Detailed Shore Change at Chesapeake Bay Dune Systems

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I. Introduction

A. Background

Assessing rates and patterns of long-term shoreline change is critical to understanding trends in environmental parameters such as habitat changes. As part of the original Chesapeake Bay Dune Systems: Evolution and Status project (FY 98, Task 15) (Hardaway *et al.*, 2001), procedures were developed to transpose one shoreline digitized from historical rectified aerial photos (dated 1937) onto a 1994 digital orthophoto quarter quadrangle (DOQQ) base. Several shore reaches around the Chesapeake Bay (*i.e.* Smith Point, Cherry Stone Inlet) were described through this procedure and provided a graphical representation of shoreline change. However, in order to analyze long-term shoreline change both spatially and temporally, a more comprehensive methodology is necessary.

The coastal geology and management literature is rife with studies describing the pros and cons of many methods of interpreting the temporal and spatial variations in shoreline change In general, calculation of long-term rates of shoreline change have relied on positioning a tidal datum, usually mean high water (MHW), on a map utilizing cartographic data or aerial photos (Everts *et al.* 1983). These methods embody error in the determination of the horizontal location of the "shoreline," the lateral position of mean high water on the date of the survey. Foster and Savage (1989) determined that the error associated with analysis of shoreline change is dependent upon the method of study. They calculated that the error can be $^{+}$/-30 feet for map data, $^{+}$/- 20 feet for aerial photographs, and $^{+}$/- 10 ft for surveyed points. In all cases, more closely spaced data points yielded tighter error limits.

Fenster *et al.* (1993) described a simple method to determine rates of shoreline change from profile data. The End Point Rate (EPR) method utilizes the distance from the baseline to the intersection with a feature or datum on the earliest and latest data; dividing this differential distance by the number of years gives a rate of shoreline change rate.

Increasing the number of shorelines provides a more detailed picture of shoreline change through time and of how adjacent shore types evolve in concert with the associated coastal landforms like spits, shoals, tidal creeks, and ebb and flood tidal deltas. The methods developed provide the foundation for quantifying shoreline change rates in the ongoing Virginia Bay-wide dune monitoring program.

B. Purpose and Scope

The purpose of this project is to develop procedures and methodology for performing detailed shoreline change analysis at dune sites in the Chesapeake Bay. The procedures created for this effort were tested along the Chesapeake Bay shorelines in Northampton County (Figure 1). The Chesapeake Bay shorelines along Northampton County were selected for the analysis since it has a significant linear shore footage of dunes. The shoreline change analysis encompasses intermittent non-dune sites as well. The analysis increases the number of rectified, digitized historical shorelines digitized onto the DOQQ base to four dates for all of Northampton County.

In addition, alongshore, landward baselines were created to quantify shoreline change. Shore positions for each date perpendicular to the baseline will be determined at 300 ft intervals alongshore. These data were used to determine the rate of shoreline change between dates as well as provided the basis for an evolutionary model of sections of shoreline.

This report details the procedures and methods on shoreline change analysis for dune sites in the Chesapeake Bay and includes the shoreline plot graphics and the data component on historical shoreline change rates along the Chesapeake Bay shorelines of Northampton County. However, to date, rigorous quality control has not been completed. Therefore, the shoreline rates are useful as trends but not as actual values.

II. Methods

A. Geo-Referencing and Photo Mosaics

In order to begin the shoreline change analysis, all the required aerial photos were acquired. High-level, black and white aerial photos taken along the Northampton County shoreline in 1937, 1989, 1992, and 2000 were retrieved from VIMS's Shoreline Studies Program and Submerged Aquatic Vegetation archives. These photos were scanned at 300 dpi, and the digital photos saved in TIFF format. All photos must be scanned at the same resolution in order to maintain scale.

The DOQQ photos were obtained for the study area. DOQQ photos are registered in UTM-1927, and that projection was maintained. The Chesapeake Bay is in UTM Zone-18. When using ArcView GIS 3.2a, the following extensions must be turned on: Image Analyst, IMAGINE Image Support, Legend Tool, MrSid Image support (for DOQQ), Spatial Analyst, TIFF 6.0 Image Support, and Projection.

Creating the master control point file

The control point file is used to register all the aerial photos to the DOQQ photos. Since the relative shoreline change from one photo set to another is the area of interest, all photos should be registered to the same set of control points. Control points must provide a wide coverage over the entire study area and are selected by examining the photos for each date and finding common points among them all. In order to accurately register the area of interest (*i.e.* the shoreline), control points may be concentrated near the coast. The selection of control points is challenging especially in areas where there has been a great deal of development. For Northampton County, old homes and road intersections are common control points. On newly acquired aerial photos, some GPS located targets may be used to aid rectification.

Registering aerial photos

Create a new view in ArcView and change the projection to UTM-1927, Zone 18. The Control Points shapefile is added to the new view. Scanned aerial photos are opened as "Image Analysis Data Source" so that they can be registered using ArcView's Image Analyst Extension. Photos are registered using the Align tool which connects points on aerial photo to the corresponding control point. Error is kept at a minimum, aided by the returned error values from ArcView Image Analyst. Photos are saved in IMAGINE image format once rectified.

Mosaic creation

Once all the photos for a particular year have been registered, the mosaic tool is used to create a photo mosaic image for the entire study area. This is a necessary step to ensure that the shoreline is consistent through the study area. The mosaic is saved in IMAGINE image format.

For Northampton County, approximately thirteen photos were scanned for each date.

Quality Control of Mosaic

Mosaic images are examined for any discrepancies at photo overlap. Then the mosaic is re-registered using the master control points shapefile to ensure maximum alignment with the mosaics from other years along the shoreline.

B. Shoreline Digitizing

Shorelines were digitized useing ESRI's ArcInfo GIS software and ERDAS's Imagine software. The defined dark/light shoreline perimeter of the coast was digitized on screen from the aerial photo mosaics. For VIMS SAV archives this is basically the "toe" of the beach face which normally resides at or a few feet bayward of MLW. For the 1994 imagery, the shoreline perimeter appears closer to MHW. In areas where shoreline perimeters was obscured or washed out, the shoreline was determined using the digitizer's best guess to estimate land-water interface.

C. Rates of Shoreline Change

An extension called "shoreline" was created by VHB (2000) for another coastal project. This extension must be loaded for the analysis. A new view with one shoreline shapefile that contains all digitized shorelines classified by year is created. A shore parallel landward baseline is drawn and saved in the shapefile. The extension is run to calculate distance. The output from the extension is a shapefile of perpendicular transects of a length and interval specified by the user. The transect shapefile provides the transect number, the distance from beginning baseline to each transect, and the distance from the baseline to each digitized shoreline.

Many areas of the Bay have unique shoreline morphology where the data created from this extension will not provide an accurate representation of shoreline change. A physical inspection of baselines in conjunction with the photo mosaics can provide the quality control to determine these areas. For example, the extension deals with the situation of a shoreline being encountered twice along a transect (*i.e.* a spit) by returning the longest distance from the baseline to the shoreline.

III. Results

A. Geo-Referencing and Photo Mosaics

While the methodology of scanning and rectifying individual photos then re-rectifying photo mosaics is time-consuming, it is a necessary step to ensure maximum alignment of the shoreline for comparison between dates. Five aerial mosaics and digitized shoreline files are included in Appendix A.

B. Shoreline Digitizing

The digitizing of the shoreline is the most difficult step in the entire shore change procedure. It requires the person at the computer to have a working knowledge of shore morphology and coastal processes. The same individual digitized the shorelines for all five dates for this project. In some areas of the photos, the exposed beaches created a white blur making it extremely difficult to determine the location of the wetted beach. On the photos from VIMS's archive, the actual shore position that was digitized was closer to the toe or base of the beach slope. This is approximately the position of MLW (+/- 5 feet). At this point in time, no rigorous quality control has been performed on the data.

In an effort to look at the shorelines for quality control, the five shorelines were plotted on the 1937 aerial photo. These plates are located in Appendix B. The plate index is shown first. Plates 11 and 12 are not shown. These plates generally show a 1937 shoreline separated in space and time from a more clustered group of recent shore positions. The extent of dune features in 1937 can be seen easily.

C. Rates of Shoreline Change

The distance from the baselines to the shoreline on all five dates were exported from ArcView. Eleven baselines were created along the entire Northampton shore. The baselines and the transect numbers are shown in Appendix C. The approximate locations of the baseline are also plotted on the 1937 photos in Appendix B.

The rates of shoreline change across the interfluve headlands along the Bay coast of Northampton County were determined only for 1937, 1992, and 2000 (Appendix D). The 1989 and 1994 shoreline were omitted for this analysis. Photo coverage was not always complete in 1989, and the 1994 shore position was felt to be more closely aligned with MHW and thus could be about 25 to 30 ft landward of the other dates. Rates of shoreline change are "normalized" to feet/year. At this point in the analysis, the trend of the change is more significant than the actual rate because the quality control has not been performed. However, most trends are probably valid.

Generally, the end-point comparisons of long-term dates tend to follow the same trend. That is the comparison of 1937 to 1992 and 1937 to 2000 show relatively similar trends along the shore. However, the short-term changes, 1992 to 2000, are quite variable and do not always follow the long-term trend. This could be the result of fluctuations in shore features and storm activity. For example, Baseline 4, has large variations in shoreline rates form 1992 to 2000. A spit has developed along the shoreline significantly affecting the rates. In areas where shore features, such as spits, shoals, creek mouths, have evolved, the patterns of shoreline change cannot be accurately assessed with this methodology. These sites must be looked at individually.

Once quality control measures have been performed on the digitized shorelines, the shoreline extension has produced distances to the shorelines, and the rates of change calculated, the photos, shorelines, baselines, and rates can be tied together to provide an accurate representation of the patterns and rates of shore change (Figure 2). Viewing all these data in concert allows us to determine the pressures placed on valuable resources by natural and anthropogenic development. At Pond Drain, a site owned by the Department of Conservation and Recreation, the shore was accreting at about 5 ft/yr over the long-term. However between 1992 and 2000, the shore eroded likely in response to storm activity, particularly the Twin Northeasters in early 1998 and Hurricane Floyd in September 1999.

IV. Discussion and Conclusions

The procedures performed for this study have shed light on the difficulty of accurately portraying shoreline change. The shoreline feature being digitized should be reviewed through each photo mosaic date for consistency. It is very difficult to see a last high tide or wetted perimeter in viewing and digitizing images on the computer screen. In the Bay, the toe of beach is a fairly consistent feature and within a few horizontal feet of MLW.

Except for the 1994 date, which came from the DOQQs, all the images were scanned at 300 dpi. While scanning at a higher dpi will not affect the view of the shoreline on the screen, the rectified mosaic will maintain a better viewing and printing quality throughout the entire analysis process.

Having the ability to view aerial imagery and coincident shoreline positions is a valuable tool in assessing the geomorphic evolution of estuarine shorelines. This is particularly true of beaches, dunes, and shoals. These features are in constant motion and the position of a tidal datum or beach feature can change from season to season and even faster during storms. . Therefore, the end-point method of analyzing long-term shoreline position has some validity in that the short term "noise" is filtered out. At the same time, it is instructive to see what that noise represents in order to fully assess shoreline evolution.

In conclusion, the methods performed in this study are a viable tool for shoreline assessment. It is important to understand how the data is acquired and processed so that after rigorous quality control, the results can be properly assessed. Northampton County has some of the highest shore change rates of all the Bay shorelines and was chosen as a challenging coast for this analysis.

V. References

Everts, C. H., J. P. Battley, Jr., and P. N. Gibson, 1983. Shoreline Movements: Report 1: Cape Henry, Virginia to Cape Hatteras, North Carolina, 1849-1989. Technical Report CERC-83-, Report 1. U. S. Army Corps of Engineers.

Fenster, M.S., Dolan, R., and Elder, J.F., 1993. A new method for predicting shoreline positions from historical data. *Journal of Coastal Research*, 9(1): 147-171.

Foster, E. R. and R. J. Savage, 1989. Methods of historical shoreline analysis, *In*: Magoon, O. T., H. Converse, D. Miner, L. T. Tobin, and D. Clark (*eds.*), *Coastal Zone '89*, American Society of Civil Engineers, 5: 4434-4448.

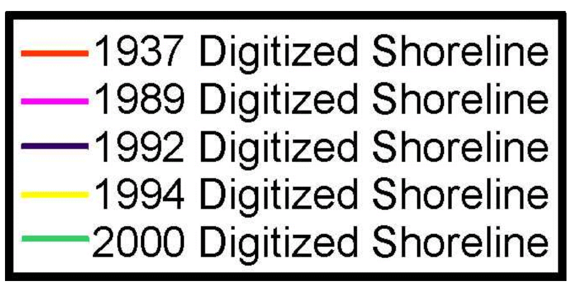
Hardaway, C.S., Jr., L.M. Varnell, D.A. Milligan, G. R. Thomas, and C.H. Hobbs, III, 2001. Chesapeake Bay Dune Systems: Evolution and Status. Contract report submitted to the Virginia Department of Environmental Quality. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA.

VHB, 2000. Vanasse Hangen Brustlin, Inc., 477 McLaws Circle; Suite 1, Williamsburg, Virginia 23185

Appendix A

Northampton County Photo Mosaics

Mosaic1937.pdf
Mosaic1989.pdf
Mosaic1992.pdf
Mosaic1994.pdf
Mosaic2000.pdf



Appendix B

Northampton County Shoreline Plates

Plates1&2.pdf
Plates3&4.pdf
Plates5&6.pdf
Plates7&8.pdf
Plates9&10.pdf
Plates13&14.pdf
Plates15&1a.pdf

Appendix C

Location of Baselines for Rate of Change Analysis

Baseline1.pdf
Baseline2.pdf
Baseline3.pdf
Baseline4.pdf
Baseline5.pdf
Baseline6.pdf
Baseline7.pdf
Baseline8.pdf
Baseline9.pdf
Baseline10.pdf
Baseline11.pdf

Appendix D

Rates of Change along the Northampton Shoreline

Rate1.pdf
Rate2.pdf
Rate3.pdf
Rate4.pdf
Rate5.pdf
Rate6.pdf
Rate7.pdf
Rate8.pdf
Rate9.pdf
Rate10.pdf
Rate11.pdf