Tufts UNIVERSITY
Natalie Perry
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Bank Susceptibility to Fastland and Nearshore Erosion in the Chesapeake Bay, Anne Arundel County, MD

Introduction

In the Chesapeake Bay, located in tidewater Maryland and Virginia, shoreline erosion is a growing concern for both private and public landowners. Throughout the Bay, erosion rates vary anywhere from less than two up to eight feet per year (Maryland Department of Natural Resources). Such drastic erosion is caused by many factors, the most important of which are sea level rise and wave action on the shore, as well as anthropogenic activities. Sea level has risen 1.3 feet in the last 100 years in the Chesapeake Bay, twice the rate of average global sea level rise (Langland and Cronin, 2003). This is due to a combination of eustatic sea level changes as well as subsidence in the Bay. As the water level rises, wave action gradually erodes the shoreline. The most drastic changes occur during storm events, when huge amounts of energy are incident on the shore.

This study looked at characteristics of the bank itself and evaluated which regions of the shore are most susceptible to erosion when subjected to sea level rise and wave processes. This study distinguished between **fastland erosion**, which is erosion of land that lies above the waterline, and **nearshore erosion**, which is erosion of sediments in the shallow region just below the waterline. Slightly different factors affect fastland and nearshore erosion. I focused on Anne Arundel County in Maryland (highlighted in Figure 1 above) because county data are detailed and Anne Arundel has one of the longest shorelines.

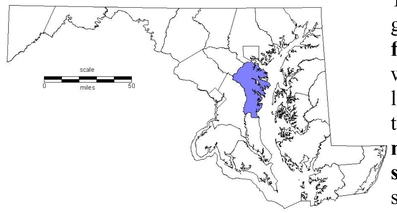


Figure 1. Area of study. State of Maryland depicted with Anne Arundel County shown in purple.

Methods

This study used detailed data from the Center for Coastal Resource Management to classify the shoreline according to many attributes, as well as a digital elevation model (DEM) from the US Geological Survey, with a resolution of about 3m.

All of the data were projected into NAD83 UTM, Zone 18N, with polyline data converted to rasters in order to perform map calculations. The result were rasters containing information on the existence of a frontal beach or marsh, percentage of vegetative cover, state of visible erosion, existence of structures, and land use. A slope raster from the DEM was also produced using Spatial Analyst (see Figure 2). These seven shoreline characteristics were combined to produce a map of susceptibility to erosion by reclassifying the rasters and ranking each characteristic with a number.

Nearshore Erosion

Table 1

Erosion	*High*	*Low*	*Undercut*
	+1	-1	+3
Beach/Marsh	*No*	*Yes(with erosion)*	*Yes (no erosion)*
	+1	+1	-1
Structure	*Bulkhead*	*Dilapidated Bulkhead*	*Breakwater*
	+2	+2	+1
Slope	*0-14.04°*	*14.04°-28.81°*	*> 28.81°*
	0	+1	+2

Erosion designated as "undercut" was the only factor to receive +3 because it is a sign that nearshore erosion has already begun. The presence of a beach or marsh is indicative of little nearshore erosion because wave activity has not removed these features, but if erosion is visible on the beach or marsh, nearshore erosion has most likely already begun. Breakwaters, but more importantly bulkheads are two structures known to have nearshore erosion at the toe of the structure. Finally, the slope of the bank is important because a very steep bank is more likely to have scouring at its toe than a shallow bank. Using the classification scheme of Palone (1998), banks were considered if designated as "steep", which are >14.04°, or designated as "extremely steep", which are >28.81°. Using Spatial Analyst and the Raster Calculator, a simple addition of the reclassified values resulted in the raster depicted in Figure 3.

Fastland Erosion

A similar analysis was performed for fastland erosion, using the values in Table 2. The presence of a beach or marsh provides protection against fastland erosion because wave energy acts on the beach or marsh and not the land immediately shoreward. However, if there is visible erosion, fastland erosion has already begun to occur. If the bank is undercut, fastland erosion may occur due to slumping, so the "slumping" reclassification of slope was multiplied by the "undercut" reclassification of erosion so as to only include this slope consideration when the bank is undercut. Runoff can also accelerate erosion. According to Palone (1998), there is a low potential for runoff to filter through sediment on slopes of >8.53°. Land with impervious surfaces also increases runoff rates. However, vegetative cover will slow runoff rates, as well as maintain consolidation of soils with roots. Structures such as bulkheads, riprap, breakwaters, groin fields, and jetties all provide some protection for the shoreline, while dilapidated bulkheads are broken structures with fastland erosion occurring behind them. All other structures are not clearly defined (such as miscellaneous) or their exact effect on erosion is unclear (such as debris). Again using Spatial Analyst and Map Algebra, a resulting map of fastland erosion susceptibility was produced (Figure 4).

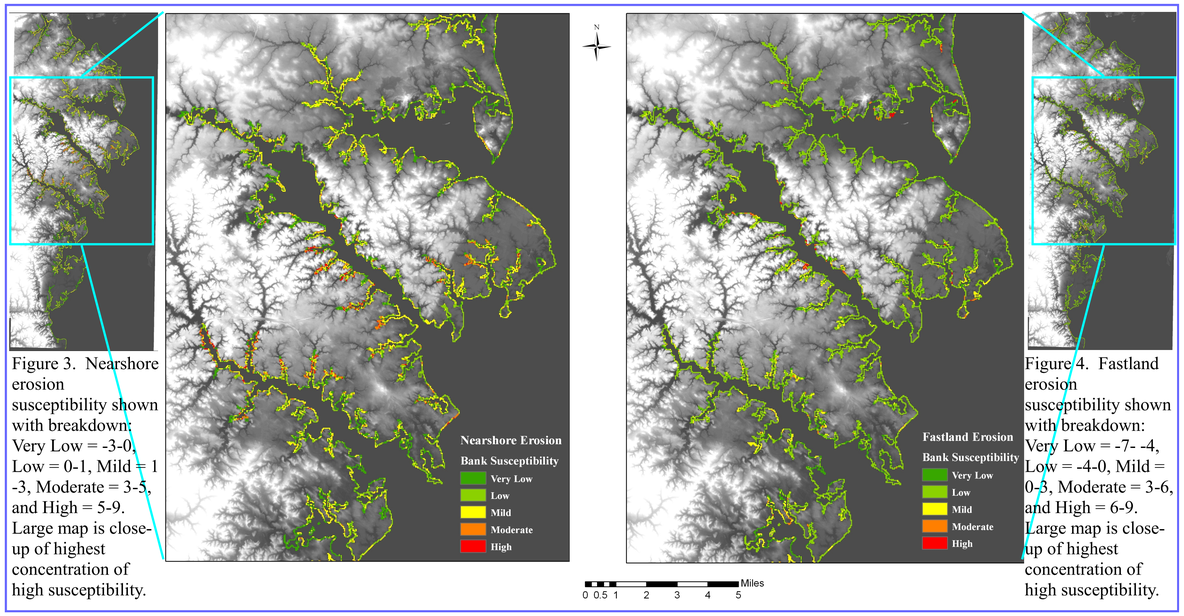


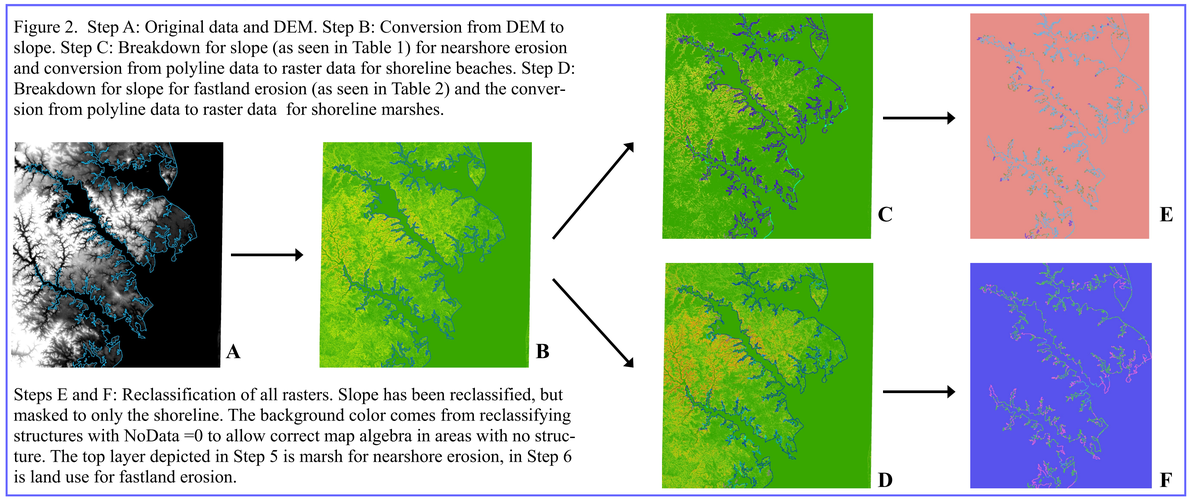
Figure 3. Nearshore erosion susceptibility shown with breakdown: Very Low = -3-0, Low = 0-1, Mild = 1 -3, Moderate = 3-5, and High = 5-9. Large map is close-up of highest concentration of high susceptibility.

Figure 4. Fastland erosion susceptibility shown with breakdown: Very Low = -7- -4, Low = -4-0, Mild = 0-3, Moderate = 3-6, and High = 6-9. Large map is close-up of highest concentration of high susceptibility.

Table 2

Erosion	*High*	*Low*	*Undercut*
	+3	-1	0
Beach/Marsh	*No*	*Yes(with erosion)*	*Yes (no erosion)*
	+1	1	-1
Structure	*Bulkhead, Riprap*	*Dilapidated Bulkhead*	*Breakwater, Groin Field, Jetty*
	-1	+1	-1
Slope (runoff)	*0-8.53°*	*> 8.53°*	
	0	+1	
Cover	*Bare(0-25%)*	*Partial(25-75%)*	*Total(>75%)*
	+2	-1	-2
Land Use	*Paved, Bare, Commercial, Industrial*	*Forest, Grass, Scrub-shrub*	*Residential, Agricultural*
	+1	-1	0
Erosion (undercut)	*Undercut*	*High, Low*	
	1	0	
Slope (slumping)	*0-14.04°*	*14.04°-28.81°*	*> 28.81°*
	0	+1	+2

Figure 2. Step A: Original data and DEM. Step B: Conversion from DEM to slope. Step C: Breakdown for slope (as seen in Table 1) for nearshore erosion and conversion from polyline data to raster data for shoreline beaches. Step D: Breakdown for slope for fastland erosion (as seen in Table 2) and the conversion from polyline data to raster data for shoreline marshes.



Steps E and F: Reclassification of all rasters. Slope has been reclassified, but masked to only the shoreline. The background color comes from reclassifying structures with NoData =0 to allow correct map algebra in areas with no structure. The top layer depicted in Step 5 is marsh for nearshore erosion, in Step 6 is land use for fastland erosion.

Results

The final maps show the shoreline of Anne Arundel County with bank susceptibility ratings from Very Low to High. Nearshore erosion appears to be a much larger concern than fastland erosion. This is in part due to the fact that many structures exist to protect fastland, but many of these same structures actually increase nearshore erosion. It is interesting to note that both nearshore and fastland erosion seem to be most imminent in the central region of our area of study, where we see the highest concentration of orange and red.

The results displayed here are precise enough to be used by individual property owners in assessing bank susceptibility. However, they should be taken in full knowledge of their limitations. There was not good data on sediment types of the fastland, which plays a major role in bank stability. Also, the fact that groins and jetties can cause erosion in neighboring properties, depending on wind and currents, was neglected. The scheme designed here for rating different susceptibility factors is based on general research of many sources; there is no authority on relative importance of bank characteristics.

References

Langland, Michael, and Thomas Cronin, eds. (2003). *A Summary Report of Sediment Processes In Chesapeake Bay and Watershed.* Water-Resources Investigations Report 03-4123.

Maryland Department of Natural Resources, Water Resources Administration. (2008). *Shore Erosion Control Guidelines for Waterfront Property Owners*, 2nd edition.

Palone, Roxane S. ed. (1998). *Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers.*

Data

Shoreline Inventories (Maryland), Anne Arundel County. Center for Coastal Resources Management, Virginia Institute of Marine Science. http://ccrm.vims.edu/gis_data_maps/data/index.html

National Elevation Dataset 1/9 Arc-Second. United States Geological Survey http://seamless.usgs.gov/data_availability.php?serviceid=Dataset_19

High-Resolution Shoreline Map Data for Tidewater Maryland- Shoreline Vector Maps, Anne Arundel County. Maryland Geological Survey Coastal and Estuarine Geology Program http://www.mgs.md.gov/coastal/maps/shorevect.html