Delaware Shoreline Inventory:

Appoquinimink River, Blackbird Creek, and St. Jones River

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Produced by the Virginia Institute of Marine Science, Center for Coastal Resources Management, Comprehensive Coastal Inventory Program

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Chapter 1. Introduction

1.1 Background

Management of small watersheds within the larger Delaware Bay watershed is challenging. The Delaware Coastal Zone Management Program seeks decision support tools that enhance coastal management at the local and state level. The rational for a coastal inventory is to provide information to inform policy development and regulation of coastal resources. The Comprehensive Coastal Inventory Program (CCI) at the Virginia Institute of Marine Science was established to develop and implement a shoreline inventory for Virginia. Protocols for mapping and reporting shoreline conditions in Virginia have been adapted for the Delaware watersheds (Berman and Hershner 1999). The protocols have also been applied throughout the coastal zone of Maryland and selected areas of North Carolina.

The highlights of the shoreline inventory developed for these watersheds include an extensive dataset that reports waterfront condition, character, and use. Information is available to users in a set of easy to interpret maps, digital GIS data, or interpretive tables. They can serve a wide variety of user groups including local planners developing comprehensive plans for waterfront development and conservation, managers evaluating status and trends in shoreline condition, and environmental protection agents who regulate or monitor activities along the shore. The simplicity of some products in final format allow for private citizens to assess conditions along their shorelines as well.

This Shoreline Situation Report series for Delaware will extend coverage of shoreline condition from the Chesapeake north along the Mid Atlantic region. This project, therefore, assists to bring about a consistently comparable shoreline evaluation along tidal estuaries comprising the entire Mid-Atlantic region. This has enormous value for comparing trends in shoreline condition and riparian lands management throughout the region, between states, and across jurisdictionally shared watersheds.

The digital format for these products can be sampled by viewing completed inventories on the website:
http://ccrm.vims.edu/gis_data_maps/shoreline_inventories/delaware/delaware_disclaimer.html.

1.2 Description of the Watersheds

This project generates shoreline inventories for the following watersheds in Delaware: Blackbird Creek, Appoquinimink Creek, and St. Jones River. This comprises roughly 143 miles of tidal shoreline. The areas were selected by staff of the Delaware Department of Natural Resources and Environmental Control (DNREC).

The Appoquinimink River includes about 60 miles of shoreline, flowing through the towns of Odessa, Middletown, and Townsend to the Delaware Bay. The watershed is reported to be 47 square miles in area (ARA, 2008) and located entirely within the borders of New Castle County. It is primarily agricultural, but a mix of land uses including residential can be found directly along the shoreline.

The Appoquinimink River Association formed in 2004 advocates for improved water quality in the river. Currently on the list of impaired rivers and streams, the Appoquinimink suffers from excessive nutrient loads, low dissolved oxygen, and the presence of toxins and pesticides. Since development along the shoreline is minimal, there has been little shoreline hardening. Phragmites, however, is prevalent along the shoreline.

On September 11, 2007, 36.76 miles of shoreline were surveyed using the techniques described below. The remaining shoreline miles were not accessible by boat and not surveyed.

Blackbird Creek also discharges into Delaware Bay directly below the Appoquinimink River. Blackbird has 43.55 miles of shoreline and is part of the National Estuarine Research Reserve System for Delaware. The reserve encompasses 1180 acres of private and public land in southern New Castle County. Much of this area lies within the non-tidal and tidal freshwater portion of the creek, several miles upriver from the mouth. Like the Appoquinimink River, the Blackbird is rural in character, primarily agricultural with a mix of forest cover. The headwaters of the Blackbird runs through Blackbird State Forest. Development occurs along the shoreline in isolated places. Pressure to expand development is a great concern to preservation of wildlife and water quality.

The shoreline survey of Blackbird Creek took place on September 11th, 12th, and 13th, 2007. At that time 35.9 miles of shoreline was surveyed. The remaining 7.65 miles were located along non-navigable stretches.

The St. Jones River has 39.19 miles of shoreline and is located southeast of the cities of Dover and Camden in Kent County. There are several impoundments in the upper portion of the watershed. The lower watershed includes expansive tidal salt marshes dominated by spartina. Land use along the shoreline is primarily agriculture and forest cover. Structures for erosion control are minimal. The river is also part of Delaware's National Estuarine Research Reserve system.

On September 12, 2007, 27.31 miles of shoreline were surveyed. This survey was conducted along all navigable water. The surveys for all three rivers follow the methodologies discussed in Chapter 2 below.

1.3 Purpose and Goals

This shoreline inventory is developed as a tool for assessing conditions along primary shoreline in three watersheds that discharge into Delaware Bay. Field data were collected between September 11-13, 2007. Conditions are reported for three zones within the immediate riparian river area: riparian land use, bank and buffers, and the shoreline. A series of maps, tabular data, and GIS files are posted to a website and available electronically to serve as a resource to all managers and planners within the three watersheds. The survey provides a baseline to which future conditions can be compared and tracked through time.

1.4 Report Organization

This report is divided into several sections. Chapter 2 describes methods used to develop this inventory, along with conditions and attributes considered in the survey. Chapter 3 identifies potential applications for the data, with a focus on current management issues. All products are located online.

1.5 Acknowledgments

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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), and Geographic Information Systems (GIS) 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 in Virginia, Maryland and Delaware (Berman and Hershner, 1999).

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

2.2 Three Tiered Shoreline Assessment

The data inventory developed for the Shoreline Inventory 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 channelward to the shoreline. This assessment approach was developed to use observations that could be made from a moving boat. To that end, the survey is a collection of descriptive measurements that characterize conditions. GPS units log location of conditions observed from a boat. No other field measurements are performed.

The three tiered shoreline assessment approach divides the shorezone into three regions: 1) the immediate riparian zone, evaluated for land use; 2) the upland bank or marsh interface, 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 that can be anticipated. GPS is used to measure the linear extent along shore where the practice is observed. The width of this zone is not measured. Riparian

Table 1. Tier One - Riparian Land Use Classes

Forest	stands greater than 18 feet high / width greater than 30 feet
Scrub-shrub	stands less than 18 feet high*
Grass	includes grass fields, and pasture land*
Agriculture	includes cropland*
Residential	includes single or multi family dwellings*
Commercial	includes small and moderate business operations, recreational facilities*
Industrial	includes large industry and manufacturing operations*
Bare	lot cleared to bare soil*
Timbered	clear-cuts*
Paved	areas where roads or parking areas are adjacent to the shore*
Unknown	land use undetectable from the vessel*

* forest fringe along the shore is present in conjunction with the dominant land use

forest buffers are considered the primary land use if the buffer width equals or exceeds 30 feet. This width is verified from digital imagery as part of the quality control in data processing.

2.2b) Bank Condition/Marsh 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 that determine water quality in receiving waters as well as beach character. 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 and characteristics, 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, and the presence of natural (beach, marsh) buffers at the bank toe (Table 2). Conditions are recorded continuously using GPS as the boat moves along the shoreline. The GPS log reflects any changes 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 structural cover like riprap is considered “cover.” The assessment is qualitative (Table 2). Bank stability characterizes the condition of the bank face.

Table 2. Tier 2 - Bank /Marsh Condition

Bank Attribute	Range	Description
Bank/marsh 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
	10-30ft	from the toe to the edge of the fastland
	> 30 ft	from the toe to the edge of the fastland
Bank/marsh stability	low erosion	minimal erosion on bank or marsh face
	high erosion	includes slumping, scarps, exposed roots
	undercut	erosion at the base of the bank
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, extensive, or embayed
beach buffer	no	no sand beach present
	yes	sand beach present
Phragmites australis	no	no *Phragmites australis* present on site
	yes	*Phragmites australis* present on site

Banks that are undercut, have exposed root systems, down vegetation, or exhibit slumping of material qualify as a "high erosion." 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. Their presence is noted in the field.

The morphology of these rivers includes highly sinuous channels bordered by extensive marshes in many areas. These marshes are also cut by tidal creeks. Where navigation permitted and conditions warranted, the surveys extended into and along these expansive marshes. Since the upland bank either doesn't exist or is so distant from the marsh edge, conditions were not recorded for the upland bank but rather the marsh edge. There is an alteration in the map symbology (see legends) where marsh condition rather than bank condition is reported. The data and tables also include this.

Table 3. Tier 3 - Shoreline Features

Feature	Feature Type	Comments
Control Structures		
riprap	L	
bulkhead	L	
breakwaters	L	first and last of a series is surveyed
groinfield	L	first and last of a series is surveyed
jetty	P	
debris	L	can include tires, rubble, tubes, etc.
unconventional	L	composed on non-traditional materials
marsh toe revetment	L	placed in front of an eroding marsh
Recreational Structures		
pier/wharf	P	includes private and public
boat ramp	P	distinguishes private vs. public landings
boat house	P	all covered structures, assumes a pier
marina	L	includes piers, bulkheads, wharfs

Sediment composition and bank slope cannot be surveyed from a boat, and are not included.

2.2c) Shoreline Features: Structures added to the shoreline by property owners are recorded as a combination of points or lines. These features include defense structures, constructed to protect the shoreline from erosion; offense structures, designed to accumulate sand in transport; and recreational structures, built to enhance public or private use of the water (Table 3). The location of these features along the shore is surveyed with the GPS unit. Linear features are surveyed kinematically without stopping the boat. Structures such as docks, and boat ramps are point features, and a static six-second GPS observation is collected at the site. Table 3 summarizes shoreline features surveyed. Linear features are denoted with an "L" and point features are denoted with a "P." The glossary describes these features, and their purpose along a shore.

2.3 Data Collection/Survey Techniques

Data collection is performed in the field from a small, shoal draft vessel, navigating at slow speeds parallel to the shoreline. To the extent possible, surveys take place on a rising tide, allowing the boat to be as close to shore as possible. The field crew consists of a boat operator, and one data surveyor. The boat operator navigates the boat to follow the shoreline geometry and collects data pertaining to shoreline features. The surveyor collects information pertinent to all land use and bank condition.

Data is logged using the handheld Trimble GeoExplorer III, GeoExplorer XT, or GeoExplorer XH GPS unit. GeoExplorers are accurate to within 4 inches of true position with extended observations and differential correction. Without post processing, these units can achieve accuracies around 3 ft (1 meter). Both static and kinematic data collection is performed. Kinematic data collection is a collection technique where data is collected continuously along a pathway (in this case along the waterway). GPS units are programmed to collect information at a rate sufficient to compute a position anywhere along the course. The shoreline data is collected at a rate of one observation every five seconds. Land use, bank condition, and linear shoreline structures are collected using this technique.

Static surveys pin-point fixed locations that occur at very short intervals. The boat actually stops to collect these data, and the boat operator must hold the boat against tidal currents and surface wind waves. Static surveys log 6 GPS observations at a rate of one observation per second at the fixed station. The GPS receiver uses an averaging technique to compute one position based on the 6 static observations. Static surveys are used to position point features like piers, boat ramps, and boathouses.

The Trimble GPS receivers being used include a function that allows a user to pre-program the complete set of features surveyed in a "data dictionary." The data dictionary prepared for this Shoreline Situation Report includes all features described in section 2.2. As features are observed in the field, surveyors use scroll down menus to continuously tag each geographic coordinate pair with a suite of characteristics that describe the shoreland's land use, bank condition, and shoreline features present. The survey, therefore, is a complete set of geographically referenced shoreline data.

2.4 Data Processing

Data processing occurs in two parts. Part one processes the raw GPS field data, and converts the data to GIS coverages (section 2.4a). Part two corrects the GIS coverages to reflect true shoreline geometry (section 2.4b).

2.4a.) GPS Processing: Differential correction improves the accuracy of GPS data by including other "known" locations to refine geographic position. Any GPS base station within 124 miles of the field site can serve as one additional location. The Reedy Point, Delaware CORS base station operated by the National Geodetic Survey was used for data processing.

Differential correction is the first step to processing GPS data. Trimble's Pathfinder Office GPS software is used. The software processes time synchronized GPS signals from field data and the selected base station. Differential correction improves the position of the GPS field data based on the known location of the base station, the satellites, and the satellite geometry. When Selective Availability was turned off in late Spring, 2000, the need to post process data has nearly been eliminated for the level of accuracy being sought in this project. However, we continue to perform the correction in our efforts to seek the highest level of accuracy possible.

Although the Trimble units are capable of decimeter accuracy (~ 4 inches), the short occupation of sites in the field reduces the accuracy to 5 meters (~16 feet). In many cases the accuracy achieved is better, but the overall limits established by the CCI program are set at 5 meters. This means that features are registered to within 5 meters (~16 feet) or better of their true position on the earth's surface. In this case, positioning refers to the boat position during data collection.

An editing function is used to clean the GPS data. Cleaning corrects for breaks in the data that occur when satellite lock is lost during data collection. Editing also eliminates erroneous data collected when the boat circles off track, and the GPS unit is not switched to "pause" mode.

The final step in GPS processing converts the files to three separate ArcInfo® shape files for each river. These are converted into three coverages for each river: a land use and bank condition coverage, a shoreline structure coverage (lines only), and a shoreline structure coverage (points only) (Table 4.)

Table 4. GIS file names

CREEK	Landuse/Bank	Structure (points)	Structures (lines)
Appoquinimink	appo_lubc	appo_astru	appo_sstru
Blackbird	bb_lubc	bb_astru	bb_sstru
St. Jones	stjo_lubc	stjo_astru	stjo_sstru

2.4b.) GIS Processing: GIS processing includes one major step that combines ESRI's ArcInfo® GIS software, and ERDAS' Imagine® software. Several data sets are integrated to develop the final inventory products. The processing is intended to correct the new GIS coverages so they reflect conditions at the shoreline, and not along the boat track. All attributes summarized in Tables 1, 2, and 3 are included. A digital shoreline coverage was generated to use as a basemap. For these inventories, 2002 digital ortho quarter quadrangles were used to delineate the land water interface using photo-interpretation techniques. The product was provided by DENREC and modified in areas using on-screen digitizing and the ArcMap software. The digital shoreline product is not referenced to a tidal datum, but is the most recent available data and developed from medium with a resolution of 1-2 meters. The imagery is also used for all background imagery used in data processing and map production. Imagery provides an important quality control tool for verifying the location of certain landscape attributes, and provides users with additional information about the coastal landscape.

GIS processing corrects the coverages generated from the GPS field data to the shoreline record. Prior to this step, the coverages are geographically coincident with the boat track; from where observations are made. They are, therefore, located somewhere in the waterway. Processing transfers these data back to the shoreline basemap so the data more precisely reflect the location being described along the shore.

Data processing uses all three data sets simultaneously: the baseline shoreline, the post-processed GPS field data, and the ArcInfo coverages. The imagery is used in the background for reference. The processing re-codes the base shoreline with the attributes mapped along the boat track. Each time the boat track data (i.e GPS data) indicates a change in attribute type or condition, the digital shoreline arc is split, and coded appropriately for the attributes using ArcInfo techniques.

The GIS processing under goes a rigorous sequence of checks to ensure the positional translation is as accurate as possible. Each field coverage; land use, bank condition, and shoreline condition, is processed separately. The final products are three new coded GIS shoreline coverages for each creek (Table 4).

Quality control and assurance measures require that each coverage be checked twice onscreen by different GIS personnel. Draft hardcopy maps are printed and reviewed in the third and final QA/QC step. Once complete, maps and tables are generated for the website.

2.4c.) Maps and Tables: Maps and tables can be viewed or downloaded as pdf files. A color printer is required on the user end. Color maps are generated to illustrate the attributes surveyed along the shore. A four-part map series has been designed to illustrate all the data.

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. If the line is hatched, there is forest fringe on site. The background imagery is a color infra-red DOQQ at a publication scale of 1:12,000. Users should note that the imagery is sometime rotated in order to meet the scale requirements. This means that "north" is not always to the top of the page.

Plate B depicts the condition of the bank or marsh edge. Two lines, and a combination of color and pattern symbology are used to describe the present conditions. The line directly on the shoreline describes bank height and stability. These are red, green or yellow lines with a red line indicating an unstable bank (high erosion), a green line indicating stability (low erosion), and a yellow line indicating evidence of undercutting at the base of bank. Bank height varies with the thickness of the line; where the thickest lines designate the highest banks (> 30 feet). As the bank height range decreases, the line thins. If conditions are being reported for the marsh edge because the marsh is so broad and the bank is nonexistent or far away, the line pattern include a series of solid circles and the color pattern remains the same. On rising tides it is often difficult to accurately assess the condition of a marsh edge if the edge is submerged at the time of the survey.

The line parallel but inland to the coded shoreline describes the bank cover. Bank cover is distinguished by colors. Bare banks (<25% cover) are illustrated in fuschia, partial cover (25-75%) is pale orange line, and total cover (>75%) is indicated by a light blue line. Plate B uses a grey scale version of the natural color image for the backdrop.

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 that follow the orientation of the shoreline. Point features use a combination of colors and symbols to plot the positions on the map. Gray scale imagery is used as a backdrop, upon which all shoreline feature data are superimposed.

Plate D described the presence of natural buffers that include beaches, marshes, and patches of the invasive species *Phragmites australis*. A pattern of small colored circles along the shoreline is used to delineate beaches and marshes. Open circles represent beaches. An embayed marsh is illustrated with solid green dots. Solid fuchsia dots delineated extensive marsh, and solid yellow dots delineate fringe marsh. Extensive and embayed marshes may be further described on plate B if no other bank condition can be seen or is present. It is possible to have both beach and marsh together at a site. The symbology changes as conditions change. In many cases, marshes especially, extend for very long distances along the shore of these rivers.

Also abundant along these watersheds is the presence of *Phragmites australis*. This species is illustrated where present as a solid blue line parallel, but inland, of the shoreline. No attempt to map the spatial extent of the patches was made for this study. In many cases the patches are quite extensive, and the distribution along the shoreline may be an indicator of how prolific the species is in its distribution.

For publication purposes each watershed is divided into a series of maps. Maps are scaled at 1:12,000 for publication at 11x17. Scale will vary if printed at a different size. There are 3 maps for Appoquinimink River, 4 maps for Blackbird Creek, and 4 maps for St. Jones River. The number of maps is determined by the geographic size and shape of the watershed. For each map there are four plates (plate 1a, 1b, 1c, 1d, etc.), for a total of 12 map compositions for Appoquinimink River, and 16 maps each for Blackbird and St. Jones. On the website, an index is provided to help users locate the area of interest and view the orientation of the maps to each other. Each plate can be individually selected and viewed from the plate list along the left hand column of the index page.

Tables 5 and 6 quantify features mapped along the rivers using frequency analysis techniques in ArcInfo. The values quantify features on a plate-by-plate basis. For linear features, values are reported in actual miles surveyed. The number of point features surveyed is also listed on a plate by plate basis. The total miles of shoreline surveyed for each plate is reported.

A total of 36.8, 35.9, and 27.3 miles of shoreline were surveyed in the field for the Appoquinimink, Blackbird and St, Jones, respectively. Since there is plate overlap as depicted in the index map on the website, total survey miles cannot be reached by adding together the total shoreline miles for each plate. The last row of Tables 5and 6 reports the total shoreline miles surveyed for the watershed, and the total amount of each feature surveyed along the measured shoreline. Table 7 reports the amount of *Phragmites australis* delineated along shore.

Chapter 3. Applications for Management

3.1 Introduction

There is a number of different management applications for which the Shoreline Inventory Reports support. This section discusses several common management problems. The Shoreline Inventories are data reports, and the data provided are intended for interpretation and integration into other programs. This chapter offers some examples for how these data can be analyzed to support current state management programs.

3.2 Shoreline Management

The first uses for shoreline inventories 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, undisturbed shoreline miles are almost nonexistent. Development continues to encroach on remaining pristine reaches, and threatens the natural ecosystems that have persisted. At the same time, the value of waterfront property has escalated, and the exigency to protect shorelines as an economic resource using stabilization practices has increased. 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 shoreline inventories provide data for such assessments.

For example, land use, to some extent, directs the type of management practices one can expect to find along the shoreline. The land use data, illustrated on plate “a” illustrates current land use at the time of survey that may be an indicator of shoreline management practices existing or expected in the future. Residential and commercial areas are frequently altered to counter act shoreline erosion problems or to enhance private access to the waterway.   In contrast forested or agricultural uses are frequently unmanaged even if chronic erosion problems exist. Small forest tracks nestled among residential lots have a high probability for development in the future. These areas are also target areas then for shoreline modifications if development does occur.   In the case of these watersheds, future development should of greatest concern since existing development is minimal. Conversion of agricultural lands to developments has threatened rural landscapes characteristic of these watersheds for many years now.

Local governments can do some enhanced and proactive planning if resources allow. The fact that two of the three watersheds targeted in this product already have substantial acreage in a reserve is a major step toward positive planning. Those areas likely to be developed in the future can be assessed now to determine the need for shoreline stabilization, and the type of stabilization that should be recommended.

To determine the potential need for stabilization along the shore, plate “b” can be used as a data resource. The bank is characterized by its height, the amount of cover on the bank face, the state of erosion. Upland adjacent to high fully covered, and stable banks are less prone to flooding or erosion problems that result from storm activity. Upland adjacent to banks of lesser height (< 5feet) are at greater risk of flooding. However, the presence of natural buffers such as beaches or marshes delineated in plate “d” can have a significant influence on the stability of a bank. If banks are classified as stable, verify the presence of a natural buffer. 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, and the shoreline should be managed in a manner that will protect, maintain, and/or enhance the natural buffer whenever if possible.

Plate “c” which delineated shoreline structures is particularly useful for evaluating new requests from property owners seeking structural methods for controlling shoreline erosion problems. Shoreline managers can evaluate the current condition 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. A review of plate “b” will provide the qualitative erosion assessment that will assist in determining project need.

Although the shoreline of these watersheds have not been heavily impacted by structures, in any setting it is sometime valuable to evaluate whether structural choices have been effective. A close examination of shore conditions can be useful. Success of structures such as groin fields 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 may have also deflated the supply of sediment available to nourish a healthy beach. The structure may actually be enhancing erosion at the base of the structure due to scour and wave reflection. 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 Stream Restoration for Non-Point Source Management

Water quality is identified as an important management issue now threatening the watersheds. The identification of potential problem areas for non-point source pollution is a useful, proactive exercise. Since we are relatively well informed about the landscape characteristics that contribute to the problem we can utilize data resources such as this shoreline inventory, in combination with other resources, to target river reaches where restoration efforts would be necessary. Some example cases are described below.

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 are also hot spots for non-point source pollution.

To identify areas with the highest potential for non-point source pollution combine these land uses with “high” bank erosion conditions, 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, 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, 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 that have eroding banks (in red) without any marsh protection (plate “d”). 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 from the Shoreline Inventory can be used to identify 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.

Plate “b” can be used to identify sites for BMPs. Look for where 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 that might be most appropriate. Marsh planting may be difficult to establish at the toe of a bank with high exposure to wave conditions. Look for other marsh fringe (plate “d”) in the vicinity as an indicator. 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.

As water quality programs move into implementation phases the importance of shoreline erosion in the lower tidal tributaries will become evident. Erosion from shorelines has been associated with high sediment loads in receiving waters (Hardaway et.al., 1992), and the potential for increased nutrient loads coming off eroding fastland is a concern (Ibison et.al., 1990). The contribution to the suspended load from shoreline erosion is not quantified. Water quality modelers are challenged by gathering appropriate data for model inputs. In Maryland, where there is a complete Shoreline Inventory for each coastal locality, data from the inventory is being used to assess shoreline areas where the introduction of sediment from shoreline erosion is possible. Using data illustrated in plate “c”, Maryland is able to identify areas that have been stabilized versus those that are undefended. They are combining these data with computed shoreline erosion rates to determine the volume of sediment entering the system at points where the shoreline is unprotected. This type of assessment may be beneficial along the lower more exposed areas of the watershed.

Continuous reaches of shoreline undergoing erosion should be flagged as hot spots for sediment input. The volume of sediment entering a system is generally estimated by multiplying the computed shoreline recession rate by the bank height along some distance alongshore. Estimated bank height is mapped along all surveyed shorelines in plate “b”. Banks designated as “eroding” and in excess of 30 feet 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 shoreline   Table 5 quantifies the linear extent of high, eroding banks on a plate by plate basis.

3.5 Summary

These represent only a handful of uses for the inventory data. Users are encouraged to consider merging these data with other local or regional datasets. Now that many agencies and localities have access to some GIS capabilities, the uses for the data are even greater. While the conditions mapped represent a snap shot in time, the opportunity to update these on a regular basis does exist. These data therefore provide a baseline of conditions to which future surveys can be compared.

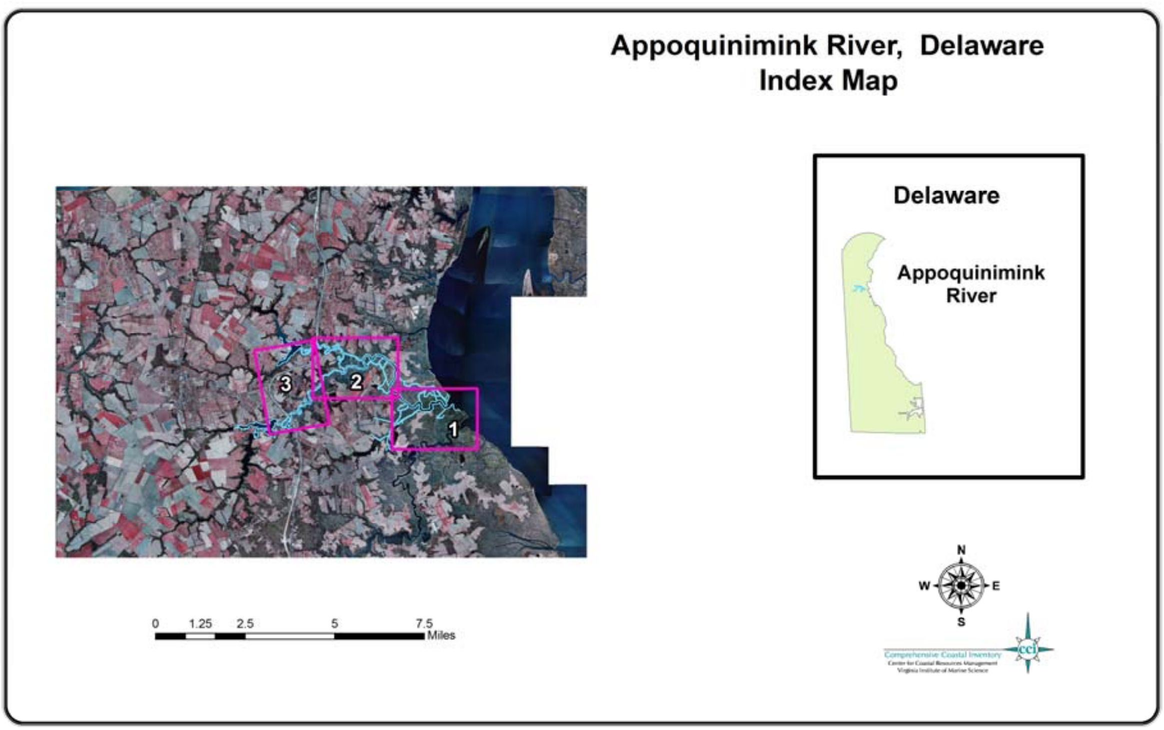
Chapter 4. The Shoreline Inventory

Shoreline condition is described for the Appoquinimink River, Black Bird Creek and St. Jones River. Characteristics are described for all navigable tidal waterways in the watersheds. Nearly 100 miles of shoreline were surveyed

The Shoreline Inventory is only available electronically. From the Delaware Shoreline Inventory Project Homepage: http://ccrm.vims.edu/gis_data_maps/shoreline_inventories/delaware/delaware_disclaimer.html, a user can access digital maps, tables, reports, GIS data, and metadata. Users can select their watershed of interest or view all the data.

The link to “maps” will take you to an index page similar to the one shown in Figure 1. This is useful if you are interested in a specific area.

Figure 1. Map index for the Appoquinimink River



Once you determine which plate you want, the menu on the bottom has links to the four maps associated with each plate (Figure 2). Riparian Land Use is in the first column. You can also select links to see maps illustrating Bank/Marsh Condition, Shoreline Features and Natural Buffers. The content and details of the four part plate series was described in detail in Chapter 2. The actual map will come up when you click on the plate number. For example, Figure 3 is the riparian land use map for plate 2 of the Appoquinimink River series. Figure 4 is the map illustrating Bank/Marsh Condition for plate 2, and Figure 5 shows all the shoreline features for that same area. You may open all four plates for the series, but can view only one at a time in most browsers. Tools for zooming and panning should be on the tool bar. The maps can be printed at full resolution up to 11x17 color. Color printers are necessary.

From the homepage, summary statistics for all data can be found under the “Tables” link. The link to the GIS data is also found on the homepage. Files are compressed and easily downloaded. The metadata is a separate link that can also be downloaded. Users are encouraged to read the metadata carefully as well as all other information in the disclaimer.

Figure 2. Table with links to maps

Riparian Land Use	Bank and Marsh Conditions	Shoreline Features	Natural Buffers
1a	1b	1c	1d
2a	2b	2c	2d
3a	3b	3c	3d

Figure 3. Sample riparian land use map for the Appoquinimink River

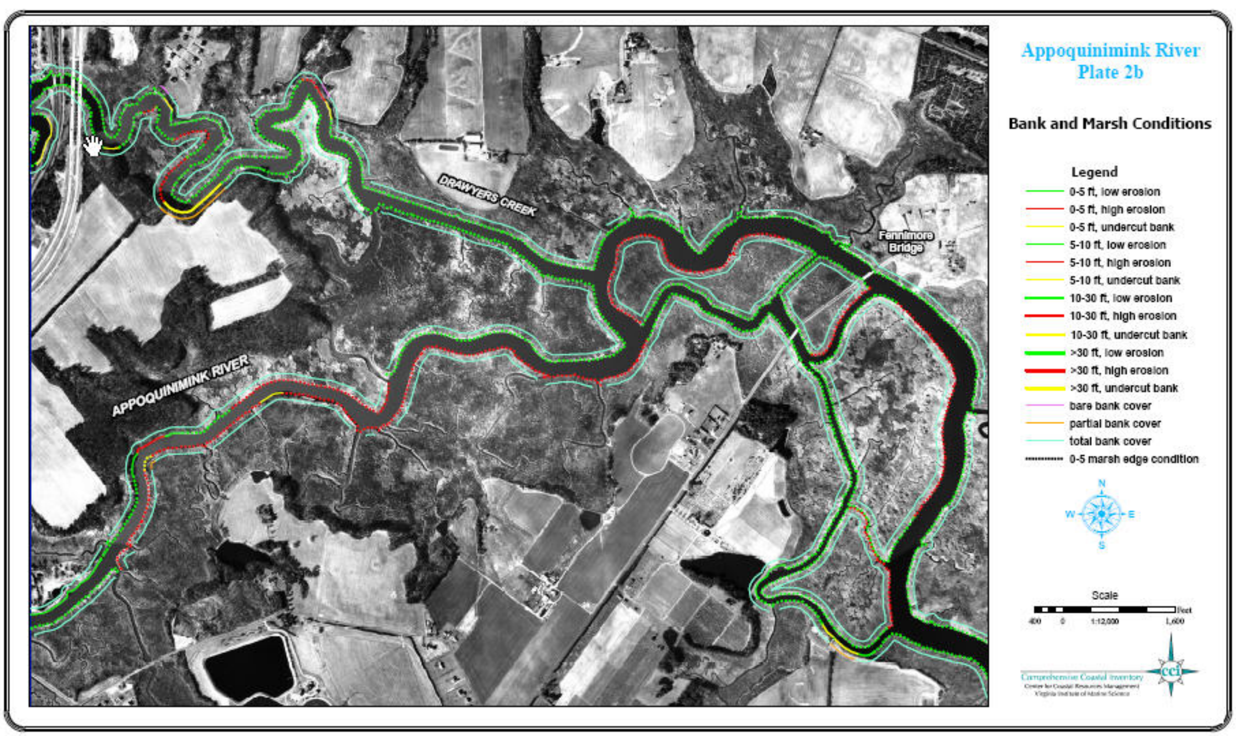


Figure 4. Map illustrating bank/marsh conditions for plate 2 on the Appoquinimink River

Figure 5. Map illustrating shoreline features for plate 2 on the Appoquinimink River.

<u>Glossary of Shoreline Features Defined</u>

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

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

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

Boathouse - 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 that offer only overhead protection. Since nearly all boathouses have adjoining piers, piers are not surveyed separately, but are assumed. Boathouses 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. Private and public ramps are denoted where possible. Private ramps are illustrated as purple squares. Orange squares represent public ramps. The location of these ramps was determined from static 6 second GPS observations.

Breakwaters - Breakwaters are structures that 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 that 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 cuspate sand bodies that may accumulate behind the structures can be. In this survey, individual breakwaters are not mapped. The first and last breakwater in the series is surveyed as a six-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 a similar level of protection as bulkheads, and includes 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 Fringe – When the dominant land use on a parcel is something other than forest cover, but the parcel retains a fringe of tree cover along the shoreline.

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 - Grasslands 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 updraft 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 downdraft 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 updraft 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. We assume those in between are 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.

Marina - Marinas are denoted as line features in this survey. They are a collection of docks and wharfs that 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. However, if a boat ramp is present it will be surveyed separately and coded as private. 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. The survey estimates the number of slips within the marina and classifies marinas as those with less than 50 slips and those with more than 50 slips.

Marsh Toe Revetment – generally a stone structure (see rip rap) placed at the seaward edge of an existing eroding marsh.

Marshes - Marshes are classified as “extensive”, “embayed” or “fringe” marshes. Extensive marshes generally occupy significant acreage. Embayed marshes are similar to pocket or headwater marshes. Fringe marshes are narrow strips of marsh vegetation that extend along the shoreline. In all cases, 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.

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 – this is a non-native, invasive wetland plant known to thrive in areas that have experienced disturbance. The plant is prolific and is known to out complete native species. Various types of eradication methods have been used to stop the growth of this plant.

Residential - Residential zones include rural and suburban size plots, as well as multi-family dwellings.

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 that 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.

Riprap is mapped as a linear feature using kinematic GPS data collection techniques. The maps illustrate riprap as a linear feature along the shore.

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

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