APPENDIX G. Preliminary Ecological Monitoring Data on the Locally-funded Bogue Banks Beach Restoration Project.

The beach fill sediments used in the Bogue Banks Beach Restoration Project were dredged during Phase I from immediately offshore of Bogue Banks and contained between 30 and 40% carbonate material. Phase II proposes to dredge sediments that average 42% carbonate material of various grain sizes. In comparison, the native beach sediments of Bogue Banks contain less than 20% carbonate material (or shells; CSE 2000). Scientists at the Institute of Marine Sciences, University of North Carolina at Chapel Hill (IMS-UNC), have tested the sensitivity of indicator fauna (coquina clams, mole crabs, and Florida pompano) to varying grain size distributions and shell content in order to better elucidate the potential impacts of sediment compatibility.

Laboratory experiments by IMS-UNC researchers testing the sensitivity of burrowing coquina clams to various sediment substrates found that the clams have slower burrowing times with increasing sediment grain sizes (Attachment G-1), confirming the findings of Alexander et al. (1993). Similar experiments with the burrowing ability of mole crabs found that burrowing times for large crabs are fastest within unsorted native beach sediments from Bogue Banks (mean grain size 0.177 mm or 2.5 phi) and significantly increase if the sediments are greater than or equal to 2 mm (-1.0 phi) or smaller than or equal to 0.0625 mm (4.0 phi; $P<0.05$; Attachment G-1). The burrowing times for small mole crabs does not significantly vary with grain sizes equal to or smaller than 1.00 mm (0.0 phi; $P<0.05$). When the sediment grain size is 4.0 mm (-2.0 phi) or greater, the time it takes a mole crab to burrow is approximately three times as long as when the sediments are unsorted natural Bogue Banks beach sands (Attachment G-1).

Experiments with shell contents ranging from the natural, unsorted content of Bogue Banks beaches to 80% shell material show that both small and large mole crabs are sensitive to increasing shell content (Attachment G-1). Significant increases in burrowing time of the crabs occur with 20% shell content as compared to the natural beach sediments of Bogue Banks ($P<0.05$; Attachment G-1). The same experiment for coquina clams indicates that their burrowing times significantly increase with 20 to 33% shell content as compared to natural concentrations on a non-nourished beach in the project area ($P<0.05$; Attachment G-1). The shell content appears to camouflage invertebrate prey from foraging fish, reducing their ability to effectively forage even when the mole crabs and coquina clams have slower burrowing times (which could make them more vulnerable to predation; Attachment G-2).

In addition to these laboratory tests, independent monitoring by the IMS-UNC is comparing the beach fill in Pine Knoll Shores and Indian Beach to control beaches in Emerald Isle. Based on this monitoring, ecological recovery of the fill has not yet occurred. This monitoring includes sampling of bird species occurrence, abundance and feeding behavior; invertebrate species occurrence and abundance (i.e., coquina clams (*Donax* sp.), mole crabs (*Emerita talpoida*), polychaete worms and amphipods); fish species occurrence and abundance; ghost crab (*Ocypode quadrata*) abundance; and physical parameters including grain size distribution and surf zone turbidity. Sampling has occurred every two months, at the ends of March, May, July and September (with data from March - July enclosed). Turbidity measurements and fish surveys

were conducted in August (Attachments G-3, G-4).

The IMS-UNC monitoring results document that the abundance of shorebirds in the Phase I fill area is 85% less than control beaches, with sanderlings (*Calidris alba*), willets (*Catoptrophorus semipalmatus*), ruddy turnstones (*Arenaria interpres*), a mixture of plovers (*Charadrius* spp.), and whimbrels (*Numenius phaeopus*) the most common species (in decreasing order of abundance; Attachment G-5). There have been too few shorebirds present in the beach fill to perform a statistically valid comparison of feeding behavior (Dr. C.H. Peterson, pers. comm., September 4, 2002), so the question as to whether shorebirds can successfully forage along the 6.75 miles of Phase I beach fill remains unanswered.

The invertebrate population of the beach, which constitutes the food source for birds, ghost crabs and fish, continues to be depressed at a statistically significantly level (Attachments G-4, G-5). Coquina clams were only 20% of their undisturbed populations, and the mole crabs were depressed at a similar magnitude. Amphipod numbers were also lower on nourished sites as compared to control sites (Attachment G-5). Polychaete worms are greater in number on the beach fill than on control beaches (Attachment G-5). Preliminary data collected by Coastal Science Associates, Inc., as part of the County's biological monitoring program found a similar trend of higher numbers of polychaete worms (Attachment G-6).

The fish found in the surf zone are different in number and dominant species in the beach fill area than the control beaches, with higher numbers of baitfish (i.e., anchovy, menhaden) in the nourished areas (versus the control) and larger fish (i.e., Florida pompano, sea mullet) in the control areas (versus the nourished areas; Attachment G-4). This trend is similar to that found by USACE (2001) in New Jersey, and may reflect a species composition shift resulting from water quality differences (with visual predators preferring less turbid waters). The water clarity (or turbidity) often exceeds the state saltwater quality standard in the surf zone of the Phase I beaches while adjacent control beaches have clear water with no elevated turbidity (Attachment G-3).

On the dry part of the beach, ghost crab monitoring has documented only half the abundance of crabs in the beach fill as compared to control beaches (Attachment G-5). The populations of ghost crabs are similar on the dune face on fill and control beaches, but differ on the flat part of the beach where fill material was placed (Attachment G-5). This is probably reflective of the lack of dune disturbance during Phase I construction. Preliminary data collected by Coastal Science Associates, Inc., as part of the County's biological monitoring program sampled ghost crab burrow counts at 15 transects in Atlantic Beach (control), Pine Knoll Shores (nourished), Indian Beach (nourished), and Emerald Isle (control; Attachment G-6). Comparison of the two datasets needs to be conducted to control for differing sampling designs and summary statistics.

One beneficial outcome of the project has been the dramatic increase in numbers and sizes of seabeach amaranth (*Amaranthus pumilus*), a federally-threatened plant. The Service has not yet determined the reasons for this spectacular response and does not know if the fill material contained seeds for this plant, if the organic material provided additional nutrients, or if the beach fill created greater amounts of the plant's preferred habitat, which is foredune and

overwash flat areas.

As the sediments placed during Phase I beaches have been reworked by the waves, the quartz portion of the sediments has been concentrated. This separation is visually seen as a quartz sand veneer in the swash zone, but field surveys by the Service and the Institute of Marine Sciences at the University of North Carolina at Chapel Hill (IMS-UNC) have found this veneer to be a few inches thick at most (unpubl. data). The shells that have been separated from the quartz also are concentrated by the waves at various locations within the swash zone, and may constitute up to 38% of the surface (Attachment G-4). The natural, undisturbed beaches of Bogue Banks average only 6% shell cover, indicating that the beaches of Phase I have more than 6 times the shell content on the beach surface in the swash zone (Attachment G-4).

In summary, monitoring by the IMS-UNC of Phase I of the Bogue Banks Beach Restoration Project has documented a statistically significant decline in productivity of most animals with few signs of recovery within 5 to 8 months post-construction. The abundance of indicator species does not vary significantly between areas that received fill at the beginning of Phase I (during November-December 2001) and areas that received fill at the end of Phase II (during March-April 2002; Dr. C.H. Peterson, pers. comm., September 4, 2002). As additional data becomes available from IMS-UNC and the County's biological monitoring program (with scheduled sampling periods in June and November annually), further analysis of any measured ecological impacts (positive or negative) and the existing conditions in the Bogue Banks Shore Protection Project area will be possible.

Please note that data enclosed within attachments G-1 through G-5 should not be reproduced without the written consent of the Institute of Marine Sciences, University of North Carolina at Chapel Hill.