



City of Norfolk

Shoreline Situation Report

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City of Norfolk - Shoreline Situation Report

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Chapter 1. Introduction

1.1 Background

In the 1970s, the Virginia Institute of Marine Science (VIMS) received a grant through the National Science Foundation's Research Applied to National Needs Program to develop a series of reports which would describe the condition of tidal shorelines in the Commonwealth of Virginia. These reports became known as the Shoreline Situation Reports. They were published on a county by county basis with additional resources provided by the National Oceanic and Atmospheric Administration's Office of Coastal Zone Management (Hobbs et.al., 1975).

The Shoreline Situation Reports quickly became a common desktop reference for nearly all shoreline managers, regulators, and planners within the Tidewater region. They provided useful information to address the common management questions and dilemmas of the time. Despite their age, these reports remain a desk top reference.

The Comprehensive Coastal Inventory Program (CCI) is committed to developing a revised series of Shoreline Situation Reports which address the management questions of today. The series reports shoreline conditions on a county by county basis. New techniques integrate a combination of Geographic Information Systems (GIS), Global Positioning System (GPS) and remote sensing technology. Reports are generally distributed in hardcopy, but dwindling resources for publications has this Shoreline Situation Report as an electronic version only. The digital GIS coverages developed for the report are available on the web at www.vims.edu/ccrm/gis/gisdata.html .

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1.2 Description of the Locality

The City of Norfolk has approximately 54 square miles of land area, with 12.7 square miles of major surface water area (Figure 1). The city is located southeast of Hampton Roads, and borders Virginia Beach to the east, Chesapeake to the south, and Portsmouth to the southwest. The Elizabeth River divides Portsmouth and Chesapeake from Norfolk. The city's primary shoreline is along the Hampton Roads waterway, the Chesapeake Bay, and tributaries to the Elizabeth River. The Lafayette River, main stem of the Elizabeth River, and the Eastern Branch of the Elizabeth River comprise the major tidal tributaries. These all drain into Hampton

Roads.

The City of Norfolk is an urban, highly developed region of Virginia with landuses dominated by high density residential districts, commercial and industrial development, and military reservations. The waterways are an integral part of life in the city, and uses on the landscape have evolved around these systems. Heavy industrial, military, commercial, and residential waterfront development prevail. There are very few untouched stretches of shoreline, and as this report will document, few shoreline miles remain unaltered.

Tidal shoreline protection at federal, state, and local levels constrains development activities at the shore, and works to enhance environmental quality at all levels. Regulations established through the Clean Water Act, and the Chesapeake Bay Preservation Act are discussed in the Comprehensive Plan. A proposed amendment to the current 1992 comprehensive plan deals at length with these issues. This amendment has not yet been approved.

1.3 Purpose and Goals

This shoreline inventory is developed as a tool for assessing conditions along tidal shoreline in Norfolk. Data was collected using image processing and photo interpretation techniques. This Shoreline Situation Report represents the first in the statewide series to utilize high resolution imagery for the vast majority of data collection. Field work ground-truthed the photo analyzed data. Conditions are reported for three zones within the immediate riparian shoreline area: riparian land use, bank and buffers, and the shoreline. A series of maps and tabular data are published on the website to illustrate and quantify results of an extensive shoreline survey. The survey covers all tidal shoreline within the city including military installations.

1.4 Report Organization

Traditionally a hardcopy report, this electronic version has four parts. This document is

part one and describes methods and uses. Part 2 are maps that delineate shoreline conditions observed. Part 3 are tables that summarize data from the maps. Part 4 is for GIS users who wish to download digital files.

1.5 Acknowledgments

This report has been funded by the Comprehensive Coastal Inventory Program (CCI) with money appropriated by the General Assembly. This work was completed entirely with staff support and management from the Virginia Institute of Marine Science's CCI Program. A host of individuals are acknowledged. In addition to those listed as preparers, the project directors would like to thank the VIMS Vessel Center, and the VIMS Publication Center for their support. Special thanks to Charlie Ragland of the City of Norfolk's GIS division for providing digital imagery to support this project. Lee Rosenberg of the city's Environmental Planning Office provided valuable input and facilitated coordination among city offices.

Chapter 2. The Shoreline Assessment: Approach and Considerations

2.1 Introduction

The Comprehensive Coastal Inventory Program (CCI) has developed a set of protocols for describing shoreline conditions along Virginia's tidal shoreline. The assessment approach uses state of the art Global Positioning Systems (GPS), Geographic Information Systems (GIS), and remote sensing techniques to collect, analyze, and display shoreline conditions. These protocols and techniques have been developed over several years, incorporating suggestions and data needs conveyed by state agency and local government professionals.

Three separate activities embody the development of a Shoreline Situation Report: data collection, data processing and analysis, and map generation. Data collection follows a three tiered shoreline assessment approach described below. The approach used to develop this

inventory differs from other Shoreline Situation Reports because the majority of initial data collection uses remote sensing techniques in conjunction with high resolution imagery available from the city. Previous inventories collected all data in the field. The image analyzed data were completely ground-truthed to evaluate the technique as a mechanism for producing future Shoreline Situation Reports in other localities with comparable image archives.

2.2 Three Tiered Shoreline Assessment

The data inventory developed for the Shoreline Situation Report is based on a three-tiered shoreline assessment approach. This assessment characterizes conditions in the shorezone, which extends from a narrow portion of the riparian zone seaward to the shoreline. This assessment approach was developed to use observations which could be made from a moving boat. To that end, the survey is a collection of descriptive measurements which characterize conditions. For this inventory, primary data collection was performed using photointerpretation techniques combined with high resolution imagery. The original three-tiered assessment approach, however, remained basically unchanged.

The three tiered shoreline assessment approach divides the shorezone into three regions: 1) the immediate riparian zone, evaluated for land use; 2) the bank, evaluated for height, stability, cover, and natural protection; and 3) the shoreline, describing the presence of shoreline structures for shore protection and recreational purposes. Each tier is described in detail below.

2.2a) Riparian Land Use: Land use adjacent to the bank is classified into one of eleven categories (Table 1). The categories provide a simple assessment of land use, and give rise to land management practices which could be anticipated. GIS was used to delineate the linear extent along shore where the practice was observed in the imagery. The width of this zone is not measured. Riparian forest buffers are considered the primary land use if the buffer width equals or exceeds 30 feet. This width is calculated from the digital imagery as part of the quality control in data processing.

Table 1. Tier One - Riparian Land Use Classes

Forest	stands greater than 18 feet / width greater than 30 feet
Scrub-shrub	stands less than 18 feet
Grass	includes grass fields, and pasture land
Agriculture	includes cropland
Single Family	single family dwelling
Multi-Family	multi family dwellings includes condominiums, and apartments
Commercial	includes small and moderate business operations, recreational facilities
Industrial	includes large industry and manufacturing operations
Bare	lot cleared to bare soil
Educational/Schools	includes public and private facilities
Military	includes all military installations
Paved	areas where roads or parking areas are adjacent to the shore

2.2b) Bank Condition: The bank extends off the fastland, and serves as an interface between the upland and the shore. It is a source of sediment and nutrient fluxes from the fastland, and bears many of the upland soil characteristics which determine water quality in receiving waters. Bank stability is important for several reasons. The bank protects the upland from wave energy during storm activity. The faster the bank erodes, the sooner the upland will be at risk. Bank erosion can contribute high sediment loads to the receiving waters. Stability of the bank depends on several factors: height, slope, sediment composition, vegetative cover, and the presence of buffers to absorb energy impact to the bank itself.

The bank assessment in this inventory addresses four major bank characteristics: bank height, bank cover, bank stability, the presence of stable or unstable natural buffers at the bank toe, and the presence of invasive species such as *Phragmites australis* at the toe (Table 2). Conditions are recorded as a continuous arc along the shoreline. The arc coding changes to reflect a change in conditions observed.

Bank height is described as a range, measured from the toe of the bank to the top. Bank cover is an assessment of the percent of either vegetative or structural cover in place on the bank face. Natural vegetation, as well as rip rap are considered as cover. The assessment is qualitative (Table 2). Bank stability characterizes the condition of the bank face. Banks which have exposed root systems, down vegetation, or exhibit slumping of material qualify as a "high erosion". Bank exhibiting undercutting at the toe are classified as such if the bank appears otherwise stable. At the toe of the bank, natural marsh vegetation and/or beach material may be present. These features offer protection to the bank and enhance water quality.

Remote sensing of bank condition was not as clear as some of the other attributes assessed using the high resolution imagery. Bank height was estimated using an additional topographic dataset provided by the City of Norfolk. Other bank and buffer characteristics were evaluated from the imagery with moderate success. All areas were revisited in the field and correction made using a combination of GIS and GPS technology.

2.2c) Shoreline Features: Features added to the shoreline by property owners are recorded as a combination of points or lines. These features include defense structures, which are constructed to protect shorelines from erosion; offense structures, designed to accumulate sand in longshore transport; and recreational structures, built to enhance recreational use of the water. The location of these features along the shore are delineated from the imagery. Verification of these attributes was conducted as part of the ground-truthing. Table 3 summarizes shoreline features surveyed. Linear features are denoted with an "L" and point features are denoted by a "P." The glossary describes these features, and their functional utility along a shore.

Structures also include typical major industrial wharfs and piers that are associated with major waterfront industry. In Norfolk this would include structures in place for shipyard and military operations.

Table 2. Tier 2 - Bank Conditions

Bank Attribute	Range	Description
bank height	0-5 ft	from the toe to the edge of the fastland
	5-10 ft	from the toe to the edge of the fastland
	10-30 ft	from the toe to the edge of the fastland
	> 30 ft	from the toe to the edge of the fastland
bank stability	low erosion	minimal erosion on bank face or toe
	high erosion	includes slumping, scarps, exposed roots
bank cover	bare	<25% cover; vegetation or structural cover
	partial	25-75% cover; vegetation or structural
	total	>75% cover; vegetation or structural
marsh buffer	no	no marsh vegetation along the bank toe
	yes	fringe or pocket marsh present at bank toe
Phragmites australis	yes	denotes presence of Phragmites alongshore
marsh stability (if present)	low erosion	no obvious signs of erosion
	high erosion	marsh edge is eroding or vegetation loss
beach buffer	no	no sand beach present
	yes	sand beach present
beach stability (if present)	low erosion	accreting beach
	high erosion	eroding beach or non emergent at low tide

2.3 Data Collection/Survey Techniques

The City of Norfolk’s Division of Geographic Information Systems provided high resolution digital orthophotography with a pixel resolution of 1 foot. At this resolution it was possible to discern features from imagery that previously could only be collected in the field. Using ArcMap, features were digitized on screen. A high resolution shoreline coverage also provided by the city was used as a base layer. The coverage was modified in areas where the shoreline did not appear to follow the natural course of shoreline illustrated in the imagery. This arc coverage was split and recoded during photo interpretation sessions. Codes represent a suite of conditions observed at any given point along the shoreline.

Table 3. Tier 3 - Shoreline Features

Feature	Feature Type	Comments
<u>Control Structures</u>		
riprap	L	
bulkhead	L	
seawalls	L	
breakwaters	L	first and last of a series is surveyed
groinfield	L	first and last of a series is surveyed
jetty	P	
miscellaneous	L	can include tires, rubble, tubes, etc.
<u>Recreational/Other Structures</u>		
docks	P	includes private and public
wharfs	L	includes private and public
military wharfs	L	associated with military property
shipyard	L	includes wharf/bulkhead construction
dilapidated docks	P	docks not safe enough for intended use
boat ramp	P	distinguishes private vs. public landings
boat house	P	all covered structures, assumes a pier
marina	L	includes piers, bulkheads, wharfs

2.4 Data Verification

The ground-truthing component was a vital step in the completion of this inventory. Since this was the first time remote sensing had played a significant role in data development, quality control was important. A system for verification and correction of data was developed. It required a minimum of two persons in the field working from a small, shoal draft vessel, navigating at slow speeds parallel to the shoreline. To the extent possible, field work occurred during a rising tide, allowing the boat to be as close to shore as possible. The boat operator navigates the boat to follow the shoreline geometry. One surveyor collects information pertinent to land use and bank condition. The second surveyor logs information relevant to shoreline structures. Depending upon available personnel, the boat operator may be required to collect shoreline structure data.

The data collection system combines ArcPad running on a COMPAQ-iPAQ hand held computer interfaced with a Trimble GeoExplorer GPS unit. The hardware and software configuration allows an operator to retrieve the remotely sensed data which have been converted to shape files, view an aerial image of the area, and see the boat position for reference on the handheld computer screen. ArcPad editing features permits changes in the original data file where discrepancies are observed.

All shoreline along navigable water were visited. The results of the ground-truthing revealed the remotely sensed collection technique was very accurate for delineating land use, shoreline structures, and topography. The technique was less accurate for estimating bank condition and the presence of tidal marsh vegetation. This may be related to time of tide when the imagery was captured. All corrections made in the field are reflected in the final GIS coverages used in map production.

2.5.) Maps and Tables: Large format, digital color maps are generated to illustrate the attributes surveyed along the shore. The City has been divided into 15 different tiles. For each tile, a three-part map series illustrates the three tiers of data collected. Plate A describes the riparian land use as color coded bars along the shore. A legend keys the color to the type of land use.

Plate B depicts the condition of the bank and any natural buffers present. Four lines, and a combination of color and pattern symbology gives rise to a vast amount of bank and natural buffer information. The line running directly on the shoreline describes bank height. Bank height varies with the thickness of the line; where the thickest lines designate the highest banks (> 30 feet). Bank stability is reflected in the color of the line. Low erosion is green, high erosion is red, and banks that are basically stable on the face but are undercut at the base are yellow.

Natural buffers, marshes or beaches, are delineated as a line of small circles channelward of the shoreline. Here, open circles indicate a natural fringe marsh along the base of the bank. Solid circles indicate a sand beach buffer at the base of the bank. It is possible to have both. Red circles indicate the buffers show signs of erosion. Green circles indicate the buffer appear stable.

There are two lines landward of the shoreline. If present, a solid blue line inland of the bank height line delineates the presence of Phragmites. This is found only in isolated areas. The line representing bank cover is located inland of this line, but in the absence of Phragmites is seen behind the shoreline. Bank cover is distinguished by colors. Bare banks (<25% cover) are illustrated in pink, partial cover (25-75%) is illustrated by an orange line, and total cover (>75%) is indicated by a pale blue line. For any attribute the length of the symbology along the shore reflects the length alongshore that the features persist. The symbology changes as conditions change.

Plate C combines recreational and shoreline protection structures in a composition called Shoreline Features. Linear features, described previously (Table 3), are mapped using color coded bar symbols which follow the orientation of the shoreline. Point features use a combination of colors and symbols to plot the positions on the map.

Tables 4 and 5 quantify features mapped in the city. These are generated using frequency analysis techniques in ArcInfo. The values quantify features on a plate by plate basis (see index). For linear features, values are reported in actual miles surveyed. The number of point features surveyed are also listed on a plate by plate basis. The total miles of shoreline surveyed for each plate is reported. A total of 167.7 miles were surveyed. Since there is plate overlap, total survey miles can not be reached by adding the total shoreline miles for each plate. The last row of Tables 4 and 5 do, however, report the total shoreline miles surveyed for the city (167.70 miles), and the total amount of each feature surveyed along the measured shoreline.

Chapter 3. Applications for Management

3.1 Introduction

There are a number of different management applications for which the Shoreline Situation Reports (SSRs) support. This section discusses four of them which are currently high profile issues within the Commonwealth or Chesapeake Bay watershed. The SSRs are data reports, and do not necessarily provide interpretation beyond the characteristics of the nearshore landscape. However, the ability to interpret and integrate these data into other programs is key to gleaming the full benefits of the product. This chapter offers some examples for how data within the SSRs can be integrated and synthesized to support current state management programs.

3.2 Shoreline Management

The first uses for SSRs were to prepare decision makers to bring about well informed decisions regarding shoreline management. This need continues today, and perhaps with more

urgency. In many areas, like Norfolk, undisturbed shoreline miles are almost nonexistent. Development continues to encroach on remaining pristine reaches, and threatens the natural ecosystems which have prevailed. At the same time, the value of waterfront property has escalated, and the exigency to protect shorelines through stabilization has increased. Generally speaking, this has been an accepted management practice. However, protection of tidal shorelines does not occur without incidence.

Management decisions must consider the current state of the shoreline, and understand what actions and processes have occurred to bring the shoreline to its current state. This includes evaluating existing management practices, assessing shore stability in an area, and determining future uses of the shore. The SSRs provide data to perform these evaluations.

Plate A defines the land use adjacent to the shoreline. To the extent that land use directs the type of management practices found, these maps can predict shoreline strategies which may be expected in the future. Residential areas are prone to shoreline alterations. Commercial areas may require structures along the shore for their daily operations. Others frequently seek structural alternatives to address shoreline stability problems. Forested riparian zones, and large tracts of grass or agricultural areas are frequently unmanaged even if chronic erosion problems exist.

Stability at the shore is described in Plate B. The bank is characterized by its height, its state of erosion, and the presence or absence of natural buffers at the bank toe. Upland adjacent to high, stable banks with a stable natural buffer at the base are less prone to flooding or erosion problems resulting from storm activity. Upland adjacent to banks of lesser height (< 5 feet) are at greater risk of flooding, but if banks are stable with marshes or beaches present, erosion may not be as significant a concern. Survey data reveals a strong correlation between banks of high erosion, and the absence of natural buffers. Conversely, the association between stable banks and the presence of marsh or beach is also well established. This suggests that natural buffers such as beaches and fringe marshes play an important role in bank protection. This is illustrated

on the maps. Banks without natural buffers, yet classified as low erosion, are often structurally controlled with rip rap or bulkheads.

Plate C delineates structures installed along the shoreline. These include erosion control structures, structures associated with military, commercial, or industrial facilities, and structures to enhance recreational use of the waterway. This map is particularly useful for evaluating requests from property owners seeking structural methods for controlling shoreline erosion problems. Shoreline managers can evaluate the current situation of the surrounding shore including: impacts of earlier structural decisions, proximity to structures on neighboring parcels, and the vicinity to undisturbed lots. Alternative methods such as vegetative control may be evaluated by assessing the energy or fetch environment from the images. Use this plate in combination with Plate B to evaluate the condition of the bank proposed for protection. Plate B will report the observed stability of the bank at the time of the survey.

A close examination of shore conditions may suggest whether certain structural choices have been effective. Success of groin field and breakwater systems is confirmed when sediment accretion is observed. Low erosion conditions surveyed along segments with bulkheads and riprap indicate structures have controlled the erosion problem. The width of the shorezone, estimated from the background image, also speaks to the success of structures as a method of controlling erosion. A very narrow shorezone implies that as bulkheads or riprap have secured the erosion problem at the bank, they have also deflated the supply of sediment available to nourish a healthy beach. This is a typical shore response, and remains an unresolved management problem.

Shoreline managers are encouraged to use all three plates together when developing management strategies or making regulatory decisions. Each plate provides important information independent of the others, but collectively the plates become a more valuable management tool.

3.3 Non-Point Source Targeting

The identification of potential problem areas for non-point source pollution is a focal point of water quality improvement efforts throughout the Commonwealth. The three tiered approach provides a collection of data which, when combined, can allow for an assessment of potential non-point source pollution problems in a waterway.

Grass land and agricultural land, which includes pasture land and cropland, respectively, have the highest potential for nutrient runoff. These areas are also prone to high sediment loads since the adjacent banks are seldom restored when erosion problems persist. Residential, bare, and commercial land uses also have the potential to contribute to the non-point source pollution problem due to the types of practices which prevail, and large impervious surface areas. In Norfolk, impervious surface cover is a significant issue for runoff and resultant water quality in receiving waters.

The highest potential for non-point source pollution combines these land uses with "high" bank erosion conditions, bare or nearly bare bank cover, and no marsh buffer protection. The potential for non-point source pollution moderates as the condition of the bank changes from "high" bank erosion to "low" bank erosion, or with the presence or absence of stable marsh vegetation to function as a nutrient sink for runoff. Where defense structures occur in conjunction with "low" bank erosion, the structures are effectively controlling erosion at this time, and the potential for non-point source pollution is reduced. If the following characteristics are delineated: low bank erosion, stable marsh buffer, riprap or bulkhead; the potential for non-point source pollution from any land use class can be lowered.

At the other end of the spectrum, forested and scrub-shrub sites do not contribute significant amounts of non-point source pollution to the receiving waterway. Forest buffers, in particular, are noted for their ability to uptake nutrients running off the upland. Forested areas with stable or defended banks, a stable fringe marsh, and a beach would have the lowest potential as a source of non-point pollution. Scrub-shrub with similar bank and buffer characteristics would also be very low.

A quick search for potential non-point source sites would begin on Plate A. Identify the "grass" or "agricultural" areas. Locate these areas on Plate B, and find those which have eroding banks (in red) without any marsh protection. The hot spots are these sites where the banks are highest (thick red line), so the potential sediment volume introduced to the water is greatest. Finally check plate C to determine if any artificial stabilization to protect the bank has occurred. If these areas are without stabilizing structures, they indicate the hottest spots for the introduction of non-point source pollution.

3.4 Designating Areas of Concern (AOC) for Best Management Practice (BMP) Sites

Sediment load and nutrient management programs at the shore are largely based on installation of Best Management Practices (BMPs). Among other things, these practices include fencing to remove livestock from the water, installing erosion control structures, and bank re-vegetation programs. Installation of BMPs is costly. Cost share programs provide relief for property owners, but funds are scarce in comparison to the capacious number of waterway miles needing attention. Targeting Areas of Concern (AOC) can prioritize spending programs, and direct funds where most needed.

Data collected for the SSR can assist with targeting efforts for designating AOCs. AOCs can be areas where riparian buffers are fragmented, and could be restored. Use Plate A to identify forested upland. Breaks in the continuity of the riparian forest can be easily observed in the line segments, and background image. Land use between the breaks relates to potential opportunity for restoring the buffer where fragmentation has occurred. Agricultural tracts which breach forest buffers are more logical targets for restoration than developed residential or commercial stretches. Agricultural areas, therefore, offer the highest opportunity for conversion. Priority sites for riparian forest restoration should target forested tracts breached by "agriculture" or "grass" land (green-fuscia-green line pattern; green-blue-green line pattern, respectively).

Plate B can be used to identify sites for BMPs. Look for where "red" (i.e. eroding) bank

conditions persist. The thickness of the line tells something about the bank height. The fetch, or the distance of exposure across the water, can offer some insight into the type of BMP which might be most appropriate. Re-vegetation may be difficult to establish at the toe of a bank with high exposure to wave conditions. Plate C should be checked for existing shoreline erosion structures in place.

Tippett et.al.(2000) used similar stream side assessment data to target areas for bank and riparian corridor restoration. These data followed a comparable three tier approach and combine data regarding land use and bank stability to define specific reaches along the stream bank where AOCs have been noted. Protocols for determining AOCs are based on the data collected in the field.

3.5 Targeting for Total Maximum Daily Load (TMDL) Modeling

As the TMDL program in Virginia evolves, the importance of shoreline erosion in the lower tidal tributaries will become evident. Total maximum daily loads are defined as a threshold value for a pollutant, which when exceeded, impedes the quality of water for specific uses (e.g. swimming, fishing). Among the pollutants to be considered are: fecal coliform, pathogens, nitrogen, phosphorous, and sediment load.

Models will be developed to address each of these parameters. In Virginia there is currently a focus on fecal coliform particularly in shellfish growing areas. In upper watersheds, nutrient and fecal coliform parameters will be critical where high agricultural land use practices prevail. Sediment loads will eventually be considered throughout the watershed. In the lower watersheds, failing septic systems, wildlife, and agriculture are major contributor to fecal loads. Sediment loads from shoreline erosion in the lower estuary can be a significant impediment to water quality. Erosion from shorelines has been associated with high sediment loads in receiving waters (Hardaway et.al., 1992), and the potential for increased nutrient loads (Ibison et.al., 1990). Virginia's TMDL program is now underway, and being administered through the

Department's of Environment Quality and Conservation and Recreation. Impaired stream segments are being used to initially identify where model development should focus. For Virginia, this streamlining has done little to reduce the scope of this daunting task, since much of the lower major tributaries are considered impaired. Additional targeting will be necessary to prioritize model development.

To address suspended sediment loads, targeting to prioritize TMDL development can be assisted by maps which delineate areas of high erosion, and potential high sediment loads. Plate B in this inventory delineates banks of high erosion. Waterways with extensive footage of eroding shorelines should be targeted. The volume of sediment entering a system is also a function of bank height. Actual volumes of sediment eroded can be estimated by using bank height, and the linear extent that the condition persists along the shore. Bank height is an attribute defined in Plate B by the width of the line. Eroding banks (in red) with heights in excess of 10-30 feet (thickest lines) would be target areas for high sediment loads. Plate A can be used in combination with Plate B to determine the dominant land use practice, and assess whether nutrient enrichment through sediment erosion is also a concern. This would be the case along agriculturally dominated waterbodies.

Chapter 4. The Shoreline Situation

The shoreline situation is described for conditions in Norfolk along all primary and secondary shoreline not contiguous to highly secured military installations. Characteristics are described for all navigable tidal waterways. A total of 167.70 miles of shoreline are described. These miles were all surveyed using remote sensing techniques and then ground-truthed in the field. Photo interpretation was made using high resolution orthophotography provided by the city. Photography was flown in 1999 and published in 2000. Bank height conditions were mapped from available contour data also provided by the city. These conditions were verified in the field.

The resulting data are displayed in a map series consisting of 15 tiles and 3 maps for each tile, or a total of 45 maps. The maps are viewed on the web in Adobe Acrobat. An index map is provided to illustrate the spatial limits of each plate. From the Table of Contents maps can be viewed, and printed. The GIS data and associated metadata files are also available.

Tile Descriptions

Plate 1

Location: East Ocean View Section including Little Creek

Major River: Chesapeake Bay, Little Creek

Shoreline Miles Surveyed: 19.34

Plate Rotation: 0 degrees

Scale: 1:12,000

Plate 2

Location: Ocean View

Major River: Chesapeake Bay, headwaters of Little Creek

Shoreline Miles Surveyed: 12.26

Plate Rotation: 90 degrees west

Scale: 1:12,000

Plate 3

Location: Willoughby Spit

Major River: Chesapeake Bay, Willoughby Bay

Shoreline Miles Surveyed: 7.78

Plate Rotation: 0 degrees

Scale: 1:12,000

Plate 4

Location: West tip of Willoughby Spit at Route 64 Hampton Roads Bridge Tunnel crossing

Major River: Willoughby Bay, James River

Shoreline Miles Surveyed: 6.9

Plate Rotation: 90 degrees W

Scale: 1:12,000

Plate 5

Location: Sewells Point at the entrance to the Elizabeth River

Major River: Willoughby Bay, Elizabeth River

Shoreline Miles Surveyed: 5.87

Plate Rotation: 90 degrees W

Scale: 1:12,000

Plate 6

Location: Tanners Point at entrance to Lafayette River to Hampton Boulevard crossing

Major River: Lafayette River, Elizabeth River

Shoreline Miles Surveyed: 10.24

Plate Rotation: 90 degrees W

Scale: 1:12,000

Plate 7

Location: From Hampton Blvd crossing to Rt 460 bridge

Major River: Lafayette River, Crab Creek, Knitting Mill Creek

Shoreline Miles Surveyed: 26.46

Plate Rotation: 90 degrees W

Scale: 1:12,000

Plate 8

Location: Central Norfolk

Major River: Northern Branch of Lafayette River, Wayne Creek

Shoreline Miles Surveyed: 21.46

Plate Rotation: 0 degrees

Scale: 1:12,000

Plate 9

Location: South Central Norfolk

Major River: Lafayette River, headwaters Wayne Creek

Shoreline Miles Surveyed: 12.81

Plate Rotation: 0 degrees

Scale: 1:12,000

Plate 10

Location: Lambert Point Terminal

Major River: Elizabeth River, entrance to Lafayette River

Shoreline Miles Surveyed: 5.70

Plate Rotation: 90 degrees W

Scale: 1:12,000

Plate 11

Location: Downtown Norfolk: including Waterside and shipyard.

Major River: Elizabeth River, southern branch, eastern branch

Shoreline Miles Surveyed: 9.10

Plate Rotation: 45 degrees W

Scale: 1:12,000

Plate 12

Location: Downtown Norfolk, Harbor Park, shipyard

Major River: Eastern and Southern Branches of the Elizabeth River

Shoreline Miles Surveyed: 17.37

Plate Rotation: 0 degrees

Scale: 1:12,000

Plate 13

Location: Eastern Branch Elizabeth River
Major River: Eastern Branch, Broad Creek,
Shoreline Miles Surveyed: 17.37
Plate Rotation: 0 degrees
Scale: 1:12,000

Plate 14

Location: Broad Creek from Rt 58 overpass to Rt. 13 overpass on of Hunting Creek.
Major River: Broad Creek
Shoreline Miles Surveyed: 11.28
Plate Rotation: 0 degrees
Scale: 1:12,000

Plate 15

Location: Confluence of Broad Creek and Eastern Branch Elizabeth River
Major River: Eastern Branch Elizabeth River, Broad Creek, Mill Dam Creek
Shoreline Miles Surveyed: 15.27
Plate Rotation: 90 degrees W
Scale: 1:12,000

Glossary of Shoreline Features Defined

Agricultural - Land use defined as agricultural includes farm tracts which are cultivated and crop producing. This designation is not applicable for pasture land.

Bare - Land use defined as bare includes areas void of any vegetation or obvious land use. Bare areas include those which have been cleared for construction.

Beaches - Beaches are sandy shores which are subaerial during mean high water. These features can be thick and persistent, or very thin lenses of sand.

Boat house - A boathouse is considered any covered structure alongside a dock or pier built to cover a boat. They include true "houses" for boats with roof and siding, as well as awnings which offer only overhead protection. Since nearly all boat houses have adjoining piers, piers are not surveyed separately, but are assumed. Boat houses may be difficult to see in aerial photography. On the maps they are denoted with a blue triangle.

Boat Ramp - Boat ramps provide vessels access to the waterway. They are usually constructed of concrete, but wood and gravel ramps are also found. Point identification of boat ramps does not discriminate based on type, size, material, or quality of the launch. Access at these sites is not guaranteed, as many may be located on private property. The location of these ramps was determined from static ten second GPS observations. Ramps are illustrated as purple squares on the maps.

Breakwaters - Breakwaters are structures which sit parallel to the shore, and generally occur in a series along the shore. Their purpose is to attenuate and deflect incoming wave energy, protecting the fastland behind the structure. In doing so, a beach may naturally accrete behind the structures if sediment is available. A beach nourishment program is frequently part of the construction plan.

The position of the breakwater offshore, the number of breakwaters in a series, and their length depends on the size of the beach which must be maintained for shoreline protection. Most breakwater systems sit with the top at or near MHW and are partially exposed during low water. Breakwaters can be composed of a variety of materials. Large rock breakwaters, or breakwaters constructed of gabion baskets filled with smaller stone are popular today. Breakwaters are not easily observed from aerial imagery. However, the symmetrical cusped sand bodies which may accumulate behind the structures can be. In this survey, individual breakwaters are not mapped. The first and last breakwater in the series are surveyed as a ten-second static GPS observation. The system is delineated on the maps as a line paralleling the linear extent of the breakwater series along the shore.

Bulkhead* - Bulkheads are traditionally treated wood or steel "walls" constructed to offer protection from wave attack. More recently, plastics are being used in the construction.

Bulkheads are vertical structures built slightly seaward of the problem area and backfilled with suitable fill material. They function like a retaining wall, as they are designed to retain upland soil, and prevent erosion of the bank from impinging waves. The recent proliferation of vertical concrete cylinders, stacked side by side along an eroding stretch of shore offer similar level of protection as bulkheads, and include some of the same considerations for placement and success. These structures are also included in the bulkhead inventory.

Bulkheads are found in all types of environments, but they perform best in low to moderate energy conditions. Under high energy situations, the erosive power of reflective waves off bulkheads can scour material from the base, and cause eventual failure of the structure.

Bulkheads are common along residential and commercially developed shores. From aerial photography, long stretches of bulkheaded shoreline may be observed as an unnaturally straight or angular coast. In this inventory, they are mapped using kinematic GPS techniques. The data are displayed as linear features on the maps.

Commercial - Commercial zones include small commercial operations as well as parks or campgrounds. These operations are not necessarily water dependent businesses.

Dock/Pier *- In this survey, a dock or pier is a structure, generally constructed of wood, which is built perpendicular or parallel to the shore. These are typical on private property, particularly residential areas. They provide access to the water, usually for recreational purposes. Docks and piers are mapped as point features on the shore. Pier length is not surveyed. In the map compositions, docks are denoted by a small green dot. Depending on resolution, docks can be observed in aerial imagery, and may be seen in the maps if the structure was built prior to 1994, when the photography was taken.

Forest Land Use - Forest cover includes deciduous, evergreen, and mixed forest stands greater than 18 feet high. The riparian zone is classified as forested if the tree stand extends at least 33 feet inland of the seaward limit of the riparian zone.

Grass - Grass lands include large unmanaged fields, managed grasslands adjacent to large estates, agriculture tracts reserved for pasture, and grazing.

Groinfield - Groins are low profile structures that sit perpendicular to the shore. They are generally positioned at, or slightly above, the mean low water line. They can be constructed of rock, timber, or concrete. They are frequently set in a series known as a groinfield, which may extend along a stretch of shoreline for some distance.

The purpose of a groin is to trap sediment moving along shore in the littoral current. Sediment is deposited on the updrift side of the structure and can, when sufficient sediment is available in the system, accrete a small beach area. Some fields are nourished immediately after construction with suitable beach fill material. This approach does not deplete the longshore sediment supply, and offers immediate protection to the fastland behind the system.

For groins to be effective there needs to be a regular supply of sediment in the littoral system. In sediment starved areas, groin fields will not be particularly effective. In addition they can accelerate erosion on the downdrift side of the groin. The design of "low profile" groins was intended to allow some sediment to pass over the structure during intermediate and high tide stages, reducing the risk of down drift erosion.

From aerial imagery, most groins cannot be observed. However, effective groin fields appear as asymmetrical cusps where sediment has accumulated on the updrift side of the groin. The direction of net sediment drift is also evident.

This inventory does not delineate individual groins. In the field, the first and last groin of a series is surveyed. Others between them are assumed to be evenly spaced. On the map composition, the groin field is designated as a linear feature extending along the shore.

Industrial - Industrial operations are larger commercial businesses providing large-scale production or services.

Marina - Marinas are denoted as line features in this survey. They are a collection of docks and wharfs which can extend along an appreciable length of shore. Frequently they are associated with extensive bulkheading. Structures associated with a marina are not identified individually. This means any docks, wharfs, and bulkheads would not be delineated separately. Marinas are generally commercial operations. Community docks offering slips and launches for community residents are becoming more popular. They are usually smaller in scale than a commercial operation. To distinguish these facilities from commercial marinas, the riparian land use map (Plate A) will denote the use of the land at the site as residential for a community facility, rather than commercial.

Marshes - Marshes can be extensive embayed marshes, or narrow, fragmented fringe marshes. The vegetation must be relatively well established, although not necessarily healthy.

Miscellaneous - Miscellaneous point features represent short isolated segments along the shore where material has been dumped to protect a section of shore undergoing chronic erosion. Longer sections of shore are illustrated as line features. They can include tires, bricks, broken concrete rubble, and railroad ties as examples.

Military - includes military installations and facilities

Paved - Paved areas represent roads which run along the shore and generally are located at the top of the banks. Paved also includes parking areas such as parking at boat landing, or commercial facilities.

Phragmites australis - also known as Reed Grass, Phragmites is an invasive plant species which out compete native wetland plants. Phragmites is typically found in areas that have been disturbed by human activity.

Residential (multi-family)- includes condominiums, townhouses, and apartment buildings.

Residential (single-family) - includes single family dwellings in all community settings: subdivision, mixed use, urban, suburban.

Riprap - Generally composed of large rock to withstand wave energy, riprap revetments are constructed along shores to protect eroding fastland. Revetments today are preferred to bulkhead construction. They reduce wave reflection which causes scouring at the base of the structure, and are known to provide some habitat for aquatic and terrestrial species. Most revetments are constructed with a fine mesh filter cloth placed between the ground and the rock. The filter cloth permits water to permeate through, but prevents sediment behind the cloth from being removed, and causing the rock to settle. Revetments can be massive structures, extending along extensive stretches of shore, and up graded banks. When a bulkhead fails, riprap is often placed at the base for protection, rather than a bulkhead replacement. Riprap is also used to protect the edge of an eroding marsh. This use is known as toe protection. This inventory does not distinguish among the various types of revetments.

Riprap revetments are popular along residential waterfront as a mechanism for stabilizing banks. Along commercial or industrial waterfront development such as marinas, bulkheads are still more common since they provide a facility along which a vessel can dock securely. The maps illustrate riprap as a linear feature along the shore.

Schools - location of schools was provided by the city and verified in the field.

Scrub-shrub - Scrub-shrub zones include trees less than 18 feet high, and is usually dominated by shrubs and bushy plants.

Seawall - Seawalls are generally smooth faced concrete structures constructed at the toe of the bank and back-filled. These were very popular in the earlier days of shoreline protection. They have since been replaced with bulkheads and later rip-rap.

* described as dilapidated if they are no longer capable of performing their intended function or use

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Table 4. City of Norfolk Shoreline Attributes - Riparian Land Use and Bank and Buffer Conditions - Plate Summary

PLATE NUMBER	TOTAL MILES SURVEYED	RIPARIAN LAND USE (miles)											BANK (bank height and erosion status - miles of shore)									BANK COVER (miles)			BUFFER CONDITION (miles)					
		bare	commercial	educational		forest	grass	industrial	military	single family		multifamily		0-5 ft			5-10 ft			10-30 ft			bare	partial	full	phragmites	BEACH PRESENT		MARSH PRESENT	
				school	dwelling					dwelling	paved	scrub-shrub	low	high	undercut	low	high	undercut	low	high	undercut	eroding					stable	eroding	stable	
1	19.34	0.87	1.86	0.00	7.79	0.50	1.18	0.00	0.00	1.77	0.31	5.06	15.04	0.23	0.00	2.17	0.42	0.00	1.29	0.20	0.00	1.51	2.44	15.40	0.17	0.00	2.77	0.00	10.15	
2	12.26	0.04	0.52	0.00	4.72	0.15	0.78	0.00	0.00	1.30	0.11	4.64	8.69	0.00	0.00	3.20	0.00	0.00	0.37	0.00	0.00	0.06	1.50	10.69	0.00	0.00	2.04	0.00	8.84	
3	7.78	0.33	1.05	0.00	1.39	0.00	0.45	0.00	1.14	1.50	0.52	1.40	4.85	0.15	0.00	2.41	0.32	0.00	0.05	0.00	0.00	0.93	3.42	3.43	0.21	0.00	4.60	0.00	0.94	
4	6.90	0.40	0.94	0.00	0.76	0.00	0.02	0.00	3.86	0.40	0.51	0.01	5.70	0.04	0.00	1.00	0.13	0.00	0.05	0.00	0.00	0.02	1.37	5.52	0.00	0.00	1.60	0.00	0.00	
5	5.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.87	0.00	0.00	0.00	4.52	0.00	0.00	1.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.87	0.00	0.00	0.00	0.00	0.00	
6	10.24	0.00	0.24	0.00	4.29	0.32	0.35	2.49	0.77	0.00	0.60	1.17	8.32	0.00	0.02	1.89	0.00	0.00	0.00	0.00	0.00	0.00	0.68	9.55	0.05	0.00	0.19	0.00	2.79	
7	26.46	0.35	0.78	0.26	17.26	0.83	1.13	0.00	0.00	1.56	1.67	2.60	25.53	0.00	0.00	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.46	0.00	0.00	0.62	0.66	11.19	
8	21.46	0.07	0.52	0.03	11.69	2.67	1.46	0.03	0.00	0.04	0.51	4.45	20.40	0.00	0.00	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.05	21.41	0.00	0.00	0.19	0.00	10.85	
9	12.81	0.14	0.00	0.06	6.25	1.29	2.54	0.09	0.00	0.06	0.38	1.99	12.18	0.00	0.00	0.61	0.00	0.02	0.00	0.00	0.00	0.00	0.12	12.69	0.00	0.00	0.01	0.00	9.88	
10	5.70	0.00	0.61	0.12	0.63	0.00	0.29	1.50	0.00	0.03	0.62	1.91	4.09	0.05	0.00	1.13	0.00	0.00	0.43	0.00	0.00	0.40	0.79	4.51	0.00	0.00	0.41	0.00	0.29	
11	9.10	0.22	3.72	0.00	0.06	0.00	1.09	1.09	0.01	1.01	1.67	0.23	8.16	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.22	8.89	0.00	0.00	0.05	0.00	0.00	
12	17.07	0.32	3.76	0.00	1.33	0.14	1.80	3.85	1.45	0.37	1.10	2.94	14.78	0.03	0.00	2.26	0.00	0.00	0.01	0.00	0.00	0.08	0.30	16.69	0.00	0.13	0.04	0.00	3.31	
13	17.37	0.12	1.07	0.00	10.10	0.55	1.43	0.10	0.00	0.30	0.39	3.32	15.08	0.08	0.00	2.16	0.05	0.00	0.00	0.00	0.00	0.06	0.30	17.01	0.39	0.13	0.01	0.02	7.44	
14	11.28	0.13	0.39	0.00	4.30	1.18	1.11	0.75	0.00	0.37	0.16	2.88	8.41	0.00	0.00	2.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.17	0.16	0.00	0.00	0.00	8.40	
15	15.27	0.00	0.00	0.00	11.27	0.75	0.81	0.00	0.00	0.12	0.29	2.03	13.68	0.02	0.00	1.52	0.05	0.00	0.00	0.00	0.00	0.00	0.10	15.17	0.19	0.00	0.01	0.02	6.00	
Norfolk Total	167.70	2.85	12.52	0.46	66.59	7.57	11.89	9.08	11.88	7.87	7.23	29.75	141.98	0.52	0.02	22.38	0.78	0.02	1.79	0.20	0.00	3.04	9.79	154.65	0.97	0.13	11.01	0.69	68.31	

Table 5. City of Norfolk Shoreline Attributes - Shoreline Features - Plate Summary

PLATE NUMBER	TOTAL MILES SURVEYED	SHORELINE FEATURES																
		No. docks	No. dilapidated docks	No. boathouses	No. ramps private	No. ramps public	No. groinfields	No. marinas	No. jetties	No. breakwaters	Miles of misc	Miles of military wharf	Miles of bulkhead	Miles of dilapidated bulkhead	Miles of riprap	Miles of seawall	Miles of shipyard	Miles of wharf
1	19.34	149	9	3	27	0	0	5	1	5	0.59	0.00	2.67	0.35	1.26	0.00	0.00	0.00
2	12.26	40	1	1	9	0	1	0	0	4	0.08	0.00	0.29	0.00	0.06	0.00	0.00	0.00
3	7.78	45	2	1	3	2	7	0	2	9	0.00	0.00	0.42	0.00	1.66	0.00	0.00	0.00
4	6.90	19	2	2	6	2	3	2	3	3	0.23	0.00	2.52	0.00	1.57	0.00	0.00	0.00
5	5.87	0	0	0	0	0	0	1	1	0	0.00	12.36	0.00	0.00	1.24	0.00	0.00	0.00
6	10.24	116	1	5	7	0	0	1	2	0	0.29	0.53	2.17	0.19	2.53	0.50	0.00	1.95
7	26.46	287	0	8	13	0	4	4	2	0	0.00	0.00	5.55	0.07	3.32	1.61	0.00	0.00
8	21.46	171	0	8	13	0	0	0	0	0	0.00	0.00	3.34	0.07	1.63	0.14	0.00	0.00
9	12.81	42	0	1	3	0	0	0	0	0	0.00	0.00	0.75	0.00	0.79	0.00	0.00	0.00
10	5.70	17	2	0	3	0	3	1	0	0	1.31	0.00	1.15	0.26	1.18	0.03	0.00	1.55
11	9.10	24	2	0	1	0	1	5	0	0	0.63	0.01	3.48	0.17	1.19	1.31	0.00	1.11
12	17.07	50	4	3	2	1	0	1	0	0	1.22	1.95	2.75	0.69	2.01	0.00	1.53	0.00
13	17.37	107	6	15	29	0	0	0	0	0	1.40	0.00	2.41	0.18	2.71	0.05	0.00	0.00
14	11.28	9	2	0	2	0	0	0	0	0	0.15	0.00	0.40	0.09	0.43	0.04	0.00	0.00
15	15.27	122	3	17	34	0	0	0	1	0	0.49	0.00	2.52	0.07	3.05	0.05	0.00	0.00
Norfolk Total	167.70	981	26	47	110	3	14	16	9	21	5.03	14.65	25.46	1.96	19.43	3.37	1.53	3.88