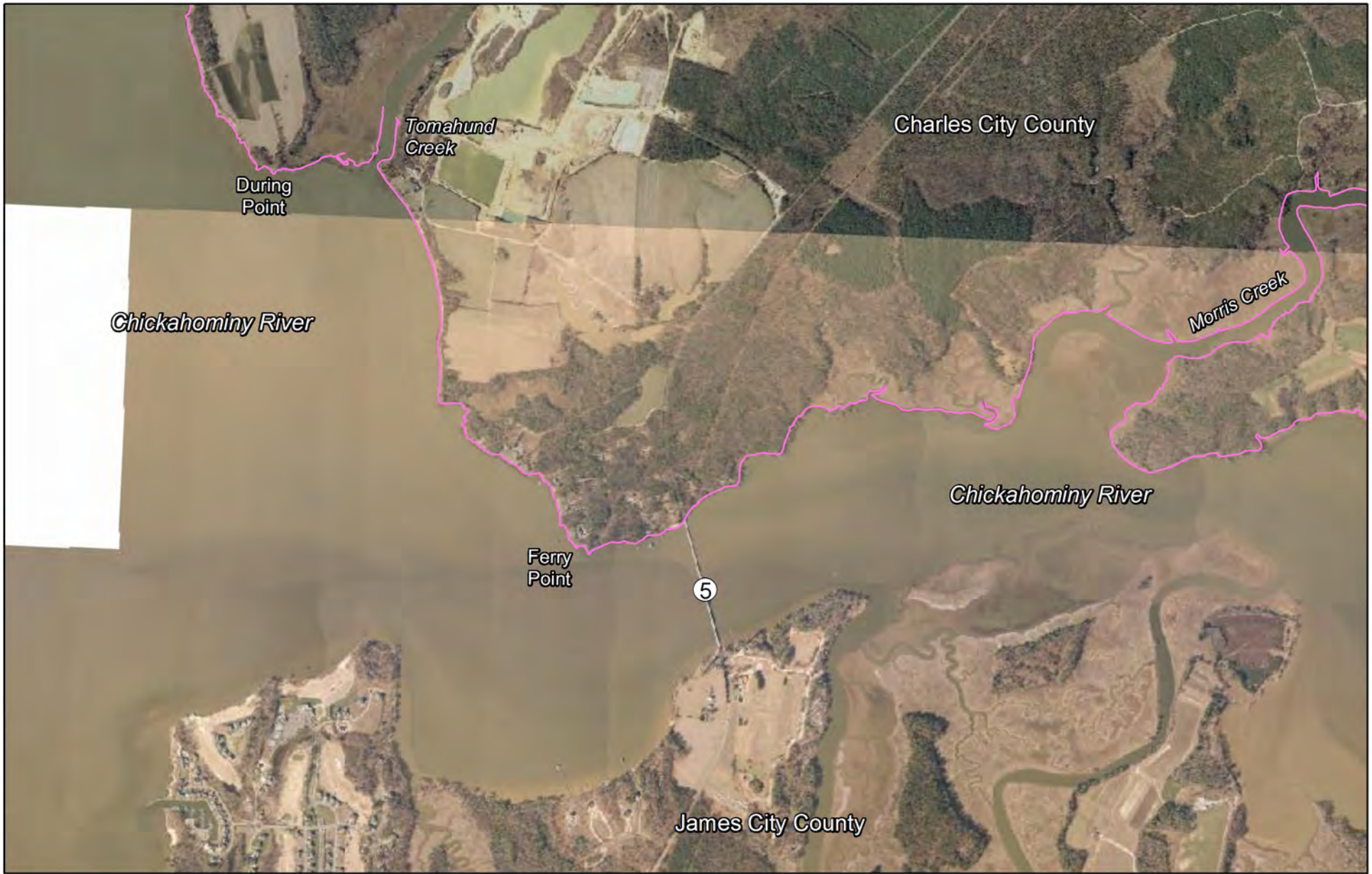
Shoreline 1994

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 10

Photo Date: 1994

Shoreline Studies Program VIMS



Legend

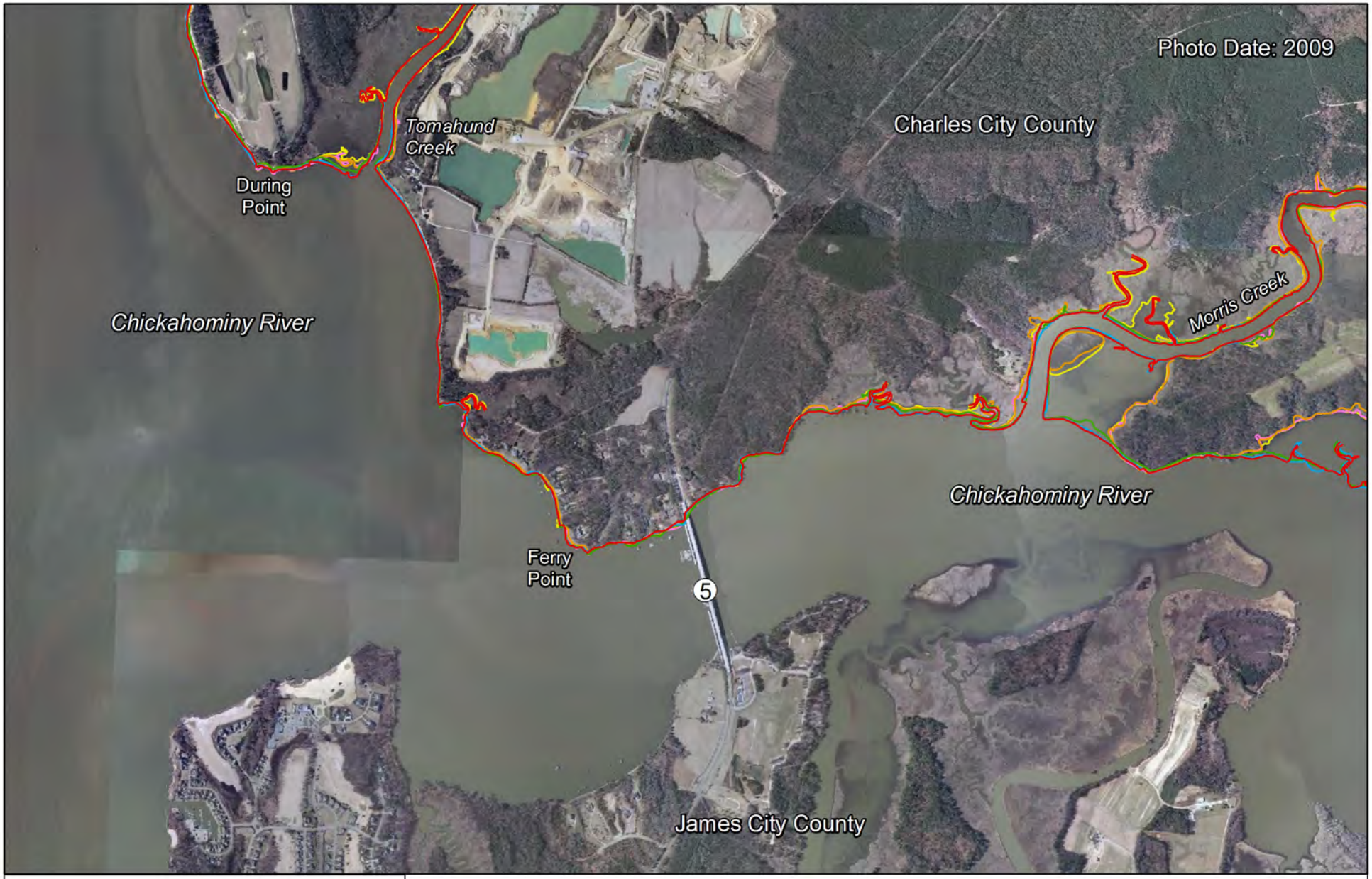
Shoreline 2002

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 10

Photo Date: 2002

Shoreline Studies Program VIMS



Legend

- Shoreline 1937
- Shoreline 1994
- Shoreline 1953
- Shoreline 2002
- Shoreline 1968
- Shoreline 2009

Charles City County, Virginia
Plate 10

0 2,000 4,000 Feet

Shoreline Studies Program VIMS

Legend

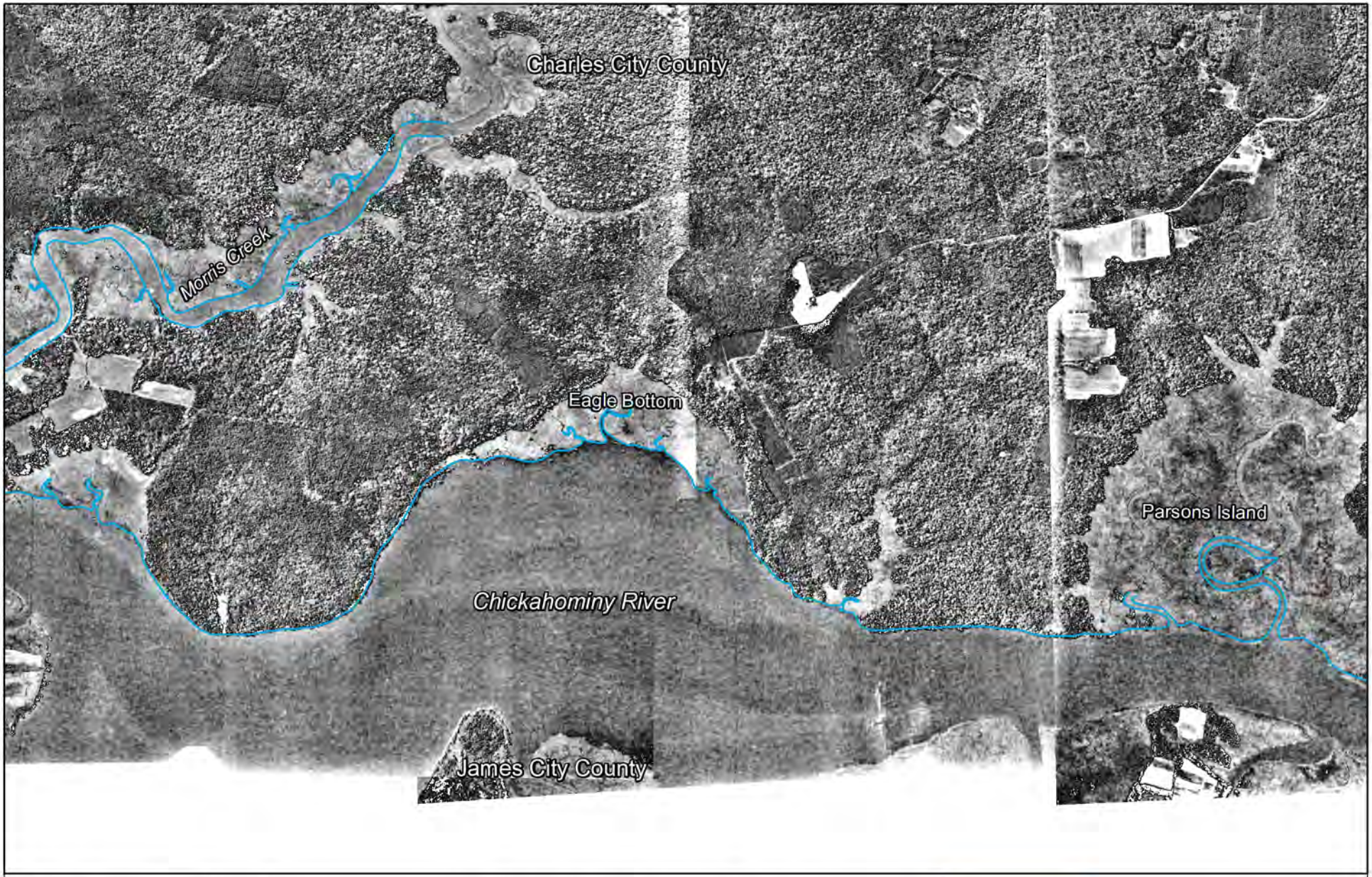
Shoreline1937

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 11

Photo Date: 1937

Shoreline Studies Program VIMS



Legend

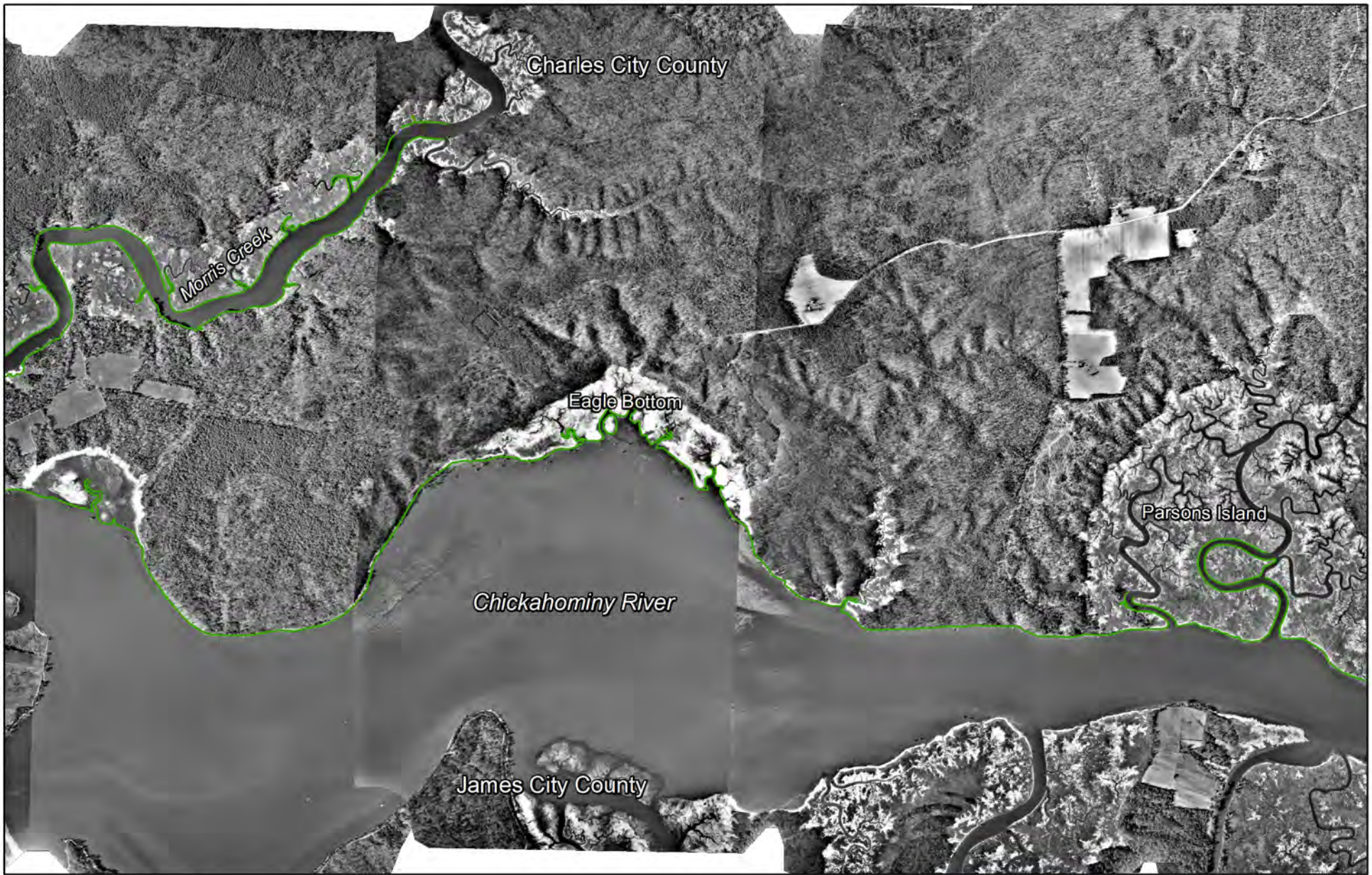
Shoreline 1953

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 11

Photo Date: 1953

Shoreline Studies Program VIMS



Legend

Shoreline 1968

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 11

Photo Date: 1968

Shoreline Studies Program VIMS

Legend

Shoreline 1994

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 11

Photo Date: 1994

Shoreline Studies Program VIMS

Legend

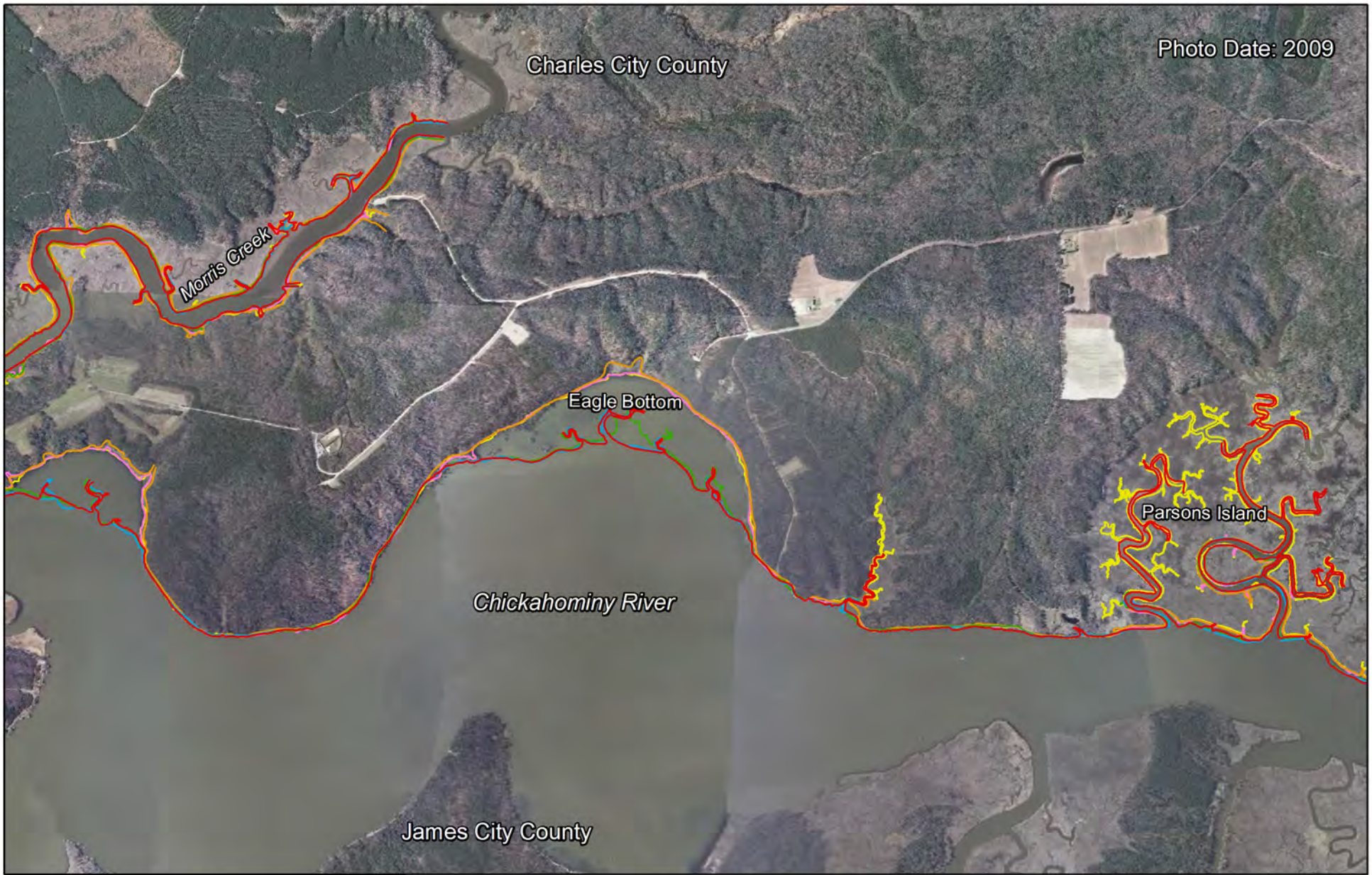
Shoreline 2002

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 11

Photo Date: 2002

Shoreline Studies Program VIMS



Legend

- Shoreline 1937
- Shoreline 1994
- Shoreline 1953
- Shoreline 2002
- Shoreline 1968
- Shoreline 2009

Charles City County, Virginia
Plate 11

0 2,000 4,000 Feet

Shoreline Studies Program VIMS

Legend

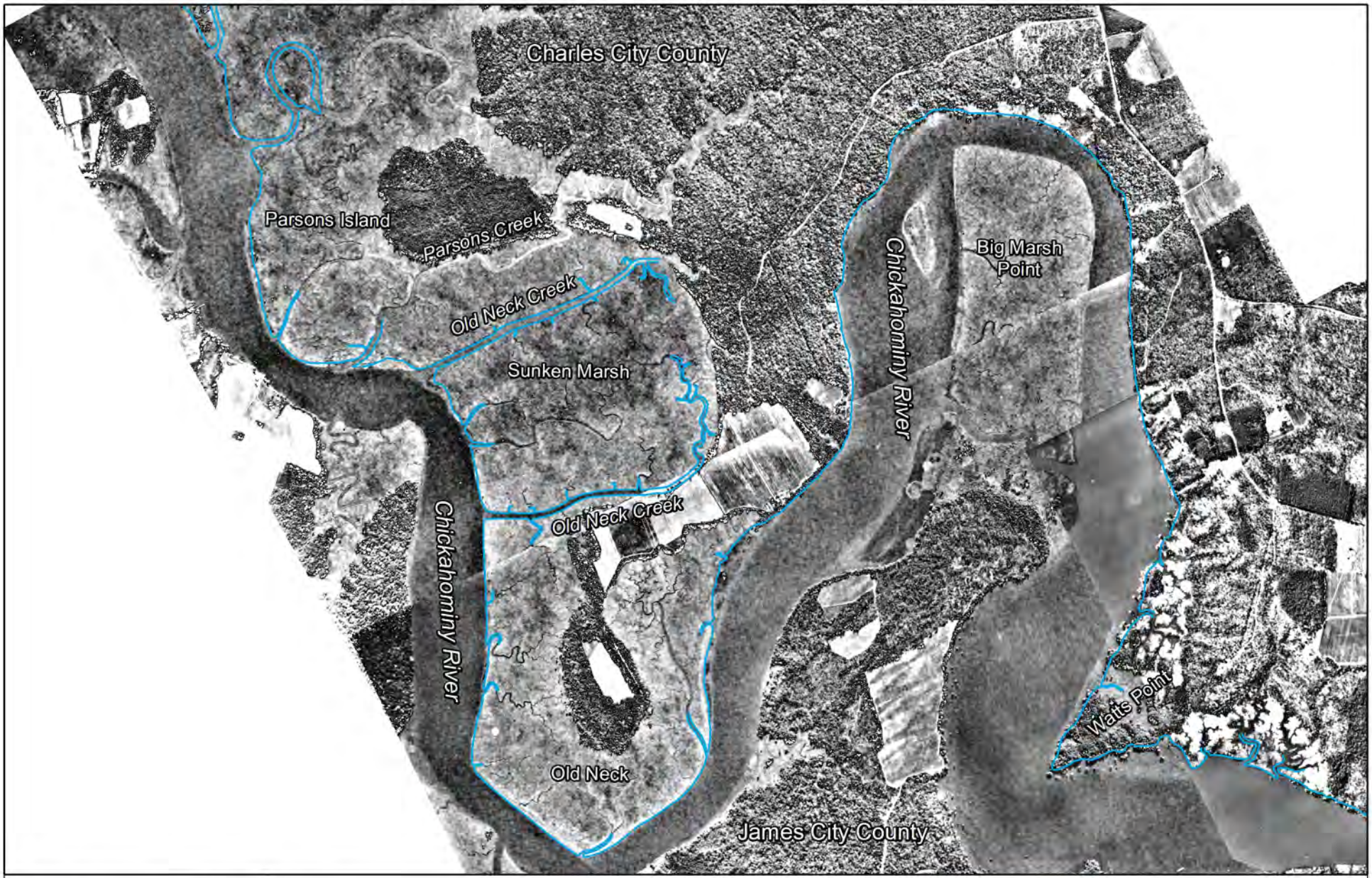
Shoreline1937

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 12

Photo Date: 1937

Shoreline Studies Program VIMS



Legend

Shoreline 1953

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 12

Photo Date: 1953

Shoreline Studies Program VIMS

Legend

Shoreline 1968

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 12

Photo Date: 1968

Shoreline Studies Program VIMS

Legend

Shoreline 1994

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 12

Photo Date: 1994

Shoreline Studies Program VIMS

Legend

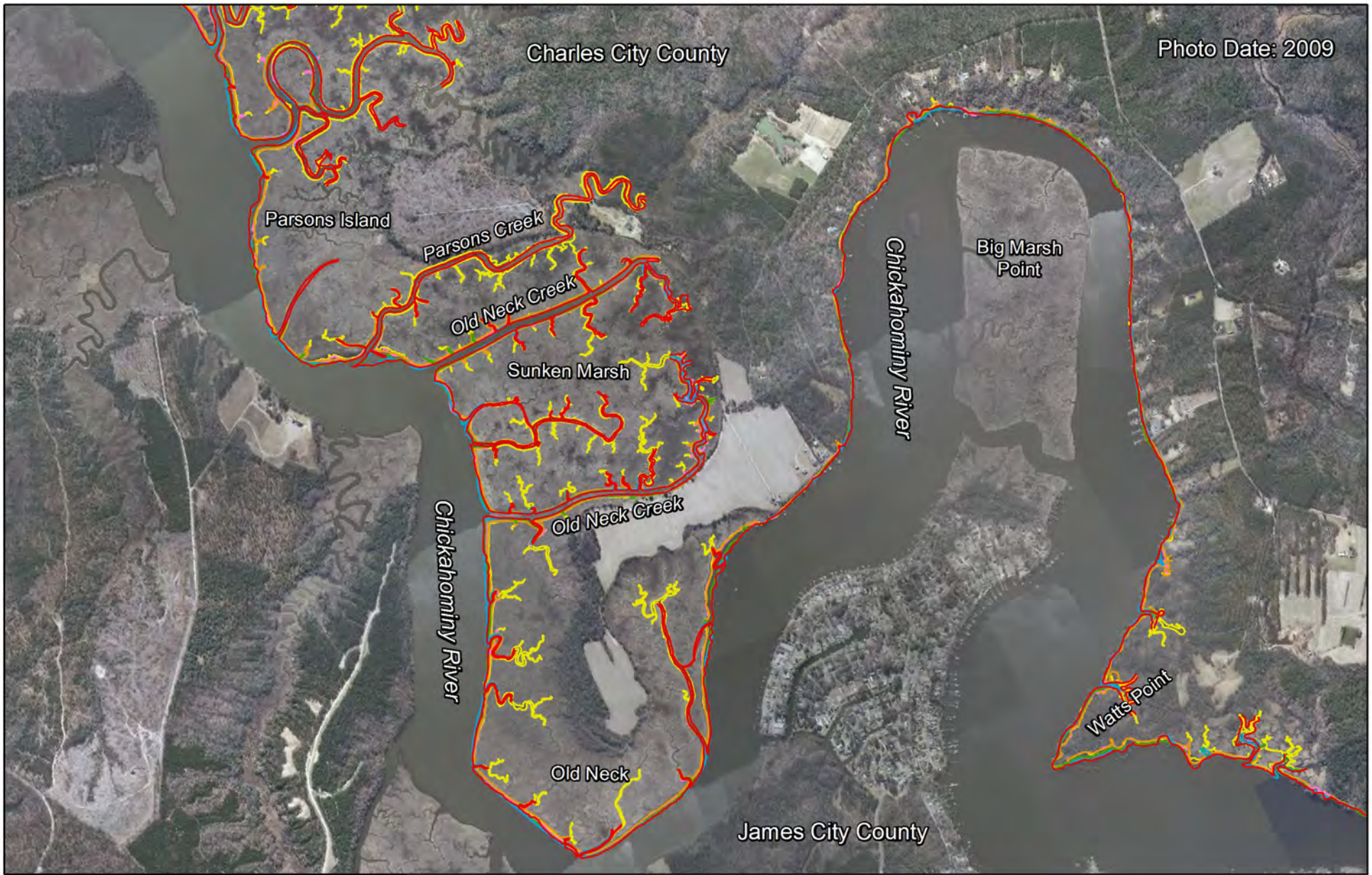
Shoreline 2002

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 12

Photo Date: 2002

Shoreline Studies Program VIMS



Legend

- Shoreline 1937
- Shoreline 1953
- Shoreline 1968
- Shoreline 1994
- Shoreline 2002
- Shoreline 2009

Charles City County, Virginia
Plate 12

0 2,000 4,000 Feet

Shoreline Studies Program VIMS

Legend

Shoreline1937

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 13

Photo Date: 1937

Shoreline Studies Program VIMS

Legend

Shoreline 1953

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 13

Photo Date: 1953

Shoreline Studies Program VIMS

Legend

Shoreline 1968

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 13

Photo Date: 1968

Shoreline Studies Program VIMS

Legend

Shoreline 1994

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 13

Photo Date: 1994

Shoreline Studies Program VIMS

Legend

Shoreline 2002

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 13

Photo Date: 2002

Shoreline Studies Program VIMS

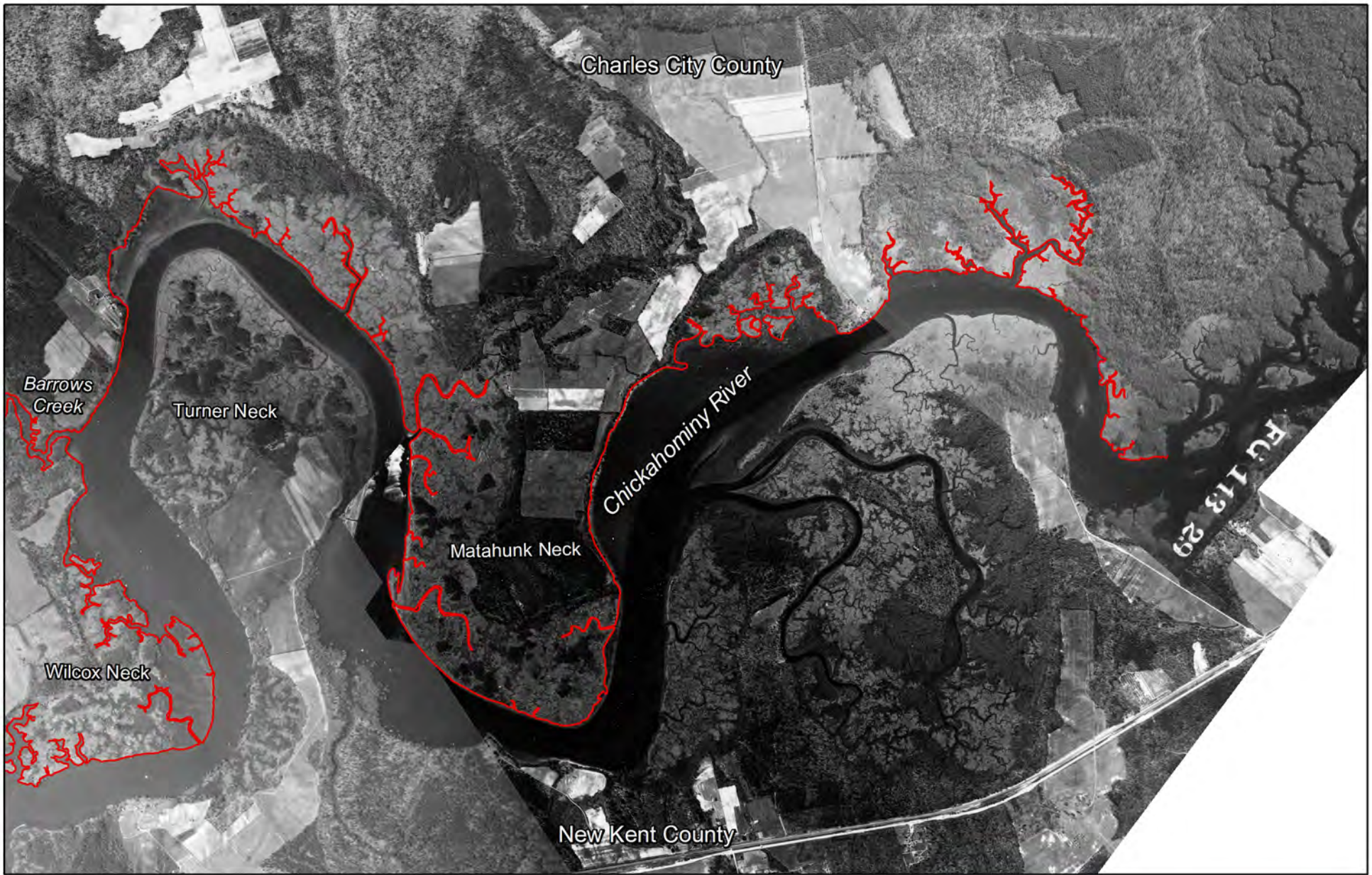
Legend

- Shoreline 1937
- Shoreline 1994
- Shoreline 1953
- Shoreline 2002
- Shoreline 1968
- Shoreline 2009

Charles City County, Virginia
Plate 13

0 2,000 4,000 Feet

Shoreline Studies Program VIMS



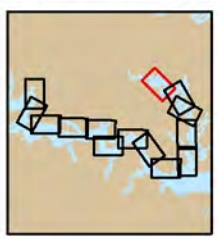
Legend

Shoreline1937

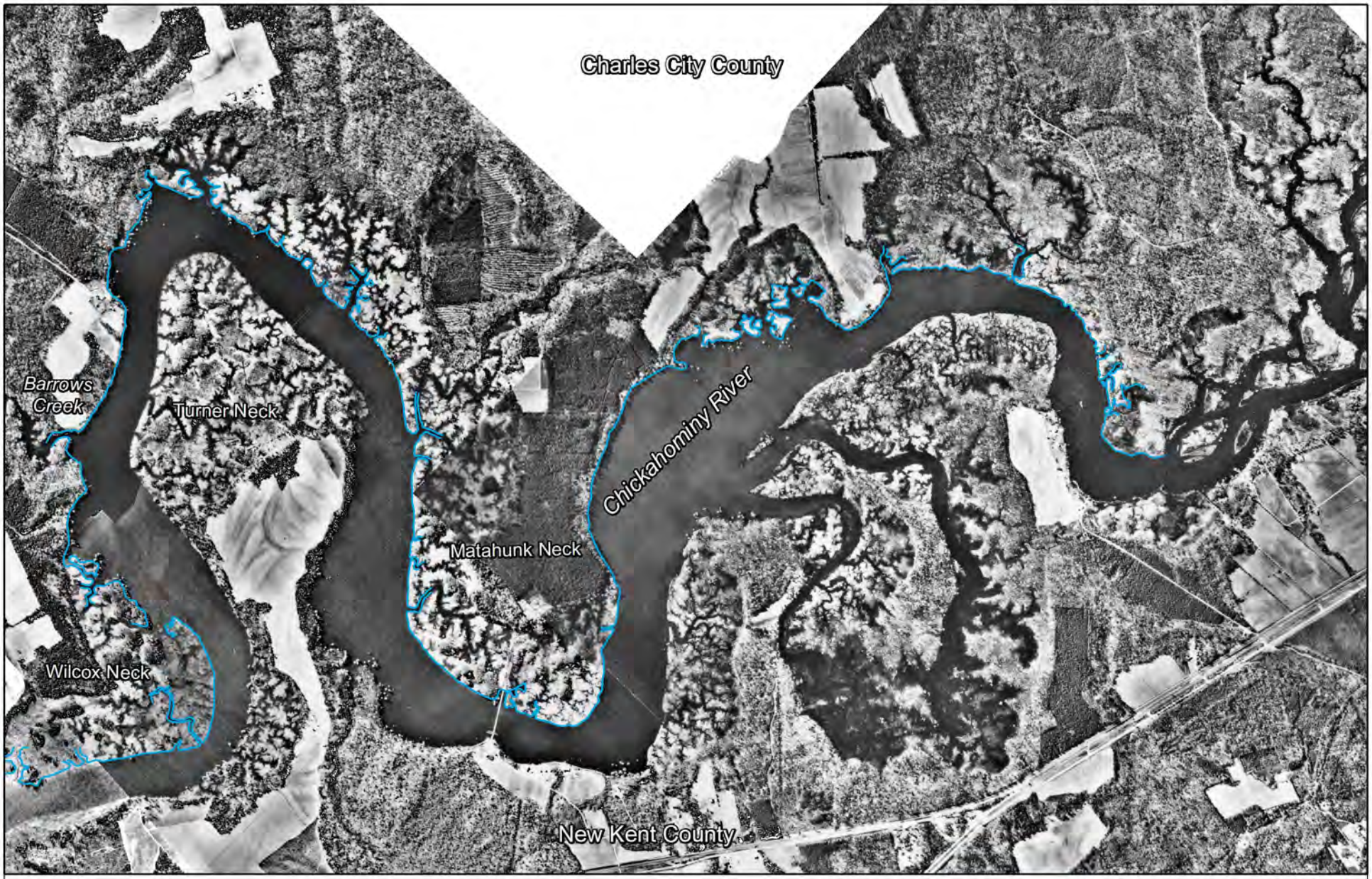
0 2,000 4,000 Feet

Charles City County, Virginia
Plate 14

Photo Date: 1937



Shoreline Studies Program VIMS



Legend

Shoreline 1953

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 14

Photo Date: 1953

Shoreline Studies Program VIMS

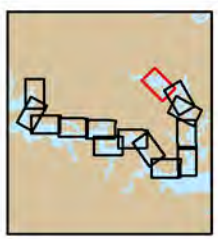
Legend

Shoreline 1968

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 14

Photo Date: 1968



Shoreline Studies Program VIMS

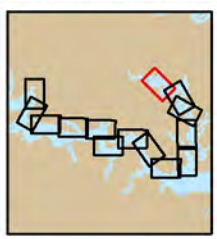
Legend

Shoreline 1994

0 2,000 4,000 Feet

Charles City County, Virginia
Plate 14

Photo Date: 1994



Shoreline Studies Program VIMS

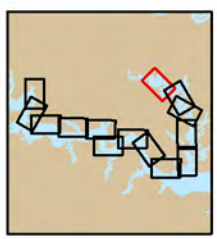
Legend

Shoreline 2002

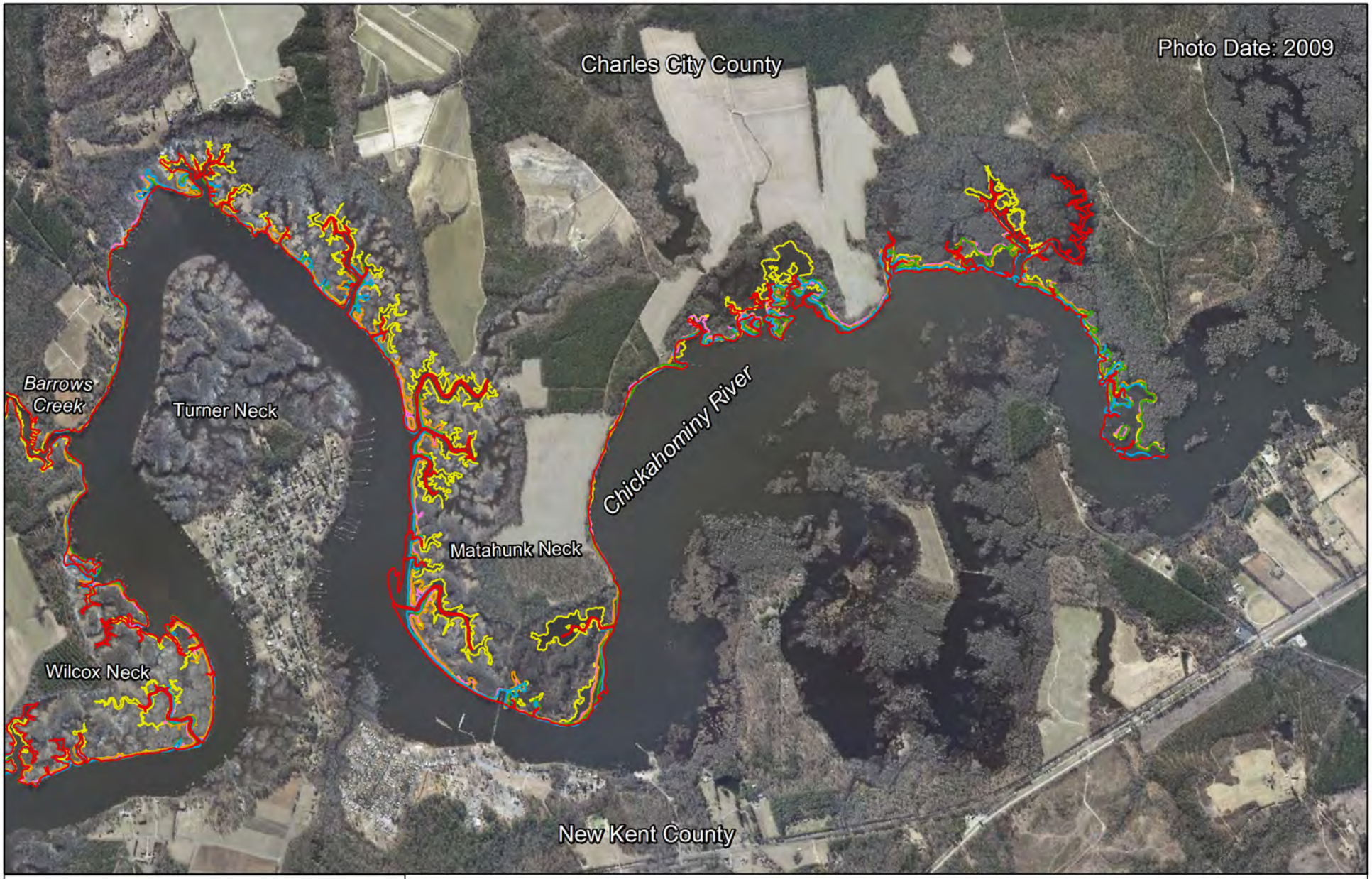
0 2,000 4,000 Feet

Charles City County, Virginia
Plate 14

Photo Date: 2002



Shoreline Studies Program VIMS



Legend

- Shoreline 1937
- Shoreline 1953
- Shoreline 1968
- Shoreline 1994
- Shoreline 2002
- Shoreline 2009

Charles City County, Virginia
Plate 14

0 2,000 4,000 Feet

Shoreline Studies Program VIMS