

Study Title: Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration

Report Title: Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration, Volume I: Main Text, Volume II: Appendices

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Sponsoring OCS Region: Minerals Management Service, Leasing Division, Sand and Gravel Unit

Applicable Planning Area(s): Offshore Dare County, North Carolina

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FY 2001: \$ 50,472; FY 2002: \$ 42,027; Cumulative Costs: \$499,999

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Key Words: sand resources, offshore North Carolina, sediment transport, wave modeling, bathymetry change, dredging, benthic, pelagic, recolonization

Background: The North Carolina Geological Survey (NCGS) characterized four sand resource areas in Federal waters offshore Dare County, North Carolina as potential borrow sites for beach nourishment. The main purpose of this study was to address environmental concerns associated with dredging sand from these Outer Continental Shelf (OCS) sites.

Objectives: Provide MMS environmental information to assess the potential impacts of offshore dredging activities and to identify ways in which dredging operations can be conducted to minimize or preclude long-term adverse physical and biological impacts to the environment. Five primary study elements were developed for addressing environmental concerns associated with offshore sand dredging: 1) evaluate potential modifications to waves due to offshore sand dredging within the proposed sand resource areas; 2) evaluate the potential impact of offshore dredging and consequent beach replenishment on sediment transport patterns, sedimentary environments, and local shoreline processes; 3) characterize benthic ecological conditions, using existing data sets and data collected from field work, in and around the proposed sand borrow sites; 4) evaluate benthic infauna present in the proposed sand resource areas, and assess the potential effects of offshore sand dredging on these organisms; and 5) develop a schedule of best and worst times for offshore sand dredging in relation to transitory pelagic species.

Description: The inshore portion of the continental shelf, seaward of the Federal-State OCS boundary and within the North Carolina Exclusive Economic Zone (EEZ), encompasses the project study area. The seaward limit of the study area is generally within about 15 km of the shoreline. Sand resource areas are located on the North Carolina OCS between the 10- and 20-m depth contours. The continental shelf surface contains a number of shore-oblique sand ridges formed during the Holocene transgression. Sand ridges 2- to 5-m high and 0.5- to 1.5-km apart represent the primary sand resource targets of this study. For sand resource areas on the northern North Carolina continental shelf, average shoal relief is about 2 to 3 m.

Four potential sand resource areas were identified offshore Dare County, North Carolina, in Federal waters by the NCGS and evaluated to determine the potential impacts of offshore sand mining for beach replenishment (Figure 1). Resource areas contain borrow sites with the greatest potential for future use. Existing physical processes and biological data were compiled and analyzed to assess the potential impacts of offshore dredging activities to minimize or preclude long-term adverse environmental impacts. Wave transformation and sediment transport numerical modeling were employed to

simulate the physical environmental effects of proposed sand dredging operations offshore and along the coastline landward of resource areas to ensure that OCS sand resources are developed in an environmentally sound manner. Biological field surveys were conducted to characterize benthic infauna and epifauna at each resource area.

Significant Conclusions: Potentially rapid and significant changes in bathymetry due to sand extraction from the OCS may impact wave propagation patterns on the continental shelf and at the shoreline. As such, substantial effort was spent understanding existing wave propagation patterns relative to those resulting from potential sand extraction scenarios. Because large natural spatial and temporal variability exists within the wave climate at a particular site, determination of physical impacts associated with sand mining must consider the influence of process variability. A method based on historical wave climate variability, as well as local wave climate changes directly attributable to borrow site excavation, was applied to determine appropriate criteria for assessing impact significance.

Under existing conditions wave transformation simulations, bottom topography offshore Bodie Island modifies incident waves as they propagate shoreward. For example, the shoal near Borrow Site 1 refracts waves, causing a slight focusing of wave energy behind the feature. Wave heights behind the shoal are about 0.4 m greater than wave heights at the northern and southern limits of the shoal. Post-dredging model simulations indicate that wave heights within borrow sites are reduced relative to existing conditions, and this effect was more pronounced in cases that had greater wave heights. As waves propagate across a borrow site, wave refraction guides wave energy away from the center of the excavation site and toward the shallow edges. The net effect is to create a shadow zone of reduced wave energy immediately landward of a borrow site and a zone of increased wave energy updrift and downdrift of the borrow site. Near Site 2, for example, wave heights increased by a maximum of 0.05 m at the northern and southern edges of the borrow site and decreased by a maximum of 0.06 m behind the borrow site. During storm conditions, where wave period was significantly larger than normal wave characteristics, waves were more affected by offshore bathymetric gradients.

Because spectral wave simulations were employed, and because different frequencies in a spectrum are refracted by varying degrees at each borrow site, regions of increased and reduced wave energy gradually diffuse as the wave field approaches shore. As such, borrow sites farther offshore affect a greater length of shoreline, however the actual magnitude of the impact is reduced because the affected wave field has a greater distance to diffuse. For example, Borrow Site 1 is larger than Site 2, but farther offshore, and therefore, wave height change from existing to post-dredging conditions at the shoreline was less than changes induced by Site 2. The area of maximum increased wave heights for post-dredging conditions was located at the northernmost corner of Site 1, where wave heights increased 0.09 m over existing conditions. Model output for storm wave conditions indicated that the length of affected shoreline where borrow site shadows propagate extended about 40 km to the north, starting from about 3 km north of Oregon Inlet.

Three independent sediment transport analyses were completed to evaluate impacts due to sand mining, including quantifying net sediment transport trends using historical bathymetry data sets; documenting sediment transport patterns at proposed offshore borrow sites using wave modeling results and existing current measurements; and predicting longshore sediment transport potential using wave modeling output. Sediment transport at borrow sites will experience rapid changes after sand dredging is completed. Local sediment that replaces dredged material will fluctuate based on location, time of dredging, and storm characteristics following dredging episodes. Average transport rates near borrow sites ranged from a minimum of about 38,000 m³/yr (Sites 3 East and 4) to a high of about 123,000 m³/yr (Site 2), while

infilling times varied between 37 to 98 years. Site 2 had the greatest infilling rate due to its shallow depth relative to other sites and its large perimeter. Difference in longshore transport potential between existing and post-dredging conditions resulted in a maximum change in computed net sediment transport potential of 34,000 m³/yr. Impact significance was determined by comparing actual change in transport potential between existing and post-dredging conditions to a significance envelope of one-half the standard deviation ($\pm 0.5\sigma$) along the shoreline. Based on this comparison, it was determined that no significant changes to longshore sediment transport would result from the modeled borrow site configurations, except when Sites 3 West and 3 East were dredged simultaneously.

Results of field surveys for biological characterization agreed well with previous descriptions concerning benthic assemblages associated with shallow shelf habitats offshore North Carolina. Numerically dominant infaunal groups included numerous crustaceans, echinoderms, mollusks, and polychaetes, while epifaunal taxa consisted primarily of decapods, sea stars, and squid. Potential benthic effects from dredging will result from sediment removal, suspension/dispersion, and deposition. Effects are expected to be short-term and localized. Seasonality and recruitment patterns indicate that removal of sand between late fall and early spring would result in less stress on benthic populations. Early-stage succession will begin within days of sand removal, through larval recruitment dominated by opportunistic taxa. Later successional stages of benthic recolonization will be more gradual, involving taxa that generally are less opportunistic and longer lived.

Zooplankton, squids, fishes, sea turtles, and marine mammals were groups in the pelagic environment considered to be potentially affected by offshore dredging. No cumulative effects to any of these pelagic groups are expected from multiple sand mining operations offshore North Carolina.

Study Results: Minimal physical environmental impacts due to potential sand dredging operations have been identified through wave and sediment transport simulations. Under representative wave conditions for each of the model grids offshore Dare County, North Carolina, it was determined that no significant changes in longshore sediment transport potential would result from modeled borrow site configurations, where Sites 3 West and 3 East were modeled separately. For sites dredged simultaneously, the impacts were estimated to exceed $\pm 0.5\sigma$, and therefore would require mitigation along the affected shoreline or a redesign of the borrow site configuration, likely a reduction in maximum design depth at one of the sites.

Data collected, analyses performed, and simulations conducted for this study indicate that proposed sand dredging at sites evaluated on the OCS offshore North Carolina should have minimal environmental impact on fluid and sediment dynamics and biological communities. Short-term impacts to benthic communities are expected due to the physical removal of borrow material, but the potential for significant cumulative benthic impacts is remote. Additionally, no cumulative effects to any of the pelagic groups are expected from potential sand mining operations.

Study Products: Byrnes, M.R., R.M. Hammer, B.A. Vittor, S.W. Kelley, D.B. Snyder, J.M. Côté, J.S. Ramsey, T.D. Thibaut, N.W. Phillips, J.D. Wood, and J.D. Germano, 2003. Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration. U.S. Department of the Interior, Minerals Management Service, Leasing Division, Sand and Gravel Unit, Herndon, VA. OCS Report MMS 2000-056, Volume I: Main Text 256 pp. + Volume II: Appendices 69 pp.

*P.I.'s affiliation may be different than that listed for Project Manager.

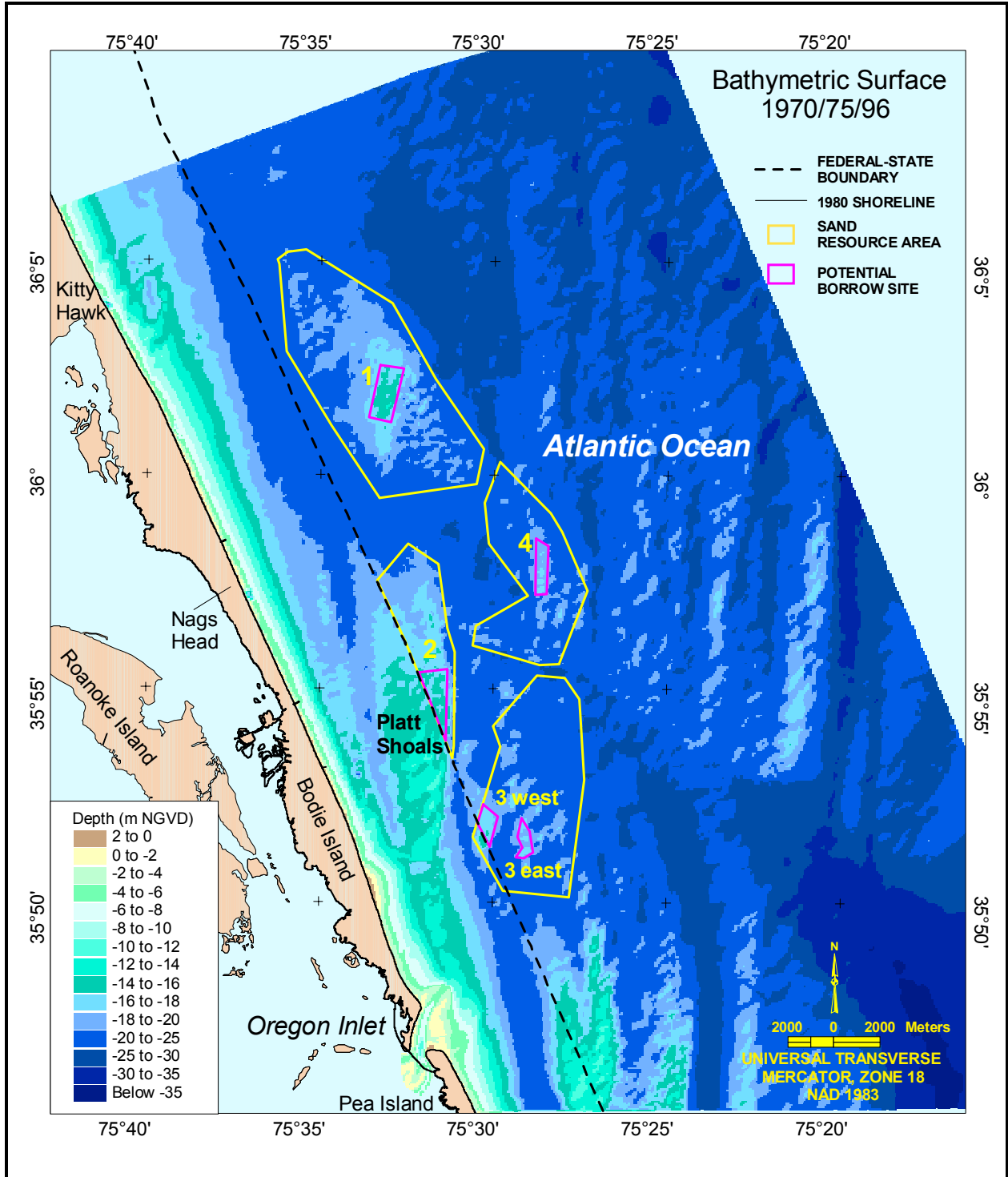


Figure 1. Location diagram illustrating potential sand borrow sites relative to shelf morphology offshore Dare County, NC.