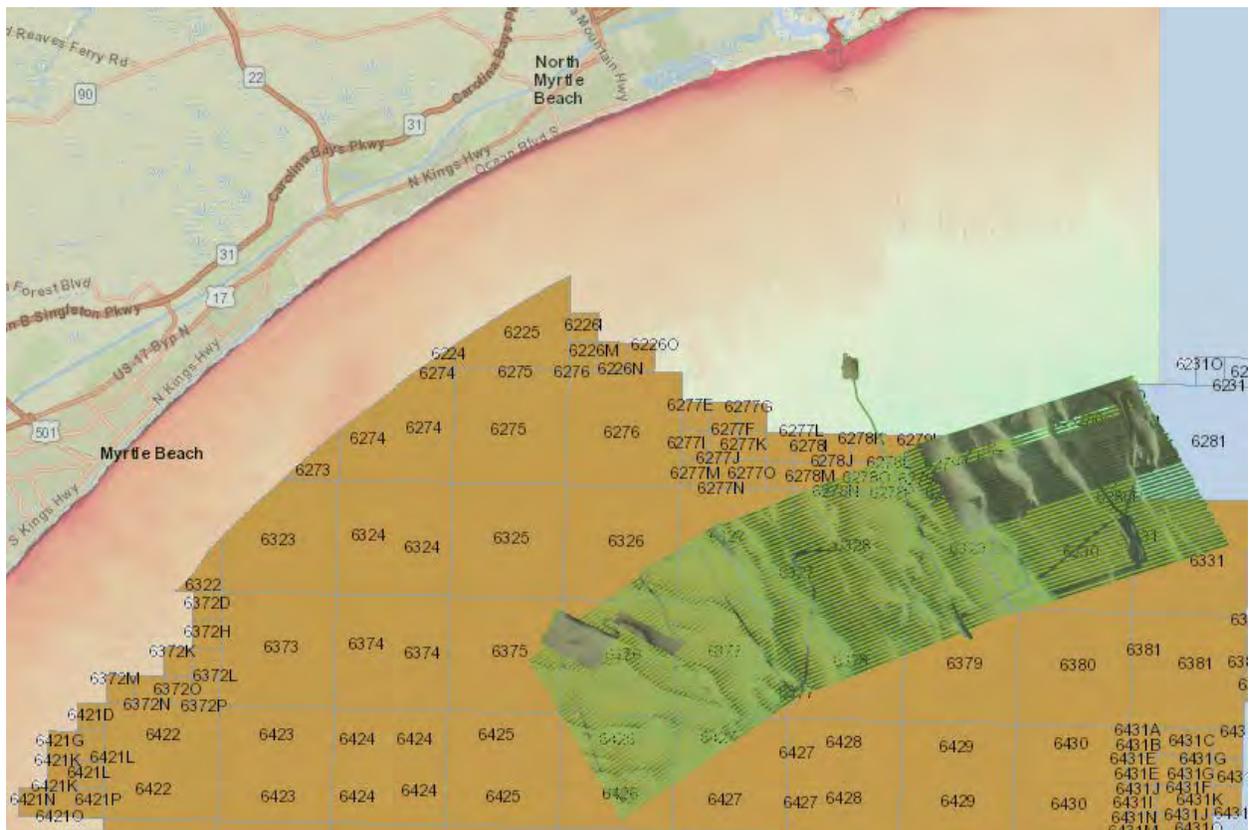


# Atlantic Offshore Wind Energy Development: Geophysical Mapping and Identification of Paleolandscapes and Historic Shipwrecks Offshore South Carolina



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May 2019

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## **DISCLAIMER**

Study collaboration and funding were provided by the US Department of the Interior, Bureau of Ocean Energy Management (BOEM), Office of Renewable Energy Programs, Washington, DC, under Agreement Number M15AC00001. This report has been technically reviewed by BOEM, and it has been approved for publication. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the US Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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## **CITATION**

Gayes PT, Knapp CC, Knapp J, Brantley D, White S, Battista B, Spirek JD, Brown DM, Christian LM, Bradley RJ, Harris MS. 2019. Atlantic Offshore Wind Energy Development: Geophysical Mapping and Identification of Paleolandscapes and Historic Shipwrecks Offshore South Carolina. Conway (SC): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2019-008. 189 p.

## **ABOUT THE COVER**

Cover image displaying multibeam echosounder imagery of the study area offshore North Myrtle Beach, South Carolina overlaid a grid of potential Wind Energy Areas, U.S. Geological Survey bathymetry, and a street map of Horry County. All rights reserved.

## ACKNOWLEDGMENTS

Many individuals and organizations contributed to the success of the project including Patricia L. Jerman, South Carolina Energy Office, for presenting the opportunity to the principal investigators to collaborate and undertake this cooperative agreement with BOEM; South Carolina Sea Grant Consortium, M. Richard Devoe, Ryan Bradley, and staff, for their guidance and assistance in managing and adhering to the project tasks and deliverables; numerous BOEM personnel including Dr. David Bigger and Brian Krevor, for their management and feedback during the course of the study, and Dr. Brian Jordan, William Hoffman, and Brandi Carrier for their assistance on the archaeological aspects of the project, and Brandi for participating in ground-truthing targets; University of South Carolina personnel Nida Reid-Williamson, Rebecca Wessinger, Michelle Morin, and other administrators in Sponsored Awards Management and Grants and Funds Management for assisting in grant preparation and administration; SCIAA personnel: Dr. Steven Smith, director, Susan Lowe and Susan Davis, for assisting in grant and business matters; Dr. Albert Goodyear, Dr. Mark Brooks, and Dr. Christopher Moore, colleagues, for their assistance and advice on prehistoric research matters; Keith Derting, Sharon Pekrul, and Tamara Wilson, for helping with the SC Archaeological State Site Files; Maritime Research Division staff members Ashley Deming, Nathan Fulmer, Joseph Beatty, Daniel Brown, Ryan Bradley, and Jessica Irwin for implementing the research and fieldwork components of the project; Mark Evans, ESRI computer support; USC geology students Chrissy Maschmeyer, Ethan Anderson, Jake Burstein, Gabby Herron, and Jahleel Stone; Staff of the College of Charleston's Department of Geology and Environmental Geosciences, School of Languages, Cultures, and World Affairs Archaeology Program; CCU geology student Amanda Roach; Outside consultants, Dr. Michael Faught, SEARCH, Inc., Dr. Amanda Evans, Coastal Environments, Inc., and David Robinson, University of Rhode Island, for their guidance on archaeological research directed towards studying and identifying prehistoric sites on the Outer Continental Shelf; Dive team members: Emily Schwalbe, Clemson University; Steven Luff, Erin Burge, Cody Sweitzer, Rikki Babuka, Coastal Carolina University; and Captain James Phillips, Brian Johnson and Evan Robertson for their expert handling of data acquisition and support aboard the R/V *Coastal Explorer*, Coastal Carolina University. The authors wish to express their sincere thanks to those individuals or organizations inadvertently not mentioned that also contributed and assisted in this endeavor.

## Executive Summary

This report documents the scope and findings of a project to study the geological and archaeological character of potential Wind Energy Areas offshore North Myrtle Beach in the Atlantic Ocean. The project was initiated under a cooperative agreement with the Bureau of Ocean Energy Management's (BOEM) Office of Renewable Energy Programs and the State of South Carolina in 2014. The South Carolina Sea Grant Consortium administered the project and formed a partnership with researchers from Coastal Carolina University, University of South Carolina, and College of Charleston to undertake the study. Project objectives included undertaking a reconnaissance level geophysical survey of the study area, assessing geoarchaeological and historical materials, and conducting geophysical survey of potential transmission cable routes. The partners embarked on multiple avenues of geological, archaeological, and historical inquiry to implement the tasks which were completed in 2018. The project follows similar BOEM-State efforts in the Mid-Atlantic region seeking to help evaluate potential habitat and cultural resource concerns and needs for potential wind farm siting, planning, and permitting in the future.

A geophysical survey of the study area, 11 to 16 miles offshore and comprised of three contiguous blocks, totaling 18 miles in length and 5 miles in width, utilized an ensemble of marine electronic equipment including a multibeam echosounder, side scan sonar, cesium magnetometer, CHIRP subbottom profiler, and a towed camera. In addition to surveying the main areas, a narrow shore-perpendicular area, 12.5 miles in length, was also surveyed to gauge the general character and potential for significant deviation from conditions found offshore as future cable corridors to the shore may be considered. This survey bridged areas focused on by this study with the locations of extensive previous geophysical surveys completed on the innermost shelf.

The inner shelf of Long Bay offshore the Grand Strand area of South Carolina is characterized by thin veneers of modern sediment overlying older, locally indurated Tertiary and Cretaceous age deposits. Surficial sediment is very patchy and outcrops of substrate forming hardbottom habitat is commonly present at or just below the modern sea floor. In some locations, such hardbottoms may exhibit relief of 0–0.5 meters above the seafloor; with higher relief outcrops supporting more extensive reef invertebrate communities. A series of paleodrainage networks extend across the SC shelf locally resulting in corridors of incision into older indurated substrate and infill by unconsolidated sediment reducing the probability of encountering hardbottom habitat at the seafloor. The study area was found to be consistent with areas mapped further inshore exhibiting localized outcropping of hardbottom habitat and surficial sediment thicknesses being most significant associated with local paleodrainage systems.

During the project, potential areas for wind energy development were identified by BOEM. As a result, some additional reconnaissance-scale geophysical data was collected in concert with NOAA and some previous datasets and results were accessed for this report to better constrain paleodrainage across the shelf and broader Wind Energy Areas defined off South Carolina. Across the region, the shallow subsurface is strongly influenced by the "Carolina Platform" in the subsurface which crests near the border area between North and South Carolina and dips to the south-southeast in Long Bay from North Myrtle beach to Winyah Bay. This affects both paleodrainage patterns and age as well as influence the nature of surficial sediment continuity and thickness to the south within Long Bay. Nevertheless, hardbottoms should be expected to be locally exposed throughout the area, particularly outside of paleochannels. This could be used to help focus future studies and optimize survey strategies of regional and site-specific areas.

Archaeological and historical research provided a context for developing the possibility for the preservation of inundated prehistoric sites, dating from the Paleoindian to Middle Archaic periods, and known and potential historic sites, shipwrecks, structures, and objects in the study area. The geophysical datasets were processed and analyzed using several software and methods to identify geological, natural, and archaeological features. Analysis of the data also revealed the presence of four buried relic

paleochannels. Although outside the project boundary, but within potential Wind Energy Areas, a near-by shipwreck, the merchant steamer *Sherman*, was also investigated. Subsequently, several targets and bottom areas were chosen for closer inspection with the remote-sensing equipment. Afterwards, 22 prioritized targets were ground-truthed and documented with underwater videography by underwater archaeologists and scientific divers which included several ledges, expanses of hard and sediment bottoms, components of an artificial reef, and the shipwreck *Sherman*.

Results from the project served to characterize seafloor and to identify potential design considerations or conditions, such as hardbottom, soil types, and subsurface features, to consider when siting future infrastructure to harvest offshore wind energy on this portion of South Carolina's Outer Continental Shelf. Several recommendations addressing future work in and around the study were posited including:

- In considering the much larger extent of areas for wind energy development for South Carolina, it should be expected that the shallow framework and hardbottom habitat potential, and associated geotechnical implications, will likely exhibit a similar patchy distribution and will be influenced significantly by the paleodrainage incisions. The specific character of the shallow subsurface and habitat exposures will likely evolve moving from north-to-south along the coast; especially as the regional subsurface framework changes character significantly from the Winyah Bay area towards the Charleston area. As a result, future mapping of small areas along the inner and mid-shelf region towards the south, would help contribute to habitat, culture resource, and geotechnical considerations across other call areas as other influences (wind resource, grid interconnect, military and transportation corridors, etc.) are weighed by industry.
- These results may guide planning for future surveys to most economically map and classify habitat concerns and optimize the area surveyed at site survey scales of resolution. Cores and borings associated with specific proposed development will greatly enhance geophysical interpretations as well as aid consideration of turbine foundation design. Selection of boring locations should also incorporate broader BOEM and state interests in sand resource potential reserves on the South Carolina shelf.
- Continue investigations at the shipwreck *Sherman* and other nearby shipwrecks to pinpoint locations and to determine eligibility to the National Register of Historic Places.
- Continue investigations at relic paleolandscapes, which have the potential to preserve evidence of early human occupation on the OCS.
- Coordinate with the U.S. Army Corps of Engineers and other regulatory agencies on the placement of artificial reefs to minimize conflict between resources in attractive offshore Wind Energy Areas.

In addition to the report, project deliverables included raw and processed datasets, and resulting GIS spatial data conforming to BOEM guidelines. Other products included 3D subsurface models, underwater imagery, and resulting materials. A Powerpoint presentation was also prepared summarizing the project's objectives, goals, and findings, along with directions for future investigations. All the geophysical datasets, underwater imagery, and relevant basemaps were uploaded to an online database (<http://helios.esri.sc.edu/mftp>) to ease dissemination of the materials to BOEM and project personnel. Innovatively, an online Story Map (<http://helios.esri.sc.edu/boem>) was created using raw and processed data layers, underwater video, and basemaps to provide a convenient means for an end user to display the datasets in a variety of configurations to explore the project findings.

The survey provided a reconnaissance-level understanding of an attractive high-wind speed Wind Energy Area offshore North Myrtle Beach. The scope of the project was planned and limited to provide baseline information of the seafloor in the study area. Consequently, survey parameters did not utilize the

BOEM survey strategies outlined in *Guidelines for Providing Geological and Geophysical Hazards, and Archaeological Information Pursuant to 30 CFR Part 285* suggested to comply with various Federal legislation; most notably Section 106 of the National Historic Preservation Act (16 U.S.C. 470) to assist in identifying potential adverse impacts to natural and cultural resources in the study area. This was principally due to the wide transect spacings that provide insufficient coverage between the various geophysical instruments. For example, 200-meter line spacing for the magnetometer was 170 meters beyond the 30-meter line spacing BOEM suggests for locating historic shipwrecks, sites, or objects on the Outer Continental Shelf. Additional survey and tighter coverage proposed in the BOEM guidelines are essential to wind energy development in the study location. The project, however, did provide a general understanding of the geophysical and archaeological characteristics of the seafloor in the study area with which to guide future wind development activities and research projects offshore South Carolina.

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## List of Abbreviations and Acronyms

ANFIS	Adaptive Neuro Fuzzy Inference System
APC	Armored Personnel Carrier
ASD	Atlantic Outer Continental Shelf Shipwreck Database
AWOIS	Automated Wreck and Obstruction System
BSEE	Bureau of Safety and Environmental Enforcement
BOEM	Bureau of Ocean Energy Management
B.P.	Before Present
Cal B.P.	Calendar years Before Present
CCU	Coastal Carolina University
CHIRP	Compressed High Intensity Radiated Pulse
CRS	Coordinate Reference System
CSE	Council of Science Editors
DEM	Digital Elevation Model
DOE	Department of Energy
DOI	US Department of the Interior
DTTF	Driver Train Test Facility
ENC	Electronic Navigation Chart
ESP	Environmental Studies Program
ESPIS	Environmental Studies Program Information System
ESRI	Earth Sciences and Resources Institute
FMGT	Fledermaus Geocoder Toolbox
$\gamma$	Gamma
GDAL	Geospatial Data Abstraction Library
GIA	Glacial Isostatic Adjustment
GIS	Geographic Information System
GLCM	Gray Level Co-occurrence Matrix
JSF	Java Server Files
kya	Kiloyears ago
LGM	Last Glacial Maximum
MALA	Middle Archaic Late Archaic
MLLW	Mean Lower Low Water
MW	Mega Watts
nT	Nanotesla
NGDC	National Geophysical Data Center
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
ODMDS	Offshore Dredged Material Disposal Site
PC1	First Principal Component
PCA	Principal Component Analysis
PUC	Port Utilities Commission
RMS	Root Mean Square
RSL	Relative Sea Level

R/V	Research Vessel
SAFMC	South Atlantic Fishery Management Council
SCGS	South Carolina Geological Survey
SCIAA	South Carolina Institute of Archaeology and Anthropology
SC-OCS	South Carolina Outer Continental Shelf
SCPA	South Carolina Ports Authority
SCUBA	Self-contained Underwater Breathing Apparatus
SEG	Society of Exploration Geophysicists
SEWC	Southeast Wind Coalition
SODAR	Sonic Detection Ranging
SPCS	State Plane Coordinate System
SU	Seismic Unix
SVP	Sound Velocity Profile
TWT	Two-way Travel
USC	University of South Carolina, Columbia
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WEA	Wind Energy Area

# 1 Introduction

The potential for wind energy development is an increasingly prominent part of energy, environmental, and economic development considerations within the State of South Carolina. Over the last fifteen years, projections of wind resource potential off the coast of South Carolina has been modeled and initial observational campaigns completed reinforcing the premise that a substantial energy potential exists offshore of the coastline. During the same period, an array of studies and initiatives have been undertaken to identify pathways and impediments to wind energy development in South Carolina. Those initiatives spanned topical issues: gauging public perception of wind energy potential in coastal communities, assessing the capacity of the existing electrical grid to accommodate wind energy production, mapping the existing regulatory pathways relevant to authorize wind energy development in South Carolina, compiling an inventory of existing links of wind industry companies and supply chain in the state and region, and compiling existing geospatial data sets important to the siting and permitting of wind farms (e.g. distribution of wind resources, environmental, shipping, military, and other considerations).

This project is part of the growing progression of initiatives that are becoming more directly related to proximal considerations by federal, state, and local industry interests associated with potential development of a wind farm off South Carolina's coast. It begins more detailed environmental and cultural assessments and mapping of specific areas where wind resources are viewed as strong and potential impediments based on previous studies are viewed as minimal. During this study, the U.S. Bureau of Ocean Energy Management (BOEM) identified potential areas for wind energy development offshore of South Carolina that encompass the initial focus area of the study as well as much larger areas offshore of northern and central South Carolina. In addition to the detailed assessment within the initial focus area, the project adjusted to include a more regional approach over a much broader area. The regional survey focused on broadly classifying areas where environmental concerns related to potential abundance of hardbottom benthic habitat might be reduced to help focus potential and prioritize future environmental and cultural resource assessments guiding future wind farm siting.

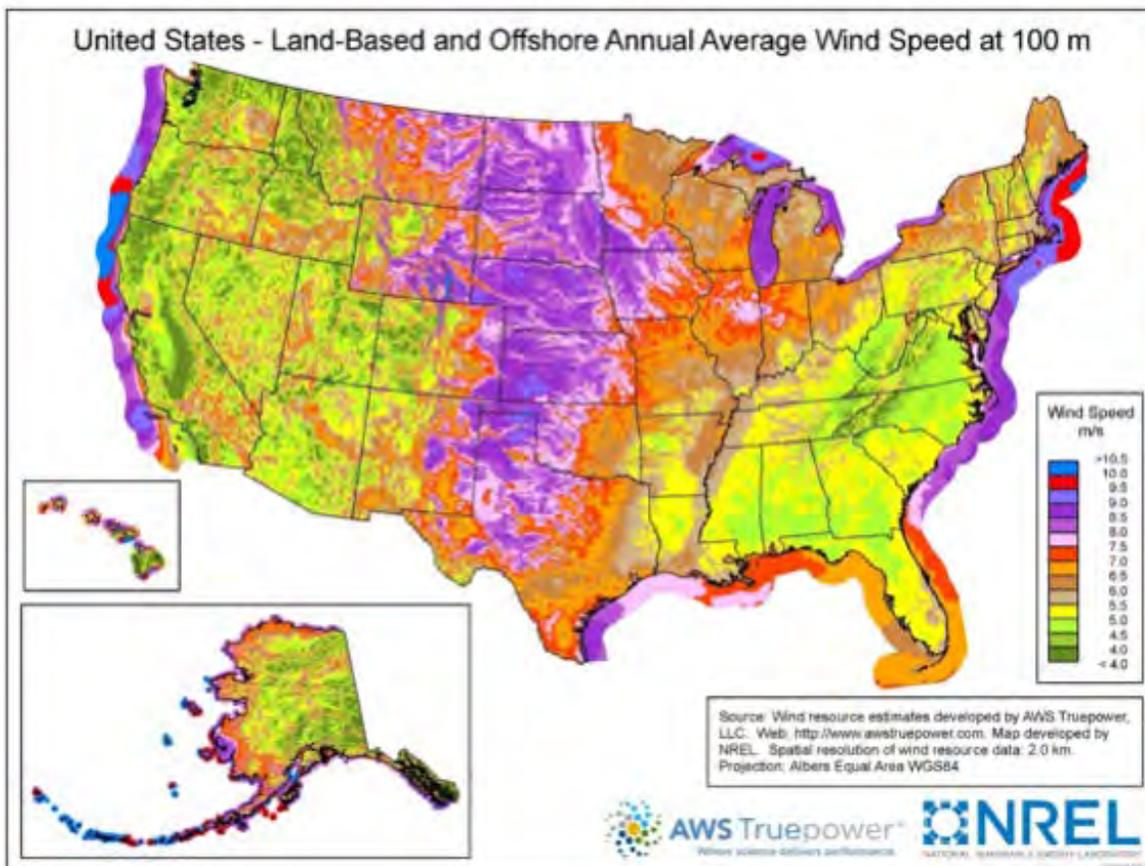
## 1.1 Potential for Offshore Wind Energy Development

### 1.1.1 Nationally

National wind resource potential maps generated by the Department of Energy's National Renewable Energy Lab (Schwartz et al., 2010; Musial et al., 2016) identified a considerable potential for wind energy production off the eastern and western seaboard of the United States. In general, along the east coast wind energy resources are particularly strong in the northeast and decrease to the south. Resources also generally increase rapidly extending from the coast offshore into the more marine dominated environment (Figure 1).

Considered on a national scale, the wind resources expected offshore the eastern seaboard from Maine to South Carolina is comparable or exceeds wind resources in areas of the mid-west of the United States where there is a large and increasing amount of installed wind energy production. The resource is closer to the large population and electrical demand concentrated along the eastern seaboard of the US. While there is extensive offshore wind energy production in other countries, offshore production in the U.S. has been slow to develop, reflecting the absence of an established offshore industry and associated influence on costs and infrastructure supporting a developing industry.

The first offshore wind turbines in the U.S. were installed off Block Island, Rhode Island and became operational in 2016. Over the last decade, there has been continued progress towards realization of wind energy production in the New England and Mid-Atlantic regions. Wind resource potential, cost of energy, and individual state energy policies helped direct initial industry focus in that region of the east



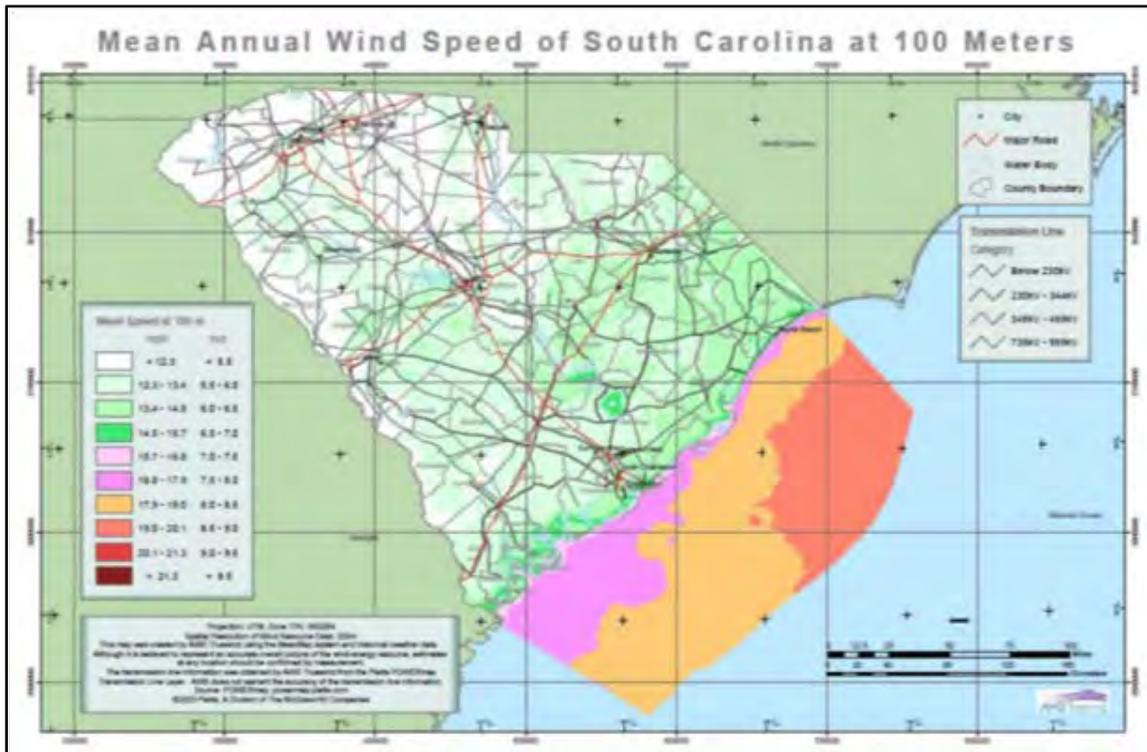
**Figure 1. NREL Offshore Wind Energy Potential**

NREL offshore wind energy potential at 100 meters map for the United States (from <https://www.nrel.gov/gis/wind.html>).

coast. As those wind activities in the Mid-Atlantic and Northeast have progressed to more advanced levels, consideration of future wind energy development off the Southeast has also continued to progress and follow a similar progression in types of studies and actions within the state and in concert with BOEM process for considering offshore development. Below is a summary of wind studies and initiatives in South Carolina as context for the timing and rationale for this and related studies at this point in the consideration of wind energy potential off the coast of South Carolina. The focus is very similar to previous studies completed through BOEM support along the Mid-Atlantic and New England States (see <https://www.boem.gov/Renewable-Energy-State-Activities/>).

### 1.1.2 Southeast U.S.

While the wind potential is significant just off the coast, the resources diminish rapidly inland from the coast. South Carolina occupies a transition zone from excellent offshore wind resources to the north and more modest resources off southern Georgia and Florida. AWS Truewind produced a more regionally focused estimate of wind energy for the State of South Carolina (Figure 2; Reed/AWSTruewind, 2005). This report, prepared for the South Carolina Energy Office, shows the character of wind resource



**Figure 2. Wind Resource potential map for South Carolina**

Wind Resource potential map for South Carolina and adjacent ocean projected at 100 meters (AWS Truwind for the South Carolina Energy Office in 2005).

potential mirrors that for the whole east coast. Wind resources increase significantly from the south to the north along the South Carolina coast as well as from the shoreline offshore. South Carolina’s wind resources are expected to be greatest offshore of the northern third of the state’s coastline within Long Bay; a broad embayment in the coast extending from Cape Fear in North Carolina to Cape Romaine in South Carolina and centered on the City of Myrtle Beach, South Carolina. In Long Bay, the wind fields are strongest closer to shore and increase more rapidly with distance offshore than areas further south in the state.

## 1.2 Offshore South Carolina

The Long Bay area is referred to as “The Grand Strand” of South Carolina reflecting the broad arcuate shape of the coast that possesses one of the longest stretches of headland coast on the east coast south of New York. It is also an area that is dominated by a very large tourism-based economy with a large electrical demand served by a coastal infrastructure largely developed over the last 50 years. Onshore wind resources, however, were generally projected as limited in terms of wind energy potential and diminish rapidly from the shoreline inland.

The Palmetto Wind Study, supported by Santee Cooper and the South Carolina Energy Office through Department of Energy (DOE) funding, completed a year-long met/ocean instrument buoy observational campaign at locations 1.5, 3, 6, and 12 miles off the coast of South Carolina at North Myrtle Beach and Winyah Bay (Ma et al. 2011). The goal of that project was to (1) validate wind resources expected in the area, (2) support a more focused modeling of the region for the observation

year, and (3) to better resolve gradient and character of the cross-shore increase in wind resources. Using the wind resource projections from the resulting observations and model, a capacity factor for a typical example turbine operating at 80 meters (m) elevation at a site 4.5 miles off Winyah Bay, South Carolina was projected to be >40%, validating the potential and basis for continued broader discussion of wind development and financing (Nichols, R. 2012, Savannah River National Laboratory, pers. comm.). The 4.5-mile location was selected as a potential demonstration site located within State waters rather than as an optimized wind resource within the greater wind resources that exist further offshore in federal jurisdiction. The demonstration project was not realized but did help advance the discussion and expectations for wind energy production in the increasingly more favorable wind field further offshore.

More recently, Sonic Detection and Ranging (SODAR) observations along the coast at North Myrtle Beach and 10 miles inland at Conway, SC suggests that the nature of the convective boundary layer in coastal South Carolina possess a more favorable vertical gradient in wind velocity above the land surface. Wind velocities are observed to be greater closer to the ground than previous considered in resource models. This velocity gradient coupled with trends in the industry towards higher tower elevations are further improving wind resource potential in the Southeast U.S. Unpublished calculations by Iowa State University for a case study of 2.3 MW turbine operating 120–140 m above ground and based on SODAR data measured at the coast in North Myrtle Beach, suggest capacity factors on par with areas actively being developed in the mid-west (~40-45%). Offshore resources are expected to also benefit from this effect and be even more favorable than previous estimates.

### **1.2.1 Previous Wind Related Studies in South Carolina**

For more than a decade, there has been a large range of activities and initiatives broadly exploring wind energy potential and related issues in South Carolina. Various studies, surveys, and capacity development by federal, state, and local entities have helped clarify opportunities and impediments to the development of wind energy in the region. They have also helped familiarize coastal communities and decision makers about related issues supporting informed discussion and decisions on energy and related environmental, regulatory, and economic issues.

Below is a brief review of the diverse and multi-disciplinary wind energy activities in South Carolina, which the present BOEM supported study provides an important contribution aiding federal, state, local, and wind developer's consideration of offshore wind development off South Carolina.

2007

- The Southeast Regional Offshore Wind Symposium assembled a broad array of interests in the region to consider wind energy potential and frame a roadmap forward to more fully consider and potentially develop wind resources in the Southeast. The meeting was hosted by Clemson University, Georgia Institute of Technology, North Carolina State University, and Coastal Carolina University. This meeting helped set in motion a sustained and active interest and consideration of wind energy potential in the region and partnerships that endure to the present day.
- Clemson University's Strom Thurmond Institute of Government and Public Affairs released a report on the "Potential Economic Impact of an Off-shore Wind Farm to the State of South Carolina." The final report is available at <http://energy.sc.gov/files/WindEnEconImpact7-2012FINAL.pdf>.

2008

- Governor Mark Sanford established the "Climate, Energy and Commerce Advisory Committee" tasked to develop recommendations to address threats of climate change to the State of South Carolina including concerns for carbon emissions across energy, residential, commercial, land use, industrial, transportation, and agricultural sectors. The final report is available at:

[http://www.offshorewindhub.org/sites/default/files/resources/sccecc\\_8-1-2008\\_climateactionplan\\_0.pdf](http://www.offshorewindhub.org/sites/default/files/resources/sccecc_8-1-2008_climateactionplan_0.pdf).

- The South Carolina Energy Office received Department of Energy funding for a broad project entitled “South Carolina Roadmap to Gigawatt-Scale Coastal Clean Energy Generation: Transmission, Regulation and Demonstration.” This initiative had three primary focus areas:
  - 1) An Offshore Wind Energy Transmission Study was completed by Clemson University that explored the capacity, potential effects, and needs of the region’s electrical grid to accommodate the potential infusion of large quantities of electricity generated offshore of South Carolina. In general, the study identified that the grid infrastructure in South Carolina was relatively robust compared to other areas of the country and could accommodate up to 350 MW of generated electricity from the offshore with moderate investment in grid updating.  
([https://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=2216&context=all\\_dissertations](https://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=2216&context=all_dissertations); [http://www.offshorewindhub.org/sites/default/files/resources/cuepra\\_8-2-2010\\_offshorewindtransmissionreport\\_0.pdf](http://www.offshorewindhub.org/sites/default/files/resources/cuepra_8-2-2010_offshorewindtransmissionreport_0.pdf))
  - 2) The Palmetto Wind Study, completed by Coastal Carolina University, deployed six met/ocean instrumentation buoys on two transects, off Georgetown and North Myrtle Beach, South Carolina. Data was collected for a full year on wind, wave, and current observations. Those observations were used to document wind resources at six locations extending from 1.5 to 12 miles from the coast and to support advance model simulation of the regional wind resource. The Savannah River National Laboratory calculated capacity factors on the order of 42% for representative offshore turbines at a site 4.5 miles offshore of the Winyah Bay area.
  - 3) The State of South Carolina established the Regulatory Task Force for Coastal Clean Energy which assembled broad technical expertise from the region to explore the regulatory framework related to potential offshore wind energy production. The Committee also considered issues of consistency and jurisdiction of state and federal interests related to offshore wind and reported four overall recommendations to the state.  
(<http://energy.sc.gov/files/RTFRecom12-3-09FINAL.pdf>).

2009

- Clemson University’s Restoration Institute established the Driver Train Test Facility (DTTF) in North Charleston to provide state-of-art testing facilities for next generation wind turbines and promote enduring partnerships with wind industry in work force development, research, and education. The DTTF was initiated through a \$45M award from the U.S. Department of Energy and \$53M from Industry. The facility and associated programs have continued to attract resources, expertise, and partnerships relate to wind energy development and innovation in the state and region. (<http://clemsonenergy.com>)

2010

- The SC Wind Energy Production Farm Feasibility Study was established through the South Carolina General Assembly (SC Act 318) to consider available information and make recommendations to position the State and promote considerations of wind energy potential in South Carolina. The final report included 2 general recommendations, 11 specific recommendations supporting clean energy production from wind, and 5 specific recommendations to help promote wind industry development in South Carolina.  
(<https://www.scstatehouse.gov/Archives/EnergyOffice/WindEnergyProductionFarmsFeasibilityStudyCommitteeFin.pdf>)
- Clemson University, Savannah River National Laboratory, and Santee Cooper undertook a vertical wind profiling study in Georgetown, SC. The study worked to test the capability of SODAR data

collection in the coastal marine environment and began to establish wind velocity data at potential hub height elevations in the South Carolina Coastal Zone.

- The University of South Carolina’s Institute for Public Service and Policy Research released a report entitled “A Feasibility Analysis of South Carolina Wind Energy Resources for Electric Power Generation.” [http://www.offshorewindhub.org/sites/default/files/resources/uscipspr\\_2-24-2009\\_windrenewableportfoliostandard\\_0.pdf](http://www.offshorewindhub.org/sites/default/files/resources/uscipspr_2-24-2009_windrenewableportfoliostandard_0.pdf)
- Santee Cooper established a small onshore turbine demonstration project in the City of North Myrtle Beach to facilitate education and outreach as well as foster familiarity with wind energy potential. Subsequently, the City of North Myrtle Beach, North Strand Wind Team, and State Energy Office received DOE funding to establish two more small turbines in North Myrtle Beach. These initiatives required the City to establish new enabling municipal code and regulations to allow wind turbine installations within the City. A Wind Energy Conference supported by the City of North Myrtle Beach and Coastal Carolina University attracted approximately 100 participants including offshore wind developers, federal and state agencies, and local interests.

2011

- South Carolina Department of Natural Resources-Marine Research Institute released a report entitled “Final Report—A Comprehensive Spatial Mapping Effort of South Carolina’s Coastal Resources and Activities.” The study compiled for the South Carolina Energy Office assembled existing information on Biological and Habitat Resources as well as Societal Uses of shelf resources in preparation for a Geospatial Planning approach to shelf activities including wind energy production.
- Geo-Marine completed a report on “Siting Analysis for Potential Near-Term Offshore Wind Farm Development: Georgia, South Carolina and North Carolina” for the Georgia Environmental Finance Authority, North Carolina State Energy Office, South Carolina State Energy Office, Southern Alliance for Clean Energy, and the U.S. DOE. The report identifies nine blocks on the continental shelf from NC to Georgia, five of which were off South Carolina, where expected resources, environmental, military, economic, and other drivers are considered most feasible for wind energy development.  
([http://www.offshorewindhub.org/sites/default/files/resources/geomarine\\_3-2-2011\\_phase2asitinganalysis.pdf](http://www.offshorewindhub.org/sites/default/files/resources/geomarine_3-2-2011_phase2asitinganalysis.pdf)).
- Clemson University’s Department of Parks, Recreation and Tourism Management completed a study funded by South Carolina Sea Grant on a “2011 Survey of Marine Recreationalists’ Attitudes Towards Potential Offshore Wind Energy In South Carolina” The study identified some level of support for offshore wind development (73% of respondents) with stronger support and interest in the North Myrtle Beach area relative to Georgetown, SC. A more local survey of North Myrtle Beach businesses by the North Myrtle Beach identified very strong interest and support from the City and members of the Chamber of Commerce.  
[http://www.scseagrant.org/pdf\\_files/2011-attitudes-toward-wind-energy-report.pdf](http://www.scseagrant.org/pdf_files/2011-attitudes-toward-wind-energy-report.pdf).

2012

- The State of South Carolina and BOEM established the joint South Carolina Intergovernmental Renewable Energy Task Force to formally consider offshore wind potential, help establish formal Wind Energy Areas offshore of South Carolina, and coordinate offshore wind energy consideration between state and federal authorities (<https://www.boem.gov/South-Carolina/>)
- Black and Vetch completed a “South Carolina Resource Study” for the South Carolina Energy Advisory Council summarizing energy production potential from various renewable energy options in the state including onshore and offshore wind energy. Offshore wind was found to hold the greatest production potential for the state.

[https://www.scstatehouse.gov/CommitteeInfo/EnergyAdvisoryCouncil/ResourceStudyComments/SCEACResourceStudy\\_FINAL.pdf](https://www.scstatehouse.gov/CommitteeInfo/EnergyAdvisoryCouncil/ResourceStudyComments/SCEACResourceStudy_FINAL.pdf)

- The City of North Myrtle Beach passed a resolution supporting wind energy development off the coast of the City and expressed interest in actively participating in wind energy development (<http://northstrandcoastalwindteam.org/city-of-north-myrtle-beach-offshore-wind-energy-resolution/>).
- The South Carolina Offshore Planning Group assembled by SC Office of Ocean and Coastal Resource Management to consider future issues and needs related to the State's natural resource potential on the continental shelf. The final report was released that considered wind energy potential and issues looking forward. It made recommendations related to planning and potential leasing of public lands on the OCS for wind energy production and other applications (<http://www.scdhec.gov/library/CR-010549.pdf>).
- Clemson University released a final report entitled "South Carolina Wind Energy Supply Chain and Offshore Wind Economic Impact Study that was prepared for the SC Energy Office. ([http://sti.clemson.edu/reports/cat\\_view/293-regional-economic-analysis-laboratory](http://sti.clemson.edu/reports/cat_view/293-regional-economic-analysis-laboratory)).
- Savannah River National Laboratory, Coastal Carolina University, and MMI Engineering completed a study for the U.S. Department of Energy on "Advanced Technology for Improving the Design Basis of Offshore Wind Energy Systems". The study (1) assessed the spatial variability of conditions conducive to breaking waves using existing data from monitoring networks and models in the region, (2) undertook field verification and sensor testing to validate results from objective one, (3) evaluated applicability of wave theory in shallow water to estimate loading from breaking waves, and (4) disseminated results to offshore wind energy community.

2015

- Coastal Carolina University, Savannah River National Laboratory, and MMI Engineering completed a study entitled "Development of Hazard Curves for Wind Energy Areas (WEA) off the Atlantic Seaboard" for the U.S. Department of Interior's Bureau of Safety and Environmental Enforcement (BSEE). The study simulated wind, wave, and current forces from historical tropical and extratropical storms in defined Wind Energy Areas from Maine to Florida updating exceedance curves and associated safety factors for potential turbine towers along the east coast. As expected, a gradient in climate zones where the southernmost (e.g. FL) WEA's were largely influenced by tropical storm systems and the northernmost (e.g. Maine) WEA were dominated by extratropical storms. In between, including off South Carolina, locations of defined WEA's are impacted by both tropical and extratropical storms. Exceedance curves varied across the east coast WEAs and suggested that load factors for consideration of tower and foundations.
- The Bureau of Ocean Energy Management funded this study entitled "Atlantic Offshore Wind Energy Development: Geophysical Mapping and Identification of Paleolandscapes and Historic Shipwrecks Offshore South Carolina" proposed by South Carolina Sea Grant-SC Energy Office, Coastal Carolina University, the University of South Carolina, and the South Carolina Institute of Archaeology and Anthropology. This study focused on mapping and habitat and cultural resource assessment off northern South Carolina. This study began prior to completion of the BOEM process for defining call areas for the State of South Carolina. Based on resource and geospatial assessments available at that time it was presumed that at least one WEA in South Carolina would likely be defined to extend from the WEA formally defined in North Carolina. As a result, the primary focus area was located 11–16 miles offshore on the City of North Myrtle Beach. This was selected to be contiguous with the Wilmington West WEA off North Carolina and responded to strong interest in offshore development by the adjacent community of North Myrtle Beach. Subsequently, formal call areas were defined by BOEM off South Carolina and a more regional assessment was completed in concert with NOAA to provide some guidance in the broader areas off northern South Carolina. This document is the final report for that study

<https://www.boem.gov/Geophysical-Mapping-and-Identification-of-Paleolandscapes-and-Historic-Shipwrecks-Offshore-South-Carolina/>.

- The Southeast Wind Coalition-SE (SEWC) received funding to coordinate a DOE Wind Energy Resource Center for the South East compiling information and promoting communication about wind energy potential, development, and supply chain capacities in the region. SEWC established a Wind Industry Supply Chain Report and Web Interface (<http://www.sewind.org/map>).
- BOEM releases its “Notice of Intent to prepare Environmental Assessment for potential wind energy development and leasing off South Carolina.”
- BOEM subsequently formally defined Wind Energy Areas offshore of South Carolina and put out a “Call for Information and Nominations.”

2016-18

- A cooperative study supported by SC and Georgia Utilities and Vaisala deployed SODARS onshore at five locations in South Carolina, North Carolina, Georgia, and Florida. The study gathered a year-long record of wind profiles at these coastal locations and supported an update of the regional wind resource mapping based on a ten-year simulation of Vaisala model system validated by the SODAR data. This report will be made publicly available in the near future. An initial presentation of the project at the Southeast Wind Conference in Atlanta in January 2018 identified that the gradient of the lower atmospheric boundary layer is significantly steeper than traditionally assumed and modeled in past wind resource assessments. The observed character of the wind field and evolution of new turbine towers and hub heights at up to 140 m above ground, rather than historical hub heights resource estimates at 80 m above ground, suggest that wind resources are not only significant offshore of South Carolina but may now be viable onshore in several areas across the state that were not previously consider possible.

2018

- Iowa State University partnered with Coastal Carolina University to estimate potential capacity factors for two example turbines commonly used in the mid-west at two SODAR sites maintained by Coastal Carolina University. One SODAR was located at the immediate coast near North Myrtle Beach and the second SODAR is located on the campus of Coastal Carolina University in Conway, which is approximately 10 miles inland from the coast. For a case study 2.3 MW turbine, capacity factors at 140 m above the ground were projected to be approximately 45% at the coast and approximately 30% 11 miles inland in Conway. For an example 3.2MW turbine, the projected capacity factor at the coast near North Myrtle Beach was approximately 40% and 28% in Conway. This represents a significance change in potential for onshore development in South Carolina. A similar increase in wind energies modeled at elevation offshore is expected associated with the more favorable gradient measured in the coastal boundary layer and movement to higher tower elevations.

Throughout the past eleven years, there have been several dozen wind energy related workshops, conferences, and public panels and presentations across the state. These have engaged agencies, academic researchers, industry, and community and state leadership and decision makers as well as the public to consider the range of issues, opportunities, and needs presented by the wind energy potential in the state. There has been significant interest and investment, demonstrated by the above timeline, from federal, state, local, public as well as the private sector related to wind energy development and associated environmental, economic, and energy strategic directions.

This report and associated collaborations have contributed to the historical progression. It may be expected to see subsequent synergistic efforts and benefits as provided by other large-scale mapping initiatives to the region for other environmental and natural resource initiatives (e.g. USGS SC Coastal Erosion Study, BOEM Geophysical mapping across the region and adjacent NC WEA as well as BOEM

supported exploration of sand resource potential on the shelf in concert with the State of South Carolina Geological Survey).

## **1.2.2 Cultural Resources Potential on SC Outer Continental Shelf**

Within the boundaries of the project area, there exists potential and known submerged prehistoric and historic sites. There is the potential for remnant paleo-landforms on the OCS to have a high probability to preserve inundated Paleoindian or Early to Middle Archaic sites, based on evidence that the current coastline did not become stable until approximately 6,000 Calendar years Before Present (cal B.P.). The existence of such sites is dependent on the occupation by humans in the area and the preservation of these site by sediment deposition in low energy environments preceding sea-level rise (Evans 2016:40; Sassaman and Anderson 1995:155). The South Carolina coast has an equally rich history of exploration and seafaring since the first Spanish voyages to the modern era. Two historic shipwreck sites are reportedly located within the project area, and there remains the potential for the discovery of new historic sites.

Of the approximately 6,765 known Paleo-Archaic sites across South Carolina, about half have been dated to habitation periods predating 5,900 cal B.P. and dating to as early as 13,500 cal B.P. (3,757 sites), while the other half date to between 3,200 and 5,900 cal B.P. after sea-levels settled at current levels (3,008 sites). Most of the known sites in South Carolina fall along or above the Fall Line. However, there are three clusters of sites along the shoreline and two estuaries (SC Archaeological Site Files). Rising sea levels or transgressions of the Atlantic Ocean covered areas that were potentially occupied by Paleoindian, Early Archaic, and Middle Archaic peoples. Possible inundated archaeological sites include habitation or exploitation sites containing evidence of lithic technology (i.e., points, tools, and charcoal), and organics (e.g., bone, antlers, wood, and textiles) (Harris et al. 2013:12).

The coast of South Carolina has a rich maritime history from the first Spanish exploratory voyages of La Florida to modern times. The Spanish made several attempts to establish a colony on the coast but were ultimately unsuccessful. The first successful colony, Charles Town, was established by the British in the 17th century (TRC 2012:166). Charles Town, now Charleston, as the first permanent colony in the south, grew into the economic, social, and political capital of South Carolina (Hart 2009:1). The official coastal ports of the Carolina Colony, Charleston, Georgetown and Beaufort, were the commercial hubs of the Lowcountry. The major exports for much of their history included rice, cotton, and lumber. The ports played active roles in the Revolutionary War, War of 1812, and Civil War. As the largest port in the southern states, Charleston was frequently targeted for its strategic military value, and Georgetown was often used as an alternate port when Charleston was cut off (TRC 2012:174-178, 185). With the major theatre of World War I and II in Europe, South Carolina performed an important supporting role in the war efforts (TRC 2012:186-189). The Navy Yard in Charleston was the center of the southeast navy district and operated as an active shipyard as well as an important training facility. The post-war years saw a decline in the naval presence as port facilities were returned to the City of Charleston (Spirek and Amer 2004:32-33). Today, the port of Charleston is one of the busiest commercial seaports in the United States (SCPA 2018a).

### **1.2.2.1 Prehistoric Submerged Landscape**

South Carolina's coast is part of the Atlantic Subdivision known as the Georgia Bight, defined as the portion of the South Atlantic Bight between North Myrtle Beach (the Grand Strand) and the Georgia-Florida Border. It is described as an embayment portion of a passive continental margin with a thin sedimentary layer over Cenozoic geology, resulting from condensed paleo-oceanographic processes. The embayment up-warps at the north end near the Cape Fear Arch and down-warps south of this latitude all the way to the South Carolina-Georgia border at the Savannah River. The elevation changes gradually, with the only active fault being the Charleston Fault (TRC 2012:109).

The geologic region for the South Carolina section of the Georgia Bight is made up of eighteen stratigraphic units from the Oligocene to the Pliocene in the south nearer Georgia waters, and eleven Eocene through Pliocene units off Charleston to the Cape Fear Arch. Some Paleocene outcrops have also been identified near the Cape Fear Arch. The Continental Shelf is mainly comprised of consolidated and unconsolidated sediments that are eroded relicts of prehistoric subaerial coastal landforms that are very similar to those that presently exist, primarily dunes, wetlands, coastal rivers, and forests. The primary cause of erosion of these landforms was sea-level change, both transgressions and regressions of a highstand-lowstand sequence. The sand sheet off South Carolina was formed by a combination of sea level rise, the landward retreat of the coastal barrier and estuarine systems, and sediment reworking caused by storm-, tidal-, and wind-generated bottom currents (TRC 2012:109). The nearshore seafloor consists of Pliocene-age rock outcrops and hard bottoms exposures with large areas of sand deposits averaging three meters deep. Studies have confirmed the presence of paleochannels cut by Coastal Plain rivers into the Pliocene-Miocene strata. In the northern Georgia Bight, these rivers include the Stono-Edisto and Pee Dee River systems (TRC 2012:111-112).

Paleoshorelines for the Georgia Bight, including South Carolina, are based on current relative sea level (RSL) curves (Harris et al. 2013:8). From the sea-level minima at the Last Glacial Maximum (LGM) of 20,000 cal B.P., the sea level rose slowly until 16,000 cal B.P., then rapidly began to slow again during the Younger Dryas event between 12,850 cal B.P. when the Wisconsin Ice Sheet began retreating (Cronin 2010:218, Harris et al. 2013:8-9). Since the Younger Dryas, sea level rose more rapidly until approximately 5,000 to 4,500 cal B.P., which is indicated by coastal barrier-island dynamics and from archaeological evidence in the Southeast where sea levels rose to within a few meters of modern levels (Harris et al. 2013:9). The interglacial shoreline is located inland of the modern coastline. In some areas, large estuaries lay between the modern and prehistoric barrier, while in other areas the modern system is eroding former deposits. The modern system reflects regressive and transgressive shoreline features with tidal, estuarine, and fluvial systems. This includes barrier islands formed during the Holocene that have remained in relatively the same position for several thousand years (Harris et al. 2013:11).

Since the 1970s, evidence of drastic prehistoric sea level change has fueled speculation on the existence of submerged prehistoric habitation and exploitation sites (Anderson et al. 2015:36). A key research component associated with locating evidence of early human occupation in the SC-OCS is the geophysical identification of relict landforms, such as rivers, bays, and estuaries that have a high potential to preserve prehistoric archaeological sites (Harris et al. 2013:12). This suggests that any surviving submerged paleo-landforms that resemble the modern geography from the Fall Line to the coastal plain would offer the greatest potential for an inundated Paleo-Archaic habitation site. For sites to be extant there are two requirements: first, human occupation must have occurred when South Carolina's OCS was subaerial; secondly, the sites must have survived marine transgression. This, in turn, requires an examination of when the first people arrived in what is now South Carolina in congruence with postulated sea-level curves of the Georgia Bight (Lacroix et al. 2014:18-20). Over the years, tantalizing evidence has emerged providing support for the presence of prehistoric peoples on the Atlantic OCS, including evidence recovered systematically as well as incidentally. Researchers from the University of Georgia and NOAA discovered three artifacts, an Archaic Period projectile point, a stone scraper, and a bone atlatl possibly from the Paleoindian or Archaic periods, during a systematic search at Gray's Reef National Marine Sanctuary, a rocky outcrop 20 miles offshore the Georgia coast (Garrison et al. 2016:250-254). Dredging operations at a borrow area associated with beach nourishment approximately five miles off Folly Beach in 2015 cast ashore an Early Archaic Period projectile point, most likely from a relic marsh area (ACE 2013; Bryan Philips elec. com. 2015). Technological advances in remote sensing equipment, software, and a commitment to undertake the search for prehistoric sites should lead to uncovering more evidence of early peoples on the OCS.

### 1.2.2.2 Potential for Prehistoric Habitation on SC OCS

The exact arrival of humans to the Pee Dee region, the northeastern part of South Carolina, has yet to be conclusively determined. Reconstructing the sequence of settlement has proved challenging for archaeologists due to lack of multiuse, stratigraphic sites recorded and to the lack of datable material culture to establish accurate site dating. There is not yet enough data available to archaeologists to establish a timeline of human migration to the area (Anderson et al. 2015:29). However, the South Carolina portion of the OCS has the potential to yield a wealth of archaeological information about the early peopling of North America. Sites found on the Coastal Plain are generally located on high ground associated with interfluves within and between estuaries. The high ground areas were a few meters above sea level at the time of formation, like estuarine environments in southern South Carolina (Harris et al. 2012:10). Sites for early human habitation and exploitation would likely occur near marine and estuarine food resources, especially when the interior was dry and cold (Erlandson 2001:287, Harris et al. 2013:10). Remote sensing and underwater survey off the South Carolina coast have revealed potential evidence of habitation, including an 11,000-year-old drowned cypress forest located 19 miles off Georgetown (Harris et al. 2013:11). Thus, it is safe to assert that similar aged sites must exist in surviving prehistoric landforms on South Carolina's Outer Continental Shelf. Based on the site characteristic of the nearest terrestrial region, sites found on the OCS dating to the Paleoindian and Early to Middle Archaic periods are most likely associated with groups that occupied the northern Coastal Plain in the Pee Dee region (Anderson et al. 2015:36; Moore et al. 2010:110).

Most Paleoindian sites in the state consist of isolated finds or lithic scatters. Complex, multicomponent sites are limited to a handful. There has yet to be located and studied a settlement site containing evidence of permanent structures or long-term habitation from this period in the Southeast (TRC 2012:39). More evidence is needed to refine or refute existing migration and settlement pattern models. It has been proposed, however, that the trend of Paleoindian settlement in the Southeast region began with Early Paleoindian groups occupying staging areas that accommodated the settlement of a more extensive region. From this micro-band level of organization, the settlement of the Southeast was gradual and progressed in a step-wise fashion (Anderson et al. 1996:16; Anderson et al. 2015:24). The specialization of lithic technology near the end of the Paleoindian Period indicates the regional settlement of populations by the Late Paleoindian Period (Anderson et al. 2015:32). With the lack of preserved organic cultural material from the Paleoindian Period, the dates defining cultural transitions are determined by lithic point type (Goodyear 2016:6-7). There are only a handful of sites in the southeast region that have provided conclusive and in situ archaeological data dating to the Paleoindian Period. There are four major Paleoindian sites excavated in the state: Flamingo Bay (38AK469), Taylor (38LX1), Topper (38AL23), and Big Pine Tree (38AL143) (Anderson et al. 2015:22). Topper site is particularly significant to archaeologists' understanding of the Paleoindian Period. As the oldest and most complex site in South Carolina, further dating has suggested the date as early as 20,000 B.P. This would make it the oldest site in the Americas, predating Monte Verde, Chile by 2,500 years (Dillehay et al. 2015:1; Goodyear 2016:6). Additional sites located on the coast closest to the project area include Site 38SU37, Surfside Spring site, and Site 38HR328.

Coinciding with the end of the Younger Dryas, the beginning of the Early Archaic Period is characterized by an adaptation to new environmental conditions and available food sources. Boreal forests were replaced on the South Atlantic Slope by mixed hardwood forests that included more deciduous species such as oak, elm, walnut, hemlock, beech, and maple (Daniel 1998:197). The megafaunal species of the Pleistocene were replaced by game species such as deer, bear, and small mammals (Anderson et al. 2015:31-32; Daniel and Goodyear 2015: 255, TRC 2012:40). Early Archaic peoples developed different subsistence sources, adapted their lithic technology, and reassembled into smaller, highly mobile, regionalized bands (Abbott 2004:12; TRC 2012:42). Early Archaic sites share similarly poor preservation quality of organic materials as the Paleoindian sites; therefore, sites are typically identified by lithic

material and dated according to projectile point type (TRC 2012:40). A greater number of Early Archaic sites have been located and studied compared to the number of Paleoindian sites (SC Archaeological Site Files). In addition to the more complex and well-documented sites from this period (Hardaway, G.S. Lewis-East, Pen Point, and Rucker's Bottom), a concentration of three clusters of Early Archaic sites have been located along the shoreline south of Charleston and in proximity to estuaries on the Pee Dee and Edisto-Savannah River basins. The presence of these sites provides supporting evidence that OCS and paleo-river channels, estuaries, and bays attracted Early Archaic peoples for the utilization of marine resources (ACE 2013; Powell 1990; Goodyear pers. com 2015).

The transition from the Early Archaic to the Middle Archaic Period is characterized by another change in environmental factors in the Southeast: seasonal variation became more drastic, which promoted the growth of pine forests, and this in turn impacted the habitat locations of white-tailed deer; sea-level rise was also slowing at this point as it came close to reaching its high point, which fostered the development of floodplains and coastal estuaries (Dawson 2016:184; Gunn and Foss 1992:6, 14; Watts et al. 1996:37). Middle Archaic peoples responded to the changes by developing a highly mobile population with a nonspecialized economy (homogeneous toolkits using local lithic material) and flexible social units (Sassaman 1993:31, 34). Complex, multicomponent sites with Middle Archaic horizons include G.S. Lewis-East, Three Springs, and the Tree House sites. Three sites located in the Coastal Plain near the project area include Sites 38HR483, 38HR23, and 38HR21. However, archaeologists have noted a distinct decrease in the number of Coastal Plain sites dating between 8,500 to 7,500 cal B.P. This Middle Archaic gap may indicate one of two potential coastal occupation settlement models (Sassaman 1993:3; SC Archaeological Site Files; TRC 2012:42). Either the number of sites on the OCS reflect the same pattern of inoccupation or the lack of sites in the Coastal Plain resulted from populations preferring to settle in the now inundated coastal zone as well as the Piedmont region. The settlement model of Middle Archaic people's preferred occupation of the riverine and estuarine areas may be reflected in the OCS until inundated (Sassaman 1993:34; Sassaman and Anderson 1995:176). The presence of shell midden sites on the coast dating to the early Late Archaic Period suggests that marine resources were also exploited during the Middle Archaic Period, thus supporting the second coastal occupation model (Russo 1996:186; Sassaman 1993:36-37).

Archaeologists agree that for a submerged prehistoric site to be found in situ, it must first survive terrestrial burial, then one or multiple transgression episodes. The area of greatest impact on archaeological preservation is in the surf zone, a high-energy condition. Drastic damage to a site can also be caused by extreme weather events such as hurricanes, peak tides, and currents (Lacroix et al. 2014:18). Medium-energy conditions include the intertidal zone, estuaries, and river deltas. These conditions mostly affect fine-grained sediments, often leaving larger objects in place, except for seagrass beds where smaller objects might be protected (Keller et al. 2014; Lacroix et al. 2014:19). The conditions most favorable for in situ site preservation are low-energy settings. Examples of such conditions include freshwater lakes located close to shorelines, fluvial systems preserved near the coast, and delta systems. Freshwater lakes near the coast can offer spits, barrier beaches, and lagoons that may provide high preservation conditions if suddenly inundated. Fluvial and delta systems can also experience similar preservation potential given similar inundation processes (Lacroix et al. 2014:19-20). Evidence off the coast of Rhode Island, including quartz flakes, chipping debris, and probable hearth feature, suggests that the greatest chance for preservation nearshore is in situations where pre-submergence topographic lows became wetlands as coastlines migrated inland, water tables rose, and peat deposits formed. It is in those areas that were "jacketed" by a protective layer or layers of peat, and then flooded and buried in-place relatively rapidly and skipped over by the beachface's erosional swash zone as it moved inland, where preservation will be most likely to occur (Dave Robinson, personal communication 2015 and 2018).

### 1.2.2.3 Historic Sites on SC OCS

Two historic shipwreck sites have been identified or reported within or near the immediate project boundaries: the wrecks of the schooner *William Richards* and the steamer *Sherman*. *William Richards* was an American built, wooden schooner that wrecked in 1888. The vessel was abandoned by the officers and crew off Frying Pan Shoals Lightship in North Carolina waters after taking on water and was reported last seen off Myrtle Beach, SC (*New York Times* 4 January 1888:3; *Wilmington Messenger* 18 March 1888). The steamer *Sherman*, or *Princess Royal* as it was originally named, was a British built iron screw steamer that operated as a passenger packet vessel in the United Kingdom from 1861 to 1862. Under new ownership, it was captured in 1863 outside Charleston harbor carrying supplies for the Confederate military. Purchased and commissioned by the Navy Department, *USS Princess Royal* served in the West Gulf Blockading Squadron for the remainder of the war (NHHC 2015). In 1865, the steamer was sold to a Boston merchant, renamed *Sherman*, and returned to packet service delivering cargo and passengers between Boston, and later New York City, and New Orleans. *Sherman* foundered off Little River Inlet, SC in January 1874 on route to New Orleans. All passengers and crew were rescued along with some cargo by two local schooners (*Cincinnati Daily Enquirer* 11 January 1874; *New York Herald* 11 January 1874).

## 1.3 Report Structure

The report presents the project scope and findings in nine chapters, numerous illustrations, tables, equations, and appendices. Chapter 1 introduces the concept of potential Wind Energy Areas offshore the United States and provides geological, natural, and cultural considerations for exploiting and developing this form of renewable energy off the coast of South Carolina. Chapter 2 provides the objectives and methodologies to document the geophysical, geoarchaeological, and historical aspects comprised in the potential Wind Energy Areas and cable corridors in the study area including discussions of the mapping, acquisition, and processing of various datasets using a suite of geophysical technologies and software. Chapter 3 describes and discusses the geophysical and habitat characterization using the findings and analysis of data recovered from the potential Wind Energy Areas and cable corridors in the study area. Chapter 4 provides the paleolandscape and prehistoric archaeological survey data and results of the study area as well as a detailed overview of the prehistoric peoples who inhabited and occupied the now inundated portion of South Carolina's OCS. Chapter 5 provides a detailed contextual description of the maritime activities that spurred the development of this area of the state as well as the maritime archaeological survey data and results of the study area. Chapter 6 discusses the results of the visual inspections by underwater archaeologists and scientific divers of the various cultural, natural, and biological features detected during the remote-sensing survey. Chapter 7 details the findings and analysis of the cable corridor surveyed from the potential Wind Energy Areas to the shore. Chapter 8 presents conclusions about the findings and further considerations to undertake additional study offshore South Carolina. Finally, Chapter 9 comprises a list of project deliverables and details about a Storymap available online displaying processed datasets, namely multibeam, CHIRP, side scan sonar, and magnetometry, and other pertinent resources. A list of references cited completes the report. Several appendices provide additional information on the workflows of acquiring and processing the remote-sensing data.

## 2 Objectives and Methodologies

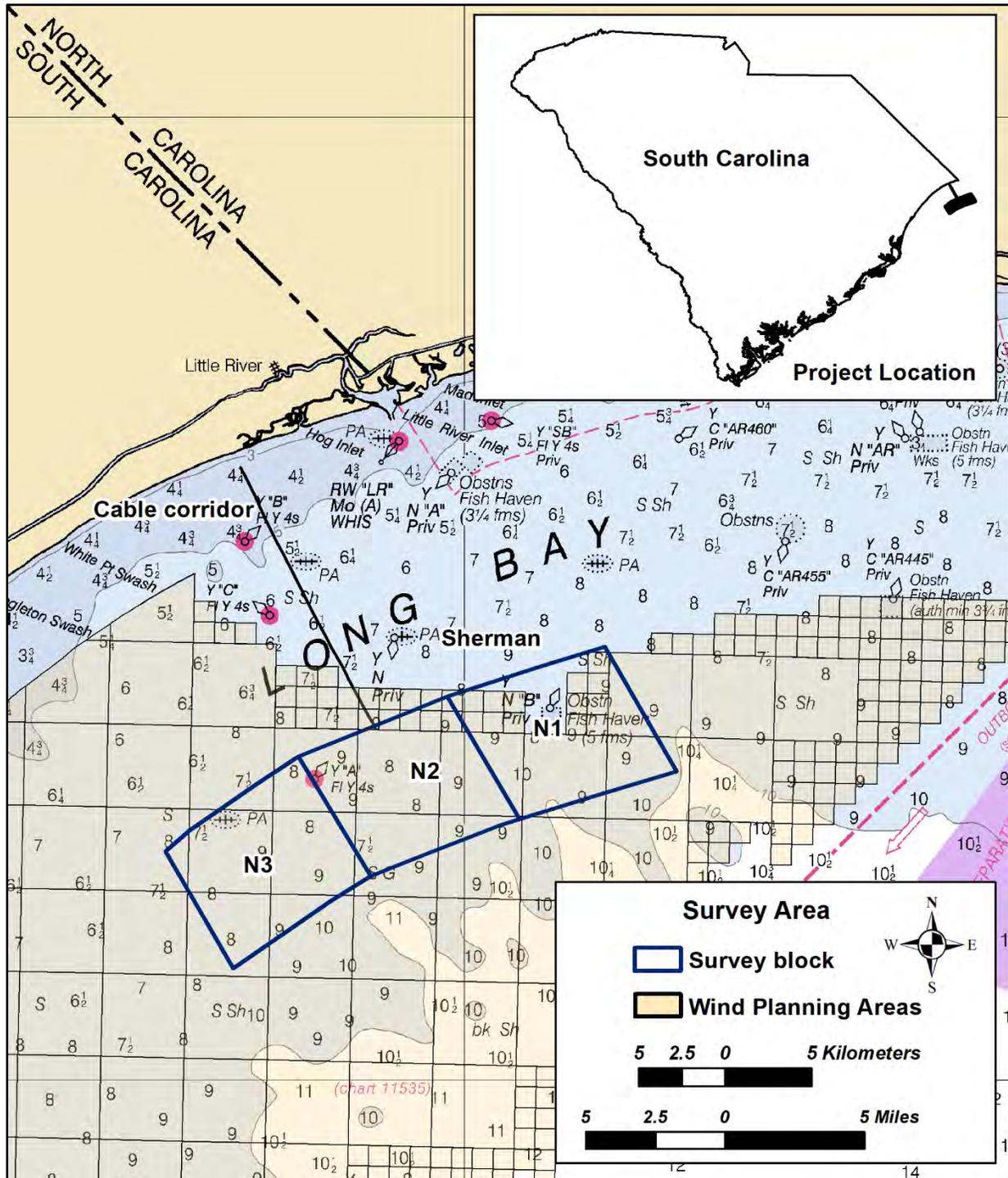
This study was designed to provide initial comprehensive and spatially focused geophysical data to further refine the location of potentially significant sensitive benthic habitats and cultural resources in areas strongly considered for wind resource development on the SC OCS (Figure 3). The overall goal is to help inform BOEM, the State, potential wind energy developers, and the public of site conditions in high potential areas as future development is more formally considered. This is part of a new phase in wind energy related initiatives in South Carolina. It begins a transition from more generalized, regional and conceptual studies examining the potential for wind development into more focused efforts within areas defined by the comprehensive BOEM Wind Energy Area designation process and formally identifying areas with high potential yield and relatively low potential conflicts for wind development. Within those areas, targeted studies such as this can help provide a more detailed basis for BOEM, other public interests, and future developers to advance towards defining, assessing, and ultimately realizing specific sites for wind farm development. To advance this goal, this study focused on three primary objectives: undertaking a reconnaissance level geophysical survey of the study area, assessing geoarchaeological and historical materials, and conducting geophysical survey of potential transmission cable routes. The partners embarked on multiple avenues of geological, archaeological, and historical inquiry to implement the tasks which were completed in 2018.

### 2.1 Geophysical Survey of Selected Study Areas Offshore SC

Hardbottom habitat is extensive but irregularly distributed offshore of South Carolina and throughout the region (see figures 3 and 4 in Barnhardt et al. 2009; Van Dolah et al. 2011; Ojeda et al. 2001, Gayes et al. 2013). It is a primary concern for permitting for a wide range of activities. Within these areas, hardbottom is defined by diverse data sets with a range of spatial resolution. The biological significance of the habitat, typically related to the overall relief of the substrate, may also be highly variable in any given area. On the inner and middle shelf of the region there are abundant low-relief hard bottoms. These low relief hard bottoms present challenges to efficiently map using the few spatially coherent data sets available, such as the National Geophysical Data Center (NGDC) Coastal Relief Model bathymetric surface that has a 90 m grid size. Such coarse resolution may provide a good first order approximation of potential habitat distribution in the region but will be increasingly challenged inshore near low-relief and highly discontinuous habitat and of more general use than needed in considering specific sites for wind farm or other development.

High resolution geophysical surveys can more thoroughly map and assess specific areas and resolve potential permitting and design considerations for a wide range of potential activities on the OCS (e.g. wind farm development, beach nourishment borrow sites, Offshore Dredged Material Disposal Sites [ODMDS], etc.). High resolution geophysical surveys are also helpful in anticipating geotechnical conditions within the shallow sub-surface which will be applicable as foundation and site-specific engineering considerations begin. This is facilitated by including additional sensors and data types in the geophysical survey. CHIRP sub-bottom profiling (high resolution seismic reflection) considerably aids in sea floor habitat and shallow framework geotechnical assessment and is typically included in comprehensive sea floor mapping and characterization surveys. This study focused an extensive high-resolution geophysical survey, including multibeam sonar, side scan sonar, and CHIRP sub-bottom profiling, in a known area of priority for potential wind energy development offshore of South Carolina.

It was anticipated that final Wind Energy Areas established for South Carolina would likely encompass a broad area of Long Bay, reflecting previous work characterizing the area as having strong wind resource potential and relatively limited conflicts with other potential applications. As a result, this effort to begin more focused geophysical mapping prioritized areas within Long Bay, recognizing that



**Figure 3. Project location and survey area**  
 NOAA nautical chart 11520, scale 1:432,720, 2018.

this would significantly improve habitat and cultural resource assessments for a small portion of the potential development area. This mapping incorporated some previously collected geophysical data, along with an additional, regional survey from an ongoing synergistic project between NOAA and Coastal Carolina University. The goal of this mapping project is to provide some guidance to habitat and cultural resource concerns, and to help prioritize areas where future high-resolution studies across the larger, overall extent of South Carolina designated Wind Energy Areas would be most beneficial.

## **2.2 Assess Geoarchaeological and Historical Materials**

Assessment of culturally or historically significant features or human activity-related hazards, such as unexploded ordnance, is also needed within areas being considered for offshore development. In addition to historical records, the same geophysical survey design for habitat assessment (multibeam, side scan sonar, and CHIRP) was also used in cultural resource assessments. Additional sensors, such as magnetometers provided further assistance in cultural resource surveys. Broader and integrated geophysical data were used to direct diver and bottom camera observations of both habitat and cultural resource assessments, which were included in the overall survey for the project.

Thus, a major objective of this study was to begin to further refine and constrain possible cultural resource concerns in higher resolution for at least a portion of anticipated development areas. As is the case with habitat assessment, high resolution surveys are a very time-consuming process and places significant limitations on the aerial extent of data coverage possible for a given project. Regional geophysical survey designs that delineate the general pathway of paleodrainage networks, for example, may similarly provide at least some basis for focusing future targeted high-resolution surveys.

## **2.3 Geophysical Survey of Potential Transmission Cable Routes**

In addition to refining environmental and cultural resource concerns that may influence the location and size of potential offshore wind energy production sites, there are similar environmental, cultural, and geotechnical concerns within potential cable corridors that are used to transmit power from an offshore wind farm to the onshore electrical grid. Various scenarios of potential grid interconnections have been projected for the Southeast U.S. with several configurations considered within Long Bay (e.g. EnerNex, 2011). The final siting of such cable corridors will be subject to the final location of wind energy production offshore and potential grid connections onshore. For this study, a test scoping corridor survey was run from the high-resolution survey area offshore to a likely grid connection point aligned with onshore infrastructure as an example of variability in conditions that may be expected over the mid- to inner shelf of the region.

## **2.4 Detailed Approach and Methodology**

A range of spatial datasets relevant to considering areas of the South Carolina shelf for wind energy development were compiled by the South Carolina Department of Natural Resources (e.g. Van Dolah et al. 2011). Similarly, data sets from state and federal agencies, universities, and industry have been incorporated into the BOEM and NOAA joint integrated Marine Cadastre (<https://www.boem.gov/MarineCadastre.gov/>). The data sets and associated tools are available to help consider the suitability of areas on the U.S. OCS for resource utilization. The types of data include spatial information on characterization of the ocean environment and wind resource potential, jurisdictional boundaries, societal usage and infrastructure, as well as energy and environmental and regulatory information. Such data sets support the work of federal/state cooperatives such as the BOEM-South

Carolina Intergovernmental Renewable Energy Task Force to assist BOEM in defining areas for potential wind energy development that optimize quality wind resource potential and minimizing potential conflicts with environmental and other existing or potential marine resource utilizations.

One of the outcomes of the BOEM and the BOEM-SC Intergovernmental Renewable Energy Task Force process of defining potential Wind Energy Areas on the OCS off South Carolina was the identification of additional information and datasets that would improve assessment of the suitability of an area of the OCS for future wind or other developments. Following the formal delineation of areas for potential wind energy development, the BOEM process puts out a call for expression of interest from potential developers within those areas. Through that process, the consideration begins to transition from regional to more site-specific concerns requiring a higher level of spatial resolution than typically broadly available. Ultimately, very high-resolution assessment across a range of conditions is required within more narrowly defined areas to support full evaluation of a site for development, formal site plans and associated permitting.

In the South Atlantic Bight, one habitat of concern to siting and permitting offshore development is the location and character of hard bottom habitat. Hard bottom habitat exists where indurated sediment exists at the sea floor and supports diverse benthic invertebrate communities and associated fisheries. They are managed as “essential fish habitat”, are highly patchy in extent, and considered much more biologically important with greater relief than substrate stands above the sea floor. Although these environments are abundant off South Carolina, they are distributed in a very discontinuous manner. Within individual hardbottom areas, habitats are intermittent and separated by areas with extensive-to-discontinuous veneers of sand and coarse shelly lags.

Figure 4 shows the regional distribution of essential fish habitat related to hardbottoms. Such regional maps integrate a wide range of data types that represent an equally wide range of confidence in classifying and spatially mapping habitat. For example, many hardbottom studies have historically focused on direct diver or bottom camera observations or presence of hardbottom associated fish catches. Such direct observations of the sea floor or indirect observation presence of fish species of ultimate management concern associated with hard bottoms provide a high confidence of habitat interpretation. They are, however, very poor approaches to map broad areas and delineate spatially complex and distributed habitat. This is especially limiting in detailed siting and ultimately permitting. In addition to the concerns for habitat that may be disturbed by construction of a wind farm and associated cabling to connect power generation to society’s electrical grid on shore, the distribution of these same habitats reflect variation in the geotechnical conditions of the shallow subsurface that may affect the engineering and design of foundations and cable corridors.

Similarly, the same, or slightly modified, approach of integrated geophysical mapping can also provide datasets to help assess the potential for culturally significant resources at or near the sea floor within the area being considered for wind farm development. Historic shipwrecks are of concern, but the surveys also allow the interpretation of potential paleo-landscapes that may have supported early human settlement of the region as well as anthropogenic hazards such as materials associated with former and present military operations in the region.

The State of North Carolina supported by BOEM and NOAA has recently undertaken a mapping and assessment of hardbottom resources within one of the Wind Energy Areas formally defined for North Carolina. That site, the Wilmington East WEA, is one of three WEAs defined off North Carolina, and is in Long Bay just north of the seaward projection of the state boundary between North and South Carolina (Taylor et al. 2016). It is also in an area of deeper water depths and increased spatial range of multibeam sonar systems, which was the primary mapping tool for that study. The Wilmington West WEA was also located in Long Bay and inshore of the Wilmington East. It similarly lies immediately adjacent to the OCS off South Carolina but was not the focus of the initial NC-BOEM habitat mapping study (Taylor et al. 2016).



**Figure 4. Regional distribution of Essential Fish Habitat**

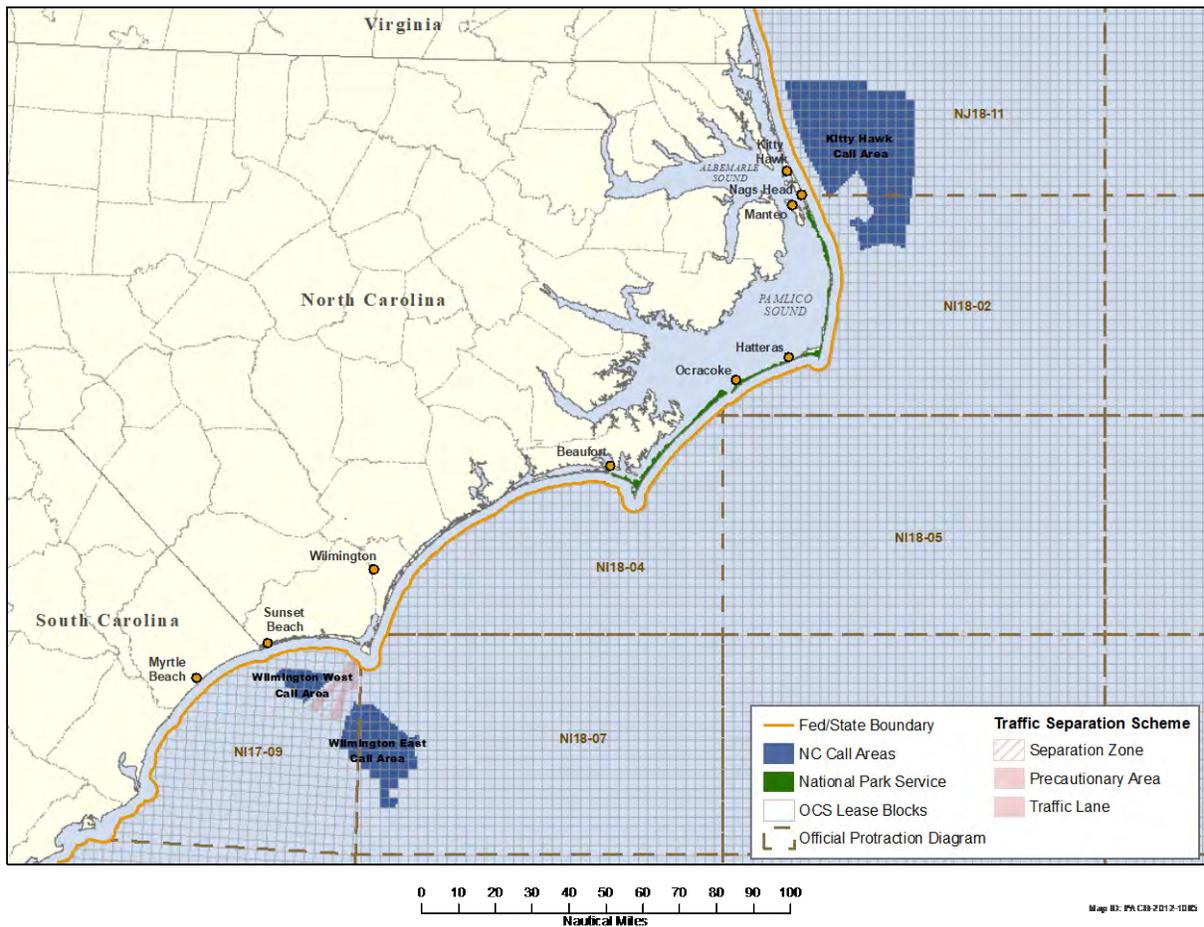
Corals offshore of northern South Carolina from the National Oceanic and Atmospheric Administration EFHMapper tool. (<https://www.habitat.noaa.gov/protection/efh/efhmapper/index.html>)

## 2.5 Detailed Survey and Validation

At the onset of this project, Wind Energy Areas had not yet been formally established offshore of South Carolina. The Bureau of Ocean Energy Management, however, working in collaboration with interests in North Carolina had previously established formal Wind Energy Areas on the OCS off North Carolina (Figure 5). Two of the three WEAs defined for North Carolina were in the northern section of Long Bay terminating along the offshore projection of the boundary between the North and South Carolina.

A 90-square kilometer area offshore of the City of North Myrtle Beach, South Carolina was selected to focus the initial high-resolution geophysical mapping of hardbottom habitat and cultural resources potential (see Figure 3). This was based on existing wind resource potential modeling and available geospatial data related to potential environmental and societal conflicts that would affect wind farm siting. The focus was placed within a coast parallel swath of the continental shelf 17 to 26 kilometers (km) (11 to 16 miles) offshore based on initial visualization studies completed by Santee Cooper (a state-owned utility that had been actively exploring wind energy potential) and Clemson University. This site also reflected the City of North Myrtle Beach’s strong interest in and sustained efforts to advance wind energy development offshore of the City. In addition, the location was immediately adjacent to and contiguous with WEAs defined off North Carolina, and thus, was viewed as most likely to be encompassed within potential WEAs offshore of South Carolina.

As initial geophysical work for this study was underway, call areas offshore of South Carolina are identified (Figure 6). Approximately 3,520-square kilometers of continental shelf was designated as a call areas offshore of the state, the majority of which (>70%) was within Long Bay. As anticipated, the initial study area for this project was included in a call area that extended south-southwest from the Wilmington West WEA previously defined off North Carolina. The detailed survey area off



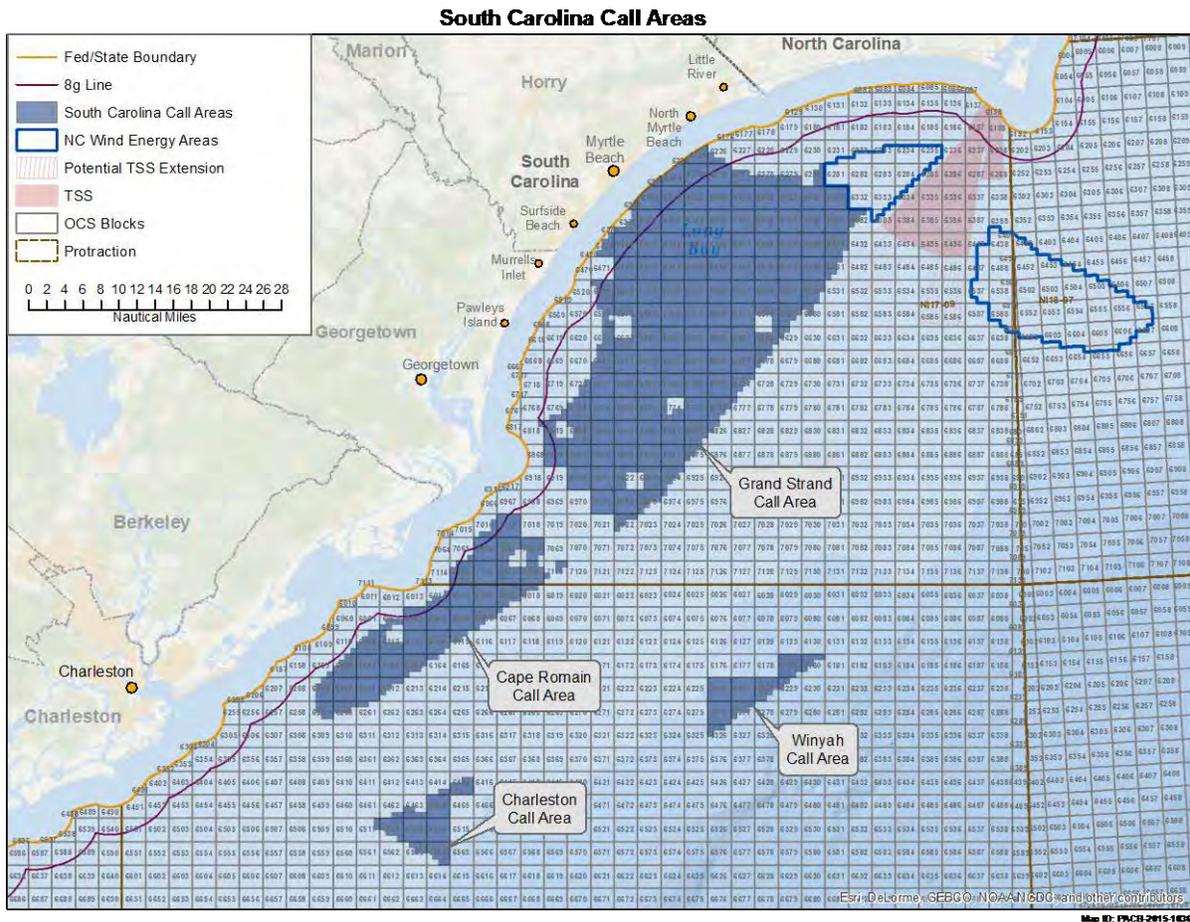
**Figure 5. North Carolina Wind Energy Areas in place at the beginning of this project**

The Wilmington East site was the focus of a BOEM-North Carolina study (Taylor et al. 2016). Figure is from the BOEM Renewable Energy Program Web Site; [https://www.boem.gov/uploadedFiles/BOEM/Renewable\\_Energy\\_Program/State\\_Activities/NC\\_Call\\_Area\\_Names.pdf](https://www.boem.gov/uploadedFiles/BOEM/Renewable_Energy_Program/State_Activities/NC_Call_Area_Names.pdf).

North Myrtle Beach, however, covered only 2.5% of the overall designated call area and 3.5% within Long Bay.

As a result, previous more widely-spaced geophysical surveys collected by Coastal Carolina University were incorporated into the project to provide some reconnaissance level characterization of the broader call areas of northern South Carolina. In addition, a new collaboration between Coastal Carolina and NOAA planned to run additional geophysical survey to test NOAA's Thematic Habitat Mapper based on the National Geophysical Data Centers Coastal 90-meter pixel Coastal Relief Model. That project was located to also help support the goals of this project in providing a first order estimate of habitat potential within the extensive call areas in Long Bay and northern South Carolina.

Geophysical track lines were conducted within the original detailed study area in what became the Grand Strand Call Area. This focus area is contiguous with the Wilmington West Wind Energy Area in North Carolina. A regional survey conducted on the NOAA Ship *Nancy Foster* was completed in July 2015 that provided reconnaissance scale characterization across several of the new South Carolina Wind Energy Call Areas. That cruise and partnership also partnered with NOAA to help test their Thematic Habitat Mapper based on 90-meter pixel bathymetric grids by adding additional geophysical sensors,



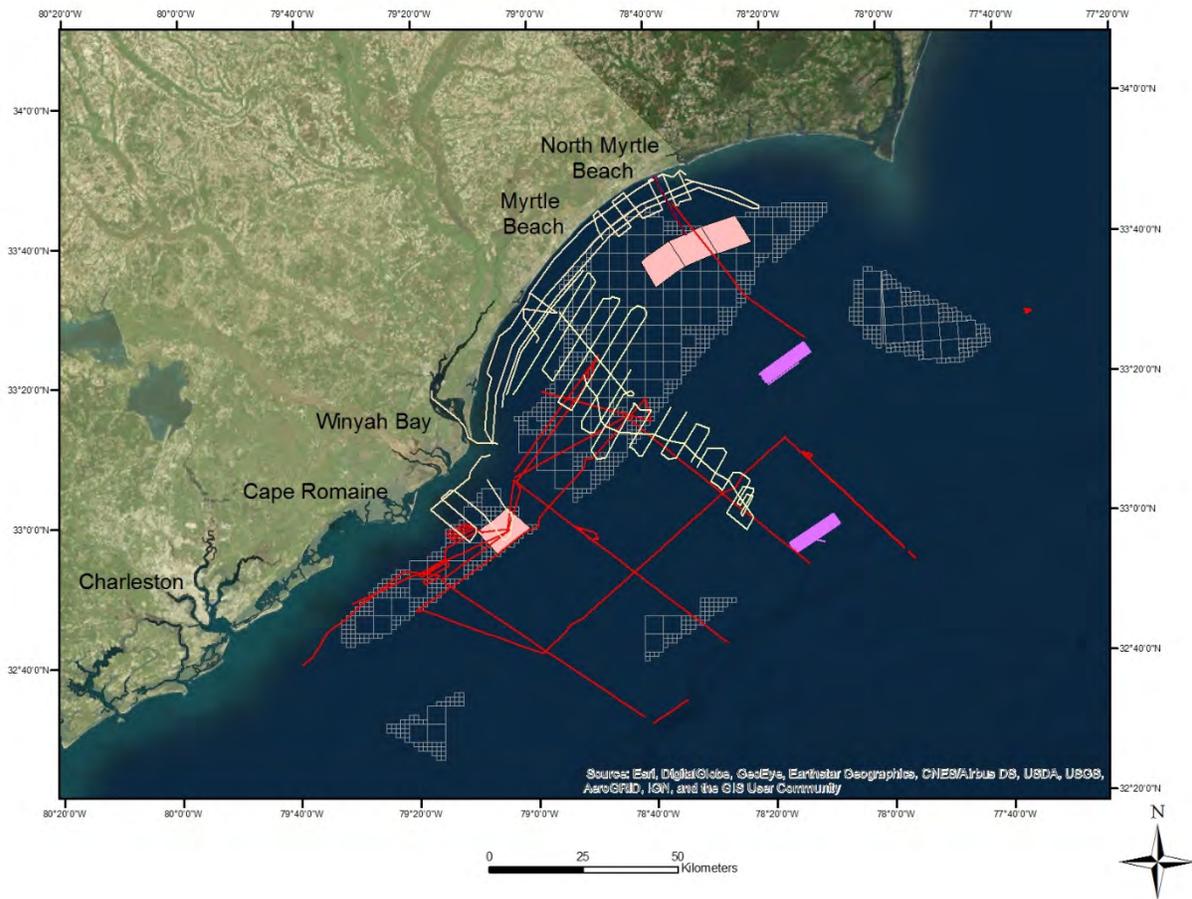
**Figure 6. South Carolina Wind Energy Areas defined by BOEM**

The initial focus area of this study was a small percentage of what became the Grand Strand Call Area. With the expansive call areas delineated in northern South Carolina a regional geophysical survey in concert with NOAA was added to this study. (Figure is from the BOEM Renewable Energy Program Web Site; <https://www.boem.gov/sc-call-areas/>.)

particularly CHIRP sub-bottom profiles. A third geophysical dataset, also conducted by CCU on the NOAA Ship *Nancy Foster* was incorporated into this study to facilitate mapping of paleochannels as locations with decreased potential for presence of hardbottom, but increased potential for cultural resource being present, particularly Paleoindian populations. Figure 7 below shows the integrated trackline map for the study and Table 1 below shows the line kilometer totals for different sensors used.

## 2.6 Identification and Description of Study Area

The survey area in the Atlantic Ocean selected for data collection was comprised of three survey blocks designated as N1, N2, and N3 and located approximately 11 miles offshore from North Myrtle Beach, South Carolina. Beginning at the North–South Carolina border and following the curvature of the coast at Long Bay, the research zone extends 29 km (18 miles) in an approximate northeast to southwest orientation with a width of 8.3 km (5 miles) and encompasses an area of 140 square km (87 square miles). According to nautical charts and local tidal measurements, ocean depth ranged from 13.7 m to 18.3 m (45-60 ft) (MLLW) with a tidal range of 1.5 to 1.8 meters (5-6 ft) within the three main survey areas.



**Figure 7. Integrated Geophysical Trackline Map used for this study**

The solid pink blocks offshore of North Myrtle Beach represent the initial detailed survey area for this study projected from the North Carolina Wilmington West Wind Energy Area offshore of South Carolina. Additional regional survey (red) and two areas of detailed geophysical survey (purple) were conducted on the NOAA Ship *Nancy Foster* in 2015 to support this project. An additional previous data set collected by CCU on the NOAA Ship *Foster* was (yellow) was also included to further refine areas in the broader Wind Energy Areas at a reconnaissance scale. Total trackline-kilometers for various instruments in the different data sets are shown below.

**Table 1. Total tracklines in kilometers in support of the project**

Survey Area	Multibeam Lines	CHIRP Lines	Side Scan Sonar Lines	Magnetometer Lines
Distance	km	km	km	km
Grand Strand Call Area	1772	447	447	1325
<i>NF</i> 2015	1662	1179	1179	0
<i>NF</i> 2004	0	612	0	0
Total	3434	2238	1626	1325

Additionally, a single line transect of a potential transmission cable corridor, beginning at the northeast boundary of the N2 survey area and headed in the direction of Cherry Grove Beach, or in a northwest to southeast direction, spanned 20.1 km (12.5 miles), and ended about 1,250 m (4,101 ft) from the beach. The corridor transect traversed water depth ranges from 6.7 m to 16.4 m (22-54 ft).

For a comprehensive survey of the regional research area project partners employed a marine electronic ensemble that included multibeam, side scan sonar, CHIRP, and a cesium magnetometer. The survey design initially called for line spacing of 150 m (492 ft) intervals with 75 m (246 ft) offset lines for magnetometer deployment but was ultimately increased to 200 m line spacing due to the large extent of the survey area, to ensure quality control of the data by only surveying during periods of fair surface conditions, and to the constraint of time. A 58 sq. km (22.3 sq. mi) portion of block N1, however, received a reduced line spacing of 100 m (328 ft) while deploying only multibeam and side scan sonar that ensured 100 percent overlap. Upon completion of the regional survey in the spring of 2016, selected expanses of bottom, natural, geological, and cultural features were identified for refinement by narrowing search parameters to 100 m (328 ft). Based on the data acquired from the regional survey, 12 expanses of seafloor were selected for refining operations with the imperative of gathering additional bottom details that included potential cultural features. Researchers utilized a tow-camera, multibeam sonar, and a sub-bottom profiler along the longitudinal centerline of each expanse. From this data, six areas of prioritization were identified and surveyed using all three of the instruments and the magnetometer. Additional surveys of the known remains of the shipwreck of *Sherman* and areas of the artificial reef known as Barracuda Alley situated in N1 were assessed utilizing the magnetometer and multibeam sonar. Line spacing parameters for *Sherman* were reconnaissance in nature to determine the location and the extent of the magnetic influence of the site.

## 2.7 Geophysical Mapping and Oceanographic Data Acquisition

The seabed geophysical data collection was directed toward the identification of suitable hard ground lithology as well as potential design considerations that must be considered in any future wind farm development plans. These considerations are diverse and include active zones of sediment transport, faults and fractures, steep slopes approaching 10 degrees and mainly associated with sand ridges and swale topography, paleochannels, together with areas where potential silt and/or clay are exposed on the seafloor. The presence of such interbedded clays, silts, and sands on the seafloor and within paleochannel complexes may prove hazardous to certain types of development activities and planned structures.

A comprehensive and integrated geophysical survey served as the baseline for the objectives of the project. The habitat and cultural resources objectives of the project target different spatial scales and complied with the standards for those types of surveys by BOEM. The geophysical remote-sensing devices to undertake and obtain the desired datasets included a multibeam echosounder, side-scan sonar, cesium magnetometer, and a CHIRP sub-bottom profiler.

All geophysical acquisition of the detailed study area location was conducted on the R/V *Coastal Explorer*. The *Coastal Explorer* is a 16-meter aluminum catamaran research vessel operated by Coastal Carolina University. The vessel was designed and constructed to support Coastal Carolina's suite of geophysical instrumentation and other diverse oceanographic sampling and sensing systems. The acquisition was collected between 2015 and 2017. The regional geophysical survey covering the South Carolina continental shelf from Cape Romaine to the North Carolina border was conducted on the NOAA Ship *Nancy Foster*. The *Nancy Foster* is a 57-meter research vessel operated by the National Oceanic and Atmospheric Administration. The vessel time was provided through a cooperative effort of NOAA, National Marine Fisheries Service staff, and Coastal Carolina University to support habitat characterization. The acquisition was collected over 16 days at sea between July 8 and 24, 2015. ESRI staff oversaw processing of CHIRP, multibeam, and side scan data, while SCIAA staff oversaw the acquisition and processing of magnetometer data.

### 2.7.1 Regional Geophysical Mapping – Multibeam

The multibeam bathymetry system on the R/V *Coastal Explorer* uses a Kongsberg EM3002 dual head multibeam echosounder. The EM3002 is utilized for survey depths less than 150 meters, operates the dual heads at 293 kHz and 307 kHz, and can ping up to 40 Hz. The dual head setup allows for 508 soundings per ping and an angular coverage sector up to 200°. The EM3002 integrates a sound velocity probe mounted at the transducer heads for initial beam forming and the acquisition software corrects for sound velocity changes throughout the water column using a sound velocity profile obtained by an AML Oceanographic Smart SV&P probe at least once per survey day. The R/V *Coastal Explorer* also incorporates a Seatex Seapath 200 RTK heading, attitude, and position sensor. The Seapath acquires attitude data (heave, pitch, and roll) with its MRU-5 Inertial Measurement Unit (IMU) at 100 Hz and sends these data to the multibeam acquisition software in real-time. The Seapath also handles heading and positional data, both horizontal and vertical, through two L1/L2 GPS antennas and Real Time Kinematic (RTK) corrections acquired through a network of RTK base stations. The standard Coastal Carolina University workflow for multibeam acquisition and processing is shown in Appendix A. NOAA hydrographic office staff have visited and reviewed Coastal Carolina’s multibeam procedures and past data products and identified that they met NOAA’s criteria to accept Coastal Carolina Data as third-party contribution to national charting efforts. The multibeam used on the NOAA Ship *Nancy Foster* was a Reson 7125 dual-beam (200/400 kHz) frequency multibeam sonar with a 128-degree swath and processed on ship using NOAA standard workflow.

Multibeam sonars emit sound pulses in the shape of a fan comprised by many individual “beams” from directly beneath a ship. These systems measure and record the time it takes for the acoustic signal from each individual beam to travel from the transmitter (transducer) to the seafloor (or object) and back to the receiver and the amplitude of the returned signal. In this way, multibeam sonars produce a “swath” of sounding and backscatter data for broad coverage of a survey area. The coverage area on the seafloor is typically two to four times the water depth. Analysis of these types of data can identify main seafloor bottom types across the survey area including exposed mud/clay, sand ridges and/or sand waves, and sand with gravel.

### 2.7.2 Regional Geophysical Mapping – Side-scan

Coastal Carolina uses a Klein 3000 dual frequency (135 and 445 kHz) side scan sonar as part of its geophysical suite of instruments. The side scan was deployed from either the *Coastal Explorer* or NOAA Ship *Nancy Foster* using a “K-Wind” depressor vane to reduce the cable payout to maintain operating depth. Layback was determined from length of cable paid out and estimated cable angle and depth of the towfish. Aboard *Coastal Explorer*, the sonar was deployed by a winch just offset 0.5 m (1.5 ft) on the port side of the vessel centerline. The workflow for Coastal Carolina University side scan system is provided in Appendix B. SCIAA processed the individual side scan sonar records using Chesapeake Technology, Inc. SonarWiz Map 4 to remove line turns, increase image clarity, identify potential acoustic targets, and to create a sonar mosaic with a resolution of 0.5 m (1.6 ft).

Side-scan sonar data provide images of the seafloor texture that reveal considerable detail, ranging from small sand ripples to larger-scale objects such as shipwrecks. In addition, the side-scan sonar backscatter can be interpreted to map the presence and extent of ocean bottom features such as soft sediment, hardbottom benthic habitats, exposed pipelines, cables, underwater wrecks, potential cultural resources, and other bottom substrate types that may affect development area delineation, introduce hazards to potential foundations, or negatively impact the environment.

### 2.7.3 Regional Geophysical Mapping – CHIRP

An Edgetech 512i sub-bottom profiling sonar was used for all CHIRP acquisition. The CHIRP was deployed from an A-Frame on *Coastal Explorer* and the NOAA Ship *Nancy Foster*. The depth of tows was typically a few meters below the surface to be free of wake and surface turbulence as possible. Towing multiple instruments on the NOAA Ship *Nancy Foster* required a side-tow configuration with a short lead to reduce the tendency of the tow fish to become drawn under the ship while underway. Layback was estimated from cable paid out and wire angle. The standard operating frequencies for the CCU CHIRP are 500-10000 Hz. As may be required with changing bottom character, frequencies may be adjusted to improve resolution (higher frequency pulses) where penetration into the sub-bottom was particularly favorable. In shelf settings, penetration is typically very limiting so little if any shifting of CHIRP pulse occurred. The workflow for Coastal Carolina University multibeam system is provided in Appendix C.

The 512i CHIRP system had two transmitters, four receiver arrays, and an output power of 2000W. The system is capable of a frequency range of 0.5-12 kHz. For this survey, a frequency of 1.2 kHz was chosen for the larger pitch/roll angle that can be accounted for during the survey in the continental shelf (less than 13° compared to less than 7° for the higher frequencies). This frequency also generates a beam width of 32°, allowing fewer passes over the survey area. In addition, this system can achieve a vertical bed separation of at least 19 cm in the uppermost 30 m below the seafloor, assuming at least a 10% change in density between strata.

CHIRP sub-bottom profilers are used extensively to image shallow (<20 m) sub-seafloor structure and stratigraphy by employing vertical incidence reflections over a range of frequencies to obtain very high depth resolution. In addition, CHIRP sub-bottom profilers are used to identify potential cultural resources and features that may affect future wind farm development. The use of CHIRP sub-bottom profilers allowed for imaging and mapping of paleochannel complexes and common stratigraphic layers throughout the study area. In addition, it allowed for the determination of stratigraphic layer thicknesses, including the thickness of the Holocene sediment cover.

Interpreted results are provided as planar vector data. These may be seen as map layers at this time and are planned to be provided in the cross-sectional images later. The interpreted layers are provided as a complement to earlier work along the nearshore of Long Bay, and these are the sediment thickness overlying the transgressive surface and depth below sea level of the transgressive surface. Paleochannels are also mapped and in various forms depending on which data provider they were interpreted from. As discussed elsewhere, the data coming from NOAA sources were provided and analyzed in Kingdom Suite. These data are found on the webmap in a layer named “Gabby Paleochannel Heatmap.” This layer provides an adaptive heatmap to simplify the volume of points produced. It may be interpreted as a depth-colored (warmer is deeper) overview of paleochannel existence when viewed from afar, and as a colored scatter plot of the channel floor when zoomed in to full extent.

### 2.7.4 Regional Geophysical Mapping – Magnetometer

A Geometrics G-882 marine magnetometer was used to measure total magnetic field intensity. The instrument consists of a cesium vapor magnetometer in a towfish, 100 m of cable to tow the instrument and transmit data, and a topside computer with acquisition software. Total field intensity is controlled in part by distance between sensor and target among other factors. Towfish altitude above seafloor was therefore maintained as constant as mapping conditions allowed. Vessel position was integrated with the magnetic signal through the MagLog Lite software interface. This acquisition software also allows for monitoring of signal intensity in real time to ensure data quality. Magnetometer data was recorded at a sample rate of 0.1 seconds at a sensitivity of 0.01nT using MagLog Lite software from Geometrics. Output data from the MagLog Lite software included magnetometer readings along with the ship

coordinates, sensor depth and altitude, sensor layback coordinates and other information. On the CCU R/V *Coastal Explorer*, the towfish was configured on the starboard side of the vessel. The magnetometer was towed in tandem with the side scan sonar (until the unit failed), multibeam, and CHIRP as often as conditions allowed at a line spacing of 200 m (656 ft) and at ship speed of 4-5 knots. The standard workflow for Coastal Carolina magnetometer is shown in Appendix D. Magnetometer data acquisition and processing was undertaken by SCIAA staff on *Coastal Explorer*. Towed in tandem with the side-scan sonar towfish, the magnetometer was very useful in revealing magnetic anomalies to be used in connection with the sonars to identify zones of potential design considerations or cultural resources.

The magnetometer was the primary archaeological prospecting tool used to search for potential shipwreck sites. The magnetometer measures the earth's ambient magnetic field through scalar measurements. The measurement expressed as the Total Field intensity in nanoteslas or gammas (nT or  $\gamma$ ) varies from 20,000 to 100,000 nT on the earth's surface. In South Carolina, the ambient Total Field intensity ranges from 40,000 to 50,000 nT. Local disturbances caused by geological features or man-made objects add to or subtract from the ambient magnetic field and are called magnetic anomalies. Man-made objects that affect the marine magnetic field include ferromagnetic materials, such as iron or steel, and concentrations of rock, for example ballast mounds, high in magnetite.

The G-882 marine magnetometer uses cesium vapor (non-radioactive Cs133) and a light source to agitate the cesium atoms to a high level. A radio frequency de-pumping coil then reduces the high state of agitation. The strength of the ambient magnetic field determines the rate of the energy transition or "pumping de-pumping" from a higher to lower level, a process known as Zeeman splitting. Digitally quantified, this transition provides a measurement of the local magnetic field around the sensor. Total field intensity is controlled in part by the distance between sensor and target among other factors. Several factors can degrade the reading that includes sea swells, magnetic effects of the vessel, lack of control or knowledge of the sensor's position, and other survey errors that limit the magnetometer's performance. Despite these limitations, the cesium magnetometer has a very high sensitivity and rapid sample rate that yields precise measurement of the local magnetic field, especially applicable to marine archaeological prospecting.

Many factors determine the detection and strength of a magnetic anomaly including mass of the source, sensor to source distance, and orientation of the sensor to the source to name a few. Although not an exact science, interpretation of magnetic anomalies depends on experience and on several guidelines, namely the amplitude or strength, signature (i.e., whether a dipole, monopole, or multi-component), and duration of the disturbance. These factors aid in determining whether an anomaly resulted from a single-source or a cluster of magnetic objects. These considerations among others were factored in to determine whether a magnetic anomaly portends an archaeologically or historically significant cultural object that warrants further investigation.

The raw magnetometer files logged by the MagLog Lite software during the survey were post-processed in Microsoft Excel to format the data. Two columns of magnetic data were created: (1) the Total Field of the magnetic data recorded by the magnetometer, and (2) a column of Residual magnetic data, basically the Total Field magnetic data converted to a simple plus or minus reading by the following process. In this case, a 2-point half-width was chosen to generate the residual data. This process entailed subtracting each Total Field reading from the previous one to record the difference between each reading. This process eliminated the earth's ambient magnetic field, diurnal variations, and geological background to obtain the residual values of potential anomalies of interest. The edited magnetometer data was then saved as a MS-DOS text (.TXT) file containing positional coordinates, Total Field and residual magnetometer readings, and other complementary information such as time and sensor altitude. Once the magnetometer data was edited and converted to a .TXT file, the information was added to Earth Systems Research Institute, Inc.'s (ESRI) ArcGIS 10.4.1 software, a GIS program. The magnetic data was then saved as a shapefile and underwent additional editing to remove magnetic spikes, faulty readings, and turns to ensure accurate information to begin the analysis process.

Spatial Analyst, an ArcGIS extension, increased functionality to the core program by providing the means to contour the magnetic data. All contours were generated in Spatial Analyst using the Kriging method. The Kriging technique is an interpolation function for magnetic data whereby weighting assigned to points within a cluster are decreased to denote a continuous raster surface and more accurately represent the magnetic field of the survey area (Bohling 2005). All magnetic data for the project was contoured at one-gamma. The grids were clipped to remove areas not covered by data. The magnetic contours overlaid the georectified imagery (i.e., multibeam and sonograms) and aided in determining spatial correlations between magnetic and acoustic anomalies.

## 3 Geophysical and Habitat Characterization

### 3.1 Bathymetric Analysis

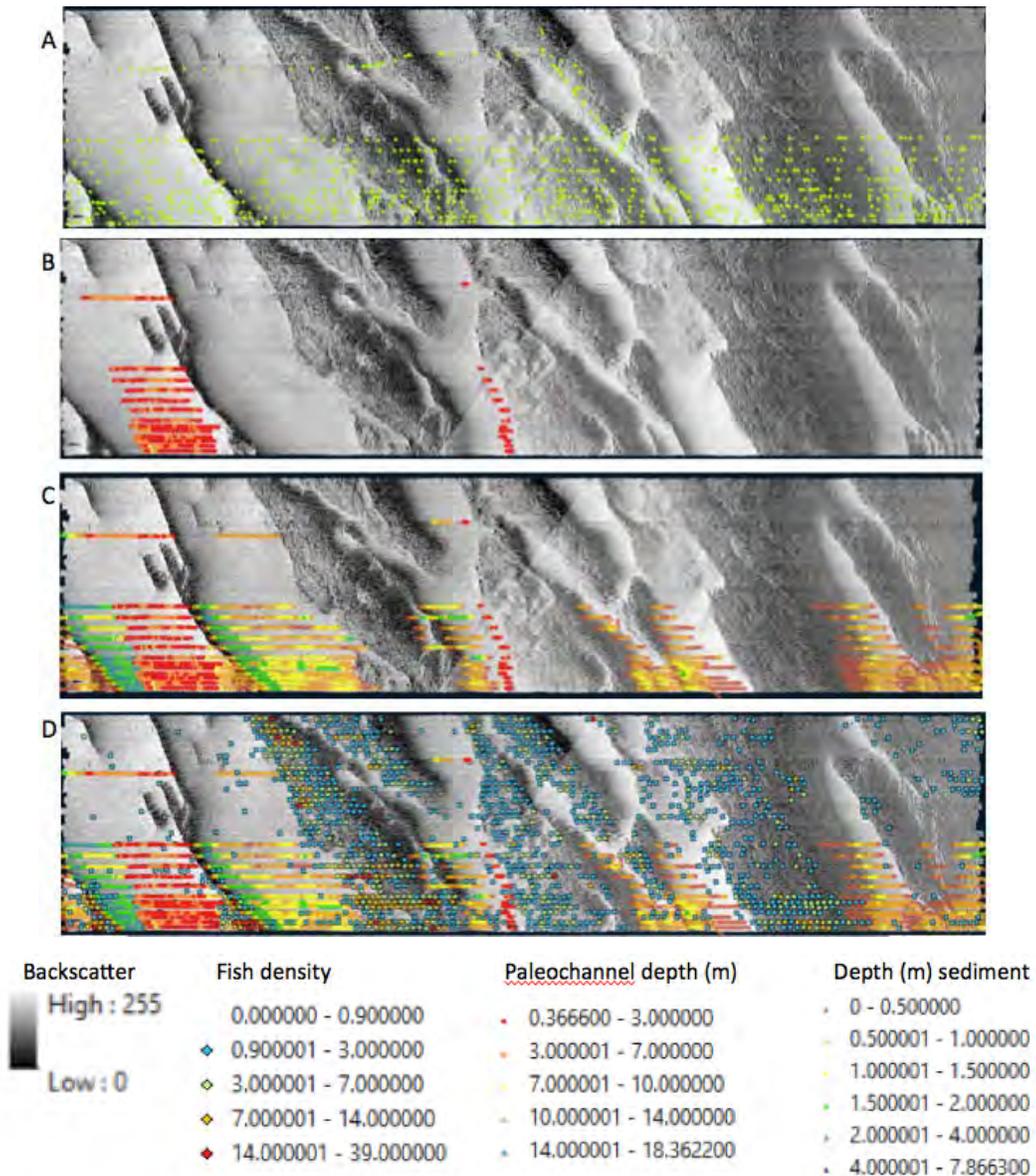
The spatial distribution and extent of hardbottom habitats, reef habitats, essential fish habitat, and archaeological artifacts are significant pieces of information for wind energy development. USC and CCU have conducted geophysical surveys including high-frequency CHIRP sub-bottom profiling and seafloor mapping (side-scan, multibeam and magnetic surveys) to assess the spatial extent of sensitive hardbottom habitats and the sediment lens in the study area for wind energy infrastructure development. Recent studies indicate that multibeam backscatter and seismic CHIRP have significant predictive capability for sediment characteristics and that classifications based on acoustic data have ecological validity (McGonigle and Collier 2014).

The integration of the diverse geophysical data types used can be used to infer a range of characteristics of the sea floor and shallow sub-surface conditions of interest in siting, design, permitting, and construction of potential wind farms in the area. Some parameters, such as water depth and variability in depth and slopes of the sea floor, are direct measurements with direct utility. Such information also helps infer or contribute to interpretations of other characterizations or conditions of interest with increasing degrees of uncertainty for more complex variables, such as biologically significant sea floor habitat (e.g. productive hard bottoms that may be regulated as essential fish habitat). Figure 8 shows a progression of parameters inferred from different geophysical data projected over backscatter response of the sea floor in part of the study area.

Individual parameters, such as location of inferred paleochannel incisions (Figure 8B) and surficial sediment thickness (Figure 8C) show a strong spatial coincidence surficial sediment backscatter response to sonar. As different sensors image the environment on different spatial scales, ranging from individual lines of survey (such as CHIRP data) to swaths of sea floor with varying across and along track resolution (such as side scan and multibeam), the integration of parameters aids both the interpolation and interpretation of conditions spatially as well as confidence in environmental interpretations of interest. In Figure 8D, fishery sonar made available on the NOAA Ship *Nancy Foster* cruise when this data was collected shows a very strong relationship to backscatter of surficial sediment as well as other inferred parameters such as absence of resolvable surficial sediment thickness and location of paleochannel incisions. This is the power of geophysical sea floor mapping, especially when the spatial efficiency of making observations of geophysical data is considered relative to individual site observations made by direct observations or sampling, which may have high degrees of confidence in interpretation but very limiting in characterizing broad areas.

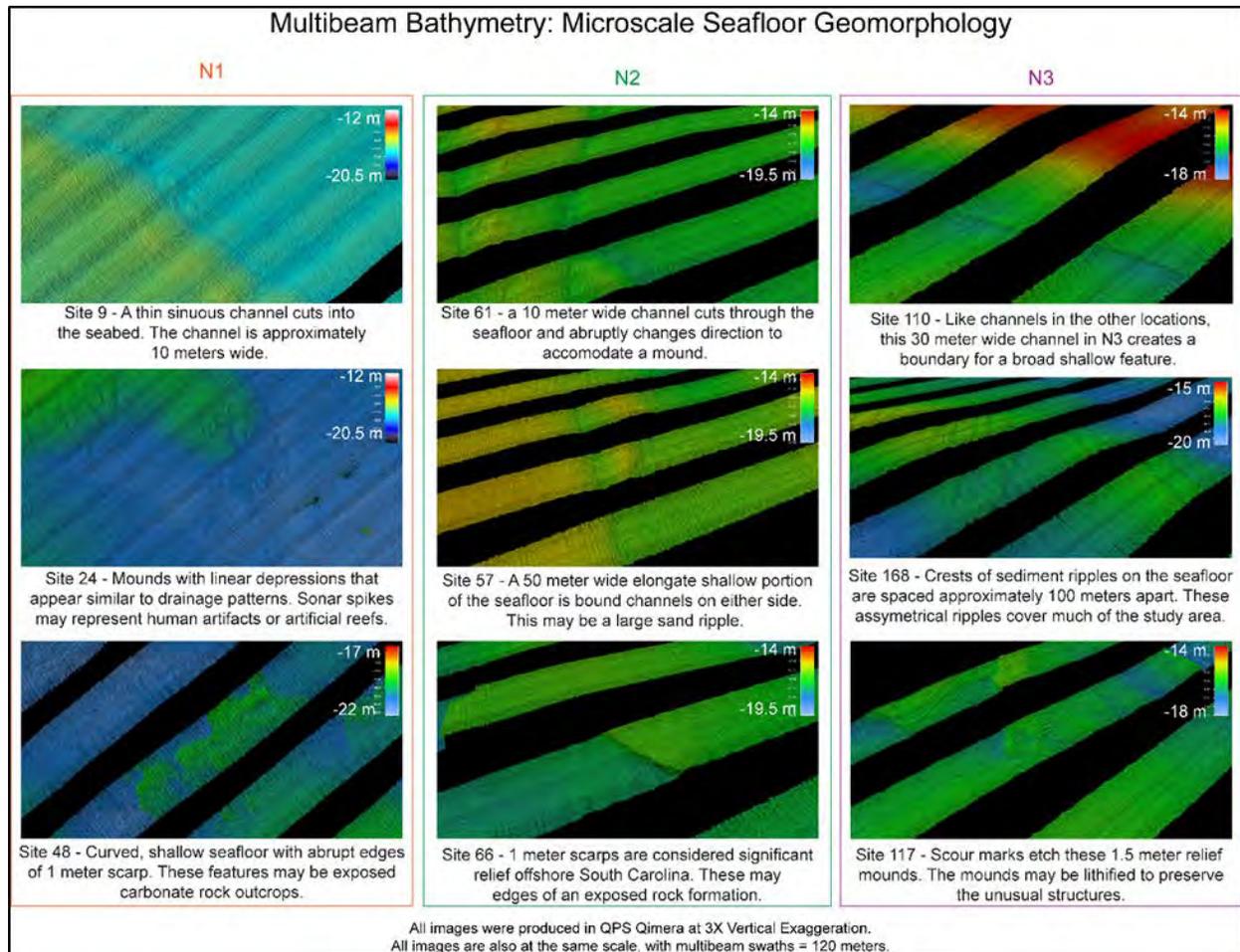
In addition, sub-bottom (CHIRP) data also provides some first-order characterization of the shallow geologic framework that will influence the geotechnical conditions of the site of interest to any future consideration of wind turbine foundation type and design. In general, the presence of paleo-valley incisions, infilled with acoustically transparent or stratified sediment, are considered some of the few areas where spatially coherent unconsolidated surficial sediment of significant thickness (>1 meter) are likely to be found in the region. Outside of those paleo-incisions, older deposits of variable degrees of induration are to be expected. Such framework will help inform locating future borings necessary for specific tower and foundation design considerations.

As surficial habitat and cultural resource assessment were the primary focus of this study, ground-truthing for the project was focused on select sites for bottom video and diver observations. As potential future wind farms move to specific siting, boreholes required for foundation and tower considerations will greatly aid the regional geologic framework interpretations from this and previous geophysical data sets and should be directly tied to specific development site surveys.



**Figure 8. Examples of different data types within an offshore study area**

Data obtained during a joint NOAA-CCU cruise on the NOAA Ship *Nancy Foster* (July 2015). The different data types contribute to overall interpretation of habitat; which is improved by integration of the diverse data types relative to any one parameter (e.g. bathymetry). All images use the NOAA Ship *Nancy Foster* Reson 7125 backscatter as a basemap. In this view, low backscatter values are shown in lighter shades of gray and high backscatter in darker shades of gray. Backscatter shown with: (A) locations of chirp profiles (green) available, (B) depth of marked paleochannel location, (C) surficial sediment thickness, (D) shown as depth of modern (Holocene) sediment and mapped fish locations, in number of fishes per 100-meter interval (Roach, 2017). Note the concentration of fish identified in the NOAA fishery sonar returns (courtesy of C. Taylor, NOAA, 2016) along the southwest border of low backscatter sand bodies denoting scouring and exposure of older substrate within troughs of large scale sedimentary bedforms responding to a predominate southwest current.



**Figure 9. Multibeam Bathymetry: Microscale Seafloor Geomorphology**  
Areas of N1, N2, and N3 the focus of the refining survey.

The collaborative effort has generated multibeam and side scan sonar coverage, as well as CHIRP sub-bottom and magnetometer data on a 180-meter line spacing. The 10-km wide swath parallels a similar high-resolution geophysical survey from the shoreline to 8 km offshore, from the North Carolina Border to Winyah Bay, completed as part of the joint USGS-SC Sea Grant South Carolina Coastal Erosion Study (e.g. Barnhardt (ed.), 2009). Across the region, a thin veneer of sediments overlies indurated Tertiary deposits. The Tertiary geologic section is locally scoured and influenced by small channels and probable karstification and enduring fluid exchange across the sea floor, which has been previously identified in the region (Harris et al. 2005; 2013). The sea floor exhibits large-scale (100s of meters) low relief shore-perpendicular bedforms like those found within the shoreface and innermost shelf through the South Carolina Coastal Erosion Study (Harris et al. 2013).

Central to the call area study is the realization that the OCS has the potential to yield a wealth of archaeological information about the early inhabitants of North America and the historic seafaring traditions of exploration, trade, and warfare. Data collection and analyses for this study identified paleo-landforms with the potential to contain evidence of human habitation during the last glacial maximum and several historic shipwrecks. Consequently, the research team refined data acquisition, processing and analyses to better understand and identify cultural archaeological and geological areas of interest.

In November 2016, the team conducted a series of refining surveys on the three blocks of our study area. Several zones (Figure 9) were chosen for further surveying based on the diversity of

geomorphic features, abundance of multibeam and side scan sonar anomalies, and magnetic anomalies that indicated potential geologic or paleo-historic significance. Sampling zones were distributed throughout the three blocks to insure a spatial distribution of observations.

In the refining cruise effort, data acquisition included (1) one shallow sub-bottom CHIRP profile, (2) camera recordings perpendicular to the shoreline, and (3) near 100% multibeam coverage in block N1. However, the source for tidal data had to be changed since Hurricane Matthew swept through the South Carolina coast in October 2016 and destroyed Springmaid Pier, which was the nearest available source of accurate tidal data. For consistency purposes, to match the tide on the refining cruise data as closely as possible to the initial dataset to insure accurate water column depths, we used numerically modeled tide data from NOAA based on previous data from Springmaid Pier. After applying the modeled tide data-files, the refining cruise bathymetric data were corrected from approximately 1-meter difference on the Z-axis to 0-0.4 meters.

### **3.1.1 Seafloor Classification**

Understanding the seafloor substrate is critical to habitat mapping. Habitat is often partially classified in terms of physical setting, which includes ecosystem bottom-type (Finkbeiner et al. 2001). The South Atlantic Fishery Management Council (SAFMC) considers hardbottom habitats to be of critical importance to the vitality of a marine ecosystem (Drayton 2003); thus, bottom-type delineation is a crucial step in habitat mapping.

Approaches to habitat mapping have evolved with the advent of multibeam sonar systems that enable the creation of a comprehensive digital elevation model (DEM) of the seafloor that can be analyzed with remote-sensing techniques. Probably the most widely-used methods of seafloor habitat mapping involve manual delineation of multibeam bathymetry maps to infer areas with critical hardbottom (Green et al. 1999; Wilson et al. 2007; Franklin et al. 2010). Habitat mapping methods that incorporate ground-reference data, for example direct seafloor visual images, often improve upon the manual interpretation of bathymetry (Kostylev et al. 2001) but are still limited by the expertise and subjectivity of the individual interpolating between bottom-type observed areas. Often there is no systematic approach defined or physical criteria applied consistently to the interpretation, thus, the results are subjective and possibly irreproducible.

Automated bottom-type classifications are gaining prevalence in the habitat mapping community (e.g. Lucieer, 2008; Finkl and Makowski, 2015; Li et al. 2017). Computer-aided classifications take advantage of imagery analysis techniques developed in the remote sensing and machine-learning disciplines to detect areas of sediment cover and hardbottom outcrops. Two categories of classification exist: unsupervised and supervised. Unsupervised methods depend solely on statistical differences of data values to segment an image. Li and others (2017) used an iterative scheme based on pixel separation distances in parameter space. Finkl and Makowski (2015) assigned an arbitrary number of classes for the computer to identify using ISO-clustering based on image color properties. Although unsupervised methods eliminate user bias from the habitat map, they can produce maps that do not reflect physical properties of the seafloor related to habitat, inhibiting meaningful interpretation.

Supervised classification schemes incorporate a learning phase of expert-defined data to distinguish between classes. Like visual interpretation and mapping, supervised classifications will assume the expert's definition is always correct and ideal when defining a class; therefore, if the expert mislabels a rock outcrop as soft-bottom, it will confuse the classifier and produce less reliable and less accurate results. Lucieer (2008) used an object-based supervised classification to identify seafloor features in side scan sonar imagery. Object-based classification compares segmented pixel groups in an unclassified image to similar pixel groups in a reference image. One class is then assigned to each group as an object. Finkl and Makowski (2015) also applied object-based supervised autoclassification to bottom-type data to the southeast Florida continental shelf. They trained the classifier on sites

representing 14 different geomorphologic features. Areas not used in training were then assigned to one of the 14 geomorphic classes.

Pixel-based supervised classification also depends on a training dataset that represents each class. The training dataset will be comprised of points representing one pixel each in an image of the study area. Values for all input datasets are extracted to these points, which allows the classifier to learn statistical rules that designate each defined class. Overall, cognitive supervised classification methods – whether object-based or pixel-based – produce maps that are typically easier to interpret and more intuitively linked to the properties under study than those produced by unsupervised classifications.

Both supervised classification schemes described above depend on discrete statistics that assign a categorical value to every spatial unit (cell) within the study area depending on that cell's pixel values. Classifiers that incorporate fuzzy set theory (Zadeh, 1965, 1973) assign a ratio value between classes to each cell in a study area that is associated with the probability that a given pixel or object belongs to a given class. For example, a discrete (or non-fuzzy) classification would assign a cell a value of either 0 or 1, representing a soft-bottom or hardbottom class respectively. A classifier that incorporates fuzzy logic could assign the same cluster of pixels a value of 0.5 – a value equally divided between class 0 (soft-bottom) and class 1 (hardbottom). This ratio output enables the interpreter to spatially explore class divisions and gives the interpreter additional information. In this example, a pixel classified with value 0.5 is equally likely to belong to a soft-bottom or hardbottom class, and, therefore, may be marked as ambiguous on a map; alternatively, it could indicate the pixel is mixed soft and hardbottom, such as a carbonate rock outcrop covered by a thin veneer of sand.

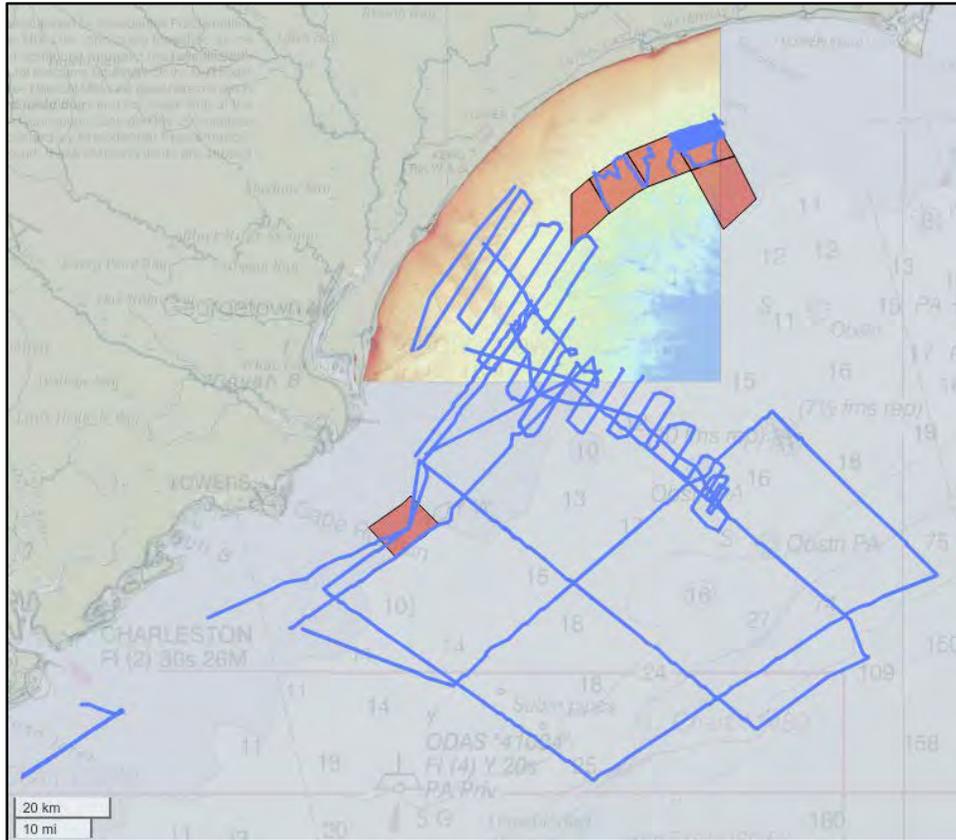
We used a supervised pixel-based classification scheme to delineate seafloor bottom-type in the wind energy area offshore South Carolina. An adaptive neuro-fuzzy inference system (ANFIS) is a neural network classifier developed to apply fuzzy logic to unknown pixels (Jang, 1993). ANFIS has already been used to map lava flow geomorphology at oceanic spreading ridges (McClinton et al. 2012). The computational power of neural networks exceeds that of other autclassification methods. Neural networks mimic the human nervous system by connecting processing nodes (neurons) via weighted paths. Due to its ability to incorporate fuzzy set theory (Zadeh, 1965, 1973), ANFIS assigns a continuum of heterogeneous classes with indistinct boundaries that mimics the distribution of soft and hardbottom habitats on the seafloor (Jang, 1993).

### 3.1.2 Subsurface Analysis

A CHIRP sub-bottom profiler was used to image shallow (<20 m) sub-seafloor structure and stratigraphy by employing vertical incidence reflections of acoustic waves over a range of frequencies to obtain very high depth resolution. The use of CHIRP sub-bottom profilers allowed for imaging and mapping of paleochannel complexes and common stratigraphic layers throughout the survey area.

CHIRP sub-bottom profiling data acquired by the R/V *Coastal Explorer* and the R/V *Nancy Foster* are included herein to address the subsurface physiography of the study areas. Each vessel provides a reconnaissance view of the South Carolina portion of Long Bay. The R/V *Coastal Explorer* operated by Coastal Carolina University focused on the northern part of Long Bay, whereas the R/V *Nancy Foster* operated by NOAA focused on the southern part of Long Bay (Figure 10). Both datasets provide qualitative physiographic information. The sub-bottom data serve to provide coherence between the other data types (i.e. bathymetry, backscatter, and magnetometry). Data from the R/V *Coastal Explorer* were provided as JSF format files which were used for data processing to yield processed SEG-Y files. Data from the R/V *Nancy Foster* were provided as already processed SEG-Y files.

All the data collected were inlines with no crosslines. The reason no crosslines were collected is unknown, but the lack of crosslines influenced the interpretations and caused some error. Cross lines would have been used to connect and interpret how horizons shift across the survey area. Since the inlines were parallel and two-dimensional, there existed a space between inlines. Across this space, it is



**Figure 10. CHIRP sub-bottom tracklines from the R/V Coastal Explorer**  
 CHIRP sub-bottom tracklines from the R/V *Coastal Explorer* (northern Long Bay, grouped red polygons) and the R/V *Nancy Foster* (large grid of southern Long Bay).

impossible to know how the horizons behave or if there were artifacts such as faults oriented parallel to the inlines. Therefore, any number of horizons that were digitized may have been a different horizon. Crosslines would help to connect the horizons by crossing the space at a single point in the inline. However, since no crosslines were collected, inline-parallel artifacts, if any existed, could not be seen, nor could the horizons be guaranteed to follow the interpretation. Therefore, some error is to be expected.

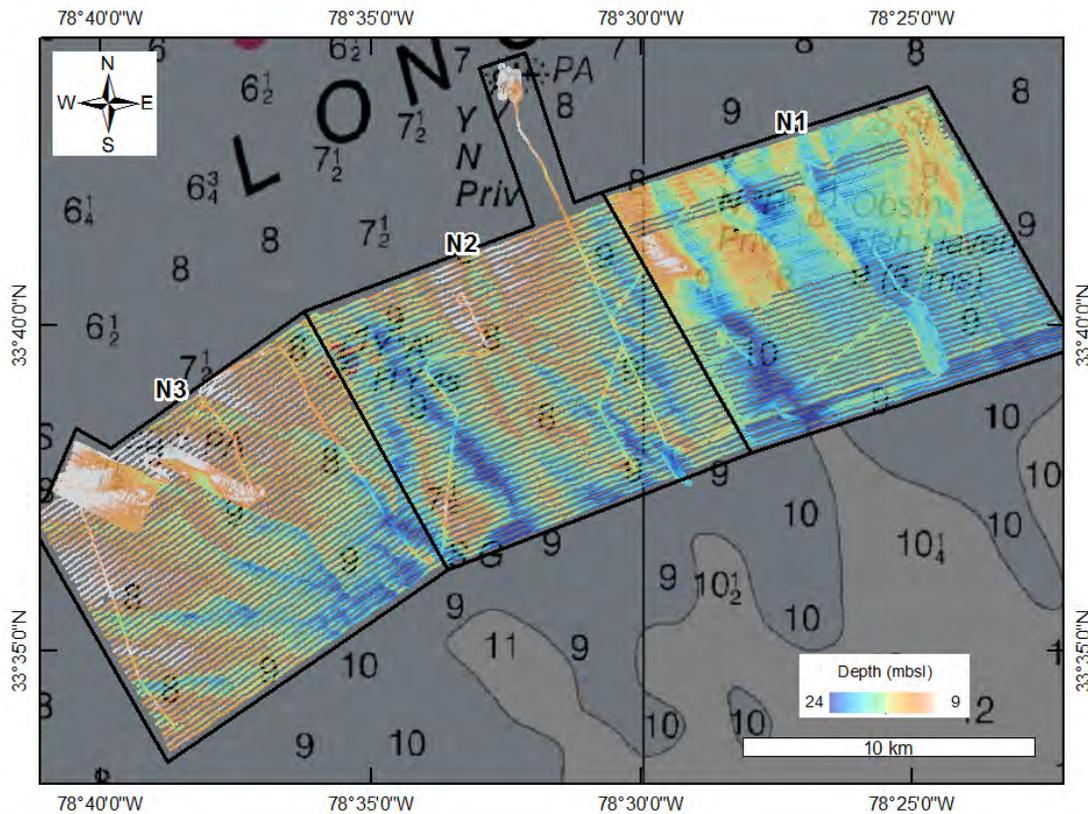
CHIRP was used to penetrate the shallow subsurface and yield a high resolution. The goal of using CHIRP was to digitize key reflectors, create isopach maps, and display the structure contour and isopach maps of paleochannel and inlet erosional events. CHIRP cannot show bathymetry three-dimensionally, though surfaces can be created from the seafloor, generating a two-dimensional bathymetry that can be compared to the processed bathymetry data. The CHIRP data will, however, be at a lower level of detail. CHIRP is also a shallow penetration method to examine a depth close to the seafloor. Additionally, CHIRP cannot preserve the polarity of reflection or provide P-wave velocity information.

## 3.2 Data Processing

### 3.2.1 Bathymetric Analysis

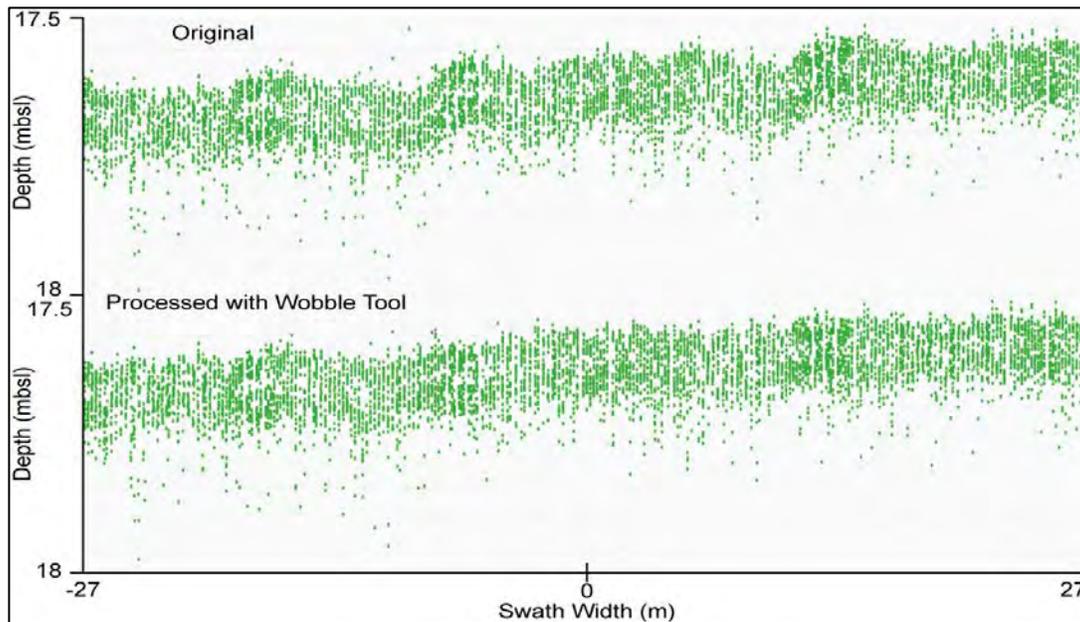
Half-meter resolution multibeam bathymetry data show various geomorphic features in our study area

(Figure 11). Our multibeam bathymetry processing workflow has experienced numerous obstacles since the acquisition phase. The most time-consuming processing step stems from the sound-velocity values associated with the raw data. Much of multibeam data were acquired with sound-velocity profiles of approximately 1450-1480 m/s, which is on the low end of the velocity spectrum for pure, distilled water, and far too low for that of sea water, which is near to approximately 1530 m/s on average. Due to this low sound velocity, much of our data exhibited a “frowning” phenomenon, much like that seen in post-migrated seismic reflection data with inaccurate velocities. We developed an efficient workflow to process out these velocity artifacts that involved: 1) select a single track-line of raw bathymetry data, 2) open QPS-Qimera’s “swath editor” tool, 3) look for the aforementioned “frowns”, 4) if frowning, change the sound velocity to a more accurate water column sound velocity factoring water temperature and salinity, 5) check the line within the swath editor tool to see if it has been properly flattened to closer represent the true nature of the seafloor, and 6) repeat process as necessary. Through manipulating the raw default velocities of the data to a more “accurate” fixed sound-velocity, we were able to flatten these artificial “frowning” multibeam swaths and begin to model a more realistic visualization and interpretation of seafloor features, aiding in the archaeological, engineering, and geoscientific goals of our study (Figure 12). Several areas of interest were identified after this first major step in multibeam bathymetry processing including: artificial reefs, seafloor channels of significant width and length, and areas of anomalous geomorphic constraints. An artificial reef made of barges, landing craft, and other artifacts were imaged which lies in the N1\_P01 region of the survey area. The most notable artifacts in the artificial reef were two barges, with the longer of the two barges reaching 40 m and the shorter one, 30 m in length (Figure 13). Throughout the dataset lie multiple sand channels of various lengths and



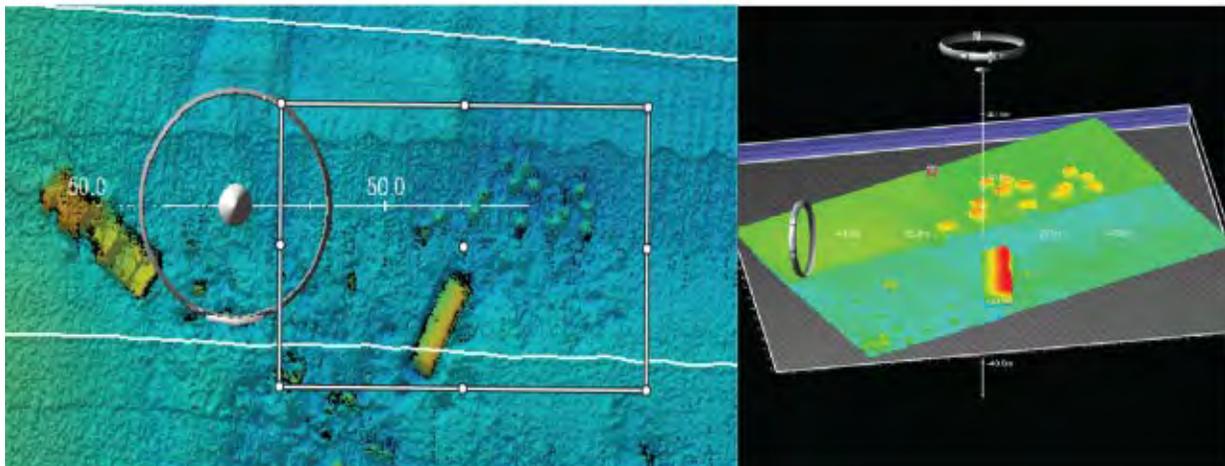
**Figure 11. Bathymetric coverage of the study area**

Depth is shown in meters below sea level (mbsl). Blocks (black outline) are labeled as N1-3. Bathymetric coverage is 50% in the majority of each block, with sub-areas of 100% bottom coverage in N1 and N3. The N2 offshoot northwards encompasses the *Sherman* shipwreck.



**Figure 12. Processing multibeam using Wobble Tool**

To reduce cross-talk between the dual-head multibeam echosounder system the Wobble Tool in Qimera was used. The processed image (bottom panel) is much smoother than the original swath (top panel)



**Figure 13. 2D and 3D view of N1\_P01 features**

2D and 3D view of artificial reef made of barges in N1\_P01.

widths. Within N1\_P02 lies a channel complex with the widest low relief channel stretching approximately 700 m wide at its widest point. All channels and sediment patterns shown throughout the bathymetry follow a pattern of perpendicularity to the coastline, giving the appearance of terrestrial sedimentation including rivers, deltas, and estuaries. An example of this is in N1\_P02, where a significantly complex set of channels can be noticed (Figure 14A).

There are several buried channels within this region. The CHIRP sub-bottom data corroborates the surficial expressions of these channels (Figure 14B), suggesting that there has been a relatively

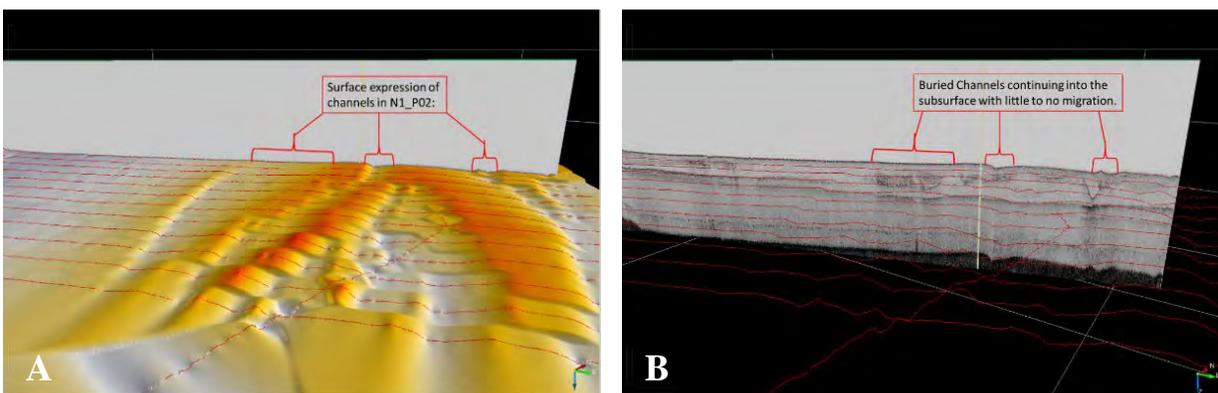
insignificant amount of seafloor drift in our study area over a relatively brief geologic timescale. In addition, within N1\_P01 there are areas of anomalous geomorphology that can be seen. When viewing this same area in our backscatter dataset, we see consistently high intensity reflections, suggesting a rocky outcrop that could prove to be an essential sea life habitat.

Another processing challenge was the pairing of our multibeam data with accurate tide data from the North Myrtle Beach area. Our dataset did not come with a co-referenced set of tide data. To supplement, we used the NOAA tide station MROS1 at Springmaid Pier, SC. The Springmaid Pier lies in the middle of Long Bay in Myrtle Beach, SC, which is slightly west of our study area, and on the coast. The entire dataset is tied to tide data from Springmaid Pier from the summer and early fall months of 2015. Accurate tide data and correct Sound Velocity Profiles (SVPs) give confidence in accurate water depths and subsequently an accurate interpretation of the seafloor bathymetry.

For the final step of processing the multibeam bathymetry data, QPS-Qimera's "Spline Filter" was run throughout the dataset. The spline filter works much like a manual processor: it iterates through the dataset and removes outliers such as any sonar pings that lie outside of a specified root mean square error (RMS) value between the surface created and the ping shown within Qimera. It does this in two passes, initially covering the data and removing any pings that are obviously large outliers, and the second pass filters out any additional noise. Qimera allows us to choose this specified RMSE value threshold weak" to "very strong", which are respectively conservative and liberal with their filtering. Given our data had an abundance of outlying pings, we chose to run a "strong spline" filter throughout the entirety of our dataset. This effectively smoothed out the seafloor bathymetry to better reflect accurate topography.

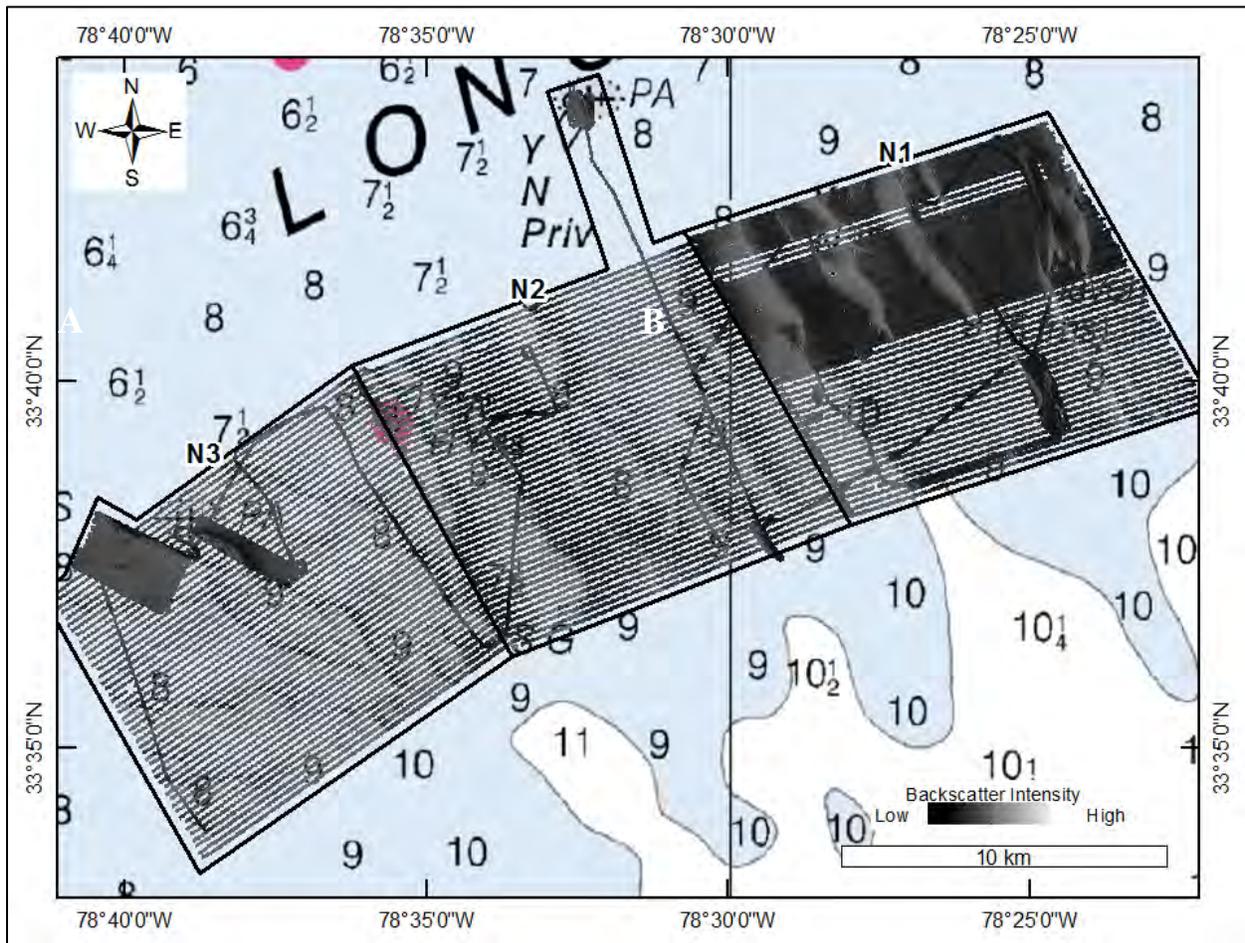
### 3.2.1.1 Backscatter

We imported processed QPD files to Fledermaus Geocoder Toolbox (FMGT). We mosaicked the point cloud for each survey into a 0.5 m by 0.5 m grid. FMGT averaged backscatter intensity values from all soundings within the spatial constraints of the pixel. The resulting 0.5 m grid represented a weighted average of sounding return intensity over a 0.25 m<sup>2</sup> area. Gridding the data at this scale limited file size while maintaining maximum data density (Figure 15). We then exported the mosaic as an ESRI Grid for further manipulation in ArcGIS 10.4.



**Figure 14. CHIRP cross-section and profile of N1\_P02**

A) CHIRP cross-section through bathymetric expression of channels in eastern N1\_P02. (B) Revealed CHIRP profile showing the small amount of migration from buried channel location to present surface expression of channels.

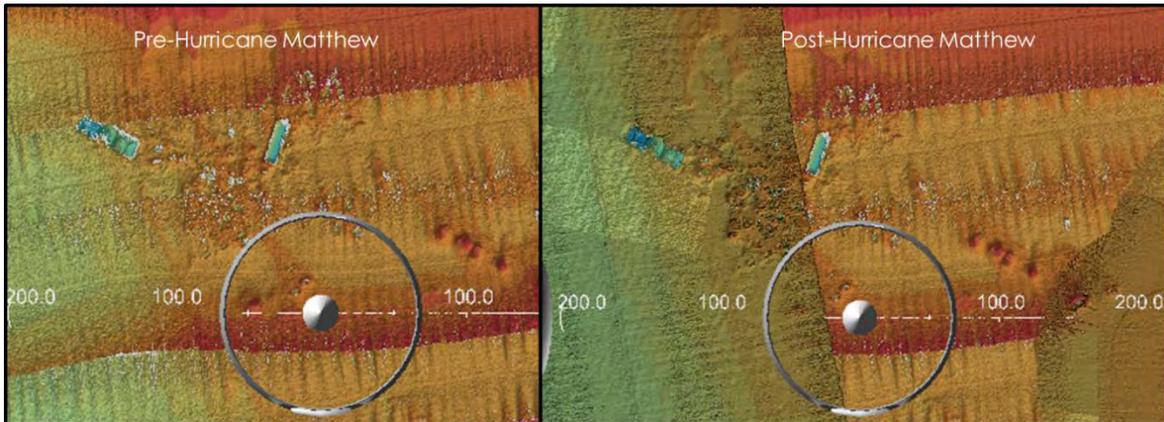


**Figure 15. Backscatter coverage of the concession area**  
 Backscatter mosaicked at a 0.5 m grid. Light-colored features indicate sonar sounding returns of high intensity. High-intensity returns can occur on hardbottom surfaces and shallow features that are closer to the sonar receiver.

### 3.2.1.2 Discussion

A geophysical survey comprised of multibeam, CHIRP, side scan sonar, and magnetometer track-lines were used to define sea floor habitat, study area geomorphology, shallow geotechnical conditions, and potential for important cultural resources to be avoided in the construction of potential future wind energy farms. The surveys were focused on recently delineated call areas in Long Bay, offshore South Carolina. Results to date have identified local areas of hard grounds that might be defined as potential areas of essential fish habitat and shipwrecks of potential archaeological interest and importance.

The refining operations have helped the team narrow the focus on these areas of interest and the results of these operations are proving significant from a geological perspective. Perhaps the most significant observation derived from the refining cruise was the lack of movement of seafloor landforms and landmarks post-hurricane. From an engineering perspective, especially one such as wind farm mentioned above through several filter options that range in their level of aggressiveness from “very development, it is important to note how a specific area is affected by large storms such as Hurricane Matthew. Figure 16 displays side-by-side the artificial reef within the study area before and after Hurricane Matthew. As shown, there was little to no movement of the reef features themselves, and only



**Figure 16. Before and after Hurricane Matthew at Barracuda Alley**

some sediment build-up along the edges of the longer barge can be observed. Channels within the dataset appear to lack significant spatial migration over a geologic timescale, and the seafloor saw a lack of significant disruption following a major hurricane.

Post-processed bathymetry shows a radial distribution of coast-perpendicular features that transition between two coastal processes: 1) there is the sediment distribution caused by the longshore currents and wave energy, and 2) there are areas related to the coastal inlets that disrupt the primary sedimentation patterns and impose patterns of terrestrial sedimentation such as those from rivers, deltas, and estuaries. A future study would help to further refine this assessment. Closely monitored acquisition parameters such as the sonar head geometries, more accurate collection of water column SVPs, gathering full bathymetry coverage, and making sure that the study is carried out on days when the sea is as calm as possible will provide a high-quality dataset. With these caveats in mind, we believe that offshore South Carolina has significant promise for future wind energy development, an area that our state has been leading in its energy practices (57% of SC's electricity was generated through nuclear power in 2013) (eia.gov, 2017).

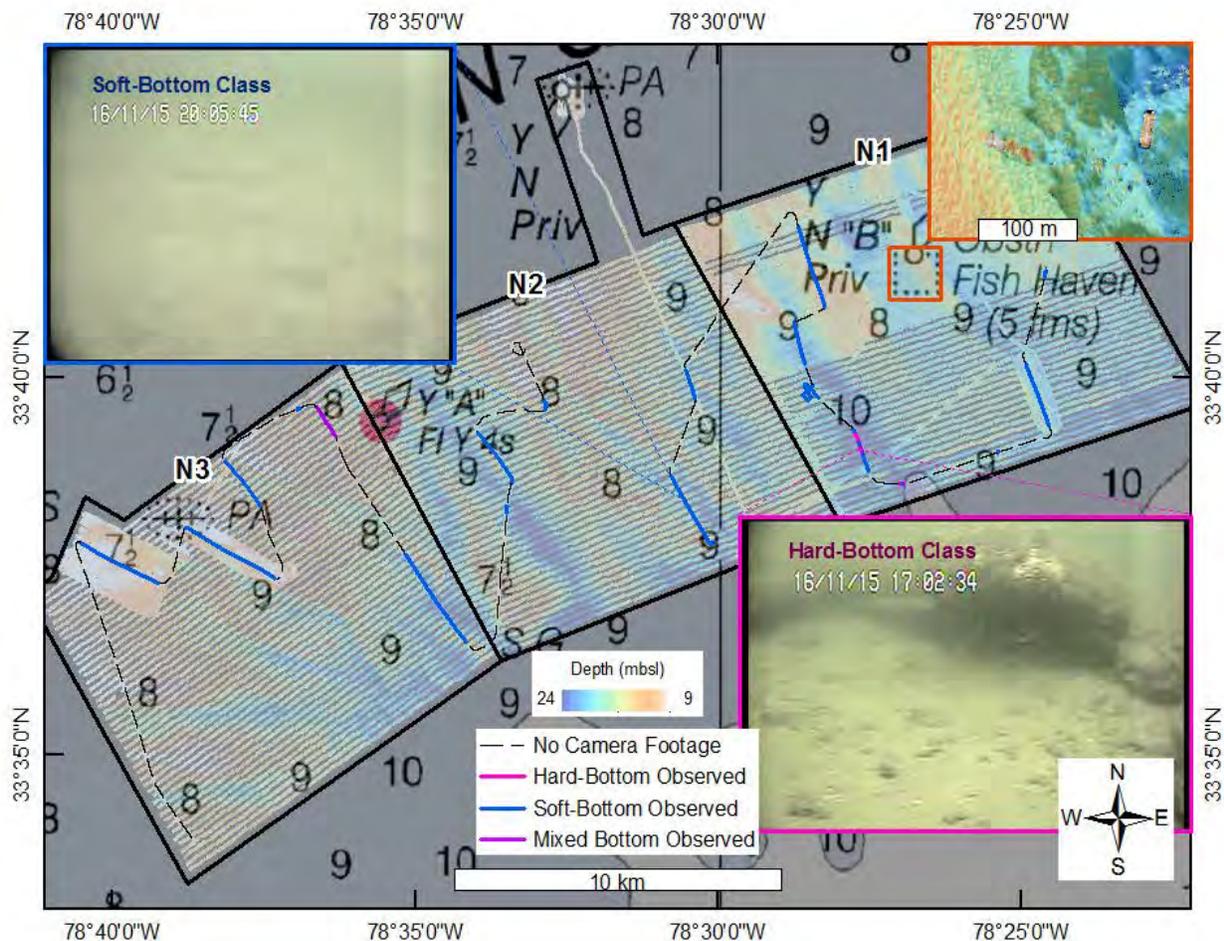
### 3.2.2 Seafloor Classification

The most important step in supervised classification is the selection of training data. Training data must represent only one class to diminish classifier confusion and produce the most accurate results. We chose points for training data from tow-camera video frame-grabs of sediment and hardbottom substrates as well as known artificial reefs (Figure 17 and 18). Only data collected in blocks N1 and N2 were assigned as training data, as these were the only blocks where spots with a majority of rocks substrate were observed. In total, we used 1,000 soft-bottom, 1,044 hardbottom, and 552 cultural artifact points to train the classifier (ANFIS) (Figure 19).

For ANFIS to distinguish between soft-bottom, hardbottom, and cultural artifacts, we needed to create datasets from the multibeam bathymetry and backscatter that reflected physical characteristics of each class. Despite post-processing sonar data in Qimera, EM3002 system noise remains in the final bathymetric grid. Filtering rasterized data to a larger pixel size can increase the signal to noise ratio (S/N), producing a smoother surface. The resample tool in ArcGIS Data Management Toolbox enables the user to change the spatial resolution of a raster dataset via different aggregation and interpolation algorithms.

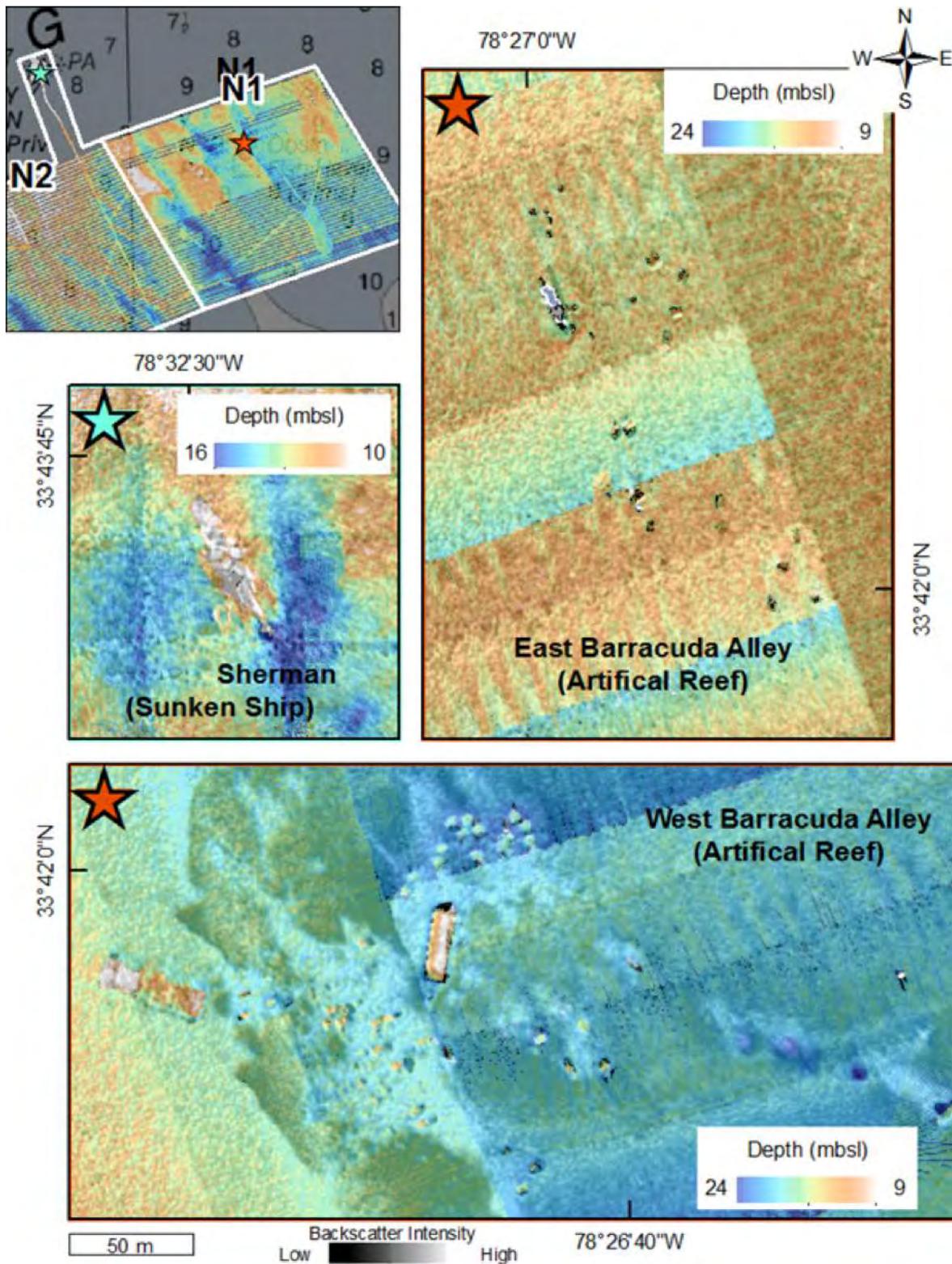
Due to the continuous nature of bathymetric data, we chose to resample our data with cubic interpolation. Cubic interpolation calculates the value of a pixel by fitting a smooth curve based on the 16 surrounding pixels. We explored different cell sizes and determined the 6 m grid provided the smoothest raster while retaining the most information.

From the smoothed bathymetric dataset, we calculated seafloor slope using Horn's Method (Horn 1981) (Figure 20). Horn's method is the default slope algorithm supported by the ArcGIS slope tool. It calculates the rate of change in the x and y direction of a given cell from the adjacent 8 pixels (Equation 1). The slope angle is then the inverse tangent of the square-root of the summed squares of each rate of change (Equation 2). Slope calculated by Horn's Method is widely used to characterize the seafloor in habitat mapping (e.g. Greene et al. 1999; Wilson et al. 2007; Li et al. 2017). The most significant difference in slope values for the three classes were between the natural bottom-types and the cultural artifacts. Points from locations with sediment-covered seafloor exhibited a narrow distribution of slope values between 0.4° and 1.2° with a mode at 0.8°. Points from locations with recorded bottom-type as mostly rock had a wider distribution of slope values, ranging from 0.4° to 5°, but the hardbottom class mode was like the soft-bottom class mode at 1°. The bimodal slope range of the cultural artifact class reflects the near-vertical walls (> 5°) and near-horizontal sides (< 1.8°) of sunken ships.

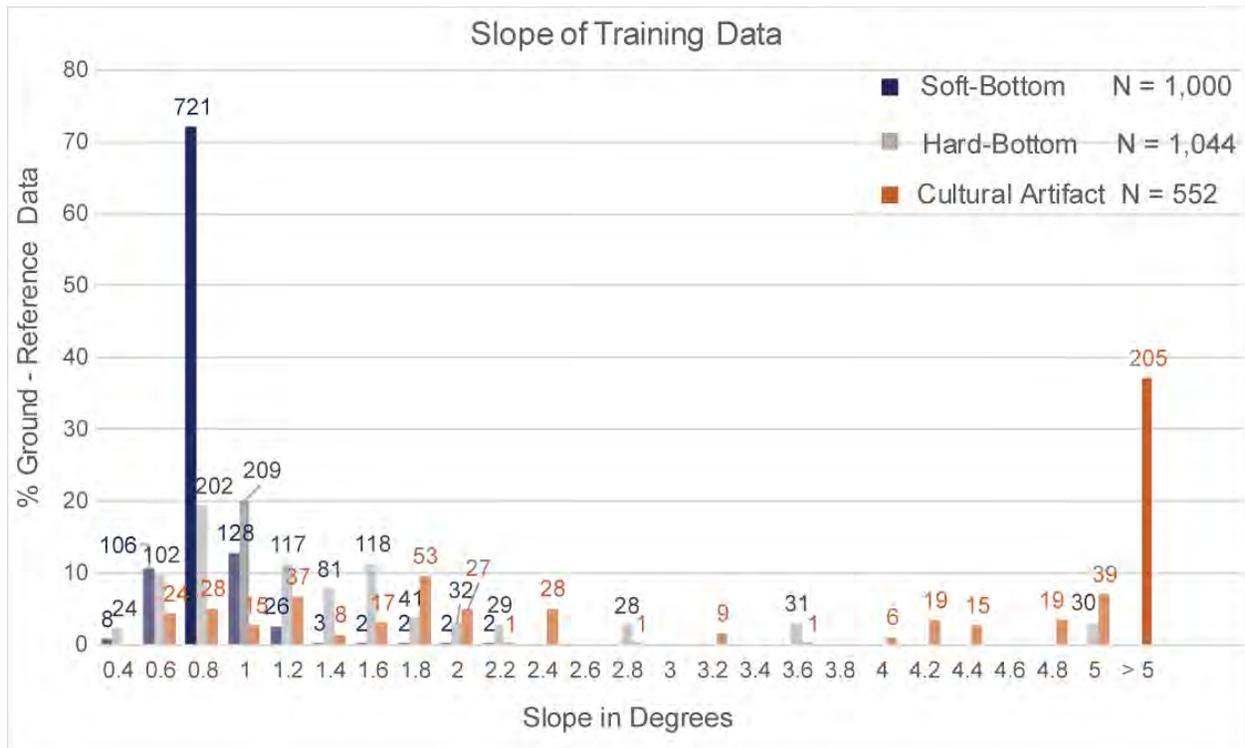


**Figure 15. Seafloor classification of project area**

Refining surveys during November 2016 included seafloor observations via tow-camera video. The video was reviewed to assign bottom-type to each observed area. Note that many segments of each survey had no camera footage. Areas showing predominantly natural hardbottom were concentrated in the southeast corner of N1. There were instances of mixed soft and hardbottom in N1 and N3.

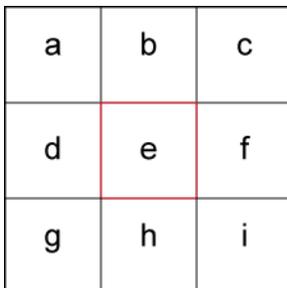


**Figure 16. Seafloor classification survey results of Barracuda Alley and *Sherman***  
 We surveyed two areas in N1 and N2 which contained known large-scale cultural artifacts. These objects are at the scale of 10s of meters, and represent artificial reefs (Barracuda Alley), and the shipwreck *Sherman*.



**Figure 17. Slope of training data**

Slope is a commonly used to distinguish hardbottom seafloor from soft-bottom cover. Points representing the soft-bottom class have a small slope, with the mode at 0.8°. Slopes of hardbottom substrate have a broader range than the soft-bottom class and have a slightly steeper mode at 1°. Cultural artifacts exhibit the widest slope range due to the flat nature of man-made walls; however, the majority of cultural artifact points exhibit the steepest slope > 5°. Backscatter amplitudes existed between the 100% sonar coverage in N1 and the remainder of the concession area; thus, contrast GLCM values were skewed toward this zone, and the dataset was not used to characterize bottom-type. Seafloor textural datasets derived from acoustic backscatter can be highly correlated; therefore, we performed principal component analysis on the three remaining GLCMs to minimize redundancy and ensure our classification would not weigh seafloor texture over the other inputs.



**Figure 18. Horn's method**

When calculating maximum slope with Horn's method, the central pixel (e) is assigned the rate of change in the x and y directions.

### Equation 1. Rate of change in x and y directions

$$\frac{dz}{dx} = [(c + 2f + i) - (a + 2d + g)]/[8 * cellsize]$$
$$\frac{dz}{dy} = [(g + 2h + i) - (a + 2b + c)]/[8 * cellsize]$$

### Equation 2. Slope calculation in degrees

$$slope\ in\ degrees = \tan^{-1} \sqrt{\left(\frac{dz}{dx}\right)^2 + \left(\frac{dz}{dy}\right)^2}$$

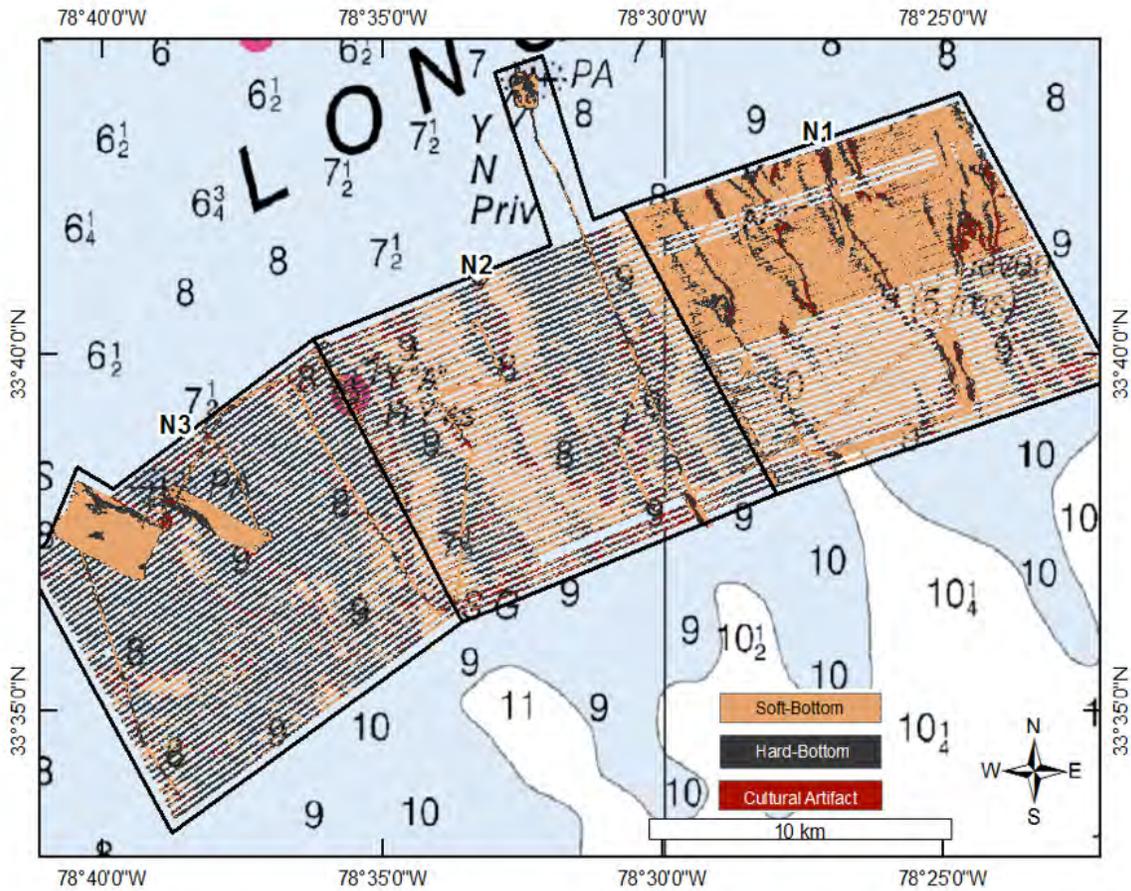
#### 3.2.2.1 Discussion

The three-step classification workflow clearly outlines the methodology by which to create an accurate classification, produce a comprehensive habitat map, and interpret the map in terms of usability for different applications. Because we followed a systematic approach to classifying bottom-type in N1, N2, and N3, we can interpret the resulting map (Figure 21) in terms of seafloor geomorphology. Based on seafloor observations and characteristic slope, backscatter intensity, and GLCM textural features, we assume areas classified as soft-bottom represent relatively flat, uniformly textured, sediment-draped seafloor that diminishes the intensity of sonar returns.

Areas classified as hardbottom seafloor likely represent rock outcrops observed in tow-camera footage from block N1. The relief caused by extruding rock increases the local slope of the seafloor, but this signature may be subdued by some draped sediment. Higher-intensity backscatter values are also common with natural hardbottom seafloor. Edges recorded by the sonar system are clearly outlined by the PC1 dataset of GLCMs and correspond to the presence of outcropping hardbottom. Although we have no camera footage of cultural artifacts, we assume seafloor with steep slopes, a dual high-intensity and sonar shadow backscatter signature, and extremely high textural values represent areas like the Barracuda Alley artificial reef and shipwrecked *Sherman* (Figure 22).

Given the geomorphologic characteristics of each class, ANIFS assigned bottom-type to 157 km<sup>2</sup> of seafloor within blocks N1, N2, and N3. The class distribution in the survey area was 46% soft-bottom coverage, 39% hardbottom substrate, and 15% coverage that mimicked cultural artifacts (Table 2). We assigned hard boundaries for each class based on natural breaks in the distribution of ground-reference data not used to train the classifier (Figure 23). This dataset included the 1,000 soft-bottom, 805 hardbottom, and 551 cultural-artifact points reserved for accuracy assessment, as well as the remaining 70,000 soft-bottom observations discussed previously. Modes (based on percentage of each class) are clearly defined at values of -0.1, 1.1, and 2.1 for soft-bottom, hardbottom, and cultural artifact classes respectively.

The probabilities associated with fuzzy inference systems allow for more refined interpretation and uncertainty analysis of classification results than discrete classifiers. The upper limit natural break for the soft-bottom class occurred at a value of 0.8; therefore, we considered pixels classified with values <0.8 to be in soft-bottom seafloor. Points representing hardbottom observations were narrowly distributed about the mode. Natural breaks clearly occurred at values of 0.8 and 1.5, constraining the class to this range. Although points representing cultural artifacts had the widest classified value distribution, over 80% of the data had a value above 1.5. This fit well with the upper limit of the natural hardbottom class; hence, we assigned pixels with values >1.5 to the cultural artifact class.

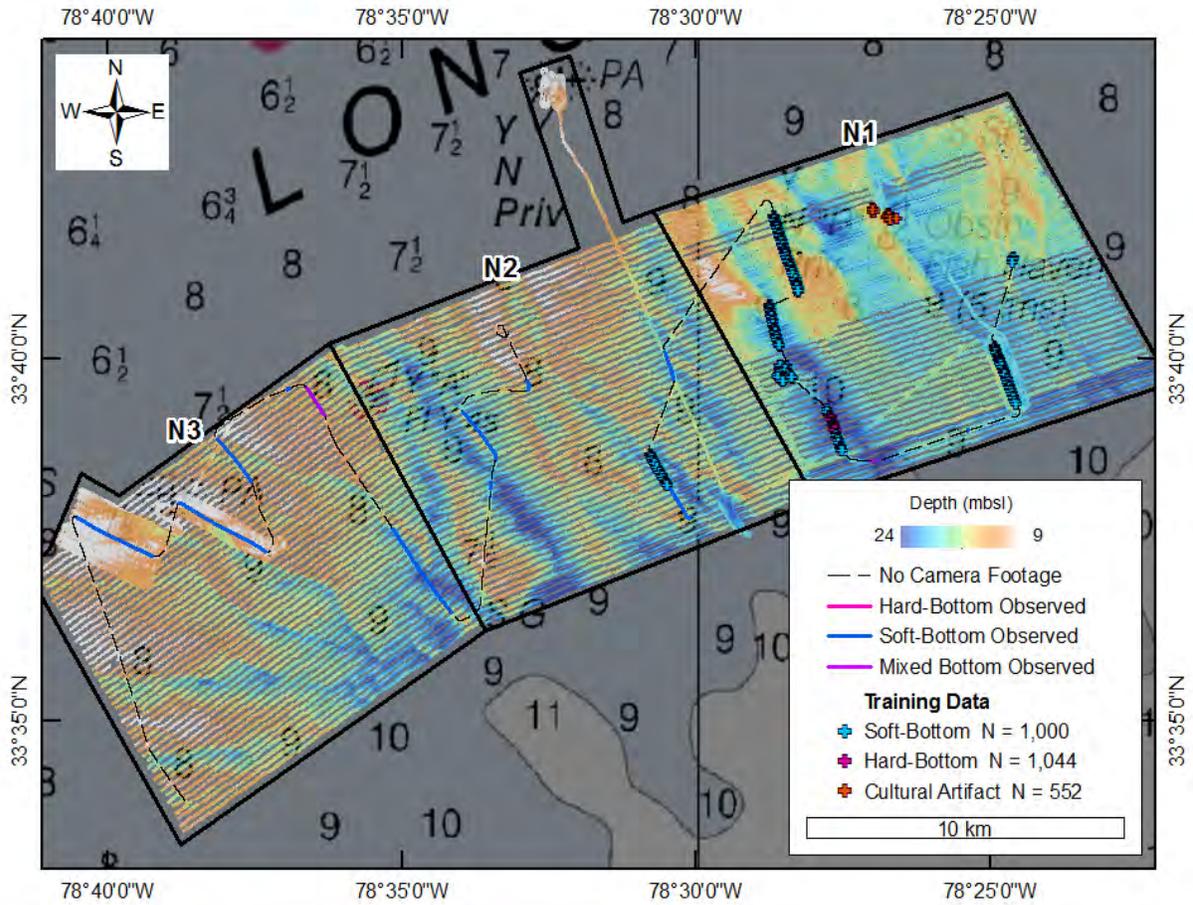


**Figure 19. Hard boundaries of blocks N1, N2, and N3**

We classified the concession areas of blocks N1, N2, and N3 into three categories: (1) naturally-occurring soft-bottom seafloor, (2) naturally-occurring hardbottom seafloor, and (3) areas representing hardbottom cultural artifacts.

The modes of backscatter intensity differ for each bottom-type class. The narrowest distribution of multibeam sonar backscatter intensity was observed for hardbottom points (Figure 24). Backscatter values for rock substrate seafloor were clustered at a value of -24 dB. Most soft-bottom data exhibited weaker sonar returns (-32 dB) as expected from sediment-covered seafloor, but some points were in areas with a return of -18 dB. Cultural artifacts again exhibited a bi-modal distribution, with the primary backscatter return intensity mode at -22 dB, and the secondary mode at -6 dB. Hardbottom returns are almost 10 times stronger than soft-bottom returns because backscatter values are recorded in the logarithmic decibel scale.

Haralick and others (1973) derived textural features from grey-level co-occurrence matrices (GLCMs) to aid image classification. The four most-useful GLCMs for seafloor characterization are contrast, homogeneity, second-moment, and entropy (Gao et al. 1998). Angular second-moment (a measure of uniformity) and entropy (a measure of randomness) describe spatial consistency or orderliness of backscatter amplitude values. Spatial variations in backscatter amplitude are described by homogeneity and contrast.

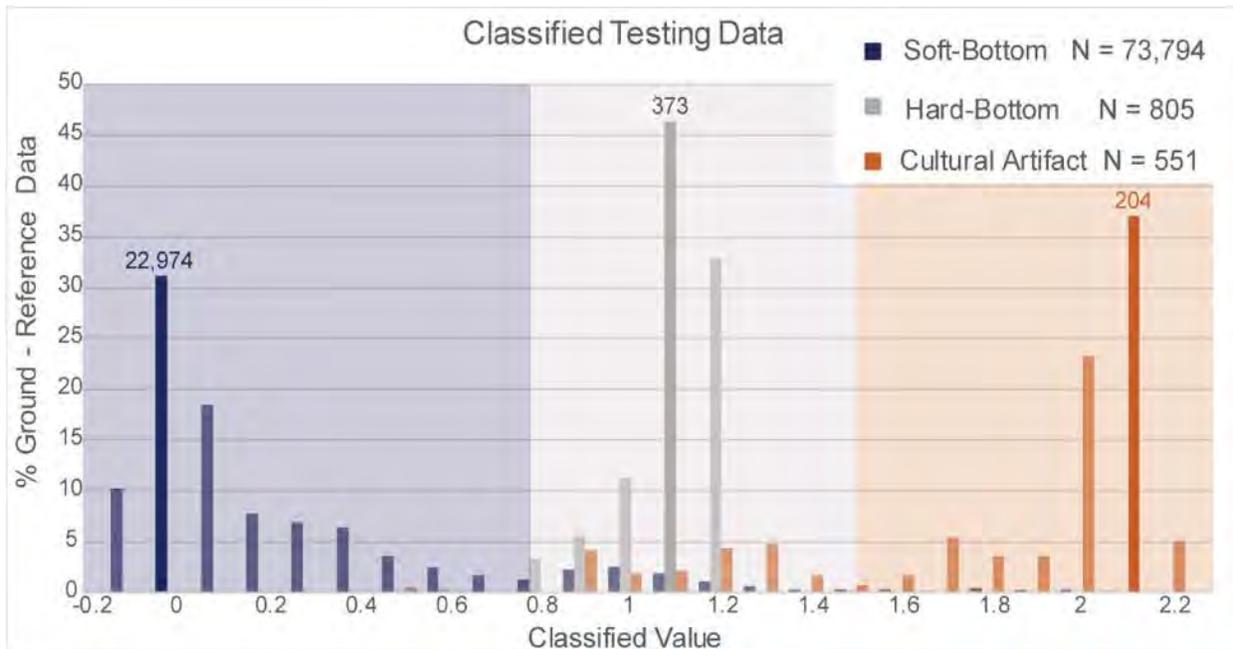


**Figure 20. Training data collected along refining cruise surveys in Fall 2016**

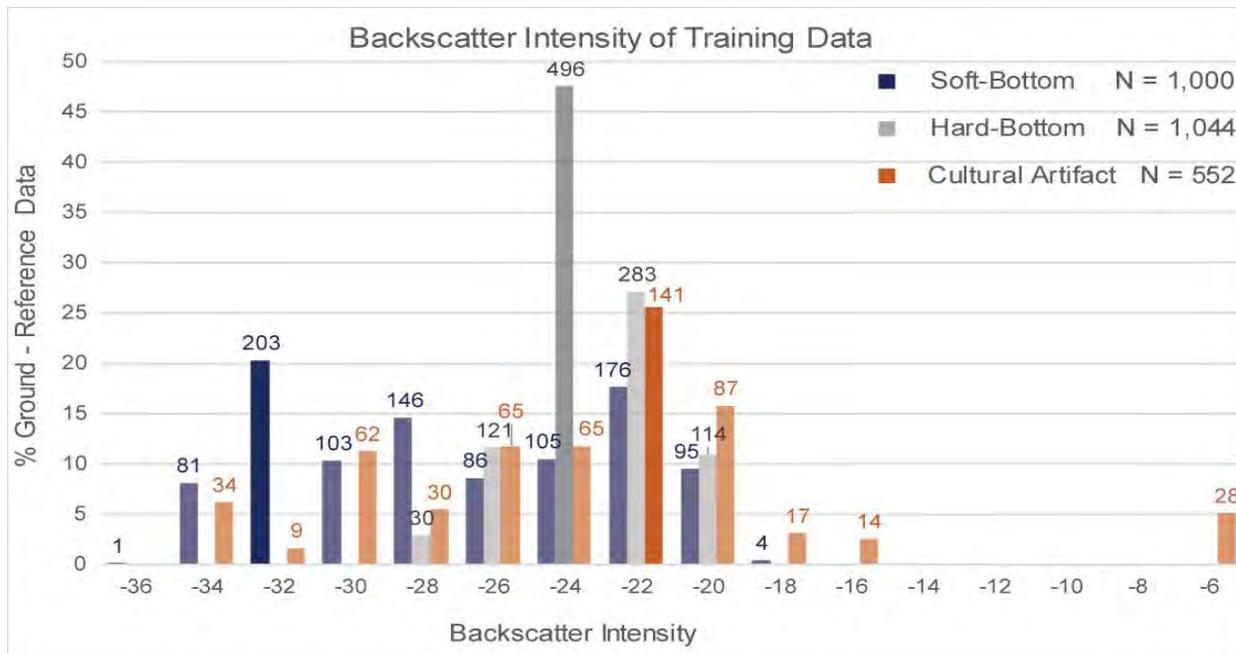
The ground-referenced dataset was derived from tow-camera imagery and spatially tied to sonar soundings along the track lines as well as areas with known artificial reefs. ANFIS performs best when trained with classes containing similar amounts of data. 1,000 soft-bottom, 1,044 hardbottom, and 552 cultural artifact points were chosen to train the classifier.

**Table 2. Amount of classified bottom type**

Concession Zone	Soft-Bottom Area	Hard-Bottom Area	Cultural Artifact Area	Total Area
	km <sup>2</sup>	km <sup>2</sup>	km <sup>2</sup>	km <sup>2</sup>
Block N1	43.5 (28%)	12.1 (8%)	2.0 (1%)	57.6
Block N2	16.7 (11%)	19.8 (13%)	19.8 (13%)	56.3
Block N3	11.8 (8%)	29.9 (19%)	1.7 (1%)	43.4
Total	72.0 (46%)	61.8 (39%)	23.5 (15%)	157

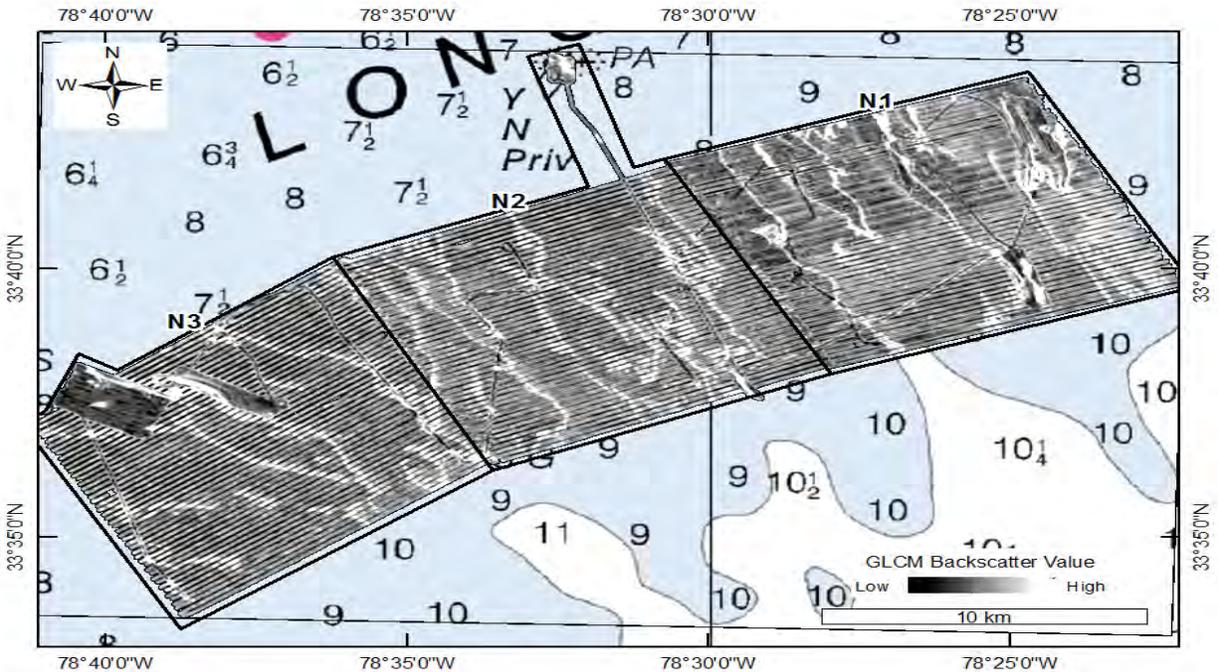


**Figure 23. Seafloor classification data**



**Figure 24. Backscatter intensity of training data**

Distributions for sonar backscatter intensity vary greatly between the three classes, but each class exhibits a distinctive mode. Soft-bottom data are clustered at -32 dB, while hardbottom data show a significantly stronger return at -24 dB. Cultural artifacts have the widest range of return intensity from -34 dB to -6 dB. Because the decibel scale is logarithmic, every 10-dB increase (for example, -34 dB to -24 dB) increases the pressure exerted on the receiver 10-fold.



**Figure 21. First principal component of GLCMs derived from backscatter mosaic**

The three GLCMs used to describe seafloor texture are homogeneity, second moment, and entropy. Ridges and ripples are clearly visible in the resulting textural image.

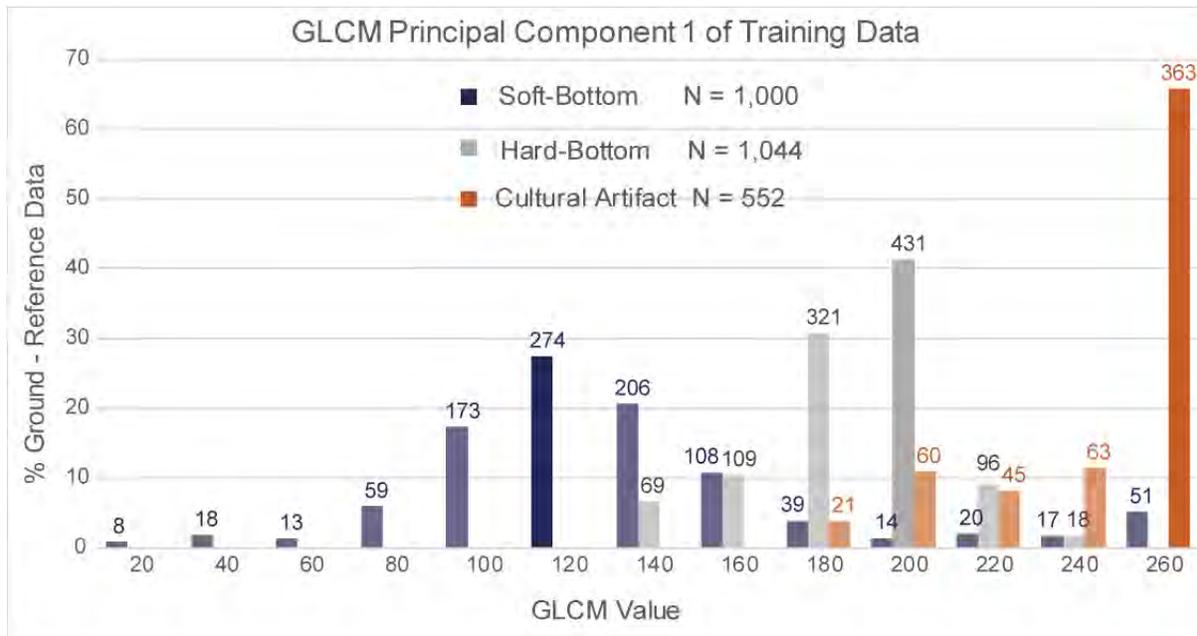
Bottom-type points not used to train the classifier were used to determine the classified value distributions that characterize soft-bottom, hardbottom, and cultural artifact classes. Class divisions reflected natural breaks of each distribution. Although we chose hard-breaks for three classes, we could have further divided each class based on probability. Data assigned values close to the modes of each class have a higher probability of belonging to that class.

The first principal component (PC1) described 96% of the textural variance between the three datasets and was used in our classification (Figure 25). PC1 values show the most distribution between all three classes (Figure 26). Soft-bottom points show the lowest value with a mode of 120; however, the distribution for this class is the widest. The total range of values representing sediment-covered seafloor is 20-260. The mode of GLCM values for naturally occurring hardbottom substrate is 200. The distribution is skewed toward lower values, causing some overlap with the soft-bottom class. Cultural artifacts have the most definitive mode at a value of 260 with >65% of the data; however, all values above 180 contribute to the class.

### 3.2.3 Subsurface Analysis

The CHIRP data processing workflow prepares raw sub-bottom data in EdgeTech's native .JSF file format for interpretation. The JSF file format (EdgeTech 2016) differs from the SEG-Y file format (of Exploration Geophysicists SEG 2002) in that it contains numerous fields specific to the instrumentation that are not found in the SEG-Y format. Maintaining a database allows for support of both file formats to be fully utilized throughout processing. A general processing workflow overview is illustrated in Figure 27.

The processing portion of the workflow involves only a few steps. A conventional seismic reflection processing workflow, such as those detailed in (Yilmaz 2001), may be simplified as modern CHIRP systems provide superior data in potentially incompatible formats with most processing systems (Henkart 2006). As such, CHIRP data are most readily processed using either or both of SioSeis and SeismicUnix. A combination is used herein. We prefer the utility SioSeis provides for CHIRP-specific processing, but SeismicUnix provides better utilities for data interaction and image export. The swell-



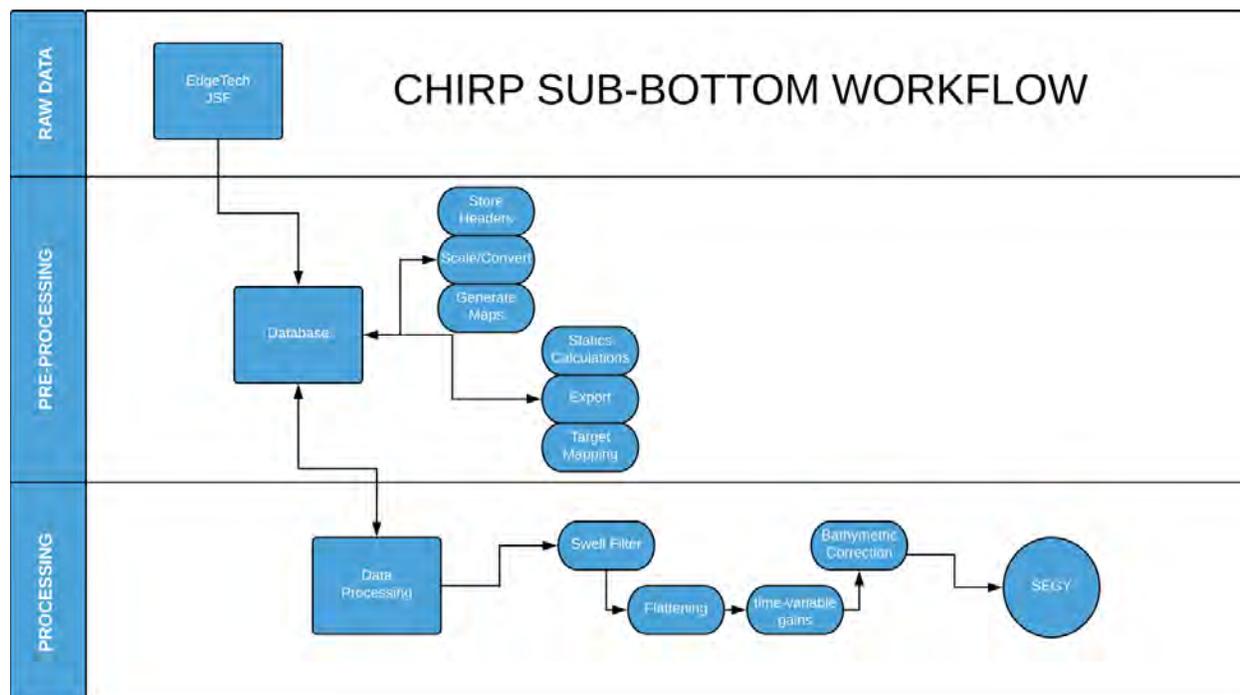
**Figure 26. GLCM principal component 1 of training data**

Grey-level co-occurrence matrices (GLCMs) describe textural features that contain information about the spatial variation of tonal differences in an image. We used three statistics to describe seafloor morphology in the concession area: angular second-moment, homogeneity, and entropy. To minimize the inherent redundancy between these three datasets and prevent a weighted bias in our classification, we used principal component analysis (PCA) to combine datasets. The first principal component (PC1) described 96% of the three datasets and was used in classification. PC1 values for the training data of each class differ greatly.

filtering step computes the average water bottom time of a group of traces (fifty in this case), then shifts the middle trace of the group by the difference of the middle trace water bottom time and the average water bottom time. As this step provides a new water bottom time, the new time may be used to flatten the water bottom to a fixed time before applying a time-varying gain function to each of the traces. Normally this step is followed by restoring the gained traces to their original water bottom time, but in our case, we desire to shift the data to match a seafloor produced by a multibeam sonar. Therefore, a new water bottom time is determined from a time-converted bathymetric sounding grid and inserted prior to restoration of the traces. The resulting sub-bottom data may be augmented by any of the attributes associated with multibeam bathymetry and/or backscatter produced by that sonar as the two datasets are now colocated in all three spatial dimensions.

### 3.2.3.1 Data

After acquiring the shipboard CHIRP data in J-star vendor format from Edgetech (JSF), several processing steps needed to be completed to extract the geographic headers and convert the files to an interpretable format. A computer program was written to process the shipboard CHIRP files. This program first designated the product folder paths for the processed data. The program then dumped the JSF headers into SQLITE databases. The program then extracted the sensor navigation from the SQLITE databases, converting the data into geographic coordinates of degree latitude and degree longitude. The program also extracted the same sensor navigation yet kept it in the State Plane Coordinate System (SPCS). After extracting the geographic headers, the raw, JSF files were converted to SEG-Y format for input into OpendTect, the interpretation software used for this project. The SEG-Y files were then converted to seismic unix (SU) files for elevation statics correction.

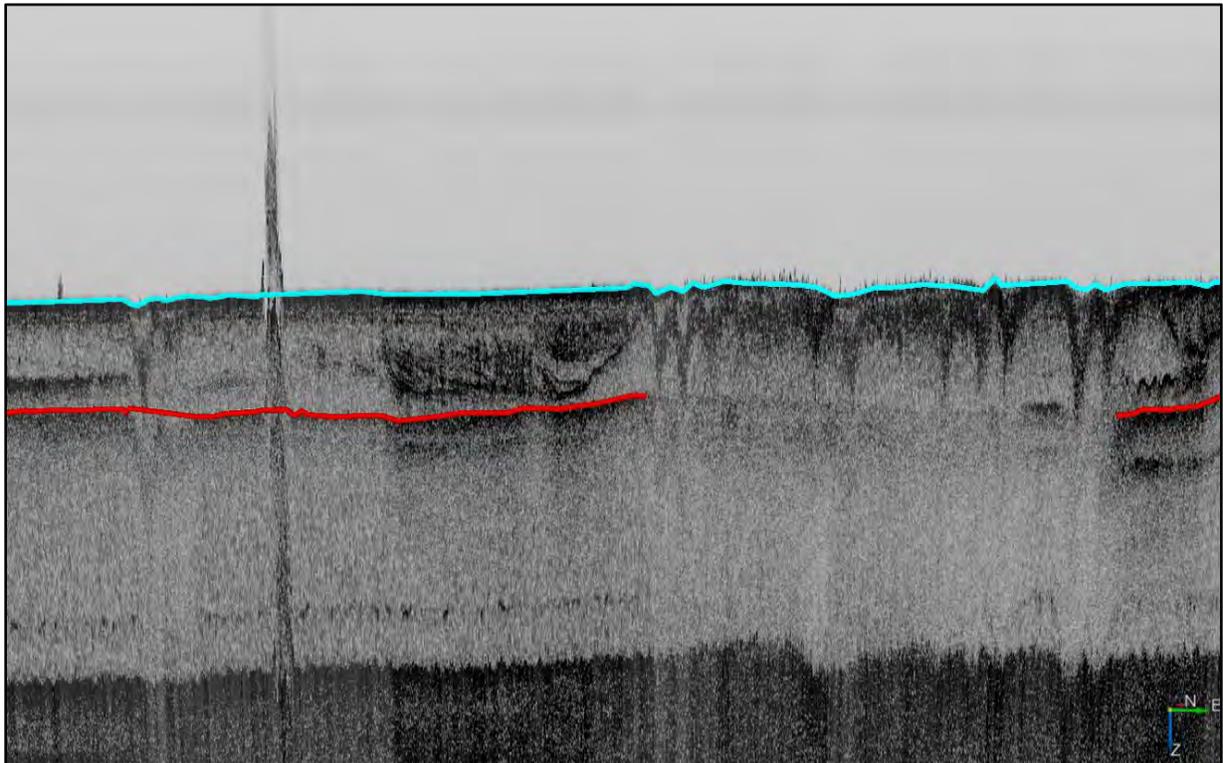


**Figure 27. CHIRP sub-bottom data processing workflow**

Raw data are split into two primary phases- pre-processing and processing. The pre-processing phase creates a database of trace headers and applies all scaling and conversion to facilitate a conventional processing workflow. Following the workflow shows raw data in the JSF format being extracted and imported into a database (pre-processing) before entering the formal processing portion of the workflow leading to a processed SEG-Y formatted output. SEG-Y is chosen as the output format for compatibility with data interpretation software discussed later.

After converting the files to SU format, elevation statics were needed to flatten the seafloor. To begin this process, the program performed first break auto-picking via choosing the maximum absolute value in a window that encompassed the upper 0.01 seconds (10 ms) of the SU files. These first break picks were converted into a statics format. Next, the header overrides were obtained for the SEG-Y output to override the current headers for the elevation statics. The elevation statics were then obtained from the database, allowing the program to flatten the seafloor horizon in the data. In the program code, the author shortened the window to 50 ms to exclude unnecessary trace length since all data below approximately 40 ms was a multiple or ghost of a multiple. Time-variable gains were then applied to the data. The chosen gain, "jon=1," multiplied the data by the time squared (tpow=2), took the signed square root of the scaled data (gpow=0.5), and clipped the data at 95% on the absolute values on trace (qclip=0.95). To create a more conservative dataset, we adjusted the clip parameter to 90% (qclip=0.90). The elevation statics were then applied to the data set. After this phase of the processing, the new headers were exported to the SEG-Y files. Due to the collection method of the CHIRP data, the seismic lines were segmented, thus, adjacent segments were merged in the final stages of the program. Also, the program created images of both the seismic data and the geographic position of each segment and merged line in a PDF portfolio.

Once the updated headers were outputted to the SEG-Y files, we imported the SEG-Y files into OpendTect V5.0.9, open source interpretation software with a user-friendly interface. After inputting the SEG-Y files, we proceeded to digitize the major reflectors that appeared in the data. To do this, we used the "Track new..." function for 2D Horizons in OpendTect. For the mode of digitizing the horizon, we chose "Draw between seeds" because the CHIRP data was smooth overall but had many fluctuations between traces. Therefore, "Draw between seeds" allows for a smooth surface between picks. The event



**Figure 28. Picture of Line\_0011 and two digitized lines**

On the left side, there are two discontinuities in the data, one bending the data down and the other bending the data up. Since the distance covered by the discontinuities is not large, we continued the horizon. On the right side is a large section where the signal is weak. Per our conservative approach, this section was not digitized, but continued on the other side of the section.

for the horizons was always CHIRP with the rest of the parameters kept at their default settings. We then chose to use similarity, applying a compare window of -10 to 10 ms. Similarity is a property that shows how two or more adjacent traces look alike. The “Similarity threshold” was left at default (0.8). For the “Properties,” we chose a color for the horizon, with different segments of the same horizon having the same color. Originally, the data set had very few horizons, so we chose similar colors to distinguish between horizons. However, with the addition of new data and many more horizons, we had to change the segments of a horizon to the same color to increase the color choices. The “Seed Shape” was left at the square default and the color was left white. We decreased the “Seed Size” to allow for more precise digitizing. After establishing the parameters for the horizon, we began to digitize.

To digitize the horizons, we chose a conservative approach designed for interpreting horizons. For general picking, we chose to follow the top of the positive amplitude and follow this strong amplitude for as long as the horizon was easily distinguishable. If the signal of the horizon became weak and semi-transparent or disappeared altogether for a good distance, we chose the conservative approach in not digitizing the horizon through this portion. If the break was very short, then we continued digitizing the line (Figure 28).

The same is true if the signal became erratic and jagged. In the case that two horizons intersected or appeared to merge, we would observe the structure of the intersection point, as well as look ahead to see if the horizons split further in the line. To further support the decision, we would also change the color scheme of the CHIRP data. Purple was chosen for its stark contrast in colors, allowed us to better see the paths the horizons took. Based on these observations, we would choose which horizon we would continue through the intersection. In most cases, we chose an “erosional” assumption of the horizons in which the

shallower layer was eroded, and the deeper horizon is carried through the intersection. The only exception to these criteria was the seafloor. We digitized the seafloor first and were very aggressive in the digitization through erratic data or anomalies that appeared. As such, the seafloor is the only continuous horizon that spans the entirety of the target area. All other horizons contain many segments, labeled for the order in which they were digitized. When digitizing one horizon, we would follow the order of the segments, starting with a) and continuing through the list. Because different inlines had different placements of weak signals and other discontinuities, the length and position of a segment would shift laterally along the inline. This shift was not large at this stage and presented no problems, but when surfaces were made, in one case, the surface was not created due to the large discrepancy. A total of sixteen (16) horizons were digitized, including the seafloor and assumed crystalline basement (Table 3). After the horizons were digitized, channels were digitized as fault stick sets since they were individual structures within the line. These stick sets were then interpolated to create a surface that followed the channels path (Figure 29).

After the channels and horizons were picked, we created surfaces for each of the horizon segments. This was done by deriving a 3D horizon from the specific section of the horizon. We used the "Inverse distance" algorithm provided by OpendTect, selecting a search radius of 250 ft because this expressed the vertical offset in the data clearly. This vertical offset was a result of the several parameters used in collecting the data. The main source was the towfish changing altitude due to changes in relative velocity. The survey velocity attempted to maintain a fixed "speed over ground," but ignored current speeds and cable paid out, so the towfish experienced a variable speed-through-water which varied the tension on the tow cable and towfish altitude. The software was also known to show up to 5 ms shifting between lines when no bottom tracking is enabled. This was a bug in the acquisition software, which resulted in changes to the elevation statics generated from the first-break picks. Using the generated surfaces, we then made isopach maps of the overall sediment thickness and of the different paleochannels in the data (Figure 30 A-C).

**Table 3. Horizon names and colors**

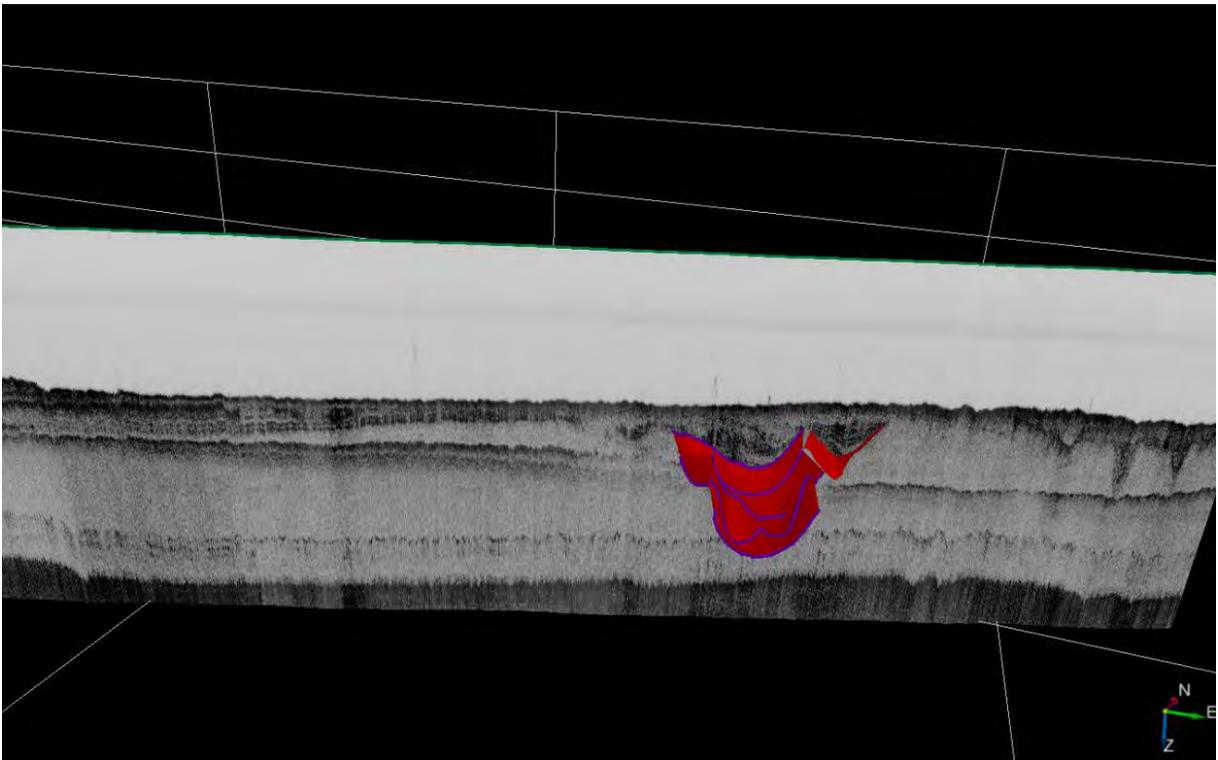
Horizon	Color
Seafloor	Cyan
Base	Teal
Horizon 1	Red
Horizon 2	Saddle Brown
Horizon 3	Spring Green
Horizon 4	Navy
Horizon 5	Green
Horizon 6	Hot Pink
Horizon 7	Orange
Horizon 8	Dodger Blue
Horizon 9	Khaki
Horizon 10	Thistle (Pale Purple)
Horizon 11	Yellow
Horizon 12	Silver
Horizon 13	Dim Grey
Horizon 14	Black

To create the isopach/isochron maps, we used the “Calculate Isopach...” workflow in OpendTect. This workflow calculates the isopach from the chosen surface to a deeper surface that we specified in the workflow. We then named the “Attribute” that was generated and chose milliseconds as the output. The output of the workflow is either depth or two-way travel (TWT) time, depending on the window parameters in OpendTect. And isochron/isopach was calculated to the basement, to a more continuous layer above the basement, and to the various channels. Due to the discontinuous horizons, the segments that showed the most area and the greatest presence throughout the data set were chosen as the reference point. To create the isopach, we created a new window and volume of depth, using a “Linear Velocity” conversion of approximately 2500 m/s, the velocity of sound through limey mud, a rough approximation of the sediment in the volume (Smoak 2015). This isochron was then imported into the new volume, causing the values to be converted to depth. Due to the fragmentation of the digitized horizons that were a result of our conservative picking, these maps are highly localized and set in relation to the seafloor.

### 3.2.3.1.1 Kingdom Suite Analysis: NOAA dataset in Kingdom Suite workflow

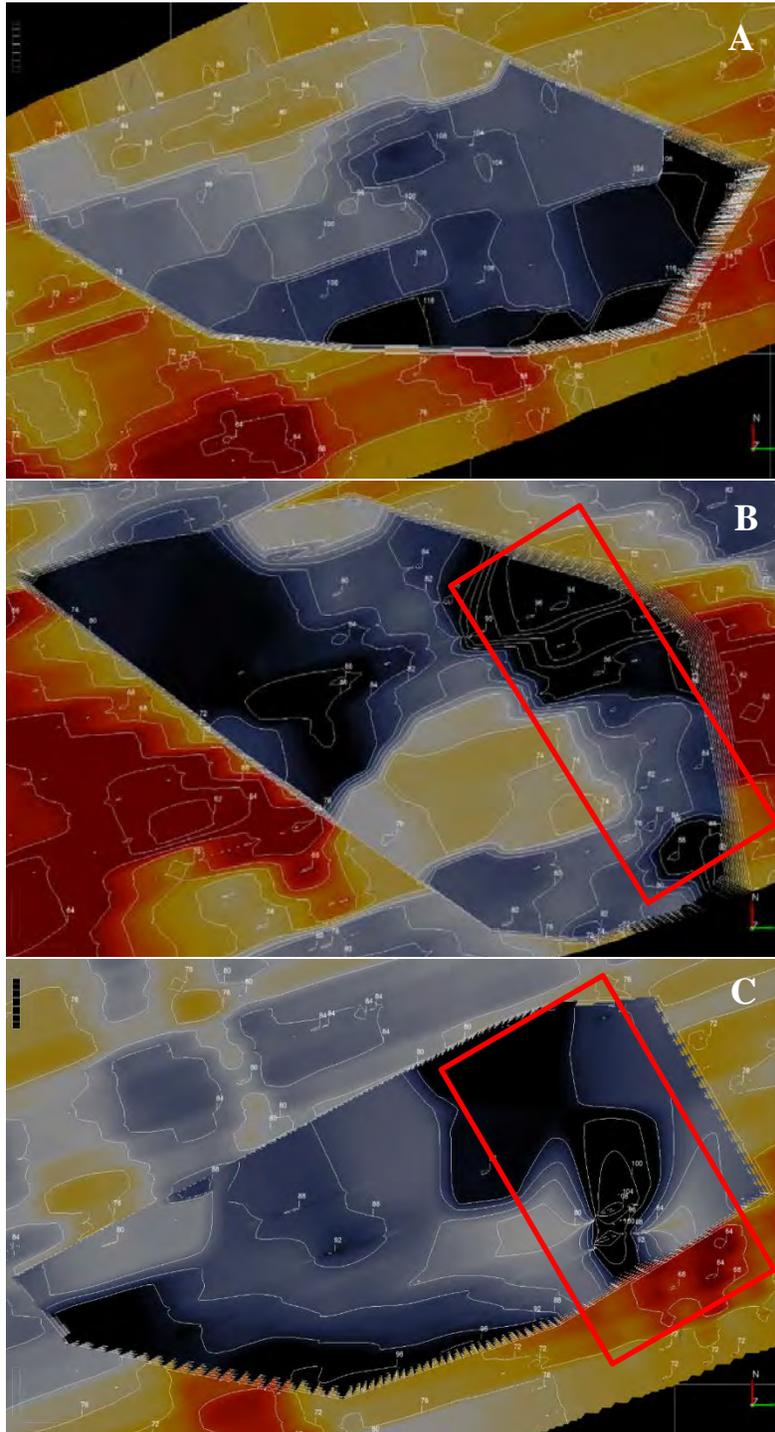
NOAA gathered CHIRP data near shore to roughly 100 km offshore South Carolina. This subsurface CHIRP and surface multibeam data was provided to ESRI-SC for interpretation. NOAA had processed the CHIRP data in Kingdom Suite Seismic software. The data files contained SEG-Y files to be viewed in Kingdom Suite, and other excel files with coordinates for location of fisheries, unconformities, and paleo valleys.

The data set was presented in four folders representing separate tracklines: NF 1506, NF 0404, NF 0503, and NF 1004. NF 1506 contained a file with a Kingdom Suite Project, however, the project could not be viewed at ESRI-SC. Instead, the four files were uploaded in Kingdom Suite as a new project



**Figure 29. A screenshot from OpendTect**

Displays one example of a channel digitized as a fault. The purple lines are the fault pick sets on each inline, and the red surface is the fault generated from the pick sets.



**Figure 30. Isopach maps generated by OpendTect**

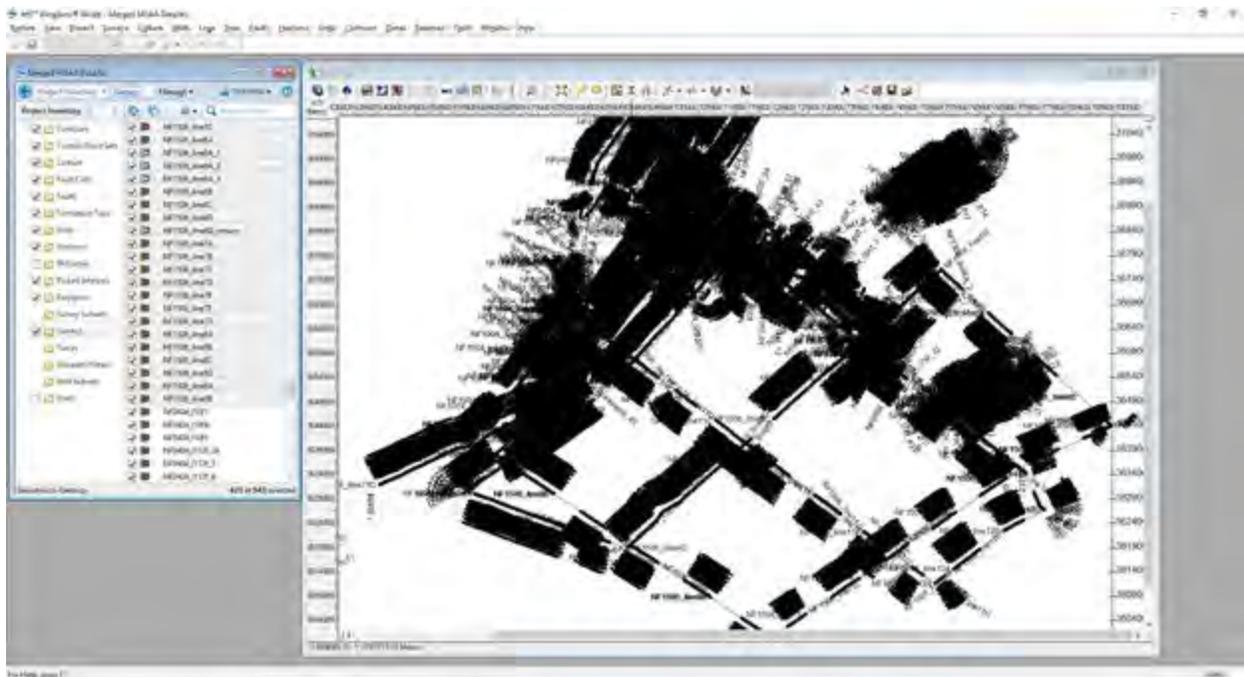
Screenshots of the isopach maps generated by OpendTect. The color scheme is shallow (brown) to middle (yellow) to deep (blue). Red rectangles outline the general boundaries of the channel. A) Isopach map with respect to the basement. B) Isopach map with respect to the large channel in the southwest portion of the area. C) Isopach map with respect to the small channel in the southeast portion of the area.

to view the complete data set simultaneously. After determining the proper coordinate system to be WGS 1984 UTM 17N, all SEG-Y files were uploaded into Kingdom Suite. The project was confirmed to be recorded in meters. Due to variability in the data headers and coordinate system, the file names were corrected using a file called 'world.txt.' Upon upload, the headers match the headers in this world.txt file. These file headers were manually selected in Kingdom Suite to be as follows:

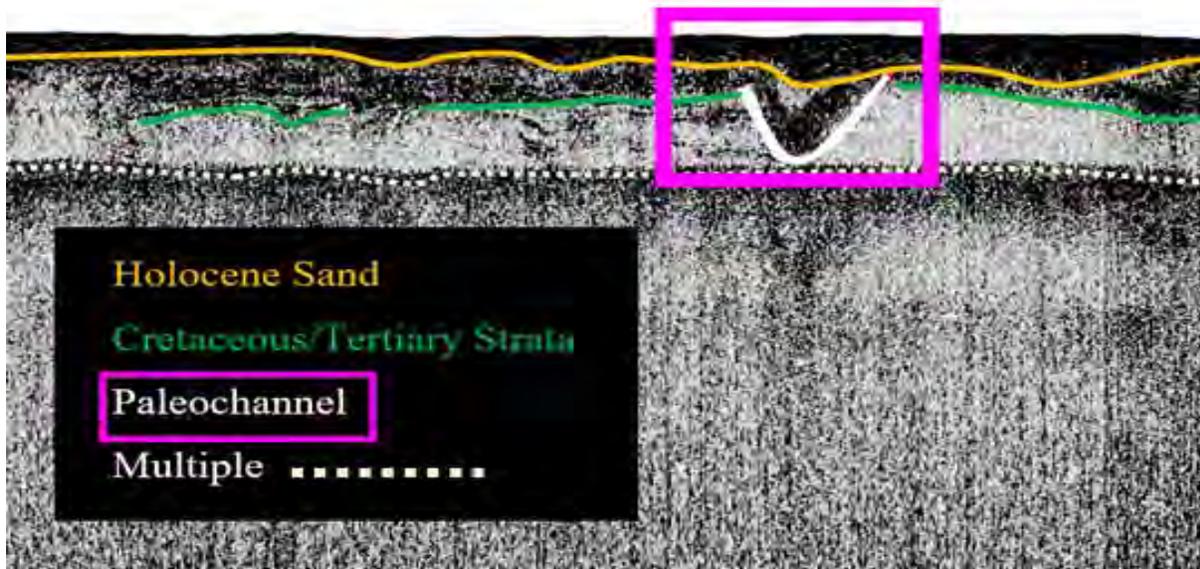
- Column 1 = Line\_name
- Column 3 = Shot\_Point
- Column 6 = X
- Column 7 = Y

A project containing all files of SEG-Y CHIRP data taken from the given data set was created called 'Merged Kingdom Data.' This file contained SEG-Y files from NF 1506, NF 0503, NF 0404, and NF 1004. This image was correlated with the shape files on ArcMap to confirm that the coordinate and lines are correct. A problem occurred during input where the ratio of trace per shot was automatically input as 2. This had to be corrected to 1 trace per shot for every uploaded line. Due to the massive amount of data, and the requirement of manual correction of the mistake, only lines that are listed in Paleochannel\_depth.excel have been corrected to 1 shot per trace: Survey > Assign 2D Shot Point Traces > Shot point scale factor = 1 trace per shot.

The CHIRP images were displayed in Kingdom Suite. To focus the search, the lines with associated paleochannels were displayed (Figure 31). The lines determined to have paleochannels comes from the Paleochannel\_depth.excel file provided originally by NOAA. The z value in the given excel data sets is a depth value in meters where NOAA assumed the velocity of the water column and unconsolidated sediment to be 1,500 m/s. The NOAA SEG-Y CHIRP track lines included in Paleochannel\_depth.excel will now be referred to as Paleo Channel Lines (PCL). The images were



**Figure 31. Kingdom Suite data set displayed by track lines**  
Kingdom Suite data set displayed by track lines on UTM 17N map.



**Figure 32. Example of prominent horizons and respective associated title**  
Horizon taken from line NF0404\_I112f\_6 approximately 40 km offshore.

interpreted to have successful data collected until roughly until 30 ms TWT.

An active horizon was set to interpret the PCL. From these images, the horizon picking tool was used to underline the points that NOAA identified to contain paleochannels. Some scientifically educated interpretations were made, however, the picking was done with the associated pre-picked paleochannel coordinates as a guide (Paleochannel\_depth.excel). Figure 32 gives an example of the interpretations made from the CHIRP images.

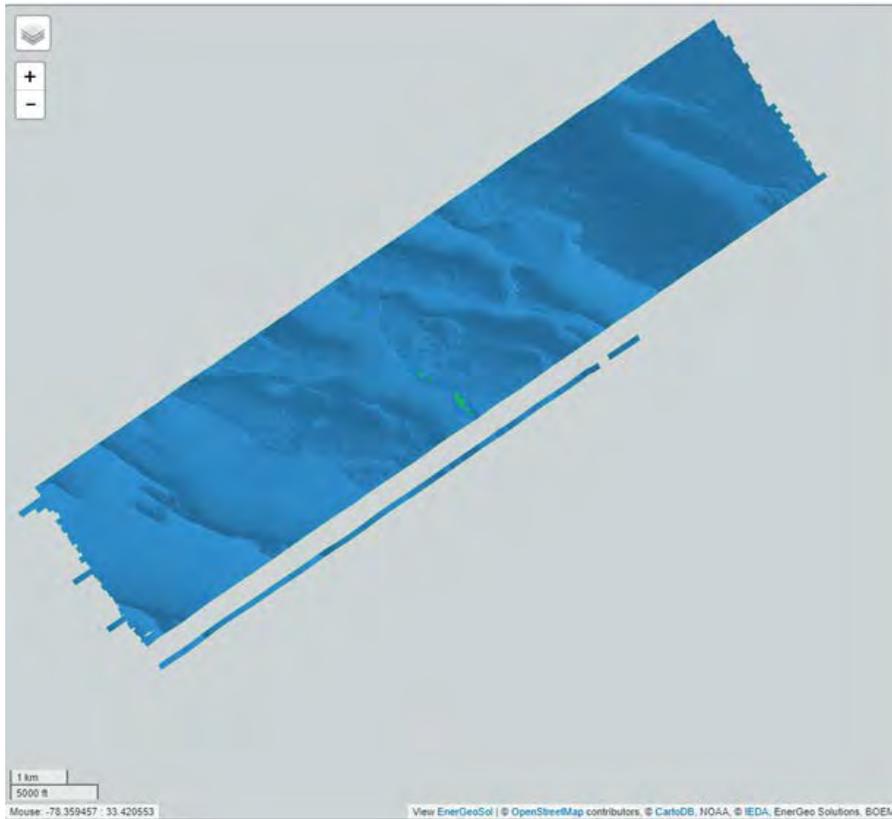
The identified paleochannels extend throughout the gathered NOAA data. Detailed Multibeam data was acquired to image the subsurface. In this data CHIRP was also acquired and displays a paleochannel following the edge of a high ledge surface. There may be a correlation between pronounced ledge features and subsurface channeling (Figure 33).

The horizons picked were displayed in Kingdom Suite VuPak. The first horizons (displayed under 'horizon picking' in Figure 34) were picked in red. These were manually picked based from the PCL information. A refined horizon picking was done called "channel" in the multibeam supported area. These were picked in pink, and the VuPak information is displayed inside the pink box in Figure 32.

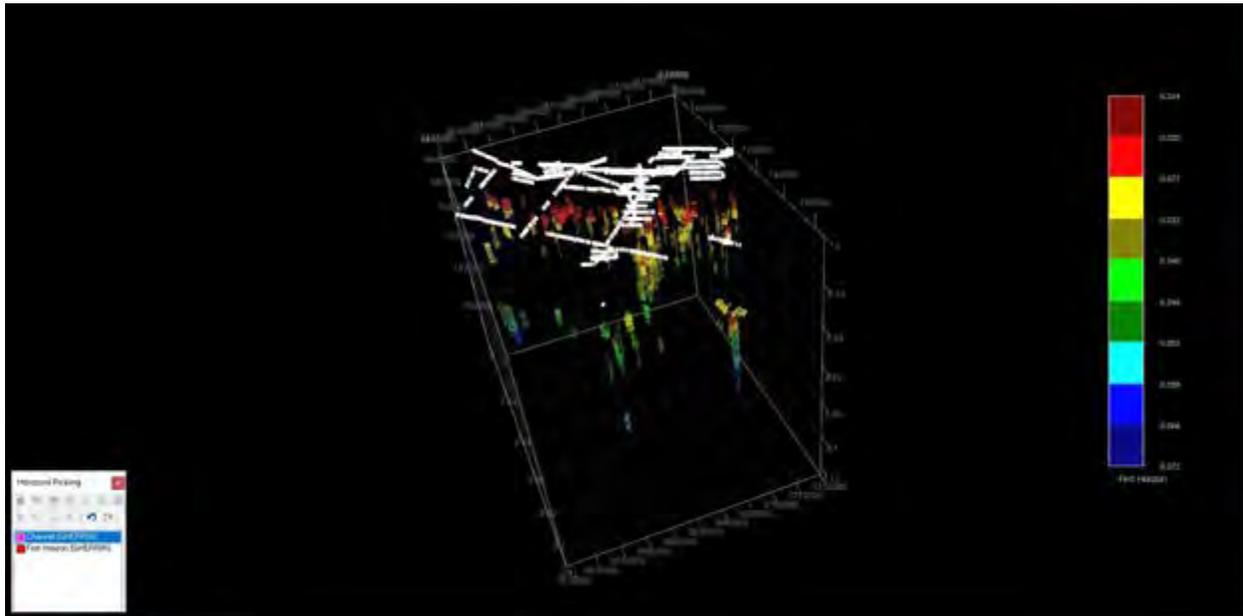
Due to the CHIRP data being great distances apart, refining the data proved to be difficult. The NOAA study area may support the evidence of paleochannels offshore South Carolina. It also provides locations of known fisheries, all of which may refine the geologically favorable call areas. Paleochannels have been identified within the boundary of BOEM call areas and therefore may eliminate these areas due to potential subsurface considerations. The paleochannel analysis allows for future research to focus the call area to areas with no identified potential subsurface design considerations. This data may refine the search locations that correlate with the BOEM call area map. The correlation between surface exposed cliff structures and subsurface channeling should be investigated in future studies.

### 3.2.3.1.2 Discussion

An overview of the processed seismic lines and a few examples can be seen in Figures 35 and 36 A-C. The complete collection of the merged seismic lines can be found on the interactive Storymap. A

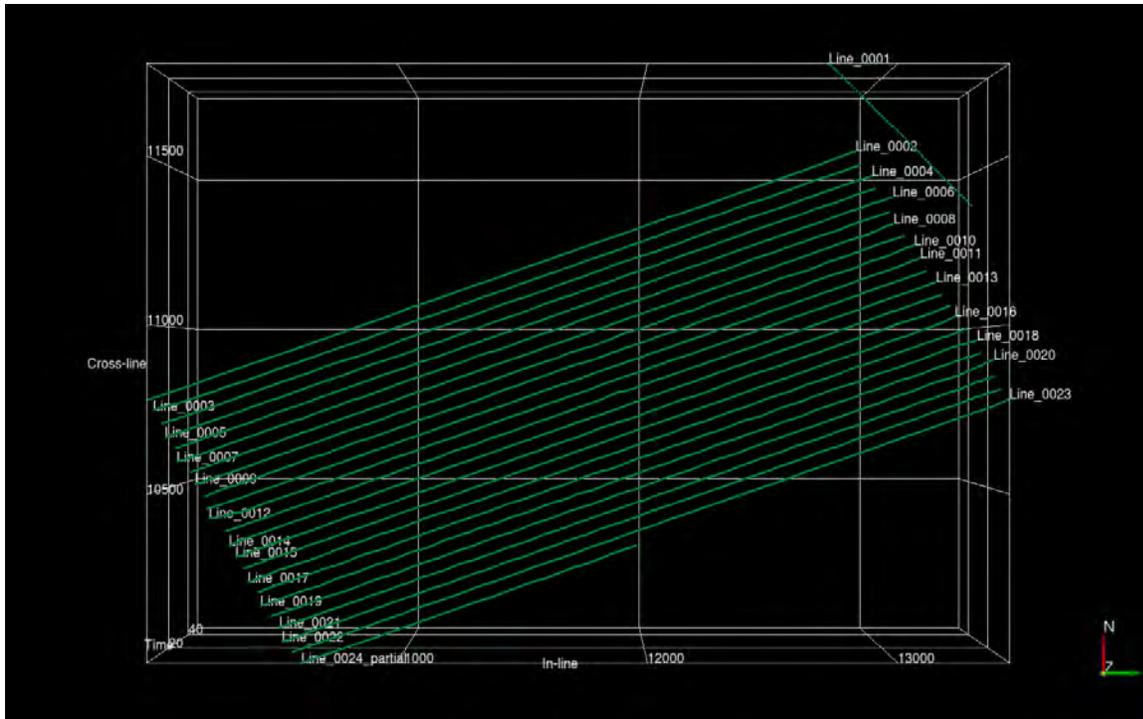


**Figure 33. Multibeam data of the surface with green highlighted subsurface channel**



**Figure 34. White lines display the track lines**

The colored lines display the channels found during 'first horizon' picking. The area with a pink square displays the refined picking of the multibeam supported data. The color bar displays TWT.



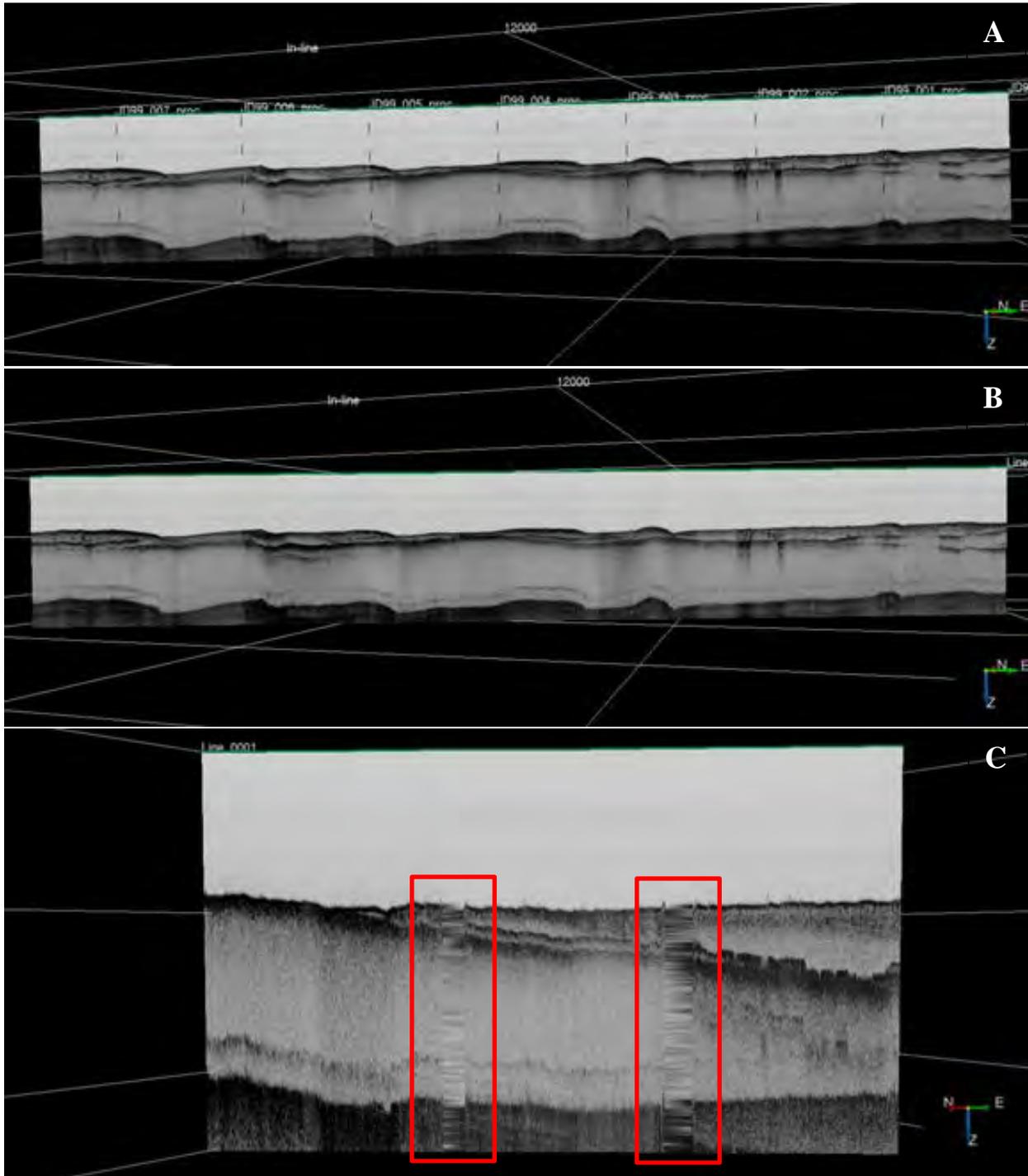
**Figure 35. Map view of all the seismic lines collected in the target area**

potential issue with merging the lines was the interpolation between the original lines. This was evident in Line 0001 (Figure 36 C), where there was an obvious interpolation error caused by the complete lack of data in the region between adjacent sections. This results in incomprehensible interpolations. Given the processed inlines and no crosslines, the digitized horizons can be seen in Figures 37 A-D. These figures were made to best represent the overall direction and change in depth of the horizons. Certain horizons change greatly with depth as they move seaward, while others remain at approximately the same depth. Creating a surface from the digitized horizons was difficult. The horizons are partitioned into many smaller horizons because of the conservative method of digitization of the horizons. This is good for horizon interpretation, but not surface creation or isopach mapping. Therefore, we modified our approach. As described in the Section 3.2.3 Subsurface Analysis, we chose the segment with the greatest area and presence throughout the surface that the seafloor calculated to. Also, due to the overlap of the segment's surfaces, the overall shape of the horizon surface is preserved.

Due to the discontinuous horizons, creating an isopach for the entire horizon was impossible. Therefore, we calculated the isopach from the seafloor to the segment of the basement with the greatest surface area (Figure 38 A-B). For the channels, we calculated the isopach from the seafloor to the segment of the surface which included the channel (Figure 39 A-C).

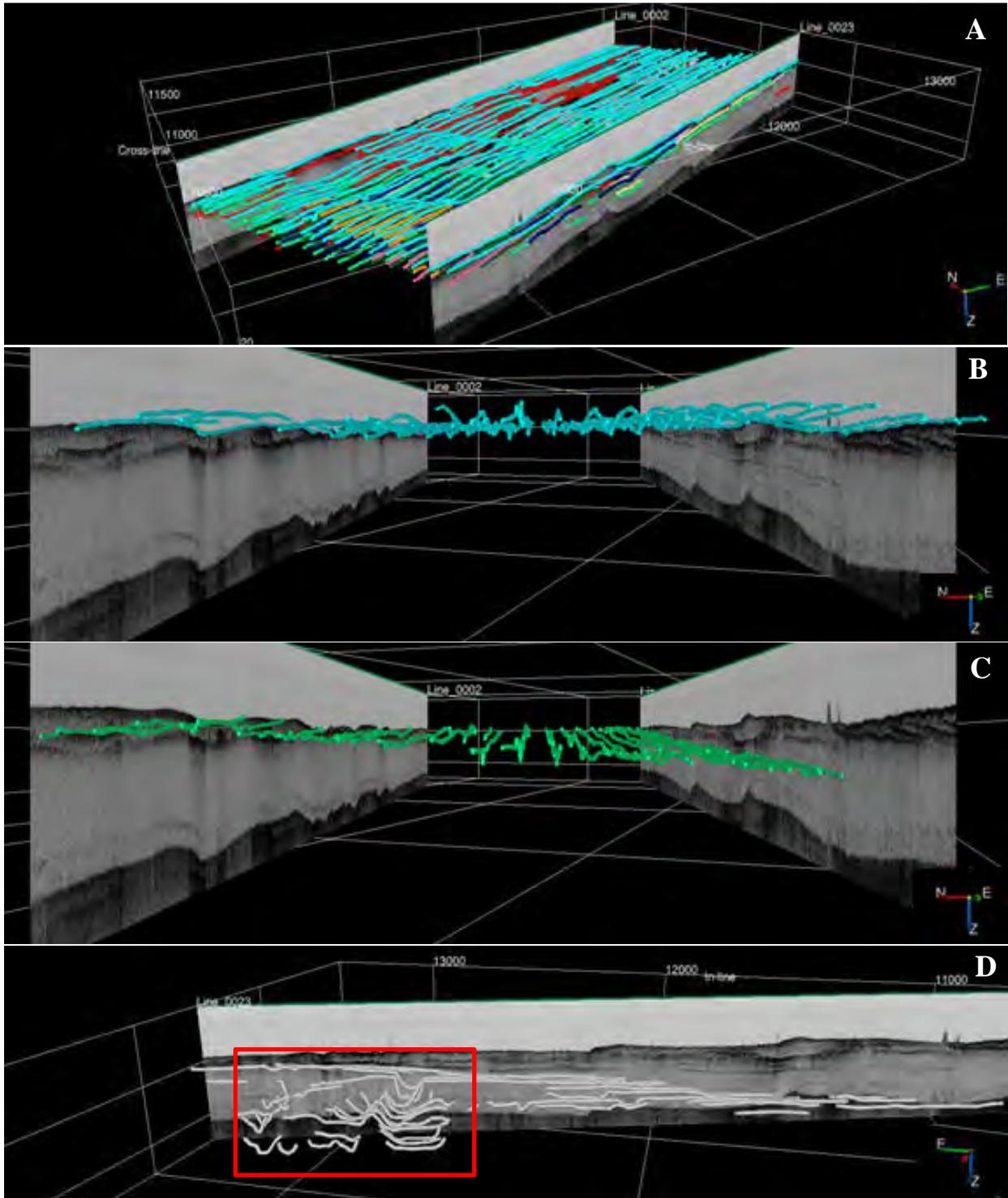
### **3.2.3.1.3 Interpretation**

Data interpretation initially included planned use of Schlumberger's Petrel software platform. As the CHIRP system is entirely single-channel and lacks a formal geometry (lacking common depth point, common mid-point, inline and crossline assignments), OpendTect is used instead to simplify the interpretation workflow. Loading the processed CHIRP sub-bottom data into OpendTect requires only the survey coordinates of the bounding box. It is important to note, however, that either software platform provides limited features for 2D, single-channel seismic reflection data. In this manner, our sole objective in using an interpretation platform is to obtain the sub-bottom horizons and buried paleochannels found in the dataset.



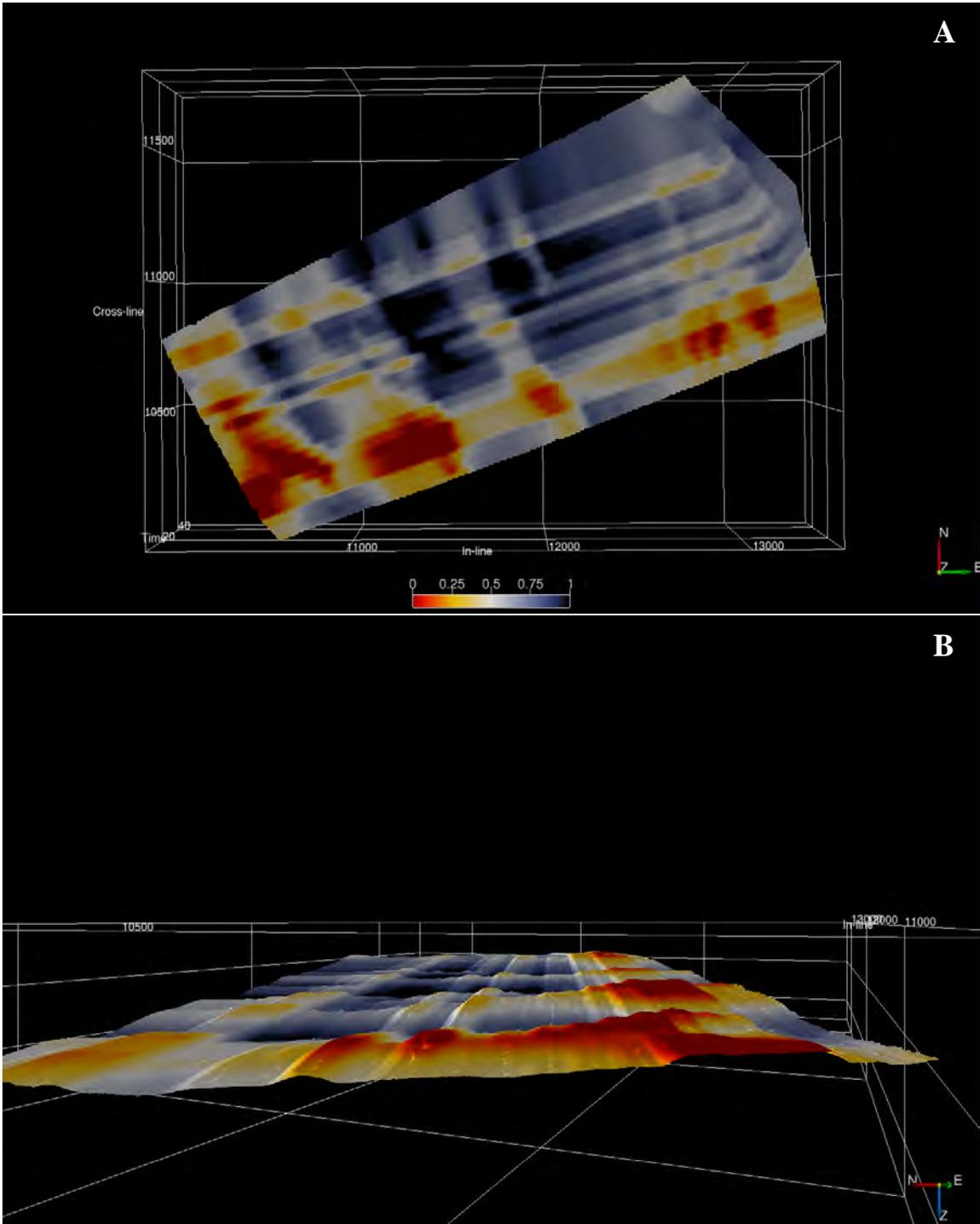
**Figure 36. Examples of seismic lines collected in the target area**

A) Collection of adjacent seismic lines that form a single long line. The dashed lines are the portioning between the surveys; B) The same adjacent seismic profiles, but they have been merged to form a cohesive whole. This greatly aids in the digitization of the horizons; C) screenshot of the merged Line\_0001. The areas within the red rectangles are the interpolated data that has no meaning.



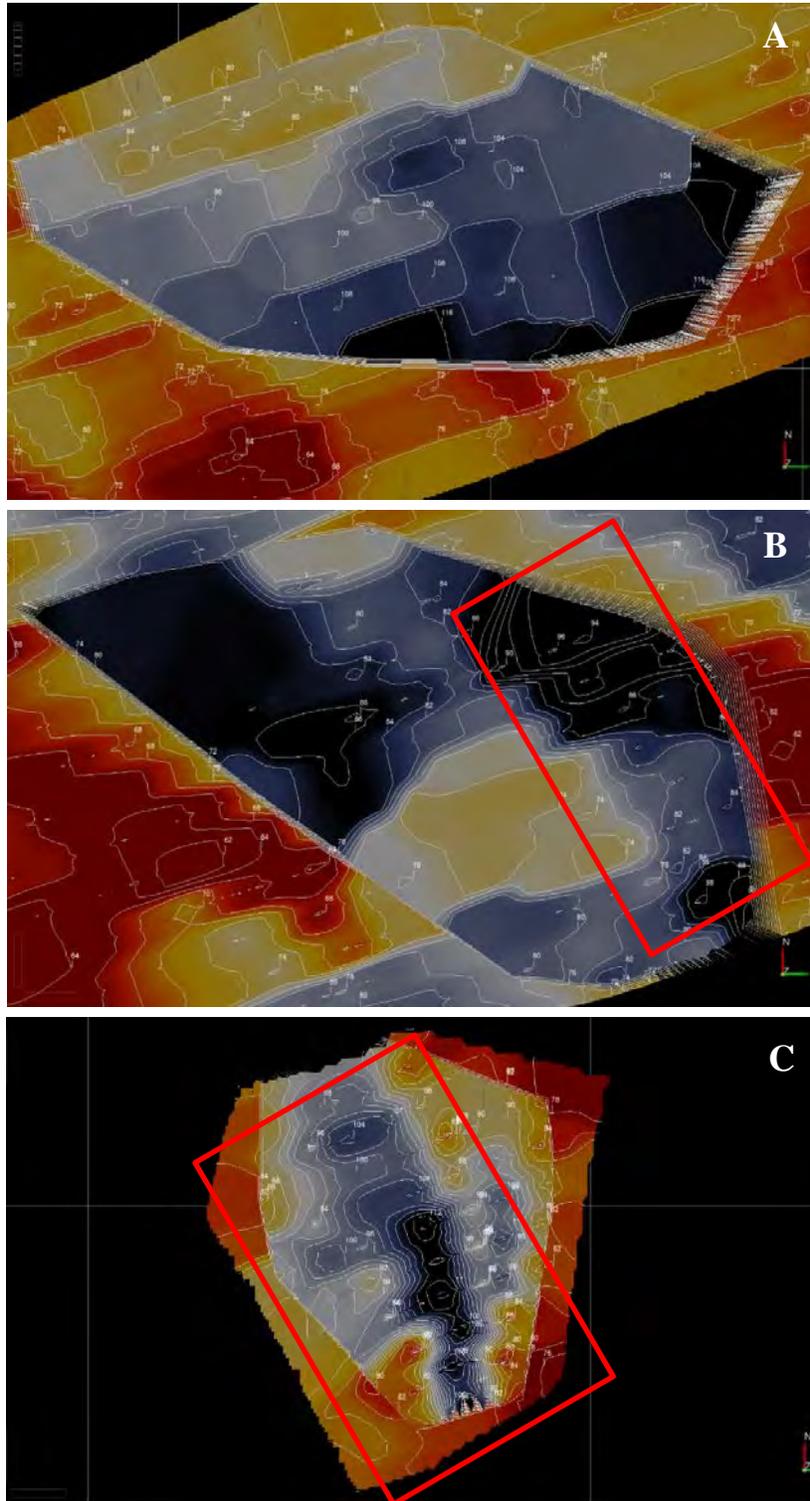
**Figure 37. Seismic horizons**

A) An overhead view of all the picked horizons; B) The seafloor horizon between two of the seismic profiles; C) One of the more prevalent horizons in the volume; D) A horizon that includes a channel outlined by a red box.



**Figure 38. OpendTect isopachs with the color bar displayed**

The color bar on the bottom has red as low time (shallow area) and blue as high time (deep area). A) Map view of the seafloor surface. B) Planar view of the seafloor surface to better observe the vertical offset.



**Figure 39. Several isopach views**

A) Isopach map of a portion of the basement. Depth ranges from 22-33m relative to sea level, 3-5m thick with respect to seafloor. B) Isopach map of Channel 1. Depth ranges from m. C) Isopach map of Channel 2. Depth ranges from 22-26m with respect to sea level, 4-7m with respect to the top of the channel. Red boxes identify channels.

From the seismic lines, there appear to be three channels, one on the southwest and two on southeast ends of the seismic lines (Figure 40). These channels are especially evident on the southern end of the data. Channel thickness can be estimated by subtracting the values from the seafloor surface from the values from the channel surface, as given in the isopach maps. The channels in Figure 40 (one not shown) differ widely in both thickness and width. The channel on the southwest has a depth of 3-6 m and a width of approximately 1 km. The channel on the right has a depth of 4-7 m and a width that varies from approximately 250 m-1 km. The last channel in the southeast section has a width of approximately 250 m and a depth of 3-5 m. These three channels cut through Horizon 12 (silver) and Horizon 5 (green).

According to Denny et al. (2013), rivers drained onto the Cretaceous and Tertiary sediment deposits, deeply incising the sediments. Therefore, the sediment layers/horizons below the dark green and silver horizons are the Cretaceous and Tertiary sediments. Also, all the horizons above the dark green and silver horizons are the Quaternary sediments, more specifically the Holocene and Pleistocene sediments. The relative thicknesses of the two-sediment series also conform to the Denny et al. (2013) findings: the Holocene sediment is less than one meter thick, and the Cretaceous and Tertiary sediments are thick. Additionally, the CHIRP data shows that as the CHIRP inline number increases and location in the survey area moves southeast, the thickness of the Cretaceous and Tertiary strata increases.

The thin layer of Holocene sediment has been eroded in the northeastern region of the survey area (Figure 41), potentially exposing the Tertiary sediments on the seafloor. It is difficult to determine whether the Tertiary sediments are exposed or if they are covered by a thin layer (less than 19 cm) of Holocene sediment due to the vertical resolution of the data.

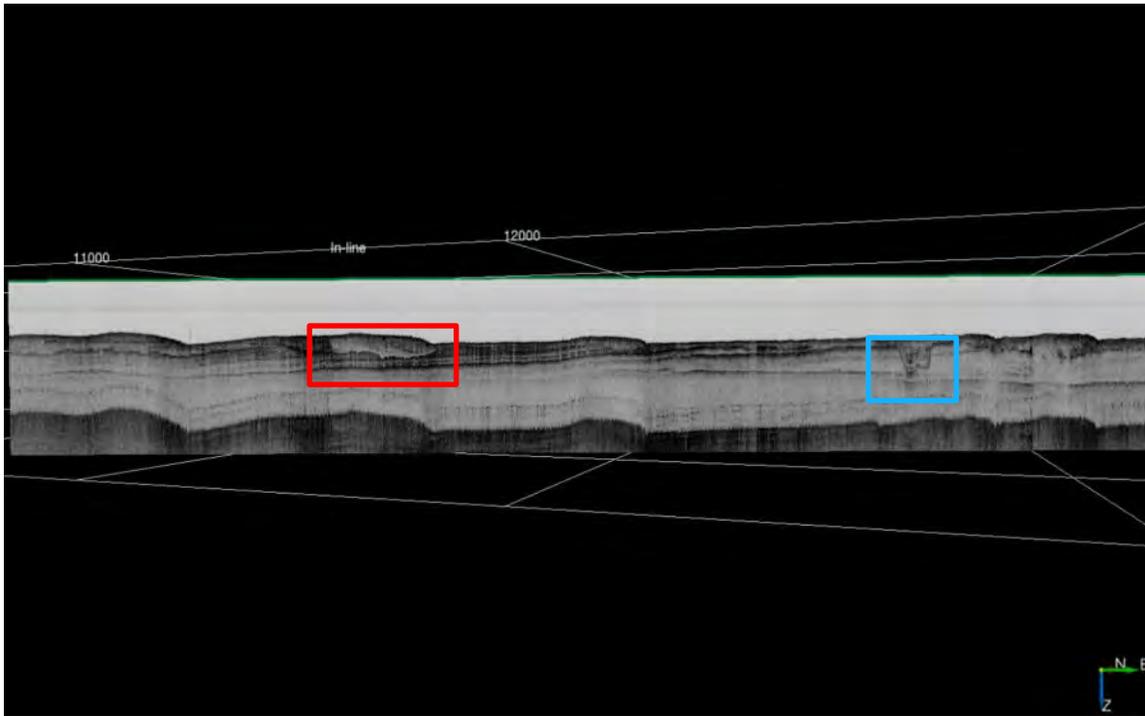
Some of the near-surface horizons, seafloor, and paleochannels for the target area in Long Bay, South Carolina have been digitized, described, and categorized. The main divide between the depositional phases in the area have been identified in the seismic data: below Horizons 5 and 12 and above Horizon 1 represents the Cretaceous and Tertiary sediments that originated from the Appalachian Mountains, and the horizons above Horizon 5 represent the thin Holocene sediments that have been eroded and displaced to expose the Cretaceous and Tertiary sediments beneath it. Moving southeast, perpendicular to the coast of Long Bay, SC, the thickness of the Cretaceous, Tertiary, and Quaternary sediments increases with distance.

Surface features reveal a radiating pattern that extends through the entire N-1 study area. Lines 29-31 reveal a complex system track, reconfirming the geologic complexity of the area (Figures 42 and 43). One horizon runs through the entire survey area, starting relatively shallow to the north and running deeper to the south. This horizon provides an anchor as it is continuous and associated with a significant reflector. Below this horizon at its deepest (most seaward) edge the CHIRP data is beset by multiples and weak reflections (Figures 44 and 45). Overlying this anchor horizon is a thick packet of tertiary sediment of the same depositional episode. An unconformity disturbs that packet throughout the study area and several buried channels cut into that unconformity (Figures 46 and 47).

According to the SCGS, surficial outcrops in the study area are Cretaceous in origin but have been modified by Pliocene and Pleistocene events. There is great spatial variability, even paleo-features, with no current explanation. Our dataset does not permit clear interpretation of these complexities, but it does support the geologic complexity in the region. Further, our dataset does not permit direct correlation to previously published works closer to the coast. SCGS has an existing BOEM project that falls between the older, coastal inundation report and our study area that we will use as a bridge between our BOEM data and the older USGS data, but SCGS will not have their results for perhaps another year.

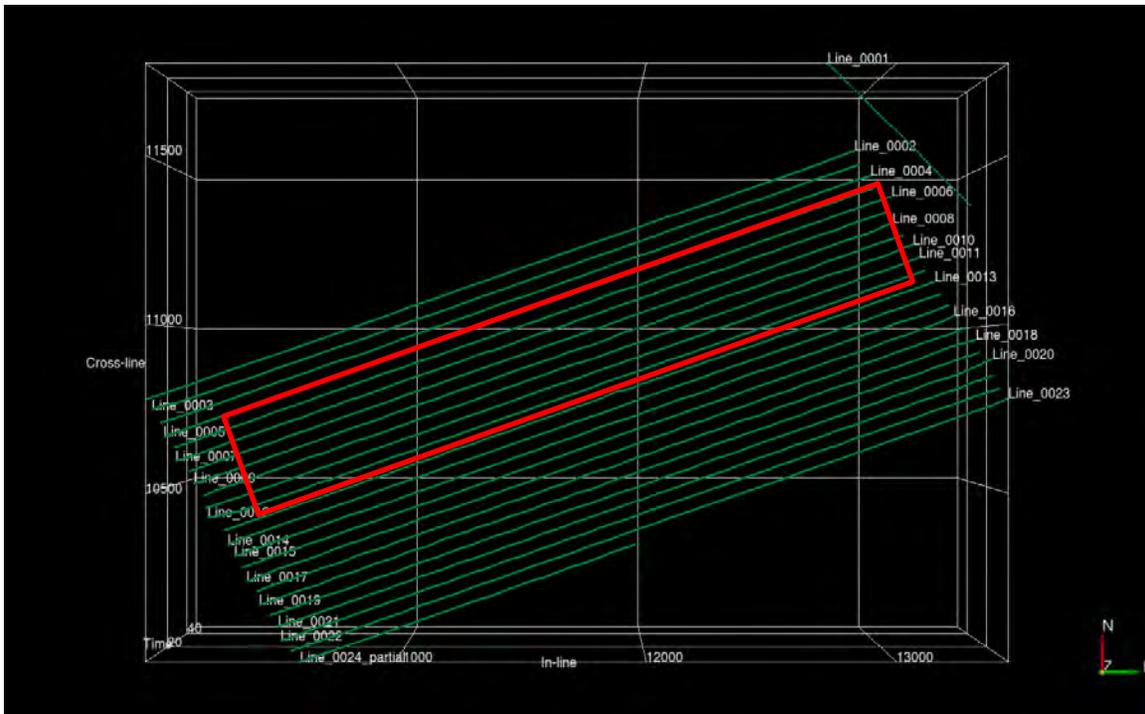
### **3.3 Habitat and Geological Mapping Surveys and Analyses**

Based on studies of geologically favorable Wind Energy Areas, we identified several designs



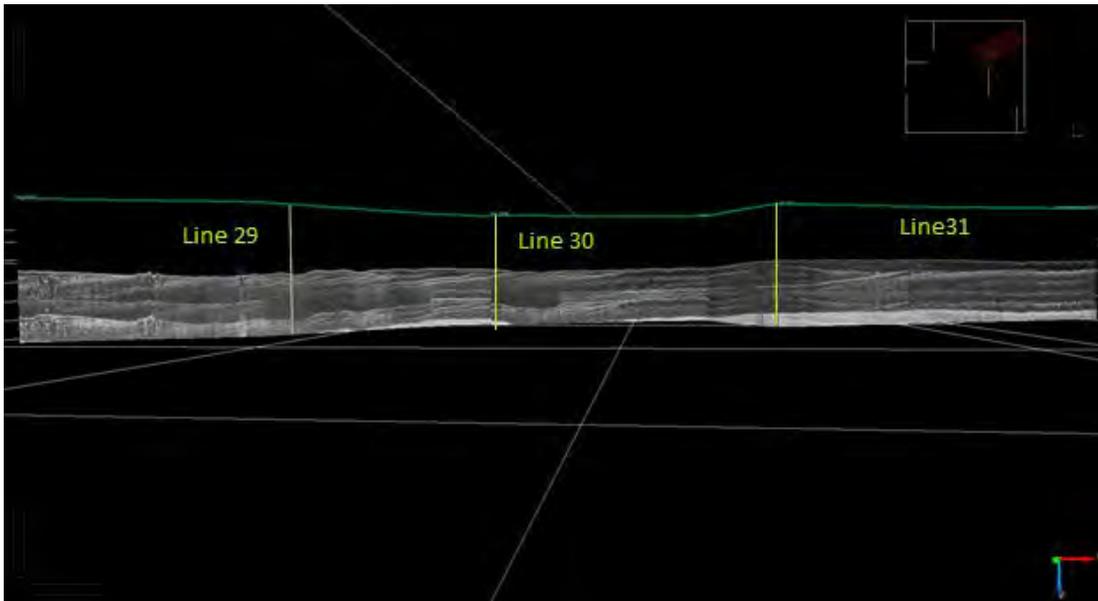
**Figure 40. Major channels in the data set**

Line\_0018 shows both major channels in the data set. Channel 1 is shown by the electric blue box, and Channel 2 is shown by the red box.



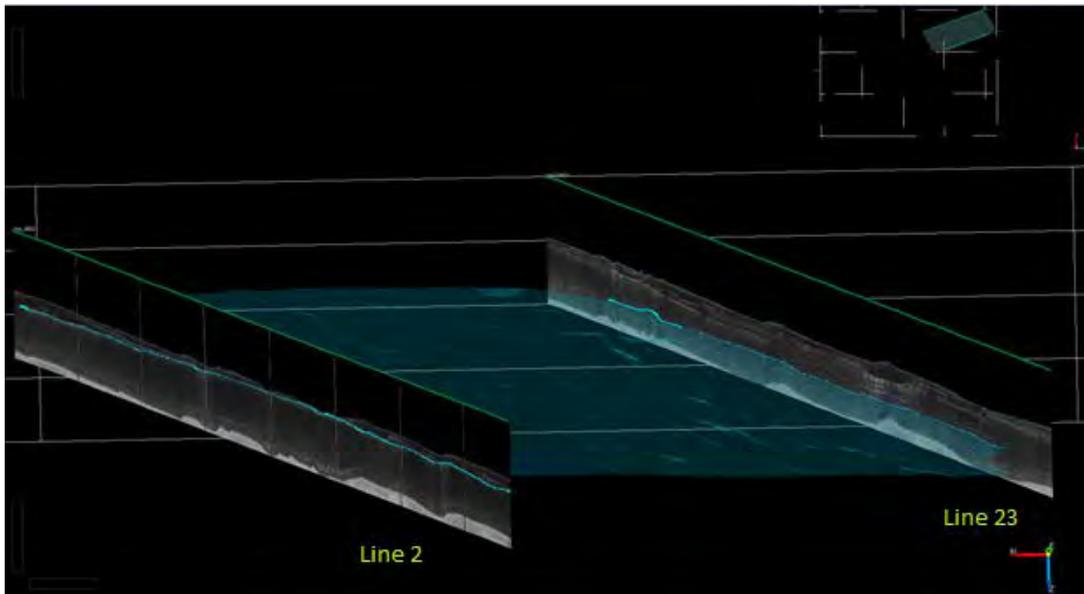
**Figure 41. Map view of the survey area**

The potentially exposed Tertiary and Cretaceous sediment is located in the red box.



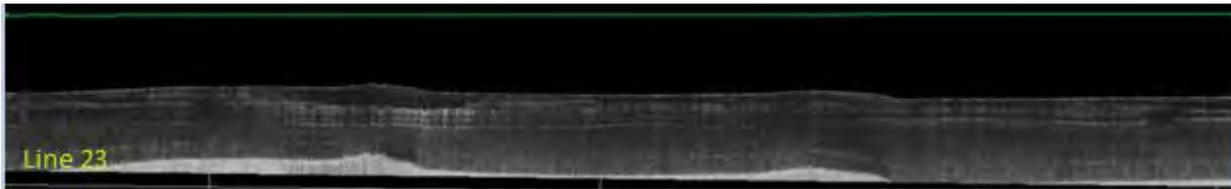
**Figure 42. Map view of N-1 block and lines 29-31**

Map view of N-1 block and lines 29-31 in upper right. Lines 23-31 reveal a complex system track. Note irregular shape of lines 29-31 through survey area.

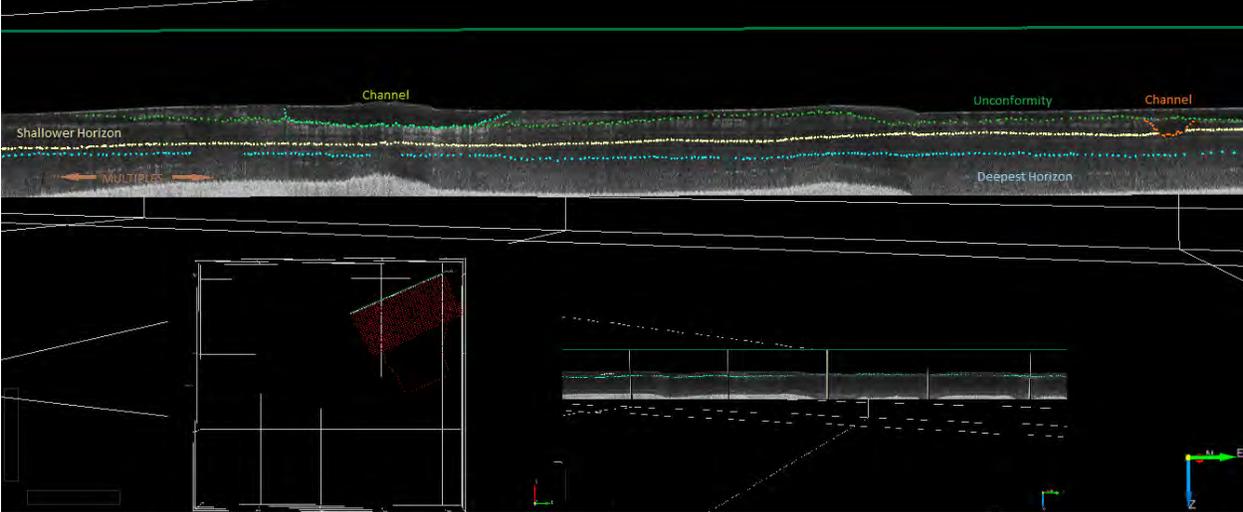


**Figure 43. The blue horizon extends through the N-1 block**

Starting shallow to the north and running deeper to the south.

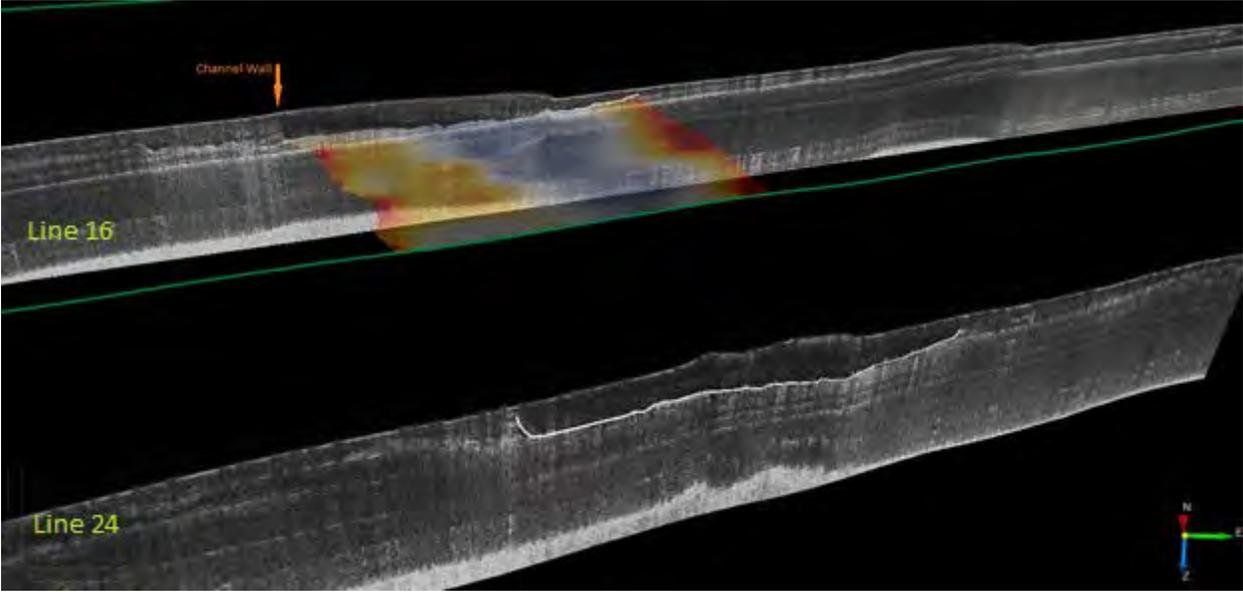


**Figure 44. Uninterpreted Line 23 CHIRP image**



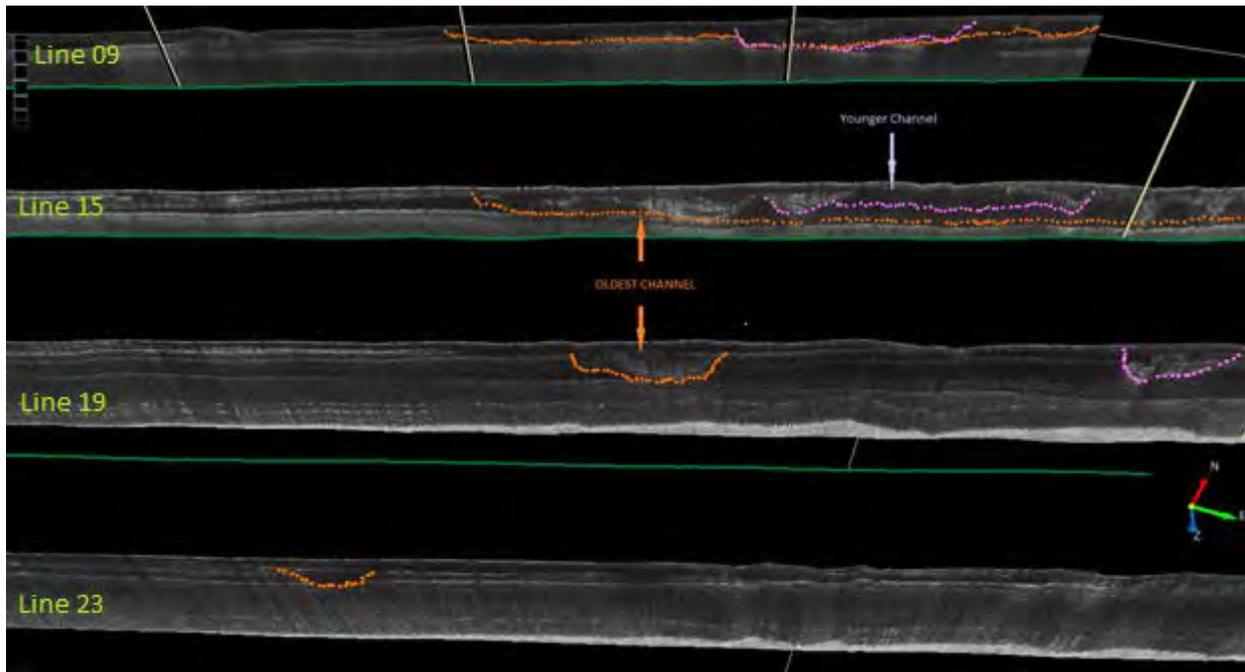
**Figure 45. Interpreted Line 23 CHIRP image**

The deepest horizon is overlaid with horizontal layers following the same general trend. Forming a single packet of sediment from one depositional episode. That top of that packet is cut by an erosional unconformity. Two buried channels cut through the unconformity. The deepest horizon cut to the opposite, north end of the N-1 block (bottom, center); the shallower horizon only covers a small section of that area.



**Figure 46. Buried channel**

Sediment horizons west of channel terminate at wall. This channel was likely much deeper, indicating significant sediment erosion from ancient ocean floor.



**Figure 47. Buried channels**

An older channel was buried. Burying sediments were later eroded by younger channels. Sediment horizons west of channel terminate at wall. This channel was likely much deeper, indicating significant sediment erosion from ancient ocean floor.

considerations in our specific study area. The features that we looked to identify, classify, and consider are as follows: (1) potential subsurface perils, (2) cultural artifacts and economic interests, (3) and lithologically hard surfaces should be considered because they characterize geologically unfavorable areas for wind development (Bot et al. 2005 and Bhattacharya 2014, SAFMC 2018).

In our study site, we identified the three above listed design considerations and used GIS to identify their relative locations. The potential subsurface risks in the study site are characterized as paleochannels and (1) have been identified to be paleochannels; (2) characterized in our area as sunken ships and other components confirmed to be Barracuda Alley, an artificial reef; and (3) found using backscatter data and the returned dB were classified into hard, mixed, and soft seabed bottom types.

Although the GIS Analysis characterized these described potential perils, further research should be conducted to identify further geologically favorable areas. The design considerations map created through GIS analysis locates the geologically unfavorable areas. The specific parameters for wind energy development will be researched more in depth, per the needs of the structure. The result produced a 22 km<sup>2</sup> area that does not contain considerations 1-3 listed above. The final area displays geologically favorable areas of interest.

### 3.2.4 Design Considerations Map

In our study area, we have identified three types of potential design considerations not only for engineering purposes, but for environmental and cultural purposes as well: 1) paleochannels, 2) cultural artifacts, and 3) hard sea floor bottom. The following is our workflow to identify, digitize, and analyze these three classes of features, which amalgamated into an overall design considerations map and, conversely, favorable location areas. We focus only on the upper portion of N1 of the overall study area because this area alone has enough CHIRP data to conduct extensive subsurface analyses.

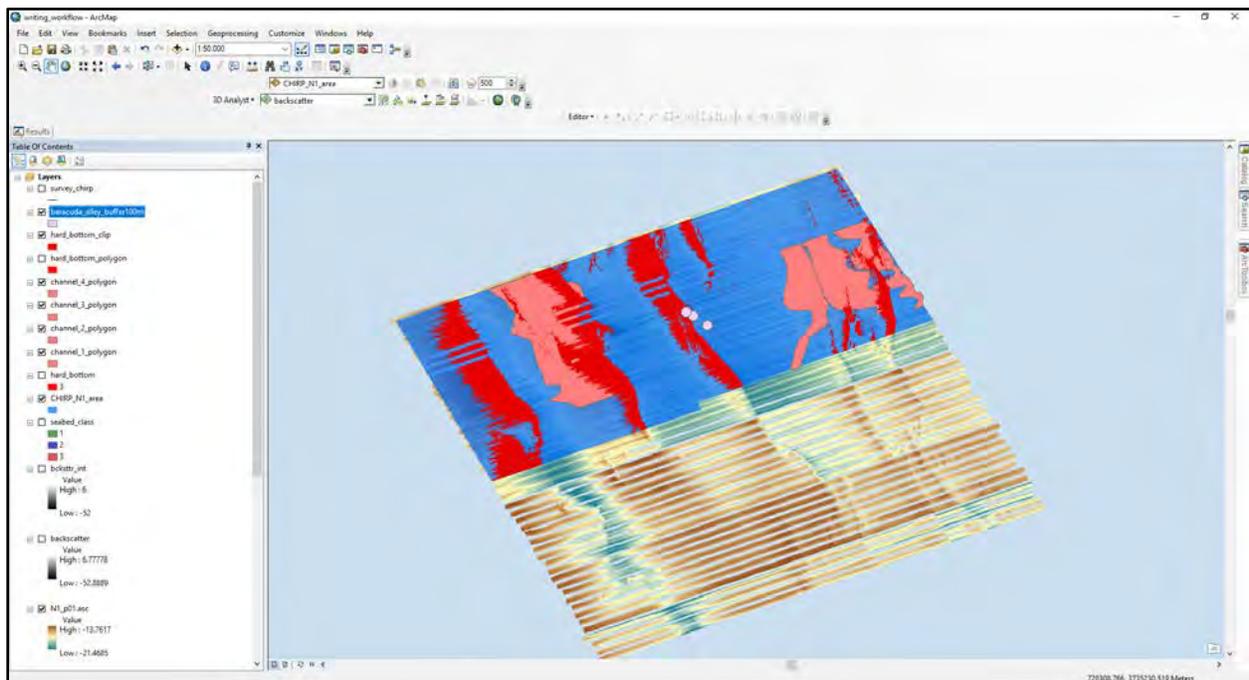
For our analysis we used the Clip tool to only use the portion of the potential design considerations that intersected our focused study area layer. We then combined our three features for our study area: 1) paleochannels, 2) cultural artifacts, and 3) hardbottom (Figure 48). The Union tool was used to combine all these features into one complete “design considerations map”. To identify and quantify favorable areas for wind development, we used the Erase Tool to take the difference between the design considerations layer and focused study area layer. The remaining area is the favorable call area, which is calculated to be approximately 22 square km, or 8.5 square miles (Figure 49).

In all, we provided a workflow in ArcGIS that accurately and quantifiably characterizes favorable wind energy areas. In total, our focused study area is calculated to be approximately 22 km<sup>2</sup>, or 8.5 mi<sup>2</sup>. This area can be further refined by utilizing our Transgressive Surface Depth raster layer, which measures the thickness of the sand lens. This can prove vital for engineering purposes in which turbines require a minimal or maximal thickness of overlying sand.

A similar workflow as outlined to classify hard, soft, and mixed bottom seabed was used to classify the depths of the located transgressive surface. First the surface was opened into ArcMap, and the reclassify tool was applied. The classifications of depths that were of interest were applied to the layer. The result may be useful in determining the depth to the transgressive layer of any given area in future chosen areas for potential leasing. The layer in Figure 50 is now classified into three depth classifications. The area was calculated using the Field Calculator and Calculate Geometry features in the attribute table.

### 3.2.4.1 Paleochannels

In an engineering aspect, paleochannels pose large threats to offshore wind turbine structures (Bot et al. 2005 and Bhattacharya 2014, SAFMC 2018). Through subsurface CHIRP imaging, Baldwin et al. (2004) identifies reflection geometries within the infill of channels that are commonly indicative of complex cut-

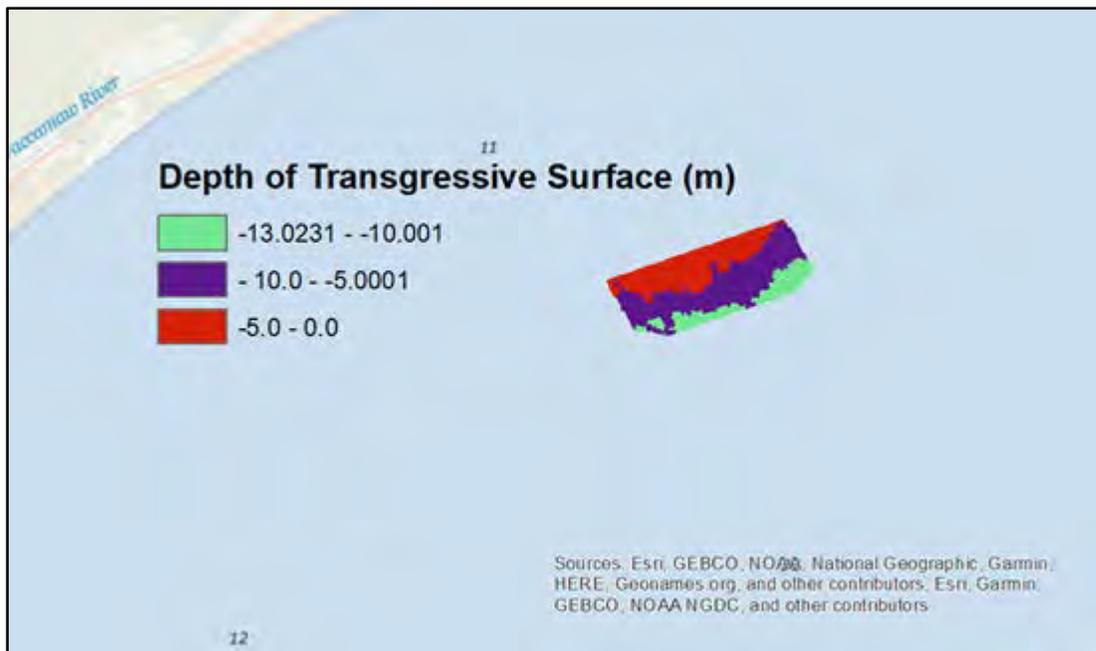


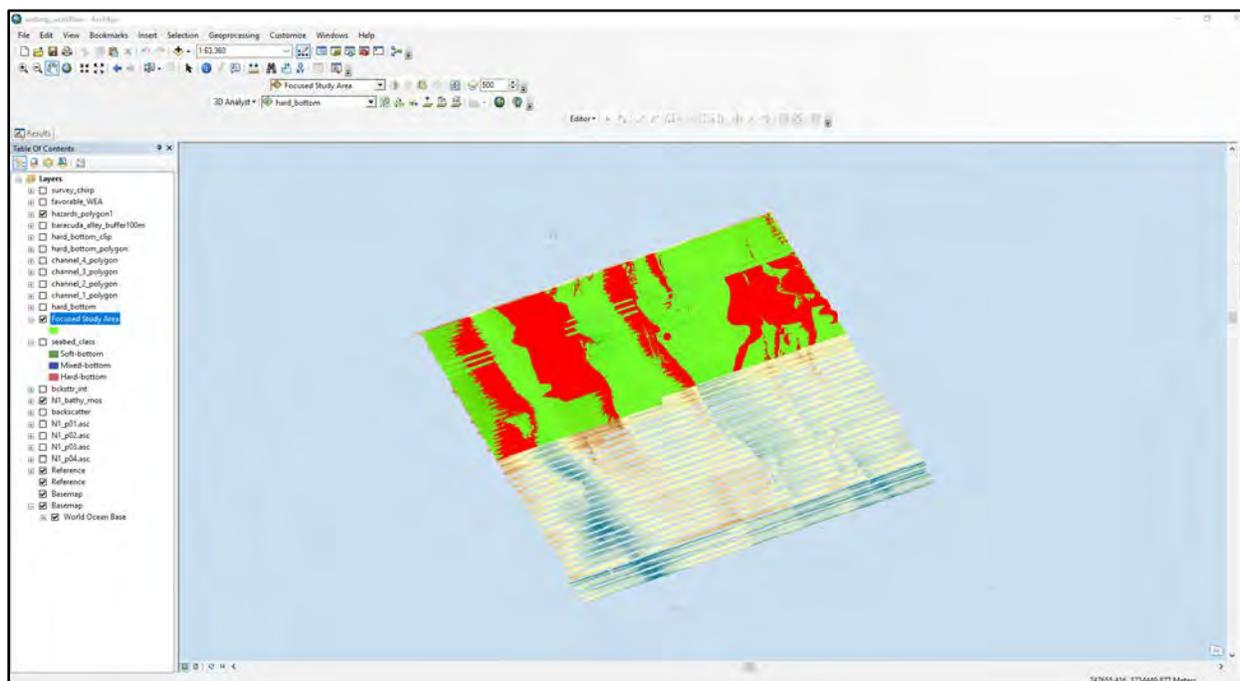
**Figure 48. Three potential design considerations**  
1) paleochannels (salmon), 2) cultural artifacts (pink), and 3) hardbottom (red) placed on top of the focused study area layer

and-fill structures and “nesting” of many incisions within a larger complex. The heterogeneity and poor induration of the infill of these channels could pose serious threats to the integrity of the foundations in

**Figure 49. Favorable wind energy areas.**

All three features combined to form a “potential design considerations map”, in which all potential features are outlined in red. Conversely, the green area represents the calculated favorable wind energy areas.



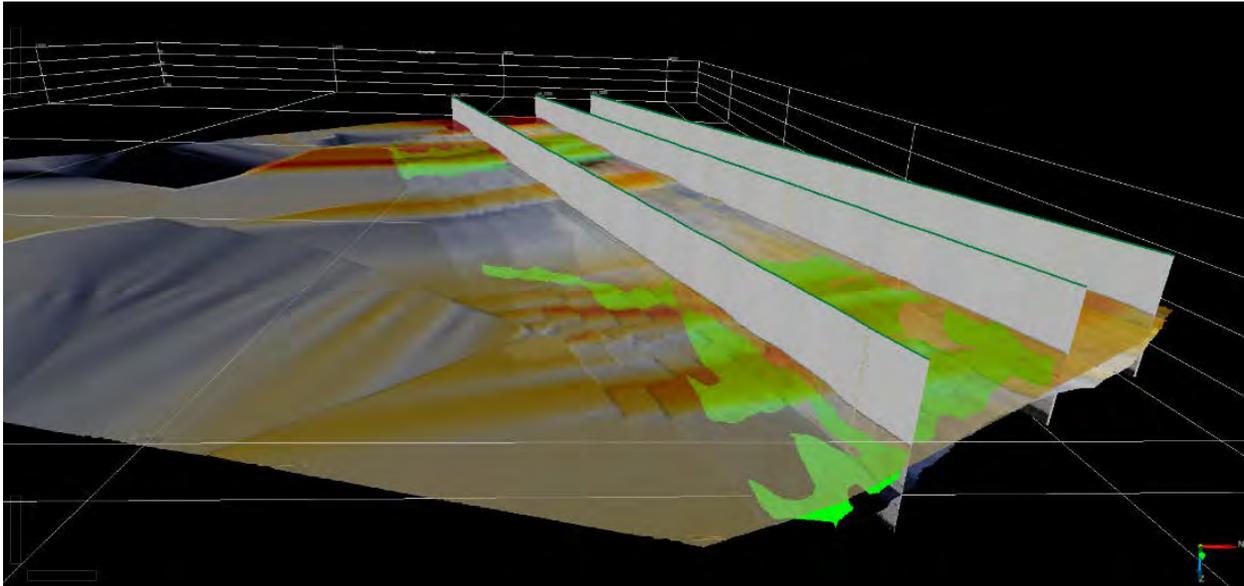


which turbines will rest. We have identified four paleochannels in our focused study area (Figure 51).

These four channels were exported from OpendTect and imported into ArcGIS as XYZ files. To further digitize the four channels, we used the Point to Raster tool. A coordinate reference system reprojection was utilized for this dataset to change the paleochannels from NAD\_1983\_StatePlane\_South\_Carolina\_FIPS\_3900\_Feet\_Intl to WGS\_1984\_UTM\_Zone\_17N. The Project Raster tool was used for this conversion. We then converted the rasters from continuous datasets to discrete, or “integer type”, datasets through the Spatial Analyst tool called Int. This was useful for later

**Figure 50. Map of the Calculated Transgressive Surfaces**

Depths of the given areas in meters. The result may be useful in determining the depth to the transgressive layer of any given area in the future



**Figure 51. Four paleochannels identified in OpendTect**

Four paleochannels identified in OpendTect, which were imported into ArcGIS 10.4.1 for further digitization and analysis.

conversions from raster to polygon. To easily convert these rasters to polygons, we first reclassified the rasters to one value using the Reclass tool. This is done to avoid creating multiple polygons for one paleochannel. Finally, the Raster to Polygon tool was used to convert these integer type rasters to polygons. The conversion from continuous rasters to discrete, or integer type, was required to use this tool.

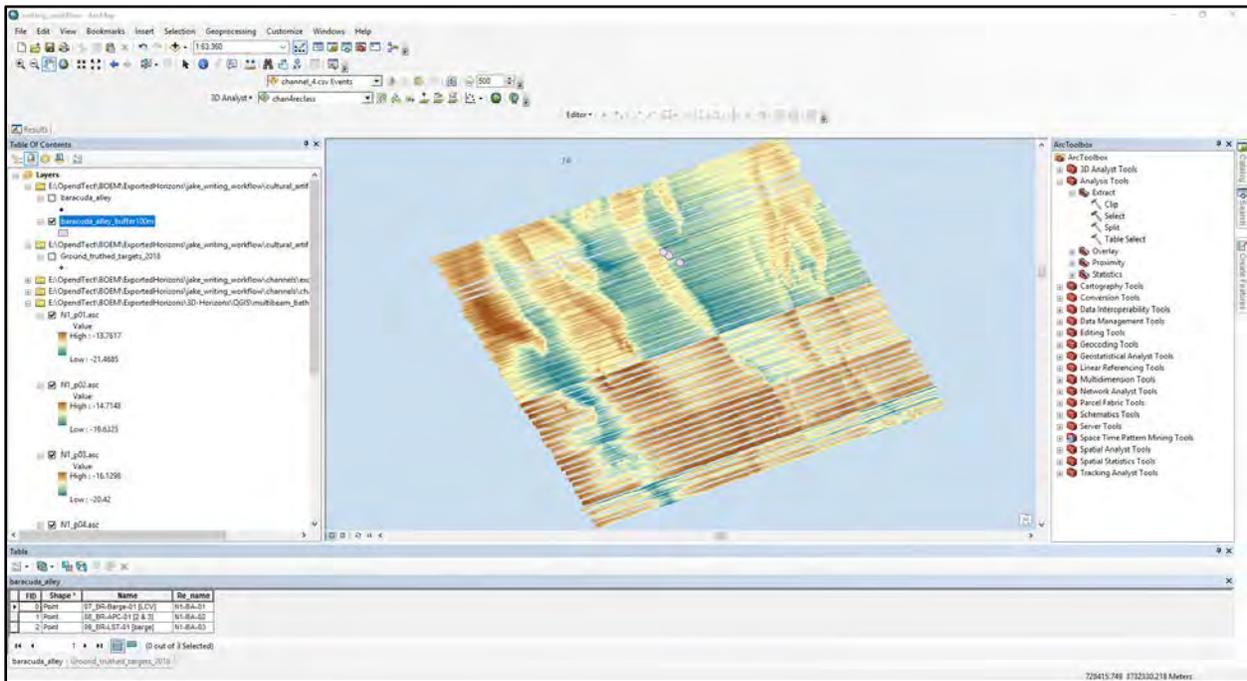
### 3.2.4.2 Cultural Artifacts

N1 contains multiple sites of cultural artifacts, which were first detected with the magnetometer, and later ground-truthed through diving operations from 14 August 2017 to 17 August 2017. These ground-truthed points were uploaded into ArcGIS.

Through diving operations, the team confirmed three cultural artifacts, denoted N1-BA-01, N1-BA-02, and N1-BA-03. These features, which compose an artificial reef named Barracuda Alley, were identified as an amphibious landing craft, a group of Armored Personnel Carriers (APC's), and a barge, respectively. The team identified the sunken vessels to host similar colonizing benthos community of organisms and fish, mostly black sea bass, porgies, juvenile grunts, and small serranids. The structures were covered in abundant ivory bush coral and solitary cup corals, with scattered gorgonians and tube-dwelling anemones in the sand.

The Extract by Select tool was used to extract only the N1-BA-01 through N1-BA-03. The Buffer geoprocessing tool was used to create a 100 m buffer around all three of these points to make sure future wind turbines are sufficiently far from these vital historic and environmental features (Figure 52).

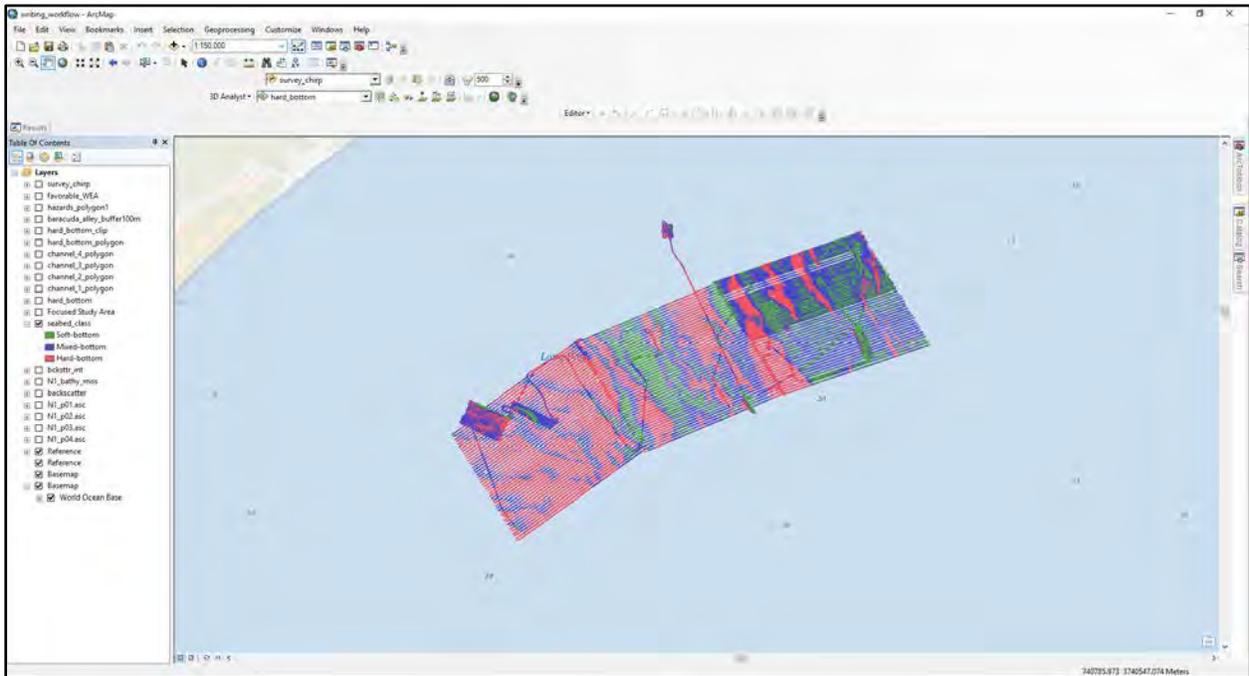
**Figure 52. A 100 m buffer applied to the three vessels**



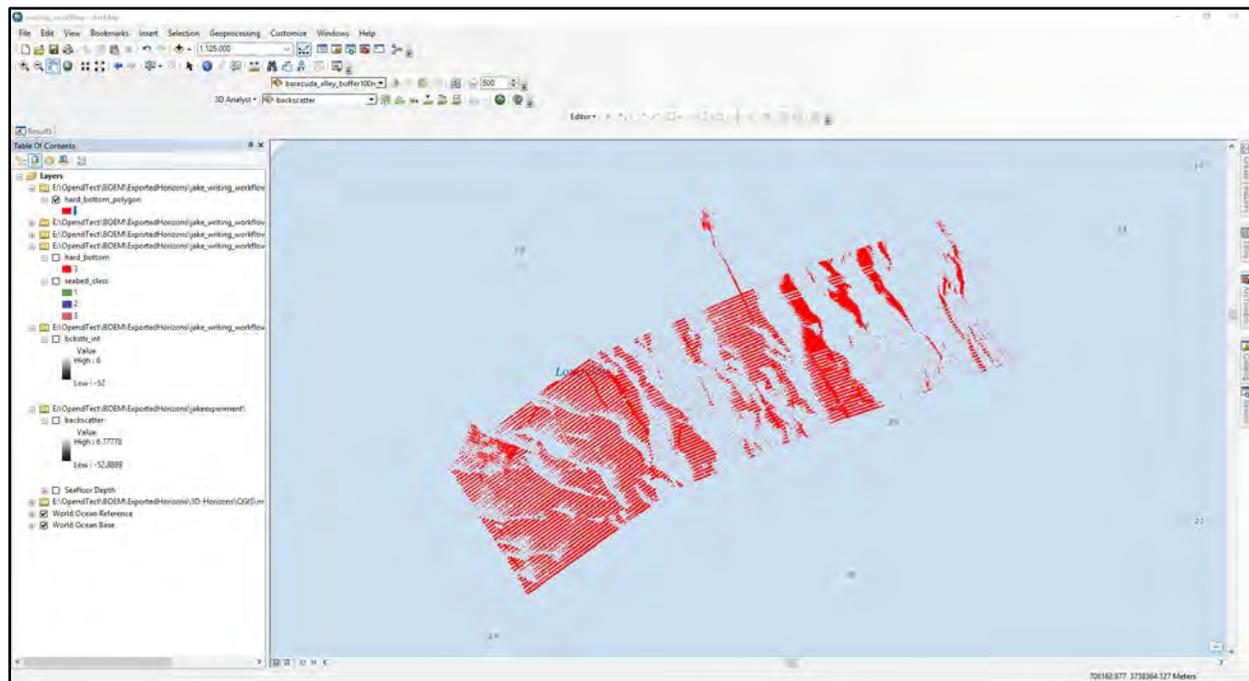
### 3.2.5 Hard Bottom

To classify our seabed, we utilized processed backscatter, along with distinctive backscatter intensity values associated with 1) soft bottom, 2) mixed bottom, and 3) hard bottom, the latter of which presents both engineering and environmental potential design considerations to our study area, as covered previously. The value associated with each bottom type was determined using an adaptive neuro-fuzzy inference system (ANFIS), which is a neural network classifier developed to apply fuzzy logic to unknown pixels (Maschmeyer, 2017). Training data was collected for the ANFIS classifier for machine learning, in which 1,000 soft-bottom, 1,044 hardbottom, and 552 cultural artifact points were recorded via tow-camera. Soft-bottom values were clustered at -32 dB, hardbottom values showed strong return at -24 dB, and mixed bottom occupied values in between.

We began our seabed classification process by importing our backscatter dataset into ArcGIS. We then utilized the Int tool to convert the continuous raster dataset into a discrete, integer type data set. To reclassify the dataset to match the seabed bottom type values, the Reclassify tool was used to create three classes: 1) soft-bottom (-52 - -32 dB), 2) mixed bottom (-31 - -25 dB), 3) hardbottom (-24 - 0) (Figure 53). To extract only the hardbottom, we used the Extract by Attribute tool. We then used the Raster to Polygon tool to convert the hardbottom raster to vector data (Figure 54). This creates a much smaller and manageable dataset.



**Figure 53. Seabed Classification map**  
Soft-bottom is colored in green, mixed-bottom in blue, and hard-bottom in red.



**Figure 22. The hard-bottom raster is now a polygon that is much more manageable**

## **4 Paleolandscapes and Prehistoric Archaeology**

### **4.1 Prehistoric Settlement (Paleoindian to Middle Archaic Periods)**

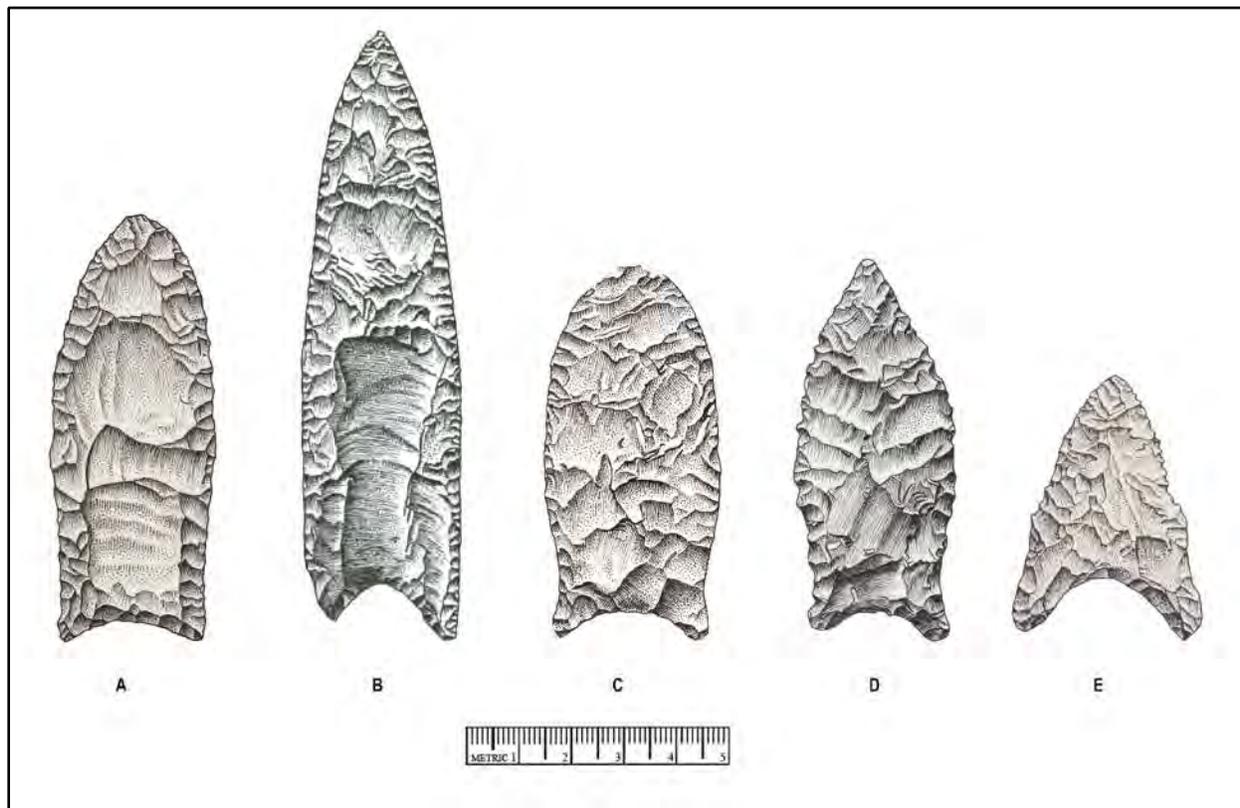
Archaeologists have been aware of prehistoric habitation of South Carolina since the discovery of stone points near Columbia in 1939 (Goodyear 2016:2). Of the 6,765 known Paleo-Archaic sites across South Carolina, about half fall within the Paleoindian (ca. 13,500–11,700 Calendar years Before Present [cal B.P.]), Early Archaic (ca. 11,700–8,900 cal B.P.), and Middle Archaic (ca. 8,900–5,900 cal B.P.) habitation periods. Late Archaic (ca. 5,900–3,200 cal B.P.) sites, dated after sea-levels stabilized at current levels, make up the other half (Christopher R. Moore, elec. comm. 2018, SC Archaeological Site Files). The predominance of Late Archaic sites suggests that additional Paleoindian to Middle Archaic sites lay offshore on the OCS. An inventory of Paleoindian and Archaic sites was undertaken utilizing the South Carolina Archaeological Site Files as part of the regional model. Most Paleo-Archaic sites fall along or above the Fall Line; however, three clusters of sites exist along the coastal shoreline and two estuaries (SC Archaeological Site Files). The concentration of habitation and exploitation sites along or above the Fall Line likely derive from access to lithic resources, though metavolcanic rock and Allendale chert have been found across the state, suggesting both migration and active trade of lithic resources (TRC 2012:40, Daniel and Goodyear 2015:323). The inventory also included Paleo-Archaic Period sites found below the Fall Line between the Santee River Basin and the Little Pee Dee River Basin, including Horry County located in proximity to the offshore survey area.

The search for sites was conducted according to each county, and cross-referenced by Paleoindian, Early Archaic, and Middle Archaic Period sites. Late Archaic sites were excluded as this period marks the limit of the timeline selected based on inundation (approximately 6,000 cal B.P.). Delineating a survey along arbitrary modern county lines may seem a poor way to conduct a prehistoric inventory, however, many of the county boundaries are based on major rivers and fall within specific watersheds. Since access to water is a factor in all prehistoric habitation sites, this method is not entirely arbitrary. Although the Little Pee Dee watershed extends east to the Waccamaw River and northeast to the Haw River in North Carolina, only site data specific to South Carolina were considered for reasons of means of access to digital site files. North Carolina does not currently retain a complete online database of prehistoric sites.

The inventory revealed a disproportionate number of Archaic sites in the database in counties along the Fall Line, where land development and infrastructure has historically seen the largest concentration of growth. This distribution of sites is apparent on the GIS map and reflects the dense prehistoric habitation (as is the case today), as well as the greater demand for surveys carried out by state road and construction regulations. Described below is a summary of the Paleoindian and Archaic Period lifeways of early humans of the American continent and the Southeast region of the United States in particular, with emphasis placed on providing a picture of early human lifeways of South Carolina. The positive location, identification, and dating of sites on the OCS would provide a tremendous contribution to archaeologists' understanding of the Paleo-Archaic archaeological record (Anderson et al. 2015:36).

#### **4.1.1 Paleoindian Period (predating 11,700 cal B.P.)**

The Paleoindian Period refers to a period of human occupation postdating the Last Glacial Maximum (LGM), ca. 20,000 B.P., and included the drastic climatic changes experienced during the Younger Dryas (a rapid regression to colder global temperatures), beginning approximately 12,850 cal B.P. (Anderson et al. 2015:13,37; Cronin 2010:218). The period is characterized by the Clovis point technology utilized by Paleoindian peoples. The period is further subdivided into the Early, Middle, and Late Paleoindian periods by archaeologists based on projectile points types: Clovis points are associated with the Early Paleoindian Period, post-Clovis fluted and unfluted lanceolate and waisted forms attributed to the Middle



**Figure 55. Examples of South Carolina Paleoindian point types**

(a) Clovis, (b) Redstone, (c) Suwannee, (d) Simpson, and (e) Dalton. (Drawing by Darby Erd, courtesy of the South Carolina Institute of Archaeology and Anthropology).

Paleoindian Period, and the Late Paleoindian Period is characterized by Dalton and related fluted types (Anderson et al. 1996:10; Anderson et al. 2015:8-9) (Figure 55). Increasing evidence also presents the existence of a pre-Clovis point technology that is temporally associated with sites predating 13,500 B.P. (Goodyear 2016:6). The impact of the Younger Dryas climatic episode on the environment resulted in drastic changes to physical geography and local fauna and flora species, most notably with the extinction of megafauna. The resulting adaptations by human populations to exploit the different resources demarcates the transition from the Paleoindian to the Early Archaic Period (Anderson et al. 2015:31-32; TRC 2012:41).

#### 4.1.1.1 Arrival of Humans in the South Carolina – Pee Dee Region

The exact arrival of humans to the Pee Dee region of South Carolina has yet to be conclusively determined. In part due to lack of multiuse, stratigraphic sites studied and in part due to the lack of material to establish accurate site dating, there is not yet enough data available to archaeologists to establish a timeline of human migration to the area (Anderson et al. 2015:29). However, based on the current data available, archaeologists have postulated two potential theories to explain the arrival of humans to the American continent via the Bering Land Bridge: a terrestrial route through the ice-free corridor to the North American interior or a maritime route along the coast. A third theory suggests a Solutrean maritime migration from Europe to explain the existence of pre-Clovis dated sites on the Eastern Seaboard (TRC 2012:17-18).

The Bering Land Bridge migration model postulates that early humans traveled from western Beringia, or modern-day Siberia, to eastern Beringia and the American continent between 20,000 and

15,000 cal B.P. Within this model are two possible migration routes early humans may have traveled. One suggests that watercraft were used to travel around the Pacific Rim and Alaskan Coast, then proceeded south along the Pacific Coast of North America and accessed the Gulf Coast and Atlantic Seaboard via the Central American isthmus. The second suggests accessing the interior of North America from eastern Beringia via an ice-free corridor that opened between the Cordilleran and Laurentide Ice Sheets as they receded. Scholars still debate the timing and method of travel south (Pitblado 2011: 341-346; TRC 2012:17-18).

After consulting and correlating the latest studies in genetic, osteological, and archaeological research of the peopling of the New World, Pitblado (2011) presents the best fit model supported by archaeologists of multiple migrations from western Beringia involving at least two major migratory events that occurred 1,000 years apart. The first major migration being the maritime Pacific Coast route that included inland travel along navigable rivers. The second migration accessed the interior continent through the ice-free corridor and that the people of this second migration developed the Clovis toolkit, distributing the technology across the continent (Pitblado 2011:351). Pitblado's proposed peopling model fits current evidence excluding eight sites that predate the possibility of this model. These sites include Page Ladson, Topper, Cactus Hill, Meadowcroft, Hebior, Schafer, and the La Sena and Lovewell localities, all of which have provided evidence of pre-Clovis technology supported by radiocarbon or optically stimulated luminescence (OLS) dates (Goodyear 2016:6; Pitblado 2011:354). For example, Topper Site on the South Carolina side of the Savannah River may be as old as 20,000 cal B.P., which predates the earliest presumed date of human occupation by 4,000 years (Dillehay et al. 2015:1; Goodyear 2005:103; Goodyear 2016:6).

Another, less endorsed, migration model that could potentially account for these early, pre-Clovis sites is the hypothesis that early peoples participated in a maritime migration from Europe to the American continent between 22,000 and 16,500 cal B.P. (TRC 2012:18). However, as Pitblado (2011) points out, none of the previously mentioned sites demonstrate evidence of maritime-based subsistence strategies, instead pointing towards a hunter-gather strategy, nor has any evidence of watercraft been recovered. Also, contributing evidence (genetic, osteological, and archaeology) consistently agree that all first Americans share a northeast Asian origin (Pitblado 2011:354-357). At this time, simply more data from this earlier period of occupation are required to substantiate or refute the current migration pattern models.

#### **4.1.1.2 Subsistence Strategies**

The Paleoindian Period experienced drastic climatic and environmental changes with the glacial retreat post-LGM and the later, temporary return to glacial conditions of the Younger Dryas. Flora and fauna in the Southeast changed rapidly because of deglaciation and warmer temperatures. Adaptable species migrated inland from the rising sea-level as well as north as the terrain became available after deglaciation. For example, areas of hardwood and pine forests extended north to replace boreal species as they moved farther north. Fauna associated with the Pleistocene (mammoth, mastodon, bison, camel, horse, giant ground sloth, and saber-tooth cat) became extinct due to the climatic changes of the Younger Dryas and made way for Holocene populations such as deer, bear, rabbit, raccoon, and squirrel. A change in food sources would have required an adaptation by the Paleoindian population to exploit the new resources (Anderson et al. 2015:13).

To understand the subsistence strategy of any culture requires a full assemblage of the cultural components. In the Southeast region, this is challenging due to the warm, humid climate and the surface geology that has a distinct lack of substantial sedimentary accumulation since the Pleistocene. For most of the recorded Paleoindian sites in the state, lithic materials are all that were recovered because soil conditions in the Southeast are unfavorable to the preservation of organic materials. Therefore, archaeologists are only able to theorize potential subsistence strategies practiced by early Paleoindian

peoples until new evidence is uncovered, especially at the local level (Anderson et al. 2015: 24, 35; TRC 2012:38-39). Emphasis is placed on the greater potential for submerged sites to preserve organic materials such as bone, textiles, wood, and ivory as seen at Page Ladson in Florida (Anderson et al. 2015:36).

Fluted projectile points found in association with human-altered megafaunal remains supports the interpretation that Clovis people were highly mobile, large game hunters (Sain 2012:7). The recovery of diverse organic assemblages datable to the Late Paleoindian Period has provided greater insight into early subsistence activities. Primarily rock shelter sites, such as Dust Cave, and submerged sites in Florida have yielded well-preserved floral and faunal assemblages that indicate the importance of small game and plant foods in addition to megafauna to Late Paleoindian subsistence. While the importance of plant food to early populations has yet to be confirmed, there is no apparent correlation between Paleoindian lithic materials and megafauna species in Georgia, South Carolina, or North Carolina (Anderson et al. 2015:35; Sain 2012:13; TRC 2012:39).

#### **4.1.1.3 Settlement Patterns**

Establishing the settlement patterns of Paleolithic populations presents the same challenges as understanding their subsistence strategies. Most Paleoindian sites in the state consists of isolated finds, or lithic scatters and complex, multicomponent sites are limited to a handful. There has yet to be located and studied a settlement site containing evidence of permanent structures or long-term use from this period in the Southeast (TRC 2012:39). More evidence is needed to refine or refute existing migration and settlement pattern models (Anderson et al. 2015:24). However, there are consistent factors that would have influenced early human settlement that are all related to environmental constraints, such as climate, subsistence requirement, location and availability of raw materials, the associated risks involved to acquire necessary resources, and the time required for travel and to acquire and produce food, tools, and other associated materials (Sain 2012:16). It is believed that earlier populations were much more mobile than subsequent groups as part of the regionalization process (Anderson 1996:16).

The trend of settlement for Paleoindian peoples in the Southeast region, as described by Anderson, began with Early Paleoindian groups establishing the foundations of early cultural regionalization by occupying staging areas that accommodated the settlement of a more extensive region. From this micro-band level of organization, the settlement of the Southeast was gradual and progressed in a step-wise fashion (Anderson et al. 1996:16; Anderson et al. 2015:24). The specialization of lithic technology, particularly the number and diversity of point types indicates the regional settlement in populations by the Late Paleoindian Period (Anderson et al. 2015:32).

The most influential of the existing models is Garner's Flint Run Lithic Determinism model that Paleoindian settlement and migration were tethered to known stone quarries as reliable sources of raw lithic materials to replenish toolkits. According to this "place-oriented" model, Paleoindian people primarily settled in base camps near the quarry with scheduled ventures to take advantage of surrounding resources and occupying temporary camps for a portion of the year before returning to the quarry occupation sites. Based on the distinct lack of evidence for megafaunal kills or lithic cache sites, this model is a more plausible explanation of Southeastern Paleoindian settlement than the "technology-oriented" model of these people as highly mobile, large game hunters. Instead, the model suggests that populations in the East were "selectively mobile within a prescribed territory" with the location of quarry sites largely influencing settlement patterns (Anderson et al. 2015:18, 31). Additional models agree with the premise of Gardner's model, but suggest that it was the water sources these quarry sites are adjacent to rather than the presence of lithic material that motivated settlement patterns (Sain 2012:43).

Support for Garner's model is evidenced in the recovery of exotic raw material types from South Carolina sites. Metavolcanic and Redstone artifacts, the primary source of which is in the Uwharrie Mountains in North Carolina's Piedmont region, have been recovered from sites in the South Carolina Piedmont and Inner Coastal Plains as well as sites as far south as Florida up to 100 to 300 km from the

source (Anderson et al 2015:31; Daniel and Goodyear 2015:324-328). At Topper, in addition to the presence of local chert, exotic raw materials were recovered from the site's Clovis deposit and included rhyolite sourced from the east-central Piedmont of North Carolina (Sain 2012:11). The wide distribution of such raw materials is indicative of the possibility for both a highly mobile and adaptive population as well as one with extensive trade networks (Sain 2012:7).

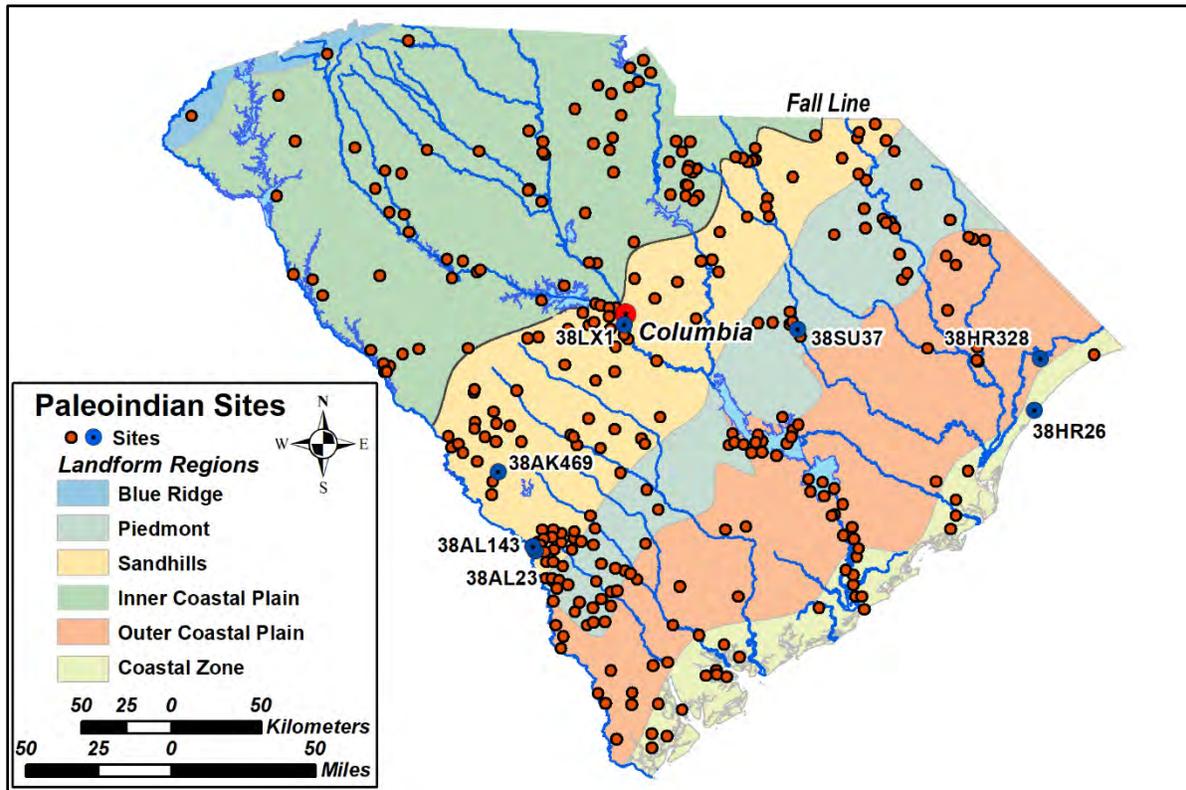
The theory that lithic blades and points comprised part of an active prehistoric trade system is reinforced by the wide distribution of metavolcanic stone. Metavolcanic stone has been recovered from its source in the Uwharrie Mountains of North Carolina, and from sites south into the Pee Dee River basin of South Carolina. Similarly, Topper chert is distributed across South Carolina and south into Georgia (Daniel et al. 2015:323; Goodyear 2016:6). Though most Clovis sites are found above the Fall Line, the majority of individual stone points are found on the coastal plain (Goodyear 2005). This may reflect discard of damaged points, the trade network of lithic resources as mentioned above, and the sampling method of the South Carolina Collectors Survey.

#### 4.1.1.4 Known Sites

To date, there are approximately 154 Paleoindian sites recorded in South Carolina. This total includes 261 fluted points (out of over 600 total) recorded as part of the South Carolina Paleoindian Survey conducted by Jim Michie, Tommy Charles, and Albert Goodyear between 1980 and 2005 (Goodyear 2005) (Figure 56). This survey continues as a function of the greater Southeastern Paleoamerican Survey and results are cataloged in the Paleoindian Data Base of the Americas (Anderson et al. 2010, Goodyear 2016:4). Regionally, more than half of the fluted stone points were found on the Coastal Plain (221), the others found on the Piedmont (116) or the Fall Line (93), with a fraction of them found in the Blue Ridge (Goodyear 2005). This contrasts with most of the habitation sites located on or above the Fall Line, suggesting trade or discard during seasonal migration by Clovis people (Evans 2014:30). Since the 1980s, nine terrestrial and underwater prehistoric chert quarries have been discovered among the Coastal Plain chert outcrops in Allendale County, South Carolina (Goodyear 2016:5). There are only a handful of sites in the southeast region that have provided conclusive and *in situ* archaeological data dating to the Paleoindian Period. There are four major Paleoindian sites excavated in the state and include Flamingo Bay, Taylor, Topper, and Big Pine Tree (Anderson et al. 2015:22). Additional sites located near the project area include Site 38SU37, Surfside Spring site, and Site 38HR328.

Flamingo Bay (38AK469) is unique as a Carolina Bay site. Archaeologists recognize Carolina Bays as important water sources for Paleoindian and Archaic hunter-gatherers; however, little work has been done to study these areas (Anderson et al. 1996:76-78). Two Allendale chert Clovis point bases were recovered from the excavation of the undisturbed Paleoindian deposit along with unifacial tools, a retouched blade, and utilized flakes (Anderson et al. 2015:22; Moore et al. 2010:110). These artifacts, especially the broken Clovis bases, are indicative of a Clovis assemblage distant from the quarry source and reflect long-range movement or trade. It may be inferred that Clovis sites found on the OCS may display similar characteristics of highly mobile lifeways (Moore et al. 2010:110).

The Taylor Site (38LX1) is located near present-day Columbia in the central South Carolina Piedmont on the Fall Line along the Congaree River. It is one of the largest Paleoindian and Early Archaic sites in South Carolina, encompassing approximately 14 hectares. Surface finds included Clovis, Suwannee, Dalton, and Palmer points (Daniel 1998:199-200). The significance of Taylor has greater implications for its Early Archaic horizon, however, below the Early Archaic assemblage was a clear Paleoindian horizon that included ten Dalton points recovered from excavation (Anderson et al. 2015:22). Topper Site (38AL23) is located on a terrace overlooking the Savannah River in Allendale County, South Carolina, part of the central Savannah River Valley. The site is the oldest and most complex Paleoindian period site in South Carolina. Subsequent testing suggests the site is as old as 20,000 B.P., which also makes it the oldest in the Americas pre-dating the previously known oldest site in Monte Verde, Chile,



**Figure 56. Paleoindian sites in South Carolina**

which was recently dated to 18,500 B.P. (Dillehay et al. 2015:1; Goodyear 2016:6). Not only is Topper the oldest site, but it is also the largest with an estimated area of 35,000 square meters, potentially greater (Goodyear 2016:10).

Topper has been identified as a complex, multicomponent, multigenerational Allendale chert quarry and manufacturing site. The focus of research has centered on studying the Clovis and pre-Clovis deposits, however, cultural deposits have been identified up to the Mississippian Period (Goodyear 2016:6-7; Sain 2012:47). Most Clovis artifacts include a variety of bifaces, denticulates, preforms, blades, cores, end and side scrapers, retouched flakes, and associated reduction debitage (Goodyear 2016:10; Sain 2012:1). Only four Clovis points were recovered on site, as well as preforms in various states of reduction and retouched blades. Archaeologists interpreted the lack of points as indicative of Clovis people resupplying toolkits with materials to be worked later while conducting their main hunting activities in the wider settlement system (Goodyear 2016:9-10; Sain 2012:3). Artifacts recovered from the pre-Clovis Period deposits consist of chert cores and choppers, debitage, unifacially retouched flakes, and small tools (Goodyear 2016:6-7). The artifacts display unique characteristics associated with smash-core technology: microlithic in size, distinctly non-bifacial, and displaying a bend-bread reduction technique to produce tools closely resembling burins. The presence of microlithic tools and core choppers may suggest the crafting of organic artifacts using bone, antler, or wood (Goodyear 2005:110).

Big Pine Tree (38AL143) is a multicomponent high-quality chert quarry site and lithic processing site with evidence of multigenerational exploitation from every cultural sequence. The site is in Allendale County in the Central Savannah River Valley, approximately two kilometers from Topper Site. A dense concentration of artifacts was uncovered from within an alluvial terrace overlooking Smith Lake Creek. Artifact types included fluted bifaces, blades, cores, and associated debitage (Sain 2012:127). Unlike Topper site, a greater density of artifacts and the large portion of retouch and utilized blades recovered,

indicative of the importance of crafting activities onsite, suggest that some level of habitation occurred at Big Pine Tree (Sain 2012:128-132).

Site 38SU37 is a large, multicomponent site incorporating several sites in close association. This Coastal Plain site is located on the banks of the Black River northeast of Sumter in a low-lying field near a swamp. Paleoindian through Woodland periods are represented in the artifact assemblage. Lithic point types are comprised of Clovis, Dalton, Hardaway, Palmer, Taylor, Kirk-corner notched, Kirk-stemmed, Stanly, Morrow Mountain, Guilford, and Savannah River. Also included in the assemblage are flakes, cores, unifaces, and bifaces. Lithic materials include Coastal Plain chert, unidentified metavolcanics, rhyolite, and other sources. The data suggests this site was at least a temporary habitation site (SC Archaeological Site Files).

The Surfside Spring site (38HR26) was identified in 1975 during dredging operations of a small pond for a development project. The site is located on the coast, just south of Myrtle Beach. Bones from several extinct megafauna were recovered from the site, including mammoth, and other species, such as bison. The faunal remains were displaced, along with two lithic tools made from consolidated marl. A freshwater spring no doubt drew both animals and humans to the site, but unfortunately, the systematic destruction of the site precluded any archaeological analysis to determine if there was any association between the tools and the megafauna. Subsequent investigation by a professor and students from Coastal Carolina University did not yield any additional information to confirm or refute an association between the two. Due to the disarticulation of the site, the function of this site is unclear (SC Archaeological Site Files).

Site 38HR328 is comprised of Late Paleoindian components, including several Hardaway and Dalton Points made of quartz, as well as some artifacts dating to the Woodland Period. This site was most likely a short-term, transitional campsite. The site is located near a swamp on the south bank of the Waccamaw River east of Conway in Horry County (SC Archaeological Site Files).

#### **4.1.1.5 Tools/Sources/Organics**

As mentioned previously, organic material has not been recovered from sites in South Carolina; therefore, it remains unknown which floral and faunal sources were favored by Early and Middle Paleoindian people (Anderson et al. 2015:13). Due to the potential for greater preservation of submerged sites, archaeologists speculate that well preserved organic material may be recovered from sites on the OCS (Anderson et al. 2015:36). With the lack of a full cultural assemblage from the Paleoindian Period, the dates defining cultural transitions are determined by lithic point type. With the limited assemblages of pre-Clovis technology recovered and distinct rationality characterizing artifacts, the most accurate descriptor of pre-Clovis technology is that artifact from this period predate Clovis (Goodyear 2016:6-7). Clovis technology, as the oldest diagnostic cultural complex identified in the Americas, defines the Early Paleoindian Period, ca. 11,500 to 10,800 B.P. (Anderson et al. 1996:10; Sain 2012:7,47). The Middle Paleoindian period, ca. 10,800 to 10,500 B.P., is defined in the Southeast by post-Clovis lithic point types including Clovis variants, Sampson, Suwanee, and Cumberland points that are characteristically fluted and unfluted lanceolate and waisted forms. Beaver Lake and Quad points are indicators of the transition into the Late Paleoindian Period, ca. 10,800 to 10,000 B.P. with fluted and unfluted Dalton points more characteristic of the end of the Paleoindian period (Anderson et al. 1996:10; Anderson et al. 2015:32).

While point types serve as diagnostic evidence, other tool types have been identified as part of the Paleoindian toolkit. A toolkit refers to the collection of tools carried by Paleoindian people to utilize for acquiring and processing food resources and materials. Types of tools identified as part of the toolkit included any number or combination of the following: bifaces, unifaces, blades, cores, preforms, side and end scrapers, graters, burins, denticulates, and utilized flakes and may have been made of bone or ivory, not only lithic material (Anderson et al. 2015:30; Sain 2012:13,51). Biface tools were perhaps the most

versatile for their apparent potential as “transportable quarries” to be used in future situations while engaging in subsistence efforts. Bifaces could have functioned as designated cutting tools, preforms for the later manufacture of projectile points, or as cores for the expedient production of flake tools as groups migrated across the landscape (Sain 2012:14).

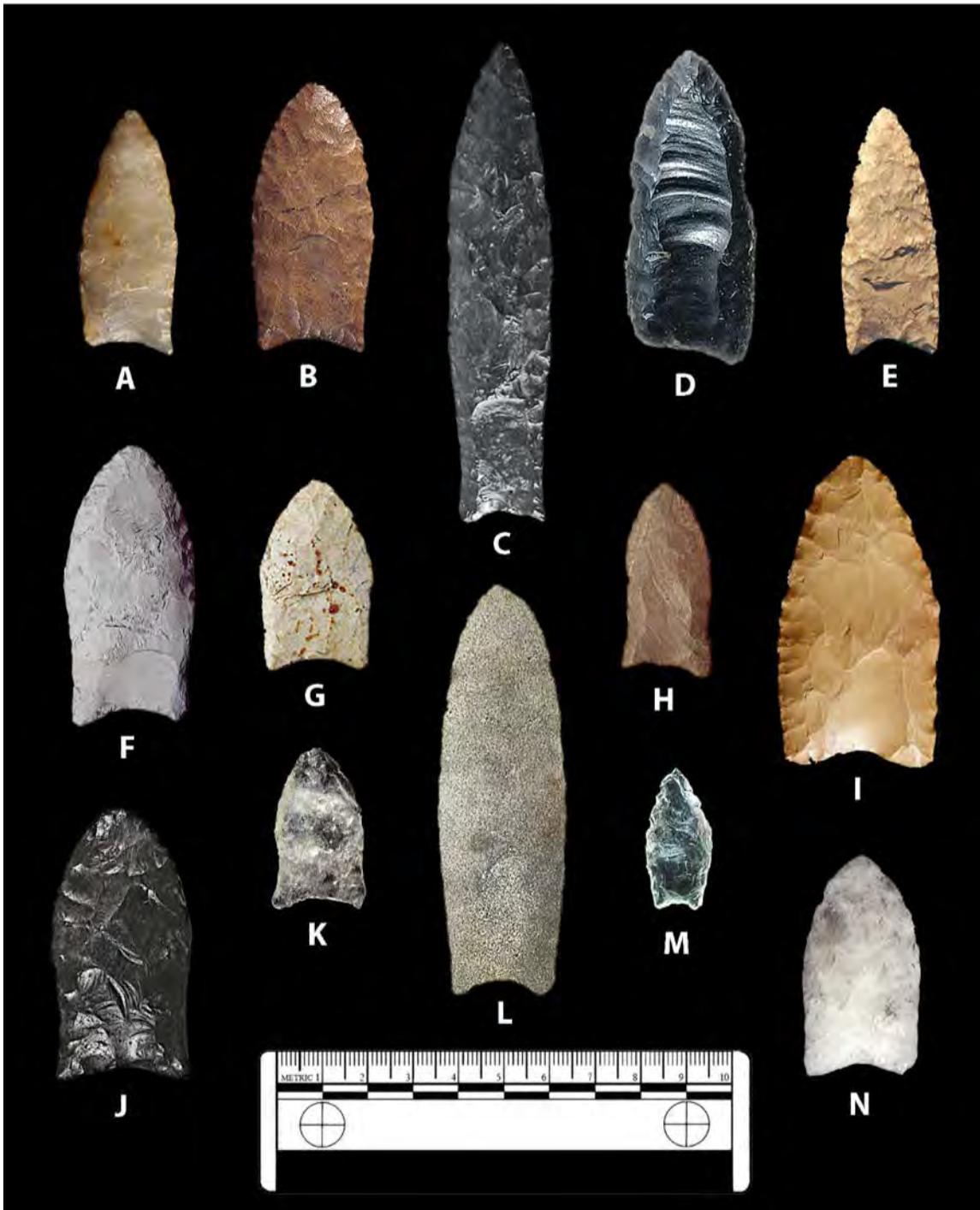
Two main components of utilizing lithic materials to manufacture stone tools are the quality of the raw materials used and the availability of the resource. The quality of the tools produced, such as blades and projectile points, directly correlates with the quality of the raw lithic material. The best lithic materials for knapping are those that are homogenous, fine-grained with the fewest inclusions, are elastic and brittle, and that give conchoidal fractures (Sain 2012:18-21). Access to sources of such quality materials, therefore, was a crucial aspect of the Paleoindian settlement strategy (Anderson et al. 2015:18). The highest quality materials used for Clovis artifact production in South Carolina include Allendale Chert, sourced to Topper and Big Pine Tree sites in South Carolina, and Uwharrie rhyolite sourced to the Piedmont region of the Slate Belt in North Carolina. Based on artifact distribution, Daniel and Goodyear (2015) found evidence of Uwharrie rhyolite points in the Pee Dee region of South Carolina originating in North Carolina quarries (Daniel and Goodyear 2015:325) (Figures 57 and 58). Recovered artifacts that are made of lower quality raw materials are more likely to be locally sourced and are more prominently found in association with Late Paleoindian assemblages. Anderson et al. (2015:13) suggest this pattern attributed to changes in subsistence, reduced migration, and/or limited access to quality materials.

#### **4.1.2 Archaic Period**

The Archaic Period began approximately 11,700 cal B.P. at the end of the Younger Dryas climatic event and terminated approximately 5,900 cal B.P. The period is subdivided into the Early (ca. 11,700-8,900 cal B.P.), Middle (ca. 8,900-5,900 cal B.P.), and Late Archaic (ca. 5,900- 3,200 cal B.P.) periods defined by archaeologists according to a chronology of distinct projectile point types (Daniel 1998:3). The Dalton and similar styled points of the Late Paleoindian Period were replaced with side-notched, corner-notched, and bifurcate point traditions in the Early Archaic (Anderson et al. 1996:60-64), followed by stemmed, bifurcate, and small lanceolate point technologies in the Middle Archaic (Christopher R. Moore, elec. comm. 2018; Sassaman and Anderson 1995:21). Below are the descriptions of the Early Archaic and Middle Archaic periods. The Late Archaic Period was excluded since sea-levels had risen to approximately current levels by 6,000 cal B.P., which predates the beginning of the Late Archaic Period (Anderson et al. 1996:58).

##### **4.1.2.1 Early Archaic Period (11,700 – 8,900 cal B.P.)**

The beginning of the Early Archaic Period roughly coincides with the terminus of the Younger Dryas, an event that resulted in drastic environmental changes, and represents the transition of Paleoindian hunter-gatherer adaptations to new subsistence resources (Daniel 2001:237). By the end of the Younger Dryas, the environmental conditions had shifted globally into a warmer climate. In the Southeast, the climate transitioned into the warmer, humid, and damper conditions with greater variability of seasonal temperatures. The change in climate impacted local biota in the region. Late glacial boreal forests retreated north and were replaced along the South Atlantic Slope by mixed hardwood forests that included more deciduous species such as oak, elm, walnut, hemlock, beech, and maple (Daniel 1998:197). Extinct megafaunal species of the Pleistocene were replaced by game species such as deer, bear, and small mammals (Anderson et al. 2015:31-32; Daniel and Goodyear 2015: 255, TRC 2012:40). In response to these changes, Early Archaic groups experienced an adaptive transition in their lifeways with different subsistence sources, a more regionalized settlement with seasonal migration in smaller highly mobile bands, and changes in lithic technology (Abbott 2004:12; TRC 2012:42).



**Figure 57. South Carolina Fluted Paleolithic points made from various lithics**

(A, I) unidentified chert; (B) unidentified chert or Jasper; (C, J) Coastal Plain chert, stained from river; (D) ridge and valley-like chert; (E, G) Coastal Plain chert; (F) Rhyolite; (H) flow-banded Rhyolite; (K, M) crystal Quartz; (L) Orthoquartzite; (N) vein Quartz. (Fig. 2.1, pg. 5, in Charles and Moore, 2018).

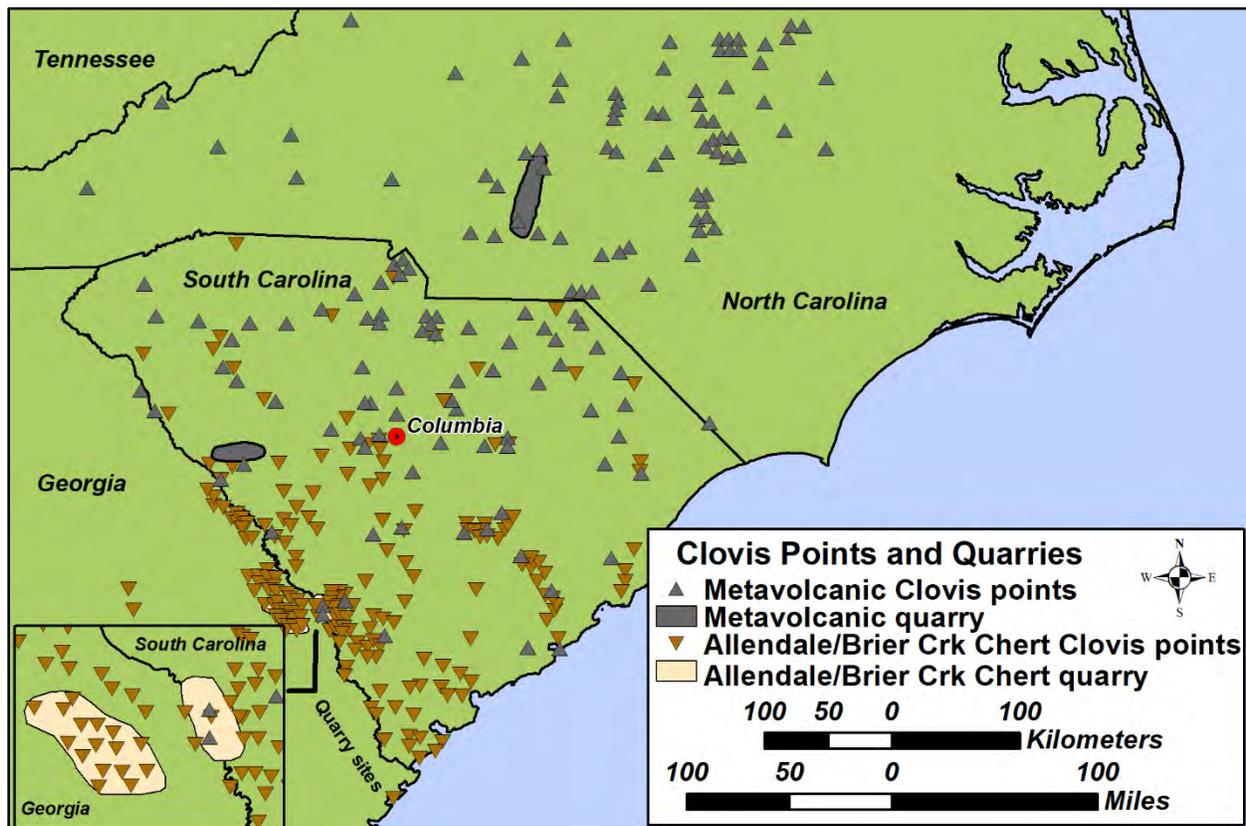


Figure 58. Clovis Points and Quarries in North Carolina, South Carolina, and Georgia

#### 4.1.2.1.1 Subsistence Strategies

As was the case in the Paleoindian archaeological record, Early Archaic assemblages of sites along the South Atlantic Slope are primarily comprised of lithic artifacts (Daniel 2001:237). Subsistence data is best represented by organic material, of which very few artifacts have been recovered from this period due to the acidity of the soil in the Southeast (Anderson et al. 1996:58; TRC 2012:39-41). However, using data from other Early Archaic sites, it can be inferred that subsistence strategies in the Southeast relied on resources such as nuts, berries, seed-bearing plants, small game, and white-tailed deer (Daniel 1998:196). Early hunter-gatherers were believed to have settled in long-term base camps during the winter months when food resource availability was most uncertain. During the remainder of the year, when food resources were more prominent and predictable, smaller foraging groups traversed between the Piedmont and Coastal Plain. Without organic data, the Early Archaic subsistence strategy of the region may be reflected in the settlement pattern of early people (Daniel 2001:254).

There is the potential on the OCS for organic archaeological materials. Sites on the OCS also may provide evidence that marine resources formed part of the Early Archaic subsistence strategy. Early bands are suspected to have directed their foraging mobility towards the coast following the winter months before moving inland towards the Piedmont for the summer months (Daniel 1998:187-188). The recent discovery of an Early Archaic stone point on Folly Beach, Charleston, South Carolina and the concentrations of Early Archaic sites along the shoreline suggests that the coast would likely have attracted early hunter-gatherers for the exploitation of marine resources (Bryan Philips elec. com 2015).

#### 4.1.2.1.2 Settlement Patterns

Like the Paleoindian period, the limited data currently available in the archaeological record from the Early Archaic period results in theorized settlement models rather than concrete knowledge of settlement strategies. There are two models that offer interpretations for the settlement patterns of Early Archaic groups in the Carolinas: Anderson and Hanson first proposed the band-macroband mobility model based on evidence from sites in the Savannah River valley (Sassaman et al. 2002:167). In contrast, Daniel more recently offered an alternative with the Uwharrie-Allendale model after testing the band-macroband model in the Yadkin-Pee Dee watershed (Daniel 2001:240).

Based on survey and analysis of eight Early Archaic sites in the Savannah River valley in the 1980s, Anderson and Hanson proposed the band-macroband model to explain settlement mobility of Early Archaic groups on the South Atlantic Slope (Sassaman et al. 2002:167). This model presents a comprehensive interpretation that considers both the biological and social requirements of early hunter-gatherers in the context of their logistical, forager adaptations (Daniel 1998:7-8). According to this model, individual bands, numbering between 50 to 150 individuals, inhabited each of the eight major river drainages between the Neuse River in North Carolina and the Ocmulgee River in Georgia. Each band migrated throughout the year along their respective drainages between the Piedmont and the Coastal Plain, settling in winter base camps for a season and occupying temporary settlements throughout their ranges for the rest of the year. The bands only occasionally migrate cross-drainages at the Fall Line as part of macroband engagement to exchange information and maintain mating networks (Daniel 2001:238-239).

The theory behind the band-macroband model relies heavily on Lewis Binford's middle range theory in combination with Goodyear's cryptocrystalline adaptive strategy. Goodyear's adaptive strategy originally applied to Paleoindian settlement patterns but was adapted for Early Archaic group mobility. The strategy suggests that early hunter-gatherers facilitated their vastly mobile lifestyle by transporting high quality, nonlocal stone tools across large territories that had limited availability of high quality raw lithic resources, as evidenced by the recovery of high quality, nonlocal stone from sites far distant from their geological source. Applying Binford's theory, Anderson and Hanson conducted an artifact analysis on the assemblages of eight sites along the Savannah River, categorizing them according to material type as curated or expedient technologies. Based on the ratios between curated and expedient at each site, they interpreted the sites uses and the band's mobility as collector or forager settlements (Daniel 1998:5-8). Using this model, for example, Anderson and Hanson interpreted the G.S. Lewis-East site as a collector winter base camp based on the high frequency of curated Coastal Plain chert tools. They interpreted the Rucker's Bottom site, which displayed a high frequency of expedient tools made of local quartz, as a forager camp (Sassaman et al. 2002:167-168).

Although recognized for its comprehensive interpretation of the biological, social, and ecological factors that impacted Early Archaic settlement patterns, both Daniel (1998, 2001) and Sassaman et al. (2002) criticize the accuracy of the band-macroband model. They both disapprove of its emphasis on collector-forager subsistence patterns and the low value it places on the importance of high-quality stone availability as part of the subsistence resources (Daniel 1998:191; Daniel 2001:239; Sassaman et al. 2002:167). Daniel argued that the band-macroband model was shortsighted because it had not been tested outside the Savannah River valley. Using the same curated-expedient analysis, Daniel applied the band-macroband model approach to Early Archaic site assemblages in the Yadkin-Pee Dee drainages. Daniel interpreted the evidence as indicative that settlement range experienced annual variation depending on food availability, that band traversed several watersheds within their ranges, and that their movements included the geological distribution of high-quality knappable stone. In contrast to the band-macroband model, he proposed in the Uwharrie-Allendale model (Daniel 1998:260; Daniel 2001:239).

According to the Uwharrie-Allendale model, early hunter-gatherers congregated in territories around the known high-quality lithic sources in the Carolinas as part of the regionalization process in the

early Holocene. Daniel identified two distinct territories centering around the accessibility of Allendale chert south of the Santee River and Uwharrie rhyolite to the area north with an area of aggregated territory between the territories. He defined these territories based on the artifact distribution of Early Archaic point made from these lithic materials and the presence of complex, long-term base camps located near known Allendale and Uwharrie quarries. Hardaway in North Carolina is located near Morrow Mountain, and G.S. Lewis-East and Pen Point in the Savannah River valley of South Carolina are near Allendale chert quarries (Daniel 2001:252-253). Although only two band territories are mentioned, Daniel acknowledges that both ranges had the capacity to sustain several bands contemporaneously (Daniel 1998:194). Further, Daniel draws a correlation between the distribution of material types to the distribution of Taylor and Hardaway Side-Notched points:

The existence of two different but presumably coeval side-notched point types, with mutually exclusive geographic distributions predominantly associated with either Allendale chert or Uwharrie rhyolite, lends credence to the two settlement ranges proposed here (Daniel 1998:195).

As evidence to the existence of an aggregation range between the Uwharrie and Allendale territories, Daniel presents the diverse assemblages of Manning, Thoms Creek, and Taylor sites located on or near the Fall Line as examples. The assemblage from Taylor, for example, had equal frequencies of chert and metavolcanic points, was accessible to both Allendale and Uwharrie groups, and is located approximately equidistant from both sources (Daniel 1998:199-200). According to Daniel, "the Uwharrie-Allendale model better explains both the concentration of sites such as Taylor along the Congaree and their marked absence elsewhere in the Carolinas." (Daniel 1998:201).

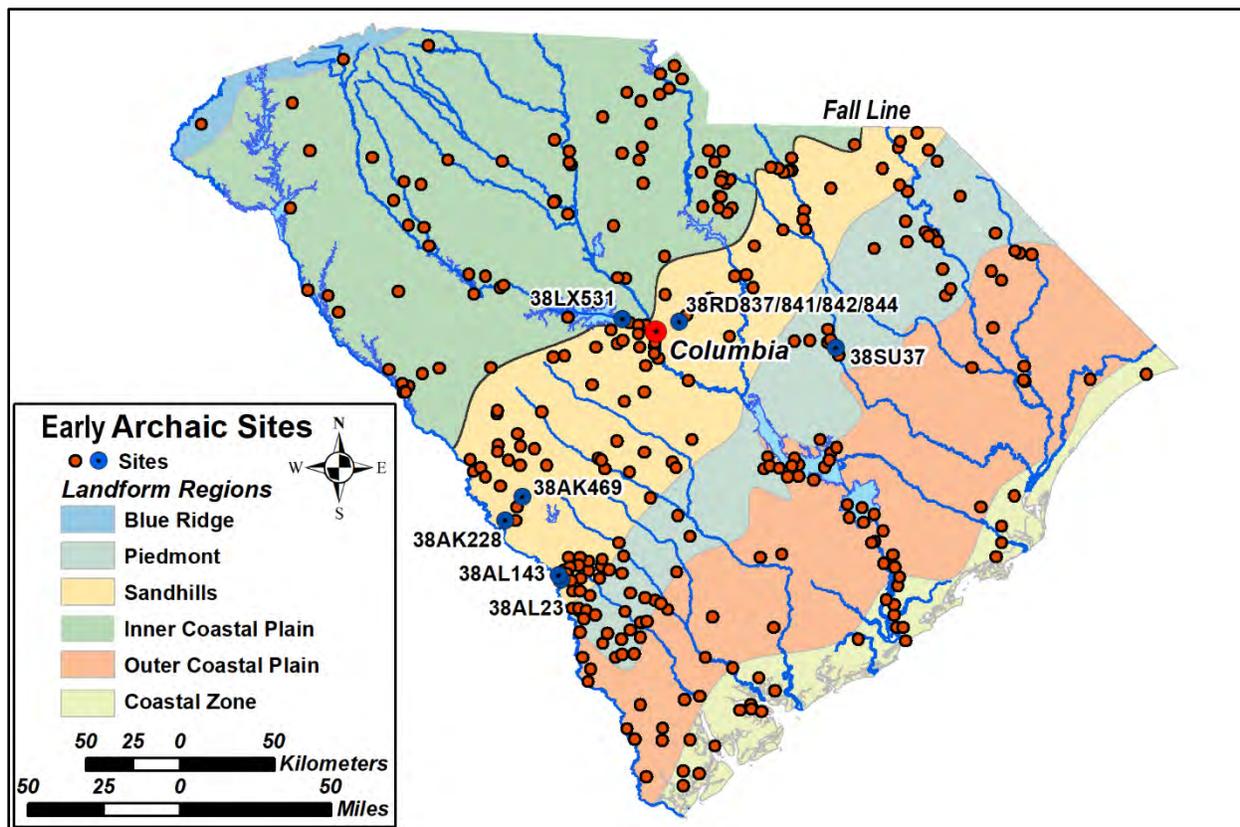
Sassaman et al. (2002) did not present a settlement model in their report on G.S. Lewis-East site. However, since both Anderson and Hanson and Daniel used G.S. Lewis-East as case studies to support their settlement models, Sassaman et al. critiqued the interpretations of both the band-macroband and Uwharrie-Allendale models of the site.

The technology of the Savannah River sites informs us less about settlement configuration than about how an Early Archaic technology was organized with respect to the availability of stone. Tool curation has little relevance for predicting settlement type without consideration of local patterns of raw material availability (Sassaman et al. 2002:169)

In their interpretation, the evidence of tools produced and utilized on site and those prepared for use elsewhere suggests that G.S. Lewis was a long-term settlement site (Sassaman et al. 2002:108). Based on the prominence of Coastal Plain chert curated and expedient tools in the assemblage, production strategies were interpreted to focus on obtaining the high-quality material from Allendale quarries to equip toolkits for long range use. The use of Coastal Plain chert in the Savannah River valley was equally influential as food resources in determining the composition of Early Archaic assemblages (Sassaman et al. 2002:168-169).

#### **4.1.2.1.3 Known Sites**

Early Archaic sites vastly outnumber the recorded Paleoindian period sites with approximately 1,319 Early Archaic sites identified in South Carolina (SC Archaeological Site Files) (Figure 59). Listed below



**Figure 59. Early Archaic sites in South Carolina**

are the more complex and well-documented sites from this period (Hardaway, G.S. Lewis-East, Pen Point, and Rucker's Bottom), specifically those that played a significant role in the study of Early Archaic settlement patterns. Due to the distribution of Uwharrie lithic material in the Pee Dee region of South Carolina, Hardaway has been included despite its geographical location in North Carolina.

The concentration of three clusters of Early Archaic sites along the shoreline south of Charleston and estuarine areas of the Pee Dee and Edisto-Savannah River basins suggests that the subaerial OCS and paleo-river channels, estuaries, and bays would likely have attracted Early Archaic people for the exploitation of marine resources. This idea is affirmed by the recent discovery of an Early Archaic stone point on Folly Beach, Charleston, South Carolina. The point was found by residents (and reportedly other points as well) after recent beach re-nourishment (Bryan Philips elec. com. 2015). The sands were dredged from a borrow eight kilometers (5 miles) offshore, the borrow site was reportedly sterile but apparently included an Early Archaic site with the blade dating to around 9,000 B.P. (ACE 2013; Powell 1990; Goodyear pers. com 2015).

Although located in the North Carolina Piedmont, the Hardaway site (31ST4), located on the Yadkin River, about 50 miles north of Charlotte, is included here due to the prevalence of Uwharrie rhyolite points recovered from the South Carolina's Pee Dee region. Hardaway is unique for its undisturbed Early Archaic horizon, complexity, and location near a high-quality lithic quarry site. The site has been interpreted as a quarry base camp, probably occupied during the winter months, which facilitated restocking toolkits with Uwharrie rhyolite (Daniel 2001:241). The site, in combination with data collected from two nearby Middle Archaic sites, was instrumental in developing the Archaic Period projectile point chronology. The significance of the site in the development of Daniel's Uwharrie-

Allendale settlement model further emphasizes the site's contribution to understanding Early Archaic lifeways in the Carolinas (Daniel 1998:1-2).

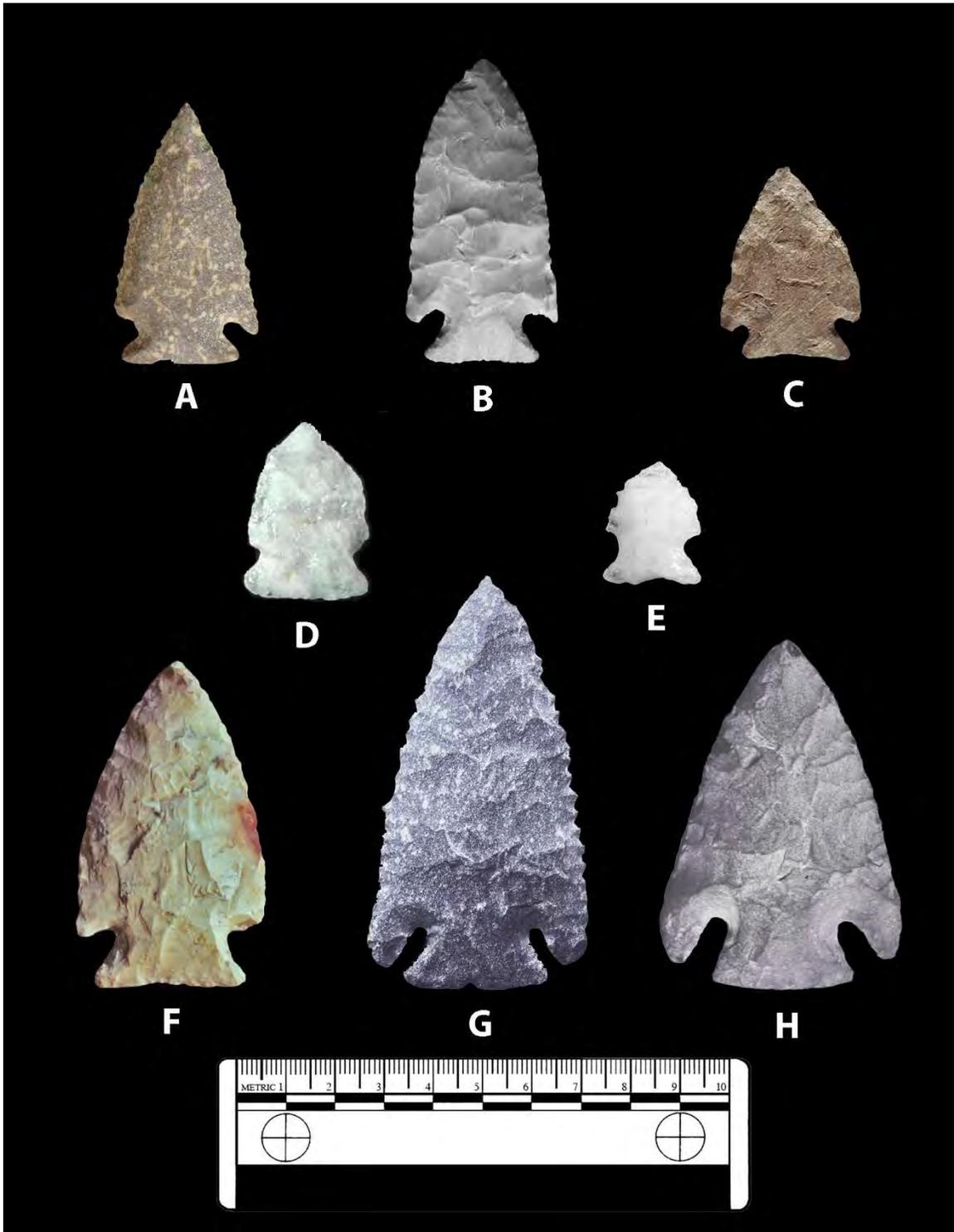
G.S. Lewis-East (38AK228) is a large, complex site with numerous and varied artifact assemblages dated to the Early Archaic in the Savannah River valley of South Carolina (Sassaman et al. 2002:1). Artifacts recovered from G.S. Lewis-East included bifaces, unifaces, cores, preforms, utilized flakes, and ground-stone tools predominately produced using Allendale chert that represents a Kirk-phase assemblage (Daniel 2001:251; Sassaman et al. 2002:107). Based on the material type and the level of tool curation in the assemblage, Lewis-East has been interpreted as a winter base camp that facilitated the restocking of Allendale chert for production of transportable tools (Daniel 2001:25; Sassaman et al. 2002:167). Although a smaller, complex site, Pen Point (38BR383), located eleven kilometers downriver from Lewis-East, displays a similarly large percentage of Allendale chert in its tool assemblage (Sassaman et al. 2002:18). The Early Archaic assemblage consists of both side and corner notched bifaces, end scrapers, other flaked stone tools, cobble tools, and debitage (Sassaman et al. 2002:13). These two sites, Lewis-East and Pen Point, support Daniel's model of lithic resource-based ranges. In contrast, Rucker's Bottom, located in Georgia on the Savannah River Piedmont, displayed more expedient tools made from local quartz than curated Allendale chert tools. This forager site assemblage may reflect the curative behavior and preference of early hunter-gatherers towards higher quality, exotic lithic material by their supplementation with locally available materials (Daniel 1998:190; Sassaman et al. 2002:168).

#### **4.1.2.1.4 Tools/Sources/Organics**

The archaeological record of the Early Archaic Southeast is limited to lithic data due to the poor preservation conditions of organic materials (TRC 2012:40). The Early Archaic Period is defined by archaeologists according to a chronology of distinctive projectile points: Hardaway Side-Notched, Taylor Side-Notched, Kirk and Palmer Corner-Notched, and McCorkle, LeCroy, and St. Albans bifurcated points (Anderson et al. 1996:10, 60-64). There is a correlation between the distributions of these points and the raw lithic materials used to produce them. The predominant raw material types include Uwharrie sources metavolcanic rock, Allendale chert, and quartz sourced to the South Carolina Piedmont particularly along the Fall Line (Anderson et al. 1996:60-64).

Hardaway Side-Notched and Taylor Side-Notched are dated to the onset of the Early Archaic Period, between approximately 11,500-9,900 cal B.P. (Sassaman et al. 2002:10). The two points share very similar characteristics with the most notable, defining characteristic their material type. Named after the Hardaway site located in the Uwharrie Mountain region of the North Carolina Piedmont, Hardaway Side-Notched points are predominantly made using Uwharrie rhyolite and Piedmont quartz. Their distribution range is centralized around the Uwharrie mountains, and its farthest southern extent is the Santee River in South Carolina. Taylor Side-Notched points coexisted at the same time as the Hardaway Side-Notched points south of the Santee River. Most Taylor Side-Notched points are made using Allendale chert sourced from the Savannah River Valley (Anderson et al. 1996:60-62; Daniel 1998:195; Sassaman et al. 2002:12). In his artifact analysis of the distribution of Hardaway and Taylor points, Daniel (1998:195) interpreted their independent distribution ranges to indicate the existence of two separate settlement bands each centered around a known high-quality lithic source.

There is a brief period of overlap between the end of the side-notch point tradition and the beginning of corner-notched technology. The two-key diagnostic corner-notched points are the Kirk and Palmer Corner-Notched, dating approximately 10,800-10,000 cal B.P. and produced by a single cultural group (Anderson et al. 1996: 64; Sassaman et al. 2002:10) (Figure 60). Kirk Corner-Notched points have



**Figure 60. Early Archaic Kirk Corner-notched points**

A, G, differentially crystallized tuff; B, C, F, H, Rhyolite; D, E, vein Quartz. (Fig. 4.5, pg. 29, in Charles and Moore, 2018).

been recovered from the Pee Dee drainage and the Allendale region of the lower Savannah River Valley. In the Pee Dee drainage, these points were predominantly made from Uwharrie metavolcanic stone (Daniel 2001:249). Meanwhile, Palmer Corner-Notched points have a wider distribution across South Carolina, primarily concentrated in the Coastal Plain region of the Santee River valley. The primary raw material used in the production of these points is quartz. Archaeologists have identified that the main differences between Kirk and Palmer Corner-Notched points are the materials used to produce them, their slightly different sizes (Kirk points being generally larger in size), and their production (Palmer points have heavily ground bases and distinct serrations on the blade margins that Kirk points are less so) (Anderson et al. 1996:63-64).

The Corner-Notched tradition is overtaken by the bifurcate-base tradition around 10,200 cal B.P. (Christopher R. Moore, elec. comm. 2018). The key diagnostic points of this tradition include McCorkle, LeCroy, and St. Albans points. Bifurcate-base points are small bifaces and display distinct basal concavities with side or corner notching. These points are limited in distribution to the northern part of South Carolina (Anderson et al. 1996:64; Daniel 1998:3). In addition to projectile points, artifact types from the Early Archaic include adzes, whetstones, end scrapers, side scrapers, unifacial and bifacial tools (both curated and expedient), preforms, flake cores, microliths utilized flake tools, graters, debitage, and pieces esquillée (Anderson et al. 1996:73; Daniel 1998:1998; Sassaman et al. 2002:68).

The importance of raw lithic material sourced from the Uwharrie and Allendale quarries seen in the Paleoindian Period was of continued value during the Early Archaic and into the Middle Archaic periods. As previously mentioned, the Uwharrie-Allendale settlement model proposed by Daniel (1998) emphasizes the significant role the two quarry sources played in the lifeways of Early Archaic peoples. As part of his research into the wider applicability of Anderson and Hanson's Band-macroband model, Daniel (1998, 2001) studied the point raw material types of Early Archaic sites along the Yadkin-Pee Dee drainage as well as the lithic tool assemblages of G.S. Lewis-East and Rucker's Bottom. From this, he noted two distinct distribution zones for Uwharrie metavolcanic stone in the northern portion of the Carolinas north of the Santee River and Allendale chert in the southern portion of South Carolina south of the Santee River with an overlapping aggregation zone between the two regions (Daniel and Goodyear 2015:325-327). Both Uwharrie metavolcanic stone and Allendale chert are valuable for their high-quality knapping capability. As such, the current interpretation is that early hunter-gatherers conserved tools and regulated the consumption of these raw materials by supplementing them with locally available materials such as quartz in the Piedmont region (Daniel 1998:190; Sassaman et al. 2002:168).

#### **4.1.2.2 Middle Archaic Period (8,900 – 5,900 cal B.P.)**

Like Early Archaic sites, most of these sites are located above the Fall Line, where there are three dense clusters of sites along the Savannah, Saluda-Enoree, and Catawba River basins. While there are many sites on the Coastal Plain, shoreline, and estuaries, they number far less than half of all the recorded sites. The discrepancy could be due to site destruction on the Coastal Plain by sea level regressions, a preference of Middle Archaic groups to settle closer to lithic resources, or a combination of the two (SC Archaeological Site Files). The Middle Archaic Period is demarcated from the Early Archaic Period primarily by environmental factors. Seasonal variation was drastic with long, dry cold winters followed by long, hot, dry summers with extremely short spring and fall conditions in between (Gunn and Foss 1992:6). The conditions fostered the expansion of pine forests beginning first in the Carolinas then spreading south to Georgia and Florida almost 2,000 years later (Watts et al. 1996:37). The rapid transition in South Carolina from hardwood to softwood dominated forests also impacted the white-tailed deer habitat locations. By the mid-Holocene, the rate of sea level rise decelerated, which promoted the foundations for floodplains and coastal estuaries development (Dawson 2016:184; Gunn and Foss 1992:14). The changes in the main subsistence resources resulted in a change in tool technology from the

specialized toolkits predominately made of nonlocal lithic materials seen in the Early Archaic Period to homogenous, local material tools in the Middle Archaic (Dawson 2016:14-15). The Middle Archaic lifeways were likely characterized by a highly mobile population with a nonspecialized economy, and flexible social units (Sassaman 1993:34). The Middle Archaic concludes shortly after the final inundation of the subaerial OCS around approximately 6,000 cal B.P., transitioning into the Late Archaic Period (Gunn and Foss 1992:5). If Middle Archaic people occupied the riverine and estuarine areas of the OCS until inundation, the question then becomes whether sites of exploitation and occupation survived the final transgressions.

#### **4.1.2.2.1 Subsistence Strategies**

The absence of organic materials seen in the Paleoindian and Early Archaic periods continues into the Middle Archaic Period. The remains of organic artifacts and features such as faunal or floral remains, burials, wooden or bone tools, needles, or evidence of structures dating to the Middle Archaic Period are scarce. Research into subsistence strategies for this period has relied mainly on lithic tools and knapping debitage (Dawson 2016:74). Pollen data from sites such as Clear Pond in the Pee Dee region and sedimentary evidence from sites across the state have contributed to the recreation of the Middle Archaic environment. These data greatly contributed to defining the transition between the Early and Middle Archaic (Dawson 2016:52; Gunn and Foss 1992:14).

Pollen studies at Clear Pond, located in the northeastern Coastal Plain in Horry County, provides evidence that pine forests began to spread more rapidly after 8,500 cal B.P. and reached modern distribution by approximately 8,000 cal B.P. (Sassaman and Anderson 1995:10; Watts et al. 1996:36). South Carolina was the first state in the Southeast to experience the expansion of pine forests into a previous hardwood dominated area, therefore, experiencing a shorter period of open canopy and grassland prairie than southern Georgia or Florida. Based on sedimentary evidence, the Middle Archaic environment on the South Atlantic Slope was favorable to big game hunting of species such as white-tailed deer (Gunn and Foss 1992:14-15; Watts et al. 1996:37). Some researchers suggest that South Carolina hunter-gatherers practiced controlled burning of forest understory to preserve deer habitat after the expansion of pine and selectively spread seeds in their territories to cultivate favored floral subsistence such as acorns. This practice is just one theory to explain the reduced mobility of Middle Archaic hunter-gatherers (Dawson 2016:17).

Shell midden and shell ring sites in South Carolina date no earlier than the Late Archaic Period. The earliest recorded shellfish site in the state is Rabbit Mound (38AL15) site in Allendale County, dating to approximately 4,500 cal B.P.; however, the earliest shellfish site located on the coast dates to 4,200 cal B.P. indicating the first evidence of sustained occupation in the coastal zone (Russo 1996:186). Although shellfish were not routinely collected until the Late Archaic Period, the knowledge required to effectively exploit this resource to the extent that such large quantities of shells were amassed to create these features would have taken years, if not generations, of experience (Sassaman 1993:36-37). Therefore, it is highly likely that this resource was an aspect of coastal subsistence strategies of the Middle Archaic and potentially may reflect the settlement patterns found associated with the Late Archaic shell sites. Although the integrity of the radiocarbon dates is debated, a few preceramic sites have been located dating to the mid-Holocene in coastal South Carolina and Georgia: Bilbo and the Fish Haul (38BU805) sites recorded the oldest dates of between 6,607 to 5,991 cal B.P. and 7,189 to 6,676 cal B.P. respectively (Russo 1996:187; Sassaman 1993:37).

#### **4.1.2.2.2 Settlement Patterns**

Due to the rare frequency of Middle Archaic sites in the coastal zone, settlement patterns for this region are hypothesized based on the interpretation of Late Archaic components as well as settlement models developed for the Middle Archaic interior regions of South Carolina (Sassaman and Anderson 1995:90).

Several models have been developed to address the different settlement strategies of more regionalized Middle Archaic bands. Due to the few representations of Middle Archaic Coastal Plain sites in the archaeological record, the study of settlement in this region is limited. Research has focused more on theorizing the reasons for the discrepancy of site distribution between the Piedmont and Coastal Plain. The Middle Archaic Abandonment model is one such example (Sassaman and Anderson 1995:149-151). Models that focus on settlement patterns in the Piedmont region include the Riverine-Interriverine model, and the Adaptive-Flexibility model (Sassaman and Anderson 1995:134-141; SC Archaeological Site Files). Further study into the Adaptive Flexibility model has demonstrated its potential applicability to Coastal Plain sites (Dawson 2016:181-182). Coastal settlement sites do not predate the Late Archaic Period and focus on shell middens and shell rings. If such marine resources were exploited by early groups, evidence of their activities most likely have since become inundated and have yet to be located (Sassaman and Anderson 1995:152).

The Riverine-Interriverine model incorporates both Middle and Late Archaic sites in the Piedmont region. This model predicts the patterns of settlement as seasonal migration by small groups of highly mobile hunter-gatherers between riverine and interriverine base camps in a smaller migration territory than practiced in the Early Archaic Period. The model is based on evidence of high density, complex sites located overlooking major rivers and small, low-density sites scattered across the uplands, often overlooking small tributaries (Sassaman and Anderson 1995:134-135). The Adaptive-Flexibility model was proposed by Sassaman (1993) as an alternative to the Riverine-Interriverine model to explain the settlement patterns of Middle and Late Archaic groups in the Piedmont region. Comparisons found that Middle Archaic assemblages were homogenous, while Late Archaic assemblages had greater interassemblage variation (Sassaman and Anderson 1995:138). After analyzing the collections of Middle and Late Archaic Piedmont sites, Sassaman (1993:31) interpreted the simplified toolkit of the Middle Archaic as indicative of a shift in lifestyles. Most likely associated with the climate changes, lifestyles in the Coastal Plain would have been more substantial due to the greater variability in environmental conditions. Based on the wide distribution of Middle Archaic sites across the Piedmont, Sassaman determined that the Middle Archaic settlement pattern did not support the Riverine-Interriverine model. Instead, he found that the higher distribution of Middle Archaic sites indicates a greater level of mobility over a larger area than predicted by the Riverine-Interriverine model. Middle Archaic groups instead migrated more frequently, occasionally returning to specific sites, rather than seasonally timed movement between selected locations (Sassaman and Anderson 1995:138-139).

Dawson (2016:22) tested Sassaman's model to determine its applicability outside the Piedmont region and found that the Adaptive-Flexibility model could be used to describe settlement patterns on the Inner Coastal Plain. Dawson found that Coastal Plain sites were, in general, larger and had more varied lithic assemblages compared to Piedmont sites. Inner Coastal Plain sites were more predominantly located on smaller tributaries rather than the relatively even distribution of Piedmont sites between major rivers and upland areas (Dawson 2016:64). Dawson interpreted Middle Archaic settlement as a transition of hunter-gatherers from unintentional to intentional modifications of their environments to optimize their resource bases through the controlled burning of forest understory to promote acorn production and foster browsing areas for deer. The simplified toolkit characteristic of the period was a result of people focusing their efforts on enriching local vegetation rather than the acquisition of nonlocal raw lithic materials. Such planned modifications to areas could represent the early beginnings of plant cultivation seen in the Late Archaic Period (Dawson 2016:17-21).

Researchers have noted a considerable absence of Middle Archaic sites from the Coastal Plain region dating between 8,500 to 7,500 cal B.P. (Sassaman 1993:3; SC Archaeological Site Files; TRC 2012:42). Possible reasons for this temporal gap in Coastal Plain sites are addressed by what Sassaman and Anderson (1995:176) term the Middle Archaic Abandonment model. They explain that the expansion of pine into the Coastal Plain resulted in mixed hardwood-softwood forests between 8,500 and 8,000 cal B.P. (Watts et al. 1996:36). This in combination with wetter conditions made resource patterning in the

Coastal Plain highly variable. The changing climate led to the negative effect on white-tailed deer populations in the region, thus presenting new challenges to Middle Archaic hunter-gatherers and making the region less desirable for long-term occupation, resulting in the preferred settlement of the Piedmont (Sassaman 1993:34; Sassaman and Anderson 1995:176). Dawson presents an alternative explanation for the seemingly reduced usage of the Coastal Plain region. Instead of the low number of sites indicating infrequent occupation, several Inner Coastal Plain sites displayed evidence that suggested multiple types of occupation occurring repeatedly at fewer, key site locations (Dawson 2016:64-65).

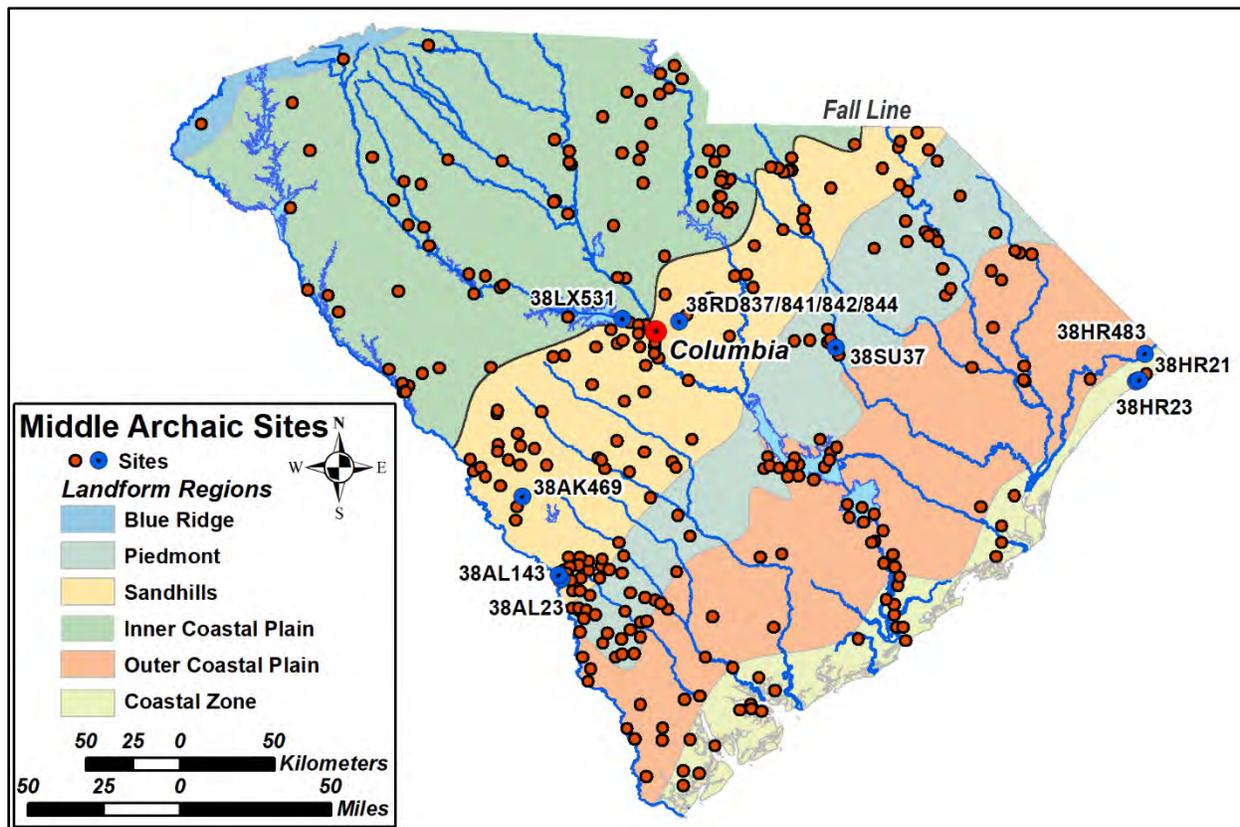
#### **4.1.2.2.3 Known Sites**

Of the 2,284 documented Middle Archaic sites in South Carolina, the clear majority are located above the Fall Line with concentrations of sites in the Savannah, Saluda-Enoree, and Catawba River basins. Few of the documented Middle Archaic sites are located on the Coastal Plain, shoreline, and estuaries (SC Archaeological Site Files) (Figure 61). Complex, multicomponent sites with Middle Archaic horizons include G.S. Lewis-East, Three Springs, and the Tree House sites. Three sites located in the Coastal Plain near the project area include Sites 38HR483, 38HR23, and 38HR21.

As mentioned previously, G.S. Lewis-East is a large, complex site with numerous and varied artifact assemblages dated to the Early Archaic in the Savannah River valley of South Carolina. The site also recovered a late Middle Archaic period to Late Archaic assemblage that is unique in that they predate the widespread distribution of pottery in the Late Archaic (Sassaman et al. 2002:21). Of the total number of bifaces recovered from the Middle and Late Archaic horizons, most of the assemblage date to the Late Archaic Period (Sassaman et al. 2002:112). Two Morrow Mountain points are included in the Middle Archaic assemblage, suggesting that G.S. Lewis-East was not a heavily occupied site during this period (Sassaman et al. 2002:16). A series of stemmed lanceolate bifaces, including four Brier Creek/Allendale (or MALA - Middle Archaic/Late Archaic) points, were also recovered from the late Middle Archaic horizon, with stratigraphic evidence supporting that they postdate the Morrow Mountain phase (Sassaman et al. 2002:17). Other artifacts found in association with these points include other biface fragments, biface preforms, flake tools, flakes, and debitage (Sassaman et al. 2002:27, 145). The Middle Archaic component dates between approximately 6,300 to 5,500 cal B.P. (Sassaman et al. 2002:109). Study into this period in the middle Savannah reveal an increasingly complex, multicultural landscape, therefore, these data from G.S. Lewis-East are significant to furthering this study, especially as one of the few sites providing radiocarbon dates (Sassaman et al. 2002:17).

The Three Springs site (38RD837/841/842/844) is a large, multicomponent prehistoric and historic site located in the Sandhills of Richland County, South Carolina (Dawson 2016:164). The lithic assemblage spans the Archaic Period and prehistoric ceramics date to Woodland and Mississippian occupations (Dawson 2016:35). The Middle Archaic component is represented by the recovery of seven Morrow Mountain points and four Guilford points (Dawson 2016:34). Other associated artifacts include bifaces, biface fragments, unifaces, thinning flakes, utilized flakes, a hammerstone, and debitage (Dawson 2016:178). These artifacts are made from a variety of lithic materials, predominantly quartz, but also Black Mingo chert, Piedmont silicate, orthoquartzite, and metavolcanic stone (Dawson 2016:30, 142). The site has been interpreted to fit Sassaman's Adaptive-Flexibility model and to represent a high residential mobility culture (Dawson 2016:166,175).

The Tree House site (38LX531) is another complex, multicomponent site located along the Fall Line in South Carolina on the south side of the Saluda River (Dawson 2016:62). The site contains components dating from the Early Paleoindian through to the Mississippian periods, but the Middle Archaic, Late Archaic, and Middle Woodland periods saw the most intensive occupations. The Middle Archaic component is represented by five Morrow Mountain points, eleven Guilford points, two Brier Creek points, as well as at least nine features, including one possible structure (Nagle and Green 2010:256-257). Additional artifacts include bifaces, scrapers, gravers, retouched flakes, utilized flakes,



**Figure 61. Middle Archaic sites in South Carolina**

cores, and lithic debitage, as well as hickory/walnut shell and pine wood (Dawson 2016:62; Nagle and Green 2010:263). Both local and non-local lithic raw materials are present in the assemblage: the diagnostic points are predominantly made of quartz, but other non-local materials such as chert and Uwharrie rhyolite were also present (Nagle and Green 2010:262-263). The Middle Archaic component of the site is interpreted as an aggregation, semi-permanent base camp that was repeatedly occupied by hunter-gatherer bands (Dawson 2016:62; Nagle and Green 2010:261).

Sites located near the project area include 38HR483, 38HR23, and 38HR21. Site 38HR483 is an Early Archaic through Woodland period site located on a bluff overlooking the Waccamaw River. This is a large site with intact sub-surface features. Many artifacts consist of metavolcanic flakes and flake fragments, suggestive of a knapping work area, and several Kirk and Morrow Mountain projectile points fashioned from metavolcanics stone (SC Archaeological Site Files). Site 38HR23 is a cache site of Archaic points and blanks for later reduction and refinement of points. The site was located on the coast north of Cherry Grove Beach and near Site 38HR21 (SC Archaeological Site Files). Site 38HR21 is an Archaic site located on a relic sand dune on the coast north of Cherry Grove Beach. The site was interpreted as a cache, with an assemblage comprised of Stanley, Morrow Mountain, and Kirk-corner notched lithic points (SC Archaeological Site Files).

#### **4.1.2.2.4 Tools/Organics/Lithics**

With the effects of environmental changes to the subsistence and settlement strategies of the Middle Archaic, so too is there a marked difference in lithic tool technology from that of the Early Archaic

(Dawson 2016:55). In response to the changing environment experienced in this period, Middle Archaic toolkits reflect the subsequent adaptations to the new subsistence demands and, while populations remained highly mobile operating in smaller bands, the size of their ranges decreased to optimize resource exploitation (Dawson 2016:14-17; TRC 2012:42-43). The Middle Archaic toolkit was more simplified, predominantly consisted of locally sourced lithic raw materials, and with a considerable increase in expedient flake tools. In general, assemblages from South Carolina show increased instances in the use of quartz as the preferred lithic material over higher quality cherts or metavolcanic stone (Dawson 2016:55). There are some examples of nonlocal lithics in Middle Archaic assemblages, which are suspected to indicate the existence of trade networks between sub-regions and with groups outside the Carolinas (Dawson 2016:23). Although local quartz and orthoquartzites were used in tool production in the lower Pee Dee region, the use of metavolcanic stone in tool production was more prevalent due in part to the overall lack of local raw material. There is a general continuation through time in the consistent distribution of metavolcanic stone in the Yadkin-Pee Dee drainage (Sassaman and Anderson 1995:168).

The Middle Archaic shares similar levels of artifact preservation as previous periods. Organic materials such as burials, floral or faunal remains, structures or post molds, etc. are extremely rare in the archaeological record (Dawson 2016:74). Therefore, archaeologists have reconstructed the temporal progression of the period based on lithic tool types. Tool types from the Middle Archaic became less diverse and more expedient, and toolkits exhibit a greater frequency of groundstone artifacts. Local lithic materials such as quartz were used more predominantly in tool production, while nonlocal material, particularly Allendale chert and Uwharrie rhyolite, were rarer outside the immediate area of their sources (Dawson 2016:14-15; TRC 2012:42). Projectile point forms transitioned from the notched styles of the Early Archaic to stemmed points in the Middle Archaic and continued into the Late Archaic (Sassaman 1993:31). There are seven distinct projectile point types represented in South Carolina from this period: Kirk Stemmed, Stanly, Morrow Mountain Types I and II, Guilford, and Brier Creek and Allendale (MALA) lanceolate points (Moore, elec. Comm. 2018; Sassaman and Anderson 1995:21). Except for the Brier Creek and Allendale lanceolate points, which are regional variants, the Kirk Stemmed, Stanly, Morrow Mountain Types I and II, and Guilford points all identified in Coe's North Carolina sequence are distributed throughout South Carolina and Georgia (Dawson 2016:55; Sassaman 1993:31). Other Middle Archaic tool types include biface, expedient utilized flake tools, debitage, cobbles, the introduction of Atlatl bannerstones, and the disappearance of end scrapers (Dawson 2016:59; Sassaman 1993:33).

The Kirk Stemmed point dates from 9,200 to 8,500 cal B.P. (Moore, elec. Comm. 2018; Sassaman and Anderson 1995:21). These points are described as narrow and elongated serrated blades with broad stems; however, sizes of collected points from Hardaway are varied, which may be indicative of retouch work to sharpen the blades (Sassaman and Anderson 1995:20). Carried over from the Early to the Middle Archaic, this point has a more limited distribution than the Kirk and Palmer Corner-notched point of the Early Archaic in South Carolina. Kirk Stemmed points are mainly clustered in the lower Piedmont and Fall Zone areas, although they are also commonly found in the western Coastal Plain near the Allendale chert quarries (Sassaman and Anderson 1995:22). The Kirk Stemmed points were the predecessor of the Stanly Stemmed point type (Dawson 2016:56; Sassaman and Anderson 1995:22).

Stanly Stemmed points date to approximately 8,900 to 8,100 cal B.P. (Moore, elec. Comm. 2018; Sassaman and Anderson 1995:21) (Figure 62). The characteristics of this point type are based on the Kirk Stemmed point but display a broader blade with a smaller stem with shallow notching (Sassaman and Anderson 1995:22). These points have only been recovered from the northern half of the state, north of the Wateree River, and are typically made of metavolcanic material originating in the Uwharrie Mountains. This material distribution pattern follows the Pee Dee River and suggests seasonal migration along watersheds or trade networks between Piedmont and Coastal Plain inhabitants. The sizes of recovered Stanly points are as varied as Kirk Stemmed points, which again may be attributed to sharpening rework; generally, Stanly points are smaller than Kirk Stemmed (Sassaman 1993:31; Sassaman and Anderson 1995:22-23).



**Figure 62. Middle Archaic Stanley points**  
All made of Rhyolite. (Fig. 5.1, pg. 37, in Charles and Moore, 2018).

Morrow Mountain Stemmed points, Types I and II, are the most abundant diagnostic blade of the Middle Archaic Period recovered in South Carolina (Sassaman and Anderson 1995:23). It is during the Morrow Mountain phase that archaeologists mark a noticeable decrease in the number of Coastal Plain sites, especially compared to the Piedmont region. In addition to the disparity in the distribution of Middle Archaic sites, Sassaman (1993:33) noted that there is also a considerable decrease in the number of Coastal Plain sites than the Early Archaic Period. He interprets this to represent less favorable habitation conditions in the Coastal Plain during the Morrow Mountain phase. Except for the Coastal Plain sites, which lack enough evidence, Morrow Mountain sites share a pattern of being small low-density scatters of various artifacts including projectile points, biface fragments, utilized flakes, debitage, and cobbles. The limited assortment of formal tool types at sites and their expedient characteristics is further evidence that Middle Archaic groups did not depend on a specialized toolkit, instead of using a flexible, multipurpose technology (Sassaman 1993:33).

The two variations, Type I and II, display different characteristics and represent two phases of point technology. Morrow Mountain Type I is a short, broad blade with a short, tapered stem and dates to approximately 8,200 to 7,600 cal B.P. The Morrow Mountain Type II is a long, narrow blade with a longer tapered stem than Type I and dates to approximately 7,600 to 6,800 cal B.P. (Dawson 2016:56; Moore, elec. Comm. 2018; Sassaman and Anderson 1995:21-23). Both Morrow Mountain Types I and II, as well as their successor the Guilford point, are a deviation from the notched and stemmed technological progression. Archaeologists suggest a possible explanation for this unprecedented technology originated with an eastward migration of groups from the Midsouth, specifically the arrival of Benton phase people to the Savannah Valley region, which may also explain the lack of habitation in the Coastal Plain (Dawson 2016:56; Sassaman and Anderson 1995:23-24).

There are several lanceolate points that succeed the Morrow Mountain points at the end of the Middle Archaic Period. These points date between 6,800 to 5,900 cal B.P. except the Allendale lanceolate points which continue to be used into the Late Archaic Period (Moore, elec. Comm. 2018; Sassaman and Anderson 1995:21; Sassaman et al. 2002:19). The Brier Creek and Allendale lanceolate points are more commonly distributed south of the Santee River Valley on the Coastal Plain (Dawson 2016:56; Sassaman and Anderson 1995:29). Guilford lanceolate points are primarily distributed in the Carolinas Piedmont region but have also been found in the Coastal Plain north of the Santee River Valley and in the Pee Dee River Valley (Dawson 2016:57; Sassaman and Anderson 1995:26). Guilford Lanceolate points are one of the least known lithic traditions in South Carolina. This is in part due to the poor condition of most of points recovered from South Carolina sites. Quartz Guilford lanceolate points from the Piedmont region are simple and often poorly shaped ovate bifaces. Evidence suggests that the Guilford technology was probably part of the same toolkit as the Morrow Mountain points at the later end of that phase. Both the Morrow Mountain and Guilford lanceolate points are believed to have a western origin; however, there is no apparent connection between the traditions and Guilford points are a newly introduced technology (Dawson 2016:57; Sassaman and Anderson 1995:25).

## **4.2 Paleolandscape**

### **4.2.1 Long Bay Relative Sea Level Rise**

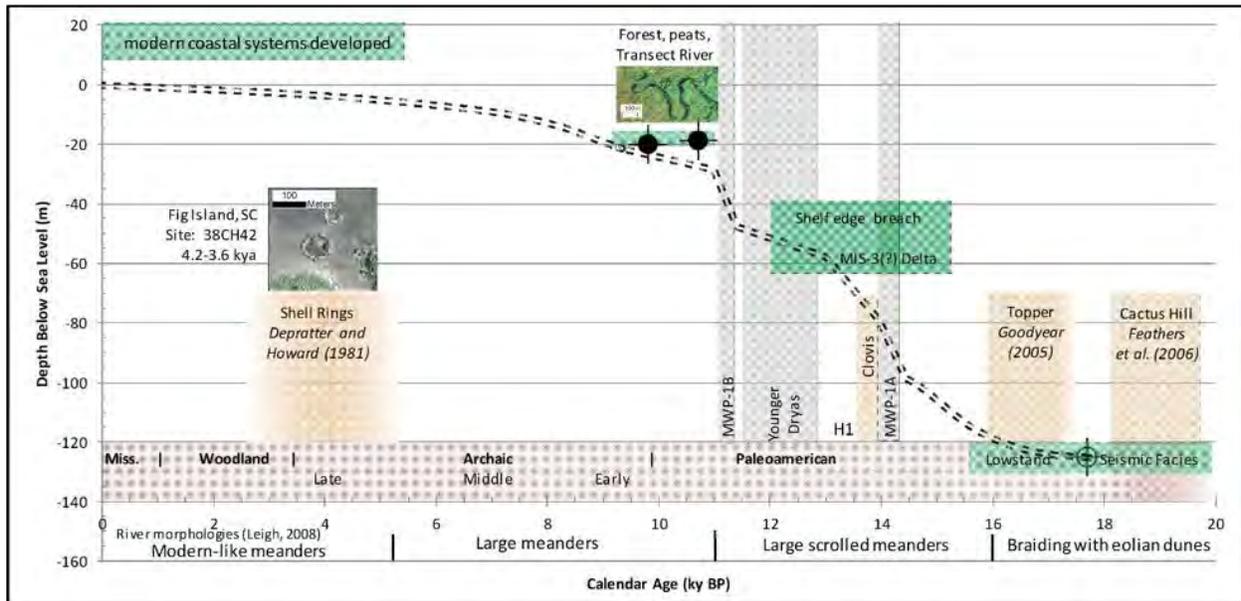
Sea-level elevation dictates the position of the open coast, protected estuaries, swamps, fluvial systems, flood plains, and associated interfluves, while the rate of sea-level rise determines how quickly these environments will be inundated. By understanding the elevation of sea-levels through time against the land, archaeological sensitivity and possible patterns of potential human habitation can be identified (TRC 2012).

Relative sea-level rise is a combination of large number of contributions, including “eustatic, static equilibrium, isostatic, local and tectonic processes” (Van De Plassche et al. 2014; and references therein). Recent work understanding the glacial isostatic adjustment (GIA) provides continental-scale models (Engelhart et al. 2011; Peltier 2015), which can be applied to modern topographic and bathymetric models to better estimate the position of shorelines (Harris 2018; Harris et al. 2013), and subsequently the other associated environments through time. For this coastline, combining several curves tuned to features on the shelf edge and high-resolution surveys across the shelf. Harris et al. (2013) defined an estimated sea-level rise model for the coast since the LGM (Figures 63 and 64).

A model for archaeological sensitivity has been defined for the South Carolina portion of the OCS (TRC 2012). “No Sensitivity” indicates no potential for now-submerged terrestrial sites, “Low Sensitivity” areas include those between the last glacial maximum (LGM) and the elevation of sea level prior to human occupation, and “High Sensitivity” regions of the OCS include those areas which were subaerial (terrestrial) since human occupation. Modelled shorelines (Harris 2018) indicate that a very narrow region seaward of the shelf break is Low Sensitivity, beyond the LGM shoreline is No Sensitivity, and the remainder of the shelf covering from just seaward of the shelf break is High Sensitivity (Figure 65).

### **4.2.2 Marine Transgression and Site Preservation**

The modern marine transgression has moved landward since the LGM sea-levels at approximately 125 m (Lambeck et al. 2002), rising rapidly during two major melt-water pulses at approximately 14 to 11.5 kiloyears ago (kya) (Fairbanks 1989). Given the glacial isostatic adjustment (Engelhart et al. 2011; Peltier 2015; Peltier 1996), multiple sea-level records, and using the GIA models of Peltier, shoreline positions can be estimated through time (Harris 2018). Included in the model are many sea-level indicators, such as



**Figure 63. Sea level Rise**

An estimation of the relative sea-level rise in this region with the time spans of identified cultures and river morphologies (modified from Harris et al. 2013).

barrier island morphologies on the shelf edge, exposed meandering channels cut into the substrate, and *in situ* estuarine and floodplain environments (see Harris et al. 2013). As many problems with this approach occur (erosion, deposition, ravinement, etc.) refinements will need to be made. However, using these models, the position of the shorelines and an approximate +2 m inland elevation have been estimated for indication of slope and potential error.

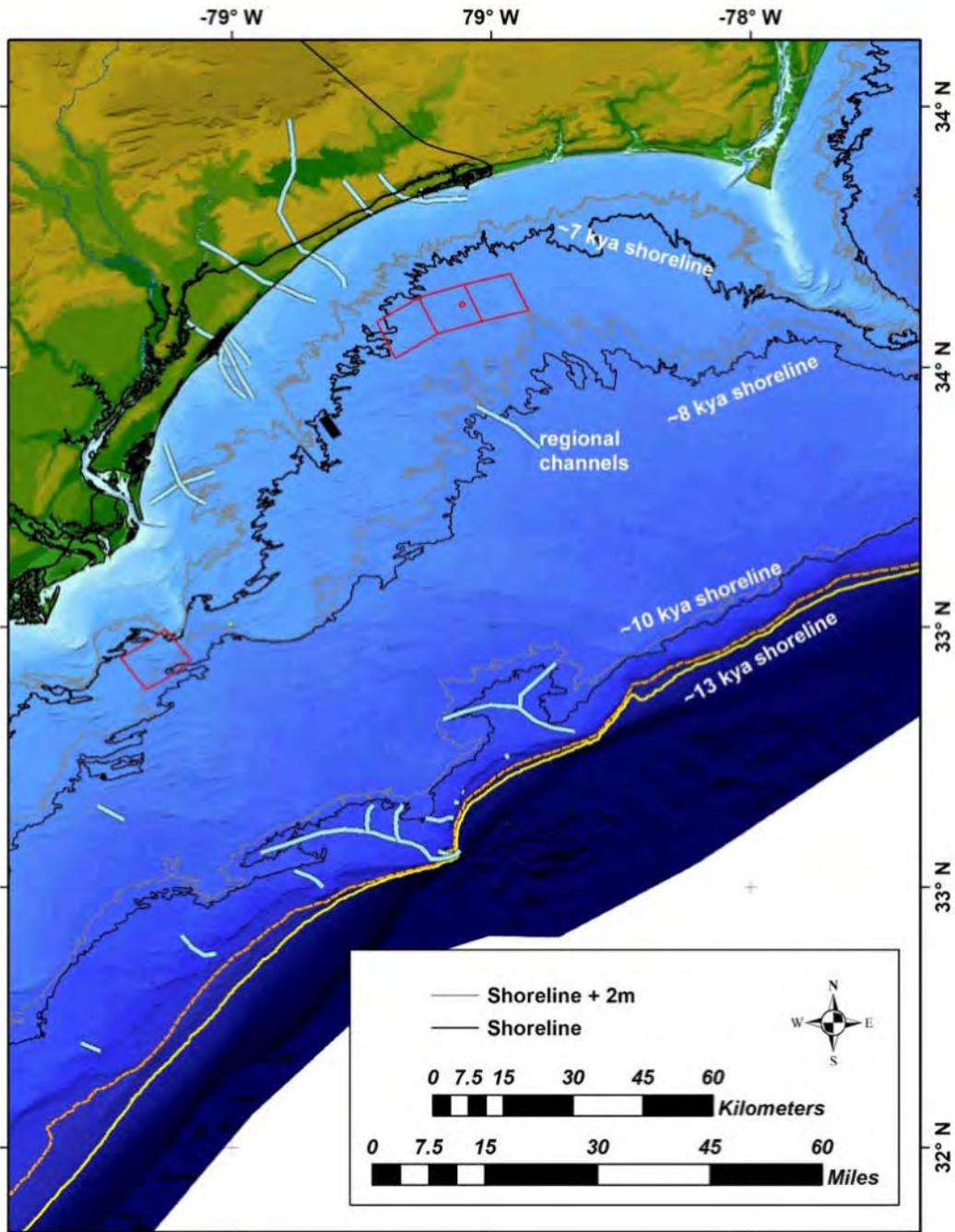
The dominant processes acting on a potential terrestrial site throughout the transgression include all the modern coastal processes, as well as storm-induced currents that erode and deposit sediment. The largest amount of destruction comes in the form of fluvial meandering, tidal creek meandering, inlet migration, and ravinement during the transgression. Areas affected directly by these destructive processes will have limited *in situ* materials. Areas of preserved interfleuves adjacent to and between these systems, have higher potential for preservation. Even in areas of intensive ravinement have the potential to retain artifacts in the gravel lag left on hard substrate where downward erosion is limited.

In this region, the most likely areas that would maintain a record of prehistoric human habitation include resistant-surface lag deposits and partially buried to exposed but resistant features. The eastern area of N1 contains a consistent track of attenuated subsurface reflectors indicating the presence of gas in the subsurface interpreted as highly-organic rich muds from the backbarrier. Following this section offshore, the gas gives way to several cross-bedded channel structures as well as transparent structures. This segment is interpreted as the more seaward channel system attached to the backbarrier system (Figure 66).

#### 4.2.3 Synthesis of Prehistoric Site OCS Model

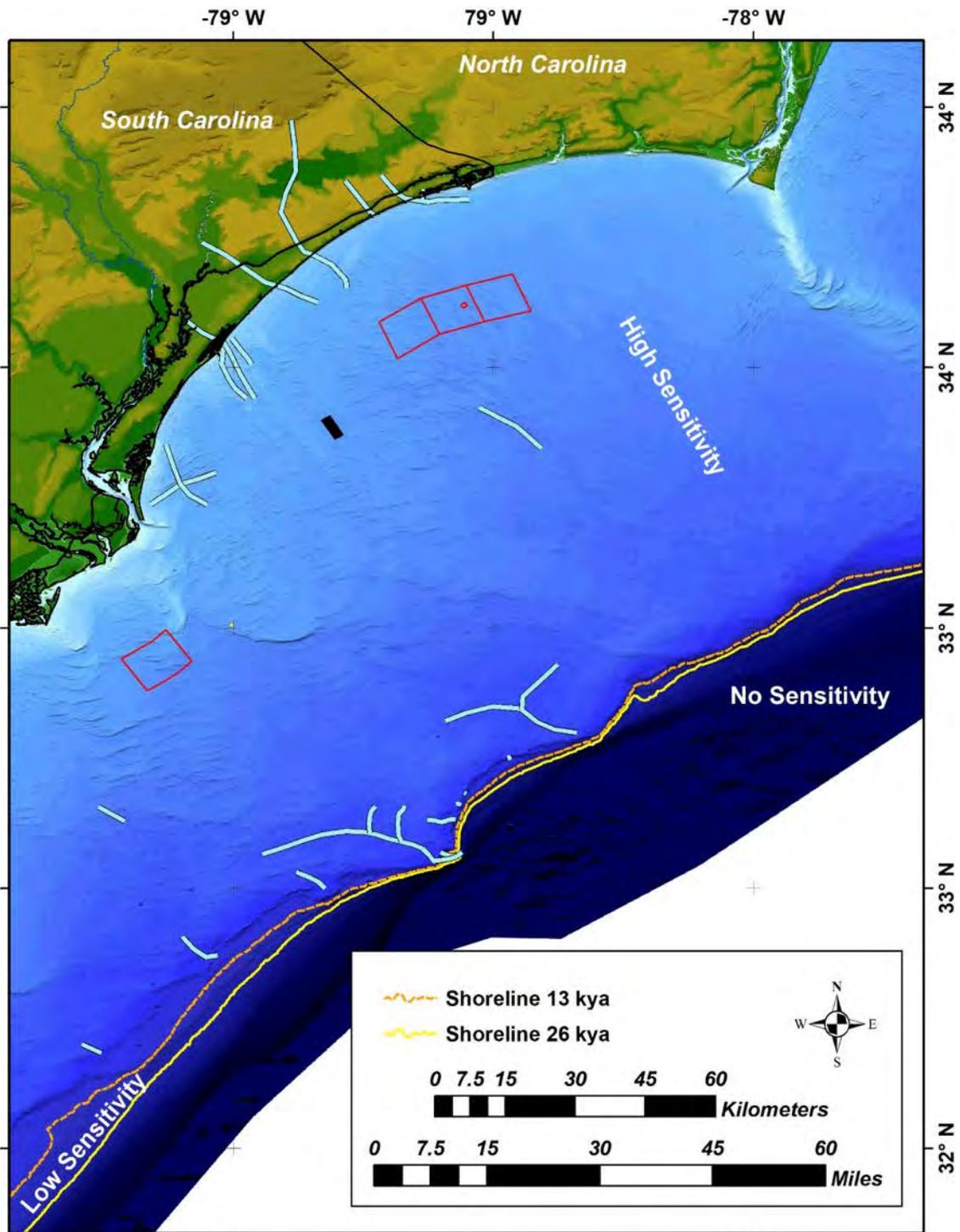
##### 4.2.3.1 Timing of Human Settlement

Sea-levels began to rise at the end of the Younger Dryas and did not level-off until at about 6,000 cal B.P. (Sassaman and Anderson 1995:155). The Middle Archaic Period ends shortly after this final inundation, therefore, any archaeological resources found on the OCS will predate the Late Archaic Period (Gunn and



**Figure 64. Three time-periods and approximate shoreline positions**

Three time-periods and approximate shoreline positions are identified on the shelf (Harris 2018). The closer inshore, the less accurate the shoreline position estimate due to modern modification of the seafloor. Paleochannels from Putney et al. Baldwin et al. and Harris et al. (2013). Image modified from Harris (2018).



**Figure 23. Three zones of primary archaeological sensitivity have been defined for the area**  
 The LGM shoreline at ~26kya (solid yellow) is very similar to the 18kya shoreline, and the 13kya shoreline (orange dash) shows the position of sea-level on the shelf edge during pre-Clovis time. The remainder of the shelf is High Sensitivity. Blue lines represent identified paleochannels on SC coast (Putney et al. 2004; Baldwin et al. 2006). The black box is a submerged floodplain with abundant cypress stumps. Image modified from (Harris 2018)..

Foss 1992:5). The earliest confirmed date of human settlement in South Carolina comes from Topper site on the Savannah River, dating to approximately 20,000 cal B.P. (Goodyear 2005:103; Goodyear 2016:6).

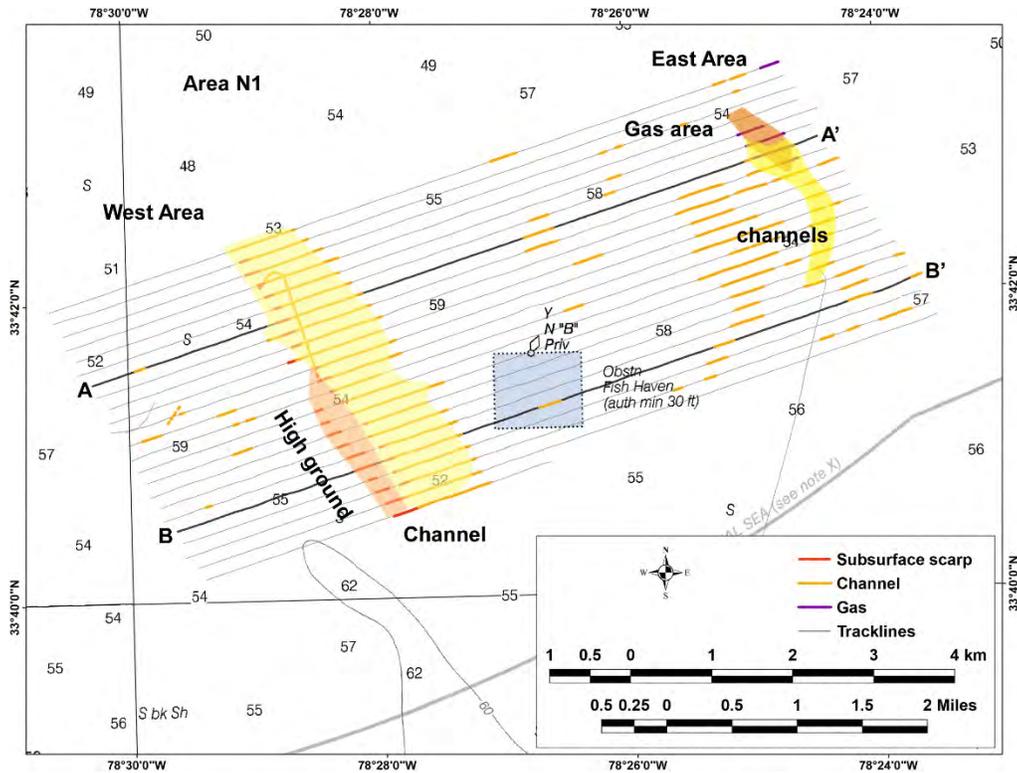
Although complex settlement sites may not exist on the OCS, bands are suspected to have directed their foraging mobility towards the coast after the winter months. These forays were highly mobile and would require only short-term camps (Daniel 1998:187-188). The coast is suspected to have attracted early hunter-gatherers for the exploitation of marine resources in the Early Archaic Period. One Early Archaic stone point was recovered on Folly Beach in Charleston, South Carolina (Bryan Philips elec. com 2015) and there are three clusters of Early Archaic sites along the shoreline south of Charleston and estuarine areas of the Pee Dee and Edisto-Savannah River basins.

Due to the lack of datable organic materials recovered from the Coastal Plain region between the Paleoindian and the Middle Archaic periods, the most reliable material associated with human occupation to survive on the South Carolina coast are shellfish sites (Russo 1996:186; TRC 2012:40). Rabbit Mount site in Allendale County is the earliest uncontested shellfish site, which dates to the Late Archaic, approximately 4,500 cal B.P. (Russo 1996:186). There are a few debated preceramic sites dating to the late Middle Archaic Period located in South Carolina that suggest even earlier exploitation of marine resources. The Bilbo site has been dated to between 6,607 to 5,991 cal B.P. and the Fish Haul site recorded dates between 7,189 to 6,676 cal B.P. (Russo 1996:187; Sassaman 1993:37).

The Middle Archaic gap archaeologists have noted in site numbers in the Coastal Plain region between 8,500 to 7,500 cal B.P. may have affected coastal occupation in one of two ways (Sassaman 1993:3; SC Archaeological Site Files; TRC 2012:42). Either the number of sites on the OCS reflect the same pattern of inoccupation or the lack of sites in the Coastal Plain resulted from populations preferring to settle in the now inundated coastal zone as well as the Piedmont region (Sassaman and Anderson 1995:176). Sassaman (1993:39) supports the idea that two distinct groups developed in the Piedmont and Coastal Plain by the Late Archaic. It is possible that the Coastal Plain group could have originated from hunter-gatherers adjusting their ranges inland as sea-levels rose to continue to access marine resources (Sassaman 1993:39).

#### **4.2.3.2 Site Location and Survival**

Archaeologists agree that for a submerged prehistoric site to be found *in situ*, it must first survive terrestrial burial and one or multiple transgression episodes. The area of greatest impact on archaeological preservation is in the surf zone, a high-energy condition. Although constant exposure to these forces results in deposit disturbance, it is the rare events such as extreme storm systems, hurricanes, iceberg grounding, and peak tides and currents that result in the most damage to archaeological sites undergoing or even having completed transgression. Large-scale landscapes, given the potential for destruction, are unlikely to survive; however, some intertidal sites could yield small pockets of *in situ* deposits. Medium-energy conditions mostly affect fine-grained sediments, often leaving larger objects in place (Lacroix et al. 2014:18-19). Examples would be the intertidal zone, estuaries, and river deltas. An exception might be topographical features such as sediments stabilized by seagrasses where smaller objects might be protected (Keller et al. 2014). The most likely environ to find *in situ* archaeological deposits is in low-energy settings. Such low-energy conditions can occur at a local scale depending on the geomorphology of a given location. Freshwater lakes close to the shoreline can offer spits, barrier beaches, and lagoons, which if inundated suddenly can provide high potential for preservation. Similarly, fluvial systems that have been preserved near the modern coast might offer similar preservation; deltaic systems as well, providing ample sediment deposit during transgression, can potentially offer stabilized conditions (Lacroix et al. 2014:19-20), and wetlands with large peat deposits also offer settings for preservation nearshore (Dave Robinson, personal communication 2015).



**Figure 66. Area N1 landscape elements**

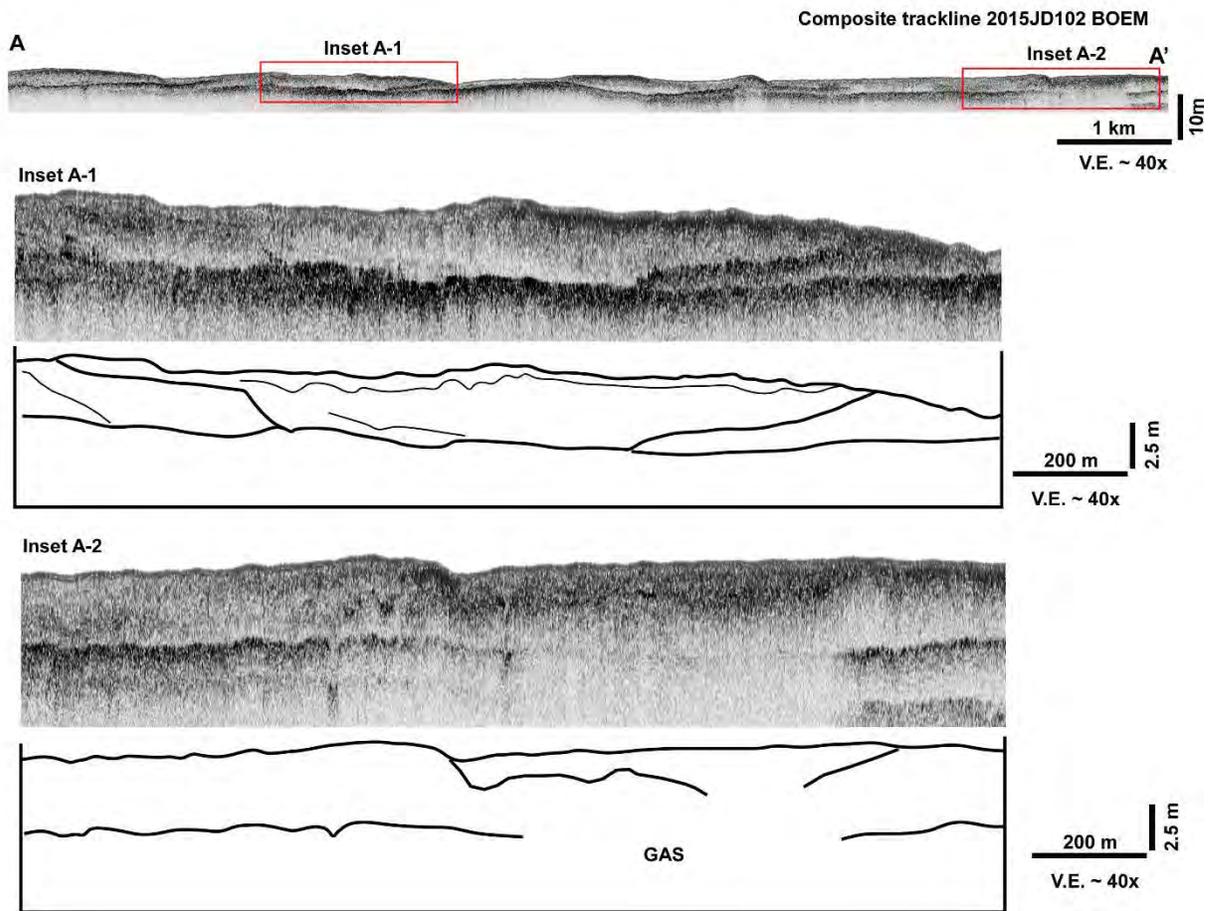
Area N1 has two major features subdividing the area. In the East, subsurface decomposing organic material inshore matches with offshore channels. This region is underlain by an abundance of cut and fill structures. In the west, a large channel system (yellow) with an older system (red) inset to a subsurface boundary to the SW. The High Ground represents one of the more probable locations for identifying paleohabitation sites, with the extreme NE section possibly having some information. Seismic tracklines are in blue.

In the small surficial and subbottom area surveyed for this archaeological investigation (see Figure 66 with channels above), areas exist with very low probability regions, and others that have the potential for high preservation of sites due to their proximity during transgressions.

Channeled areas created during the transgression are reworking all surficial materials and will have destroyed all landscape features and artifacts. However, the areas outside the channels have the potential to produce information on early human habitation in North America. The plan view map highlights two major channeled regions to the NE and SW, with high ground to the SW outside the primary channel areas. Profiles across these two regions (Figure 67 and 68, see location in Figure 66) show the shallow subsurface where former high ground is preserved and a likely candidate for preserved surficial and subsequently prehistoric materials. Figure 69 highlights those type of prehistoric points that most likely lay inundated on the SC-OCS.

#### 4.2.4 Paleolandscape Analysis and Results

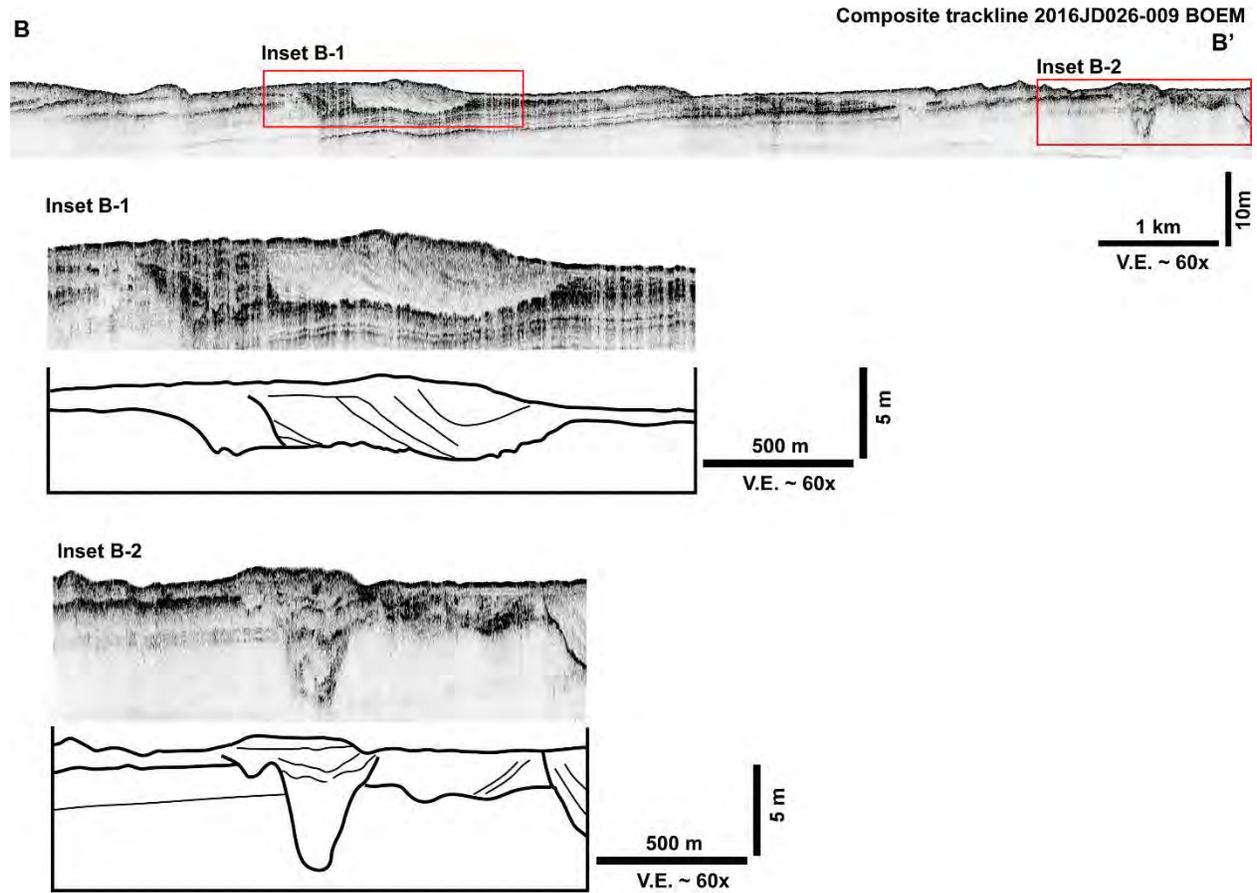
To date, no systematic archaeological survey in North America has revealed substantial evidence of prehistoric occupation of the subaerial OCS. Most evidence that reinforces the theory of OCS occupation comes from geological studies of OCS bathymetry and sediment studies. Given the limited scenarios for preserving organics such as bone, wood, or textiles surviving, lithics and evidence of exploitation such as lithic scatters, shell middens, and charcoal remains the best evidence available to finding prehistoric sites on the OCS. The first obvious challenge is the scale of the survey. Even with accurate coordinates, it can be impossible to locate large sites like a shipwreck, finding a stone point or shell midden is comparable to



**Figure 67. Cross-section A-A' highlighting areas of interest for Paleolandscape preservation**  
 For location profile see Figure 66.

searching for a needle in a sea of haystacks. The reason for this is the erosion of paleolandscapes during sea-level transgression and regression events over a roughly 14,000-year period. During transgression, the OCS also experienced isostatic lift, eustatic lift, wave action, shifting surf zone and tidal zones, and variations of fast versus slow inundation of the subaerial OCS (Harris et al. 2013:8). The second challenge is the sites are underwater, presenting the same environmental challenges that maritime archaeologists face. Thus, all evidence discovered that suggests prehistoric occupation has been found accidentally by fishing activities, mainly dredging and bottom trawling, or by recreational SCUBA divers (Masters and Flemming 1983:611).

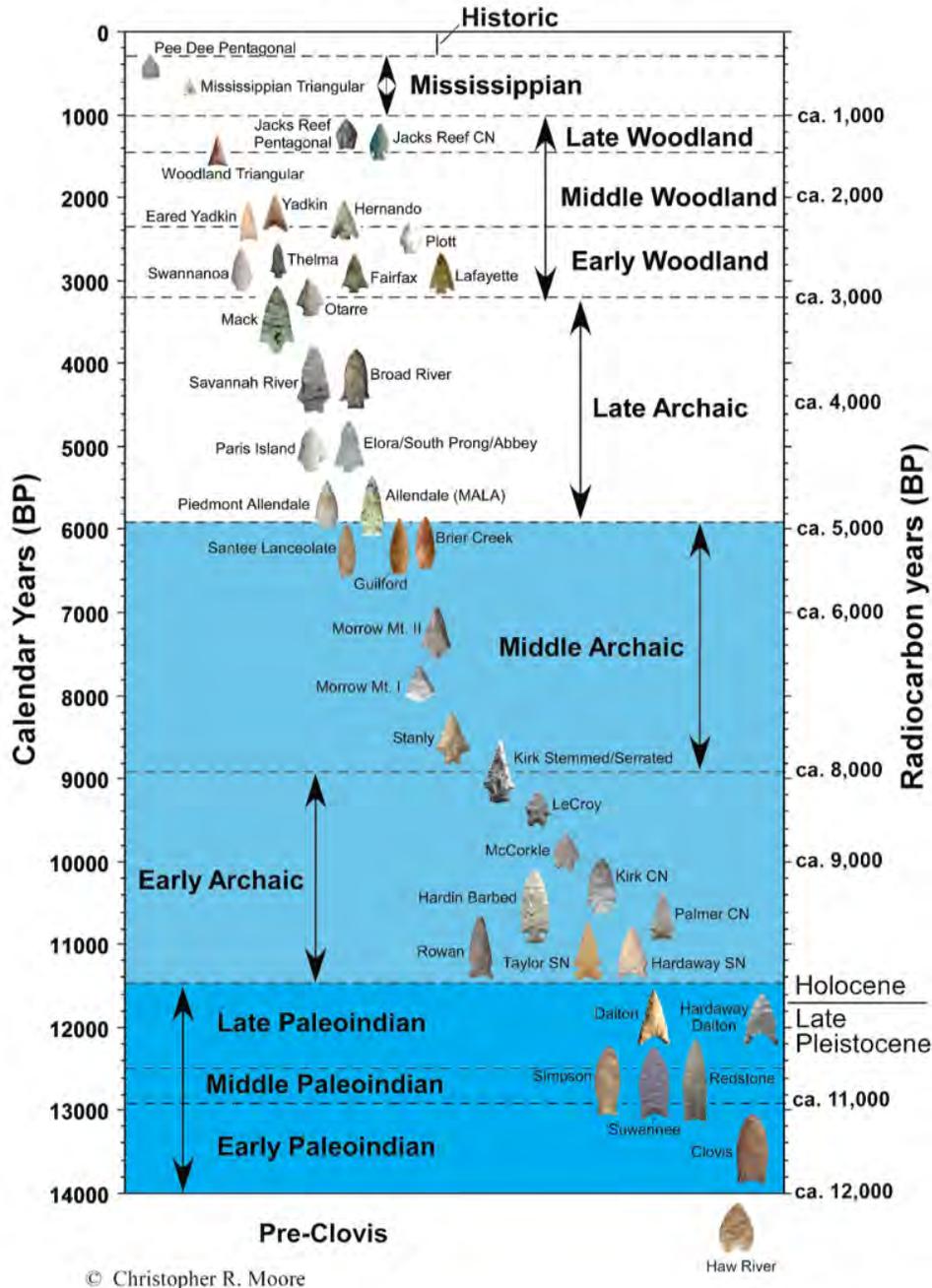
Despite numerous advances in remote sensing technology over the past decades, the suite of tools utilized to search for submerged prehistoric sites remains limited in their ability to detect physical evidence of habitation or exploitation (Faught 2014:40). Utilization of remote sensing to detect relict landforms is, methodologically speaking, the best place to begin. If relict landforms are located, primarily using multi-beam and sub-bottom profilers, then coring for sediment profiles may provide more evidence. Core samples may reveal shells, faunal fragments, black earth, burned rock, charcoal, and pollen (Flatman



**Figure 68. Cross-section B-B' and areas of potential interest for Paleolandscape preservation**  
 Areas outside of channels and with insets identifying large paleochannels. For location profile see Figure 66.

and Evans 2014:4). It is possible, however, for shells to occur in rings naturally. Tidal inlets and extensive estuaries harbor large populations of oysters (*Crassostrea virginica*) and clams (*Mercenaria mercenaria*) that were utilized by Archaic cultures from 6,000 to 4,000 cal B.P. and deposited in large middens or shell rings (Harris et al. 2013:11). Likewise, charcoal and burnt rock can occur naturally through wildfires (Faught 2014:42). Based on the site characteristic of the nearest terrestrial region described above, sites found on the OCS dating to the Paleoindian and Early to Middle Archaic lithic scatters are most likely associated with groups that occupied the northern Coastal Plain in the Pee Dee region. Although archaeologists have high hopes for well-preserved sites on the OCS, sites are more likely to be small and consist of lithic remains made of metavolcanic stone including discarded or broken points and/or blades, flakes, and debitage (Anderson et al. 2015:36; Bryan Philips elec. com. 2015; Moore et al. 2010:110).

# Projectile Point Sequence for South Carolina



**Figure 69. Southeastern Projectile Point Sequence**

Time periods shaded in blue indicate point types by period inundated on the Outer Continental Shelf. Adapted from Fig. 1.3, pg. xiv, in Charles and Moore, 2018.

## 5 Historic Archaeology

The coastal waters of South Carolina have played a significant role in the maritime history and development of the North American continent. Early Spanish vessels returning from the Caribbean to Spain sailed along the Gulf Stream bordering this stretch of the Atlantic coastline before steering eastwards to commence the transatlantic voyage back to Europe. Looking to expand their New World colonies, Spain first attempted to settle in South Carolina in the 16th century but were ultimately unsuccessful (TRC 2012:166). The English were the first to establish a permanent colony with the founding of Charles Towne, now Charleston, which eventually grew to become the seat of the colonial government, the hub of the economic market, and center of society (Hart 2009:1). The coastal ports of Charleston, and later Georgetown, acted as the gateways to exporting staple crops and natural products and importing valuable European luxury goods during the colonial period. As the largest port in the southern states, Charleston played active roles in the Revolutionary War, War of 1812, and Civil War (TRC 2012:174-178, 185). More removed from the European theatre, South Carolina provided an important supporting role in the war efforts of World Wars I and II (TRC 2012:186-189). The Navy Yard in Charleston became the center of the southeast navy district, not only as an active shipyard but also as an important training facility. The post-war years saw a decline in the naval presence as port facilities were returned to the City of Charleston (Spirek and Amer 2004:32-33). Today, the port of Charleston is one of the busiest commercial seaports in the United States (SCPA 2018a).

### 5.1 Early European Exploration

The earliest recorded European exploration of the American continent began with the Norse voyages and brief settlements at L'Anse aux Meadows in Vinland, or modern-day Newfoundland, in the 11<sup>th</sup> century (TRC 2012:166; Wallace 2006). The next known European visitor in America was Christopher Columbus in 1492. Apart from John Cabot's exploration of Atlantic Canada on behalf of the English in 1497 and cod fishermen from Portugal and France on the Grand Banks, exploration of the Caribbean, Gulf Coast, and Central and South America was dominated by the Spanish (TRC 2012:166). The earliest European settlement attempt in South Carolina consisted of Vásquez de Ayllón's survey of the coast in 1525 and subsequent colonial endeavor in 1526. Even though the Spanish settlement failed, other European nations were enamored with the riches they believed the Spanish were seeking. The English were the first to successfully settle the area with the founding of Charles Towne in 1670 (Coclanis 1991:22; Rogers and Taylor 1994:10).

#### 5.1.1 Spanish Exploration

Following the Columbus voyages, Spain invested considerable resources into the exploration of the Caribbean, Gulf Coast, and Central and South America for valuable resources (TRC 2012:166). Their first known visit to the United States was the identification of La Florida by Juan Ponce de León, former governor of Puerto Rico. Ponce de León's attempts to establish a colony on the west coast were unsuccessful and eventually abandoned in 1521 (Peck 2001:183; Weber 1992:28). Five years later, Lucas Vásquez de Ayllón made the next attempt to settle La Florida (Peck 2001:1830).

Learning from Ponce de León's efforts, Ayllón invested in a survey of the coast of La Florida. In 1525, he sent Pedro de Quejo with two caravels to survey the coast from the location of Ponce de León's colony at Anastasia Island by St. Augustine to the Chesapeake and Delaware Bays (Hoffman 2014:72; Peck 2001:187-189). The purpose of the expedition was to reconnoiter a viable location for settlement as well as to locate a strait through to East Asia (Peck 2001:189). Spanish explorers, including Ponce de León and Ayllón, learned that the most favorable resource and settlement locations were those located in

areas of high Native American occupation (Hoffman 2014:73), and most likely, Ayllón intended to establish his colony near an established village or town (Weber 1992:31).

Ayllón sailed in 1526 with six ships carrying approximately six hundred men, women, children, and black slaves as well as a few priests (Landers 2014:119; Peck 2001:189). The group made landfall near the South Santee River and Winyah Bay in South Carolina, but not before one vessel, *Chorruca*, the Capitana of the fleet, was lost on the sandbars of Winyah Bay on 9 August 1526. No lives were lost. However, the loss of a full cargo of supplies had a devastating impact on the success of the settlement. This is the earliest recorded shipwreck on the Atlantic Seaboard (Hoffman 1990:67; Peck 2001:190; TRC 2012:166). Once on shore, Ayllón deemed the location unsuitable for the colony, primarily due to the lack of any nearby Native American settlements. Instead, he sent his ships with the women, children, and infirm south while the able-bodied men rode south herding the remaining livestock over land. The two parties reunited on the Gualdape River, named by Ayllón after the local Native American population. It was there that Ayllón established the first town in the United States, San Miguel de Gualdape (Hoffman 1990:67; Peck 2001:19; Weber 1992:31). The town consisted of houses, pens for livestock, storage buildings for food, and the church (Peck 2001:193).

The exact location of San Miguel de Gualdape is unknown to modern scholars. The archaeological remains of the settlement have yet to be found, and there is insufficient data available to determine its location from a navigational standpoint (Hoffman 2014:70; Peck 2001:191-193). Many modern scholars agree with Hoffman's (1990:73-74) assessment that San Miguel de Gualdape was located near modern-day Sapelo Sound, Georgia (Hoffman 2014:69; Landers 2014:119; Peck 2001:192; Weber 1992:31). However, Peck (2001:192-193) argues that, based on the description of the colony's location in the primary records, that Hoffman's proposed site is unlikely. Since the colony's position was never recorded on a map, its location can only be inferred from historic descriptions, which state that it was located south of the Jordan River (Hoffman 1990:73). Peck argues that the Jordan River of Ayllón's expedition is more likely the Waccamaw River instead of the Santee River as Hoffman suggests (Peck 2001:184). He argues that the topography of Sapelo Sound is not as prominent as the primary accounts indicate and that San Miguel de Gualdape was more likely located at the mouth of the Savannah River around Tybee Roads, near a population of Native Americans known as the Guale (Peck 2001:192-193).

Regardless the location, the settlers of San Miguel de Gualdape struggled to survive the first winter. The colony was too late in the season to plant the crops they brought, and the loss of a ship's cargo led to near-starvation. This combined with physical exhaustion, untreated disease, and an unseasonably cold winter led to mutiny after the death of Ayllón in October 1526. Two weeks following Ayllón's death, the settlers decided to abandon the colony after a rebellion by the settlers and attacks from the alienated Guale destroyed San Miguel de Gualdape (Landers 2014:120; Peck 2001:193-194). The surviving settlers, approximately 150, returned to the Antilles (Hoffman 1990:79-80) (Figure 70). Ayllón's exaggerated endorsement of a utopia in La Florida inspired subsequent attempts to settle the area in the latter half of the 16<sup>th</sup> century by not just the Spanish, but also the French and English (Hoffman 2014:74; Peck 2001:197). By this point, both the French and English were more active in the Americas attempting to impede Spanish trade during periods of conflict. To defend their interests, the Spanish began traveling in *flotas*, or convoys, wherein several merchant vessels would travel together under the protection of Spanish war galleons as they voyaged from Spain to the colonies and back (TRC 2012:166). The colonies of St. Augustine and Santa Elena were established not only to exploit inland resources but also to aid in the defense of Spanish maritime resources (Hoffman 2014:74; TRC2012:116).

The Santa Elena River and the adjoining Cape Santa Elena were identified by Ayllón's expedition as they journeyed south to establish San Miguel de Gualdape. The site is located on modern-day Parris Island, South Carolina. It is unknown why Ayllón did not choose this location for his colony, most likely because there were no substantial Native American communities nearby. It was first settled by the French under Jean Ribault in 1562 with the short-lived establishment of Charlesfort; before the Spanish under Pedro Menéndez de Avilés established the settlement of Santa Elena in 1565 (Hoffman 2014:74; Peck



three possible routes existed to reach the Pacific Ocean from the Atlantic: the Northwest passage explored by Frobisher, the middle passage of the St. Lawrence River discovered by Cartier, and a yet undiscovered southern passage located somewhere in La Florida. The first English settlement attempts at Roanoke were considered to have a greater potential of success because of the strong Native American presence on the island that could support the settlers and strategically valuable as a base camp for further inland exploration of riverways (Hoffman 1990:273).

English interest in colonizing the Carolina territory occurred during the mid-seventeenth century concurrent with other Barbados expansion projects in the Caribbean. Because of the sugar revolution in the 1640s, Barbados residents found themselves isolated in a cash-crop economy that required an outside colony to supply the island with subsistence crops. Between the 1650s and 1670s, Barbados initiated the colonization of Surinam, St. Lucia, and Jamaica. When these efforts failed, they resorted to settling South Carolina to provide the needed resources to support the sugar-based economy on Barbados (Roberts and Beamish 2013:49-51,58). In March of 1663, King Charles II granted the Carolina territory to the Lords and Proprietors. At their behest, Captain William Hilton set out later that year with the Company of Barbadian Adventurers to explore and survey the coast of La Florida (Roberts and Beamish 2013:54; Rogers and Taylor 1994:5). The account from Hilton's explorations described Carolina as the most suitable settlement location for its fertile soil, abundant timber, good conditions for husbandry, and plentiful fish and wildlife (Gingrich 2009:11; Roberts and Beamish 2013:54). It took several years to finalize the logistics before the venture was prepared to sail at the end of the 1660s (Roberts and Beamish 2013:55).

The colonizing expedition consisted of three vessels that traveled to Carolina in 1669 with several stops for additional settlers and supplies. It was initially planned to settle at Port Royal, however, it was determined that Port Royal was too close to Spanish occupied sites (Coclanis 1991:22; Rogers and Taylor 1994:10). This would not have been an issue had the settlers arrived after July of 1670 and the ratification of the Treaty of Madrid, in which Spain recognized English settlements north of St. Augustine (Roberts and Beamish 2013:58; Rogers and Taylor 1994:10). Instead, the settlement was established on the Ashley River at Albemarle Point based on the recommendation of the local Native American leader, the Cacique of Kiawah. The original population of the settlement in 1670 totaled 155 people, 88 percent of whom migrated from England or Barbados, and the majority of which were indentured servants or slaves (Coclanis 1991:22; Rogers and Taylor 1994:10). The population also included an upper class of predominantly English gentry and Barbadian planters and merchants (Coclanis 1991:22; Roberts and Beamish 2013:62). Many of the Barbadian planters were agents or family members tending the land grants of prominent Barbadians who had remained in Barbados instead of migrating to the colony, investing distantly in the colony to increase their material wealth. These investors appropriated the more valuable land tracks adjacent to the Ashley and Cooper Rivers (Roberts and Beamish 2013:62-63; Waterhouse 1982:393). Their holdings in the Carolina colony were crucial to supplying Barbados with the timber, pasturage, and staple resources. To avoid oversaturating the sugar market, the colony focused on producing cotton, tobacco, indigo, and ginger (Roberts and Beamish 2013:57). Rice quickly became another important crop cultivated in the colony (Rogers and Taylor 1994:10). Approximately ten years after its founding, the Lords Proprietors ordered the colony to move northeast to Oyster Point at the confluence of the Ashley and Cooper Rivers. The new settlement of Charles Towne was fully established by 1680 and became the center of the colony, maintaining strong maritime trade with Barbados (Hart 2009:1; Roberts and Beamish 2013:58,62-63; Rogers and Taylor 1994:11).

Shortly after the founding of Charles Towne, the first groups of French Huguenots and Scottish immigrants arrived at the colony (Rogers and Taylor 1994:11). Early Huguenot settlers were impoverished refugees inhabiting London at the time. Little planning was put into their resettlement beyond fundraising and securing passage, and the petition for charity was based on their low economic standing. They first attempted to settle along the Santee River, segregated from the established English settlers, however, when this settlement was unsuccessful many relocated to Charles Towne and eventually

assimilated with their English neighbors (Gingrich 2009:9,18-19). The number of French Protestants immigrating to the Carolina colony increased after 1685 when the French King Louis XIV revoked the Edict of Nantes, thus denying rights to Huguenots in France. Approximately 1,500 Huguenots emigrated to South Carolina over the following ten years (Rogers and Taylor 1994:12). Within a few generations, the Huguenot community had fully assimilated into Carolina society (Gingrich 2009:33).

The Huguenots were more successful in their settlement than the Scots. With more simple goals for their settlement, the Huguenots were flexible and more willing to adapt to circumstances, whereas the Scottish settlers were defeated by their preconceived notions that overinflated their confidence and prohibited them from adapting to the reality of settlement (Gingrich 2009:12). The Scottish settlers were driven to immigrate to escape the political regime of the Restoration. Scottish landowners and merchants founded the Carolina Company in 1682, which provided financial assistance to Scottish immigrants. In 1684, approximately 150 Scots immigrated to South Carolina on commercial ships, initially arriving at Charles Town. Soon after their arrival, the Scots founded the settlement of Stuart's Town at Port Royal, south of Charles Town, near the abandoned Spanish town of Santa Elena (Gingrich 2009:9-10; Rogers and Taylor 1994:12). This attempt was unsuccessful due to a combination of poor leadership, British status, and economic ambitions that infringed into the Native American slave trade that was dominated by a group of wealthy and influential Barbadians settlers (Roberts and Beamish 2013:63). The settlement was finally abandoned after attacks from the Spanish and Native Americans in 1686 (Gingrich 2009:7; Roberts and Beamish 2013:63; Rogers and Taylor 1994:13).

## 5.2 Shipping and Seafaring of Carolina Colony

The first fifty years after the establishment of the Carolina colony, there were few wealthy families. Rather, there were many ambitious settlers looking to establish themselves in the new colony (Waterhouse 1982:392). Immigrants continued to arrive from Europe, England, the West Indies, and the northern colonies. For example, in 1695 a group from Dorchester, MA founded a settlement on the Ashley River, which they named after their hometown in New England (Rogers and Taylor 1994:14). As the Native American population decreased, inhabitants expanded their settlement into the interior lands (Bridwell 1982:3). The main resources produced by the colony for export were deer skins, naval stores, rice, and indigo (Bridwell 1982:9).

In South Carolina, the Atlantic and intercolonial trade were mostly restricted to Georgetown, Beaufort, and Charleston. Produce from the inland plantations were brought downriver to market by merchants and transferred to ocean-going vessels destined for English ports or other British colonies in America and the Caribbean. According to the Navigation Acts of the British Empire, which were upheld by officials in Charleston and later Beaufort and Georgetown, and reflected by similar colonial laws, all decked ocean-going or coastal vessels had to be registered. Local vessels designed to carry produce from the plantations to market were intentionally not decked or only partially decked to get around this restriction. Instead, these local vessels carried permits for local trade that were purchased by the boat owner and listed the owner and the boat captain (Bridwell 1982:3; Harris 2014:14-15).

Styles and designs of locally built vessels reflected the cultural backgrounds of the Carolina settlers. European immigrants contributed the variety of hull shapes and sail designs from France, England, and the northern American colonies; Barbadian immigrants brought designs that were typical of the West Indies; and African traditions influenced the design of the prominently used canoes (Harris 2014:15). The shipbuilding industry in South Carolina developed in the three port cities of Charleston, Georgetown, and Beaufort. Initially, early colonial shipbuilding focused on providing repairs and maintenance for visiting vessels to restore their seaworthiness, and then expanded into building coastal and ocean-going vessels. The shipbuilding industry quickly grew, especially in Charleston, into one of the most lucrative industries by the time of the Revolution and many shipwrights were able to rise to positions of wealth (Harris 2014:13-16,30; Hart 2009:42).

## 5.2.1 Charleston

Charleston's rise to prominence as the major port in the colony was based on its strategic position equidistant between New England and the British Caribbean to engage in the British Empire's transatlantic trade and as an important stopping-point on the Atlantic seaboard (Hart 2009:52-53). The colony's development was supported by the residence of the governor and the meeting of General Assembly, which drew the plantation aristocracy into the semi-annual residence in the city (Hart 2009:38-39). Trade in South Carolina was regulated by the Navigation Acts, which applied to all members of the British Empire, as well as colonial duties set by the Assembly. Officials were appointed to enforce both sets of laws: a naval officer or an appointed deputy to represent the King's interests, and the provincial officers including the receiver, comptroller, the country waiter, and the governor's representative for the entry of vessels laws (Bridwell 1982:10-11). By the mid-18<sup>th</sup> century, Charleston's economy had grown to support the establishment of its own provincial currency (Hart 2009:41). Charleston's markets have been described by historians as "a staging post for the Atlantic economy" since it operated as the economic center for the Lowcountry's larger market system (Hart 2009:50-51).

The economy in South Carolina was in its infancy in 1733, and naval stores were the predominant export, seconded by rice (Bridwell 1982:12). The Carolinas produced substantial quantities of two high-quality kinds of wood used for boatbuilding: both live oak and cedar were found to extend the lifespan of ships (Harris 2014:31-32). Before the Naval Stores Act of 1705 was ratified, Britain precariously relied on Baltic sourced naval stores before the colonial economy was developed. The Baltic market was unreliable especially during wartimes when supplies could be cut off and thus increasing their price (Williams 1935:170-172). With the Naval Stores Act, Britain enacted a bounty to encourage the American colonies to focus on naval store production (Williams 1935:174). The production of pitch and tar from longleaf pine made the Carolinas the predominant source of naval stores in the American colonies. Even many stores provided by New England originated from the Carolina territory (Williams 1935:176). A series of investigations by the Board of Trade into the quality of colonial produced stores concluded in the reduction of the value of naval stores in the 1720s, and South Carolina's market shifted (Hart 2009:38; Williams 1935:183-184).

The market shifted to the more lucrative rice exports, especially after 1731 when Parliament allowed for the direct shipping of rice to the Iberian Peninsula. This allowed American merchant vessels to bypass the requirement to ship first to Britain for redistribution and additional costs. Subsequent acts in 1764 and 1765 further reduced the associated fees and inconveniences of the rice trade (Morgan 1995:438-439). Another major crop was introduced in the 1740s and soon became a staple with the introduction of indigo production in South Carolina (Morgan 1995:447). Rice exports and slave imports formed the bases of the staple economy with almost half of the South's slaves arriving at Charleston and much of the rice crop exported through the port between 1730 and 1780. During this period, Charleston rate of growth exceeded that of Boston and rivaled that of New York (Hart 2009:38-39).

After 1740, the markets in Charleston developed into a "provincial service center" that acted as the urban center of British Atlantic luxury goods (silks, patterned linens, woolens, buttons, etc.) in the South. The growth into a service center contributed to the establishment of a complex consumer society consisting of the primary sale of new goods and the resale of goods between residences (Hart 2009:40-41). Charleston also developed a manufacturing and service market that produced many desired goods by local skilled trades and craftspeople (Hart 2009:42). Charleston tradespeople were often employed in the country to provide services on plantations including both essential and luxury goods. After the 1750s, plantation owners were more likely to purchase locally made household and personal goods rather than import custom products from London (Hart 2009:44). For example, after the 1740s a significant number of tailors were listed as Charleston residents at the same time there was the decrease in the import of British ready-made garments (Hart 2009:48). The growing complexity and capacity of its craftspeople reflect the central importance of Charleston in the economic landscape of South Carolina (Hart 2009:46).

Shipbuilding was not a large industry in colonial South Carolina, especially in the early years of settlement. Charleston merchants relied on British and New England vessels to transport their products to England and other British colonies (Bridwell 1982:14; Harris 2014:12-13). Charleston supported skilled shipwrights capable of producing masts, sails, and blocks to refit and repair vessels, which was an important aspect of the colony from the beginning since almost every vessel entering port usually required some level of repair to restore its seaworthiness (Harris 2014:13; Hart 2009:42). Charleston developed an early shipbuilding industry in the late 17<sup>th</sup> century with Magus Popell the first shipwright to arrive in Charleston from Barbados in 1679. Initially, vessels were designed like those used in the West Indies, small and speedy. Eventually, influence from New England settlers introduced the European inspired colonial tradition adapted to the North American coast (Harris 2014:10). A boom in the production of ocean-going vessels began during King George's War (aka. The War of Austrian Succession) in the 1740s and lasted until the 1760s, which originated as an attempt to replenish the numerous merchant vessels lost to French and Spanish privateers (Harris 2014:31).

In the colony, master shipwrights were those trained at both royal and private shipyards in Britain and mainly produced ocean-going vessels. Whereas, other shipwrights in coastal communities primarily produced the local small craft used for coastal trade. These locally trained shipwrights often worked at various shipyards and usually gained the experience necessary to build the larger merchant or war vessels (Harris 2014:38). Shipwrights, like every other industry in the colony, relied heavily on slave labor in their shipyards. Often, shipwrights would purchase slave carpenters from plantations until their businesses could afford experienced shipyard slaves (Harris 2014:30). Local vessels were created to accommodate the transportation of goods along rivers and the coastal estuaries as well as to evade colonial regulations, which were enacted to reinforce the British Navigational Acts (Harris 2014:13). Three types of vessels were particularly common: canoes, piraguas, and flats were frequently used to transport merchandise downriver to the port markets (Bridwell 1982:13). The dugout design of canoes was contributed by West Indies immigrants familiar with African watercraft of the northwest coast. These canoes were used in Africa to transport materials and slaves from the interior to the coast in a similar natural environment to South Carolina (Harris 2014:11). Piraguas, which were larger than canoes with two masts and square sterns to support a rudder, and flats which were between 45 and 50 feet in length and commonly used to transport merchandise downriver to the port markets (Bridwell 1982:13).

## 5.2.2 Georgetown

Following the conclusion of the Yamasee War (1715-1717), fought between Native Americans and settlers in the southern province, South Carolina settlers turned their interests north to continue trade with Native Americans (Bridwell 1982:2-3). Founded in 1729, Georgetown was surveyed and parceled by William Swinton on the banks of the Sampit River where it flows into Winyah Bay (Bridwell 1982:2; Rogers and Taylor 1994:23). Some scholars have argued the approximate area of Georgetown was the location of Ayllón's 1525 settlement based on the topographic and cartographic depictions in the historical accounts; however, no substantial evidence has been found to support this theory (Bridwell 1982:2). Georgetown's strategic location near the confluence of the Pee Dee and Waccamaw rivers into Winyah Bay should have made it a major port in South Carolina, but a combination of geographic and historic factors denied it from ever reaching the prominence of Charlestown harbor (Bridwell 1982:2).

Georgetown filled a need for the growing population, trade, and wealth in the northeastern part of the state. In recognition of quality meat and naval stores produced in the Winyah area, the Assembly in Charleston authorized a packer (or inspector) in 1714, followed by the assignment of tax inquirers in 1716 to accommodate the growing northern market (Bridwell 1982:3). The parish of Prince George Winyah was created in 1722 to establish local government between the Santee and Cape Fear rivers. As production of marketable goods increased in the Winyah area, the inhabitants insisted on the establishment of an official port to avoid the expenses associated with dealing with Charleston merchants

and lawyers. A period of unrest in the late 1720s erupted when residents refused to pay taxes or go to Charleston to attend court. Georgetown became an official Port of Entry with the arrival of the first collector of customs in 1732, thereby enabling Winyah products such as deer skins, naval stores, rice, and indigo, to be directly exported to London thus saving the costs associated with shipping goods to Charleston (Bridwell 1982:3-6,9). The 1730s was a turning point in the percentages of trade goods, both in Georgetown and in South Carolina. The importance of naval stores exports began to decline at this time, while rice and indigo exports began to rise. The chief imports before the 1730s were primarily staple items such as sugar, molasses, rum, wine, salt, bread, and corn. From the 1730s there was a steady increase in the number and variety of luxury goods imported into the colony including coffee, chocolate, earthenware, glass, silks, and furniture (Bridwell 1982:23).

Despite the rapid increase in trade in Georgetown, especially after its establishment as a port of entry, the market never grew to match that of Charleston. Charleston had the advantage in its earlier founding, both in the development of the export market as well as its status as the colony capital and center of government and religion. As such, Charleston attracted a greater number of South Carolina's wealth and powerful inhabitants. Geographically, Charleston was more centralized than Georgetown and drew more commerce from plantations along the Ashley and Cooper Rivers, as well as from coastal villages north and south of the port (Bridwell 1982:11-12). In one year, between 1736 and 1737, Georgetown exported 1,143 barrels of rice, 2,630 barrels of pitch, 3,984 barrels of tar, and 2,194 barrels of turpentine. By comparison, that same year Charleston exported 42,619 barrels and 519 bags of rice, 11,987 barrels of pitch, 8,018 barrels of tar, and 4,411 barrels of turpentine. During the colonial period, the rate of export from Georgetown remained consistent with approximately 20 to 30 vessels entering and clearing the port. Whereas a total of 217 vessels entered and 228 cleared the port of Charleston between 1736 and 1737, which doubled over the colonial period (Bridwell 1982:12).

Most of these vessels sailed to English ports, with other destinations including Bermuda, Philadelphia, Boston, New York, North Carolina, and Charleston. By the later colonial period, second only to England, exports from Georgetown were destined for West Indies ports (Bridwell 1982:12). Most of the ocean-going merchant vessels were not registered in South Carolina, but from either northern colonies or Britain. River vessels used to transport merchandise to Georgetown were locally owned canoes, piraguas, and flats (Bridwell 1982:13). Georgetown began developing a shipbuilding industry as early as 1745 with vessels made throughout the Winyah region. Around the same time, Benjamin Darling, a New England shipwright, arrived in Georgetown. His shipyard and at least those of John Frinck, Charles Minors, and Daniel Holland are known to have become active in the region. In total, they built several ocean-going vessels between 1745 and 1750 and continued to "produce vessels on a regular basis" (Bridwell 1982:14). From 1750 to the beginning of the American Revolution, the Winyah area saw the most intense period of shipbuilding with a total of 22 known schooners, brigantines, sloops, snows, and ships constructed (Bridwell 1982:14-15).

### **5.2.3 Revolutionary War**

The Revolutionary war resulted from years of grievances between the American colonists and British Parliament. Having become self-sufficient colonies with their own local forms of government, the colonial assemblies felt they should be recognized as equal to Parliament and be permitted to self-govern themselves independent of Parliament's interference. The Colonies argued that they were British subjects living overseas and therefore deserved the same liberties as British subjects in the homeland. Parliament disagreed; still viewing the colonies as tools to support the British Empire and believing the strength of the empire relied on the centralization of a single legislative body. To reassert control over the American Colonies, Parliament issued extensive taxation over colonial trade, interfered directly with domestic colonial affairs, and established a standing British military presence in the Colonies (Greene 2013: 227-228, 244, 271, 276). These subversive measures began as early as 1763 and hostilities igniting in

Massachusetts and escalating right up until the Declaration of Independence in 1776 (Allison 2011:8-10; Bridwell 1982:24).

At the onset of the American Revolution, the Royal Navy was the strongest sea power in the world. The American Colonies had no navy and more experience as privateers than as navy sailors. Nevertheless, sea power and control of the major ports were crucial aspects of the war (TRC 2012:174). Beginning in June 1775, John Adams, from Massachusetts, was trying to gather support for a Continental Navy but was met with resistance especially from southern delegates. Except for Charleston, the southern colonies had few vessels of their own since most of their produce was transported on British vessels. Few truly believed all ties would be cut with Britain and a navy would be undertaken by only the northern states since they had the shipyards capable of constructing a fleet of frigates in short order (Miller 1974:40). The Continental Congress eventually approved the navy, authorizing construction of thirteen vessels and purchasing or pressing a variety of merchant sloops, schooners, brigs, and brigantines. The individual colonies also outfitted their own navies to assist in maritime war effort, with the strongest navies provided by Rhode Island and South Carolina (Volo 2007:53-54).

Commissioning privateers during wartime was a way for the Continental government to reduce their investment in outfitting a sizable standing navy. Privateering was considered an attractive and alternative means of income to merchant traders in war time, although, as private ventures, privateers operated independently from the U.S. Navy and could not be regimented as such (McCranie 2011: 17-18,197; Garitee 1977:132). The exact numbers of captures are variable due to incomplete and conflicting records; however, American privateers reportedly captured over 3,000 British vessels during the Revolutionary War (Miller 1974:259-261). In addition to the damage they inflicted on British maritime trading, the privateers were also vital in securing badly needed arms and stores for the American war effort (Miller 1974:259-261; TRC 2012:175). For example, at the start of the Revolutionary War, Charleston merchants, realizing the dangers of shipping goods overseas and attendant rate hikes in insurance and freight rates, responded by seeking domestic market alternatives and privateering ventures another avenue for merchants, ship owners, and seamen to make a profit at the same time as contributing to the war effort (Borick 2009:18-19). Between the efforts of the privateer fleet and the State navies, Congress was able to piece together a Continental Navy (Miller 1974:57; TRC 2012:174).

The early naval activity during the war occurred mainly in the northern colonies with many of the early victories going to the British. Not until the later years of the war did the Royal Navy employ a blockade strategy along the coast (Allison 2011:8-10; Miller 1974:36). With a fleet consisting mostly of American designed schooners and other maneuverable vessels, the efforts of the Continental fleet were focused on harassing the British supply vessels, evading the British blockade, and resupplying the Continental army (TRC 2012:174). In South Carolina, early naval efforts were mostly privateer ventures to obtain gunpowder. After learning that a powder ship was expected in St. Augustine, a sloop from Beaufort, SC was sent to intercept the shipment, and one hundred and eleven barrels of gunpowder was successfully captured from the Royal Navy man-of-war (Miller 1974:36). With a total of 24 warships and a handful of row galleys and gun boats, the South Carolina State Navy played an important role in defense of the South Carolina coast and Charleston harbor capturing 35 vessels in Carolina and Florida waters as well as in the Caribbean (Miller 1974:310; TRC 2012:175; Volo 2007:54). The State Navy contributed three vessels captained by Charles Rowley, David Lock, and James Pyne to join the Continental Navy in the defense efforts during the siege of Charleston in 1780. With the British capture of Charleston, the South Carolina State Navy had been almost destroyed or captured in the defensive efforts (Borick 2009:81-82, 222; Volo 2007:55).

At the beginning of the Revolutionary War, Charleston was one of the four largest cities in the American colonies, equal in economic significance to New York, Boston, and Philadelphia, but was also the wealthiest colony in the Empire that demonstrated the greatest economic growth rate. It was the most important southern port at the time (Borick 2009:18-19) (Figure 71). The capture of Charleston would not only demoralize the Continental effort but would also act as a launching point for further British



**Figure 71. Detail of South Carolina coastline from Charleston Harbor to Little River Inlet, 1775**  
(Library of Congress, Geography and Map Division).

incursions in the south. At the behest of Lord George Germain, General Sir Henry Clinton planned and executed the capture of Charleston in 1780, previously delayed due to insufficient resources, opposition from the French in 1778, and bad weather. After the failed attempt by a combined American and French force to retake Savannah in 1779, Clinton felt Charleston would provide the additional strategic advantage of hindering the colonials and their allies from retaking Georgia (Allison 2011:11; Borick 2009:18).

Amassing a force of 8,500 troops, Clinton and his forces left New York on December 26, 1779. Word of this incoming fleet arrived in Charleston the following January, giving Continental Army General Benjamin Lincoln time to prepare the town defenses in anticipation of the attack (Murdock 1966:142). Lincoln was convinced the reinforced defenses would hold until a French or Spanish fleet could come to the city's aid. In addition to strengthening the city's fortifications, Continental troops and militiamen were brought in to provide extra manpower, and the Marine Committee ordered Commodore Abraham Whipple to take the last squadron of the Continental Navy to defend the harbor. Lincoln planned to use the American ships as floating gun platforms aligned bow to stern to present broadside to any vessel approaching the channel. Conditions, however, were unfavorable to this strategy. Instead, the larger vessels of the fleet were withdrawn to defend the line between Fort Moultrie to the Middle Ground Shoals, while the smaller vessels were left to pester the British (Miller 1974:420-422).

Having failed to take Charleston in his earlier attempt in 1776, Clinton designed the assault to encircle the city from the land and sea in a joint effort between the British army and the Royal Navy (Miller 1974:420). On March 29, 1780, Clinton led a British force across the Ashley River to the Charleston isthmus, supplied with guns and arms by the Royal Navy vessels that needed to lighten their

drafts to clear the bars at the mouth of the harbor. To secure their main supply route, the Americans scuttled several of their own vessels, including four Continental Navy frigates and several State Navy vessels, at the mouth of the Cooper River (Murdock 1966:142; TRC 2012:175; Volo 2007:55). However, with the land route cut off and the harbor blockaded by the Royal Navy, Charleston remained besieged for a little over a month before Lincoln was forced to surrender the city (Miller 1974:423; Stoesen 1962:71). Shortly after Charleston was secured, the British captured and occupied Georgetown. No attempt was made by Continental forces to retake Charleston, in large part due to the considerable effort and resources such a campaign would have cost. Instead, partisan forces led by General Francis Marion liberated Georgetown on May 28, 1781, and it remained in American control until the end of the war operating an important supply depot to Continental forces (Bridwell 1982:28; Stoesen 1962:82). Although General Charles Cornwallis surrendered at Yorktown in October 1781, Charleston remained occupied by British forces until December 1782 (Allison 2011:12; Stoesen 1962:82). Historians recognize the capture of Charleston as the greatest British victory of the war, and one of the greatest losses for the Continental effort (Miller 1974:423; Murdock 1966:138).

Successfully throwing the yoke of the British empire at the end of the war in 1783, one of the first acts of the newly established federal government was to form a method of revenue that did not infringe on the jurisdiction of the individual States. Having just concluded a war over the unfair taxation of the American citizens, the government refused to impose any system of domestic tax. However, the States did agree to transfer responsibility of American commerce (i.e. maritime trade) to the federal government. The Tonnage Act of 1789 gave the federal government control of shipping duties in all United States ports, which included the authority to regulate the taxation of all imports and the collection of said revenues (Miller 2010:13-14). Under this new federal system, South Carolina was divided into districts: the Beaufort district, the Charleston district, and the Georgetown district. While the customs service was the responsibility of the federal government, other port duties such as the quarantine system, appointment of the harbor master and commissioners of pilotage, and the ordinances regulating the use of waterfront properties continued to be legislated by the state or local governments (Bridwell 1982:32).

In South Carolina, many of the state's planters were turning huge profits on cotton. Meanwhile, rice production became the main staple crop in Georgetown and the surrounding Lowcountry (Symonds 2017:264; Tuten 1991:2). Many planters relied on factors, who acted as middlemen or contracted brokers to assist in the planters selling their rice at the optimal times to get the best prices. These factors set up their businesses in Savannah, Charleston, Georgetown, and Wilmington, NC (Tuten 1991:21). Even with the rice market, Georgetown's foreign trade following the Revolutionary Wars declined and eventually stagnated by 1840. As a result, planters and merchants were once again reliant on shipping their goods to Charleston to access the foreign markets (Bridwell 1982:38-42).

#### **5.2.4 War of 1812**

While America was building its new nation in relatively peaceful times, war had once again broken out in Europe following the French Revolution and rise of Napoleon Bonaparte. Interference to American international shipping by both the British and the French led the federal government to enact a series of economic countermeasures beginning in 1806 (Campbell 2015:41). Although the United States gained independence after the Revolutionary War, Britain continued to regard it as a colony. The Admiralty, with the support of Parliament, encouraged the impressment of both American sailors and British subjects on American vessels to replace deserters from the Royal Navy. These disrespectful actions towards the new nation are argued to be the cause of the War of 1812 (Daughan 2011:413-417). South Carolina was particularly incensed at the nearly two decades of interrupted trade caused by the European war, which meant lower value on South Carolina produce and higher freight costs for international shipping (Campbell 2015:39-41).

Instigated over a maritime dispute, the War of 1812 was by and large a naval war with major engagements occurring on the Atlantic Ocean as well as the Great Lakes (TRC 2012:178). However, the United States had not maintained its navy from the Revolutionary Wars, with between fifteen and eighteen vessels in various states of deterioration by 1812 (Emmons 1850:60-70). Once again Congress was divided on the value of a United States Navy. In the years leading up to the outbreak of war, Thomas Jefferson's Republicans preferred instead to rely on the privateer fleet to reduce government expenses (McCranie 2011:15-20). However, President James Monroe's government was convinced of the need for an established federal navy to protect the American coast. Secretary of the Navy Paul Hamilton was requested to submit his recommendations, which included the construction of 22 new naval vessels. The final decision was to refit three existing naval vessels that were in the best condition of the fleet, to increase the number of officers and seamen, and to outfit more dockyards (Dudley and Crawford 1985[1]:51-55). It was not until 1813, upon the realization that the war would not be over quickly and in recognition of the early American naval victories, that Congress committed to the establishment of a United States navy consisting of eighteen seaworthy vessels (Dudley 2003:178; Good, ed. 2012:13-108). In the meantime, letters of marque were issued to merchant applicants to engage in privateering ventures. Numbers vary, but at least 250, perhaps as many as over 500, letters of marque were issued over the course of the war. American privateers reportedly captured over 1,250 during the War of 1812 (Emmons 1850:60-70, 170-196; Good, ed. 2012:13-108). At least 26 privateers were known to operate out of Charleston, although they listed New York, Philadelphia, Baltimore, and Norfolk as their home ports (Mouzon 1954:34-35).

South Carolina was just as unprepared for war as the federal government. The coastal defenses were in a state of disrepair, particularly the forts protecting Georgetown and Beaufort with Charleston's fort hardly any better. There was insufficient equipment for the garrison troops and militia forces and poorly trained soldiers in both forces (Campbell 2015:39-41). The State's naval defenses were equally diminished. Charleston harbor was briefly blockaded by the Royal Navy in October 1812; however, it was the limits of the Royal Navy rather than the defenses of the city that resulted in the abandonment of the blockade. This brief blockade demonstrated Charleston's inability to counter the Royal Navy's effort to throttle ocean-going trade from the port. The continuation of coastwise trade was possible after arming American designed merchant vessels, such as schooners and barges, that were more capable of navigating the coastline than British ships of the line. Throughout the war, Charleston was beset by a lack of vessels and sailors, and a porous coastal defense (Campbell 2015:45-46).

Following the conclusion of the war with France in 1813, the British Navy had more resources available to concentrate on the war with the United States (Dudley 2003:135). At this time, Admiral Sir John Borlase Warren was replaced by Vice Admiral Alexander Cochrane in directing the naval campaign on the American coast. Under Cochrane's direction, the blockade of the eastern seaboard strengthened around major ports and eventually stretched the entire length of the eastern coast. The blockade was so effective that vessels, including the U.S. Navy, were restricted to port (Dudley and Crawford 1985[3]:1-3). Charleston fell under the restrictions of the blockade in late summer of 1813 to the point that the naval commander Captain John H. Dent's fleet of schooners was unable to offer any support against the Royal Navy (Campbell 2015:51). There was a push by South Carolina planters in 1814 to reinforce Charleston's landward defenses following the British occupation of Washington, D.C. In their movements towards Washington, the British decimated Chesapeake Bay plantations. South Carolinians feared similar destruction of their own properties should an attack on Charleston occur. The war was concluded with the Treaty of Ghent at the end of 1814, thus returning Britain and America to the status quo (Campbell 2015:51-52).

Following the War of 1812, rice and cotton continued to drive the economy of South Carolina. However, as the cotton and slave industries moved farther inland to the west, planters began shipping their produce through Mobile and New Orleans more frequently than Charleston. Much of the cotton that was exported through Charleston was shipped to New York first rather than directly to Europe, which

made it less lucrative to Charleston merchants. While the port continued to export increasing volumes of rice and cotton, the overall commerce as well as the population was on a decline. Efforts were made to improve the local economy in the 1830s with the completion of the South Carolina Railroad and construction of the Santee Canal, which connected the midlands of the state on the Santee River with Charleston via the Cooper River (Bridwell 1982:38-42; Thompson 2015:4-6). However, city politics hindered the modernization of the waterfront, particularly by denying the direct access of the railroad to the wharves. The steady economic decline was further hindered by the outbreak of the Civil War and was unable to recover in the aftermath (Yuhl 2005:4).

Between 1800 and the 1840s, Georgetown merchants and planters pushed for the construction of a canal to Charleston to expedite trade. This movement was inspired by the success seen with the establishment of the Santee Canal. While waiting on approval and funds for a canal, efforts were made to improve access to the harbor (Bridwell 1982:38-42). By the 1840s, the practice of Georgetown district rice planters shipping their goods to Charleston was believed by Georgetown merchants to have caused the decline of the local economy (Bridwell 1982:43). To reverse the local economic recession, Georgetown turned to the lumber industry and production of naval stores to supplement the rice exports. Naval stores had always occupied a considerable portion of the market since the 1730s, and the cultivation of naval stores, that is tar, turpentine, pitch, and rosin, had always existed as a supplementary business for planters (Tuten 1991:56; Williams 1935:176). The industry experienced a resurgence with the availability of new steam-powered mills that revolutionized the industry. Beginning in the 1840s, lumber mills and turpentine distilleries were constructed in and around Georgetown, which helped revitalize the port. Most of the lumber came from mills located on the Waccamaw River. One such mill was owned by Captain Henry Buck, originally from Maine. He established his steam sawmill in Horry District as well as his own town and port (Bucksville and Bucksport). His mill was the largest of four in the area at the time, and he quickly amassed a fortune from the lumber industry. The other three steam-powered mills in the area included two sawmills and one rice mill; however, the production turned out by Buck's mills drew increased numbers of vessels to Georgetown harbor in the 1840s and 1850s. In addition to lumber, Georgetown also shipped naval stores, shingles, and logs and sawed timber bound mainly for the West Indies but also to northern ports. The boom in the lumber and turpentine markets drew new people to Georgetown, predominately North Carolinians, attracted south by the turpentine distilleries since most of the North Carolina resources were being depleted. By 1860, ten turpentine distilleries were operating in the Georgetown district (Bridwell 1982:46).

The maritime economy of the nation saw a drastic boom after 1850 when the British completely overhauled their navigation regulations. The changes opened trade in all British ports to non-British merchants without suffering additional duties above those charged to domestic merchants. The new Navigation Act allowed for more open trade outside its Empire on the condition that foreign powers provide the same courtesy (12 & 13 Victoria I. 1849:70-74). The federal government was quick to amend the American navigation laws, which reciprocated the concessions established by the British (Bulwer 1850:1-2). The increase in American foreign commerce between 1850 and 1860 was more than double the value of the previous decade. The growth not only resulted in greater wealth to American merchants, but in a greater amount of coastwise traffic on the eastern seaboard (Noble 1997:26). The opening of trade coincided with the revitalization of Georgetown through the lumber industry and the richest period of Antebellum South Carolina (Bridwell 1982:46; Yuhl 2005:2-3). The nationwide economic boom continued until the outbreak of the Civil War (Noble 1997:26).

### **5.2.5 Civil War**

The Civil War began in 1861 with the Confederate attack on the federally occupied Fort Sumter in Charleston. Before the initiation of hostilities, South Carolina was the first of the southern states to declare its secession from the union of states in 1860 in protest to President Abraham Lincoln's anti-

slavery stance, which would have negatively impacted the South's economy. Eventually, eleven southern states seceded, and together they formed the Confederate States of America (Durham 2005:1; Symonds 2017:264). Within days of the attack on Fort Sumter, President Lincoln introduced his plan to blockade the Southern ports and coastline, which was officially initiated with *USS Sabine* blockading Pensacola, Florida (Durham 2005:2). Unlike the blockades established by the Royal Navy during the Revolutionary War and the War of 1812, Lincoln's plan was less a blockade to restrict the movements of the Confederate Navy and more an attempt to place all southern states under siege by cutting off economic trade (Symonds 2009:33).

If there was one thing the north and south could agree on it was the sheer scale of Lincoln's proposed blockade plan, both perceiving it extremely difficult to successfully blockade 3,549 miles of coastline with only a few seaworthy vessels available to the U.S. Navy at the beginning of the war. To facilitate enforcing the blockade, depots were necessary to ensure a secure port to resupply blockade vessels with coal, any needed repairs, and other stores and equipment. Along the southeastern Atlantic coastline, the Union navy Blockade Board decided upon Hilton Head Island at Port Royal Sound in South Carolina as the most strategically valuable location (Durham 2005:2-4). The battle for Port Royal Sound and Hilton Head Island occurred on 7 November 1861 with the victory going to the Union. Operating out of Port Royal Sound, the South Atlantic Blockading Squadron was able to expand and strengthen the blockade along the coasts of South Carolina and Georgia. With the loss of Hilton Head Island, the Confederates realized the futility in defending the offshore islands and decided instead to abandon them to concentrate their troops and resources more effectively at mainland points. Although other strategically advantageous coastal points were monitored, they were not fortified (Durham 2005:6-9).

Recognizing the significance of army forces in a war that was predominantly a land conflict, the new Confederate government did not place much stock in building a navy. Initially, the few vessels in Confederate possession were those seized immediately after secession was declared. The fleet of ten vessels could hardly be called a navy (Symonds 2009:11). The Civil War was the first example of steamship naval warfare after centuries of sail. The period was one of the rapid maritime technological developments including steam propulsion, the screw propeller, iron hulls, the first military use of submarines, and shell artillery (Symonds 2009:10; TRC 2012:184). In an early proposal, sponsored by Matthew Fontaine Maury, the Confederate State Navy was to outfit a gunboat flotilla with the new heavy guns rather than invest in the expense of an ocean-going navy. The Confederacy's original plan was to rely on the combined defenses of their coastal forts assisted by the gunboat squadrons to protect the coast. This proposal was disregarded after the unveiling of the ironclad warship *Merrimack* in Hampton Roads, which revolutionized naval strategy by demonstrating the effectiveness of the new technological advancements. Confederate secretary of the navy Stephen Russell Mallory was then tasked with establishing a permanent standing navy (Symonds 2009:11-13).

Recognizing that the Confederacy would never be able to match the Union navy in terms of numbers, Mallory concentrated his resources to overcome insufficient numbers with fewer invulnerable vessels. He insisted on the need for ironclad ships (Symonds 2009:14-15). The Confederacy invested in the design and construction of ironclad *Virginia*, while coincidentally, the Union had commissioned the construction of *Monitor* (Symonds 2009:18). The value of these vessels was demonstrated to both navies after their only engagement on March 9, 1862 at Hampton Road. Both the Union and Confederacy invested and commissioned fleets of ironclads to replicate their success at Hampton Roads. The Union had better resources than the Confederacy in their endeavor: greater capital, more raw materials, and the infrastructure to manufacture the hull's iron plating and engines. Despite the limited resources, the Confederacy had small squadrons of ironclads defending Richmond, Wilmington, Charleston, Savannah, and Mobile by 1864 (Symonds 2009:25-28).

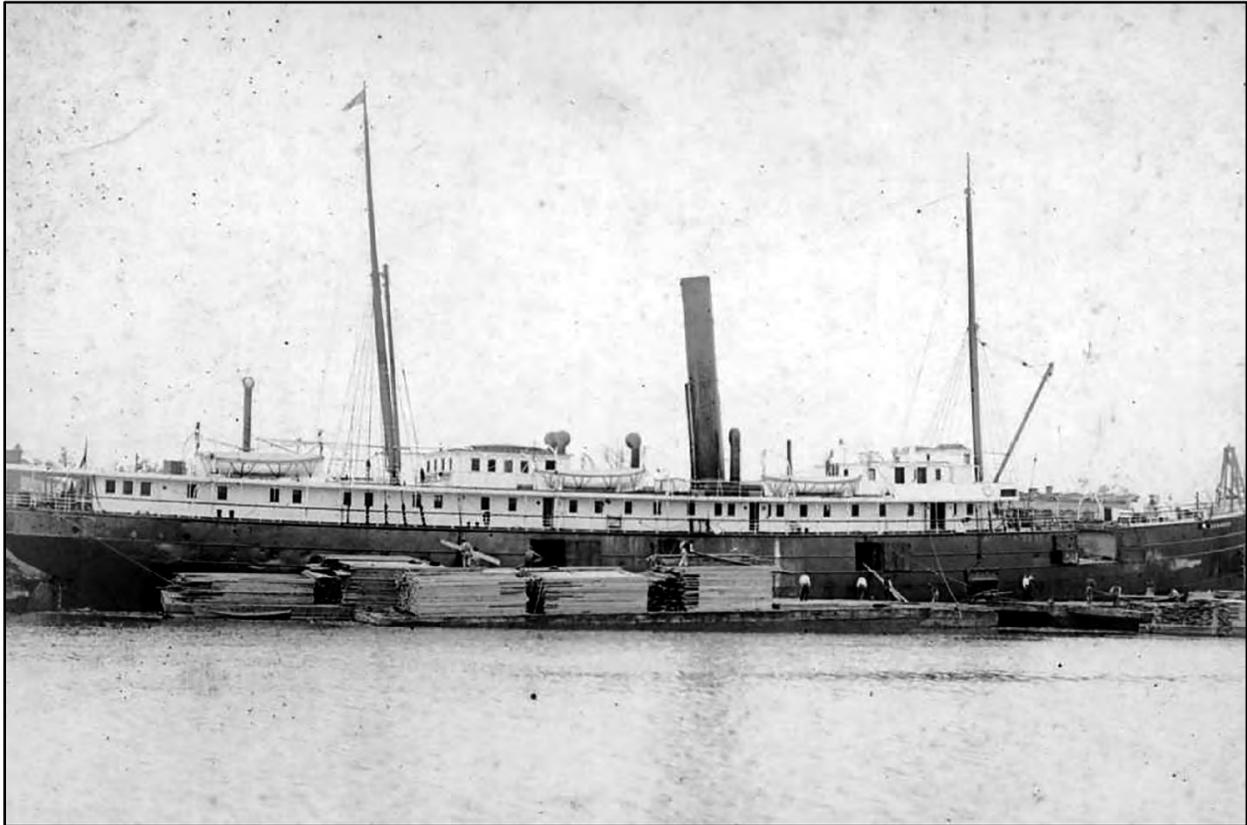
In the early years of the war, the blockade focused on specific southern ports rather than the entire coast. Even though the blockade had yet to reach its greatest strength, already its effects were felt in southern markets and the full implications of its impact realized. The blockade stifled the maritime trade

of an economy that had been booming in the prewar years (Durham 2005:1; Symonds 2017:264). Initial attempts to direct southern merchants towards privateering were short-lived since British neutrality limited access to most ports with prize courts. Also, the drastic change in naval warfare that occurred during the Civil War meant the traditional practice of privateering became far too dangerous when faced with the new classes of warships. Instead, the unique circumstances of the war resulted in the emergence of a new form of merchant maritime activity, blockade running. Meanwhile, the strategy of *guerre de course* was engaged in by a select number of Confederate Navy warships, which destroyed a total of 284 Union merchant ships during the war (Symonds 2017:271-272). Although the practice was crucial to supplying the Confederate military forces, blockade running was not regulated the way privateering had been, and the goal was to export and import goods rather than attempt to capture them from enemy vessels (Symonds 2017:49-52; TRC 2012:184-186).

In response to the shortages and high prices of goods, private entrepreneurs began engaging in blockade running to meet consumer needs for large profits (Durham 2005:5-6). Blockade running was a high risk, high reward venture that took advantage of market shortages to turn a substantial profit (Symonds 2017:264). The most successful blockade running operations were those with experienced sailors intimately familiar with the coastal waterways and vessels with shallow drafts, steam-powered, fast, and maneuverable (Durham 2005:9-10; TRC 2012:185). As the blockade strengthened around Savannah and Charleston, blockade runners favored Wilmington, North Carolina (TRC 2012:185). Hundreds of blockade runners successfully evaded the Union vessels, enabling the Confederates to import war materials past the blockade to supply its armies. Over the course of the war, the Union Navy captured blockade runners valued more than \$30 million, and successfully prevented the South's export of cotton to Europe, thus diminishing their overseas credit (Symonds:2009:32-33). *Princess Royal* was one such blockade runner captured off Charleston on January 29, 1863 with a cargo of war material. Later sold and commissioned to the Union navy, *USS Princess Royal* was part of the blockading fleet along the Gulf of Mexico coastline for the remainder of the war (CMRT 2018).

Beginning in December 1861, the port of Georgetown fell under the Union blockade for the duration of the war. Except for a few blockade runners able to pass the blockade, for the most part, Georgetown shut down as a port for the war. With inadequate harbor defenses, Union warships were able to enter the harbor and access Georgetown at will. Many planters removed their households further inland to prevent their slaves from joining the Union and to avoid Union harassment. Despite the heavy presence of the Union Navy, Georgetown was not captured until after the fall of Charleston in early 1865 when the Confederacy retreated from Charleston and relocated to Georgetown to establish it as the new base of operations. Charleston had been under siege for almost the entire duration of the war, due to the strong coastal defenses encircling the harbor that withstood the attacks of the Union navy. It was clear by January 1865 that the Union was posed to capture Charleston via a land assault. On February 17, the Confederates retreated from the city. Both Charleston and Georgetown remained under Union occupation until the end of the war (Bridwell 1982:50-51).

The conclusion of the Civil War marked the decline of the South Carolina economy (Symonds 2017:49-52; TRC 2012:184-186). Between the physical destruction of the fields during the war, emancipation, and the financial collapse of the south following the Civil War, the rice industry never recovered to its prewar production levels. Before the outbreak of the Civil War, Georgetown County was the leading producer of rice on the Atlantic coast. By the end of the war, rice production had fallen approximately 90 percent. The economic cost of the war to Georgetown County was the greatest in South Carolina with over 70 percent of the fields no longer cultivated (Tuten 1991:25-26). The lumber and naval stores industries replaced rice as the staple produce in Georgetown and the lumber industry played an important transitional role for planters as the rice markets declined (Bridwell 1982:43; Tuten 1991:55) (Figure 72). The Buck family continued to lead the lumber industry up to the 1890s when the mills were closed. At end of the nineteenth century, a corporation of northern capitalists established the Atlantic Coast Lumber Company. It took four years for the company to purchase the lands around



**Figure 72. Ship loading lumber at Georgetown waterfront, ca. 1890–1915**

At the Atlantic Coast Lumber Company wharf. (Morgan and Trenholm Collection, Georgetown County Library).

Georgetown and secure the foresting rights from desperate rice planters. The company grew into the largest enterprise in Georgetown County, consisting of three mills, countless logging camps, hundreds of miles of railroad, a fleet of steamships, and offices and yards in Norfolk, Philadelphia, New York, and Boston. In the twentieth century, the industry expanded to include pulpwood (Tuten 1991:55-56).

In the years following the Civil War, American shipping shifted from overseas trade to focus on establishing and strengthening specific trade routes with South and Central America and the Caribbean. Domestic coastwise trade continued transporting cargos such as coal, lumber, sand, stone, and lime. Often old sailing vessels were converted into barges to be towed by steamships or tugs to facilitate the transport of larger loads. Railroad freight was continually growing in popularity, especially for transporting perishable goods (TRC 2012:186). The American shipbuilding industry experienced some growth in the 1890s, however, by the early twentieth century, the U.S. merchant fleet was still insufficient in numbers.

### **5.2.6 World War I**

When war broke out in Europe in July 1914 after the assassination of the heir to the Austro-Hungarian Empire, the conflict engaged all the major world powers at the time. President Woodrow Wilson endorsed a policy of American neutrality at the outset of the war, unwilling to be drawn into a conflict that did not concern American interests. However, he strongly advocated for the merchant marine, recognizing its value to support American commerce. In 1916, his proposal to Congress for the creation of the U.S. Shipping Board was approved. The Board's main purpose was to bolster the merchant marine to meet the demands of American trade with foreign countries, as well as establish naval reserves for the defense of

said commerce. Under the direction of the Board, the merchant marine fleet was expanded, and contracts for serviceable, seaworthy vessels were issued. Known as the Emergency Fleet Corporation, dozens of new shipyards and fabrication plants were built to facilitate the construction of a fleet of wooden and steel hulled vessels (TRC 2012:187-188).

It was not until early 1917 that Wilson declared that America was at war with Germany and the Central Powers. The change of heart came after Germany opened unrestricted submarine warfare, which authorized U-boats to resume targeting neutral merchant vessels. German U-boats had been decimating British and neutral shipping to handicap the Allies by restricting access to food and military supplies (Hagan 2017:45-46; TRC 2012:189). With the addition of the American Navy to the war, the British Admiralty proposed a convoy system to protect shipping, but this strategy was unpopular with President Wilson and the secretary of the navy. However, after months of employing the convoy system, there was a noticeable reduction in the rate of Allied losses to the U-boats, which finally convinced them of the effectiveness and value of the strategy. At that point, the Navy Department redirected the efforts of the U.S. naval shipbuilding industry from capital ship construction to convoy escort vessels (Hagan 2017:45-46; TRC 2012:189). In addition to implementing the convoy system, the U.S. Navy also sent a battleship division of four dreadnoughts to the North Sea to join the Royal Navy's Grand Fleet in the blockade of the German coast. The remainder of the U.S. Atlantic Fleet was stationed along the eastern seaboard to guard the American Atlantic coast (Hagan 2017:47).

Activity in Charleston before the United States entered the war was quiet. On the night of January 31, 1917, shortly after receiving the news that Washington had cut diplomatic relations with Berlin, the German crew of the freighter *Liebenfels* attempted to block the Navy Yard channel by scuttling the vessel in the Cooper River. The crew was arrested and charged, and the *Liebenfels* was salvaged and outfitted at the Navy Yard into an armed cargo carrier (Moore 1985:39). For the duration of the war, the Navy Yard built and repaired warships and came to specialize in converting captured enemy vessels for various military uses by the U.S. Navy (Moore 1985:39; Spirek and Amer 2004:30). Despite the presence of the Navy Yard, the port had few defenses. When warned of possible U-boat activity off the South Carolina coast, the city was unprepared to counter them. The fleet stationed at Charleston was insufficient and ill-equipped with no mines, submarine nets, or means of outfitting a convoy (Moore 1985:43).

Recruits were trained in infantry tactics, boats under oar and sails, artillery, radio, signaling, and lead and compass. The Navy Yard later became a receiving station for aviation recruits in February 1918, which remained its primary role until the end of the war (Moore 1985:42-44; Spirek and Amer 2004:29-30). The operation of the Navy Yard required thousands of employees to manage and maintain and constantly required increasing numbers of workers for various shipbuilding trades and workers for the clothing factory. As a result, Charleston and the state received a restorative economic boost from the wartime activity (Moore 1985:49; Spirek and Amer 2004:31).

By 1920, the City of Charleston had regained responsibility of the port facilities not directly owned by the Navy. The Port Utilities Commission (PUC) was established in 1921 to take over port properties from the negligent Charleston Terminal Company and began a campaign to renovate most of the rundown terminals and facilities. These repairs consumed much of the PUC's efforts in early years; however, it soon made concentrated efforts to promote the port of Charleston to entice business (Bowman 2017:18-20). Promotional efforts began first with gaining local support from South Carolina businesses and advertising at the State Fair in Columbia. In partnership with the State Port Committee, the PUC successfully lobbied the state legislature to name Charleston the official State Port and established the State Port Commission to develop the port. The PUC remained actively involved to represent Charleston's interests and attract international investment (Bowman 2017: 26-29). The PUC was successful in building the port economy up, both domestically and internationally, establishing trade relations with major cities such as Hong Kong, Bombay, Melbourne, Amsterdam, Cape Town, and Rio de Janeiro (Bowman 2017:4-5). The Commission's success lasted until the stock market crash in 1929, which had a devastating impact on Charleston maritime commerce and the end to the PUC (Bowman

2017: 46). Between 1930 and 1940, Charleston's economy became as unstable as the rest of the nation: the volume of tonnage and railcars handled decreased, the port suffered overhead deficits, Charleston experienced a decrease in tourism and a rise in city debts and impoverished citizens. The city appealed to the federal government for assistance. Between 1933 and 1936, the New Deal agencies invested almost \$35 million into Charleston and the federal government spent an additional \$6.6 million on the Navy Yard between 1933 and 1939 (Bowman 2017:49-50). In 1942, the once again self-sustaining city replaced the long-bankrupted PUC with the South Carolina State Ports Authority (Bowman 2017:6).

### **5.2.7 World War II**

While American merchants had participated in an unofficial capacity as a naval auxiliary since the colonial period, the U.S. Merchant Marine Corps was not established until 1938. That year, President Franklin Roosevelt created the U.S. Maritime Commission and approved the mass production of a fleet of Liberty ships, anticipating the need for a large fleet of ships to carry troops and supplies for the looming war in Europe. At the same time, he also established the U.S. Maritime Service, the predecessor of the U.S. Merchant Marine, which was responsible for training the seamen recruits in navigation, engine operation and maintenance, and air and submarine attack countermeasures. Although trained as a naval auxiliary and consisting of thousands of pressed former mariners, Navy, and Coast Guard personnel, the Merchant Marine was not officially considered part of the armed service (USMM 2006).

With the outbreak of World War II in 1939, the United States once again adopted a policy of neutrality. Nevertheless, in anticipation of the eventual involvement of the U.S. in the war, President Roosevelt took measures to strengthen the merchant marine. To do so, he replaced the U.S. Shipping Board with the U.S. Maritime Commission and proposed the Long Range Shipping Program to build 500 new vessels within six years. Within the first year, approximately 150 cargo ships were completed. By this time, France had fallen under German occupation, and Italy had allied with the Axis Powers. With the responsibility for the war effort falling to Britain, maintaining its sea power and supply routes became an even greater challenge for the island nation. Recognizing the increased demand for serviceable vessels, the U.S. Maritime Commission discontinued the Long Range Shipping Program for the Emergency Shipbuilding Program. Over 2,600 cargo steamers, Liberty Ships, and over 500 Victory Ships (the improved Liberty Ship design) were rapidly produced for wartime service (TRC 2012:188-189).

The Lend-Lease Act, passed in 1941, permitted the United States to provide Britain with vessels and a continuous supply of arms and defensive materials while maintaining their neutrality by delaying payment. Initially providing 50 World War I destroyers, the Liberty ships were later brought into service (TRC 2012:188-189). The ramifications of the Lend-Lease Act were the provocation of Germany to extend its submarine warfare to target U.S. shipping, even operating off the American east coast beginning in 1942. Almost 400 U.S. merchant vessels were destroyed in the initial six months before the U.S. employed a convoy system to counter U-boat attacks (TRC 2012:189). The Battle of the Atlantic, as it came to be known, continued until 1943 when the Allies developed better weapons and tracing equipment to successfully counter U-boat attacks and convoys were large enough to overwhelm U-boat attempts to isolate Britain (TRC 2012:190).

For Charleston, the effects of the U.S. joining the war resulted in the expansion of the Navy Yard to facilitate the demands of the Navy destroyer escort contract. Existing infrastructure was dedicated to destroyer construction and ship repair. The South Yard was constructed to extend the shipyard to include workshops, another dry dock, shipbuilding ways, additional storage facilities, a naval hospital, and marine barracks. In addition to destroyer and destroyer escorts, the Yard also repaired and refitted harbor tugs, hospital ships, gunboats, patrol craft, and Coast Guard cutters. In preparation for the D-Day assault in Europe and the invasions of the Pacific Islands, production at the shipyard began focusing on the construction of landing craft and supply vessels in 1942. The Navy Shipyard was one of the largest military employers during the war with approximately 26,000 employees. With the considerable amount

of work that continued throughout the war, the Navy Yard recruited women and blacks to the workforce, which later led to social change and civil rights events in the city. Although the biggest employer, the Navy Yard was not the only shipbuilder in the city. Several smaller, privately owned companies also operated during the war, constructing tugs, minesweepers, and smaller naval vessels (Spirek and Amer 2004:31-33).

Unlike the previous war, security of the harbor was better able to protect against the threat of U-boat lurking off the coast. The navy commissioned commercial vessels to patrol and guard the harbor. Between the two World Wars, the U.S. Navy lost few vessels off the South Carolina coast: none were lost to U-boat attack, having either run aground or been intentionally sunk near Charleston as part of training exercises (Spirek and Amer 2004:32-33).

### **5.2.8 Post-WWII Shipping Activities**

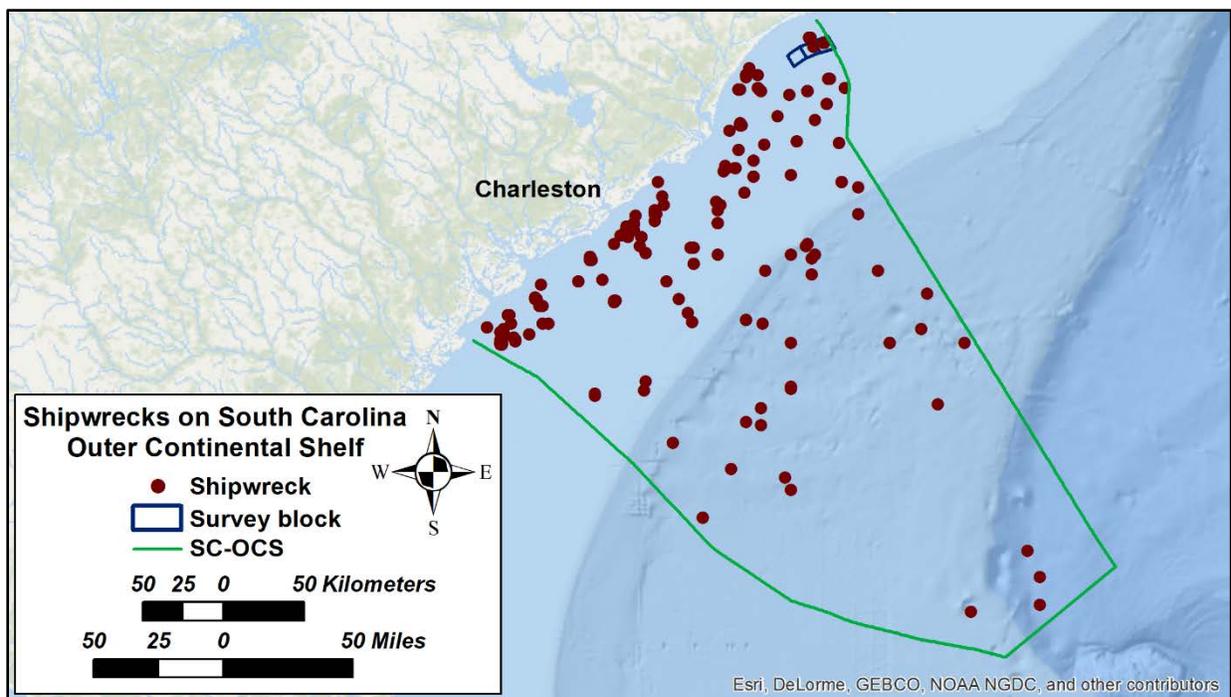
Following the end of WWII, the U.S. had ascended to a major world power, and the U.S. merchant marine was once again featured on the world stage. The immediate postwar years saw a boom in American maritime commerce as many Liberty ships were sold off to other countries (TRC 2012:189). Beginning in 1948, the U.S. became actively involved in providing billions of dollars' worth of cargo to war-affected areas in Europe and the Pacific under the Marshall Plan.

The maritime world was undergoing a period of considerable changes. Steam engines were being replaced by diesel. The advent of container ships in the late 1950s became more prominent with their ability to hold larger loads in undivided holds. Passenger ship liners were going out of business, unable to compete with the newly accessible passenger airlines. As labor costs increased, government regulations tightened, and the U.S. economy shifted from manufacturing and trade to the service industry, the number of American owned and operated shipping lines decreased. Only the tanker industry, which was transporting 21 percent of world's oil in 1954, remained strong in the U.S. (TRC 2012:190). The number and use of recreational sail and motor-powered vessels in U.S. waters increased after the war as Americans were afforded more leisure time and wealth (TRC 2012:191).

Charleston's wartime prosperity continued into the post-war years. Except for the Navy Shipyard, most of the port facilities were released back to the City of Charleston, which transferred ownership to the State Port Authority in 1947 (Spirek and Amer 2004:33). Today, Charleston is still ranked among the top ten U.S. seaports in terms of dollar value of goods imported and exported and has shown steady growth over the past twenty years (SCPA 2018a, 2018d). The main exports include paper and paperboard products, auto parts, and logs/lumber, while the main imports are auto parts and furniture (SCPA 2018c). Most of the cargo transferred in Charleston is traded with Northeast Asia and North Europe, together accounting for 65 percent of all cargo traded (SCPA 2018e). The port of Georgetown has grown to specialize in breakbulk and bulk cargo. Forest products continue to be one of the top commodities along with steel, cement, and aggregates (SCPA 2018b).

### **5.3 Shipwrecks in the Project Area**

According to the Atlantic Outer Continental Shelf Shipwreck Database compiled and maintained by BOEM, the South Carolina portion of the OCS contains approximately 242 shipwrecks (Figure 73). Within the proposed survey grid for the SC-BOEM Cooperative Agreement there are reportedly the remains of seven historic watercraft. These include the American schooner *Williams Richard* that wrecked in 1888, the Norwegian steam merchant D/S *Torungen* lost in 1942, and five other water craft—four landing craft and one unspecified vessel—associated with Barracuda Alley, an artificial reef. Further historic research indicated that the D/S *Torungen*, bound from Halifax, Canada to Charleston, actually



**Figure 73. Shipwrecks on South Carolina Outer Continental Shelf**  
Shipwrecks recorded in the Atlantic Outer Continental Shelf Shipwreck Database.

sank off the coast of Nova Scotia after being struck by a German U-boat torpedo in WWII (U-boats.net 2018). *William Richard* is reportedly in the survey block, N2, and the Barracuda Alley components in survey block, N1. Just to the north of the survey block is the 1874 wreck of the iron screw steamer *Sherman*. The shipwreck is located outside the northern boundary of the survey block, but still within a call area.

### 5.3.1.1 *William Richards*

*William Richard* was an American schooner built in 1869 at Schellinger’s Landing in New Jersey. It was owned by L. B. Smith and registered in 1884 as hailing from Mauricetown, New Jersey. The *Record of American and Foreign Shipping* lists the schooner’s dimensions as 60.7 ft in length, 21 ft in breadth, and 4.8 ft in depth with a total tonnage of 41 tons (ASA 1884). In 1887, the vessel was listed again in the *Record* under the same owner, but instead listed Bridgeton, New Jersey as its hailing port. The dimensions are the same as those registered in 1884 except for a lower tonnage recorded at 39 tons instead of 41 tons (ASA 1887).

The schooner wrecked the following year in 1888. The wrecked schooner was reported by the captain of a passing steamship, *Cherokee*, on route from New York to Charleston. *William Richard* was seen abandoned east-northeast of the Frying Pan Shoals Lightship off the North Carolina coast at 9:30 AM on January 2, 1888. The schooner was described as “dismantled and waterlogged” with her deck load gone, the hatches torn off, and a boat still rigged to the stern davits. The captain of *Cherokee* reported that a steamship was sighted to the south, which he believed was carrying the rescued officer and crew (*New York Times* 4 January 1888:3). On March 18, 1888, two months after the reported abandoning, the *Wilmington Messenger* printed an announcement of “Recognition of Services” to the Captain and Mate of the British steamship *Tinor* for saving the lives of the officers and crew of the schooner *William Richard*. The Captain and Mate of *Tinor* received medals from the U.S. government in recognition of their services (*Wilmington Messenger* 18 March 1888). Considering the likelihood that the current location of the wreck

of *William Richard* off the coast of Myrtle Beach, South Carolina, it is more probable that the abandoned vessel drifted south to an unknown location before sinking to the seafloor.

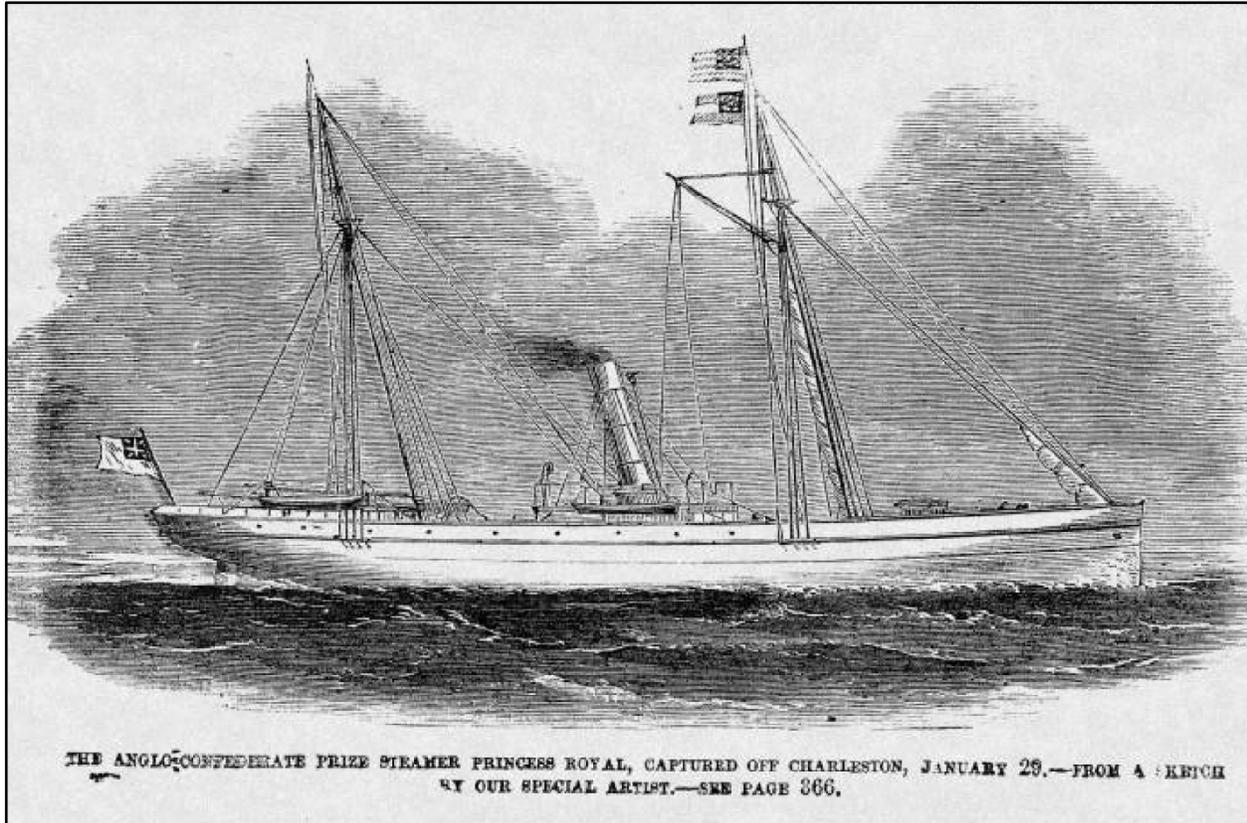
### 5.3.1.2 *Sherman*

The iron screw steamer *Sherman* was originally christened *Princess Royal*. The British passenger-cargo vessel was built by Tod & MacGregor at the Meadowside Yard on the River Clyde in Glasgow, Scotland in 1861. The 774-ton vessel was 200.5 ft in length, 28.2 ft in breadth, and 15.5 ft in depth with a two-cylinder engine and a single screw propeller. The steamer was first registered in 1861 under the ownership of Mathew Langlands & Alexander Drysdale (M. Langlands & Sons) in Glasgow (*Greenock Advertiser* 22 June 1861:1; CMRT 2018). The vessel served as a packet ship transporting passengers and goods between Glasgow, Greenock, and Liverpool (*Glasgow Herald* 30 July 1861:2, 9 November 1861:3).

On November 8, 1861, *Princess Royal* was involved in a collision with a schooner in the River Clyde channel (*Glasgow Herald* 9 November 1861:3). In 1862, *Princess Royal* was sold twice in December: first to Julius Frederick Sichel of Manchester, and then to Johannes Roth & Thomas Oxley of London. The steamer ultimately ended in the ownership of Fraser Trenholm & Co., a Charleston-based blockade running firm. The company employed *Princess Royal* to transport cargo to support the Confederacy during the Civil War (CMRT 2018). Shortly after it was purchased, *Princess Royal* carried a cargo of two horizontal steam engines, boilers, and propellers, cannons, munitions, and general cargo and passengers including engineers and munitions experts from London to Charleston. The steamer made a stop in Newfoundland for coal before continuing to Halifax, Nova Scotia. From Halifax, it sailed to Bermuda before attempting to pass the U.S. Navy blockade. *Princess Royal* was captured off Charleston on January 29, 1863 by Union ships *Unadilla*, *Housatonic*, and *Augusta* while attempting to evade the blockade. During the capture, the steamer was run aground but later towed off and taken to the Philadelphia prize court. In March 1863, *Princess Royal* was sold to the U.S. Navy (CMRT 2018; *Frank Leslie's Illustrated Newspaper* 28 February 1863:366) (Figure 74).

Commissioned as *USS Princess Royal* under Commander Melancton Brooks Woolsey, and classified as a cruiser, was sent to the Gulf of Mexico to serve in the West Gulf Blockading Squadron. The ship's battery was composed of two 30-pdr Parrott rifles, one IX-inch smoothbore Dahlgren, and four 24-pdr howitzers. The warship participated in an engagement with Confederate land forces at Donaldsonville, Louisiana on 28 June. *Princess Royal* was then ordered off the coast of Texas and remained there to the end of the war in 1865. *Princess Royal* captured the schooner *Flying Scud*, *Neptune*, the schooner *Flash*, the schooner *Alabama*, *Cora*, and the schooner *Anna Sophia* and assisted with the capture of the schooner *Wave* (NHHC 2015). In a report dated November 27, 1864, Commander Woolsey describes the capture of the schooner *Flash* off the coast of Mexico. The schooner had just left Galveston and was bound for Tampico. On board was a cargo of cotton, one English ensign and an exemption paper from military duty for the captain. Woolsey assigned a prize crew to take the captured schooner to the New Orleans prize court, while he continued into Galveston to obtain more coal (*ORN* 1907:739). The capture and sale of the schooner *Flash* and its cargo in New Orleans were advertised in the *Times-Picayune* on March 23, 1865 (*Times-Picayune* 23 March 1865). After the war, in September 1865, *USS Princess Royal* was listed with at least a dozen other vessels for sale by the United States at the Philadelphia Navy Yard (*Press* 2 September 1865).

Sold to William F. Weld & Co. of Boston and registered in Boston, the steamer was renamed *Sherman* (CMRT 2018). The steamer once again served as a passenger-cargo vessel, sailing between Boston and New Orleans. Newspaper advertisements offered freight and passage with departure times to New Orleans aboard the steamer (*Boston Daily Advertiser* 3 January 1866). On January 9, 1866, *Sherman*



**Figure 74. Captured *Princess Royal* off Charleston**

*Frank Leslie's Illustrated Newspaper* 28 February 1863:366.

was rescued by two other steamers in a northeastern gale off Boston Light struggling to make it into the harbor with damaged machinery that was only partially operational. *Sherman* was towed by the steamers *Clover* and *American Eagle* into the channel where it was able to anchor (*Boston Daily Advertiser* 9 January 1866; *New York Times* 10 January 1866).

At some point in 1867, *Sherman* was sold to H. B. Cromwell & Co. of Boston and in 1868 was operated by Merchants Steamship Co. in New York City. At that time, it switched to sailing regular voyages between New York City and New Orleans until 1874 (*New Orleans Republican* 11 August 1871; CMRT 2018; *Times-Picayune* 5 February 1869, 27 October 1870). During its service under the Merchants Steamship Co., *Sherman* was involved in three known incidents with other vessels causing damage, two of which resulted in lawsuits. On March 23, 1868, *Sherman* was towed into Charleston in a disabled state having been rescued northwest of Georgetown Lighthouse by the steamer *James A. Gary*. The owners of the rescue vessel later sued the owners of *Sherman* for damages (*Boston Shipping Journal* 9 June 1868; *Charleston Daily News* 23 May 1868). Then on November 6, 1869, as *Sherman* was being towed by tug escort up the channel into New Orleans, it collided with the bark *Mathilde* as it was coming downriver. Witness reports of the event printed in the *New Orleans Republican* were conflicting. However, the report of events stated that the collision occurred near midnight approximately fourteen miles downriver from New Orleans. *Mathilde* and two other vessels were being towed by one tug down the middle of the stream. The collision occurred while *Sherman* crossed the channel from the eastern to the western shore, causing serious damage to both vessels. The court ruled in favor of *Mathilde* and its tug escort, finding *Sherman* at fault. The owners of *Sherman* were fined the cost of damages to *Mathilde* (*New Orleans Republican* 1 March 1871). The third incident occurred off Key West on September 13, 1873. It was reported that the steamer *Sherman* collided with the pilot boat *Invincible* and resulted in the sinking of *Invincible* (*New Orleans Republican* 21 September 1873:4).

*Sherman* met its end on January 10, 1874 off Little River Inlet near the North Carolina-South Carolina state line. On route from New York to New Orleans with a cargo of general merchandise, the steamer started taking on water at an alarming rate. The captain and crew immediately headed for the nearest harbor, which happened to be Little River Inlet, SC. Closer to shore, the captain sent a boat ashore for assistance. The captain of the schooner *Spray* with two civilians went out to aid *Sherman* followed closely by the schooner *Florence*. The crew, passengers, and some baggage and cargo were taken off the steamer to the two assisting schooners. *Spray* sailed for Wilmington, NC. *Florence*, with the captain of *Sherman*, attempted to save as much as possible off the sinking steamer before also sailing for Wilmington. *Sherman* reportedly went down twelve miles south of the Little River bar in ten fathoms of water (*Cincinnati Daily Enquirer* 11 January 1874; *New York Herald* 11 January 1874).

## 5.4 Cultural Resources Mapping Survey and Analyses

### 5.4.1 Previous Archaeological Work

No systematic archaeological work to uncover prehistoric or historic sites has transpired prior to this assessment of the study area. Due to their proximity to the coast and accessibility, nearby wrecks are visited by local dive shops. Two dive shops, Express Watersports and Coastal Scuba, in the Myrtle Beach area provide sport diving activities on nearby wrecks, artificial reefs, and ledges. Only Coastal Scuba of North Myrtle Beach, SC offers half-day excursions with departures from Little River Inlet to the shipwreck of the *Sherman*. Coastal Scuba's website characterizes the site of *Sherman* as one rich in marine life and material culture ([http://coastalscuba.com/myrtle-beach-scuba-diving-sites/\[4/20/2018\]](http://coastalscuba.com/myrtle-beach-scuba-diving-sites/[4/20/2018])).

### 5.4.2 Database Consultation

State and federal shipwreck and obstruction databases were consulted to determine known or reported shipwrecks within a one-mile radius of the survey areas. These include: The Atlantic Outer Continental Shelf Shipwreck Database (ASD), Automated Wreck and Obstruction System (AWOIS), NOAA's electronic navigational charts (ENC) and the Marine Resources Division of South Carolina Department of Natural Resources listing of artificial reefs.

Private contractors as part of a BOEM funded study assembled the Atlantic Outer Continental Shelf Shipwreck Database (ASD) in 2012 using primary and secondary sources, and several other databases of shipwrecks along the Atlantic U.S. coastline. The inventory contains approximately 10,526 shipwrecks along the Atlantic seaboard, of which 242 are in the SC-OCS administrative boundary. The accuracy of the information, relating to location, varies from certain to too vague for many of the shipwrecks, particularly before the advent of modern navigational instruments (TRC Environmental Corporation 2012:155-156).

The Automated Wreck and Obstruction System (AWOIS) database was originally created by NOAA's Coast Survey in 1981 to assist in estimating the effort required to investigate objects in planned hydrographic survey areas in U.S. coastal waters. The database, containing over 13,000 wrecks and 6,000 obstruction reports nationwide as of 2016, is focused on those objects that pose navigation hazards, and therefore does not contain a complete list of known or reported wrecks and obstructions. Additionally, due to a variety of factors AWOIS positions oftentimes do not correspond to charted position. In the SC-OCS there are no wrecks or obstructions listed within the study area (<https://nauticalcharts.noaa.gov/data/wrecks-and-obstructions.html> [8/14/2018]).

NOAA electronic navigational charts (ENC) also compiled by the Coast Survey contain features that are navigationally significant and are the authoritative source for known information about wrecks and obstructions in U.S. coastal waters. Although more comprehensive than the AWOIS database, the ENC database lacks the historic information and context provided by the former database. There is one charted wreck in the N3 survey area (<https://noacoastsurvey.wordpress.com/tag/noaa-enc/> [1/30/2018]).

The Marine Resources Division of the South Carolina Department of Natural Resources (SCDNR) manages over 45 man-made reefs in the estuarine and coastal waters of South Carolina. The reefs are composed of durable structures and materials including concrete and steel structures, ships and smaller vessels, barges, tanks, and subway cars. These are placed to develop and enhance marine fisheries resources due to a relative lack of natural occurring hardbottoms along the SC coast. The artificial reefs also provide recreational opportunities for sport fishermen and divers (SCDNR 2006).

#### **5.4.2.1 Database Findings**

Review of the separate and complementary databases revealed two shipwrecks and an artificial reef located either within or near the project area. Located in the N1 block, the SCDNR artificial reef PA-02, known colloquially as “Barracuda Alley” and Little River Offshore Reef, is comprised of approximately 21 man-made structures, and includes two landing craft, two barges, a tugboat, Armored Personnel Carriers (APCs), concrete culverts, and concrete rubble. NOAA’s nautical chart Cape Hatteras to Charleston (11520) identifies the site as an obstruction and fish haven and comprises an area two-tenths of a square mile. The ASD includes the landing craft and the Norwegian steam vessel D/S *Torungen* in the composition of the artificial reef listed in the database. Further research revealed that the 1,948-ton Norwegian steam vessel was reportedly sunk off the coast of Nova Scotia on 22 February 1942. According to multiple sources, D/S *Torungen* was on route to Charleston from Nova Scotia with a load of paper and cellulose when it was struck by a torpedo and sunk by the German submarine U-96 with a loss of all 19 of the officers and crew (<http://warsailors.com/singleships/torungen.html>[1/30/2018]). Based on these findings it is recommended that BOEM strike the vessel from the ASD. Within the N2 block, the ASD database contains a record for the schooner *William Richard*, lost on 29 December 1887. The last known report of the schooner mentions a passing steamer which observed the partially submerged and dismantled wreck floating approximately 30 miles to the east-northeast of Frying Pan Shoals, and the ASD coordinates of the wreck are dubious as the final resting place of the floating wreck (*New York Times* 4 January 1887:3). A shipwreck symbol found in the N3 block appears on the NOAA nautical chart Cape Hatteras to Charleston (11520) and provides only an approximate location. The ENC wreck database lists the site simply as “submerged, dangerous and always underwater.” It was unlisted in the AOWIS database. The popular dive destination *Sherman* was the only other near-by wreck that appeared in the databases and was over three-miles to the north of the project area.

#### **5.4.3 Archaeological Data Review**

Each of the datasets was reviewed to detect historic cultural resources on the seafloor in the survey areas. Additionally, analysis of subsurface features identified areas bearing the potential to preserve evidence of prehistoric human occupation on the OCS. A magnetometer was the main device used for detecting exposed or buried shipwrecks, which current professional standards call for line spacing between 20-30 m (66-98 ft) to sufficiently survey for small, wooden historic shipwrecks. In this project, the wide spacing of over 200 m between transect lines greatly reduced the chances of locating small sites in the survey area. The multibeam echosounder and side scan sonar, with wider acoustic coverage, expanded the potential of discovering smaller archaeological sites exposed on the seafloor. Subsequent field work in the survey area from an archaeological perspective would require tighter line spacing to detect an exposed or buried early historic shipwreck.

##### **5.4.3.1 Magnetometer**

A total of 137 magnetometer lines, each approximately 11.3 km (7 mi) in length, were recorded in the three survey areas, in addition to the 20.1 km (12.5 mi) corridor transect. Equipment issues, resulting

from malfunction or data not acquired during a transect, resulted in a few data gaps. During refining operations additional magnetometer data was acquired at six areas and the shipwreck of the *Sherman*. Review of the data resulted in only one unknown magnetic anomaly near the shipwreck of the *Sherman*. Two other anomalies were associated with components from Barracuda Alley, an artificial reef in the N1 survey area (Figures 75 and 76).

#### **5.4.3.2 Side Scan Sonar**

Deployment of the side scan sonar resulted in 24 full transects, with one partial line, spaced approximately 169 m (555 ft) apart. The effective range of the side scan sonar was 100 m (328 ft) on each side with a combined swath width of 200 m (656 ft). The survey resulted in a coverage area of 58 sq. km (22.3 sq. mi) of the northern portion of survey box N1. The combined factors of unit failure and time constraints prevented complete coverage of N1 and the other two survey blocks. Review of the sonar data detected several acoustic anomalies of interest to investigate during the refining operations, as well as components of the Barracuda Alley artificial reef in N1 (Figure 77)

#### **5.4.3.3 Multibeam**

Employing the multibeam echosounder resulted in 161 transects, spaced approximately 200 m (656 ft) apart in the three main survey areas, as well as the corridor transect. This total was augmented by multibeam transects at and transiting to each refining area, and at the shipwreck of the *Sherman*. The multibeam had a range of 55 m (180 ft) on each side producing a 110 m (360 ft) wide swath. The survey resulted in a 58 sq. km (22.3 sq. mi) full coverage area in the northern portion of survey block N1, and limited by time, the remaining areas of the survey blocks were spaced 183 m (600 ft) lines apart which was considered adequate for the project completion. Review of the dataset revealed several features of potential interest, as well as elements of Barracuda Reef artificial reef.

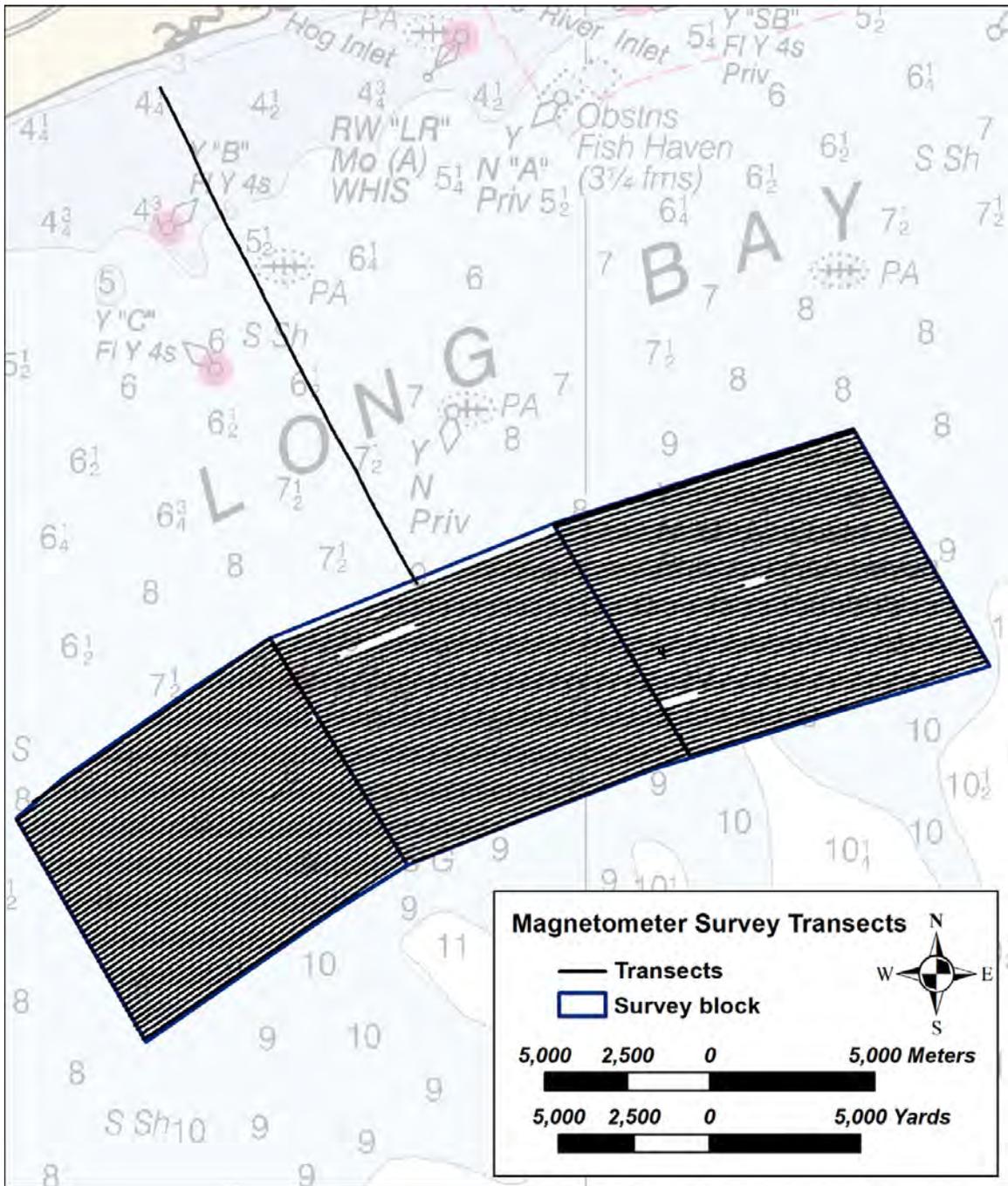
### **5.4.4 Archaeological Survey Findings**

#### **5.4.4.1 Survey Area N1**

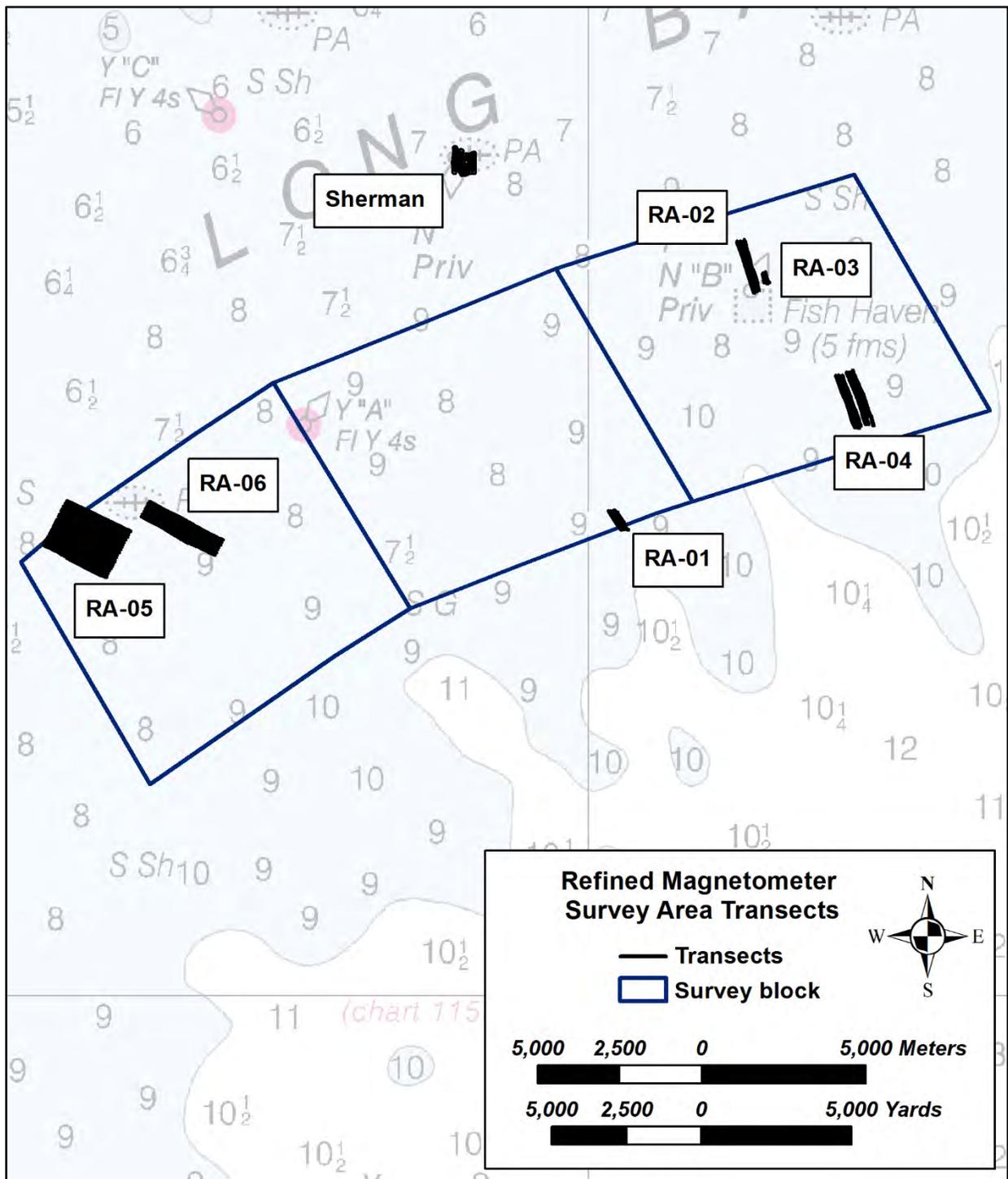
The only magnetic anomalies detected in the survey area of block N1 were associated with the SCDNR's artificial reef Barracuda Alley, ranging from 2 to 38 gammas (Figure 78). The ferromagnetic components of Barracuda Alley, namely the barges, APC's and the landing craft appeared in the data as several magnetic anomalies. Side scan sonar, deployed for only the northern most portion of N1, revealed components of the artificial reef as well as numerous "blooms," which are likely to be schools of fish. The multibeam data provided acoustic imaging of the components of Barracuda Alley, geological features, including a ledge and potential paleochannels. (Figures 79 and 80). No potential archaeological sites were detected. Three areas in N1 were selected for additional refined survey using the magnetometer and multibeam (see Figure 76). Both RA-02 and RA-03 gathered additional data at Barracuda Alley artificial reef, with the former at the main concentration and the latter at an isolated component to the southeast. RA-04 was selected by ESRI to gather additional bottom imagery, and both the magnetometer and multibeam did not reveal any anomalies of potential cultural significance.

#### **5.4.4.2 Survey Area N2**

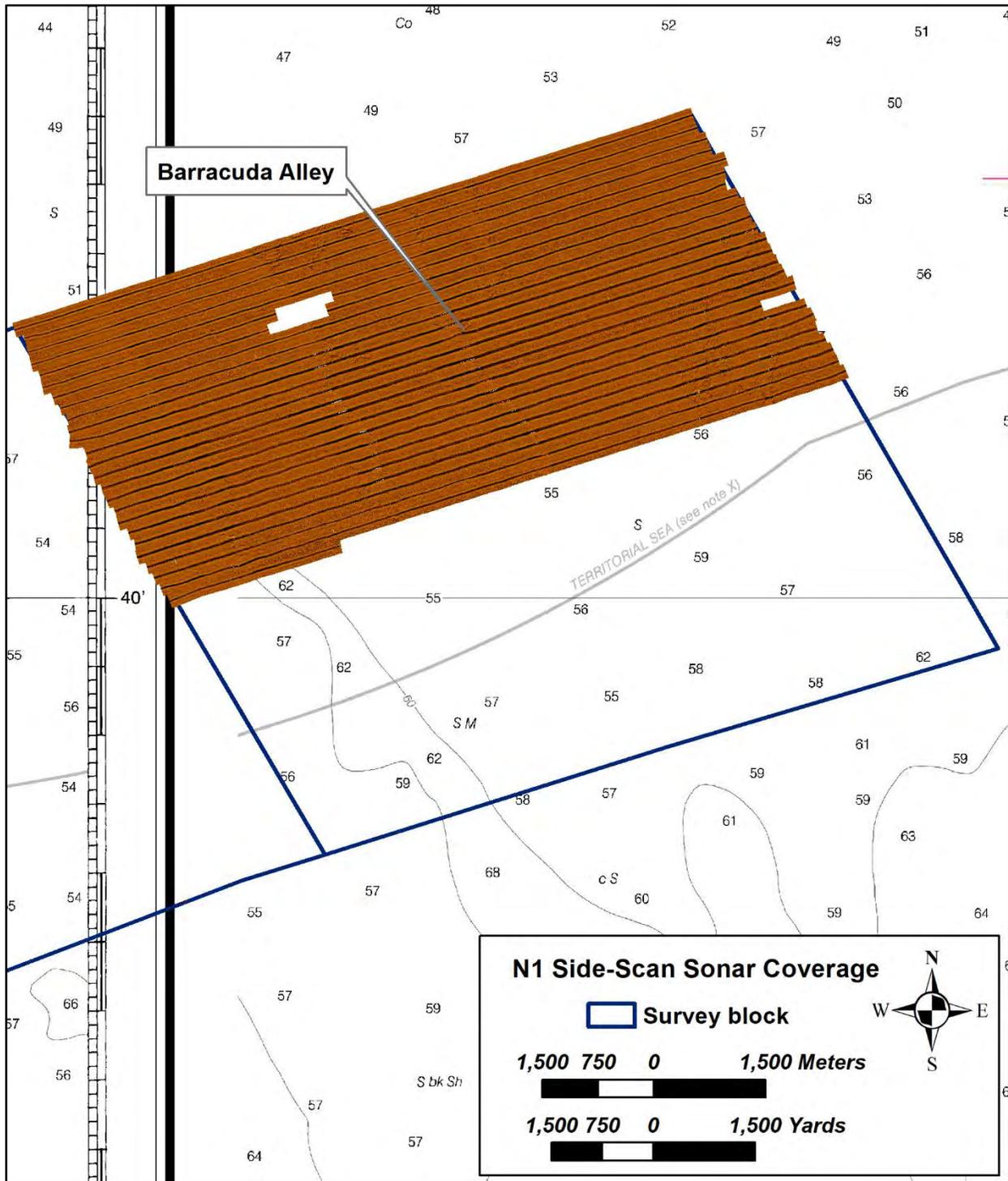
The magnetometer did not detect a single magnetic anomaly equal to, greater than, or less than one (1)



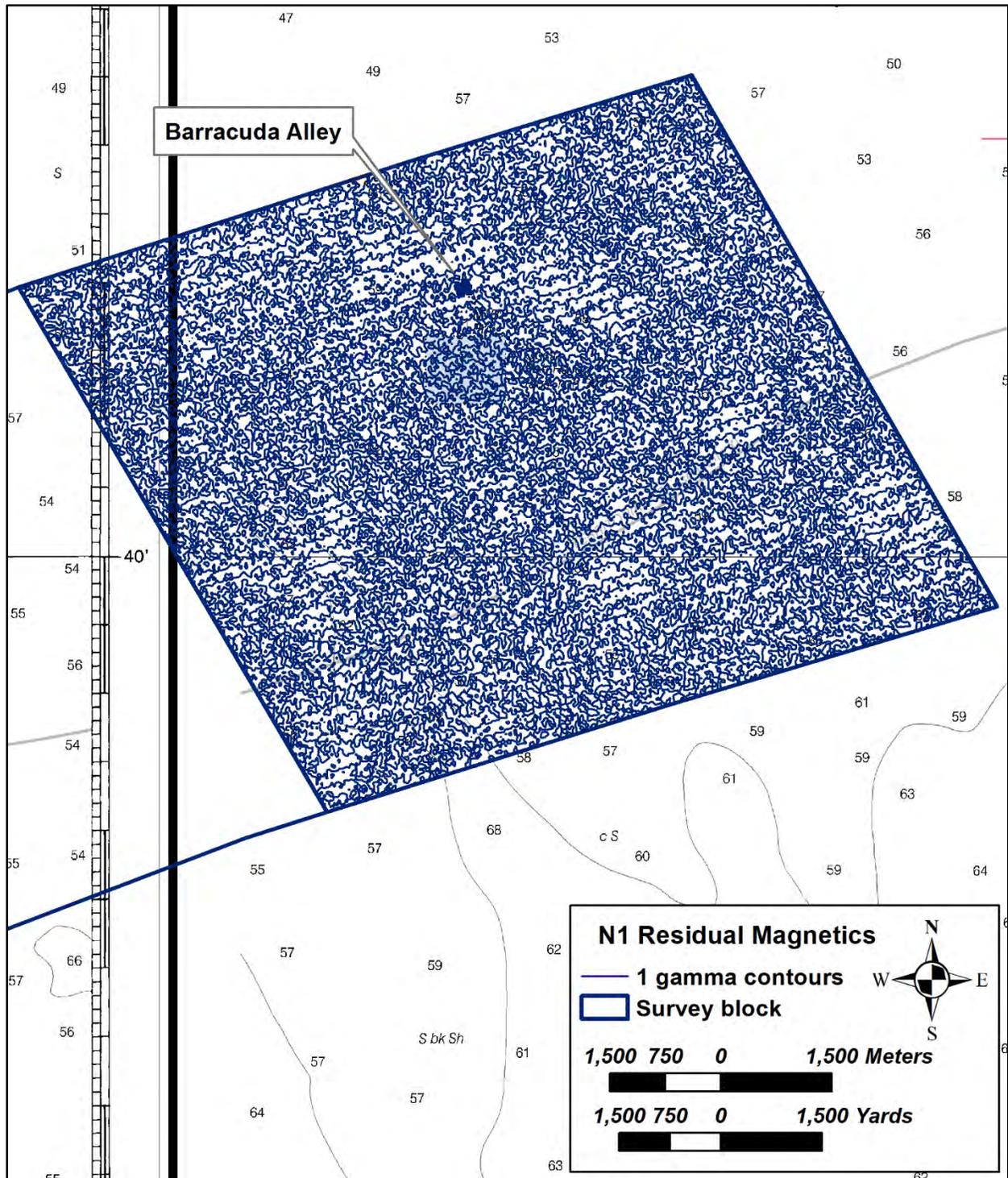
**Figure 75. Magnetometer transects of survey area**  
 NOAA nautical chart 11520, scale 1:432,720, 2018.



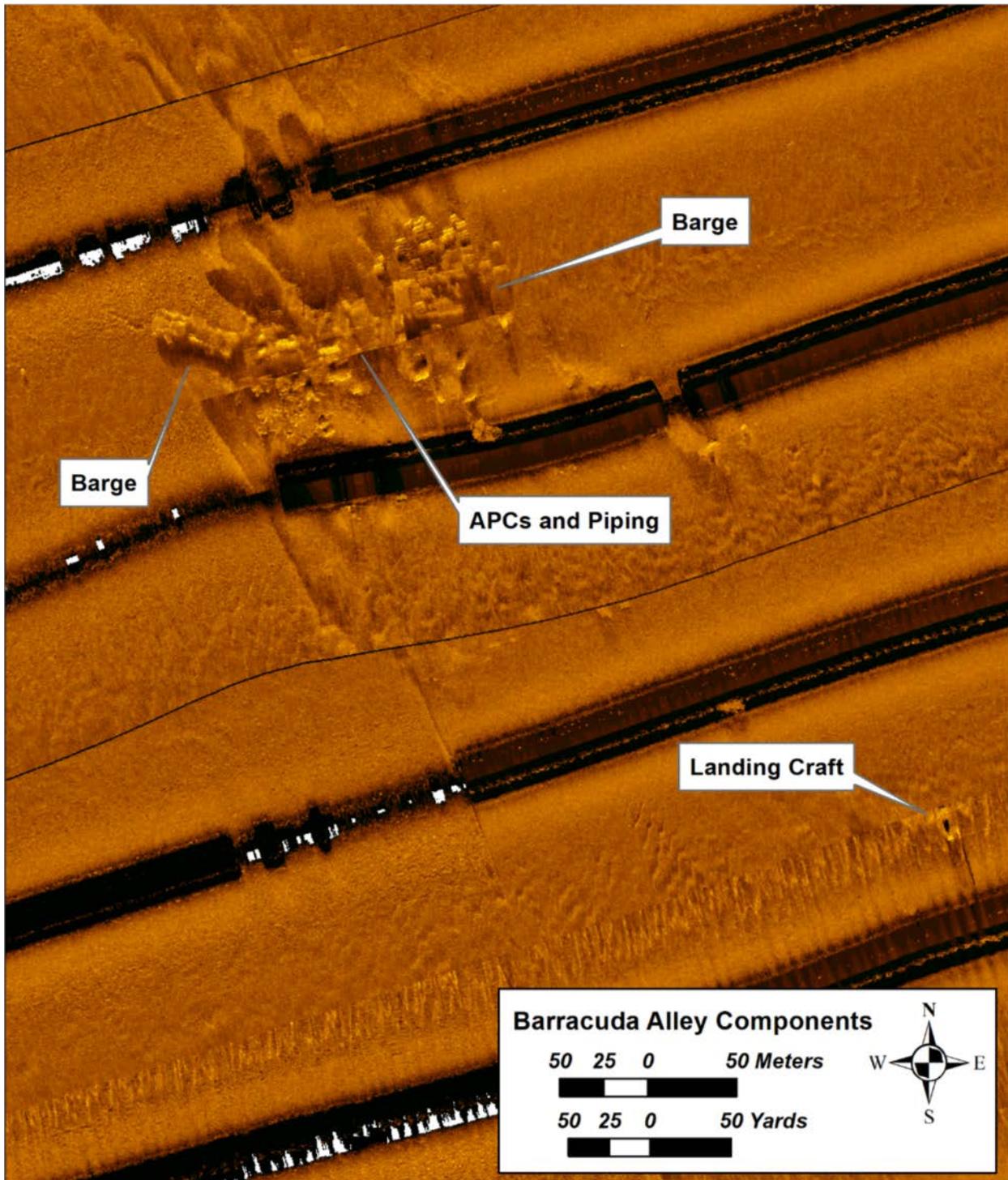
**Figure 76. Refined magnetometer survey areas transects in the main survey area**  
 NOAA nautical chart 11520, scale 1:432,720, 2018.



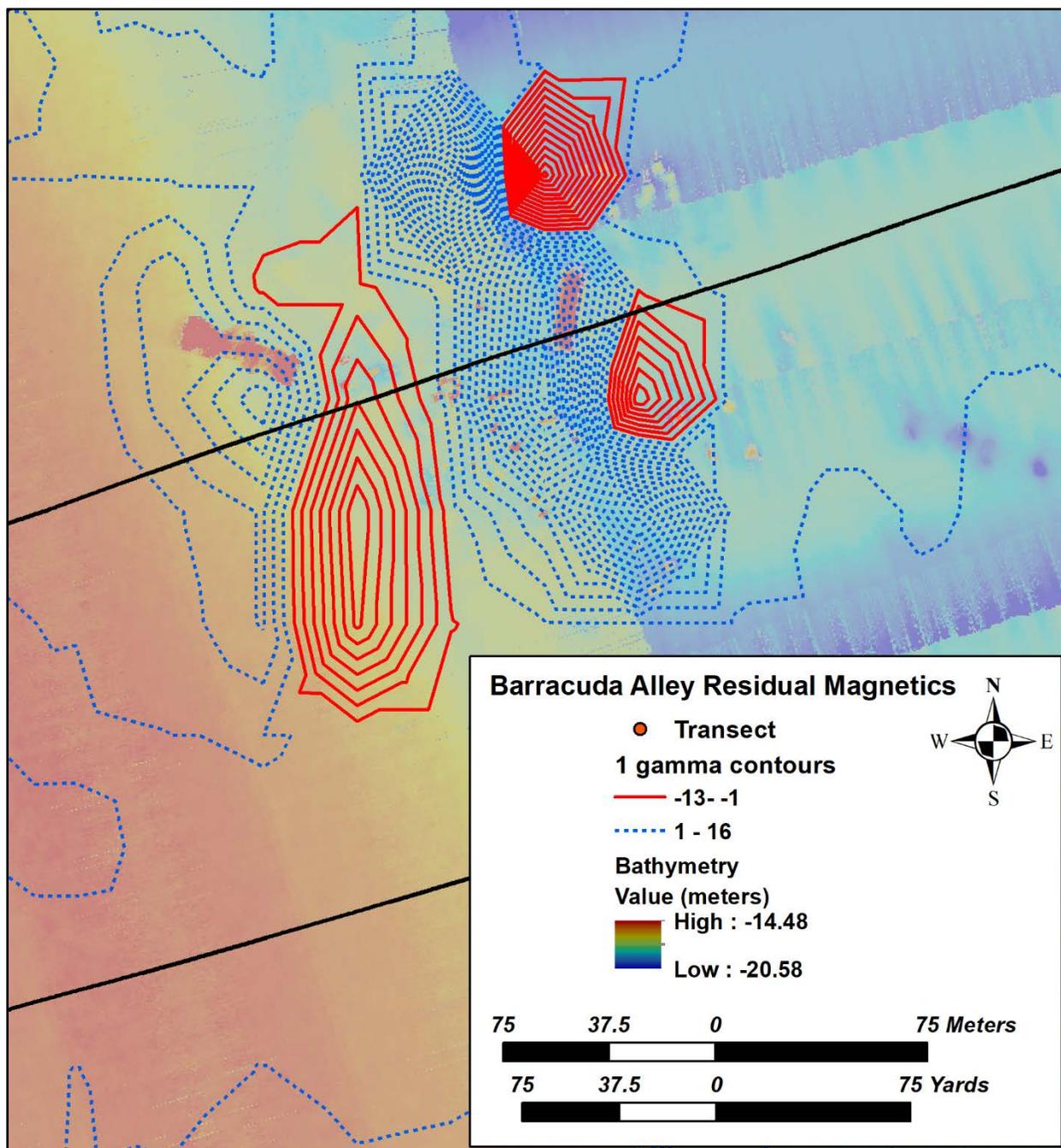
**Figure 77. Side-scan sonar coverage of the N1 survey area**  
 Noting location of Barracuda Alley artificial reef. NOAA nautical chart 11536, scale 1:80,000, 2018.



**Figure 78. Residual magnetic contours of the N1 survey area**  
 NOAA nautical chart 11536, scale 1:80,000, 2018.



**Figure 79. Detail of side-scan sonar coverage of Barracuda Alley in N1 survey area**  
 Artificial Reef created by S.C. Department of Natural Resources.



**Figure 80. Detail of Barracuda Alley N1 survey area**  
 Residual magnetic contours overlaid multibeam echosounder bathymetry. Artificial Reef created by S.C Department of Natural Resources.

gamma (Figure 81). Employing the multibeam echo sounder, detected potential paleochannels and a ledge, but no evidence of historic cultural materials. One area in this block, RA-01, was chosen to gather additional bottom imagery by ESRI; the magnetometer and multibeam did not detect any anomalies of potential cultural significance (see Figure 76).

#### **5.4.4.3 Survey Area N3**

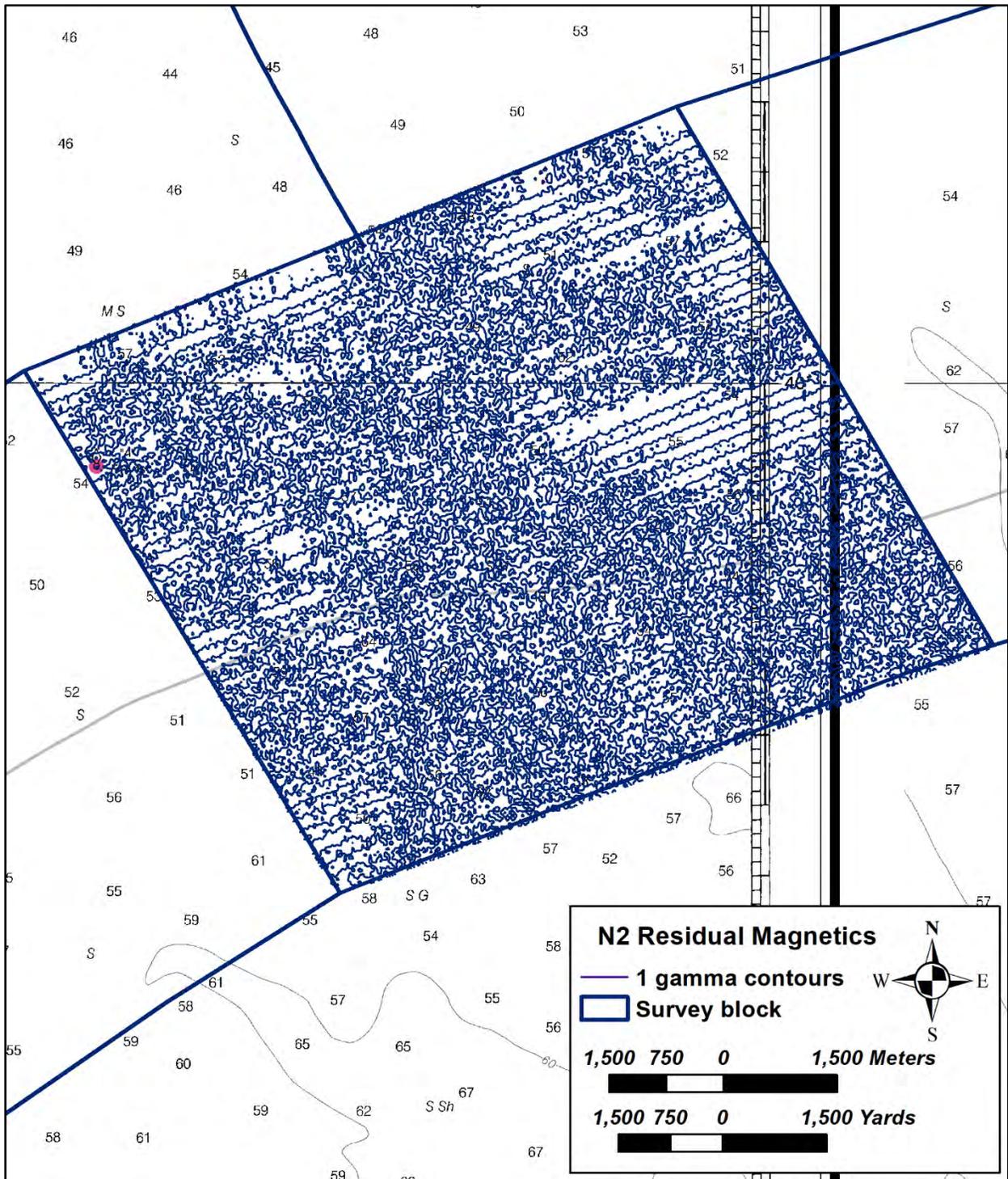
Despite the charted location of an unidentified shipwreck in the survey area N3 not a single magnetic anomaly equal to, greater than, or less than one (1) gamma was detected (Figure 82). The multibeam echo sounder did reveal several geological features and a potential paleochannel, but no evidence of historic cultural materials. Two areas in this block, RA-05 and RA-06, were chosen to gather additional bottom imagery by ESRI; the magnetometer and multibeam did not reveal any anomalies of potential cultural significance (see Figure 76).

#### **5.4.4.4 Corridor**

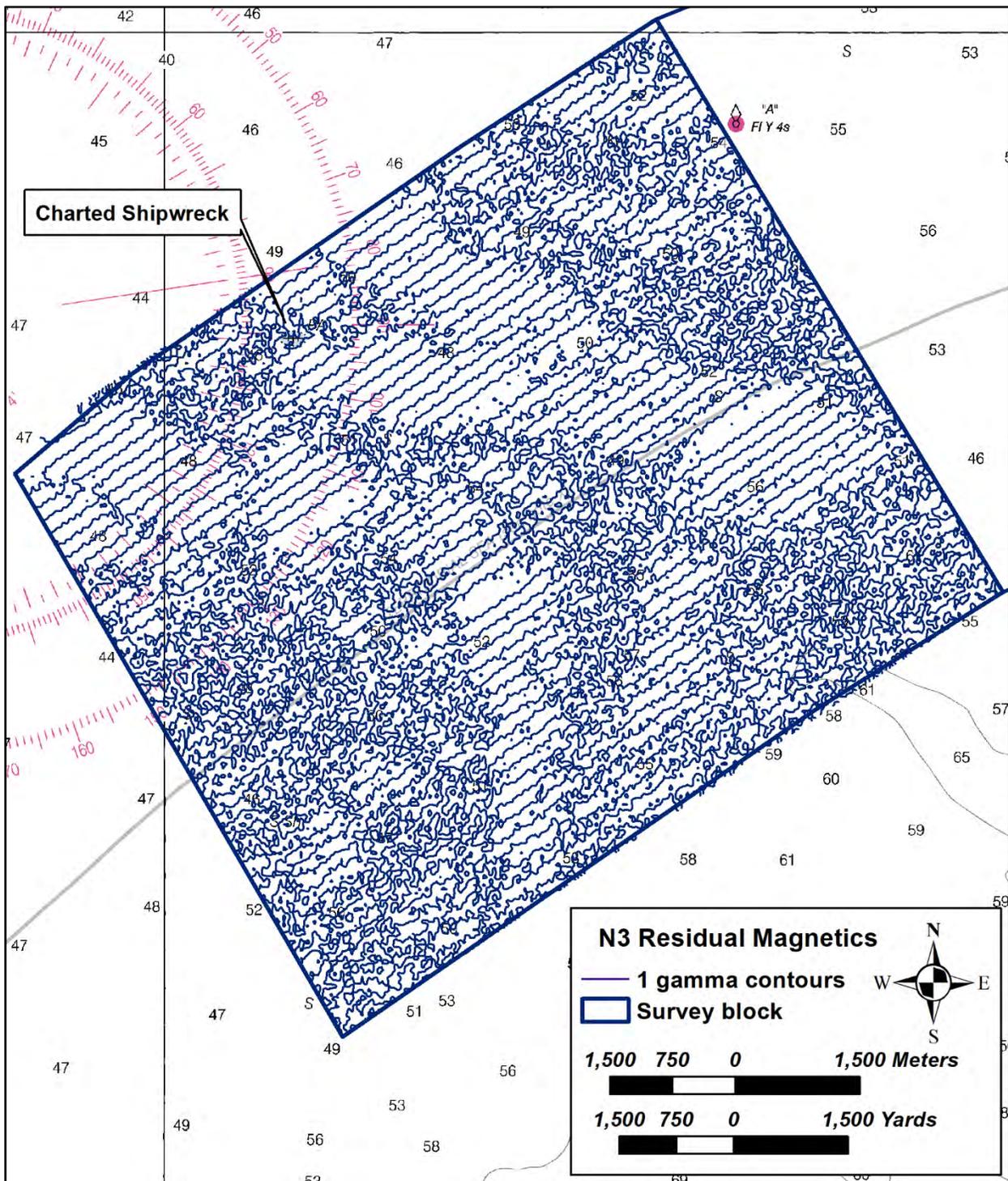
The magnetometer did not detect a single magnetic anomaly equal to, greater than, or less than one (1) gamma (Figure 83). The multibeam echo sounder also did not reveal evidence of historic cultural materials.

#### **5.4.4.5 Sherman**

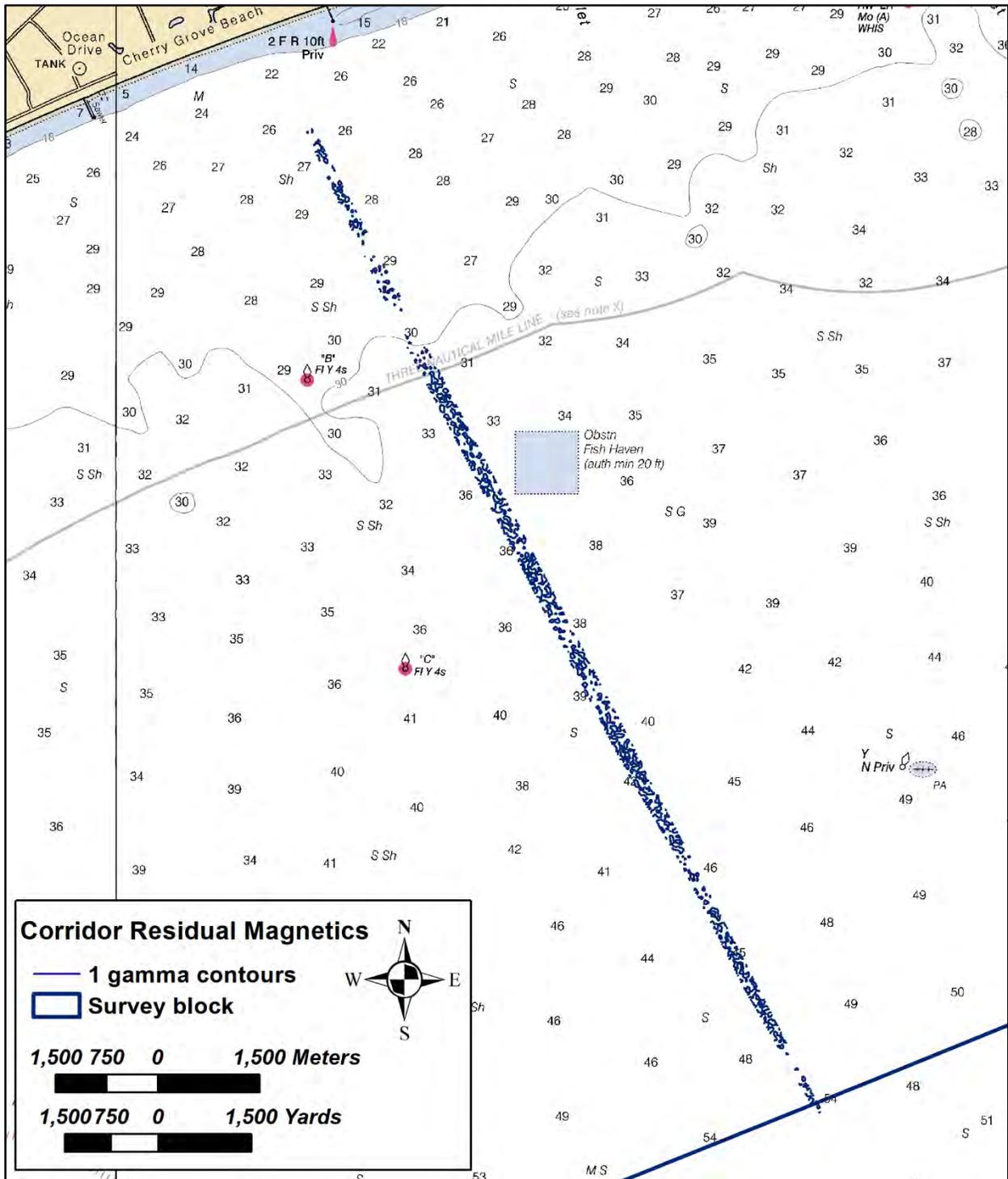
As part of refining operations, the shipwreck of the *Sherman* was surveyed 17 November 2016 using the magnetometer and multibeam echo sounder. With line spacing approximately 69 m (75 yd), researchers generated a crosshatch pattern over the site with heading's north to south and east to west until losing the magnetic signal surrounding the shipwreck. The magnetometer registered a multicomponent anomaly with an amplitude of 131 gammas and duration of 17 seconds on the site (Figure 84). The magnetic anomaly covered a 12,204 sq. m (13,347 sq. yd) area at a five (5) gamma contour interval. Multibeam data depicted the general outline and three main concentrations of shipwreck structure with an overall length of 61.5 m (202 ft) and width of 10.6 m (35 ft) (Figure 85). These dimensions closely mirror the historical dimensions, with the length of 60.9 m (200 ft) and beam of 8.8 m (29 ft). The shipwreck was orientated approximately north to south. The site contained three main areas of relief: north at the bow, amidships, and south at the stern. There was no indication of scattered ship structure in the immediate vicinity of the shipwreck. The magnetics suggest the site remained intact, with no large outliers of iron hull, except for perhaps an outlying magnetic anomaly to the west. The isolated magnetic anomaly, *Sherman-02*, located approximately 132.5 m (145 yd) to the west of the site, was dipolar, had an amplitude of 4 gammas, a duration of 6 seconds and covered an approximate area of 380 sq. m (1,247 sq. yd). Given that the multibeam imagery revealed nothing in this area, it is likely that this is a buried disarticulated section of the shipwreck or perhaps modern debris.



**Figure 81. Residual magnetic contours of the N2 survey area**  
 NOAA nautical chart 11535, scale 1:80,000, 2018.



**Figure 82. Residual magnetic contours of the N3 survey area**  
 NOAA nautical chart 11535, scale 1:80,000, 2018.



**Figure 83. Residual magnetic contours of the Corridor survey area**  
 NOAA Nautical chart 11535, scale 1:80,000, 2018.

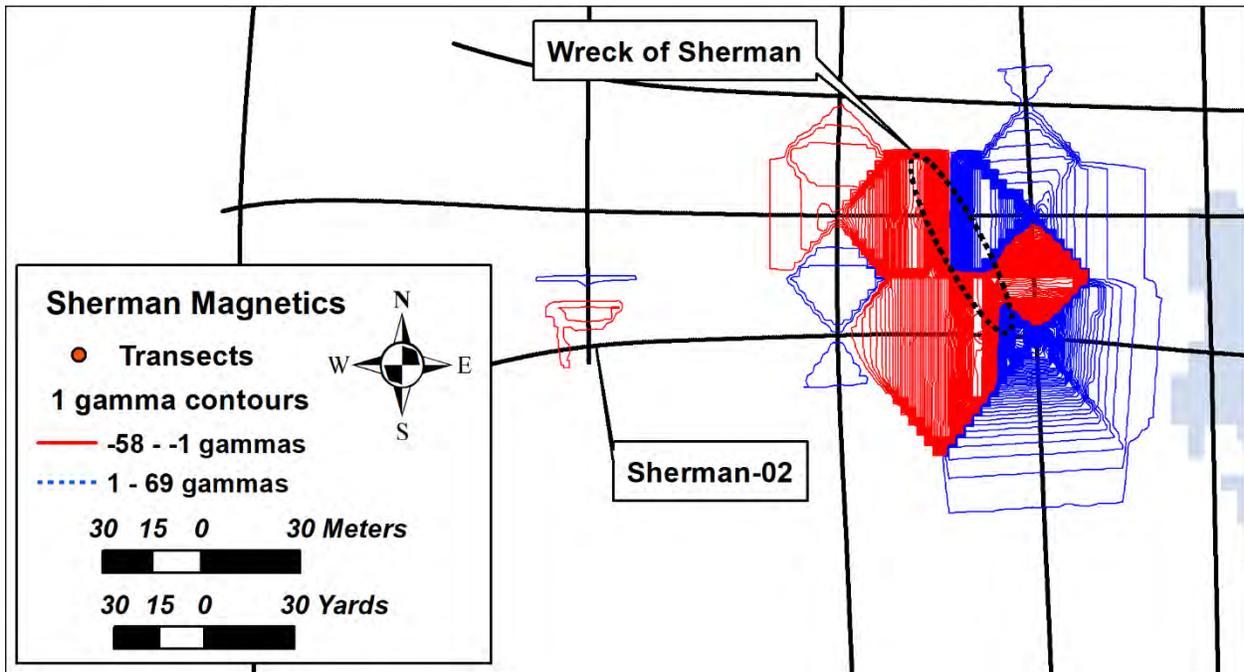


Figure 84. Residual magnetic contours of the wreck of *Sherman* and environs  
 NOAA nautical chart 11536, scale 1:80,000, 2018.

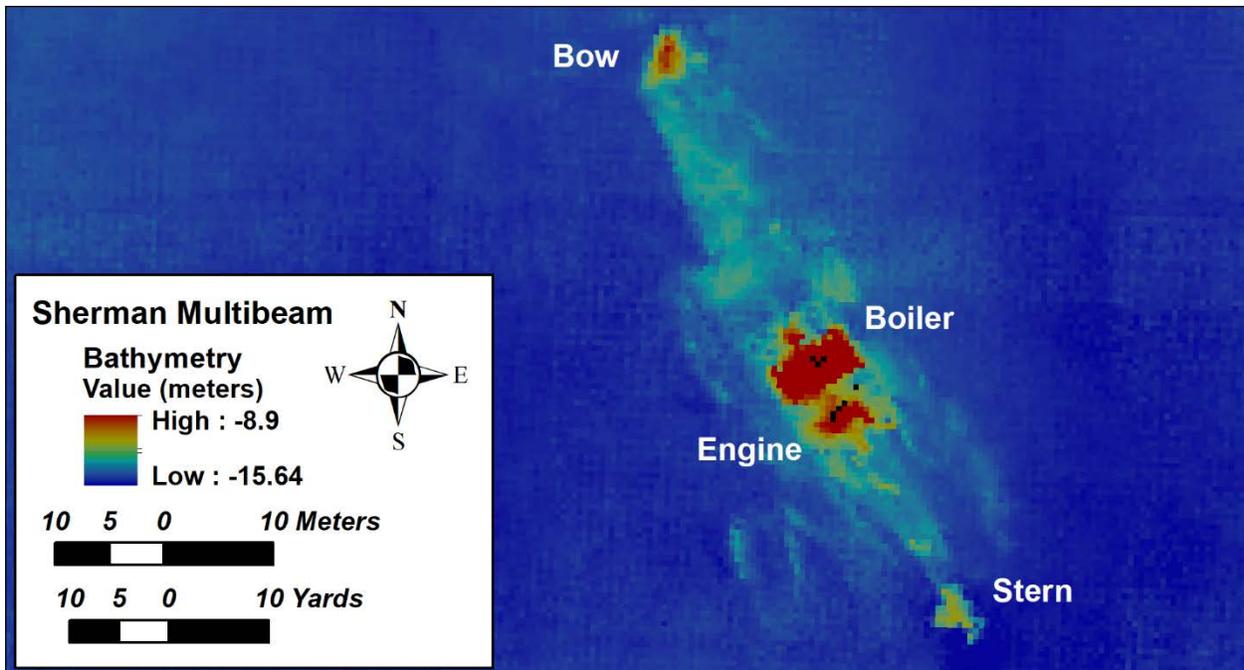


Figure 85. Multibeam echosounder bathymetry of the Wreck of *Sherman*.

## 6 Ground-truthing Operations

### 6.1 Diver Ground-truthing

Diving operations commenced on 14 August 2017 and were carried out over a four-day period lasting until the 17<sup>th</sup> with the objective of conducting non-disturbance, reconnaissance level ground-truthing of prioritized cultural, natural, and geological features within, and slightly without, the SC-BOEM Cooperative Agreement project area off North Myrtle Beach, South Carolina. Aboard CCU's R/V *Coastal Explorer* was a dive team comprised of four underwater archaeologists including two from SCIAA, one from Clemson, one from BOEM, as well as four scientific divers and two support staff from CCU. The team was there to visually assess, inspect and video record prioritized features detected during the remote sensing operations.

A team of divers ground-truthed high-potential cultural, natural, and geological features within, and slightly without, the SC-BOEM Cooperative Agreement project area off North Myrtle Beach, South Carolina. In total, the team dived on 19 prioritized targets that included cultural, natural and geological features, including the shipwreck of the *Sherman*, a magnetic target, components of the artificial reef Barracuda Alley, natural features and suspected paleochannels (Figure 86).

Prior to the dive each team reviewed the general characteristics of the target displayed in the ArcMap project on the laptop. After descending and reaching the bottom at the buoyed target, each team performed a general reconnaissance of the area looking to identify features observed in the data and then to investigate in more detail. If nothing obvious resembling the remote-sensing imagery was detected, each team then used a cave reel or excess buoy line to undertake a circle search to locate the target or feature identified in the data. Alternately, if at a supposed paleochannel feature, then the team went in the general direction or bearing of the feature. If following along a ledge then all divers relocated and followed the feature. At each of the natural and geological features the dive team retrieved sediment grab samples placed in a plastic storage bag. At each site, the team recorded the targets using either a GoPro or Sony Handycam camera.

### 6.2 N1 Ground-truthed Targets

#### 6.2.1.1 Barracuda Alley Components

The team dove on three Barracuda Alley components on 15 August 2015.

#### 6.2.1.2 N1-BA-01

At a depth of 18.2 m (60 ft), the target was the southern-most feature at Barracuda Alley, and was originally interpreted as a barge based on review of the multibeam and side scan sonar imagery but found by the divers instead to be an amphibious landing craft. Standing upright and at its highest point about 2.7 m (9 ft) proud from the sandy bottom, the hull was complete, but the interior was gutted. There was no scatter from the site lying in the immediate vicinity of the watercraft. The hull measured approximately 16.7 m (55 ft) in length and 4.5 m (15 ft) in breadth. The coral colonizing the structure was in excellent condition, indicating that it was not frequented by divers, most likely due to its isolated position from the main concentration of the artificial reef.

#### 6.2.1.3 N1-BA-02

Descending to a depth of 17.3 m (57 ft) on the southern-most object, the dive team found several Armored Personnel Carriers (APCs). Review of the multibeam data indicated three separate rectangular



objects, oriented northwest to southeast. Further inspection of the other two near-by objects proved the same. All three had similar colonizing benthos community of organisms and fish, mostly black sea bass, porgies, juvenile grunts, and small serranids. The structures were covered in abundant ivory bush coral and solitary cup corals, with scattered gorgonians and tube-dwelling anemones in the sand. Bottom sediments were mostly composed of coarse sands and shelly debris. Approximately 91.4 m (100 ft) NW of the northernmost APC were two anchors blocks, about 1.8 x 2.7 x .9 m (2 ft. x 3 ft. x 1 ft) alone in the sand.

#### **6.2.1.4 N1-BA-03**

Review of the multibeam and side scan sonar revealed a large rectangular structure on the bottom identified as a barge. At a depth of 19.2 m (63 ft) the barge measured approximately 42.6 m (140 ft) long, 12.1 m (40 ft), and stood about 2.4 m (8 ft) high off the bottom. The barge formed the westernmost component of a conglomeration of near-by objects. The dive team descended onto the barge and found adjacent to the wreck a substantial amount of loose structure presumably from the barge. Both ends of the barge were intact, but there were gaping breaches on both sides of the barge permitting observation into the interior areas of the hull. The deck was in fairly good shape, and on the west end of the barge deck there was a bollard, including an upright, small tubular A-frame. There were numerous schools of small fish, great barracudas, and several large cobias, or ling swimming about the barge. Located to the east of the barge were four or more APCs, some upside down, connected to the barge by a stout line. There were also several large metal tubes, approximately 2.7-3.6 m (3-4 ft) in diameter. All the structures were covered in marine growth and numerous corals. The bottom was composed of a coarse sandy bottom with shell hash (Figure 87 and 88).

#### **6.2.1.5 N1-01**

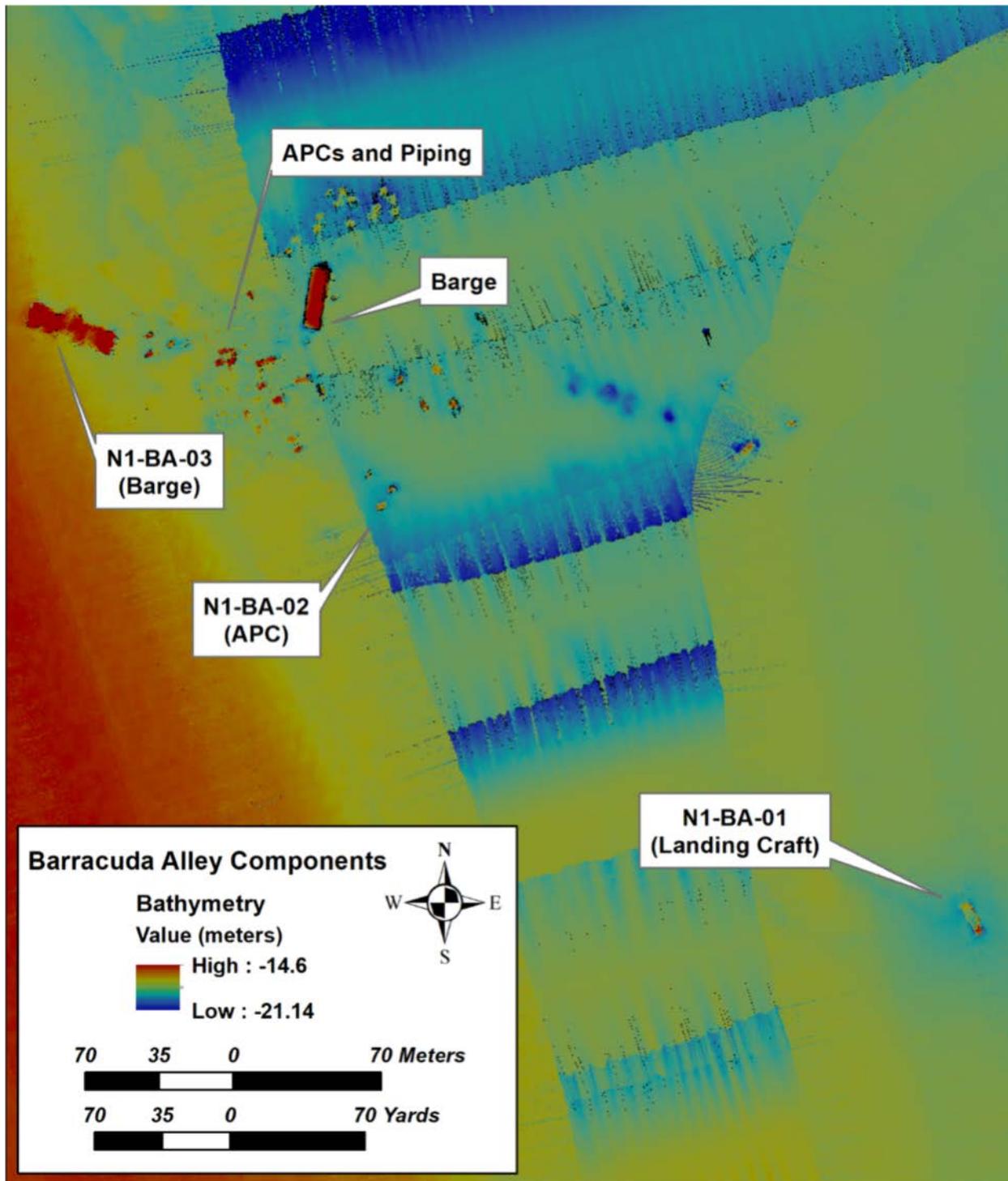
A team dove on this target on 15 August 2017. Review of the multibeam and side scan sonar revealed a 243.8 m (800 ft) crescent-shaped bottom feature, most likely a ledge (Figure 89). Descending to the bottom at a depth of 21.3 m (70 ft), the dive team confirmed the feature was a ledge, which consisted of similar sea life and bottom to *Sherman's* ledge (see below *Sherman-03*), composed of sponges, soft coral, mobile invertebrates, but was smaller, more fractured, and less relief off sea bottom. The adjacent bottom was sandy. There was no evidence of snagged anchors or fishing tackle to suggest fishing regularly occurred at this bottom feature.

#### **6.2.1.6 N1-02**

This target was dived on 15 August 2017. Analysis of the multibeam and side scan sonar imagery suggested remnants of a shallow, incised paleochannel spanning approximately 304.8 m (1,000 ft) in a southeasterly drift. The dive team, descending at the southeastern terminus of the feature at depth of 18.3 m (60 ft) found a bottom composed of fine-grained sand inhabited with occasional sand dollars, sea stars, and atypical echinoids. There were also some small infauna cnidarians, and a few planktivorous jacks. The team searched and meandered in a northwesterly direction but did not find any observable evidence of a defined channel.

#### **6.2.1.7 N1-03**

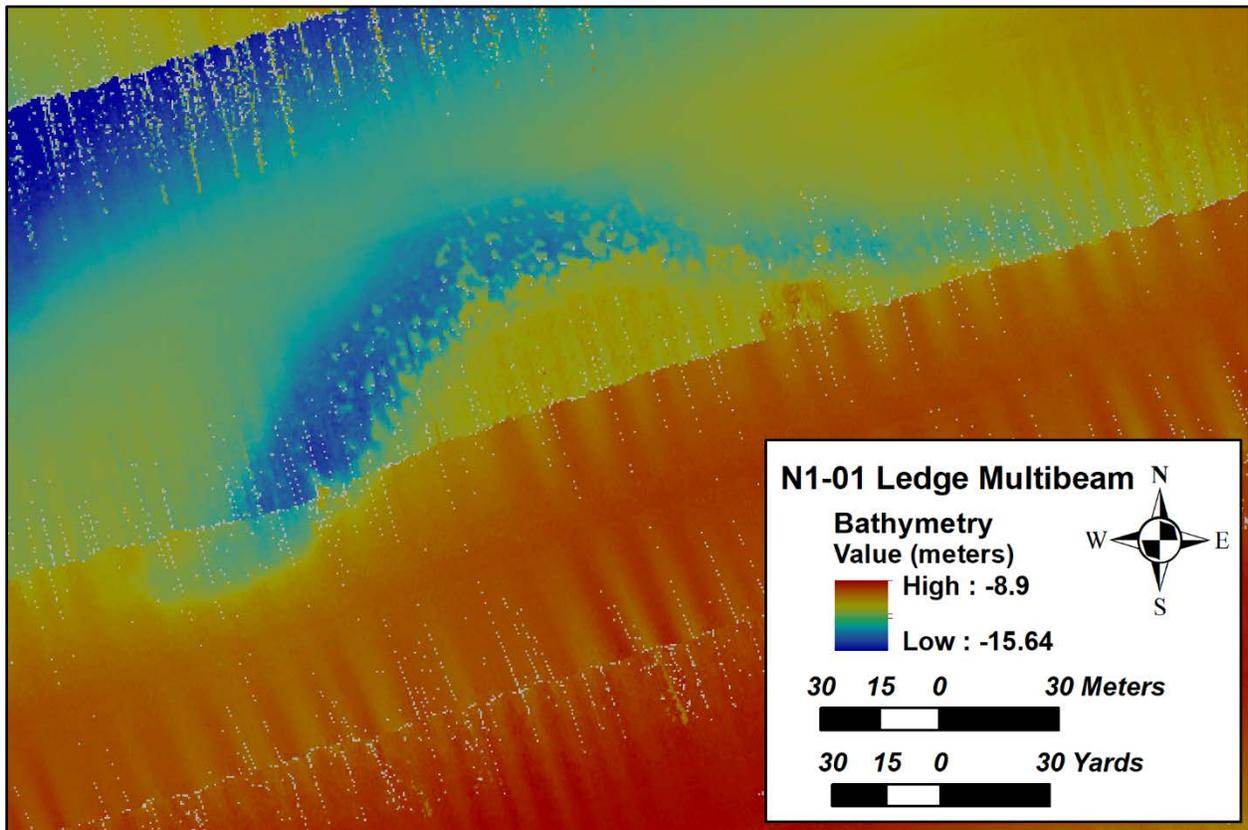
A team dove on this site on 16 August 2017. Review of the multibeam imagery suggested a bowl-shaped ledge approximately 61 m (200 ft) across. The ledge was similar in composition, both geologically and biologically, to the other ledges. The ledge had about 1 m (3 ft) of relief off the sandy bottom. The ledge was covered in soft corals covered and with fine sand and sediment. There were numerous mobile and immobile invertebrates inhabiting the ledge, along with numerous fishes, including several sheepsheads.



**Figure 87. Detail of multibeam echosounder coverage of Barracuda Alley in N1 survey area**  
Artificial Reef created by S.C. Department of Natural Resources.



**Figure 88. Underwater imagery of Barracuda Alley components**  
Top, northwestern side and end of the barge. Bottom, lower back end of an Armored Personnel Carrier.



**Figure 89. Multibeam image of N1-01 ledge**

A loggerhead turtle bolted from underneath the ledge to startle the divers.

The divers moved NW, and noticed the ledge sloping downwards into the bottom. There was little sign of human fishing activity, except for one snagged line and a lone beer can.

## 6.3 N2 Ground-truthed Targets

### 6.3.1.1 N2-01

The target was investigated on 16 August 2017. Review of the multibeam imagery revealed a slight, defined rise on the bottom, about 5 x 13 m (16 ft. x 43 ft) oriented northeast to southwest, suggestive of a ballast mound. There was no magnetic anomaly associated with the target. The dive team landed on flat, featureless bottom composed of soft fine sand and sediments with lots of sea biscuits at a depth of 20 m (65 ft). There was nothing observed to indicate a feature resembling the multibeam image. The divers moved roughly NNE and crossed through a patch of shell hash, and then back onto the expanse of soft and fine sediments. Continuing in the same direction, the divers started to come across a patch of upright soft sponge and coral, and then started to see fish. Moving in the same direction the divers found a span of hard bottom and marine flora and fauna, and lots of fish. The hard bottom lens was broken up and interspersed with sand patches. Relief was about .3 to .6 m (1-2 ft) or so off the bottom. The hardbottom expanse was about 6-9 m (20-30 ft) in width before entering another expanse of soft and fine sands inhabited by numerous sea biscuits (Figure 90).



**Figure 90. Various bottom types and marine life in the study area**

Top left: patchy live bottom at dive target N2-01; Top right: mantis shrimp at dive target N3-02; Bottom left: starfish on smooth, fine bottom at dive target N3-02; Bottom right: pipefish wrapped around a sea biscuit at dive target N3-03.

### **6.3.1.2 N2-02**

A team dove on this site on 16 August 2017. Review of the multibeam and backscatter indicated a small infilled paleochannel feature oriented approximately N-S. Aiming for the deepest and most defined part of the feature and located at depth of 17.3 m (57 ft), the dive team descended onto a fine sand bottom. Travelling S-SW, the divers observed no notable change in depth, and no hard substrate underneath the veneer of sand. Numerous starfish and other mobile invertebrates were observed during the dive.

### **6.3.1.3 N2-03**

The target was investigated on 16 August 2017. Review of the multibeam and backscatter data indicated a ledge, oriented N-S and spanning a distance approximately 102.4 m (336 ft). The dive team landed on a large defined ledge, with about 1.2-1.5 m (4-5 ft) of relief. There were also numerous overhangs forming shallow caves. Moving towards the N, the ledge descended to a couple feet of relief off the bottom. Headed south the ledge had collapsed in areas, but still had high relief in this range of the ledge. Sections of the collapsed ledge formed sloping hardbottom down onto the bottom composed of soft sand. The upper part of the ledge consisted of live bottom and sand, before disappearing under an expanse of sand. There was a plethora of marine flora and fauna, and several schooling fish including spadefish, passed over the ledge and disappeared, along with sea bass, sheepshead, flounders, and several cobias, or lings circling around the ledge, and could truthfully be characterized as a swirling mass of life. Just before reaching bottom on the descent a shark was spotted disappearing into the gloom (Figure 91).

### **6.3.1.4 N2-04**

A team dove on this site on 17 August 2017. Review of the multibeam and backscatter data indicated a potential paleochannel in a general N-S drift with some meandering. The dive team dropped onto a bottom composed of a sandy, loamy, silty mix punctuated with dark grey biologically made mounds at a depth of 15 m (50 ft). There were numerous starfish and sand dollars, but not much else. The divers encountered no distinct ridge or edge while moving northwards (Figure 92).

## **6.4 N3 Ground-truthed Targets**

### **6.4.1.1 N3-01**

A dive team examined this site on 14 August 2017. Review of the multibeam and backscatter imagery revealed an ovoid bottom feature approximately 17 x 12 m (39 x 56 ft) in a NW-SE direction. The dive team descended on to a flat, featureless bottom at a depth of 15 m (50 ft). Fine tawny sediment and fine sand covered the bottom. There were many live sand dollars, roughly the size of a palm, moving about leaving trails behind, including one resembling a sombrero. In the water column a school of fish passed by, along with a fish that burrowed under the sand and an orange sea horse. An animal protruded from the sand, with polyps on the stalk and resembling a cephalopod, would retract when touched. The team circle searched about the area in approximate 15.2 m (50 ft) circles (n=3). The area contained little of interest and discovered nothing that looked like the backscatter image, suggesting the disturbance was an ephemeral target, perhaps a large school of passing fish.

### **6.4.1.2 N3-02**

A team dove on this target on 15 August 2017. Review of the multibeam imagery indicated a depression or deeper area 18 X 28 m (59 ft. x 92 ft) area in a general NW-SE direction. Aiming for the deepest area,



**Figure 91. N2-03 ledge with plethora of marine fauna and flora**

The ledge was alive with masses of various fish.

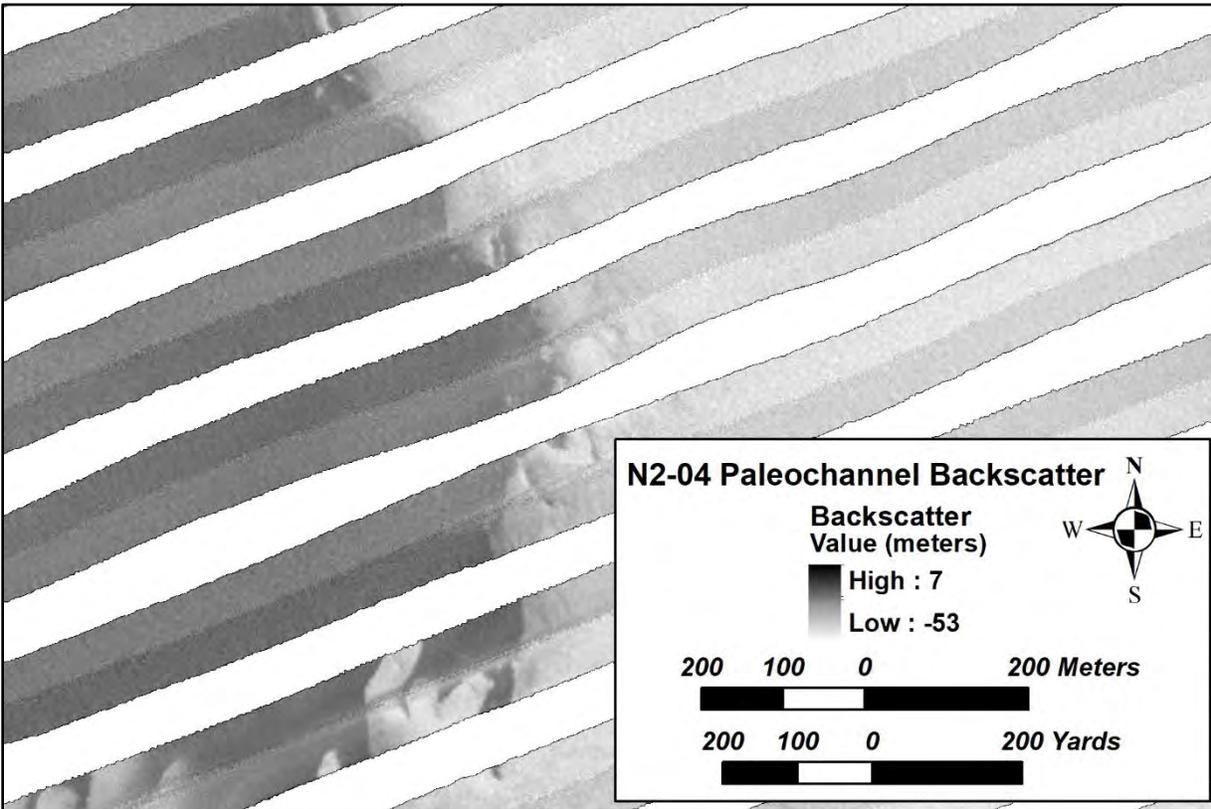
the dive team did not observe a defined depression, and a search did not reveal any other observable area like the terrain depicted in the remote sensing imagery. The bottom was composed of smooth sands and soft fine sediment. Moving northwards, the divers observed areas of undulations along the bottom with areas of broken shells or a harder bottom. There was a plethora of sand dollars and sea biscuits, univalve mollusks, and starfish (see Figure 90).

#### **6.4.1.3 N3-03 and N3-04**

The team dove on those two areas on 16 August 2017. Review of the multibeam and backscatter indicated an interesting break in a potential paleochannel. The channel was oriented northwest to southeast, with a break of approximately 457.2 m (1,500 ft), where the southern section of the channel suddenly offset to the east. Two target locations in the break were chosen to inspect this feature, one to the east and the other to the west and moving either in a southerly or northerly direction along the defined channel.

#### **6.4.1.4 N3-03 and N3-04**

The team dove on those two areas on 16 August 2017. Review of the multibeam and backscatter indicated an interesting break in a potential paleochannel. The channel was oriented northwest to southeast, with a break of approximately 457.2 m (1,500 ft), where the southern section of the channel suddenly offset to the east. Two target locations in the break were chosen to inspect this feature, one to the east and the other to the west and moving either in a southerly or northerly direction along the defined channel.



**Figure 92. Backscatter of N2-04**  
Identified as a potential relict paleochannel.

#### 6.4.1.5 N3-03

At the eastern section of the break, the dive team landed on a smooth bottom with fine sand sediments, along with broken shells at a depth of 18.5 m (61 ft). Moving roughly SE, the team meandered in switchbacks to note any channel edges but found none. They did encounter an area with a substantial amount of broken shell, dead sea biscuits and sand dollars, along with numerous live ones of each as well (see Figure 90). There were numerous bottom-dwelling fish, a solitary black sponge, and areas of harder substrate, interspersed with softer sediments with lots of sea biscuits. The harder area was like a ribbon bordered by the softer sediments on either side.

#### 6.4.1.6 N3-04

At the western area of the break, the dive team landed on a fine sand bottom. The team traveled N-NW and observed sea biscuits, sand dollars, and starfish, along with evidence of crabs and fish that burrow in the sand. No hard substrate was seen during the dive. There was gentle rise, about a meter (3 ft) change in depth, from the descent location to the ascent point.

#### 6.4.1.7 N3-05

The team investigated this site on 17 August 2017. Analysis of the multibeam and backscatter imagery suggested a relic paleochannel in a N-S direction. Aiming for a defined edge, the dive team descended on a loamy bottom that transitioned to fine sand while travelling S-SW at a depth of 18.8 m (62 ft) The

divers did not observe a distinct edge that indicated the paleochannel. Little sea life was noted, although sprinkled on the bottom were a few sand dollars, sea biscuits, starfish, and jawfish. One octopus was observed burrowed in hole in the bottom. Depth increased a little over a meter (4 ft) from the descent location to the ascent spot.

#### **6.4.1.8 N3-06**

A team dove on this target on 17 August 2017. Review of the multibeam and backscatter imagery revealed a ridge running approximately E-W, perhaps indicating a paleochannel. The dive team descended onto a flat bottom, with slight undulations, composed of soft sediments, muddy, and in some areas of sand intermixed with fines at a depth of 19.2 m (63 ft). The divers conducted one approximately 12.1 m (40 ft) circle search to try and find the edge, but not locating one, then moved in a general SE direction. The bottom was also covered in patches of green algae growth. There were numerous sea biscuits in this area, including an octopus home composed of a piece of sedimentary rock buried in the bottom.

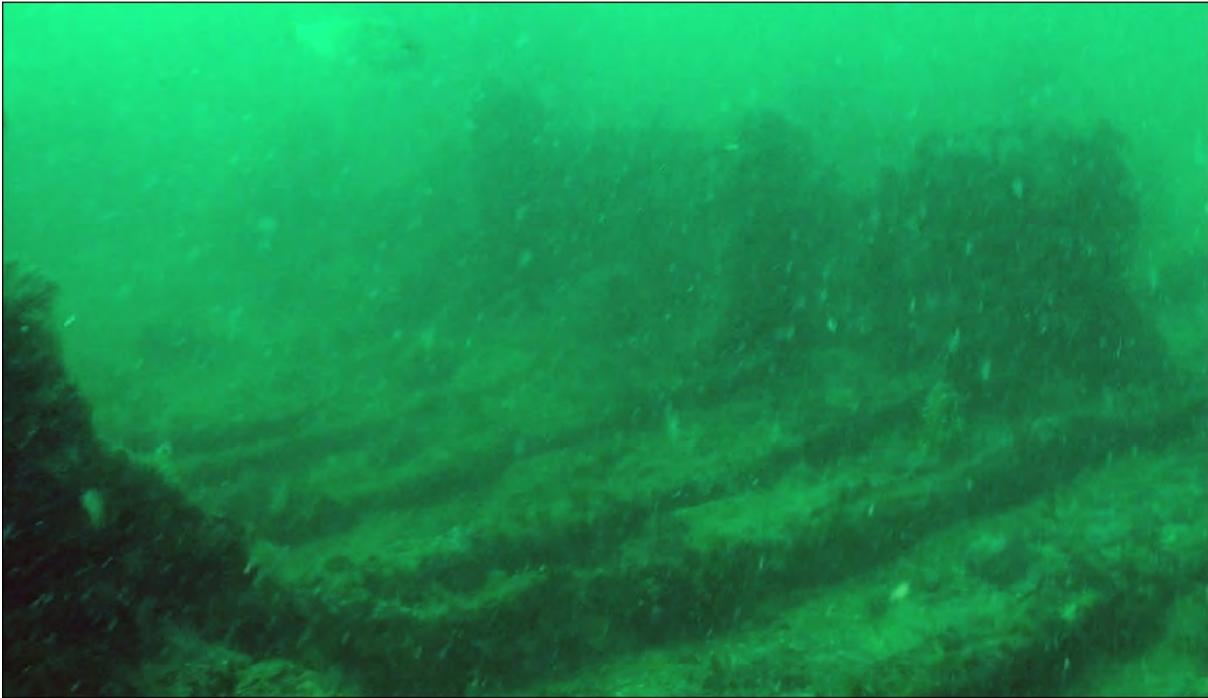
#### **6.4.1.9 N3-07**

A team examined this site on 17 August 2017. Review of the multibeam and backscatter data indicated a ruffled expanse of bottom, about 365.7 m (1,200 ft) E-W, on an otherwise smooth bottom. The dive team descended onto a flat, fine sandy bottom, and found broken scattered shells, along with mobile invertebrates including sand dollars, sea biscuits, and starfish. The dive team observed no observable ridges as indicated by the imagery, perhaps suggestive of a transitory phenomenon.

### **6.5 Sherman Shipwreck and Adjacent Features**

#### **6.5.1.1 Shipwreck of *Sherman***

The dive team investigated the shipwreck on 14 August 2017. The wreck lay in approximately 15 m (49 ft) of water. Visibility ranged from at least 6-9 m (20-30 ft), and higher in the water column was excellent. A buoy was dropped around amidships, and the divers landed near the location of a large marine boiler, about 4.5 m (15 ft) off the bottom, and just aft the steam engine, rising about 20 ft. off the bottom. The top of the boiler was broken which exposed the fire tubes. On either side of the shipwreck were substantial sections of collapsed upper hull lying outboard of the lower floor section of the vessel. Upper hull sections on the port side of the wreck included evidence of at least one lower deck, consisting of iron decking protruding at a right angle (Figure 93). Floors of the lower hull were observed, along with the exposed frames of the upper hull. Intermingled among the wreckage was coal, some ingots—perhaps lead ballast, and disarticulated structure, including numerous bent pipes. Moving aft and at the lower base of the engine, there was a geared flywheel with the propeller shaft still attached. The propeller shaft, supported in several locations by pillow blocks, continued towards the stern section and eventually terminated at a four-bladed propeller (Figure 94). The propeller was still shrouded by the counter-stern and the rudder. This section of the wreck rose off the bottom about 6 m (20 ft). Moving forward from the boiler to the bow on the starboard side again revealed more upper hull structure lying on the sandy bottom. A windlass was located near the bow on the starboard side lying on the bottom of the wreck. At the bow, the remaining structure was crumpled and did not protrude too far off the bottom. There was no evidence of any artifacts or cargo, and as noted above, the site is a popular sporting diving destination for Myrtle Beach dive shop sponsored-dives. The shipwreck now serves as an artificial reef hosting a variety of marine fauna and flora, including numerous fishes, large barracudas, and bait fish invertebrates.



**Figure 93. Underwater imagery of the wreck of *Sherman***  
Top, collapsed hull with extant lower deck; Bottom, fire tubes in the marine boiler.



**Figure 94. Propeller blade at the wreck of *Sherman***

#### **6.5.1.2 Magnetic Anomaly *Sherman*-02**

A team investigated the anomaly on 14 August 2017. Review of the multibeam image prior to diving did not reveal any bottom disturbance to suggest the location or identity of the source of the magnetic anomaly. The target was suspected to be a dislodged section of the nearby *Sherman*, located approximately 132.5 m (145 yds) due west of the magnetic anomaly. The dive team descended 15 m (49 ft) onto the mag anomaly location and immediately identified hard bottom with several varieties of living and dead corals. Using light hand-fanning to expose down to the hardbottom, identified coal, most likely dislodged from the near-by *Sherman* wreck site. To locate the source of the magnetic anomaly, the team continued light hand-fanning in the immediate vicinity, but only found some fishing gear, some of which was metallic, but not the cause of the disturbance. The magnetic anomaly registered approximately 4 gammas. The ground truthing effort did not identify the source of an anomaly of this size. It is possible that the coal found might be associated with an earlier wreck that is shallowly buried in highly transportable modern sediments. Recommendation is to mark the location of the anomaly and apply an avoidance buffer until a tightly spaced sub-bottom profiler survey can be conducted in the vicinity.

#### **6.5.1.3 *Sherman*-03**

Multibeam imagery pictured a defined and extensive ledge feature, generally running from NW to SE. The dive team found bottom relief of approximately 2.7 m (3 ft) with some areas greater, as well as broken live bottom area. There were abundant coal chunks and fist-sized limestone. The ledge and bottom features consisted of typical inshore benthic community of sponges, soft corals, macroalgae and mobile

invertebrates. Black sea bass, grunts, porgies, and other species comprised the fish community typical of near-shore hardbottom. Associated sediments consisted mostly of coarse sands and shell debris. Cultural features consisted of several abandoned modern anchors and debris from fishing along the ledge.

## **7 Cable Corridor**

### **7.1 High Resolution Geophysical Survey of Potential Cable Corridors**

Future offshore wind energy production is expected to be focused seawards of 16 km (10 miles) from the coast. This reflects the rapid increase in wind resources with increasing distance offshore and the need to minimize visual impacts of wind turbines to coastal communities. As a result, most of the geophysical mapping for this study was focused more than 16 kilometers from the coast. Offshore wind energy generation is connected to onshore demand through narrow corridors where transmission cables are typically buried a meter or two below the seafloor. Construction within such corridors presents similar environmental, geotechnical and cultural resources concerns as the offshore wind farms and requires similar geophysical surveying to be completed.

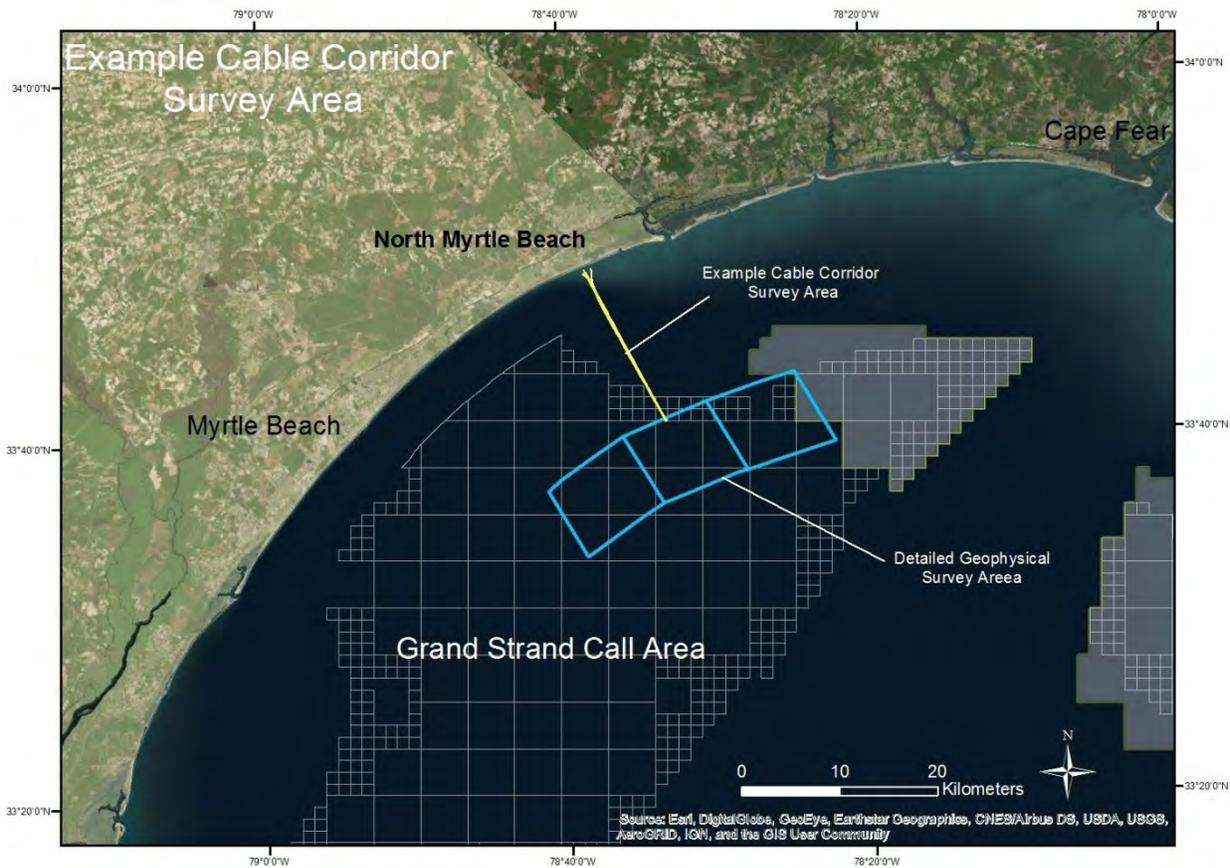
The siting of future cable corridors will be highly dependent on the location and configuration of the offshore wind farm. It will also be influenced by the onshore infrastructure and configuration of the regional transmission grid. Previous regional siting studies have considered potential wind farm locations and potential transmission corridor pathways in the Southeast (Enernex 2011; Wang 2013). Based on the configuration of the existing electrical grid onshore there are several probable points that offshore cabling will make landfall along the northern coast of South Carolina.

For this study, a representative cable corridor was identified for survey that connected the offshore geophysical survey area with a likely onshore point reflecting known grid infrastructure (Wang 2013) (Figure 95). Adjacent to the detailed geophysical survey for this study, the probable shore-connection would be at the point that State Highway 65 terminates at the beach. This would provide a relatively direct and short pathway along existing infrastructure to the Nixon's Crossroads substation near the City of North Myrtle Beach. The seaward terminus of the corridor was projected to the mid-point of the offshore geophysical survey area.

### **7.2 Geophysical Survey of Potential Transmission Cable Routes**

Offshore wind energy generation is connected to onshore demand through narrow corridors where transmission cables are typically buried on the order of a meter below the seafloor. Construction within such corridors presents similar environmental, geotechnical and cultural resources concerns as the offshore wind farms and requires similar geophysical surveying to be completed. The siting of future cable corridors will be highly dependent on the location and configuration of the offshore wind farm. Future offshore wind energy production off South Carolina is expected to be focused seawards of 16 km (10 miles) from the coast. This reflects the increase in wind resource potential with increasing distance offshore and need to minimize visual impacts of wind turbines to coastal communities. Increased cost and complexity of connecting and installing interconnections and cables will similarly influence the final placement of future farms off the coast and the specific path of transmission corridors. Other issues of concern, such as navigation corridors and potential access or use conflicts for areas, have already been incorporated in selection of call areas and relevant datasets exist in BOEM's Marine Cadastre and other publicly available spatial data portals.

The primary focus of detailed mapping for this study was concentrated along the northernmost extent of the BOEM defined call areas off South Carolina and contiguous with the Wilmington West Wind Energy Areas' defined by BOEM offshore of the state of North Carolina. It will also be influenced by the onshore infrastructure and configuration of the regional transmission grid. Previous regional siting studies have considered potential wind farm locations and potential transmission corridor pathways in the Southeast (Enernex 2011; Wang 2013). Based on the configuration of the existing electrical grid onshore



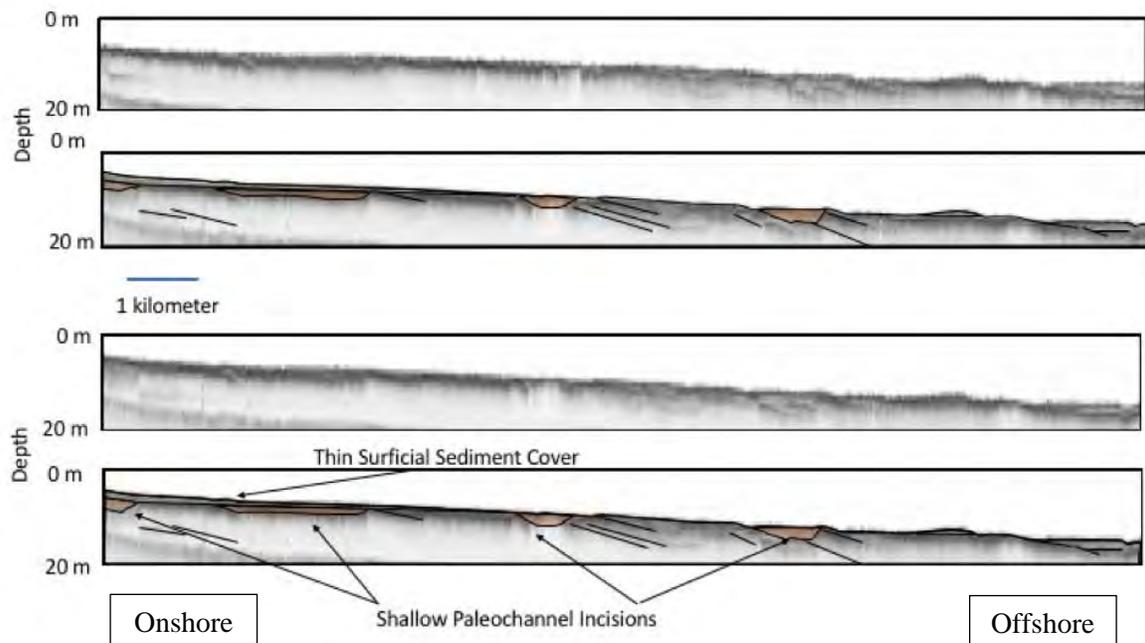
**Figure 95. Location of geophysical survey with an example cable corridor**

Geophysical tracklines (yellow) completed within a representative corridor connecting the offshore detailed survey area of this study within the Grand Strand Call Area (blue) and the SC Highway 90 onshore grid infrastructure corridor. The geophysical survey within this corridor serves to generally characterize the nature of the sea floor and shallow subsurface and potential for future concerns as specific cable corridors may be defined nearby. Two shore-perpendicular CHIRP profiles were collected along the length of the example corridor and a narrow 130-to-70-meter-wide mosaic of backscatter and multibeam bathymetry was imaged across the narrow corridor.

there are several probable points that offshore cabling will make landfall along the northern coast of South Carolina.

As a result, a representative corridor was surveyed to provide general characterization of the sea floor between the center of the offshore detailed survey area in the Grand Strand Call Area and a point onshore identified as a logical, if not likely, point to connect to existing onshore grid infrastructure at the Nixon's Cross Road Sub-station in North Myrtle Beach. A narrow, 200-meter wide band of shore perpendicular tracklines was surveyed using side scan sonar and multibeam sonar to allow a geophysical characterization of this representative cable corridor in the area (Figure 96).

In CHIRP profiles, the shallow subsurface framework of the example cable corridor can be generally characterized by a series of seaward dipping reflectors extending to or just below the seafloor shown in A, Figure 96. At many areas along the profiles, those reflectors can be seen to intersect with the seafloor and locally result in change in the slope of the sea floor or a slight increase in elevation that is characteristic of low relief hardbottoms in the region as shown in B, Figure 96. Where coherent deposits of modern surficial sediment exist in the region, they are apparent as a transparent fill overlying a planer



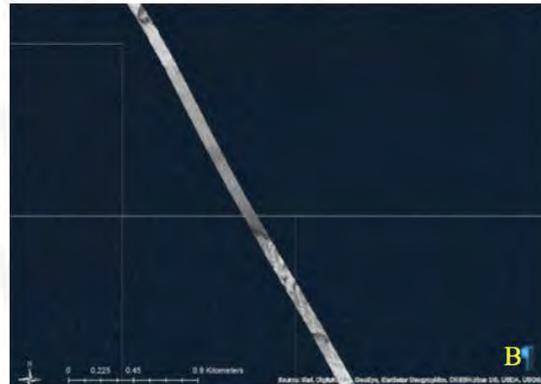
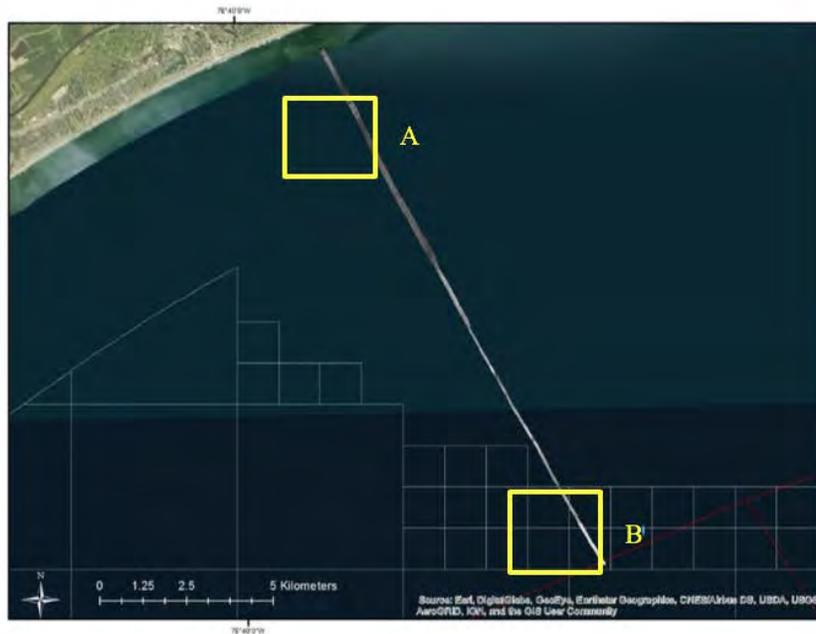
**Figure 96. CHIRP data from example cable corridor**

Interpreted shore-perpendicular CHIRP profiles extending from near the beach to the mid-point of the offshore detailed survey area, A-top raw images, and B-bottom two images.

marine unconformity that can frequently be observed truncating older inclined reflectors. It is very common in the area for the Holocene Marine Unconformity to be either a patchy sediment veneer coincident with the sea floor or thinly covered by a discontinuous layer below the resolution of the CHIRP system (<50cm thick; Barnhardt et al. 2009). A thin coherent surficial sediment lens, generally less than a meter thick, is resolvable in the CHIRP profiles only in the onshore portion of the corridor.

Offshore, it appears the marine unconformity is either coincident with the modern sea floor or likely discontinuously covered by a thin veneer of surficial sediment at or near the resolution of the CHIRP. Locally, the older, seaward dipping substrate is shallowly incised (1-2 meters) by small channel forms that are infilled with a thin veneer of acoustically transparent sediment. Some of these older channels may locally contain loosely cemented horizons but, in general, areas incised by paleochannels are less likely to form extensive hardbottom outcrops; particularly higher relief hardbottoms which are of increased ecological importance. The location of paleochannels provides a potential source of unconsolidated sediment; particularly where former estuarine and tidal inlet systems followed the path of the paleodrainage during the transgression. Areas where ebb tidal delta complexes migrating landwards during sea level rise were large enough to bypass sediment seawards during the transgression are some of the few dispositional settings on the inner shelf in the region where sand resources are sufficient for use in beach nourishment projects. One small positive relief lens of largely acoustically transparent sediment overlying the unconformity that may be an isolated partial remnant of an old ebb tidal delta complex that survived the transgression is observed around 12 kilometers offshore.

The backscatter signal is consistent with the more extensive mapping of this study offshore and the USGS Coastal Erosion Study which surveyed the inner eight kilometers of the shelf across much of Long Bay. Figure 97 shows the character of the backscatter of the sea floor within the narrow corridor from just outside the surfzone to the landwards edge of the detailed survey block of this project 16-kilometers offshore. In general, backscatter increases from the beach seawards which is consistent with

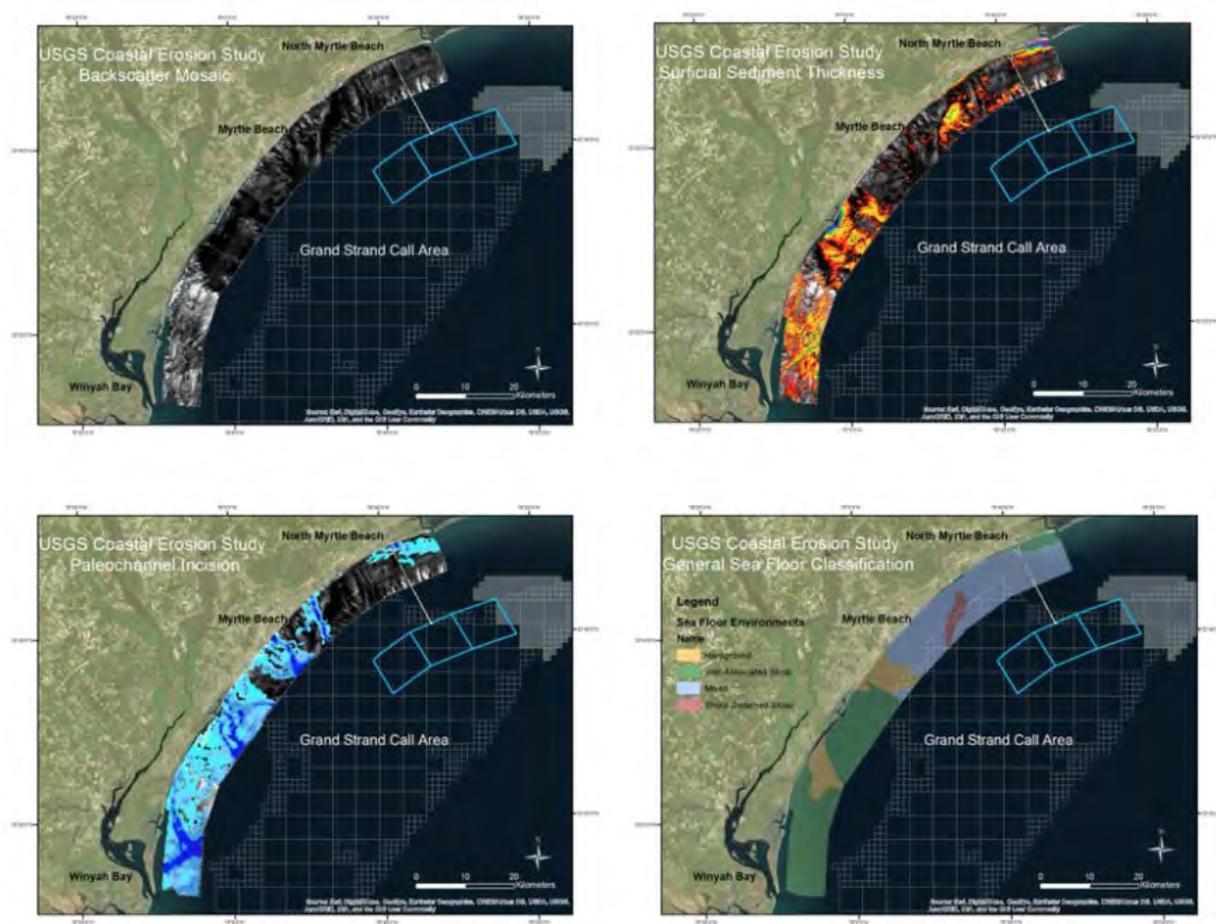


**Figure 97. Seafloor sonar backscatter mosaic of the representative cable corridor**

A and B enlargements of the innershore and offshore areas better illustrating the backscatter patterns.

chirp interpretations of a seawards thinning surficial sediment lens and regional character of the inner shelf as patchy, thin and variable surficial sediment lenses thinly covering older potential hardground substrates. Locally, where a coherent surficial sediment lens is discernable in CHIRP records sedimentary bedforms are more common on the backscatter maps. Offshore, in addition to generally higher backscatter response common in areas of thin, discontinuous surficial sediment veneer in the region outcrops from low to moderate relief (~10cm) exist. These results align well with the detailed mapping of this study seawards of 16 kilometers and previous mapping of the Coastal Erosion Study (Barnhardt et al. 2009).

In the middle section of the example corridor survey a field of transverse bedforms (Murray and Theiler, 2009) is evident on backscatter records with characteristic shore-perpendicular crests. These are continuous with a broader field of similar bedforms mapped inshore in the USGS Coastal Erosion Study.



**Figure 98. Key map products from the Coastal Erosion Study in Long Bay**

Survey in Long Bay showing, clockwise from top-left: a) extent of backscatter mosaic, b) interpreted thickness of surficial sediment above the marine unconformity on CHIRP data, c) location of paleochannels and d) generalized sea floor environment (USGS Coastal Erosion Study Geophysical).

These features are interpreted to be actively influenced by shore parallel tidal flows in the region. The thin, low backscatter sand bodies typically exhibit an asymmetric cross-sectional profile with the steep side of the bedform facing southwest. There is often a gradient in backscatter starting as high backscatter within the throughs of the bedforms with decreasing backscatter values across the bedform towards and over the crest. Both these patterns, as well as past sediment grabs (Denny et al., 2013), suggest a dominant flow and sediment transport towards the southwest. In these settings, within the high backscatter throughs low relief hardbottoms and discontinuous shelly lags are very common. These transverse bedforms appear to be sediment-starved in character and based on CHIRP profiles.

The inner eight kilometers of the representative corridor survey overlaps with the geophysical survey completed by the U.S. Geological Survey SC Coastal Erosion Study (Baldwin et al., 2005; Barnhardt et al. 2009, Denny et al. 2013). That work, ground truth by dozens of vibracores and hundreds of surficial sediment samples, provides a valuable resource for considering the inshore portions of potential cable corridors within Long Bay. Figure 98 provides the key map products from the Coastal Erosion Study beneficial to considering habitat and substrate concerns. These include interpreted map products of the inshore seafloor backscatter, paleochannel incisions, inferred surficial sediment thickness and a generalized sea floor habitat type.

For such a narrow survey swath through a very heterogenic area characterized by thin discontinuous sediment cover represented by the corridor survey, it should be expected that the potential for localized outcroppings adjacent to much of the survey corridor is high; especially laterally seawards of two kilometers from the coast. Considering the extensive Coastal Erosion Study map products across the inner most, it is evident that localized pathways for possible cable corridors across the inner 8-kilometers from the coast may be targeted south of the City of Myrtle Beach. These follow the regional paleodrainage system. Such corridors would be dependent on onshore connections to the regional electrical grid and ultimate location and configuration of any future offshore wind farm.

For the northern half of South Carolina's Long Bay, localized outcropping and exposures of hardground environments should be expected where fewer large paleovalley complexes were found, and those that were trend more sub-parallel to the coast (Figure 98 C). The prospect for hardbottoms with low to modest relief (e.g. < 0.5m) increases with distance from the coast. An additional geophysical data set completed for a BOEM – SC Sand Resource study, not incorporated here, provides geophysical coverage inshore of the detailed survey area of this study and seawards of the extensive coastwise survey from the USGS Coastal Erosion Study. Collectively, these datasets should aid specific cable corridor pathway and associated site surveys considerably in the border area offshore of the Nixon's Crossroad sub-station.

## 8 Conclusions

Future offshore wind energy production is expected to be focused seawards of 16 km (10 miles) from the coast. This reflects the rapid increase in wind resources with increasing distance offshore and the need to minimize visual impacts of wind turbines to coastal communities. As a result, most of the geophysical mapping for this study was focused more than 16 kilometers from the coast. Offshore wind energy generation is connected to onshore demand through narrow corridors where transmission cables are typically buried a meter or two below the seafloor. Construction within such corridors presents similar environmental, geotechnical and cultural resources concerns as the offshore wind farms and requires similar geophysical surveying to be completed.

### 8.1 Habitat and Geological Mapping Surveys and Analyses

The inner-to mid-shelf offshore of the northern section of Long Bay in South Carolina can be characterized by a discontinuous and variable veneer of unconsolidated modern sediment overlying older geologic strata that locally outcrops and forms hard bottom habitat. Throughout the area, hardbottom habitat is common and locally a significant habitat to species of fish of interest and management. Locations of extensive hardbottom habitat have been well constrained in areas of detailed, integrated geophysical survey reported here; particularly where validated through various types of ground-truthing. This report provides a detailed mapping and inventory within a relatively small percentage of formally defined Wind Energy Areas offshore of South Carolina.

Within Long Bay, paleochannels have been incised into the older geologic framework locally supporting coherent surficial sand sheets mappable with geophysical methods ( $>0.5\text{m}$ ). These structures afford one of the best first order features to help consider habitat and geotechnical potential that may affect wind farm siting and permitting and may be generally mapped in a much more efficient regional survey design. Within these corridors, hardbottom substrate may be relatively uncommon from erosion by river systems during previous low stands of sea level and subsequent infill of modern (Quaternary) sediment. Such a more regional geophysical survey was completed for this study in collaboration with NOAA to help delineate the general paleodrainage pattern in Long Bay.

In general, these channel systems become more common and the associated surficial sediment infilling becomes more common and continuous towards the southwest within Long Bay. There are local channel incisions within the study area, but these do not appear to be as continuous nor extensive as those mapped in the region further to the southwest in Long Bay. While such channels may reduce the potential for hard bottom habitat locally, they may also increase the potential of cultural resources being present associated with better preservation potential of coastal environments during the recent transgression and potential for concentration of human activity along these riverine and estuarine settings that have subsequently been inundated by rising sea level. Nevertheless, this information may help optimize approach to future surveys; whether for wind resource or sand resource potential utilization.

Sea bed bottom type classified as lithologically hard should be avoided because of benthic habitat and heterogeneity (Bot et al. 2005 and Bhattacharya 2014, South Atlantic Fishery Management Council). This has been a primary focus of this study. In addition to habitat and cultural resource distribution of interest to wind farm siting, the data included in this report can provide some preliminary basis for considering other potential design parameters such as: 1) inference of shallow subsurface stratigraphy and general geotechnical character, 2) surficial sediment mobility and 3) potential for localized scour or bedform response to future structures. These parameters may be of increasing interest as specific wind farm configurations and decisions regarding foundation and tower type are considered.

As tower and foundation design are considered for the region, boreholes to directly establish the nature and variability of geotechnical conditions at depth to support turbine structures should be acquired. Preliminary analysis of potential wave, wind and current forcing by historic tropical and extratropical storms that may help inform tower and foundation have been completed and should also be accessed as specific foundation and tower designs are proposed. Guidance from regional geologic framework would suggest optimal areas for construction should be smooth and relatively static. Minimal Quaternary cover and a large amount of sand in the Eocene layer devoid of deformation provides a sufficiently thick layer for the given pile to be supported by. The depth of the Eocene sand layer grossly depends on the needs of the structure. (Bot et al. 2005 and Bhattacharya 2014).

In summary, areas that have potential design considerations to offshore wind energy development include the following (Bot et al. 2005 and Bhattacharya 2014, South Atlantic Fishery Management Council):

- Soil types that have poor shear strength such as clays;
- Scours, sand banks, and lithologically complex layers because they are heterogeneous and most often dynamic;
- Regional surface structures such as sandy bedforms and deltaic deposits;
- Sea bed bottom type classified as lithologically hard because of benthic habitat and heterogeneity

Attractive potential wind energy areas include the following parameters:

- Smooth and relatively static areas
- Minimal Quaternary cover and a large amount of sand in the Eocene layer devoid of deformation and a thick layer;

## 8.2 Cultural Resources Mapping Survey and Analyses

The findings of the survey resulted in increasing the archaeological awareness in the OCS study area off North Myrtle Beach, South Carolina, despite limited survey area and density. Research suggested the presence of two shipwrecks located within the survey blocks, but one was found instead to be located off Newfoundland, and the other, a wooden schooner, may have eluded detection due to the gaps caused by the wide line spacing, or alternately, the record suggests the vessel was floating and may have continued in that matter before finally sinking elsewhere. Although not detecting the presence of other historic shipwrecks, additional survey and tighter line spacing may locate sites that escaped this reconnaissance level survey. The presence of several infilled paleochannels does suggest the preservation potential to locate human occupation and exploitation sites that will require additional survey, and other geophysical techniques, such as boring, to continue exploring the preservation potential in the study area. Continued survey, whether for research purposes or for compliance purposes as outlined under BOEM survey parameters, in the study area may yield significant archaeological and historical information about the prehistory and history along this part of the Atlantic Ocean coastline.

Any future submerged cultural resource survey work at the proposed call areas offshore North Myrtle Beach should reference the *Guidelines for Providing Archaeological and Historic Property Information Pursuant to 30 CFR Part 585* as set forth by BOEM. Surveying for historic shipwrecks, structures, and objects using the 30 m (98.4 ft) line spacing suggested in the guidelines may detect smaller targets with potential archaeological or historical significance. The project line spacing of 200 m (656 ft) and the lack of subbottom data in all areas was simply too expansive for detecting anything other than perhaps a battleship. Only by happenstance and running directly over a site with ferromagnetic materials would a target be identified, although if exposed, the multibeam may have provided a potential safety net. Review of the various datasets, however, indicated that did not occur, although modern components of an

artificial reef were detected by the magnetometer, side scan sonar, and multibeam. No historical or archaeological materials were detected by the various marine remote sensing instruments. Additional considerations concerning future archaeological work in the project area includes:

- Continuing investigations at the shipwreck of the *Sherman* to prepare a National Register of Historic Places nomination, as the wreck is eligible under several criteria; namely A, associated with historic events, blockading and blockade running during the Civil War, and D, likely to yield important information in history. Another aspect to explore is the wrecks potential as an underwater park with interpreted materials to explain the fascinating history of the steamer as a British merchant steamer, Confederate blockade runner, U.S. naval warship, and an American merchant ship, and the archaeological remains. Recreational divers already visit the site, and plundered the site, and all that remains is the durable fabric of the hull and related components that once identified would increase their understanding of the wreck's place in history.
- Documenting near-by charted shipwrecks in potential areas for wind energy development to pinpoint locations and to determine extent of archaeological preservation and if warranted develop NRHP nominations. This venture would also serve to confirm or correct the locations and identities of the shipwrecks listed in the Atlantic Outer Continental Shipwreck Database.
- Developing an understanding of the preservation potential of prehistoric sites by undertaking boring operations at identified sub-surface relic Paleolandscapes, for example, along the margins of paleochannels, oxbow lakes, wetlands, peat deposits, and other areas of high probability for preserving evidence of prehistoric human occupation on the OCS.
- The National Fishing Enhancement Act (Act) of 1984 (33 U.S.C. §2101 et seq.) encourages the creation of offshore artificial reefs for enhancing recreational and commercial fishery resources, although they are increasingly utilized by sport divers. The installation of artificial reefs is under the oversight of several Federal, State, and Local agencies. The Army Corps of Engineers issues the permits required to create artificial reefs on the OCS. Under the Act and other pertinent legislation, including section 106 of the National Historic Preservation Act, agencies and the public provide comments about the project. In recognizing the myriad uses of the OCS, and particularly pertinent to this project, it is recommended that BOEM, if not already doing so, respond to PNs related to the siting of artificial reefs to recommend alternate sites to avoid conflict. For example, Barracuda Alley located in survey area N1 illustrates that as the reef is situated within an area of sustained winds. Siting of potential artificial reefs in the future should undergo thorough review to avoid similar future issues between fishing, diving, and renewable resources.

### **8.3 Geophysical Survey of Potential Transmission Cable Routes**

The siting of future cable corridors will be highly dependent on the location and configuration of the offshore wind farm. It will also be influenced by the onshore infrastructure and configuration of the regional transmission grid. Previous regional siting studies have considered potential wind farm locations and potential transmission corridor pathways in the Southeast (Enernex 2011; Wang 2013). Based on the configuration of the existing electrical grid onshore there are several probable points that offshore cabling will make landfall along the northern coast of South Carolina.

For this study, a representative cable corridor was identified for survey that connected the offshore geophysical survey area with a likely onshore point reflecting known grid infrastructure (Wang, 2013). Adjacent to the detailed geophysical survey for this study, the probably shore-connection would be at the point that State Highway 65 terminates at the beach. This would provide a relatively direct and short pathway along existing infrastructure to the Nixon's Crossroads substation near the City of North

Myrtle Beach. The seaward terminus of the corridor was projected to the mid-point of the offshore geophysical survey area.

Inshore of the area of detailed geophysical survey of this study, it is unlikely single, linear shore-perpendicular corridor of >1-meter unconsolidated sediment cover will be easily identified. It may be possible to optimize potential corridors to maximize extent of sediment cover and to avoid potential hardbottom material through. This should consider the paleochannel patterns defined by this and other studies further in shore and the region.

From the regional paleochannel survey, potential cable corridors from future offshore wind farms should find several relatively linear and direct, near shore-perpendicular pathways within paleochannel corridors; particularly adjacent to and then south of Murrells Inlet, South Carolina.

For the northern half of South Carolina's Long Bay, localized outcropping and exposures of hardground environments should be expected. The prospect for hardbottoms with low to modest relief (e.g. < 0.5m) increases with distance from the coast. An additional geophysical data set completed for a BOEM – SC Sand Resource study, not incorporated here, provides geophysical coverage inshore of the detailed survey area of this study and seawards of the extensive coastwise survey from the USGS Coastal Erosion Study. Collectively, these datasets should aid specific cable corridor pathway and associated site surveys considerably in the border area offshore of the Nixon's Crossroad sub-station.

## **8.4 Future Study Needs**

The wind energy areas off South Carolina cover a vast area that, while beneficial for a number of management interests, may be prohibitive to map completely at very high resolution. It is evident from the results of this study and previous work in the broader region that the character of sea floor habitat and potential for environmental, cultural resource or geotechnical concerns is expected to change in progressing to the South within Long Bay. As other planning parameters and industry focus may constrain potential wind farm siting in the future; detailed geophysical and cultural resource mapping will be needed. With a more constrained potential area of development collection of boreholes to ground-truth geophysical data and interpretations and provide direct geotechnical data should be undertaken. As a potential interim step, a series of small, perhaps 8x8 kilometer, areas could be identified in which detailed geophysical surveys completed within the larger call areas to serve as a measure of the changing character and associated issues to expect in areas further to the South and offshore.

## 9 Deliverables

### 9.1 Web Map/Story Map

#### 9.1.1 A Story Emerges

Leaflet, a simple and powerful Javascript mapping library has been integrated with several supporting libraries and hosted on <https://helios.esri.sc.edu/boem> to provide an online web-mapping interface. This approach was chosen over a conventional ESRI webmap because it allows for direct and rapid integration of the data layers coming from custom workflows in various formats. That said, a few map layers coming from other hosted sources are provided in the Leaflet web map, and many of them come from external ArcRest servers.

The webmap is also provided as a storymap, meaning switching and zooming of map layers has been synchronized with the text such that the reader may be guided through complex illustrations with little effort. Data preparation requires all data to satisfy three primary requirements- data must 1) exist as a raster GeoTiff or vector GeoJSON, 2) conform to the WGS84 Coordinate Reference System (CRS), and 3) be hosted on the same server. For efficiency, all GeoTiff have been preprocessed as map tiles for rapid display. Further, large vector datasets are preprocessed such that only those within the current viewport of the map are loaded. This provides a responsive user experience.

#### 9.1.2 Bathymetry & Backscatter

Bathymetry and backscatter data were acquired using a dual-head, Kongsberg multibeam sonar. The sonar allows for the determination of seafloor depth as well as the derivation of backscatter intensity. The processed results of both datasets are in ArcGrid files that are fully compatible with the Geospatial Data Abstraction Library (GDAL) that is found in a number of GIS platforms. The GDAL is applied directly to the grid files to facilitate the production of custom map tiles used in a Leaflet web GIS map. For both BOEM and NOAA-provided data, the bathymetry and backscatter imagery have been merged onto common map tiles. To be specific, color represents bathymetry and shading represents backscatter intensity (Figure 99). The combined tiles provide half-meter resolution for all provided BOEM data, one-meter resolution for all nearshore NOAA data, and five-meter resolution for all offshore NOAA data.

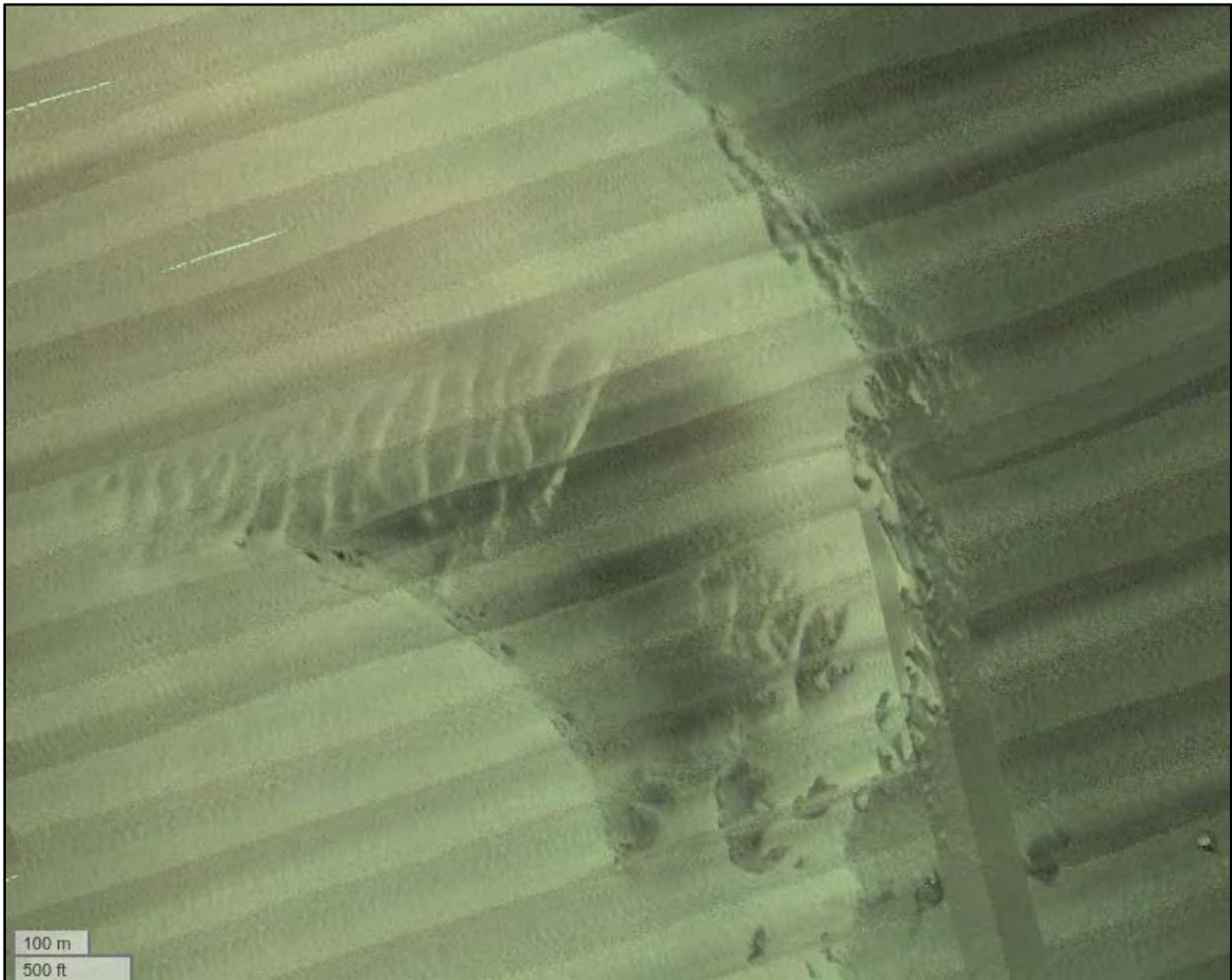
All the layers discussed in other GIS and Bathymetry/Backscatter sections are also provided in the webmap. Among these are the bottom classification map.

The towed sidescan sonar had very limited use during all the surveys involved in this investigation. A map layer is provided even though the data were not used. The backscatter derived from the multibeam sonar head were superior and widespread.

#### 9.1.3 Magnetometer

Magnetic data provided by the USC-SCIAA were available as raster and vector in two formats, 1) observed magnitude, and 2) differentiated or residual. The raster data were chosen for inclusion into the web map because both the observed and difference gradient could be integrated into a common map tile. As such, the color represents magnitude (teslas) and the intensity represents the gradient, like slope in a digital elevation model (Figure 100).

Ground-truthed targets were also provided by SCIAA. Some of the targets were the focus of reconnaissance dives where video footage was taken. These targets and their associated videos are also provided in the webmap.



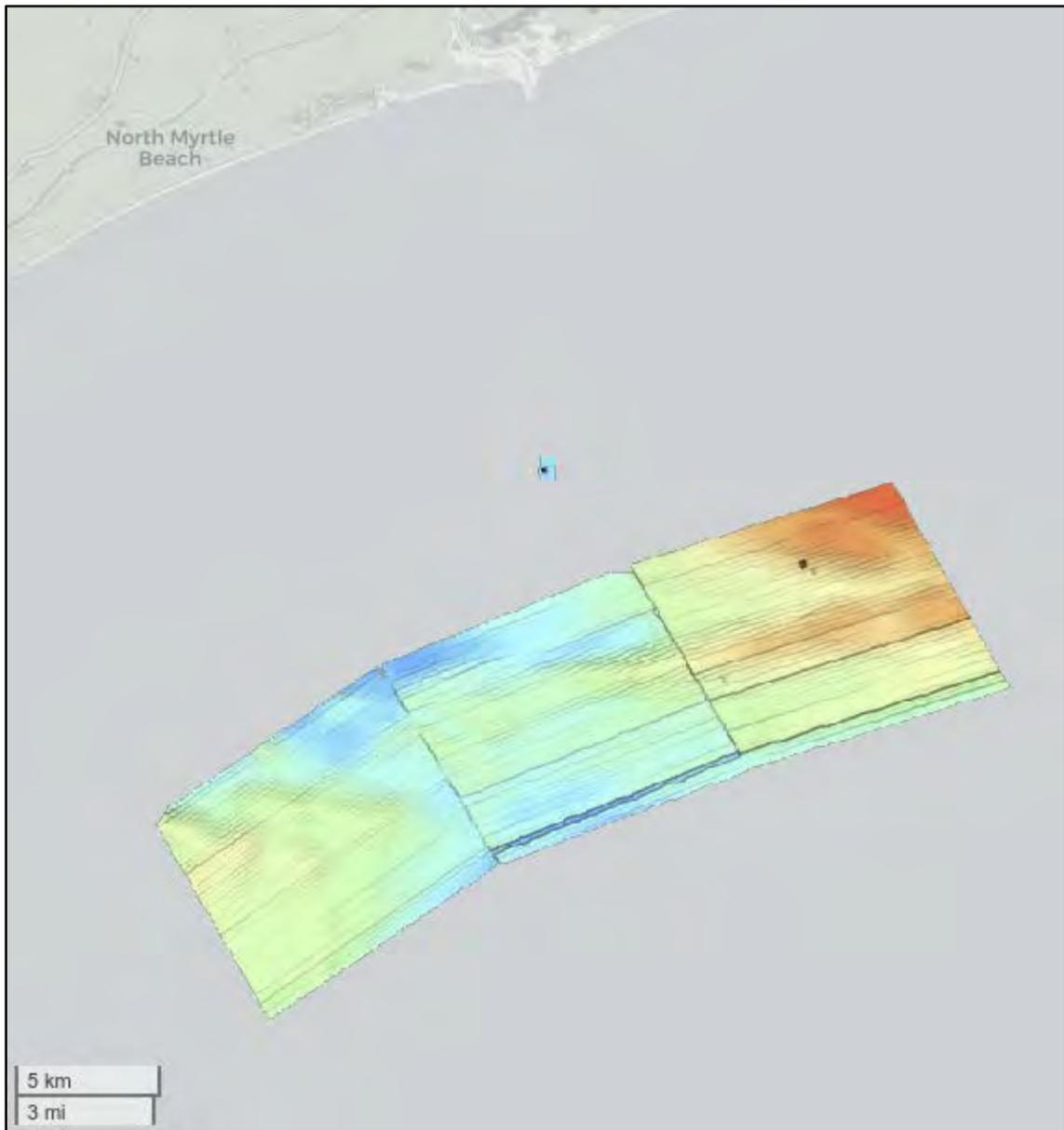
**Figure 99. Backscatter intensity used to recover details**

Using the backscatter intensity in place of hillshading allows for recovering the detail lost by expanding the bathymetry colormap to honor the depths of the regional dataset. Notice how little color variation there is yet how much detail is found in the shading layer. This combined bathymetry/backscatter imaging approach yields the most information per pixel, showing the data at half-meter resolution while providing outstanding vertical detail on a nearly flat surface (< 1 m local variation).

#### 9.1.4 Chirp Sub-bottom Data

Chirp tracklines are specially tagged in the webmap to launch a modal dialog containing the cross section of the selected line. This is a convenient means of integrating cross-sectional data into the two-dimensional map. An example may be seen in the Figure 101.

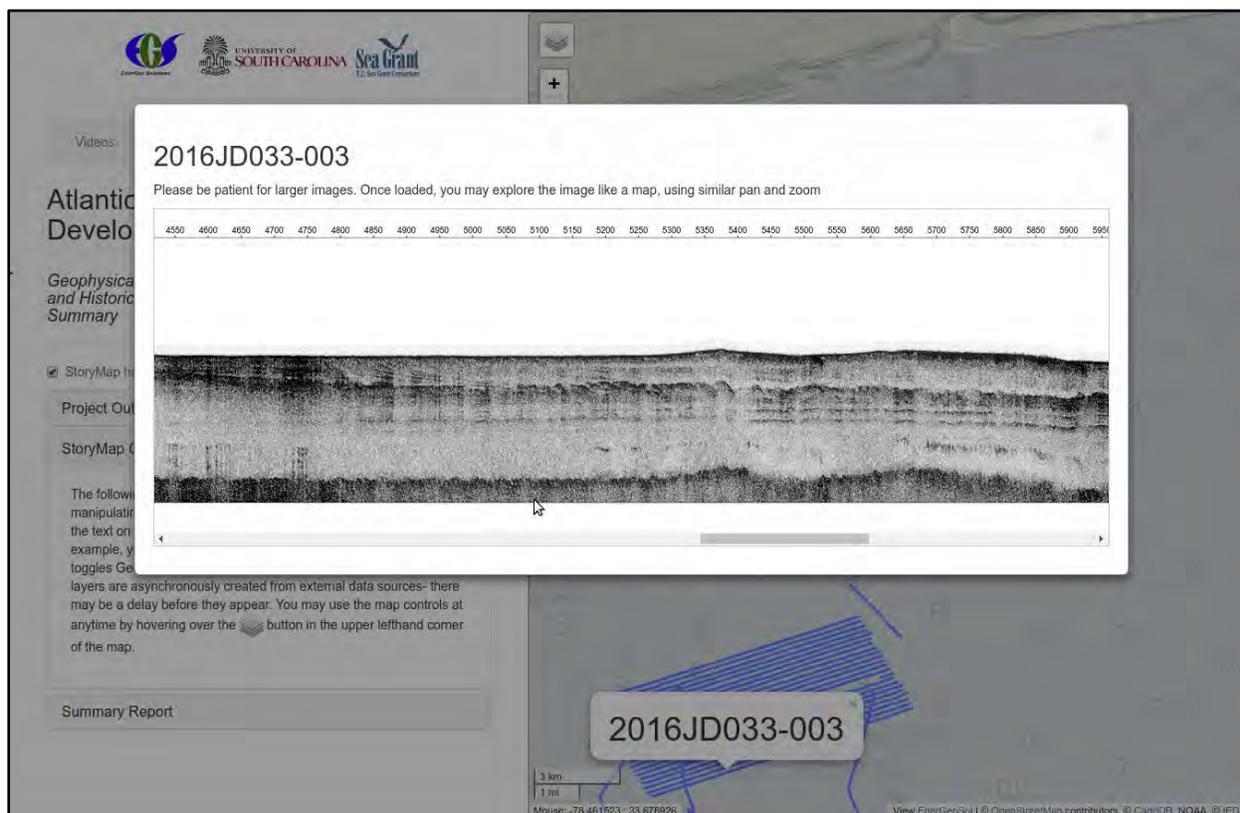
Interpreted results are provided as planar vector data. These may be seen as map layers at this time and are planned to be provided in the cross-sectional images later. The interpreted layers are provided as a compliment to earlier work along the nearshore of Long Bay, and these are the sediment thickness overlying the transgressive surface and depth below sea level of the transgressive surface. Paleochannels are also mapped, and in various forms depending on which data provider they were interpreted from. As discussed elsewhere, the data coming from NOAA sources were provided and analyzed in Kingdom Suite. These data are found on the webmap in a layer named “Gabby Paleochannel



**Figure 100. Magnetometer data represented in teslas by the color**

Magnetometer data represented in teslas by the color, and as a gradient as seen in the shading layer. This example having 35-meter resolution shows artifacts from a shipwreck and an artificial reef as strong shadows resembling dots on the map above.

Heatmap.” This layer provides an adaptive heatmap to simplify the volume of points produced. It may be interpreted as a depth-colored (warmer is deeper) overview of paleochannel existence when viewed from afar, and as a colored scatter plot of the channel floor when zoomed in to full extend.



**Figure 101. Modal cross-sectional view of CHIRP sub-bottom data**

Modal cross-sectional view of Chirp sub-bottom data. The modal dialog appears upon clicking the trackline in the map. The cross section may be explored in the same pan-and-zoom manner as the map.

## 9.2 Data and Information Products

The following data and information products will be provided adjunct to this report:

1. GIS Spatial Data Files (to be provided according to BOEM guidelines)
2. 3D Subsurface Models
3. CD-ROM or DVD containing all databases and technical summaries for each of the following:
  - Habitat and Geological Mapping Surveys and Analyses
  - Cultural and Historical Resource Mapping Surveys and Analyses
  - Geophysical Survey of Potential Transmission Cable Routes
4. CD-ROM or DVD containing Final PowerPoint Study Summary.

## References

- 12 & 13 Victoria I. 1849. An Act to amend the Laws in force for the Encouragement of British Shipping and Navigation. London (UK): Public Act, 12 & 13 Victoria I., c. 29: p.70-75.
- Abbott LE, Jr. 2004. An Assessment of Lithic Extraction Technology at Metavolcanic Quarry in the Slate Belt of North Carolina. Paper presented at: Society for American Archaeology 2004; Montreal, Canada.
- [ACE] Army Corps of Engineers. 2013. Folly Beach Shore Protection Project and Use of Outer Continental Shelf Sand. Finding of no Significant Impact. Charleston (SC): Department of the Army.
- Allison R. The American Revolution: A Concise History. New York (NY): Oxford University Press, Incorporated.
- [ASA] American Shipmasters' Association. 1884. Record of American and Foreign Shipping. New York.
- [ASA] American Shipmasters' Association. 1887. Record of American and Foreign Shipping. New York.
- Anderson DG, Sassaman KE. 1996. The Paleoindian and Early Archaic Southeast. Tuscaloosa (AL): University of Alabama Press.
- Anderson DG, Miller DS, Yerka SJ, Gillam JC, Johanson EN, Anderson DT, Goodyear AC, Smallwood AM. 2010. PIDBA (Paleoindian Database of the Americas) Current Status and Findings. *Archaeology of Eastern North America* 38:63-90.
- Anderson DG, Smallwood AM, Miller DS. 2015. Pleistocene Human Settlement in the Southeastern United States: Current Evidence and Future Directions. *Paleo America*. 1(1):7-51.
- Baldwin WE, Morton RA, Denny JF, Dadisman SV, Schwab WC, Gayes PT, Driscoll NW. 2004. Maps Showing the Stratigraphic Framework of South Carolina's Long Bay from Little River to Winyah Bay. U. S. Geological Survey Open-File Report: OF 2004-1013.
- Baldwin WE, Morton RA, Putney TR, Katuna MP, Harris MS, Gayes PT, Driscoll NW, Denny JF, Schwab WC. 2006. Migration of the Pee Dee River System Inferred from Ancestral Paleochannels Underlying the South Carolina Grand Strand and Long Bay Inner Shelf. *Geological Society of America Bulletin*. 118(5-6): 533-549.
- Barnhardt W, Schwab WC, Gayes PT, Morton R, Driscoll N, Baldwin W, Denny J, Harris MS, Katuna MP, Putney TR, Voulgaris G, Warner JC, Wright EE. 2009. Coastal Change Along the Shore of Northeastern South Carolina-The South Carolina Coastal Erosion Study. US Geological Survey Circular 1339.
- Bhattacharya S. 2014. Challenges in Design of Foundations for Offshore Wind Turbines. *Engineering and Technology Reference*. 1:1-11.
- Bohling G. 2005. Kriging. Lawrence (KS): Kansas Geological Survey.
- Borick CP. 2003. A Gallant Defense: The Siege of Charleston, 1780. Columbia (SC): University of South Carolina.

- Bot S, Van Lancker V, Deleu S, De Batist M, Henriët J, Haegeman W. (2005). Geological characteristics and geotechnical properties of Eocene and Quaternary deposits on the Belgian continental shelf: Synthesis in the context of offshore wind farming. *Netherlands Journal of Geosciences - Geologie En Mijnbouw*. 84(2): 147-160.
- Bowman, M. (2017). Promoting the Revival of a Southern Port: Port Boosters in Charleston, South Carolina, 1921-1950. Ann Arbor (MI): College of Charleston.
- Bridwell RE. 1982. "That We Should have a Port": A History of the Port of Georgetown, South Carolina, 1732-1865. Georgetown (SC): Georgetown Times.
- Bulwer, H. L. 1850. Message from The President of the United States, communicating Copies of the Correspondence with the British Minister Relative to the Trade in British Vessels between the Atlantic and Pacific Ports of the United States and the Granting of American Registers to British-built Vessels purchased by Citizens of the United States; also to an Increase of Duty on British Produce or Manufactures, 31st Congress, 1st Session, Senate Executive Document No. 36. Washington (DC): Government Printing Office.
- Caccioppoli B, Robinson D, King J, Gibson C. 2018. Developing Protocols for Reconstructing Submerged Paleocultural Landscapes and Identifying Ancient Native American Archaeological Sites in Submerged Environments: Field Report: 2013–2016. Prepared for the U.S. Department of the Interior's Bureau of Ocean Energy Management, Sterling, Virginia, under BOEM Award M12AC00016, by the Coastal Mapping Laboratory, Graduate School of Oceanography, University of Rhode Island, Narragansett, RI.
- Campbell R. 2015. "Not Without his Enemies and Perhaps his own Nemesis": Governor Joseph Alston and the War of 1812. *The South Carolina Historical Magazine*. 116(1): 29-54.
- Charles T, Moore CR. 2018. Prehistoric Stone Tools of South Carolina. Glendale, SC: Piedmont Archaeological Studies Trust.
- [CMRT] Caledonian Maritime Research Trust. 2018. Scottish Built Ships – *Princess Royal* Scotland: Caledonian Maritime Research Trust. [accessed 12 Apr 18].  
[http://www.clydeships.co.uk/view.php?builder=&builder\\_eng=&category=&disposal=&flag=&imo=&launch\\_after=&launch\\_before=&lost=&official\\_number=&owner=&port=&propulsion=&ref=22597&role=&vessel=PRINCESS+ROYAL&year\\_built=](http://www.clydeships.co.uk/view.php?builder=&builder_eng=&category=&disposal=&flag=&imo=&launch_after=&launch_before=&lost=&official_number=&owner=&port=&propulsion=&ref=22597&role=&vessel=PRINCESS+ROYAL&year_built=)
- Coclanis PA. 1991. *The Shadow of a Dream: Economic Life and Death in the South Carolina Low Country, 1670-1920*. New York (NY): Oxford University Press.
- Cronin TM. 2010. *Paleoclimates: Understanding Climate Change Past and Present*. New York (NY): Columbia University Press.
- Daniel IR, Jr. 1998. *Hardaway Revisited, Early Archaic Settlement in the Southeast*. Tuscaloosa (AL): University of Alabama Press.
- Daniel IR, Jr. 2001. Stone Raw Material Availability and Early Archaic Settlement in the Southeast United States. *American Antiquity*. 66(1):237-265.
- Daniel IR, Jr., Goodyear AC. 2015. North Carolina Clovis. In: Smallwood A, Jennings T, editors. *Clovis: On the Edge of a New Understanding*. College Station: Texas A&M University. p. 319-331.

- Daughan GC. 2011. *1812: The Navy's War*. New York (NY): Basic Books.
- Dawson AR. 2016. *Sifting Through the Sand: Adaptive Flexibility in the Middle Archaic Occupations of the Sandhills Province of South Carolina* [dissertation]. Columbia (SC): University of South Carolina.
- Denny JF, Schwab WC, Baldwin WE, Barnhardt WA, Gayes PT, Morton RA, Warner JC, Driscoll NW, Harris MS, Wright EE, Volgaris G, Katuna MP, Putney TR. 2013. Holocene Sediment Distribution on the Inner Continental Shelf of Northeastern South Carolina: Implications for the regional sediment budget and long-term shoreline response, *Continental Research*. 56: 56-70.
- Dillehay TD, Ocampo C, Saavedra J, Sawakuchi AO, Vega RM, Pino M, Collins MB, Cummings LS, Arregui I, Villagran XS, Hartmann GA, Mella M, González A, Dix G. 2015. New Archaeological Evidence for an Early Human Presence at Monte Verde, Chile. *PLOS One*. 10(12): <https://doi.org/10.1371/journal.pone.0141923>.
- Dudley WG. 2003. *Splintering the Wooden Wall: The British Blockade of the United States, 1812-1815*. Annapolis (MD): Naval Institute Press.
- Dudley WS, Crawford MJ. 1985. *The Naval War of 1812: A Documentary History*. Vol 1, 2, and 3. Washington (DC): Navy Historical Center, Department of the Navy.
- Durham RS. 2005. *High Seas and Yankee Gunboats: A Blockade-Running Adventure from the Diary of James Dickson*. Columbia (SC): University of South Carolina Press.
- Emmons GF. 1853. *The Navy of the United States, from the Commencement, 1775-1853: with a Brief History of Each Vessel's Service and Fate*. Washington (DC): Printed by Gideon & Co.
- Enernex, 2011 Eastern Wind and Integration and Transmission Study. Report prepared for The National Renewable Energy Laboratory.
- Engelhart SE, Peltier WR, Horton BP. 2011. Holocene relative sea-level changes and glacial isostatic adjustment of the U.S. Atlantic coast. *Geology*. 39(8): 751–754.
- Erlandson JM. 2001. The Archaeology of Aquatic Adaptations: Paradigms for a New Millennium. *Journal of Archaeological Research*. 9(4): 287-350.
- Evans AM. 2014. *Examining and Testing Potential Prehistoric Archaeological Features on the Gulf of Mexico Outer Continental Shelf*. New Orleans: U.S. Department of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region.
- Faught MK. 2014. Remote Sensing, Target Identification and Testing for Submerged Prehistoric Sites in Florida: Process and Protocol in Underwater CRM Projects. In: Evans AM, Flatman JC, Fleming NC, editors. *Prehistoric Archaeology on the Continental Shelf*. New York (NY): Springer. p. 37-52.
- Flatman JC, Evans AM. 2014. Prehistoric Archaeology on the Continental Shelf: The State of the Science in 2013. In: Evans AM, Flatman JC, Fleming NC, editors. *Prehistoric Archaeology on the Continental Shelf*. New York (NY): Springer. p. 1-13.
- Garitee JR. 1977. *The Republic's Private Navy: The American Privateering Business as Practiced by Baltimore during the War of 1812*. Middletown (CT): Published for Mystic Seaport by Wesleyan University Press.

- Gayes PT, Pietrafesa LJ, Bao S, Yan T, Gur T. 2015. Development of Hazard Curves for WEAS off the Atlantic Seaboard. Report on BSEE Contract No. E14PC00008.
- Gayes PT, Viso R, Jutte P, Van Dolah RF. 2003. Charleston Offshore Dredged Materials Disposal Site-Geophysical Characterization of the Sea Floor-Charleston ODMDS 2004 and 2005. Report to the US Army Corps of Engineers.
- Gayes PT, Ward C, Hill J, Okano S, Marshall J, Johnson B, Phillips J, Craig B, Viso R. 2013. Hardbottom and Cultural Resource Surveys of the Post 45 Charleston Harbor Project Study Area. Charleston (SC): Technical Report to the US Army Corps of Engineers.
- Garrison EG, Hale JC, Cameron CS, Smith E. 2016. The archaeology, sedimentology and paleontology of Gray's Reef National Marine Sanctuary and nearby hard bottom reefs along the mid continental shelf of the Georgia Bight. *Journal of Archaeological Science: Reports*. Volume 5, February 2016:240-262.
- Gingrich K. 2009. "That Will Make Carolina Powerful and Flourishing": Scots and Huguenots in Carolina in the 1680s. *The South Carolina Historical Magazine*. 110(1): 6-34.
- Good TS. 2012. American Privateers in the War of 1812: The Vessels and their Prizes as Recorded in Niles' Weekly Register. Jefferson (NC): McFarland & Co.
- Goodyear AC, III. 2005. Evidence for Pre-Clovis Sites in the Eastern United States. In: Bonnicksen R, editor. *Paleoamerican Origins: Beyond Clovis*. College Station (TX): Center for the Study of the First Americans. p. 103-112.
- Goodyear AC, Charles T, Michie JL. 2005. South Carolina Fluted Point Survey CGM. In Anderson DG, Miller DS, Yerka SJ, Gillam JC, Johanson EN, Anderson DT, Goodyear AC, Smallwood AM. 2010. PIDBA (Paleoindian Database of the Americas) Current Status and Findings. *Archaeology of Eastern North America*. 38:63-90.
- Goodyear AC, III. 2016. The Search for the Earliest Humans in the Land Recently Called South Carolina. In: Adam King, editor. *Archaeology in South Carolina: Exploring the Hidden Heritage of the Palmetto State*. Columbia (SC): University of South Carolina Press. p. 1-13.
- Greene JP. 2013. *Creating the British Atlantic: Essays on Transplantation, Adaptation, and Continuity*. Charlottesville (VA): University of Virginia Press.
- Gunn JD, Foss JE. 1992. Copperhead Hollow (38CT58): Middle Holocene Upland Conditions on the Piedmont-Coastal Plain Margin. *South Carolina Antiquities*. 24:1-17.
- Hagan KJ. 2017. The US as a New Naval Power, 1890–1919. In: Rodger N, Buchet C, editors. *The Sea in History - The Modern World*. Rochester (NY): Boydell and Brewer. p. 38-48.
- Hart E. 2009. *Building Charleston*. Charlottesville (VA): University of Virginia Press.
- Harris LB. 2014. *Patroons and Periaguas: Enslaved Watermen and Watercraft of the Lowcountry*. Columbia (SC): University of South Carolina Press.
- Harris MS. 2018. Paleogeography and Sea-level positions on the SE US Continental margin since the LGM: implications to potential habitation sites. In: Goodyear AC, Moore CR, editors. *Early*

- Human Life on the Southeastern Coastal Plain. Gainesville (FL): University of Florida Press. p. 90-107.
- Harris MS, Sautter LR, Johnson KL, Luciano KE, Sedberry GR, Wright EE, Siuda ANS. 2013. Continental shelf landscapes of the southeastern United States since the last interglacial. *Geomorphology* 203:6-24.
- Hoffman PE. 2014. "Until the Land was Understood": Spaniards Confront La Florida, 1500-1600. In: Díaz Balsera V., May RA., editors. *La Florida: Five Hundred Years of Hispanic Presence*. Gainesville (FL): University Press of Florida. p.69-82.
- Keller J, Sherwood CR, Marano J, Lawson C, Beavers R. 2014. Biscayne National Park HMS Fowey Pre-Stabilization Report. National Park Submerged Resources Center: Lakewood, Colorado.
- Lacroix D, Bell T, Shaw J, Westley K. 2014. Submerged Archaeological Landscapes and the Recording of Contact History: Examples from Atlantic Canada. In: Evans AM, Flatman JC, Flemming NC, editors. *Prehistoric Archaeology on the Continental Shelf: A Global Review*. New York (NY): Springer. p. 13-36.
- Lambeck K, Yokoyama Y, Purcell T. 2002. Into and out of the Last Glacial Maximum: sea-level change during Oxygen Isotope Stages 3 and 2. *Quaternary Science Reviews*. 21: 343–360.
- Landers J. 2014. "Giving Liberty to All": Spanish Florida as a Black Sanctuary, 1673-1790. In: Díaz Balsera V, May RA, editors. *La Florida: Five Hundred Years of Hispanic Presence*. Gainesville (FL): University Press of Florida. p. 117-140.
- Ma Y, Xu K, Gayes PT, Pietrefesa LJ, Peng M. 2011. Palmetto Wind Research Project – Final Report. Final Report to Santee Cooper.
- Maschmeyer, C. 2017. University of South Carolina NCE Report November 1. Columbia (SC): University of South Carolina
- Masters PM, Fleming NC. 1983. *Quaternary Coastlines and Marine Archaeology: Towards the Prehistory of Land Bridges and Continental Shelves*. New York: Academic Press.
- McCranie KD. 2011. *Utmost Gallantry: The U.S. and Royal Navies at Sea in the War of 1812*. Annapolis (MD): Naval Institute Press.
- Miller AS. 2010. "The Lighthouse Top I See": Lighthouses as Instruments and Manifestations of State Building in the Early Republic. *Buildings and Landscapes: Journal of the Vernacular Architecture Forum* 17(1): 13-34.
- Miller N. 1974. *Sea of Glory: the Continental Navy Fights for Independence, 1775-1783*. New York (NY): D. McKay Co.
- Moore JH. 1985. Charleston in World War I: Seeds of Change. *The South Carolina Historical Magazine*. 86(1): 39-49.
- Moore CR, Brooks MJ, Ivester AH, Ferguson TA. 2010. Geoarchaeological and Paleoenvironmental Research in FY10. In: *Annual Review of Cultural Resource Investigations by the Savannah River Archaeological Research Program, Fiscal Year 2010, Savannah River Archaeological Research*

Program, South Carolina Institute of Archaeology and Anthropology, University of South Carolina, Columbia. pp. 57-84.

Morgan K. 1995. The Organization of the Colonial American Rice Trade. *The William and Mary Quarterly*. 52(3): 433-452.

Mouzon HA. 1954. Privateers of Charleston in the War of 1812. Charleston (SC): Historical Commission of Charleston, S.C.

Murdock RK. 1966. A French Account of the Siege of Charleston, 1780. *The South Carolina Historical Magazine*. 67(3): 138-154.

Murray AB, Thieler ER. 2004. A New Hypothesis and Exploratory Model for Formation of Large Scale Inner-shelf Sediment Sorting and “Rippled Scour Depressions.” *Continental Shelf Research*. 24(3): 295-315.

Musial W, Heimiller D, Beiter P, Scott G, Draxl C. 2016. Offshore Wind Energy Resource Assessment for the United States. National Renewable Energy Laboratory Technical Report, NREL/TP-5000-66599.

Nagle K, Green W. 2010. Archaeological Data Recovery Excavations at the Tree House Site (38LX531) Lexington County, South Carolina. Columbia (SC): SCE&G, Columbia, by S&ME, Inc.

[NHHHC] Navy History and Heritage Command. 2015. *Princess Royal*. Washington (DC): Naval History and Heritage Command. [accessed 18 April 2018].  
<https://www.history.navy.mil/content/history/nhhc/research/histories/ship-histories/danfs/p/princess-royal.html>

### **Newspaper Sources**

United Kingdom

Greenock Advertiser (Scotland)

United States

Louisiana

New Orleans Republican

Times–Picayune (New Orleans)

Massachusetts

Boston Daily Advertiser

Boston Shipping Journal

New York

Frank Leslie’s Illustrated Newspaper

New York Herald

New York Times

North Carolina

Wilmington Messenger

South Carolina

Charleston Daily News

Ohio

Cincinnati Daily Enquirer

Noble, DL. 1997 *Lighthouses and Keepers: The U.S. Lighthouse Service and Its Legacy*. Annapolis (MD): Naval Institute Press.

- [ORN] Official Records of the Navy. 1907. Report of Commander Woolsey, U.S. Navy, Commanding USS *Princess Royal*, Regarding the Capture of the Schooner Flash, November 27, 1864. In: House Documents, Volume 45 (59th Congress, 2nd Session). 1907. Washington (DC): Government Printing Office. p.739.
- Ojeda GY, Gayes PT, Sapp AL, Jutte P, Van Dolah RF. 2001. Grand Strand Nourishment Project Study. Habitat Mapping and Sea Bottom Change Detection on the Shoreface and Inner Shelf Adjacent to the Grand Strand Beach Nourishment Project. Report to the US Army Corps of Engineers.
- Peck DT. 2001. Lucas Vásquez de Ayllón's Doomed Colony of San Miguel de Gualdape. *The Georgia Historical Quarterly*. 85(2): 183-198.
- Peltier WR. 2015. Home Page: W.R. Peltier, Paleo-topography dataset for ICE-6G(VM5a) model. Retrieved July 28, 2015, from <http://www.atmosp.physics.utoronto.ca/~peltier/data.php>
- Peltier WR. 1996. Global sea level rise and glacial isostatic adjustment: an analysis of data from the east coast of North America. *Geophysical Research Letters*. 23(7): 717–720.
- Pitblado NL. 2011. A Tale of Two Migrations: Reconciling Recent Biological and Archaeological Evidence for the Pleistocene Peopling of the Americas. *Journal of Archaeological Research*. 19(4): 327-375.
- Putney TR, Katuna MP, Harris MS. 2004. Subsurface stratigraphy and geomorphology of the Grand Strand, Georgetown and Horry Counties, South Carolina. *Southeastern Geology*. 42(1): 217–236.
- Powell J. 1990. Points and Blades of the Coastal Plain: A Guide to the Classification of Native American Hafted Implements in the Southeastern Coastal Plain Region. West Columbia (SC): American Systems of the Carolinas, Inc.
- Reed R. 2005. Wind Energy Resource Maps of South Carolina. AWS Truewind Report prepared for the South Carolina Energy Office.
- Roach A. 2017. Paleodrainage, Transgressions and Essential Fish Habitat. Master's Thesis. Conway (SC). Coastal Carolina University.
- Roberts J, Beamish I. 2013. Venturing Out: The Barbadian Diaspora and the Carolina Colony, 1650–1685. In: LeMaster M, Wood BJ, editors. *Creating and Contesting Carolina: Proprietary Era Histories*. Columbia (SC): University of South Carolina Press. p. 49-72.
- Rogers GC., Jr., Taylor CJ. 1994. *A South Carolina Chronology, 1497-1992*. Columbia (SC): University of South Carolina Press.
- Russo M. 1996. Southeastern Mid-Holocene Coastal Settlements. In: Anderson DG, Sassaman KE, editors. *Archaeology of the Mid-Holocene Southeast*. Gainesville (FL): University Press of Florida. p.177-199
- Sain DA. 2012. Clovis Blade Technology at the Topper Site (38AL23): Assessing Lithic Attribute Variation and Regional Patterns of Technological Organization. *Occasional Papers – Southeastern Paleoamerican Survey*. Book 2. Columbia (SC): University of South Carolina.
- Sassaman KE. 1993. Twenty-Five Lessons in Twenty-Five Years of Middle and Late Archaic Archaeology. *South Carolina Antiquities*. 25(1&2): 30-42.

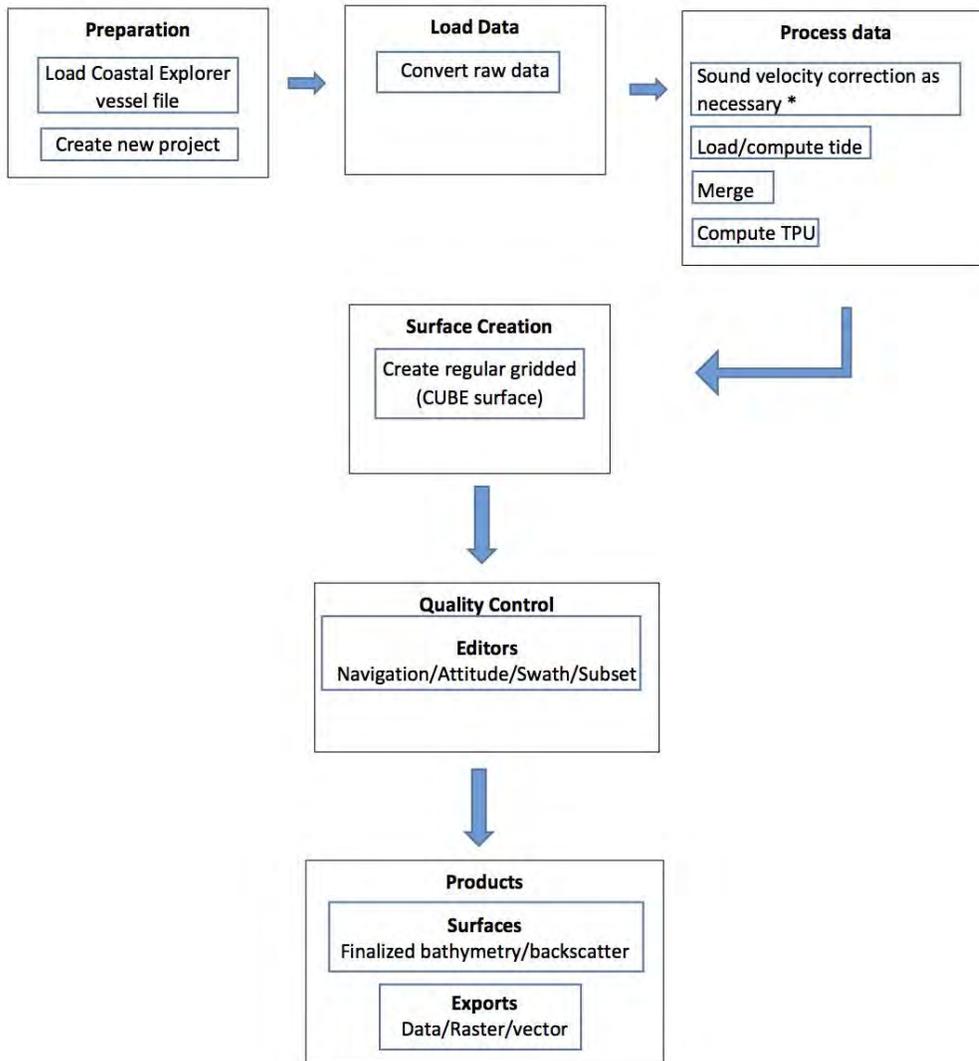
- Sassaman KE, Anderson DG. 1995. Middle and Late Archaic Archaeological Records of South Carolina. In: Savannah River Archaeological Research Program, SCIAA, University of South Carolina. Savannah River Archaeological Research Papers 6. Columbia (SC): University of South Carolina.
- Sassaman KE, Daniel IR, Jr., Moore CR. 2002. G. S. Lewis-East: Early and Late Archaic Occupations along the Savannah River, Aiken County, South Carolina. In: Savannah River Archaeological Research Program, SCIAA, University of South Carolina. Savannah River Archaeological Research Papers 12. Columbia (SC): University of South Carolina.
- Schwartz M, Heimiller D, Haymes S, Musial W. 2010. Assessment of Offshore Wind Energy Resources for the United States. National Renewable Energy Laboratory Report, Contract No. DE-AC36-08-GO28308.
- [SARMC] South Atlantic Fishery Management Council. 2018. SAFMC Fishery Ecosystem Plan II Implementation Plan. North Charleston (SC): SAFMC.
- South Carolina Archaeological Site Files. South Carolina Institute of Archaeology and Anthropology. Columbia (SC): University of South Carolina.
- [SCPA] South Carolina Port Authority. 2018a. Historical Container Volumes. Charleston (SC): South Carolina Port Authority. [accessed 18 Apr 18]. <http://www.scspace.com/about/cargo-value/>
- [SCPA] South Carolina Port Authority. 2018b. Port of Georgetown. Charleston (SC): South Carolina Port Authority. [accessed 18 Apr 18]. <http://www.scspace.com/locations/port-of-georgetown/>
- [SCPA] South Carolina Port Authority. 2018c. Top Commodity Groups. Charleston (SC): South Carolina Port Authority. [accessed 18 Apr 18]. <http://www.scspace.com/about/top-10-list/>
- [SCPA] South Carolina Port Authority. 2018d. Top Ten U.S. Seaport Districts in Dollar Value of Goods Handled, Calendar Year 2015. Charleston (SC): South Carolina Port Authority. [accessed 18 Apr 18]. <http://www.scspace.com/about/cargo-value/>
- Spirek JD, Amer CF. 2004. A Management Plan For Known and Potential United States Navy Shipwrecks in South Carolina. Columbia (SC): The South Carolina Institute of Archaeology and Anthropology, University of South Carolina.
- Stoesen AR. 1962. The British Occupation of Charleston, 1780-1782. *The South Carolina Historical Magazine*. 63(2): 71-82.
- Symonds CL. 2017. The Sea and the American Civil War. In: Rodgers NAM, Buchet C, editors. *The Sea in History – The Modern World*. Rochester (NY): Boydell and Brewer, Boydell Press. p.263-273.
- Taylor JC, Viehman TS, Paxton AB, Fegley SR, Voss CM, Pickering EA, Summers BW, Alder AM, Buckel CA, Freeman C, Vander Pluym JL, Peterson CH, Ebert EE. 2016. Benthic Habitat Mapping and Assessment in the Wilmington East Wind Energy Call Area. OCS Study BOEM 2016-003/NOAA Technical Memorandum NOS NCCOS 196.
- Thompson MD. 2015. *Working on the Dock of the Bay: Labor and Enterprise in an Antebellum Southern Port*. Columbia (SC): The University of South Carolina Press.
- [TRC] TRC Environmental Corporation. 2012. Inventory and Analysis of Archaeological Site Occurrence on the Atlantic Outer Continental Shelf. New Orleans, LA: U.S. Dept. of the Interior, Bureau of

- Ocean Energy Management, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study BOEM 2012-008.
- Tuten JH. 1991. *Lowcountry Time and Tide: The Fall of the South Carolina Rice Kingdom*. Columbia (SC). University of South Carolina Press.
- U-boat.net. 2018. Torungen, Norwegian Steam Merchant. Guðmundur Helgason. [accessed 23 Apr 18]. <https://uboat.net/allies/merchants/ships/1360.html>
- [USMM] U.S. Merchant Marine. 2006. *U.S. Maritime Service: the Forgotten Service*. American Merchant Marine at War. [accessed 10 Apr 18]. <http://www.usmm.org/usms.html>
- Van De Plassche O, Wright AJ, Horton BP, Engelhart SE, Kemp AC, Mallinson D, Kopp RE. 2014. Estimating tectonic uplift of the Cape Fear Arch (south-eastern United States) using reconstructions of Holocene relative sea level. *Journal of Quaternary Science*. 29(8): 749–759.
- Van Dolah RF, Boynton JB, Schulte KS, Felber JC. 2011. *Final Report: A Comprehensive Spatial Mapping Effort of South Carolina's Coastal Resources and Activities*. Submitted to the South Carolina Energy Office.
- Volo JM. 2007. *Blue Water Patriots: The American Revolution Afloat*. Westport (CT): Praeger Publishers.
- Wallace B. 2006. L'Anse aux Meadows [Internet]. *The Canadian Encyclopedia*. Canada: Historica Canada. [accessed 17 Mar 18]. <http://www.thecanadianencyclopedia.ca/en/article/lanse-aux-meadows/>
- Waterhouse R. 1982. The Development of Elite Culture in the Colonial American South: A Study of Charles Town, 1670–1770. *Australian Journal of Politics & History*. 28(3): 391-404
- Watts WA, Grimm EC, Hussey TC. 1996. Mid-Holocene Forest History of Florida and the Coastal Plain of Georgia and South Carolina. In: Anderson DG, Sassaman KE, editors. *Archaeology of the Mid-Holocene Southeast*. Gainesville (FL): University Press of Florida. p.28-38.
- Weber DJ. 1992. *The Spanish Frontier in North America*. New Haven (CT): Yale University.
- Williams J. 1935. English Mercantilism and Carolina Naval Stores, 1705-1776. *The Journal of Southern History*. 1(2): 169-185.
- Yuhl, SE. 2005. *A Golden Haze of Memory: The Making of Historic Charleston*. Chapel Hill (NC): University of North Carolina Press.

# Appendix A: CCU multibeam echosounder acquisition and processing workflow

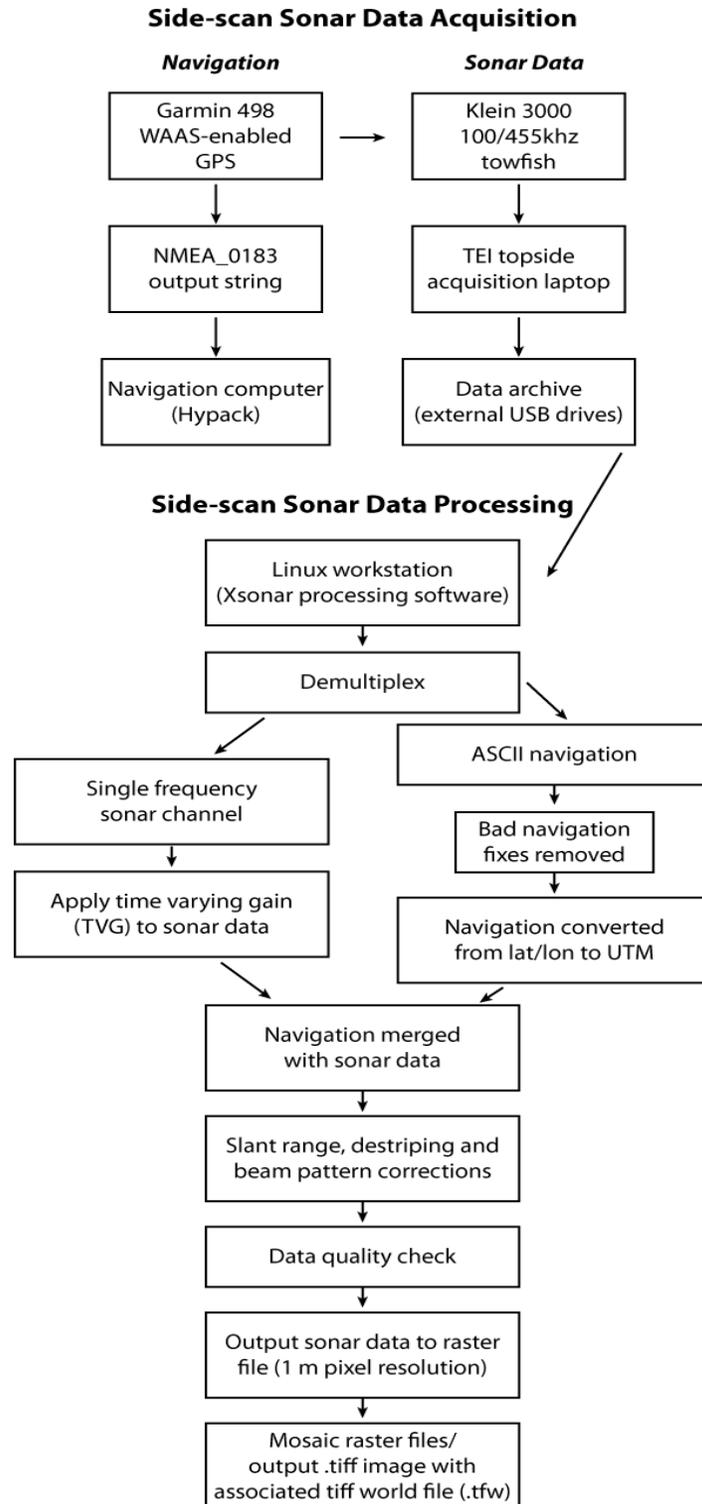
Coastal Carolina University's Major Multibeam workflow/steps based on CARIS 10.2 training manual guidelines

## Multibeam Data Processing Workflow

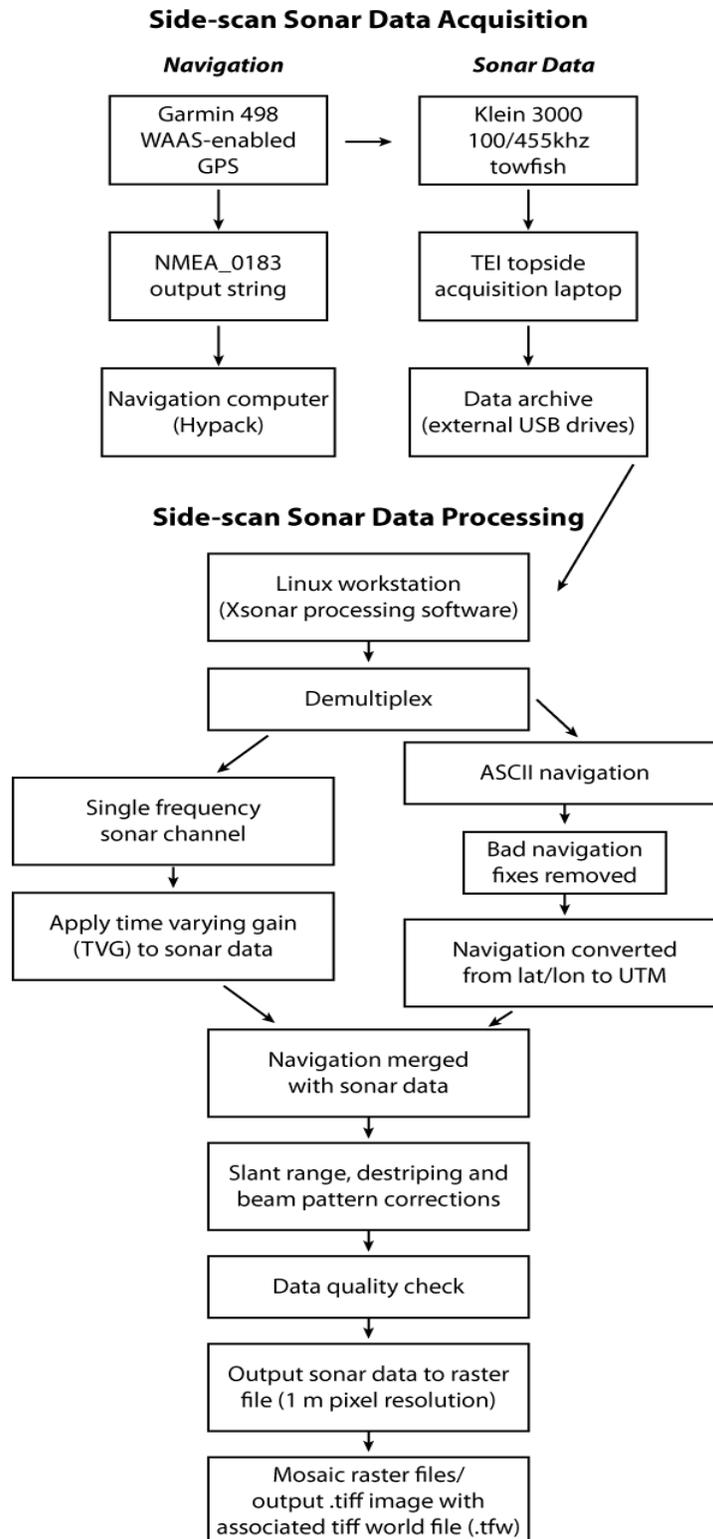


\*Sound velocity correction is applied during real time data acquisition

## Appendix B: CCU side scan sonar acquisition and processing workflow

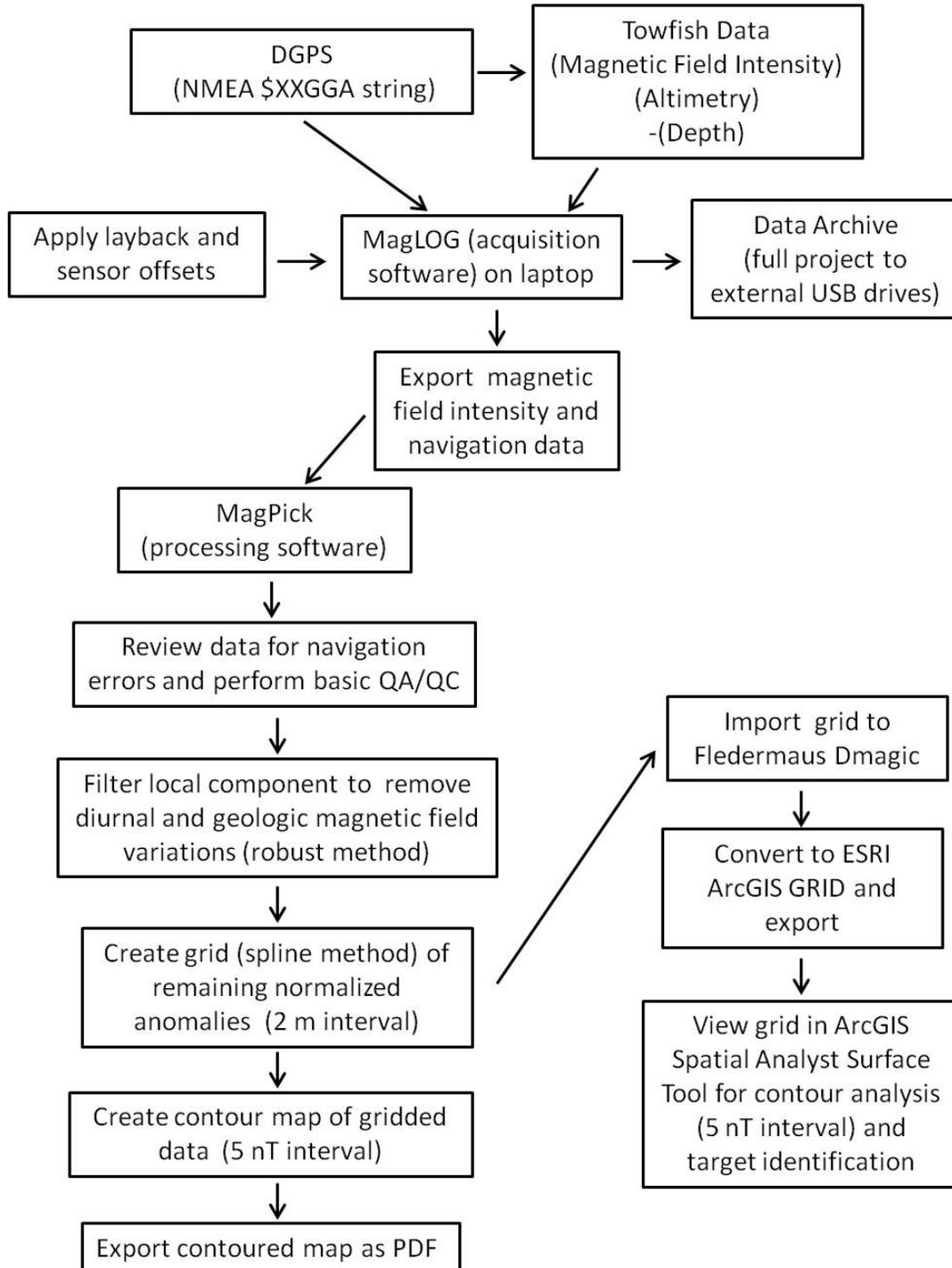


## Appendix C: CCU CHIRP acquisition and processing workflow



## Appendix D: CCU magnetometer acquisition and processing workflow

### Magnetometer Data Acquisition & Processing





### **Department of the Interior (DOI)**

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.



### **Bureau of Ocean Energy Management (BOEM)**

The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.