Abstract

Heritage at Risk?
An Assessment of Environmental Factors in
Archaeological Site Damage in
Albemarle Sound, North Carolina

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This thesis is a multi-disciplinary geological and maritime archaeological study. This study's purpose is to create exploratory models that utilize analyses of geophysical factors within and around northeastern North Carolina's Albemarle Estuarine System in relation to archaeological sites there. These models should help determine what sites are being threatened within the Albemarle Estuarine System's shore zone. Four geological aspects will be analyzed: waves derived from wind, shoreline erosion, sediment accumulation, and inundation from sea-level rise. By analyzing these four properties, change over time and possible patterns of potential site damage within Albemarle Sound can be monitored. In addition to studying those four principles, the recent maritime archaeological research of Franklin Price (2006), Adam Friedman (2008), and Amy Leuchtmann (2011) regarding intertidal terrestrial site dispersal in Albemarle Sound will be compared with geologic data. Combined, the two datasets endeavor to model environmental phenomena of significance in predicting damage to archaeological sites in and around the shore zone.

Heritage at Risk?
An Assessment of Environmental Factors in Archaeological Site Damage in Albemarle Sound, North Carolina

A Thesis

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Master of Arts in Maritime Studies

By

Jeanette A. Hayman

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DEDICATION

For my committee. For my colleagues. Thank you.

For my family. Thank you and I love you.

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CHAPTER ONE: INTRODUCTION

Introduction

The modern landscape within and around Albemarle Sound evolved as a result of natural environmental processes and human occupation. The major tributaries feeding into Albemarle Sound, the rich fertile soils in the intertidal and coastal zones, and the estuarine waters provided several environments conducive to the steady growth of multiple industries, like fishing and farming. As a result, the economy and maritime landscape surrounding Albemarle Sound has both affected and been changed by human behavior and activity (Ready 2005:50).

The human occupation in the Albemarle Sound region of North Carolina has left behind a substantial archaeological record. The intertidal zone in particular has seen many phases of occupation and use. The Office of State Archaeology (OSA) in Raleigh, NC conducted numerous archaeological surveys within this zone yielding results from prehistoric occupation (Paleo-indian to ceramic) to historic occupation (colonial to 20th century). Site function ranges from short-term limited activity to long-term habitation. These archaeological surveys have been conducted over the past few decades, all showing a wide range of site types from hundreds of years of activity and behavior.

This thesis proposes to study the potential effects of environmental phenomena on approximately 300 archaeological sites within the Albemarle Sound. Developing exploratory and predictive models could show the level of risk to any given site, submerged, intertidal, or terrestrial, based on the geophysical forces acting on them. To create these models, data from East Carolina University's Departments of History (Program in Maritime Studies) and Geological Sciences will be analyzed and projected in an *ArcGIS* Coverage program. This includes data derived from master's theses in the Program in Maritime Studies by Franklin Price

(2006), Adam Friedman (2008), Amy Leuchtmann (2011), and Lindsay Smith (2010), culminating in the present Albemarle Sound Cultural Landscape Database (ASCLD).

In addition to the cultural landscape database, a second component of this thesis includes a study of geophysical processes occurring within the Sound. Four geophysical properties are analyzed based on previous studies from ECU's Department of Geological Sciences and other publically available databases and resources. More specifically, a study of wave energy, sediment accumulation, shoreline erosion, and inundation from sea-level rise are analyzed. The shorezone surrounding Albemarle Sound is the study area, chosen for its large archaeological record, previous historical and maritime research, and quantity of available geologic information. The geologic information includes areas from the upper Roanoke to Elizabeth City, therefore overlapping the maritime data.

Research Questions

Norman A. Easton states that "archaeology is embedded within and affected by local, regional, and world geological processes" (Easton 1997:324). It is the challenge of this thesis to assess whether comprehension of geophysical properties is essential to the study of cultural heritage within the shorezone. The following questions will be asked:

Primary-

- How does a detailed knowledge of geophysical site formation processes assist in assessing regional threats to shorezone cultural heritage?
- What is the effect of environmental forces on the maritime cultural remains in the Albemarle Sound?
- How will understanding these environmental forces alter our opinion of site impacts and management?

Secondary-

- Which processes are potentially the most damaging around and within Albemarle Sound?
- Where are the areas where erosion and accumulation impact sites the most?
- Can exploratory models based on geological and archaeological data determine the extent of threats to a site?

Research Design

This study combines historical, archaeological and geological datasets. Through analysis of the coastal characteristics, several exploratory models, indicating areas of potential shoreline erosion and environmental risk, will assess what archaeological sites are within the most sensitive areas. The data for the archaeological and geological aspects of this thesis have already been collected from numerous other projects. The combination of these datasets shows potential environmental impacts on cultural remains in the Albemarle Sound region.

Chapter Two will provide the geographical and historical past of the Albemarle Estuarine System, from its geologic formation to post-Civil War economy. This chapter will outline the formation of Albemarle Sound, detailing water quality, river systems, sediment types, and topography. It will then chronicle the cultural history and settlement patterns from the habitation of the Tuscarora, Algonquian, and Yeopim Indians through European colonization to the 20^{th} century. The aim is to show how the region's history is important and significant by communicating the potential existence of archaeological sites and site types.

Chapter Three will introduce theoretical concepts that inform the research for this thesis. The concept of environmental mitigation within the greater framework of policy and management has been studied by scientists in the Netherlands in relation to reducing negative impacts on their cultural heritage. Thijs J. Maarleveld (2003a; 2003b) has researched factors contributing to the maritime archaeological record's formation processes. Maarleveld (2003a:121-122) admits that predictive assessment of uncontrolled agents is one aspect that needs to be further understood by archaeologists who hope to reduce the negative impacts of environmental agents on cultural resources. He writes that "geological survey is…instrumental. Its evaluation should aim both at formation sequences and at successive palaeo-geographic and palaeo-environmental conditions" (Maarleveld 2003b:136).

Keith Muckelroy (1978) and Michael Schiffer (1987) are well-known for independently researching site formation processes. Muckelroy (1978) discussed environmental attributes acting on archaeological remains in relation to a specific site. Some of these attributes are: perpendicular offshore fetch, wind, tidal streams, coarse/fine material, minimum/maximum depth of site, principle deposit and slope of seabed at site (Muckelroy 1978:160-162). Muckelroy (1978:160, 163) argued that "the number of forces acting on a site is more significant than their individual forces."

Michael Schiffer (1987) introduces specific environmental agents of deterioration: chemical, physical, and biological (Schiffer 1987:147). Schiffer discusses individual deterioration of objects in the archaeological record, including but not limited to stone, ceramics, glass, organics, grains and plant products, textiles, bone, and metals. Additionally, and applicable to this thesis, Schiffer discusses regional formation processes. Schiffer believes that regional formation processes are "affected principally by physical and biological agents stemming from climatic and geological factors" (Schiffer 1987:235). Climatic features include temperature, precipitation, and wind patterns, and geologic features include minerals, rocks, land forms, and the processes shaping them (Schiffer 1987:236).

David Stewart, a professor in East Carolina University's Program in Maritime Studies, has reviewed Muckelroy and Schiffer's theoretical concepts relating to the effect of formation processes on submerged archaeological sites. Referencing such well known sites as the *Yassiada* 7th-century vessel, Cape Gelidonya shipyard, and the *Uluburun* wreck, Stewart discusses these sites and suggests ways to identify and account for processes acting on each site (Stewart 1999:568). Like Maarleveld, Stewart mentions the importance of paleo-study, in this instance, paleoecology. Of further interest is Stewart's research on waves, tides, and currents, in shallow surf sites. Continuing with the idea that knowledge of current processes is not sufficient, Stewart reiterates the importance of historical study. Just as an archaeologist would study the history of the archaeological remains, so should s/he study the history of the geophysical processes that are currently acting on and have acted on the sites. Stewart (1999:585) concludes that "it is necessary for nautical archaeologists to attempt to understand the factors that have combined to form the sites they excavate."

In 1999, Ingrid Ward followed Muckelroy and Schiffer's work, conducting research about geophysical processes acting on the *Pandora* wreck in Australia. Ward set out to define the link between "the physical attributes of the wreck site with the processes controlling wreck formation" (Ward 1999: 562). Ward developed a model measuring the rate of wreck disintegration, wherein the rate is equal to the sum of the rates of the physical, biological and chemical processes acting on the wreck. Within her model, the physical processes measured are waves, currents and the movement of sediment. Ward (1999:566) states that there are five stages of physical deterioration acting on remains making up the site formation process: these are detailed in Chapter Three. This project was one of the first of its kind, showing an initial approach to the multidisciplinary study of geology and maritime archaeology.

Between 1998 and 2000, Rory Quinn of the University of Ulster in Northern Ireland, conducted a series of geophysical surveys over *La Surveillante*, a French frigate that sank in Bantry Bay, County Cork, Ireland in 1797. Quinn conducted historical, archaeological, and geological research on the site, resulting in a flow diagram of *La Surveillante* wrecking. The flow diagram was modeled after Ward et al.'s (1999) illustration and included bathymetric, sub-bottom profiling, and sediment analysis data. Conclusions illuminated slow sedimentation rates and a low-energy hydrodynamic environment preserved the wood. The anaerobic environment preserved what was buried while copper sheathing protected exposed remains. It was finally concluded that *La Surveillante's* site formation was dominated not by physical, but by biological and chemical processes (Quinn et al. 2002: 413, 420-421).

Furthermore, environmental determinism, possibilism and probabilism will show that it is important to identify relationships between humans and their environment. This section aims to illuminate potential symbiotic relationships between culture and environment. Determinism is explained and a brief history of the geographical theory shows that it has undergone much scrutiny in the academic world. In time, this concept was altered slightly to account for human agency, and became known as possibilism and later, probabilism. This chapter ends with an example of how one studies geological and archaeological histories together through the field work of Robinson et al. (2010).

In 2008, Clark Alexander, Mike Robinson, Chester Jackson, Chris McCabe, and David Crass conducted a survey along the Georgia coast, to evaluate sites susceptible to erosion. This project was prepared for the Georgia Coastal Management Program and Department of Natural Resources. These sites came from a larger list provided by the National Register of Historic Places and the Georgia Archaeological Site File. Site files included information on location, survey forms, reports, maps, and publications. Twenty-one sites were examined, where current shoreline positions were recorded using a Trimble GeoXT submeter accuracy GPS. Collected data characterized degree of preservation, threat or damage to the site, potential for submerged components, site type, and site boundary. Sites were mapped and compared to aerial photographs showing the current shoreline. The shoreline change rates were determined using the SCARPS! *ArcView* GIS tool. This program calculates shoreline change by measuring the difference between two or more historic shorelines within the GIS (Robinson et al. 2010:2-7). The results of this study are further detailed in Chapter Three.

Chapter Four chronicles the methodologies used to correlate all existing data, including the Albemarle Sound Cultural Landscape Database (ASCLD). Fifty archaeological sites from the OSA files provide even more detail about cultural heritage within the Albemarle Estuarine System. After the historical and archaeological data is entered, the geological data is explained. ECU's Department of Geological Sciences (2001) and the North Carolina Coastal Geology Cooperative Program (2002) conducted core sampling and high-resolution seismic surveys in Albemarle, Currituck, Roanoke, and Croatan Sounds (ECU Department of Geology 2002a). The cores allowed ECU Geologists to evaluate physical changes and variations in sediment flux that have occurred over the last 200 years. Sediment analysis showed regional trends in grain size, increasing from west to east and inflections in grain size that correlate to inflections in the amount of organic matter caused by natural processes (storms) (ECU Department of Geology 2002b).

In addition to core sampling, mapping of shoreline change within the Albemarle-Pamlico Estuarine System (APES) has taken place in numerous stages. In an effort to better understand and manage resources at the boundaries of the Albemarle-Pamlico Estuarine System, ECU's

Department of Geological Sciences conducted several surveys estimating the erosion of the shoreline. Shorelines were categorized and assessed for erosion potential (Corbett et al. 2008). At the local level, Lisa Cowart determined erosion rates at Cedar Island, North Carolina, using fetch, wave energy, elevation, aerial photography comparison, and vegetation (Cowart 2008, 2009). Cowart analyzed several parameters, and determined that shoreline composition played a major role in controlling shoreline erosion (Cowart 2009:i). As a result of her efforts, it was concluded that the Neuse River Estuary is eroding and Cowart was able to conservatively model the system's shoreline change rates. Several other studies are utilized including Riggs and Ames (2003), Megan Murphy (2002), Erin Letrick (2003) and Corbett et al. (2007).

Chapter Five evaluates, enumerates and analyzes the values taken from the geological studies to show the individual processes occurring in the sound. This includes geo-spatial analysis of accumulation rates, wave energy and inundation. Shoreline erosion is also discussed in this chapter. The geological data provided by the ECU Department of Geological Sciences determined conservative estimates for accumulation rates and shoreline erosion. Estimates were also taken from publically available databases and included in the values derived. Inundation from sea-level rise was computed using Light Detection and Ranging (LiDAR) and Digital Elevation Modeling (DEM) measurements. The LiDAR and DEM information provides present topographic information of the area, including the region's elevation and susceptibility to inundation. Shoreline erosion rates were quantified using pre-existing values that were established from composition types. Composition of the shoreline determines its susceptibility to inundation as well as the rate at which it can erode from wave impaction and relative sea-level rise. LiDAR data determined that the shore zone of the Albemarle Sound is relatively low, and therefore vulnerable to inundation.

In addition to LiDAR, the Wave Exposure Model (WEMo) developed by the Center for Coastal Fisheries and Habitat Research (CCFHR) at the National Oceanic and Atmospheric Administration (NOAA) is used. WEMo uses two modes to calculate waves: Representative Wave Energy (RWE) and Relative Exposure Index (REI). The first mode uses "linear wave theory to calculate wave height and derived wave energy while taking into consideration wind generation and local water depth characteristics" (Malhotra and Fonseca 2009:1). The second mode "uses directional wind speed, frequency of wind, and fetch data in addition to water depth collected at a site to calculate how exposed that site is to wind-generated waves in comparison to any other site" (Malhotra and Fonseca 2009:1). RWE values were quantified using wind data from Duck Pier, North Carolina, from the years 2000-2005. Sediment accumulation rates were quantified from Erin Letrick's (2003) master's thesis for ECU's Department of Geological Sciences, as well as from field work conducted by Corbett et al. (2007). These rates determined the amount of sediment accumulating throughout the sound, in the central trunk of the estuary, and at the mouths of the rivers.

Chapter Six incorporates geological results with historical and archaeological data taken from ECU's ASCLD and the OSA's files. Both the ASCLD and OSA provided the historical and archaeological framework, culminating in the best representation of archaeological sites available for analysis and comparison.

Information collected from the ASCLD and the OSA was inputted into *ArcGIS ArcMap 9.3* to spatially represent locations of the ~300 historical and archaeological sites. The ASCLD spatial locations were then correlated with the results for wave energy and sediment accumulation and the OSA sites were correlated with shoreline erosion and inundation from sea-level rise rates. The ASCLD sites are prioritized based on location within high to low risk zones.

OSA sites are prioritized based on location within 30 meters (100 feet), 100 meters (300 feet), and 300 meters (1000 feet) of the current shoreline as well within a distance of estimated inundation (0.38 meters, 1.0 meters, and 1.4 meters). These predictive models show the number of sites currently or possibly at risk of loss from coastal processes and therefore prioritized for research in coastal and cultural management.

Conclusion

The combined geological information will cover the four geophysical properties being studied: waves, accumulation, erosion, and inundation from sea-level rise. Patterns in each are displayed on geo-spatial maps and show a range from high to low risk. Together, the geophysical properties indicate where there is the biggest threat from specific environmental factors in Albemarle Sound. Finally, archaeological sites will be placed on these maps to show sites within these specific zones. This information can then be used as a model that can be applied to any site for assessing threat to the archaeological record within a shorezone as well as aid in coastal management and cultural heritage policy.

The relevance of this thesis lies in the significance of evaluating threat to existing archaeological sites. The identification of sites currently at risk from geological activity could assist in implementing management policies for protecting North Carolina's heritage. This research also has the potential to assess current geographical areas under the same duress with the possibility of discovering new archaeological sites and site types. If patterns of change can be analyzed to predict short-term and long-term sensitivity, so can they be used to identify areas around Albemarle Sound that could have been occupied and are now submerged or damaged from erosion.

CHAPTER TWO: ENVIRONMENTAL AND CULTURAL HISTORY

Introduction

The study area for this investigation includes Albemarle Sound, its adjacent tributaries (Chowan River, Yeopim River, Perquimans River, Little River, Pasquotank River, North River, Alligator River, and Scuppernong River), and the terrestrial shoreline (Figure 2.1).

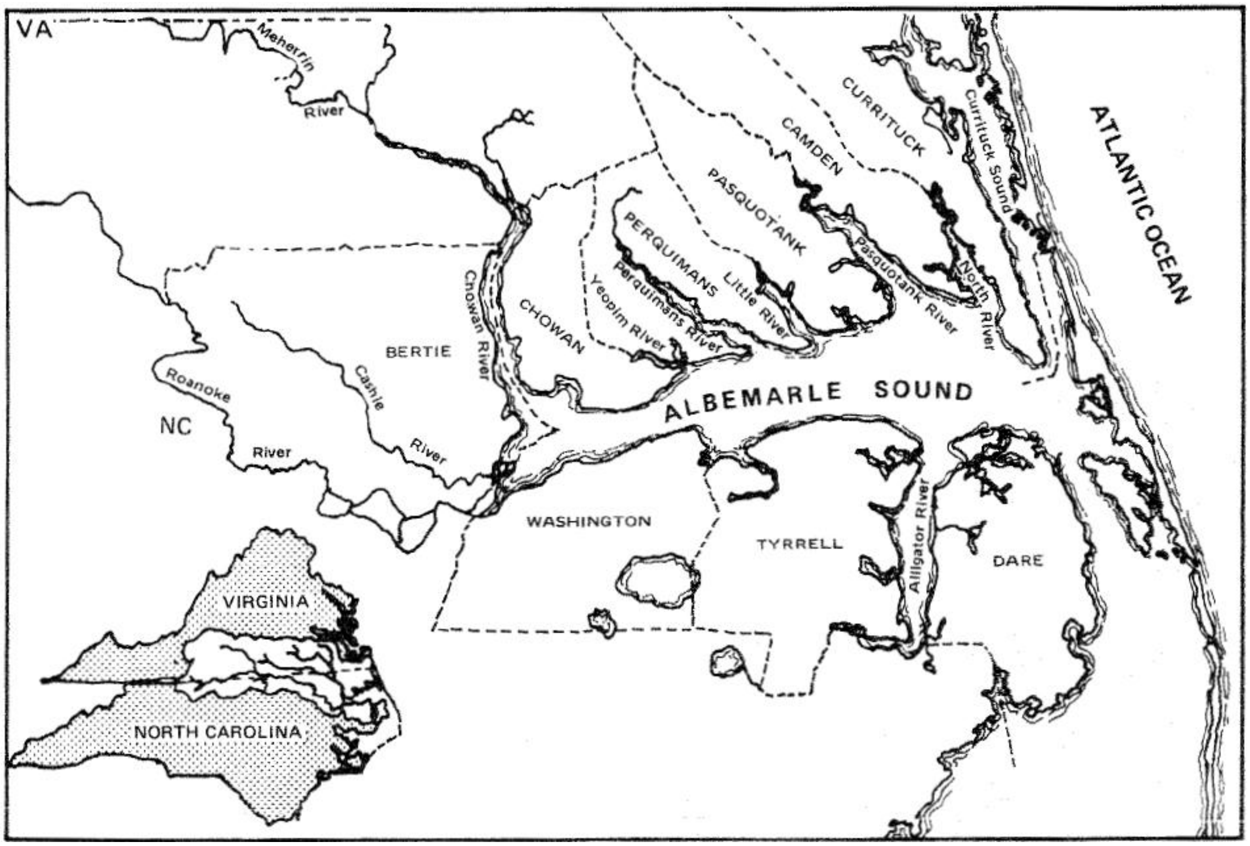

FIGURE 2.1. Eastern North Carolina coastal zone and Albemarle Sound (Copeland et al. 1983:1).

This area has evolved as a result of human occupation and natural environmental processes. The major tributaries that feed into Albemarle Sound, the rich fertile soils in the intertidal and coastal zones, and the estuarine waters provide several environments conducive to the steady growth of multiple industries, like fishing and agriculture. As a result, the economy and the maritime landscape surrounding Albemarle Sound have both affected and been changed by human behavior and activity. This chapter discusses the geographical, geological, and historical past of the Albemarle Sound region and how interaction between the evolving cultures and landscape have changed.

Geographical Formation of the Albemarle Estuarine System

The North Carolina coast formed approximately 125 million years ago, and is defined by seven marine terraces, representing individual paleo-coastlines (Powell 1989:9). The climate was warmer and sea level was about six meters (20 feet) higher than today. Approximately 20,000 years ago, during the Last Glacial Maximum, sea level was estimated to have been about 122 meters (400 feet) lower than the present day level, as water was frozen into the ice sheets (McKnight 1999:552). This reveals how change in sea level is a prominent factor influencing coastal topography.

The present formation of the Albemarle Estuarine System (AES) in northeastern North Carolina did not begin until the transition from the Terminal Pleistocene to the Holocene, approximately 15,000 to 10,000 years BP. Thermal oscillation was unsteady and over time, the period of glaciation and low sea-levels evolved to a period of deglaciation causing low coastal valleys to flood and permanently submerge due to rising sea-levels (Roberts 1989:48).

Situated within the Albemarle Embayment (Figure 2.2), a major Pliocene-Pleistocene depositional basin, the NC coastal plain separated into northern and southern provinces (Figure 2.3). The northern and southern provinces have different geologic frameworks that have different coastal morphologies. The southern province has steeper land slopes, producing many shorter barrier islands and inlets and narrower back-barrier estuaries. The northern province has a more gentle low land slope and thus long, narrow islands with only four inlets, characterizing the semi-isolated Albemarle-Pamlico Estuarine System (APES) (Riggs 2002:63-95).

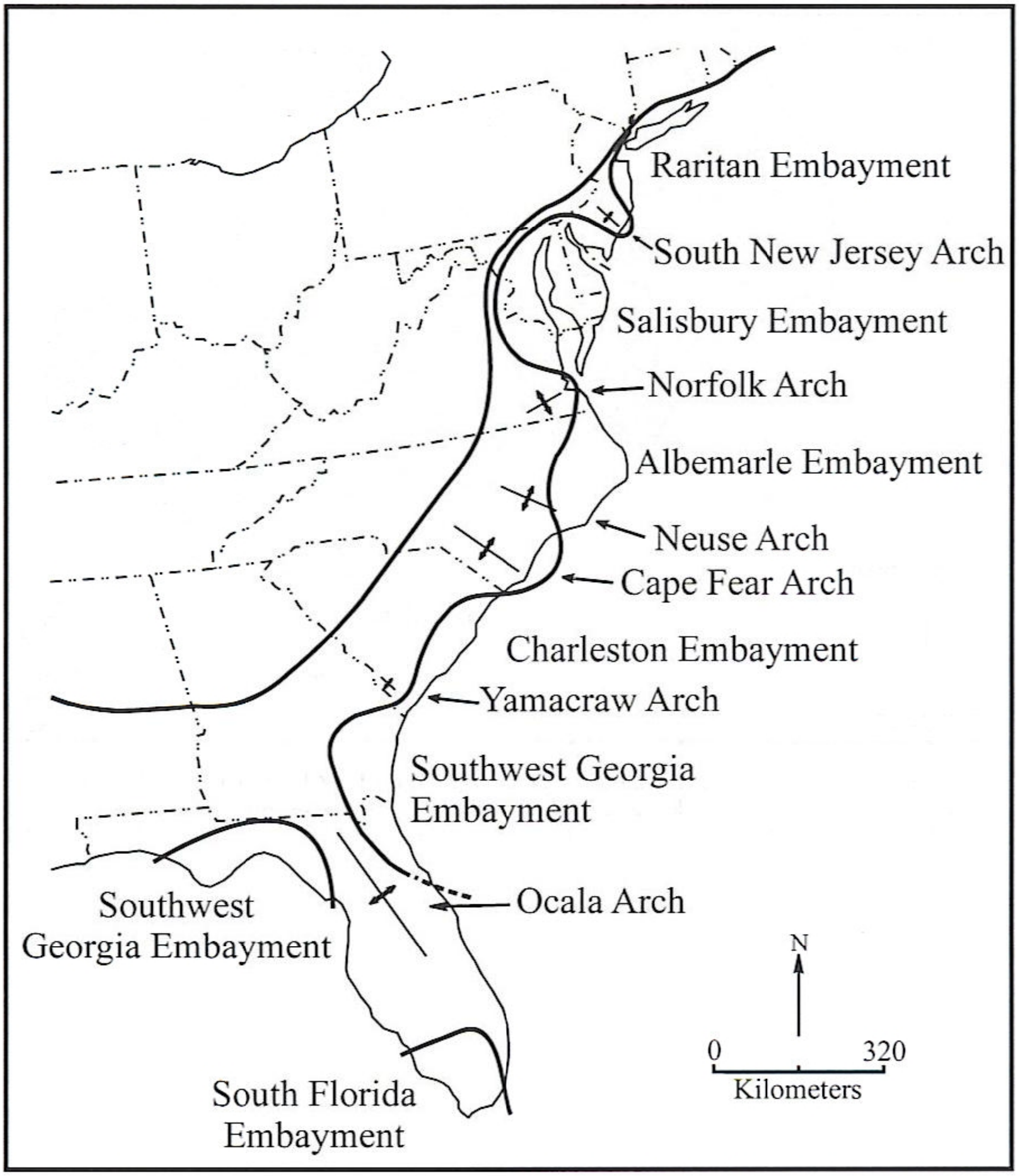

FIGURE 2.2. Major embayments of Atlantic and Gulf Coasts, including structural arches. (Vance 2004:10).

The AES occupies the drowned river valley and associated flood plains of the paleo-Roanoke River in the northern province (Riggs et al. 1995:213-234). As the paleo-Roanoke River valley filled with Pleistocene and Holocene sediments, it was simultaneously drowned by sea-level rise, creating a system characterized largely by tributaries and open water sounds (Riggs et al. 1995:213-234).

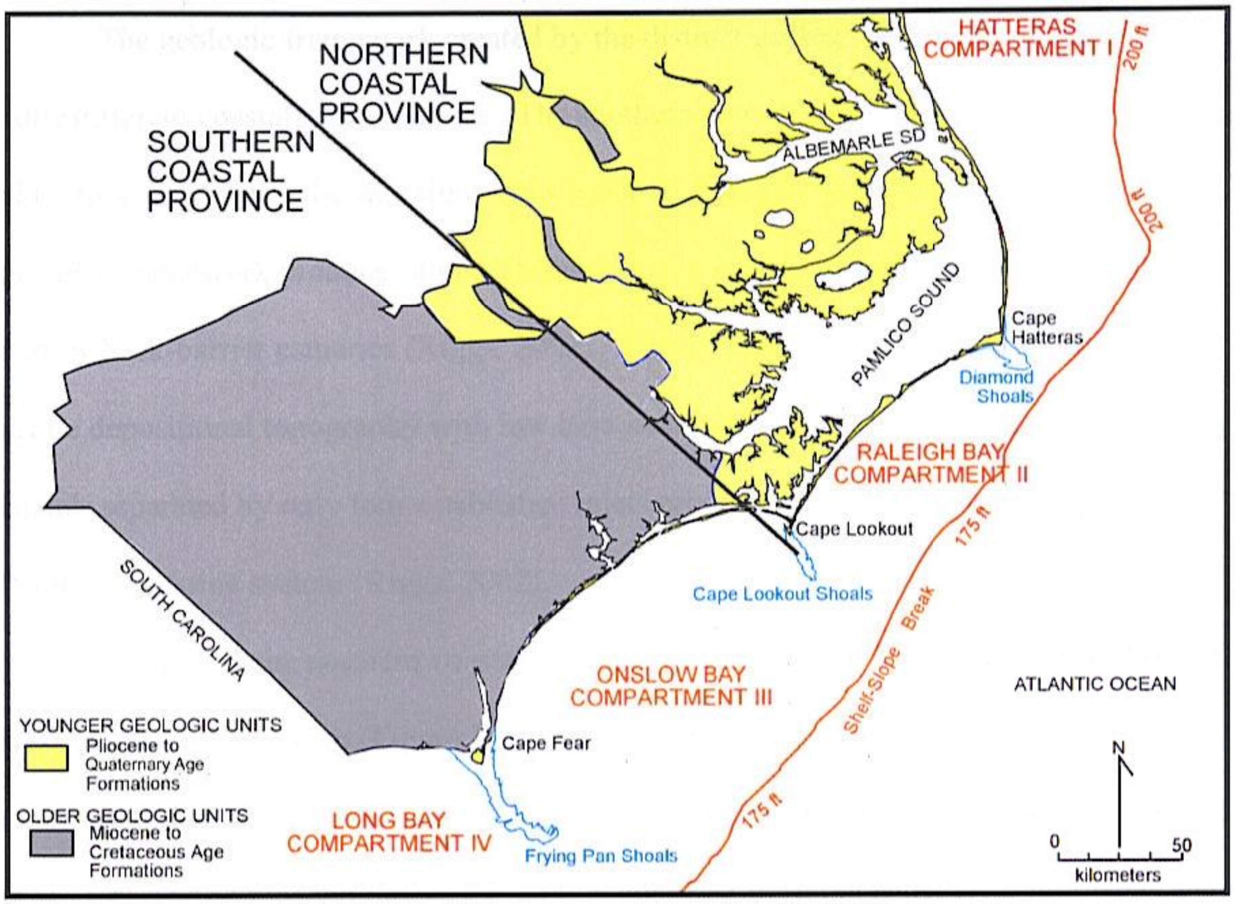

FIGURE 2.3. Northern and Southern provinces of North Carolina. (Riggs and Ames 2003:21).

Hydrology and Geology of the Albemarle Estuarine System

The entire Albemarle Estuarine System comprises Albemarle Sound, Currituck Sound, and those estuaries draining into these sounds, the largest of which are the Roanoke and Chowan River estuaries (Giese et al. 1979:5). Associated tributaries are the Perquimans, Little, North, Yeopim, Pasquotank, Alligator, and Scuppernong rivers, and this collective region is hydrologically connected to the northern part of the Pamlico Sound. The Albemarle Sound is approximately 480 mi² and has an east-west dimension of 89 km (55 miles), averaging 11 km (seven miles) wide. The maximum depth of the Albemarle Sound is almost nine meters (30 feet), though the central area averages five meters (18 feet) (Giese et al. 1979:129; Powell 1989:2) (Figure 2.4).

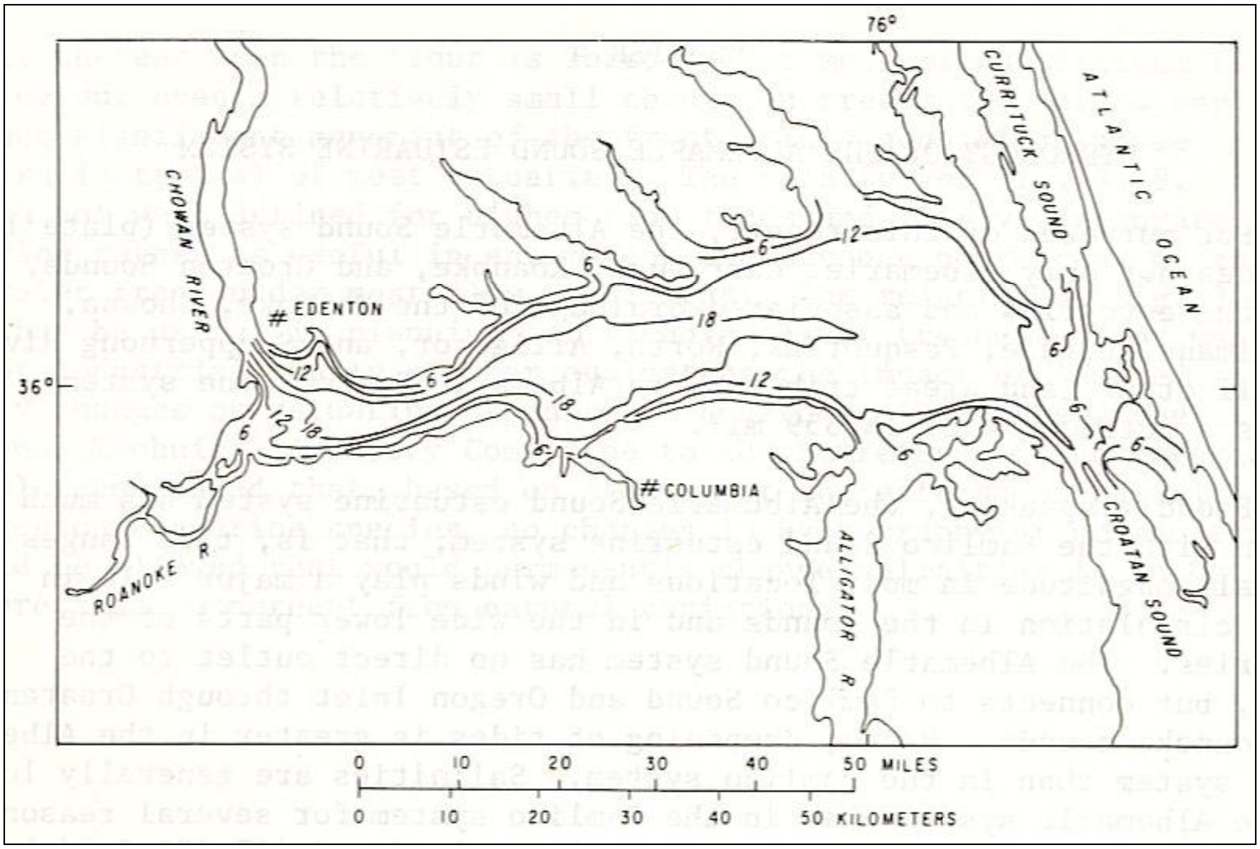

FIGURE 2.4**.** Depth of Albemarle Sound (in feet) (Giese et al. 1979:130).

The confluence of the Blackwater and Nottoway Rivers north of the North Carolina-Virginia border forms the 80 km (50 mile) long Chowan River (Figure 2.5). It flows south and empties into the Albemarle Sound near Edenton, where it widens to about three kilometers (two miles) and can have a depth of nearly four meters (12 feet). The average flow of the Chowan River at its mouth is approximately 4,600 ft^3/sec. The total drainage is estimated at 4,943 mi^2 (Giese et al. 1979:147). The Roanoke River basin totals 9,666 mi^2, but only 3,506 mi^2 of this drainage lies within the North Carolina border. The southeasterly direction of the river empties into the Albemarle Sound downstream of Plymouth, North Carolina (Figure 2.6). The greatest width is only about 0.5 kilometers (0.3 miles) at the mouth of the river and depths reach more than 5.5 meters (18 feet) (Giese et al. 1979:159-161). The system drains a total area of 18,359 mi² (Giese et al. 1979:129).

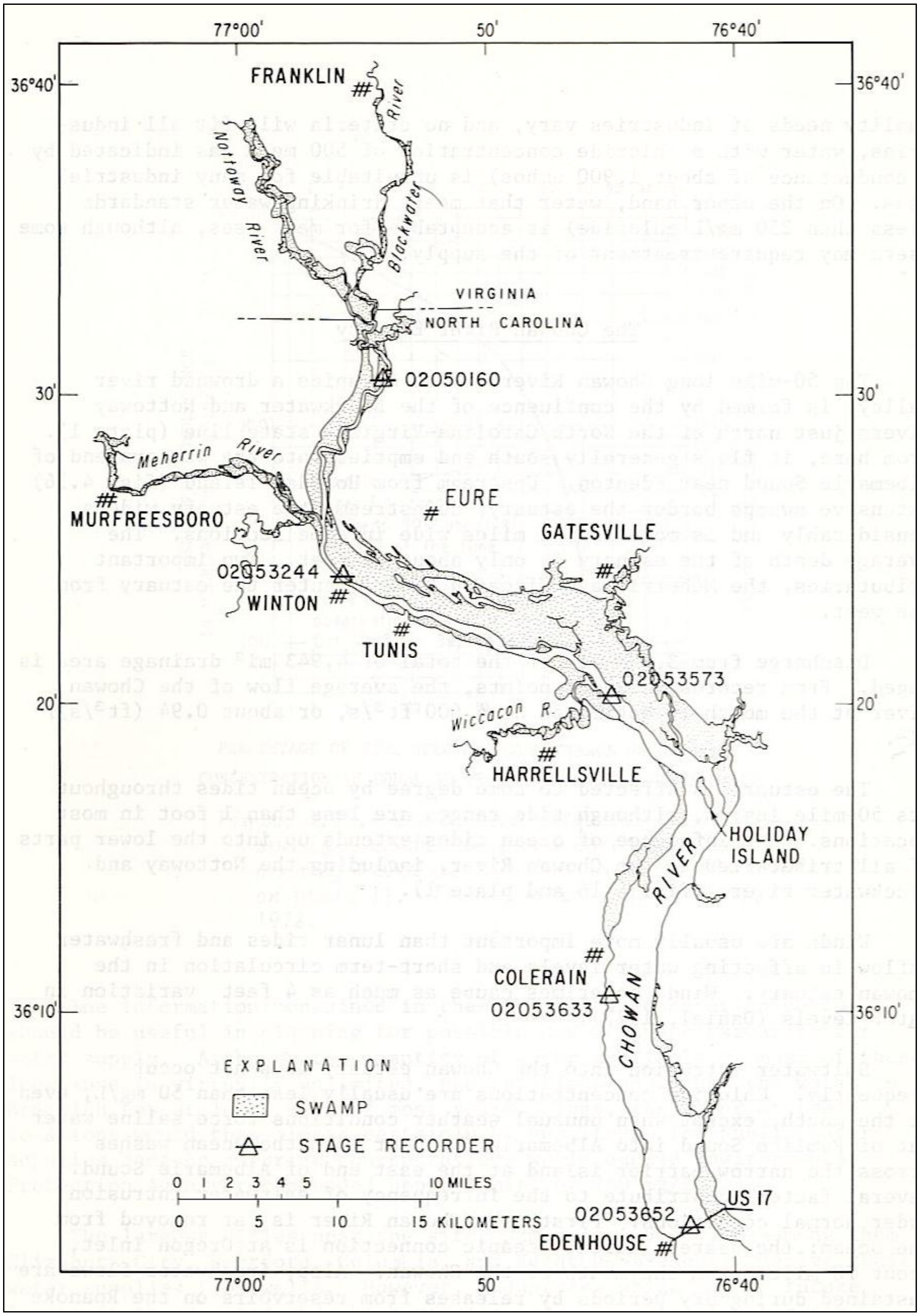

FIGURE 2.5. Chowan River, including major tributaries. (Giese et al. 1979:148).

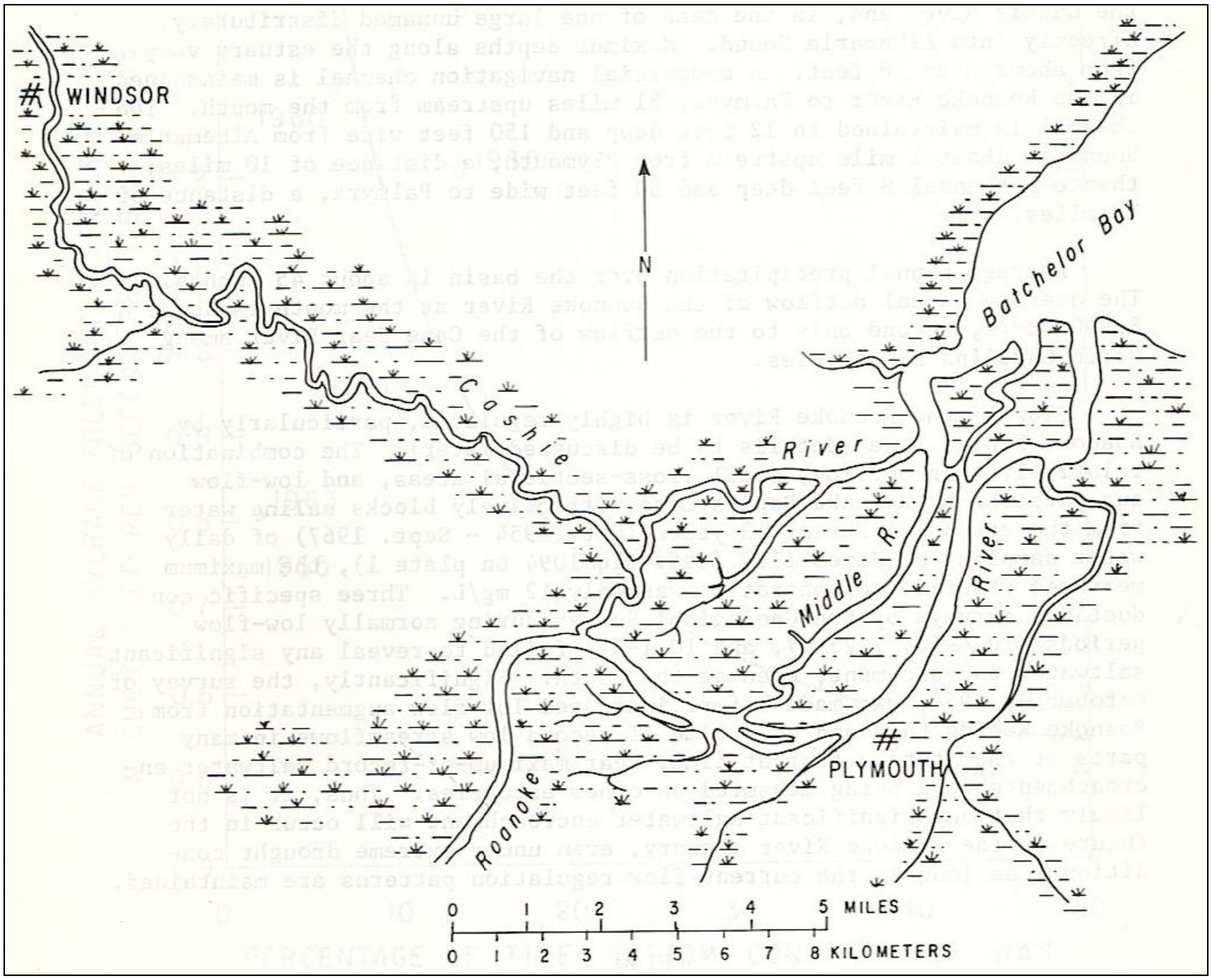

FIGURE 2.6. Roanoke River, lower distributary system (Giese et al. 1979:162).

The tributaries and the majority of the Albemarle Sound are dominated by freshwater. Saline water enters the eastern part of Albemarle Sound through the Croatan and Roanoke Sounds ultimately via Oregon Inlet (Giese et al. 1979:135). Mixing saline ocean water and river freshwater results in a relatively stable salinity throughout the area (Figure 2.7). Salinity is generally at a minimum in the spring as a result of heavy runoff and a maximum in the winter as saline water advances landward. Wind and tides prevent significant salinity stratification, resulting in an average of five parts per thousand (ppt), plus or minus 2-3 ppt between the surface and bottom water (Giese et al. 1979: 137). Water temperature ranges from 37º F in the winter to 82º F in the summer, with little or no vertical temperature variation (Giese et al. 1979:131).

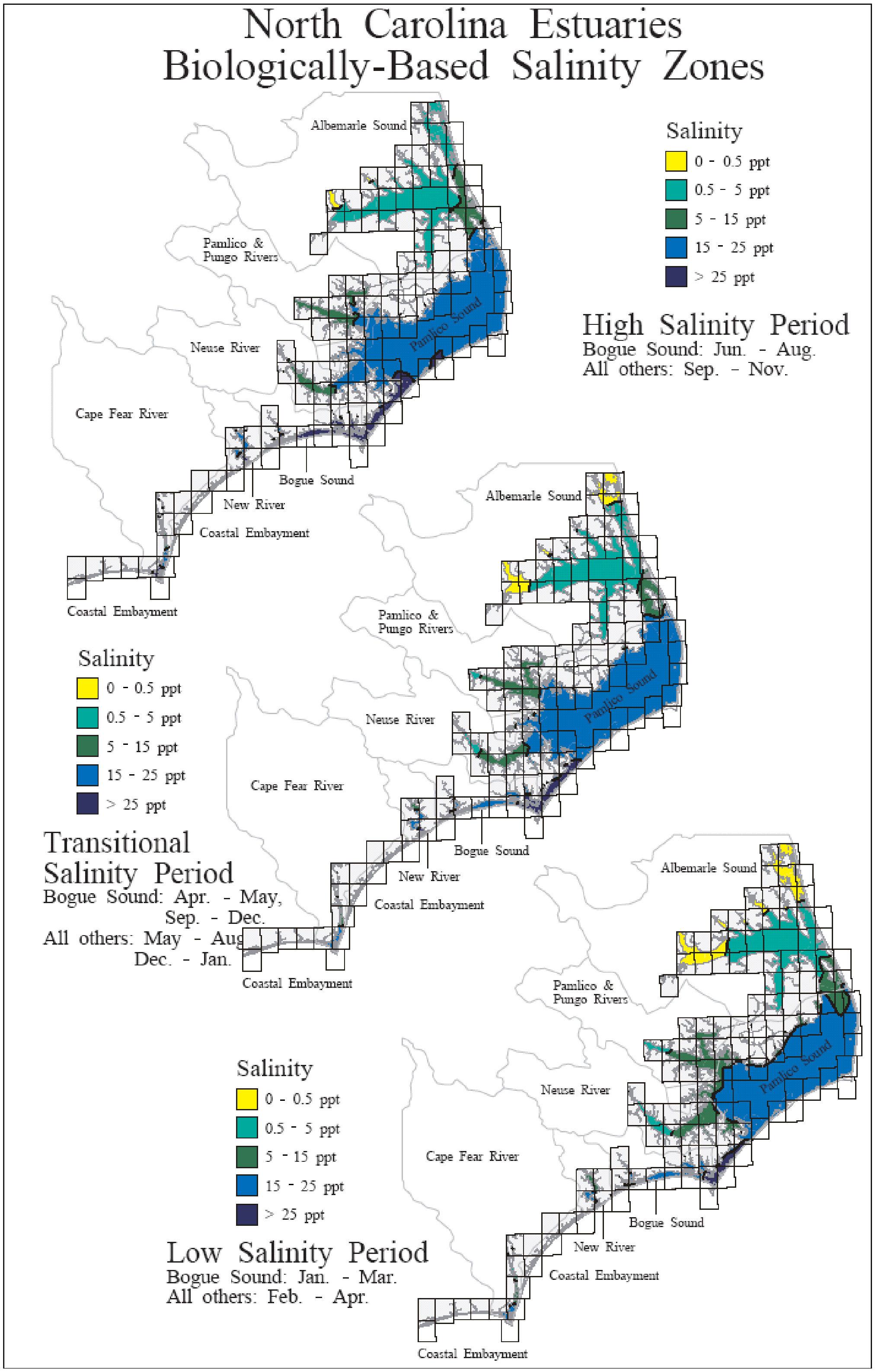

FIGURE 2.7. Salinity zones and period for coastal North Carolina (Courtesy of NOAA's Coastal Services Center, Charleston, South Carolina; NOAA's National Ocean Service, Office of Response and Restoration, Seattle, Washington; and NOAA's Strategic Environmental Assessments Division, Silver Spring, Maryland, 2007).

The Plio-Pleistocene sediments range from gravel and sand to clay and peat, and represent fluvial, estuarine, barrier island, and continental shelf depositional environments (Riggs and Ames 2003:21, 26-29, 41, 46, 55). The modern sediment is derived predominantly from the Roanoke and Chowan Rivers and from shoreline erosion (Riggs 1996:169-185; Riggs and Ames 2003:152). The suspended sediment entering from the tributaries mixes with organic-rich sediments eroding from marshes and swamp forests (Riggs 1996:169-185). Silt, clay, and an abundance of organic matter increase with depth to the east and an estimated 70% of the sediment can be classified as silty-clay with an abundance of organic matter (Riggs et al. 1993:173; Riggs 1996:169-185).

Erosion rates vary along the shoreline, depending upon geographical location, orientation, and exposure to wave energy (Riggs and Ames 2003:18). Riggs and Ames (2003:316) calculated the average rate of erosion for the Albemarle Sound region to be 0.4 meters (1.3 feet) per year. Shoreline erosion rates will be discussed more thoroughly in Chapter Four, Chapter Five, and Chapter Six.

Environmental Factors and the Suitability of Albemarle Sound for Settlement

The entire geography of the AES, from water quality to topography, shoreline composition to vegetation, was a natural place for settlement, both prehistoric and historic. The social, political, economical, and behavioral changes in the Albemarle Sound from 1663 through the Civil War affected and were affected by the landscape and its resources. An understanding of the transformation at the local level and the life of the inhabitants around the Albemarle Sound is significant to appreciating the entire region's history.

Before the eight Lord Proprietors established the first European settlement in the Albemarle Sound in 1663, Algonquian, Tuscarora, and Yeopim Indian tribes inhabited the area, taking advantage of the bountiful land surrounding the Sound (Butler and Watson 1984: 5, 8-9, 11). Over the next 400 years, political, social, and economic changes drastically altered the Albemarle Region's landscape, most of that change occurring within the first 200 years of settlement, from 1663 to 1863. During this time, the geographical landscape of the Albemarle significantly promoted the region's progression from a simple fishing and agricultural colony into a successful economy based around maritime trade and manufactured goods.

The Atlantic Coast of the United States has a passive margin and, therefore, a lack of geologic activity. This deficiency causes a buildup of sediments, creating broad coastal plains and such geologic features as barrier islands, salt marshes, lagoons, and estuaries (Castro and Huber 2007:39). According to Castro and Huber (2007:259), estuaries are useful environments for natural harbors, and are among the most productive environments on earth. In coastal plain estuaries, dense seawater commonly is found on the bottom of the water column while less dense fresh water floats on top. Seawater on the bottom moves back and forth with the tidal rhythms, and the change in salinity affects species. As a result, the species that live in an estuary depend upon that species' ability to withstand external conditions or change its internal salinity by osmosis.

Some fish are osmoregulators, meaning the salt concentration in their body remains somewhat constant despite salinity fluctuation in their environment. Herring and shad are such types inhabiting Albemarle Sound; they will absorb or get rid of water through their gills and kidneys depending on the salinity in their surrounding environment (Castro and Huber 2007:263). As these species travel from the North Atlantic Ocean into the Albemarle, they compensate for changes in salinity by getting rid of excess water and absorbing solutes from the seawater as they enter the less saline sound. The regularity of this migration is one reason the human population in the Albemarle Sound developed so rapidly in the beginning stages of its recorded history. Another reason is the unique boundary of the Albemarle Sound, that “lies between the Chesapeake Bay and Hampton roads and Nansemond river, on the north, the ocean on the east…and on the west, the outline would include all the Dismal Swamp” (DeBow 1857:464). Commodities, like tobacco, corn, cotton, wheat, lumber, as well as agriculture were the result of the estuarine environments that surround the Sound. The land along stream and river banks is extremely fertile, yielding an abundance of natural growth and attracting the first native and European settlers to the region (DeBow 1851:106).

History of the Albemarle Region, North Carolina

The first English settlers to the Albemarle region arrived as early as the late 16th century and the first official settler acquired the first registered land deed in 1660 from Yeopim King Cistacaneu (Winborne 1838:222). The Yeopim Indians, an Algonquian tribe, inhabited this land for hundreds of years before the first European settlers arrived. The Chowanoc Indians, another Algonquian group, inhabited the area west of the Chowan River (Figure 2.8).

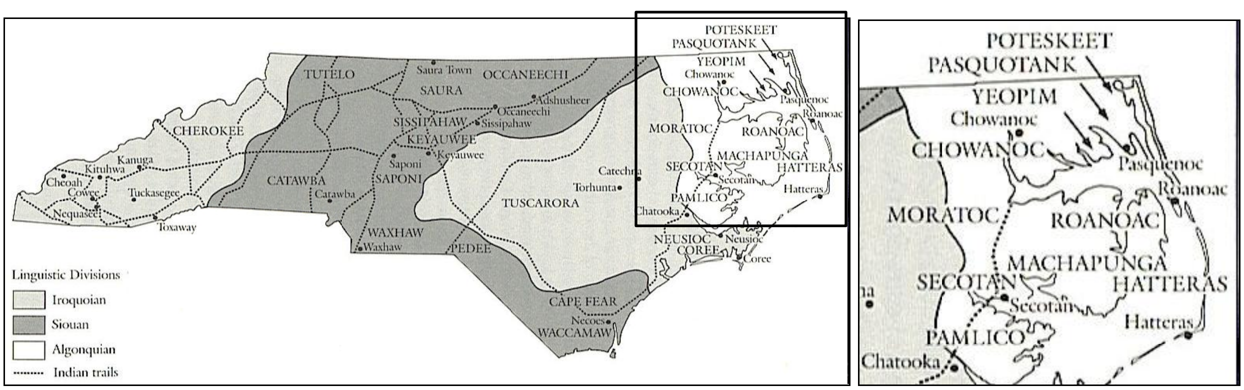

FIGURE 2.8. Indian settlements during early European settlement (Powell 1989:23).

The settlement was discovered to be rather large and occupied the area for over 1,000 years. For the first few years, the new European settlers and Chowanocs existed harmoniously, engaging in whaling and farming. The Europeans grew tobacco, while the Chowanocs grew vegetables and furnished milk, butter, and cheese (Powell 1989:21-22). Migration was slow; initial transportation occurred via the sound and tributaries in small canoes and boats, as land travel proved difficult.

In 1585, Sir Walter Raleigh first explored North Carolina after landing at Roanoke. Ralph Lane became the first governor of the Roanoke colony but this colony was not successful. Not enough time was given for planting and an opportunity arose to leave, so Lane and the settlers abandoned this settlement. A second attempt at colonization occurred a few years later with John White as governor. "The Lost Colony" had an unfortunate run-in with Indians and all attempts at settling Roanoke was abandoned until the early 17th century and the successful settlement at Jamestown, Virginia. The success of Jamestown led a few explorers to venture south into the Albemarle Sound region, then known as the Sea of Rawnocke or Roanoke Sound (Barefoot 1995:84). The explorers were eager to find more fertile lands and fresh hunting grounds south of Virginia. In 1622, John Pory ventured south and explored the Chowan region (Powell 1958:81). Finding the region "very fruitful and pleasant…yielding two harvests a yeere", the Albemarle began attracting more attention (Butler and Watson 1984:54). On 30 October 1629, Charles I sent his Attorney General, Sir Robert Heath to settle the territory between 31 degrees and 36 degrees north latitude. This meeting resulted in a charter naming the area "Carolana" (Powell 1958:xvi, 81). Heath failed to colonize the province, and it would be another 24 years before Roger Green of Nansemond County, Virginia, obtained a grant for land along the Roanoke and Chowan Rivers. Unfortunately, this grant failed to make public records, but for the next seven years, Virginians traveled here and began settling. The first permanent European settler to obtain a legal land deed in present day North Carolina was Nathaniel Batts in 1660 (Powell 1958:82).

Nathaniel Batts moved his fur trading operation to the junction of the Roanoke and Chowan Rivers in 1655, followed by more settlers from southern Virginia. On 24 September 1660, Batts bought the west bank of the Pasquotank River, "from its mouth at the Albemarle Sound up to the headwaters of New Begin Creek, almost ten miles of shoreline" from King Cistacaneu (Simpson 2006:25). The witness to this deed, George Durant, would purchase the next land deed one year later (Figure 2.9).

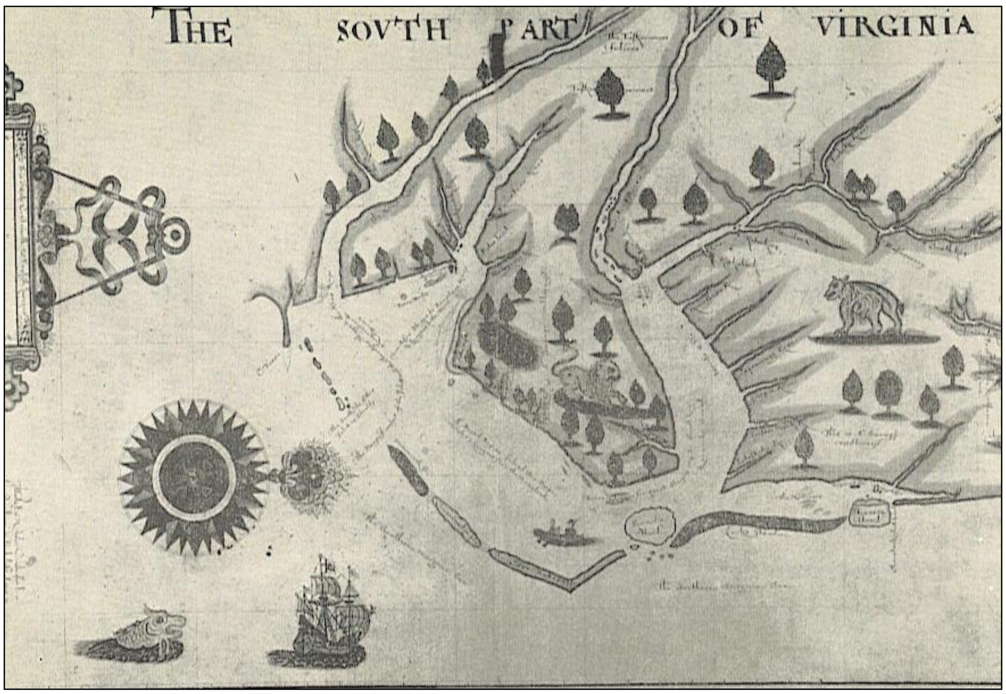

FIGURE 2.9. 1657 Nicholas Comberford Map (Powell 1958).

George Durant, Attorney General and Speaker of the House of Burgess, purchased a tract of land between the Perquimans River and Albemarle Sound, known as Wecocomicke, from Chief Kilcocanan of the Yeopim Indians on 1 March 1661 (Powell 1958:xxiv). His purchase yields the second oldest recorded land title in the state, after Nathaniel Batts. Records indicate that it is the oldest surviving record of a Perquimans County land grant (Powell 1958:xxiv). It was only a few years before word of the temperate climate, abundance of flora, fauna, and fertile soil generated interest from Charles II and eight Lord Proprietors from Virginia (Lefler and

Newsome 1973:15-16). By 1663, there were nearly 500 people living between Albemarle Sound and Virginia (Powell 1989:52).

On 3 April 1663, eight men applied to Charles II for a grant to territory south of Virginia. The Lord Proprietors sent directions to the Governor of Virginia, Sir William Berkeley, to arrange for "granting land, collecting rent, and establishing a government" (Powell 1958:xxvi). The Albemarle region was not included in the original boundaries of Carolina, in the Carolina Proprietary Grant of 1663. The following year, revisions to the 1663 grant extended Carolina's boundaries from the southern boundary of Virginia to the northern border of Florida (Winborne 1838:223).

William Drummond became the first governor of Carolina, a title given by Governor Berkeley, in 1664 (Lefler and Newsome 1973:55). By 1665, the Grand Assembly of the Albemarle, the first assembly of settlers, occurred. Berkeley was determined to hold a monopoly on the fur trade and in 1666, granted a petition by the assembly to allow holding of their land deeds under similar conditions as Virginians (Robinson 1955:44). During the first government of Carolina, the colony separated into three counties: Albemarle to the north, Clarendon in the center near the Cape Fear River, and Craven to the south (Robinson 1955:265; Powell 1958:xxvi). Each county would have governors, a legislature and courts, and be divided into precincts (Robinson 1955:55).

Albemarle was the only county to have a governor and a legislature. Clarendon County lasted until 1667 and Craven County lay beyond the boundaries of northern Carolina. In 1670, Albemarle County separated into four precincts: Chowan, Pasquotank, Perquimans, and Currituck. Each precinct contained a court administered by the justice of the peace and five delegates to the lower house (Lefler and Newsome 1973:41-42). To encourage settlement, the

Lord Proprietors offered land grants and the right to participate in law making (Robinson 1955:55). The laws to stimulate growth and promote immigration were not enough and Albemarle County entered a period of unrest and slow production. Tobacco, livestock, and mixed grains were the only commodities exported to New England, Bermuda, Barbados, and the West Indies (Butler and Watson 1984:56). In an unlucky turn of events, the Parliamentary Navigation Acts of 1660 hampered the colony's ability to export goods further hindering the colony's only form of economic influx. The Albemarle colonists slipped through a loophole in the Acts and continued to export tobacco to Europe under the pseudonym "fish". Parliament countered with the Plantation Duty Act of 1673, charging one penny per pound on tobacco, attacking the Albemarle settlers' dependency on this trade (Butler and Watson 1984:56).

Unimpressed with the slow economic progress, the Proprietors focused their attention toward Charleston, South Carolina, in 1670. Ignoring the Albemarle region caused the settlers to feel neglected and act out against unjust treatment. As if a feeling of neglect was not enough, the Albemarle region also suffered from isolation, as the sound and virtually no roads kept them separated from the rest of Carolina. Communication with Virginia continued, but the forests, swamps, and rivers made it difficult (Lefler and Newsome 1973:43). Laws passed in 1669 designed to promote the colony's welfare did not produce the expected results, causing further unrest in the colony.

For the next thirty years, the Proprietors' failure to establish an efficient government became the greatest obstruction in the region's early history. Governors failed to defend the colony from outside threats, to encourage welfare, and to maintain order (Lefler and Newsome 1973:45-46). After a few decades of corrupt government officials and, eventually, the conviction and banishment of Seth Sothel in 1689, Philip Ludwell became governor north of the Cape Fear

(Lefler and Newsome 1973:46). By 1694, Albemarle ceased to be a separate political unit and became part of Carolina, beginning the colony's division into North and South Carolina (Butler and Watson 1984:62). Into the first decade of the 18th century, a governor based in Charleston ruled North Carolina through a local deputy governor. In 1693, Ludwell was the first governor to rule from Charleston with Alexander Lillington as Deputy Governor (Winborne 1838:225).

In the beginning of the 18th century, several economic, social, and political issues hit Carolina and directly affected Albemarle County's inhabitants. A closer look at the local level summarizes this century as one of political instability, hostile relations, expansion, and independence. The Vestry Act of 1701 was the first piece of political documentation to cause upset, as it decreed the Church of England the official religion of the Carolina colony. Until this act, religious homogeneity did not exist, as Carolina was made up of Quakers, Moravians, Scots-Irish, Presbyterians, and Baptists (Levy 1960:247). The Quakers were the dominant religious group in the Albemarle region, having emigrated from Virginia in the first years of migration.

In 1672, George Fox, a Quaker, came to the Perquimans River to deliver the first religious service recorded in North Carolina (Barefoot 1995:75). Soon after, Quakers began moving to the northern lands along Albemarle Sound and were responsible for religious activity there. In 1694, John Archdale, a Quaker, became governor, and the Quaker Church dominated the government, upsetting the Anglicans. This situation only lasted a few years. In 1699, Henderson Walker became governor. A friend of the Church of England, Walker persuaded the General Assembly to make the Church of England the colony's official religion (Crabtree 1958:21-22). The Vestry Act of 1701 was a direct attack on the Quakers and thus, an attack on the society surrounding the Albemarle.

In 1702, Queen Anne's War in Europe resulted in an increase in shipping costs. The entire Albemarle region relied heavily on exporting their commodities. Chowan County exported corn. Perquimans County also exported corn, as well as animal furs and skins, naval stores, livestock, and to some degree, wheat and the commercial production of tobacco (Watson 1987:8, 2003:8-97). Tyrell, Halifax, and Martin counties exported cotton (Manning 1979:91). Pasquotank County participated in the woven cloth trade (Markham 1964:12). The Church of England refused to help the Quaker dominated society, dividing the colony into sections that supported England and those opposed, causing the first of many conflicts.

In 1711, Edward Hyde became North Carolina's first official governor (Crabtree 1958:26). The Cary Rebellion, which took place in Bath County, was a religious and political conflict between Quakers and Anglicans, between government and people. This insurrection did not take place in the Albemarle but greatly affected it. The neglect of crops and plantations, and a deteriorating government, coupled with a severe drought caused further economic hardship. A previously amicable relationship with the neighboring Indians caused further suffering for the colonists (Powell 1989:21-22).

Expansion south towards Pamlico Sound caused tension between the settlers and the Indians. By encroaching on their lands and hunting grounds, the English drove the Tuscarora Indians into initiating warfare over the next few years. A majority of the conflict would occur in North Carolina's Pamlico-Neuse region. A massacre occurring in Bath and its surrounding region caused settlers to beg for assistance from the Albemarle. The Albemarle inhabitants ignored the pleas from Bath, as they believed this was not their fight, and left Bath to defend itself. Fortunately, Bath eventually emerged victorious and a peace treaty between the North Carolina government and the Indians ended the Tuscarora War (Powell 1989:78).

By 1729, the Lords Proprietors had failed to establish a sound government and surrendered authority to the Crown. The boundary lines, wars, political, and religious conflicts that occurred during the settlement's first 50 years had been too much of an effort and did not result in the prosperous colony envisioned. The only outcome was expansion (Powell 1989:84). In 1671, the county of Albemarle separated into the precincts of Carteret, Berkeley, and Shaftesbury. In 1681, Carteret divided into Currituck and Pasquotank, Berkeley became Perquimans, and Shaftesbury became Chowan (Jackson et al. 1976). In 1728, following a boundary dispute between North Carolina and Virginia, the border was drawn to place Currituck in North Carolina, to the delight of its inhabitants (Robinson 1955:293). As early as 1666, Bermudians established themselves along the Pasquotank River and engaged in shipbuilding. Named for an Indian tribe, Pasquotank became a county in 1739 and held its first courts at Relfe's Point (Robinson 1955:191). Perquimans was organized in 1670 from Albemarle County. Originally called Phelps Point, Hertford (renamed in 1758 for the Marquis of Hertford) became a port of entry for the Albemarle as early as 1701 (Robinson 1955:279).

Chowan County, like Perquimans, was organized in 1670. Chowan separated into Bertie County in 1722 and Tyrrell County in 1729 (Jackson et al. 1976). As an original Albemarle county, Chowan was home to Edenton, one of the three oldest communities in the state (Robinson 1955:181). In 1710, Edenton was the symbolic capital of the colony and included the governor's residence. By 1722, Edenton was an incorporated town named after Governor Charles Eden, and served as the capital of North Carolina until 1743 (Crabtree 1958:29-30). Initially named Port of Roanoke, and the Indian term, "Matecomak Creek", Edenton had two shipyards and its principle industry was fishing, principally shad and herring (Robinson 1955:181). This county was also known for its naval stores, including such commodities as shingles, staves, pitch, and tar (Watson 2003:8-97). Edenton was the most populous and growing region of the Albemarle, owing its reputation to construction of a courthouse in 1712 and the central establishment of the Anglican Church (Ready 2005:151) (Figure 2.10). Changing boundary lines subsequently divided the economic, social, and political behaviors. Those that remained true to an agrarian lifestyle stayed in the Albemarle. This lifestyle valued dependency on slave labor. The Quakers opposed slavery and began moving west. Quakers who remained in Perquimans met annually at the Old Neck Meeting House, beginning in 1706 (Barefoot 1995:74). At these meetings, Quakers discussed ways of improving the social atmosphere by removing the rich planter's dependency on slave labor. Incidentally, rapid expansion west, immigration, and the imposition of royal government overshadowed the slavery issue.

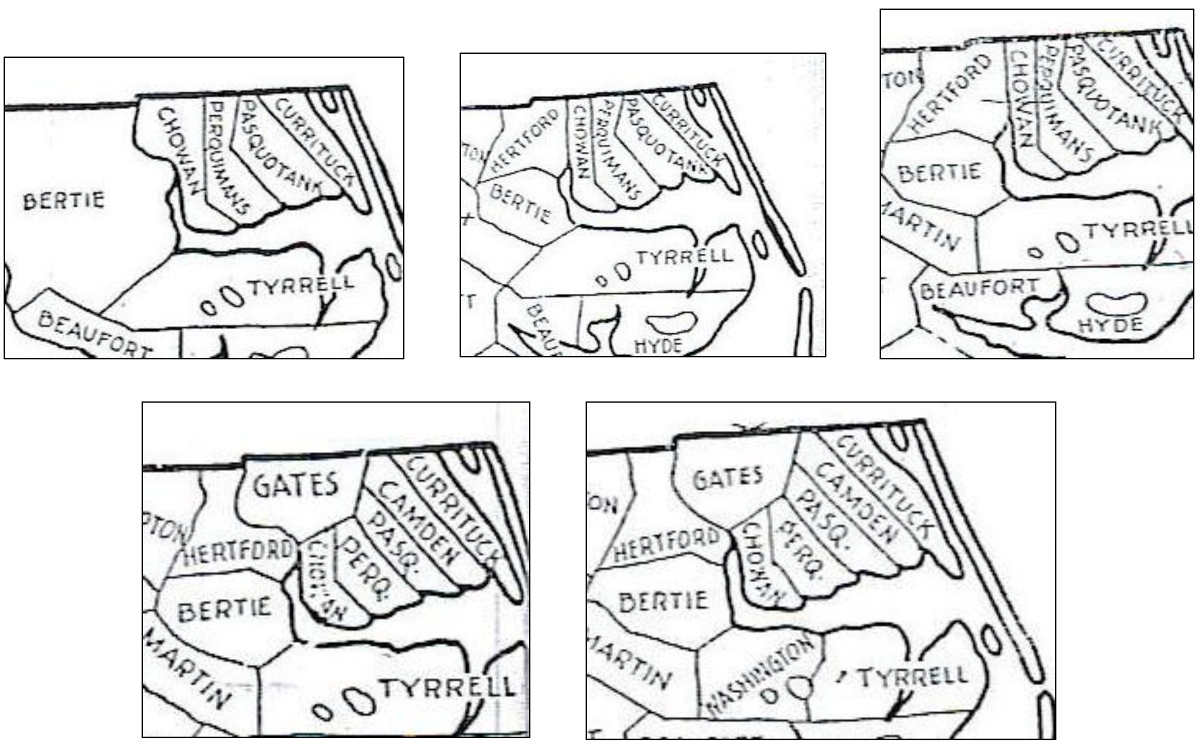

FIGURE 2.10. Eastern North Carolina county maps for 1740, 1760, 1775, 1780, and 1850 (Jackson et al. 1976).

By the 1730s, during George Burrington's governorship, the population entered an era of rapid growth from immigration. Within the colony, there was a massive movement west. This movement caused a division between the west and east. Between the 1730s and 1750s, a more diverse and complex society emerged within North Carolina, causing a change in the landscape. Forests were cleared and vast amounts of land were put into cultivation. Mills, roads, and lighthouses were built along the coast, and the rivers and sounds were cleared for ferry use (Powell 1989:52). This expansion fueled issues in Albemarle Sound's political and social settings, beginning with the Regulation movement.

The Regulation occurred because of demographic changes, repressed frustration, inequitable taxation, and corrupt government officials (Whittenburg 1977:215). In 1766, Governor Tryon noticed that the "province is settling faster than any on the continent…upwards of one thousand wagons passed thro' Salisbury with families from the northward, to settle in this province chiefly…" (Saunders 1994:248). The immigration brought new language, culture, beliefs, and religions to England's colony.

Governor Tryon, as well as the other royal governors firmly believed in the English mercantile system, while a group known as the Regulators, opposed it. Mercantilism and trade restrictions contributed to the Albemarle region's poverty and those planters who had been there since their arrival (Butler 1976:6). Albemarle planters appealed to the Board of Trade and threatened to resort to "such usefull Manufactorys for their necessary Cloathing &c as will prevent the sale of considerable quantitys of European Goods and consequently be prejudicial to the Trade of Great Britain" (Saunders 1994:196).

During the Regulation movement, Albemarle inhabitants focused attention on their plantations and ports. Edenton, the main port in Albemarle Sound, exported sixty-five percent of the corn grown in North Carolina by the eve of the Revolutionary War (Watson 1987:8).

Incorporated in 1722, Edenton would play a crucial role in the region's development through the Revolutionary War and into the 19^{th} century.

Edenton ranked second of North Carolina's five ports, behind Brunswick on the Cape Fear River (Higginbotham 1976:239). Edenton had long been the port of exchange between goods shipped to and from the West Indies and to other colonies in New England. The Roanoke River also served as an important pathway. To escape trading goods from the backcountry through Virginia and South Carolina, goods were shipped down the Roanoke River to the Albemarle Sound, and from there to other markets (Powell 1989:140).

The Albemarle Sound's natural landscape yielded a plethora of goods. The fishing industry sold shad to the northern colonies and shipped salted herring to England (Sawyer 1850:583). Items shipped to Baltimore included tobacco, naval stores, shingles made from cypress and juniper trees, and deerskins (Sawyer 1850:583; Thompson 2002:36). Lumber from pine trees, native to the Great Dismal Swamp region, naval stores, and hemp fueled local shipbuilding industries along the rivers (Thompson 2002:36). The inhabitants in the West Indies knew the land surrounding the Albemarle Sound could provide them with valuable lumber and food in exchange for sugar, rum, and slaves (Higginbotham 1976:238; McRee 1857:44).

Each North Carolina port contained a naval officer and deputy, and at Edenton, a collector and a comptroller (Clark 1994:530). In 1768, James Iredell became comptroller of customs for Port Roanoke and in 1774, the naval officer appointed Iredell collector. Iredell categorized his records into three classifications: 1) Africa, southern Europe, and the West Indies; 2) Great Britain and Ireland; and 3) the British mainland colonies (Higginbotham 1976:xxiii, 238). Iredell's organization and attention to detail drove the Port of Roanoke and Edenton into a significant role during the Revolutionary War.

In 1773, England came to the aid of the Honorable East India Company, creating a monopoly on the colonial tea trade. Boston, Massachusetts, retaliated by dumping tea into the harbor. Parliament countered this resistance by enacting the Coercive Acts, known to the colonists as the Intolerable Acts, and closed Boston Harbor. North Carolina responded with the meeting of the First Provincial Congress.

The First Provincial Congress met in New Bern in 1774. At this meeting, the assembly agreed to boycott trade with Britain, showing support for Boston. At Edenton, a group of women met at the house of Elizabeth King and signed a petition supporting Boston. At this meeting, the women promised not to drink tea or wear garments of English manufacture. The gathering and meeting of the Provincial Congress demonstrated the cohesion of the colonists of North Carolina and the Albemarle Sound in defying the Crown (Crow 1975:15, 17).

Apart from the Edenton Tea Party, Edenton and the Port of Roanoke remained in a state of awareness. Lord Cornwallis of England gradually made his way north, defeating the colonists in almost every battle. Benedict Arnold landed at Portsmouth, Virginia and General Nathaniel Greene believed that the Redcoats in Virginia "are preparing to form a junction with Lord Cornwallis by the way of Albemarle Sound" (Higginbotham 1976:225-226). In a letter from General Greene to Thomas Burke, a delegate to the Continental Congress, Greene states that he heard about "a large number of fine heavy cannon" located at Edenton and that they be removed quickly "as high up the Roanoke as they can be transported by water. By leaving the Town naked of public property we render them less object for the enemy" (Clark 1994:435). General Greene's information was not misleading. In a letter to Sir Henry Clinton, Arnold wrote that he intended to:

> sweep the Albemarle Sound as high as Edington,

> and to go to New Bern and destroy their Shipping
> Stores…This movement, I am convinced will have
> a good effect, first, by destroying the Navigation of
> North Carolina, and thereby distressing the
> Inhabitants, and secondly, by taking off their
> attention from my Lord Cornwallis… (Clark 1994:985).

Cornwallis was unable to rendezvous with Arnold, and Edenton and the Albemarle area remained safe.

At the end of the Revolutionary War, as the 18th century ended, North Carolina entered another period of political, economic, and social transition. In 1778, concern for individual rights and the power of the state government dominated the legislature. Emphasis toward internal improvements in transportation, education, and the institution of slavery controlled the lifestyles of North Carolinians in the first half of the 19th century.

In 1790, the first Census of North Carolina showed that the district of Edenton contained 53,700 people, the fifth largest district in North Carolina. Edenton District, containing the counties of Perquimans, Pasquotank, Camden, Currituck, Gates, Hertford, Bertie, and Tyrrell, also included the town of Edenton. The four districts leading North Carolina's population came from west of Edenton, with the exception of Newbern District, lying south of Edenton (Jackson et al. 1976). A new class of commercial farmers and professional men brought new ambitions to modernize agriculture and finance transportation. This undeveloped transportation and a lack of education restricted agrarian progress.

From the 17th century and the first settlers to the region, the Albemarle was dependent on slave labor, mimicking that of the Chesapeake. Slaves and slave owners were fundamental players in the region's politics, economy, and environment. The first permanent slaves in the Albemarle region date to 1663 when at least four settlers brought their slaves from Virginia (Butler and Watson 1984:195). White elitists depended on slavery in economic expansion. Early farming was small, producing a small variety of commodities to export to New England and sustain the local inhabitants. Large plantation owners purchased slaves to expand their labor force, leading to economic growth in the 1760s (Kay and Cary 1995:27). Large-scale activities like agriculture, clearing forests, and trade caused the dependency on slaves to grow, and the black population to soar.

Josiah Collins came to Edenton in 1774 and in the 1780s, joined other influential men, like William Davie and Charles Pettigrew, in attempting to drain Lake Phelps and farm its fertile land (Barefoot 1995:125). The project failed, but Collins and other plantation owners of the southern Albemarle Sound were determined to contribute to the internal improvements of North Carolina. In 1785, Collins constructed a series of canals draining nearby swamps and allowing a large acreage for harvest. In a letter from Charles Pettigrew to Henry Patillo, Pettigrew wrote; "They have now completed a Canal near six miles…being a communication between [Lake Phelps] & Scuppernong River, which promises infinite advantage" (Lemmon 1971:62-64). These endeavors came about through slave labor. Collins owned 328 slaves, one of four planter families to own more than 300 slaves in North Carolina history (Barefoot 1995:127).

As the white population grew due to immigration from the end of the 18th century to the mid-19th century, the black population grew as well. Between 1790 and 1800, the population of slaves in Edenton District grew from 19,198 to 21,632 (Jackson et al. 1976). As plantations and industries grew, the number of slaves grew as well. Slaves also worked in the shad and herring industries, working the seine, or dip nets, to catch the fish. By 1807, James Cathcart Johnston, heir to the Hayes plantation outside Edenton and cousin of James Iredell, Jr., would head one of the largest Albemarle Sound commercial shad fisheries. In 1840, 17 fisheries employed 765 slaves and by 1846, upwards of one thousand slaves worked the seines (Watson 1996:36-38).

The Quaker population vehemently opposed slavery. In 1816, the Quakers formed the Manumission Society, attempting to eradicate the institution of slavery. In 1829, the Manumission Society met a brief hiatus, eventually disbanding in 1834. Finding that their efforts were fruitless in an economy that thrived on slavery, Quakers migrated west in the 1830s, leaving one meetinghouse in Perquimans County called Piney Woods (Barefoot 1995:80). Upon the Quaker's departure, the Albemarle continued agricultural living, growing tobacco and hemp, and exporting naval stores. As the 19th century progressed, the Albemarle began to realize commercial improvement could not have occurred without slave labor, and the need for more reforms was necessary. Due to poor transportation south and west, trade occurred mostly with Virginia towards the end of the 18th century (Saunders 1994:v). By 1805, the Great Dismal Swamp Canal opened, connecting Albemarle Sound to Chesapeake Bay. At this time, developments in transportation occurred simultaneously with educational reforms. The "remarkable development of the public school system, the revival of old projects for improving and extending the States inland waterways, and the unparalleled growth of interest in North Carolina history" can be attributed to the efforts of Archibald DeBow Murphey (Hoyt 1914:ii).

Archibald DeBow Murphey spent his life developing plans for improving roads and canals within North Carolina. Less concerned with travel to other states, Murphey believed that "North Carolina can be made a great and respectable State. If we can hold our Course a little time longer, We shall assume an imposing Attitude that will no less astonish Ourselves than our Neighbours" (Hoyt 1914:156). From 1815 to 1819, Murphey prepared reports calling for a system of roads, canals, ferries, and railroads. Improved transportation facilities would decrease the cost of shipping, allowing farmers to produce more and enjoy larger incomes. These internal improvements would also “knit the state together”, making markets more accessible, both regionally and worldwide (Ready 2005:164-166). Opening the Great Dismal Swamp Canal and intracoastal highway allowed easier connection between northern states and the Cape Fear. Between 1815 and 1825, several steam engine navigation companies operated on the sounds, connecting New Bern to Elizabeth City, Edenton and Plymouth (Powell 1989:260-261).

Murphey died in 1832, and his internal navigation improvement program was momentarily stalled. Fortunately, a few years later, during political reconfiguration, Murphey’s idea of an integrated inland transportation system was used as a platform in antebellum North Carolina. Instead of producing goods that could be sold outside the state, North Carolina only produced quantities that met the needs of local inhabitants (Powell 1989:314). One industry that never failed was fishing. Powell (1989:315) notes “there were 32 fisheries along the coast while others operated in the Albemarle Sound and on the Roanoke River.”

At the onset of the Civil War, the inhabitants in the Albemarle Region were forced to participate in more than just farming and fishing. After the fall of Fort Hatteras in 1861 and the landing of Federal troops on Roanoke Island in 1862, the Confederates stationed in Albemarle Sound had no choice but to surrender or evacuate the region. The towns of Plymouth and Elizabeth City were targets for raids that included destroying property and territorial occupation. Plymouth changed hands several times but the Union maintained control over much of eastern North Carolina for the Civil War’s duration. In 1856, the North Carolina Railroad connected west and east North Carolina, industrializing small towns along the way (Powell 1989:357-360).

At the end of the 19th century and into the 20th century, North Carolina entered a long period of resurgence. The shipping industry so prevalent before the Civil War was directed out of Albemarle Sound to Beaufort and Wilmington (Dill 1946:62). The highway system, as part of Murphey's vision, saw more transportation over roads than within waterways. Pleasure craft and smaller vernacular fishing vessels encompassed the majority of the waterway traffic (Watson 1982:44).

One way of life that persevered in several counties surrounding Albemarle Sound was agriculture and farms. Perquimans County contained corn, wheat, cotton and tobacco industries, as well as flourishing in peanut and soybean cultivation (Watson 1987:97-100). Peanuts became a cash crop for Edenton. After the lumber and fishing industries declined at the turn of the century (Daniel 1977:2), Edenton became home to the Planter's Nut and Chocolate Company in 1909 (Paramore 1967:87-89). Naval stores, as well as fishing and lumber industries, existed in Bertie County through the 1950s. Water traffic was dominated by pleasure craft or small fishing vessels, and the busy 19th century only saw the occasional appearance of a transport barge (Watson 1982:44). Beyond economic and social renewal, the state needed to regenerate its natural resources. From the end of the Civil War into the 1980s, the state had a number of goals, including controlling and limiting air and water pollution, preserving the wetlands, estuaries, beaches and historical sites, and ultimately, stopping erosion and soil loss (Powell 1989:556).

Conclusion

The geographical layout of North Carolina hindered and slowed development at first, but later became a unifying feature. The first half of the 19th century saw several improvements in North Carolina, and in Albemarle Sound. From tobacco to lumber, canals to railroads, and churches to schools, the Albemarle County inhabitants tilled the land, exploited the rivers, and spent time manipulating the landscape to their advantage. The roads, canals, ferries, bridges and railroads are the evidence of change, emerging before the Civil War, and remaining until today.

For hundreds of years, the potential of the Albemarle Region drew many settlements and the landscape has been manipulated to conform to the culture currently inhabiting the shorelines and inland areas. Not only can cultures be traced back to prehistoric times, but there is no evidence to suggest that the area was ever unoccupied once it was initially settled. This is significant in proving the area's sustainability, as well as the potential for cultural resources. The purpose of this chapter was to show how many generations have used the land and in turn, how the landscape changed over time. The next chapter will introduce the theoretical concepts that both inform and define the historical and archaeological record. These concepts are used as the foundation for the methodology and enhance the significance of promoting heritage management.

CHAPTER THREE: THEORY

Introduction

Several ideologies were prevalent throughout the early decades of the 20th century in the academic fields of social and natural sciences. These ideologies held that the natural environment and human culture were inexplicably intertwined, both defined and informed by each other. As such, complementary theories are crucial in examining patterns between a cultural and natural environment. As this thesis is a culmination of archaeological, historical, and geophysical studies, an analysis of several theories and concepts in relation to the aforementioned disciplines will be applicable. Trigger (1989:18) states that "theoretical concepts derived from geography influence archaeology, either directly or through anthropology and history." The theoretical concepts of environmental determinism/possibilism, regional site formation, and management policy with an emphasis on environmental mitigation, will be examined.

Environmental determinism was first used as a theory outside archaeology. It is a concept argued and critiqued amongst geographers and political scientists. Its significance to maritime archaeology is its ability to show a relationship between cultural heritage and the natural landscape. As this thesis aims to create exploratory models based on natural causes affecting historical and archaeological sites, environmental determinism, and later possibilism/probabilism, provides the foundational theory leading into regional site formation processes. Theories derived from other disciplines are used to strengthen the significance of this research. Environmental determinism suggests a relationship of dependency and adaptation between the landscape and human culture. Possibilism, a response to determinism, introduces human agency in relation to the codependence of culture and environment. Regional site formation goes one step further to specify the archaeological record as the cultural component and the environment in which sites are discovered as the natural component. Finally, environmental mitigation seeks to reduce environmental impact on cultural heritage, and promote coastal and cultural heritage protection. Mitigation is used as the final plan to manage and perhaps protect cultural resources from impending natural processes. It is further detailed through the field research of Robinson et al. (2010), wherein archaeological sites on the Georgia coast are documented and prioritized for management purposes. This research will be detailed later in this chapter, as will each theory in relation to its research importance. The first concept, environmental determinism, is mentioned in Bruce Trigger's (1989) *A History of Archaeological Thought*, wherein its transition from geography to archaeology is revealed.

Environmental Determinism, Possibilism, and Probabilism

The systematic study of cultural variation is rooted in defining geographical patterns (Trigger 1989:122). Interest in the relationship between human societies and their environmental settings encouraged an analysis of paleoenvironments and the adaptation of cultures to their environments. It has been suggested that the environment limited adaptation potential, and therefore the natural environment determined human choices. In archaeology, environmental determinism is associated with interest in the relationship between a culture and its environmental setting, encouraging a functional view centered on human behavior (Trigger 1989:250). Within geography, and before adoption of the view by archaeologists, this theory grew from a much narrower definition.

Environmental determinism is the view that the natural and physical environments determine culture. It was founded in the late 19th century by German geography professor Friedrich Ratzel, who was initially fascinated by Herbert Spencer's perspective on Darwin's theory of natural selection (Hardin 2009:9-10). Eventually, geographers started to discuss the merits of studying human geography in relation to habitable space. The initial concept of environmental determinism received attention in many countries but the semantics caused critique of and eventual opposition to, the theory. The biggest argument is that human nature is not strictly or certainly defined by stimulus-response or cause-effect relationships (Hardin 2009:11-12).

Coined as a term only in the late 19th century, environmental determinism had been argued since the days of Hippocrates (460 BC – ca. 370 B.C.). Hippocrates investigated human ailments aiming to find a cause for sickness. In Part Three of *On Airs, Waters, and Places* (400 B.C.)**,** Hippocrates recorded the cause and effect relationship using variable treatments, determining that the nature of a particular culture and its behavior were associated with environmental attributes (Adams 2009:5). His "shrewd observations about the geography of disease and the role of the environment in shaping the health of a community" were incontrovertible (McGovern 2002:730). Hippocrates portrayed a city exposed to hot winds, and went on to describe the many illnesses of the inhabitants, concluding that "disease is connected with the change of the seasons" (Adams 2009:5). The concept of climate affecting individual cultures was widely accepted for centuries, and built upon to include other natural environmental aspects. Hippocrates is credited as a pioneering figure in human ecology, leading others, like Friedrich Ratzel, to research the interrelationship of organisms to their environments (Hardin 2009:47-48).

Friedrich Ratzel viewed the natural environment as the "prime mover that generated human activities, social paradigms, as well as human adaptations and responses" (Hardin 2009:57-58). He believed in "geographic influences on the course of history" (James and Martin 1981:170), and found similarities between organisms in nature and human culture (Hardin

2009:76). Ratzel furthered his views by declaring that interactions between the inhabited world and the natural environment "increased in complexity and sophistication as human societies progressed to higher levels of development and urbanization" (Hardin 2009:77). Ratzel believed that the "cultural environment itself, including religion, linguistics, and ethnicity" directed human activity (Fuson 1969:101). He emphasized the significance of mountains, rivers, and other bodies of water and discovered that settlement patterns and population migrations could be inferred from their proximity to such natural resources (Dickinson 1969; Hardin 2009:80).

In Germany, Ratzel's views and lectures on environmental determinism went largely unnoticed in geography but the underlying principle became a major influence on Hitler's belief that Germany had the right to dominate weaker nations. *Lebenstraum* or *living space*, was a term used by Hitler to justify the mass genocide of many different cultures as well as conquering neighboring countries (Hardin 2009:79). In the United States, the fundamental definitions of environmental determinism were interpreted by Ratzel's protégé, Ellen Semple and another scholar, Ellsworth Huntington.

In the early-20th century, determinism was first used to argue that race was a response to the inhabitant's environment. In his *Character of Races* (1924), Huntington agreed and expanded on Hippocrates theory, arguing that "racial character was spatially referenced" and that civilization was heavily influenced by climate (Huntington 1924:225-226). Huntington's publication dealt mainly with the race consciousness, the idea of human choice being pre-determined by racial features attained from living in specific environments. Huntington's theory was widely accepted for many years as the theoretical concept of environmental determinism dominated the discipline of geography (Gallagher and Shirlow 2009:2).

Following the example of Huntington, Ellen Semple attempted to clarify the relationship between climate and culture while furthering the discussion on the limitations of this argument. Semple's methodology was based on the teachings of her mentor, Friedrich Ratzel. In her publication, *Influences of Geographic Environment* (1911), Semple stated that "…a people may present at any given time only a partial response to their environment…", indicating that there are other contributing factors to cultural evolution (Semple 1911:44). Furthermore, she concluded that:

> man can no more be scientifically studied apart from the ground which he tills, or the lands over which he travels, or the seas over which he trades, than polar bear or desert cactus can be understood apart from its habitat. Man's relations to his environment are infinitely more numerous and complex than those of the most highly organized plant or animal. So complex are they that they constitute a legitimate and necessary object of special study… (Semple 1911:204).

Semple was cautious to delimit her argument of geographical influences, so as not to restrict any other interpretations. Where Huntington strictly believed that environmental factors were responsible for human culture, Semple argued in favor of a combination of factors, including but not limited to, environment and adaptive human behavior (Semple 2010:40). One example of this can be seen in the use of mountain passes by robbers. As travelers were forced to travel through mountain passes as a result of an area's morphology, freebooters were able to make a living off those travelers by camping in the mountain passes. Known as *marginal land theory*, this example showed that the environment could pose limitations on human activities that force some kind of adaptation and determinism, like living in the mountains to make a living off frequent travelers (Beck 1981; Hardin 2009:78).

The fundamental argument of environmental determinism, that geography influenced the behavior and culture of a particular society, was quickly criticized in other fields during the 1920s. The argument was to replace "environmental determinism" with a term that more aptly described its meaning without strict definitions. The belief that humans were strictly defined by their environment was argued against by French geographer Paul Vidal de la Blanche. Following Semple's line of thought, de la Blanche stressed "interdeterminacy as the dominant feature of cultural change" and introduced the new concept of possibilism (de la Blache in Trigger 1989:250). It was de la Blache's intention to revise geography to include other disciplines, like his own educational background in ancient history, classical literature, Greek geography, and archaeology (Hardin 2009:94). Even though he recognized a connection between humankind and their environment, de la Blache distinguished that "the way man reacts or adjusts to these given conditions depends on his own traditional way of living" (James and Martin 1981:190). This, he argued, was not determined, but rather, possible, or probable.

The geographical theory of environmental possibilism implies that the environment can set limitations for cultural development but does not, on its own, define that culture. Instead, humans make decisions in dealing with environmental limitations and those decisions define that culture. As can be seen in the Albemarle, the earliest European settlers initially followed the Native American lifestyle. The landscape limited their economic potential to fishing and agriculture, thus defining their economy as a maritime and agrarian focused operation. As technology grew and populations headed west, the inhabitants around Albemarle Sound responded by growing cottons, fur, corn, and lumber, for export and prosperity. By the 20^{th}

century, overland transportation bested maritime transport, and the Albemarle Sound returned to the simple maritime and agrarian centered operations of their roots.

The main arguments against environmental determinism were essentially embedded in semantics. The use of the term *determined* implied a precise and unwavering definition with no chance for misinterpretation. The progression from strict environmental determinism to possibilism helps show how environment could affect the characteristics of a society, but does not imply that it is the only cause. The shift from environmental determinism to possibilism, from a solid theory to a general idea, can best be summed up by Gerald Hardin's (2009:30) dissertation entitled *Environmental Determinism*: *Broken Paradigm or Viable Perspective?:*

> Environmental determinism was once viewed as a purposeful way of studying human development in relationship to environmental conditions. It was an idea that questioned the consistency of an environment, what was meant by determinism, what was nature, what was human nature, and what environmental conditions were relevant to human behavior?

Environmental determinism was also heavily criticized by archaeologists, especially by post-processualists, who argued that determinism overlooked human agency. In Matthew Johnson's *Archaeological Theory* (1999), post-processualists argued that a human being has agency, effectively negating the preconceived notion that stimulus-response is pre-determined. Post-processualists contend that human agency refers to the "active strategies of individuals…arising from conflict" and thus the necessity to bend the rules. The implication is that humans are not controlled by the system around them but rather knowingly bend and manipulate their surroundings (Johnson 1999:103-104). It is along this line of thought that the encouragement of "experimentation with multiple interpretations" leads into site formation processes from possibilism (Johnson 1999:106), and more specifically, regional site formation theory and its conceptualization in the works of Keith Muckelroy and Michael Schiffer.

Regional Site Formation

In the latter half of the 20th century, Keith Muckelroy focused attention to discussing the environmental attributes acting on archaeological remains. At the publication of Muckelroy's *Maritime Archaeology* in 1978, a study of underwater environmental archaeology in British waters became the first of its kind to study the effects of geophysical properties on archaeological wreck sites. Environmental attributes were chosen based on their significance in parallel studies in biology and coastal geomorphology (Muckelroy 1978:162). These attributes are as follows:

- Maximum offshore fetch
- Sea horizon from the site
- Percentage of hours during which there are strong winds or winds from multiple directions
- Maximum speed of tidal streams
- Minimum depth of site
- Maximum depth of site
- Depth of principle deposit
- Average slope of seabed
- Underwater topography
- Nature of coarsest material

- Nature of finest material (Muckelroy 1978: 162).

Based on available archaeological and environmental data, 20 wreck sites around the United Kingdom were chosen for comparison with the 11 environmental attributes. Muckelroy's study drew several conclusions. The first conclusion of this study was that the combination of the last three attributes was the major factor in determining the survival of underwater archaeological remains. The second conclusion was that multiple disturbing forces acting on a site are greater than the strength of any one force (Muckelroy 1978:163).

While this study was one of the first of its kind attempting to generate a predictive model in assessing geophysical stress at a given site, there were several limitations. For example, the small sample size, only 20 sites, and their uneven distribution limits the study's ability to successfully predict wreck loss in a larger geographical area (Muckelroy 1978:164-165). To remedy limitations, Muckelroy admitted the need to understand processes leading to material loss from a wreck-site, the process of wrecking, salvage operations, and disintegration of perishables (Muckelroy 1978:165). These three processes are examined in detail in Muckelroy's *Maritime Archaeology* (1978), but for this study, his data on seabed movement and sediment disturbance is more applicable.

In 1978, the basic concepts for sediment disturbance were derived largely from marine geomorphology (Muckelroy 1978:176). Conclusions, drawn from the same 20 UK underwater archaeological sites, show that topography and sediment material (coarse or fine-grained) are the most significant attributes affecting wreck-site preservation. As sediment distribution is related to water movement, wave action must be considered. The speed and duration of any onshore wind, coupled with fetch (distance traveled) and bathymetry provide the best estimation of sediment disturbance, distribution, and shoreline erosion (Muckelroy 1978: 176).

Independent of Muckelroy, Michael Schiffer also studied environmental agents of deterioration. Schiffer (1987) stated that “the environmental processes involved in forming the regional archaeological record have to be considered” and fall under the law of “n-transforms”. The other law is called “c-transforms” (Schiffer 1987:22). “C-transforms” represent cultural formation processes, “pertaining to the behavioral and organizational properties of a sociocultural system to variables describing aspects of the archaeological outputs of that system” (Schiffer 1975:838). The “c-transformation” is normally responsible for the deposition of artifacts into the archaeological record resulting from human behavior. According to Schiffer, before an artifact enters the archaeological record, it goes through four cultural systemic stages. They begin with the artifact as a material obtained from the natural environment. When the artifact is chosen from the environment, it is modified into a useable form. Following manufacture, the object is used for a specific function, either *socio-function* (social use), *techno-function* (practical use), or *ideo-function* (ideological use). Finally, the artifact is either reused or if discarded, it enters the archaeological record (Schiffer 1972:158, 1996:14).

“N-transforms” are the interaction between culturally-deposited materials and their environment (Schiffer 1975:838). Muckelroy was one of the first to apply this concept to submerged wreck-sites. Here, “c-transforms” refer only to the final stage, entry into the archaeological record. Use of the “n-transforms” will be applicable, relating archaeological sites to their environment, the environmental processes acting on them, or depositional factor responsible.

Environmental properties being examined are wave energy derived from wind data, sediment accumulation, inundation from sea-level-rise, and shoreline composition and erosion. They will be relevant in combining Muckelroy and Schiffer’s independently conceptualized theories with Ward and Quinn's regional archaeological investigations. Whereas Keith Muckelroy discussed environmental processes acting on wreck-sites in the UK, Michael Schiffer discussed the significance of regional formation processes. Schiffer (1987:235-236) explained that correlation of physical and biological agents (climate and geology) "determine specific precipitation regimes, types of storms and prevailing winds, erosion and sedimentation patterns".

The theoretical concepts devised by Muckelroy and Schiffer have been recently tested. Ingrid Ward researched geophysical processes acting on the *Pandora* wreck in Australia (Ward 1999; Ward et al. 1999). Starting with Muckelroy's flow diagram representing the evolution of a shipwreck (Muckelroy 1978:158) (Figure 3.1), Ward expanded it to create a more current model measuring the rate of wreck disintegration (Figure 3.2). Ward determined that the rate of wreck disintegration was equal to the sum of the physical, biological, and chemical processes (Ward 1999:562-566). Ward's study specifically measured current speed and direction, directional wave, tide, and current gauge, regional winds, and sediment collections from grab samples and a single vibracore (Ward et al. 1999:43-44). Ward measured these physical features and was able to create a newer flow chart that indicated five stages of physical deterioration in regional site formation. These stages are as follows:

- The time of wrecking refers to current events involved the moment a wreck occurs.
- After wrecking occurs, the remains are exposed to the initial physical elements and forces, including waves, currents, and sediments.
- The remains go through episodic or continuous elements from nature. Storms and hurricanes are examples of episodic events, while waves and currents illustrate continuous events. Sedimentation rates will adjust according to the episodic or continuous event.

- The moment when the rate of erosion peaks.
- Following an extreme moment or peak, the environment returns to a low energy state favoring accumulation and redeposition of sediments (Ward 1999:566).

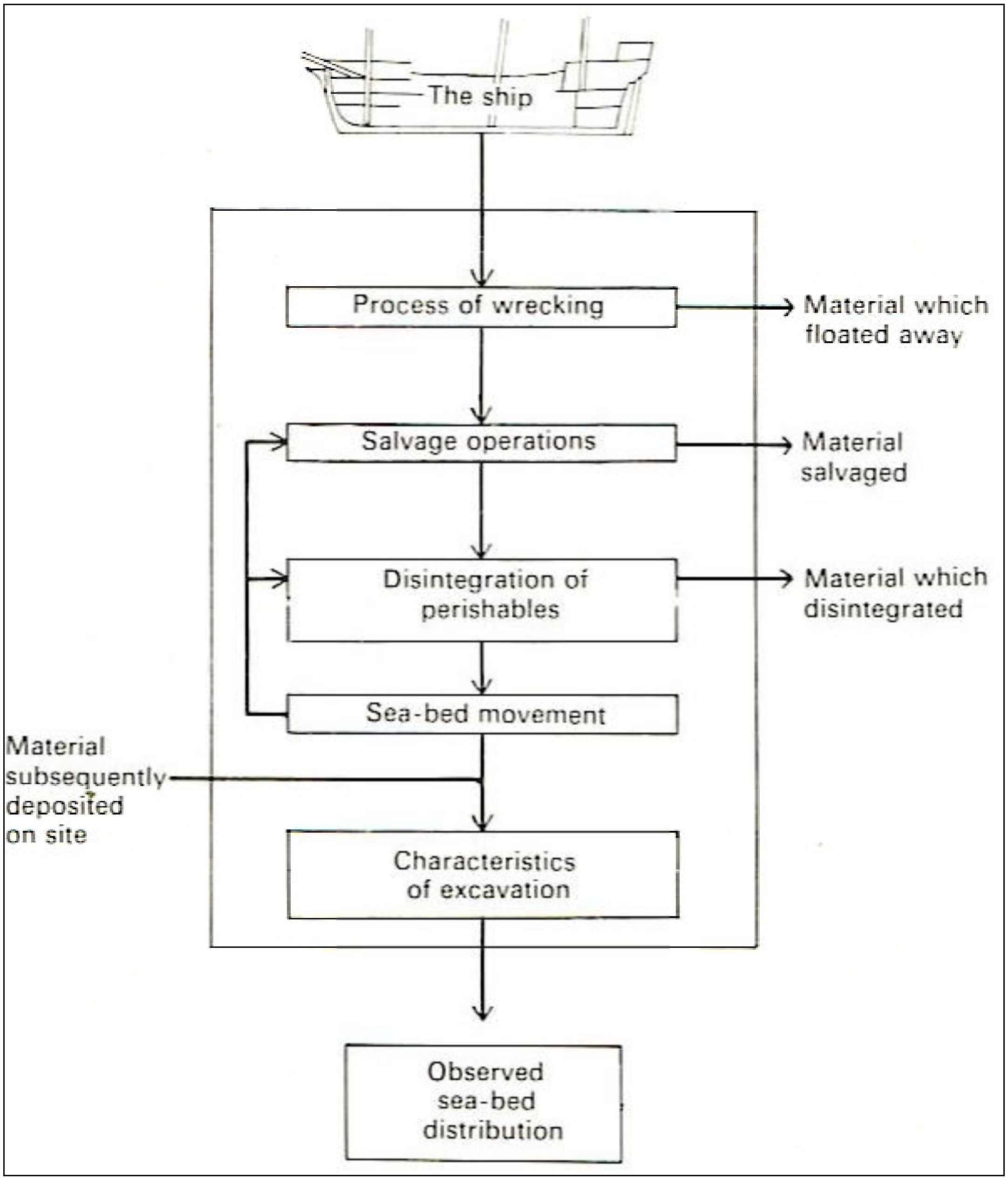

FIGURE 3.1. Muckelroy's flow diagram (Muckelroy1978:158).

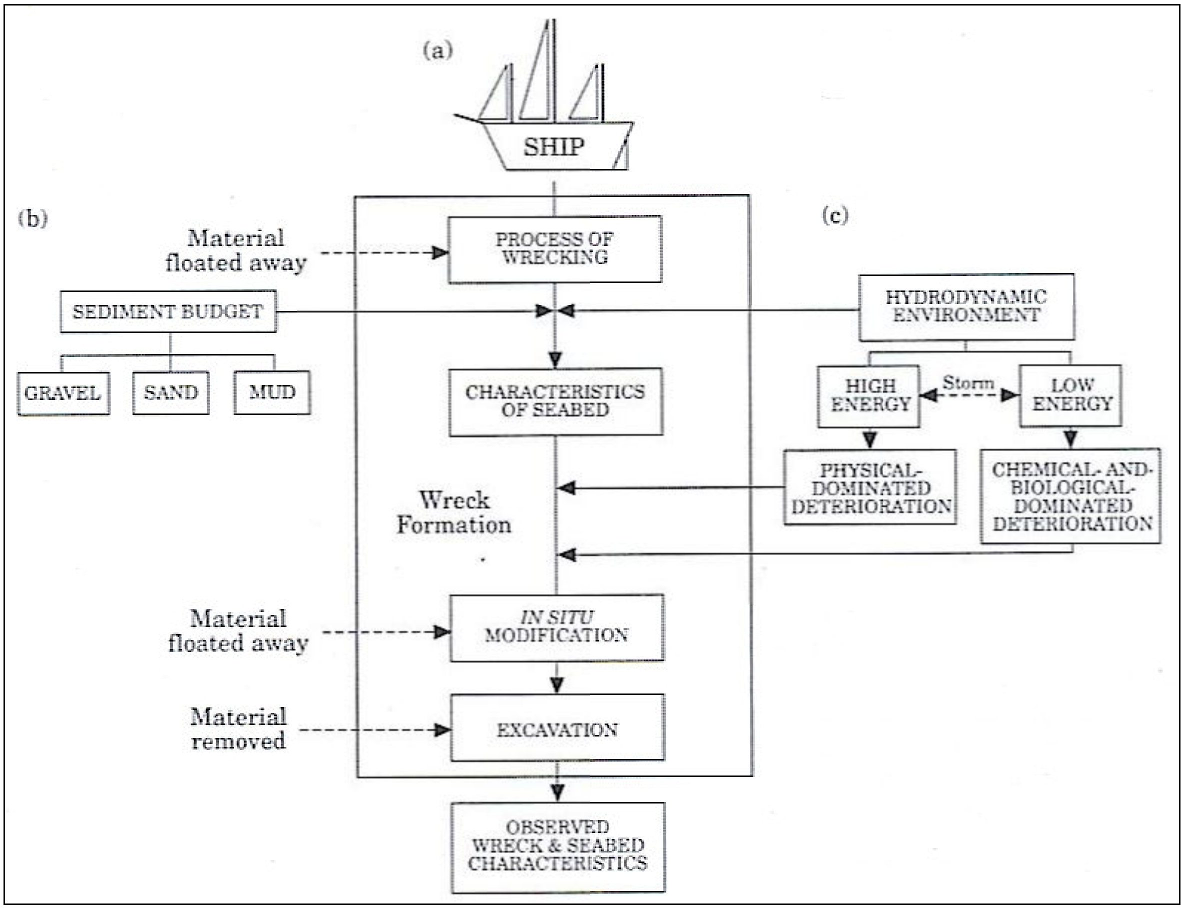

FIGURE 3.2. Ward's flow diagram, expanding upon Muckelroy's (Ward 1999:564).

Using this adapted diagram with *Pandora* data, Ward et al. (1999:41, 52) was able to conclude that wreck disintegration was largely due to sediment accumulation and removal, then concluded that "preservation of wrecks can be better predicted from an understanding of the sedimentary processes that operate in the depositional environment."

Between 1998 and 2000, Rory Quinn conducted a series of geophysical surveys over *La Surveillante* in Bantry Bay, County Cork, Ireland. The French frigate wrecked in 1797 on fine-grained substrate in a low energy environment (Quinn et al. 2002:413). This study is applicable here because Quinn interpreted the wrecking process using another flow diagram, modeled after both Muckelroy (1978) and Ward (1999) (Figure 3.3). Quinn's objective was to understand the *La Surveillante* site in relation to the underwater landscape (Quinn et al. 2002:415).

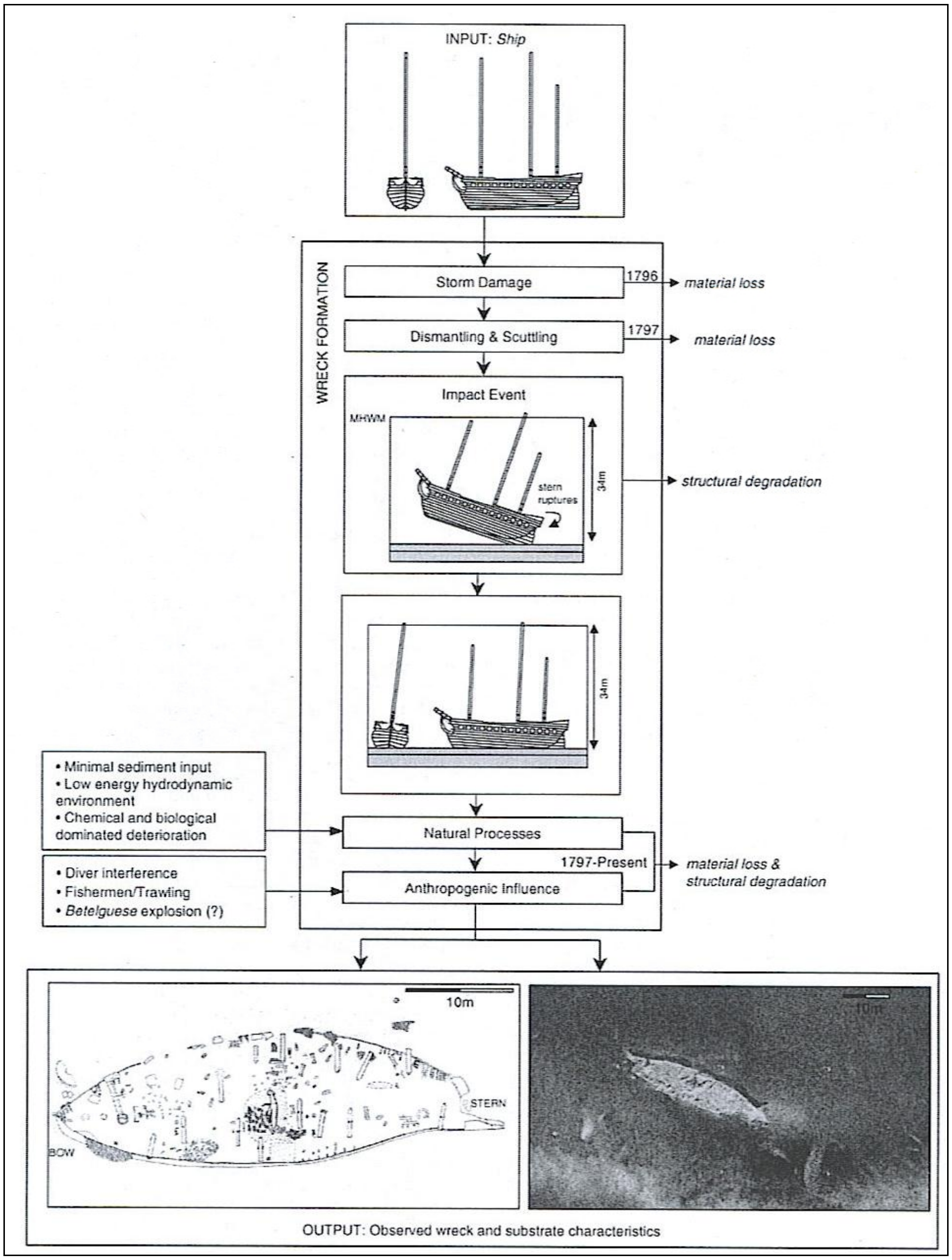

FIGURE 3.3. Quinn's interpretation of the wrecking process of *La Surveillante* (Quinn et al. 2002:420).

Equipment utilized in this survey comprised a digital echo-sounder, dual-frequency side-scan sonar, Chirp sub-bottom profiler and an Overhauser effect magnetometer. Results from the geophysical surveys allowed for a successful dive survey and site excavation in 1999 (Quinn et al. 2002:416, 421). In the *La Surveillante* situation, understanding the geophysical processes acting in the underwater environment allowed archaeologists and divers to control their time in the hostile environment.

Site Management Theory – Environmental Mitigation

Knowledge of environmental processes acting on *La Surveillante* aided dive operation planning. The scientists were able to modify their methodologies and fieldwork once they had specific knowledge of the underwater environment. A similar practice is used in several other countries where the environment proposes challenges to studying submerged archaeological remains. One such area is the Netherlands, where Thijs J. Maarleveld applied the concept of environmental mitigation to help reduce negative impacts on cultural heritage.

Maarleveld's (2003b) "Mitigation as archaeological strategy" dealt with general approaches and considerations to assuage negative influences on cultural heritage. In considering possible approaches to cultural resources management, Maarleveld sought to explain ways of reducing environmental, economic, and social impacts on sites and then exploit those sites "to the benefit of the resource" (Maarleveld 2003b:135). Maarleveld admitted it is impossible to stop earth moving processes that cause serious threats to cultural heritage, but it is possible to control management and planning related to protecting the area (Maarleveld 2003b:136).

Maarleveld's two-policy approach affects protection of both known sites and currently un-surveyed sites with archaeological potential. For known sites, protection is relatively straightforward. Planning procedures can treat the sites, preserving and conserving their value through time. The second approach becomes more difficult, as its aim is to protect an entire region that possibly contains buried sites. These sites are often discovered in areas of sediment accretion (Maarleveld 2003:136). In this policy geological surveys become the basis for mitigation.

One such geophysical survey took place on the Georgia coast, to prioritize coastal archaeological sites based on their potential loss due to shoreline erosion. Michael Robinson, Clark Alexander, Chester Jackson, Christopher McCabe, and David Crass (2010) used Geographic Information Systems (GIS) to spatially map 21 archaeological sites potentially susceptible to shoreline erosion (Robinson et al. 2010:316). This project's aim was to document sites before they were lost in hopes of recording historical and archaeological information. These sites "could provide important information for interpreting and managing sites" but are located where natural processes are erasing them from existence (Robinson et al. 2010:312). As such, it is important to identify zones that are rapidly eroding in hopes of establishing some protection and mitigation of coastal cultural heritage. In doing so, "the immediacy of erosion threats can be prioritized into a list of sites that are in danger of, or are presently, being lost to erosion" (Robinson et al. 2010:314). This understanding of historic shoreline erosion rates enabled researchers to interpret settlement patterns along the coast, providing a justification for cultural response to environmental change (Robinson et al. 2010:315).

The Georgia research also enabled the authors to "prioritize a list of sites based on the order of site loss from erosion, [assisting] coastal managers in identifying and documenting sites most at risk" (Robinson et al. 2010:312). The capability to prioritize archaeological sites can aid in situations where funding is low and budgets are strict. Instead of excavating entire sites, small shovel tests can be performed to identify site boundaries on the changing shoreline. Sites that are most at risk, or have high archaeological significance, can then be given priority over lower risk sites. Robinson et al. (2010) then conservatively created a prioritized list of archaeological sites for the Georgia Historic Preservation Division. Their study also discovered more archaeological sites with high information potential on the low-lying back-barrier islands. Extending this methodology to the entire region could produce an even greater planning strategy for cultural heritage management (Robinson et al. 2010:322-325).

A geological evaluation aims to both identify the formation sequences and distinguish the paleoenvironmental conditions. Both can be better evaluated using historical geographical data. The historical record can include geographical histories, nautical charts, and tidal maps (Maarleveld 2003:123). In Dutch waters, preservation quality is based on the following attributes that lead to an anaerobic environment: subsiding subsoil, rising sea-level, and fine-grained soft sedimentation. Attributes are monitored for short-term change and Maarleveld believes this study is the first approach to protecting un-surveyed sites (Maarleveld 2003a:124-125).

Conclusion

By actively mapping change that occurs in a given region, patterns can begin to emerge. Patterns can be discovered by ascertaining individual processes currently acting on a site. As patterns begin to emerge, predictions can be made. Predictive models, according to Maarleveld, can be a useful tool in developing archaeological heritage management (Maarleveld 2003:121). Predictive modeling can apply to both sites that are known to exist and those zones that have the potential of archaeological information.

The concept of predictive and exploratory modeling is the basis for this study, as the cultural heritage of the Albemarle Region rests in an area that is constantly changing. The following chapter details the historical, archaeological and geological studies used in evaluating zones that are constantly changing. Multi-disciplinary resources are invaluable to this study and are described in detail as to the extent of individual results as well as how they relate to one another.

CHAPTER FOUR: METHODOLOGY

Introduction

Following the theoretical framework set forth in the previous chapter, research for this paper is divided into two groups: cultural (historical and archaeological), and geological. Historical research shows the maritime economy's development throughout Albemarle Sound after European settlement in the 16^{th} century. Archaeological research and past fieldwork provided data about the wide variety (prehistoric to historic) of sites within the Albemarle Sound shore zone. Geological research shows natural processes that occurred in and around the Sound over the past few hundred years, including wind and wave activity, current speed and direction, salinity change, temperature fluctuation, sediment accumulation, erosion rates, and inundation patterns from sea-level-rise. Finally, geospatial analysis of archaeological and historical site locations in relation to geological activity reveals what natural processes are potentially damaging sites throughout the Albemarle Estuarine System.

A brief history was essential to provide a framework for the social, political, economic patterns, and events that show development of Albemarle Sound as a maritime economy through time. Research identified both a progression of the region's maritime and agricultural economy as well as social behavior impacted by political events and geographical space. This thesis is heavily dependent upon previous research. As such, a detailed description of all sources utilized is necessary both for explaining the values extracted as well as the significance of pre-existing datasets. The previous research done for the historical and archaeological aspects of this thesis are examined, followed by geological data.

Previous Historical and Archaeological Research

Research within the Albemarle Sound and Albemarle Estuarine System has taken place in many disciplines, including geography, geology, political science, anthropology, and history. The historical record is extensive and well documented. The archeological record both informs and defines the historical record. Numerous books (Powell 1958, 1989; Butler and Watson 1984; Ready 2005), historic papers (Hoyt 1914; Higginbotham 1976; Jackson et al. 1976; Clark 1994; Saunders 1994), and newspaper articles provided insight into everyday life and, in some cases, patterns of living around the Sound. East Carolina University's Joyner Library maintains a section of the library devoted entirely to North Carolina history. Defining the social, political, and economic development of the Albemarle Region was crucial; the availability of several types of resources was invaluable. Primary and secondary sources established historical trends in the Albemarle. The historical record proved to support the archaeological record, which in turn, strengthens interpretation of Albemarle Sound's entire past.

North Carolina Office of State Archaeology and State Archives

The North Carolina Office of State Archaeology and the State Archives provided invaluable primary historical resources as well as prehistoric and historic archaeological site surveys. The State Archives provided all the primary documents in the form of government papers, county specific records, and local newspapers. The Office of State Archaeology contains all records for eastern North Carolina archaeological site surveys. The records are available by county or geographic quadrant. If applicable, archaeological surveys, coupled with environmental surveys, provided the most thorough examination of any given site. When available by site survey, the following information was collected for this thesis: county number, bibliographic references, site component (prehistoric and/or historic), quadrant map (unrelated to county lines), map zone and datum (18 UTM NAD 27), spatial orientation (easting and northing), date the site was recorded, environmental components, and cultural components. The significance of these entries is explained later in this chapter.

Program in Maritime Studies - East Carolina University

Graduate students in the Program in Maritime Studies at East Carolina have collaborated in research projects, resulting in the current Albemarle Sound Cultural Landscape Database (ASCLD). Under the direction of Dr. Nathan Richards, three master's students have compiled detailed information on 243 wrecks in the Albemarle Estuarine System. The wrecks are located from the upper Roanoke River to Elizabeth City. Franklin Price was the first to research patterns of shipwrecks and abandoned vessels in the Roanoke River, culminating in an MA thesis, *Conflict and Commerce: Maritime Archaeological Site Distribution as Cultural Change on the Roanoke River, North Carolina* (2006). This study statistically documented geo-spatial patterns of shipwrecks and abandoned vessels only within the Roanoke River, resulting in the initial Roanoke River Database. By collating historical resources with archaeological data, Price showed evidence of cultural change through the assemblage of shipwrecks and abandoned vessels.

At the close of Price's fieldwork, the National Oceanic and Atmospheric Administration (NOAA) awarded an Ocean Exploration Grant to East Carolina University. This grant was used to expand upon Price's database by evaluating possible cultural resources in the Perquimans River as well as a reevaluation of sites in the lower Roanoke River. Remote-sensing was performed in 2005 during an ECU field school, and during an underwater archaeological investigation of the Roanoke River near Plymouth, North Carolina, by Richard Lawrence in 2003 (Lawrence 2003). Following these field operations, Lawrence Babits, Nathan Richards, Frank Cantelas, and J.P. Walsh conducted additional surveys of these rivers in 2006. These surveys led to two other master's theses, first by Adam Friedman, and the second by Amy Leuchtmann.

Friedman's thesis, *Illicit Trades: The Role of Legality and Geographic Convenience in the Patterning of Maritime Commercial Activities on the Roanoke River, North Carolina*, completed in 2008, studied "themes related to the role of industrial legality as a patterning force on the cultural landscape of the Roanoke River" (Friedman 2008:1). Friedman's fieldwork and analysis of statistical and spatial information through additional remote sensing furthered the records in the Roanoke River Database.

Amy Leuchtmann studied the evolution of maritime trade occurring on the Pasquotank, Perquimans, Chowan, Roanoke, and Scuppernong Rivers. This thesis was designed to examine the shift from Albemarle's maritime centered trade to predominantly terrestrial trade while using the archaeological record to determine if it "reflects, refutes, or redefines the region's economic evolution as it is generally accepted in the written history" (Leuchtmann 2011:152). Leuchtmann discovered that the archaeological record did reflect the historical record, and this is evident in two major conclusions. Using geo-spatial and statistical analysis, Leuchtmann discovered that the heaviest losses of watercraft coincided with the Civil War. This was also the last peak of maritime shipping, before the construction of and heavy reliance on railroads and highways. The economic shift revealed a decline in water transportation, reflecting a decline in vessels lost by the 1930s (Leuchtmann 2011:153-154). Her conclusions confirmed the idea that the archaeological record can complement the historical record. By extending the study to the tributaries of the Albemarle Sound, the previously named Roanoke River Database was changed to the current Albemarle Sound Cultural Landscape Database. All encompassing, this database includes remote sensing surveys (side scan sonar, magnetometry, and multibeam sonar), visual inspection, terrestrial archaeological research and historical research.

The ASCLD exists in a Microsoft *Access* Relational Database with information pertaining to 243 wrecks. A separate record exists for each wreck, containing information on the following attributes: name, identification number, Underwater Archaeology Branch (UAB) number, area, date of build, geographical location of build, rig type, propulsion, hull type, deck, masts, function of loss, function of use, cargo, loss date, home port, port to, port from, cause of loss, geographical location of loss, spatial location, location confirmation, length, breadth, tonnage, further notes, and references.

The geo-spatial information from the ASCLD is an amalgamation of verified and estimated locations. According to Price (2006:41-42), "vessel location was considered historically confirmed if the specific location of the vessel existed in the historical record…A watercraft was considered as having an archaeologically confirmed location if the vessel had been archaeological investigated". Of 243 wrecks in the ASCLD, 168 wrecks are confirmed either historically (103), archaeologically (54), or confirmed by both historical and archaeological records (7). This leaves 50 unconfirmed wrecks though they may have general historical or archaeological references. The remaining 25 wrecks are completely unconfirmed (Figure 4.1).

The primary objective of this data accumulation was to produce an accurate map representing spatial patterning of the 243 ASCLD (Appendix A) wrecks and 50 prehistoric and historic archaeological sites from the OSA (Appendix B).

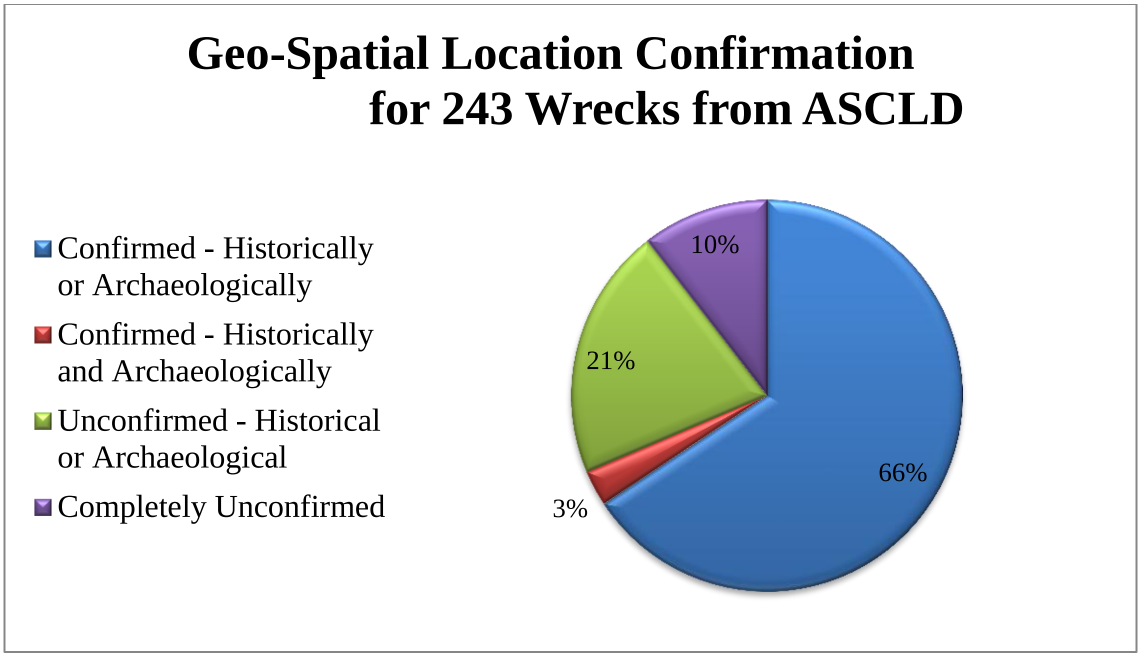

FIGURE 4.1. Chart showing percentages of wrecks with confirmed spatial location versus unconfirmed spatial location (By author, 2011).

For this thesis, only the following attributes from the ASCLD are used: name, identification number, UAB number, area, hull type, geographical location of loss, build year, loss year, and spatial location. Name, identification number and UAB number are all used as references should any person wish to conduct further research on any wreck. Area and geographical location of loss (Figure 4.2) are significant as the environments within and around the Albemarle Estuarine System are different and changing at different rates. The different environments are discussed in relation to accumulation rates and shoreline composition. Environmental processes acting on wrecks vary depending on the wreck type. Similar geophysical processes will have different reactions with different hull types. For example, in areas where sediment is accumulating around a shipwreck, methanogenic bacteria below the mud line will feed on metal-hulled and wooden ships, increasing the rate of deterioration (Rodgers 1989:335-340).

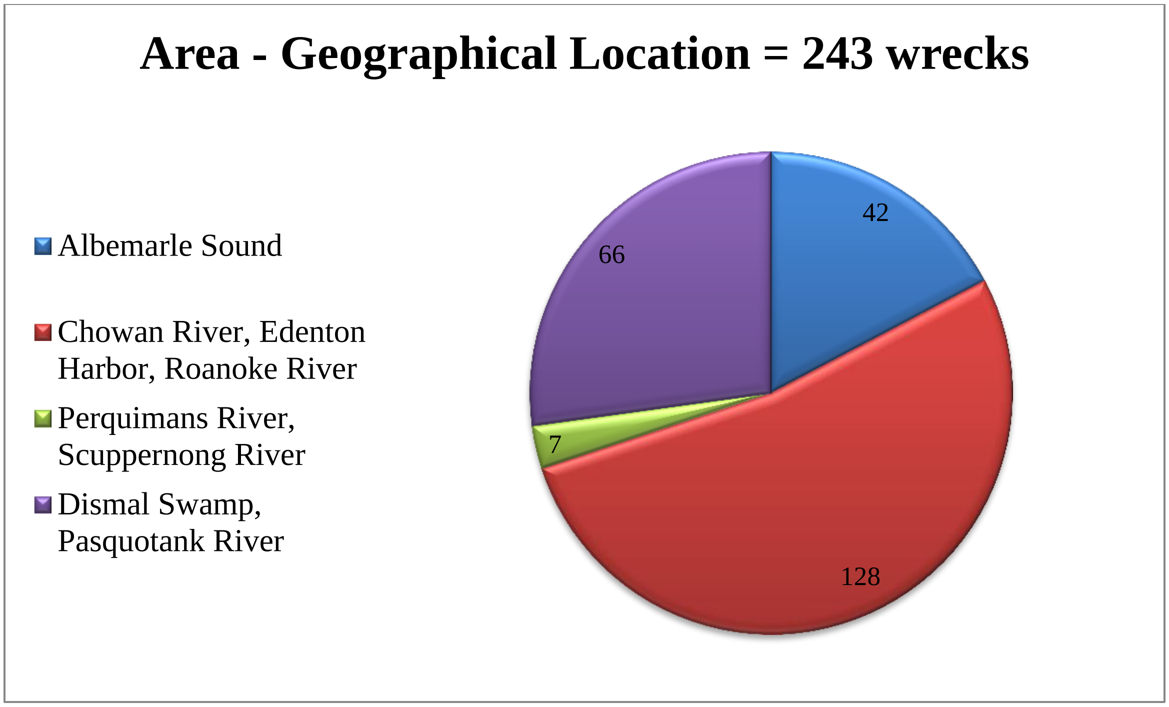

FIGURE 4.2. Chart showing distribution of geographical locations of surveyed wrecks for ASCLD (By author, 2011).

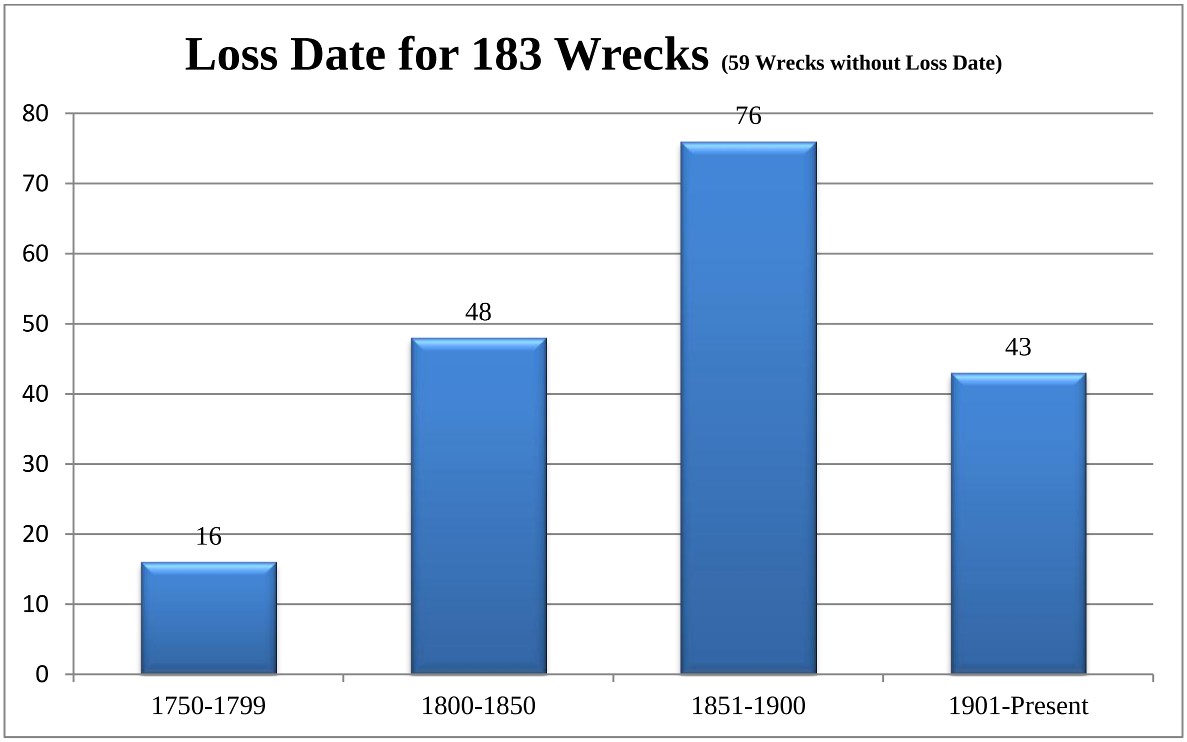

FIGURE 4.3. Chronological distribution of vessel loss (By author, 2011).

Loss year is especially important in showing the relationship of vessels lost compared to historical era when they were lost (Figure 4.3). For example, Figure 4.3 shows that 44% of the vessels were lost during the 19th century, during which the Civil War took place. According to the ASCLD, 35 wrecks were lost between 1861 and 1870, the most losses within one decade. There are 59 wrecks without a loss date. The same method was applied to OSA archaeological sites and the specific attributes were entered into a separate Microsoft *Excel* spreadsheet. County number and quadrant map are referenced to locate all information available for each specific site at the OSA. The site component gives the site's general age and in some cases, shows that a site was occupied at different periods. Map zone and spatial location are used to accurately place sites along with those from the ASCLD into *ArcGIS* shapefile (Figure 4.4).

The date a site was recorded is significant in showing the site's condition at that time. It is also a valuable reference in calculating shoreline erosion as some surveys included the distance to the water, which may or may not be the same today. The date of site survey can also be used as a seasonal reference should the site need to be revisited under similar environmental circumstances. The environmental component includes: site condition (SC), nearest permanent water type (NPWT), distance to water (DtoW), elevation (E), topographic situation (TS), drainage basin (DB), percent destroyed (%D), soil composition (SoilC), NRCS soil type code, site size (SS), destruction causes (DC), slope face direction (SFD), slope percentage (%S), modern vegetation (MV), ground visualization (GV), destruction date (DD), and soil series name. The cultural section provides the anthropological setting and site use details. The cultural information includes: cultural component (CC), lithics (L), period of occupation (PofO), site function (SF), site type/feature, historic definition, historic affiliation, ceramic temper, midden (M), tool type (TT), and other (human or non-human) (Appendix B).

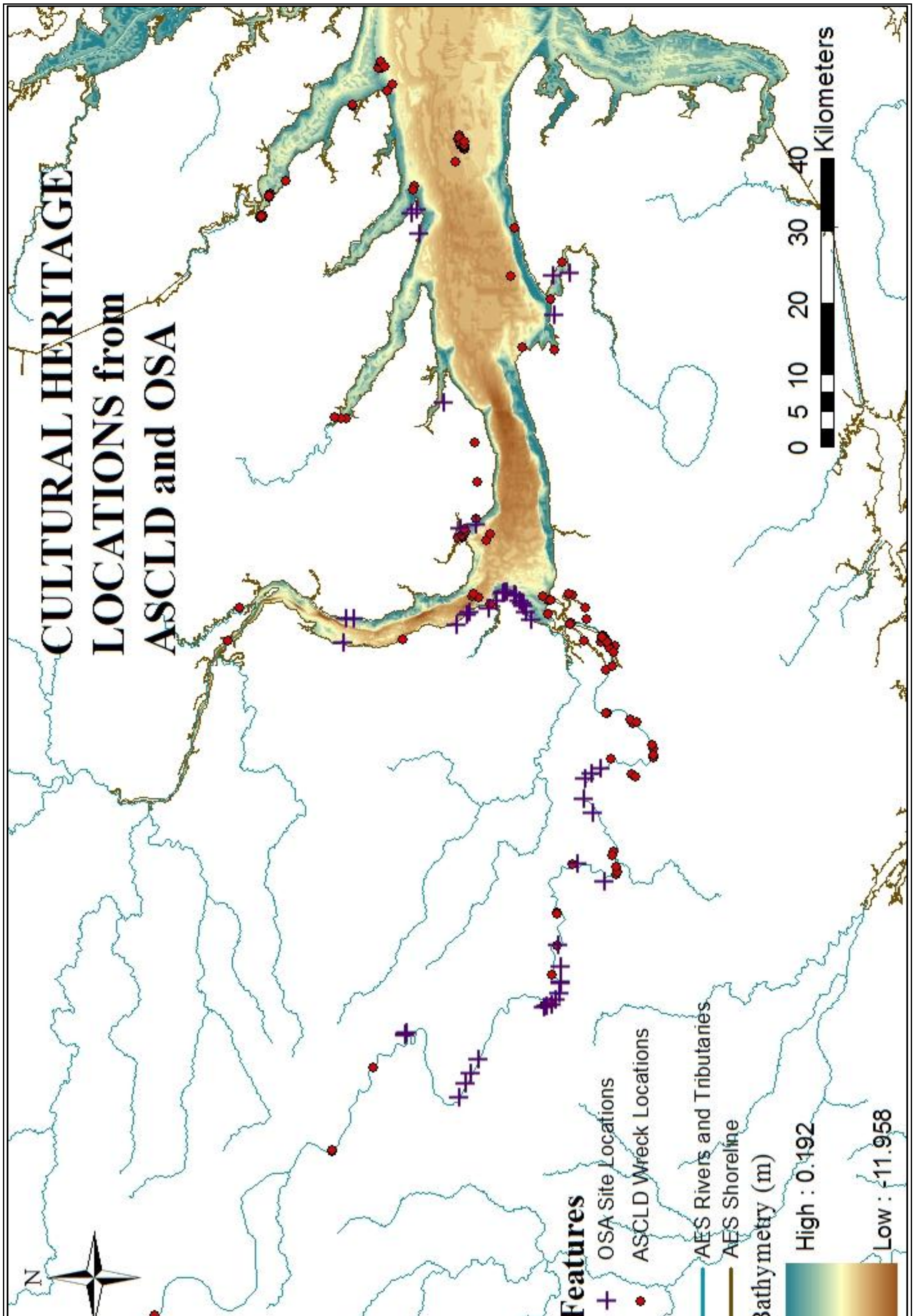

FIGURE 4.4. Location of shipwrecks from ASCLD and OSA archaeological sites, tributaries, shoreline, and bathymetry (Map by author, 2011).

Cultural and environmental components are only mentioned to show the type of archaeological sites at risk, and the tangible history of habitation around the Albemarle Region.

Problems with Archaeological Data Accumulation

There are often problems in utilizing data from varied sources. This was especially true for this thesis as some data did not include all possible information. Of information collected within the ASCLD, not all details were available for each wreck. Some wrecks only had a name and location, and more often than not, hull type was not specified (Figure 4.5). Hull type is an important variable as it can determine preservation. Since the majority of hull types are not specified, it is not considered in the overall analysis. Further inspection of sites with unknown hull types could advance the database further.

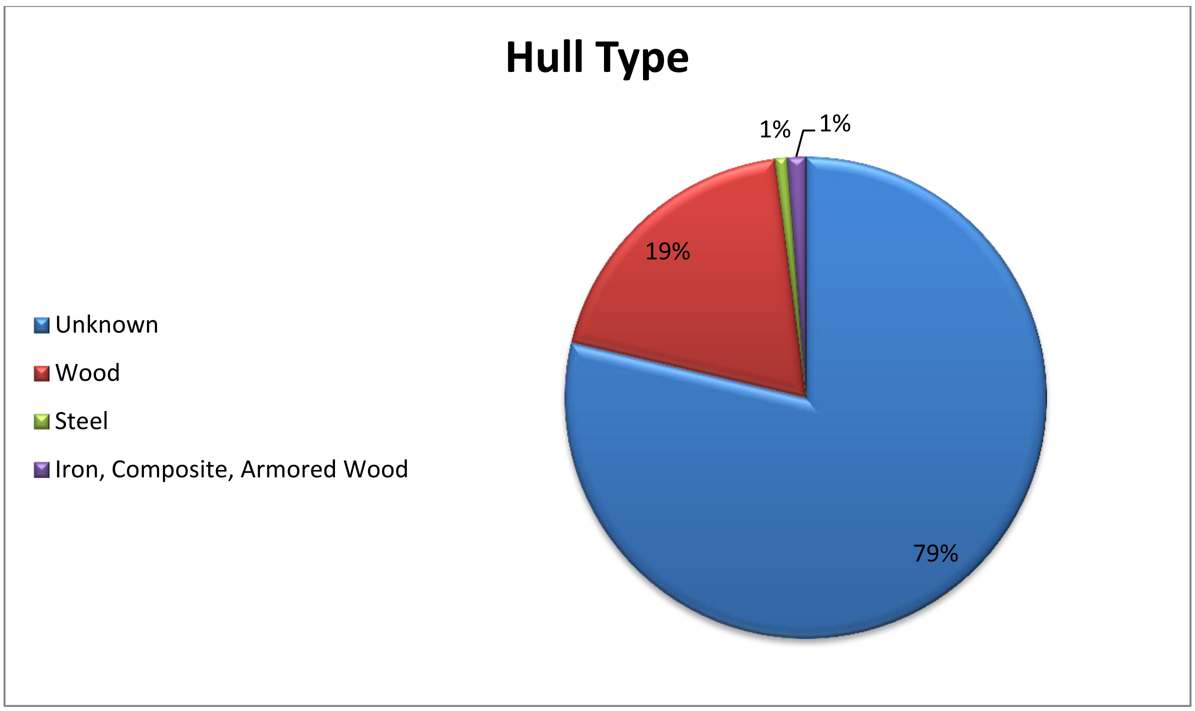

FIGURE 4.5. Percentages of hull types from ASCLD (By author).

From the OSA, some surveys did not include much environmental or cultural information but all include spatial location. The OSA site surveys were conducted during or before 1984, with the exception of one in 1990. Some sites have not been surveyed in over 20 years and are in need of current updated information. The ASCLD was created within the last 10 years, containing the most up-to-date information on these wreck sites.

Unfortunately, this very same database also posed some of the biggest problems. For example, Leuchtmann, who utilized this database for her 2011 thesis, discovered errors in formulating a research design around incomplete, yet pre-existing, data (Leuchtmann 2011:32). What would appear to be a large sample size (~243 wrecks) actually shows that 33 sites were no longer considered cultural resources due to their removal or because they were destroyed. Leuchtmann (2011:33-34) also noted that multiple researchers using a single database can complicate information within the resource, yielding discrepancies and misinformation. This was found to be the case in this thesis. The lack of information about wreck sites indicates a clear need for further archaeological fieldwork and historical research.

Previous Geological Research

Geological research and data accumulated for Albemarle Sound, the Albemarle Estuarine System, and the Albemarle-Pamlico Estuarine Systems negated any need for further fieldwork. The analysis of this data will aid in determining areas of change within the system. The previous geological research came from several sources, beginning with the United States Geological Survey/ECU/North Carolina Geological Survey, North Carolina Coastal Geology Cooperative in 2001.

United States Geological Survey (USGS) / East Carolina University (ECU) / North Carolina Geological Survey (NCGS), North Carolina Coastal Geology Cooperative (NCCGC)

In the summer of 2001, the North Carolina Coastal Geology Cooperative (NCCGC), in collaboration with ECU, the United States Geological Survey (USGS), and the North Carolina Geological Survey (NCGS), commenced research in northeastern North Carolina, including the

Albemarle Estuarine System. The goal of the proposed five-year study was to "obtain and synthesize geologic data throughout the NE-NC coastal system" (ECU NCCGC 2002:6). The area was divided into four segments, each pertaining to a work year, with Segment I beginning in July/August 2001 (Figure 4.6).

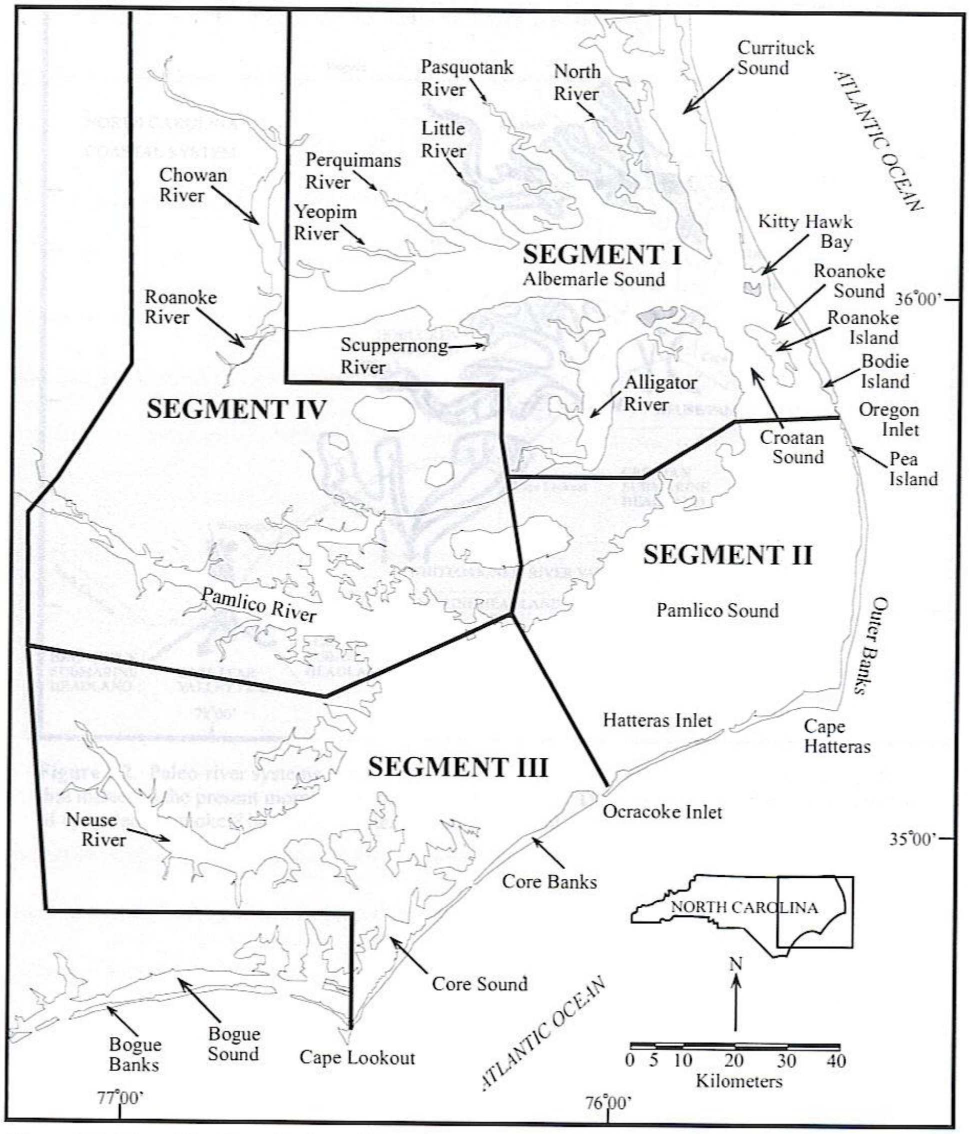

FIGURE 4.6. Map showing areas to be studied by NCCGC, beginning Summer 2001 (ECU NCCGC 2003:18).

Research in each segment attempted to "characterize all estuarine and marine environments in the system, define the geologic framework controlling the modern coastal system, and describe the modern processes that are driving ongoing coastal change" (Vance

2004:1). This collaborative effort led to several master's theses and doctoral dissertations in East Carolina's Department of Geological Sciences and are used as a foundation for this study (Murphy 2002; Letrick 2003; Vance 2004; Cowart 2009).

Department of Geological Sciences - East Carolina University

Comprehension of shoreline erosion and accumulation rates within Albemarle Sound and its surrounding tributaries is essential. ECU's Department of Geological Sciences has made their data on shoreline erosion, as well as sediment accumulation rates available for this thesis. In 2001, 20 short cores (<50cm) were taken from the AES. This project's aim was to document environmental change over the last 200+ years using geochemical, sedimentological, and micropaleontological tracers (Corbett et al. 2007:717-719). Cores were extracted and sectioned for testing carbon (^{13}C) and nitrogen (^{15}N) isotopic compositions, water content, percent organic matter (%OM), radionuclide tracers (^{210}Pb, ^{137}Cs, ^{226}Ra), and grain size (Corbett et al. 2007:719-721). The radionuclide tracers assist in understanding spatial and temporal sediment dynamics. These tracers were used in calculating sediment mixing, mass accumulation rates, and removal (Corbett et al. 2007:719). The linear accumulation rate in the western most core was high due to the junction of the Roanoke and Chowan Rivers. It was estimated to be in the range of 0.54-0.57 cm y^{-1} while more eastern cores indicated accumulation rates ranging from 0.08-0.18 cm y^{-1}. All cores averaged 0.15 cm y^{-1} for the entire AES (Corbett et al. 2007:720-722). The head of the Pasquotank River also has a higher value, accumulating sediment at 0.25 cm y^{-1} (Corbett et al. 2007:721).

Sedimentological data confirmed that grain size increased "to the east and down lateral rivers" (Corbett et al. 2007:720). Accumulation was controlled by a function of fetch and water depth; sediments within this wave-base range are more susceptible to removal and resuspension during high-energy storm events (Corbett et al. 2007:723). Micropaleontological data from the Outer Banks confirmed the rate of sea-level rise at 0.5 cm y^{-1}, indicating that sediment accumulation in the AES is shaped by both short-term storm events and long-term sea-level rise (Corbett et al. 2007:723).

Additional accumulation rate, sea-level rise, and estuarine shoreline erosion data came from a North Carolina Sea Grant awarded to Stanley Riggs and Dorothea Ames in 2003. Their project resulted in several publications and a master's thesis by Erin Letrick (2003). Information used in this thesis from Riggs and Ames (2003), Letrick (2003) and Corbett et al. (2007) was inputted into a Microsoft *Excel* Spreadsheet. The following attributes were obtained from Letrick's (2003) thesis: location, site, latitude, longitude, core length (cm), water depth (m), surface salinity, bottom salinity, surface temperature, and bottom temperature (Appendix C). The spreadsheet was then added to *ArcGIS ArcMap 9.3* and converted to a separate shape file (Figure 4.7).

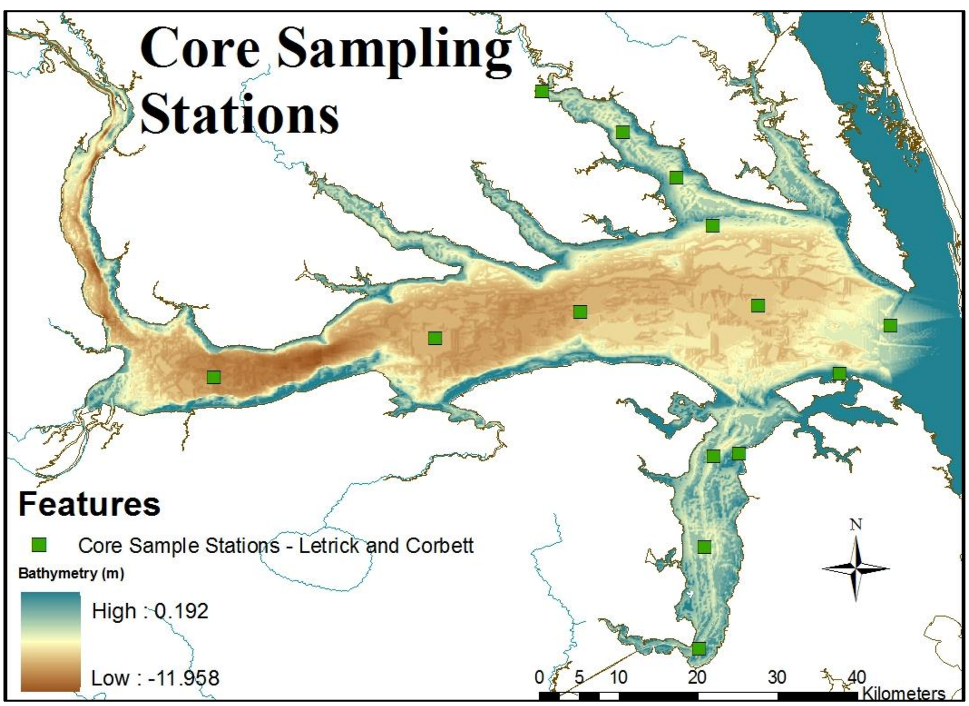

FIGURE 4.7. Geo-spatial representation of Letrick and Corbett core sampling stations, tributaries, shoreline, and bathymetry (Map by author).

When these new separate layers are added to *ArcGIS ArcMap 9.3*, all attributes for each location are available using the *Identify* tool. The significance of this tool, as well as the analysis tools available within *ArcGIS ArcMap 9.3*, is explained later. In the following chapter, these locations will be extracted by reclassifying specific attributes defined to show areas of greatest to least threat from coastal properties.

Further research was drawn from work done in the Albemarle-Pamlico Estuarine System by Lisa Cowart. In 2008, Cowart studied factors responsible for erosion at Cedar Island, North Carolina, in the Neuse River Estuary. Utilizing a point-based approach allowed Cowart a "simple, accurate, and efficient way to determine shoreline change over a large area at a high resolution" (Cowart 2008:3). Using aerial photography from 1958 and 1998, Cowart determined shoreline change rate at points taken every 50 meters (164 feet) along the shoreline. The distance between the 1998 and 1958 shoreline was divided by 40 (the number of years between the two images) to estimate the rate of change (Cowart 2008:16-18).

Cowart also measured fetch, using the Wave Exposure Modeling (WEMo) software program and discovered that erosion potential was higher in areas with longer fetches due to wave strength and power. Shoreline composition also played a major role in shoreline change. Relative sea-level rise theoretically causes marine submergence and inundation, as well as deepening and widening the estuary (Cowart 2008:9). Using fetch, shoreline composition, and aerial photography from 1958 and 1998, her analysis discovered a -0.24 m/yr^{-1} shoreline change for Cedar Island, and determined that 88% of the shoreline was eroding, 2% was stable, and 10% was accreting (Cowart 2008:10, 16-18).

Problems with Geological Data Accumulation

Utilizing results from another researcher's field work presents problems. It is usually better to collect one's own data, but sometimes, cost and time limit the ability to complete first-hand fieldwork. As this thesis utilizes data from several studies, error can play a small part. For example, Murphy's (2002) study remapped sites from Hardaway (1980) and added an additional five sites along the Albemarle-Pamlico shoreline, and six sites along the back-barrier shorelines. Upon further investigation by Riggs and Ames (2003), it was discovered that Murphy had problems with resolution in scanning aerial photographs and faults in procedure for georeferencing those photos and digital shorelines. As such, Riggs and Ames were compelled to carry out a reanalysis of Murphy's study sites (Riggs and Ames 2003:144).

Reevaluation of any person's fieldwork can yield discrepancies in results. Therefore, for this study, all estimates from data obtained from outside sources are considered carefully and conservatively. The aim here is to create exploratory models by mapping areas of potential risk and to identify what sites might be affected. As such, conservative estimates will suffice, but further fieldwork could yield results that are more accurate.

Analysis

The final stage in deciphering areas of greatest threat to archaeological sites within the Albemarle Estuarine System was combining shoreline erosion, accumulation rates, and Representative Wave Energy (RWE) in *ArcGIS ArcMap.* Individual parameters for each natural process were then defined, based on conservative values, and the relationship determines risk. Inundation from sea-level rise was inferred from both previous research and DEM calculations. The values chosen are further discussed in the next chapters.

The first sources of information and the basic research were the NCCGC and Department of Geological Sciences. The second source of information specifically pertaining to Albemarle Sound is publicly available and comes from the National Oceanic and Atmospheric Association's (NOAA) website. This information includes: Light Detection and Ranging (LiDAR), Wave Exposure Models (WEMo), National Climate Data Center (NCDC), National Data Buoy Center (NDBC), the National Geophysical Data Center (NGDC), and the Coastal Services Center Digital Coast (CSCDC). All information was inputted and analyzed using ESRI *ArcGIS 9.3*.

NOAA Public Data

LiDAR is currently being used by the North Carolina Floodplain Mapping Program to generate the most up-to-date digital elevation data for analyzing flood hazards. By emitting timed pulses of laser light from the air to the ground and then measuring the time between those pulses as they are reflected from the ground, a very precise topographic map can be created. LiDAR was used in conjunction with DEMs in analyzing the terrestrial landscape of the Albemarle Region to show areas of possible flooding from relative sea-level rise (Figure 4.8).

ESRI *ArcGIS 9.3*

ArcGIS 9.3 is a software created by ESRI that integrates data types from several sources, enabling the user to display the information and conduct complex analyses. The benefit of *ArcGIS*, or any geographic information system (GIS) is its capability to capture, store, query, analyze, and display data. One of the useful things it can do is identify specific features in a spatial context, or in relation to one another. The maps that have been rendered for this thesis all individually identify specific attributes.

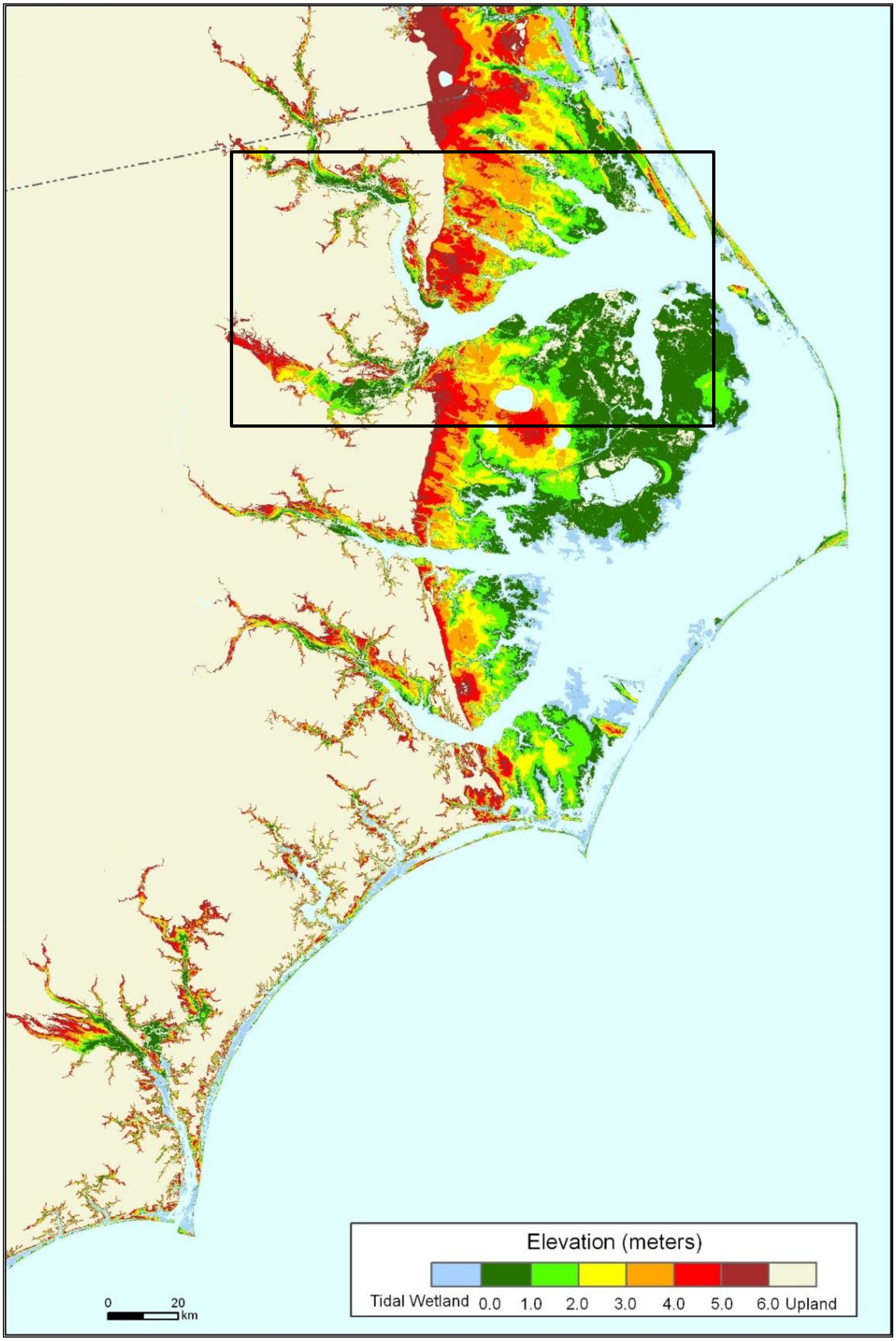

FIGURE 4.8. LiDAR image for coastal North Carolina (Titus and Wang 2008).

For example, the information that is input into Microsoft *Excel* file can be made available within that map's data layer. This helps a user to understand where features of interest lie and what characteristics are associated with them (Figures 4.9, 4.10, 4.11).

Within *ArcGIS*, the following applications were used: *ArcMap*, which visually displayed the data*; ArcCatalog*, which organized and managed GIS data*;* and *ArcToolbox*, which stored data conversions, coordinate systems, and projections. The benefit of storing data in GIS is that any information can then be selected from defined parameters and represented in other geo-spatial or statistical analyses.

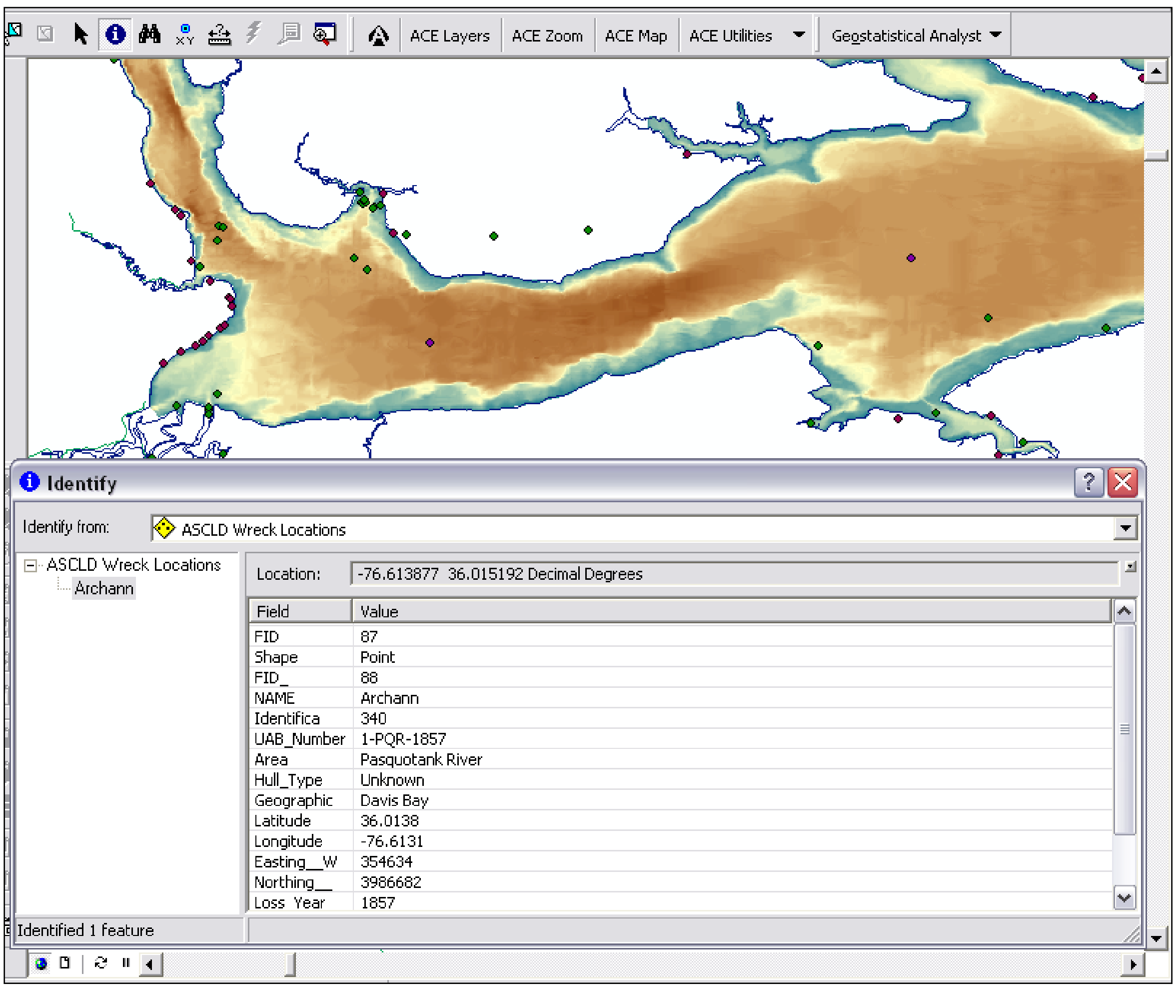

FIGURE 4.9. Identify drop-drown screen, showing available information for each ASCLD points (By author, 2011).

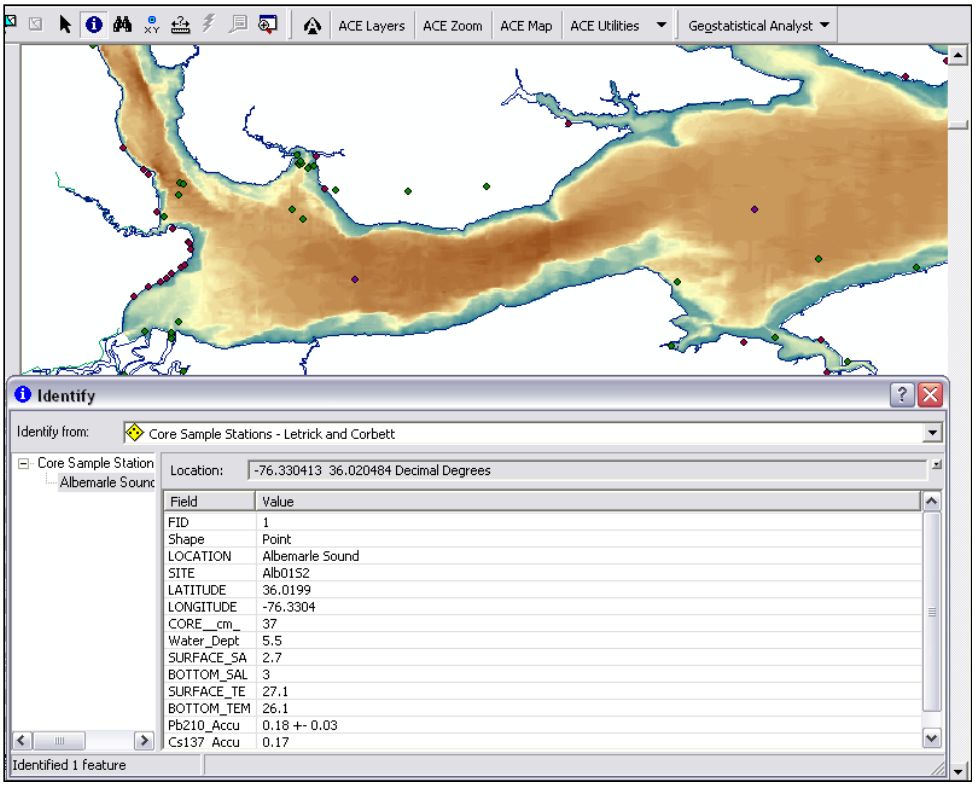

FIGURE 4.10. Identify drop-drown screen, showing available information for each core sample station (By author, 2011).

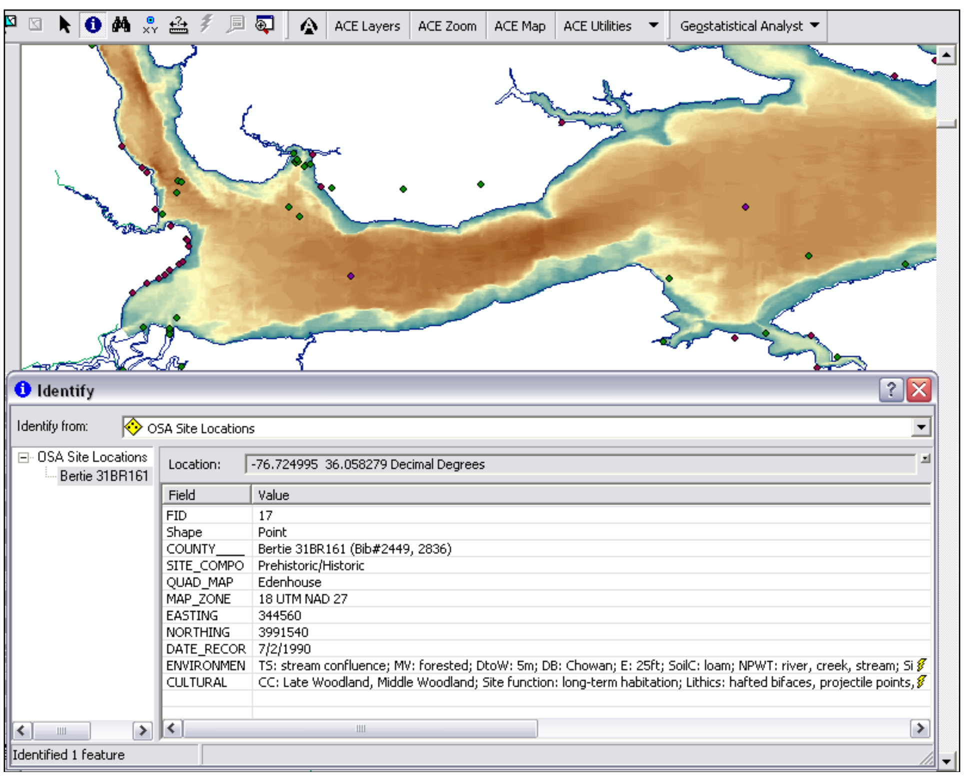

FIGURE 4.11. Identify drop-drown screen, showing available information for each OSA point (By author, 2011).

Tools used in GIS aided in selecting attributes that defined areas of high to low sensitivity based on measured geophysical features. By extracting historical/archaeological data within zones, sites susceptible to these properties were identified.

Wave Exposure Modeling (WEMo)

WEMo was developed by the Center of Coastal Fisheries and Habitat Research. It calculates wave energy and wave exposure. Representative Wave Energy (RWE) calculates wave height and derived wave energy while considering wave generation processes and water depth characteristics. Relative Exposure Index (REI) combines water depth with directional wind speed, wind frequency, and fetch at a site to calculate that sites' exposure compared to another (Malhotra and Fonseca 2009:1). To calculate wave energy and exposure, three pieces of data are needed: bathymetry, shoreline, and wind data. The bathymetry grid and shoreline dataset have to be projected in the same coordinate system (Malhotra and Fonseca 2009:18) and can be retrieved from the National Geophysical Data Center (NGDC) and the Coastal Services Center Digital Coast website (CSC).

Mark Fonseca and Amit Malhotra, creators of WEMo, provided bathymetry data for Albemarle Sound from the Coastal Relief Model database. The horizontal resolution is approximately 86 meters and projection is UTM zone 18S NAD83. Wind data was obtained from the National Data Buoy Center for Duck Pier from 2000-2005 and saved into RWE mode. The shoreline projection shapefile also is in UTM zone 18S NAD83 and was obtained from NOAA's NGDC Coastline Extractor.

To evaluate Albemarle Sound's wave energy, forty-three points were randomly chosen and digitized once bathymetry, wind data, and shoreline projections were entered in RWE mode.

The random generation of points allowed for many measurements within Albemarle Sound, Alligator River, and Chowan River (Figure 4.12).

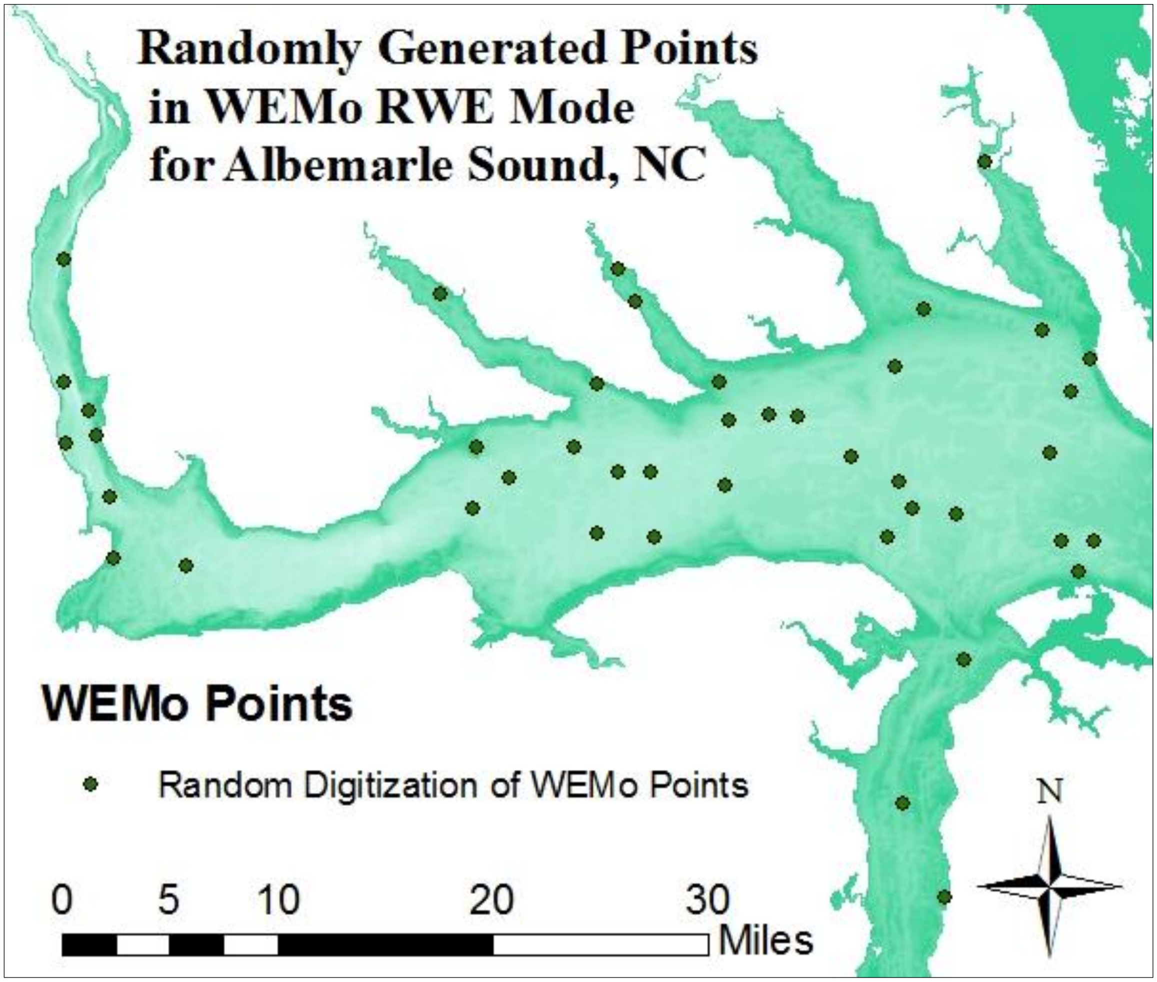

FIGURE 4.12. Geo-spatial representation showing position of points where RWE is measured (Map by author, 2011).

After the points were digitized, building these points created a topology and shapefile for the points. The shapefile was added to the table of contents. The point data layer was then selected from the prompt and 16 fetch rays were specified for more precise calculations. The option of a faster algorithm was also selected, making use of the shoreline redundant. WEMo calculated RWE for each of the forty-three points, clipping the fetch rays as it progressed and appending the RWE indices to the point file's attributes. The *Identify* tool was then used to view and analyze the resulting calculations, specifically spatial location, relative wave energy (RWE), maximum wave height (MaxWvH), average wave height (AvgWvH), maximum wave direction (MaxWvDR), average wave power (AvgWvPr), maximum wave power (MaxWvPr), and depth (Figure 4.13). These results are spatially represented in Chapter 5.

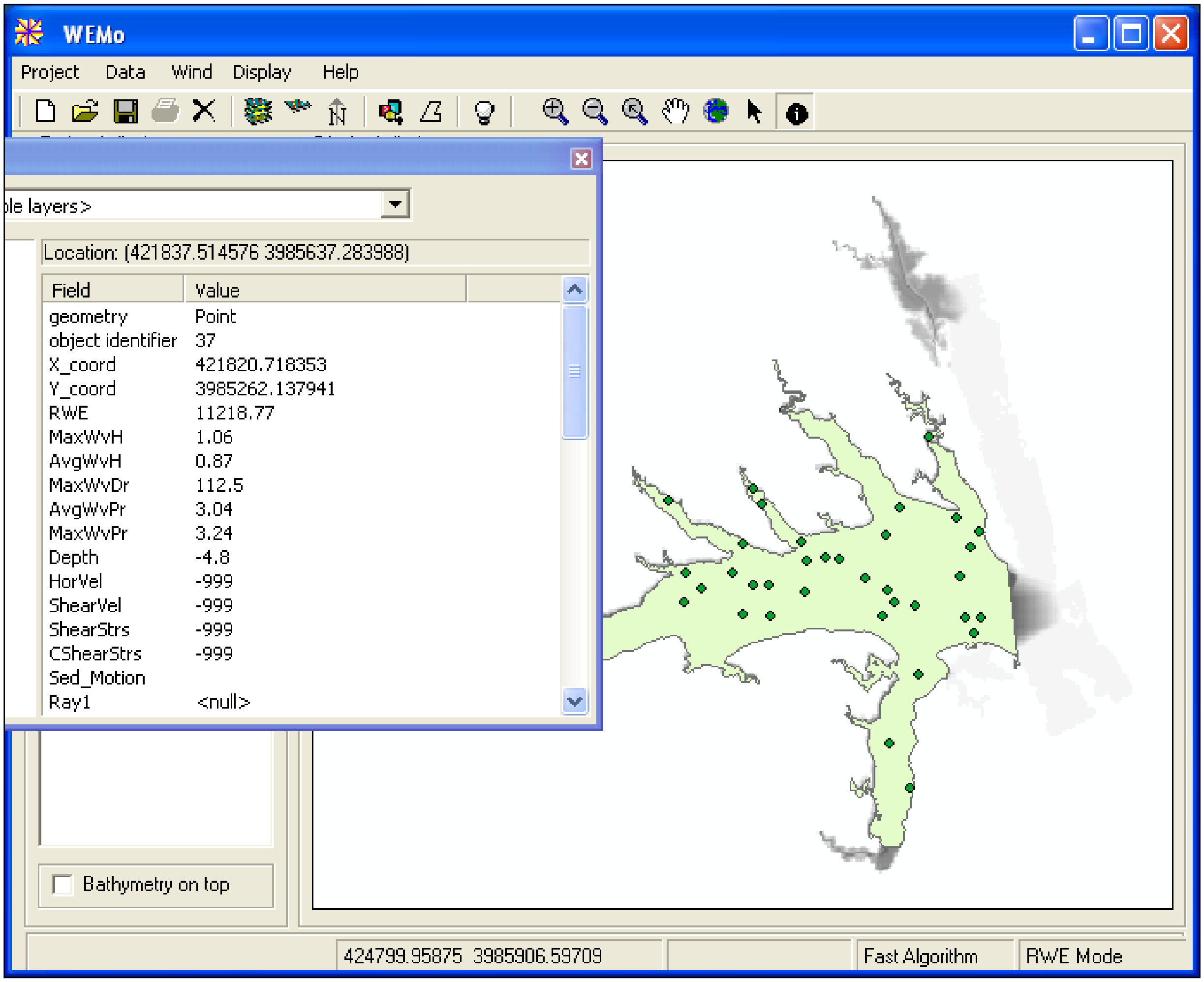

FIGURE 4.13. Screenshot of WEMo map showing attributes identified with Identify feature (By author, 2011).

Waves

Waves are a result of wind action and can have a detrimental effect on archaeological site preservation. In water that has high sediment, organic, and salt content, water can act like sandpaper on an archaeological site, weathering and eroding features and ultimately sites. In areas where wind rates are high, wave energy can be great as well. Submerged sites are susceptible to constant tidal and wave energy across them. Sites located in the shorezone, as defined by Corbett et al. (2007:2) are subject to wave erosion, damage from wave breakage, and wind erosion as a strong wind can pick up particles causing damage. Wave energy is the first parameter where attributes will be selected based on high to low values.

Accumulation Rates

Accumulation rates from the core sampling done by ECU's Department of Geological Sciences will be used as the second defining parameter. Sediment accumulation can bury an archaeological site. Ward (1999:563) argues that chemical and biological activity, which can alter wood, metal, glass, and stone, are related to these sedimentary processes. The rate at which a site is buried, and the environment in which it is buried, can aid in determining survival. The spatial representation of low to high accumulation rates is discussed in Chapter Five.

Shoreline Erosion

Shoreline erosion can remove sites from the archaeological record. Artifacts can be washed away and shipwrecks can be entirely eroded as the shoreline on which they rest changes. Sites that are not on a present day shoreline are still at risk. As noted earlier in this chapter, sea-level is rising at a semi-constant state. Sites that are currently inland will eventually be inundated as rising water levels flood the coast.

The complexity and variability of the shoreline's composition around Albemarle Sound makes it vulnerable to erosion. The majority of the shoreline is composed of wetlands, marshes, bluffs, and sandy beaches, all heavily susceptible to erosion (Figure 4.14). As noted by Riggs and Ames (2003:18), the shoreline "is an environment of highly variable conditions" where the amount of work "depends on the topography and composition, source, amount, and energy expanded… causing shoreline to change and evolve through time." This means the shoreline does not change at one constant rate but specific areas may erode, accrete, or remain stable based on composition.

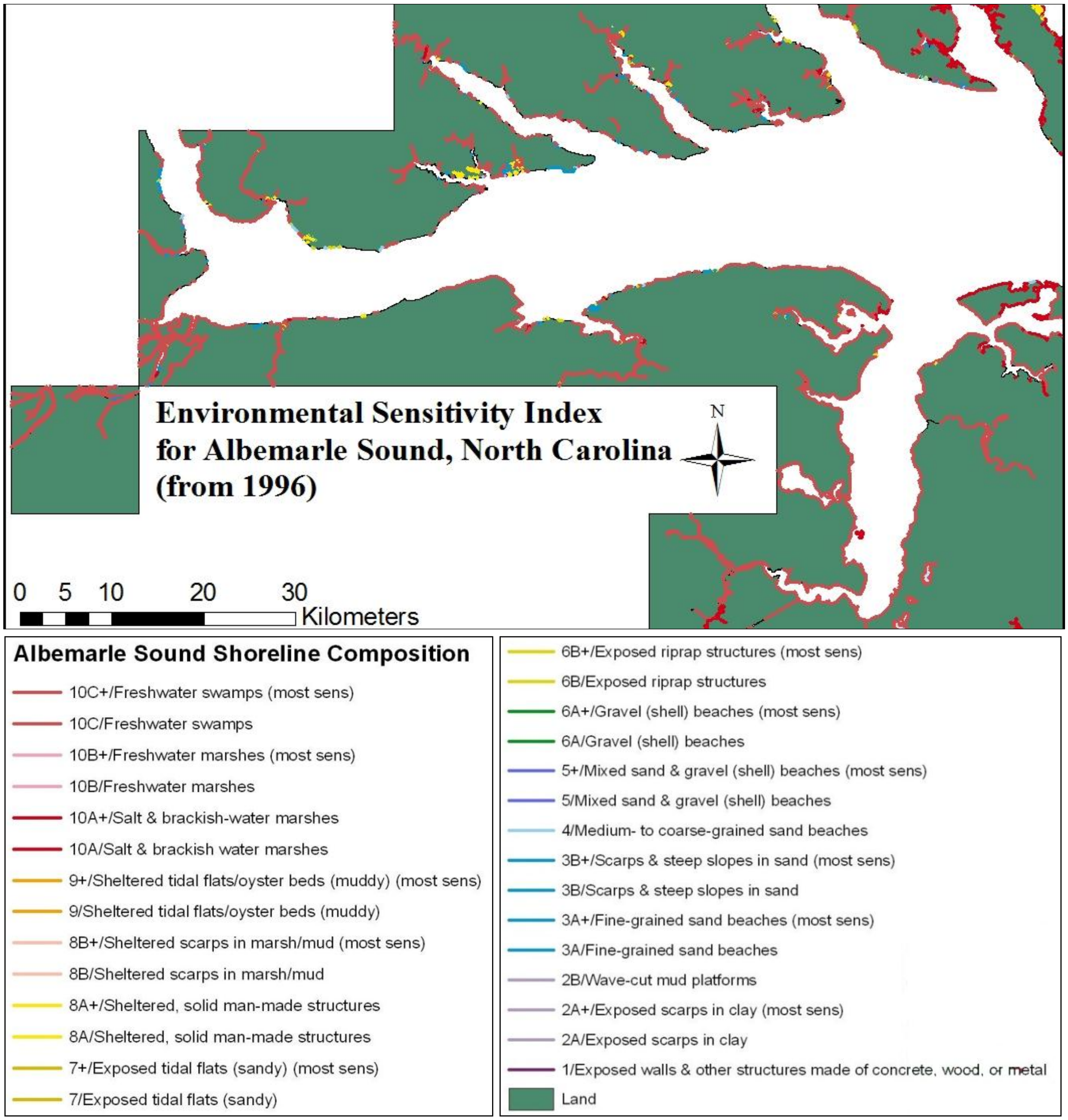

FIGURE 4.14. Sensitivity of Coastal Environments (Courtesy of NOAA's Coastal Services Center, Charleston, South Carolina; NOAA's National Ocean Service, Office of Response and Restoration, Seattle, Washington; and NOAA's Strategic Environmental Assessments Division, Silver Spring, Maryland, 2007).

A 2007 study done on the Georgia coast, discussed in Chapter Three, used geographic information system (GIS) technology to prioritize sites threatened by erosion. Robinson et al. (2010) selected 21 archaeological sites on the Georgia barrier islands. Using a combination of aerial photography, historical maps, GPS, and GIS, the length of shoreline was georectified to identify coastal changes in relation to selected archaeological sites. Of the 21 sites, 11 were eroding, eight were stable, and two were accreting (Robinson et al. 2010:312, 320, 325). As Albemarle Sound is a semi-enclosed body of water, erosion rates are different than those on coast or barrier islands. Therefore, the rates of erosion, accretion and stability are more apt to resemble those from Lisa Cowart's (2008) Cedar Island study and Corbett et al.'s (2008) study of the Albemarle-Pamlico Estuarine System. Corbett et al. (2008:1) estimated that an average erosion rate of approximately 0.3 meters (one foot) per year was calculated for the entire Neuse River Estuary. Shoreline erosion rate is the third parameter used in identifying sensitive areas.

Inundation from Sea-Level Rise

The final potential risk, inundation from sea-level rise, is also conservatively estimated for Albemarle Sound (Corbett et al. 2008). NOAA's tide gauge measurements for relative sea-level rise in North Carolina estimate a rate of between 0.07 to 0.17 inches per year (Corbett et al. 2008:2). Due to the low topographic gradient of the coastal plain, much of northeastern North Carolina is within a few feet of current sea level. As a result, inundation from constant sea-level rise can cause areas to suddenly flood and sites to become temporarily, or permanently, submerged.

During the third year of the NCCGC in 2003, major flooding occurred in response to significant storm surge (Figure 4.15). The five to ten foot storm surge flooded the "western portion of Albemarle Sound, and the lowlands along the Chowan River estuary" (ECU NCCGC

2003:14). In addition to inundation from storm surge, 6-10 cm of sediment accumulated within the inner Albemarle Sound central basin (ECU NCCGC 2003:14). As it stands, relative sea-level rise can be conservatively estimated for eastern North Carolina using the North Carolina Sea-Level Rise Assessment Report (2010). Based on calculations derived from several studies, three estimates were made concerning inundation for North Carolina: a lower estimate of 0.38 meters, a middle estimate of 1.0 meters, and an upper estimate of 1.4 meters (NCDENR 2010:11).

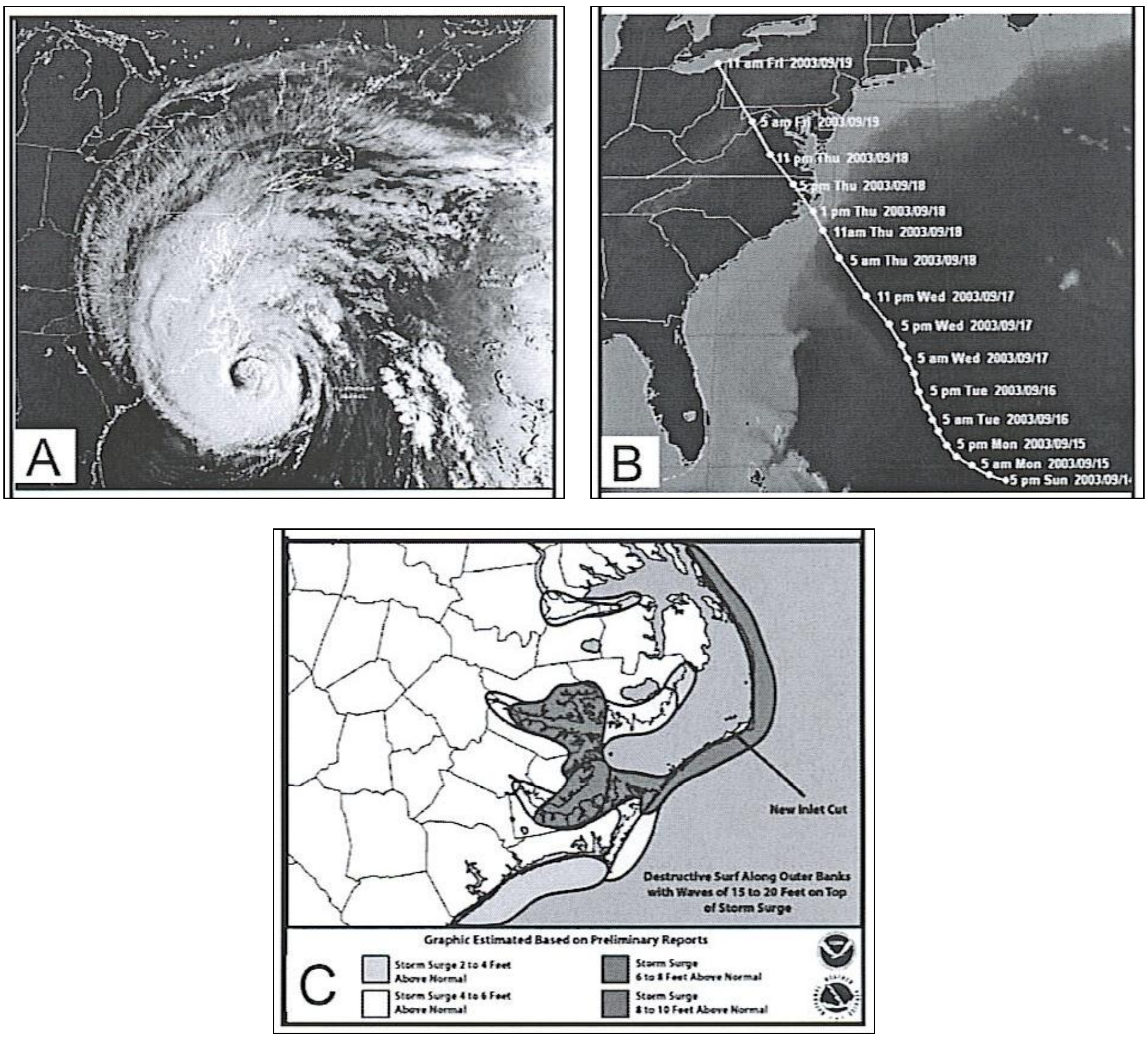

FIGURE 4.15. A) Satellite image of Hurricane Isabel B) Path of hurricane C) Projected storm surge (ECU NCCGC 2003:6).

The four properties, RWE, accumulation rates, inundation from sea-level rise, and shoreline erosion, were entered into *ArcMap* as separate layers. Each parameter was reclassified and specific values were attributed to each separate layer. The defined projection for waves should agree with Riggs and Ames (2003) in defining the most threatened areas as those with low, medium, and high RWE values, or areas with the longest fetch. For this study, only RWE values were used. Accumulation rates within the central trunk were defined at 0.325 cm y^{-1}, the western area 0.57 cm y^{-1} and the eastern areas 0.08 cm y^{-1}. Inundation from sea-level rise was defined using the three estimates from the NCDENR (2010) and applied to a DEM layer.

Shoreline change was complicated, as indicated by several previous studies. Shoreline composition plays a major role in determining what values were used for shoreline erosion. To simplify, only two shoreline composition types were predominant and an estimated erosion rate was evaluated. This is further explained in the next chapter. Ultimately, these simple estimates were used to assess risks. These results are detailed in Chapter Six.

Conclusion

The collaboration of historical, archaeological, and geological datasets allowed the author to delineate environmental properties threatening archaeological sites within the Albemarle Estuarine System. Research for this thesis was dependent upon previous datasets. It was the aim to utilize available databases to nearly negate the need for field research. This methodology shows how significant and important existing data can be when faced with funding or time constraints.

Chapter Five presents results from the four specified parameters and yields discussions on their individual values and affects. The datasets generated in this chapter show a visual representation of the Albemarle's geologic activity. Chapter Six will integrate the environmental models with the spatial locations of confirmed archaeological sites. The OSA sites are identified by varying distances from the shoreline and location within a projected inundation zone. ASCLD sites are prioritized based on location within a high to low risk zone, based on the relationship between wave energy and sediment accumulation. The models will identify sites located in sensitive areas as well as present management and prioritization options.

CHAPTER FIVE: ESTABLISHING ENVIRONMENTAL BASELINES

Introduction

The historical, archaeological, and geological aspects of northeastern North Carolina's Albemarle Estuarine System need to be researched individually to determine what areas are actively changing and thus, the cultural heritage that might be damaged in the near future. The aim of this chapter is to use the derived data to determine individual risk parameters for four geo-spatial properties. Four geo-spatial projections are created: the values from WEMo's relative wave energy (RWE), sediment accumulation rates, inundation from sea-level rise, and shoreline erosion rates.

Accumulation Rates, Shoreline Erosion, Waves, and Inundation from Sea-Level Rise

Short cores analyzed sediment accumulation rates over the last 200 to 300 years (AD 1700-1800) (Figure 5.1). This data suggests a change in organic matter source over time. $\delta^{15}N$ revealed decreasing values to the east and a decrease in isotopic values in Albemarle Sound's open areas, with coarse material and low organic matter (<2%) (Corbett et al. 2007:721).

The high accumulation rates to the west are due to the junction of two major river systems, the Roanoke to the southwest and the Chowan to the northwest. The only area east of this junction where the accumulation is of the same magnitude is the Pasquotank River. Using rates of accumulation determined in the 2001 field research, an average estimate of 0.325 cm/y^{-1} was used to define the accumulation rates for central Albemarle Sound. The most western core, S1, contained the highest ^{210}Pb accumulation rate at 0.57 ± 0.07 cm y^{-1}. The most eastern core utilized, S4, contains a ^{210}Pb rate of 0.08 ± 0.02 cm y^{-1}. Within the lateral rivers, the Alligator and Pasquotank, the ^{210}Pb accumulation rates for cores S7 and S10 are 0.21 ± 0.07 cm y^{-1} and 0.16 ± 0.02 cm y^{-1} respectively (Corbett et al. 2007:720).

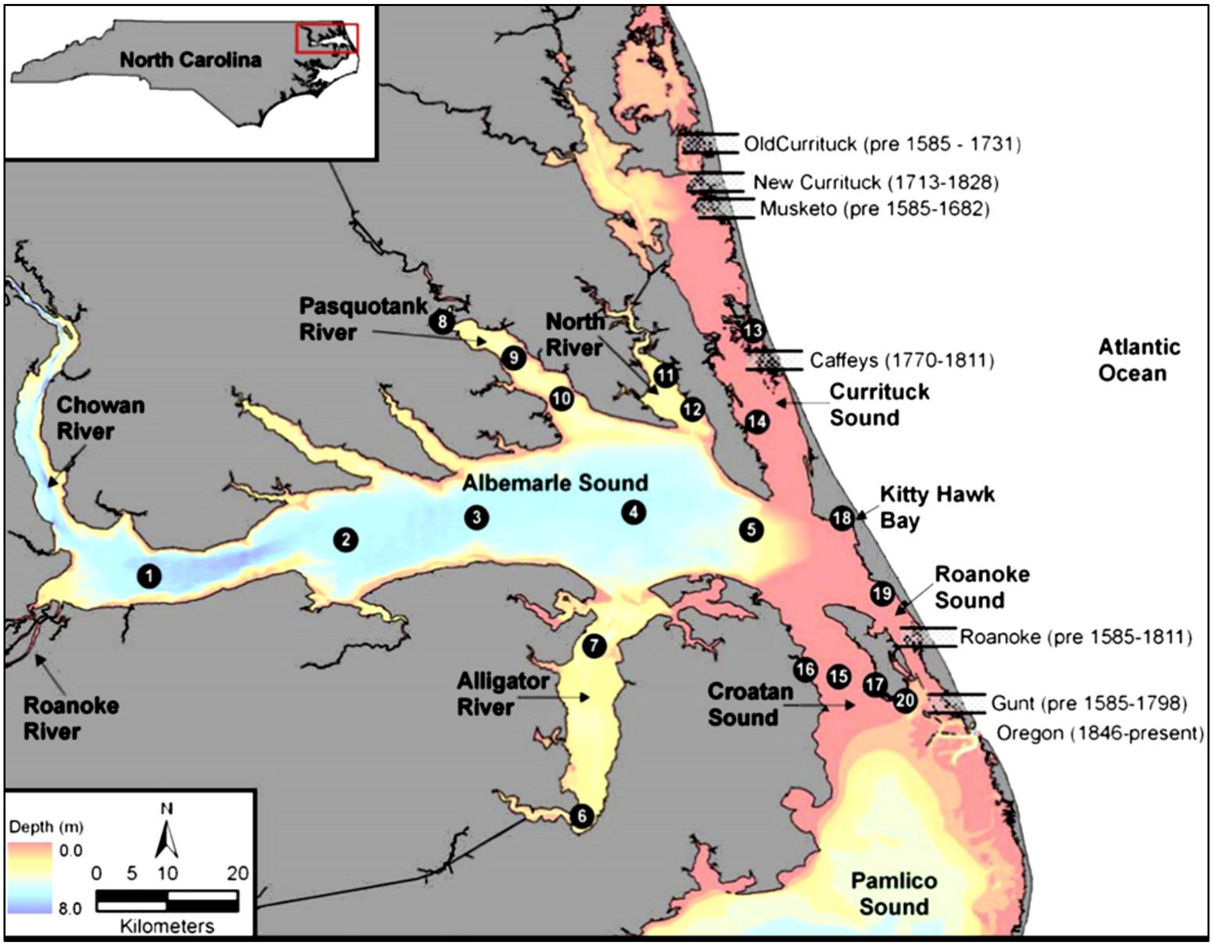

FIGURE 5.1. Bathymetric map showing location of core samples throughout AES (Corbett et al. 2007:718).

These values were entered into Microsoft *Excel* which was ultimately imported into *ArcMap.* By specifying the ^{210}Pb-derived sediment accumulation rates in the attribute table, areas of highest and lowest accumulation within Albemarle Sound could be determined. An interpolation was derived using the inverse distance weighting (IDW) tool, mapping rates across the system where they were previously not specified (Figure 5.2). To more conservatively represent the limited accumulation rates for the AES, the values were reclassified to represent areas of low, medium and high accumulation, based on the numerical values generated (Figure 5.3).

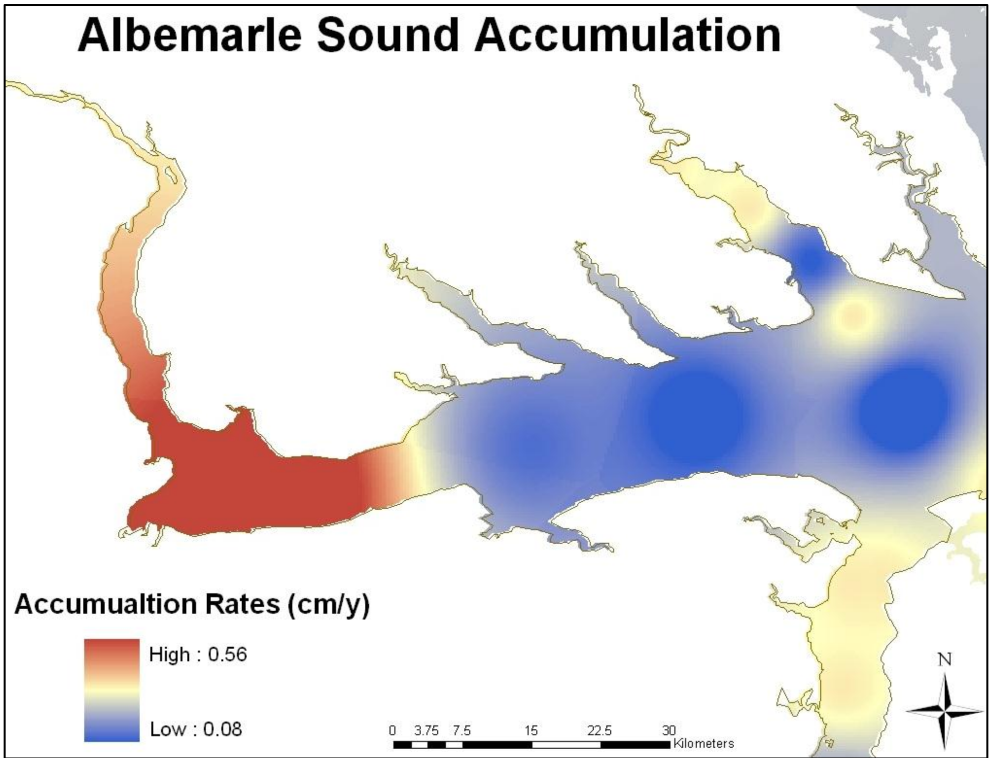

FIGURE 5.2. Geo-spatial representation of accumulation rates (By author, 2011).

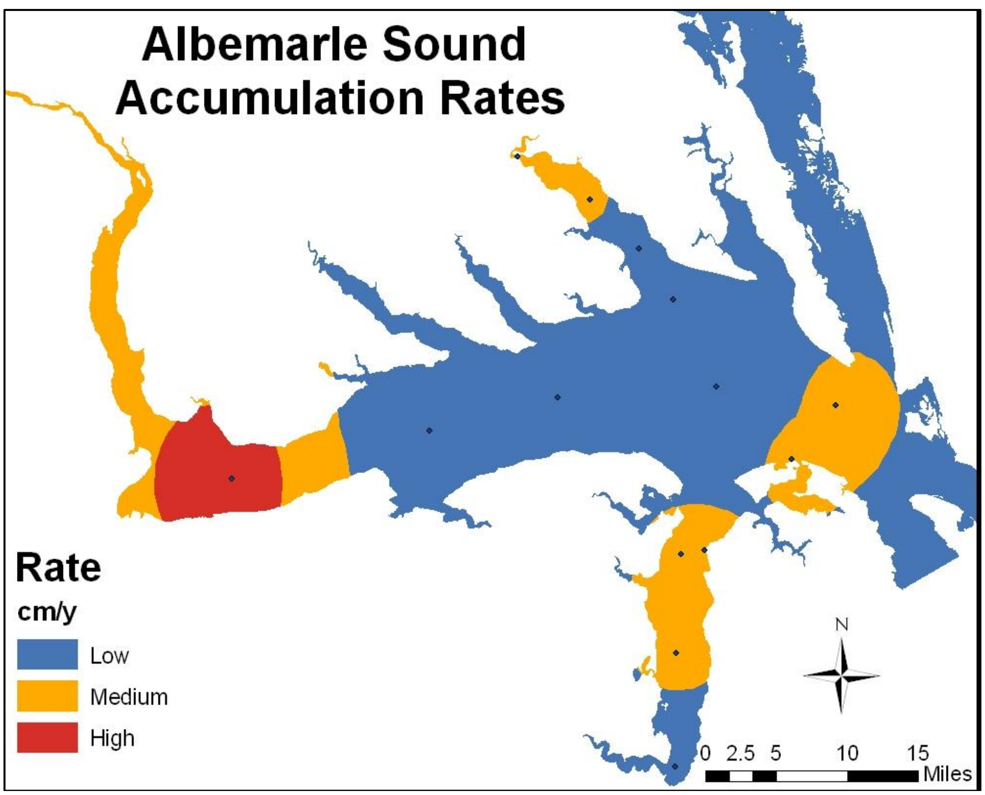

FIGURE 5.3. Geo-spatial representation of accumulation rates within the Albemarle Sound, reclassified into 3 quantile classes. Core sample locations are also indicated by points (Map by author, 2011).

The sediment types seen in Albemarle Sound are largely terrigenous sediments. These can be classified by a range including sand, silt, clay, and peat, indicating the dominant size ranges from 2-4 mm to <4 µm (Goldberg and Macphail 2006:12). Terrigenous sediments are primarily clastic, composed of "rock, other sediment, or soil material that reflect a history of erosion, transport, and deposition" (Goldberg and Macphail 2006:11). The coarse-grained sediments, located on the channel margins, are supplied mainly from shoreline erosion (Wells and Kim 1989:276). This would indicate that shoreline erosion plays a role in sediment accumulation.

The classification, abundance, and distribution of shoreline types surrounding Albemarle Sound have been studied by numerous disciplines, including geography, geology, and ecology. As a major aim of this thesis was to use information previously collected from other fields, a comprehensive sample was used. The following studies were incorporated: Copeland et al. (1983), Riggs and Ames (2003), Murphy (2002), and Cowart (2008).

In 1983, B. Copeland, R. Hodson, S. Riggs and J. Easley Jr. conducted work for the U.S. Fish and Wildlife Service, analyzing the estuarine profile and ecology of Albemarle Sound. The report included a section on publications concerned with analyzing an estuarine shoreline's environmental structure and function (Copeland et al. 1983:iii). According to the report, there are five types of shorelines: marsh, low bank, high bank, bluff and swamp forest (Figure 5.4).

The shoreline types applicable here are low bank, high bank, bluff, and swamp forest. Low bank is the most abundant type of shoreline, especially in Camden County (54%), Pasquotank County (76%), and Tyrrell County (66%). The average erosion rate for this shoreline type was determined to be 0.7 meters (2.3 feet) per year, up to four meters (13 feet). This zone is composed of sand and clay; sandy coasts being particularly vulnerable to erosion from wave attack (Copeland et al. 1983:9-13).

County	Marsh	Low bank	High bank	Bluff	Swamp forest	Subtotal
Bertie	0	8	9	4	11	32
Camden	8	25	0	0	13	46
Chowan	0	8	14	1	29	52
Currituck	15	11	2	0	5	33
Pasquotank	1	36	4	0	6	47
Perquimans	1	22	24	0	15	62
Tyrrell	2	27	1	0	11	41
Washington	0	7	5	0	9	21
Total	27	144	59	5	99	334
Percent	8%	43%	18%	1%	30%	

FIGURE 5.4. Predominant shoreline types of Albemarle Sound, North Carolina (Copeland et al. 1983:10).

High banks constitute 18% of total shoreline miles around Bertie County (28%), Chowan County (27%), Perquimans County (39%), and Washington County (24%). The average erosion rate for this area is 0.6 meters (2 feet) per year, up to four meters (13 feet). These banks are composed of uncemented sands highly susceptible to erosion except in areas with high vegetation to absorb wave energy. Bluffs account for 1% of the shoreline in the Chowan River, Bertie County (12%) and Chowan County (2%). This shoreline is composed of sand and clay at a relief of greater than 20 feet above Mean Water Level (MWL), receding at an average rate of 0.8 meters (2.5 feet) per year, and up to 2.5 meters (8.2 feet) per year. Swamp forests account for 30% of the mapped shoreline, characterized by inundation from broad river floodplains. The average recession rate is 0.7 meters (2.3 feet) per year, ranging up to one meter (3.2 feet) per year (Copeland et al. 1983:9-13). Pocosins constitute 65% of the shoreline of Albemarle Sound, characterized by flooding during the winter and water logging during the remainder of the year (Copeland et al. 1983:19).

Riggs and Ames (2003) completed a soft-cover book for the North Carolina Department of Environment and Natural Resources and North Carolina Sea Grant College Program (North Carolina State University) entitled *Drowning the North Carolina Coast: Sea-Level Rise and Estuarine Shoreline Erosion*. The purpose of this study was to map shoreline erosion rates for the APES as well as determine short- and long-term coastal evolution in an effort to better manage shoreline resources (Riggs and Ames 2003:19). Within this report, they incorporated the research of Megan Murphy (2002), as well as analyzed previous studies conducted in the 1970s. It was determined that distribution and abundance of northeastern North Carolina shoreline types (Figure 5.5) as well as natural and human modifications (Figure 5.6), generate an average shoreline erosion rate of 0.8 to one meter (2.8 to 3.2 feet) per year. The highest rates of erosion occur in areas with low banks and marshes, followed by high-banks, swamp forests, and bluffs.

In 2002, Megan Murphy mapped the shorelines of the Albemarle-Pamlico Estuary, following research done in 1980. Field work, GPS mapping, and georeferenced aerial photographs from the 1950s to 2001 revealed that "marshes erode at a mean rate of 2.3 meters (7.4 feet) per year, while low-sediment banks erode at a rate of 1.5 meters (5 feet) per year" (Murphy 2002:i-ii). Within Albemarle Sound, Murphy mapped one site at Woodard's Marina, located on the southern shoreline in Tyrrell County. This particular shoreline was composed of a three to 4.5 meter (10-15 foot)-wide fringing marsh, sand apron, and strandplain beach. The wetland type was Pocosins swamp forest and the mapped shoreline extended 0.09 kilometers (0.06 miles). The predominant sediment type was peat and clay. This area was exposed to a 30.6 kilometer (19 mile) fetch from the northeast, which contributed to the average erosion rate of 1.0 meter (3.4 feet) per year, with 2.4 to 2.7 meters (8 to 9 feet) of erosion occurring from 1998 to 2001 alone (Murphy 2002:97-102). Due to a discrepancy in the aerial photographs and problems with georeferencing photos, Murphy's calculations were not precise, and were criticized, then reanalyzed by Riggs and Ames (Riggs and Ames 2003:144).

STUDY REGION	ALBEMARLE SOUND	PAMLICO RIVER	NEUSE RIVER	CORE-BOGUE SOUNDS	TOTALS
Miles Mapped	436 mi (27%)	483 mi (30%)	452 mi (29%)	222 mi (14%)	1593 mi (100%)
Low Sediment Bank	159 mi (36%)	112 mi (23%)	124 mi (27%)	76 mi (34%)	471 mi (30%)
High Sediment Bank	59 mi (14%)	19 mi (4%)	24 mi (5%)	9 mi (4%)	111 mi (7%)
Bluff Sediment Bank	4 mi (1%)	5 mi (1%)	12 mi (3%)	— —	21 mi (1%)
Swamp Forest	101 mi (23%)	7 mi (2%)	2 mi (<1%)	— —	110 mi (7%)
Marsh	113 mi (26%)	340 mi (70%)	290 mi (64%)	137 mi (62%)	880 mi (55%)

FIGURE 5.5. Distribution and abundance of shoreline types (1978) (Riggs and Ames 2003:75).

STUDY REGION	ALBEMARLE SOUND	PAMLICO RIVER	NEUSE RIVER	CORE-BOGUE SOUNDS	TOTALS
Cypress Fringe Sediment Bank	82 mi (19%)	5 mi (1%)	29 mi (6%)	— —	116 mi (7%)
Marsh Fringe Sediment Bank	15 mi (3%)	27 mi (6%)	53 mi (12%)	47 mi (21%)	142 mi (9%)
Sand Apron Marsh	17 mi (4%)	8 mi (2%)	32 mi (7%)	9 mi (4%)	66 mi (4%)
Significant Shoreline Erosion in 1975-1977	390 mi (90%)	457 mi (95%)	408 mi (90%)	200 mi (90%)	1455 mi (91%)
Significant Sand Accretion in 1975-1977	4 mi (1%)	2 mi (<1%)	23 mi (5%)	3 mi (1%)	32 mi (2%)
Human-Modified Shoreline by 1977	41 mi (9%)	24 mi (5%)	20 mi (4%)	19 mi (9%)	104 mi (7%)

FIGURE 5.6. Natural and human modification features (1978) (Riggs and Ames 2003:76).

In Cowart's thesis, wave energy was derived by comparing fetch values for the eight major compass heading directions (N, NE, E, SE, S, SW, W, NW) (Cowart 2008:18). Fetch was calculated using a Wave Exposure Model (WEMo). Using fetch values from the shoreline points, Cowart determined a maximum value of 9.3 kilometers (5.8 miles), with an average of 1.5 kilometers (0.9 miles). She ascertained that the majority of shoreline points, approximately 95%, had a value greater than 1.5 km (Cowart 2008:18). Oncoming wave energy was focused on the headland area, whereas areas embayed between headlands received reduced wave energy. The lowest average fetch areas were determined to have the highest shoreline change rates (less erosive) while higher fetch values had more negative shoreline change rates (more erosion) (Cowart 2008:24).

To provide an adequate and representative estimate for the geophysical parameters needed for the predictive models, data collected and created by the author, as well as the previous datasets mentioned were utilized, averaged, and applied to the maps. Since the greatest rates of sediment accumulation occur near the Roanoke River, Chowan River, and Pasquotank River, the largest accumulation rates were applied to those regions. When specifying the values needed, accumulation rates included low (0.08 cm y^{-1}), medium (0.33 cm y^{-1}), and high (0.57 cm y^{-1}) values.

Shoreline erosion rates vary depending upon fetch, shoreline composition, and a number of other variables (Riggs and Ames 2003:75-76). For the model, shoreline composition and erosion rates obtained from previous studies were utilized to determine areas where erosion might be greatest. The majority of shoreline types surrounding Albemarle Sound are low bank, high bank, bluff, and swamp. Copeland’s (1989) study indicated an average erosion rate of 0.7 meters (2.3 feet) per year for low bank. Riggs and Ames (2003) computed an average erosion rate of 1.0 meters (3.2 feet) per year. In averaging these results, an average estimate for low bank shoreline erosion was 0.85 meters (2.8 feet).

For regions designated as high banks, chiefly shorelines around Perquimans County, Chowan County, Bertie County, and Washington County, several rates were used. Copeland et al. (1989) calculated an average erosion rate of 0.6 meters (2 feet) per year. Riggs and Ames (2003) estimated an erosion rate of 0.7 meters (2.3 feet) per year. The average erosion rate for high bank areas was 0.6 meters (2.2 feet) per year. Copeland's estimate for bluff regions, along the Chowan River, Chowan County and Bertie County, was 0.8 meters (2.5 feet) per year. Riggs and Ames (2003) determined an average erosion rate of 0.7 meters (2.4 feet) per year. The average estimate for bluff shoreline regions was 0.7 meters (2.45 feet) per year. For shorelines described as swamps, including Pocosins swamps, Copeland (1989) estimated an average rate of 0.7 meters (2.3 feet) per year while Riggs and Ames (2003) averaged 0.6 meters (2.2 feet) per year. Murphy (2002) approximated a value for erosion rates at Woodard's Marina of 1.1 meters (3.4 feet) per year. This shoreline type was discovered to be 100% Pocosin swamp and therefore, that estimate is included in the average erosion rate. The combination of these estimates reveals a conservative average erosion rate for swamps of 0.8 meters (2.6 feet) per year. To simplify shoreline erosion for the entire AES, an average of 1.0 meter (~3.3 feet) per year was used.

Any low lying area is susceptible to inundation. The broad river floodplains can become inundated from storm events and general sea level rise (SLR). The North Carolina Sea-Level Rise Assessment Report was prepared by the N.C. Coastal Resource Commission's Science Panel on Coastal Hazards (NCDENR 2010). This report measures global and regional SLR along the North Carolina coast, and specifically projects SLR rates for the year 2100. Several studies provided data on rates of relative SLR in North Carolina (Horton et al. 2009; IPCC 2007; Kemp 2009; Kemp et al. 2009; Pfeffer et al. 2008; Rahmstorf 2007; and Zervas 2004). Utilizing these studies to better understand the threat of sea-level rise, three possible rates of acceleration were determined, indicating low to upper estimates for SLR by the year 2100. The lowest estimate is 0.38 meters (1.3 feet), the middle estimate is 1.0 meters (3.3 feet), and the upper estimate is 1.4 meters (4.6 feet) above present (NCDENR 2010:11). Inundation was derived from LiDAR and DEM values and represented in *ArcMap* (Figure 5.7).

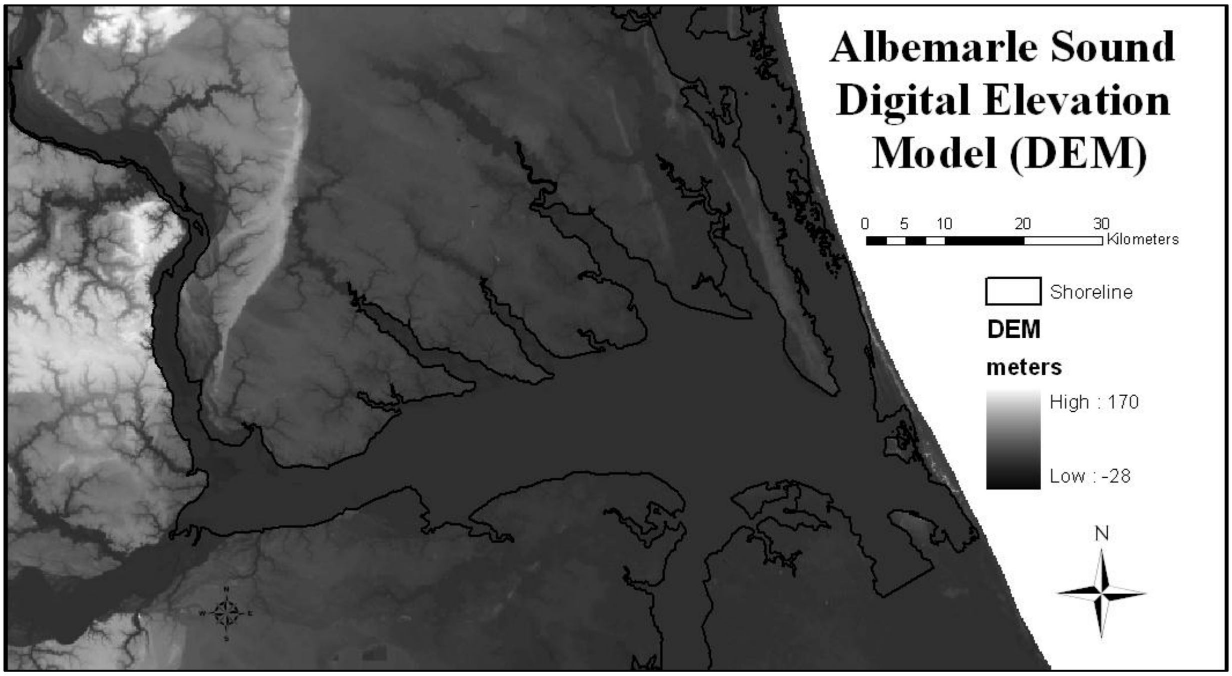

FIGURE 5.7. Digital Elevation Model (DEM) of Albemarle Sound, North Carolina (By author, 2011).

To evaluate the potential impact of waves, a Wave Exposure Model (WEMo) was used to measure Representative Wave Energy (RWE) for Albemarle Sound. WEMo, in RWE mode, was used to calculate the average wave energy flux per unit wave crest width (W/m, J/m, or kg-m /s^3) (Malhotra and Fonseca 2009:10). For the Albemarle Sound, between the boundaries of the Roanoke and Chowan Rivers and Elizabeth City, WEMo calculated RWE values (Figure 5.8) based on maximum wave height (MaxWvH), average wave height (AveWvH), maximum wave direction (MaxWvDr), and depth (Appendix D). As noted by Riggs and Ames (2003) (Figure 5.9), erosion rates are higher in areas of longer fetch or higher wave energy. Based on this concept, higher risk areas occur where RWE are the greatest. For the values derived using

WEMo, it was assumed that high risk zones occured where RWE values were greater than 10000 J/m and low risk zones were located where values were less than 1000 J/m (Figure 5.10).

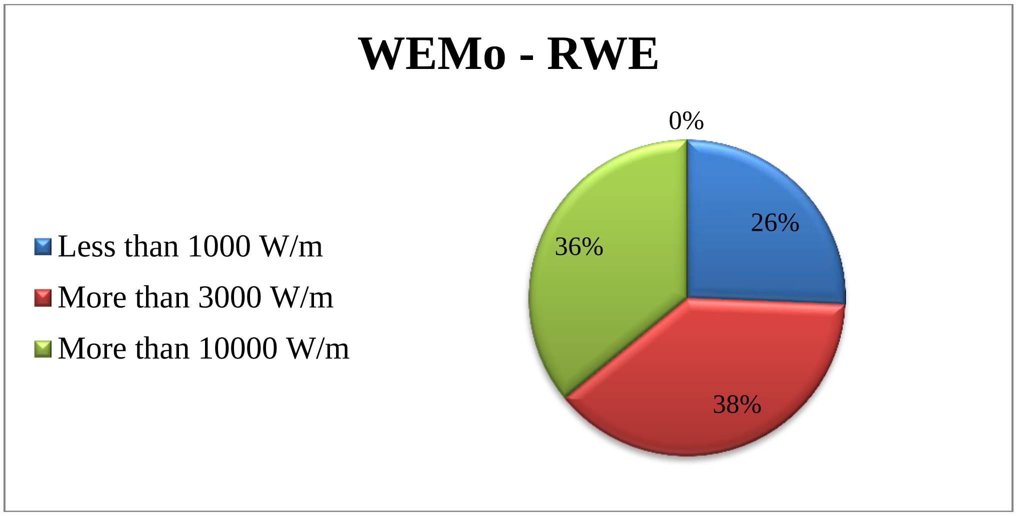

FIGURE 5.8. Pie chart depicting RWE percentages for Albemarle Sound, North Carolina (By author, 2011).

SHORELINE VARIABLES	DEFINITION	POTENTIAL FOR EROSION LOW	HIGH
1. Fetch	Average distance of open water in front of shoreline	Short Fetch (< 1,000 ft)	Long Fetch (miles)
2. Geographic Location	Location within the sounds, trunks or tributary estuaries, and within the northern or southern province, etc.	S Province or Head of Tributary Estuaries	N Province Sounds or Trunk Estuaries
3. Offshore Bottom Character	Water depth and bottom slope in the nearshore area	Shallow, Gradual Slope (< 2 ft)	Deep, Steep Slope (> 2 ft)
4. Geometry of Shoreline	Shape and regularity of shoreline	Highly Irregular, or in Cove	Straight or on Headland
5. Height of Sediment Bank	Bank height at shoreline or immediately behind sand beach	High (> 5 ft)	Low (< 5 ft)
6. Composition of Sediment Bank	Composition and degree of cementation of bank sediments	Rock, Tight Clay	Uncemented Sand, Peat
7. Fringing Vegetation	Type and abundance of vegetation (aquatic plants, marsh grasses, shrubs, trees, etc.) occurring in front of sediment bank	Very Abundant, Dense	Absent
8. Boat Wakes	Proximity of property to, frequency and type of boat channel use	Absence of Boats	Marinas, Intracoastal Waterway
9. Storms	Storms are the single most important factor determining specific erosional events	Type, Intensity, Duration and Frequency of Storms	

FIGURE 5.9. Shoreline erosion variables and definitions (modified from Riggs et al. 1978) (Riggs and Ames 2003:55).

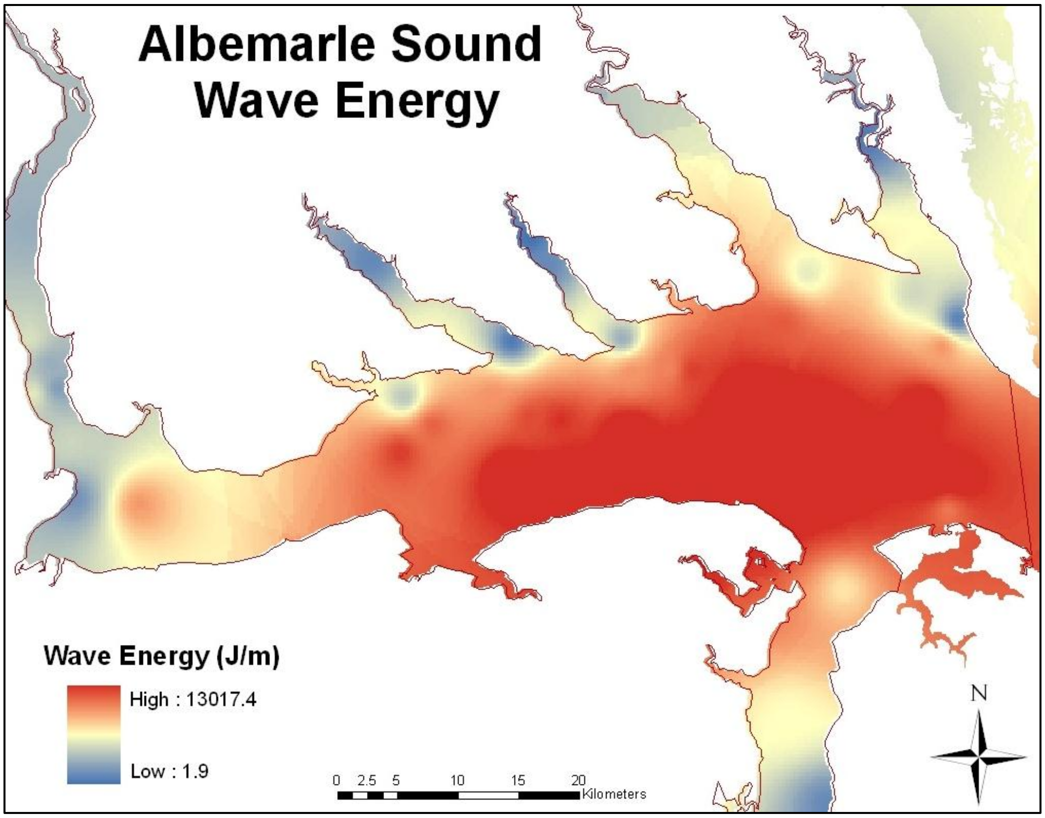

FIGURE 5.10. Geo-spatial representation of RWE (wave energy) in the Albemarle Sound (By author, 2011).

Finally, the values were reclassified into three quantile classes, delineating low to high energy areas (Figure 5.11). The three separate classes were then used in combination with the three classes for sediment accumulation to determine the greatest risk areas, i.e., those where high wave energy overlap with low accumulation rates. This is assumed because low accumulation rates cause longer episodes of exposure to harmful natural processes. Low sensitivity zones are those areas where low wave energy correlate with high accumulate rates. Higher rates of accumulation can mean a site will spend less time exposed to those erosive properties.

Using available datasets can be time effective when conducting research to produce predictive representations. The combination of these studies can produce a conservative model of system change for Albemarle Sound, North Carolina. As waves are the result of wind, generating

WEMo results was an important decision. Combined with data from the previously mentioned studies, an exploratory model illustrating areas of potentially greatest cultural resource risk can be rendered.

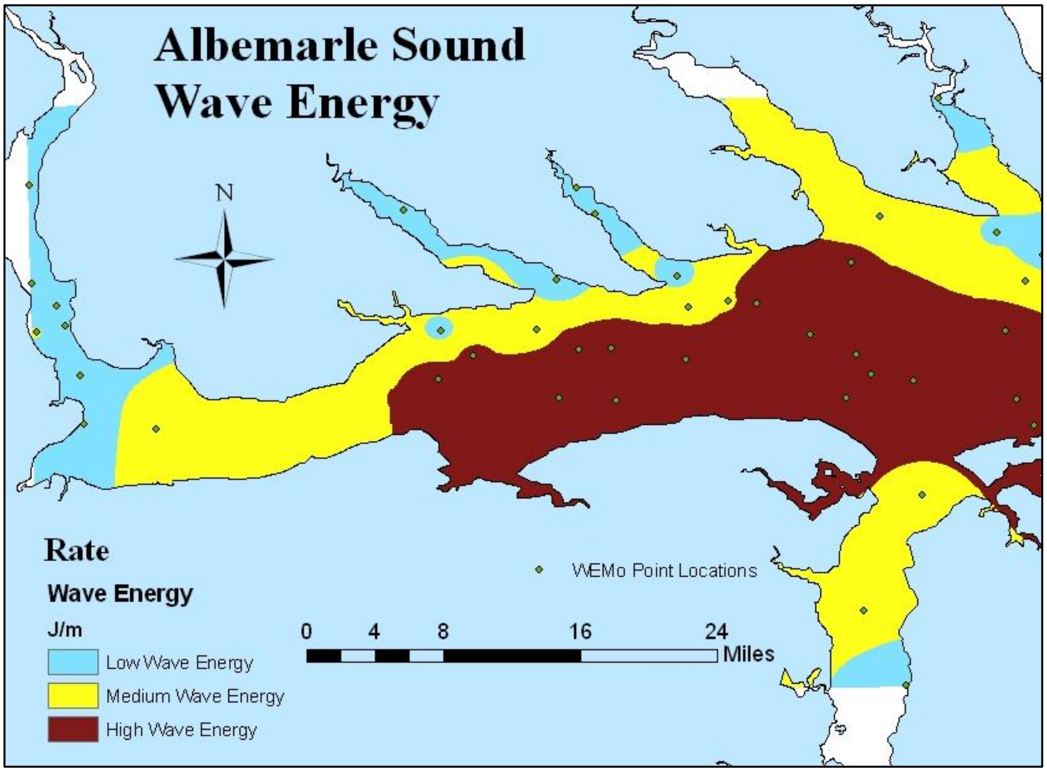

FIGURE 5.11. Geo-spatial representation of RWE, requantified into 3 classes (By author, 2011).

Conclusion

The purpose of this chapter was to convey the dynamic environment of Albemarle Sound and show how each individual parameter is represented in the area. Through geo-spatial mapping created from estimates derived from previous studies and through the use of WEMo, this chapter showed the areas of Albemarle Sound have different levels of risk. Sediment accumulation is greatest at the junction of the Roanoke and Chowan Rivers and at the Pasquotank River's mouth. Wave energy is greatest along the southern Albemarle shoreline, resulting from dominant storm winds from the northeast. Shoreline erosion rates were derived from previous studies concerning shoreline composition. Relative sea-level rise was derived from LiDAR and DEM images demonstrating the Albemarle's susceptibility to inundation from relative SLR.

The next chapter integrates these rates with archaeological locations and details why certain geographical areas and archaeological sites are at a higher risk to loss than others. Sediment accumulation rates will be related to wave energy values to determine what ASCLD sites are within a specific risk zone. Risk zones are determined by this relationship and illuminate areas of low to high sensitivity. Inundation rates are related to shoreline erosion rates and will determine the OSA sites that could be at risk to either or both of these properties in the future. These hazard potential maps, once developed, can be used by cultural heritage management firms to determine priority for survey and research of a site or geographical area as they are strewn across a dynamic, but variable landscape.

CHAPTER SIX: CORRELATING ARCHAEOLOGICAL DATA WITH ENVIRONMENTAL MODELS

Introduction

This research focuses on wave energy, sediment accumulation, shoreline erosion, and inundation from SLR as these are thought to be potential threats to cultural resources. ASCLD sites are sub-aerial and are mapped in relation to wave energy and sediment accumulation. The high risk areas are those where high wave energy and low accumulation overlap. Low rates of accumulation can cause prolonged exposure to wave energy and other damaging properties. Lower risk zones are those where low wave energy and high accumulation overlap. This relationship is considered low risk because faster burial of a site can reduce time the site is exposed to harmful geophysical properties. OSA sites are terrestrial and are mapped in relation to shoreline erosion and inundation from SLR. Shoreline erosion is given three estimations, to show long-term to short-term projections: 300 meters (1000 feet and 300 years), 100 meters (300 feet and 100 years), and 30 meters (100 feet and 30 years). The lower-to-upper inundation estimations from the NCDENR (2010) were also used. OSA sites located in the short-term erosion projections and within inundation estimations (for the year 2100) are considered most at risk to loss and thus given higher priority.

Shoreline Erosion and Inundation from Sea-Level Rise Modeling

Three buffer zones were created around the Albemarle Sound shoreline in relation to the amount of time it would take for the shoreline to erode that distance using a rate of erosion of 1.0 meter (~3 feet) per year. These buffer zones are 300 meters (1000 feet) or 300 years, 100 meters (300 feet) or 100 years, and 30 meters (100 feet) or 30 years. When identifying these sites, only those that were completely within buffer zones were used. The first projection illustrates an erosion distance of 300 meters landward (Figure 6.1), identifying OSA sites within that distance and potentially affected in the next 300 years.

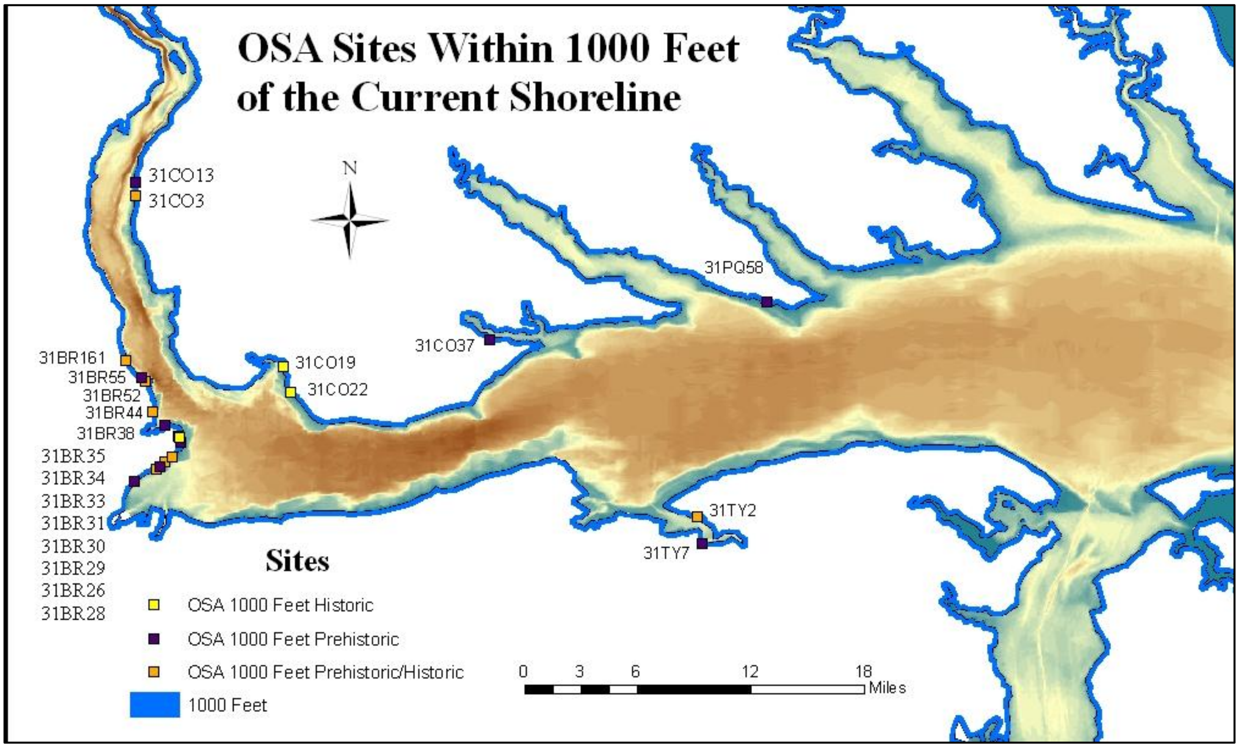

FIGURE 6.1. Geo-spatial representation of OSA sites within 300 meters (1000 feet) or 300 years (By author, 2011).

This projection predicts that there are potentially 21 OSA sites within 300 meters of the current shoreline. This is representative of the cultural heritage that stands to be lost within the next 300 years. Table 6.1 tabulates the OSA sites in this projection, including historical component, date the site was recorded, distance to water, and elevation (at time of survey). The OSA sites are listed by date recorded, beginning with the earliest survey date.

TABLE 6.1
OSA sites located within 300 meters (1000 feet) or 300 years (By author, 2011)

County Number	Site Component	Date Recorded	Distance to Water	Elevation
31TY2	Prehistoric/Historic	1953	Unknown	Unknown
31TY7	Prehistoric	1953	40 meters	1.5 meters
31CO3	Prehistoric/Historic	1973	120 meters	Unknown
31BR29	Prehistoric	1977	50 meters	3.7 meters

31BR28	Prehistoric	1977	75 meters	15 meters
31BR26	Prehistoric/Historic	1977	100 meters	4 meters
31BR30	Prehistoric/Historic	1977	150 meters	4.9 meters
31BR31	Prehistoric/Historic	1977	65 meters	1.8 meters
31BR33	Prehistoric	1977	65 meters	4 meters
31BR35	Historic	1977	125 meters	4.3 meters
31BR38	Prehistoric	1977	130 meters	Unknown
31BR44	Prehistoric/Historic	1977	60 meters	2.1 meters
31BR52	Prehistoric/Historic	1977	200 meters	7.9 meters
31BR55	Prehistoric	1977	50 meters	Unknown
31CO13	Prehistoric	1977	30 meters	Unknown
31CO22	Historic	1978	35 meters	4 meters
31CO19	Historic	1978	0 meters	1 meter
31CO37	Prehistoric	1978	25 meters	2.1 meters
31PQ58	Prehistoric	1978	80 meters	0.6 meters
31BR161	Prehistoric/Historic	1990	5 meters	7.6 meters
31BR34	Prehistoric	No Date	125 meters	5.5 meters

The next projection represents sites located within 100 meters (300 feet) of the current shoreline (Figure 6.2). This identifies sites that could potentially be eroded within 100 years, coinciding with inundation estimations for the year 2100. This subset of sites is even more susceptible to loss than those in the previous projection and could be considered medium risk, representing both a short-term and long-term outlook depending on actual location within that distance. There are nine sites located within this distance. Table 6.2 identifies these sites.

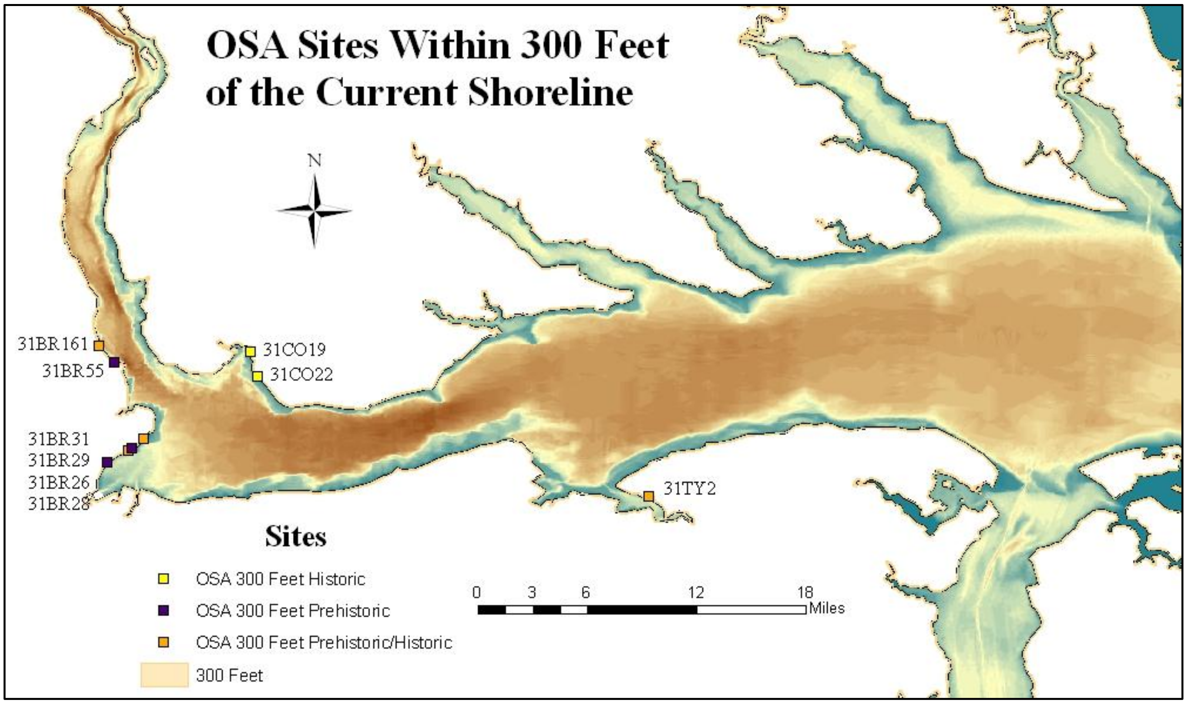

FIGURE 6.2. Geo-spatial representation of confirmed OSA sites within 100 meters (300 feet) or 100 years (By author, 2011).

TABLE 6.2
OSA sites located within 100 meters (300 feet) or 100 years (By author, 2011)

County Number	Site Component	Date Recorded	Distance to Water	Elevation
31TY2	Prehistoric/Historic	1953	Unknown	Unknown
31BR28	Prehistoric	1977	75 meters	15 meters
31BR26	Prehistoric/Historic	1977	100 meters	4 meters
31BR29	Prehistoric	1977	50 meters	3.7 meters
31BR31	Prehistoric/Historic	1977	65 meters	1.8 meters
31BR55	Prehistoric	1977	50 meters	Unknown
31CO22	Historic	1978	35 meters	4 meters
31CO19	Historic	1978	0 meters	1 meter
31BR161	Prehistoric/Historic	1990	5 meters	7.6 meters

The final shoreline erosion projection identifies sites located within 30 meters (100 feet) or 30 years of the current shoreline (Figure 6.3). This projection is designed to identify sites that are at immediate risk to shoreline erosion. There are three sites located within this projection. These three sites could be considered the most at risk sites from shoreline erosion (Table 6.3).

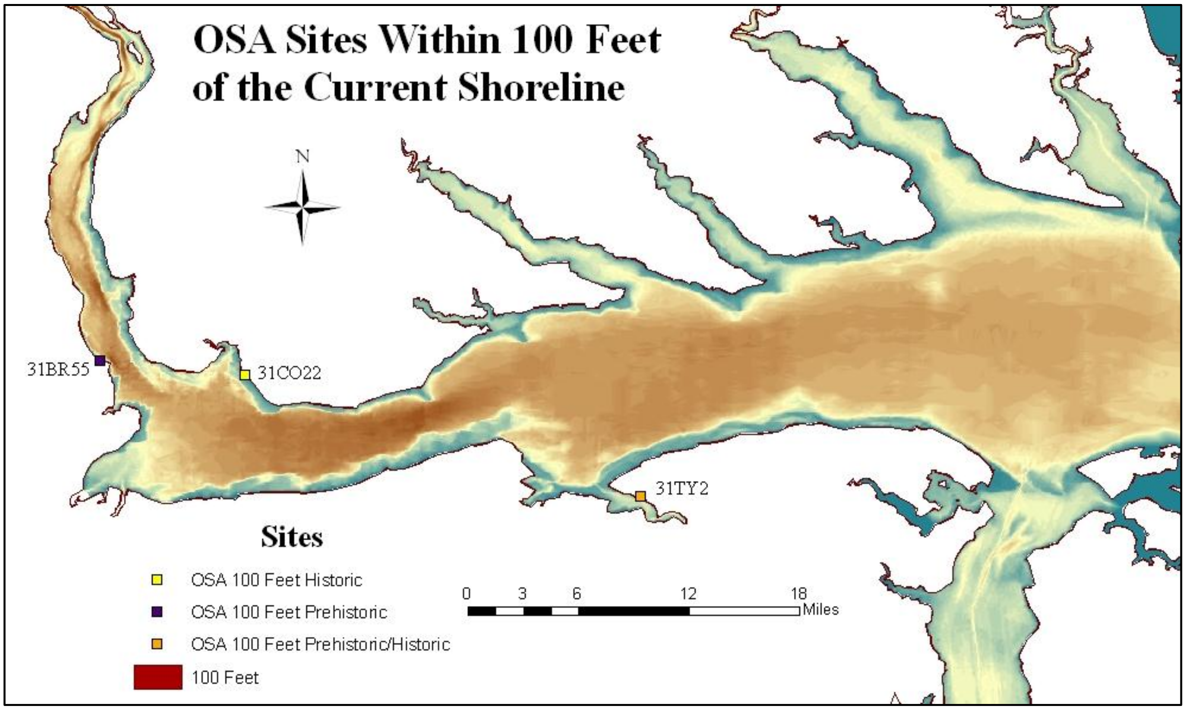

FIGURE 6.3. Geo-spatial representation of all OSA sites within 30 meters (100 feet) or 30 years (By author, 2011).

TABLE 6.3
OSA sites located within 30 meters (100 feet) or 30 years (By author, 2011)

County Number	Site Component	Date Recorded	Distance to Water	Elevation
31TY2	Prehistoric/Historic	1953	Unknown	Unknown
31BR55	Prehistoric	1977	50 meters	Unknown
31CO22	Historic	1978	35 meters	4 meters

Inundation from SLR was computed using values derived from the NCDENR and a DEM for Albemarle Sound. The values within the DEM were reclassified to account for the three estimations made by the NCDENR for inundation elevation by 2100 (2010:11). The first projection shows the lower estimation of 0.38 meters (actual 0.5 meters) above present sea-level (Figure 6.4). This projection shows the current shoreline and anything below 0.5 meters as light blue (water).

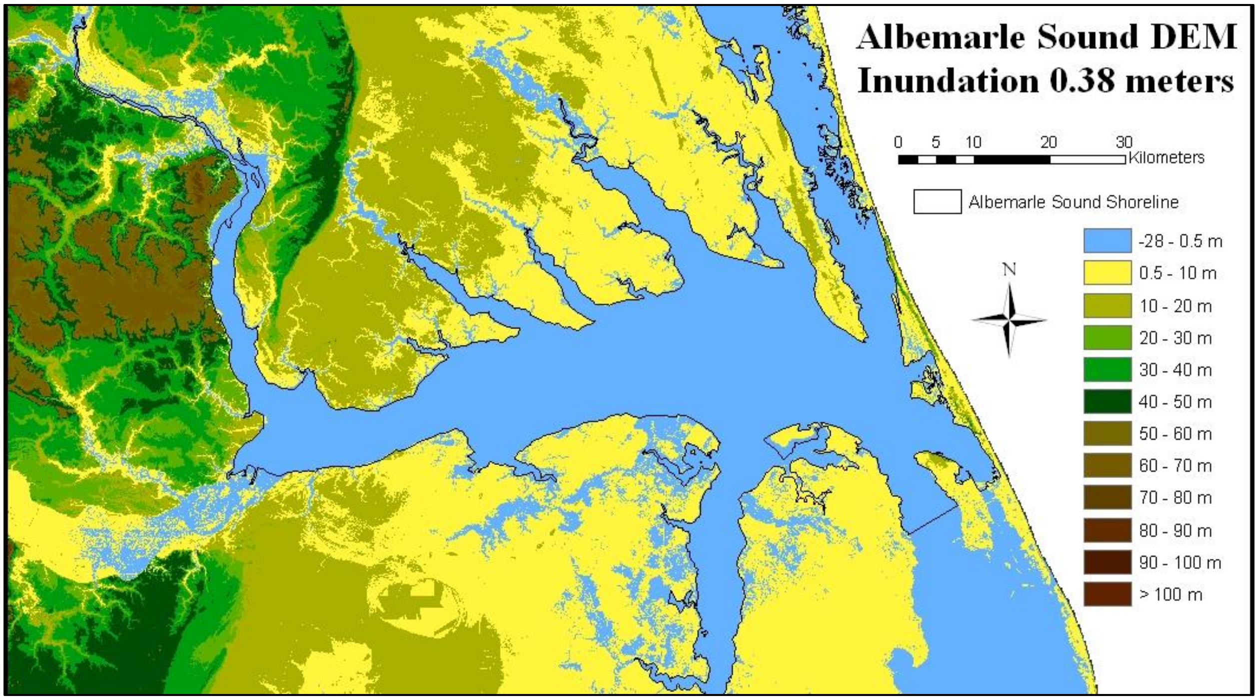

FIGURE 6.4. Geo-spatial representation of lowest estimation of inundation. No OSA sites present (By author, 2011).

OSA sites were input into this projection and OSA sites within this inundation zone were selected. Upon rendering this calculation, it was determined that there were no OSA sites located at an elevation less than the 0.38 or 0.5 meter inundation levels. There are also no indications in the OSA files of sites located at an elevation of less than 0.38 meters at their time of survey.

The second projection shows the middle estimation of inundation 1.0 meter (~3 feet) above the present sea-level (Figure 6.5). This projection also shows the modern shoreline and everything 1.0 meter or less is light blue (water). This projection shows that there are two sites from the OSA located at an elevation of less than 1.0 meter and within a shoreline erosion buffer zone, represented as red squares.

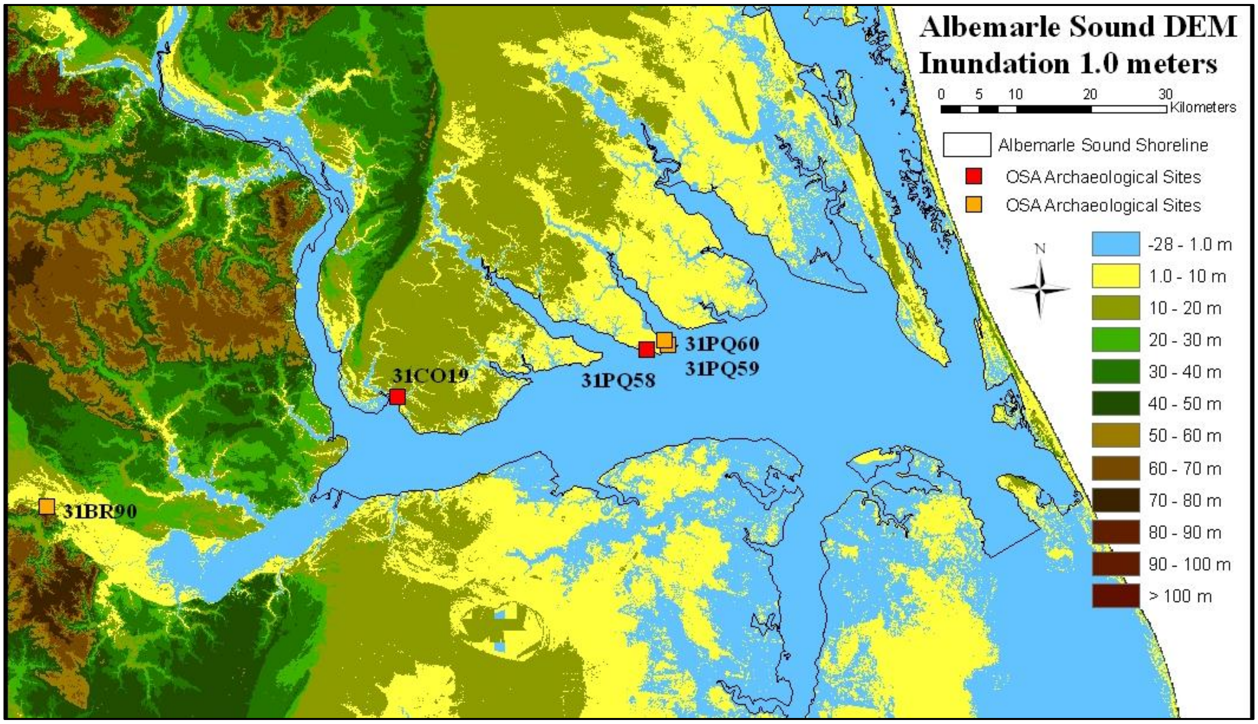

FIGURE 6.5. Geo-spatial representation of OSA sites within the middle estimation of inundation (By author, 2011).

31PQ58 (300 m buffer zone) is a prehistoric site located in Perquimans City in the Stevenson Point quadrangle. This site was surveyed in 1978 and recorded to be 80 meters (262.5 feet, within the 300 m buffer zone) from the water and at an elevation of 0.6 meters (2 feet). The cultural component of this site is Late Archaic and Woodland, and hafted bifaces and projectile points were discovered. 31CO19 (91 m buffer zone) is a historic site located at Edenton and also surveyed in 1978. The site survey identifies the period of occupation as 20th century. The survey also mentions that the site was 0 meters from the water and at an elevation of only 0.9 meters (3 feet). In 1978, it was recorded that this site was already undergoing heavy erosion. It is possible, if this site still exists, that it is the most at risk OSA site, susceptible to both shoreline erosion (91 meters) and inundation (1.0 meters).

There are an additional three sites that are not included in the shoreline erosion diagrams but their surveys indicate they are at an elevation of less than 1.0 meter. They are represented as orange squares. 31PQ59 is a prehistoric/historic site located at Stevenson Point and was surveyed in 1978. At the time of survey, it was recorded to be at an elevation of 0.6 meters (2 feet) and 120 meters (393.7 feet) from the water. 31PQ60 is a prehistoric site also located at Stevenson Point and surveyed in 1978. At the time of survey, this site was 20 meters (65.6 feet) from the water and at an elevation of 0.6 meters (2 feet). 31BR90, known as the Rhodes Site, is prehistoric and located in the Hamilton quadrangle. At the time of survey, 1982, this site was at an elevation of 0.9 meters (3 feet). This site was recorded as being under heavy erosion, specifically stream bank shoreline erosion. There was no distance to water recorded for this site.

The third projection shows the upper estimation of inundation 1.4 meters (4.6 feet) above present sea-level (Figure 6.6). This projection shows the modern shoreline and everything 1.5 meters or less is light blue (water). There are no additional sites from the OSA indicating an elevation of less than 1.5 meters currently within an erosion buffer zone. However, there is one site not indicated in a shoreline buffer zone that is recorded as being at an elevation less than 1.5 meters and less than 30 meters from the water.

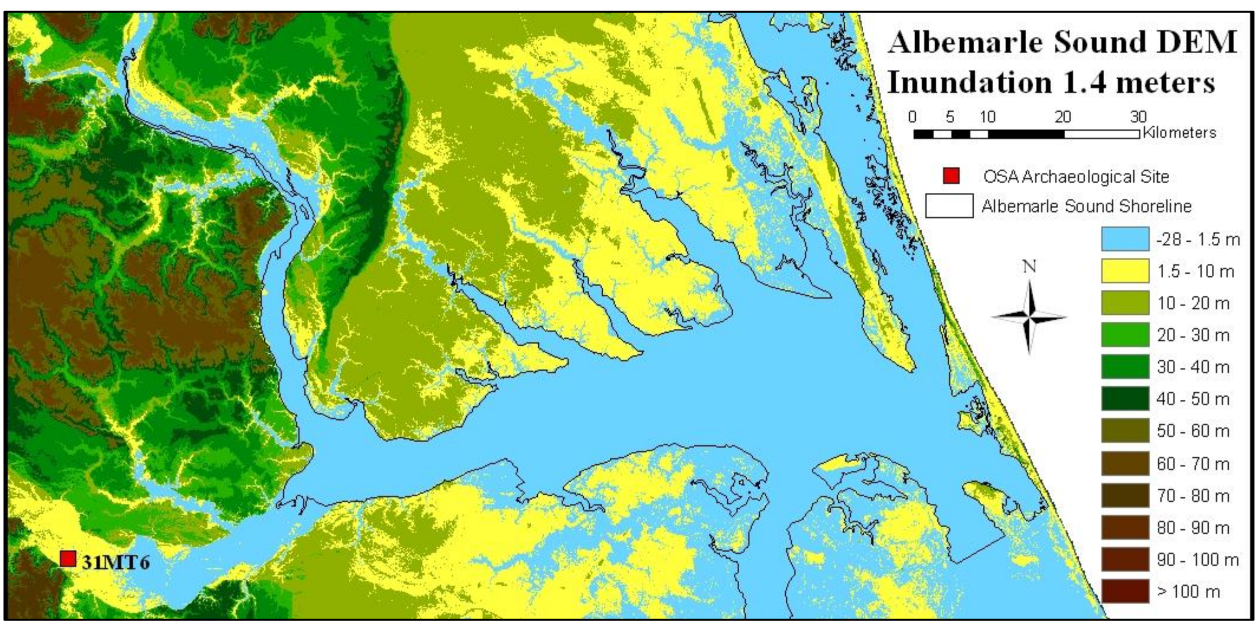

FIGURE 6.6. Geo-spatial representation of OSA site within the upper estimation of inundation (By author, 2011).

31MT6 is a prehistoric site located in Williamston/Quitsna. It was surveyed in 1971 and recorded at an elevation of 1.2 meters (4 feet) and 5 meters (1.5 feet) from the water. This site is also mentioned as suffering from heavy erosion and at the time of survey, contained a shell midden, hafted bifaces, projectile points, and human and non-human bones and teeth. Like 31BR90, this site is located along the Roanoke River which could be why they are not included in an erosion buffer zone.

Critique of Shoreline Erosion and Inundation from Sea-Level Rise Modeling

The four sites that are within an inundation elevation but not located within a shoreline erosion buffer zone should not be discounted. From their surveys, it is clear they are at least within the long-term erosion extent of 300 meters (1000 feet). 31PQ59 and 31PQ60 are located along the shoreline of the Little River and their surveyed distances from the water puts them within the 300 meter and 30 meter erosion buffer distances respectively. It is possible their spatial locations are not accurate or there is discrepancy with their surveyed distances from 1978. 31BR90 and 31MT6 are located along the Roanoke River, which would explain why they are not included in the shoreline erosion buffer zones, as the erosion model does not extend to the rivers.

The extent of the shoreline as represented in GIS is a major critique of this representation. Currently, this example only tabulates estimated shoreline change for Albemarle Sound and the Chowan River. The Roanoke River is not included. If the Roanoke River were included, this zone would also include all OSA sites (and any terrestrial ASCLD sites) along the Roanoke River (Figure 6.7). As such, those sites had to be excluded from this model.

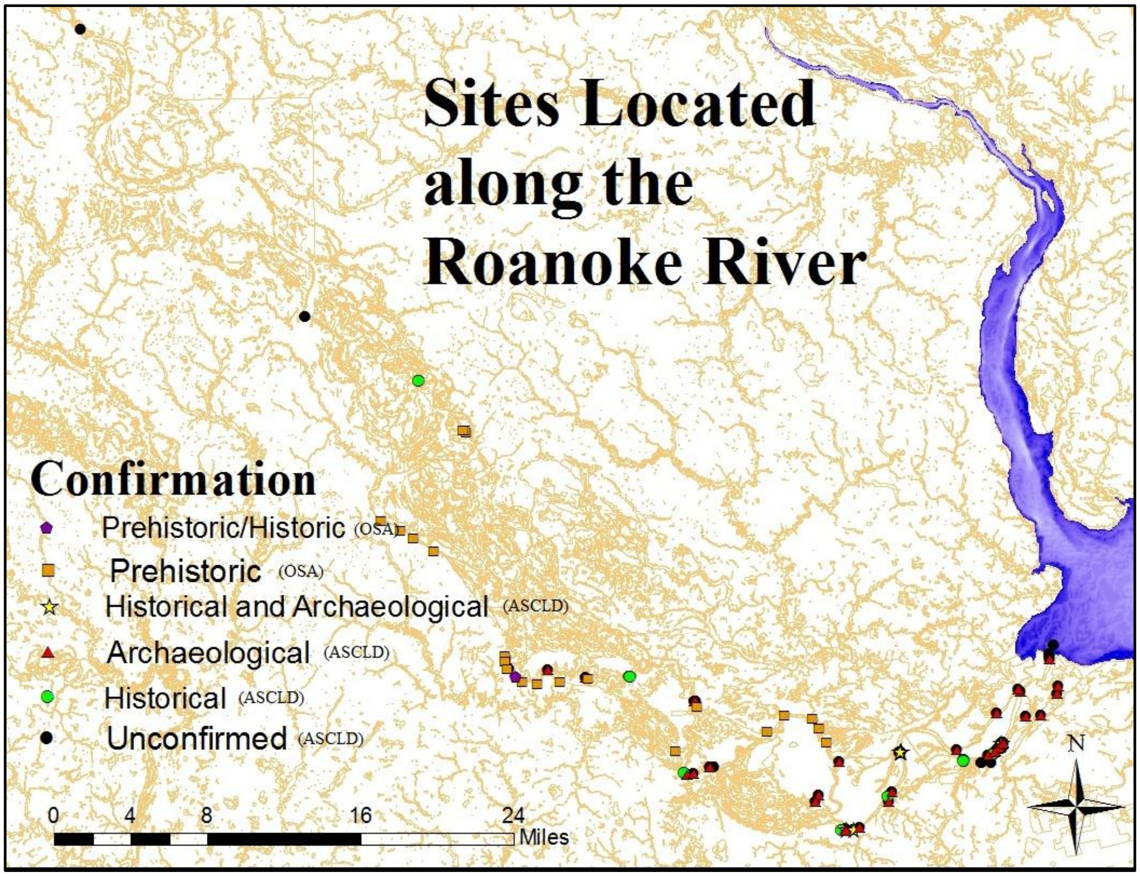

FIGURE 6.7. Geo-spatial representation sites located along the Roanoke River (By author, 2011).

Buffer distances should also be evaluated. The buffer zones are used to show that there are sites within a region which may be at risk because of the dynamic nature of the system. Therefore, they can only be prioritized based on their location within the three zones even though some sites may be closer to an eroding shoreline than others. One way to remedy this would be to apply methods similar to Cowart's (2009) or Robinson et al.'s (2010) shoreline mapping, more precisely indicating areas of erosion, stability, and accretion. This would more accurately describe changes of the shoreline and accordingly indicate precisely which sites are located in risk zones. As such, this representation does indicate that there are several sites located close enough to a potentially eroding shoreline and within an inundation area to necessitate further study.

The most susceptible site, based on all the data, is 31CO19, which is within 100 years (or 100 meters) of an eroding shoreline and less than 1.0 meters (0.9 meters) in elevation. As this site was indicated as being 0 meters from the water at the time of survey, it is possible this site is already lost. 31PQ58 was at an elevation of approximately 0.6 meters (2 feet) in 1978 and a distance of 80 meters (262.5 feet). Therefore, this site lies within the middle inundation estimation and could be susceptible to loss within 87½ years from potential shoreline erosion (or the year 2065). 31PQ59 was at an elevation of 0.6 meters and surveyed as being 120 meters from the water. If this information is accurate, this site could become inundated in the next hundred years or suffer from shoreline erosion within the next 131 years (or the year 2109). 31PQ60 was at an elevation of 0.6 meters and recorded as being 20 meters from the water in 1978. Using erosion and inundation values, this site lies in the medium estimation for inundation but could be currently eroding (21½ years or the year 2000). As such, this site could also be given priority over 31PQ58 and 31PQ59 to determine its current location and susceptibility to damage.

Sub-aerial Risk Analysis Modeling

Sub-aerial risk analysis modeling is used to identify regions sensitive to rapid change. The values for sediment accumulation and RWE were all added to a single *ArcMap* document to compute what sites were within each zone. High areas are defined as those zones where high wave energy overlaps with low sediment accumulation. Low risk zones, and possible preservation regions, exist where low wave energy overlaps with high accumulation. Numeric values were attributed to high, medium, and low classification for both sediment accumulation and wave energy. Using *Spatial Analyst* and the *Plus (Addition) Tool*, the numeric values were added to one another to determine geographical areas of risk. The risk is calculated by assigned values based on location; high wave energy has a numeric value of three, and low accumulation has a numeric value of three. Added together, the numeric value for high risk areas is six. This was done for all nine combinations of wave energy and accumulation to determine five risk zones for the Albemarle Sound (Table 6.4).

TABLE 6.4
Numeric, color, and sensitivity values for Albemarle Sound (By author, 2011)

	High Wave Energy (3)	Medium Wave Energy (2)	Low Wave Energy (1)
Low Accumulation (3)	6 Red High Risk	5 Orange Medium to High Risk	4 Yellow Medium Risk
Medium Accumulation (2)	5 Orange Medium to High Risk	4 Yellow Medium Risk	3 Green Medium to Low Risk
High Accumulation (1)	4 Yellow Medium to High Risk	3 Green Medium to Low Risk	2 Blue Low Risk

Finally, sub-aerial sites from the ASCLD were added to determine location within a geographical area of risk (Figure 6.8). These sites are represented in subsequent tables per risk zone to more easily correlate the sites with their potential risk rating (Tables 6.5, 6.6, 6.7, 6.8, and 6.9). Within these tables, the sites are listed alphabetically (italics denote ship names) and site name, confirmation type, date of build, and date of loss are specified.

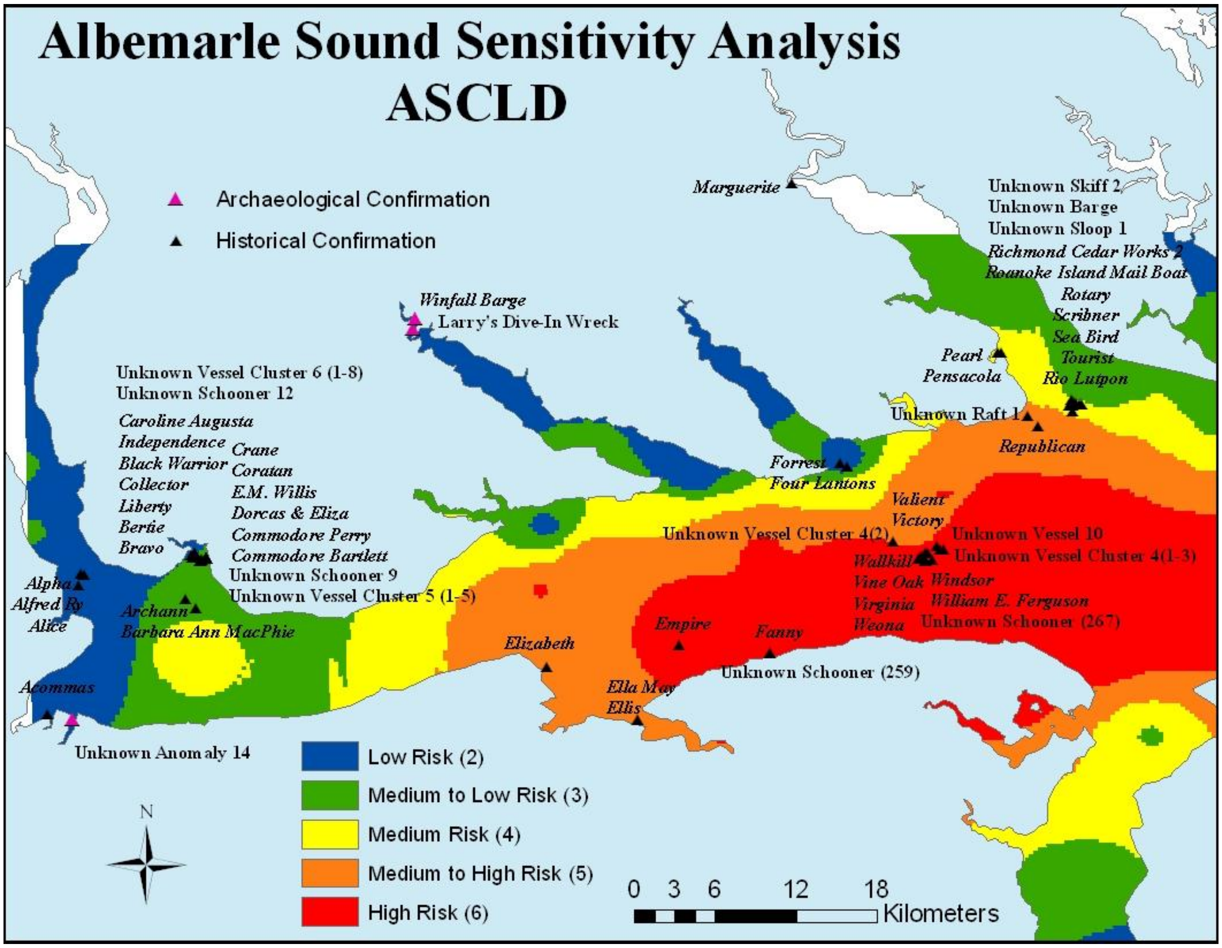

FIGURE 6.8. Geo-spatial representation of ASCLD site locations within sensitivity zones (By author, 2011).

There are 15 sites located within the highest sensitivity area, or the red zone (Table 6.5). All 15 sites are only historically confirmed. This means that these sites have the potential to exist here as historical records have placed them there at one time. Therefore, it could be suggested that this geographical area be researched first to determine the possibility of cultural heritage.

TABLE 6.5
ASCLD sites located in the highest sensitivity area (Red 6) (By author, 2011)

Site Name	Confirmation	Date of Build	Date of Loss
Empire	Historical	1847	1850
Fanny	Historical	1845	1862
Unknown Schooner (259)	Historical	Unknown	1846
Unknown Schooner (267)	Historical	Unknown	1877
Unknown Vessel 10	Historical	Unknown	1826
Unknown Vessel Cluster 4(1)	Historical	Unknown	1789

Unknown Vessel Cluster 4(3)	Historical	Unknown	1789
Valient	Historical	Unknown	1824
Victory	Historical	Unknown	1825
Vine Oak	Historical	1873	1887
Virginia	Historical	1904	1912
Wallkill	Historical	Unknown	1874
Weona	Historical	1892	1929
William E. Ferguson	Historical	1847	1851
Windsor	Historical	1832	1850

These sites are located at the southern edge of the Albemarle shoreline and in the central trunk of the estuary. This area receives the greatest amount of wave activity and sites that may exist here are consequently the most susceptible sites to damage or loss from wave action.

There are six sites located within a medium to high risk area, designated in the orange zone (table 6.6). These sites are also only historically confirmed. Three of the sites, *Elizabeth*, *Ella May*, and *Ellis* are all located near the Scuppernong River. The *Republican* and Unknown Raft 1 are located in the western portion of the Pasquotank River mouth. The last site, Unknown Vessel Cluster 4 (2), is located in the central trunk of the estuary. These geographical areas, designated as a medium to high risk zone, could also be given higher priority for research to determine if there is cultural heritage being actively lost from environmental or even anthropogenic influences.

TABLE 6.6
ASCLD sites located in the medium to high sensitivity area (Orange 5) (By author, 2011)

Site Name	Confirmation	Date of Build	Date of Loss
Elizabeth	Historical	Unknown	1877
Ella May	Historical	Unknown	1901
Ellis	Historical	Unknown	1862
Republican	Historical	1841	1850
Unknown Raft 1	Historical	Unknown	Unknown
Unknown Vessel Cluster 4(2)	Historical	Unknown	1789

There are 12 sites located in the medium risk area (Table 6.7). These sites are also only historically confirmed. *Pearl* and *Pensacola* are located along the western bank of the Pasquotank River. The remaining ten sites are historically located at the mouth of the Pasquotank River. As mentioned previously, this area accumulates sediment more rapid than the central trunk of the estuary. If these sites do exist in their designated positions, it is possible they have been buried. Further study of this area could potentially determine the extent of anthropogenic influences on maritime cultural heritage.

TABLE 6.7
ASCLD sites located in the medium sensitivity area (Yellow 4) (By author, 2011)

Site Name	Confirmation	Date of Build	Date of Loss
Pearl	Historical	Unknown	1844
Pensacola	Historical	1914	1956
Richmond Cedar Works	Historical	1903	1953
Rio Lupton	Historical	Unknown	1889
Roanoke Island Mail Boat	Historical	Unknown	1889
Rotary	Historical	1859	1882
Scribner	Historical	Unknown	1879
Seabird	Historical	1854	1862
Tourist	Historical	1894	1907
Unknown Barge	Historical	Unknown	1933
Unknown Skiff 2	Historical	Unknown	1901
Unknown Sloop 1	Historical	Unknown	1886

There are thirty sites within the medium to low risk area, all of which are historically confirmed (Table 6.8). There are 28 sites located near the bank of the Chowan River mouth. This area is close to Edenton, one of the main ports and towns in early North Carolina history. There are 15 sites that are said to be lost during the 19th century, six during the 20th century, and nine during the 18th century. Of those lost in the 18th century, eight are lost after the dates of the Revolutionary War, and one, *Four Lantons,* was lost during the middle of the war. The ASCLD describes this as a transport cargo vessel, but there is little else known about it. The majority of ships lost during the 19th century were lost before the Civil War. There are two ships, *Black Warrior* and *Forrest*, lost during the war. *Black Warrior* was abandoned, set on fire, and sunk to prevent capture by federal forces (Berman 1972; Elliot 2005). *Forrest* was also abandoned and burned on a marine railway to prevent capture by Union naval forces (United States Coast Guard 1897).

TABLE 6.8
ASCLD sites located in the medium to low sensitivity area (Green 3) (By author)

Site Name	Confirmation	Date of Build	Date of Loss
Archann	Historical	1848	1857
Barbara Ann MacPhie	Historical	1904	1952
Bertie	Historical	1920	1925
Black Warrior	Historical	1859	1862
Bravo	Historical	1832	1836
Caroline Augusta	Historical	1830	1844
Collector	Historical	1824	1829
Commodore Bartlett	Historical	1901	1928
Commodore Perry	Historical	Unknown	1817
Crane	Historical	1917	1929
Croatan	Historical	1864	1929
Dorcas & Eliza	Historical	1848	1888
E.M. Willis	Historical	1911	1925
Forrest	Historical	Unknown	1862
Four Lantons	Historical	Unknown	1760
Liberty	Historical	Unknown	1825
Unknown Schooner 12	Historical	Unknown	1788
Unknown Vessel Cluster 5 (1)	Historical	Unknown	1803
Unknown Vessel Cluster 5 (2)	Historical	Unknown	1803
Unknown Vessel Cluster 5 (3)	Historical	Unknown	1803
Unknown Vessel Cluster 5 (4)	Historical	Unknown	1803
Unknown Vessel Cluster 5 (5)	Historical	Unknown	1803
Unknown Vessel Cluster 6 (1)	Historical	Unknown	1803
Unknown Vessel Cluster 6 (2)	Historical	Unknown	1788
Unknown Vessel Cluster 6 (3)	Historical	Unknown	1788
Unknown Vessel Cluster 6 (4)	Historical	Unknown	1788
Unknown Vessel Cluster 6 (5)	Historical	Unknown	1788
Unknown Vessel Cluster 6 (6)	Historical	Unknown	1788

Unknown Vessel Cluster 6 (7)	Historical	Unknown	1788
Unknown Vessel Cluster 6 (8)	Historical	Unknown	1788

There are nine sites located in the low risk area (Table 6.9). All three archaeologically confirmed sites are within this risk zone. One site, Unknown Anomaly 14, is located near the mouth of the Roanoke River, an area that is rapidly accumulating. There is little recorded for this site, but as it is potentially being actively buried, it is not currently considered a high priority for cultural resource management. *Larry's Dive-In Wreck* and *Winfall Barge* are located in a low wave energy and medium accumulation area in the far north reaches of the Perquimans River. Both wrecks are said to have wooden hulls (*Winfall Barge* is armored wood) and so could be nicely preserved should accumulation rates bury the sites at a rapid pace. Incidentally, these sites could be researched as to the relationship between rapid burial, river output, and cultural preservation. Should any of these sites show signs of erosion or deterioration, there could be further research into the forces causing site deterioration when wind and wave activity are not contributing factors.

TABLE 6.9
ASCLD sites located in the lowest sensitivity area (Blue 2) (By author)

Site Name	Confirmation	Date of Build	Date of Loss
Acommas	Historical	Unknown	1862
Alfred Ry	Historical	Unknown	1850
Alice	Historical	Unknown	1836
Alpha	Historical	1857	1865
Independence	Historical	Unknown	1778
Larry's Dive-In Wreck	Archaeological	Unknown	Unknown
Unknown Anomaly 14	Archaeological	Unknown	Unknown
Unknown Schooner 9	Historical	Unknown	1862
Winfall Barge	Archaeological	Unknown	Unknown

There were no sites or areas where high accumulation overlapped with high wave energy. This is to be expected for a shallow system such as the Albemarle Sound. In a deeper system, this may not be the case, but for the AES, the relationship between wave energy and sediment accumulation is depth dependent. In sum, for this research area, ASCLD sites located in the western and northern Albemarle Sound are less at risk than those located in the eastern and southern areas. This is because the greater accumulation rates at the junction of two major river systems combined with low wave energy favors preservation. In the eastern region, sites suffer from greater wave energy and lower rates of accumulation, potentially causing greater damage to those sites and geographical areas from erosive coastal properties. Further study of these geographical zones could increase the probability of discovering potential archaeological sites that might be at risk from these coastal properties.

Critique of Sub-aerial Risk Analysis Modeling

Similarly to shoreline erosion and inundation mapping, sub-aerial risk analysis was evaluated to illuminate the relationship between wave energy and sediment accumulation. In analyzing wave energy (Figure 5.10), it was discovered that the highest wave energy strikes the southern shoreline of Albemarle Sound, including the Scuppernong and Alligator Rivers. This data was derived from wind speed and direction obtained from NOAA's National Data Buoy Center (NDBC) for Duck Pier, North Carolina, from 2000-2005. The WEMo model works best utilizing data from less than five years of wind data (Malhotra and Fonseca 2009:16). As such, more modeling could be done utilizing wind data from individual years, storm years, hurricane years, and years preceding 2000. Furthermore, as described in Riggs and Ames (2003:55), there is a high probability that a shoreline receiving higher levels of wave energy is more susceptible to damage from erosion.

As mentioned previously, the Albemarle Sound shoreline, or any shoreline, erodes due to several factors: composition, wave energy, and susceptibility to inundation. That is why it was important to measure the rates of erosion and accumulation. Sediment accumulation should be affected by wave power to some degree, but it is largely affected by where materials are being input into the system. Note, higher accumulation rates occur in areas of medium to low wave energy, and this occurs in the estuary’s western part where the rivers discharge. Lower accumulation, as derived from cores taken in the estuary’s center, coincides with higher wave energy and is farther from the major sedimentary source. This inverse relationship also shows this system’s depth dependency.

The problems with measuring sub-aerial sensitivity for this research area are in the data used. The cores were located in central areas, as shown in Figure 5.1. To more accurately combine accumulation rates with wave energy, taking core samples closer to the coast and within the tributaries could provide a more accurate model. This could strengthen the renderings by making the study area extend to the reaches of the cultural heritage. Also, it could be that sediment transport frequency or amount may be more important to burial than sediment accumulation.

There is also error within the ASCLD database itself. Currently, there are two sites known to be located in different areas than their current spatial locations. *Marguerite* is spatially located in the northern part of the Pasquotank River, according to its ASCLD record, though does not show up as being within any sensitivity area (Figure 6.8). However, other records have this site located in the Scuppernong River, near Spruélls Bridge (Berman 1972). *Black Warrior* is spatially located near the Chowan River but historical sources indicate location in the Pasquotank River near Cobb Point Battery (Rawson and Woods 1897 [6]:594-597, 606-609, 616-619, 622-623, 634-635; Civil War Naval Chronology 1971 [6]:206; Elliot 2005:53, 317-318; Scharf 2010:388). These known errors suggest the possibility of more error that could skew this data and these models. Further research utilizing these datasets or within this system could decrease the error in these models.

Critique of Predictive Modeling

As Albemarle Sound is a complex and changing environment with a long history, these exploratory models show there are specific areas that are changing, and therefore, sites within those zones could be given higher priority for research and management. As it is impossible to stop natural processes without causing a detrimental effect to the ecosystem, archaeological sites that are not presently at risk will be one day. Following Maarleveld's (2003) two policy approach, these renderings could be used as a foundation for the protection, preservation, and conservation of known sites as well as assist in protecting areas where the potential of archaeological heritage is great. Preservation areas should also be considered in management. Rate of burial can determine preservation level. Fast burial has the best chance of preserving the ship, especially in low energy and soft substrate environments (Piero 2004:62). Slow burial can cause exposed parts of the wreck to erode from waves and wind. Wind can act like sandpaper, whereas waves can damage the entire structure of the wreck. High velocity waves can raise oxygen content in the water as well as abrade rust that otherwise acts as a biofouling mechanism (Shrier 1963:3.4). Both wind and waves can also transport lighter objects away from original deposition areas.

According to Ward et al. (1999:42), "the primary control upon wreck deterioration is the nature of sedimentation, including its temporal variation." Changes within sedimentation affect the biological and chemical properties within that sediment column as well. Color changes in core samples indicate changes in anoxic conditions (Ward et al. 1999:48). As corrosion requires water and oxygen, a change in the oxygen content could facilitate the degradation of certain hull types or smaller parts that have fallen off a ship (Uhlig 1948:14). The relationship between waves and grain size would indicate that regional accumulation is controlled by wave energy. This is evident in Albemarle Sound as it has been concluded that grain size increases to the east, as a function of depth, source, and wave energy (Corbett et al. 2007:720). As such, high wave energy could cause sediment transport, exposing previously buried areas through scouring (Ward et al. 1999:50).

According to Quinn (2006:1419), “scour occurs at the seafloor when sediment is eroded from an area in response to forcing by waves and currents.” Sediment removal causes previously buried submerged resources to become exposed, increasing degradation. It has been argued that the most detrimental impact of scouring processes on site formation occurs during the first stages of the wrecking process, a time when physical elements dominate site destruction (Quinn 2006:1431). Quinn et al. (1997) researched geophysical evidence for paleo-scour marks at the *Mary Rose* site. The depositional environment of *Mary Rose* indicated a variable history.

Following the initial wrecking process, *Mary Rose* went through a period of relatively high deposition, preserving that which was buried. Areas that were not buried were subjected to geophysical forces that degraded the wreck “to a level concordant with the seabed” (Quinn et al. 1997:14). Buried longitudinal scour pits could become significant markers for maritime archaeologists as fragmented material could be discovered within those pits. Scour pits could also contain importance evidence for reconstructing the site formation processes taking place (Quinn et al. 1997:15), where scours are discovered. Even though scours were not studied during this thesis, further study on scour marks could take place in relation to wreck orientation and environmental substrate (Caston 1979:198).

Prioritization and Management

One benefit of predictive modeling is the ability to prioritize and manage cultural heritage. When time or funding inhibits the ability to conduct research, prioritizing sites can aid coastal managers in researching sites and geographical areas susceptible to morphological change. The majority of sites from the ASCLD are historically confirmed, but this does not imply the sites are actually there. Price (2006:41-42) notes that historical records indicate a higher probability for site existence, as mentioned within historical records. The lack of archaeological confirmation necessitates further study of these areas and these potential sites.

The opportunity to revisit at risk sites from the OSA is also available. There has not been recent work done on these sites or these areas since they were first surveyed. According to the shoreline erosion and inundation modeling completed for this study, there are six sites worthy of further research and survey. Priority for further research could be given to these sites should they still exist and merit archaeological survey. The benefit of revisiting previously surveyed sites lies in the importance of site management.

The shoreline is constantly changing. As the shoreline moves landward, those sites previously outside the shorezone will become subject to the natural processes acting in those areas. Sites that have been on land could deteriorate due to water-logging as well as periodic episodes of dryness as the water level changes. High wind activity and wave action could also remove smaller artifacts that have either broken off larger ones or small remains like projectile points and debitage. These lighter objects can be moved from their position and become damaged, lost, or reburied somewhere else.

Even though historic preservation offices and coastal managers are often needed to document and preserve cultural heritage, budget constraints and lack of funding can pose major problems to their work (Robinson et al. 2010:325). The ability to prioritize sites based on risk as well as geographical areas that might contain archaeological and/or historical information is essential for archaeological site mitigation. By determining those sites most at risk, effective management and priority for research can be established.

Due to the amount of data collected from previous research, as well as the obvious spatial inaccuracies, these models should only be used to infer possible sites and geographical areas that could be negatively affected in both the short-term and long-term future. The information within the ASCLD represents the best known information for the system yet still has spatial and historical inaccuracies. As it has been mentioned, even sites that appear to be spatially located may not actually exist there, or may exist elsewhere, as is the case for *Black Warrior* and *Marguerite*. There are 75 wrecks from the ASCLD that contain unconfirmed locations. Forty of these sites are unconfirmed but might have historical or archaeological references. This leaves 25 sites that are completely unconfirmed. This is one of the drawbacks to this study as the databases are frequently incomplete. More research could increase the value of the database, and that is why being able to prioritize sites and geographical areas is so significant.

Research can be done in a logical and methodical way, with the end result of increasing the information within an invaluable cultural resource (the ASCLD). Even though this risk assessment is conservative and based on incomplete databases, it can still be used for predictive purposes. NOAA’s Office of Response and Restoration published an Environmental Sensitivity Index for North Carolina, including social and economic markers (Figures 6.9 and 6.10). The representations created in this study show that the databases utilized within the scopes of this thesis only present a small fraction of what is at risk, archaeologically, historically, economically, and socially.

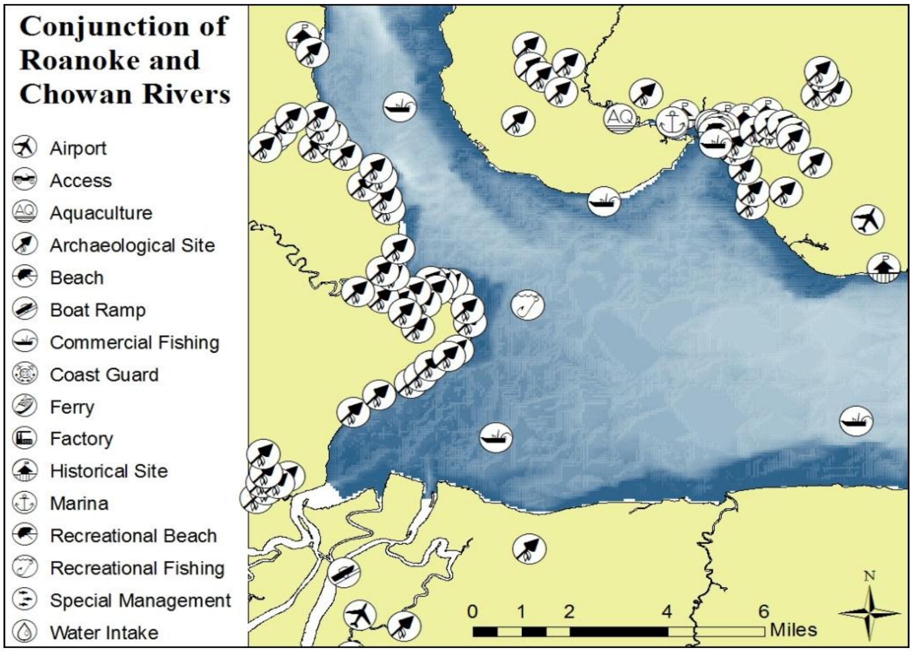

FIGURE 6.9. Close-up of NOAA's social and economic markers at the conjunction of the Roanoke and Chowan Rivers, including archaeological sites (NOAA 2007. Map rendered by author, 2011).

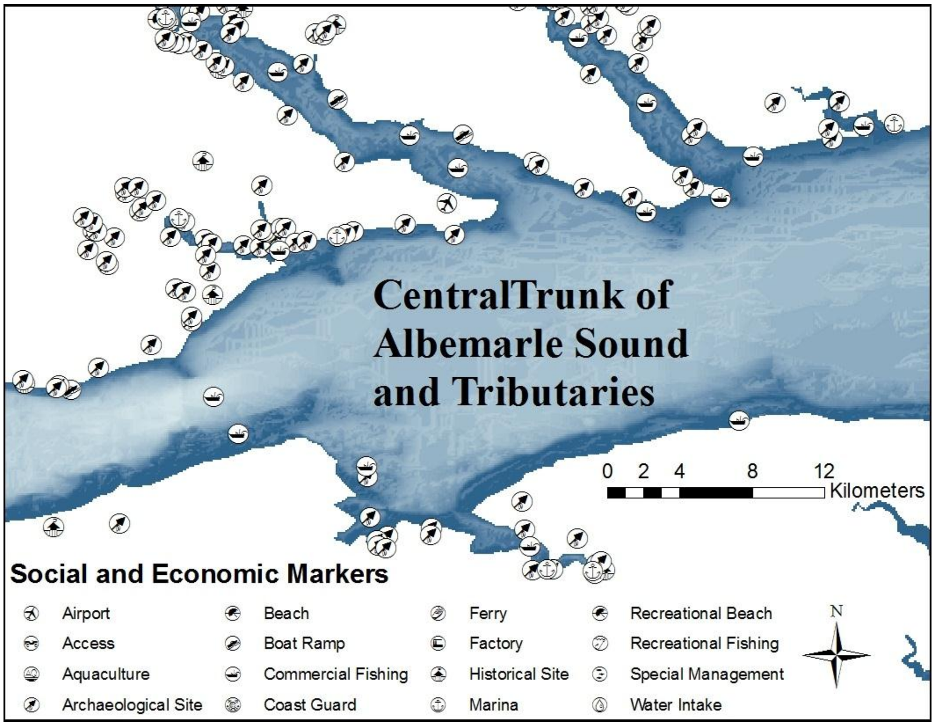

FIGURE 6.10. Close up of the social and economic markers in the central trunk (NOAA 2007. Map rendered by author, 2011).

Archaeological and historical sites, like the ones identified in this study, are clearly evident on the NOAA maps as well as other features indicating the social and economic importance of the marine environment to the past and present inhabitants of Albemarle Sound.

Conclusion

The models created in this study are very conservative in predicting areas of risk by estimating the values of the geophysical properties measured within the Albemarle Estuarine System as derived from previous studies. Further analysis of shoreline change, utilizing similar field methods from Cowart (2008) and Robinson et al. (2010), could offer additional and more precise calculations of shoreline erosion, accretion and stability. Furthermore, sediment sampling at the mouths of the tributaries could create more precise accumulation rates. Finally, wave data could be derived for hurricane seasons and years prior to 2000 and after 2005, furthering the geophysical information of the AES. Should such calculations take place, the areas that are currently designated low to high sensitivity could change, possibly affecting the sites within those areas and level of risk from those coastal properties. The OSA sites could also be better prioritized based on distance from an eroding, accreting, or stable coastline. By prioritizing these geographical areas, coastal managers can organize research and preservation regulations to assist in environmental management. Mitigation strategies can be implemented increasing the probability of discovering potential archaeological heritage.

CHAPTER SEVEN: CONCLUSION

Introduction

Analyzing the Albemarle Estuarine System in relation to the archaeological record has provided a thorough picture of the area's maritime, cultural, and geographical history. The Albemarle Estuarine System is complex but utilizing past studies of the geophysical properties within the area has helped determine patterns that can be used to show changes within and around the system. The geography of the Albemarle Sound revealed the significance of the landscape to settlement, and importance of anthropogenic influences on the environment. The social, political, and economical history presented patterns of settlement, confined to the shores of the rivers, smaller tributaries, and shoreline. Revealing the relationship between the inhabitants and the landscape in Chapter Two provided a foundation for further exploring the archaeological data in relation to the geophysical factors acting on the remains. As the environment is an estuarine landscape, it was significant to show the use and manipulation of that landscape through time and how it affected and was affected by the many generations of settlement. Historical patterns indicate the shorezone was a major zone of habitation and industry and this is verified in the archaeological record. Furthermore, as the history of the Albemarle Region is so embedded within this changing area, it is important to analyze the natural properties in this area that might affect the maritime history.

The archaeological sites that occupy the shorezone of the Albemarle Estuarine System provide an invaluable resource for studying the entire history of the Albemarle Sound. These sites reflect both the development of the area through time as well as changes that have occurred as a result of the changing landscape. In comparing the historical and archaeological data with theoretical concepts, behavior patterns emerged, often reflected in the landscape. This indicates the significance of choice in response to an ever-changing environment. A theoretical framework for the research and analysis of this thesis incorporated concepts from geography, anthropology, archaeology, and marine policy.

Chapter Three used theory to connect the history presented in Chapter Two with the archaeological and geological data detailed in Chapters Four, Five, and Six. Establishing the relationship between land and humans was essential in providing the significance of a natural and historical analysis. Following the establishment of that relationship, a comprehension of site formation processes shows how the cultural and natural components begin to transform and exist as single entities. Finally, a look at environmental mitigation and policy strategies allowed for evaluating this research based on the importance of prioritization and management. This created a more complete and thorough understanding of the relationship between the natural and cultural environments, as they have changed one another and as they might affect one another in the future.

Chapter Four presented the research methodology for this thesis. Included in this section were the historical, archaeological, and geophysical datasets used in analyzing the system as a whole. Chapter Five established the environmental baselines used from previous geological studies as well as wave energy computed in WEMo. Chapter Six finally correlated the archaeological data with the environmental models, culminating in a list of sites from both the OSA and ASCLD that could be given priority for survey or future research for coastal managers and archaeologists. The goal of this thesis was to create renderings that predicted what known sites within the Albemarle Estuarine System might be affected by wave energy, sediment accumulation, shoreline erosion and inundation from sea-level-rise. These properties were researched, quantified, and analyzed to evaluate whether there are historical and archaeological sites at risk of being lost to the dynamic landscape found in Albemarle Sound.

Discussion and Observations

Drawing a parallel between the historical, archaeological, and geological data sets for the Albemarle Estuarine System allowed for the most complete and multi-disciplinary analysis of the area. Each parameter is introduced in Chapter Four, defined in Chapter Five, and related in Chapter Six. Identifying and evaluating each of the individual parameters and then examining them in relation to one another revealed a complex system, affecting the cultural remains within the shore zone differently.

Using previous research generously supplied by ECU's Department of Geological Sciences and the public data available online from NOAA, a conservative representation of physical changes was created for the Albemarle Sound. LiDAR and DEM data were able to show possible areas of increased future inundation due to low elevation and rising sea-level. Relative SLR could have a major impact on the low lying shores of the Albemarle Estuarine System and whatever archaeological sites exist there. Sites that currently exist in the landward areas of the shorezone are susceptible to either temporary or permanent submergence from a steady rise in sea level. This could drastically alter the preservation of the site should the environment in which is rests changes. NOAA's Wave Exposure Modeling (WEMo) was used to combine bathymetry, shoreline, and wind data to show the parts of the shore most affected by variations in relative wave energy (RWE). Waves are one of the parameters defined by Riggs and Ames (2003) that influences the rate of shoreline erosion. Sediment accumulation rates and shoreline erosion rates were also obtained from several studies. Accumulation was discovered to be the greatest in areas where major river systems met the sound (Pasquotank River) or at the junction of major river systems (Roanoke River and Chowan River). Shoreline erosion, also a contributing factor in accumulation, is known to be greatly defined by shoreline composition. Identification of the type of shoreline indicated a conservative erosion rate, averaging approximately one meter per year for Albemarle Sound.

These figures were all represented in *ArcMap 9.3*. The first projections indicate OSA sites that are within specific distances of the current shoreline. Buffer distances of 300 meters (1000 feet and 300 years), 100 meters (300 feet and 100 years), and 30 meters (100 feet and 30 year) represented long-term to short-term outlooks. Inundation was subsequently rated by a low estimation (0.38 meters), a medium estimation (1.0 meter) and a higher estimation (1.4 meters). All three estimations are made for the year 2100, or 100 years in the future. Sites that existed in both the shoreline erosion models and inundation models were subsequently rated more at risk than other sites. For the ASCLD sites, an inverse relationship between wave energy and sediment accumulation was used to identify those within low, medium to low, medium, medium to high, and high sensitivity areas. The most sensitive areas are where high wave energy overlaps with low accumulation. The least sensitive areas are located where low wave energy overlapped with high rates of sediment accumulation.

The locations of the ASCLD wrecks were provided from the previous research done at East Carolina University's Program in Maritime Studies. Franklin Price, Adam Friedman, and Amy Leuchtmann had all completed master's theses that comprised remote sensing surveys (side scan sonar, magnetometry, and multibeam sonar), visual inspection, terrestrial archaeological research and historical research for the Roanoke River and greater Albemarle Sound. Further research should be done on any of these sites or geographic areas for the purposes of increasing information on environmental and cultural databases.

Inadequacies and Further Research

There were several limitations presented in this research. One of the main goals of this thesis was to use previously rendered datasets, but as discussed this also has limitations and can create challenges. Spatial transformation was crucial as the compiled research utilized projection coordinates of different types. The coordinate zones were transformed to match one another but did not extend to the same boundaries, negating some of the available archaeological data. In addition to spatial limitations, the figures utilized were averaged estimates. Therefore, to create the best average value, the final value was estimated from several samples. Following methodological parameters for those faced with estimation problems, this analysis followed two objectives: presenting several samples that best represented the parameter in question as well as provide the methods used for estimating these parameters (values) (Emery and Thomson 2001:214). Following those objectives, it was pertinent to use as many sources available with the best representation of data, even though this also caused some of the inaccuracies previously mentioned.

Another limitation was not in the amount of data available, but in the amount of detail within the datasets. The ASCLD contains information on over 240 wrecks within the Albemarle Estuarine System, from the northern Roanoke River to Elizabeth City in the Pasquotank River. Of these, it was previously discussed that the majority of the individual site files did not contain every value. According to Figure 4.4, 79% of the ASCLD wrecks have ‘unknown’ hull types. As this constitute over ¾ of the variable hull type, it was deemed unnecessary to go into extensive detail about the individual wrecks with a hull type specification. Instead, a brief description of preservation in estuarine environments was used.

The correlation of archaeology, history, geography and geology is only just emerging. The most recent study by Robinson et al. 2010 on the Georgia coast measured shoreline erosion in relation to known archaeological sites. This represents one of the first studies to combine geological methodologies with historical and archaeological datasets. As such, it shows the amount of information to be gained through the combination of several datasets. It was the aim of this thesis to follow that same reasoning, but utilize more than one parameter to define areas of sensitivity. Therefore, measuring wave energy with sediment accumulation, and shoreline composition and erosion with inundation from sea-level rise, several predictive representations were conceived to provide the greatest illustration of factors affecting shorezone cultural remains in the Albemarle Sound.

Conclusion

This thesis has revealed the benefit of predictive modeling, as it aids in the probability of locating archaeological remains in geographically threatened areas. In applying the theoretical frameworks of environmental determinism/possibilism and site formation processes, this thesis showed how the landscape continues to have an effect on culture, and in this case, archaeological remains. Finally, following the idea of the importance of mitigation and management, sites in the designated risk zones within the Albemarle Sound were prioritized, aiding overall coastal, cultural, and archaeological site management.

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Appendix A. Albemarle Sound Cultural Landscape Database (Table by author).

	NAME	Identification Number	UAB Number	Area	Hull Type	Geographical location of loss	Lat.	Long.	Easting (WGS 84)	Northing (WGS 84)	Loss Year
1	Unknown vessel cluster 5 (3)		EDS-1803	Edenton Harbor							
2	A. Von Nyvenheim		ABS-1932	Albemarle Sound	Unknown	Edenton	36.0317	-76.5929	356487	3988638	1932
3	Alice	276	ABS-1836	Albemarle Sound	Unknown	Albemarle Sound	36.0287	-76.6912	347624	3988454	1836
4	Alpha	271	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.0366	-76.6902	347729	3989329	1865
5	Alva	242	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.1227	-76.7447	342990	3998967	1909
6	Barbara Ann MacPhie	234	0	Albemarle Sound	Unknown	Bulls Bay Creek	36.0197	-76.6202	354005	3987347	1952
7	Bravo	275	1-ABS-1836	Albemarle Sound	Unknown	Albemarle Sound	36.0462	-76.6095	355018	3990271	1836
8	Carolina Augusta	258	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.0451	-76.6098	354989	3990149	1844
9	Catherine Taylor	270	1-ABS-1850	Albemarle Sound	Unknown	Albemarle Sound	36.0462	-76.6095	355018	3990271	1850
10	Chansfield	272	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.0462	-76.6095	355018	3990271	1860
11	Collector	278	ABC-1829	Albemarle Sound	Unknown	Scuppernong Point	36.0462	-76.6095	355018	3990271	1829
12	Commodore Perry	285	ABS	Albemarle Sound	Unknown	Edenton	36.0466	-76.6065	355289	3990311	1817
13	Elizabeth	268	1-ABS-1877	Albemarle Sound	Unknown	Albemarle Sound	35.9742	-76.379	377257	4092898	1877
14	Ella Crosby	265	ABS	Albemarle Sound	Unknown	Albemarle Sound	35.9346	-76.3828	376855	4088510	1911
15	Ella May	247	1-ABS-1901	Albemarle Sound	Unknown	Albemarle Sound	35.9395	-76.3178	382651	4088972	1901
16	I.D. Coleman	255	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.2975	-76.2165	390770	4017632	
17	J. Daggit	243	ABS-1907	Albemarle Sound	Unknown	Albemarle Sound	36.2975	-76.2162	390797	4017632	1907
18	Jane	283	ABS-1824	Albemarle Sound	Unknown	Albemarle Sound	36.297	-76.2174	390689	4017578	1824
19	John W. Harding	251	1-ABS-1893	Albemarle Sound	Unknown	Albemarle Sound	36.2967	-76.2175	390679	4017545	1893
20	Joseph A. O'Brien	239	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.297	-76.2167	390751	4017577	1912
21	Joseph N. Billings	264	ABS	Albemarle Sound	Unknown	Laurel Point	36.2969	-76.2164	390778	4017566	1879
22	Kaye C. Green	233	ABS-1998	Albemarle Sound	Unknown	Albemarle Sound	36.297	-76.2159	390823	4017576	1998
23	Manteo Mail Boat	262	ABS-1888	Albemarle Sound	Unknown	Albemarle Sound	36.2969	-76.2155	390859	4017565	1888
24	Margaret Kemble	273	ABS-1846	Albemarle Sound	Unknown	Albemarle Sound	36.2969	-76.2153	390877	4017564	1846
25	Marion A. Greene	245	1-ABS-1903	Albemarle Sound	Unknown	Wade's Point	36.2967	-76.2141	390984	4017541	1903
26	Marva Dough	282	ABS-1824	Albemarle Sound	Unknown	Edenton	36.2966	-76.2143	390966	4017530	1824
27	Neuse	236	0	Albemarle Sound	Unknown	Albemarle Sound	36.2966	-76.2161	390805	4017532	1939
28	Parrott	261	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.2856	-76.1873	393376	4016280	1889
29	Pearl	274	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.1845	-76.0772	403139	4004950	1844
30	Rio Lupton	260	ABS-1884	Albemarle Sound	Unknown	Albemarle Sound	36.1514	-76.0283	407497	4001230	1889
31	Roanoke Island Mail Boat	254	ABS-1889	Albemarle Sound	Unknown	Albemarle Sound	36.1512	-76.0269	407623	4001207	1889
32	Tourist	244	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.1486	-76.0286	407467	4000920	1907

33	Unknown Barge	237	ABS-1933	Albemarle Sound	Unknown	Albemarle Sound	36.1491	-76.0275	407566	4000974	1933
34	Unknown Schooner	267	1-ABS-1877	Albemarle Sound	Unknown	Albemarle Sound	36.0456	-76.1255	407625	3989492	1877
35	Unknown Schooner	259	ABS-1846	Albemarle Sound	Unknown	Albemarle Sound	35.9836	-76.2293	389180	3982828	1846
36	Unknown Skiff 2	246	1-ABS-1901	Albemarle Sound	Unknown	Albemarle Sound	36.1491	-76.0295	407387	4000976	1901
37	Unknown Vessel 10	279	ABS-1826	Albemarle Sound	Unknown	Albemarle Sound	36.0549	-76.1179	399314	3990615	1826
38	Unknown Vessel Cluster 4 (1)	406	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.053	-76.1134	399717	3990400	1789
39	Unknown Vessel Cluster 4 (2)	407	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.0579	-76.1473	399717	3990400	1789
40	Unknown Vessel Cluster 4 (3)	286	ABS	Albemarle Sound	Unknown	Albemarle Sound	36.0528	-76.116	399717	3990400	1789
41	Valient	281	ABS-1824	Albemarle Sound	Unknown	Edenton	36.0506	-76.1258	398597	3990147	1824
42	Victory	280	ABS-1825	Albemarle Sound	Unknown	Albemarle Sound	36.0504	-76.124	398759	3990123	1825
43	Wallkill	269	1-ABS-1874	Albemarle Sound	Unknown	Albemarle Sound	36.047	-76.1303	398187	3989752	1874
44	Crane	307	CWR-1929	Chowan River	Wood	Bennets Creek	36.0467	-76.6065	355289	3990322	1929
45	Edenton	231	CWR-1930	Chowan River	Wood	Mount Gould	36.034	-76.4979	365051	3988757	1930
46	Francis A. Perker	309	CWR-1852	Chowan River	Unknown	Chowan River	36.2981	-76.2175	390681	4017700	1852
47	Greyhounds	310	1-CWR-1751	Chowan River	Wood	Chowan River	36.2977	-76.2171	390716	4017655	1751
48	Hazard	311	CWR-1795	Chowan River	Wood	Chowan River	36.2977	-76.2168	390743	4017655	1795
49	New Landing Ferry	303	1-CWR-1862	Chowan River	Unknown	New Landing	36.2964	-76.2154	390867	4017509	1862
50	Olive	312	CWR-1903	Chowan River	Unknown	Chowan River	36.2873	-76.1883	393288	4016469	1903
51	Amelia Almira	291	DSC-1851	Dismal Swamp	Unknown	Dismal Swamp					1851
52	Fanny	292	DSC-1851	Dismal Swamp	Unknown	Dismal Swamp					1851
53	Fawn	293	DSC-1864	Dismal Swamp	Unknown	Dismal Swamp					1864
54	John Edmonson	294	DSC-1851	Dismal Swamp	Unknown	Dismal Swamp					1851
55	Kingston	295	1-DSC-1902	Dismal Swamp	Unknown	Turner's Cut					1902
56	Rising States	296	DSC-1845	Dismal Swamp	Unknown	Dismal Swamp					1845
57	Ada	297	1-EDS-1892	Edenton Harbor	Unknown	Edenton	36.015	-76.7002	346787	3986949	1892
58	Bertie	298	EDS-1925	Edenton Harbor	Unknown	Edenton	36.0451	-76.6098	354989	3990149	1925
59	Burrough's Site 000	427		Edenton Harbor	Wood	Edenton					
60	E.M. Willis	299	EDS-1925	Edenton Harbor	Unknown	Edenton	36.0467	-76.6065	355289	3990322	
61	Four Lantons	300	EDS-1760	Edenton Harbor	Wood	Edenton	36.108	-76.1779	393981	3996569	1760
62	Hetzell	301	1-EDS-1873	Edenton Harbor	Unknown	Edenton	36.2975	-76.2172	390707	4017633	
63	Independence	413		Edenton Harbor	Unknown	Edenton	36.0488	-76.6165	354392	3990570	1778
64	John's Island Wreck-EDS0001	428		Edenton Harbor	Unknown	Pembroke Creek	36.054	-76.6171	354340	3991150	
65	Liberty	414		Edenton Harbor	Unknown	Edenton	36.0477	-76.6152	354507	3990446	1825

66	Longfield	302	EDS-1820		Edenton Harbor	Unknown	Edenton	36.2978	-76.2155	390860	4017665	1820
67	Rotary	304	EDS		Edenton Harbor	Wood	Edenton	36.1504	-76.0255			1882
68	Unknown Schooner 12	415			Edenton Harbor	Unknown	Edenton	36.0487	-76.6135	354662	3990554	1788
69	Unknown Schooner 9	306	1-EDS-1862		Edenton Harbor	Unknown	Edenton	36.0467	-76.6065			
70	Unknown Vessel Cluster 5 (1)	305	EDS-1803		Edenton Harbor	Unknown	Edenton	36.0467	-76.6065	355289	3990311	1803
71	Unknown Vessel Cluster 5 (2)	402	EDS-1803		Edenton Harbor	Unknown	Edenton	36.0466	-76.6065	355289	3990311	1803
72	Unknown Vessel Cluster 5 (3)	403	EDS-1803		Edenton Harbor	Unknown	Edenton	36.0467	-76.6065	355289	3990311	1803
73	Unknown Vessel Cluster 5 (4)	404	EDS-1803		Edenton Harbor	Unknown	Edenton	36.0466	-76.6065	355289	3990311	1803
74	Unknown Vessel Cluster 5 (5)	405	EDS-1803		Edenton Harbor	Unknown	Edenton	36.0467	-76.6065	355289	3990311	1803
75	Unknown Vessel Cluster 6 (1)	416			Edenton Harbor	Unknown	Edenton	36.0496	-76.6143	354592	3990655	1788
76	Unknown Vessel Cluster 6 (2)	417			Edenton Harbor	Unknown	Edenton	36.0496	-76.6143	354592	3990655	1788
77	Unknown Vessel Cluster 6 (3)	418			Edenton Harbor	Unknown	Edenton	36.0496	-76.6143	354592	3990655	1788
78	Unknown Vessel Cluster 6 (4)	419			Edenton Harbor	Unknown	Edenton	36.0496	-76.6143	354592	3990655	1788
79	Unknown Vessel Cluster 6 (5)	420		0	Edenton Harbor	Unknown	Edenton	36.0496	-76.6143	354592	3990655	1788
80	Unknown Vessel Cluster 6 (6)	421		0	Edenton Harbor	Unknown	Edenton	36.0496	-76.6143	354592	3990655	1788
81	Unknown Vessel Cluster 6 (7)	422		0	Edenton Harbor	Unknown	Edenton	36.0496	-76.6143	354592	3990655	1788
82	Unknown Vessel Cluster 6 (8)	423		0	Edenton Harbor	Unknown	Edenton	36.0496	-76.6143	354592	3990655	1788
83	A. Rhea McCabe	341	1-PQR-1853		Pasquotank River	Unknown	Pasquotank River	35.8771	-76.7478	344230	4082664	1853
84	Acommas	352	1-PQR-1862		Pasquotank River	Unknown	Elizabeth City	35.9432	-76.7124	347517	4089941	1862
85	Alfred Ry	349	PQR-1850		Pasquotank River	Unknown	Pasquotank River	36.0359	-76.6877	347953	3989247	1850
86	Annie	321	PQR-1918		Pasquotank River	Wood	Elizabeth City	36.325	-76.7048	346976	4021345	1918
87	Appomattox	339	PQR-1862		Pasquotank River	Wood	Elizabeth City	36.338	-76.7467	343241	4022854	1862
88	Archann	340	1-PQR-1857		Pasquotank River	Unknown	Davis Bay	36.0138	-76.6131	354634	3986682	1857
89	Atlas	348	PQR-1850		Pasquotank River	Unknown	Wade's Point	36.0311	-76.5477	360558	3988505	1850
90	Bible College Wreck	432	PQR0028		Pasquotank River	Wood	Elizabeth City			2820483	940985	
91	Black Warrior	353	PQR-1862		Pasquotank River	Unknown	Cobb's Point	36.0451	-76.6098	354989	3990149	1862
92	Commodore Bartlett	318	PQR-1928		Pasquotank River	Unknown	Elizabeth City	36.0466	-76.6065	355289	3990311	1928
93	Croatan	317	PQR-1929		Pasquotank River	Unknown	Pasquotank River	36.0467	-76.6065	355289	3990322	1929
94	Dorcas & Eliza	330	1-PQR-1888		Pasquotank River	Unknown	Pasquotank River	36.0467	-76.6065	355289	3990322	
95	Ellis	338	PQR-1862		Pasquotank River	Unknown	Cobb's Point	35.9395	-76.3178	382651	4088972	1862
96	Empire	347	PQR_1850		Pasquotank River	Unknown	Elizabeth City	35.9888	-76.2904	385165	4094408	1850
97	Fanny	354	PQR-1862		Pasquotank River	Unknown	Cobb's Point	35.9836	-76.2293	390595	4093759	1862
98	Forrest	337	PQR-1862		Pasquotank River	Unknown	Elizabeth City	36.1102	-76.1826	393561	3996818	1862

99	Goat	320	PQR-1918	Pasquotank River	Unknown	Fatty Creek	36.298	-76.2176	390672	4017689	1918
100	Grace Garnet	346	PQR-1850	Pasquotank River	Unknown	Elizabeth City	36.298	-76.217	390726	4017688	1850
101	Guy	325	PQR-1911	Pasquotank River	Unknown	Elizabeth City	36.2976	-76.2174	390689	4017644	1911
102	Hilda	322	PQR-1913	Pasquotank River	Unknown	Pasquotank River	36.2976	-76.2167	390752	4017644	1913
103	J.C. Ehringhaus	345	PQR-1850	Pasquotank River	Unknown	Elizabeth City	36.2973	-76.216	390815	4017610	1850
104	John J. Ward	327	1-PQR-1904	Pasquotank River	Unknown	Pasquotank River	36.2969	-76.217	390724	4017566	
105	Julia Ann	344	PQR-1850	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2162	390796	4017543	1850
106	L.O. Muir	323	PQR-1912	Pasquotank River	Unknown	Elizabeth City	36.2971	-76.2157	390841	4017587	1912
107	Maggie Etta	329	PQR	Pasquotank River	Unknown	Banks Landing	36.2977	-76.2154	390869	4017653	1889
108	Monocacy	314	PQR-1956	Pasquotank River	Unknown	Pasquotank River	36.2962	-76.2142	390975	4017486	1956
109	Nina	326	PQR-1909	Pasquotank River	Unknown	Elizabeth City	36.2873	-76.1913	393019	4016473	1909
110	Ocean Bird	332	PQR-1887	Pasquotank River	Unknown	Pasquotank River	36.2875	-76.1897	393163	4016493	1887
111	Partridge	319	1-PQR-1918	Pasquotank River	Unknown	Pasquotank River	36.2667	-76.1704	394868	4014165	1918
112	Pecan Farm Flat	433	PQR0038	Pasquotank River	Wood	Elizabeth City			2829666	945840	
113	Pensacola	313	PQR-1956	Pasquotank River	Unknown	Pasquotank River	36.1843	-76.0754	403301	4004926	1956
114	Richmond Cedar Works 2	315	PQR-1953	Pasquotank River	Steel	Fatty Creek	36.1531	-76.0286	407472	4001419	1953
115	Sawyer's Creek Wreck	434	PQR0039	Pasquotank River	Wood	Sawyer's Creek			2830825	951409	
116	Scribner	334	PQR-1879	Pasquotank River	Unknown	Fatty Creek	36.1501	-76.0229	407981	4001081	1879
117	Sea Bird	336	PQR-1862	Pasquotank River	Wood	Cobb's Point	36.1496	-76.0211	408143	4001024	1862
118	Unknown Raft 1	328	1-PQR-1903	Pasquotank River	Unknown	Pasquotank River	36.1421	-76.0574	404868	4000227	
119	Unknown Sloop 1	333	PQR-1886	Pasquotank River	Unknown	Pasquotank River	36.1451	-76.0273	407580	4000531	1886
120	Unknown Vessel Cluster 1 (1)	351	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.297	-76.2167	408264	4017375	1839
121	Unknown Vessel Cluster 1 (2)	355	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.297	-76.2167	408264	4017375	1839
122	Unknown Vessel Cluster 1 (3)	356	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.297	-76.2167	408264	4017375	1839
123	Unknown Vessel Cluster 1 (4)	357	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.297	-76.2167	408264	4017375	1839
124	Unknown Vessel Cluster 2 (1)	350	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839
125	Unknown Vessel Cluster 2 (10)	366	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839
126	Unknown Vessel Cluster 2 (11)	367	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839
127	Unknown Vessel Cluster 2 (12)	368	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839
128	Unknown Vessel Cluster 2 (2)	358	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839
129	Unknown Vessel Cluster 2 (3)	359	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839
130	Unknown Vessel Cluster 2 (4)	360	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839

131	Unknown Vessel Cluster 2 (5)	361	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839
132	Unknown Vessel Cluster 2 (6)	362	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839
133	Unknown Vessel Cluster 2 (7)	363	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839
134	Unknown Vessel Cluster 2 (8)	364	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839
135	Unknown Vessel Cluster 2 (9)	365	PQR-1839	Pasquotank River	Unknown	Elizabeth City	36.2967	-76.2175	390679	4017545	1839
136	Unknown Vessel Cluster 3 (1)	335	PQR-1878	Pasquotank River	Unknown	Elizabeth City	36.2966	-76.2161	390805	4017532	
137	Unknown Vessel Cluster 3 (2)	401	PQR-1878	Pasquotank River	Unknown	Elizabeth City	36.2966	-76.2161	390805	4017532	
138	Vine Oak	331	PQR-1887	Pasquotank River	Unknown	Pasquotank River	36.0485	-76.1291	398297	3989917	1887
139	Virginia	324	PQR-1912	Pasquotank River	Unknown	Elizabeth City	36.0486	-76.1271	398477	3989926	1912
140	Weona	316	1-PQR-1929	Pasquotank River	Unknown	Pasquotank River	36.047	-76.1275	398439	3989749	1929
141	William E. Ferguson	342	PQR-1851	Pasquotank River	Unknown	Pasquotank River	36.0456	-76.1255	398617	3989592	1851
142	Windsor	343	PQR-1850	Pasquotank River	Unknown	Elizabeth City	36.0461	-76.1213	398996	3989643	1850
143	Hertford Barge	431	PRR003	Perquimans River	Wood	Perquimans River	36.1918	-76.46817	367994	4006230	
144	Larry's Dive-In Wreck	430	PRR002	Perquimans River	Wood	Perquimans River	36.1995	-76.4677	368044	4007085	
145	Republican	290	PRR-1850	Perquimans River	Unknown	Wade's Point	36.1352	-76.0506	405472	3999455	1850
146	Winfall Barge	429	PRR001	Perquimans River	Wood	Winfall	36.2066	-76.4666	368158	4007868	
147	Albemarle (CSS)	159	0	Roanoke River	Armored Wood	Plymouth	35.8686	-76.7492	342079	3970790	1864
148	Bazely (USS)	158	0008ROR	Roanoke River	Wood	Jamesville	35.8128	-76.8885	329381	3964839	1864
149	Bombshell (USS and CSS)	160	ROR-1864	Roanoke River	Unknown	Roanoke River	35.8681	-76.7517	341851	3970744	1864
150	Cable Wreck 19APR048	225	0	Roanoke River	Unknown	Jamesville	35.8134	-76.8886	329374	3964900	
151	Chainplate Wreck (Isabella Ellis?)	162	0021ROR/1-ROR-1854	Roanoke River	Wood	Broad Creek	35.8712	-76.8361	334237	3971221	1864
152	City of Long Branch	161	1-ROR-1893	Roanoke River	Wood	Roanoke River	35.8625	-77.0104	318473	3970568	1892
153	Commerce	164	ROR-1883	Roanoke River	Wood	Williamston	35.8585	-77.0379	315984	3970178	1883
154	Copper Wreck (Comet?)	165	0020ROR/10ROR-1864	Roanoke River	Wood	Broad Creek	35.8712	-76.8358	334264	3971227	1864
155	Currituck	376	0	Roanoke River	Unknown	Unknown					1878
156	Cut Cypress Wreck	229	0	Roanoke River	Steel	Roanoke River	35.8646	-76.8932	329061	3970592	
157	Deadwater Wreck 20APR224	223	0	Roanoke River	Wood	Roanoke River	35.8396	-76.9132	327202	3967856	
158	Dolly (CSS)	166	ROR-1865	Roanoke River	Unknown	Roanoke River	36.2094	-77.3841	285676	4009810	1865
159	Emma	377	0	Roanoke River	Unknown	Unknown					1878
160	Empire	371	0	Roanoke River	Wood	Roanoke River	35.9408	-76.6955	347060.97	3978716.04	1851
161	Floating Betty	168	ROR-1865	Roanoke River	Wood	Roanoke River	35.8376	-76.8491	332993	3967516	1865
162	Fort Branch Barge	167	0005-RORmi	Roanoke River	Wood	Roanoke River	35.9385	-77.1635	304835	3979296	1952

163	Hamilton	169	ROR-1917	Roanoke River	Iron	Roanoke River	35.8613	-76.7609	341000	3970000	1917
164	Immigrant (formerly "Unknown Tug 2")	212	0010ROR	Roanoke River	Wood	Roanoke River	35.8405	-76.845	333363	3967832	1957
165	J.T. Murdock	374	0	Roanoke River	Unknown	Roanoke River					1890
166	L. and W. Showell	375	0	Roanoke River	Unknown	Roanoke River	35.9408	-76.6955	347060.97	3978716.04	1893
167	Lady of the Lake	172	ROR-1851	Roanoke River	Unknown	Roanoke River	35.9425	-76.6952	347092	3978946	1851
168	Liberty	174	1-ROR-1857	Roanoke River	Wood	Plymouth	35.8677	-76.7509	341922	3970694	1857
169	Light Boat MM (formerly "Unknown Light Boat")	210	0	Roanoke River	Wood	Broad Creek	35.8713	-76.8361	334237	3971231	1864
170	Lucille Ross	176	ROR-1950	Roanoke River	Unknown	Jamesville	35.8133	-76.8928	328991	3964904	1950
171	Mast Wreck (Long Shoal Light Boat?)	177	0019ROR/1-ROR-1864	Roanoke River	Wood	Broad Creek	35.8712	-76.8359	334253	3971227	1864
172	Mayflower	179	ROR-1920	Roanoke River	Wood	Plymouth	35.8608	-76.7517	341845	3970734	1920
173	North Carolina	211	0	Roanoke River	Unknown	Roanoke River	35.86135?	-76.7609	341000	3970000	1831
174	Norwood	373	0	Roanoke River	Unknown	Roanoke River					1890
175	Otsego (USS)	180	0009ROR	Roanoke River	Wood	Roanoke River	35.813	-76.8816	330005	3964849	1864
176	Pioneer	370	0	Roanoke River	Unknown	Roanoke River					1846
177	Poplar Point Barge	181	0004RORmi/0025-ROR	Roanoke River	Wood	Roanoke River	35.9324	-77.1276	308060	3978552	
178	Ranger	182	1-ROR-1896	Roanoke River	Wood	Hamilton	35.9473	-77.202	301390	3980345	1896
179	Roanoke River Light Ship	184	ROR-1870	Roanoke River	Wood	Willow Bend	35.9324	-77.0869	311734	3978469	1862
180	Rodney Philips McPhie, Jr.	185	ROR-1959	Roanoke River	Wood	Plymouth	35.8752	-76.7404	342879	3971510	1959
181	Rotary	186	1-ROR-1882	Roanoke River	Wood	Roanoke River	35.8613	-76.7609	341000	3970000	1882
182	Solicitor (formerly "Unknown Tug 3")	213	0013ROR	Roanoke River	Wood	Plymouth	35.9147	-76.7234	344492	3975863	1952
183	Southern Kraft No. 3	224	0	Roanoke River	Wood	Jamesville	35.8124	-76.8886	329367	3964796	1975
184	Southfield (USS)	188	ROR-1864	Roanoke River	Wood	Plymouth	35.8758	-76.7423	342893	3971581	1864
185	Susan Preston MacPhie	187	ROR-1959	Roanoke River	Wood	Plymouth	35.8749	-76.741	342828	3971479	1959
186	Tom's Wreck 19APR063	222	0	Roanoke River	Wood	Jamesville	35.8142	-76.8755	330552	3964973	
187	Unknown Anomaly 1	378	0	Roanoke River	Unknown	Roanoke River	35.8956	-76.7183	344917.4634	3973736.66	
188	Unknown Anomaly 10	392	0	Roanoke River	Unknown	Roanoke River	35.8718	-76.783	339032.6993	3971199.653	
189	Unknown Anomaly 11	393	0	Roanoke River	Unknown	Roanoke River	35.8988	-76.7452	342499.7346	3974137.834	
190	Unknown Anomaly 12	395	0	Roanoke River	Unknown	Roanoke River	35.8742	-76.7419	342745.5221	3971400.009	
191	Unknown Anomaly 13	398	0	Roanoke River	Unknown	Roanoke River	35.912	-76.6886	347632.1397	3975512.364	
192	Unknown Anomaly 14	399	0	Roanoke River	Unknown	Roanoke River	35.939	-76.6955	347063.6906	3978518.249	
193	Unknown Anomaly 15	400	0	Roanoke River	Unknown	Roanoke River	35.9165	-76.7247	344383.0482	3976062.191	

194	Unknown Anomaly 2	379	0	Roanoke River	Unknown	Roanoke River	35.8967	-76.7039	346221.8644	3973836.307	
195	Unknown Anomaly 3	380	0	Roanoke River	Unknown	Roanoke River	35.8699	-76.7473	342252.9082	3970929.124	
196	Unknown Anomaly 4	383	0	Roanoke River	Unknown	Roanoke River	35.8732	-76.7428	342666.489	3971287.919	
197	Unknown Anomaly 5	384	0	Roanoke River	Unknown	Roanoke River	35.8764	-76.7398	342941.246	3971639.726	
198	Unknown Anomaly 6	385	0	Roanoke River	Unknown	Roanoke River	35.8668	-76.7532	341712.5149	3970603.871	
199	Unknown Anomaly 7	386	0	Roanoke River	Unknown	Roanoke River	35.8666	-76.7548	341567.3945	3970575.664	
200	Unknown Anomaly 8	390	0	Roanoke River	Unknown	Roanoke River	35.8629	-77.0144	318118.9584	3970626.864	
201	Unknown Anomaly 9	391	0	Roanoke River	Unknown	Roanoke River	35.8347	-76.9163	326914.3448	3967312.266	
202	Unknown Ferry Boat	369	0	Roanoke River	Unknown	Roanoke River	36.4294	-77.5904	267776.09	4034705.55	1878
203	Unknown Flat 1E	203	0	Roanoke River	Unknown	Plymouth	35.875	-76.7408	342844	3971490	
204	Unknown Flat 1W	206	0	Roanoke River	Unknown	Plymouth	35.8727	-76.7432	342626	3971241	
205	Unknown Flat 2E	204	0	Roanoke River	Unknown	Plymouth	35.875	-76.7409	342839	3971490	
206	Unknown Flat 2W	207	0	Roanoke River	Unknown	Plymouth	35.873	-76.7432	342628	3971269	
207	Unknown Flat 3E	205	0	Roanoke River	Unknown	Plymouth	35.8749	-76.7407	342854	3971482	
208	Unknown Flat 3W	208	0	Roanoke River	Unknown	Plymouth	35.8728	-76.7433	342621	3971254	
209	Unknown Flat 4 W	209	0	Roanoke River	Unknown	Plymouth	35.8726	-76.7433	342614	3971230	
210	Unknown Hulk 1	227	0	Roanoke River	Unknown	Plymouth	35.8642	-76.7776	339500	3970352	1863
211	Unknown Hulk 2	228	0	Roanoke River	Unknown	Plymouth	35.8637	-76.7777	339490	3970301	1863
212	Unknown Jamesville Barge	230	0	Roanoke River	Unknown	Jamesville	35.8127	-76.8886	329371	3964829	
213	Unknown Lighter	194	0	Roanoke River	Unknown	Roanoke River	36.2095	-77.3837	285707	4009827	1865
214	Unknown Punt 1	198	0	Roanoke River	Unknown	Speller's Ferry	35.9127	-77.0263	317156	3976170	
215	Unknown Punt 2	199	0	Roanoke River	Unknown	Speller's Ferry	35.9127	-77.0263	317161	3976165	
216	Unknown Punt 3	200	0	Roanoke River	Unknown	Speller's Ferry	35.9126	-77.0261	317175	3976158	
217	Unknown Punt 4	201	0	Roanoke River	Unknown	Speller's Ferry	35.9125	-77.0262	317161	3976146	
218	Unknown Punt 5	202	0	Roanoke River	Unknown	Speller's Ferry	35.9128	-77.0264	317149	3976177	
219	Unknown Schooner 1	196	0	Roanoke River	Unknown	Broad Creek	35.8703	-76.8365	334194	3971131	1864
220	Unknown Schooner 2	197	0	Roanoke River	Unknown	Broad Creek	35.8707	-76.8363	334217	3971170	1864
221	Unknown Schooner 3	216	0	Roanoke River	Unknown	Plymouth	35.876	-76.7407	342858	3971599	1864
222	Unknown Schooner 4	217	0	Roanoke River	Unknown	Plymouth	35.8761	-76.741	342827	3971614	1864
223	Unknown Schooner 5	218	0	Roanoke River	Unknown	Plymouth	35.8764	-76.7413	342805	3971644	1864
224	Unknown Schooner 6	219	0	Roanoke River	Unknown	Willow Bend	35.9323	-77.0868	311744	3978453	1862
225	Unknown Schooner 7	220	0	Roanoke River	Unknown	Willow Bend	35.9326	-77.0869	311732	3978490	1862
226	Unknown Schooner 8	221	0	Roanoke River	Unknown	Willow Bend	35.9324	-77.0874	311693	3978470	1862

227	Unknown Scow 1	189	ROR-1870		Roanoke River	Wood	Roanoke River	35.9495	-76.691	347484	3979671	1860
228	Unknown Scow 2	190	ROR-1870		Roanoke River	Wood	Roanoke River	35.9492	-76.6907	347513	3979645	1860
229	Unknown Skiff	226		0	Roanoke River	Wood	Roanoke River	35.8338	-76.8482	333061	3967096	
230	Unknown Tug 1	191		0	Roanoke River	Unknown	Roanoke River	35.8613	-76.7609	341000	3970000	1874
231	Unknown Vessel	192	1-ROR01865		Roanoke River	Unknown	Hamilton	35.8613	-76.7609	341000	3970000	1865
232	Unknown Vessel 2	381		0	Roanoke River	Unknown	Roanoke River	35.8716	-76.7449	342467.251	3971122.71	
233	Unknown Vessel 3	382		0	Roanoke River	Unknown	Roanoke River	35.8722	-76.744	34254937659	3971181.933	
234	Unknown Vessel 4	387		0	Roanoke River	Unknown	Roanoke River	35.9402	-77.1988	301657.4359	3979555.59	
235	Unknown Vessel 5	388		0	Roanoke River	Unknown	Roanoke River	35.8574	-77.0347	316269.9686	3970052.258	
236	Unknown Vessel 6	389	RR0025		Roanoke River	Unknown	Roanoke River	35.8581	-77.0294	316752.3991	3970122.21	
237	Unknown Vessel 7	394		0	Roanoke River	Unknown	Roanoke River	35.8691	-76.7483	342159.1606	3970851.025	
238	Unknown Vessel 8	396		0	Roanoke River	Unknown	Roanoke River	35.8755	-76.7406	342865.7105	3971547.361	
239	Unknown Vessel 9	397		0	Roanoke River	Unknown	Roanoke River	35.9181	-76.6876	347730.586.3976181.345		
240	Vesta	372		0	Roanoke River	Unknown	Norfleet's Landing-Upper Roanoke	36.1595	-77.2791	294980	4004048	1879
241	Windlass Wreck	195	0023ROR		Roanoke River	Wood	Broad Creek	35.871	-76.8366	334188	3971202	1864
242	Estella Randall	287	SCR-1910		Scuppernong River	Composite	Columbia	35.9248	-76.2721	385236	3976355	1910
243	Lawrence	288	SCR-Pre1885		Scuppernong River	Unknown	Scuppernong River	36.2966	-76.2158	390832	4017532	
244	Marguerite	289	SCR-1903		Scuppernong River	Wood	Spruells Bridge	36.297	-76.2147	390931	4017575	1933

Appendix B. Office of State Archaeology site locations and attributes (By author).

COUNTY (#)	SITE COMPONENT	QUAD MAP	MAP ZONE	EASTING	NORTHING	DATE RECORDED	ENVIRONMENTAL	CULTURAL
Tyrell 31TY2	Prehistoric/Historic	Columbia W.	18 UTM NAD 27	383710	3977620	2/28/1953	SC: Wooded; NPWT: Creek, river, stream	CC: ceramic, lithic; L: primary debitage
Tyrell 31TY7	Prehistoric	Columbia W.	18 UTM NAD 27	384050	3975370	1/1/1953	DtoW: 40m; E: 5ft; NPWT: river, creeks, stream	CC: ceramic, lithic; L: primary debitage
Tyrell 31TY8	Historic	Columbia W.	18 UTM NAD 27	379380	3977535	1/25/1984	TS: Upland flats; DtoW: 300m; DB: Pasquotank; %D: 76-100; E: 6ft; SoilC: loamy sand; NRCS STC: 84; NPWT: river, creek, stream; Site Size: 601-5000sq.m.; DC: cultivation, land cleaning	PofO: 18th-19th-century; Refined from: 1760
Bertie 31BR28 (Bib#1322)	Prehistoric	Westover	18 UTM NAD 27	345000	3981270	2/17/1977	TS: sandy beach; DtoW: 75m; DB: Roanoke; E: 15m; NPWT: salt water; SC: heavy erosion	CC: woodland
Bertie 31BR27 (Bib#1322)	Prehistoric	Westover	18 UTM NAD 27	345790	3981890	2/17/1977	TS: sandy beach; E: 8ft; NPWT: saltwater; SC: light erosion; DtoW: 0m	CC: woodland
Bertie 31BR26 (Bib#1322)	Prehistoric/Historic	Westover	18 UTM NAD 27	346490	3982250	2/17/1977	DtoW: 100m; E: 13ft; NPWT: saltwater; SC: light erosion	CC: late Archaic; PofO: 18th century
Bertie 31BR29 (Bib#1322)	Prehistoric	Westover	18 UTM NAD 27	346820	3982460	2/18/1977	DtoW: 50m; DB: Roanoke; E: 12ft; NPWT: saltwater; SC: light erosion	CC: late Archaic; Lithics: primary debitage

Berite 31BR30 (Bib#1322)	Prehistoric/Historic	Westover	18 UTM NAD 27	347130	3982840	2/18/1977	DtoW: 150m; E: 16ft; NPWT: saltwater; SC: light erosion	CC: ceramic, lithic, Archaic, Woodland; Lithics: primary debitage
Berite 31BR31 (Bib#1322, 3277)	Prehistoric/Historic	Westover	18 UTM NAD 27	347650	3983240	2/18/1977	DtoW: 65m; E: 6ft; NPWT: saltwater; DB: Roanoke; SC: light erosion	CC: ceramic, lithic, Archaic, middle Archaic, Woodland; Lithics: primary debitage; PofO: 18th century
Bertie 31BR32 (Bib#1322)	Prehistoric	Westover	18 UTM NAD 27	347860	3983419	2/18/1977	DtoW: 25m; DB: Roanoke; E: 5ft; NPWT: saltwater; SC: light erosion	CC: Late Woodland, Woodland
Bertie 31BR33 (Bib#1322, 3277)	Prehistoric	Westover	18 UTM NAD 27	348220	3984470	2/18/1977	DtoW: 65m; DB: Roanoke; E: 13ft; NPWT: saltwater; SC: light erosion	CC: Archaic. Middle Archaic; Lithics: primary debitage
Bertie 31BR34 (Bib#1322, 3277)	Prehistoric	Westover	18 UTM NAD 27	348110	3984990	2/23/1077	DtoW: 125m; DB: Roanoke; E: 18ft; NPWT: saltwater; SC: light erosion	CC: Archaic, Middle Archaic
Bertie 31BR35 (Bib#1322, 3277)	Historic	Westover	18 UTM NAD 27	348140	3984860	2/23/1977	SFD: southeast; MV: row crop, cultivated; DtoW: 125m; DB: Roanoke; E: 14ft; SoilC: sandy loam; NPWT: saltwater; SC: light erosion	PofO: 18th-19th century
Bertie 31BR38 (Bib#1322, 3277)	Prehistoric	Edenhouse	18 UTM NAD 27	347215	3985920	2/23/1977	TS: Stream confluence; DtoW: 130m; SC: light erosion; SoilC: sandy loam; NPWT: saltwater	CC: Ceramic; Midden: present

Bertie 31BR44 (Bib#1322)	Prehistoric/Historic	Edenhouse	18 UTM NAD 27	346345	3987070	2/24/1977	TS: Bluff; DtoW: 60m; E: 7ft; SC: light erosion; NPWT: saltwater; SoilC: sandy loam	CC: not discernible; PofO: 18th - 19th century
Bertie 31BR52 (Bib#1322, 3504, 4341) Edenhouse Site, Project Site # R2512-EH	Prehistoric/Historic	Edenhouse; Project Tracking # 93-7024; CH93-E-4220-0153; ER99-7663	18 UTM NAD 27	345920	3989680	3/2/1977	TS: bluff; Slope face direction: east; Slope % low: 3%; Slope % high: 3%; MV: row crop/cultivated; DtoW: 200m; DB: Chowan; Groun Viz. low&high: 50%; % Destroyed: 76-100%; E: 26ft; SoilC: sandy loam; NRCS type code: GoA; NPWT: river, creek, stream; Destruction causes: cultivation, major earth moving, vandalism, pothunting; SC: light erosion, preserved/unmodified, heavy construction; Site size: 601-5000m^2; Destruction date: 1996	CC: Middle Archaic, Late Woodland, ceramic, lithic; Lithics: bifaces, primary debitage, cores, hafted bifaces, projectile points, secondary and tertiary debitage; SF: short-term habitation, long-term habitation, human skeletal remains; Other: human bone/teeth, non-human bone/teeth, fire cracked rock, unworked marine/river shell, wood, ethnobotanical/faunal; ceramic temper - shell, simple stamped surface treatment (st), fabric impressed (st), coarse sand (st), cordmarked (st); PofO: 17-18th century (1660-1740) - Historic definition: domestic, agricultural; site type/feature: home, residence, wells, root cellar, palisade

Bertie 31BR55 (Bib#1322)	Prehistoric	Edenhouse	18 UTM NAD 27	345680	3990040	3/2/1977	DtoW: 50m; SoilC: sandy loam; NPWT: river, creek, stream; SC: light erosion	CC: Lithic; Lithic: primary debitage
Bertie 31BR161 (Bib#2449, 2836)	Prehistoric/Historic	Edenhouse	18 UTM NAD 27	344560	3991540	7/2/1990	TS: stream confluence; MV: forested; DtoW: 5m; DB: Chowan; E: 25ft; SoilC: loam; NPWT: river, creek, stream; Site size: 5001-10000m^2; SC: heavy erosion, wooded; Destruction causes: erosion, cultivation	CC: Late Woodland, Middle Woodland; Site function: long-term habitation; Lithics: hafted bifaces, projectile points, bifaces, primary debitage, secondary debitage; Other: non-human bone/teeth, fire-cracked rock, ethnobotanical/faunal; shell and medium sand ceramic temper
31CO22	Historic	Edenton	18 UTM NAD 27	355850	3988560	5/25/1978	SFD: southwest; DtoW: 35m; E:13ft; SoilC: sandy loam; NPWT: salt water; SC: preserved/unmodified	PofO: 18th-20th-century
31CO19 (Bib#3277)	Historic	Edenton	18 UTM NAD 27	355390	3990800	5/24/1978	TS: streambank; SFD: west; DB: Chowan; DtoW: 0m; E: 3ft; SoilC: sand; NPWT: saltwater; SC: heavy erosion	PofO: 20th-century
31CO37 (Bib#3277)	Prehistoric	Yeopim River	18 UTM NAD 27	369660	3992880	6/8/1978	TS: streambank; MV: forested; DtoW: 25m; E: 7ft; NPWT: River, creek, stream; SC: heavy erosion	CC: Late Woodland, Woodland; Midden: Present

31PQ58 Perquimans City	Prehistoric	Stevenson Point	18 UTM NAD 27	388740	3995830	7/27/1978	TS: Upland flats; No slope, no vegetation; DtoW: 80m; DB: Pasquotank; E: 2ft; SoilC: silty loam; NRCS type code: Ro; Soil series name: Roanoke silt loam; NPWT: saltwater; SC: preserved/unmodified, clear cut; Destruction causes: land clearing	CC: Late Archaic, Woodland; SF: limited activity; Lithics: hafted bifaces/projectile points; Tool type: Savannah River stemmed (l)
31PQ59 (Bib#3277)	Prehistoric/Historic	Stevenson Point	18 UTM NAD 27	391510	3996300	7/31/1978	TS: Upland flats, no slope; MV: row crop/cultivated; DtoW: 120m; DB: Pasquotank; E: 2ft; SoilC: loam; NRCS: YeA; Soil series: Yeopim loam; NPWT: RCS	CC: Lithic; SF: Isolated artifact find; Lithics: bifaces, tertiary debitage; PofO: 19th-century
31PQ60 (Bib#3277)	Prehistoric	Stevenson Point	18 UTM NAD 27	391050	3996930	7/31/1978	TS: upland flats, no slope; MV: rowcrop/ciltication; DtoW: 240m; DB: Pasquotank; E: 2ft; SoilC: silty loam; NRCS: Ch.; Soil series: Chapanoke silt loam; SC: preserved/unmodified, cultivated; NPWT: saltwater; SS: 1-10m; DC: cultivation	CC: Middle Archaic; SF: isolated artifact find; L: hafted bifaces/projectile points; TT: Morrow Mtn. I stemmed
31MT38 Martin City	Prehistoric	Palmyra	18 UTM NAD 27	291280	3992150	6/22/1971	DtoW: 105m; E: 90ft; SoilC: loamy sand; NPWT: river, creek stream; SC: light erosion	CC: Lithic; L: primary debitage, ground/pecked stone
31MT36 Martin City	Prehistoric	Palmyra	18 UTM NAD 27	295610	3989450	6/22/1971	TS: Bluff; DtoW: 125m; SoilC: loamy sand; NPWT: river, creek, stream; SC: light erosion	CC: Lithic, Ceramic; L: primary debitage, ground/pecked stone

31MT26	Prehistoric	Palmyra	18 UTM NAD 27	292860	3991240	6/18/1971	DtoW: 185m; E: 83ft; SoilC: loamy sand; SC: light erosion	CC: Lithic; L: primary debitage, ground/pecked stone
31MT29	Prehistoric	Palmyra	18 UTM NAD 27	293930	3990630	6/21/1971	DtoW: 110m; E: 76ft; NPWT: river, creek, stream; SC: light erosion	CC: Ceramic, Lithic; L: primary debitage, ground/pecked stone
31BR13	Prehistoric	Quitsna	18 UTM NAD 27	317275	3975455	6/16/1971	TS: Bluff; DtoW: 180m; DB: Roanoke; E: 7ft; NPWT: river, creek, stream; SC: heavy erosion, pasture	CC: Ceramic
31BR90 Site Name: Rhodes Site Site #: 0006ROR	Prehistoric	Hamilton	18 UTM NAD 27	308150	3978220	9/21/1982	TS: Bench; SFD: East, MV: Forested; DB: Roanoke; %D: 26-50%; E: 3ft; SoilC: clay loam; NPWT: river, creek, stream; SS: 601-5000m^2; SC: heavy erosion, stream bank shoreline erosion; DC: Erosion	CC: Late Woodland, Middle Woodland; M: Present; SF: Short-term habitation; Other: Ethnobotanical, faunal
31MT45	Prehistoric	Hamilton	18 UTM NAD 27	301240	3980420	6/25/1971	DtoW: 120m; E: 72ft; NPWT: river, creek, stream; SC: light erosion, residential	CC: Lithic, Ceramic; L: primary debitage
31MT23	Prehistoric	Hamilton	18 UTM NAD 27	301280	3979930	6/18/1971	DtoW: 130m; E: 69ft; NPWT: river, creek, stream; SC: Wooded, fallow	CC: Ceramic
31MT17	Prehistoric	Hamilton	18 UTM NAD 27	301450	3979320	6/17/1971	TS: Bluff; DtoW: 140m; E: 66ft; NPWT: river, creek, stream; SC: heavy erosion, fallow	CC: Ceramic, Lithic; L: primary debitage, ground/pecked stone

31MT61 Other Site #: HOGTOWN	Prehistoric/Historic	Hamilton	18 UTM NAD 27	302080	3978660	12/30/1981	TS: Floodplain; %S: 5%; SFD: Northeast; MV: rowcrop/cultivation; DtoW: 110m; GV: 30%; E: 56ft; SoilC: sand; NPWT: river, creek, stream	PofO: 18th-19th-century, ~1760; Historic affiliation: English and Native American; Historic definition: Commercial transportation
31MT21	Prehistoric	Hamilton	18 UTM NAD 27	302680	3978170	6/17/1971	TS: Natural levee; DtoW: 80m; E: 46ft; SoilC: candy clay; NPWT: Lake; SC: heavy erosion	CC: Ceramic; M: Present
31MT59 Site name: Fort Branch, Other #: MTFB1; 0001ROR (Bib#: 1076, 3203)	Prehistoric	Hamilton	18 UTM NAD 27	304090	3978040	1/1/1961	TS: Bluff; MV: Forested; E: 39ft; NPWT: river, creek, stream; SC: Wooded	PofO: 19th-century ~1863; Historic Affiliation: European-American; Historic definition: Military
31MT2	Prehistoric	Hamilton	18 UTM NAD 27	303870	3977930	1/9/1971	DtoW: 90m; E: 59ft; SoilC: sandy clay; NPWT: river, creek, stream; SC: light erosion	CC: Lithic, Ceramic; M: Present; L: primary debitage
31MT45	Prehistoric	Hamilton	18 UTM NAD 27	305820	3978040	6/9/1971	DtoW: 100m; E: 66ft; NPWT: river, creek, stream; SC: light erosion	CC: Lithic, Ceramic; L: primary debitage, ground or pecked stone; M: Present
31MT6	Prehistoric	Williamston or Quitsna	18 UTM NAD 27	315260	3971810	6/10/1971	TS: First terrace; SFD: Southeast; MV: rowcrop/cultivation; DtoW: 5m; DB: Roanoke; E: 4ft; %S: 1%; SoilC: sandy loam; NPWT: river, creek, stream; SS: >50,000m^2; SC: Heavy erosion	CC: Late Woodland, Lithic; SF: Short-term habitation; L: secondary debitage; Other: Non-human bone/teeth; Ceramic temper: fine sand-simple stamped; medium sand-fabric impressed

31BR7 Site name: Jordan's Landing	Prehistoric	Windsor South	18 UTM NAD 27	323040	3973180	3/1/1971	%S: 4%; DtoW: 300m; DB: Roanoke; E: 10ft; SoilC: sandy loam; NRCS: WkB; NPWT: river, creek, stream; SC: Heavy erosion	CC: Lithic, Contact Native American, Middle Woodland, Late Woodland; SF: Shell midden; L: hafted bifaces/projectile points, primary debitage; other: human bone/teeth, non-human bone/teeth, ethnobotanical/faunal, turtle shell
31BR8	Prehistoric	Windsor South	18 UTM NAD 27	328000	3972000	5/1/1971	DtoW: 60m; DB: Roanoke; E: 6ft; SoilC: sand; NPWT: river, creek, stream; SC: Heavy erosion	CC: Lithic, Ceramic; M: present; L: primary debitage
31BR9	Prehistoric	Windsor South	18 UTM NAD 27	324595	3974445	6/12/1973	TS: Hill or ridge top; SFD: Northwest; MV: rowcrop/cultivation; DtoW: 30m; DB: Roanoke; E: 10ft; SoilC: sand; MPWT: swamp; SC: light erosion	CC: Woodland; SF: short-term
31BR3	Prehistoric	Valhalla	18 UTM NAD 27	342800	4007050	8/27/1952	TS: Sandy beach; DtoW: 40m; E: 5ft; SoilC: sand; SC: Heavy erosion	CC: Ceramic, Late Woodland, Woodland; SF: Human skeletal remains, shell midden
31CO3 (Bib#1322)	Prehistoric/Historic	Valhalla	18 UTM NAD 27	345510	4005470	9/17/1973	TS: Hill or ridge top; DtoW: 120m; NRCS: Wa	CC: Ceramic, Woodland
31CO13	Prehistoric	Valhalla	18 UTM NAD 27	345530	4006600	4/1/1977	TS: Sandy beach; DtoW: 30m; NRCS: Wa; SC: light erosion, totally destroyed	

31BR10 (Bib#5207)	Prehistoric	Windsor South	18 UTM NAD 27	327460	3973240	6/11/1971	TS: Second terrace; MV: Fallow; DtoW: 90m; %D: 76-100%; E: 15ft; SoilC: sandy loam; SC: Light erosion	CC: Lithic; L: primary debitage; unifacial tools, secondary debitage
31BR11	Prehistoric	Windsor South	18 UTM NAD 27	326950	3974100	6/11/1971	DtoW: 170m; DB: Roanoke; E: 26ft; SoilC: sand; SC: Heavy erosion	CC: Lithic; L: primary debitage
31BR82 "LB2"	Prehistoric	Woodville	18 UTM NAD 27	298730	3999300		TS: Upland flats; MV: rowcrop/cultivation; DtoW: 280m; DB: Roanoke; E: 20ft; SoilC: Sandy loam	CC: Early Archaic, Middle Archaic, Late Archaic, Lithic; L: Hafted bifaces/projectile points, cores, secondary debitage
31BR183	Prehistoric	Woodville	18 UTM NAD 27	298700	3999520		TS: Upland flats; MV: rowcrop/cultivation; DtoW: 260m; DB: Roanoke; E: 20ft; SoilC: Sandy loam; DC: Cultivation	CC: Late Archaic, Lithic; L: Hafted bifaces/projectile points, cores, secondary debitage
31BR91 Dickerson Site (Bib#1563, 1791, 3201)	Prehistoric	Woodville	18 UTM NAD 27	298500	3999500	5/20/1983	TS: First terrace; MV: rowcrop/cultivation; DtoW: 50m; DB: Roanoke; %D: 51-75%; E: 25ft; SoilC: sandy clay loam; SS: 601-5000m^2; DD: 1983; DC: Major earth moving, excavation	CC: Late Woodland, Middle Woodland, Early Woodland, Late Archaic; SF: Short-term habitation, human skeletal remains; L: primary debitage; Ethnobotanical /faunal

Appendix C. Information from Erin Letrick 2003 and Corbett et al. 2003 (Table by author).

LOCATION	SITE	LATITUDE	LONGITUDE	CORE (cm)	Water Depth (m)	SURFACE SALINITY	BOTTOM SALINITY	SURFACE TEMPERATURE	BOTTOM TEMPERATURE	Pb210 Accumulation (cm y^-1)	Cs137 Accumulation (cm y^-1_
Albemarle Sound	Alb01S1	35.9762	76.5808	40	5.2	N/A	N/A	N/A	N/A	0.57 +- 0.07	0.54
Albemarle Sound	Alb01S2	36.0199	76.3304	37	5.5	2.7	3	27.1	26.1	0.18 +- 0.03	0.17
Albemarle Sound	Alb01S3	36.05	76.1665	42	5.8	2	3.8	26.3	26.5	0.13 +- 0.03	0.11
Albemarle Sound	Alb01S4	36.0567	75.9665	28	5.5	5.3	5	27	26.1	0.08 +- 0.02	0.11
Albemarle Sound	Alb01S5	36.1473	76.0174	16	3.4	3.8	4.3	27.8	26.8		
Albemarle Sound	Alb01S6	36.0342	75.8168	15	3.7	5.7	5.7	27	27		
Albemarle Sound	Alb01S7	35.9804	75.8735	19	1.5	5.3 (mid)		26.8 (mid)			
Alligator River	All01S1	35.6691	76.0323	25	2.7	3.4	2.9	28.2	26.4		
Alligator River	All01S2	35.8866	76.0168	25	4.3	3.8	4.2	28.8	26.6		
Alligator River	All01S3	35.8897	75.9876	13	1.8	3.9 (mid)		27.2 (mid)			
Alligator River	All01S5	35.7846	76.0269	30	3.4	3.9 (mid)		26.7 (mid)			
Pasquotank River	Pas01S1	36.2986	76.2096	31	2.4	0.6	2.6	29.6	28.3		
Pasquotank River	Pas01S2	36.2525	76.1191	40	3.7	3.1	3.5	31.1	27.4		
Pasquotank River	Pas01S3	36.2008	76.0584	61	4	3.9	3.8	30.1	28.1		

Appendix D. Wave Exposure Modeling Points and Characteristics (By author).

Point Data #	X_COORD	Y_COORD	RWE	MaxWvH	AvgWvH	MaxWvDr	AvgWvPr	MaxWvPr	Depth
1	344742.8068	4006283.387	2347.95	0.72	0.49	202.5	2.36	2.92	-5.35
2	344742.8068	3997120.278	4203.63	0.81	0.54	157.5	2.49	3.09	-5.85
3	346629.3291	3994964.253	2356.03	0.64	0.51	202.5	2.44	2.82	-2.64
4	347168.3355	3993077.73	1787.95	0.74	0.47	157.5	2.31	2.86	-1.77
5	345012.31	3992538.724	4512.31	0.76	0.51	135	2.4	3	-4.97
6	348246.3482	3988496.176	3866.96	1.06	0.64	112.5	2.67	3.39	-6.29
7	348515.8514	3983914.622	1311.37	0.62	0.43	67.5	2.43	3.43	-0.88
8	353905.9151	3983375.616	7830.1	1.03	0.81	112.5	3.03	3.43	-5.85
9	375466.1701	3987687.667	10276.01	1.12	0.87	112.5	3.13	3.54	-5.81
10	378161.202	3989843.692	9309.46	1.12	0.89	112.5	3.15	3.54	-5.81
11	375735.6733	3992269.221	3403.63	1.05	0.64	112.5	2.78	3.46	-3.76
12	373040.6414	4003588.355	883.22	0.65	0.42	135	2.14	2.61	-2.87
13	384629.2785	3996850.775	288.48	0.43	0.35	112.5	2.29	3.41	-0.61
14	383012.2594	3992269.221	7992.8	1.09	0.85	112.5	3.09	3.52	-5.54
15	386246.2976	3990382.699	9928.09	1.12	0.9	112.5	3.2	3.52	-5.81
16	384629.2785	3985801.144	12789.95	1.01	0.89	112.5	3.17	3.34	-6.11
17	388941.3295	3985531.641	12300.07	0.96	0.84	90	3.07	3.32	-6.08
18	388671.8263	3990382.699	10551.43	1.11	0.92	112.5	3.21	3.51	-6.02
19	386246.2976	4005474.877	0	0	0	0	0	0	-6.02
20	387593.8136	4003049.348	910.88	0.69	0.4	135	2.05	2.69	-1.69
21	410771.0877	3958581.322	939.75	0.62	0.4	202.5	2.09	2.9	-0.88
22	407537.0494	3965588.405	5277.8	0.88	0.69	157.5	2.68	2.97	-2.41
23	412118.6036	3976368.533	5955.54	0.86	0.69	225	2.69	2.92	-3.41
24	393792.3869	3997120.278	2457.06	1.04	0.63	112.5	2.6	3.43	-2.13
25	394600.8964	3994155.743	7996.97	1.11	0.86	112.5	3.06	3.53	-5.19
26	394331.3932	3989304.686	12535.38	1.09	0.91	112.5	3.2	3.44	-5.81
27	397565.4315	3994694.749	8392.55	1.11	0.88	112.5	3.12	3.53	-5.21
28	399721.457	3994425.246	10219.01	1.12	0.92	112.5	3.19	3.53	-5.51
29	406459.0367	3985531.641	11846.22	1.13	0.86	112.5	3.09	3.46	-4.91
30	408345.559	3987687.667	12799.92	1.13	0.92	112.5	3.21	3.49	-5.21
31	411579.5972	3987148.66	12807.2	1.1	0.93	112.5	3.22	3.43	-5.21
32	407267.5462	3989574.189	12947.54	1.12	0.94	112.5	3.25	3.5	-5.21

33	403764.0048	3991460.711	13024.35	1.13	0.95	112.5	3.26	3.52	-5.56
34	406998.043	3998198.291	9530.12	1.11	0.88	112.5	3.09	3.49	-4.61
35	409154.0685	4002510.342	4638.33	1.04	0.76	135	2.83	3.35	-3.71
36	420742.7056	3982836.609	8765.46	0.94	0.73	45	2.77	3.23	-3.12
37	421820.7184	3985262.138	11218.77	1.06	0.87	112.5	3.04	3.24	-4.8
38	419395.1897	3985262.138	11404.64	1.04	0.87	112.5	3.08	3.3	-4.61
39	418586.6801	3991730.214	11657.54	1.12	0.94	112.5	3.21	3.41	-5.51
40	420203.6992	3996311.769	7842.87	1.01	0.82	157.5	3.01	3.36	-4.8
41	421551.2152	3998737.297	664.16	0.43	0.37	0	2.43	3.33	-0.61
42	418047.6737	4000893.323	3942.1	0.98	0.74	157.5	2.8	3.32	-3.01
43	413735.6227	4013559.973	308.22	0.34	0.2	225	1.46	1.91	-0.97