10.0 SUMMARY AND CONCLUSIONS

10.1 Inlet Dredge and Disposal History

Improvements for navigation at Beaufort Inlet, North Carolina, comprising the Morehead City Harbor Federal Navigation Project, began in 1911 when a 300-ft wide channel was dredged through the ocean bar at a depth of -20 ft mean low water (MLW). Through 1935, a channel was more or less maintained at this depth but not in a fixed location.

In 1936, the outer (bar) channel was increased to -30 ft depth and 400 ft width, the channel location was fixed, and an inner channel and basin were dredged to -30 ft. Subsequent improvements, through the latest in 1994, expanded the outer channel to its existing authorized dimensions of -47 ft depth (+2 ft overdredge allowance) and 450-ft width, and interior channels and harbor to -45 ft depth.

Since the commencement of dredging in 1911, through 2004, approximately 72.1 million cubic yards (Mcy) of sediment have been dredged to construct and maintain the Morehead City Harbor Federal Navigation Project. Of this, about 54.9 Mcy were for maintenance dredging (45.1 Mcy from the outer channel, 9.8 Mcy from the inner channel) and 17.3 Mcy were for new work. Maintenance dredging requirements have more or less increased with each deepening of the project.

- Total dredging prior to 1936 amounted to about 2.5 million cubic yards (Mcy), but the material was likely sidecast to the ebb tidal shoal and retained within the littoral system. From 1911 to 1936, average annual maintenance dredging requirements were about 90,300 cy/yr.
- Since the principal navigation project improvements began in 1936, total dredging through 2004 totaled 69.6 Mcy, of which 17.0 Mcy was new work and 52.6 Mcy was maintenance dredging. Of the maintenance dredging quantity, 50.4 Mcy is estimated to be of littoral origin, equating to about 740,600 cy/yr on annual average from 1936-2004.

10.2 Present Dredge and Disposal Practices

The present rate of maintenance dredging at the project, averaged over 1995-2004, is about 1,170,000 cy/yr. Of this amount, approximately 1,120,300 cy/yr is estimated to be of littoral origin. This is comprised of 956,100 cy/yr from the outer channel and 164,200 cy/yr from the inner channel (assuming 100% and 77% littoral origin, respectively).

Existing dredge disposal practices do not offset the current littoral impact of the inlet. From 1978 to 2004, 13.8 Mcy of dredged material from the navigation project has been placed onto the beaches of Bogue Banks. Of this amount, 10.8 Mcy is estimated to have been beach-compatible material. Since 1978, this equates to about 372,000 cy/yr.[29] The effective rate of beach disposal is thus about 33% of the rate of maintenance dredging of littoral material from the inlet (1,120,300 cy/yr). This equates to a net, current shortfall of at least 748,300 cy/yr between the effective rate of beach disposal and the annual rate of maintenance dredging of littoral material.

Of the beach disposal volume, 38% (about 142,000 cy/yr, considering only the beach-compatible fraction) has been placed within 2.4 miles west of the inlet, where most of it is likely transported directly back to the inlet. The remaining beach-compatible volume (equating to about 205,200 cy/yr) has been placed between about 2.4 and 5.5 miles west of inlet, in addition to about 0.7 Mcy placed to central Bogue Banks by Section 933 beach disposal from the outer channel in 2004. Excepting the latter, all of the beach disposal material was dredged from the inner channel/harbor, and placed to the beach directly or through the upland disposal area of Brandt Island. The non-compatible fraction of dredged material placed to the beach consists of clayballs, large shell, fine sands and silt – a significant portion of which was observed to remain along the dry beach and nearshore wading depths at least 8 months after placement.

From 1984 to 2003, an additional 4.1 Mcy of sand have been placed to central Bogue Banks apart from the federal navigation project. This consists of 0.63 Mcy from the Intracoastal Waterway, 3.58 Mcy from offshore borrow areas for the non-federal Carteret County beach nourishment project, and 0.16 Mcy from the offshore disposal area of the navigation project to construct post-storm (FEMA) beach restoration.

Nearshore disposal of dredged material has been placed in ambient seabed depths of -26 to -40 feet, within 9500 ft west of the inlet. Slightly less than half (46% to 48%) of the eligible dredge material from the outer channel has been placed to the nearshore disposal area since the practice began in 1997. The remainder was placed in the offshore disposal area (excepting 0.7 Mcy placed to Bogue Banks by Section 933 disposal in 2004). The rate of nearshore disposal of maintenance dredged material, averaged over 1997-2004, is on the order of 543,000 cy/yr; however, the depth and location of the nearshore disposal area is such that the material provides no benefit to the beaches. Dredged material placed to both the nearshore and offshore disposal areas is effectively

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[29] The 10.8 Mcy value reflects 77% beach-compatibility of the 13.1 Mcy of material placed from the inner harbor/Brandt Island and 100% compatibility of the 0.7 Mcy material placed from the outer channel by Section 933 beach disposal in 2004. It presumes that beach disposal from Brandt Island/Inner Harbor dredging will not be conducted for at least another 3 years after the most recent project in 2004; and thus equates to 10.8 Mcy placed over a minimum interval of 1978-2007.

removed from the littoral system and does *not* mitigate the effects of dredging at the navigation project.

Reported dredging quantities from the navigation project are mostly based upon "pay" volumes. Experience and limited available data indicate that these quantities under-estimate the actual volume of dredged material. Thus, estimates of dredging in this study are likely to be conservative (under-valued).

It appears that essentially all of the dredged maintenance material from the Outer Channel and the seaward end of the Inner Channel is of littoral origin and beach quality. The quality of dredged material further inland along the Inner Channel/Harbour varies. The pattern of shoaling along the navigation channel – compared with the inlet's bathymetric contours and adjacent shorelines -- clearly implies the littoral origin and transport pathways of the material that deposits within the navigation project. The bulk of this material, which is subsequently dredged and removed from the littoral system by nearshore and offshore disposal, is transported along the shoreline and the shallow platform of the ebb tidal shoal from the beaches into the inlet and navigation channel.

10.3 Inlet Morphological Changes

The division between pre- and post- navigation project conditions at Beaufort Inlet is typically taken as about 1936, when the channel was deepened and mostly fixed in location. In this way, bathymetric surveys in 1900 and 1933 represent pre-project conditions. Surveys in 1952, 1974, 1998 and 2004 represent post-project conditions.

The natural, pre-project inlet was characterized by a generally symmetric, broad, ebb tidal shoal with an ocean bar of about -10 to -15 ft controlling depth. The channel migrated across the shoal. Sand was exchanged between the beaches and the inlet and was bypassed across the bar. The present study found that the net rate of natural sand bypassing was about 94,000 cy/yr, on average, from east to west in pre-inlet conditions (1900-1933). During this period, the ebb shoal was gaining in sand volume at a net rate of about 208,000 cy/yr.

In contrast, the existing (post-project) inlet condition is characterized by a non-symmetrical ebb shoal that has simultaneously deepened, decreased in volume, elongated, and been displaced toward the sea. The shoal and ocean bar are wholly severed by the fixed navigation channel, maintained at about -45 ft controlling depth, which precludes natural sand bypassing across the inlet. The effect of the channel is concisely described by the Corps' Section 111 report (USACE 2001, p. 14, par. 4.14):

> The deep ocean entrance channel through the Beaufort Inlet ebb tide delta collects any ebb tide shoal material set in motion by wave and tide action under normal and storm conditions. The channel also intercepts littoral materials transported to the inlet from the adjacent beaches. Once the material deposits in the entrance channel, it cannot escape the channel by natural processes. Rather, it is removed and deposited offshore during each maintenance operation. The volume of littoral material removed annually from the Beaufort Inlet entrance channel and inner portion of the Morehead City Harbor exceeds the annual rate of longshore transport moving into the inlet. With the amount of material being removed from the inlet system by dredging exceeding the rate of supply, the expected result would be the deflation or erosion of the ebb tide delta.

For the first 16 years after initial construction of the major project improvements in 1936, the ebb shoal continued its pre-project trend of net volume gains. But, beginning soon after 1952, both the west and east lobes of the inlet's ebb tidal shoal began to exhibit significant, net volumetric losses. Since 1952, the average-annual rate of net loss from the inlet's submerged ebb shoal has been fairly consistent at about 680,500 cy/yr. About one-half of this amount were losses above the -20 ft MLW depth contour. Losses to the ebb shoal have been 3.6 to 8.2 times greater on the west (Bogue Banks) side of the bar channel than on the east (Shackleford Banks) side of the channel. This range of values reflects measurements that exclude and include changes above the waterline, respectively.

Overall, from 1936 through 2004, net volumetric losses to the submerged ebb shoal total about 26.6 Mcy; or 375,000 cy/yr on average. During this period, losses of the ebb shoal volume below the waterline have been 4.3 times greater on the west side of the bar channel (81% of the total) than on the east side of the channel (19% of the total).

Computed above -20 ft and -30 ft depths, respectively, the prevailing rate of ebb shoal deflation – compared to the existing shoal volume -- suggests that the active ebb shoal platform will be depleted of sand within the next 35 to 110 years, more or less.

Limited available data suggest that the inlet's flood shoal volume was mostly stable in pre-project conditions (+1100 cy/yr) and net erosional in post-project conditions (-54,600 cy/yr). Estimates of flood shoal volume changes are of uncertain accuracy because of a general paucity of survey data. There are likewise little historical data describing tidal flow and prism at Beaufort Inlet. Changes in the inlet throat's cross-sectional flow area imply that the existing tidal prism may be between 30% and 67% greater than pre-project conditions.

Prior to the principal navigation improvements, from 1876-1933, Bogue Banks was advancing eastward *toward* the inlet, and Shackleford Banks was retreating eastward *away* from the inlet. The inlet channel migrated between the two islands. During the first 40 years after improvements, from 1933-1974, the shoreline processes reversed. Bogue Banks retreated rapidly back toward its 1876 location, and efforts were made to stabilize its eastern shoreline by small groins and structures built to protect Fort Macon (c. 1950's). Shackleford Banks advanced westward, slowly at first, and then very rapidly from 1959 to 1974, approaching its current location. Over the next 30 years, from 1974 to 2004, the Bogue Banks shoreline was mostly net stable and/or advanced slightly as a result of beach fill placement from inner-harbor dredging. Since 2004, the sand spit at Fort Macon has advanced along and into the western bank of the navigation channel inside the inlet throat. From 1974-2004, Shackleford Banks consolidated its rapid westerly growth and has likewise prograded directly along and into the eastern bank of the channel at the inlet throat.

10.4 Wave and Littoral Transport Changes

Computer modeling was used to predict the wave energy and longshore sediment transport potential across Beaufort Inlet and along the adjacent shorelines of Shackleford Banks and Bogue Banks. The modeling examined both pre-project (c. 1900) and existing (c. 2004) conditions. Both conditions indicate an overall net *westerly-directed* littoral drift (east to west transport potential) along both Shackleford and Bogue Banks, excepting a localized reversal at the east end of Bogue Banks leeward of the inlet shoals.

In existing conditions, at the east end of Bogue Banks within 2.4 miles of the inlet, there is a strong net easterly reversal in transport potential directed toward the inlet. The location of the "nodal point" that divides this easterly "reversal" transport from the island's prevailing westerly transport varies between seasons and years; but on average, it is predicted to be at about 2.4 miles west of the inlet, in the vicinity of the Triple S and Oceanana Piers in eastern Atlantic Beach. West of this "nodal point", there is a potential for large volumes of sand to move both east and west along Bogue Banks; but in the net, transport potential toward the west is predicted to be slightly more dominant.

In the present case, however, sand moving to the east along Bogue Banks can be "intercepted" by the navigation channel or by the inlet's deflating ebb shoal and is thus no longer available for transport back to the west as it would be in a natural system. As sand is intercepted, there arises a deficit in the natural littoral supply, and the potential result is erosion to the west. In this way, an altered inlet (such as Beaufort) acts like a "sink" to all or part of the *gross* transport of sand that is directed toward the inlet. That is, the inlet's potential littoral impact can approach the rate of *gross* transport at the inlet; it is *not* limited to the rate of *net* transport.

Along Shackleford Banks, both easterly- and westerly-directed transport potential is computed, but the westerly-directed transport potential is generally much greater, especially within 1 to 2 miles of the inlet. The total computed transport potential directed toward the inlet is on the order of 600,000 cy/yr from the west (Bogue Banks) and 500,000 cy/yr from the east (Shackleford Banks).

The effects of the navigation channel, ebb shoal changes, change in shoreline orientation, offshore disposal, and nearshore disposal upon the waves and sediment transport patterns were compared by modeling pre-project and existing conditions. The principal changes from pre-project to existing conditions demonstrate a 2000-ft eastward shift of the transport reversal "nodal point" along eastern Atlantic Beach toward the inlet. Near the inlet, the transport potential directed from Bogue Banks into the inlet significantly *increased* (on the order of at least +300,000 cy/yr), while the transport potential from Shackleford Banks into the inlet *decreased* (on the order of about -200,000 cy/yr). The breaking wave energy increased along both sides of the inlet, but the increases along Bogue Banks were about 3.2 times greater than along Shackleford Banks.

Overall, predicted changes in wave energy and longshore transport potential were mostly limited to within 3.5 to 4.5 miles west of the inlet (about one mile west of the Sportsman Pier in central Atlantic Beach), and to within 2 to 3.8 miles east of the inlet on Shackleford Banks. Potential effects of the inlet upon the adjacent islands, however, are not necessarily limited to or caused by direct changes in the local wave conditions. Because the adjacent islands' beaches are littorally connected to (and/or controlled by) the inlet's tidal shoal complex, changes in wave and transport conditions at the inlet – coupled with dredging -- can have far-reaching effects to the adjacent beaches *beyond* those areas where local wave and transport conditions have been altered.

The deepening of the ebb tidal shoal has increased the wave energy along the west bank of the channel (Bogue Banks/Ft. Macon), along the navigation channel, and at the inlet throat and entrance to the interior sound. The magnitude of wave height increases depends upon the specific location and direction of the waves. In many cases, there was a four-fold increase in wave height across the channel and inlet mouth, from pre-project to existing conditions. Future increases in wave height are predicted, based upon continued future deflation of the ebb tidal shoal. Further wave height increases of about 10% and 20% at the inlet are predicted for 15- and 30-years projections of ebb shoal deflation. Increasing wave height at the channel and inlet can be expected to adversely impact navigation, and to increase wave energy within the harbors and sound, including portions of the Rachel Carson National Estuarine Research Reserve.

10.5 Beach Volume and Shoreline Changes

Comprehensive shoreline and beach survey data – from which one may deduce accurate, large-scale, quantitative conclusions of shoreline and beach volume change – do not exist at this location. Comparative shoreline data are limited to nautical charts, aerial photographs, and post-1958 beach surveys. The former charts and aerial-mapped shorelines include inherent inaccuracies and limitations. Comparison of shorelines from these data, for the purposes of assessing shoreline change rates, compound these maps' potential inaccuracies; and, the potential "error" in the map comparisons can equal or exceed the actual shoreline change of interest. Long-term beach surveys are limited to the eastern end of Bogue Banks and include the anomalous effects of beach fill placement. The effect of beach fill upon shoreline change is highly dependent upon the timing and spatial limits of both the fill activity and the survey. While the presence of beach fill can be said to "reflect actual conditions of the beach", it does *not* typify the shoreline nor allow a meaningful interpretation of natural or prevailing shore processes, nor does it allow meaningful computation of shoreline change rates.

In sum, there are insufficient data to develop a meaningful, definitive comparison of pre- and post-project shoreline change rates along the islands adjacent to Beaufort Inlet. While existing shoreline data provide a useful *general* description of shoreline behavior, quantitative conclusions regarding shoreline change cannot be reliably made.

Beach profile survey data on Shackleford Banks are limited to two, island-wide Corps surveys in 1991 and 2000. Long-term beach profile data on Bogue Banks are limited to Corps surveys from 1958 to 2000, widely spaced along the eastern 5 to 6 miles of the island (central Atlantic Beach to Fort Macon). Comparative surveys that span *all* of Bogue Banks are limited to 1999 through 2004, of which only a two-year period (2002-04) includes profiles that extend sufficiently far offshore to determine total volume change and offshore seabed change[30].

Measured shoreline and volume changes are poorly correlated. That is, along Bogue and Shackleford Banks, shoreline changes are a poor indicator of volume change, and vice-versa. Changes in the dune line (the location of the dune face, behind the beach berm) do not reveal significantly different or meaningful trends in shoreline behavior relative to changes in the mean high water shoreline. This is due in part to the alongshore spacing of the profile survey data.

Beach profile volume changes measured above the -30 ft depth contour were typically between 2.5 and 4 times greater than changes measured above the -15 ft depth

[30] Recent surveys in 2005 are not included in this study's analysis

contour. This principally relates to volume *losses*. Volume *gains* associated with beach fill placement appear mostly above -15 ft, with some equilibration extending to -20 or -25 ft depth. Future beach profile surveys and analysis should extend to at least the -25 or -30 ft NGVD contours.

After removing (subtracting) the volume of beach fill placement, the available survey data along eastern Bogue Banks, from 1958 to 2004, suggest beach volume losses above -20 to -30 ft NGVD, on the order of

- -360,000 cy/yr erosion along Fort Macon State Park (within 1.4 miles west of the inlet);
- -520,000 cy/yr erosion along the entire zone of easterly-transport reversal comprising eastern Atlantic Beach and Fort Macon State Park (within 2.4 miles west of the inlet);
- -670,000 cy/yr erosion along the western and central remainder of Atlantic Beach (2.4 to 6.4 miles west of the inlet)

There are only very limited data west of Atlantic Beach from which to develop comprehensive estimates of beach profile volume change (i.e., deeper than -11 to -15 ft depth). Changes from 2002 to 2004 are on the order of

- -200,000 to -400,000 cy/yr erosion along Pine Knoll Shores (6.4 to 11 miles west of the inlet)
- +100,000 cy/yr of modest gains or general stability along Salter Path/Indian Beach (11 to 13.4 miles west of the inlet)
- -100,000 cy/yr erosion along central-east Emerald Isle with localized variation (13.4 to 19 miles west of the inlet), and
- Variable erosion/accretion along west Emerald Isle (up to 23.6 miles west of the inlet)

These estimates are computed above -20 to -30 ft NGVD depth, with the effects of beach fill placement removed. Observed nearshore changes (above -11 to -15 ft depth) are typically less than about one-third of the values listed above. Estimated volume loss along Shackleford Banks is on the order of 900,000 cy/yr; but this is based upon only a single set of Corps surveys from 1991 to 2000.

Deepening ("deflation") of the offshore profile is evident in all of the survey data, and is not limited to the shore within the ebb tidal shoal complex. Along the -20 to -30 ft depth contours, between 1958 and 2000, the seabed elevation decreased by about 3 ft through at least 5 miles west of the inlet (-0.07 ft/yr). Approaching the inlet, the elevation decreased by 7 feet (-0.17 ft/yr). Surveys from 2002-04 imply profile deepening on the order of 0.5 feet (-0.25 ft/yr). None of the available profile data indicate significant stability or accretion in the nearshore/offshore profiles along Bogue Banks or Shackleford Banks.

For a typical beach profile along central Bogue Banks, applicable theory predicts that a 3-ft deepening of the offshore profile will ultimately translate to a 305-ft horizontal recession of the mean high water shoreline. Analogous cases are documented in North Carolina (e.g., Bald Head Island, adjacent to the Wilmington Harbor Entrance) where the shoreline exhibited general stability while the submerged profile was deepening -- followed by a sudden, severe and pervasive erosion of the shoreline following the chronic deflation of the offshore profile. As at Beaufort Inlet, the offshore profile changes were linked to changes in the ebb shoal of the adjacent inlet subsequent to navigation improvements that severed the natural shoal complex.

10.6 Historical Inlet Impacts to the Littoral System

Since the inception of principal navigation improvements for the Morehead City Harbor federal navigation project (computed over 1933-2004), the net littoral volume removed from the inlet system as a result of the project, after accounting for beach disposal, is computed as 48.7 Mcy, or, about 685,800 cy/yr on annual average. Of this total impact, about 23.6 Mcy (48%) and 3.8 Mcy (8%) has occurred as volume losses ("deflation") of the ebb and flood tidal shoals, respectively. Of these two values, loses to the flood shoal are less certain.

The remaining 21.2 Mcy (44%) of the historical impact represents a net loss to the littoral system *beyond* the limits of the inlet ebb shoal complex. On annual historic average, this equates to 300,000 cy/yr of outstanding impact to the inlet-adjacent barrier islands beyond the inlet complex, i.e., beyond 2.4 miles west and 2.1 miles east of the inlet channel.

Increases in post-project breaking wave energy, inlet-directed littoral transport potential, and the rate of post-project ebb shoal deflation were all at least 3.2 to 4.3 times greater on the west side of the channel than on the east side. From this, it is concluded that between 76% and 81% of the outstanding 300,000 cy/yr littoral impact is associated with the west (Bogue Banks) shoreline of the inlet. This equates to between 228,000 cy/yr and 243,000 cy/yr – and totals to between 16.2 and 17.3 Mcy of historic littoral impact -- beyond the losses that occurred within the zone of easterly-reversal transport, 2.4 miles west of the inlet. These volumes account for the placement of beach disposal. The remainder of the outstanding littoral impact is attributed to Shackleford Banks, beyond 2.1 miles east of the inlet, amounting to between 4.1 and 5.1 Mcy; or, 57,000 and 72,000 cy/yr on annual average.

An alternate examination of the navigation project's littoral impacts yields similar values to those above, but provides additional insight into the physical origin of the impacts relative to pre-project conditions. Over 1933-2004, the littoral impacts of the navigation project were approximately comprised of

- 386,500 cy/yr (27.4 Mcy) of direct impact to the inlet complex by measured volumetric depletion of the inlet sand reservoir, plus
- 206,000 cy/yr (14.6 Mcy) of impact to the inlet complex and the littoral system by 'forgone accretion' of littoral influx that previously accrued to the inlet shoals but is now intercepted by the channel and dredging, plus
- 94,000 + 65,400 = 159,400 cy/yr (11.3 Mcy) of direct impact to the adjacent beaches (beyond the inlet complex) from interception of littoral drift that would have otherwise bypassed or backpassed through the inlet system, respectively.

The project's cumulative effects are thus: (a) 27.4 Mcy of measured depletion of the inlet shoals, plus (b) another 14.6 +11.3 = 25.9 Mcy of impact to the beaches by diversion of the natural littoral transfer between the inlet and the beaches. Beach disposal of compatible material from the navigation project, *beyond* the inlet complex, reduces the latter number by 4.7 Mcy. Thus, the net direct, historical littoral impact to the beach beyond the inlet complex is 21.2 Mcy [equating to about 299,000 cy/yr]. Additional to this is the indirect effect of the 27.4 Mcy of sand depleted from the inlet shoal complex.

Computed in similar fashion for *existing* conditions (1994-2004), the approximate net impact of the navigation project is comprised of

- 426,700 cy/yr of depletion of the inlet's existing volumetric reserves, and
- 206,000 cy/yr of littoral influx from the adjacent beaches that would otherwise have accrued to the inlet/beach shoal system ("foregone accretion"), and
- 94,000 + 255,900 = 349,900 cy/yr of littoral influx from the adjacent beaches that would otherwise have been bypassed or backpassed, respectively, across the inlet.

The second and third elements represent a 555,900 cy/yr littoral impact to the beaches beyond the boundaries of the inlet shoal complex [2.4 miles west and 2.1 miles east of the inlet channel]. About 228,800 cy/yr of this impact is mitigated by beach disposal of suitable material from the navigation project beyond these boundaries (additional to beach disposal already included above). Thus, in current dredging practices, there is a net outstanding, impact of (555,900-228,800=) *327,100 cy/yr* to the littoral system beyond the limits of the inlet shoal complex, *plus* additional indirect littoral impact of *426,700 cy/yr* of sand depleted from the inlet shoal complex itself.

10.7 Comparison with Corps' Section 111 Findings

The technical findings of the Corps' Section 111 Study (USACE 2001), outlined in the prior section, are in fundamental agreement with the findings presented above. The Corps' estimates of volumetric impact to the littoral system are greater than those described in the present study (amounting to 409,300 cy/yr of littoral impact beyond the inlet ebb shoal complex versus a conservative estimate of 300,000± cy/yr in the present study). The Corps' study likewise finds significant nearshore profile deepening along both inlet-adjacent shores that is related to the deflation of the ebb tidal shoal. Nonetheless, the Corps' study dismisses the bulk of its technical findings and ultimately concludes – based *singularly* upon its analysis of pre-project versus post-project *shoreline change* rates -- that there is no evidence that the harbor project has had an impact on any of shorelines in the vicinity of the harbor project. This finding is not supported by the bulk of the Corps' technical analysis, nor by the statutory mandate of the Section 111 legislation of federal law (see page 74).

10.8 Recommended Actions

This study concludes that there is both an historic and ongoing adverse littoral impact of the Morehead City Harbor federal navigation project upon the shores adjacent to the project. To mitigate both historic and future anticipated impacts, modifications to dredging and disposal practices of the navigation project are warranted and recommended. Descriptions of these modifications and related improvements, and potential means toward their implementation, are presented in the following section.

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11.0 RECOMMENDATIONS FOR SAND MANAGEMENT PRACTICES AT MOREHEAD CITY HARBOR PROJECT

In light of the long-term and ongoing littoral impacts associated with construction and maintenance of the Morehead City Harbor Federal Navigation Project, documented in this study, the following recommendations are presented for consideration by the project's Federal and Non-Federal Sponsors with specific regard to the following topics:

1) Resource Recovery and Protection *(Section 11.1)*
2) Mitigation Measures of Historical Inlet Impacts *(Section 11.2)*
3) Enabling Legislation for Effective Sand Management Practices *(Section 11.3)*

Toward implementation of measures to enable these goals, additional recommendations are presented in regard to:
4) Requisite Near-Term Engineering Studies *(Section 11.4)*

Recommendations addressing each of these topics are presented in Sections 11.1 through 11.4, below.

11.1 Resource Recovery and Protection (Sand Management Plan)

Existing dredge and disposal practices at the navigation project must be modified and executed in a comprehensive manner by which:
(1) high-quality dredged material is restored to the active littoral system; and the net equivalent of the natural, pre-project sand bypassing rate across the inlet is restored,
(2) the quality of dredged material placed to beaches is assured to be beach-compatible
(3) existing sand resources (disposal areas) are protected from contamination by the disposal of non-beach-compatible sediments, and
(4) the influx of littoral material to the navigation project, requiring dredging, is reduced or minimized.
The most appropriate manner to accomplish these objectives is the adoption and dedicated implementation of a Sand Management Plan. The Corps of Engineers also refers to this as a Dredged Material Management Plan. The Plan should stipulate means to accomplish the four objectives outlined above.

Implementation of a Sand Management Plan may be best accomplished by a Memorandum of Agreement (MOA) between the affected parties in conjunction with statutory requirements that stipulate and require best management practices for maintenance and improvements of the navigation project. The latter would formulate minimum requirements for consistency with the State of North Carolina Coastal Zone

Management (CZM) Plan and potentially also require Water Quality Certification (WQC), as additionally described in Section 11.3, below.

An alternative would be modification of the Federally authorized navigation project to formally adopt the requirements of a Sand Management Plan; however, it is presently believed that this is a less plausible, potentially less effective, and certainly a more time-consuming process for implementation. Modifications to the authorized project would require lengthy project re-evaluations and reports by the Corps' Wilmington District, lengthy review and possible dismissal by Corps' higher authority, and require Congressional Authorization(s) including passage of a Water Resources and Development Act (WRDA). Further, if approved, the final plan would be subject to numerous federal caveats and/or potential availability of Federal funds.

Requisite elements of the Sand Management Plan are outlined in terms of the following Measures:

Measure 1: Recovery of Dredged Material to the Littoral System

1a.) Resource recovery pertains to dredging and disposal practices that ensure littoral material dredged from the inlet is effectively returned to the active littoral system. These practices must likewise seek to minimize adverse impacts to navigation (i.e., increased maintenance dredging requirements). Present practices of periodic beach disposal equate to only 33% of the maintenance dredging rate of littoral material from the inlet -- leaving a net, current shortfall of at least 748,300 cy/yr (67%) between the effective rate of beach disposal the annual rate of maintenance dredging. Likewise, the current practice of nearshore disposal does *not* restore dredged material to the littoral system. Nearshore disposal is therefore not a preferred alternative for resource recovery and should not be considered for any dredge disposal of beach-compatible sand unless the material is consistently placed in ambient seabed depths of -18 ft MLW or less and in alongshore locations that are of documented net benefit to the littoral system. Thus, *present dredging and disposal practices must be modified to ensure that dredged littoral material is returned to active littoral system.*

1b.) Future, modified dredging and disposal practices must address
(1) the total amount of littoral material excavated under current maintenance levels,
(2) future maintenance dredging activity that re-establishes authorized project depths, and
(3) future new work dredging, including wideners, deepening, channel re-orientation, etc.

The second of these three items specifically refers to requisite future maintenance dredging to the current authorized depth of 47'+2' along the outer channel. Over the last several years, the outer channel has been maintained to only 45'+1' or 45'+2'. This has adversely impacted commercial shipping interests at the federal project, according to the port Pilots. Restoration to the authorized depth of 47'+2' is recommended, with the one-time increase in maintenance dredging (relative to existing conditions) potentially yielding up to an additional 400,000 cy of littoral material for placement to the adjacent shorelines. This action would represent a significant benefit to both beach and navigation interests.

1c.) All littoral material dredged from the inlet by maintenance dredging and new work must be placed to the adjacent beaches. This study's analysis suggests that between 76% and 81% of the navigation project's littoral impacts have accrued to the west (net downdrift) side of the inlet, suggesting that at least 76% to 81% of all annually dredged littoral material should be placed to Bogue Banks. The remainder should be theoretically placed to Shackleford Banks. However, given that Shackleford Banks comprises a National Seashore and that the island is essentially undeveloped, the island's managing interests may or may not desire dredge disposal to this shoreline. In the latter case (which remains to be determined), all of the dredged littoral material would be disposed to Bogue Banks.

1d.) Disposal of littoral material dredged from the Federal navigation project should restore the natural sand bypassing across the inlet. This study demonstrates that the pre-navigation project, net natural bypassing of sand across the inlet was on the order of 94,000 cy/yr, *from east to west*. Disposal of the majority of the annual maintenance-dredged material to Bogue Banks is consistent with restoring the historical, net natural bypassing of sand at this location.

1e.) Beach disposal of dredged material must be placed in suitable locations *and* geometry to ensure physically effective remediation to adjacent beaches. The available beach profile data suggests that significant offshore losses appear to occur along most of the entirety of the adjacent islands. It is therefore appropriate that beach placement be distributed along most of the entirety of the adjacent island shorelines; i.e., it must not be limited to the shorelines immediately proximate to the inlet. Effective placement of this material to the beach requires active engineering management during initial design and during construction to ensure that the material is placed in a berm of rational width, height and slopes extending more or less fully along a prescribed length of shoreline per each disposal event. This requires active monitoring and modification of the beach fill placement dimensions during the course of construction, even in the case where payment for construction is measured at the dredge area (versus beach fill). Minor changes in Federal construction documents and supervision are typically required to accomplish the monitoring and real-time modification of beach fill placement to ensure the optimal effectiveness of beach disposal activity of dredged material from the navigation project.

1f.) Methods of beach disposal can include direct pump-out from hopper dredge, or nearshore disposal to a rehandling area from which subsequent transfer to the beach can be made by cutterhead pipeline dredge. Representative distances of disposal operations from the navigation project to various locations along Bogue Banks -- with relative distances to the offshore disposal area – are illustrated in ***Figure 40***, following page. The figure also illustrates an example of a nearshore rehandling area/disposal berm, including typical shoreline lengths reached from the example rehandling area. While direct pump-out from a hopper dredge is the preferred alternative, nearshore disposal to a rehandling area may be a viable alternative to economically stockpile material for subsequent transfer to the beach. This approach has been successfully employed at other Federal projects, including the Brevard County, Florida Federal Shore Protection Project in 2000-01, and 2003 (Bodge, 2002). Beach disposal from the Inner Channel/Harbor could be likewise accomplished by hopper dredge; or, per current practice, by cutterhead pipeline dredge directly or via an upland stockpile. However, future dredging practices must be modified to ensure that disposal/nourishment material is beach quality, as described in "Measure 2", below.

1g.) Resource recovery as described in the Sand Management Plan must become standard operating procedure and/or best management practice required for project maintenance and new work. It must not entail single-occasion approval or require annual renewal, such as required by Section 933 type beach disposal.

1h.) Costs of implementation of the Sand Management Plan should be borne as a part of the overall project costs. In this way, the dredging and disposal practices outlined in the Plan become the fundamental operational requirements, and do *not* comprise specific additive or betterment costs. To the extent that implementation of proper dredge and disposal activities specified in the Plan increase the costs of maintaining and/or improving the project, it is recognized that appropriations for the project must increase. The Non-Federal Sponsor should recognize the need for these increased appropriations and be prepared to assist the Corps of Engineers in securing the requisite funding.

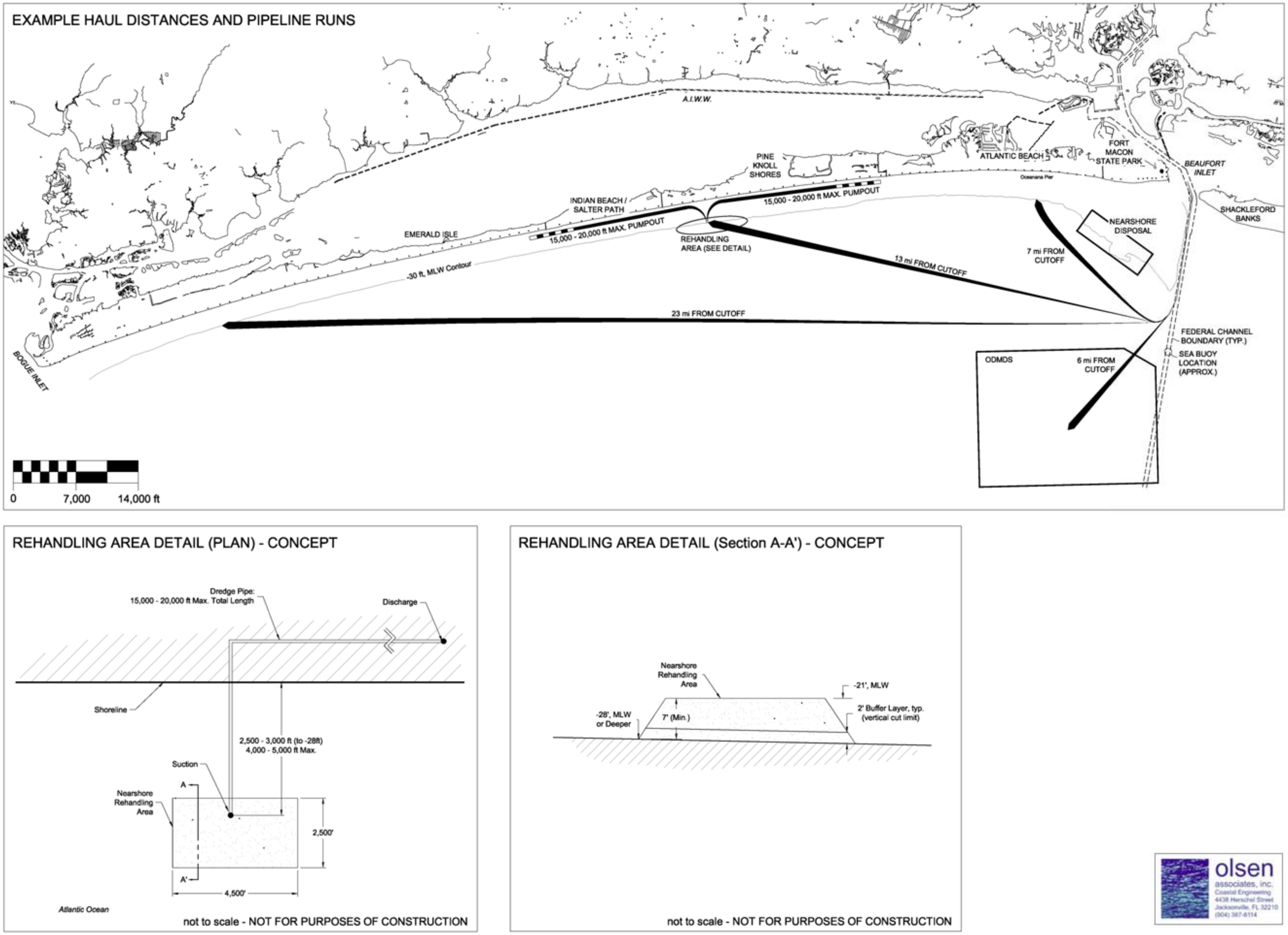

Figure 40: Typical hopper dredge sail distance form the cutoff channel to potential nearshore rehandling or pump-out sites along Bogue Banks. Locations of dispoal and nearshore rehandling areas are for purposes of illustrative example only.

Measure 2: Ensuring Quality of Dredged Beach Disposal Material

2a.) Available data to-date indicates that all of the maintenance-dredged material from the Outer Channel (Range A and Cutoff) and seaward portions of the Inner Channel (Range B) consists of high quality, beach-compatible material. This material must be placed to the beach, by direct or indirect (rehandling) methods described above.

2b.) The quality of maintenance-dredged material from the Inner Channel/Harbor varies. The normal limits of occurrence of beach-quality material within the Inner Channel/Harbor ranges must be identified and delineated by geotechnical investigation and local knowledge; and, material from within these limits must be placed to the beach or in a segregated stockpile area for subsequent transfer to the beach.

2c.) It is no longer environmentally acceptable to place non-compatible material to the beach. It is recognized, however, that a significant fraction of the material dredged from the Inner Channel/Harbor is littoral in origin and must be returned to the beach either directly or by equivalent quantity from a compatible source outside of the project and active littoral system. Comprehensive geotechnical investigation must be made of material contained within the upland disposal site (Brandt Island) prior to transfer of any material to the beach. Non-compatible material must be isolated or avoided and not placed upon the beach per considerations of the following paragraph.

2d.) In regard to dredged material from the Inner Channel/Harbor, economic evaluation should be made of the costs of:
(A) segregating beach quality material for subsequent beach disposal, versus
(B) equivalent beach fill placement from alternate sources.
That is, the practical limitations and/or costs of (A) segregating beach-quality material from Inner Channel/Harbor dredging for subsequent placement to the beach should be weighed against (B) the cost of beach-placement of an equivalent volume of beach compatible material from an alternate (offshore) source. If the latter is more practical or economical, then material from the Inner Channel/Harbor may be disposed of outside of the littoral system subject to the beach placement of an equivalent volume of beach-quality material from an alternate source outside of the littoral system and navigation channel limits.

2e.) The beach compatibility (quality) of all new-work dredging must be determined by adequate geotechnical investigation and engineering analysis.

Measure 3: Protection of Existing Sand (Disposal) Resources

3a.) The existing mounds of nearshore and offshore disposal material from the Outer Channel are sand resources that must be protected as potential future sand borrow areas. These areas can serve as sand sources for future beach fill placement as mitigation of navigation project impacts, shore protection projects, and/or emergency post-storm beach restoration. As such, non-beach-compatible sediments must not be disposed at or near these resources in the future. The Sand Management Plan must include strategic delineation of those areas that shall not be used for future disposal of material unsuitable for beach placement and shall define what constitutes unsuitable material. It is additionally noted that the majority portion of the existing offshore disposal mounds are located in federal waters. The U.S. Environmental Protection Agency (USEPA) has significant jurisdiction over the material placed in these waters. The U. S. Dept. of Interior Minerals Management Service (MMS) has significant jurisdiction over the use of seabed resources removed from, or altered in, these waters.

3b.) Use of existing nearshore and offshore disposal mounds as sand sources for beach fill placement, subject to engineering and environmental evaluation, is consistent with resource recovery, and this practice should be encouraged. This practice would return sand to the littoral system that was otherwise removed from the system by historic dredging and disposal activities.

Measure 4: Modifications to Reduce Littoral Influx to the Navigation Project

4a.) Modifications to the project, adjacent shores and dredging practices should be implemented that would reduce entrainment of littoral material to the inlet and channel. This would simultaneously reduce the amount of requisite maintenance dredging, improve navigation safety, and increase the stability and shore protection of the adjacent beaches. Recommended modifications include the following.

4b.) Reconstruct, improve, and/or add coastal structures along the shoreline west of the inlet to reduce the rate of easterly transport into the inlet and simultaneously improve beach conditions along Fort Macon State Park and eastern Atlantic Beach. This would principally take the form of re-constructing and/or modifying the existing groin field near the Fort. Existing structures at this location include a long groin west of the Fort and a relic groin field on the east (inlet) side of the Fort. These structures are low and extremely porous and allow significant sand transport into the inlet. Improvements to these structures must likewise ensure the integrity of the shoreline along the Fort structure. There is an additional existing short groin at the west end of the State Park. ***Figure 42*** illustrates the recent condition of the long groin at the Fort. ***Figure 43*** depicts the inlet area in planform, with depth contours in 2004. As seen in these graphics, the existing long groin immediately west of the Fort provides some impoundment of the easterly-directed transport; however, significant (excess) transport occurs over, through and around the structure – resulting in pervasive deposition of sand along the west bank of the navigation channel. The relic groin field along the east side of the Fort (not shown) is more or less completely buried by sand and of uncertain structural condition.

Figure 42: Existing rock groin at east end of Fort Macon State Park (August 2005).

4c.) Implement strategic placement of sand along the adjacent shorelines – addressing the location, lengths, geometry and frequency of sand placement as a function of available dredge disposal volume.

1. Historic beach disposal practices along eastern Bogue Banks comprise the placement of relatively large volumes of sand (including non-beach compatible material) in 6-10 year intervals with a nominal template. This typically results in an anomalously wide or irregular beach fill (including fine sediment) that is subject to accelerated losses – including transport back into the inlet. It likewise results in large temporal variations of the shoreline between beach disposal events – beginning with a wide fill planform subject to accelerated losses and ending with an over-eroded beach that is subject to accelerated storm damage. Routine annual placement of beach-compatible dredged material to the beaches would result in relatively smaller volumes of sand placed at higher frequency. This allows the geometry and locations of beach disposal to be adapted each year to the prevailing requirements. Sand would be placed along the reach(es) where need is greatest and so as not to locally 'overload' the system with sand (and fine sediments) that would rapidly return to the inlet.

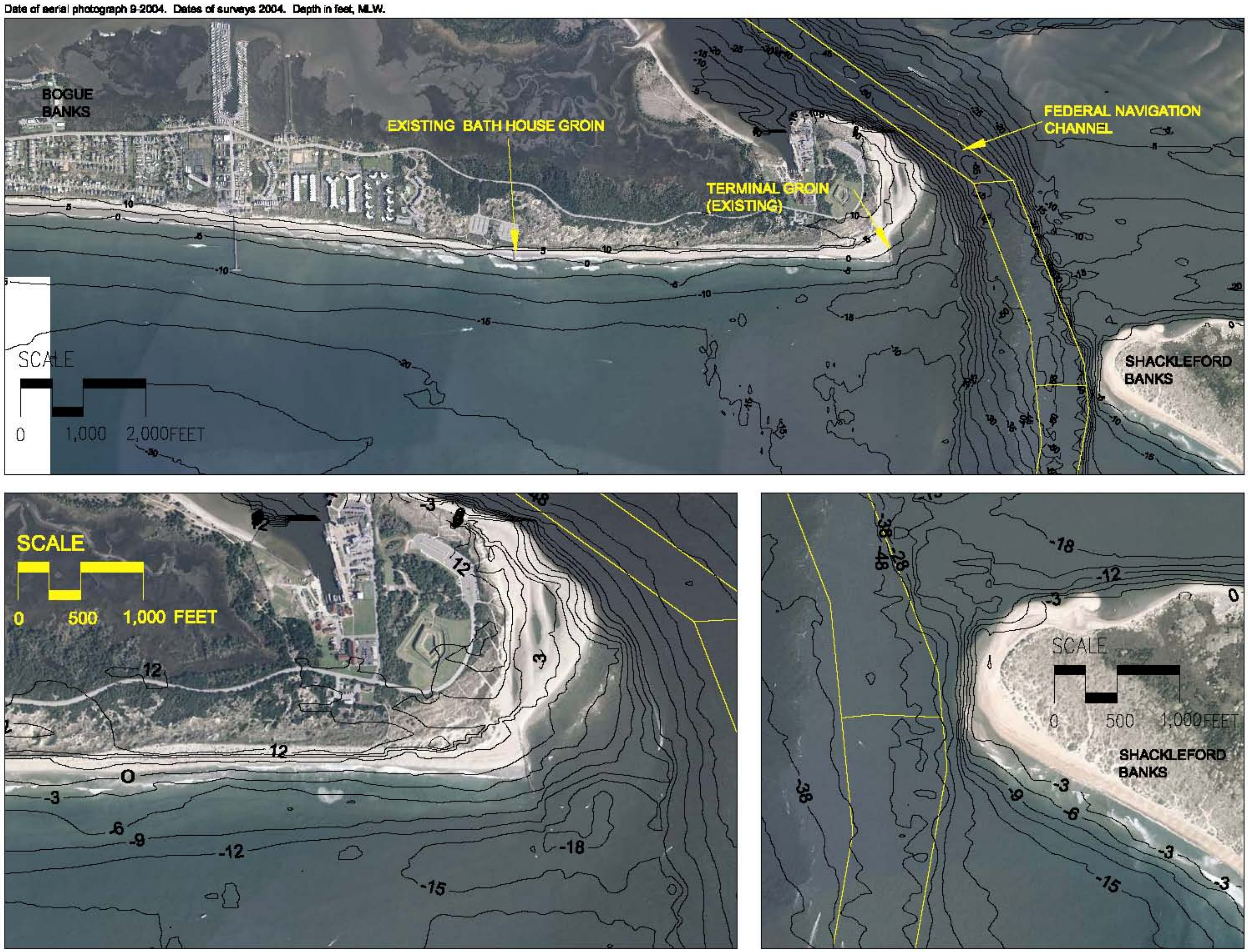

Figure 43: Shorelines in the vicinity of Beaufort Inlet illustrating the transport of sand toward and into the navigation project. Aerial photograph and bathymetry (feet, MLW) represent conditions in 2004.

2. In like manner, the prescribed beach disposal template must be appropriately specified and managed during construction to ensure that the beach is not locally overly-filled and that the target length of fill shoreline for each disposal event is more or less achieved. Historic practices have sometimes resulted in excessively wide localized fill as the Contractor is directed to continue disposal in order to achieve a prescribed berm width, regardless of the slope of the material into the sea or the length of shoreline that is ultimately filled. Constructing appropriate beach disposal geometry, along a target length, does not necessarily require measurement for payment at the beach (as opposed to traditional measurement at the dredge site, which is standard practice for a navigation project).

3. Restricting the disposal of non-beach-compatible material to the shoreline (Section 11.1.3, above) will significantly improve the geometry of the fill placement, per above, and likewise significantly reduce the volume of disposal material that is ultimately transported by natural forces from the beach back to the inlet.

4. Material placed along Fort Macon State Park and eastern/central Atlantic Beach – certainly within 2.4 miles west of the inlet – is mostly expected to return to the inlet because of the net (reversal) easterly transport. However, because of the area's high erosion rates, some significant level of beach disposal along this area must be maintained. Specifically, historic volumetric erosion rates within 2.4 miles west of the inlet are on the order of 500,000 cubic yards per year. Historic dredge disposal since 1978 is on the order of 200,000 cubic yards per year (including non-beach-compatible material), resulting in a net deficiency on the order of 300,000 cy/yr. Per the above, strategic temporal and spatial placement of the fill material, along with improved sediment quality and structural enhancements, would increase the longevity of the fill and decrease the rate of its transport into the inlet.

4d.) Modify the orientation of the navigation channel. Primarily this might include abandonment of maintenance of the east bank of the existing channel as it approaches Shackleford Bank, and addition of a widener toward Bogue Banks, near the intersection of the Cutoff and Range A bar channel. This orientation is more conducive to prevailing navigation. To the extent that Shackleford Banks is at, or within, the navigation channel's east limit – as it is in present conditions – the current practice of maintenance dredging at this location entails removing sediment directly from the Cape Lookout National Seashore and dumping it outside of the littoral system. Corollary modifications might include widening the channel eastward (away from Bogue Banks) at the intersection of the Cutoff and Range B inner channel.

4e.) Consider introduction of terminal structures at the west end of Shackleford Banks to reduce the westerly-directed transport of sand into the inlet and to improve stability of this island. This action may be warranted in the likely event that Shackleford Banks will continue to migrate westward toward or into the channel, even if the channel orientation is shifted westward. It is expected, however, that transport would eventually impound and bypass such structures. Ultimate interest in this option may be limited because the island comprises part of a National Seashore.

11.2 Measures for Mitigation of Historical Inlet Impacts

It is recommended that priority importance be given to resource recovery of annually dredged material and protection of existing sand resources, per Section 11.1 above, relative to mitigation of historical inlet impacts to the adjacent shorelines. In the long-term, mitigation of historical impacts can be achieved by routine beach disposal of all beach-compatible sediment dredged from the navigation project. This is because the present volume of annual maintenance dredging requirements exceeds the apparent, historical rate of littoral impact beyond the ebb shoal complex.[31] Nonetheless, it would require a significant number of years for future annual beach disposal to completely mitigate historical losses, during which time the adjacent beaches will be in a compromised state (principally due to offshore-profile loss) that is more susceptible to erosion and storm damage. Specific recommendations are presented as follows:

a.) Because of the time required for future resource recovery to mitigate the historical beach impacts, authorization and implementation of a Federal Shore Protection Project for Bogue Banks -- that incorporates mitigative measures for impacts of the Federal navigation project -- is warranted and should be pursued.

1. Direct and equitable mitigation may be achieved by an increased percentage of federal cost share for a shore protection project authorized by Congress -- justified in accordance with the Principles of Section 111. Practically, however, the authorized project's *recognition* of historical inlet impacts from a federal navigation project is as or more important than the numeric value (if any) of an increased federal cost-share for mitigation.
2. This observation reflects two realities of prevailing federal policies: (1) Standard interpretation of Section 111 is that a federal shore protection project does not mitigate historical inlet impacts; it mitigates ongoing or future impacts. (2)

[31] Specifically, the present rate of maintenance dredging is 1,120,300 cy/yr (littoral fraction), versus a computed, average-annual historical impact of 300,000 cy/yr to the shorelines beyond 2.4 miles west and 2.1 miles east of the inlet. Impacts within the latter zone (ebb shoal complex) are additional.

Priority is given to those shore protection projects that address downdrift beach erosion resulting from federal navigation projects.

3. Future routine beach disposal of all suitable maintenance-dredged material, as outlined above, would mitigate future impacts and thus limit potential increase of federal cost-share associated with Section 111; however, it would not obviate the documented historical inlet impacts that can be cited as part of justification and authorization of a Federal Shore Protection project for Bogue Banks. The latter serves to justifiably elevate the significance of the shore protection project.

b.) The sand sources for a Federal Shore Protection Project at Bogue Banks should include both (1) beach-compatible material from the Morehead City Harbor federal navigation project and (2) offshore sand deposits (including those from prior dredge disposal). For example, initial construction may be prescribed from offshore sand deposits; and, all or part of future periodic renourishment may be prescribed from beach disposal of material dredged from the federal navigation project.

c.) Any future Shore Protection Project cannot supplant the Sand Management Plan (i.e., dedicated resource recovery of all suitable dredged material); however, the Shore Protection Project can be *supported* by the Sand Management Plan. There are significant cost benefits to *all* parties, federal and non-federal, by allowing the Sand Management Plan to support the Shore Protection Project. Conceivably, for example:

- the General Construction cost of the Shore Protection Project can be partly borne by the Operations & Maintenance cost of navigation dredging -- to the extent that the Shore Protection Project is the disposal site for navigation dredging; or,
- the cost of maintenance dredging could be wholly or partly offset by the Shore Protection Project – to the extent that the navigation channel is acting as an offshore sand source for the Shore Protection Project.

While it has been traditionally anathema to mix navigation and shore protection (O&M and CG) funds, the fact of the matter is that the two projects can be justifiably intermixed at this location to the mutual physical and economic benefit of both. In sum, allowing the Shore Protection Project to be constructed or maintained by the navigation project also means that added costs of beach disposal from the federal navigation project [to the limits of the Shore Protection Project] can be subsidized by more than one funding Federal and/or non-federal funding source.

d.) Mitigation of material lost from the inlet ebb or flood shoals should be considered a low priority relative to resource recovery and beach disposal. That is, dredge disposal to the ebb or flood tidal shoals is not presently recommended. In principal part, this is because such action is likely to result in rapid re-shoaling of the channel.

11.3 Enabling Legislation for Effective Sand Management Practices

There is presently a statewide lack of sufficient regulatory authority to legally require strict implementation of proper sand management at North Carolina's coastal inlets. Enhanced statutory legislation should be sought to facilitate modification of the North Carolina Coastal Zone Management Plan which incorporates and/or requires the enforcement of a Sand Management Plan (directly or in principle), such as that described above for Beaufort Inlet.

For example, existing State of North Carolina "Policies on Beneficial Use and Availability of Materials Resulting from the Excavation or Maintenance of Navigational Channels" states the following:

> **15A NCAC 07M.1101 Declaration of General Policy**
> Certain dredged material disposal practices may result in removal of material important to the sediment budget of ocean an inlet beaches. This may, particularly over time, adversely impact important natural beach functions especially during storm events and may increase long term erosion rates…. Therefore, it is the policy of the State of North Carolina that material resulting from the excavation or maintenance of navigation channels be used in a beneficial way wherever practicable. [Eff. October 1, 1992]
>
> **15A NCAC 07M.1102 Policy Statements**
> (a) Clean, beach quality material dredged from navigation channels within the active nearshore, beach, or inlet shoal systems must not be removed permanently from the active nearshore, beach or inlet shoal system unless no practicable alternative exists. Preferably, this dredged material will be disposed of on the ocean beach or shallow active nearshore area where environmentally acceptable and compatible with other uses of the beach.
> (b) Research on the beneficial use of dredged material, particularly poorly sorted or fine grained materials, and on innovative ways to dispose of this material so that it is more readily accessible for beneficial use is encouraged…. [Eff. October 1, 1992]

These existing State of North Carolina policies leave significant leeway for interpretation that can, and does, presently result in the federal government's disposal of significant amounts of the State's natural littoral resources outside of the littoral system.

As a contrasting example, the State of Georgia Code includes the following sections (O.C.G.A. Title 52, Chapter 9, River and harbor Development, Ga. Code Ann. §§ 52-9-1 and 52-9-2 (May 14, 2004)):

> **Section 52-9-1.**
> The [Georgia] General Assembly recognizes the need for maintaining navigation inlets, harbors and rivers to promote commercial and recreational uses of our coastal waters and their resources. The General Assembly further recognizes that dredging

activities to deepen or maintain navigation channels within tidal inlets, as well as the entrances to harbors and rivers, often alter the natural drift of sand resources within the littoral zone. This alteration can be exacerbated when the sand resources are deposited in designated upland or offshore disposal areas instead of being returned to the natural river-sand transport-beach system. This alteration can adversely impact natural resources, recreation, tourism, and associated coastal economies. Moreover, the General Assembly believes in the duties of government to protect life and property. Therefore, it is the policy of this state that there shall be no net loss of sand from the state's coastal barrier beaches resulting from dredging activities to deepen or maintain navigation channels within tidal inlets, as well as the entrances to harbors and rivers.

Section 52-9-2.

(a) With regard to all sand that is suitable for beach replenishment originating from the dredging of navigation channels within tidal inlets, as well as the entrances to harbors and rivers:

(1) Such sand shall be used to replenish the adjacent coastal beaches, if feasible, either by deposition of sand into the near shore littoral zone or direct placement on affected beaches;

(2) If such sand is placed elsewhere, then a quality and quantity of sand from an alternate location necessary to mitigate any adverse effects caused by the dredging shall be used to replenish affected coastal beaches; provided, however that this paragraph shall apply only where beach replenishment is necessary to mitigate effects from the dredging and dredged material removal from the natural river-sand transport-beach system of a specific project and beach replenishment from another source is the least costly environmentally sound mitigation option;

(3) The disposition of sand shall be completed in cooperation with and, when required by applicable state or federal law, with the approval of the local governing authority and the Department of Natural Resources according to the requirements of Part 2 of Article 4 of Chapter 5 of Title 12, the 'Shore Protection Act'; and

(4) All such activities shall provide protection to coastal marshlands as defined in paragraph (3) of Code Section 12-5-282 and to nesting sea turtles and hatchlings and their habitats.

(b) The [Georgia] Department of Natural Resources and the party undertaking the dredging shall coordinate to determine the option under subsection (a) of this Code section for beach replenishment that is most beneficial to the adjacent or affected coastal beaches, including, where applicable, identifying an alternate source of sand for purposes of paragraph (2) of subsection (a) of this Code section, after taking into consideration environmental impacts and any limitation of applicable state and federal law.

Recent modifications incorporate these Sections of the Georgia Code as an enforceable policy of the Georgia Coastal Management Program (GCMP), pursuant to the federal Coastal Zone Management Act (CZMA), *and will therefore comprise part of federal* *consistency for federal dredging activities.*[32] The principles expressed in these Sections basically reflect those described in the Sand Management Plan outlined above. Similar provisions to those stipulated by the State of Georgia code, above, are incorporated to the State of Florida Statutes [*F.S. 161.142*] and have been likewise adopted by the State of South Carolina.

In regard to this issue, the specific recommendation is that:

a.) Statutory legislation should be enacted to facilitate modification of the North Carolina Coastal Zone Management Plan which incorporates and/or requires the enforcement of a Sand Management Plan (directly or in principle), such as that described above, in Section 11.1, for Beaufort Inlet.

11.4 Requisite Near-Term Engineering Studies

Toward initial implementation of the Sand Management Plan outlined in Section 11.1, above, the following engineering studies are recommended in the near-term future.

a) Geotechnical engineering investigation of outer-channel resources

Conduct geotechnical investigation to identify quantity and quality of existing offshore sand resources associated with the navigation project (i.e., nearshore disposal and offshore disposal mounds). The purposes of this study are (1) to develop preliminary limits for sand borrow areas based upon suitability for dredging, and (2) to develop limits in which to *exclude* placement of non-beach-compatible dredged materials. These two study objectives are inter-related. The study is principally engineering (not geologic) in nature. The testing schemes and the ultimate delineation of feasible sand borrow areas is a function of numerous elements related to dredging, and is not simply a function of sediment quality. Limited prior data exist but must be supplemented[33]. The degree to which the Corps' Shore Protection Project Feasibility Study investigated this subject is unknown at the time of this writing. It is noted that approvals for investigation of sand on the Outer Continental Shelf (>3 nautical miles from shore) are required from the Minerals Management Service (see below), prior to initiating significant field study.

[32] J. King, 2005.

[33] Corps of Engineers data are available for at least six core borings, with associated sediment grain size data, from April 2002 within and near the ODMDS area. These data were previously used to support dredging from the ODMDS as a sand source for beach nourishment along Emerald Isle authorized by FEMA pursuant to Hurricane Isabel, in 2004.

b.) Development and Permitting of Offshore Borrow Areas

Pursuant to draft delineation of candidate offshore borrow areas at nearshore and offshore disposal mounds (above), conduct cultural resources investigation, wave refraction and littoral transport studies, environmental analyses and all related studies, and acquire State and Federal permits for the dredging of sand from designated areas for purposes of beach fill along Bogue Banks. The purpose of this is pre-emptive development of one or more offshore borrow areas ready for use, particularly for interim emergency projects. Recent experience throughout the southeast demonstrates that prior identification and preparation of suitable sand borrow areas is critical for rapid response after severe storm impacts. The work could likewise support implementation of a Shore Protection Project.

Development of sand borrow areas across most of the offshore disposal mounds will also require specific environmental assessments, coordination and lease agreements with the U. S. Dept. of Interior, Minerals Management Service (MMS). Sand in federal waters (>3 nautical miles from shore) comprises resources of the Outer Continental Shelf for which MMS has jurisdiction.

Cultural resource investigations of candidate offshore borrow areas will be of principal importance given the number and potential value of historic shipwrecks in the vicinity of Beaufort Inlet.

c.) Geotechnical investigation of Inner Channel / Harbor areas:

1. Conduct geotechnical investigation to identify/confirm the limits of beach-quality material within the Inner Harbor/Channel dredging limits.
2. Conduct geotechnical investigation to confirm limits of beach-quality material within the existing Brandt Island disposal site.

The purpose of these studies is to identify limits of the channel and the upland disposal area from which future dredged material is likely suitable for beach placement. Large areas within Brandt Island that contain material suitable for beach placement should be *excluded* from disposal of non-suitable material, as practical. The degree to which these studies may have been recently initiated by the Corps of Engineers is not known. If previously studied, the scope of the Corps' investigations (data) should be reviewed. It is noted that the Corps' historic geotechnical data of the Brandt Island disposal site were very limited relative to the significant variation of material within that site. Recent data since the most recent (2004) beach disposal activity may have greatly supplemented both the Corps' physical knowledge and the implied results of prior studies.

d.) Preliminary Coastal Engineering Study of Fort Macon Groin Field Improvements.

Conduct a Phase One coastal engineering investigation of improvements to the groin field at Fort Macon State Park. The purpose of this study is to evaluate the condition and performance of the existing structures and to develop conceptual alternatives for enhancement or modifications of these structures. The objectives of the structural improvements are to (1) decrease sand transport into the inlet, (2) improve beach conditions along eastern Bogue Banks, and (3) ensure beach stability along the Fort's inlet (interior) shoreline. These objectives must be met in a manner consistent with the environmental, recreational, and historic preservation goals of the State Park.

e.) Continue beach profile monitoring and analysis.

The collection and analysis of annual beach surveys along the entirety of Bogue Banks should be continued. The findings of the present study demonstrate the critical need for the survey data and analysis to extend offshore to at least -30 ft NGVD, or deeper. Profile data should be likewise collected along Shackleford Banks at the same locations as the only prior surveys – conducted by the Corps in 1991 and 2000.

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