ASSESSMENT OF THE NORTH CAROLINA SHORELINE DATUM

Implications of Evolving Methodologies and Technologies

Coastal Management Fellowship Project Proposal submitted to the National Oceanic and Atmospheric Administration Coastal Services Center

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ABSTRACT

The North Carolina Division of Coastal Management has begun a shoreline project to evaluate shoreline identification techniques used for coastal management. The NOAA CSC Fellow matched with this project has an opportunity to be involved in a project at the crossroads of science, technology and public policy. A dataset acquired in August 2004 of airborne laser and digital photographic techniques will be used to compare the two most common shoreline datums for the entire oceanfront shoreline (i.e., the wet/dry line and the mean high water line). Results of this comparison have the potential to allow the design and implementation of more rigorous shoreline survey methodology that is a more time- and cost-efficient method of shoreline survey. Because the shoreline is also used in the state's erosion rate calculations, a review of which is also within the scope of this project, that directly effect building setbacks and development within the ocean hazard zone that includes tidal inlets, the social and economic impacts must also be reviewed.

1. INTRODUCTION

An objective analysis of both short- and long-term trends of shoreline movement is an integral factor in coastal management. In 2004 the North Carolina Division of Coastal Management (DCM) launched a collaborative initiative to review and assess the adequacy of its current methodology for identifying and analyzing the oceanfront shoreline. Building setbacks are determined by using the 50-year erosion rate as a multiplier. The state currently is using rates calculated from 1998 data and acquired data in 2004 for an update. On average, this rate has been recalculated every five years.

Since the inception of the North Carolina Coastal Area Management Act (CAMA) in 1974, the state has relied upon the visually interpreted wet/dry line, a horizontal datum, interpreted from aerial photography to define the shoreline. This technique, though widespread, can be highly subjective and often irreproducible. Further, the acquisition, digitization and geo-referencing of aerial photographs into a GIS-based spatial framework is both time- and cost-intensive. Recent advances in surveying technology, in particular the advent of airborne LIDAR (Light Distance and Ranging) surveys and ground-based GPS surveys to accurately represent true three-dimensional beach topography, are able to provide a three-dimensional elevation grid from which the position of mean high water (MHW), a vertical datum, can be identified.

The present-day MHW represents a vertical tidal datum based on a 19-year period of tidal observations. This sampling window encompasses the significant variations in the moon and sun during an 18-year astronomical that cause slowly varying changes in the range of tide. The current MHW is based on measurements taken during the 1983-2001 national tidal datum epoch (NTDE). The shorelines represented on National Ocean Service topographic maps (NOS T-sheets) are considered to represent an interpreted MWH line (Graham et al., 2003; Parker, 2003), and these maps can be utilized for historic shoreline delineation requiring data that pre-date reliable, orthorectified aerial photography along the North Carolina coast (circa 1960).

Excluding gentle beach slopes and large tidal ranges, the position of the wet/dry line is considered to closely approximate the high water line that also approximates the MHW line (Anders and Byrnes, 1991; Moore, 2000). Unpublished data from Assateague Island in southern Virginia (List, pers. comm.) support this hypothesis (i.e., the two shoreline datums are on average <5 feet apart). However, the similarities and differences between the wet/dry line and the MHW line have never been studied along the entire North Carolina oceanfront shoreline. A drastic difference between the positions of these two datums will suggest that the current method of long-term trend analysis (historic MHW minus modern wet/dry) of the shoreline in North Carolina is inaccurate. On the other hand, little to no difference in the position of these two datums will suggest that they can be used interchangeably.

If this proxy hypothesis is correct for the North Carolina coast, changing the shoreline datum used in coastal management can potentially save time and money by utilizing the more easily acquired MHW line. Coastal managers in North Carolina will then be able to incorporate many more shoreline datasets into the DCM database with confidence that they are proxies of one another. As this database increases in size, it will be advantageous to use linear regressions of a large time series of all available data to determine rates of shoreline change, rather than simply two dates in an end-point rate. This end-point methodology (see Dolan et al., 1991) has been used to calculate coastal erosion rates since the inception of the CAMA. By comparing end-point and time series methodologies, DCM can assess the similarities and differences of both methods, possibly assess the accuracy of each, and gain a more thorough understanding of both short- and long-term shoreline dynamics.

1.1 Problem Statements

1. There is a poor understanding of the similarities and differences of the two most commonly used shoreline datums (i.e., wet/dry line and MHW line) along the North Carolina oceanfront shoreline. A comparison study has never been done on a statewide scale.
2. Current wet/dry line identification is a time- and cost-intensive process requiring aerial overflights and digital, rectified product prior to shoreline identification. Technological advances now allow faster and cheaper data acquisition from which a vertical datum (i.e., MHW line) can be extracted.
3. Current wet/dry line identification is a subjective process than can be interpreter-dependent and, therefore, possibly irreproducible. Technological advances now allow an objective and reproducible shoreline delineation using the MHW line.
4. Long-term shoreline analysis currently relies on the comparison of only two shorelines known as the end-point method – the modern wet/dry from aerial photos and the historic MHW from NOS T-sheets. A drastic difference in datum location (with respect to each other) will suggest that the current method of long-term trend analysis of the shoreline in North Carolina is inaccurate. On the other hand, little to no difference in the position of these two datums will suggest that they can be used interchangeably.

5. An erosion rate calculation based on a linear regression of multiple shorelines might prove to be far superior and more accurate than the current end-point methodology used to assess shoreline change along the North Carolina coast.
6. There is no central database of historic and modern shoreline data (or data from which a shoreline can be interpreted) for the North Carolina coast. Many datasets utilized by other governmental agencies and academic researchers are not at present in the DCM shoreline database. Further, many shoreline datasets are known but unavailable in the digital format needed for GIS-based analysis.

1.2 Ongoing State Efforts

The last shoreline mapping project occurred in 1998 based on the wet/dry line identified from aerial orthophotography acquired by the North Carolina Department of Transportation (DOT). In a joint effort with the US Army Corps of Engineers (USACE), the Division of Coastal Management (DCM) recently acquired a set of digital orthophotos in August 2004 from a LIDAR (Light Distance and Ranging) and digital imagery aerial survey of the entire North Carolina oceanfront shoreline. The 2004 erosion rate update will be based on these data. DCM is in the process of having the 2004 digital photos rectified and mosaiced and will generate a shoreline based on the wet/dry line. An erosion rate update will then be calculated using the end-point method that has been utilized for all preceding erosion rate calculations. These tasks will be completed prior to the arrival of the NOAA CSC Fellow.

In preparation for a more rigorous approach to shoreline delineation and erosion-rate analysis, DCM recently submitted a joint proposal with the North Carolina Center for Geographical Infromation and Analaysis (CGIA) to NOAA. The 18-month investigation is projected to commence during May of FY 2005. This effort will create a graphical, interactive, online inventory of historic shoreline data in addition to related data from which historic shorelines can be identified (e.g., aerial photos, maps such as NOS T-sheets, LIDAR, GPS surveys, etc.). The ability to locate, catalog, and streamline access to these data through technological innovation provides the ability for DCM to expand its current shoreline database and further populate its digital shoreline database as part of its CZMA section 309 program enhancement strategy currently funded by NOAA.

The joint DCM and USACE LIDAR and digital imagery project dataset is a unique opportunity to identify and compare two distinct shoreline datums collected simultaneously during a spring low tide (i.e., wet/dry line from aerial imagery and MHW from the three-dimensional LIDAR elevation grid). These data cover the entire North Carolina oceanfront shoreline from VA to SC.

During the same time period (late August 2004), a GPS-derived shoreline survey from which the MHW line vertical datum can also be extracted for comparison was obtained by Dr. Jeffrey List from the US Geological Survey. This continuous survey extends for about 100 miles along the Outer Banks from Corolla (just south of VA) to Cape Hatteras. Dr. List's SWASH (Surveying Wide Are Shorelines) project is important not only for a shoreline datum comparison with the USACE-DCM LIDAR and aerial photo survey, but

also represents the latest of a time series of more than thirty shorelines that began more than five years ago along the North Carolina Outer Banks. The SWASH project is federally funded into the foreseeable future.

2. GOALS AND OBJECTIVES

Compare the shoreline datums along the entire North Carolina coast to assess whether or not the wet/dry line is similar to the MHW line.
HYPOTHESIS: *These datums are proxies of each otherin North Carolina (within 5 feet).*

Continue to identify, acquire, and digitize shoreline datasets to create a robust time series of historic positions, use this time series to calculate a long-term rate of shoreline change, and compare the results to a the shoreline change rate determined by traditional end-point methods (2004 minus 1954).
HYPOTHESIS*: While rates may be similar, the time series will allow calculation of standard deviations and foster a better understanding of short-term shoreline fluctuations occurring in concert with long-term trends.*

Allow North Carolina DCM to assess the effectiveness and accuracy of current shoreline dentification and trend analysis. Upon project completion, provide DCM with confidence it is applying the best methodology and technology to manage coastal hazards.

Provide the NOAA CSC Fellow an exceptional professional and personal development opportunity by gaining practical experience on a rigorous and intense shoreline study requiring collaboration with multiple federal and state agencies. The Fellow will have opportunities to present results to the North Carolina Coastal Resources Commission and their Science Panel on Coastal Hazards, professional meetings including Coast GeoTools '07 and Coastal Zone '07 and co-author a final paper for publication in a peer-reviewed, scholarly journal.

3. MILESTONES AND OUTCOMES

In addition to specific duties outlined below, Fellow will have the opportunity for field visits, ongoing involvement in public hearings and educational outreach, and participation (e.g., oral presentations and white paper authorship) in meetings of the North Carolina Coastal Resources Commission (6 times per year) and their Science Panel on Coastal Hazards (8-10 times per year). This experience provides additional professional and personal development via exposure to specific coastal issues affecting North Carolina as well as the policy process in general.

The timeline summarized below is presented graphically in Figure 1.

August-September 2005
Fellow begins. Orientation includes overview of DCM staff and hierarchy, DCM's position within state government, overview of DCM responsibilities including the

CAMA and Dredge and Fill legislation, field trips to coast and DCM satellite offices (Wilmington, Morehead City, Washington, and Elizabeth City), site visits with agencies involved in coastal policy and management (e.g., USACE, NC Sea Grant, NC Geological Survey). In addition, Fellow will have the opportunity for ongoing attendance throughout duration of appointment at pertinent public hearings and meetings of both the Coastal Resources Commission (CRC) and the CRC Science Panel to obtain a more thorough understanding of the science policy process with respect to coastal management in North Carolina.

Fellow and mentor discuss goals and justification for shoreline datum assessment project, identify progress to date as well as short- and long-term goals (timeline) of overall investigation. Mentor works with Fellow to develop an individual work plan including responsibilities and expectations from both DCM and Fellow to include deliverable products (e.g., presentations, white papers, etc.).

October-December 2005
Fellow begins familiarizing themselves with the shoreline datum assessment project based on literature review by utilizing libraries at local universities (Duke, UNC Chapel Hill, and North Carolina State). Fellow establishes relationship with partner agencies conducting shoreline research along North Carolina coast (e.g., US Geological Survey, Duke University, UNC Chapel Hill Institute of Marine Science, NC State, East Carolina University, UNC Wilmington, NC Geological Survey) and may participate in site visits and fieldwork.

November 2005 – July 2006
PHASE I of shoreline datum assessment – shoreline datum comparison
Fellow will work with Dr. Jeffrey List from the USGS to assist in the QA/QC of processed LIDAR data and assist DCM GIS staff in uploading data to mainframe. Use GIS software to statistically compare the MHW LIDAR shoreline and the wet/dry shoreline acquired concurrently during the same survey flight. Analyze trends and standard deviations to assess the differences and similarities between the two proxies.

May-December 2006
Fellow will have the opportunity to participate in the final third of the proposed Carolina CoastalMap project that is a joint endeavor between DCM and the North Carolina Center for Geographical Information and Analysis. Assist DCM and CGIA by including the 2004 both shorelines (MHW and wet/dry line) into database. Additional participation may include assisting CGIA with shoreline data location, acquisition and/or digitization as well as development and field testing of the graphical, interactive shoreline inventory user interface.

July 2006 – January 2007
Phase II of shoreline datum assessment – erosion rate methodology comparison
Fellow will continue to work with CGIA and identify an appropriate time series of historic shoreline data with which to run statistical calculations including rates of change, average rates of change, minimum and maximum rates of change, and standard

deviations. These results will then be compared to the end-point derived erosion rates calculated by DCM prior to arrival of Fellow (spring-summer 2005). Fellow will help analyze the similarities and differences in trends in both datasets and help determine which methodology is more accurate.

March – August 2007
Fellow will wrap up both phases of project and make final presentations of methods and results in addition to identifying further research that should be addressed in future (or continuing) investigations. Likely presentations will be given to DCM management, partner agencies in the shoreline datum assessment project, the Coastal Resources Commission and their Science Panel on Coastal Hazards. The Fellow will be expected to attend Coastal GeoTools '07 and Coastal Zone '07 to network and present project highlights in addition to working with mentor to co-author a manuscript outlining the project and results for publication in a peer-reviewed, scholarly journal. It is also expected during that during these last six months, the Fellow will be allowed time to work on transitioning out of the Fellowship at DCM into future career goals such as searching and interviewing for jobs and/or educational opportunities.

4. PROJECT DESCRIPTION

The North Carolina shoreline datum assessment project will utilize a recently acquired dataset of LIDAR and digital imagery to compare the two most common shoreline datums used in coastal management – the wet/dry and MHW line (Phase I). This will be the first study of its kind in NC. Based on these results, a time series of all available shoreline data (possibly datum-dependent) will be compiled for statistical calculation of shoreline change to include standard deviations in order to understand short-term fluctuations superimposed on long-term trends. The results of this time series analysis will be compared to those derived from the current end-point methodology used to analyze long-term coastal change and calculate erosion rates in North Carolina (Phase II). The lessons learned from both phases of this intensive project will be used to evaluate current methodology and possibly implement technology to boost the efficiency and accuracy of coastal analysis and management tools within North Carolina.

5. FELLOW MENTORING

The primary investigator for the North Carolina shoreline datum assessment project is DCM's coastal hazards analyst Jeffrey Warren. It is therefore appropriate that he also mentor the NOAA CSC Fellow during the course of the project. Jeff has an extensive academic background in marine geology and will defend his PhD (UNC Chapel Hill) during the current academic year. In addition to North Carolina, his field experience includes coastal and marine studies in Antarctica, eastern Asia, northern Mexico, and the Bahamas. Jeff has won numerous awards for his research, teaching, scientific presentations, and technical writing. Additional science policy experience includes projects with organizations such as Sigma Xi, the Scientific Research Society and the Southern Technology Council that have led to multiple policy publications (Jeff's complete curriculum vitae is included as Appendix A). After working together with the

Fellow to develop a work plan (to include outlining expectations, identifying milestones and deliverables, and creating a clear pathway for professional and personal development), Jeff and the Fellow will work side-by-side to review, assess, research, interpret, disseminate, and potentially modify shoreline methodologies used in North Carolina.

The Fellow will also be establishing working relationships with coastal professionals outside of DCM. Flexibility of mentorship is fundamental to allow the Fellow the opportunity to take the initiative and identify additional mentoring possibilities of their choosing as they arise. For example, the Fellow will be working directly with the Coastal Resources Commission Science Panel on Coastal Hazards. These 11 members (five geologists, five coastal engineers, and one marine biologist) are acknowledged experts in their field and represent a wealth of knowledge and experience. One member, Spencer Rogers of North Carolina Sea Grant, has already expressed an interest to provide mentorship during the Fellow's tenure with DCM (refer to North Carolina Sea Grant letter of support in Appendix B).

6. PROJECT PARTNERS

During the course of this project, DCM will continue to collaborate with agencies that include the US Geological Survey (USGS), the US Army Corps of Engineers (USACE), NC Sea Grant, the NC Center for Geographic Information and Analysis (CGIA), the North Carolina Department of Transportation (DOT) and the North Carolina Geological Survey (NCGS). The specific contributions of these agencies relative to this proposal are outlined below. Letters of support from each of these agencies are included in Appendix B.

USGS: Dr. Jeffrey List, an oceanographic researcher from the USGS Coastal and Marine Geology Program in Woods Hole, MA has been actively researching shoreline dynamics along the complete northern third of the North Carolina coast between Corolla and Cape Hatteras. The SWASH (Surveying Wide Area Shorelines) project continues to be funded at the federal level. Dr. List's database of GPS-derived shoreline positions continues to grow and represents an objective and valuable time series of more than thirty shorelines spanning more than five years. Driving aboard the mechanized SWASH research platform, DCM has assisted and will continue to assist Dr. List and his staff in these shoreline surveys. Dr. List has expressed his desire to collaborate with DCM by sharing his complete time series of GPS data. Further, he will continue to allow DCM staff to be active field participants during future SWASH shoreline surveys. Active involvement in acquiring data that will be shared with DCM is an invaluable experience and allows DCM staff a better understanding of methodologies employed as well as shoreline morphology in general. Dr. List is also developing a timeline and budget for processing the LIDAR data acquired during the August 2004 joint DCM-USACE airborne survey of the entire oceanfront coastline. A shoreline based on the MHW datum will be generated from these raw data. Please see letter of support in Appendix B.

USACE: As part of their CHARTS (Compact Hydrographic Airborne Rapid Total Survey) system, the USACE acquired bathymetric and topographic LIDAR coverage of the North Carolina oceanfront coastline in July and August 2004. A partnership with DCM contributed funding to allow the simultaneous collection of aerial digital imagery. This dataset offers an unparalleled opportunity to compare and contrast the two most common shoreline datums (wet/dry versus MHW). In addition, the Wilmington District oversees an extensive collection of aerial photography of the coast and estuaries as well as the permit files for beach nourishment and dredge disposal activities within the state. The chief of the coastal hydrology and hydraulics division, Dr. Greg Williams, PE (who is also an active member of the CRC Science Panel on Coastal Hazards), has offered human resources and possible financial support for this project in order to convert these data into a digital format to better understand natural- and human-induced shoreline dynamics. Please see letter of support in Appendix B.

NC Sea Grant: Sea Grant provides research, education, and outreach programs that target individuals, groups, government agencies and businesses to develop an understanding of the coastal environment and promote the sustainable use of marine resources. North Carolina's Sea Grant program has emphasized solid, peer-reviewed scientific research and coupled it with outreach. This agency is a reliable source of timely information and valid solutions for complex coastal issues. Building on their long history of collaboration with DCM, Spencer Rogers, a coastal engineer with North Carolina Sea Grant at UNC Wilmington Center for Marine Science and an active member of the CRC Science Panel on Coastal Hazards, has agreed to participate in the North Carolina shoreline datum assessment project. Rogers will act in an advisory capacity to offer general oversight and advisement during the course of the investigation. He is also willing to provide ad-hoc mentorship in the spirit of fostering the Fellow's personal and professional development. Please see letter of support in Appendix B.

NC CGIA: CGIA is working directly with DCM on Carolina CoastalMap, a proposed online, graphical interactive database of historic shorelines and related data. A NOAA Fellow likely will be directly involved in testing and evaluating the new database and mapping tools in conjunction with work involving beach nourishment data. In terms of professional development for the NOAA Fellow, North Carolina has an active coordination structure anchored by the North Carolina Geographic Information Coordinating Council that promotes opportunities to meet GIS professionals and gain hands-on experience with geospatial data. Please see letter of support in Appendix B.

NC DOT: The North Carolina DOT Photogrammetry Unit has worked closely with DCM for decades including the acquisition of aerial photography along the North Carolina shoreline (oceanfront and estuarine). DOT continues to supply expertise and facilitate the generation of orthophotography, Digital Elevation Models, and LIDAR analysis. The latest collaborative effort is currently being planned for winter 2004 as an overflight and aerial photography mission with coverage of the state's entire 3,600-plus miles of shoreline (oceanfront and estuarine). Please see letter of support in Appendix B.

NCGS: The North Carolina Geological Survey is a major contributor of shoreline data for North Carolina. The NCGS currently participates in a consortium of agencies and investigators performing coastal research along the North Carolina coast. Referred to as the North Carolina Coastal Co-op, the NCGS is able to bridge efforts, share data, and collaborate with agencies such as the USGS Coastal and Marine Geology Program, the National Park Service, the US Fish and Wildlife Service, and several universities (East Carolina University, University of Delaware, and the Virginia Institute of Marine Sciences). The products of this consortium include maps of historic shorelines and coastal landforms from LIDAR data, surveys and aerial photography. The NCGS has expressed its willingness to provide access to these shoreline data and has invited DCM to become an active participant and supporter of the North Carolina Coastal Co-op agenda. Please see letter of support in Appendix B.

7. COST SHARE DESCRIPTION

The Fellow will be assigned to the DCM headquarters office at the Parker Lincoln Building, 2728 Capital Boulevard, in Raleigh, North Carolina.

Years 1 and 2: DCM will provide office space, new personal computing equipment equipped with state-of-the-art versions of the ArcView suite and other pertinent GIS and database software, a four-wheel-drive field vehicle for approved site visits and related official travel, administrative support, mailing and telephone costs, and other overhead for direct and indirect support of NOAA CSC Fellow. The $15,000 will be provided out of the annual DCM budget from sate-appropriated funds ($7,500 for Year 1 and $7,500 for Year 2).

8. SUMMARY

The North Carolina shoreline assessment project provides a challenging opportunity for a NOAA CSC Fellow who wants to be involved with the integration of science and technology and its potential economic and social implications on coastal management. Technically advanced shoreline measurement and analysis techniques offer an opportunity to create more accurate and efficient coastal management tools. Specific to North Carolina, the comparison of how the shoreline is defined has far-reaching implications. Using technology has the potential to provide a higher degree of accuracy and increase both time and cost efficiency, but certainly has the potential to influence coastal development by its direct affect on erosion rate calculations and related building setbacks. The Fellow matched with this project will be involved in the full spectrum of coastal management and policy implementation, including field observations, scientific review, technical analysis, attendance at public forums and hearings, collaboration with other state and federal agencies, and presentations at national research conferences and in front of the North Carolina Coastal Resources Commission. The Fellow will be expected to have strong analytical skills and be interested in the implementation of science and technology within the realm of public policy and coastal management.

9. REFERENCES

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