CHAPTER 5: *ENVIRONMENTAL CONSEQUENCES*

In order to maintain a consistent basis upon which to base comparisons and differences in the indicated impacts or changes associated with each alternative, Delft3D model runs used the 2006 conditions of the inlet and adjacent shorelines and the same input parameters (tides, waves, wind, etc.). Subsequent to the release of the DEIS, issues were raised by some Figure Eight Island property owners on the north end of the island over the location of the proposed terminal groin. To address these concerns, the Figure "8" Beach HOA agreed to reevaluate the location of the terminal groin. Coordination with the property owners ultimately resulted in the consideration of a terminal groin located approximately 420 feet north of the location proposed in the DEIS (referred to below as the northern location). The evaluation of the northern location of the terminal groin was modeled using the same 2006 conditions, which are indicative of erosive conditions experienced by Figure Eight Island, as used for the DEIS. This provided a direct comparison of the results for the northern location to the model results for the previous terminal groin location as well as the results obtained for the other alternatives evaluated in the DEIS. Also, due to the length of time that elapsed since the completion of the DEIS and the natural changes in the configuration of Rich Inlet and the adjacent shorelines that had occurred in the interim, model runs for Alternatives 2, 3, 4, and 5D were modeled using the 2012 inlet and shoreline conditions. Alternatives 5A, 5B, and 5C were not modeled using the 2012 conditions.

The conditions on Figure Eight Island are largely driven by the location of the bar channel of Rich Inlet. In 2006, the bar channel of Rich Inlet was oriented in the northeastern alignment or direction which caused substantial erosion along the north end of the island. Over the next several years, the bar channel migrated southward toward Figure Eight Island, prompting accretion along the north end of the island. In contrast to the model runs of the 2012 conditions, which reflect significant accretion along the northern end of Figure Eight Island, the 2006 modeling shoreline conditions represent the erosive conditions experienced along the north end of the island. However, periods of erosive conditions are when shoreline protection measures are required, and an evaluation of the respective alternatives' performance during such periods is imperative.

During the time the Figure "8" Beach HOA was evaluating a new location for the terminal groin structure, as described for Alternatives 5C and 5D, the bar channel continued orienting itself southward resulting in optimal accretion on the island's north end. New model runs were conducted to assess the northern terminal groin location and these runs used both the 2006 and the 2012 conditions of Rich Inlet. It should be noted that the 2006 new model runs differ from the original 2006 conditional runs due to some modification in the model grids used in the early model runs, as well as some minor corrections in depths over portions of the model domain. In addition, the friction coefficient was modified in the newer runs to better match conditions in the salt marsh environment.

Given the historic behavior shown in the geomorphological analysis of Rich Inlet, the bar channel is expected to continue its cyclical migration, and once again assume a more northern alignment toward Hutaff Island in the future. As previously described, the channel migration and reorientation toward Hutaff Island may already have been gradually occurring during the last four to five years. If the channel completes its northward swing, the new orientation is expected to result in another round of erosive conditions on the north end of Figure Eight Island. For the purposes of Chapter 5 in this EIS document, the modeling results from the 2006 conditions were used to evaluate the environmental and economic impacts and performances of each alternative, as this shoreline setting was indicative of erosive conditions along the north end of the island. Periods of erosive conditions are when shoreline protective measures are required, and an evaluation of the impacts and performance of the respective alternatives during such periods is imperative. Although both 2006 and 2012 shoreline conditions were assessed, it was determined that the modeled 2006 conditions create a fair and equal basis upon which to evaluate the alternatives and their potential impacts in light of the overall stated purpose and need. In Question (3) on page 203 of this Chapter, there is an effort to show the various shoreline changes using both 2006-07 and 2012 conditions of the inlet and adjacent shorelines. See Appendix B for all modeling results.

1. What are the alternatives eliminated from further consideration?

<u>Options within Alternative 3: Options 1, 2A, 2B, 3, 4A, 4B, and Without the Closure Dike.</u>

A screening process was carried out for Alternative 3 to determine which option provided the optimal position and alignment of Rich Inlet to alleviate the erosion occurring on the northern portion of Figure Eight Island. Furthermore, these options were evaluated to determine which would provide minimal impacts to the environmental conditions including the hydrodynamics through Nixon Channel and Green Channel. The rationale for elimination of these options is summarized below. A detailed description of modeling results and specifications for each option are provided in Section 11.0 within Appendix B.

Alternative 3, Option 1 (Figure 3.3) was eliminated from further consideration because landward extension of the main channel was found to divert flow from the Green Channel connector and increase flow velocities adjacent to the salt mash facing the inlet which could lead to increased erosion of the salt marsh shoreline. The diversion of flow from the Green Channel connector could also lead to eventual closure of this connector. Based on these results, Option 1 was eliminated from detailed consideration.

Alternative 3, Option 2A included relatively longer cuts into Nixon and Green Channels in comparison to Option 2B (Figure 3.4). Modeling results suggested that the longer cut into Nixon Channel was a necessary component to significantly reduce the flow and subsequent erosion along the estuarine shoreline of Nixon Channel. Therefore, the shorter cut into Nixon Channel as described in Option 2B was eliminated. The model results did not show any appreciable difference for the flow into Green Channel with either the long or short connector. Accordingly, the shorter connector into Green Channel, as included within Option 2B, would be preferred over the longer cut as described within Option 2A.

Alternative 3, Option 3 did not include any connection from the main bar channel toward Green Channel (Figure 3.5). According to model results, Option 3 produced the greatest departure from existing flow conditions inside Rich Inlet and was therefore eliminated from further conditions.

Alternative 3, Options 4A and 4B did not include a connector into Green Channel, and instead included an extension of the main channel through Rich Inlet through the middle ground shoal (Figure 3.6). Option 4A included a long cut into Nixon Channel while Option 4B included a relatively shorter cut. The Delft3D model results for these two screening options verified the need to extend the Nixon Channel cut 1,158.2 m (3,800 ft.) as described in Option 4A in order to move flows away from the Nixon Channel shoreline. However, the landward extension of the main channel produced an indirect connection into Green Channel as well as increased the potential for erosion of the salt marsh shoreline. Therefore both Options 4A and 4B have been eliminated from further evaluation.

Constructing the inlet optimal modifications without the closure dike would create two entrance channels at Year 0. Between Years 1 and 2, the tidal flat between the two entrance channels would disappear and by Year 3, a single entrance channel would be present. Between Years 3 and 5, the entrance channel would begin returning to present dimensions due to shoaling and side slope adjustments. The single entrance channel at Year 5 would be narrower than the entrance channel at Year 3, with more gradual slopes on either side of the inlet. The offshore limit of the entrance channel would migrate approximately 152.4 m (500 ft.) to the southwest, with approximately 304.8 m (1,000 ft.) between the -3.0 m (-10 ft.) contours on either side. The back channel between Nixon Channel and Green Channel would fill in, welding some of the tidal flats in the mouth of the inlet to the salt marsh area. In the absence of the closure dike, the reformation of the ebb shoal on the south side of Rich Inlet would not be as advanced at the end of Year 5 as for the with dike scenario and the north side of the ebb tide delta would not diminish in size to the same degree as for the with dike case. Based on these model results, modifying the inlet ocean bar channel of Rich Inlet without constructing a closure dike across the existing entrance channel was eliminated from detailed consideration.

<u>Options within Alternative 4: Mason Inlet, Banks Channel, and Upland Borrow Pits, and AIWW Dredged Material Disposal Site</u>

<u>Mason Inlet</u>

Material removed from Mason Inlet as part of the 30-year program to keep the inlet in its new location is used to manage the shoreline along the southern half of Figure Eight Island. Based on the Mason Inlet permit conditions, the Mason Inlet maintenance material could also be used to mitigate project related negative shoreline impacts on Shell Island. However, much of this material is committed to use in maintaining the southern half of Figure Eight Island and therefore would not be available as a source of nourishment to the area north of Bridge Road.

Banks Channel (maintenance dredging)

In 1969, during the early development of Figure Eight Island, Banks Channel was dredged to a depth of -5.5 m (-18 ft.) and a width of 91.4 m (300 ft.) with most of the 1.3 million cubic yards removed used to elevate the southern half of the island (Cleary & Jackson, 2004). Maintenance of the navigation channel in Banks Channel since 1985 has removed approximately 2.16 million cubic yards of shoal material with the majority of the material placed on the Figure Eight Island shoreline south of Bridge Road. The equivalent annual rate of disposal of the Banks Channel material is around 108,100 cubic yards per year or about 9.8 cubic yards/lineal foot of beach/year. Similar to the material from within Mason Inlet, this material has already been committed to maintaining the southern half of Figure Eight Island.

Upland Borrow Pits

Upland borrow pits located between 30 and 50 miles from Figure Eight Island include:

- Riverside Sand Company, Wallace, NC,
- Hutcheson Landscaping, Burgaw, NC, and
- Morton Minerals Jackson Pit, Jacksonville, NC.

The volume of beach fill material needed to construct the beach fill described under Alternative 3 would be 1,152,300 cubic yards with an additional 5.5 million cubic yards needed to maintain the beach fill over the 30-year analysis period. Of these three borrow pits, only the Riverside Sand Company appears to have sufficient capacity to satisfy this requirement. In addition, the utilization of upland borrow pits have been determined as not practicable due to the high cost of truck haul and potential damage to the island’s bridge and roads. It is estimated that the initial beach fill would require 71,700 truckloads of material with a cost of approximately $52.4M. This option has been eliminated from further evaluation.

AIWW Dredged Material Disposal Site

The southern disposal site, known as Cameron Island, is owned by the Figure "8" HOA and has been incorporated into the Mason Inlet Relocation Project management plan as a temporary stockpile area for shoal material removed from the confluence of Mason Creek with the AIWW. The Figure "8" Beach HOA uses material from Cameron Island to supplement nourishment along the southern portion of the island. In 1999, approximately 750,000 cubic yards of material was removed from Cameron Island and deposited on the Figure Eight Island shoreline south of Bridge Road. The USACE uses Cameron Island as a disposal area during maintenance of the AIWW Mason Inlet crossing. Therefore, this site will not be available for utilization with the Figure Eight Island Shore Management Project.

Options within Alternative 5A: Dredging Options 1 and 3 and the Construction of a 2100-foot Terminal Groin.

The length of a terminal groin in this document refers to the total length of the structure including a shore anchorage section and the portion of the structure that would extend seaward of the 2007 mean high water shoreline.

Although Dredging Option 1, which includes 660-740 foot wide cut, provides the most amount of fill material, it offers only a marginal improvement in performance over Dredging Option 2. Because of the relatively large footprint of this option and the potential environmental consequences associated with it, this option has been eliminated from further evaluation.

On the other hand, Dredging Option 3, which includes a 395-416 foot wide cut, is the smallest of the dredging options in terms of both cost and impact. However, it has two disadvantages. First, the bottom width of the channel is relatively narrow, making the channel less conducive to navigation, especially towards the end of the 5-year maintenance cycle. Second, due to its narrow width, the new channel connector would close within one to two years. This is briefly discussed in the Delft3D modeling study in Appendix B. This option has been eliminated from further evaluation.

Additionally, the performance of a 2,100-foot long terminal groin was evaluated utilizing Delft3D model runs. The 2,100-foot long terminal groin did not result in appreciable benefits, whether the accretion fillet was artificially filled or not. Similarly, the 2,100-foot groin was modeled at an angle of 10, 20 and 30 degrees toward Figure Eight Island. These results did not depict beneficial results compared to the 1,600- foot groin (Appendix B). Therefore, these options have been eliminated from further evaluation.

<u>Options within Alternative 5B and 5D: Sand Source Options in Mason Inlet, Banks Channel, Upland Borrow Pits, and AIWW Dredged Material Disposal Site #4.</u>

This alternative considered the utilization of the same borrow sources containing beach compatible material for use as beach fill along Figure Eight Island as mentioned above for Alternative 4. For the same reasons previously discussed in Alternative 4, these sources have been eliminated from further consideration.

<u>Alternative 5D: Option with a 1,300-foot terminal groin and beach fill from Nixon Channel</u>

A terminal groin extending 305 feet seaward of the 2007 mean high water shoreline and a 995-foot shore anchorage section extending landward of the 2007 mean high water shoreline (total length of terminal groin 1,300 feet) was evaluated with the structure positioned closer to the south shoulder of Rich Inlet, due to property owners opposition to on the extreme north end of Figure Eight Island. This alternative included a beach fill extending south from the terminal groin to baseline station 60+00. The results of the model tests indicated volume losses from the fill would be unacceptable with only 6% of the fill placed above the -6-foot NGVD contour remaining at the end of the 5-year simulation. Therefore, Alternative 5D with the 1300-foot terminal groin was eliminated from further consideration.

2. How were the environmental impacts analyzed?

This chapter includes both a qualitative and quantitative comparative assessment of the direct, indirect, and cumulative impacts associated with the alternatives under consideration for the Figure Eight Island Shoreline Management Plan. Impacts will relate to the resources and interest factors described in Chapter 4.

The Council on Environmental Quality regulations (40 CFR §§ 1508.7 and 1508.8) defines direct effects as those caused by the action and occur at the same time and place. Indirect effects are defined as those caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems. Cumulative impact is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

Effects and impacts as used in these regulations are synonymous. Effects includes ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative. Effects may also include those resulting from actions which may have both beneficial and detrimental effects, even if on balance the agency believes that the effect will be beneficial.

Anticipated impacts to habitats were determined by Coastal Planning & Engineering, Inc. (CPE) through the analysis of numerical modeling results, historical and recent erosion rates, recent biological characterization investigations, and results from past research and studies. Delft3D, the primary modeling package used for this project, simulated flows forced by a combination of waves, tides, winds, and density gradients, along with sediment transport and bathymetric change using advanced transport formulations that account for bedload and suspended load transport.

With regard to the model results, the Delft3D model responds to prescribed or predetermined input conditions including waves, tides, winds, etc. The model results are by no means intended to represent predictions of what changes to expect in the future with certainty, as this would require an ability to predict future weather and oceanic conditions. Rather, the Delft3D model results for Alternative 2, Abandon/retreat alternative, under a prescribed set of forcing conditions forms a basis for comparing relative changes in Rich Inlet and the adjacent shorelines that could be attributable to physical changes in the system associated with each alternative. Such a relative comparison is achieved by imposing the same set of forcing conditions in the model for each alternative and identifying relative differences in the response of the modeled system to changes observed for Alternative 2. In other words, the model results are only an indication of how the inlet system and adjacent beaches would respond to a given set of forcing conditions (waves, tides, winds, etc.) and physical modification to the system associated with Alternatives 2, 3, 4, 5A, 5B, 5C and 5D.

Waves in Delft3D were simulated using SWAN (Simulating Waves Nearshore), an advanced wave transformation model that incorporates most wave transformation processes, including breaking, shoaling, refraction, reflection, diffraction, and bottom friction. Water levels, currents, and bathymetric changes are simulated using Delft3DFLOW. Delft3D simulated the relevant coastal processes over short-term (days-storms) and long- term (seasons-years) time scales. These models were employed to determine impacts for Alternatives 2, 3, 4, 5A, 5B, 5C, and 5D. Because the physical conditions pertaining to Alternatives 1 and 2 are similar, the impacts determined for Alternative 1 were inferred utilizing model results derived for Alternative 2.

The basic model set-up for evaluating the relative differences in the impacts of the alternatives on Figure Eight Island, Hutaff Island, Rich Inlet and its environs used conditions representative of the eroded conditions on Figure Eight Island that existed in 2006. Additionally, the model set-up was modified and run again for Alternatives 2, 3, 4, and 5D to reflect conditions existing in 2012 in which the Rich Inlet bar channel had assumed an alignment toward Figure Eight Island. Alternatives 5A and 5B were not simulated using the 2012 conditions, as the more northerly alignment associated with Alternatives 5C and 5D were determined to meet the purpose and needs of the applicant. Furthermore, objections of certain property owners who would be required to convey an easement interest made approval of Alternatives 5A and 5B by the Figure "8" Beach HOA unlikely. Alternative 5C was not simulated using the 2012 conditions as the Figure "8" Beach HOA had identified Alternative 5D as its Applicant's Preferred Alternative prior to running the model with the 2012 conditions.

A shoreline change numerical model, GENESIS, was used to provide a "second opinion" regarding shoreline changes indicated by the Delft3D model, particularly with regard to the terminal groin alternatives.

For additional information on the model, including calibration and results please refer to Appendix B.

In order to determine changes to habitat acreages within the Permit Area, several methods were employed. Direct impacts were determined via two methodologies. First, the footprints of project-related activities (i.e. proposed areas to be dredged, beach fill locations, the construction toe of fill, etc.) were entered into ArcGIS and overlaid upon the baseline habitat map delineated from 2008 aerial photography. The area of specific habitat types which fell within this footprint were determined to be directly impacted and the acreages were extrapolated. In addition, direct impacts were also defined as the indicated changes to the shoreline at Year 0 from the Delft3D modeling results in relation to the baseline habitat map. The modeled mean lower low water (MLLW) lines were initially determined from a 2007 shoreline survey and entered into Delft3D. The indicated shoreline locations for each modeled alternative (2, 3, 4, 5A, 5B, 5C, and 5D) were then overlaid onto the baseline habitat map. The habitats were then clipped along the MLLW lines. Any portions of the habitats that were located seaward of the MLLW were also considered to be impacted by the modeled changed position of the MLLW.

This methodology was also employed to determine indirect impacts by utilizing the Year 5 shoreline obtained from the Delft3D model. Note that, while several upland habitat types are present within the permit area, this Delft3D analysis of indirect impact only evaluates habitats which are present on the oceanfront of the islands and the shorelines along the mouth of the inlet within the permit area. These results should be interpreted with caution as they are not intended to be a precise prediction of habitat change considering they are, in part, based on modeling simulations and are therefore only intended to provide insight as to potential changes. Table 5.1, below, is an attempt to depict the range of impacts, using acreage amounts only, that could be incurred for each alternative in terms of the geographic scope of habitats present within the project area. While it is understood that the footprints of project-related actions and shoreline change over time will result in habitat impacts, it is difficult to calculate the overall net impacts (positive or negative) due to the potential conversion of habitat types. Table 5.1 illustrates the estimated amount of habitat acreage that will undergo some type of change with each alternative. The table does not reflect whether the changes are positive or negative for that is contingent on what resource is being evaluated. The impact of the changes to the resources are further qualified in the discussion section for each alternative.

Table 5.1. Estimates of the amount of habitat gain (+) or loss (-) in acres over a 5-year period for each alternative using the 2006 shoreline conditions.

	Impact Type	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5A	Alt. 5B	Alt. 5C	Alt. 5D
Inlet Dunes and Dry Beaches	**Direct**	0	0	+35-40	+0-5	-0-5	-0-5	-0-5	-0-5
	Indirect	-0-5	-0-5	-0-5	+0-5	-0-5	-0-5	+0-5	-0-5
Oceanfront Dunes	**Direct**	0	0	+0-5	+0-5	+0-5	0	+0-5	0
	Indirect	0	0	0	0	0	0	0	0
Oceanfront Dry Beach	**Direct**	*	0	+20-25	+15-20	+15-20	+0-5	+15-20	+0-5
	Indirect	-0-5	-0-5	-0-5	0	0	0	0	0
Intertidal Flats and Shoals	**Direct**	0	0	-20-25	0	-25-30	0	-25-30	0
	Indirect	0	+0-5	-0-5	+0-5	-0-5	-0-5	-0-5	-0-5
Wet Beach	**Direct**	0	0	0	0	0	0	0	0
	Indirect	-0-5	0	-5-10	-5-10	- 5-10	-0-5	-5-10	-0-5
Salt Marsh	**Direct**	0	0	0	0	-0.7***	-0.7***	-0.4***	-0.4***
	Indirect	0	0	0	0	0	0	0	0
Softbottom	**Direct**	-25	0	-100-110	-25**	- 80-90	-25-30	-80-90	-25-30
	Indirect	0	0	0	0	0	0	0	0

*** - Historically, the extent of fill placed on the dry beach has varied and therefore the area of impacts can only be generalized**
****- These impacts do not reflect the potential impacts to the softbottom community located within a potential offshore borrow source due to its unknown size and extent.**
*****- These impacts are associated with the construction of the groins sheet pile anchoring and are considered temporary.**

3. What impact would each alternative have on the shorelines of Figure Eight Island and Hutaff Island over a 5-year period?

This section will describe the general changes along the oceanfront and inlet shoreline as inferred by the numerical model known as Delft3D. Delft3D simulates changes in hydrodynamics, sediment transport, and the morphology of the inlet and nearshore environments in response to changes imposed by project alternatives over a 5 year period. This section will not only present the model results for all alternatives that used the 2006-07 conditions, but will also include the results for those alternatives modeled utilizing the 2012 conditions. A complete description of the model results is provided in Appendix B. Reference Figure 5.1 for shoreline transects noted throughout this section. A brief summary of the model results for both conditions follows.

- <u>Alternative 1</u>

The Delft3D model was not specifically run under Alternative 1 conditions due to the unscheduled nature of beach nourishment activities along the north end of the island. Rather, the results derived from Alternative 2 were utilized as a proxy for Alternative 1. Shoreline change rates along Figure Eight Island north of Bridge Road for the period 1999 to 2007 range from +4.9 feet/year just north of Bridge Road to -99.6 feet/year near the south shoulder of Rich Inlet. These shoreline change rates have been adjusted to account for the numerous beach nourishment activities along the north end of the island. As needed, it is expected that Figure Eight Island would continue to pursue beach nourishment along this stretch to help prevent erosion. Along Hutaff Island, the southern 2,000 feet has behaved somewhat erratically due to the changing position and orientation of the bar channel of Rich Inlet, but the general trend between 1999 and 2007 was erosion. Under Alternative 1, the shorelines on both islands would be expected to continue to behave as they have in the past.

- <u>Alternative 2</u>

Volumetric changes along the beaches of Figure Eight Island and the southern end of Hutaff Island were determined from the results of the Delft3D model. Volume change computations extended from the dune seaward to the depth of closure which is -24 feet NAVD. Volumetric changes were computed for the two beach segments on Figure Eight Island, described in Table 5.2 and shown on Figure 5.1, and the southern 6,640 feet of Hutaff Island (Hutaff Island baseline stations 148+60 to 215+00). This section of Hutaff Island was divided into two segments one extending from 148+60 to 175+00 (2,640 feet) and the other from 175+00 to 215+00 (4,000 feet). The modeled beach volume changes for Alternative 2 were used as a baseline to compare and contrast differences in the relative impacts of the other alternatives on both Figure Eight Island and Hutaff Island.

Table 5.2. Figure Eight Island beach segments

F90+00 to 60+00	(Bridge Road to 322 Beach Road North)
60+00 to 105+00	(322 Beach Road North to just south of Rich Inlet)

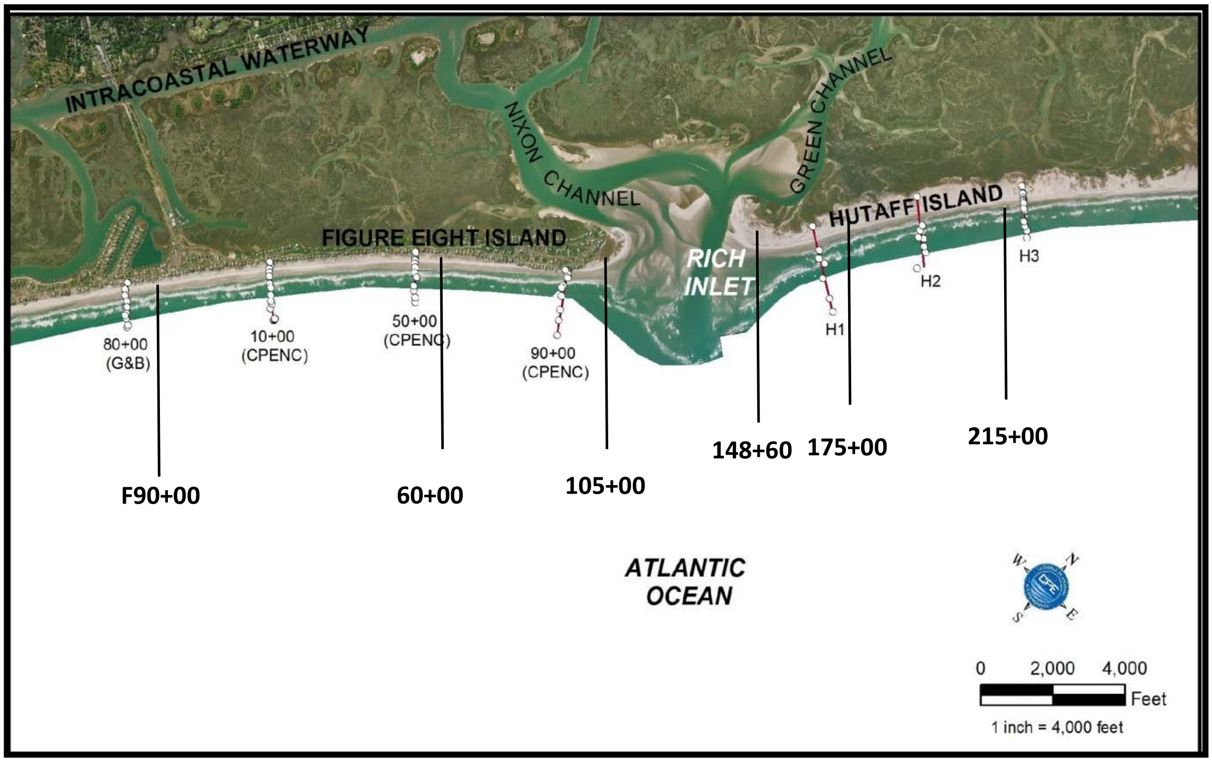

Figure 5.1. Island segments used for model volume change computations.

The shoreline change rates along Figure Eight Island for Alternative 2 are applicable to Alternative 1 since the impacts associated with the previous beach fills have been removed. Also, since no modification would be made to Rich Inlet, past shoreline changes along Hutaff Island described for Alternative 2 are applicable to Alternative 1.

Under Alternative 2, future shoreline changes would be expected to mimic past changes, depending on the periodic shifting of the alignment of the bar channel in Rich Inlet.

Historic shoreline changes along Figure Eight Island and Hutaff Island were also extrapolated from an analysis of aerial photos taken between 1938 and 2007 performed by Dr. William Cleary. These shoreline changes are reported in Sub Appendix A of Appendix B and summarized in Chapter 6.

For the area of Figure Eight Island north of Bridge Road, shoreline change rates varied from -1.4 feet/year near Bridge Road to -99.6 feet/year near Rich Inlet during the 1999 to 2007 time period (Table 6.1 in Appendix B), the time period in which the ocean bar channel of Rich Inlet shifted its orientation toward Hutaff Island. For the area in the vicinity of the existing sandbag revetments located along a portion of the northern oceanfront shoreline (stations 74+00 to 95+00), shoreline change rates from 1999 to 2007 ranged from -23.3 feet/year to -42.5 feet/year. For the area south of the sandbags to Bridge Road, the shoreline changes between 1999 and 2007 displayed a wide range of behavior including periods of both erosion and accretion. The maximum rate of accretion in this area between 1999 and 2007 was +4.9 feet/year while erosion rates were as high as -29.2 feet/year.

Along Hutaff Island, shoreline change rates in the 2,000-foot shoreline segment just north of Rich Inlet during the 1999-2007 time period ranged from accretion of +0.5 feet/year to erosion of -25.4 feet/year (Table 6.3 in Appendix B). Farther north, shoreline change rates for the period ranged from +6.3 feet/year to +16.8 feet/year. However, near the location of Old Topsail Inlet, which closed sometime around 1996, the shoreline was generally erosional.

Delft3D model results – 2006 conditions. Based on the environmental conditions used for the Delft3D model simulations, the model indicated a portion of the spit area projecting off the north end of Figure Eight Island into Rich Inlet would be eroded and converted to a submerged sand flat at the end of the 5-year simulation. The Delft3D model was allowed to run two additional years during which time the spit eroded back to near station 105+00.

Modeled shoreline volume changes over a 5-year simulation period for Alternative 2 along the 12,500 feet of Figure Eight Island situated between Bridge Road and Rich Inlet resulted in a loss of 66,000 cubic yards/year. Specifically, the volume changes includes 18,000 cubic yards/year of accretion between stations F90+00 and 60+00 and a loss of 84,000 cubic yards/year between stations 60+00 and 105+00. (Table 5.3a). Along the southern 2,640 feet of Hutaff Island, the model results indicated this section of the island would accrete at a rate of 53,000 cubic yards/year while the section between 175+00 and 215+00 eroded at a rate of 35,000 cubic yards/year. In general, the model results for Alternative 2 given the 2006 conditions agreed reasonably well with observed volume changes along both Figure Eight Island and Hutaff Island between April 2005 and October 2008, the time period used to calibrate the Delft3D model (see Appendix B).

Table 5.3a. Alternative 2 - Delft3D average annual volume changes on Figure Eight and Hutaff Island at the end of the 5-year simulation– 2006 conditions.

Beach Segment	Delft3D volume changes (cy/yr.)
Figure Eight Island	
F90+00 to 60+00	+18,000
60+00 to 105+00	-84,000
Hutaff Island	
148+60 to 175+00	+53,000
175+00 to 215+00	-35,000

Table 5.3b. Alternative 2 - Delft3D average annual volume changes on Figure Eight and Hutaff Island at the end of the 5-year simulation – 2012 conditions.

Beach Segment	Delft3D volume changes (cy/yr.)
Figure Eight Island	
F90+00 to 60+00	+35,000
60+00 to 105+00	-43,000
Hutaff Island	
148+60 to 175+00	-36,000
175+00 to 215+00	-116,000

Delft3D model results – 2012 conditions. In 2012, the bar channel of Rich Inlet was aligned toward the southeast or toward Figure Eight Island (Figure 5.2b). By year 3 of the simulation the bar channel had migrated to a position centrally located between the south end of Hutaff Island and the north end of Figure Eight Island and was oriented perpendicular to the alignment of the adjacent shorelines (Figure 5.5b). The channel maintained this general position and orientation after years 4 and 5 of the simulation. However, the outer end of the channel appeared to be swinging toward the north end of Figure Eight Island at the end of year 5 of the simulation (Figure 5.7b).

The sand spit off the north end of Figure Eight Island remained fairly stable over the entire 5-year simulation. The southern tip of Hutaff Island was relative stable during the first two years but began to retreat north during years 3 and 5 of the simulation.

For the 2012 conditions, the volume change on Figure Eight Island between stations F90+00 and 60+00 averaged +35,000 cubic yards/year, which was greater than the volume change observed for the 2006 condition. Volumetric losses from the area between 60+00 and 105+00 were less compared to the 2006 results (Table 5.3b). The improved behavior of the Figure Eight Island shoreline under the 2012 conditions was primarily due to the bar channel of Rich Inlet maintaining an alignment either toward the north end of Figure Eight Island or perpendicular to the alignment of the adjacent shorelines.

While the orientation of the Rich Inlet bar channel was favorable for Figure Eight Island, the south end of Hutaff Island experienced considerable volume loss even in the area between stations 148+60 and 175+00 which had accreted given the 2006 conditions.

The highly variable nature of shoreline changes along both Figure Eight Island and Hutaff Island were factored into the development of shoreline change thresholds presented in Chapter 6 with the shoreline change thresholds representing possible future shoreline changes along both islands in the absence of any modifications to Rich Inlet.

The modeled morphological changes within the project area that would occur over the 5-year simulation period for Alternative 2 are shown in Figures 5.2a to 5.7a for the 2006 conditions and Figures 5.2b to 5.7b for the 2012 conditions.

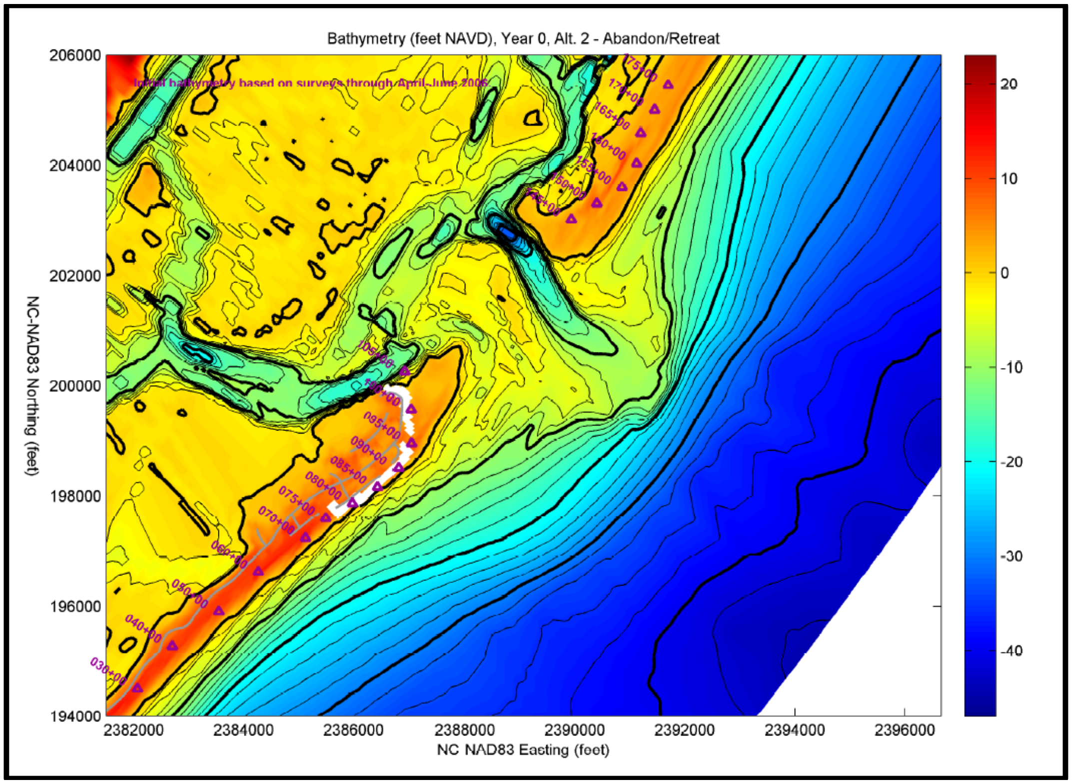

Figure 5.2a. Alternative 2 – Year 0 – 2006 conditions.

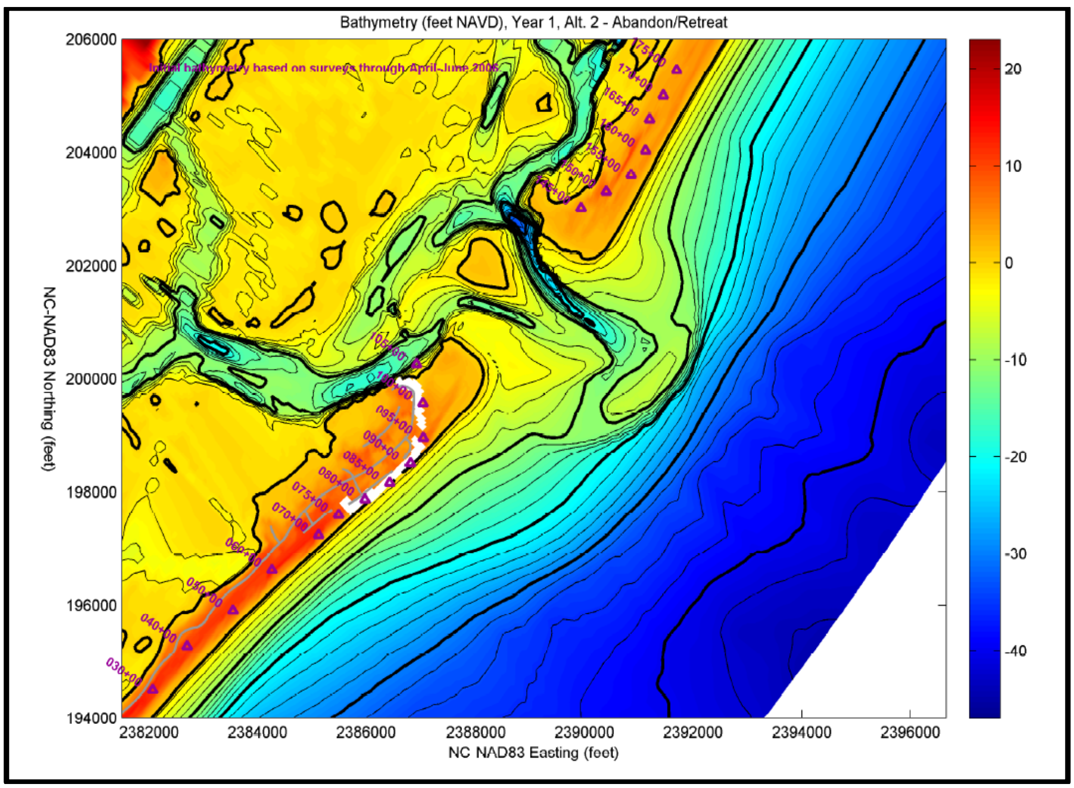

Figure 5.3a. Alternative 2 – Year 1 – 2006 conditions.

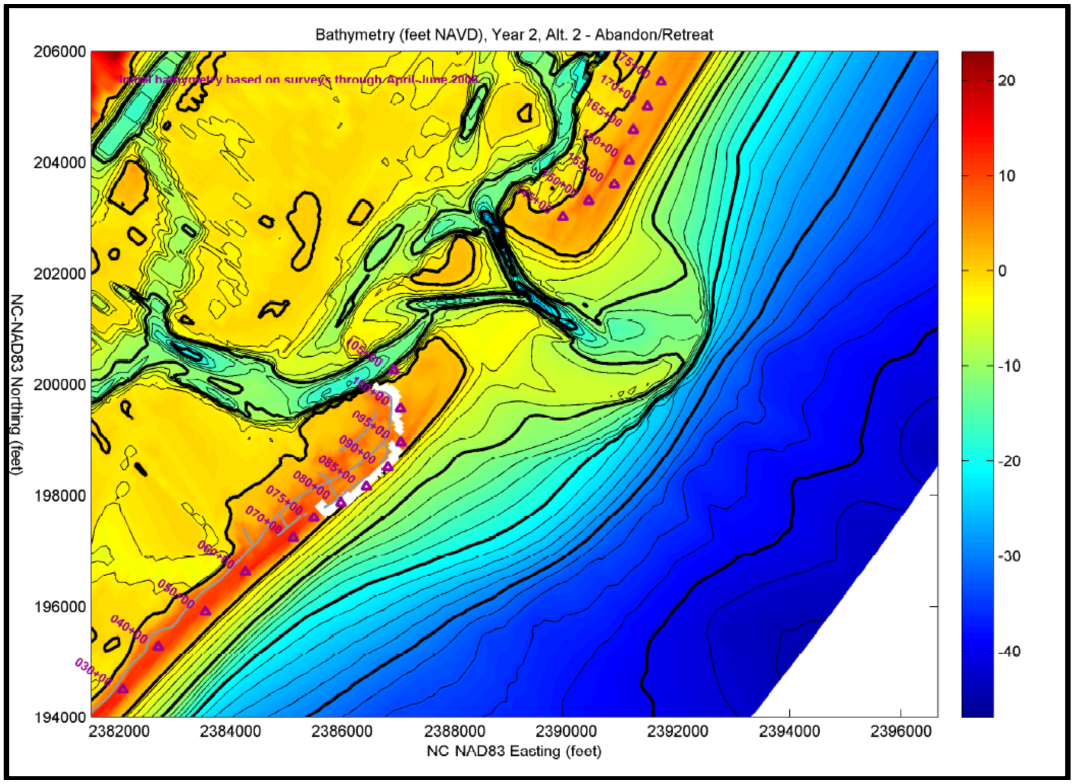

Figure 5.4a. Alternative 2 – Year 2 – 2006 conditions.

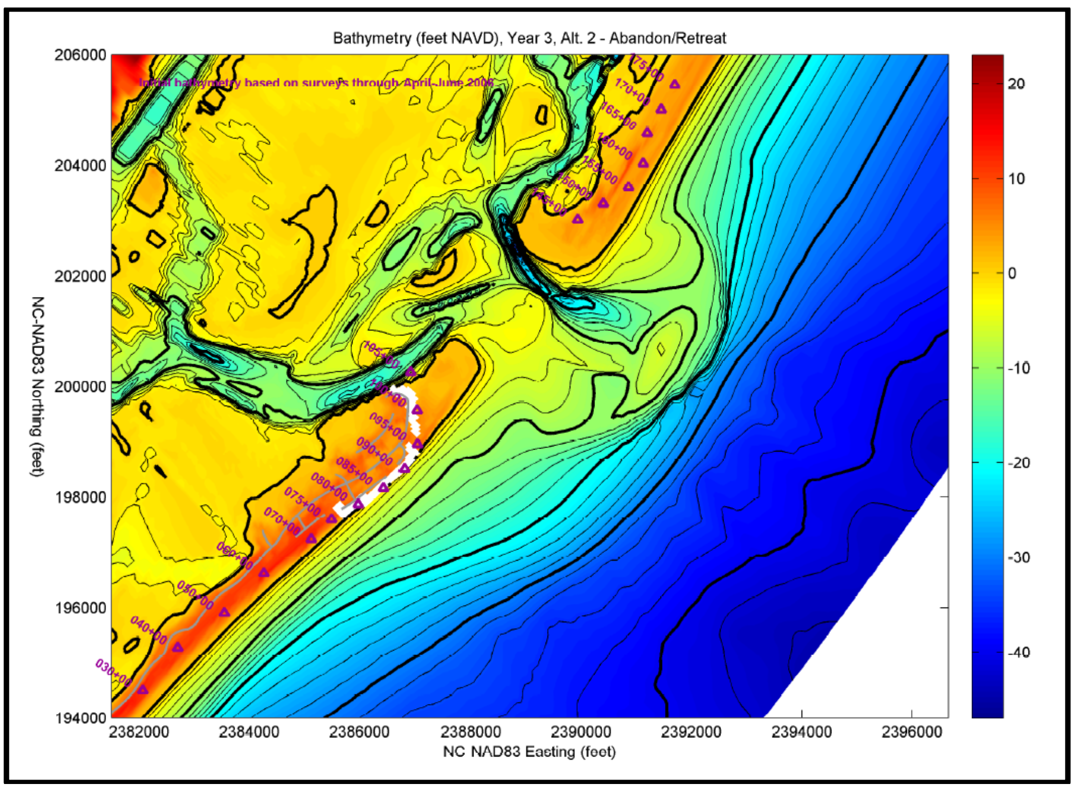

Figure 5.5a. Alternative 2 – Year 3 – 2006 conditions.

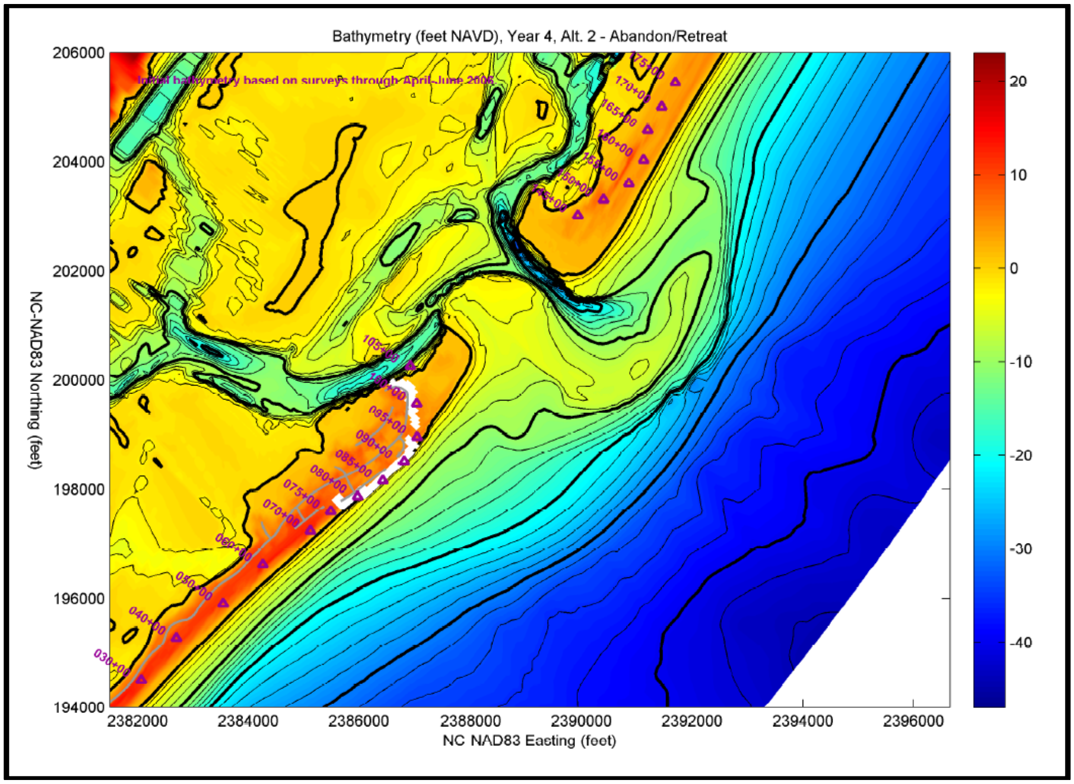

Figure 5.6a. Alternative 2 – Year 4 – 2006 conditions.

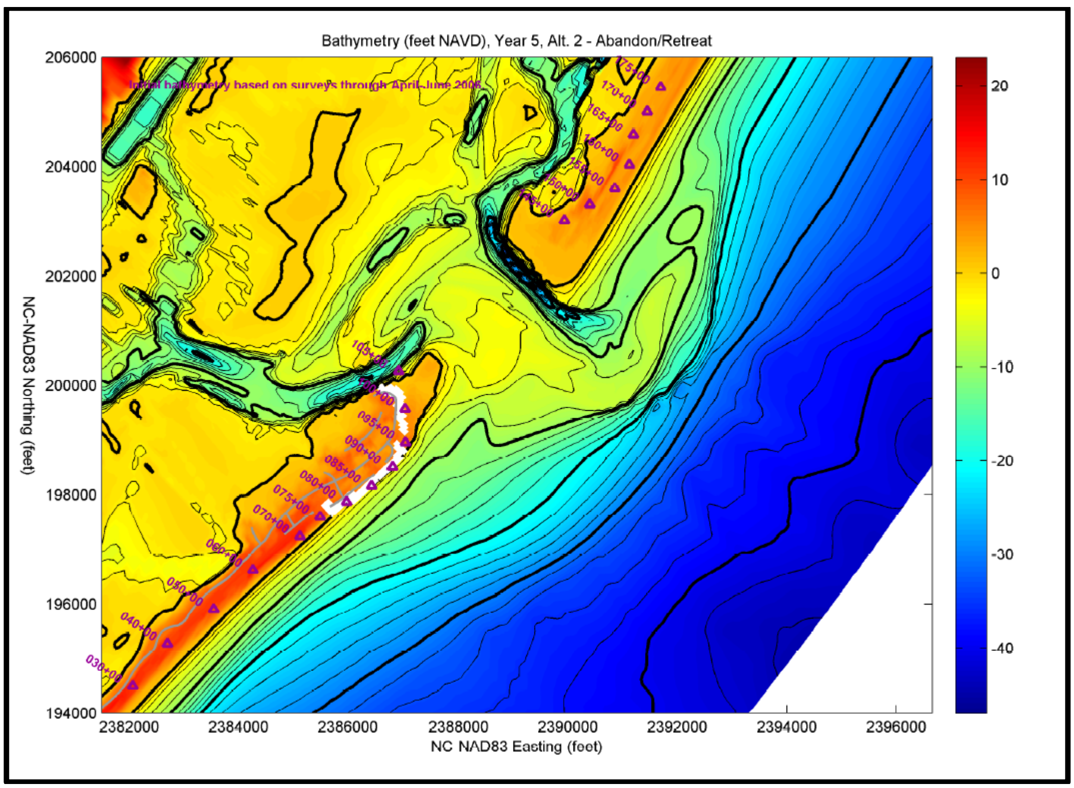

Figure 5.7a. Alternative 2 – Year 5 – 2006 conditions.

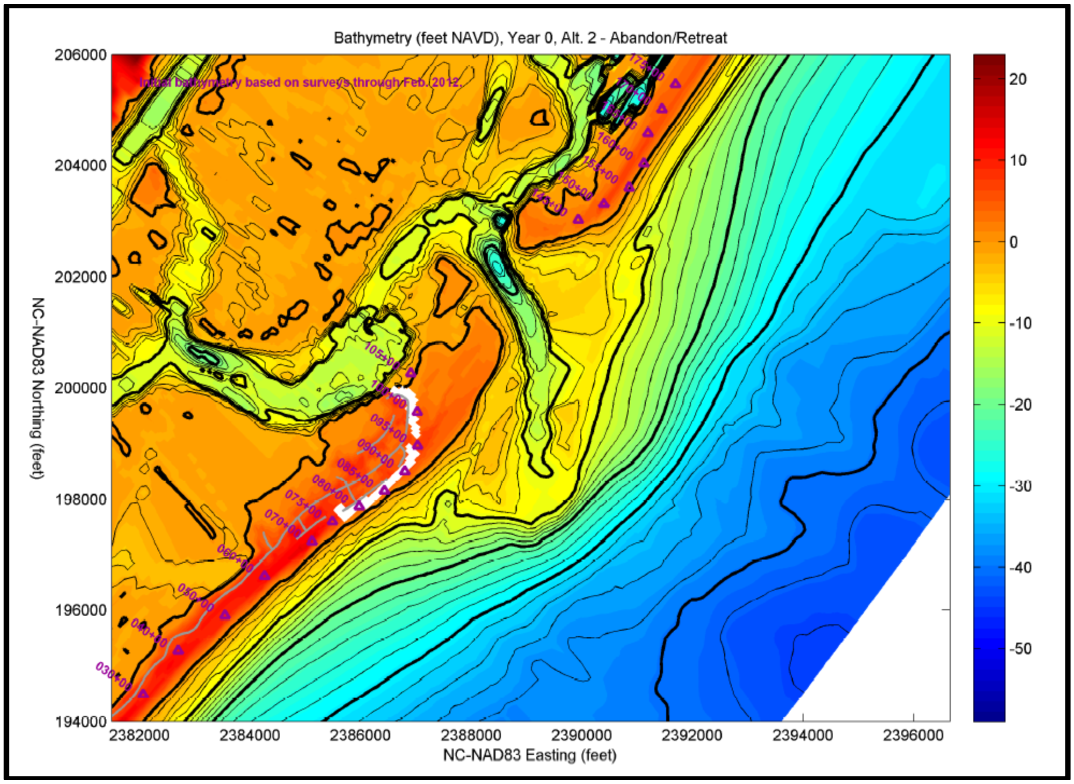

Figure 5.2b. Alternative 2 – Year 0 – 2012 conditions.

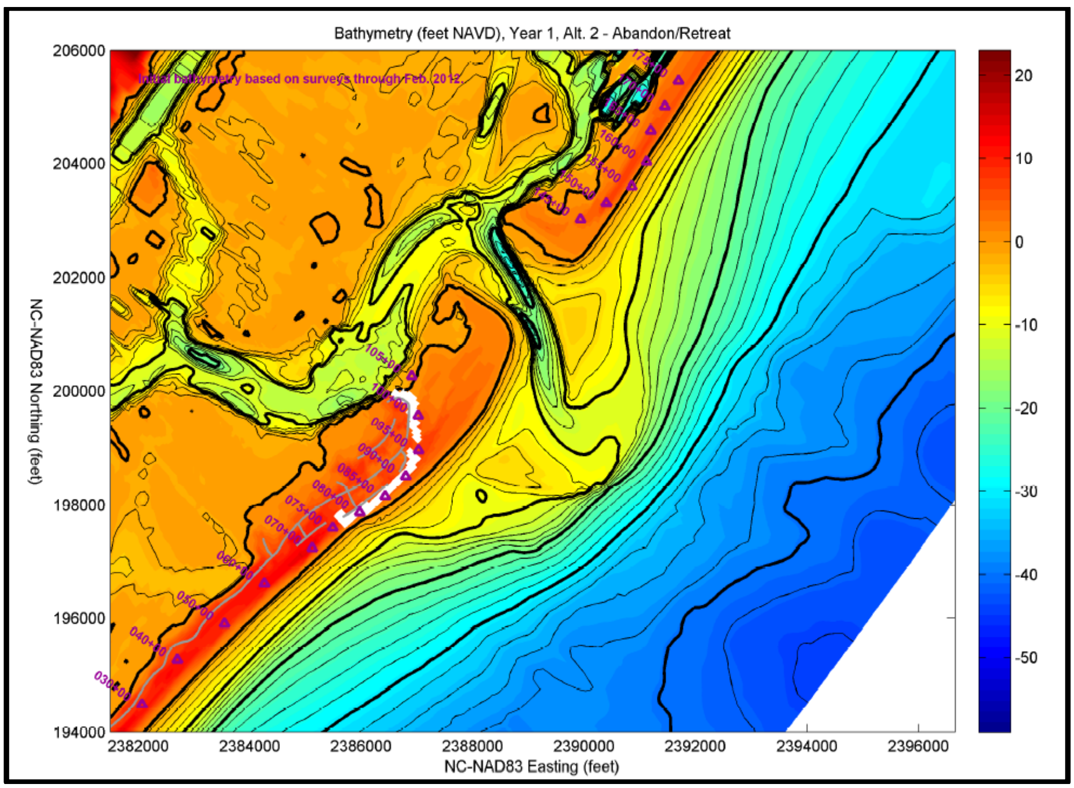

Figure 5.3b. Alternative 2 – Year 1 – 2012 conditions.

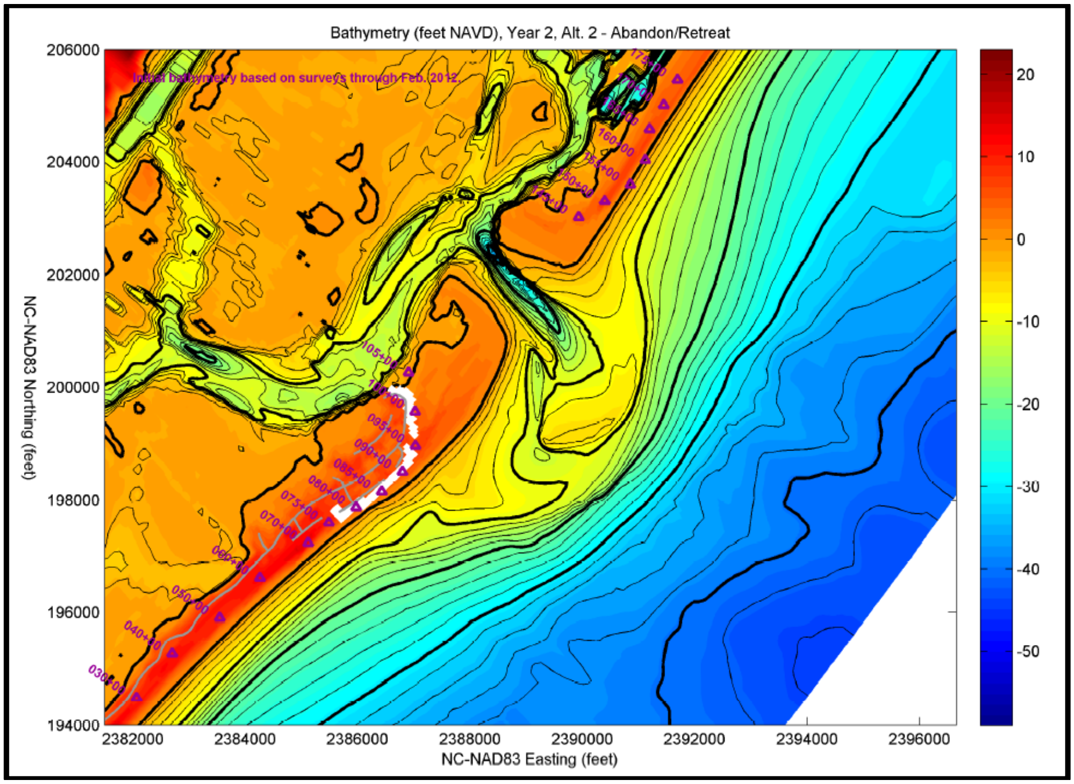

Figure 5.4b. Alternative 2 – Year 2 – 2012 conditions.

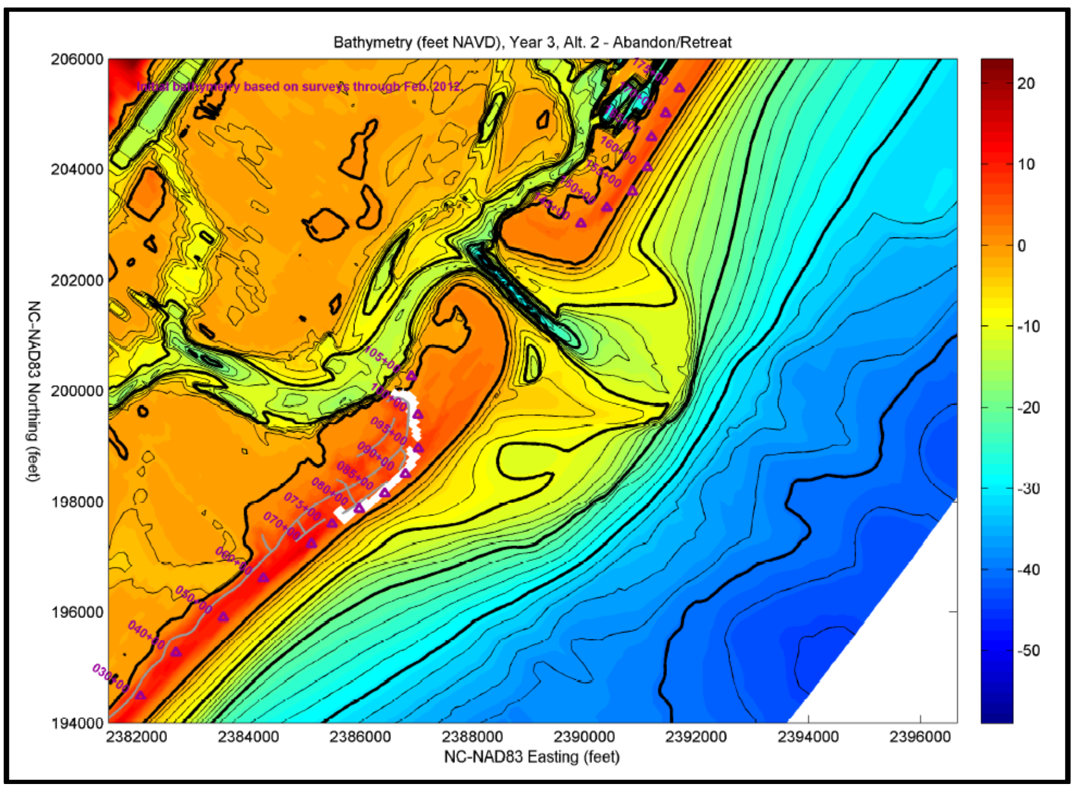

Figure 5.5b. Alternative 2 – Year 3 – 2012 conditions.

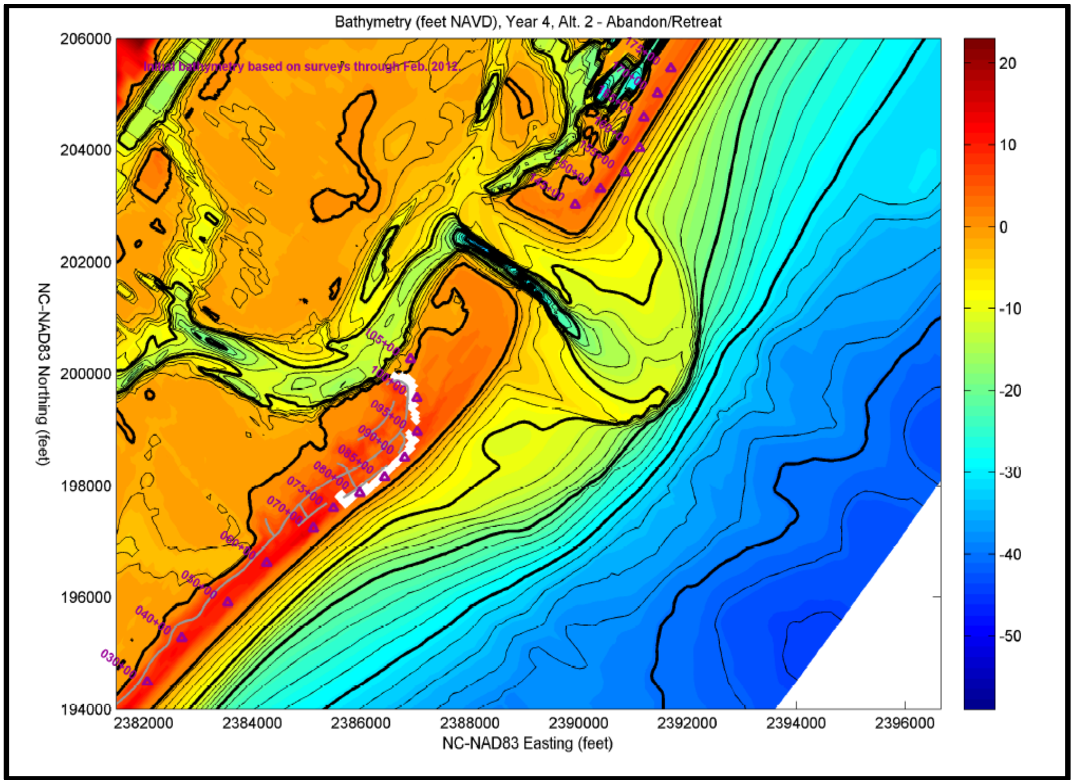

Figure 5.6b. Alternative 2 – Year 4 – 2012 conditions.

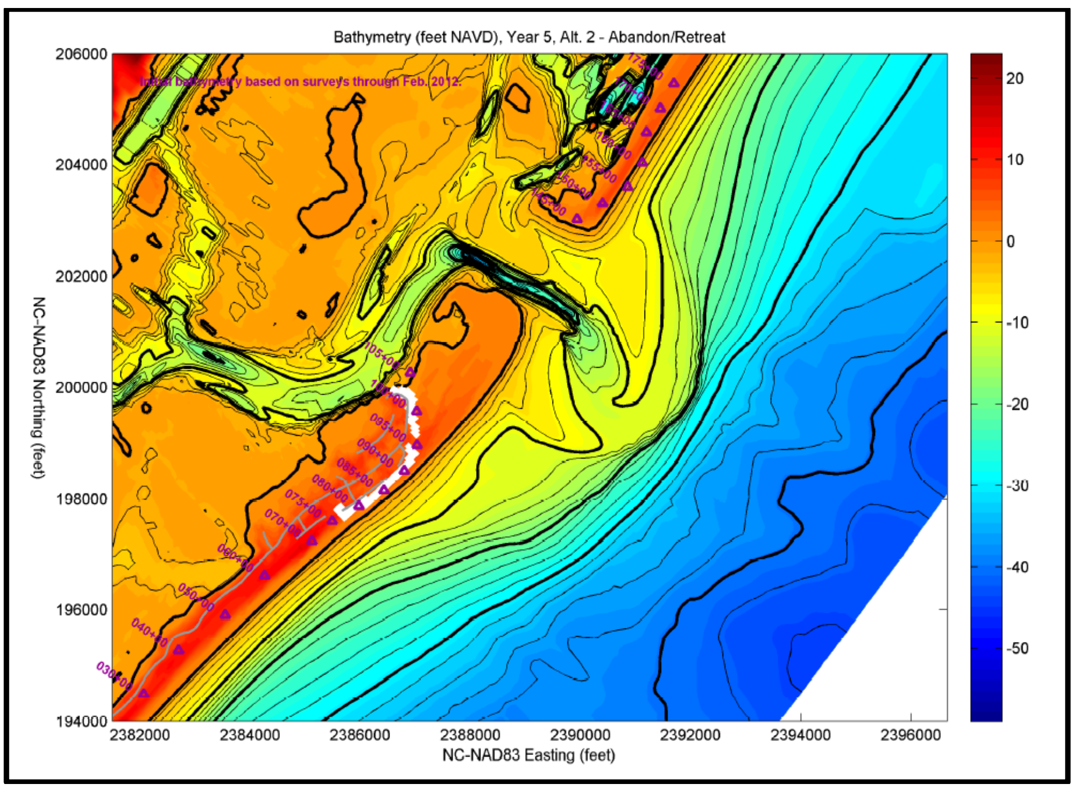

Figure 5.7b. Alternative 2 – Year 5 – 2012 conditions.

<u>Alternative 3</u>

Alternative 3 includes beach fill along the ocean shoreline of Figure Eight Island from near Rich Inlet south to Bridge Road and along 1,400 feet of the Nixon Channel shoreline on the backside of Figure Eight Island. The impacts of the inlet channel modifications on the morphology of Rich Inlet, shoreline changes on both Figure Eight Island and Hutaff Island, and flows through the inlet and the connecting channels were simulated over a 5-year period using the Delft3D numerical model (Appendix B). The evaluation included the channel modifications with and without the closure dike next to Hutaff Island. Alternative 3 was simulated using both the 2006 and 2012 conditions.

Shoreline changes along the ocean shoreline of Figure Eight Island under Alternative 3 focused on the performance of the beach fill as indicated by the results of the Delft3D model. Over the southern 8,000 feet of the fill (stations F90+00 to 60+00) almost 98% of the initial fill volume remained at the end of the 5-year simulation, as losses were shown to be only 2,000 cubic yards/year (Table 5.4a) given the 2006 conditions. For the 2012 conditions, losses were slightly higher with a volume loss rate of -11,000 cubic yards/year with 90.0% of the fill remaining at the end of the 5-year simulation (Table 5.4b). The percent of the initial beach fill remaining at the end of each year of the 5 year simulation, under the 2006 and 2012 initial conditions are given in Tables 5.4c and 5.4d, respectively.

For the area between stations 60+00 and 105+00, losses were shown to be 99,000 cubic yards/year for the 2006 conditions, but much higher, averaging 180,000 cubic yards/year, for the 2012 conditions (Tables 5.4a and 5.4b). At the end of the 5-year simulation, 24.5% of the fill remained in this beach segment for the 2006 conditions (Table 5.4c) but under the 2012 conditions (Table 5.4d), all of the fill in this area was lost with erosion moving into the pre-nourished profile. It should be noted, under the 2006 conditions, approximately 43% of the fill remained in this area after 4 years (Table 5.4c). However, following the migration of the channel back to a position closer to Hutaff Island, the model results indicated that, between years 4 and 5 of the simulation, erosion of the fill accelerated. Under the 2012 conditions, the Rich Inlet bar channel was aligned toward the southwest during the first 4 years of the simulation but not to the same degree as the alignment under the 2006 initial conditions. Between year 4 and 5 of the simulation, the bar channel shifted to a more northerly orientation which resulted in accelerated volume losses off the north end of Figure Eight Island.

While the model results for the 2006 condition showed 24.5% of the fill remaining on the entire active profile at the end of 5 years, losses from the fill placed above the -6-foot NAVD contour exceeded the placement volume, i.e., the model indicated erosion could encroach into the pre-nourished beach by the end of year 4. Similar results were obtained for the 2012 conditions with erosion above the -6-foot NAVD contour impacting the pre-nourishment profile between years 4 and 5 of the simulation.

Table 5.4a. Alternative 3 - Delft3D average annual rate of volume change on Figure Eight and Hutaff Island at the end of the 5-year simulation – 2006 conditions.

Beach Segment	Delft3D volume changes (cy/yr.)
Figure Eight Island	
F90+00 to 60+00	-2,000
60+00 to 105+00	-99,000
Hutaff Island	
148+60 to 175+00	-31,000
175+00 to 215+00	-26,000

Table 5.4b. Alternative 3 - Delft3D average annual rate of volume change on Figure Eight and Hutaff Island at the end of the 5-year simulation – 2012 conditions.

Beach Segment	Delft3D volume changes (cy/yr.)
Figure Eight Island	
F90+00 to 60+00	-11,000
60+00 to 105+00	-180,000
Hutaff Island	
148+60 to 175+00	-30,000
175+00 to 215+00	-103,000

Table 5.4c. Percent of Alternative 3 initial beach fill volume remaining after each year of the 5-year Delft3D model simulation – 2006 conditions.

Beach Segment	Percent of Beach Fill Remaining after:				
	1 year	2 years	3 years	4 years	5 years
F90 to 60	99.5	108.3	110.0	106.8	98.0
60 to 105	72.2	60.8	51.1	43.3	25.4
Entire Fill Area (F90 to 105)	84.5	82.2	77.6	71.9	57.6

Table 5.4d. Percent of Alternative 3 initial beach fill volume remaining after each year of the 5-year Delft3D model simulation – 2012 conditions.

Beach Segment	Percent of Beach Fill Remaining after:				
	1 year	2 years	3 years	4 years	5 years
F90 to 60	86.7	91.9	95.0	96.3	90.0
60 to 105	59.9	35.0	9.0	-17.1	-37.8
Entire Fill Area (F90 to 105)	71.4	60.6	47.8	34.0	19.8

Given the 2006 conditions, the Delft3D model indicated the repositioning of the bar channel could result in the elongation of the sand spit off the north end of Figure Eight Island. The growth of the sand spit toward Rich Inlet simulated by the model mimics observed responses to similar channel modifications implemented at Oregon Inlet, Bogue Inlet, and Shallotte Inlet. For the 2012 conditions, construction of the new bar channel would actually cut across the distal end of the sand spit, however, based on the model results, the sand spit would initially reform during the first two years post-construction but would then begin to erode.

Constructing the inlet modifications with the closure dike extending off the south end of Hutaff Island will close the present entrance channel. Part of the new main inlet bar channel will occupy the present location of the flood channel on the southwestern side of the inlet. The modeled morphological changes to Rich Inlet that occurred over the 5-year simulation period for Alternative 3 are shown in Figures 5.8a to 5.13a for the 2006 condition and Figures 5.8b to 5.13b for the 2012 conditions. The model was allowed to run two additional years with the results at the end of year 7 of the simulation shown in Figure 5.14a for the 2006 condition and Figure 5.14b for the 2012 condition.

For both the 2006 and 2012 conditions, the inner portion of the new bar channel gradually migrated toward the north, or toward Hutaff Island, during the first 3 years following construction, with the thalweg of the inner portion of the channel moving completely outside the initial channel corridor. The outer portion of the bar channel initially assumed a southwesterly orientation toward Figure Eight Island resulting in a significant build-up of the ebb tide delta off the north end of Figure Eight Island. By year 5 of the simulation for both the 2006 and 2012 conditions, the bar channel migrated to the north and was completely out of the initial channel corridor.

The model was allowed to run for two additional years (Figures 5.14a and 5.14b) during which time the model indicated the bar channel would breach the outer bar and assume an alignment toward the south end of Hutaff Island. The northward movement of the bar channel between year 4 and year 5 of the simulation resulted in accelerated volume losses off the north end of Figure Eight Island under both the 2006 and 2012 conditions. Based on these model results, the bar channel of Rich Inlet would need to be returned to its preferred position and alignment within 5 years following its relocation in order to maintain its preferred alignment.

As expected, the channel connecting the inlet gorge with the mouth of Green Channel shoaled significantly as the sand dike eroded and assumed the characteristics of a sand spit projecting off the south end of Hutaff Island. This result was observed for both the 2006 and 2012 condition. Most of the sand spit eventually became sub tidal under both conditions as well. While the Nixon Channel connector also experienced significant shoaling, the connector maintained some of its cross-sectional integrity throughout the 5-year simulation, concentrating flow away from the backside of Figure Eight Island.

For the 2006 conditions, the sand spit projecting into Rich Inlet from Figure Eight Island elongated between year 1 and 2 and then stabilized until year 4. Between years 4 and 5 of the simulation, the sand spit began to experience significant erosion retuning to a condition similar to that which existed at the beginning of the simulation. At the end of year 7 of the simulation (Figure 5.14a), the sand spit was completely eroded with the shoreline receding to a point south of baseline station 105+00. For the 2012 condition, the sand spit was relatively stable through year 3 of the simulation but began to erode after that but not to the same extent as observed for the 2006 condition.

Over the primary 5-year simulation period, the north side of the ebb tide delta diminished in size and shifted toward the southwest exposing the southern end of Hutaff Island to direct wave attack. Some of the material on the north side of the inlet migrated onshore and merged with the shoreline, however, the volume of material lost offshore due to the shifting location of the ebb tide delta overshadowed any volume gains directly on the beach resulting in a net volume loss off the southern end of Hutaff Island at the end of year 5 of the simulation.

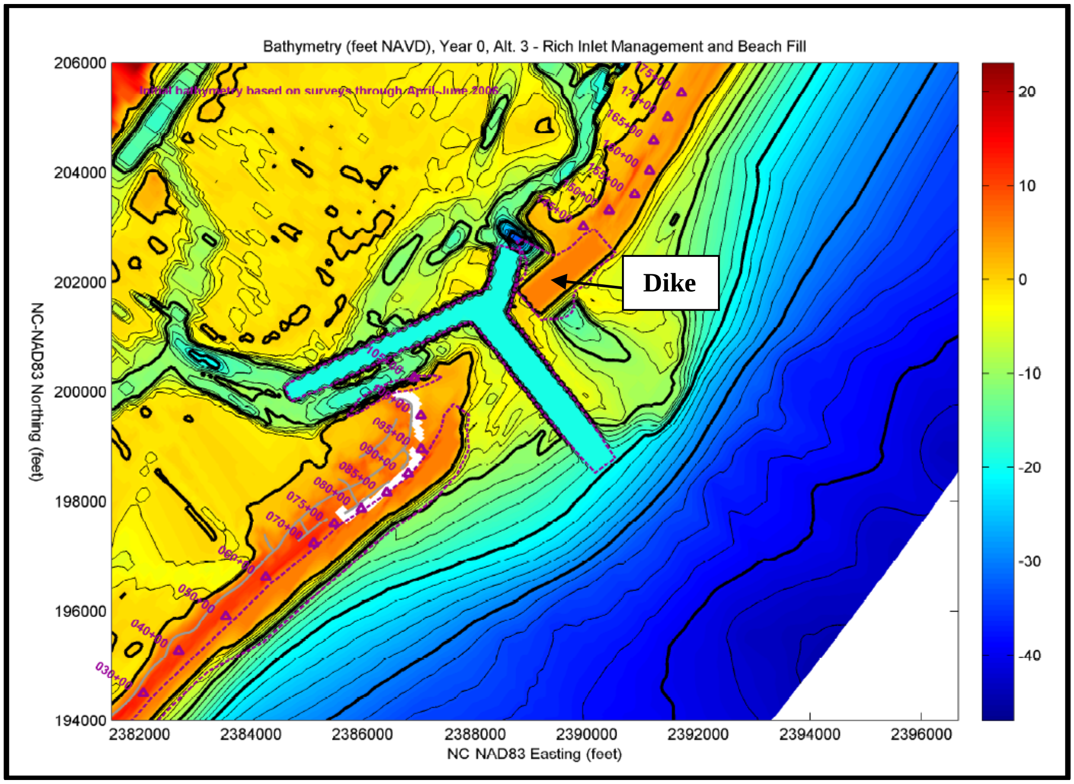

Figure 5.8a. Alternative 3: Year 0 Post-construction – 2006 conditions.

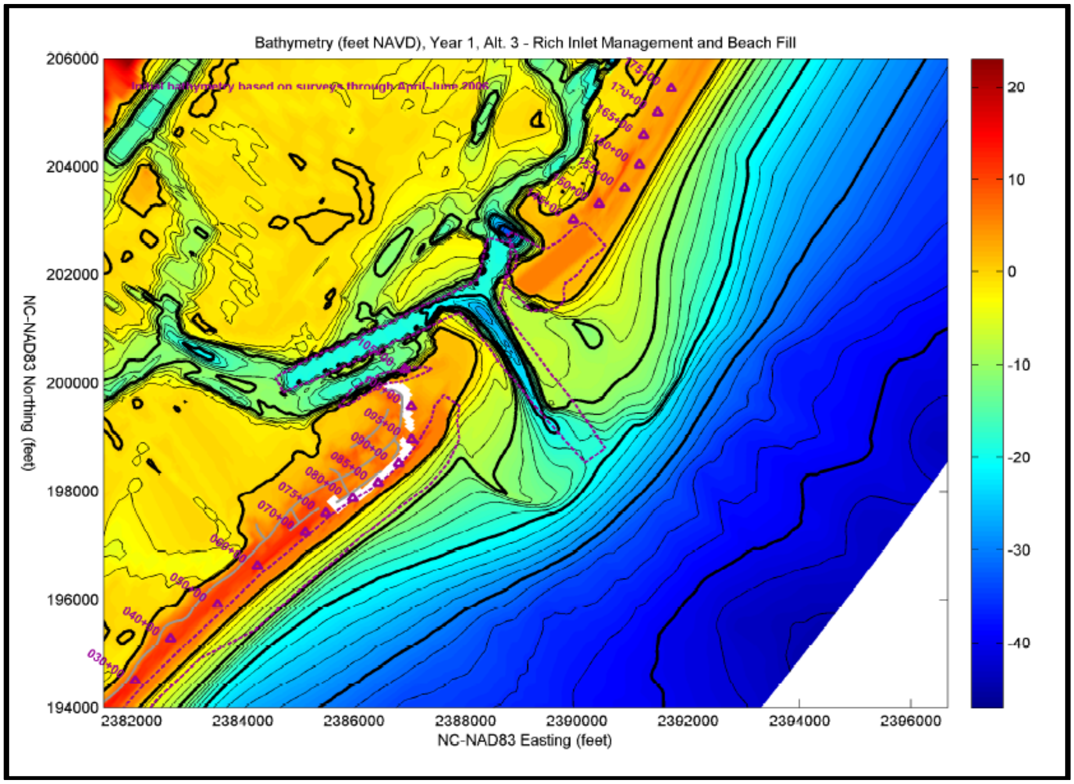

Figure 5.9a. Alternative 3: Year 1 after construction – 2006 conditions.

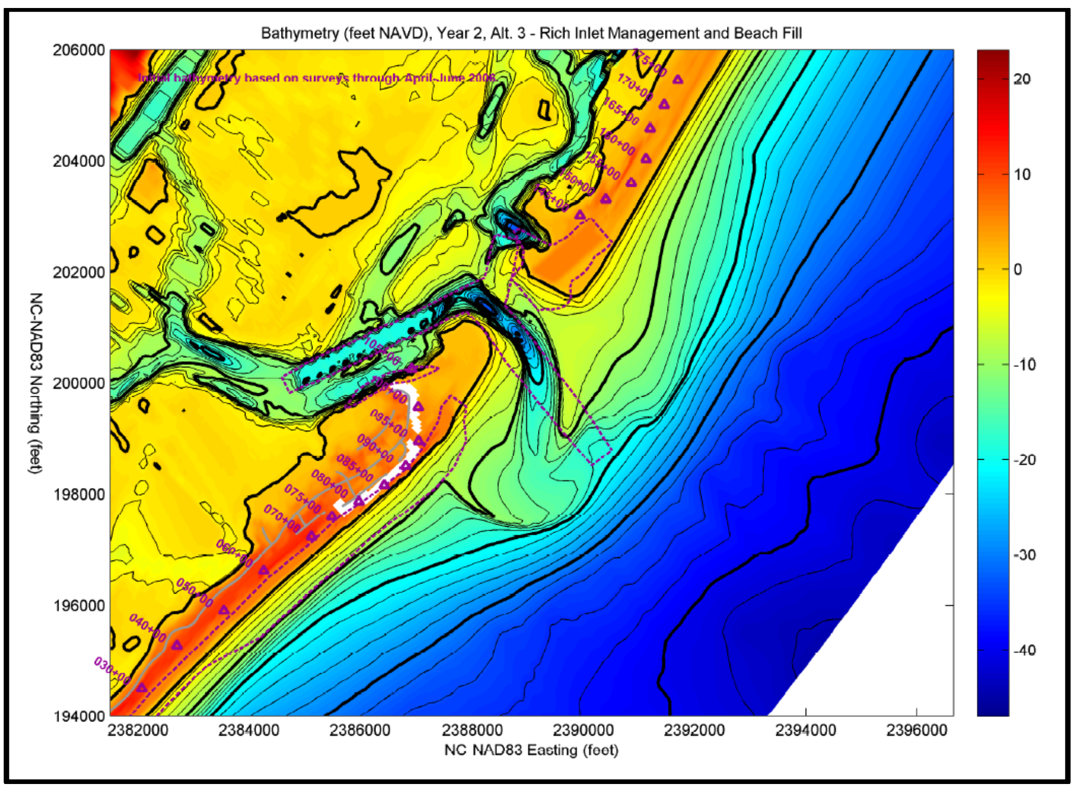

Figure 5.10a. Alternative 3: Year 2 after construction – 2006 conditions.

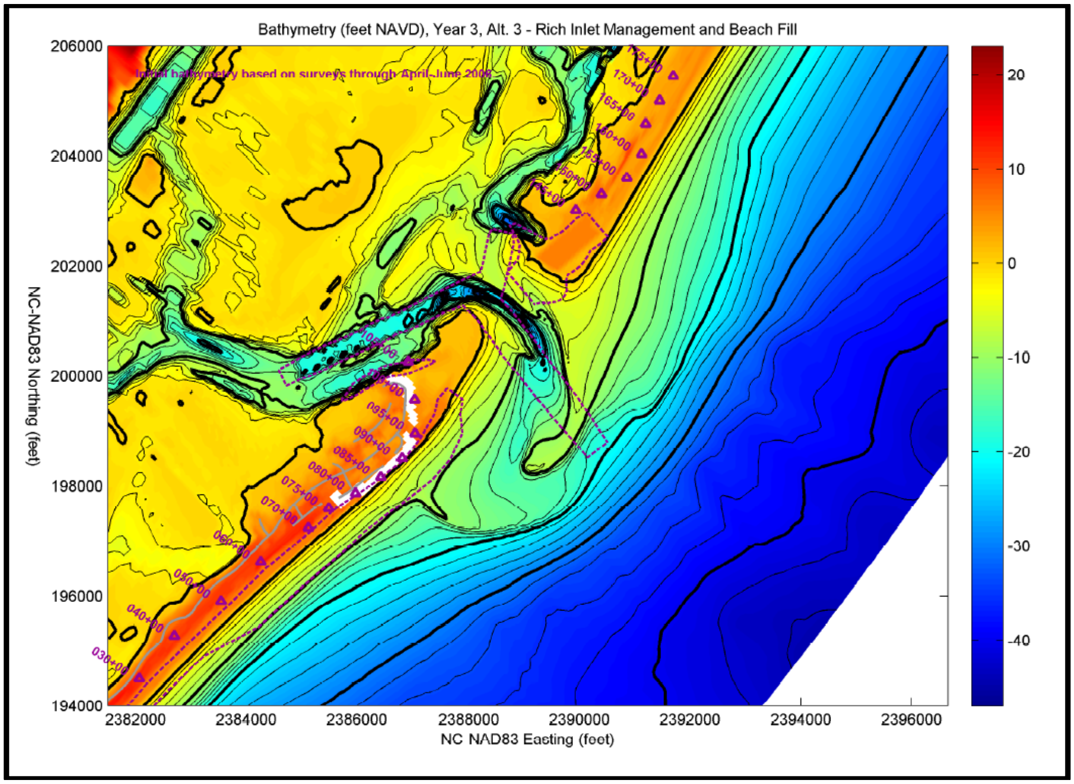

Figure 5.11a. Alternative 3: Year 3 after construction – 2006 conditions.

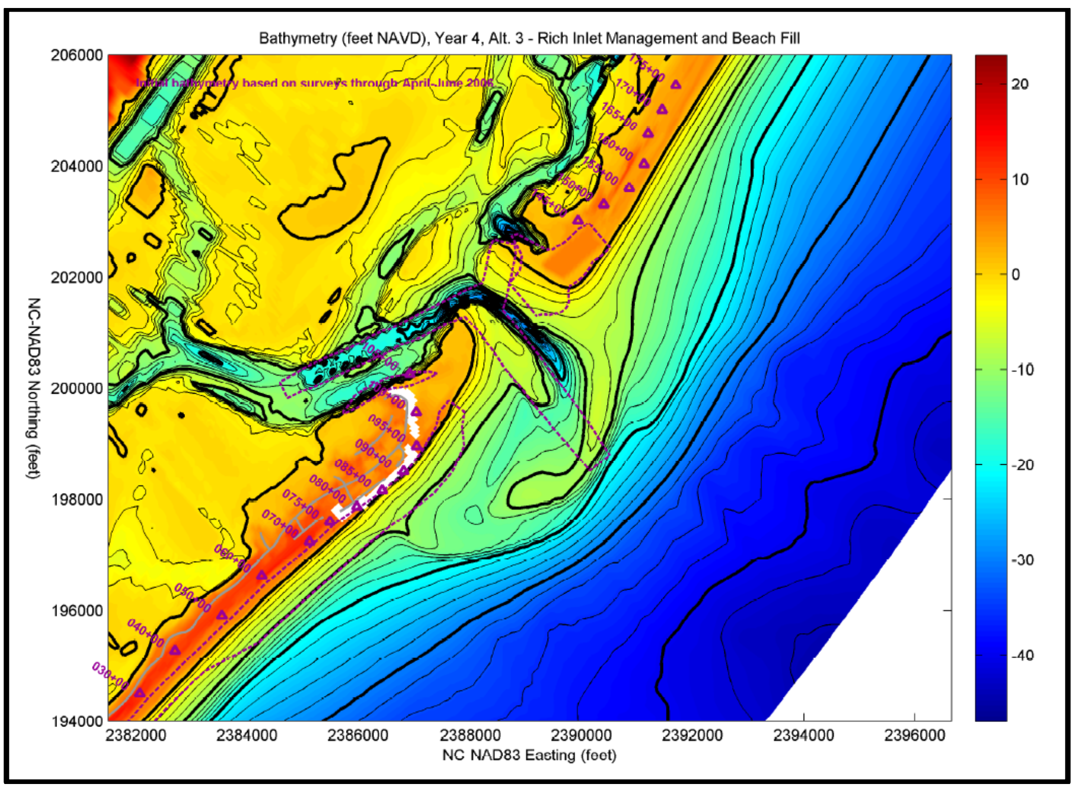

Figure 5.12a. Alternative 3: Year 4 after construction – 2006 conditions.

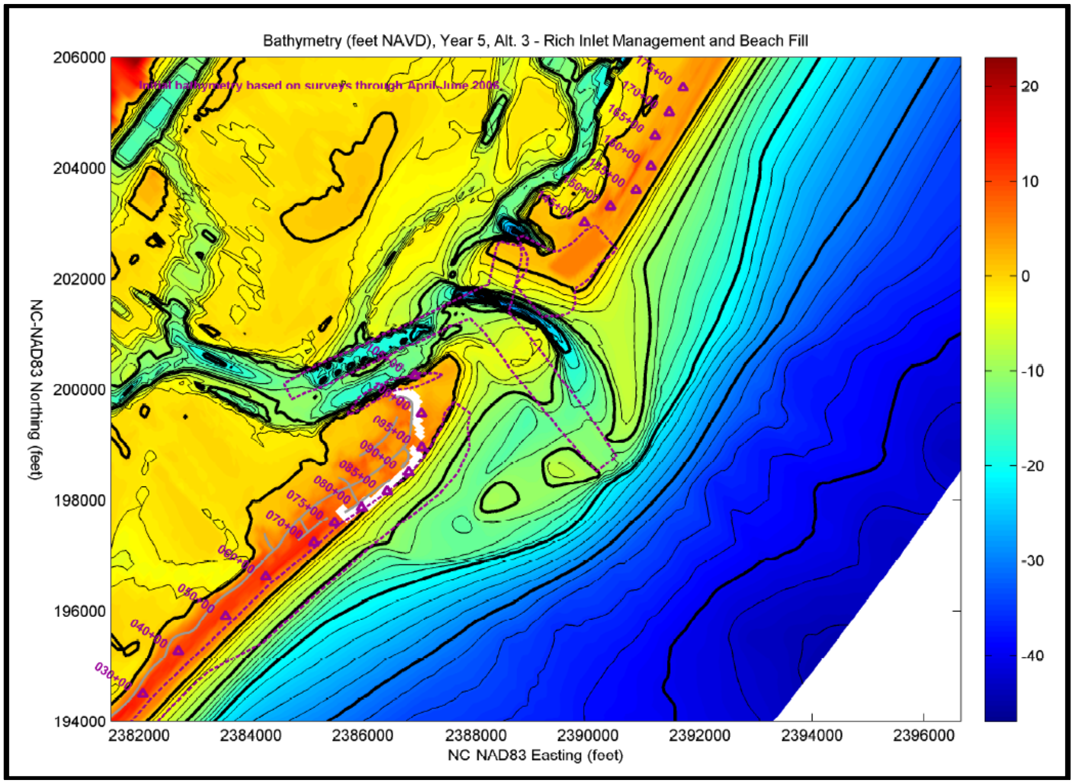

Figure 5.13a. Alternative 3: Year 5 after construction – 2006 conditions.

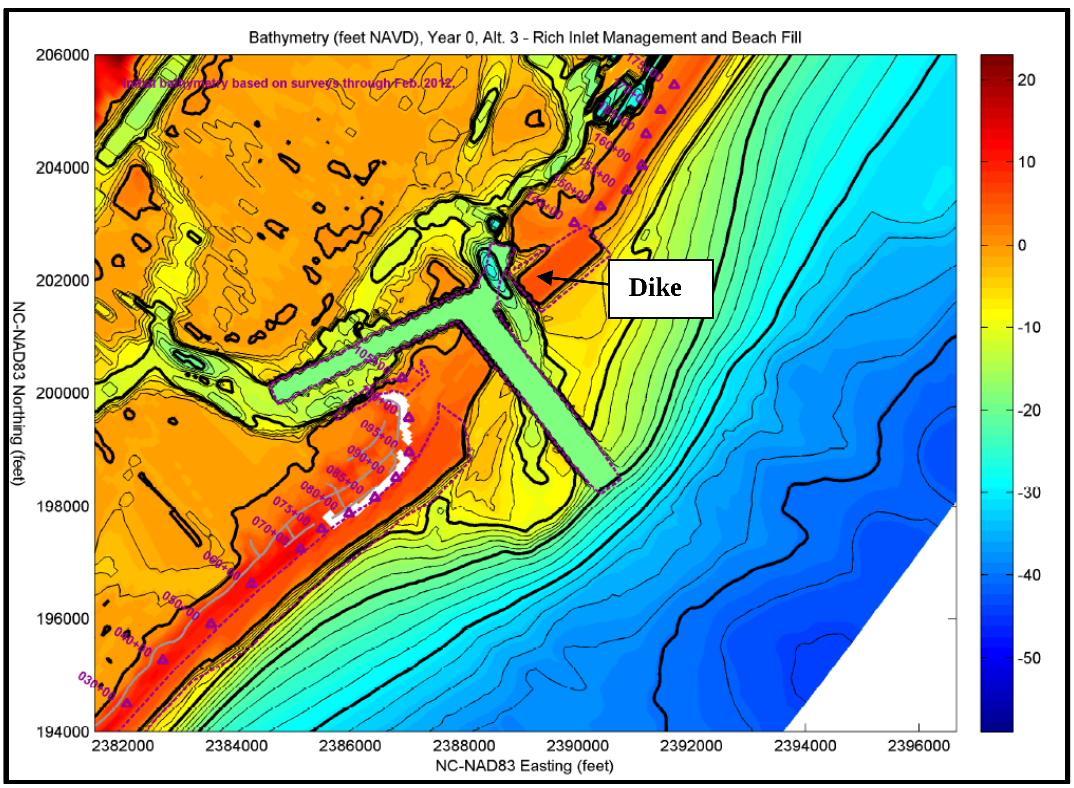

Figure 5.8b. Alternative 3: Year 0 after construction – 2012 conditions.

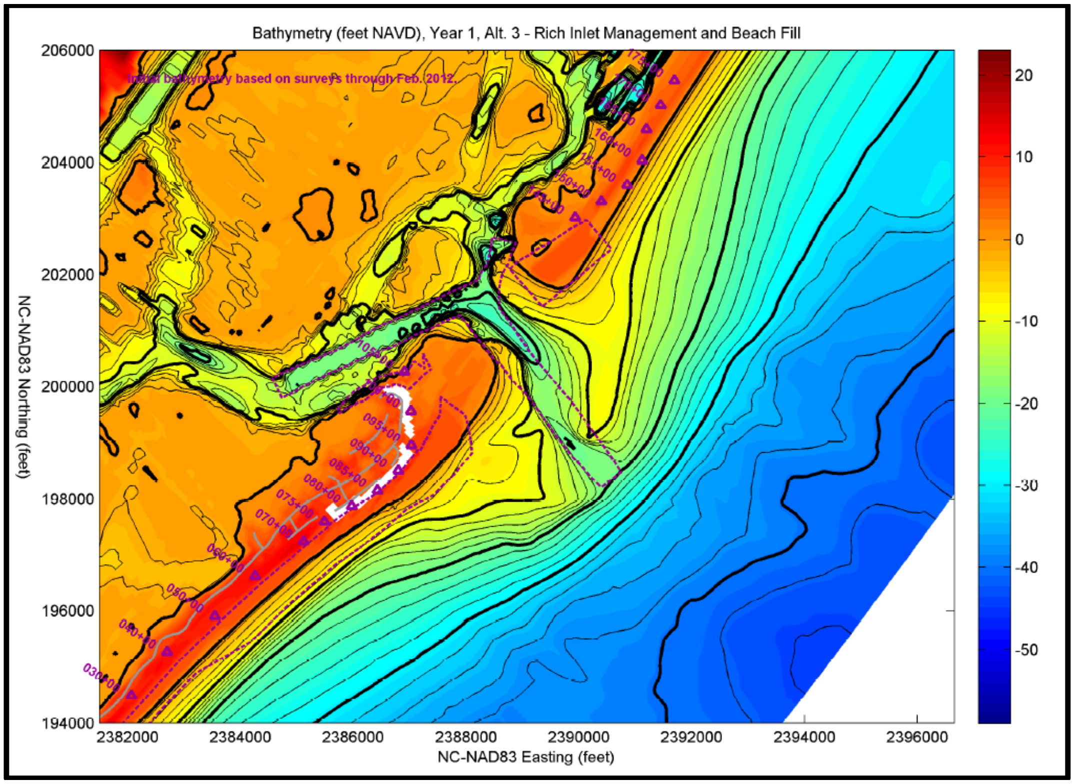

Figure 5.9b. Alternative 3: Year 1 after construction – 2012 conditions.

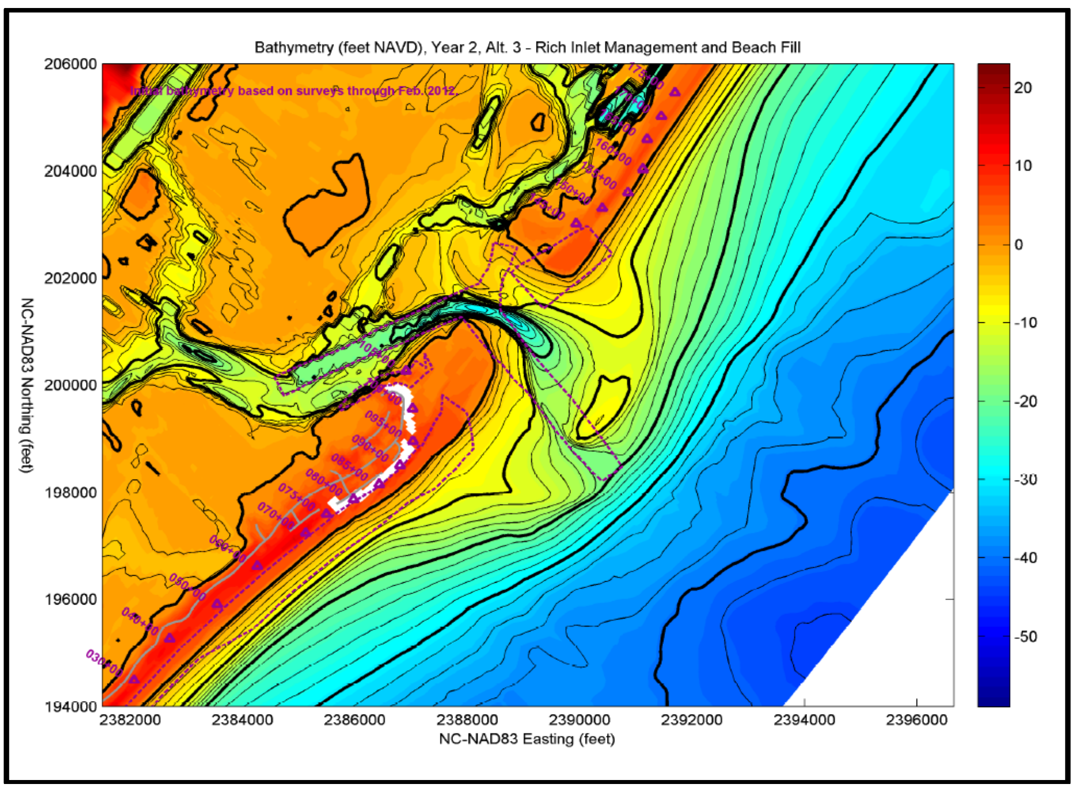

Figure 5.10b. Alternative 3: Year 2 after construction – 2012 conditions.

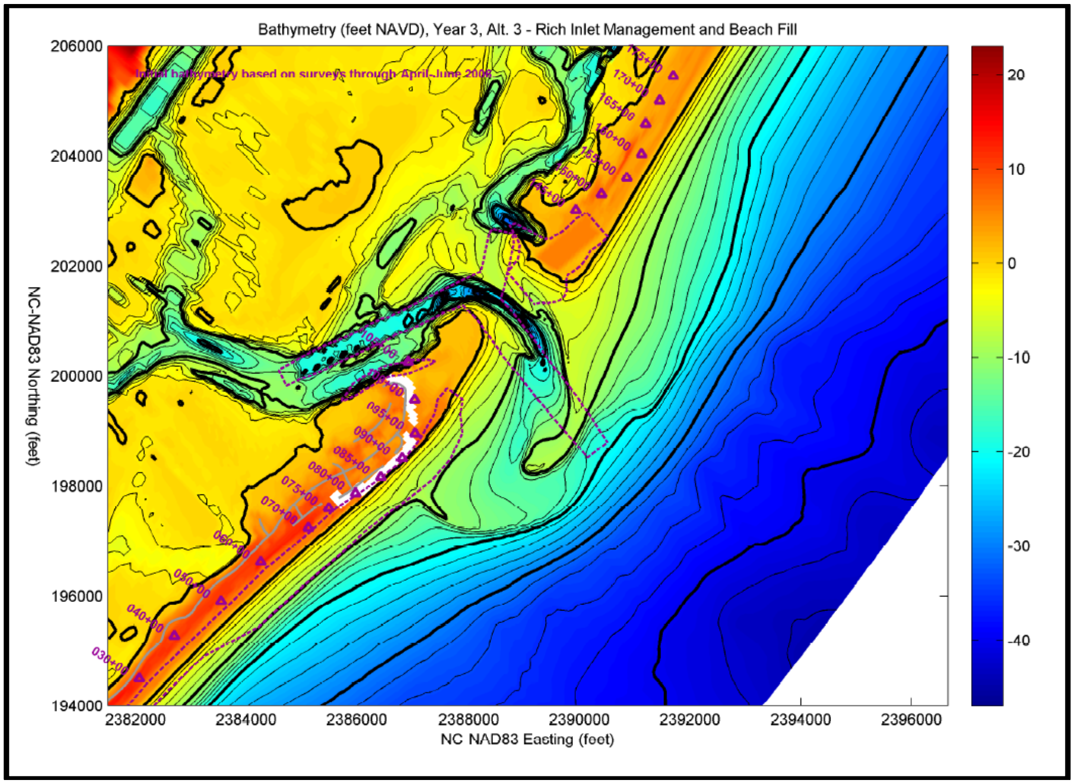

Figure 5.11b. Alternative 3: Year 3 after construction – 2012 conditions.

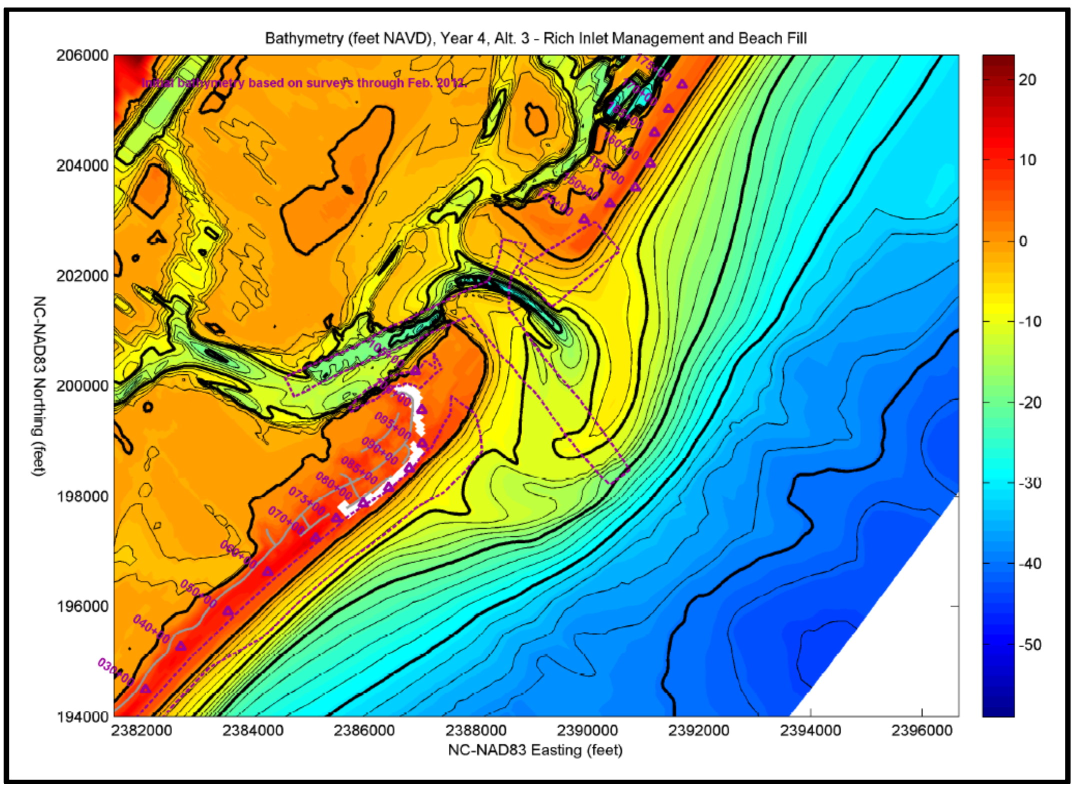

Figure 5.12b. Alternative 3: Year 4 after construction – 2012 conditions.

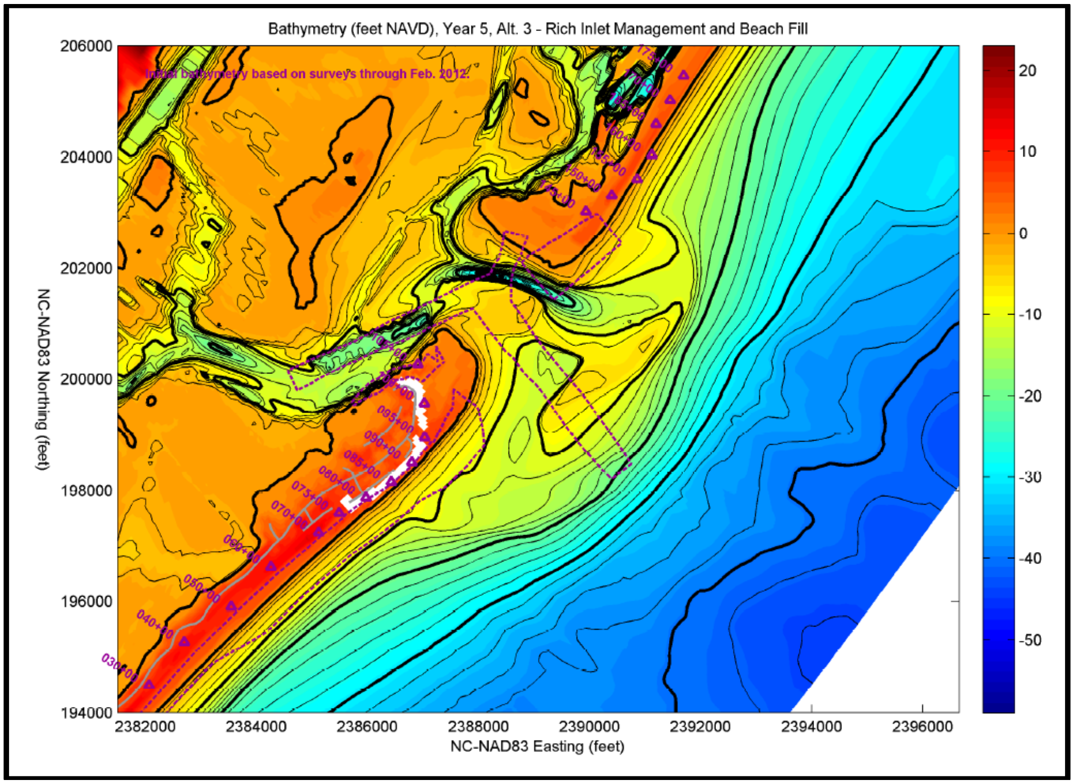

Figure 5.13b. Alternative 3: Year 5 after construction – 2012 conditions

- <u>Alternative 4</u>

Alternative 4 includes beach fill from Rich Inlet south to Bridge Road and along 1,400 feet of the Nixon Channel shoreline located behind the north end of Figure Eight Island, without Inlet Management. The beach fill along the ocean shoreline of Figure Eight Island under Alternative 4 was based on the volume of material needed to address shore erosion as indicated by the Delft3D five-year model simulation. The fill densities and design berm widths for Alternative 4 are provided in Table 5.5.

Table 5.5. Alternative 4 oceanfront beach fill placement volumes and design berm widths

Shoreline Segment (Baseline Stations)	Placement Volume (cy/lf)	Design Berm Width (ft.)
F90+00 to F100+00 (transition)	0 to 20	0 to 17
F100+00 to 20+00	20	17
20+00 to 30+00 (transition)	20 to 50	17 to 43
30+00 to 60+00	50	43
60+00 to 70+00 (transition)	50 to 100	43 to 86
70+00 to 80+00	100	86
80+00 to 82+50 (transition)	100 to 200	86 to 172
82+50 to 100+00	200	172
100+00 to 105+00 (transition)	200 to 0	172 to 0

As with Alternative 3, the focus of shoreline changes along Figure Eight Island for Alternative 4 will be the performance of the beach fill that would be placed between Bridge Road and Rich Inlet. The Delft3D model for Alternative 4 included the same inlet conditions as presented in Alternative 2 and included the same design of the beach fill along the ocean shoreline and Nixon Channel as that described for Alternative 3. The beach fill design for Alternative 3 was based on the volume of material that would be removed from the Rich Inlet complex to reposition the inlet bar channel and reconfigure the channels leading into Nixon and Green Channels, not on the volume needed to address shoreline erosion issues. Therefore, based on the fill performance obtained from the Delft3D simulations for Alternative 3, the beach fill for Alternative 4 was designed to reflect shore protection needs.

Volumetric changes along the southern end of Hutaff Island and the two (2) beach segments on Figure Eight Island, determined from the results of the 5-year simulation of Alternative 4 by the Delft3D model, are summarized in Table 5.6a for the 2006 conditions and Table 5.6b for the 2012 conditions. The model volume changes for Alternatives 2 and 3 are also included in these tables for comparison purposes.

Table 5.6a. Average annual rate of volume change (cubic yards/year) at the end of the 5-year simulation - Figure Eight Island and the southern end of Hutaff Island obtained from the Delft3D model for Alternatives 2, 3 and 4 – 2006 conditions.

Alternative	Figure Eight Island		Hutaff Island	
	F90+00 to 60+00	60+00 to 105+00	148+60 to 175+00	175+00 to 215+00
2	+18,000	-84,000	+53,000	-35,000
3	-2,000	-99,000	-31,000	-36,000
4	+30,000	-176,000	+57,000	-30,000

Table 5.6b. Average annual rate of volume change (cubic yards/year) at the end of the 5-year simulation - Figure Eight Island and the southern end of Hutaff Island obtained from the Delft3D model for Alternatives 2, 3 and 4 – 2012 conditions.

Alternative	Figure Eight Island		Hutaff Island	
	F90+00 to 60+00	60+00 to 105+00	148+60 to 175+00	175+00 to 215+00
2	+35,000	-43,000	-36,000	-116,000
3	-11,000	-180,000	-30,000	-103,000
4	+16,000	-130,000	-30,000	-121,000

Since no modifications were made to Rich Inlet or the connecting channels under Alternative 4 for the 2006 conditions, the south end of Hutaff Island behaved in a manner similar to Alternative 2, gaining an average of 57,000 cubic yards/year compared to 53,000 cubic yards/year computed for Alternative 2. Farther north on Hutaff Island (stations 175+00 to 215+00) volumetric changes were similar for Alternatives 2, 3 and 4.

For the 2012 conditions, while there were some minor differences in the shoreline response in the two segments on Hutaff Island (Table 5.6b), the differences were not significant in terms of model accuracy. The primary difference in the response of Hutaff Island between the 2006 and 2012 conditions were somewhat higher volumetric losses along the northern segment (stations 175+00 to 215+00) for the 2012 condition compared to the 2006 condition.

Given the 2006 conditions, volumetric changes from the beach fill for Alternative 4 between stations F90+00 and 60+00 averaged a gain of 30,000 cubic yards/year over the 5-year simulation period. The biggest difference in the performance of the beach fill between Alternative 3 and Alternative 4 occurred in the beach segment between 60+00 and 105+00 where erosion removed the entire Alternative 4 fill by year 4. Also by the end of year 4, erosion had progressed into the pre-nourished beach profile north of station 80+00 as all of the fill placed above the -6-foot NAVD contour was also lost by the end of Year 4.

Similar results were produced by the model for the 2012 conditions with the shoreline segment between F90+00 and 60+00 gaining an average of 16,000 cubic yards/year over the 5-year simulation with erosion of the pre-nourished profile occurring north of station 95+00 in Year 4 of the simulation. However, as shown in Table 5.7b, a significant portion of the fill remained on the profile after Year 4 (22.7%) but was virtually gone at the end of Year 5.

The results of the five-year Delft3D simulation for Alternative 4 for the 2006 conditions are provided on Figures 5.14a to 5.19a with the results for the 2012 conditions shown on Figures 5.14b to 5.19b.

The time history of the fill performance for Alternative 4, given in terms of the percent of fill remaining in the two beach segments between F90+00 and 60+00 and from 60+00 to 105+00 after each year of the 5-year simulation, is given in Table 5.7a for the 2006 conditions and Table 5.7b for the 2012 conditions. The negative values in these tables indicate erosion into the existing (i.e., pre-nourishment) upland area.

Table 5.7a. Percent of Alternative 4 initial beach fill volume remaining after each year of the 5-year Delft3D model simulation – 2006 conditions.

Beach Segment	Percent of Beach Fill Remaining after:				
	1 year	2 years	3 years	4 years	5 years
F90 to 60	124.3	151.4	165.1	168.6	158.0
60 to 105	57.0	30.5	6.4	-16.3	-34.3
Entire Fill Area (F90 to 105)	75.8	64.3	50.8	35.4	19.5

Table 5.7b. Percent of Alternative 4 initial beach fill volume remaining after each year of the 5-year Delft3D model simulation – 2012 conditions.

Beach Segment	Percent of Beach Fill Remaining after:				
	1 year	2 years	3 years	4 years	5 years
F90 to 60	92.2	103.9	111.2	126.7	132.2
60 to 105	64.3	65.7	42.5	22.7	0.6
Entire Fill Area (F90 to 105)	72.1	76.4	62.0	51.8	37.4

For the 2006 conditions, the Alternative 4 beach fill performed better compared to Alternative 3 between F90 and 60, actually gaining 58% more material than was initially placed. However, between stations 60+00 and 105+00, the Alternative 4 fill performed poorly losing essentially the entire fill placed in this segment by the end of year 4 of the simulation. A similar pattern was produced for the 2012 conditions but with overall volume changes less than indicated by the 2006 conditions. The difference of the performance of the fills between Alternatives 3 and 4 in the area from stations 60+00 to 105+00, given the 2006 condition, can be attributed to the changes in the configuration of the ebb tide delta induced by the repositioned channel associated with Alternative 3. In this regard, the model indicated changes in Rich Inlet under Alternative 4 were very similar to the model results for Alternative 2 hence the shoreline responses on both Figure Eight Island south of station 60+00 and on Hutaff Island for Alternative 4 were also similar to Alternative 2.

The simulated performance of the fill between 60+00 and 105+00 for both conditions mimics what has been observed following six (6) previous beach nourishment attempts on the north end of Figure Eight Island. The performance of some of the beach fills placed on the north end of Figure Eight Island since 1993-94 are documented by Dr. Cleary in Sub-Appendix A of Appendix B. While the six (6) previous beach fills were relatively small (less than 300,000 cy) compared to the beach fill volume simulated for Alternative 4, all of the fill material included in these six (6) beach fills was lost from the area fronting the sandbag revetments within a matter of months following placement.

Given the loss of all of the fill material between stations 60+00 and 105+00 by the end of year 4 under the 2006 conditions and essentially all of the material for 2012 conditions, periodic nourishment under Alternative 4 would need to be accomplished every four (4) years in order to prevent encroachment into the pre-nourished beach profile.

The sand spit on the north end of Figure Eight Island elongated slightly during the first two years of the simulation for both the 2006 and 2012 conditions and then stabilized over the last 3 years. Unlike Alternative 2 in which the sand spit began to erode after Year 4, the transport of sand northward from the beach fill toward Rich Inlet apparently was able to prevent erosion of the sand spit even through Year 7 of the simulation.

Model results showing bathymetric changes in Rich Inlet and the adjacent shorelines produced by the Delft3D model for Alternative 4 given 2006 and 2012 conditions are shown in Figures 5.14a to 5.19a and Figures 5.14b to 5.19b, respectively.

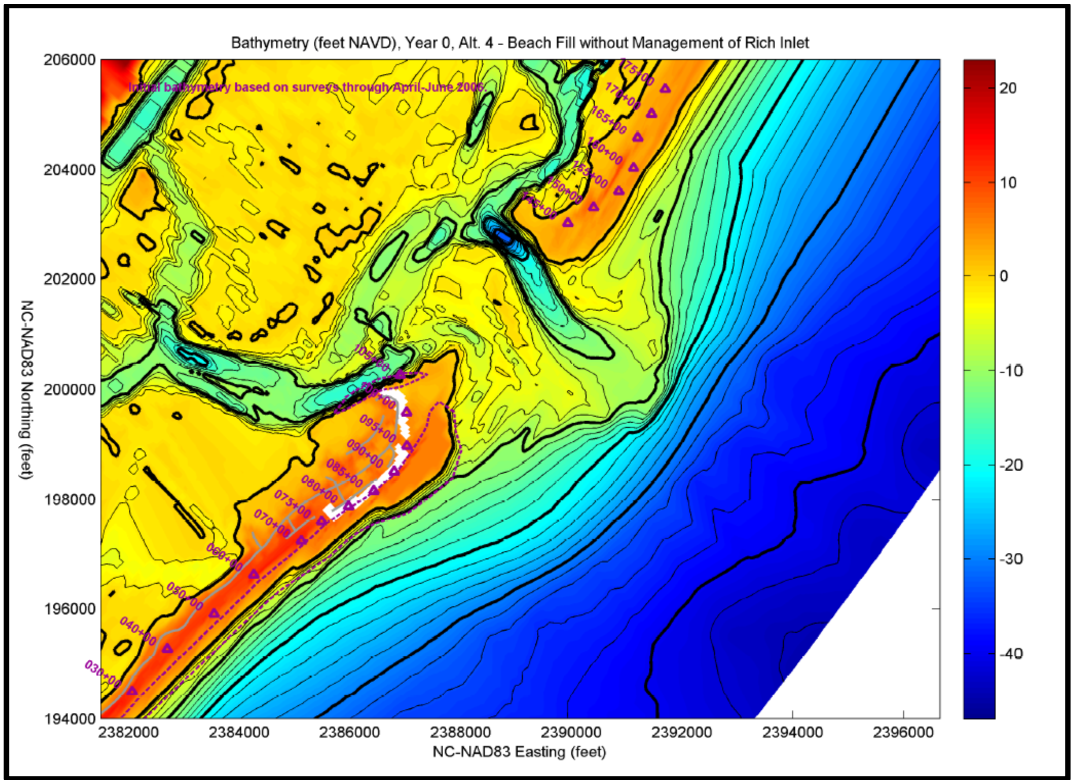

Figure 5.14a. Alternative 4: Year 0 after construction – 2006 conditions.

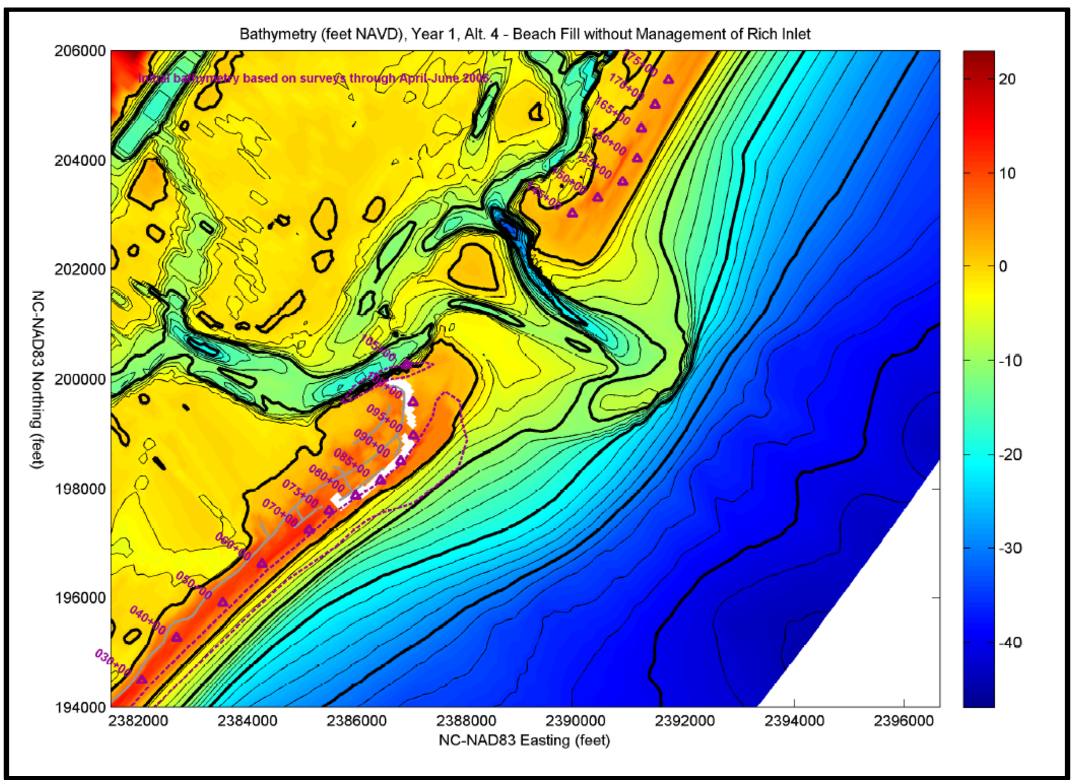

Figure 5.15a. Alternative 4: Year 1 after construction – 2006 conditions.

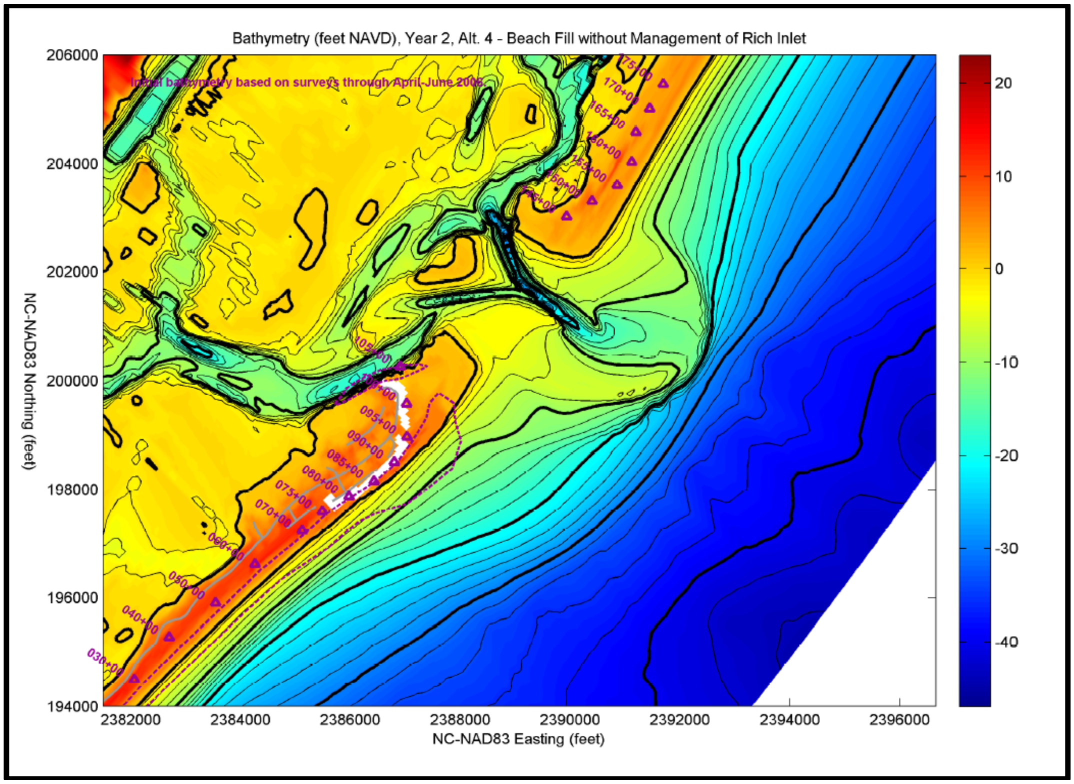

Figure 5.16a. Alternative 4: Year 2 after construction – 2006 conditions.

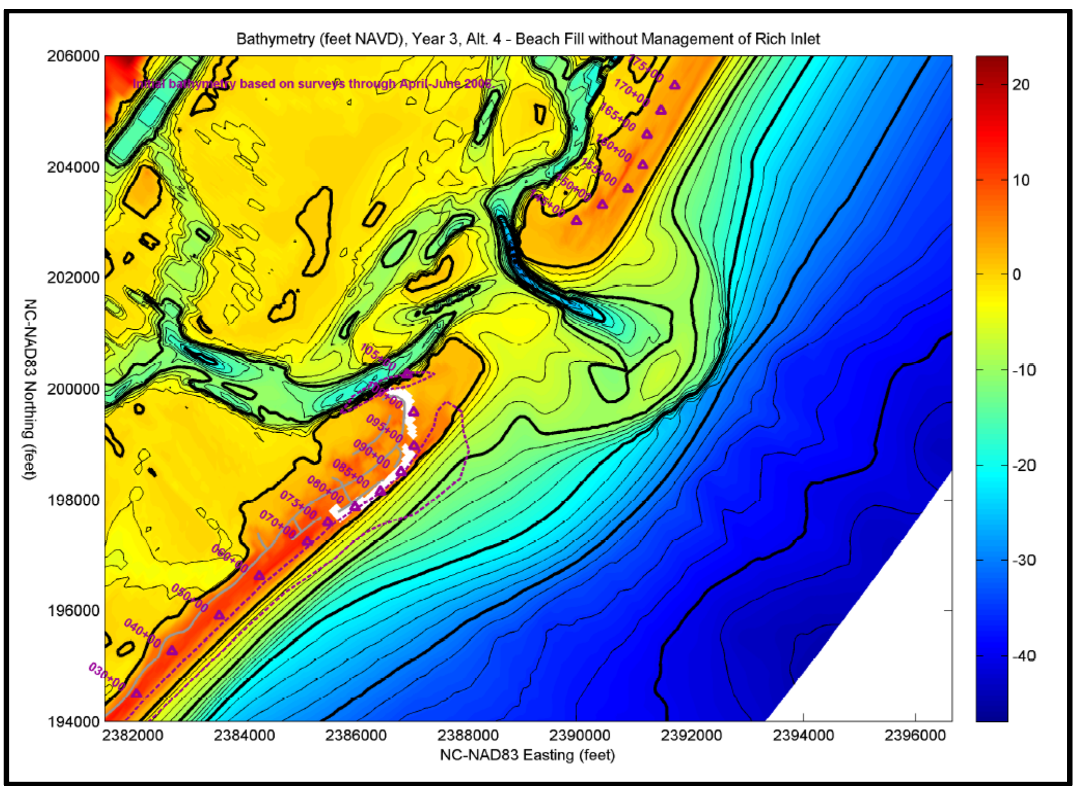

Figure 5.17a. Alternative 4: Year 3 after construction – 2006 conditions.

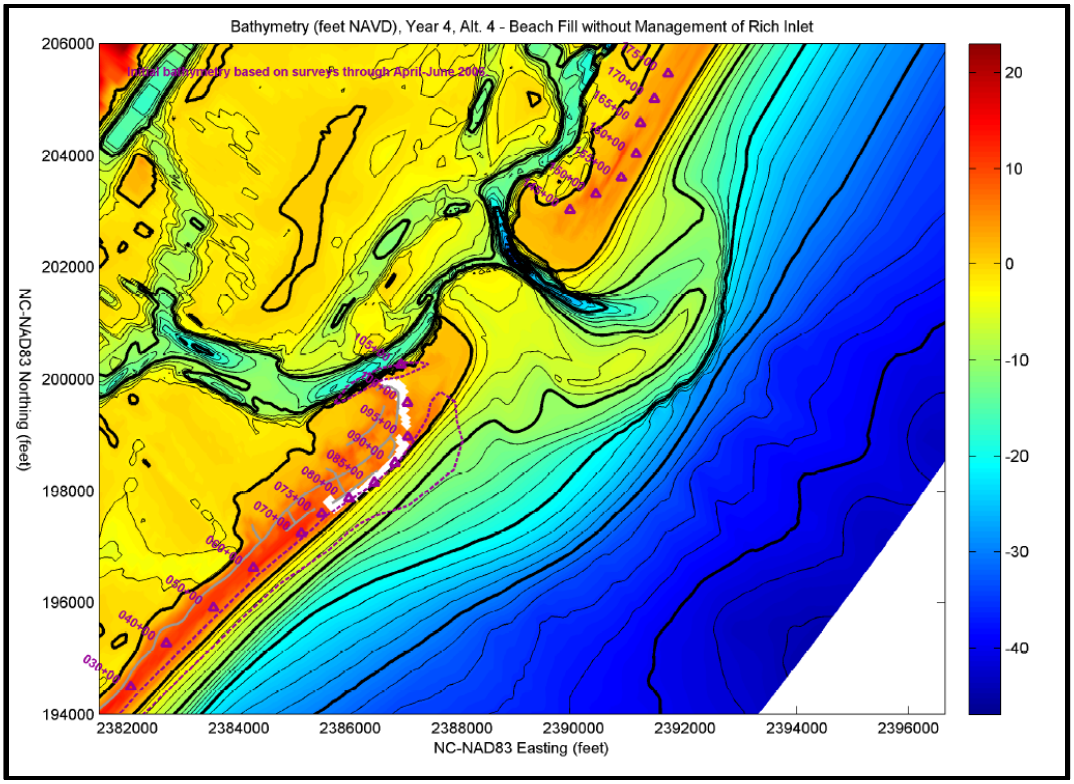

Figure 5.18a. Alternative 4: Year 4 after construction – 2006 conditions.

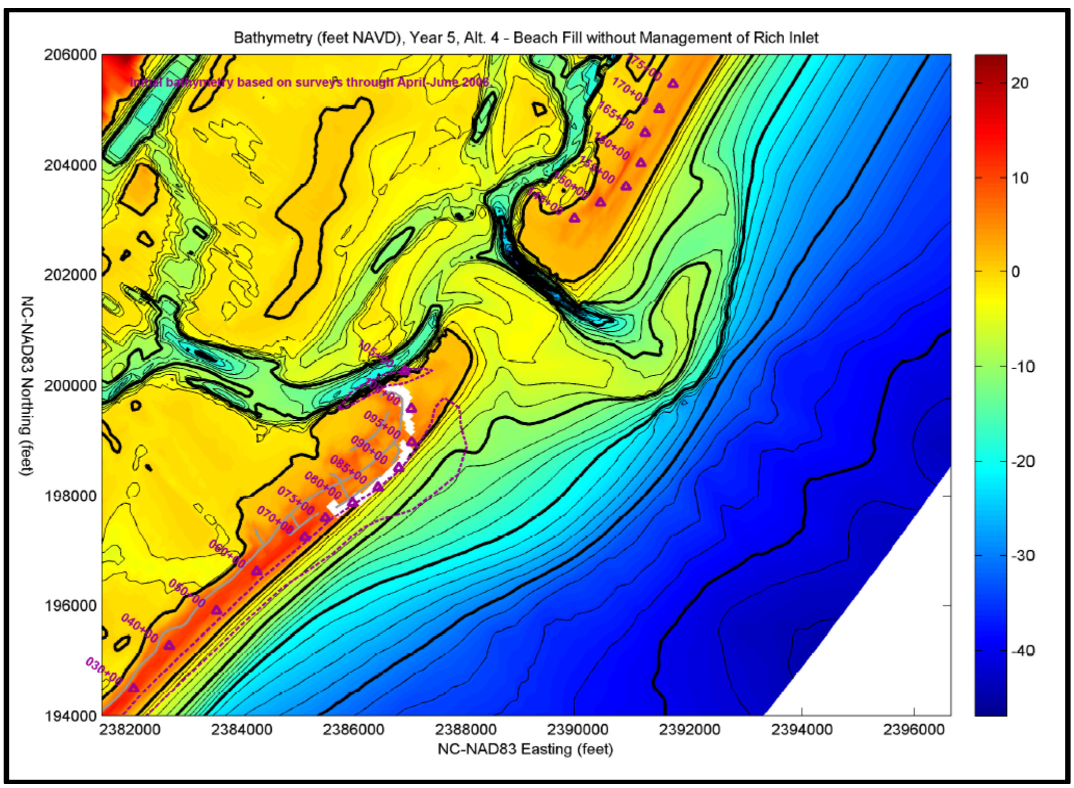

Figure 5.19a. Alternative 4: Year 5 after construction – 2006 conditions.

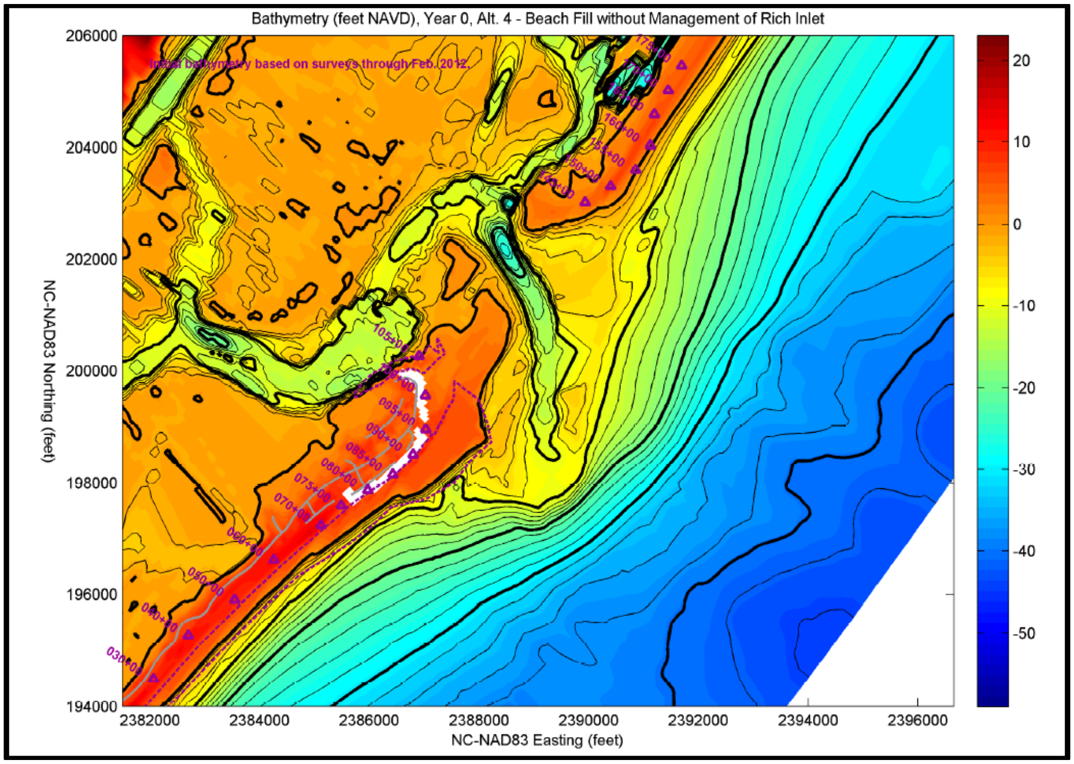

Figure 5.14b. Alternative 4: Year 0 after construction – 2012 conditions.

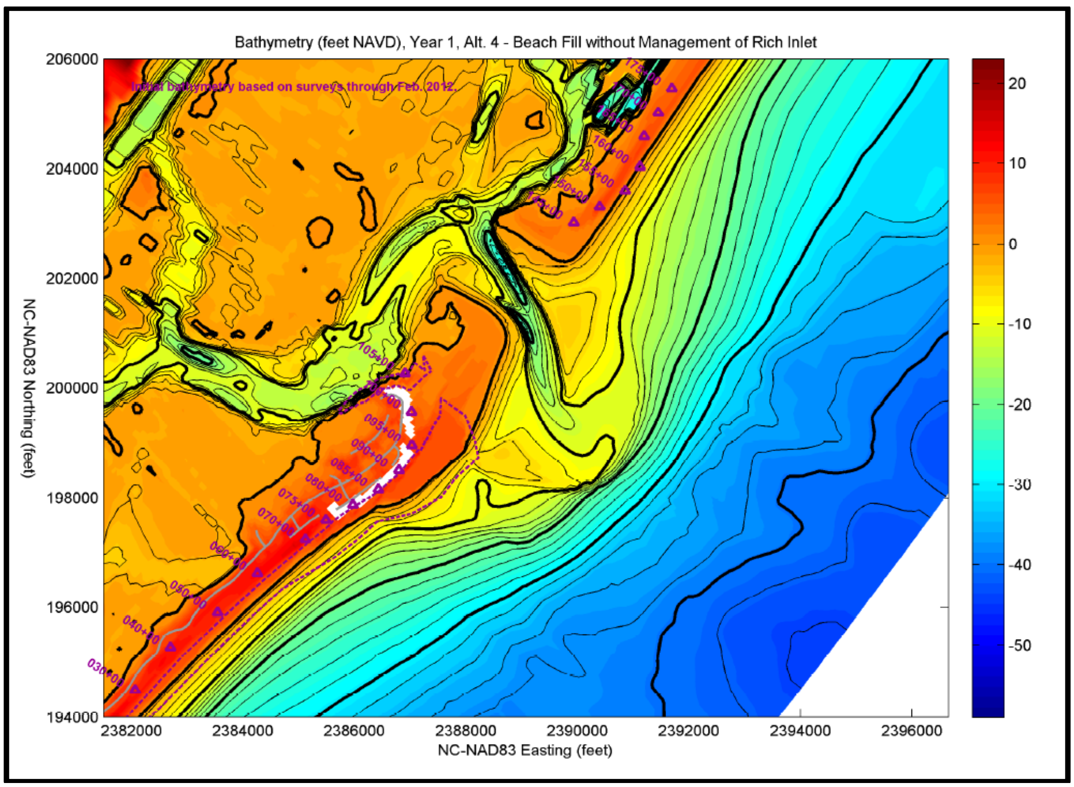

Figure 5.15b. Alternative 4: Year 1 after construction – 2012 conditions.

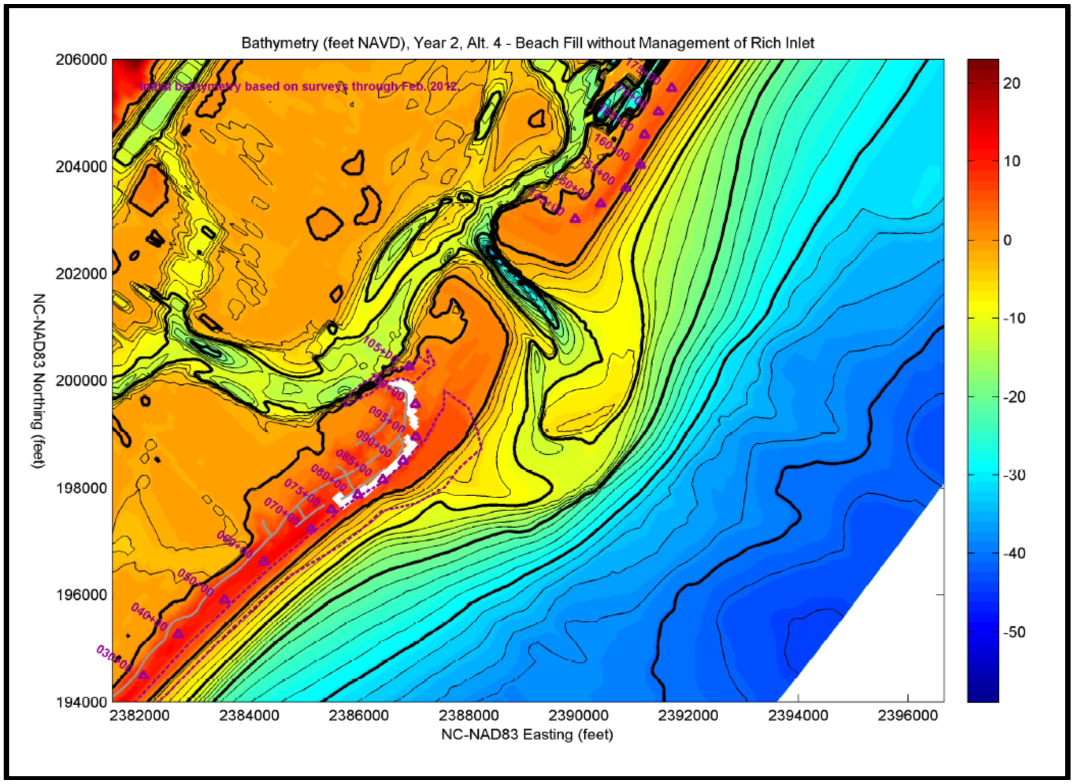

Figure 5.16b. Alternative 4: Year 2 after construction – 2012 conditions.

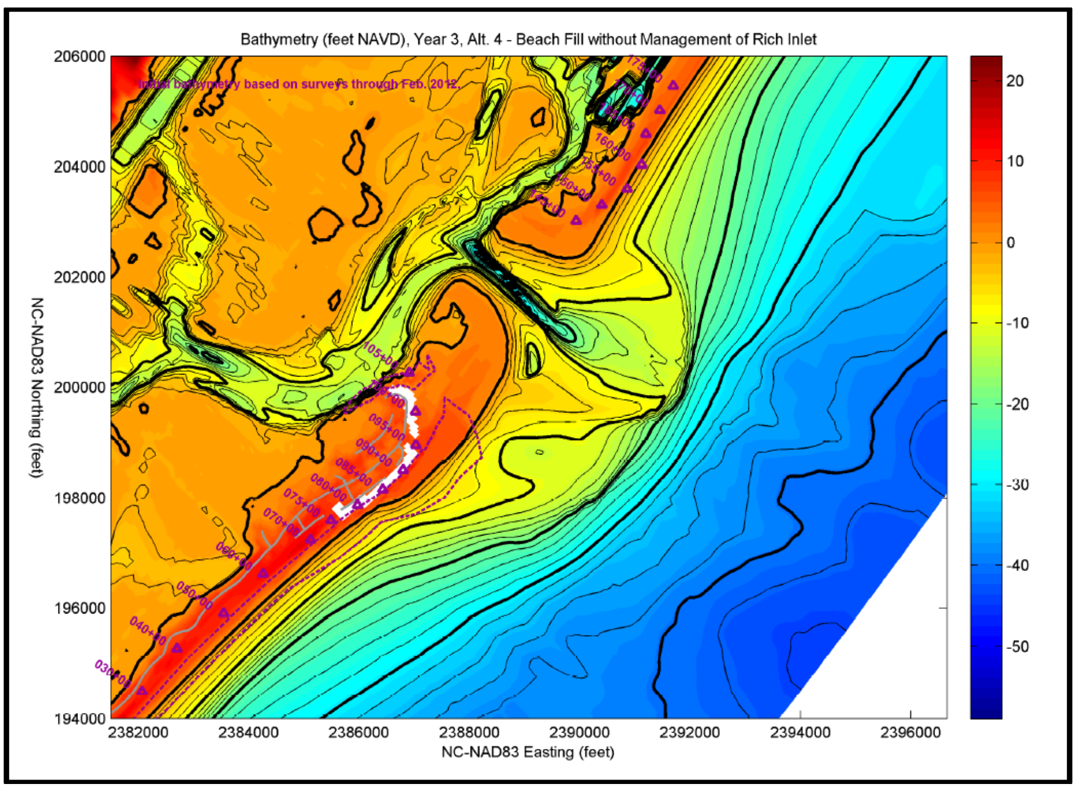

Figure 5.17b. Alternative 4: Year 3 after construction – 2012 conditions.

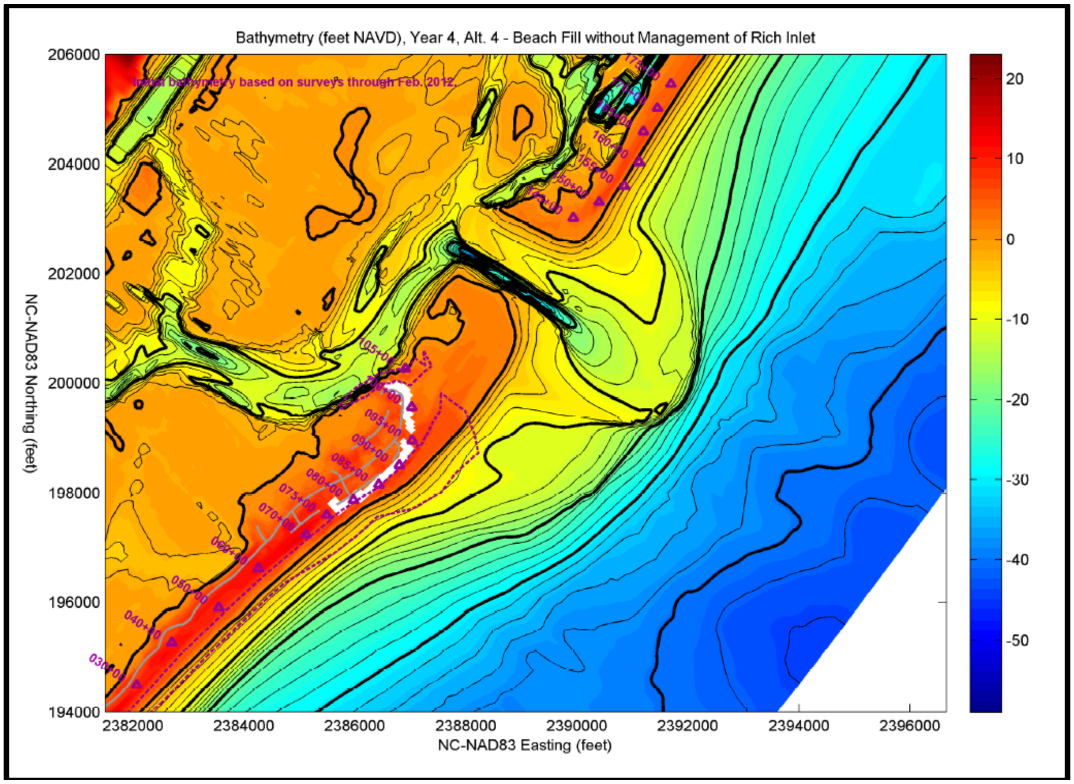

Figure 5.18b. Alternative 4: Year 4 after construction – 2012 conditions.

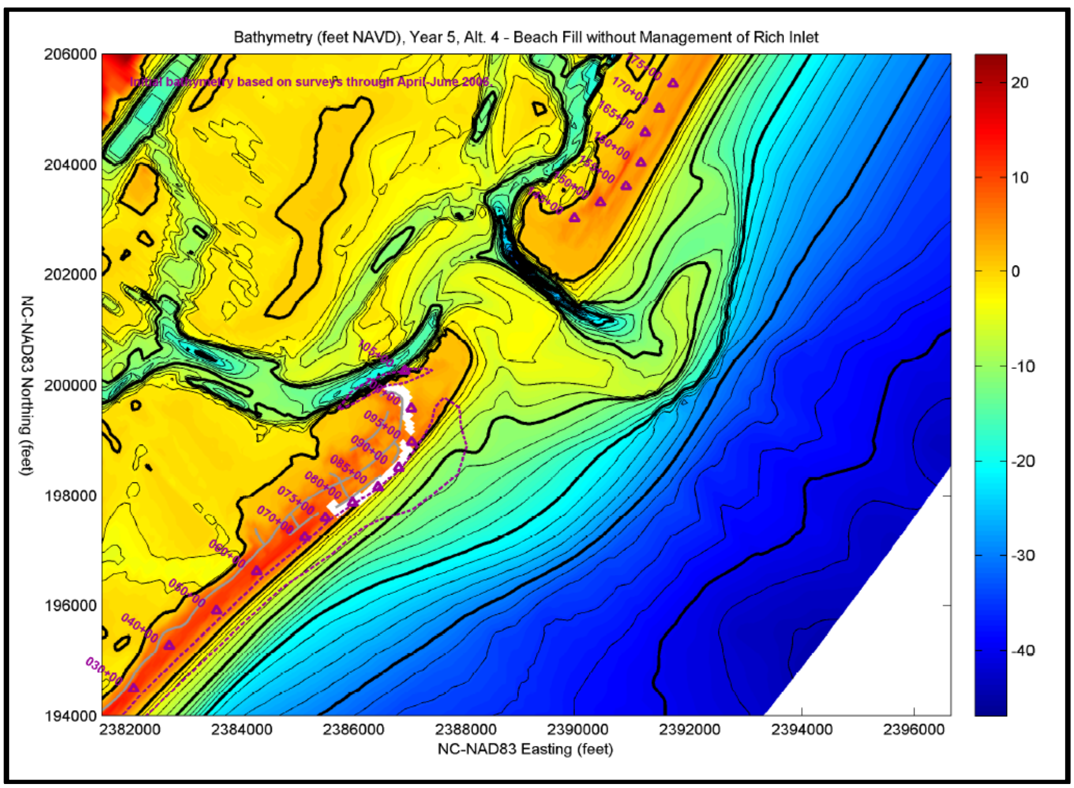

Figure 5.19a. Alternative 4: Year 5 after construction – 2012 conditions.

Terminal Groin Alternatives (Alternative 5)

In early 2010, the State of North Carolina explored the environmental impacts attributable to a series of five (5) terminal groins located in Florida and North Carolina within the "North Carolina Terminal Groin Study Final Report" (NCDENR, 2010). This report included a review of past scientific, engineering, and publicly accessible information and data related to the five terminal groin projects, two (2) of which are located in North Carolina. Amongst the conclusions drawn from the report, it stated that "the environmental effects of a terminal groin structure alone could not be assessed for the sites without considering the associated beach nourishment activity" (NCDENR, 2010). Because all of the terminal groin alternatives considered for Figure Eight Island include a beach nourishment project to be constructed in conjunction of the terminal groin, the findings from the study would generally apply and are therefore included below where applicable.

One of the terminal groin structures used in the NCDENR report was the Oregon Inlet terminal groin located in the Outer Banks of North Carolina. In 1989, the North Carolina Department of Transportation (NCDOT) initiated construction of the Oregon Inlet terminal groin on Pea Island National Wildlife Refuge to provide protection from erosion occurring along the base of the Herbert C. Bonner Bridge, which spans the Oregon Inlet and connects Hatteras Island to Bodie Island, in Dare County. Permit stipulations required regular monitoring of the physical conditions along a six mile segment of the shoreline extending from the terminal groin southward on Pea Island. This post-construction monitoring was initiated after the completion of the terminal groin in 1991. As of June 2, 2011, results showed that the project erosion rates were much less than historical rates in the first four miles of the study area (Overton, 2011). In the fifth and sixth mile, the rates were closer to the historical rate; however, they did not exceed the historical rate at any point. Overton (2011) points out that the construction of the groin does not appear to have caused adverse impacts to the shoreline over the six-mile study area. It should be noted that since 1991, a total of 4.3 million cubic yards of material from the dredging of Oregon Inlet by the USACE has been placed on the beach, or immediately offshore of the beach within the study area. It is presumed that the placement of the terminal groin has helped to retain a net of 18.7 million cubic yards of material on the beaches within the study area (Overton, pers. comm.). In summary, as stated above, the construction of the groin does not appear to have caused an adverse impact on the shoreline over the six mile study area (Overton, pers. comm.; Overton, 2011). Also, it may be presumed that some of this decrease of erosion can be attributed to the placement of the material along this stretch of shoreline. However, the placement of fill along Pea Island does not distract from the general improvement of the shoreline conditions along the north end of Pea Island following the installation of the terminal groin since terminal groins are to be used in conjunction with beach fill.

The other terminal groin in North Carolina is located along the northeast beach at Fort Macon State Park adjacent to Beaufort Inlet, which is a federally maintained channel with an authorized depth of 47 feet. Outside of the DENR terminal groin report, no research or studies to our knowledge have analyzed physical or biological changes associated with this structure. The groin and associated seawall was initially constructed in 1961-1962 in response to the westward migration of the inlet shoulder induced by the projection of Shackleford Point into the inlet. The beach erosion structures were built in phases and reached completion in 1970. The resulting structure included a seawall-terminal groin system 2,250 feet in length. However, the original groin only extended about 1,100 feet seaward of the pre-construction shoreline. Today, much of the groin is buried in dry beach.

Four alternatives were evaluated for Figure Eight Island that included a terminal groin on the north end of the island near the south shoulder of Rich Inlet. The terminal groin alternatives, designated as 5A, 5B, 5C, and 5D, were evaluated using the Delft3D model using 2006 data. Alternatives 5A and 5B were originally presented in the DEIS, released in January 2012, while Alternatives 5C and 5D were added based on opposition received from several property owners on the north end of Figure Eight Island relative to the proposed position of the terminal groin presented in the DEIS. The position and alignment of the four terminal groin alternatives are shown on Figure 5.20. The addition of Alternatives 5C and 5D prompted a new round of model tests to obtain comparison of the relative differences in the impacts of the four terminal groin alternatives on both Figure Eight Island and Hutaff Island as well as Rich Inlet and its environs.

In general, the new round of model tests included runs using conditions existing in both 2006 and 2012. As stated in Chapter 3, all four (4) terminal groin alternatives were modeled using the revised model set-up for the 2006 inlet and shoreline conditions; but only Alternative 5D of the groin options was simulated using the 2012 conditions.

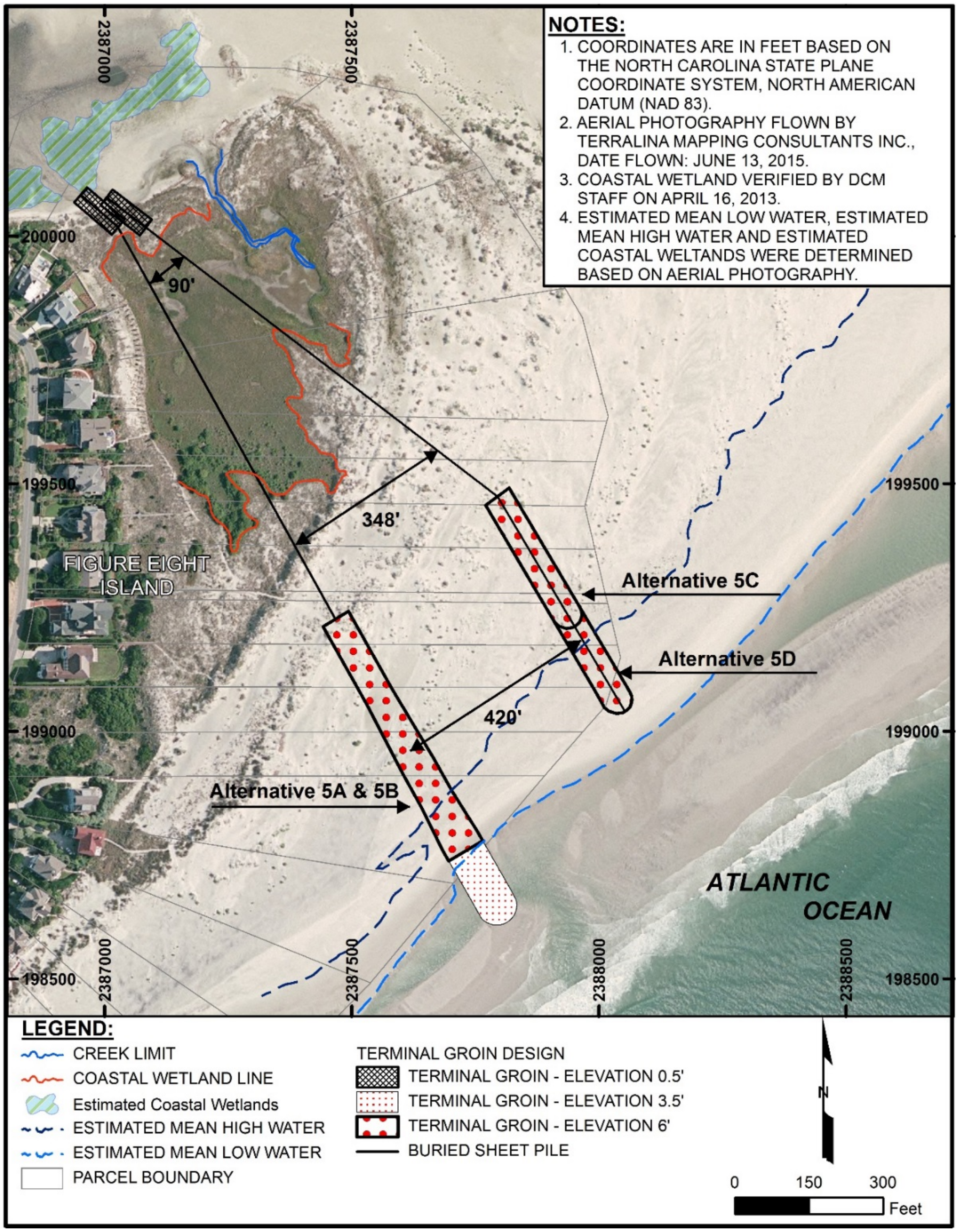

Figure 5.20. Terminal groin layout for all four (4) terminal groin alternatives on the north end of the island.

- Alternative 5A

Alternative 5A includes a 1,600-foot long terminal groin constructed near baseline station 100+00 and a beach fill extending from the terminal groin south to station F90+00 which is just south of Bridge road. A beach fill would also be placed along 1,400-feet of the Nixon Channel shoreline. Material to construct the beach fills would be obtained from the previously permitted area in Nixon Channel and a new channel connecting Nixon Channel to the gorge of Rich Inlet.

The Delft3D model results for Alternative 5A, given the 2006 conditions, which are shown in Figures 5.22 to 5.27, indicated that the new channel connecting Nixon Channel to the inlet gorge would shoal rather rapidly during the first two years following construction. The channel also migrated northwest eventually merging with the channel that skirts around the landward lobe of the flood tide delta. Following this initial two year adjustment, shoaling decreased with the channel actually experiencing some scour during the last year of the simulation. A plot of the model indicating shoaling in the new channel connector and in the previously permitted area in Nixon Channel is provided on Figure 5.21. The model also indicated that the beach fill placed along the Nixon Channel shoreline did provide some erosion protection during the 5-year simulation period.

Between year 2 and year 5 of the simulation, the general response of Rich Inlet under Alternative 5A included the inlet ocean bar channel migrating toward Hutaff Island which resulted in the buildup of material in the ebb tide delta on the north side of Rich Inlet and the elongation of the south end of Hutaff Island into Rich Inlet.

The sand spit projecting off the north end of Figure Eight Island initially elongated, projecting into the dredged channel cut across the flood tide delta. This initial elongation appeared to be due to sediment moving out of the fill area and past the terminal groin. The sand spit began to recede between years 1 and 5 of the simulation with the eroded portions of the spit morphing into a subaqueous feature.

By the end of year 4 of the simulation, the fillet south of the terminal groin had stabilized, protecting approximately 1,500 feet of shoreline south of the terminal groin. The stable nature of the sand fillet would indicate material was able to move past the structure.

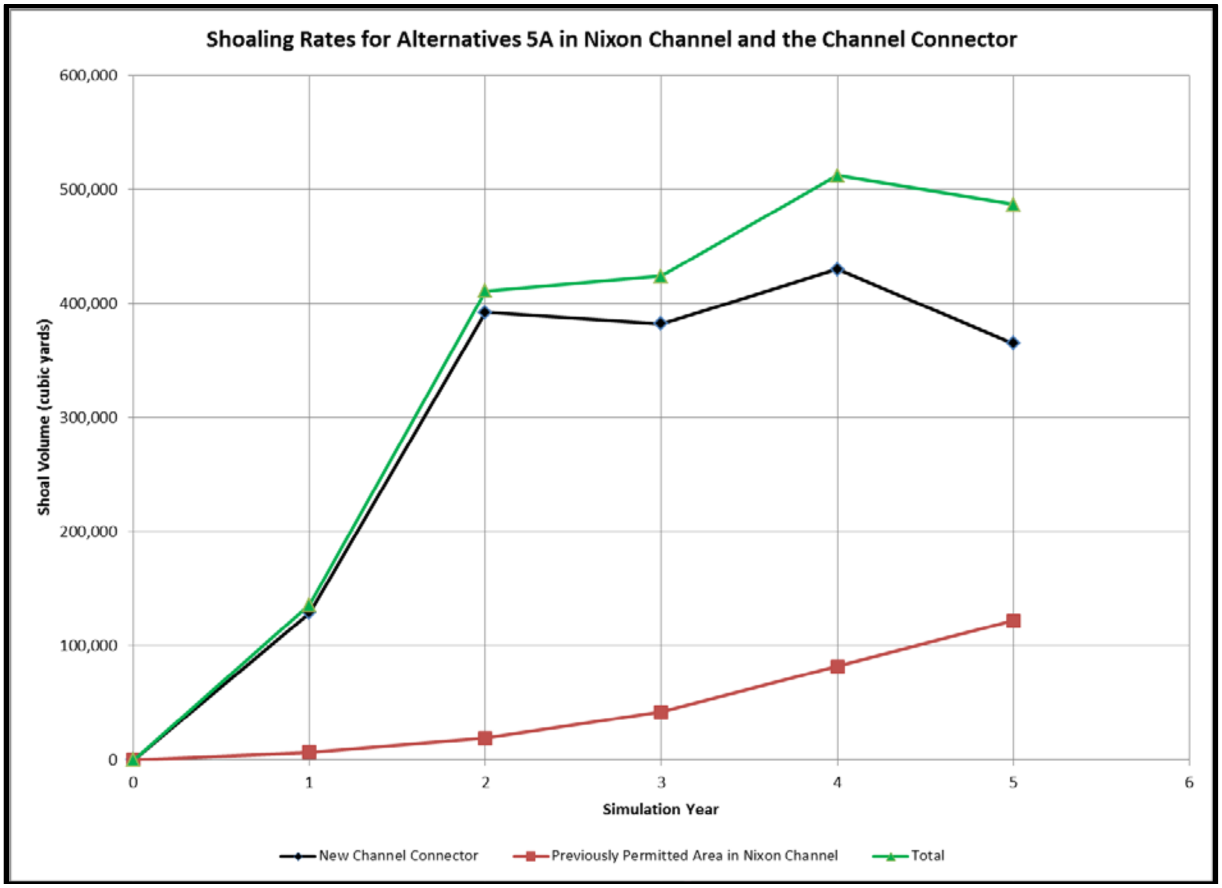

Figure 5.21. Delft3D model indicated shoaling in Nixon Channel and the channel connector – Alternative 5A.

Figure Eight Island.

A focus of shoreline changes along Figure Eight Island for Alternative 5A was on the performance of the beach fill that would be placed between Bridge Road and Rich Inlet. Table 5.8 provides the model indicated volume changes along the north end of Figure Eight Island and the south end of Hutaff Island, under the 2006 conditions. Alternative 5A was not modeled using the 2012 conditions.

The Delft3D model shows that the beach segment between F90+00 and 60+00 gained material over the 5-year simulation (Table 5.8). This was apparently due to higher rates of sand transport to the south out of the northern beach segment. The fill distribution density in the area immediately south of the terminal groin, as described in Chapter 3, would create a large seaward bulge in the shoreline that would be conducive to horizontal spreading of the fill material southward of the nodal point.

Table 5.8. Average annual rate of volume change (cubic yards/year) - Figure Eight Island and the southern end of Hutaff Island obtained from the Delft3D model for Alternatives 2, 3, 4 and 5A- 2006 conditions.

Alternative	Figure Eight Island		Hutaff Island	
	F90+00 to 60+00	60+00 to 105+00	148+60 to 175+00	175+00 to 215+00
2	+18,000	-84,000	+53,000	-35,000
3	-2,000	-99,000	-31,000	-36,000
4	+30,000	-176,000	+57,000	-30,000
5A	+20,000	-85,000(1)	-33,000	-52,000

(1)Fill for 5A ends at the terminal groin (~station 100+00)

In the beach segment between 60+00 and 100+00, the beach fill lost about 56.0% of the initial placement volume during the first two years of the simulation (Table 5.9). Losses from the fill moderated slightly over the next 3 years; however, by the end of year 5, only 7.4% of the initial fill volume remained on the beach profile above the -24-foot depth of closure. The volume of fill remaining on the profile above -6 feet NAVD at the end of year 5 was 15.9%. While the fill continued to provide protection to the pre-nourished beach through year 5 of the simulation, particularly the upper portion of the profile, beach nourishment would be needed at the end of year 5 in order to provide continuing protection to the upland areas.

Table 5.9. Percent of Alternative 5A initial beach fill volume remaining after each year of the 5-year Delft3D model simulation

Beach Segment	Percent of Beach Fill Remaining after:				
	1 year	2 years	3 years	4 years	5 years
F90 to 60	104.4	116.5	121.4	124.9	123.7
60 to 100	61.7	44.0	25.5	15.3	7.4
Entire Fill Area (F90 to 100)	82.3	79.0	71.8	68.2	63.6

Volumetric losses from the beach fill for Alternative 5A between stations 60+00 and 100+00 averaged 85,000 cubic yards/year over the 5-year simulation period. As mentioned above and described in Chapter 3, the design of the beach fill for Alternative 5A included a much higher concentration of fill north of station 50+00 to the terminal groin. The bulbous shape of the fill induced high rates of sediment transport out of this area to both the north and south.

The high rates of loss for the area between 60+00 and 100+00 were primarily attributable to losses that occurred seaward of the end of the terminal groin as the upper portion of the beach remained fairly stable (see Figures 5.22 through 5.27). The model results support the movement of sediment past the terminal groin and into Rich Inlet while the retention of material in the upper part of the beach profile would provide a quasi-permanent increase in the protective beach fronting the ocean front structures in this area.

Hutaff Island.

The southern 2,640 feet of Hutaff Island eroded under Alternative 5A at the end of the 5 year model simulation. The erosion along the south end of Hutaff Island appeared to be related to differences in the behavior of the bar channel which could have been induced by the presence of the terminal groin. During the majority of the 5-year simulation under Alternative 5A, the bar channel did not assume an orientation toward Hutaff Island until after year 4 of the simulation. This delayed response of the inlet appeared to be due to differences in flow patterns associated with the new channel between the Rich Inlet gorge and Nixon Channel. This difference in flow pattern could have been due to the presence of the terminal groin. Once the new channel shoaled to near pre-project conditions, the pattern of flow from the interior channels became similar to the flow patterns under pre-project conditions and the inlet bar channel began to respond accordingly.

Farther north, between stations 175+00 and 215+00, model indicated losses averaged 52,000 cubic yards/year over the 5-year simulation. Again, this response could have been related to the behavior of the bar channel under Alternative 5A, which could have been an impact induced by the terminal groin.

Along the salt marsh shoreline facing the entrance of Rich Inlet, currents are expected to be reduced slightly for about 3 to 4 years as flow is shifted from the back channel into the new dredge cuts thereby reducing potential shoreline and salt marsh erosion at that location.

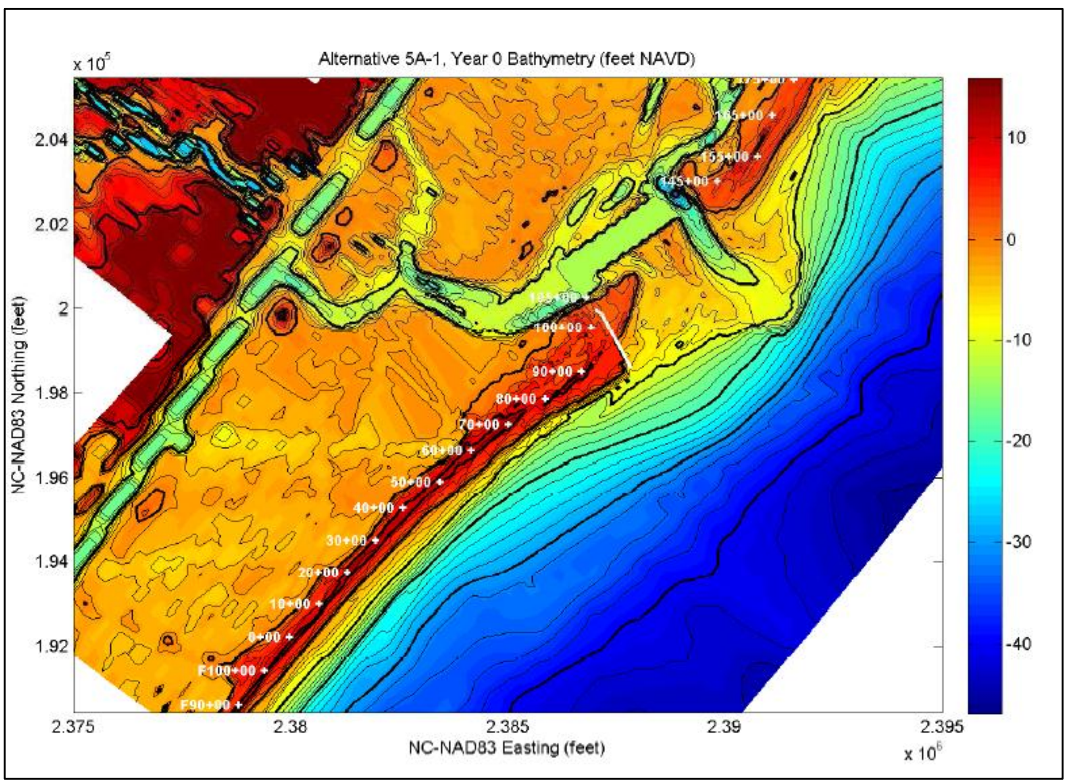

Figure 5.22. Alternative 5A: Year 0 after construction – 2006 conditions.

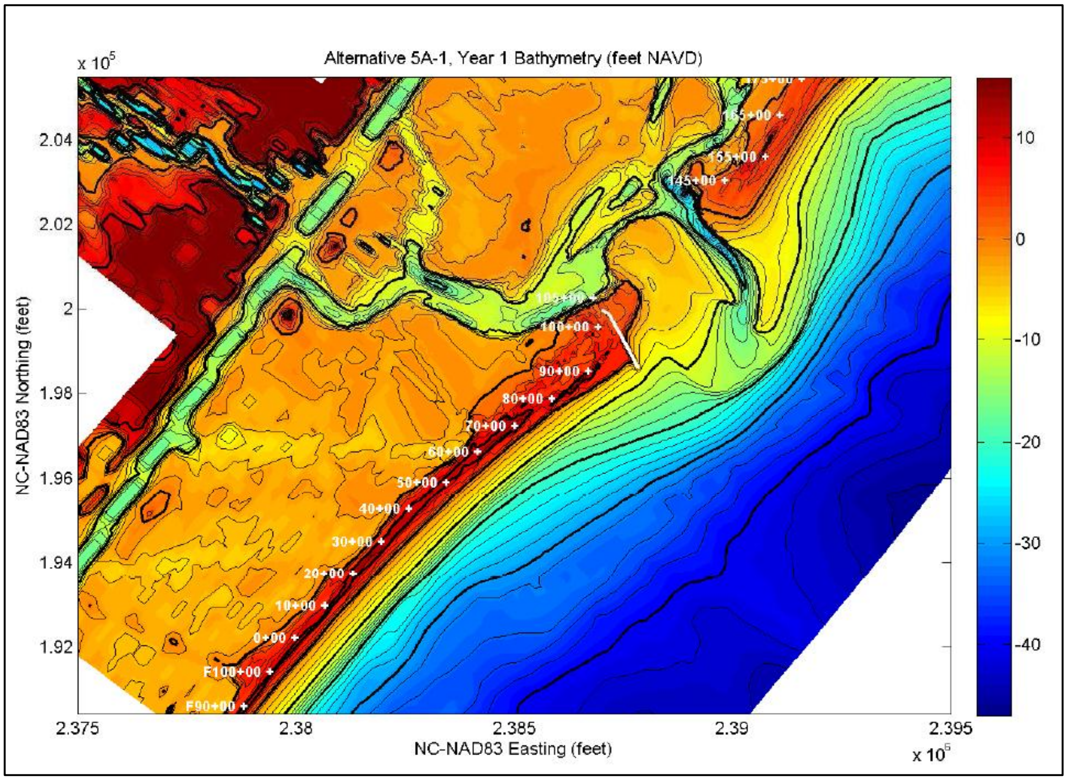

Figure 5.23. Alternative 5A: Year 1 after construction – 2006 conditions.

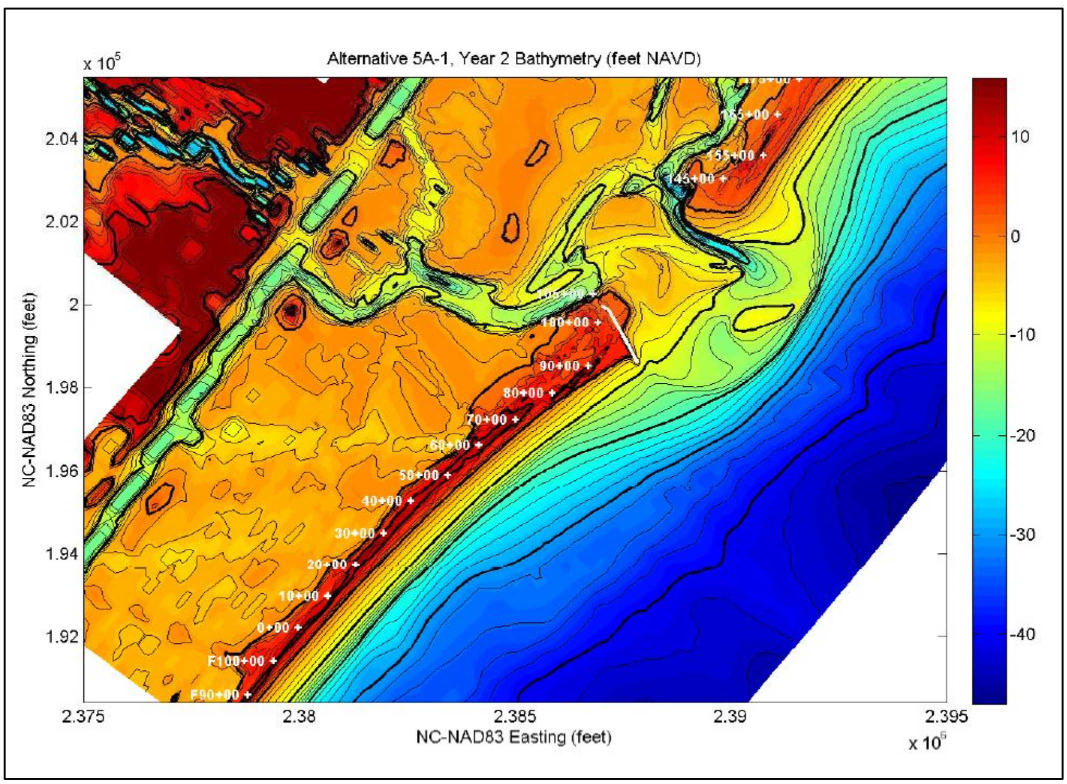

Figure 5.24. Alternative 5A: Year 2 after construction – 2006 conditions.

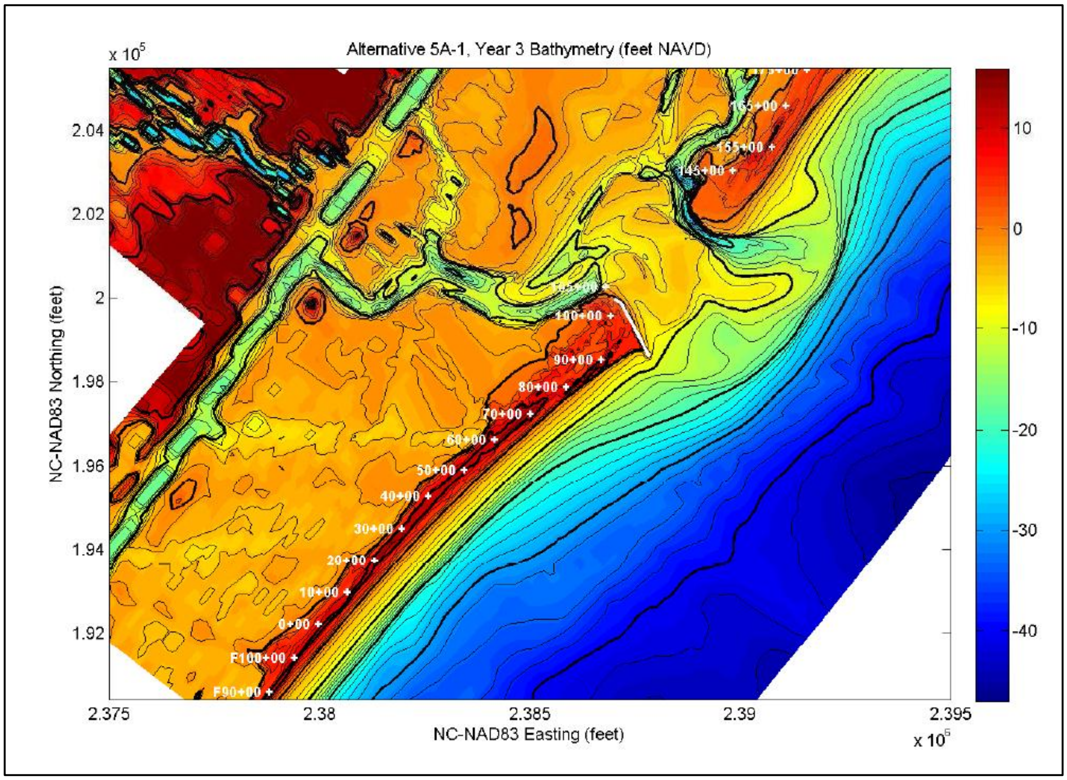

Figure 5.25. Alternative 5A: Year 3 after construction – 2006 conditions.

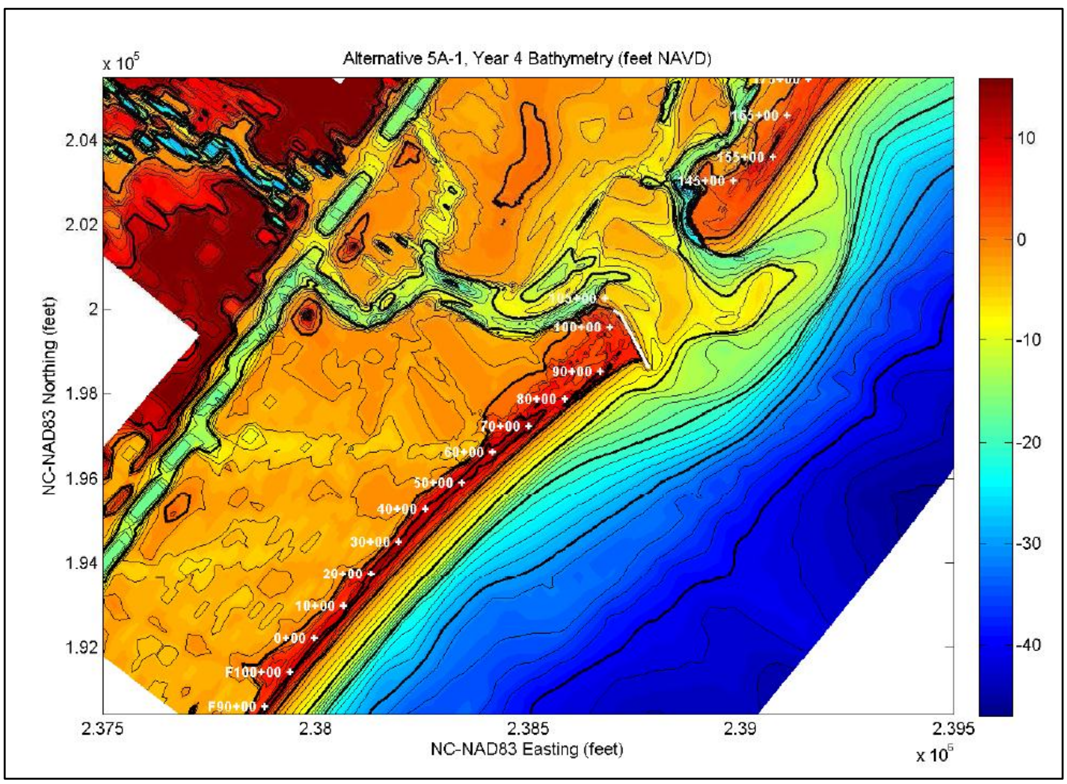

Figure 5.26. Alternative 5A: Year 4 after construction – 2006 conditions.

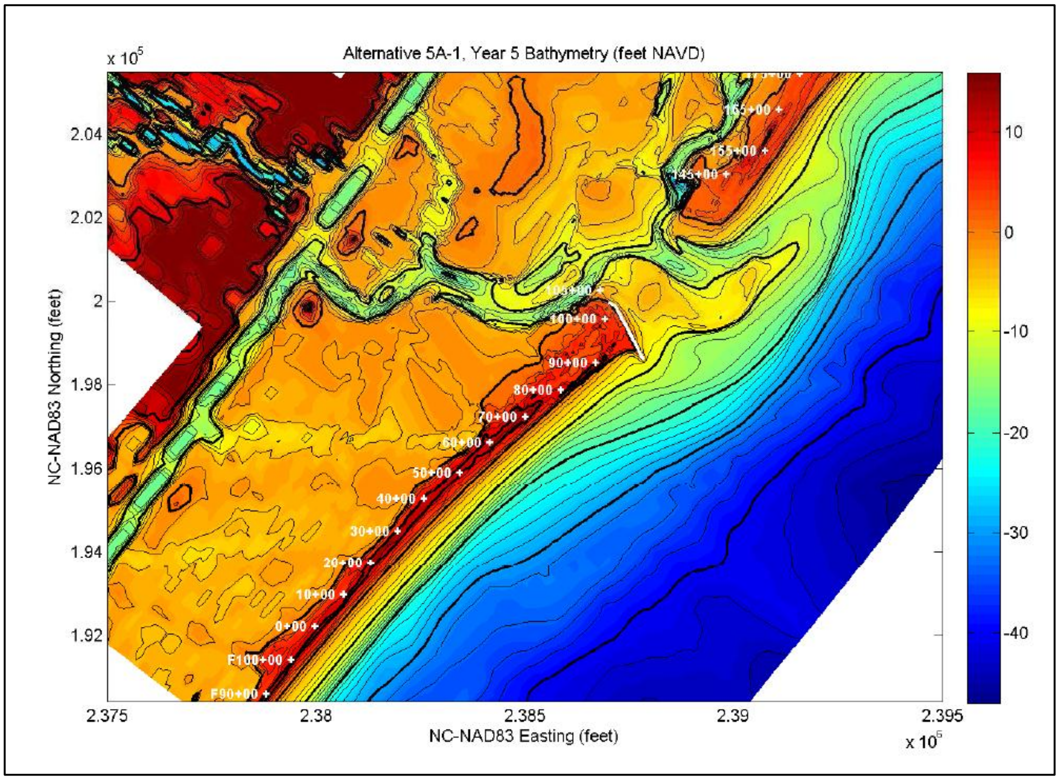

Figure 5.27. Alternative 5A: Year 5 after construction – 2006 conditions.

- Alternative 5B

The terminal groin for Alternative 5B would have the same design as that described for Alternative 5A as would the beach fill along Nixon Channel. With regard to the beach fill along the ocean shoreline, analysis of the Delft3D model results for Alternative 5A indicated the initial beach fill was excessive, particularly along the segment of the beach south of station 80+00. Also, the segment of the shoreline between stations F90+00 and 30+00 accreted while the area between stations 30+00 and 60+00 experienced very minor losses. Again, the beach fill design associated with Alternative 5A was based on the optimal utilization of the material removed to construct the new channel connector from the inlet gorge into Nixon Channel not on the beach fill volume needed to offset shoreline erosion tendencies. Therefore, the beach fill for 5B was designed to address erosion protection needs along the northern portion of Figure Eight Island.

Based on the analysis of the model results for Alternative 5A, the beach fill for Alternative 5B was limited to the area between station 60+00 (approximately 322 Beach Road North) and the terminal groin (station 100+00). Material to construct the beach fill for Alternative 5B would be derived from maintenance of the previously permitted area in Nixon Channel.

The Delft3D model results for Alternative 5B are provided on Figures 5.28 to 5.33 for the 2006 conditions. Again, due to the unlikely approval of the position and alignment of the terminal groin under Alternative 5B, the new round of Delft3D model runs did not include runs using the 2012 conditions.

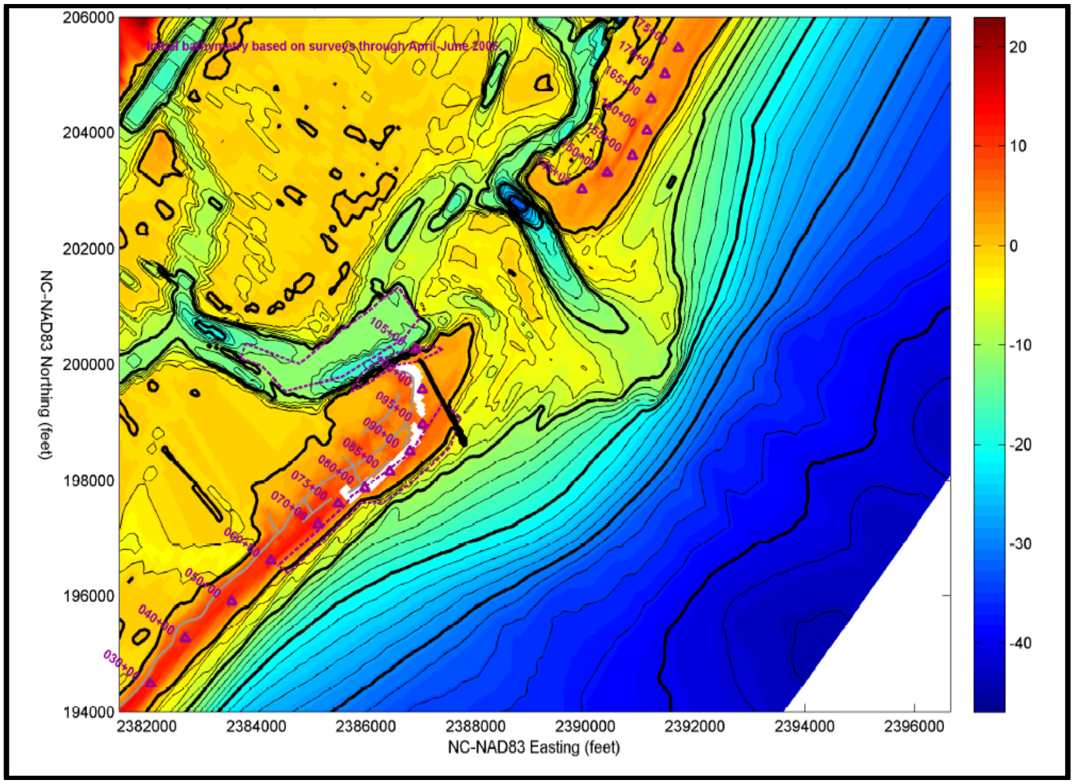

Figure 5.28. Alternative 5B: Year 0 after construction – 2006 conditions.

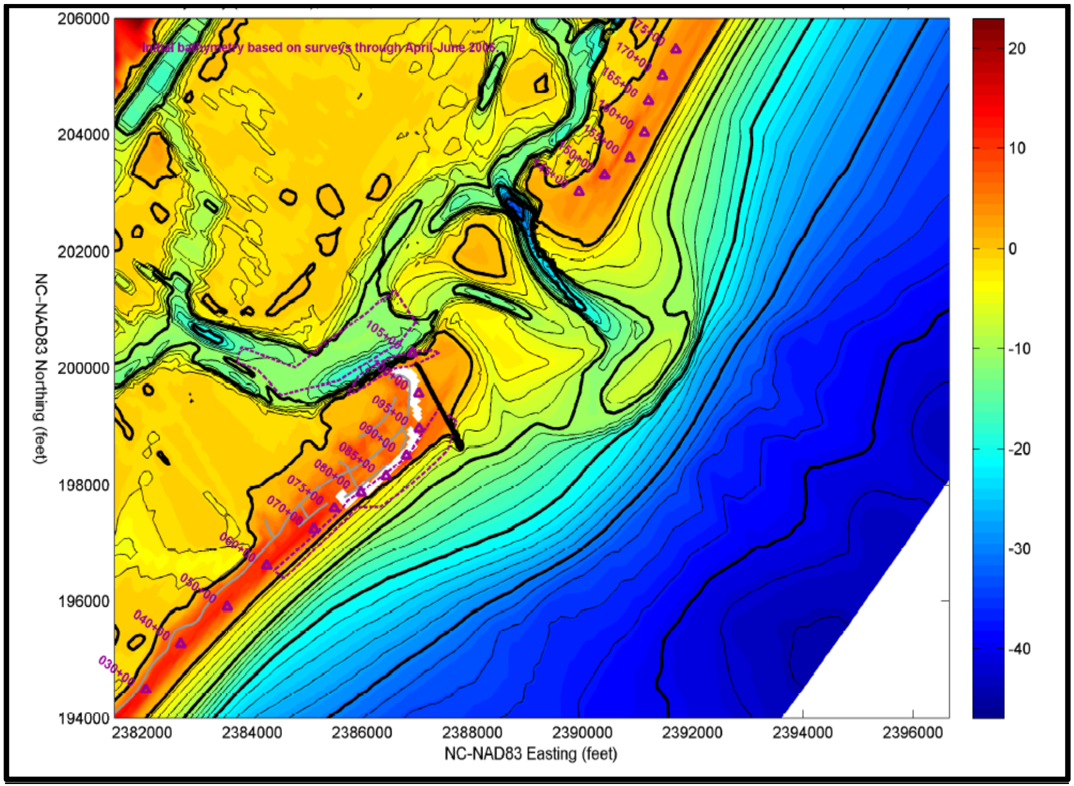

Figure 5.29. Alternative 5B : Year 1 after construction – 2006 conditions.

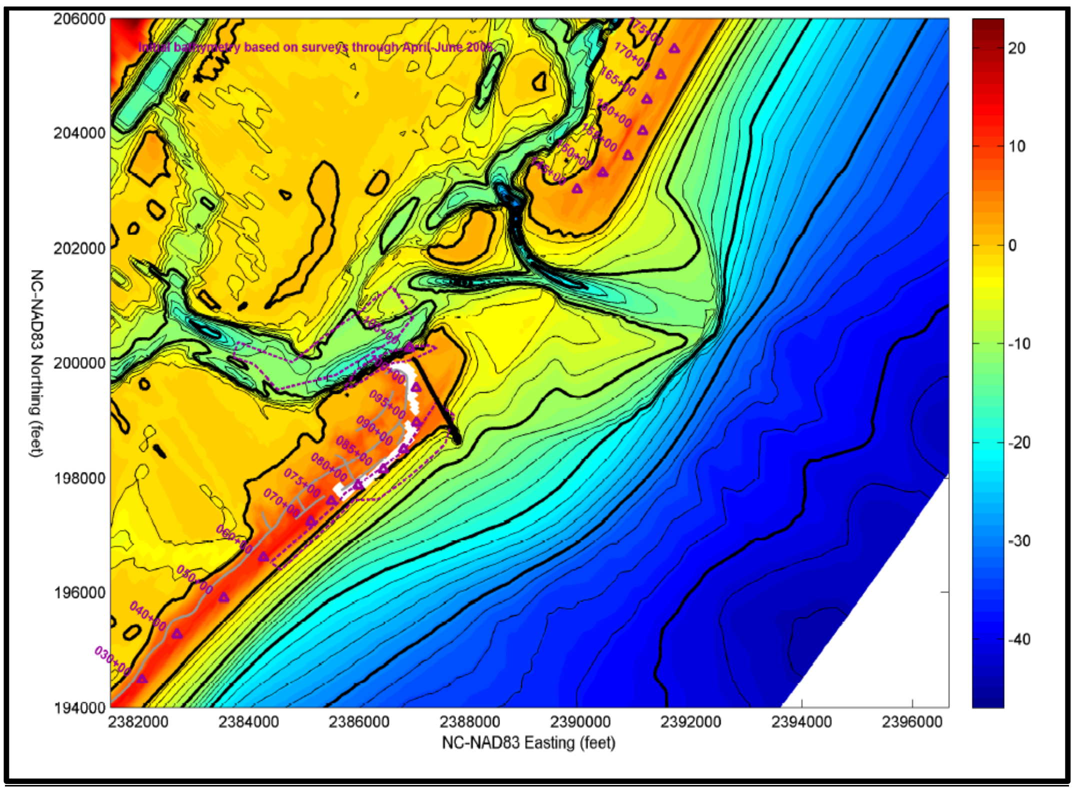

Figure 5.30. Alternative 5B: Year 2 after construction – 2006 conditions.

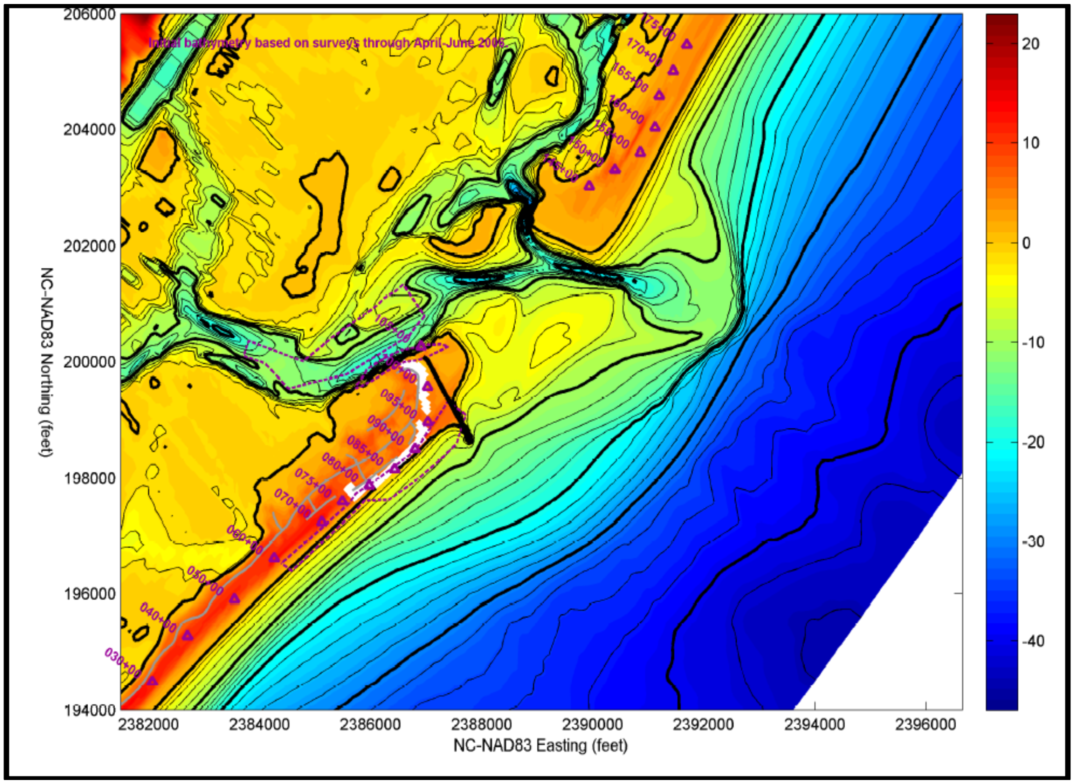

Figure 5.31. Alternative 5B: Year 3 after construction – 2006 conditions.

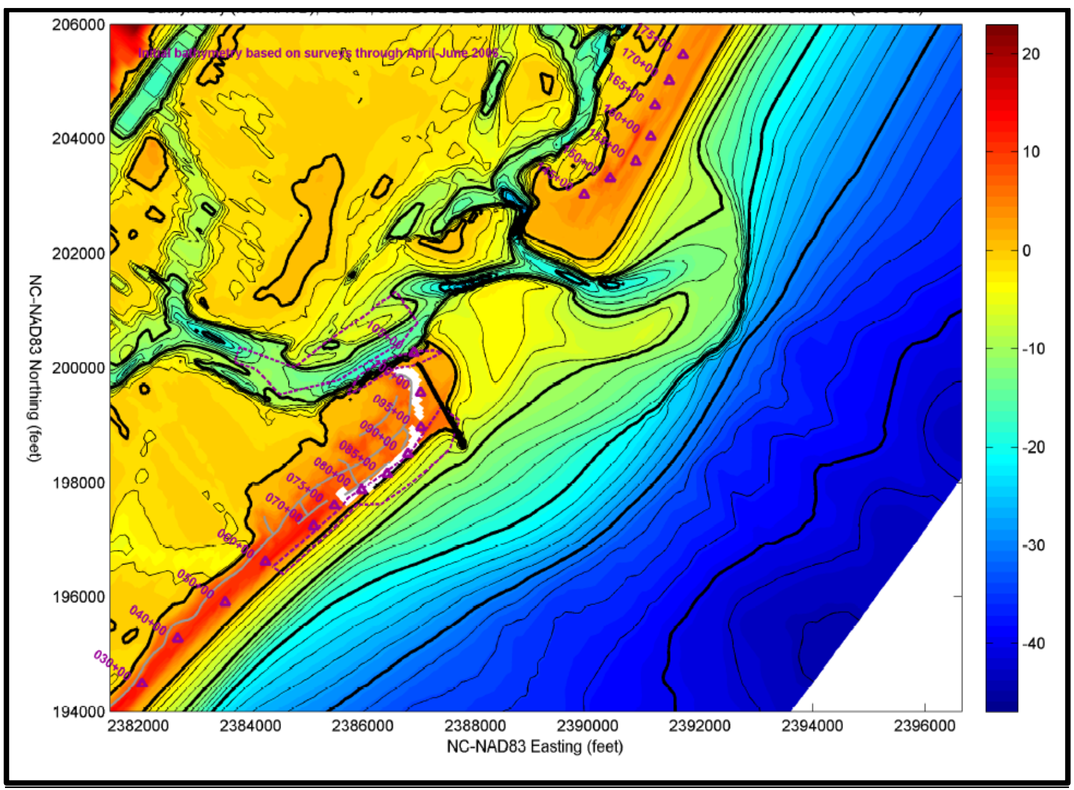

Figure 5.32. Alternative 5B: Year 4 after construction – 2006 conditions.

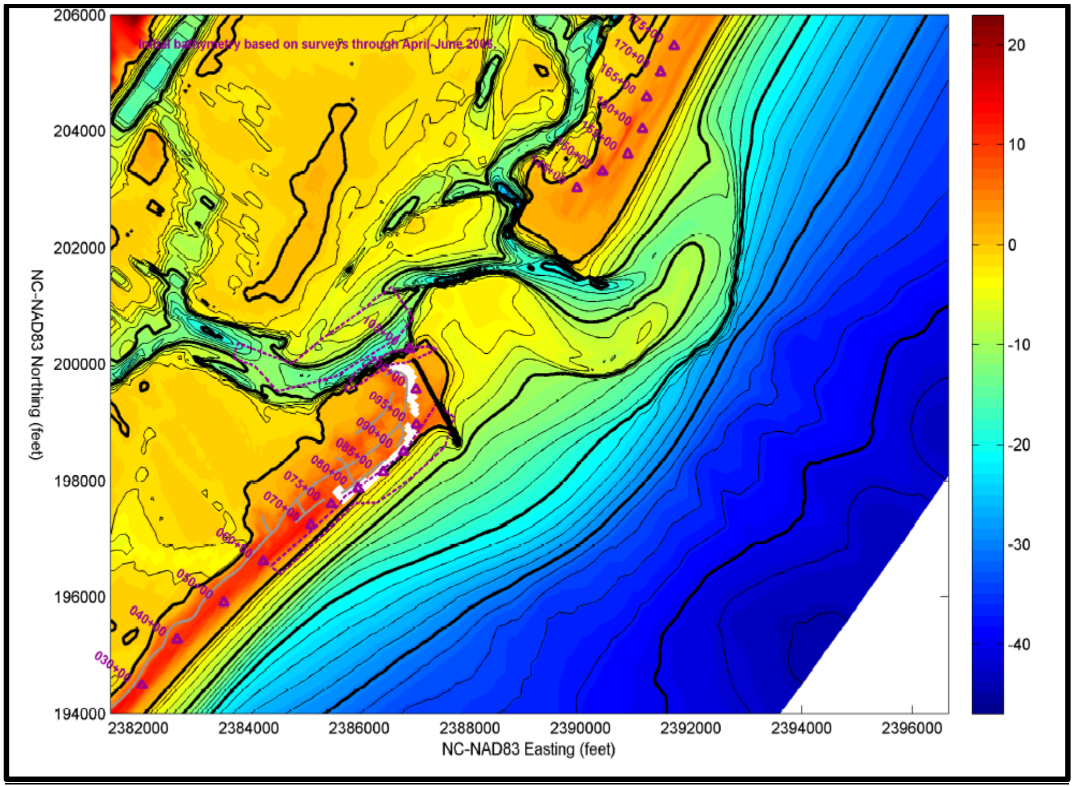

Figure 5.33. Alternative 5B: Year 5 after construction – 2006 conditions.

Figure Eight Island.

The percentage of the initial beach fill remaining on the profile above the -24-foot depth of closure for Alternative 5B is provided in Table 5.10. By the end of year 4 of the simulation, the model indicated essentially all of the fill would be lost and the area would need to be nourished. The percent of fill remaining given in Table 5.10 is for the entire active profile out to a depth of -24 feet NAVD. A closer inspection of the fill performance found 7.3% of the fill placed above the -6-foot NAVD contour remained on the beach after 5 years and that the fill retained above -6 feet NAVD would continue to prevent encroachment into the pre-nourished upland areas in this segment.

Table 5.10. Percent of Alternative 5B initial beach fill volume remaining after each year of the 5-year Delft3D model simulation

Beach Segment	Percent of Beach Fill Remaining after:				
	1 year	2 years	3 years	4 years	5 years
F90 to 60(1)	NA	NA	NA	NA	NA
Entire Fill Area 60 to 100	59.6	33.8	10.1	-7.6	-29.8

(1)No fill would be placed between stations F90+00 and 60+00.

While some of the sand spit located north of the terminal groin remained at the end of year 5 of the simulation, most of the spit had morphed into a submerged sand flat.

Volume changes in the two beach segments on Figure Eight Island and Hutaff Island obtained from the results of the Delft3D model simulation for Alternative 5B are provided in Table 5.11.

Table 5.11. Average annual rate of volume change (cubic yards/year) - Figure Eight Island and the southern 6,640 feet of Hutaff Island obtained from the Delft3D for Alternatives 2, 3, 4, 5A, and 5B – 2006 conditions.

Alternative	Figure Eight Island		Hutaff Island	
	F90+00 to 60+00	60+00 to 105+00	148+60 to 175+00	175+00 to 215+00
2	+18,000	-84,000	+53,000	-35,000
3	-2,000	-99,000	-31,000	-26,000
4	+30,000	-176,000	+57,000	-30,000
5A	+20,000	-85,000	-33,000	-52,000
5B	+50,000	-51,000	+72,000	-21,000

<u>Hutaff Island.</u>
Under Alternative 5B, the southern 2,640 feet of Hutaff Island accreted at a rate of 72,000 cubic yards/year compared to 53,000 cubic yards/year for Alternative 2. While the model indicated rate of accretion for Alternative 5B was greater than that indicated for Alternative 2; the numerical difference may not be significant given the inherent accuracy of the model results. Also, the segment of Hutaff Island between stations 175+00 and 215+00 lost only 21,000 cubic yards/year compared to a loss rate of 52,000 cubic yards/year for Alternative 5A, even though both alternatives had the exact same terminal groin design. This difference in the response of the model along Hutaff Island may have been associated with the creation of a larger channel connecting Nixon Channel with the gorge of Rich Inlet under Alternative 5A compared to the much smaller dredging impact in Nixon Channel for Alternative 5B.

- <u>Alternative 5C</u>

Alternative 5C includes a 1,300-foot long terminal groin constructed near baseline station 105+00 and a beach fill extending from the terminal groin south to station F90+00 which is just south of Bridge road. The Alternative 5C beach fill is comparable to the beach fill under Alternative 5A. The position of the Alternative 5C terminal groin is north of the position of the terminal groin presented in the DEIS (Figure 5.20). A beach fill would also be placed along 1,400-feet of the Nixon Channel shoreline. Material to construct the beach fills would be obtained from the previously permitted area in Nixon Channel and a new channel connecting Nixon Channel to the gorge of Rich Inlet.

Changes in the morphology of Rich Inlet and the adjacent shorelines over the 5-year simulation for the 1,300-foot groin associated with Alternative 5C are shown in Figures 5.34 to 5.39 for the 2006 conditions.

The channel connecting Nixon Channel to the inlet gorge shoaled rather rapidly during the first two years of the simulation. The channel also migrated northwest, eventually merging with the channel that skirts around the landward lobe of the flood tide delta.

Following this initial two year adjustment, shoaling decreased with the channel actually experiencing some scour during the last year of the simulation. The beach fill placed along the Nixon Channel shoreline did provide some erosion protection during the 5-year simulation period.

Between year 3 and year 5 of the simulation, the general response of Rich Inlet under Alternative 5C included the inlet ocean bar channel migrating toward Hutaff Island which resulted in the buildup of material in the ebb tide delta on the north side of Rich Inlet and the elongation of the south end of Hutaff Island into Rich Inlet.

The sand spit projecting off the north end of Figure Eight Island initially elongated, projecting into the dredged channel cut across the flood tide delta. This initial elongation appeared to be due to sediment moving out of the fill area and past the terminal groin. The sand spit began to recede between years 4 and 5 of the simulation with the eroded portions of the spit morphing into a subaqueous feature.

By the end of year 4 of the simulation, the fillet south of the terminal groin had stabilized, protecting approximately 1,500 feet of shoreline south of the terminal groin. The stable nature of the sand fillet would indicate material was able to move past the structure and continue to feed the sand spit.

Figure Eight Island.

A focus of shoreline changes along Figure Eight Island for Alternative 5C was on the performance of the beach fill that would be placed between Bridge Road and Rich Inlet (Table 5.13).

The Delft3D model shows that the beach segment between F90+00 and 60+00 gained material over the 5-year simulation (Table 5.13). This was apparently due to higher rates of sand transport to the south out of the northern beach segment. The fill distribution density in the area immediately south of the terminal groin, as described in Chapter 3, would create a large seaward bulge in the shoreline that would be conducive to horizontal spreading of the fill material southward of the nodal point. However, accretion tendencies of the same order of magnitude were also indicated by the model in this area for Alternatives 2 and 4. This seems to imply the configuration of the fill north of station 60+00 does not have a significant influence on the behavior of the shoreline south of station 60+00.

In the beach segment between 60+00 and 105+00, the beach fill lost about 58.4% of the initial placement volume during the first two years of the simulation (Table 5.12). Losses from the fill moderated slightly over the next 3 years, however, by the end of year 5, only 2.5% of the initial fill volume remained on the beach profile above the -24-foot depth of closure. The volume of fill remaining on the profile above -6 feet NAVD at the end of year 5 was 15.9%. While the fill continued to provide protection to the pre-nourished beach through year 5 of the simulation, particularly the upper portion of the profile, beach nourishment would be needed at the end of year 5 in order to provide continuing protection to the upland areas.

Table 5.12. Percent of Alternative 5C initial beach fill volume remaining after each year of the 5-year Delft3D model simulation – 2006 conditions.

Beach Segment	Percent of Beach Fill Remaining after:				
	1 year	2 years	3 years	4 years	5 years
F90 to 60	104.4	116.5	121.4	124.9	123.7
60 to 105	64.3	41.6	25.9	13.4	2.5
Entire Fill Area (F90 to 105)	83.3	77.0	71.0	66.1	59.8

The average annual rate of volume change in the two shoreline segments on Figure Eight Island, defined previously, and the southern 6,640 feet of Hutaff Island derived from the five (5) year Delft3D model simulation for Alternative 5C are summarized in Table 5.13. The volume changes for these same beach segments computed for Alternatives 2, 3, 4, 5A, and 5B are also included in the table for comparison purposes.

Table 5.13. Average annual rate of volume change (cubic yards/year) - Figure Eight Island and the southern 6,640 feet of Hutaff Island obtained from the Delft3D model for Alternatives 2, 3, 4, 5A, 5B, and 5C – 2006 conditions.

Alternative	Figure Eight Island		Hutaff Island	
	F90+00 to 60+00	60+00 to 105+00	148+60 to 175+00	175+00 to 215+00
2	+18,000	-84,000	+53,000	-35,000
3	-2,000	-99,000	-31,000	-36,000
4	+30,000	-176,000	+57,000	-30,000
5A	+20,000	-85,000	-33,000	-52,000
5B	+50,000	-51,000	+72,000	-21,000
5C	+20,000	-93,000	-33,000	-52,000

Volumetric losses from the beach fill for Alternative 5C between stations 60+00 and 105+00 averaged 93,000 cubic yards/year over the 5-year simulation period. As mentioned above and described in Chapter 3, the design of the beach fill for Alternative 5C included a much higher concentration of fill north of station 50+00 to the terminal groin. The bulbous shape of the fill induced high rates of sediment transport out of this area to both the north and south.

The high rates of loss for the area between 60+00 and 105+00 were primarily attributable to losses that occurred seaward of the end of the terminal groin as the upper portion of the beach remained fairly stable (see Figures 5.34 through 5.39). The model results support the movement of sediment past the terminal groin and into Rich Inlet while the retention of material in the upper part of the beach profile would provide a quasi-permanent increase in the protective beach fronting the ocean front structures in this area.

Hutaff Island.

The southern 2,640 feet of Hutaff Island eroded under Alternative 5C. The response on Hutaff Island appeared to be related to differences in the behavior of the bar channel. Under Alternative 2, the outer portions of the bar channel was oriented toward Hutaff

Island during the majority of the 5-year simulation while under Alternative 5C, the bar channel did not assume an orientation toward Hutaff Island until after year 4 of the simulation. This delayed response of the inlet appeared to be due to differences in flow patterns associated with the new channel between the Rich Inlet gorge and Nixon Channel compared to flow patterns that developed out of Nixon Channel under without project conditions. Once the new channel shoaled to near pre-project conditions, the pattern of flow from the interior channels became similar to the flow patterns under Alternative 2 and the inlet bar channel began to respond accordingly.

In any event, the shoreline response along Hutaff Island under Alternative 5C was essentially the same as that observed under Alternative 5A, both of which included dredging of a new channel connecting Rich Inlet with Nixon Channel.

Along the salt marsh shoreline facing the entrance of Rich Inlet, currents are expected to be reduced slightly for about 3 to 4 years as flow is shifted from the back channel into the new dredge cuts thereby reducing potential shoreline and salt marsh erosion at that location.

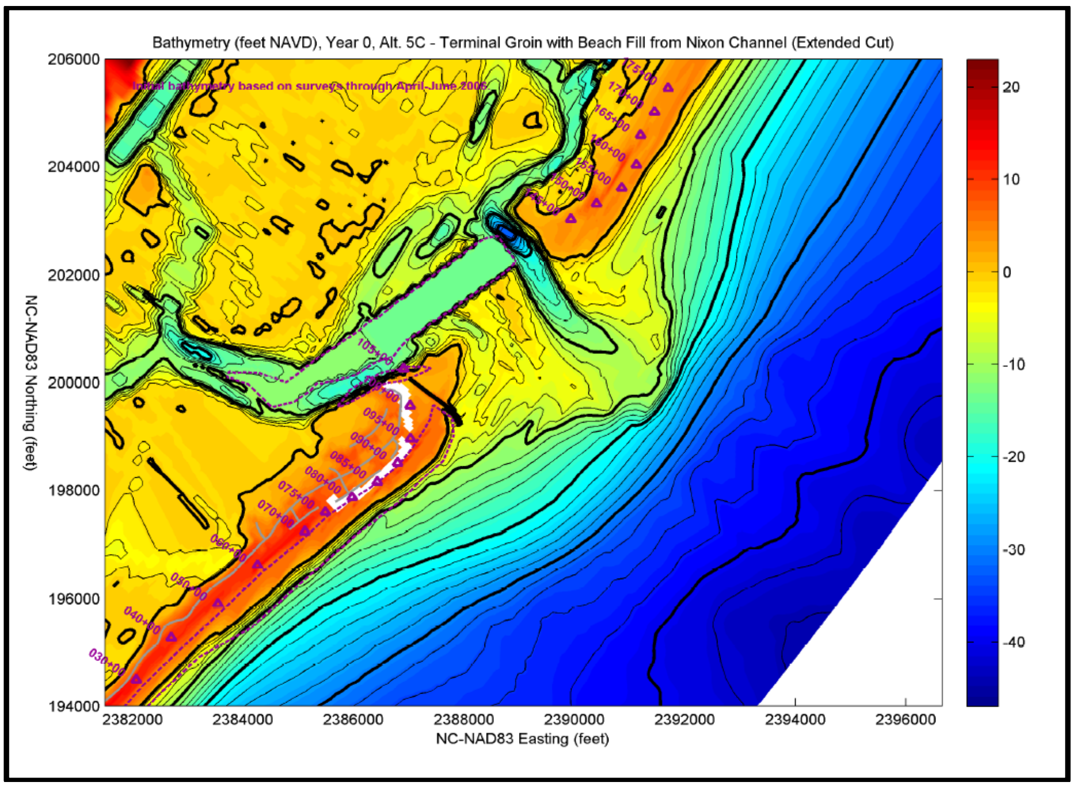

Figure 5.34. Alternative 5C: Year 0 after construction – 2006 conditions.

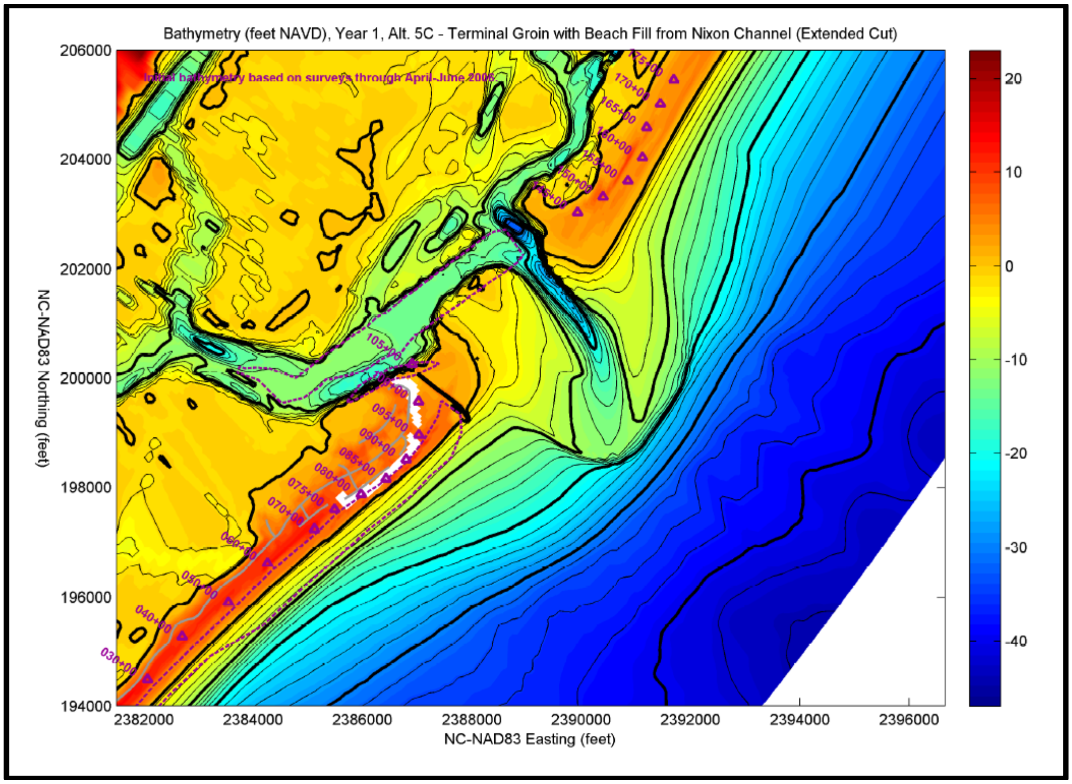

Figure 5.35 Alternative 5C: Year 1 after construction – 2006 conditions.

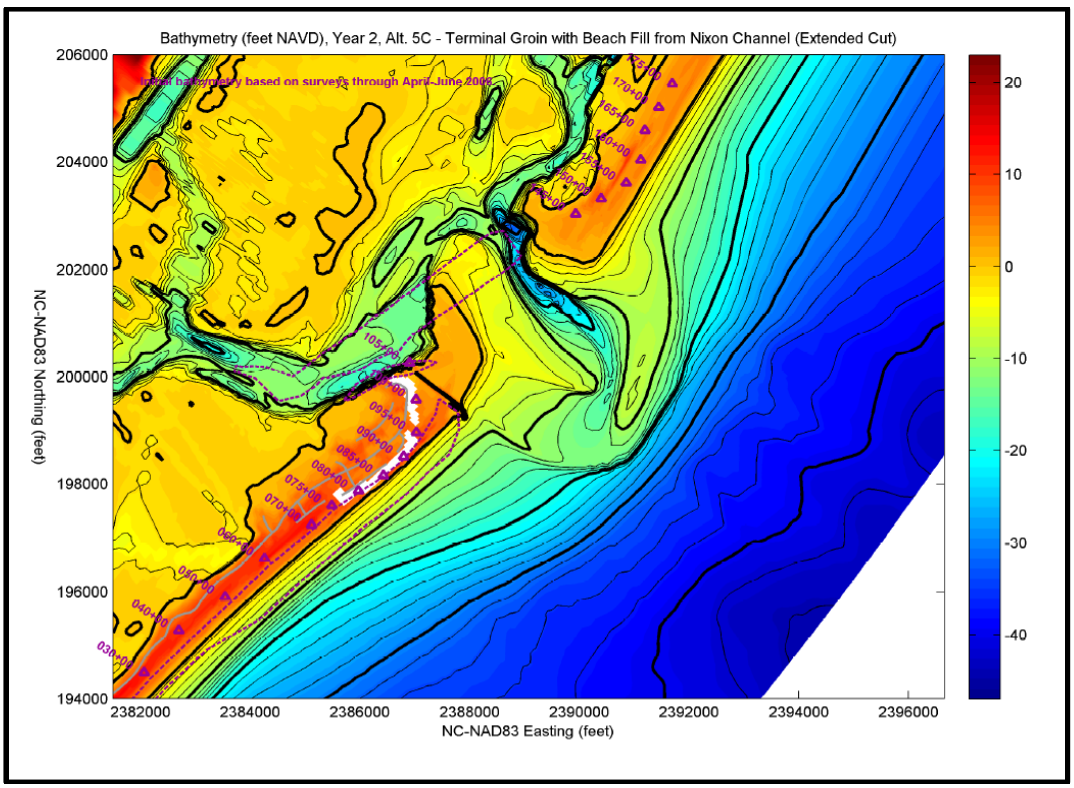

Figure 5.36 Alternative 5C: Year 2 after construction – 2006 conditions.

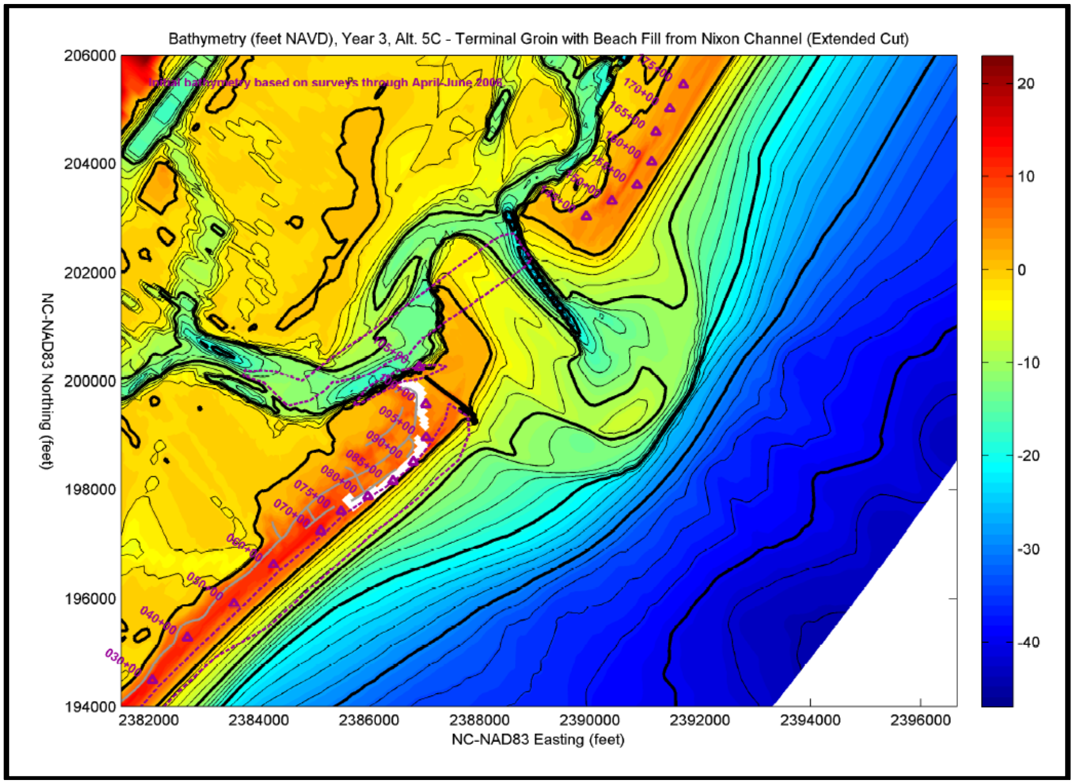

Figure 5.37. Alternative 5C: Year 3 after construction – 2006 conditions.

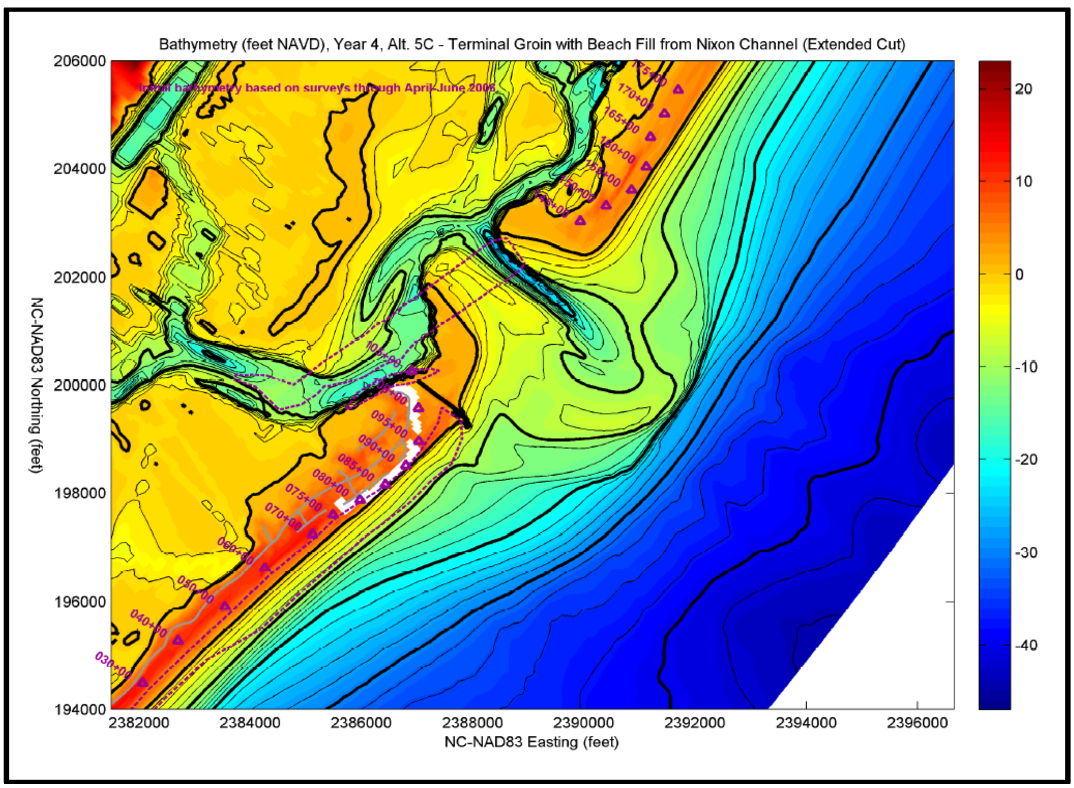

Figure 5.38. Alternative 5C: Year 4 after construction – 2006 conditions.

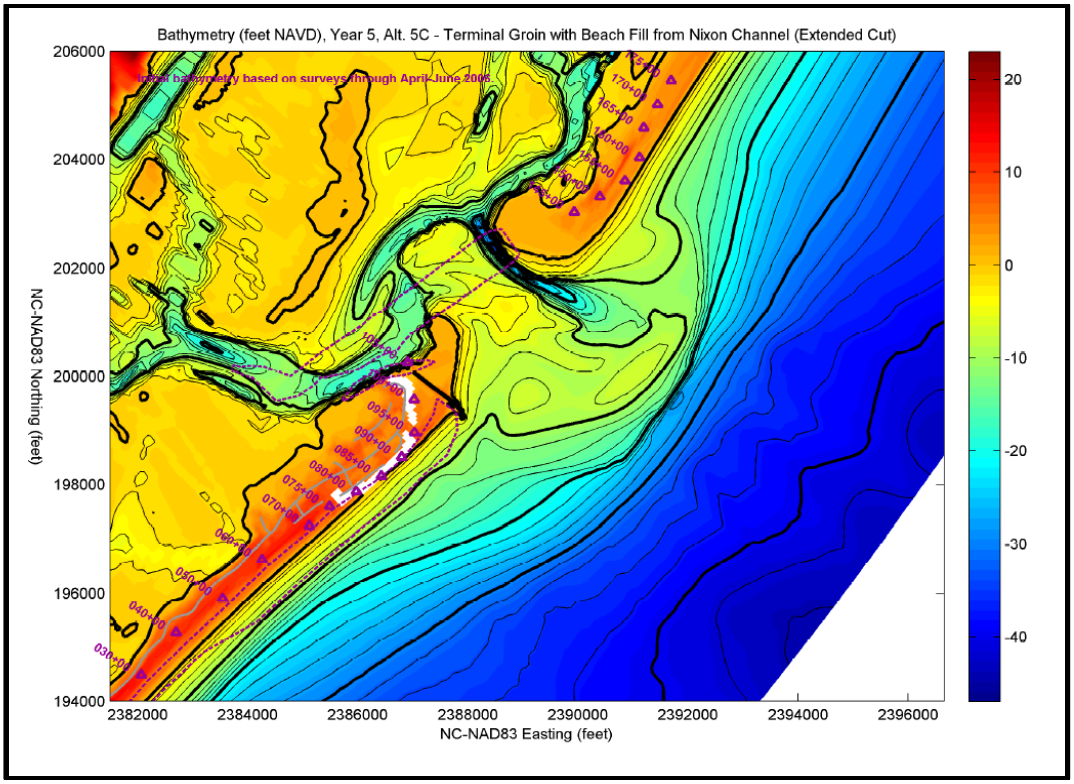

Figure 5.39. Alternative 5C: Year 5 after construction – 2006 conditions.

- Alternative 5D (Applicant's Preferred Alternative)

Alternative 5D includes a 1,500-foot terminal groin that would project 505 feet seaward of the 2007 mean high water shoreline compared to 305 feet for Alternative 5C. The general position and alignment of the Alternative 5D groin is north of the position of the terminal groin presented in the DEIS. Alternative 5D replaces Alternative 5B presented in the DEIS, as the "Applicant's Preferred Alternative." In this regard, the primary difference between Alternative 5D and Alternative 5B is the position of the terminal groin. A comparison between Alternative 5D and Alternative 5B is provided below.

Alternative 5D includes the same beach fill along Nixon Channel as Alternative 5C but would provide a much smaller beach fill along the ocean shoreline comparable to that described for Alternative 5B. In this regard, the ocean shoreline beach fill for Alternative 5D would begin at the terminal groin and extend south to station 60+00, effectively filling the area generally referred to as the accretion fillet. Based on the modeled shoreline behavior for Alternative 5C as well as the fill performance associated with Alternatives 3 and 4, no initial beach fill would be needed south of station 60+00 to Bridge Road. However, this area would be included in the shoreline monitoring program and could be nourished in the future should conditions warrant.

Changes in the morphology of Rich Inlet and the adjacent shorelines over the 5-year simulation for the 1,500-foot terminal groin associated with Alternative 5D are shown in Figures 5.40a to 5.45a for the 2006 conditions and Figures 5.40b to 5.45b for the 2012 conditions.

Figure Eight Island.

The percent of the initial beach fill remaining on the profile above the -24-foot depth of closure for Alternative 5D is provided in Table 5.14a for the 2006 initial and Table 5.14b for the 2012 condition. For the 2006 conditions, the model results indicated essentially all of the fill would be lost between years 4 and 5 of the simulation and the area would need to be nourished. The percent of fill remaining given in Table 5.14a is for the entire active profile out to a depth of -24 feet NAVD. A closer inspection of the fill performance found 27.5% of the fill placed above the -6-foot NAVD contour remained on the beach after 5 years given the 2006 conditions.

For the 2012 conditions, all of the fill out to the -24 foot depth contour was also lost between year 4 and 5, however, volume losses under the 2012 condition were less than the 2006 condition. The percent of fill retained above -6 feet NAVD under the 2012 conditions was also greater than under the 2006 conditions with over one-half of the fill placed above the -6-foot NAVD depth contour remaining on the profile after year 5 of the simulation.

Volume changes in the two beach segments on Figure Eight Island and Hutaff Island obtained from the results of the Delft3D model simulation for Alternative 5D are provided in Table 5.15a for the 2006 conditions and Table 5.15b for the 2012 conditons.

Periodic nourishment of the beach fill along the ocean shoreline would require 290,000 cubic yards every five (5) years based on the 2006 conditions and 225,000 cubic yards for the 2012 conditions. Nourishment of the beach fill along the Nixon Channel shoreline would require 30,000 cubic yards every five (5) years under both conditions resulting in total five-year nourishment requirements of 320,000 cubic yards and 255,000 cubic yards for the 2006 and 2012 conditions, respectively.

Table 5.14a. Percent of Alternative 5D initial beach fill volume remaining after each year of the 5-year Delft3D model simulation – 2006 condition.

Beach Segment	Percent of Beach Fill Remaining after:				
	1 year	2 years	3 years	4 years	5 years
F90 to 60[(1)]	NA	NA	NA	NA	NA
Entire Fill Area 60 to 105	80.2	45.0	24.3	10.4	-21.2

[(1)]No fill would be placed between stations F90+00 and 60+00.

Table 5.14b. Percent of Alternative 5D initial beach fill volume remaining after each year of the 5-year Delft3D model simulation – 2012 condition.

Beach Segment	Percent of Beach Fill Remaining after:				
	1 year	2 years	3 years	4 years	5 years
F90 to 60(1)	NA	NA	NA	NA	NA
Entire Fill Area 60 to 105	81.5	119.8	76.6	37.4	-0.9

(1)No fill would be placed between stations F90+00 and 60+00.

For the 2006 conditions, some of the sand spit located north of the terminal groin remained at the end of year 5 of the simulation; however, most of the spit had morphed into a submerged sand flat. Under 2012 conditions, the sand spit remained fairly stable through year 4 of the simulation and only experienced some slight erosion during year 5. At the end of the 5-year simulation under the 2012 conditions, the sand spit was still a viable feature on the north end of Figure Eight Island (Figure 5.45b).

Table 5.15a. Average annual rate of volume change (cubic yards/year) - Figure Eight Island and the southern end of Hutaff Island obtained from the Delft3D for Alternatives 2, 3, 4, 5A, 5B, 5C, and 5D – 2006 conditions.

Alternative	Figure Eight Island		Hutaff Island	
	F90+00 to 60+00	60+00 to 105+00	148+60 to 175+00	175+00 to 215+00
2	+18,000	-84,000	+53,000	-35,000
3	-2,000	-99,000	-31,000	-36,000
4	+30,000	-176,000	+57,000	-30,000
5A	+20,000	-85,000	-33,000	-52,000
5B	+50,000	-51,000	+72,000	-21,000
5C	+20,000	-93,000	-33,000	-52,000
5D	+63,000	-58,000	+72,000	-21,000

Table 5.15b. Average annual rate of volume change (cubic yards/year) - Figure Eight Island and the southern end of Hutaff Island obtained from the Delft3D for Alternatives 2, 3, 4, 5A, 5B, 5C, and 5D – 2012 conditions.

Alternative	Figure Eight Island		Hutaff Island	
	F90+00 to 60+00	60+00 to 105+00	148+60 to 175+00	175+00 to 215+00
2	+35,000	-43,000	-36,000	-116,000
3	-11,000	-180,000	-30,000	-103,000
4	+16,000	-130,000	-30,000	-121,000
5A	NA	NA	NA	NA
5B	NA	NA	NA	NA
5C	NA	NA	NA	NA
5D	+29,000	-45,000	-38,000	-122,000

Hutaff Island.

For the 2006 condition under Alternative 5D, the southern 2,640 feet of Hutaff Island accreted at a rate of 72,000 cubic yards/year. The response along Hutaff Island to Alternative 5D was basically the same as observed under Alternative 5B which is not surprising since the only difference in the two alternatives was the location of the terminal groin.

Given the 2012 conditions, the response of Hutaff Island to Alternative 5D was comparable to the response observed for Alternatives 2, 3, and 4, none of which included a terminal groin. The similar response of Hutaff Island to the various alternatives implies the 2012 conditions, particularly the conditions within Rich Inlet, exert a greater influence on the island than the man-induced changes associated with the alternatives.

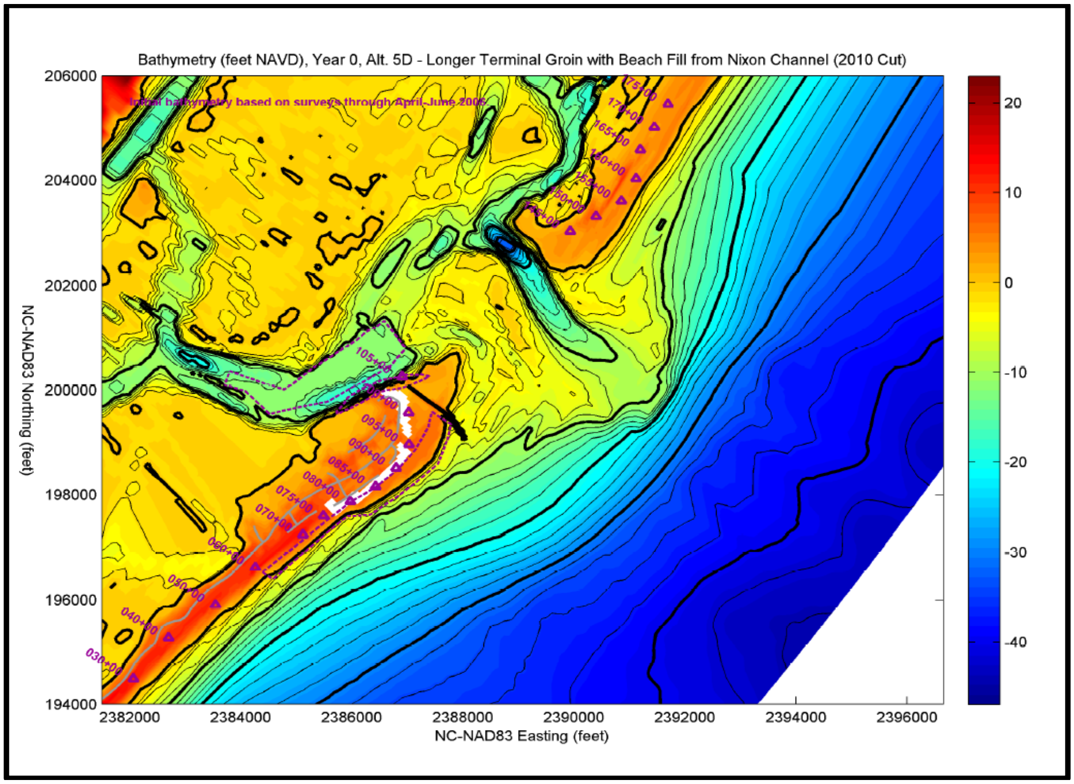

Figure 5.40a. Alternative 5D: Year 0 after construction – 2006 conditions.

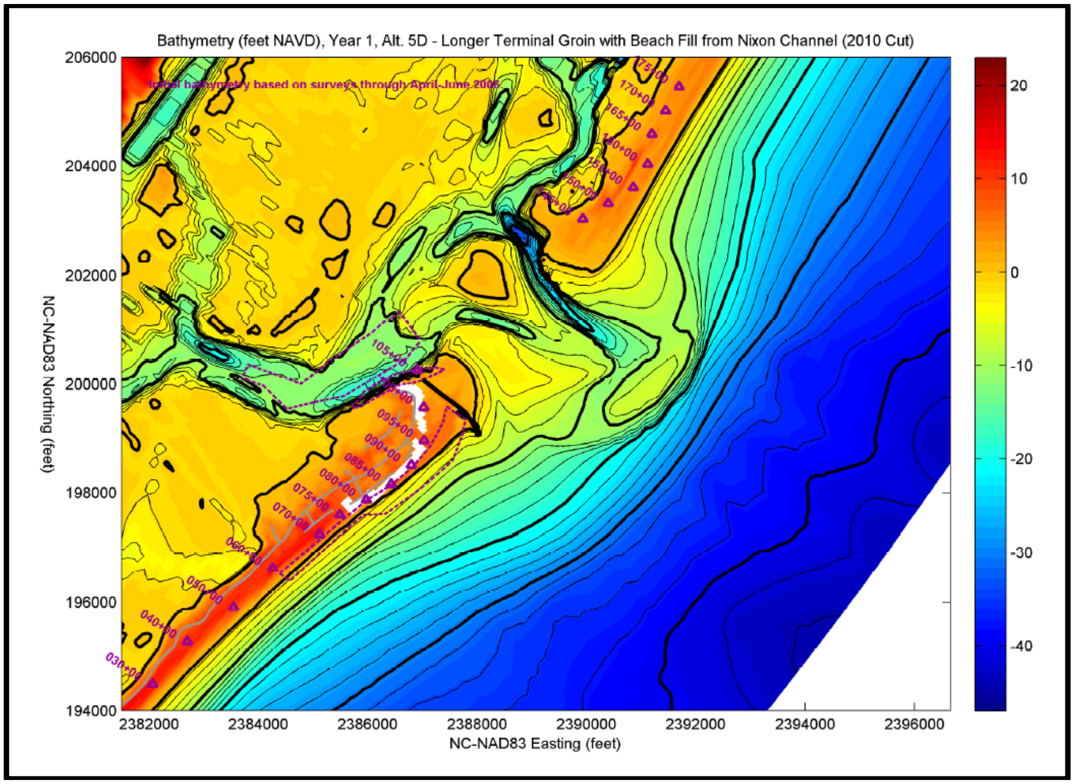

Figure 5.41a. Alternative 5D: Year 1 after construction – 2006 conditions.

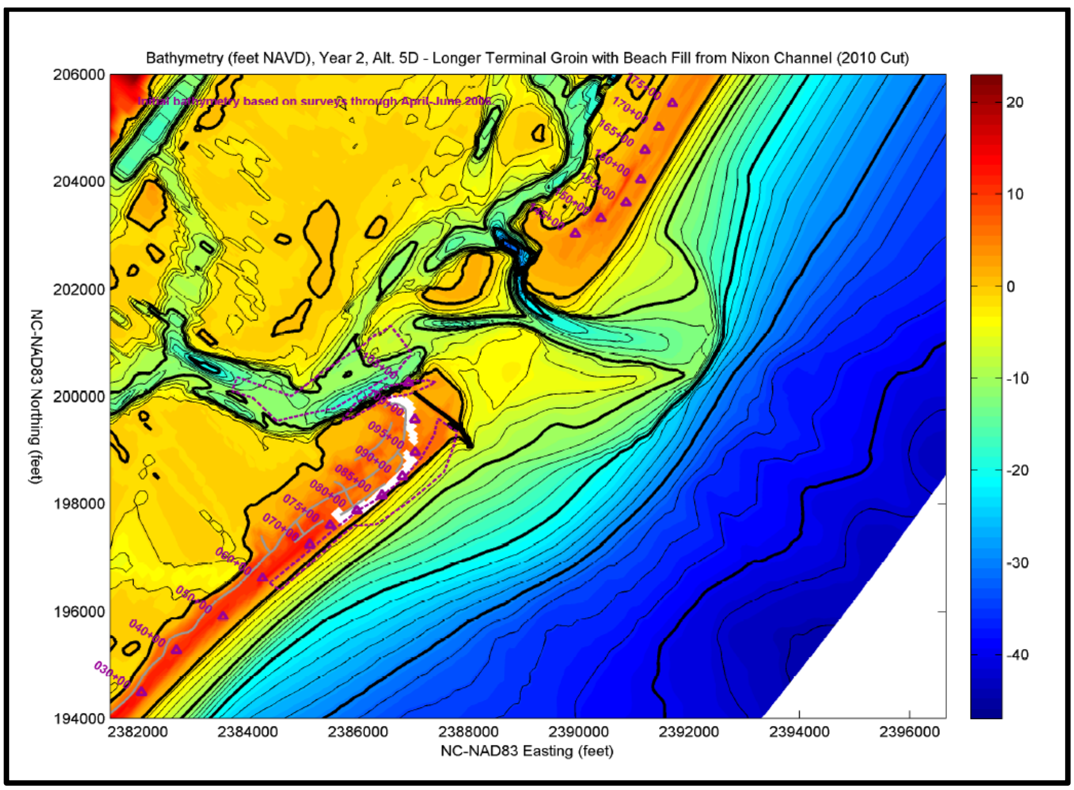

Figure 5.42a. Alternative 5D: Year 2 after construction – 2006 conditions.

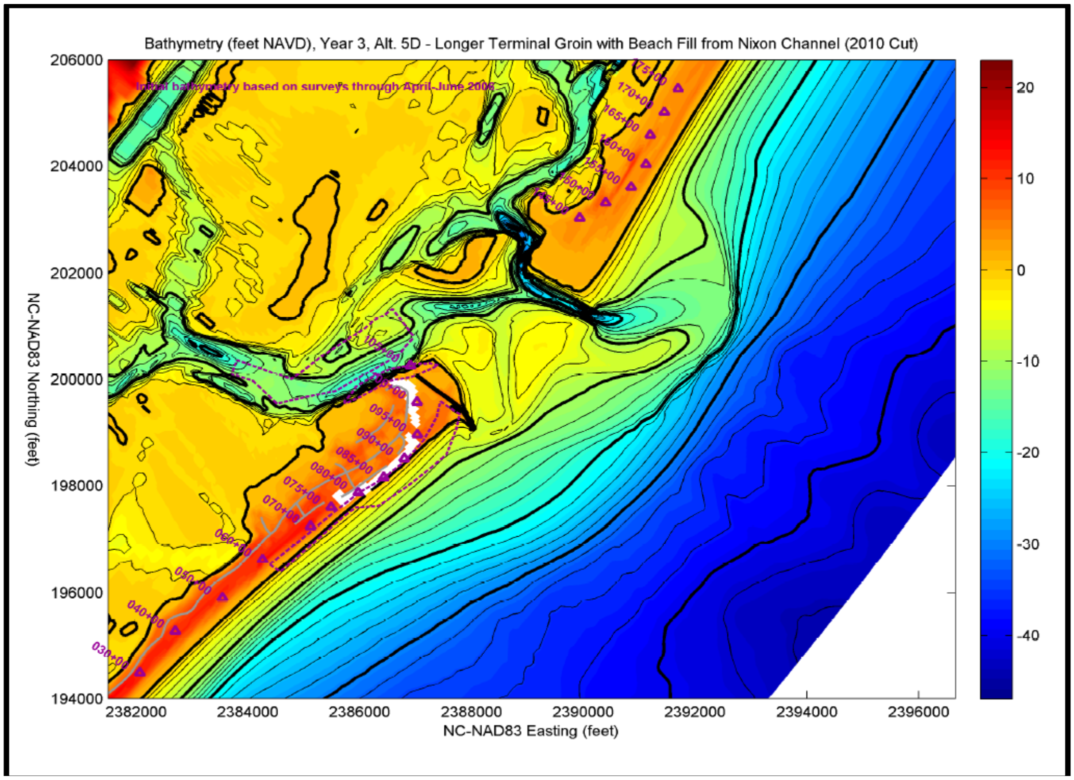

Figure 5.43a. Alternative 5D: Year 3 after construction – 2006 conditions.

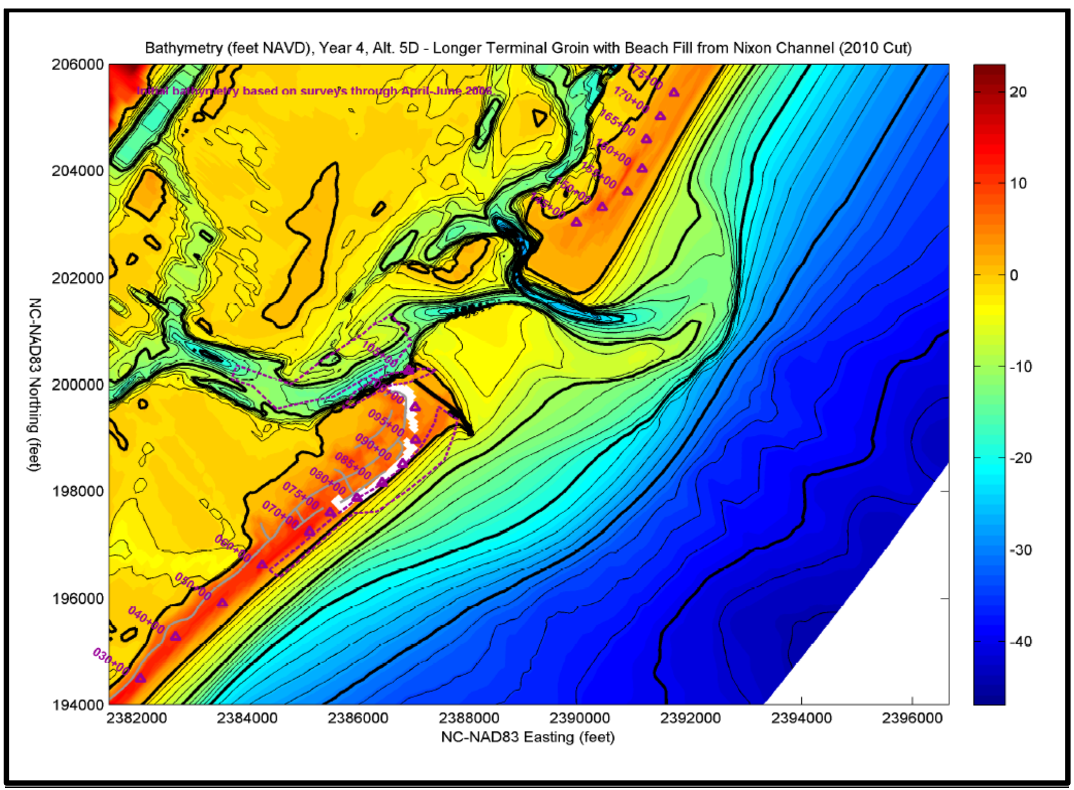

Figure 5.44a. Alternative 5D: Year 4 after construction – 2006 conditions.

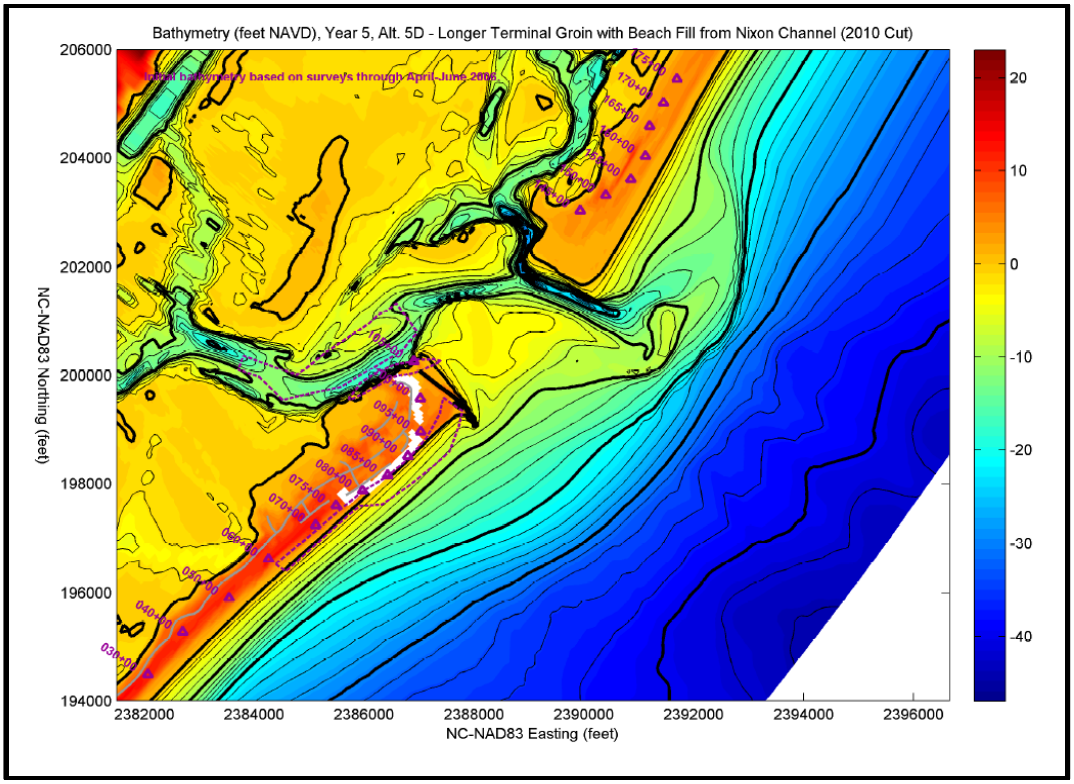

Figure 5.45a. Alternative 5D: Year 5 after construction – 2006 conditions.

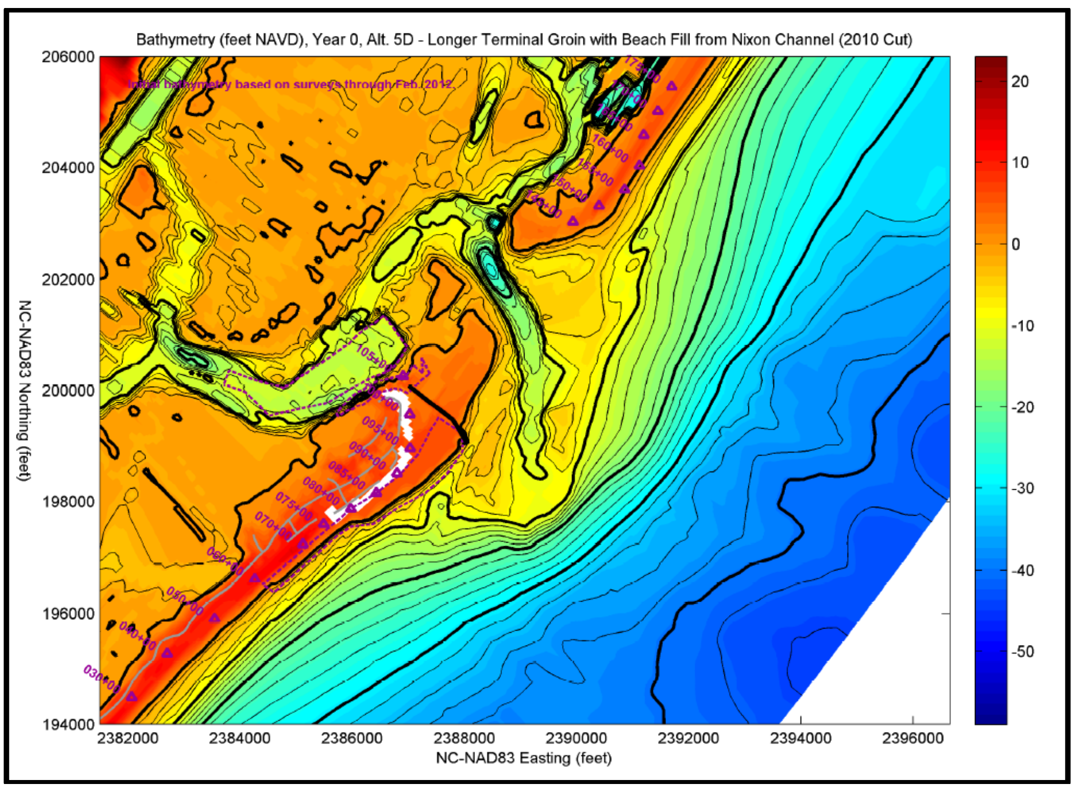

Figure 5.40b. Alternative 5D: Year 0 after construction – 2012 conditions.

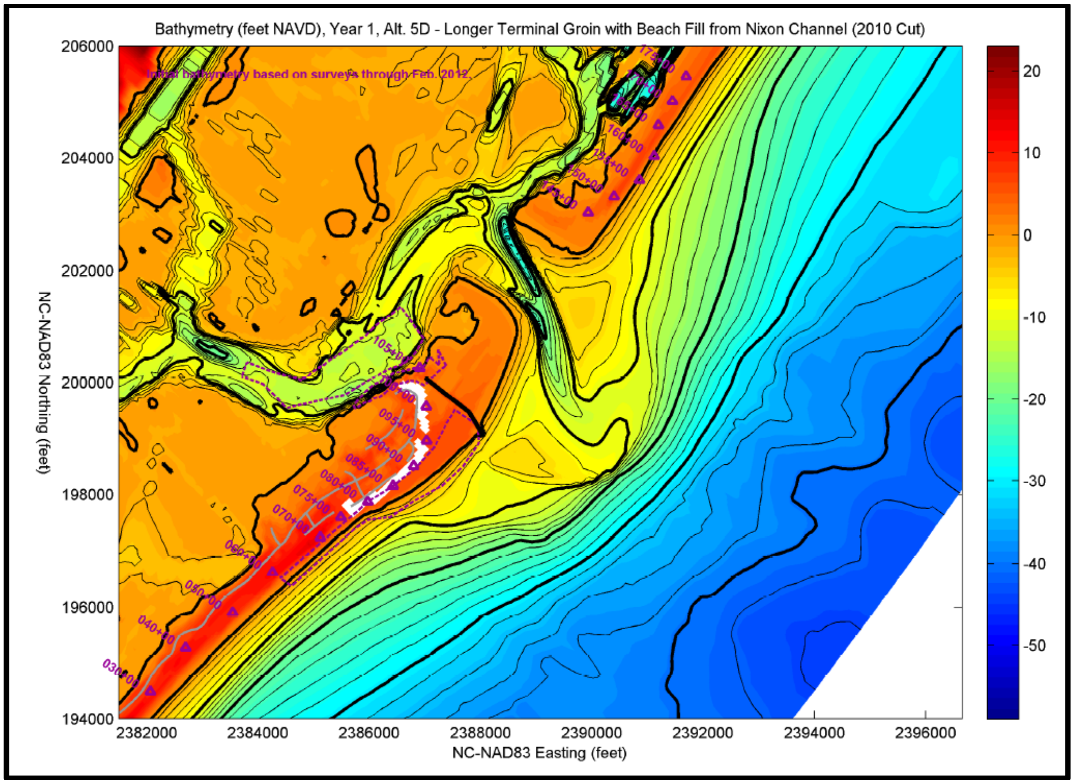

Figure 5.41b. Alternative 5D: Year 1 after construction – 2012 conditions.

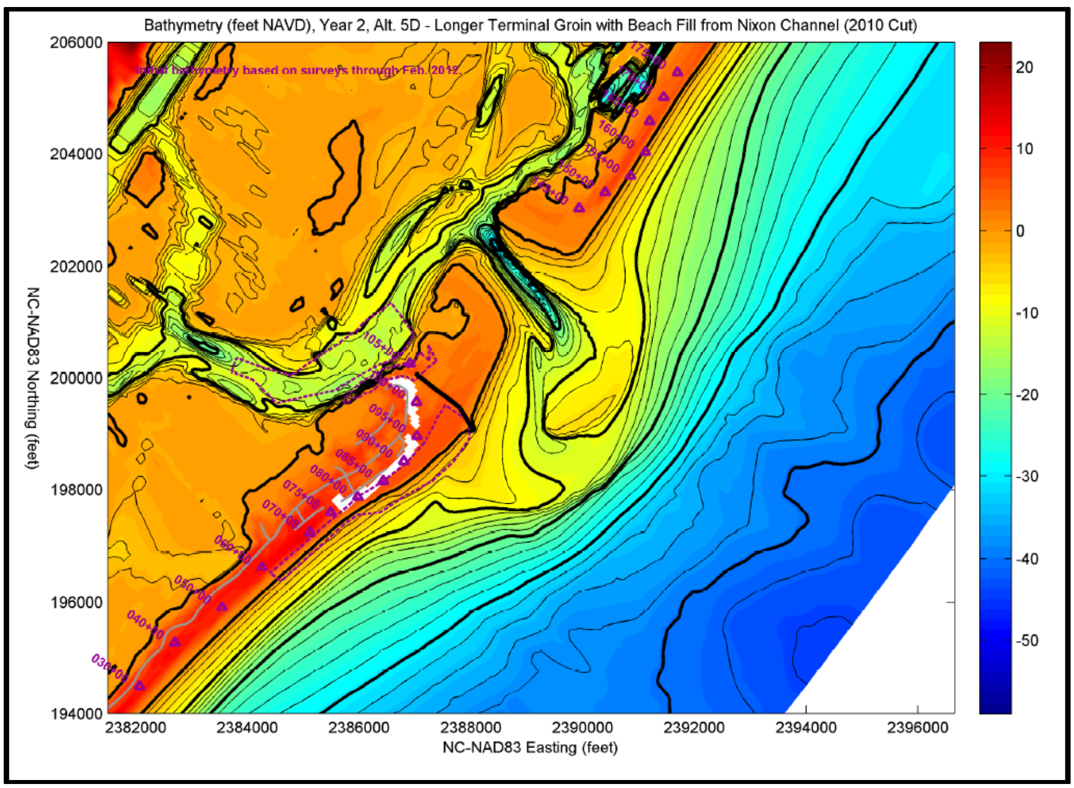

Figure 5.42b. Alternative 5D: Year 2 after construction – 2012 conditions.

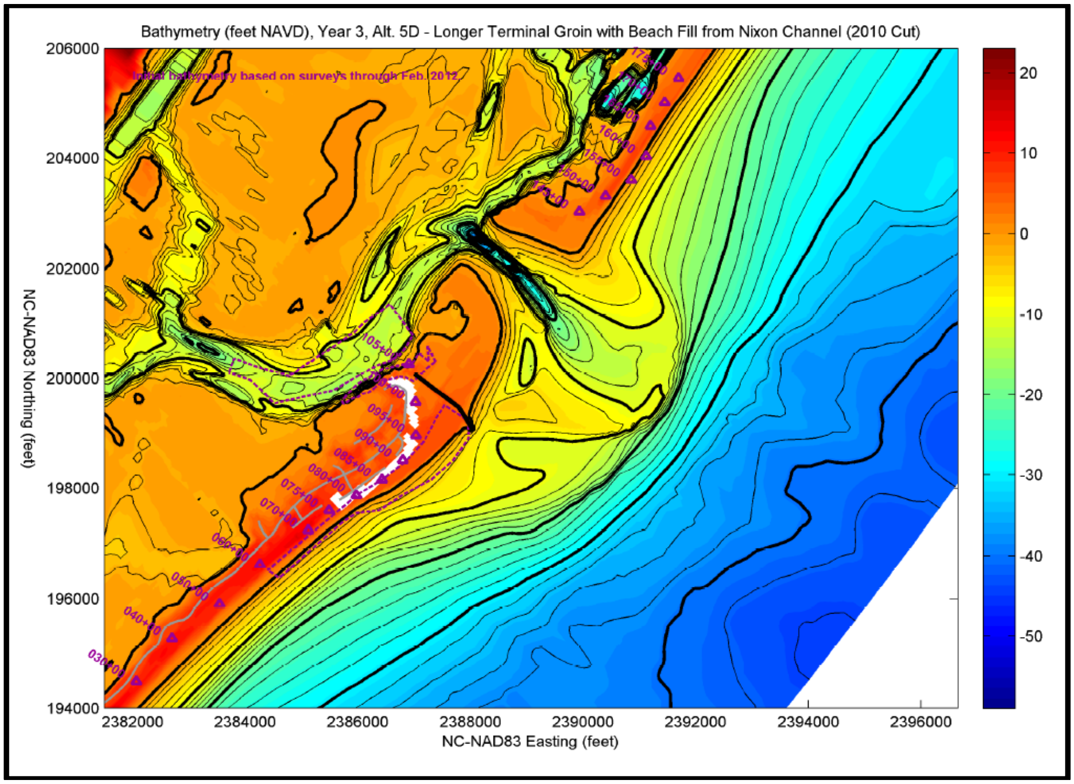

Figure 5.43b. Alternative 5D: Year 3 after construction – 2012 conditions.

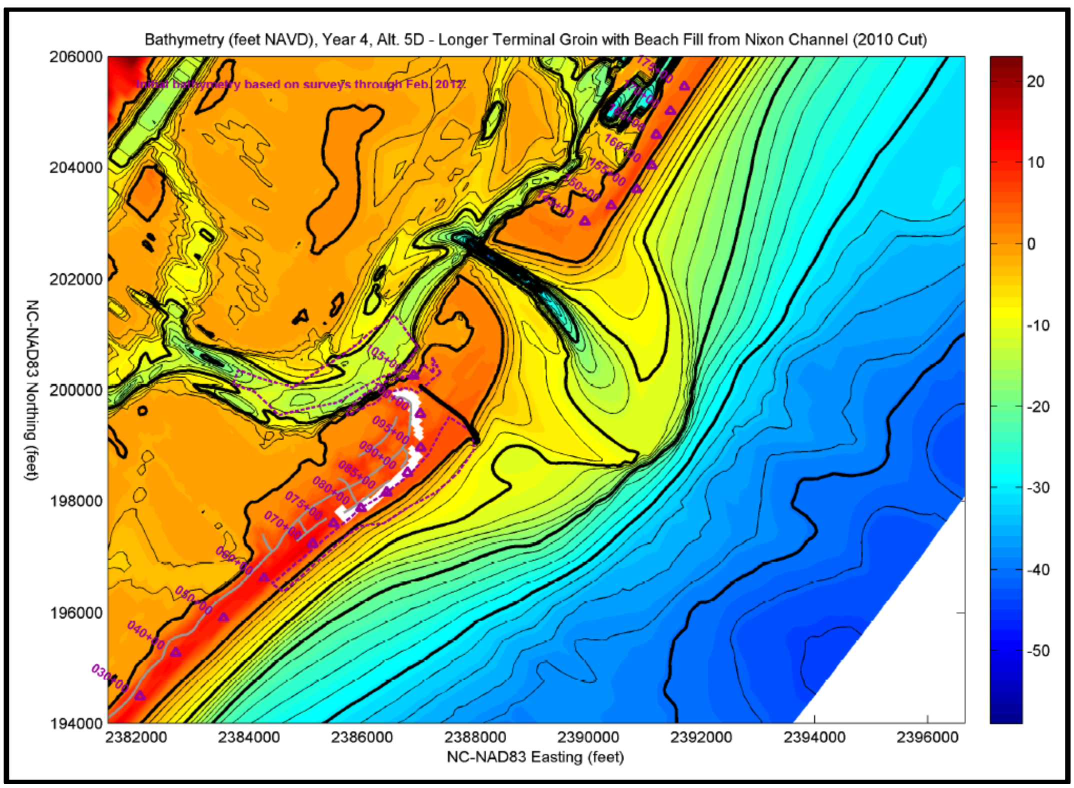

Figure 5.44b. Alternative 5D: Year 4 after construction – 2012 conditions.

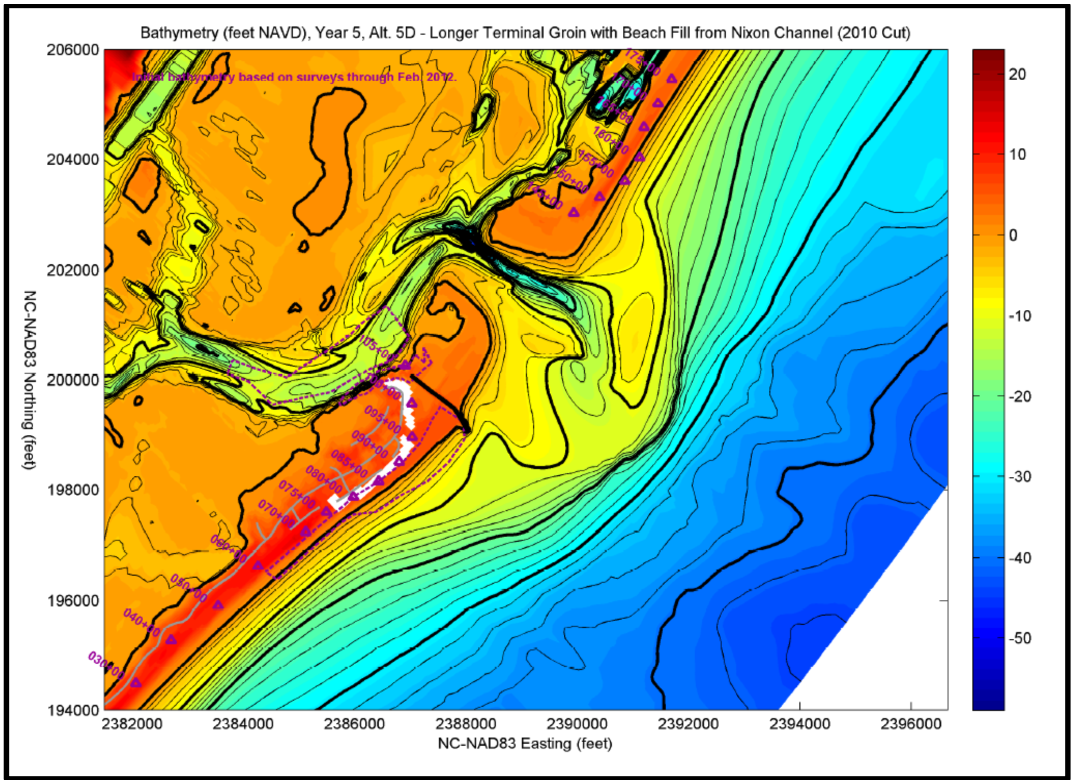

Figure 5.45b. Alternative 5D: Year 5 after construction – 2012 conditions.

The results obtained by the model at the end of the 5-year simulation for Alternative 5D is presented in Section 11.4.6 in Appendix B. For Alternative 5D, the terminal groin was moved approximately 420 feet north of the Alternative 5B terminal groin and the beach fill extended to completely fill the area south of the revised terminal groin position. The volume of material needed for the beach fill along the ocean shoreline under Alternative 5D is 264,500 cubic yards and would use material from maintenance of the previously permitted area in Nixon Channel to construct and maintain the beach fill.

The responses of Rich Inlet to both terminal groin options were very similar as the ocean bar channel tended to migrate toward Hutaff Island with the outer end of the channel assuming an alignment almost parallel to the south end of Hutaff Island. The responses of the interior channels were also similar as the configuration of the channels leading into Nixon Channel and Green Channel were essentially identical.

With regard to shoreline volume changes, the section of Figure Eight Island north of Station 60+00 eroded at a rate of 58,000 cubic yards/year under Alternative 5D. In the section of Figure Eight Island between stations F90+00 and 60+00, the 5-year model results for Alternative 5D indicated an accretion rate of 63,000 cubic yards/year.

The sand spit on the north end of Figure Eight Island experienced some erosion under Alternative 5D, but the mean high water shoreline did not reach the terminal groin. The position of the northern tip of the sand spit at the end of the 5-year simulation was basically the same as Alternative 5B (see Figures 5.46.a and 5.46b). In this regard, the southern tip of Hutaff Island migrated to the south during the first 3 years of the simulation for Alternative 5D and then appeared to stabilize.

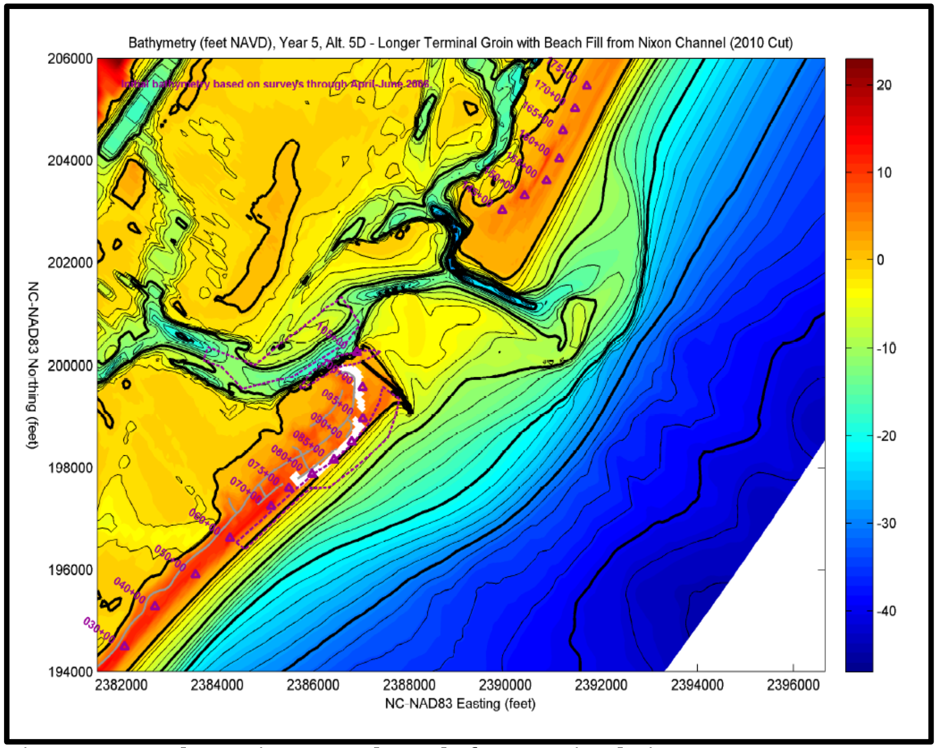

Figure 5.46a. Alternative 5D at the end of 5-year simulation – 2006 conditions.

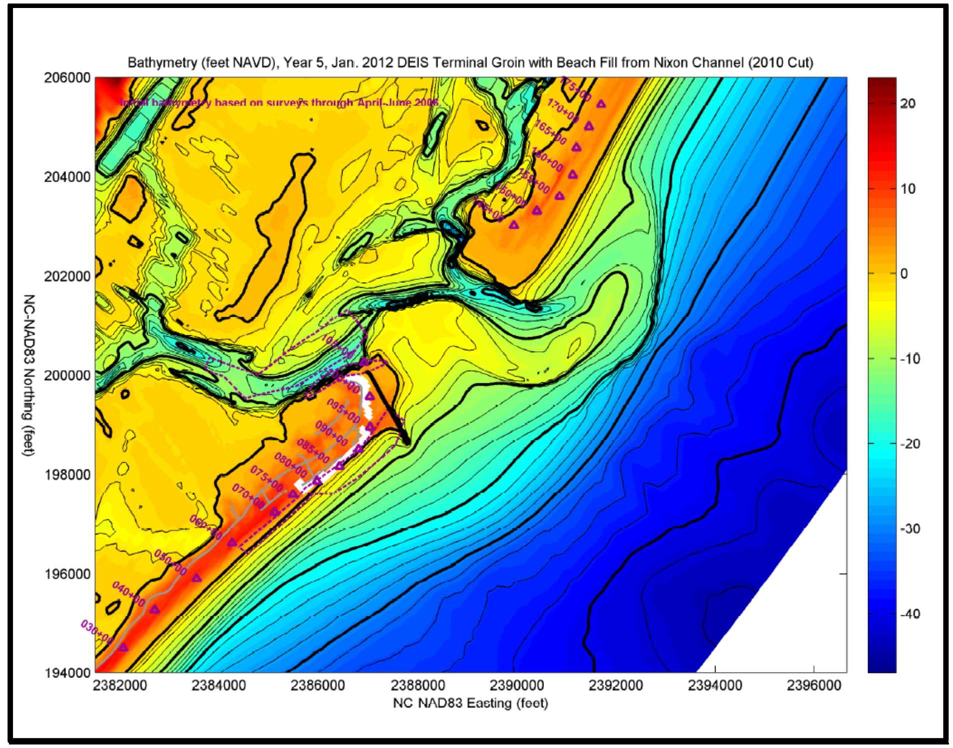

Figure 5.46b. Alternative 5B at the end of 5-year simulation – 2006 conditions.

Sea Level Rise.

Many physical processes have the potential to influence shoreline change, sea level rise being one of them. The International Panel on Climate Change (IPCC, 2007) has concluded that global mean sea level rose at an average rate of about 1.7 ± 0.5 mm/year during the twentieth century. Recent climate research has documented global warming during the twentieth century, and has predicted either continued or accelerated global warming for the twenty-first century and possibly beyond (IPCC, 2007). This rate, which is difficult to predict, is anticipated to increase over the next 100 years. Rahmstorf (2007) predicts that global sea level in 2100 may rise 0.5 m (1.6 ft.) to 1.4 m (4.6 ft.) above the 1990 level. In 2012, the State of North Carolina passed legislation (House Bill 819) declaring that only "historic rates of sea-level rise may be extrapolated to estimate future rates of rise but shall not include scenarios of accelerated rates of sea-level rise unless such rates are from statistically significant, peer-reviewed data and are consistent with historic trends." As such, the State of North Carolina has not adopted a planning benchmark for sea level rise, and no such benchmark is currently under consideration.

According to www.tidesandcurrents.noaa.com, the regional trends in North Carolina show an increase of 0 to 3 mm/yr. (0 to 0.00984 ft./yr.), or a 0 to 1 ft./century. Guidelines from the USACE suggest that relevant sea level rise data should include a minimum of 40 years of data. Several monitoring stations within proximity to Figure Eight Island contain this level of data including stations located in Beaufort (collecting data since 1953), Wilmington (collecting since 1935), and Southport (collecting since 1933), North Carolina. Data from these stations show that the rate of increase in sea level rise in Beaufort is 0.84 ft./century while the rate in Wilmington and Southport are both 0.68 ft./century.

Sea-level change can cause a number of impacts in coastal and estuarine zones, including changes in shoreline erosion, inundation or exposure of low-lying coastal areas, changes in storm and flood damages, shifts in extent and distribution of wetlands and other coastal habitats, changes to groundwater levels, and alterations to salinity intrusion into estuaries and groundwater systems (e.g., CCSP, 2009). North Carolina has been identified by NOAA as one of three states with significant vulnerability to sea level rise. The state possesses the largest estuarine system on the U.S. Atlantic coast, with an extensive barrier island chain, and over 2,300 square miles of coastal land vulnerable to a 1 m rise in sea level (Poulter et al, 2009).

The impacts of historic rates of rise in sea level are implicitly included in the historic shoreline change data used for Figure Eight Island. By extrapolating data from long term sea level monitoring sites located in Wilmington, NC, Southport, NC, and Beaufort, NC, rate of rise in sea level applicable to the project area is shy of 1 foot per century. Some projections suggest the rate of sea level rise could double within the next 50 to 100 years. However, since changing sea level rates only influence shoreline change minimally compared to other physical factors, doubling the rate of sea level rise would not double the historic rate of shoreline change.

No significant direct or indirect impacts are expected to occur as a result of sea level rise for any of the project alternatives over the 30-year evaluation period. If sea levels continue to increase as predicted, then unmanaged areas of the dry beach and dune communities may become more vulnerable to erosion leading to negative cumulative impacts to these habitats. However, the project alternatives involving beach nourishment may help to avert potential adverse cumulative impacts. As an example of how sea level rise may or may not affect the performance of a beach nourishment project, the Wrightsville Beach and Carolina Beach federal storm damage reduction projects can be evaluated. Both of these project have been in existence since 1965 (51 years) and have been subjected to the same rate of sea level rise applicable to Figure Eight Island. A review of the nourishment rates for these two projects with and without sea level rise shows no significant change in the volume or frequency of periodic nourishment needed to maintain the projects as evidenced by the cumulative nourishment volume curves provided on Figures 5.47a and 5.47b for Carolina Beach and Wrightsville Beach, respectively.

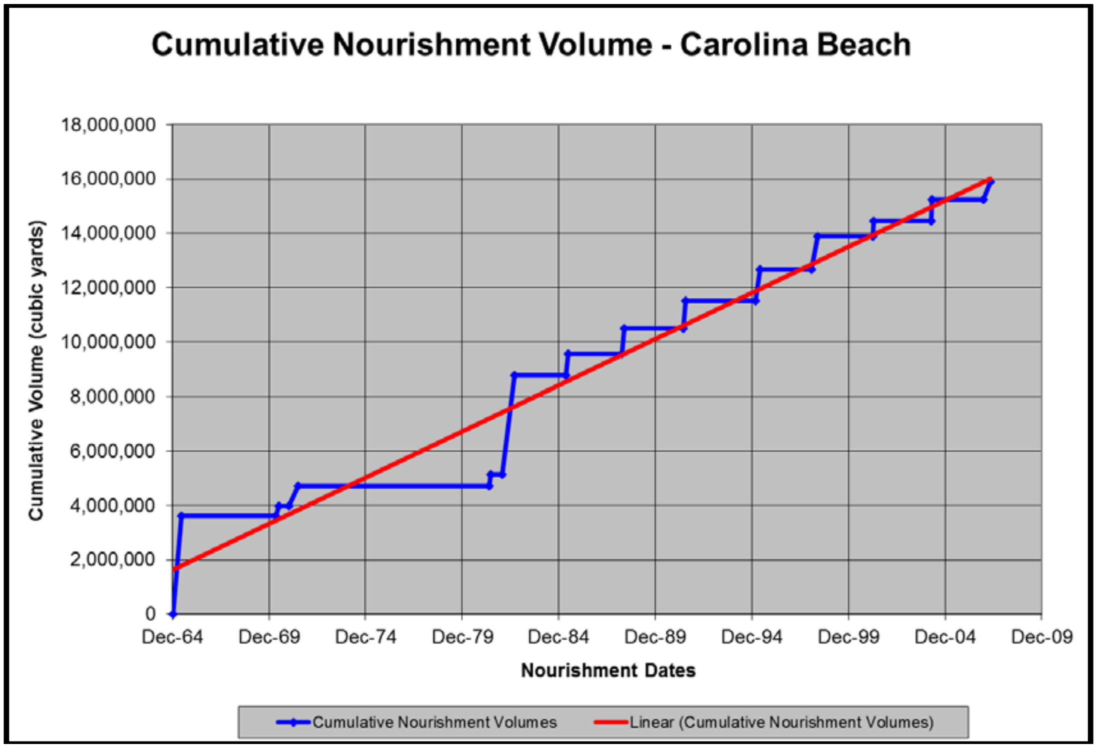

Figure 5.47a. Cumulative nourishment volume for the Carolina Beach project since 1964.

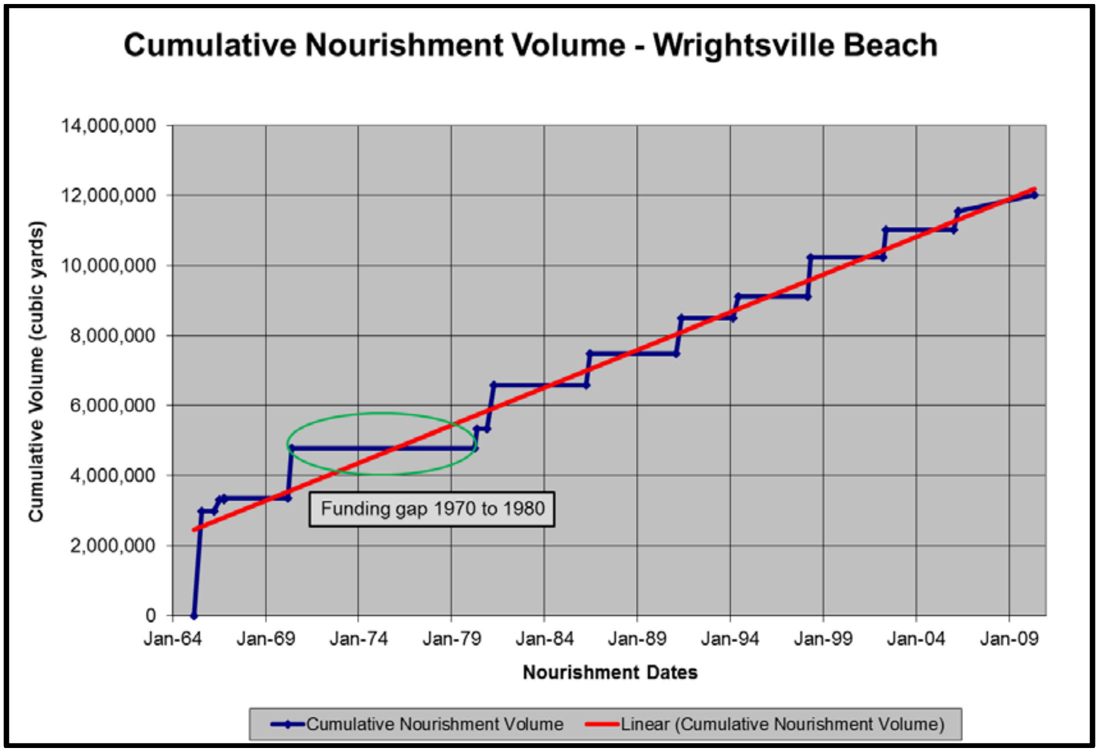

Figure 5.47b. Cumulative nourishment volume for the Wrightsville Beach project since 1965.

4. What other projects occurring or being implemented within the vicinity of Figure Eight Island may cumulatively affect this project?

There are a number of shoreline protection activities which have occurred or are scheduled to occur on or in proximity to Figure Eight Island. These activities, as listed below, have or could impose cumulative impacts on resources within the Permit Area.

- Maintenance of Mason Inlet with Beach Nourishment
- Maintenance of the AIWW
- Maintenance of Banks Channel
- Nixon Channel Maintenance with Beach Nourishment

Refer to Appendix F, the Cumulative Effects Assessment, for more information regarding the above and other activities used in determining the cumulative effects for the project.

5. What are the general environmental impacts associated with the project?

The various environmental consequences associated with the alternatives are described within this section. While each alternative contains unique features, several of these alternatives involve similar work construction which will elicit comparable environmental consequences. These include dredging and/or beach nourishment activities, which are associated with Alternatives 1, 3, 4, 5A, 5B, 5C, 5D. The environmental impacts associated with these activities are described below.

General Environmental Consequences Related to Dredging

The general environmental impacts of dredging include a direct temporary increase in turbidity and TSS (total suspended sediments) within the water column. Sediment loading increases turbidity and TSS, which can result in a decrease in biological productivity, clogging of fish gills, and reduced recruitment of invertebrates. Furthermore, turbidity can suppress SAV growth, cause low oxygen events leading to fish kills, and cause mortality of organisms in the substrate, including oysters. High concentrations of suspended solids can cause many problems for aquatic life. High TSS can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Low dissolved oxygen can lead to fish kills. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight (Mitchell and Stapp, 1992). Dredging within the permit area is expected to result in temporary increases in suspended sediment or particulates and turbidity in the immediate area of construction activity. Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates. Recruitment of invertebrate larvae, growth of filter feeding invertebrates, and visual foraging for prey by adult fish are also affected by turbidity from dredging (Reilly and Bellis, 1983).

What are Direct, Indirect, and Cumulative Impacts?

The CEQ regulations (40 CFR §§ 1500 -1508) define the impacts and effects that must be addressed and considered by Federal agencies in satisfying the requirements of the NEPA process.

Direct impacts are caused by the action and occur at the same time and place.

Indirect impacts are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable.

Cumulative impacts are the impact on the environment, which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions.

Cleary and Knierim (2001) observed that dredging within Nixon Channel and the associated beach nourishment along the northern portion of Figure Eight Island resulted in a temporary increase of turbidity and TSS primarily at the discharge site located on the ocean shoreline. The highest weekly average of turbidity and TSS recorded at the discharge site was 44.0 mg/l and 301.0 mg/l, respectively (Cleary and Knierim, 2001). Turbidity values at control sites located approximately 10,000 feet from the location of the fill operation averages 7.7 NTU while TSS values averaged 47.7. During the Bogue Inlet Channel Erosion Response Project, turbidity levels were shown to remain within ambient conditions (9.7 to 35.2 NTUs) during the dredging operations. The State standard for turbidity is 25 NTU while TSS does not have a defined standard. Any increase in turbidity associated with the excavation of the channels to the oceanfront shoreline should be of short duration. Natural conditions support fluctuating turbidity levels in the nearshore and offshore water column of the Permit Area. Storm events are known to increase these levels due to the re-suspension of sand and fine materials. These fluctuating turbidity levels would continue with or without the dredging efforts proposed with these alternatives. No cumulative effects are expected to occur from the dredging and placement activities. Turbidity would be anticipated to be elevated only immediately adjacent to the dredge operation and would only persist while dredging and the subsequent beach filling occurs. These short term direct impacts could result in the clogging of fish gills.

Dredging activity will also impact infaunal resources. Dredging results in a direct mortality of all organisms present within the dredged material (Posey and Alphin, 2002). Although the recruitment pattern is altered, the recovery of species after sediment removal is relatively quick, depending upon the opportunistic nature of the species (Deaton et al., 2010; Posey and Alphin, 2002). At dredge sites monitored off the coast of New Jersey, infaunal assemblages recovered within one year after disturbance, while biomass and taxonomic richness took 1.5 to 2.5 years to recover (Deaton et al., 2010). The diversity of micro and macrofauna tend to be dominated by opportunistic species that recover quickly when affected by natural causes (Mallin *et al*., 2000; Deaton et al., 2010; Posey and Alphin, 2002). Softbottom communities may also change with natural shifting patterns of sediment erosion or deposition (Deaton et al., 2010). Posey and Alphin (2002) suggests that effects of beach nourishment from dredging of an offshore borrow area is minimal compared to the natural variability of the system. The temporal spacing between the periodic maintenance events within the proposed dredged areas should allow for full recovery of benthos populations.

Dredging activities are scheduled to occur between November 16th and March 31st. The timing of construction activities was specifically scheduled to occur outside of the sea turtle nesting season, the West Indian manatee summer occurrence in North Carolina, the piping plover (and other shorebirds) migratory and breeding seasons, and the seabeach amaranth flowering period. Fish and larval biota which utilize the channel within the inlet are not anticipated to be significantly impacted during dredging because the dredge will be positioned outside of the main channel. While some of the larvae will enter into Nixon Channel, many will also enter into Green Channel and thereby avoid any chance for entrainment. Many motile fish species will escape entrainment by the dredge by simply avoiding the dredge. Furthermore, the proposed method of dredging will employ a hydraulic cutterhead dredge opposed to a hoper dredge. Hopper dredges have been documented to incur more impacts to biota including fish and fish larvae in comparison to the cutterhead dredge used for this project. However, dredging, regardless of the season or specific location in relation to the inlet, will result in a limited mortality of fish at all life stages due to entrainment within the dredge.

A hydraulic cutter-suction pipeline dredge (pipeline dredge) would be used for Alternatives 1, 3, 4, 5A, 5B, 5C and 5D. In addition to the pipeline dredge, Alternative 4 would involve the use of a hopper dredge with direct pumpout capabilities to transport material to the beach from the offshore borrow site(s). As opposed to hopper dredges, pipeline cutterhead dredges are mounted (fastened) to barges and are not usually self-powered. Rather, they are towed to the dredging site and secured in place by special anchor piling, called spuds. A pipeline dredge sucks dredged material through one end, the intake pipe, and then pushes it out the discharge pipeline directly into the disposal site. Hopper dredges dredge material into their containment areas. The water portion of the slurry is drained from the material and is discharged from the vessel during operations. When the hoppers are full, dredging stops and the ship travels to a pump-out station located on an offshore barge. The dredge locks up with the station and empties the sediment via pipeline and the material is pumped to the onshore disposal site. The use of hopper dredges often results in a higher rate of turbidity and TSS.

Compared to similar types of dredging methodologies, a pipeline dredge creates minimal disturbance to the seafloor resulting in lower suspended particulates and turbidity levels. Anchor (2003) conducted a literature review of suspended sediments from dredging activities. This report concluded that the use of a hydraulic dredge (i.e., pipeline dredge) limits the possibilities for re-suspension of sediment to the point of extraction. Also, since the sediment is suctioned into the dredge head, the sediment cannot directly enter into the middle or upper water column. Other benefits with the use of a pipeline dredge is that they minimize safety and navigational concerns as the dredge will be well lit, stationary, and will include usage of buoys to mark the location of anchors. Additionally, unlike a hopper dredge, no incidences of sea turtle takes from a pipeline dredge have been identified during the research and development of this document. According to NOAA Fisheries, unlike a hopper dredge, pipeline dredges have not been implicated in sea turtles or other federally listed threatened or endangered species, most likely due to the slow advance of the dredge combined with it's associated noise. Therefore, the use and methods involved with this type of machinery reduces or eliminates the likelihood of an incidental take.

DREDGEPAK® or similar navigation and positioning software will be used by the contractor to accurately track the dredge location. The software will provide real-time dredge positioning and digging functions to allow color display of dredge shape, physical feature data as found in background Computer Aided Design (CAD) charts and color contour matrix files from hydrographic data collection software described above on a Cathode Ray Tube (CRT) display. The software will also provide a display of theoretical volume quantities removed during actual dredging operations.

As with typical dredging and beach nourishment activities, the work includes the use of a dredge plant, pipelines, support barges, and bulldozer equipment. In the case of hopper dredges, a mooring barge would be positioned just offshore to allow the dredge to connect with pipelines leading to the beach. Dredging work generally occurs on a 24 hour/7 days a week schedule within the dredging window resulting in the presence of equipment within navigable waters and along the shoreline. During that time, navigation within the work zone is prohibited for safety reasons disrupting use of certain travel areas. Dredgers are required to operate within United States Coast Guard requirements to reduce the potential of boat accidents. In addition to navigation, the presence and operation of the equipment on the land and water can result in an increase of noise and aesthetics within the localized area. This is expected to last for the extent of the operation.

General Environmental Consequences Related to Beach Fill

Along with dredging activities, the placement of beach material will also impact several resources. The placement of beach fill material will impact the infaunal resources found within the wet beach community as well as nesting turtles and nesting, resting, and foraging birds found along the dry beach community. The addition of beach fill to Figure Eight Island will cause short-term direct impacts to the adjacent wet beach community. Beach fill material will equilibrate offshore where it will, at least temporarily, cover the softbottom community.

The recovery rates of the macroinvertebrate species within the infaunal communities impacted by beach fill activities vary from less than one month (Gorzelany and Nelson, 1987) to between one and two years (Rakocinski et al., 1996). Of the many factors driving these recovery rates, the seasonal timing of the nourishment activity and degree of geotechnical compatibility between the fill and native beach sediments (Wilber et al, 2009). When beach nourishment projects were constructed during times that avoided the spring larval recruitment period and sediment match was good, estimated recover times were relatively rapid (Hayden and Dolan, 1974; Gorzelany and Nelson, 1987). When beach nourishment occurred during the spring and sediment match was poor due to high silt levels (Rakocinski et al., 1996) or high percentage of shell hash (Peterson et al., 2000), recovery times were longer (or a short-term impact was documented and subsequent post-construction monitoring was not conducted for an adequate amount of time to determine recovery times) (Rakocinski et. al, 1996; Peterson, 2000). In a study conducted in Italy where three beaches were nourished at the same time with varying levels of sediment compatibility, it was observed that the two beaches receiving poorly matching sediments remained nearly defaunated one year following nourishment. The beach that received sediment similar to the native beach, the macrofaunal assemblage did not differ significantly from the non-nourished nearby beach following construction (Colosio et. al, 2007). A study conducted in Louisiana also suggested that a poor sediment match lead to the slow recovery of ghost crab abundance on barrier island beaches following the construction of a beach restoration project (Bilodeau and Bourgeios, 2004). As an example, results from an infaunal monitoring following the beach nourishment associated with the Bogue Inlet Channel Relocation Project at Emerald Isle, NC demonstrated that infaunal species found in the marine intertidal (wet beach) environment decreased in population immediately following construction (Carter and Floyd, 2008). Amphipods, an important food source for fisheries and bird resources, showed the slowest recovery, as it was documented that they had not reached pre-construction population levels until 17 months following the beach fill project. During the same time frame, coquina clam populations found along beach filled areas had converged with populations in nearby control sites indicating recovery (Carter and Floyd, 2008). Nelson (1985) indicates that organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels. This may support the reasoning for some organisms to withstand burial up to 10 cm. Other studies reported by Maurer (National Research Council, 1995) supported the burial capabilities of nearshore species, which found that these species are capable of burrowing through sand up to 40 cm. Although the wet beach infauna can adapt to fluctuations in the natural environment, the addition of sediment to the wet beach would have immediate, short-term negative impacts specifically in areas where beach fill will exceed 40 cm in conjunction with the compaction or pushing of fill from bulldozers leveling the material as it is being placed on the beach. Although the marine intertidal infauna can adapt to fluctuations in the natural environment, the addition of sediment to the wet beach would have immediate, short-term negative direct impacts. Rakocinski *et al.* (1996) found that the mole crab populations exhibited a pattern of initial depression after being covered by sediment but fully recovered in less than one year after beach nourishment. In the same study, Rakocinski et al. found that the dominant species of amphipod and a dominant species of polychaete had not recovered within that same time frame and that the amphipod did not recover until two years after the beach renourishment. Temporary burial of infaunal organisms could indirectly affect the birds and fish that forage on these organisms in the short and long-term. Negative cumulative effects could occur if the diversity and abundance of infaunal populations do not recover between nourishment events if the events are occurring within short time periods of each other and/or if the material placed on the beach is less compatible with the native beach sediment. A study by Van Dolah *et al.* (1994) found the use of fill sediments that closely match the native sediments showed an ecological recovery of infaunal species within eight months. Thus, the use of borrow area sediments that are compatible with the native beach and the proper temporal spacing between events should prevent any negative long-term cumulative impacts to the marine intertidal communities, however direct impacts may occur. An examination of multiple studies exploring the impacts of dredge and fill projects on invertebrate communities was performed by Wilber, et. al in 2009. Table 5.16 , taken from this study, provides a brief summary of the findings that suggests that overall, recovery of these organisms occurs within an order of weeks to years (Wilber, et. al, 2009). Based on the documented recovery of infaunal organisms, the time intervals between nourishment operations and the compatibility of fill material are essential to allow for the complete recovery of the organisms.

Table 5.16. Peer-reviewed studies that address beach nourishment impacts to invertebrate communities and their approximate recovery times. (taken from Wilber et. al, 2009)

Study	Target Biota	Important Results	Process	Recovery Time
Gorzalany and Nelson, 1987 (East coast of Florida)	Macroinvertebrates	No change in density or species richness associated with beach nourishment	Fill	<1 month
Hayden and Dolan, 1974 (Cape Hatteras, NC)	Mole crab	Decrease in mole crab density immediately down current from discharge	Fill	< 2 weeks
Johnson and Nelson, 1985 (East coast of Florida)	Macroinvertebrates	Immediate 50% decrease in infaunal abundance, 6% decrease in taxonomic richness	Dredge	9-12 months
Peterson et. al, 2000 (Bogue Banks, NC)	Mole crab, bean clam, and ghost crab	Reduced densities of mole crabs, bean clams, and ghost crab burrows 10 weeks post-nourishment	Fill	Not given

Posey and Alphin, 2002 (Southeastern NC)	Macroinvertebrate community	Shifts in abundance at both control and dredged sites	Dredge	9 months
Rakocinski et. al, 1996	Macroinvertebrate community	Decreased species richness and total density	Fill	Between 1 and 2 years

***It should be noted that the NC studies in this table were conducted prior to the implementation of NC Sediment Criteria Standards.**

Although primary nursery areas (PNAs) are located within the Permit Area, no PNA will be directly impacted by beach fill activity. PNAs are generally defined as being located in the upper portions of creeks and bays. These are usually shallow areas with soft, muddy bottoms surrounded by marshes and wetlands. Low salinity and the abundance of food in these areas are ideal for young fish and shellfish. The 1,400 foot section of estuarine shoreline along Nixon Channel where beach fill is proposed for Alternatives 3,4, and 5A-are characterized by high salinity water with a sandy bottom.

Beach nourishment presents both positive and negative effects on nesting sea turtles. In most cases where beach nourishment has taken place, the oceanfront shoreline has been greatly eroded with tidal fluctuation occurring at the base of the dune. This reduces the suitable nesting areas for sea turtles and destroys nests with eggs that have been established. As a result of beach fill, wider beaches can benefit sea turtles since they require dry beaches to nest, preferring to nest along wide sloping beaches or near the base of the dunes. Potential adverse effects on nesting habitat include alteration of beach substrate characteristics and modification of the natural beach profile. Physical characteristics such as density, compaction, shear resistance, moisture content, slope, sand color, grain size, grain shape, sand mineral content, and gas exchange can affect the success of sea turtle nests (Nelson and Dickerson 1988, Crain et al. 1995). Substrate alteration may affect the ability of female turtles to nest, the suitability of the nest incubation environment, and the ability of hatchlings to emerge from the nest. Escarpments formed during and after beach nourishment may prevent nesting females from reaching suitable nesting habitat, result in the selection of marginal or unsuitable nesting sites in front of escarpments, or result in nest exposure as escarpments recede landward. Numerous studies have described the effects of beach nourishment on nesting success (Crain et al. 1995, Steinitz et al. 1998, Ernest and Martin 1999, Herren 1999). These studies indicate a reduction in nesting success during the first post-nourishment year, followed by a return to normal levels by the second or third year. Declines in nesting success have been attributed to substrate compaction, escarpment formation, and/or modification of the natural beach profile. Beach nourishment also has the potential to improve poor quality nesting habitats associated with chronically eroded beaches (Brock et al. 2009). Davis et al. (1999) and Byrd (2004) documented increases in nesting success immediately following the nourishment of eroded beaches. Increases in nesting success were attributed to the addition of dry beach habitat.

Embryonic development and hatching success are influenced by temperature, gas exchange, and moisture content within the nest environment (Carthy et al. 2003). Changes in substrate characteristics such as grain size, density, compaction, organic content, and color may alter the nest environment, leading to adverse effects on embryonic development and hatching success (Nelson and Dickerson 1988, Nelson 1991, Ackerman et al. 1991, Crain et al. 1995). Nourished beaches often retain more water than natural beaches, thus impeding gas exchange within the nest (Mrosovsky 1995, Ackerman 1996). Uncharacteristically dark sediments absorb more solar radiation, thus potentially resulting in warmer nest temperatures. Dark sediments may produce nest temperatures that are too high for successful embryonic development (Matsuzawa et al. 2002). Higher temperatures may significantly reduce incubation periods and contribute to a higher incidence of late-stage embryonic mortality (Ernest 2001). Nest temperature also influences sex determination in hatchlings, with warmer temperatures producing more females and cooler temperatures producing more males (Wibbels 2004). Consequently, dark sediments may alter hatchling sex ratios. Investigations of beach nourishment effects on hatching success have reported variable results; including positive effects (Broadwell 1991, Ehrhart and Holloway-Adkins 2000), negative effects (Ehrhart 1995, and no effect (Raymond 1984, Nelson et al. 1987, Broadwell 1991, Ryder 1993, Steinitz et. al. 1998, Herren 1999, Brock et al. 2009). The variation in findings has been attributed to differences in the physical attributes of individual projects, the extent of erosion on the pre-nourishment beach, and construction techniques (Brock et al. 2009).

The turbidity plume at the disposal end of the pipeline does not usually increase above ambient conditions when the material being dredged is of a coarse grain size as this material typically settles rapidly compared to finer material, as observed during the dredging and inlet relocation project at Bogue Inlet in 2005. Smaller fish species within the area of the turbidity plume could be affected due to suspended particulates entering into their gills reducing oxygen intake. However, most fish within the surf zone are highly mobile and can avoid the plume by migrating to other areas. In North Carolina, the effects of a Brunswick County beach nourishment project on surf fish, benthic invertebrates, and water quality, were evaluated from March 2001 to May 2002. Seining and trawling before and after the project found no significant differences in fish abundance or diversity among disturbed, undisturbed, and reference sites during any season. This was attributed to the high mobility and schooling behavior of the dominant fish species (anchovies and drum family), resulting in clustered and variable distribution (Deaton, 2010).

The increase in dry beach as a result of beach nourishment is expected to benefit some shorebirds, water birds and colonial birds that utilize this habitat. Several bird species utilize this habitat for roosting, foraging and nesting. Typically, the placement of beach compatible material serves to protect the dunes and beaches thereby benefitting the bird resource utilizing those areas. These beach fill events generally do not occur on a regular basis and the periodic loss of habitat utilized for foraging/resting shorebirds could occur pending storm events.

6. What are the environmental and economic impacts associated with each specific alternative?

The following sections describe the additional environmental and economic impacts anticipated for each alternative being considered. The effects description for the selected resources are derived from the changes presented in the Delft3D modeling results using the 2006 inlet and shoreline conditions and from the geomorphological analysis using historical aerials. As previously stated, these model runs are based on predetermined input conditions and are not intended to represent predictions of what changes to expect in the future as this would require an ability to predict future weather and oceanic conditions. In fact, the observed changes up to the current conditions did deviate from what was concluded at the end of the 5-year modeling period. This reiterates the difficulties in predicting long-term changes in coastal inlets with the use of models and verifies the limitations that modeling possesses. The reason for choosing the 2006 conditions was the fact that this set of conditions represented the worst-case scenario when erosion was at its highest during the modeling evaluation period. Even though current conditions benefit Figure Eight Island, analysis of the ebb tide channel's historic behavior indicates that it will realign in a northern direction returning the erosive rates on Figure Eight. The following assessment is an equal evaluation of all the alternatives using the same baseline conditions under the erosive conditions, which are the 2006 conditions.

A: IMPACTS ASSOCIATED WITH ALTERNATIVE 1: NO ACTION

Under Alternative 1, the Figure "8" Beach HOA and individual property owners would continue to respond to erosion threats in the same manner as in the past. These measures include beach scraping (or bulldozing) to create and/or repair damaged dunes, intermittent beach nourishment, and the deployment of sandbags (Figure 1.1). As stated earlier, 19 homes currently have installed sandbags and several intermittent beach nourishment projects have involved varying volumes of fill ranging from 50,000 to 350,000 cubic yards along various northern reaches of the oceanfront shoreline on Figure Eight Island since 1993 (Table 5.17).

Table 5.17 Figure Eight Island's Historical Beach Nourishment on the North End

Project Date	Volume (c.y.)	Source	Profiles
Feb. 1993	274,000	Nixon Channel	60+00 to 105+00
January 1997	Not avail.	Nixon Channel	15+00 to 105+00
March 2001	350,000	Nixon Channel	0+00 to 90+00
November 2005	261,235	Nixon Channel	30+00 to 95+00
Spring 2009	295,000	Nixon Channel	67+00 to 95+00
Spring 2011	275,000	Nixon Channel	0+00 TO 95+00

The impacts associated with a continuation of existing conditions, as defined by Alternative 1, are described below.

ESTUARINE HABITATS

<u>*Salt Marsh Communities*</u>

Direct and Indirect Impacts: The salt marsh resources within the Permit Area are located primarily along the sound sides of Figure Eight, Hutaff, and the salt marsh islands in proximity to the AIWW. In addition, an area of salt marsh is located along the northeastern portion of Figure Eight Island between the end of Beach Road North and the sandy spit near Rich Inlet. As depicted in aerial photographs taken by Geofiny, Inc. between 2006 and 2010, large quantities of sand have entered the estuary and subsequently built a very large shoal. Dr. Cleary's shoreline analysis suggests that portions of the salt marsh along the shoreline behind Rich Inlet have experienced erosion in response to the development of this large flood tide delta. While the erosion rates in this area have been significantly greater than the pre-1993 rates, this increase cannot be directly attributable to dredging in Nixon Channel due to the influence of the migrating sand lobes into Nixon Channel associated with the morphological changes that have occurred to Rich Inlet since 1993. Regardless, this erosion of the salt marsh shoreline would be expected to continue so long as the flood tide delta directs the majority of the flow close to the eroding shoreline (Cleary, pers. comm.). In addition, erosion of salt marshes has been occurring along the Nixon Channel shoreline. This erosion is related to movement of the Nixon Channel thalweg toward Figure Eight Island. Recent photographs have shown exposure of high marsh peat and shrub stumps along the estuarine shoreline in this location which have helped validate this process (Cleary, pers. comm.). Due to the dynamic nature of the inlet system and the proximity of the salt marsh resources to the evolving shoreline, direct and indirect impacts to salt marshes are expected to continue under Alternative 1.

Cumulative Impacts: As stated earlier, the main channel within the gorge of Rich Inlet has remained in place for approximately 20 years. With the main channel remaining stable, it is expected that the salt marsh communities will continue to respond to naturally evolving shorelines. However, the salt marsh resources found along the sound side and within the northern spit of Figure Eight could be impacted over time due to erosion. The area of salt marsh located in proximity to the sand spit along the north eastern terminus of Figure Eight Island could degrade should the feeder creek become blocked with accreting sand along its entrance on the Nixon Channel shoreline or could undergo conversion to an unvegetated shoal due to shifting configuration of the ebb tide channel. In a 1989 aerial photo, this salt marsh complex is shown as an unvegetated sandy beach or shoal with no signs of marsh or vegetated tidal creek present in the area. It is expected that the salt marsh complex within this spit area will undergo natural transitions and experience conversion of community types over time under Alternative 1.

Along Hutaff Island, some oceanfront areas may experience breaches in the primary dune due to storms and high wave action, resulting in the formation of natural washover features which may extend into adjacent high salt marsh. In this natural process, these washover areas may cause salt marsh to become inundated and transition into overwash fans, causing potential corresponding shifts in infaunal community composition, as well as shifts in finfish and bird community composition. Little is known about how resident species adapt to irregularly flooded marshes which are inundated for weeks at time. These resident species include, among other species, several types of fish (*e.g.*, killifish and mummichogs), brownwater snakes, crustaceans (various species of crabs), birds (yellowthroat, marsh wren, harrier, swamp sparrow, and five species of rails), and several species of mammals (nutria, cotton rat, and raccoon) (CCSP, 2009). Washover events may increase if the predicted increase in the rate of sea level is validated. Therefore, beyond the existing natural processes of erosion and development, no cumulative impacts are anticipated with Alternative 1.

Submerged Aquatic Vegetation

Direct, Indirect, and Cumulative Impacts: For Alternative 1, three confirmed and 17 probable SAV occurrences have been identified within the Permit Area (Figures 4.3a and 4.3b in Chapter 4). The three confirmed occurrences are specifically found within tidal creeks along the edge of salt marshes west of Green and Nixon Channel. Because the confirmed locations of existing SAV resources occur removed from the areas experiencing erosion along Rich Inlet and Nixon Channel, impacts to SAV resources are not expected. SAV resources require light to penetrate the water column for healthy growth. A prolonged increase in turbidity and TSS would serve to decrease the amount of available light. Cleary and Knierim (2001) observed that dredging within Nixon Channel and the associated beach nourishment along the northern portion of Figure Eight Island resulted in a temporary increase of turbidity and TSS primarily at the discharge site located on the ocean shoreline. No measurements were taken in proximity to the dredge site within Nixon Channel. Temporarily increased values would not be anticipated to affect the natural long-term growth of SAV. Furthermore, cumulative impacts are not expected to be incurred as SAVs are expected to migrate to their preferred depth should sea levels rise over the next 30 years as currently predicted.

Shellfish Habitat

Direct, Indirect, and Cumulative Impacts: Due to the remote location of shellfish resources from Rich Inlet and Nixon Channel, no significant adverse impacts are anticipated to shellfish resources with the implementation of the No Action alternative.

UPLAND HAMMOCK

Direct and Indirect Impacts: The activities associated with Alternative 1 is not anticipated to cause direct or indirect impacts to the upland hammock resources located within the Permit Area due to the distance of the resource from the oceanfront shoreline. The closest upland hammock is located on Figure Eight Island approximately 305 m (1,000 ft.) from Rich Inlet as shown in Figure 4.1 in Chapter 4.

Cumulative Impacts: Upland hammocks within the permit area may be threatened by potential sea level rise overtime if predictions are validated. As stipulated by North Carolina HB 819, only “historic rates of sea-level rise may be extrapolated to estimate future rates of rise but shall not include scenarios of accelerated rates of sea-level rise unless such rates are from statistically significant, peer-reviewed data and are consistent with historic trends". However, if any rise is validated, the increase in sea level could result in potential cumulative impacts to coastal upland hammocks present in the permit area. Outside of natural effects, such as severe storms/hurricanes and possibly sea level rise, no project impacts to upland hammocks are anticipated.

INLET DUNES AND DRY BEACHES

Direct and Indirect Impacts: The rate of erosion on the north end of Figure Eight Island reduced habitat for shorebirds, including the endangered piping plover, and reduced recreational area for humans. Based on the 2006 environmental conditions used for the Delft3D model simulations, the model indicated a portion of the spit area projecting off the north end of Figure Eight Island into Rich Inlet eroded and converted into intertidal and subtidal habitat at the end of the 5-year simulation (Figures 5.2a through 5.7a). The conversion of approximately 7 acres of inlet dune and dry beach habitat to intertidal and subtidal habitat would reduce the area available for nesting shorebirds (including the endangered piping plover) and colonial waterbirds on the south side of the inlet. This erosion reduced habitat for nesting turtles and foraging/resting shorebirds on the Figure Eight Island side of the inlet. However, the opposite held true on the Hutaff Island side of the inlet, which displayed accretion of approximately 5 acres on the southern portion of Hutaff Island. This increase of shoreline provided additional turtle nesting and shorebird foraging/resting habitat that was lost on the south side of Rich Inlet.

In Alternative 1, material from the dredging of the previously permitted area in Nixon Channel has been utilized, and is expected to continue, for periodic beach nourishment along the oceanfront shoreline of Figure Eight Island north of Bridge Road. Any beach fill should provide some indirect protection to inlet dunes and expand dry beaches as some of the placed material would be expected to be transported north towards the inlet, but would be on a temporary and short-term basis. Because these dredge and fill activities occur sporadically and are not part of a dedicated beach nourishment project, the amount of material placed on Figure Eight Island has not been enough to overcome the current high rate of erosion.

Along the southern tip of Hutaff Island, the inlet dunes and dry beaches expanded allowing for additional habitat for shorebirds and nesting sea turtles on the north side of Rich Inlet (Figure 4.19). This accretion benefited the inlet dunes and dry beaches along Hutaff Island and the resources that utilize them.

Cumulative Impacts: Under Alternative 1, effects on inlet dunes and dry beach habitats depend on how the inlet bar channel behaves. As shown by Dr. Cleary's geomorphic analysis of Rich Inlet, these inlet habitats undergo significant changes in response to the reorientation of the ebb tide delta. Although the relative position of the inlet has been stable over the past century, fluctuations in orientation of the main ebb-channel have forced subsequent periods of erosion and accretion on the adjacent shorelines of Figure Eight and Hutaff Islands (Cleary, 2009). The inlet bar channel maintained a northerly orientation toward Hutaff Island between the mid-1990's until 2010 which resulted in erosion along the northern end of Figure Eight Island and accretion along the southern end of Hutaff Island. The bar channel naturally shifted to a southerly alignment toward Figure Eight Island in 2010, and this resulted in accretion along the north end of Figure Eight and erosion on the south end of Hutaff Island. While this orientation is favorable for Figure Eight Island, based on the past history of the inlet channel, the bar channel is expected to again shift back toward Hutaff Island which will initiate another round of erosion on the north end of Figure Eight. This shift will likely prompt the planning of a beach nourishment event. Outside of the natural fluctuation of the ebb-channel, cumulative impacts to inlet dunes and dry beaches would not be expected.

Regardless of the orientation of the inlet, the inlet dunes and dry beaches have persisted collectively within the inlet complex on a cyclical parttern of erosion and accretion. A review of data collected by Audubon North Carolina for piping plover between 2008 and 2014 showed that piping plovers have continued to utilize the habitats within the Rich Inlet complex despite the natural modifications over time. Specifically, of the seven landscape types where piping plovers were observed foraging within this area, the oceanfront beach in proximity to the inlet was the second most utilized habitat type for foraging piping plovers (Addison and McIver, 2014).

INTERTIDAL FLATS AND SHOALS

Direct Impacts: As mentioned in Chapter 4, shorebirds, colonial waterbirds and other waterbirds utilize intertidal flats and shoals in the inlet complex for foraging and resting while traveling to their wintering and nesting grounds. Breeding and non-breeding federally threatened species and species of special concern also utilize intertidal shoals (Table 4.5). Macroinfaunal species found within intertidal flats and shoals are a primary food source for several migratory and resident shorebirds, waterbirds, as well as for many commercially and recreationally important fish. These unconsolidated communities lack structure and are dynamic in nature. Therefore, the unconsolidated and unvegetated communities that occur in the inlet complex are expected to continue to be naturally redistributed with Alternative 1. Periodic storms and seasonal climatic changes influence abundance and diversity of micro- and macrofauna, tending toward a more opportunistic community (Mallin *et al*., 2000; Deaton et al., 2010).

Because the previously permitted dredging area in Nixon Channel associated with Alternative 1 does not include intertidal flats or shoal areas, this alternative is not expected to have direct impacts on those habitats. Additionally, Delft3D modeling showed that intertidal flats or shoals would not be directly impacted by this alternative. Therefore, beyond existing natural processes and the effects of channel maintenance activities within Nixon Channel, no additional direct impacts are anticipated with Alternatives 1.

Indirect and Cumulative Impacts: Due to maintenance dredging-related increases in suspended sediment and turbidity (which could be transported to the interior of the inlet complex during flood stages of the tidal cycle); minor secondary impacts could be introduced. The intertidal flat biotic community's density and abundance may fluctuate over time, but overall would be expected to remain persistent. During flood stages of the tidal cycle, dredged material that remains in suspension could be transported into the interior portions of the inlet complex and settle on the intertidal flats and shoals. However, the material shoaling the Nixon channel has a low silt content, and is fairly coarse, will result in only minor and ephemeral increases in both suspended sediment and turbidity.

Like inlet dunes and dry beaches, effects on intertidal flats and shoal habitats depend on the orientation of the ebb-tide channel and how it behaves. The formation and reformation of these habitats are dynamic and ever changing, especially during certain time periods and responding to storm events. Delft3D model results inferred from those performed for Alternative 2 suggest that by year five and estimated 357,000 cubic yards of material will be transported into the inlet. With this influx of material, the extent of the intertidal flats and shoals may increase over time. As the sand spit on the north end of Figure Eight Island began to evolve into intertidal sand flats within 5 years, as shown by the model, the increased sedimentation within the inlet complex is expected to facilitate the development of additional intertidal flats and shoals as stated previously with the conversion of inlet dunes and/or dry beach. With this net influx of material, the model results indicated a net change to approximately 0-5 acres of intertidal flats and shoals within the inlet complex. As such, this ephemeral habitat type would be expected to persist during natural adjustment periods of the bar channel, despite the bar channels positioning or location. Therefore, foraging and resting bird species, including piping plover, utilizing the intertidal flats and shoals should not be affected by Alternative 1 under normal conditions.

This determination can be somewhat validated with the presence of bird species, particularly piping plover, observed and recorded by Audubon North Carolina. During the period from 2007-2011, the bar channel underwent a major shift from a central position within the inlet to a southerly position. The shifting resulted in a change to inlet flats and shoal habitats located within Rich Inlet. A review of Audubon North Carolina data for piping plover for this timeframe suggested that the number of birds appear to have adjusted to the geomorphic shifting of these habitats. The range of sighted individuals for a 4-day period were a maximum of 164 in the Fall of 2007 to a minimum of 87 in 2011. In the spring, the individual numbers were 75 in 2007 to 66 in 2011 (Audubon North Carolina, pers. comm., 2012). Overall, the numbers appear to be within normal range of variations. It was also observed that piping plovers heavily favored the intertidal zones in Rich Inlet for foraging, using the areas approximately 90% of the time. This adjustment was also demonstrated in the Piping plover bird surveys conducted by Dr. Webster for Figure Eight HOA. During the period of 2001-2006, his data showed a constant presence of the species, ranging from a high of 51 individuals in 2001 to a low of 10 individuals in 2004.

OCEANFRONT DRY BEACH AND DUNE HABITATS

Oceanfront Dune Communities

Direct and Indirect Impacts: The direct and indirect impacts associated with Alternative 1 are expected to include a continuation of natural shoreline changes in the Permit Area. As a result, the dune community along portions of Figure Eight Island that exhibit higher erosion rates would be expected to be highly susceptible to regular storm events. During times in which the Rich Inlet bar channel is oriented toward Hutaff Island, as it was between the mid-1990's and 2010, high tides extended to the first line of oceanfront structures on the north end of the island with 19 structures along the ocean shoreline protected by temporary sandbag revetments installed along the seaward toe of the dune. Subsequent to the shifting of the bar channel to a more southerly location, the northernmost portion of Figure Eight Island has experienced substantial accretion. However, should the inlet channel re-orient itself to a more northerly position at some point, a continuation of erosion during that time could result in an additional 21 homes on the extreme north end of Figure Eight Island requiring protection by new sandbag revetments. The footprint of the sandbag revetments has a direct negative impact on the natural dunes in this area by preventing the growth of vegetation. These new sandbag structures will also have a state permit expiration date and when required to be removed, the dune communities will again be susceptible to erosion. The existing dune system along Figure Eight Island south of 302 Beach Road North has been maintained with the help of beach scraping activities which provides some short-term beneficial protection to these dune communities.

The natural dune communities located on Hutaff Island are anticipated to migrate westward as natural processes influence the environment. Although the physical location of the dune system may change as natural overwashing and other storm-induced events occur, the dune communities at Hutaff Island are expected to remain intact with minimal direct and indirect impacts.

Cumulative Impacts: The long-term result of beach scraping, rebuilding of dunes following storms, installation of sandbag revetments, and disposal of navigation maintenance material on portions of the Figure Eight Island shoreline are not anticipated to provide adequate protection to the dune communities. As these resources remain vulnerable to storm damage, dune vegetation would most likely be threatened resulting in a degraded habitat used by several species, such as seabeach amaranth. Seabeach amaranth prefers overwash flats at accreting ends of islands and lower foredunes and upper strands of non-eroding beaches; these preferred habitats are located on the middle and southern portions of Figure Eight Island. As mentioned in Chapter 4, seabeach amaranth is an effective sand binder, building dunes where it grows. Due to lack of long-term protection against storm influenced damage, negative cumulative impacts to the dune-stabilizing seabeach amaranth, and subsequently the dune communities at Figure Eight Island in general, are expected with the implementation of Alternative 1.

The dune communities located on Hutaff Island would be expected to migrate westward as natural processes influence the environment, but the dune communities are expected to remain intact. However, if the predicted increase in rates of sea level rise (IPCC, 2007) is validated, this could potentially threaten the long term viability of dunes within the permit area as storm surges could degrade these resources.

Although the location of the dunes may change as overwash and other storm-induced events influence the environment, the anticipated indirect and cumulative impacts to the dune community on Hutaff Island in response to Alternative 1 would be negligible as these processes occur under natural conditions.

<u>*Oceanfront Dry Beach Communities*</u>

Direct Impacts: Under current conditions, the northern section of Figure Eight Island has experienced accretion over the last few years benefitting the oceanfront dry beach area. This is largely due to the southerly position of the ocean bar channel. The accretion has provided additional sea turtle nesting and bird habitat. Other benefits received from this widening of dry beach is the increase for recreational use and the additional protection of the oceanfront shoreline. However, based on the documented history of Rich Inlet, the ocean bar channel is expected to eventually assume a more northerly alignment in the future which could initiate a new round of accelerated erosion along the north end of Figure Eight Island.

With the eventual shift of the bar channel to an alignment toward Hutaff Island, the dry beach community along Figure Eight Island may be directly impacted differently during and following all beach nourishment, beach scraping, and sandbag installation events associated with Alternative 1. Beach nourishment activity will initially disturb the dry beach habitat due to the use of bulldozers, however ultimately it will serve to increase the amount of dry beach habitat. As described previously in General Environmental Consequences Related to Beach Fill, the infaunal communities will be directly impacted due to burial, however due to the resilient nature of these organisms, the use of compatible material and timeframe of placement, the impacts will be temporary. Beach scraping affects dry beach by relocating sand from the lower portion of the beach (including the wet beach) to a higher area on the berm thereby causing a disturbance to the infaunal communities and the nesting and resting habitats for shorebirds including plovers, willets, and sanderlings provided by the dry beach. While sandbags may provide protection to the structures behind them, they are impermeable structures and therefore will not absorb wave energy which could cause local beach scour to accelerate. The acreage of this impacted area would be determined by the specific fill plan, which has varied in the past.

The composition, color, and grain size of the beach sand can affect the incubation time, sex, and hatching success of turtle hatchlings (Deaton et al., 2010). Physical characteristics such as density, compaction, shear resistance, moisture content, slope, sand color, grain size, grain shape, sand mineral content, and gas exchange may affect the success of sea turtle nests (Nelson and Dickerson 1988, Crain et al. 1995). The fill placed upon Figure Eight Island will conform to the State sediment criteria rules and therefore is not expected to impact the nesting success of sea turtles. Because the material utilized for the nourishment will meet State Sediment Criteria, the widened dry beach is expected to increase sea turtles nesting habitat with native compatible material. The proposed project would be conducted during the winter and, therefore, would not impact potential nesting activity by birds or turtles.

With the current location of the ocean bar channel, oceanfront dry beach communities along the southern portion of Hutaff Island has experienced erosion and are reduced in width. This has reduced the optimal conditions for nesting turtles and resting/foraging shorebirds. With the eventual shift of the bar channel to an alignment toward Hutaff Island, the southern portion of Hutaff Island is expected to accrete and restore oceanfront dry beach communities. No direct impacts to the oceanfront dry beach communities are expected within the permit area under Alternative 1.

Indirect and Cumulative Impacts: Delft3D model results suggested net indirect impacts of approximately 0-5 acres of oceanfront dry beach habitat incurred over the 5-year period. Modeled shoreline volume changes over the 5-year simulation period for Alternative 2 (which are also applicable to Alternative 1) along the 12,500 feet of Figure Eight Island situated between Bridge Road and Rich Inlet resulted in a loss of 66,000 cubic yards/year. Specifically, the volume changes included 18,000 cubic yards/year of accretion between stations F90+00 and 60+00 and a loss of 84,000 cubic yards/year between stations 60+00 and 105+00. (Table 5.3a). Along the southern 2,640 feet of Hutaff Island, the model results indicated this section of the island would accrete at a rate of 53,000 cubic yards/year while the section between 175+00 and 215+00 eroded at a rate of 35,000 cubic yards/year. In general, the model results for Alternative 2, given the 2006 conditions, agreed reasonably well with observed volume changes along both Figure Eight Island and Hutaff Island between April 2005 and October 2008, the time period used to calibrate the Delft3D model (see Appendix B). As previously described, the positioning of the bar channel has an effect on the accretion and erosion locations on either island. Consequently, the magnitude of oceanfront dry beaches are likely to fluctuate with the shifting of the ebb tide channel. This would likely dictate where sea turtles would nest. Although sea turtles have continued to nest along the eroding oceanfront shoreline of Figure Eight Island, the number of nests would be expected to decline due to the continued loss of suitable dry nesting beach habitat, particularly in the areas with sandbag revetments, despite sporadic beach nourishment events. Furthermore, the survival rate of hatchlings in this area could be reduced due to possible inundation of encroaching mean high water marks through severe erosion.

Although Figure Eight Island is currently experiencing substantial accretion, the cyclical loss of dry beach habitat is expected to eventually return to this location pending the realignment of the bar channel over time. This would therefore result in an overall reduction of adequate turtle nesting habitat, shorebird and water bird habitat, suitable habitat for the federally protected seabeach amaranth, and some recreational opportunities along this oceanfront portion of the island.

If sea levels continue to increase as predicted, then unmanaged areas of the dry beach community may become more vulnerable to erosion leading to negative cumulative impacts to the dry beach. However, as an example of how sea level rise may or may not affect the performance of a beach nourishment project, the Wrightsville Beach and Carolina Beach federal storm damage reduction projects can be evaluated. Both of these project have been in existence since 1965 (50 years) and have been subjected to the same rate of sea level rise applicable to Figure Eight Island. A review of the nourishment rates for these two projects, with and without sea level rise, shows no significant change in the volume or frequency of periodic nourishment needed to maintain the projects.

WET BEACH COMMUNITIES

Direct and Indirect Impacts: The marine intertidal community along Figure Eight Island, which includes macro infaunal species such as polychaete worms (Phylum Annelida), coquina clams (*Donax variabilis and D. paruvula*) and mole crabs (*Emerita talpoida*), will be directly impacted during and following all beach nourishment and beach scraping events associated with Alternative 1. These infaunal communities will be directly impacted due to immediate burial. Areas where fill will exceed 40 cm are expected to experience higher rates of infaunal mortality. As mentioned in Chapter 4, Nelson (1985) indicates that organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels. Indirect impacts would be expected to affect shorebird, crustacean and fish foraging, and will impact recreational fishing through a temporary reduction in bait species during and immediately after construction. However due to the rapid recruitment of these organisms and compatible beach fill material, the impacts should be temporary for Alternative 1.

Sandbags used to provide storm protection for imminently threatened structures on Figure Eight Island may reduce the area of wet beach by providing a temporary barrier to the migration of wet beach along the active beach profile. These structures are generally installed when the mean hide tide is within twenty feet of a home or other infrastructure, which is the state requirement prior to authorizing oceanfront sandbags. This leaves minimal or no wet beach habitat to support infaunal communities. While the expiration of the sandbag permits may result in the removal of some of the sandbag revetments, future erosion threats to other ocean front structures could lead to the installation of an additional 21 sandbag revetments over the 30-year planning period. This is expected to have negative indirect impacts to the wet beach areas along certain sections of the Permit Area. Based on future shoreline change analysis, less than 5 acres of marine intertidal are anticipated to be indirectly impacted within the Permit Area, specifically along the oceanfront shoreline and in proximity of Rich Inlet on Figure Eight Island.

The marine intertidal communities on Hutaff Island are not anticipated to be impacted.

Cumulative Impacts: The periodic beach nourishment and beach scraping activities occurring on Figure Eight Island, will temporarily impact the marine intertidal communities, but is not expected to result in long term impacts. Sandbag placement could potentially result in cumulative impacts on wet beaches along the ocean shoreline of Figure Eight Island over a longer period if intermittent nourishment events are not taking place.

Placement of sandbags would be expected to occur as long as there are oceanfront homes being threatened. Location and timing may vary, but sandbag revetments are anticipated with the continuation of erosion on Figure Eight Island.

MARINE HABITATS

Softbottom Communities

Direct and Indirect Impacts: Softbottom communities are dynamic in nature where periodic storms and seasonal climatic changes influence abundance and diversity of micro and macrofauna, tending toward a more opportunistic community (Mallin *et al*., 2000; Deaton et al., 2010). Softbottom communities may also change with natural shifting patterns of sediment erosion or deposition (Deaton et al., 2010). Despite their dynamic state, softbottom resources would directly and possibly indirectly be impacted by increased levels of turbidity, immediate removal, and immediate burial of infaunal biota during dredging operations. These effects would occur during and following the dredging within maintenance events within Nixon Channel. The previously permitted dredging area within Nixon Channel encompasses approximately 25 acres of softbottom habitat, and therefore up to that amount could be impacted with each event. In addition to dredging, the placement of fill material along Nixon Channel shoreline will cover softbottom communities; consequently impacting any infaunal resources inhabiting the area. This could, in turn, affect any fish species that use the softbottom habitat along this shoreline for foraging on the benthic community. The same holds true for fill placement activity along the oceanfront. Dredge material will be placed directly on nearshore softbottom habitat, covering any infaunal species present at the time nourishment occurs. Also, the beach fill material will equilibrate, or move offshore over time where it will, at least temporarily, cover the softbottom community. Both direct and indirect covering of oceanfront softbottoms could potentially affect any migrating or year round fishery resources that feed on the infaunal species within this habitat. See the section entitled "General Environmental Consequences Related to Beach Fill" above for more details pertaining to impacts to the softbottom community.

Because the beaches along Hutaff Island will not receive disposal material, impacts to softbottom resources outside of natural shifting processes on or around Hutaff Island in response to Alternative 1 are not anticipated.

Indirect impacts associated with Alternative 1 include the temporary loss of prey for foraging fish and invertebrates from the softbottom habitats within the 25 acre footprint of the previously permitted area within Nixon Channel. Additional indirect impacts to the softbottom habitat could be incurred as a result of the placement of material on the existing dry beach as the profile reaches equilibrium. Over time, the slope of the fill would adjust and equilibrate seaward covering additional softbottom areas with various depths of beach fill. Some of the adjustment depths will be greater than what the infaunal community can tolerate, leading to indirect mortality of the species populating the nearshore softbottom. This could, in turn, affect the foraging behavior of fish species utilizing the oceanfront softbottom community for a food source. The rate of adjustment for the toe of slope ranges from 6 months to 12 months and depends largely on weather conditions and on the content of material used for beach fill. If the time of equilibrium is short, then mortality might be higher since there is minimal time for the infaunal species to adjust. In general, the recolonization of these infaunal species typically tends to occur within the order of several months, which depends greatly on the compatibility of the material used for nourishment. It should be reiterated that the material placed over the softbottom habitat area meets the State's sediment criteria requirements and is considered to be compatible to the native sediment. By using compatible material, combined with the adaptive nature of the infaunal species in this harsh environment, the response of the softbottom community should reflect a normal short-term recovery period along the oceanfront shoreline. This short-term recovery is expected to minimize any effects on the feeding behavior of fish species.

Cumulative Impacts: Activities associated with Alternative 1 are not anticipated to cause cumulative impacts to the softbottom communities due to the short recovery period of the infaunal species which utilize them. Furthermore, these habitats are dynamic in nature and due to continued sediment transportation through Rich Inlet; they will reform following dredging operations.

WATER QUALITY

Turbidity and TSS

Direct and Indirect Impacts: Excessive sediment loading increases turbidity and sedimentation, which can result in the clogging of fish gills and reduced recruitment of invertebrates. Furthermore, turbidity can suppress SAV growth, cause low oxygen events leading to fish kills, and cause mortality of organisms in the softbottom community, including shellfish. For Alternative 1, the periodic dredging of Nixon Channel and the placement of beach fill material along stretches of Figure Eight Island is expected to result in temporary increases in suspended sediment and turbidity. Areas of increase are expected along the nearshore environment where placement occurs and within Nixon Channel where the cutterhead is suctioning. As stated previously in the General Environmental Consequences Related to Dredging section, measurements for turbidity and TSS were taken before, during, and after the dredging within Nixon Channel and the associated placement of beach fill along the oceanfront shoreline of Figure Eight Island in 2001. Cleary and Knierim (2001) determined that both parameters increased at the point of discharge on the oceanfront shoreline, however, these values returned to ambient conditions rapidly. Therefore, any increase in turbidity associated with the dredge and fill activities associated with Alternative 1 would be of short duration, which was also observed during the Bogue Inlet Channel Relocation Project in Emerald Isle, NC. Any increase of turbidity or TSS will be minimized further because the silt content of the material in the existing permit area in Nixon Channel is relatively low, averaging about 1%.

Cumulative Impacts: Natural conditions within the Permit Area exhibit extreme fluctuations in turbidity and TSS levels as a result of the winnowing away of exposed peat and mud layers near the soundside shoreline along northern Figure Eight Island. Under the Alternative 1, erosion of the soundside shoreline would continue with minimal changes in turbidity levels as a result. Turbidity and TSS levels would be expected to increase within the inlet and along the oceanfront shoreline during storm events. Therefore, naturally fluctuating turbidity and TSS levels would continue with or without beach nourishment and dredging efforts undertaken with Alternative 1. No cumulative impacts are anticipated.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: The simulated change to the tidal prism within the permit area was not specifically modeled for Alternative1; however it was simulated for Alternative 2 (Abandon and Retreat) which is similar to this alternative, but without beach nourishment and dredging. As derived from the Delft3D model, the tidal prism through Rich Inlet averaged 502.9 million cubic feet over the five year simulation period. This average tidal prism during any one year of the simulation showed only minor variations with no definitive trends, i.e., no indication the tidal prism was increasing or decreasing over the five year simulation. Of the total volume of water flowing through Rich Inlet, 55.3% passed through Nixon Channel and 36.1% through Green Channel. The remaining 8.6% passed through the marsh area behind the inlet. Under Alternative 1, the only conditional change that has the potential to effect the tidal prism is when a dredging event, associated with the periodic beach nourishment, occurs within the 25 acre previously permitted area in Nixon Channel. Dredging within the footprint in Nixon Channel is expected to result in minimal hydrodynamic or salinity level changes for both short and long-term conditions.

Larval Transport

Direct Impacts: The sporadic dredging and beach fill operations associated with Alternative 1 are not anticipated to significantly impact larval transport into Rich Inlet. Larvae of some fish species are expected, however, to be entrained within the dredge while operating in Nixon Channel. These include the larvae of winter and early spring spawners such as spot, Atlantic croaker, southern and summer flounders, menhaden. However, because the peak of juvenile settlement generally occurs within the estuary in spring through early summer (Ross and Epperly 1985), these impacts are anticipated to be limited. Furthermore, due to the relatively small volume of water pumped through the dredge compared to the volume included within the tidal prism, impacts to many species of fish larvae are expected to be minimal.

Indirect and Cumulative Impacts: No indirect or cumulative impacts are anticipated under Alternative 1.

PUBLIC SAFETY

Direct and Indirect Impacts: The erosion rate along the ocean shoreline and the back side of the northern portions of Figure Eight Island previously threatened the integrity of nineteen (19) homes on the ocean shoreline and one home on the Nixon Channel shoreline, and may pose an imminent threat to an additional twenty-one (21) homes along the ocean shoreline over the next 30 years. If these homes and the associated infrastructure were to become severely damaged or destroyed due to erosion or storm induced impacts, public safety could be compromised as structural debris and leaking sewage from destroyed septic systems could present hazardous conditions. The activities associated with Alternative 1 will provide some level of protection from storm induced erosion in the near term, and thereby provide positive direct and indirect impacts to public safety. However, the sporadic temporal nature and geographic extent of the shoreline protection measures associated with Alternative 1 will not ensure adequate protection for all areas experiencing erosion; therefore some direct and indirect impacts may occur in regards to public safety. Although Figure Eight Island is a private island with restricted access, homeowners and authorized visitors would continue to access the impacted areas and the general public would continue to have access by boat. These impacts may include the release of sewage and other hazardous materials onto the beach and into the coastal waters as well as closed areas of beach impeding recreation.

Cumulative Impacts: The activities described within Alternative 1 are anticipated to only provide short-term protection from erosion and storm induced damage to Figure Eight Island's infrastructure. For Alternative 1, the distance between a structure or infrastructure element (roadway, utility, etc.) was measured relative to the 2007 shoreline positon and once the shoreline encroached within 20 feet of the foundation of a structure or within 20 feet of a road right-of-way, or 20 feet from a utility, under Alternative 1, action would be taken to protect the threatened structure or infrastructure element using sandbags. Eventually the erosion would continue past the sandbags resulting in the need to either move the structure to a new location or demolish it. Ultimately, demolition activities, road undermining, and exposure of utilities would continue as long as the erosion continues to threaten the infrastructure. The longer the situation exists, the higher the risk of personal injury. These impacts may be further exacerbated if the predicted rise in sea level occurs over the next thirty (30) years.

AESTHETIC RESOURCES

Direct Impacts: During dredging and fill events, the presence of construction equipment would temporarily detract from the aesthetics of the waterways and beach of Figure Eight Island. This activity would generally take place over a 3-4 month period, but would take place during the winter months when the majority of the residence and/or guests are not present on the island and use of surrounding waterways are at their lowest. Under Alternative 1, the aesthetic view is also expected to be somewhat interrupted by the continued presence of sandbags on the oceanfront and Nixon Channel shoreline.

Indirect and Cumulative Impacts: Should the Rich Inlet's bar channel reconfigure to the position where it was causing chronic erosion along portions of Figure Eight Island, the threatened homes and infrastructure could eventually succumb to the threat of damage and destruction associated with the loss of the protective shoreline resulting in potential negative impacts to the natural beauty of the beach. Continued erosion along the oceanfront shoreline in the northern portion of Figure Eight Island could also result in a significant loss of land, personal property, and roads, which could degrade the aesthetic quality within that section of Figure Eight Island. This would be limited to that portion of the island and narrow in scope. These impacts may be further exacerbated if the predicted rise in sea level occurs over the next thirty (30) years. It is expected that the presence of sandbags will persist over a long period of time.

RECREATIONAL RESOURCES

Direct Impacts: Figure Eight Island is a private island with limited public access by land, however public access is available by boat. The recreational opportunities along the oceanfront shoreline are primarily utilized by private homeowners and visitors to the island. Visitors can also access the inlet, adjacent waterways, and beach via boat. An assessment of boat usage within proximity to Rich Inlet, as shown in Table 4.14, indicates that the majority of recreational boaters congregate along the banks of Hutaff Island, in the open water behind the inlet, and within any exposed shoals. Many boaters also utilize the northern spit of Figure Eight Island as an area to anchor and access the island.

Negative direct impacts as a result of Alternative 1 may include the reduction of recreational opportunities such as sunbathing, beachcombing, surf fishing, and walking along the beach during beach scraping and beach fill events. Impacts to recreation are expected to be minimal since scraping and filling activities are generally taking place during winter months when recreational activities are at their lowest levels.

Indirect and Cumulative Impacts: If chronic erosion returns along the northern portion of Figure Eight Island when the bar channel shifts toward Hutaff Island, recreational opportunities such as beachcombing, sunbathing, surf fishing, and walking along Figure Eight beach may be negatively impacted in this location. Access could be restricted during the time of high tide due to the presence of sandbags.

As previously mentioned, dry beaches, shoals, and intertidal flats are constantly changing within Rich Inlet complex and their location and size heavily depend on the positioning of the bar channel. Recreational boaters utilize the entire Rich Inlet complex, whether anchoring on either of the two island dry beaches or on any exposed shoals or intertidal flats. Boat usage under Alternative 1 is not expected to decline regardless of which side of the inlet is experiencing erosion. The concentration of boaters will constantly shift as the availability of anchoring locations shift and as the tides cycle. Even as the bar channel changes over time and regardless of its location, the available boating possibilities and access is not expected to, or will minimally, decline over time. Any cumulative impacts from Alternative 1 to recreational boaters should be minimal and inappreciable.

NAVIGATION

Direct, Indirect, and Cumulative Impacts: The continued sporadic maintenance activities in Banks Channel, AIWW, and Nixon Channel, will benefit navigation due to a maintained depth created by on-going dredging activities. During the dredging, however, navigation will be temporarily directly impacted due to the presence of pipelines within the waterway. At no time will complete restriction of navigation occur in Nixon Channel during dredge operations. Restrictions will be determined by the United States Coast Guard (USCG) and will be limited to the areas where the dredge and the pipelines are located. Even if dredging within Nixon Channel does not occur, this is not expected to reduce the navigational use of this channel.

INFRASTRUCTURE

Direct and Indirect Impacts: For Alternative 1, existing infrastructure located within the most erosive locations on Figure Eight Island are expected to receive some benefits from beach nourishment, beach scraping projects, and sandbags. However, these activities have shown to be only short-term protective measures.

Cumulative Impacts: The implementation of Alternative 1 will have a negative cumulative impact on the sustainability of existing infrastructure on Figure Eight Island due to the ineffectiveness of historical beach nourishment projects along the northern section of the island over time. Past nourishments at this location have proven to provide short term protection due to the inability for the material to persist on the nourished beach. Therefore, the continuation of beach nourishment events, beach scraping, and sandbags are anticipated to afford only temporary protection to those homes and infrastructure located on the northern end of Figure Eight Island. Under the 2006 conditions, several of the homes located on the northern portion of Figure Eight Island with protective sandbags are considered to be unsafe during storm events. Based on Delft3D and other analysis, it is anticipated that 40 homes could be lost over a 30 year period due to erosion along the northern portion of the island.

Currently, Figure Eight Island is experiencing substantial accretion due to the position of the bar channel. However, the resumption of past erosion trends once the bar channel of Rich Inlet shifts back toward Hutaff Island, and the eventual failure and/or removal of the sandbags on the north end of Figure Eight Island could result in the loss of 6,440 feet of roads and associated infrastructure (water and sewer lines) from Comber Road to Inlet Hook. The total replacement costs for the roads and infrastructure, which was used as a proxy for the value of these features, would be $3.3 million over the 30-year planning period.

SOLID WASTE

Direct Impacts: No direct impacts will be anticipated for Alternative 1 due to the short term protection provided by beach nourishment, beach scraping, and installation of sandbags.

Indirect and Cumulative Impacts: The chronic erosion of the oceanfront and soundside shoreline along the north end of Figure Eight Island, resultant of the Rich Channel ocean bar channel oriented towards the north, could return and result in the degradation and destruction of residential homes, public roads, and service utilities. Alternative 1 provides imminently threatened structures with only temporary protection and therefore, they may ultimately need to be demolished in the event of a severe storm or the return of chronic erosion. The debris generated from the demolition of these structures could indirectly and cumulatively impact the amount of solid waste deposited in local sanitary landfills. The volume of material to be placed in the landfill may have to be accounted for in the New Hanover County's long range plan for solid waste facilities.

Cumulative impacts could also result from the gradual deterioration of the sandbag revetments. While permit restrictions may dictate future removal of the existing and future sandbag structures, removal of all of the sandbag debris is problematic as the material settles deep into the sand. Over time, any remaining material could be uncovered and become flotsam which could pose a threat to marine animals.

NOISE POLLUTION

Direct Impacts: Sporadic maintenance dredging in Nixon Channel and the AIWW, which are included in Alternative 1, would temporarily raise the noise level in the areas of the dredge and the discharge point on the beach. Homes within proximity of the discharge point would experience higher noise levels due to ongoing usage of bulldozers leveling the material. This would be short-term since the equipment would be constantly relocating as work moves down the beach. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. Also, dredging and beach placement would occur during times when residents and visitors are less likely to be present.

Indirect and Cumulative Impacts: No indirect or cumulative impacts pertaining to noise pollution are anticipated due to the low frequency of beach nourishment events and the time of year.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: As the bar channel is expected to return to an unfavorable position for Figure Eight during the 30-year period, this would be expected to result in economic loss to New Hanover County and the State in the form of reduced revenues from property taxes should homes become inhabitable due to damage induced by erosion and/or storms. While there is a high degree of uncertainty with regard to the timing of the response of individual property owners to the threat posed by continued erosion as well as the cost of the actions they would take, values for home demolition, relocation, and property values were assigned to each threatened property in order to obtain a relative value of the potential economic impact of erosion. The damages associated with the continuation of the erosion threat under Alternative 1 could also have an impact on the values of adjacent properties, however, these secondary impacts were not included in the economic assessment. The economic assessment was based on the timing when certain actions would be required to either relocate or demolish a threatened structure. Table 5.18 depicts the summary of the average annual economic impact associated with Alternative 1 based on 2006 shoreline conditions. Average annual economic impacts were computed using a 6% discount rate and a 30 year amortization period.

Over the thirty year analysis period, the total implementation cost associated with Alternative 1 would be about $92.5 million. This includes $16.9 million for the value of 30 structures that would be demolished, $1.4 million to demolish the structures, $2.4 million to relocate 10 structures, $38.3 million for the loss of land, $1.2 million for temporary sandbag revetments, $3.3 million for damages to roads and infrastructure on the north end of Figure Eight, and $29.0 million for beach nourishment. The 10 structures that were assumed to be relocated to another lot on Figure Eight Island have an appraised value of $6.5 million with their value assumed to remain the same even though they would no longer be on an ocean front lot. However, the land on which they were situated would eventually be lost. The lost value of these 10 lots is included in the total land loss value.

Table 5.18- Summary of average annual economic impact of alternative 1 over a 30 year period

Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
$1,803,000	$184,000	$1,204,000	$3,191,000

B. IMPACTS ASSOCIATED WITH ALTERNATIVE 2: ABANDON/RETREAT

For Alternative 2, the Figure "8" Beach HOA and the individual property owners would not take any action to slow erosion or appeal the removal of existing sandbags. This alternative would not include the beach scraping/bulldozing or intermittent beach nourishment projects described above in Alternative 1. Once structures become imminently threatened or the owners are required to remove existing sandbags, the structures would either be abandoned (demolished) or moved to another lot on the island. Compared to Alternative 1, the actions taken by individual property owners to either relocate or demolish their threatened homes would occur earlier in the 30-year analysis period.

ESTUARINE HABITATS

Salt Marsh Communities

Erosion along the Nixon Channel Shoreline

Direct and Indirect Impacts: Similar to Alternative 1, Alternative 2 assumes a continuation of the historic erosion and accretion rates along portions of Figure Eight Island and the southern tip of Hutaff Island, respectively. This erosion of the salt marsh shoreline would be expected to continue so long as the flood tide delta directs the majority of the flow close to the eroding shoreline (Cleary, pers. comm.). Additional erosion of salt marshes has been occurring along the Nixon Channel shoreline. This erosion is related to movement of the Nixon Channel thalweg toward the island. Recent photographs have shown exposure of high marsh peat and shrub stumps along the estuarine shoreline in this location which have helped validate this process (Cleary, pers. comm.). Due to the dynamic nature of the inlet system and the proximity of the salt marsh resources to the evolving shoreline, both positive and negative direct and indirect impacts to salt marshes are expected to continue.

Cumulative Impacts: As stated earlier in the discussion within Alternative 1, the gorge within Rich Inlet has remained in place for approximately 20 years. With the main inlet being stable, it is expected that the salt marsh communities will continue to respond to naturally evolving shorelines with the implementation of Alternative 2. Under Alternative 2, and similar to Alternative 1, salt marsh resources found along the sound side and within the northern spit of Figure Eight could be impacted due to erosion over time while areas further east along this shoreline may gain salt marsh as the sand spit and large shoal migrates in response to the inlet configuration. The area of salt marsh located in proximity to the sand spit along the northeastern terminus of Figure Eight Island could degrade should the feeder creek become blocked with accreting sand along its entrance on the Nixon Channel shoreline or could undergo conversion to an unvegetated shoal due to shifting configuration of the ebb tide channel. In a 1989 aerial photo, this salt marsh complex is shown as an unvegetated sandy beach or shoal with no signs of marsh or vegetated tidal creek present in the area. It is expected that the salt marsh complex within this spit area will undergo natural transitions and experience conversion of community types over time under Alternative 2.

Along Hutaff Island, some oceanfront areas may experience breaches in the primary dune due to storms and high wave action, resulting in the formation of natural washover features which may extend into adjacent salt marsh. In this natural process, these washover areas may cause salt marsh to transition into an overwash fan, causing potential corresponding shifts in infaunal community composition, as well as shifts in finfish and bird community composition. Little is known about how resident species adapt to irregularly flooded marshes which are inundated for weeks at a time. These resident species include, among other species, several types of fish (*e.g.*, killifish and mummichogs), brownwater snakes, crustaceans (various species of crabs), birds (yellowthroat, marsh wren, harrier, swamp sparrow, and five species of rails), and several species of mammals (nutria, cotton rat, and raccoon) (CCSP, 2009). Washover events may increase if the predicted increase in the rate of sea level is validated. Therefore, beyond the existing natural processes of erosion and development, no cumulative impacts are anticipated with Alternative 2.

Submerged Aquatic Vegetation

Direct, Indirect, and Cumulative Impacts: As with Alternative 1, three confirmed and 17 probable SAV occurrences have been identified within the Permit Area (Figures 4.3a and 4.3b). The three confirmed occurrences are specifically found within tidal creeks along the edge of salt marshes west of Green and Nixon Channel. Because the confirmed locations of existing SAV resources occur removed from to the areas experiencing erosion along Rich Inlet and Nixon Channel, impacts to SAV resources are not expected. SAV resources require light to penetrate the water column for healthy growth. With no dredge or fill activities associated with Alternative 2, the potential for elevated turbidity or TSS is not a factor with this alternative outside of natural storm events. Cumulative impacts are not expected to occur as these resources would naturally migrate to their preferred depth should sea levels rise over the next 30 years as currently predicted.

Shellfish Habitat

Impacts to shellfish habitat for Alternative 2 are the same as those discussed above for Alternative 1.

UPLAND HAMMOCK

Impacts to upland hammock habitat for Alternative 2 are the same as those discussed above for Alternative 1.

INLET DUNES AND DRY BEACHES

Direct Impacts: No direct impacts are expected unless a single storm event occurred directly resulting in changes to the inlet dune and beaches. Predictions of storms and their magnitude are unable to be determined.

Indirect and Cumulative Impacts: Over the Delft3D 5-year modeling period, the results for Alternative 2 suggested erosional conditions occurring on Figure Eight Island, or the inlet's south side, and accretional conditions along Hutaff Island side of the inlet. These model results, under 2006 shoreline conditions, showed portions of the sand spit on the extreme north end of Figure Eight Island being converted to intertidal and subtidal habitat within 5 years (Figures 5.2a through 5.7a). The conversion of approximately 7 acres of inlet dune and dry beach habitat to intertidal and subtidal habitat would reduce the area available for nesting shorebirds (including the endangered piping plover) and colonial waterbirds on the south side of the inlet. However, the Delft3D model results indicated accretion of inlet dunes and dry beaches of approximately 5 acres on the southern portion of Hutaff Island. This accretion is expected to offset some of the impacts experienced on Figure Eight Island by providing nesting habitat for sea turtles and shorebirds and colonial waterbirds. With the natural history of this inlet and absent a catastrophic natural event, it is expected that this natural cycle or shifting would occur throughout the 30-year review period and would continue a natural equilibrium of available habitat throughout the inlet complex. This shift may be cumulatively beneficial for nesting due to the absence of homes and more restricted access on Hutaff Island.

Effects on inlet dunes and dry beach habitats depend on how the inlet bar channel behaves. As shown by Dr. Cleary's geomorphic analysis of Rich Inlet, these inlet habitats undergo significant changes in response to the reorientation of the ebb tide delta. Although the relative position of the inlet has been stable over the past century, fluctuations in orientation of the main ebb-channel have forced subsequent periods of erosion and accretion on the adjacent shorelines of Figure Eight and Hutaff Islands (Cleary, 2009). The inlet bar channel maintained a northerly orientation toward Hutaff Island between the mid-1990's until 2010 which resulted in erosion along the northern end of Figure Eight Island and accretion along the southern end of Hutaff Island. The bar channel naturally shifted to a southerly alignment toward Figure Eight Island in 2010 and this has resulted in accretion along the north end of Figure Eight and erosion on the south end of Hutaff Island. While this orientation is favorable for Figure Eight Island, based on the past history of the inlet channel, the bar channel is expected to eventually shift back toward Hutaff Island which will initiate another round of erosion on the north end of Figure Eight. With the exception of the natural cycle of erosion and accretion resulting from the fluctuation of the ebb-channel, cumulative impacts to inlet dunes and dry beaches would not be expected.

Regardless of the orientation of the inlet, the inlet dunes and dry beaches have persisted collectively within the inlet complex. A review of data collected by Audubon North Carolina data for piping plover between 2008 and 2014 showed that piping plovers have continued to utilize the habitats within the Rich Inlet complex despite the natural modifications over time. Specifically, of the seven landscape types where piping plovers were observed foraging within this area, the oceanfront beach in proximity to the inlet was the second most utilized habitat type for foraging piping plovers (Addison and McIver, 2014).

Again, the location and magnitude of erosion and accretion within inlet dunes and dry beaches of Rich Inlet is contingent on the positioning of the bar channel. It is difficult to determine long-term effects on either habitats as the ebb tide channel could or could not shift greatly within a 30-year period.

INTERTIDAL FLATS AND SHOALS

Direct Impacts: Intertidal flats and shoals have developed in a dynamic inlet system and therefore tend to be ephemeral in nature, especially with regard to dynamic island formations within the Inlet. Alternative 2 is not expected to result in direct impacts to these habitats.

Indirect and Cumulative Impacts: Delft3D modeling suggested that by year five, Alternative 2 resulted in a net increase of 357,100 cubic yards of sediment in the inlet complex, or an average accumulation of 71,400 cubic yards/year. Volume changes within discrete areas in the inlet complex obtained by the Delft3D model at the end of the 5-year simulation are shown in Figure 5.48. (*Note: the model elevation changes have an accuracy of ±0.2 feet at any one grid point, therefore, the volume change values within each discrete area shown in Figure 5.48 have an uncertainty of ±10,000 cubic yards.)* With this influx of material, the extent of the intertidal flats and shoals may increase over time. As the sand spit on the north end of Figure Eight Island began to evolve into intertidal sand flats within 5 years, as shown by the model, the increased sedimentation within the inlet complex is expected to facilitate the development of additional intertidal flats and shoals as stated previously with the conversion of inlet dunes and/or dry beach. With this net influx of material, the model results indicated a net change to approximately 0-5 acres of intertidal flats and shoals within the inlet complex. As such, this ephemeral habitat type would be expected to persist during natural adjustment periods of the bar channel, despite the bar channel's positioning or location. Therefore, foraging and resting bird species, including piping plover, utilizing the intertidal flats and shoals should not be significantly adversely affected by Alternative 2 under normal conditions.

This determination can be somewhat validated with the presence of bird species, particularly piping plover, observed and recorded by Audubon North Carolina. During the period from 2007-2011, the bar channel underwent a major shift from a central position within the inlet to a southerly position. The shifting resulted in a change to inlet flats and shoal habitats located within Rich Inlet. A review of Audubon North Carolina data for piping plover for this timeframe suggested that the number of birds appears to have adjusted to the geomorphic shifting of these habitats. The range of sighted individuals for a 4-day period were a maximum of 164 in the Fall of 2007 to a minimum of 87 in 2011. In the spring, the individual numbers were 75 in 2007 to 66 in 2011 (Audubon North Carolina, pers. comm., 2012). Overall, the numbers appear to be within normal range of variations. It was also observed that piping plovers heavily favored the intertidal zones in Rich Inlet for foraging, using the areas approximately 90% of the time. This adjustment was also demonstrated in the Piping plover bird surveys conducted by Dr. Webster for Figure Eight HOA. During the period of 2001-2006, his data showed a constant presence of the species, ranging from a high of 51 individuals in 2001 to a low of 10 individuals in 2004.

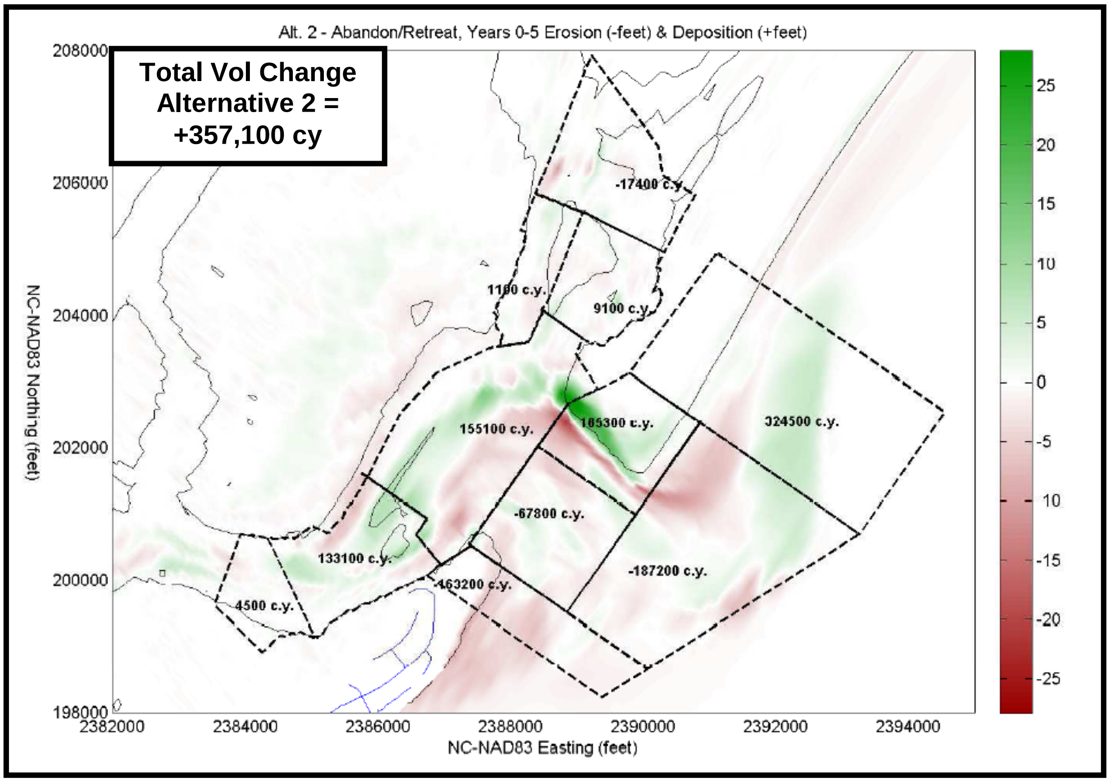

Figure 5.48- Modeled volume changes in discrete areas within the Permit Area under Alternative 2.

OCEANFRONT DRY BEACH AND DUNE HABITATS

Oceanfront Dune Communities

Direct Impacts: The implementation of Alternative 2 is not expected to impose any direct impacts to the oceanfront dune communities.

Indirect and Cumulative Impacts: The existing dune system along a portion of Figure Eight Island has been maintained through beach scraping activities, the installation of sandbag revetments, and periodic beach nourishment. Without a continuance of these actions, which is the case under Alternative 2, negative indirect and cumulative impacts could occur within the dune community due to unabated erosion of the foredune and dune system along the northern 3.8 km (2.4 mi) of oceanfront shoreline of Figure Eight Island. While erosion has temporarily halted due to the change in the orientation of Rich Inlet's ocean bar, chronic erosion along this section of island is expected to be reinitiated at some undetermined point in time when the channel eventually repositions itself. This erosion, over time, will continue under Alternative 2 and will impact the existing dune system on the island, particularly in the area north of 302 Bridge Road North. Without installing new sand bag revetments in the event that structures are again imminently threatened, the sandbag revetments previously installed at 19 homes on the ocean shoreline and one home on the Nixon Channel shoreline will eventually fail, be voluntarily removed by the property owners, or be required to be removed by the State of North Carolina. As a result, the remaining dunes could be subjected to direct impacts of waves and storm tides which could gradually erode any remaining vestige of the dunes in this area.

The dune communities located on the southern portion of Hutaff Island would be expected to migrate westward as natural processes including rolling over, or transgression, will influence the environment. If the predicted increase in rates of sea level rise (IPCC, 2007) is validated, this could potentially threaten the long term viability of dunes within the permit area as storm surges could degrade these resources.

As these resources remain vulnerable to storm damage, dune vegetation would most likely be threatened resulting in a degraded habitat used by several species, such as seabeach amaranth. Seabeach amaranth prefers overwash flats at accreting ends of islands and lower foredunes and upper strands of non-eroding beaches; these preferred habitats are located on the middle and southern portions of Figure Eight Island. As mentioned in Chapter 4, seabeach amaranth is an effective sand binder, building dunes where it grows. Due to lack of long-term protection against storm influenced damage, negative cumulative impacts to the dune-stabilizing seabeach amaranth, and subsequently the dune communities at Figure Eight Island in general, are expected.

Although the location of the dunes may change as overwash and other storm-induced events influence the environment, the anticipated indirect and cumulative impacts to the dune community on Hutaff Island in response to Alternative 2 would be negligible as these processes occur under natural conditions.

Oceanfront Dry Beach Communities

Direct Impacts: For Alternative 2, current conditions for the northern section of Figure Eight Island has experienced accretion over the last few years benefitting the oceanfront dry beach area. This is largely due to the southerly position of the ocean bar channel. The accretion has provided additional sea turtle nesting and bird habitat. Other benefits received from this widening of dry beach is the increase for recreational use and the additional protection of the oceanfront shoreline.

With the current location of the ocean bar channel, oceanfront dry beach communities along the southern portion of Hutaff Island has experienced erosion and are reduced in width. This has reduced the optimal conditions for nesting turtles and resting/foraging shorebirds. No direct impacts to the oceanfront dry beach communities are expected within the permit area under Alternative 2.

Indirect and Cumulative Impacts: Even though the ocean bar channel is currently positioned to promote accretion on the northern portion of Figure Eight Island, historical analysis has shown that the channel will again shift at some undetermined point in time. When that repositioning occurs, the northern oceanfront shoreline of Figure Eight Island would experience erosion while the southern section of Hutaff's oceanfront shoreline would undergo accretion. The Delft3D model showed continued erosion for Alternative 2 in the northern portion of Figure Eight Island with a net loss of approximately 0-5 acres of oceanfront dry beach habitat. For Hutaff, the opposite occurred with the southern portion of the island gaining several acres of oceanfront dry beach habitat. The average annual rates of volume change for the various beach segments determined from the model over the five (5) year simulation for Alternative 2 are summarized in Table 5.19. With Alternative 2, the erosion of the Figure Eight Island and shoreline is expected to continue, resulting in net impacts to approximately 0-5 acres of oceanfront dry beach habitat. The average annual rates of volume change for the various beach segments determined from the model over the five (5) year simulation for Alternative 2 are summarized in Table 5.18.

Table 5.19. Average annual rate of volume change (cubic yards/year) - Figure Eight Island and the southern end of Hutaff Island obtained from the Delft3D model for Alternative 2.

Alternative	Figure Eight Island		Hutaff Island	
	F90+00 to 60+00	60+00 to 105+00	148+60 to 175+00	175+00 to 215+00
2	+18,000	-84,000	+53,000	-35,000

The volumetric change computed from the results of the Delft3D model for Alternative 2 from Bridge Road to Rich Inlet averaged -66,000 cubic yards/year of erosion over the 5-year simulation period. This computed rate of change agrees reasonably well with the observed rate of volume loss for the September 1999 to April 2007 time period which was -97,600 cubic yards/year. The annual volume loss off the north end of Figure Eight Island is also of the same order of magnitude as the rate of volume accumulation in Rich Inlet as indicated by the Delft3D model. A continuation of this rate of volume loss would result in a reduction of adequate turtle nesting habitat, shorebird and water bird habitat, and recreational opportunities along Figure Eight Island.

However, engineering analysis suggests that the southernmost 2,640 foot portion of the oceanfront shoreline on Hutaff Island (stations 148+60 to 175+00) is expected to accrete with an average of 53,000 cu yds. of material per year over a 5-year period. This would serve to offset some of the impacts indicated on Figure Eight Island by providing nesting habitat for sea turtles and shorebirds.

An additional factor that may affect oceanfront dry beach is the potential for sea level rise. Local monitoring stations suggest that this rise may be on the order of less than 1 foot over the next century. Should the sea levels continue to rise at this predicted rate, unmanaged areas of the dry beach community may become more vulnerable to overwash events and lead to additional cumulative impacts. However, an example of how sea level rise may or may not affect the performance of a beach nourishment project, the Wrightsville Beach and Carolina Beach federal storm damage reduction projects can be evaluated. Both of these projects have been in existence since 1965 (50 years) and have been subjected to the same rate of sea level rise applicable to Figure Eight Island. A review of the nourishment rates for these two projects with and without sea level rise shows no significant change in the volume or frequency of periodic nourishment needed to maintain the projects (Figures 5.47a and 5.47b).

WET BEACH COMMUNITIES

Direct, Indirect, and Cumulative Impacts: Without storm protection activities, such as beach scraping, beach nourishment, or the use of sandbags, no impacts to the wet beach would occur under natural conditions.

MARINE HABITATS

Softbottom Communities

Direct, Indirect, and Cumulative Impacts: Impacts to the softbottom communities outside of natural processes including storms are not expected with Alternative 2.

WATER QUALITY

Turbidity and TSS

Direct, Indirect, and Cumulative Impacts: Natural conditions within the Permit Area support extreme fluctuations in turbidity levels as a result of the winnowing away of exposed peat and mud layers on the soundside shoreline of the northern portion of Figure Eight Island. Under Alternative 2, erosion of the soundside shoreline would continue with minimal changes in turbidity levels as a result. Turbidity and TSS levels would be expected to temporarily increase during storm events but would decrease quickly due to the content of the natural sediment and the short duration of most storms.

Nutrients

Direct, Indirect, and Cumulative Impacts: The implementation of Alternative 2 is not anticipated to impact the nutrients within the waters located in the Permit Area.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: Over the 5-year Delft3D simulation period, the average tidal prism of Rich Inlet was 502.9 million cubic feet. The average tidal prism during any given year of the simulation showed only minor variations and no definitive trends for an increase or decrease in the tidal prism. Of this total volume passing through the inlet, 55.3% passed through Nixon Channel, 36.1% through Green Channel, and the balance of 8.6% passed through the marsh area directly behind Rich Inlet.

For Salinity levels, there are no known signs, or expected signs, of changes outside of natural conditions for Alternative 2

<u>*Larval Transport*</u>

Direct, Indirect, and Cumulative Impacts: Outside of natural conditions or periodic storm events, the transport of larvae is not expected to be disrupted.

PUBLIC SAFETY

Direct, Indirect, and Cumulative Impacts: Currently, Figure Eight Island is experiencing substantial accretion due to the location of the bar channel. However, based upon historical data, it is anticipated that the channel will shift to a more northerly position, and erosion is anticipated to occur on Figure Eight Island. Under the 2006 conditions, the erosion rate along the ocean shoreline and the soundside of the northern 3.8 km (2.4 mi) of Figure Eight Island threatened the integrity of approximately nineteen (19) homes and would have direct, indirect and cumulative impacts to public safety. Over the next 30 years, an additional 21 homes could become imminently threatened. Alternative 2 includes both the abandonment and the relocation (retreat) of these homes and their supporting infrastructure. The activity associated with demolition of abandoned homes could expose workers to risk of injury. There is also a strong possibility that some debris could fall into the nearshore which could pose health threats to swimmers or boaters. As the erosion undermines existing roads and sanitary systems, exposes electrical lines, and ruptures or requires the relocation and rerouting of the water supply system, the public would be exposed to increased risk of injury and/or infection. Ultimately, demolition activities, road undermining, and exposure of utilities would continue as long as the erosion continues to threaten the infrastructure. The longer the situation exists, the higher the risk of personal injury.

There would be no safety concerns with dredge and beach nourishment activities since these actions are not included within Alternative 2. No known additional safety issues are expected within the Rich Inlet Complex and along Hutaff Island

AESTHETIC RESOURCES

Direct Impacts: The current aesthetic view is somewhat interrupted by the continued presence of sandbags along a portion of the northern Figure Eight Island and Nixon Channel shoreline. This interruption is expected to be short-term due to the likelihood that the sandbags will be removed.

Indirect and Cumulative Impacts: Shoreline impacts on the north end of Figure Eight Island will depend on how the inlet bar channel behaves. The present orientation of the bar channel, which is toward Figure Eight Island, has resulted in some ephemeral accretion along the north end of the island. As long as the bar channel remains in this alignment, demolition and/or relocation of the threatened homes would be delayed. However, based on the past behavior of Rich Inlet, the bar channel is expected to again assume an alignment toward Hutaff Island which will initiate a new round of severe erosion and beach nourishment in response to the renewed erosion threat. The timing of the bar channel shift back toward Hutaff Island is unknown. However, in assessing the economic impact of Alternative 2, actions by the homeowners to either demolish or remove the threatened homes was assumed to be delayed by 5 years. In the long-term, a northerly shift will likely result in erosion within 3.8 km (2.4 mi) of oceanfront shoreline along the northern portion of Figure Eight Island, which could cause a significant loss of land, personal property, and roads. This on-going loss could negatively affect the aesthetic quality or value of Figure Eight Island, but this could also be minimized or foreseen as no different aesthetically than current and/or future construction of homes. Homes and infrastructure that become threatened could be destroyed due to the eventual loss of the protective shoreline. The advanced state of disrepair of the threatened homes would continue to distract from the aesthetic setting of the island along the oceanfront shoreline until such time the threatened homes are removed. Along the Nixon Channel shoreline, all existing homes have sandbags. Once removed, no additional sandbags are expected to be deployed. During those times when demolition activities are underway, the presence of construction equipment would have potential to temporarily detract from the aesthetics of Figure Eight Island. However, this would be no different aesthetically than current and future on-going construction of homes.

RECREATIONAL RESOURCES

Direct, Indirect, and Cumulative Impacts: Figure Eight Island is a private island with limited public access by land, however public access is available by boat. As previously mentioned, dry beaches, shoals, and intertidal flats are constantly changing within Rich Inlet complex and their location and size heavily depend on the positioning of the bar channel. An assessment of boat usage within proximity to Rich Inlet, as shown in Table 4.14, indicates that the majority of recreational boaters congregate along the banks of Hutaff Island, in the open water behind the inlet, and within any exposed shoals. Many boaters also utilize the northern spit of Figure Eight Island as an area to anchor and access the island. Boat usage under Alternative 2 is not expected to decline regardless of which side of the inlet is experiencing erosion. The concentration of boaters will constantly shift as the availability of anchoring locations shift and as the tides cycle. Even as the bar channel changes over time and regardless of its location, the available boating possibilities and access is not expected to, or will minimally, decline over time. Any cumulative impacts from Alternative 2 to recreational boaters should be minimal and non-appreciable.

The recreational opportunities along the oceanfront shoreline are primarily utilized by private homeowners and visitors to the island. Visitors can also access the inlet, adjacent waterways and beach via boat. If homes are demolished and removed or relocated, recreational activities such as sunbathing beachcombing, surf fishing, and walking along the beach will be affected during the demolition and removal activities, but would be expected to resume once the work is completed. Therefore, impacts are likely to be short term. Although Delft3D model results suggest that the northern portion of Figure Eight will experience a loss in areas to recreate, accretion on the southern portion of Hutaff Island will provide additional locations for individuals to absorb all or some of the loss on Figure Eight Island.

NAVIGATION

Direct Impacts: Current conditions are such that the majority of the Rich Inlet Complex, including Nixon and Green Channels, are navigable and be can be used by most small to medium sized watercrafts.

Indirect and Cumulative Impacts: Historically, Rich Inlet has been a relatively stable inlet and has provided access to the ocean, as well as general use of Nixon and Green Channels, for recreational boaters for decades. In a cursory review of aerial photos dating to the early 1990's, the inlet and the two channels appear to be navigable during normal conditions regardless of the positioning of the ocean bar channel. There is expected to be times when conditions are not optimal for certain sized vessels, but at no time should Alternative 2 impede the general navigation use of the area.

The Delft3D model simulation for Alternative 2, under the 2006 initial conditions, included a relatively deep channel skirting around the landward lobe of the middle ground shoal immediately landward of the gorge of Rich Inlet. This channel connected into Nixon Channel. There was a deeper channel behind the north end of Figure Eight Island which dead ended before reaching the inlet gorge. There was also a relatively deep channel connecting into the mouth of Green Channel.

Over the 5-year simulation, the channel skirting around the landward lobe of the middle ground shoal remained navigable, maintaining depths in the 6 to 10-foot range. The channel behind the north end of Figure Eight Island breached the middle ground shoal and connected to the inlet gorge during most of the 5-year simulation. However, due to the orientation of the breach, which was perpendicular to incoming waves, navigating the channel would have posed safety issues. The channel skirting around the landward lobe of the middle ground shoal would have remained the preferred route. The channel connecting into the mouth of Green Channel remained open and navigable throughout the 5-year model simulation.

Over the 30-year study period, cumulative effects on navigation are expected to be minimal since Rich Inlet complex has been historically open and somewhat stable for over 75 years, as shown in Dr. Cleary's geomorphological analysis of the inlet. Navigational conditions are anticipated to shift and change periodically, but despite these natural changes, boater use is likely to continue.

INFRASTRUCTURE

Direct Impacts: Under Alternative 2, it is likely that the current sandbags protecting the homes along the Figure Eight island's northern oceanfront and Nixon Channel shorelines will be removed due to requirements outlined by State law. The current location of the ocean bar channel is providing some protection, due to accretion, along the most threatened section of Figure Eight Island. The sandbagged homes along the Nixon Channel shoreline remain threatened, however, and could become structurally unsound once sandbags are removed.

Indirect and Cumulative Impacts: For short- and long-term effects on Figure Eight Island's infrastructure, the magnitude and severity will depend on the position of the ebb tide channel. If the bar channel shifts northerly as historic records have shown, the natural long-term chronic erosion of the northern Figure Eight oceanfront shoreline could result in the abandonment and the ultimate destruction of up to 40 homes, roads, and service utilities. If threatened structures are not moved, they will presumably be demolished and the debris would be deposited in local sanitary landfills. The same would apply to damage of the roads and service utilities. Alternative 2 would therefore have a negative impact on existing Figure Eight infrastructure as the bar channel begins its eventual migration northward.

The eventual failure and/or removal of the sandbags on the north end of Figure Eight Island and the resumption of past erosion trends once the bar channel of Rich Inlet shifts back toward Hutaff Island could result in the loss of 6,440 feet of roads and associated infrastructure (water and sewer lines) from Comber Road to Inlet Hook. The total replacement costs for the roads and infrastructure, which were used as a proxy for the value of these features, would be $4.7 million over the 30-year planning period. Since no actions would be taken to protect the roads and infrastructure under Alternative 2, the damages to the infrastructure would occur early in the analysis period resulting in slightly higher average annual cost compared to Alternative 1.

No homes or infrastructure are present on Hutaff Island.

SOLID WASTE

Direct Impacts: If any infrastructure is compromised with the removal of sandbags and is not relocated, then they may need to be demolished with the debris deposited in local sanitary landfills. This is not likely to create any abnormal increase to solid waste.

Indirect and Cumulative Impacts: As historically demonstrated, the ebb tide channel is expected to migrate northward resulting in an erosional increase on the northward portion of Figure Eight. This would cause homes and infrastructure to become more vulnerable and likely to be demolished if not relocated. The cumulative effect of demolition and removal of homes and infrastructure debris could reduce the amount of space available at the local landfill over the next thirty (30) years. The volume of material that may have to be placed in the landfill is not likely to be considered significant, but ultimately this additional material may have to be accounted for in New Hanover and Pender County's long range plan for solid waste facilities.

NOISE POLLUTION

Direct, Indirect, and Cumulative Impacts: With the implementation of Alternative 2, the demolition of homes on Figure Eight Island would temporarily raise the noise level in the areas due to the use of heavy machinery, however this level would be short-term and minimal. It is expected that a typical home on Figure Eight Island would take several days to demolish and remove the debris. It is also conceivable that a number of these homes will be removed during the months when residents and visitors are not present, or at its lowest, on the island.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: Currently there are 80 vacant lots on Figure Eight Island. Of these vacant lots, 16 are for sale with an average market value of $1,560,812 (O'Mahoney, 2013). It is unknown if additional owners of the vacant lots would be willing to sell their land to satisfy the need of homeowners looking to relocate their homes. While the prices for vacant lots are significantly lower on nearby Topsail Island, moving any of the existing homes from Figure Eight Island over land to a new location off the island would not be possible given the width and height restrictions imposed by the draw bridge over the AIWW. Moving the structures over water would also not be practicable given the absence of facilities that are needed to place the structures on barges. Furthermore, the homes on Figure Eight Island are relatively large and therefore would present difficulties when attempting to move via barge. As a consequence of these difficulties, of the 40 homes that were recently imminently threatened or may become imminently threatened over the next thirty years, 16 have the possibility to relocate to one of the existing vacant lots for sale on Figure Eight Island under current circumstances. It is difficult to discern or predict exactly how many homes could be relocated over a 30-year period due to the variability of lots that would or would not be for sale. The remaining homes would most likely be abandoned and demolished with the waste material placed in landfills. The equivalent average annual cost for relocating and/or abandoning the 40 homes under Alternative 2 would be $169,000 per year over a 30-year period.

The abandonment and demolition of homes on Figure Eight Island would result in economic loss to New Hanover County and State in the form of reduced revenues from property taxes. Alternative 2 would result in the loss of the same 40 structures as Alternative 1. However, the lost tax value would occur earlier during the 30-year analysis period as temporary erosion response measures such as temporary sandbag revetments would not be used to delay the demise of the structures and land.

The 2013 orientation of the inlet bar channel is toward Figure Eight Island. This favorable alignment, in terms of impacts on Figure Eight Island, has resulted in some accretion of the shoreline from Comber Road north to Rich Inlet. Eventually, the Rich Inlet bar channel is expected to assume an orientation back toward Hutaff Island at which time the north end of Figure Eight Island is expected to experience a renewed round of severe erosion. When this inevitable shift will occur is unknown and this uncertainty was incorporated into the economic impact analysis by delaying demolition and removal costs by 5 years. Table 5.20

depicts a summary of the average annual economic impact associated with Alternative 2 based on 2006 shoreline conditions.

Over the 30-year analysis period, the total implementation cost associated with Alternative 2 would be about $63.7 million. This total cost includes $16.9 million for the value of 30 structures that would be demolished, $1.4 million to demolish the structures, $2.4 million to relocate 10 structures, $4.7 million for damages to roads and infrastructure on the north end of Figure Eight, and $38.3 million for the loss of land. As with Alternative 1, the value of the land for the 10 homes that would be relocated to another lot on Figure Eight Island is included in the total land loss amount, however, the value of the 10 structures was assumed to remain the same even though they would no longer be situated on an ocean front lot.

Table 5.20 Summary of Average Annual Economic Impact of Alternative 2

Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
$2,166,000	$275,000	$169,000	$2,610,000

C. IMPACTS ASSOCIATED WITH ALTERNATIVE 3: RICH INLET MANAGEMENT WITH BEACH FILL

The main bar channel of Rich Inlet would be relocated and maintained in a position closer to the north end of Figure Eight Island and oriented along an alignment essentially perpendicular to the adjacent shorelines. The relocation of the main ebb channel (dredged to a depth of -19 ft. NAVD) would be accompanied by new channels connecting the main ebb channel with Nixon Channel and Green Channel. Approximately 1.79M cubic yards of material removed to relocate the channel and construct the new connecting channels, construct a closure dike across the existing ebb channel located next to Hutaff Island, provide beach fill along 426.7 m (1,400 ft.) of the Nixon Channel shoreline just south of Rich Inlet, and nourish 3,810 m (12,500 ft.) of ocean shoreline extending from Rich Inlet south to Bridge Road.

The new inlet bar channel position would be periodically maintained with maintenance episodes dictated by shoaling of the new channel or natural shifts in the channel position outside the preferred channel corridor. Based on the Delft3D model results, approximately 666,000 cubic yards would have to be removed from the new bar channel every five (5) years to maintain the preferred position and alignment. Shoaling of the Green Channel connector ceased after year two of the simulation while shoaling in the Nixon Channel connector moderated considerably. These reduced rates of shoaling in the two channel connectors indicate they had achieved some equilibrium and would probably not need to be maintained as frequently as the bar channel. For planning purposes, future maintenance of the channels would be limited to just the bar channel. Maintenance of the Nixon and Green Channel connectors would be deferred until such time monitoring surveys find maintenance is required to restore flow volumes or in the case of Nixon Channel, divert the flow away from the shoreline in the critically eroding area.

ESTUARINE HABITATS

Salt Marsh Communities

Direct Impacts: No salt marsh resources are anticipated to be directly impacted through dredge or fill operations in association with Alternative 3. The preferred dredging option included with this alternative has been designed to minimize the potential for shoreline erosion and subsequent impacts to salt marsh area facing the entrance of the inlet.

The geotechnical investigation of the 92.4 acre channel corridor between Nixon Channel and the inlet gorge determined that two (2) vibracores contained approximately 29,700 cubic yards of incompatible clay material above the designed -19.0 ft. NAVD 88 bottom of the channel. This material will be excavated and placed in an upland disposal site located at the junction of the Intracoastal Waterway and Nixon Channel. For the disposal site, erosion control measures, including improvements to the dike surrounding the upland disposal area, will be implemented to control material from eroding into adjacent salt marsh resources (Figure 5.49). Therefore, no direct impacts to salt marshes are anticipated as a result of sedimentation during the dredge, beach fill placement, and disposal of incompatible material operations.

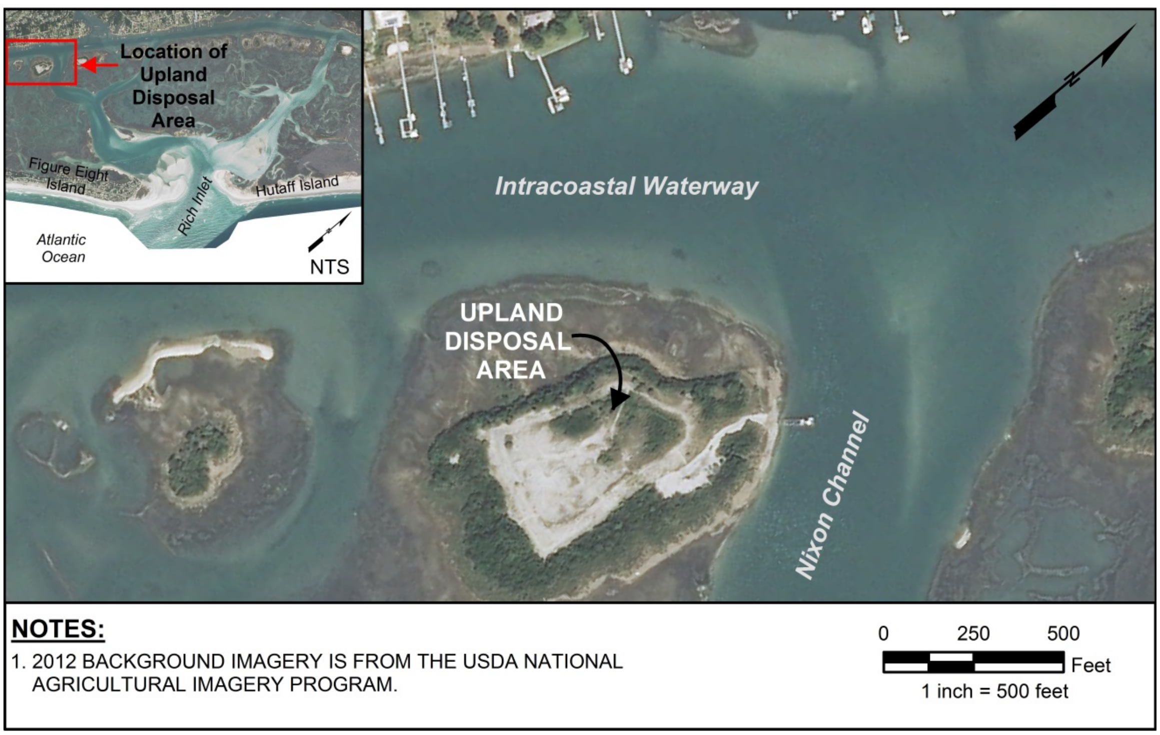

Figure 5.49. Map depicting the upland disposal area, located at the junction of the Intracoastal Waterway and Nixon Channel, in which incompatible material from the Alternative 3 channel will be deposited.

Although primary nursery areas (PNAs) are located within the Permit Area, no PNA will be directly impacted by beach fill activity. PNAs are generally defined as being located in the upper portions of creeks and bays. These are usually shallow areas with soft, muddy bottoms surrounded by marshes and wetlands. Low salinity and the abundance of food in these areas are ideal for young fish and shellfish. The 1,400 foot section of estuarine shoreline along Nixon Channel where beach fill is proposed for Alternatives 3 is characterized by high salinity water with a sandy bottom.

Indirect Impacts: Immediately following construction of the new bar channel and cuts into Nixon and Green Channel, the newly established flow pathways are expected to follow the alignments of the dredge cuts and positively benefit the salt marsh resources which are currently eroding behind Rich Inlet. At the end of Year 5 of the Delft3D simulation, the new connector channel maintained some of its integrity and was still diverting flow away from the marsh shoreline. Within Nixon Channel, flow is anticipated to be centered near the middle of the channel instead of its southern bank, which should also serve to reduce the erosional stress near the north end of Beach Road. This, in addition with the placement of 57,000 cubic yards of fill along the Nixon Channel shoreline, will reduce the potential for the eventual erosion of the salt marsh in this area. The fill placed along Nixon Channel terminates south of the creek that serves to feed the area of high marsh along the northern end of Figure Eight Island. As such, no significant adverse impacts are anticipated to this high marsh area.

Engineering model results for the proposed modification of the Rich Inlet do not show any significant impact on flow circulation patterns between the inlet and the AIWW (refer to Appendix B—Engineering Analysis). Along the salt marsh shoreline west of the entrance of Rich Inlet, currents will be reduced as flow is shifted from the back channel along the salt marsh into the new dredge cuts. The evolution of the dike across the existing channel into a recurved sand spit off the south end of Hutaff Island could modify current patterns in the entrance to Green Channel resulting in some minor erosion of the marsh shoreline along the lower reaches of Green Channel. Although unrelated to the marsh system in proximity to Figure Eight Island, no significant changes were observed following three (3) years of salt marsh monitoring designed to evaluate the changes to the salt marsh in response to a similar inlet channel relocation project within Bogue Inlet in 2005 (CPE, 2008).

Cumulative Impacts: Barrier island management practices such as inlet stabilization, and maintenance dredging may prevent inlet migration and the formation of flood tide deltas upon which marshes typically may form (Hackney and Cleary, 1987). Alternative 3 includes the maintenance of the new Rich Inlet bar channel every five (5) years with maintenance of the Nixon and Green Channel connectors possible sometime in the future. These actions, along with other inlet modification and inlet maintenance projects in southeast North Carolina have the potential to create a cumulative deficit of inorganic sediment accumulation in the back barrier marsh habitat. Natural vertical accretion rates as high as 2.4 to 3.6 mm per year have been measured within salt marsh communities in North Carolina, however the maximum rate at which wetlands can accrete is not well understood (Craft e*t al.*, 1993). Without the accumulation of sediment, the salt marsh habitat may subside and lose its important habitat value for species such as rails, bitterns, wading birds and marsh sparrows, several of which are species of conservation concern according to Partners in Flight (Hunter et al. 2001, Pashley et al. 2000, Rich et al. 2004, and Johns 2004). Other species which may be impacted include several types of fish (*e.g.*, killifish and mummichogs), brown water snakes, crustaceans (various species of crabs), and several species of mammals (nutria, cotton rat, and raccoon) (CCSP, 2009). Over the 5-year Delft3D simulation period, the constructed sand dike off the south end of Hutaff Island eroded with some of the material moving into the area near the mouth of Green Channel. From the mouth of Green Channel across the middle ground shoals immediately behind the inlet and into Nixon Channel, there was an overall net gain of 280,100 cubic yards relative to Alternative 2 (Figure 5.50). However, most of this net gain was material that shoaled the new channels connecting into Nixon and Green Channels. In general, the inlet complex experienced a net loss of 477,500 cubic yards primarily as a result of the construction of the new channels. Due to the potential reduction of sediment through Rich Inlet, salt marshes may incur cumulative impacts with the implementation of Alternative 3.

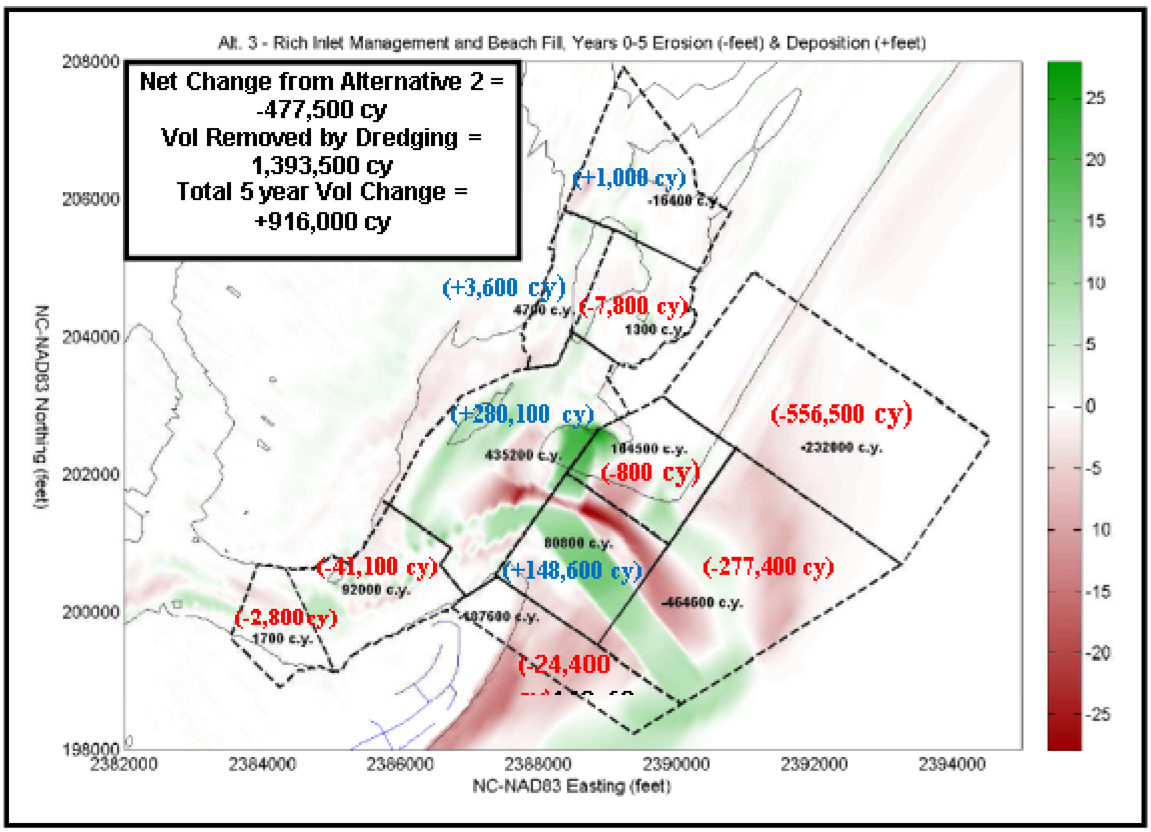

Figure 5.50. Modeled volume changes in discrete areas within the Permit Area for Alternative 3. Values in blue and red indicate an increase or decrease in material volume, respectively, compared to the baseline conditions shown in shown in Alternative 2.

<u>Submerged Aquatic Vegetation</u>

Direct and Indirect Impacts: SAV resources are found away from the throat of Rich Inlet in areas that are protected from naturally induced changes in water quality such as increase in turbidity and TSS. Relocation of the channel and construction of the sand dike are predicted to cause a short term increase in turbidity and TSS levels during construction operations; however, turbidity is expected to remain within the State standard of 25 NTUs. The construction of the dike is anticipated to last approximately one month while the relocation of the inlet channel is anticipated to last approximately 10 weeks. Despite the duration of these activities, the low silt percentage and the well-sorted sands in the inlet are expected to keep turbidity and TSS levels below the state standard outside the immediate area of construction. In 2005, Bogue Inlet was relocated and utilized a similarly designed closure dike as a part of that project. Turbidity measurements were recorded on a regular basis during the construction of that dike and results indicated that levels never exceeded the State standard. The highest recorded levels of turbidity was 16.4 NTU.

The relatively coarse grain size and low silt content (approximately 1.18%) of the material to be removed to reconfigure the channels in the Rich Inlet complex will limit the movement of the sediment plume during construction of the dike to the confluence of the inlet channel with Nixon and Green Channels, that is, the plume is not expected to travel any appreciable distance into the sound (see Appendix B). As previously mentioned above, 29,700 cubic yards of clay material detected within Cut 1 will be removed and transported to an upland disposal area during the dredging of the connector channel between Nixon Channel and the inlet gorge. This fine material will pass close to identified SAV resources (Figures 4.3a and 4.3b); however it will be contained in a pipeline during transportation reducing the likelihood of any SAV resources being covered under Alternative 3.

Since the dimensions of the new channel were selected to maintain a similar tidal exchange through the inlet that presently exists, the salinity within the permit area is expected to maintain its existing condition and therefore SAVs are anticipated to be minmally impacted (see Appendix B). Furthermore, dredging activity would occur during winter months when SAV resources are biologically less active. Therefore, there are no anticipated SAV impacts due to changes in water quality.

Cumulative Effects: Turbidity and TSS levels are predicted to remain localized and below the state standard soon after all channel maintenance events, as observed following dredging in Nixon Channel in 2001 (Cleary and Knierim, 2001). The highest weekly average of turbidity and TSS recorded at the discharge site on Figure Eight Island was 44.0 mg/l and 301.0 mg/l, respectively, during this monitoring (Cleary and Knierim, 2001). Maintenance events will be restricted to within the original dredge footprint and will occur during the winter months when SAV resources are biologically inactive. Cumulative impacts to SAV under Alternative 3 are not expected.

Shellfish Habitat

Direct and Indirect Impacts: No shellfish beds are present within the footprint of the channels to be dredged. The relocation of the channel and construction of the sand dike are predicted to cause a short term increase in turbidity and sedimentation levels. However, due to the low silt percentage and the well-sorted sands in the inlet, the turbidity levels are expected to remain below the state standard outside the immediate area of dike construction. Therefore, shellfish resources are not anticipated to be impacted by sedimentation within the inlet complex due to their remote location in relation to the proposed activity associated with Alternative 3. As mentioned above, 29,700 cubic yards of clay material detected within Cut 1 will be removed and transported to an upland disposal area during the dredging of the connector channel between Nixon Channel and the inlet gorge. This fine material will pass close to identified shellfish resources (Figure 4.4a and 4.4b); however it will be contained in a pipeline during transportation reducing the likelihood of any shellfish resources being covered.

Cumulative Effects: Turbidity levels are predicted to remain localized and below the state standard. Salinity throughout the inlet complex will remain unchanged as Nixon Inlet, with the new channel, is expected to maintain a similar tidal prism as what is observed within the existing inlet. Therefore, cumulative impacts to shellfish habitat under Alternative 3 are not expected.

UPLAND HAMMOCK

Direct, Indirect, and Cumulative Impacts: The activities associated with Alternative 3 are not expected to cause any direct, indirect, or cumulative impacts to the upland hammock resources located within the Permit Area due to the distance and relative elevation of the resource from the proposed activities.

Because these alterations to the flow and tidal prism are minimal they are not expected to allow for salt water intrusion to the adjacent upland hammocks (refer to Appendix B - Engineering Analysis). Changes in the rate of sea level rise, however, has the potential to impact upland hammocks, should they increase substantially over time. According to the International Panel on Climate Change, global mean sea level rose at an average rate of about 1.7 ± 0.5 mm/year during the twentieth century (IPCC, 2007). Recent climate research has documented global warming during the twentieth century, and has predicted either continued or accelerated global warming for the twenty-first century and possibly beyond (IPCC, 2007). This rate, which is difficult to predict, is anticipated to increase over the next 100 years. Rahmstorf (2007) predicts that global sea level in 2100 may rise 0.5 m (1.6 ft.) to 1.4 m (4.6 ft.) above the 1990 level. As stipulated by North Carolina HB 819, only "historic rates of sea-level rise may be extrapolated to estimate future rates of rise but shall not include scenarios of accelerated rates of sea-level rise unless such rates are from statistically significant, peer-reviewed data and are consistent with historic trends". However, if any rise is validated, the increase in sea level could result in potential cumulative impacts to coastal upland hammocks present in the permit area. There was virtually no difference in the average tidal prism associated with Alternative 3 versus Alternative 2. The average tidal prism of Rich Inlet over the five-year simulation period for Alternative 3 was 508.3 million cubic feet or only 1.07% greater than Alternative 2. This relatively small difference is not significant given the accuracy of the model. Flows through

Nixon and Green Channels under Alternative 3 were also only slightly different than Alternative 2 with Nixon Channel carrying 57.8% of the total and Green Channel accounting for 33.7% compared to 55.3% and 36.1% for Alternative 2, respectively. Outside of natural effects from sea level rise, no project impacts to upland hammocks are anticipated.

INLET DUNES AND DRY BEACHES

(NOTE: In the discussion for these habitat types, we have defined the north side where beach nourishment stops as the "inlet" and the south side where beach nourishment starts as "oceanfront". See OCEANFRONT DRY BEACHES AND DUNES further below for discussion addressing the south side where beach nourishment starts.)

Direct Impacts: Under Alternative 3, several biological resources, including seabeach amaranth, shorebirds, and turtles, which utilize the inlet beaches and dunes (along with their associated overwash areas) as foraging, resting, and nesting habitat, may be affected during and immediately following the implementation of Alternative 3. Activities under this alternative occurring in and adjacent to the inlet consist of dredging channels, the placing of fill material along Nixon Channel shoreline and the oceanfront inlet shoulder, and constructing the channel dike. As depicted under the 2006 conditions, no areas of inlet dunes, dry beach, or overwash would be removed or directly affected by the dredging activity.

The placement of 57,000 cubic yards along the Nixon Channel shoreline, which will create approximately 1.2 acres of additional dry beach, will cover a small portion of the native dry beach. This area has and continues to experience high erosion rates and contains approximately 0.6 acres of inlet dry beaches. The expansion of this shoreline footprint will increase the dry beach and provide additional resting, and potential nesting, habitat for shorebirds. Bird survey data provided by Audubon North Carolina showed piping plovers foraging along this shoreline in 2010. Although the birds were observed feeding, it is presumed that the addition of the inlet dry beach habitat will serve to expand the area for resting piping plovers, along with other shorebirds, during their feeding activity. The Nixon Channel shoreline also contains a small amount, less than 300 linear feet, of low lying inlet dunes and the placement of fill material at the foot, and expanding outward, of this dune system will provide additional protection to this habitat.

The construction of the 36.5 acre dike on the southern end of Hutaff Island will span across the existing inlet channel and onto the inlet overwash and dry beach habitats. The completed dike will result in the expansion of the inlet dry beach along the spit of Hutaff Island resulting in positive effects in terms of foraging and nesting habitat for birds and protection for inlet dunes. However, the construction of the sand dike may reduce inlet overwash habitat within the spit of Hutaff Island. This reduction of overwash areas would impact shorebirds, including the piping plover, by limiting the foraging habitat during construction. In Audubon North Carolina's bird surveys, data shows that piping plovers consistently used this area during 2008-2012 survey period for foraging and roosting.

Impacts to the bird resources are expected to be lessened due to the construction period being outside of the bird's fall and spring migration time, and with the expected presence of overwash habitat in the surrounding areas of Rich Inlet.

Indirect Impacts: For the 2006 conditions in the Delft3D model simulation, the sand spit projecting into Rich Inlet from Figure Eight Island elongated between year 1 and 2 and then stabilized until year 4. Between years 4 and 5 of the simulation, the sand spit began to experience significant erosion retuning to a condition similar to that which existed at the beginning of the simulation. The initial growth resulted in the formation of dry beach areas that could benefit the birds which utilize this habitat for nesting, resting, and foraging. However, erosion between Year 4 and Year 5, resulted in an overall net loss of about 5.2 acres dry beach habitat on the northern spit on Figure Eight Island at the end of the 5-year period. This loss includes the approximately 0.8 acres of inlet dry beach that was initially created with the fill placement along the Nixon Channel shoreline. The majority of the indirect impacts to dry beaches would be gradual throughout the 5-year period which should provide an adjustment period for bird species in adapting to the dry beach habitat changes.

Under Alternative 3, Delft3D modeling results suggested that the closure dike is expected to take on the characteristics of a sand spit projecting off the south end of Hutaff Island maintaining the dry beach and the potential for overwash habitat as well within one year following construction. Much of that material is expected to be transported into the inlet system as the dike degrades and welds onto the southern portion of Hutaff Island. The extent of the inlet dry beach habitat in this area under Alternative 3 at the end of the 5-year simulation was larger than the dry sand beach area at year 0 for Alternative 2, the baseline conditions. In total, it is anticipated that approximately 0-5 acres of inlet dunes and dry beaches may be indirectly impacted as a result of the implementation of Alternative 3.

Audubon North Carolina bird survey data revealed that piping plovers frequented Rich Inlet dry beach and overwash areas within the spits, or ends, of both Hutaff and Figure Eight Islands between 2008 and 2012. Observed behavior consisted of foraging and roosting, or resting, within both ends of the islands. Within this timeframe, both island spits experienced overwash and inlet dry beach habitat changes, and the birds' behavior and use of each side of the inlet gorge changed accordingly. These changes within an inlet system tend to be frequent, and quantifying indirect impacts for inlet dry beaches and overwash areas is extremely difficult due to their ephemeral nature. As stated above, Alternative 3 is expected to reduce the amount of inlet dry beach and overwash within the inlet system over the simulated 5-year period. This is anticipated to have some degree of impact on the foraging and resting behavior of shorebirds, including piping plover, but to what extent is uncertain. It is expected that the shorebirds will continue to use both island spits and that the change will be gradual, giving the birds time to adjust.

With channel maintenance expected to be needed every 5 years to maintain the preferred position and alignment of the bar channel, the cycle of spit growth and erosion, as observed during the 5-year simulation under Alternative 3, is expected to continue.

Cumulative Impacts: Alternative 3 includes channel maintenance and beach renourishment up to once every five (5) years. For the 30-year review period, this could include up to six separate channel maintenance events. Maintenance is likely to be limited only to the inlet bar channel with Nixon and Green Channels only dredged in order to restore flow or to divert flow away from the nourished area along the Nixon Channel shoreline. By limiting the footprint to the bar channel, the 5-year model simulation showed approximately 629,000 cubic yards of material will be dredged each maintenance cycle, which is approximately 33% of the total of 1,923,700 cubic yards dredged during the initial construction. It is not anticipated that any inlet dry beach or overwash habitat will be directly affected during maintenance, especially since there will be no dike work after the initial construction. The need for channel maintenance would be dictated by shoaling of the bar channel or migration of the channel outside the channel corridor to a more northerly position. Maintenance activities will assure the continued favorable position and alignment of the bar channel to reduce, or maintain acceptable rates of, oceanfront erosion in order to protect vulnerable oceanfront properties and utilities along the north end of Figure Eight Island. This should provide a favorable environment for the continued existence of the sand spit off the north end of Figure Eight Island, which would include overwash and inlet dry beach habitat. With on-going maintenance of the bar channel in Rich Inlet, Hutaff Island's inlet dunes and dry beaches could be diminished as the channel is maintained in a southward position.

Assuming the bar channel is repositioned to its preferred position every five (5) years, the cycle of spit growth and erosion should continue. By limiting maintenance to the bar channel and reducing the amount of material removed from the inlet, inlet dry beach and overwash habitats are expected to be maintained and available for shorebird foraging and resting activities. Cumulative effects of Alternative 3 on these habitats should be minimal and non-appreciable over the 30-year study period.

INTERTIDAL FLATS AND SHOALS

(NOTE: In the discussion for these habitat types, we have defined the north side where beach nourishment stops as the "inlet" and the south side where beach nourishment starts as "oceanfront".)

Direct Impacts: Under Alternative 3, approximately 20-25 acres of direct impacts to the intertidal flats and shoals will be incurred as a result of dredging activities and construction of the sand dike within the inlet complex. Of this total, approximately 11 acres of intertidal flats and shoals are within the footprint of the closure dike. These impacts will result in the conversion of intertidal flats and shoals to alternate habitat types; namely subtidal habitat in the dredged area and dry beach habitat in the dike construction area; consequently removing the infaunal community residing in these areas. The removal of this habitat and the encompassed infaunal community is expected to negatively affect various foraging bird species, including piping plovers and the red knot, who utilize the intertidal flats and shoals for feeding in this location. In the Audubon North Carolina bird surveys conducted between July 2008-May 2012, approximately 45% of the total individual piping plovers observed foraging within Rich Inlet were sighted within the landscape of the flood and ebb shoal islands located within the footprint of Alternative 3. Of the foraging habitat used by these individuals, over 90% were observed feeding in the intertidal zone. As noted in these surveys, most individuals were observed during the Spring and Fall months.

During dredging and dike construction work within the inlet, the presence and noise of heavy equipment may have an effect on the behavior of bird species utilizing the inlet, but this is expected to be minimal and non-appreciable. A during-construction bird monitoring for a similar project approximately 26 miles north of New River Inlet can be referenced to help validate this. In a recent ebb tide channel relocation project in New River Inlet, during-construction bird monitoring was conducted within the approximate 2.5 month construction period between November 2012 and February 2013. For this project, the dredge activity in the inlet channel involved the dredging of a roughly 40-acre footprint, which included the removal of approximately 575,000 cubic yards of material and placing the material along approximately 2.0 miles of oceanfront shoreline. The bird monitoring area consisted of 5 transects, which included areas on either side of the inlet, portions of the oceanfront shoreline, and intertidal flats and shoals within the inlet. This designated monitoring area basically encompassed the entire inlet complex. The results of the during construction monitoring showed the constant presence of shorebirds throughout the inlet complex, including several sightings of piping plover and red knot. Eleven individual surveys were conducted during the construction period and results showed an average of 1,840 individuals from a variety of species observed per survey (Coastal Planning & Engineering, 2013). The bird species, which are expected to be the same species found in Rich Inlet, appeared to adjust to the presence of construction equipment and noise, and continued to inhabit the inlet complex throughout the entire construction period. In another bar channel relocation project in Bogue Inlet, the 2005 during construction bird monitoring also showed the continued use of the inlet complex while dredging and a dike construction in the inlet were on-going from January to April, 2005. Shorebirds, including piping plover, were observed during the monitoring efforts for both projects appeared to adjust to the presence of construction equipment and noise and are of the same species found in Rich Inlet. The same continued use and inhabitation for Rich Inlet complex is expected throughout the entire construction period.

In addition to bird use, fish are also known to forage upon the infaunal communities within the intertidal flats and along the shoal areas. Species found feeding in these habitats of the inlet area include trout, spot, pompano, bluefish, flounder, and red drum. Many of these species have commercial importance in the fish industry. With the direct removal of 20-25 acres of these potential foraging areas, this would reduce available prey or food sources and could change feeding behavior within the inlet complex.

One implemented measure to reduce potential impacts to bird and fish resources is the use of a "winter" time for dredging. Dredging in a November 16th – March 31st window would take place when the species populations utilizing the intertidal flats and shoal are at their lowest. Additionally, this dredging time would occur when their food source within the infaunal community is at its lowest.

Indirect Impacts: Indirect impacts are likely to occur as a result of dredging within Rich Inlet, Nixon Channel, and Green Channel as well as the construction of the closure dike. As stated above, impacts to the 20-25 acres of intertidal flats and shoals within this area will cause the immediate mortality of macroinfaunal species which is a prey source for foraging birds and fish populations. The effects level or magnitude in the loss of this food source is uncertain, but studies of dredging and disposal effects on nearshore and estuarine fish populations have reported rapid recovery or minimal effects (Courtenay *et al.*, 1980; de Groot, 1979a; de Groot, 1979b; Posey and Alphin, 2000). These effects are anticipated in part due to the winter time construction when biological activity is lowest. Following the project to relocate the ebb tide channel at Bogue Inlet in NC, a three year monitoring study was conducted to help determine any potential project effects on the infaunal community within the inlet. The infaunal community for this project is similar in nature to Rich Inlet and also inhabit a harsh environment that is highly susceptible to change. Results show that natural disturbances in the Bogue Inlet study area, including Hurricane Ophelia, may have equaled project-related effects and that the effects of disturbance in the project area have abated while the natural biological successional paradigm was evident. The inlet environment remains dominated by physical stress, natural within a high energy inlet (Carter and Floyd, 2008).

Over the 5-year Delft3D simulation period, the constructed sand dike off the south end of Hutaff Island eroded with some of the material moving into the area near the mouth of Green Channel. From the mouth of Green Channel across the middle ground shoals immediately behind the inlet and into Nixon Channel, there was an overall net gain of 280,100 cubic yards relative to baseline conditions at year 0 for Alternative 2 (Figure 5.53). However, the construction of the connectors into Nixon and Green Channels and the construction of the sand dike across the existing bar channel will remove a net volume of 1,393,000 cubic yards. Within the entire inlet complex, the model results at the end of the 5-year simulation indicated a net loss of 477,500 cubic yards relative to year 0 for Alternative 2. This net loss of material on the inside of the inlet complex could reduce the extent of intertidal flats and shoals relative to the without project condition. Therefore, indirect negative impacts to the foraging and resting bird species and fish utilizing the intertidal flats and shoals within the inlet complex are anticipated. The unconsolidated and unvegetated communities that remain in the inlet complex would continue to redistribute as they lack structure and are dynamic in nature.

Other major changes in the inlet shoal system under Alternative 3 would be associated with the reconfiguration of the ebb tide delta as it responds to the new bar channel position and alignment. These changes include volume losses from the south end of Hutaff Island, the outer portions of the ebb tide delta on the north side of the inlet, erosion due to the migration of the new channel to the north, and shoaling of the constructed position of the new bar channel.

Taking into account the net volume of material removed by dredging and the volume changes throughout the inlet complex, Alternative 3 accumulated 916,000 cubic yards of littoral material at the end of the five-year simulation.

Cumulative Impacts: Although some intertidal flats and shoals will be converted to subtidal habitat following construction, volume changes determined from the results of the Delft3D 5-year modeling suggest much of this initial habitat loss will recover elsewhere in the inlet as the ebb tide channel begins to fill in. Assuming the ebb tide channel may need maintenance dredging once every five (5) years, the previous project's direct and indirect impacts to the intertidal flat and shoal habitats could reoccur up to a maximum of six times during the 30-year study period. The exception of the impacts is not having to reconstruct the closure dike and likely not having to dredge within Nixon Channel and Green Channel. Maintenance dredging within Nixon Channel and Green Channel would be infrequent if needed at all. The 5-year period between each maintenance event will provide some time for intertidal flats and shoals to reform prior to any subsequent maintenance events. With the on-going frequency of these inlet habitat types changing in their natural conditions, it is extremely difficult to quantify the overall cumulative effects of Alternative 3. Given that the maintenance dredging volume estimates are 67% less than the initial dredged amount, the overall cumulative impacts to these habitats are not expected to increase after the affects have taken place during the initial net loss. The presence of intertidal flats and shoals outside the dredging footprint and in other sections of Nixon and Green Channels and their surrounding tributaries would also help minimize potential cumulative impacts to these habitats and the resources that use them.

OCEANFRONT DRY BEACH AND DUNE HABITATS

(<u>NOTE</u>: In the discussion for these habitat types, we have defined the north side where beach nourishment stops as the "inlet" and the south side where beach nourishment starts as "oceanfront".)

<u>*Oceanfront Dune Communities*</u>

Direct Impacts: The existing dune system along the northern portion of Figure Eight Island has been maintained through the use of sandbags and some beach scraping activities. For Alternative 3, a dune with a crest elevation of 4.6 m (15.0 ft.) NAVD would be provided in the area from baseline station 77+50 to 95+00 or in the area presently devoid of a dune and where homes are presently protected by sandbag revetments. The footprint of the artificial dune would encompass approximately 4.6 acres which would result in a positive impact to this habitat. This stabilization measures will allow for long term growth and development of dune vegetation and provide habitat for roosting shorebirds. The dune communities located on Hutaff Island are not expected to be directly impacted by the implementation of Alternative 3.

Indirect and Cumulative Impacts: As described, the ocean bar channel positioned in a northerly direction favors accretion along the southern portion of Hutaff Island. If the channel is located in this position when the new channel alignment is dredged, the ebb tide delta would reconfigure in response to the new channel position and alignment. After the inlet channel is relocated, the current position of the ebb tide delta should shift to the southeast which could result in erosional conditions along the south end of Hutaff Island. This would leave parts of the oceanfront dunes exposed and more susceptible to storm-induced damage increasing the potential for overwash. Based on the model results for Alternative 3 under the 2006 conditions, the new bar channel is expected to shoal and eventually migrate back toward Hutaff Island within 5 years after its initial relocation. This could prompt maintenance activities to return the channel to its preferred position and alignment. If channel maintenance is required every five (5) years over the 30-year study period, as indicated by the model, some of the same impacts that occurred following the initial relocation could again be manifest. Therefore, Alternative 3 may lead to cumulative impacts to the oceanfront dunes along Hutaff Island.

With the potential of maintenance dredging at a maximum of once every five (5) years and up to six (6) separate events over a 30-year period, the oceanfront shoreline of Figure Eight Island would be nourished with the material from each of those events. Future maintenance of the channels would be limited to just the bar channel. For the 2006 conditions, the model indicated a 5 year shoal volume of 629,000 cy. Based on the need to reposition the bar channel of Rich Inlet every five (5) years, the five year nourishment requirement for this area would be 495,000 cy under 2006 conditions. Nourishment of the Nixon Channel area would require about 30,000 cy which brings the total 5-year nourishment requirement to 525,000 cy for the 2006. Consequently, this maintenance dredging and associated beach fill will serve to provide long-term protection of the oceanfront dunes along the northern portion of Figure Eight Island resulting in the protection of the nesting, foraging, and resting habitat for wildlife utilization.

Oceanfront Dry Beach Communities

Direct Impacts: The beach nourishment plan included in Alternative 3 would benefit the dry beach communities on the north end of Figure Eight Island shoreline through the expansion of this habitat. Beach nourishment would enhance the dry beach habitat along 12,500 feet of Figure Eight Island from the intersection of Beach Road and Beachbay Lane to Rich Inlet (F90+00 to 105+00). Implementation of Alternative 3 is expected to have a footprint of approximately 50-55 acres of dry beach habitat along the oceanfront shoreline on Figure Eight Island as a result of fill placement. In addition, the beach fill on the Nixon Channel shoreline will span approximately 1.8 acres. The design beach width of the oceanfront dry beach, following anticipated adjustments in response to wave action, will vary along the length of the 12,500-foot fill area. Within the area where the sandbags are present and erosion rates tend to be historically higher, the design width of the dry beach will average 124 feet. The remaining areas will average a design beach width of 46 feet, including the existing dry beach.

Placement of approximately 50-55 acres of beach fill will cover approximately 25-30 acres of existing dry beach. Beyond the existing dry beach, placement will create an additional 23 acres of dry beach habitat. The result of this placement is anticipated to produce a direct net gain of approximately 20-25 acres of dry beach.

As mentioned in Chapter 4, wider beaches in the Permit Area would benefit several natural resources including seabeach amaranth, shorebirds, and sea turtles. The widening of the dry beach footprint would immediately benefit sea turtles by increasing their nesting habitat area. Although nesting activity still occurs within the current oceanfront shoreline, nesting numbers are expected to be higher with additional dry beach.

While widening the beach itself is beneficial, using suitable material for successful nesting is essential in providing natural conditions. The composition, color, and grain size of the beach sand can affect the incubation time, sex, and hatching success of turtle hatchlings (Deaton et al., 2010). Physical characteristics such as density, compaction, shear resistance, moisture content, slope, sand color, grain size, grain shape, sand mineral content, and gas exchange may affect the success of sea turtle nests (Nelson and Dickerson 1988, Crain et al. 1995). The fill placed upon Figure Eight Island will conform to the State sediment criteria rules and therefore is not expected to impact the nesting success of sea turtles. The grain size of the native beach along Figure Eight Island is 0.18mm while the grain size of the fill material will range from 0.22mm to 0.25mm. Substrate alteration may affect the ability of female turtles to nest, the suitability of the nest incubation environment, and the ability of hatchlings to emerge from the nest. Escarpments formed during and after beach nourishment may prevent nesting females from reaching suitable nesting habitat, result in the selection of marginal or unsuitable nesting sites in front of escarpments, or result in nest exposure as escarpments recede landward. Numerous studies have described the effects of beach nourishment on nesting success (Crain et al. 1995, Steinitz et al. 1998, Ernest and Martin 1999, Herren 1999). These studies indicate a reduction in nesting success during the first post-nourishment year, followed by a return to normal levels by the second or third year. Declines in nesting success have been attributed to substrate compaction, escarpment formation, and/or modification of the natural beach profile. Beach nourishment also has the potential to improve poor quality nesting habitats associated with chronically eroded beaches (Brock et al. 2009), such as the northern portion of Figure Eight Island. Davis et al. (1999) and Byrd (2004) documented increases in nesting success immediately following the nourishment of eroded beaches. Increases in nesting success were attributed to the addition of dry beach habitat.

Embryonic development and hatching success are influenced by temperature, gas exchange, and moisture content within the nest environment (Carthy et al. 2003). Changes in substrate characteristics such as grain size, density, compaction, organic content, and color may alter the nest environment, leading to adverse effects on embryonic development and hatching success (Nelson and Dickerson 1988, Nelson 1991, Ackerman et al. 1991, Crain et al. 1995). Nourished beaches often retain more water than natural beaches, thus impeding gas exchange within the nest (Mrosovsky 1995, Ackerman 1996). Uncharacteristically dark sediments absorb more solar radiation, thus potentially resulting in warmer nest temperatures. Dark sediments may produce nest temperatures that are too high for successful embryonic development (Matsuzawa et al. 2002). The wet and dry Munsell colors found on the native beach were compared by CPE geologists to the material identified in the inlet and channel borrow areas. The results of the comparison indicate that the color of the potential fill material is similar to the material currently found on the beach. The hue indicates only slight variations in the amount of red and yellow between the native and fill material. The native beach and fill chromas are within the same range. The average wet and dry Munsell color along Hutaff Island and Figure Eight Island were determined to be 5 and 6, respectively (refer to Appendix D- Geotechnical Investigations). The average Munsell color within Nixon Channel and Rich Inlet (fill material) were determined to be 6 and 7, respectively. The fill material value is, on average, within one shade of the value of the native beach. The variations in color found between the fill sources and the native beach are not considered to be significant (Larenas, pers. comm.). Therefore negative effects to sea turtle nesting from the fill are not anticipated due to the compatible quality of material used to expand the dry beach area on Figure Eight Island. Higher temperatures may significantly reduce incubation periods and contribute to a higher incidence of late-stage embryonic mortality (Ernest 2001). Nest temperature also influences sex determination in hatchlings, with warmer temperatures producing more females and cooler temperatures producing more males (Wibbels 2004). Consequently, dark sediments may alter hatchling sex ratios. Investigations of beach nourishment effects on hatching success have reported variable results; including positive effects (Broadwell 1991, Ehrhart and Holloway-Adkins 2000), negative effects (Ehrhart 1995, and no effect (Raymond 1984, Nelson et al. 1987, Broadwell 1991, Ryder 1993, Steinitz et. al. 1998, Herren 1999, Brock et al. 2009). The variation in findings has been attributed to differences in the physical attributes of individual projects, the extent of erosion on the pre-nourishment beach, and construction techniques (Brock et al. 2009). As stated above, the grain size, color, and other attributes of the material placed along the northern portion of Figure Eight Island as part of Alternative 3 will comply to the State sediment criteria which will help reduce potential impacts.

Indirect and Cumulative Impacts: Overall, by moving the channel and inducing movement of the ebb shoal southward, Alternative 3 is expected to enhance the performance of most of the beach fill placed north of Bridge Road. The only exception is the fill along the northern 2,000 feet which could experience high rates of loss between the fourth and fifth years after channel realignment due to the movement of the channel back toward Hutaff Island. In general, the improved performance of the fill as indicated by the model results will enhance the oceanfront dry beach for Figure Eight Island.

As a result of the construction of Alternative 3, the south end of Hutaff Island may become erosional. This occurs due to the migration of the ebb shoal towards the south. The amount of erosion between Profiles 145+00 and 175+00 will be about 275,000 cubic yards over 5 years. Most of the volume loss computed for Hutaff Island was in the offshore area off the extreme south end of the island which was associated with the reconfiguration of the ebb tide delta in response to the new channel position and alignment. This change in the configuration of the ebb tide delta would also expose the southern end of Hutaff Island to direct wave attack which would increase the potential for sediment transport off the south end of the island and into Rich Inlet. This is expected to leave the south end more vulnerable to storm erosion with reduced offshore protection due to the migration of the ebb tide delta to the southeast. Based on the model results and Rich Inlet's historical condition, the new bar channel would be expected to shoal and eventually migrate back toward Hutaff Island within 5 years after its initial relocation. This could prompt maintenance activities to return the channel to its preferred position and alignment. If channel maintenance is required every five (5) years as indicated by the model, some of the same impacts that occurred following the initial relocation could again be manifest. Therefore, Alternative 3 may lead to cumulative impacts to the oceanfront dry beach along portions of Hutaff Island.

Although the construction of the closure dike across the existing entrance channel would add 393,000 cubic yards of material on the southern end of Hutaff Island, Delft3D modeling results suggest that 0-5 acres of coastal dry beach habitat would be indirectly impacted by Alternative 3.

With the potential of maintenance dredging every five (5) years, the oceanfront dry beach community on Figure Eight Island would be nourished with material from each event. As such, the project will serve to provide long-term protection of the oceanfront dunes along the northern portion of Figure Eight Island resulting in the protection of the nesting, foraging, and resting habitat for wildlife utilization. According to Greene (2002), beach nourishment can benefit endangered and threatened sea turtles by restoring habitat along eroded beaches. Some studies have found no significant difference between nourished and non-nourished beaches in the number of eggs per nest, as well as, hatching and emergence success (Nelson *et al*., 1985; Ryder, 1991). Other projects have shown increased numbers of nests, hatchlings, and survival rate of young turtles (Raymond, 1984). The wider beach will benefit sea turtles since they require dry beaches to nest, preferring to nest along wide sloping beaches or near the base of the dunes. The increase in dry beach on Figure Eight Island is also expected to positively affect the shorebirds, water birds and colonial birds that utilize this habitat. However, dry beach habitat supporting these birds is expected to be reduced on Hutaff Island. Therefore, Alternative 3 is expected to provide beneficial impacts to birds and turtles for foraging and nesting as well as recreational space for residents and visitors on Figure Eight Island while negative impacts may be incurred along Hutaff Island.

WET BEACH COMMUNITIES

Direct Impacts: The implementation of Alternative 3 will cause short-term impacts to infaunal communities that will be buried along approximately 10-15 acres of the wet beach community along the 12,500 linear feet of fill placed on Figure Eight Island's oceanfront shoreline and 1,400 linear feet on Nixon Channel shoreline. However, as soon as the fill material is placed, an additional 10-15 acres of wet beach habitat will be created further seaward resulting in no net change in wet beach acreage. Bird survey data provided by Audubon North Carolina showed piping plovers foraging along the Nixon Channel shoreline in 2010. The addition of beach fill along the oceanfront shoreline and Nixon Channel shoreline could directly impact infaunal organisms used as prey for shorebirds and other predators. As mentioned in Chapter 4, Nelson (1985) indicates that organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels. Also, as previously stated, with the use of beach compatible material, infaunal organisms are expected to recruit in the newly formed wet beaches at a quicker rate, reducing the recovery period. This will, in turn, reduce the potential affects to bird and fish species that prey upon the benthic community and cause any impacts to be short-term in nature.

Indirect Impacts: As indicated by 5-year Delft3D modeling, indirect impacts of approximately 5-10 acres of wet beach habitat along the ocean shoreline of Figure Eight Island would be anticipated as a result of the gradual shifting of the marine intertidal beach habitat. The gradual shifting occurs when the wet beach is displaced seaward after the nourishment takes place and is shown to continue as the intertidal zone equilibrates and adjust to the constructed beach. Indirect impacts to the wet beach could affect shorebird, crustacean, and fish foraging on the infaunal community. In addition, there could be impacts to recreational fishing through a temporary reduction in bait species during and immediately after construction. The shifting of the marine intertidal beach habitat is expected to be gradual over a five year period, providing enough time and at a slow enough rate such that infaunal organisms can adjust. It is also anticipated that beach nourishment will occur during the winter months or seasonal period when some of the infaunal community has migrated further offshore and their populations on the wet beach are lower. Thus, impacts to shorebirds, crustaceans, and fish foraging on these infaunal organisms are expected to be lessened. This in turn will also minimize any potential impacts upon recreational fishing. Additionally, the use of compatible beach material is expected to mimic the native material and should not interfere with the burrowing capacity of the benthic community, resulting in a shorter recovery time period.

Cumulative Impacts: As a result of the inlet maintenance and subsequent renourishment activity, which could total up to six separate events over the 30-year study period, negative effects could potentially occur if the diversity and abundance of infaunal populations do not recover to pre-construction levels between nourishment events. However, organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels (Nelson, 1985). Other studies reported by Maurer (National Research Council, 1995) supported the burial capabilities of nearshore species, which found that these species were capable of burrowing through sand up to 40 cm. As stated above, Nelson (1985) has demonstrated the adaptability and rapid recovery for organisms residing in the marine intertidal zone. With a minimum five year period between any maintenance events, there is expected to be ample time for any species to recover; and with the reason stated in the indirect impacts discussion above, any cumulative impacts to these resources under Alternative 3 are expected to be non-appreciable.

MARINE HABITATS

Softbottom Communities

Direct Impacts: The activities associated with Alternative 3 would result in direct impacts to approximately 100-110 acres of softbottom community within the Permit Area. This includes an estimated 72.8 acres within the dredge area and 36.5 acres within the fill footprint of the closure dike (Figures 3.4a and 3.4b). Target excavation depths are -19ft NAVD for all dredge areas. The existing depths within these areas vary with some areas as shallow as approximately -4 feet NAVD and as deep as -28 feet NAVD. The fill depth of the dike will be 31-34 feet over the 2006 bottom elevations, which were approximately-25 to -28 feet NAVD. This puts the majority of the dike at approximately 6.0 feet NAVD. Excavating the new channel alignment and dike construction will cause an immediate mortality of infaunal and non-motile epibenthic organisms inhabiting the substrate of the 100-110 acre softbottom community. This removal will cause the loss of prey for foraging fish and invertebrates within Rich Inlet, Nixon Channel, and Green Channel. It is uncertain what the magnitude and severity of this removal will cause on the feeding behaviors of migrating fish. Some of the impacts should be reduced by a winter dredging timeframe and with the presence of adjacent foraging softbottom communities located in the ebb tide delta and in undisturbed flood tide areas of Green and Nixon Channels. More information regarding infaunal impacts related to dredging can be found under the section entitled "General Environmental Consequences Related to Dredging" above.

Indirect Impacts: As described above, construction of the beach would result in the direct deposition of material seaward of the mean low water line, which covers softbottom habitat. Over time, the slope of the fill would adjust and equilibrate seaward covering additional softbottom areas with various depths of beach fill. Some of the adjustment depths will be greater than what the infaunal community can tolerate, leading to indirect mortality of the species populating the nearshore softbottom. This could, in turn, affect the foraging behavior of fish species utilizing the oceanfront softbottom community for a food source. The rate of adjustment for the toe of slope ranges from 6 months to 12 months and depends largely on weather conditions and on the content of material used for beach fill. If the time of equilibrium is short, then mortality might be higher since there is minimal time for the infaunal species to adjust. In general, the recolonization of these infaunal species typically tends to occur within the order of several months, which depends greatly on the compatibility of the material used for nourishment. It should be reiterated that the material placed over the softbottom habitat area meets the State's sediment criteria requirements and is considered to be compatible to the native sediment. By using compatible material, combined with the adaptive nature of the infaunal species in this harsh environment, the response of the softbottom community should reflect a normal short-term recovery period along the oceanfront shoreline. This short-term recovery is expected to minimize any effects on the feeding behavior of fish species.

For the dredging and dike construction activities associated with Alternative 3, the mortality of the infaunal resources from the softbottom community will also indirectly impact fish and benthic resources that forage upon the infaunal community. In general, although the recruitment pattern may be altered, the recovery of infaunal species after sediment removal is relatively quick, depending upon the opportunistic nature of the species (Deaton et al., 2010; Posey and Alphin, 2002). The results from an infaunal monitoring following the Bogue Inlet Channel Relocation Project demonstrated that all diversity index values were considerably reduced at the main ebb habitat 1-year post-construction (Carter and Floyd, 2008). Recovery of benthic communities has been proven to follow a predictive succession of community changes, as was demonstrated in the first year of the Bogue Inlet monitoring. Once the initial disturbance abates within the order of several weeks, Stage I of the benthic successional paradigm occurs. Stage I pioneering taxa usually consists of small opportunistic polychaetes (*e.g., Scolelepis squamata, Capitella capitata,* and *Streblospio benedicti)* and/or bivalves (*Donax variabilis*) (Bolam and Rees, 2003). The monitoring results at Bogue Inlet revealed that some of these opportunistic species were colonizing the main ebb habitat in high numbers immediately after construction ceased. These included the polychaete species, *S. squamata,* and *Paraonis fulgens,* both of which exploit disturbed areas due to their similar life history traits (i.e. high intrinsic growth rates and/or high larval availability) (Bolam and Rees, 2003; Grassle and Grassle, 1974). A 6% increase in the amphipod abundance of *Neohaustoruis schmitzi,* was observed at the inlet's main ebb habitat 2-years post-construction. This species also exhibits population rapid responses to disturbance events due to their direct development (*i.e.,* fertilization is internal) (Mallin *et al.,* 1999). Even with the removal of the benthic community within the dredging footprint at Bogue Inlet, the disturbance was considered abated as diversity subsequently increased by year two after construction and continued to increase by the third year (Carter and Floyd, 2008). The inferences from this study can be applied to Alternative 3 as the areas to be dredged are similar in physical nature and in location/position within the inlet gorge. Alternative 3 is expected to have similar results as other dredging projects and the infaunal species within the softbottom community should respond accordingly, thus resulting in minimal and short-term impacts to fish species.

Cumulative Impacts: Alternative 3 is expected to undergo the above indirect impacts each time a maintenance event occurs, which could potentially take place up to six (6) separate times over the 30-year study period. The one exception is that Nixon and Green Channels are not expected to be dredged on a five year cycle and the dike construction is an one-time activity. In the modeling results, both of these channels equilibrated after a two year period and it showed that maintenance would be infrequent compared to the inlet channel. With a minimum five years between any maintenance events within Rich Inlet, softbottom communities should have sufficient time to recover as described in the indirect impacts above. This is due to the resilient nature of the constituents of softbottom habitat and the time it takes for full recovery.

The fishery resources using the softbottom habitat within the inlet complex for foraging would be affected during, and immediately after, each maintenance dredging event. It is uncertain what the magnitude and severity of removing the softbottom community would be on the feeding behaviors of migrating fish. However, the presence of adjacent softbottom communities within the ebb tide delta and in undisturbed areas of Green and Nixon Channels would continue to provide a food source. These other foraging habitat areas, along with winter-time dredging, will help in reducing the magnitude and severity of any cumulative effects.

WATER QUALITY

<u>*Turbidity and TSS*</u>

Direct and Indirect Impacts: The dredging of Rich Inlet, Nixon Channel, Green Channel, the construction of the sand dike, and placement of material on the ocean and estuarine shoreline will result in the suspension of silt and fine fractions in the water column. In 2001, measurements for turbidity and TSS were taken before, during, and after dredging within Nixon Channel and placing the material along the oceanfront shoreline of Figure Eight Island. It was determined that both parameters increased at the point of discharge on the oceanfront shoreline, but the values returned to ambient conditions rapidly. During this project, the highest weekly average of turbidity and TSS recorded at the discharge site was 44.0 mg/l and 301.0 mg/l, respectively (Cleary and Knierim, 2001). In the 2005 Bogue Inlet Project, turbidity monitoring during the construction of the closure dike in the inlet was also measured and the results never exceeded the State standard of 25 NTUs. The highest reading was recorded at 16.4 NTU. There is no State standard for TSS.

With regards to Alternative 3, the effects on water quality are expected to be similar to turbidity and TSS levels. Additionally, the low silt/clay content of the material within the areas being dredged should result in relatively low concentrations of suspended sediment outside the immediate area of deposition. For the higher silt/clay content within the dredging footprint of Rich Inlet, the material will be deposited within an existing confined disposal island. The material will be discharged within the diked island and the silts/clays will settle prior to the effluent being returned to open water. Effects from the increase of turbidity and TSS could impair fish that are present during the time of operations. However, any potential impact is expected to be short-term due to the following reasons: 1) time of dredging and beach nourishing when biological activity is at its lowest, 2) the content of the material being dredged, 3) documented measurements from similar projects, 4) type of dredge plant, and 5) the ability of fish to avoid higher concentrated areas.

Cumulative Impacts: Dredging of the new bar channel and renourishment of the Figure Eight Island beach are anticipated to occur at a maximum, approximately once every five (5) years. This could include up to a total of six separate maintenance and renourishment events over the 30-year study period. Each maintenance event will take approximately eight (8) weeks to complete, pending weather and working conditions. After each dredging, there will be adjustment within the -19 foot channel and in-filling is expected within months. Figure 3.5 indicates that, based on the 2006 conditions, shoaling of the Entrance Channel would approach the 60% shoaling threshold almost 4 years after initial construction. Shoaling of the Green Channel connector occurred rapidly during the first two years of the simulation as shown in Figure 3.5. Any periods of infilling and adjustment may increase turbidity and/or TSS levels, but should not exceed dredging levels. It is not expected that turbidity and/or TSS levels from each single event would contribute to any subsequent maintenance dredging and beach fill work since the activities are considered short-term in nature. Also, it should be acknowledged that levels can increase dramatically during times of storms. Although the time period of increases from storms are more likely in days, the environments in the inlet and along the nearshore oceanfront are exposed to high levels of turbidity and TSS. Due to factors described above, no cumulative impacts regarding suspended particulates and turbidity are expected with the implementation of Alternative 3.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: For Alternative 3, as shown by Delft3D modeling results, the tidal prism of the inlet throat decreased by 4.2% which was less than the decrease obtained for Alternative 2, the without project condition. The smaller reduction in tidal prism for Alternative 3 was expected given the excavation of the new inlet bar channel and the two channels connecting the inlet throat with Nixon and Green Channels. Flow through Nixon Channel increased to around 53% compared to 49% for Alternative 2 while the flow through Green Channel was about 36% or 3% less than Alternative 2. Again the balance of the flow, 11% in this case, moved through the marsh areas.

Shoaling of Green Channel occurred fairly rapidly during the first two years of the simulation as the sand dike across the existing inlet channel eroded and morphed into a sub-tidal sand spit. Nixon Channel also shoaled rapidly during the first two years, however, the rate of shoaling decreased allowing the channel to maintain some of its cross-sectional integrity.

As shown in the 5-year Delft3D simulation, the magnitude of the changes in tidal flow and the overall hydrodynamics in the inlet complex that would accompany the implementation of Alternative 3 are relatively small and any changes in salinity levels within the project area will be minimal. Therefore, hydrodynamics and salinity are expected to be similar to natural or current levels during and after construction and following any subsequent maintenance events under Alternative 3.

Larval Transport

Direct Impacts: For Alternative 3, larvae of some fish species are expected to be entrained within the dredge while operating in the inlet, Nixon Channel, and Green Channel. These include the larvae of winter and early spring spawners such as spot, Atlantic croaker, southern and summer flounders, menhaden. However, because the peak of juvenile settlement generally occurs within the estuary in spring through early summer (Ross and Epperly 1985), these impacts are anticipated to be limited. Furthermore, due to the relatively small volume of water pumped through the dredge compared to the volume included within the tidal prism, impacts to many species of fish larvae are expected to be minimal. The dredging and beach fill operations associated with Alternative 3 are not anticipated to significantly impact larval transport into Rich Inlet.

Indirect and Cumulative Impacts: With Alternative 3, maintenance dredging could occur up to a maximum of once every five (5) years, or up to six (6) separate events over the 30-year study period. A maintenance event would likely take place only within the ebb tide channel of Rich Inlet. The Delft3D modeling results showed that Nixon and Green Channels would not require maintenance every five (5) years, but more infrequently if at all. By limiting the maintenance to the ebb tide channel, this would reduce the amount of dredging time and certainly the footprint to be dredged. Like the original channel construction, maintenance would be implemented during the winter months between November 16-March 31 when larval transport is at its lowest. With potential dredging events spaced at a maximum of every five (5) years, this is also expected to reduce any potential cumulative impacts. Additionally, as discussed in the Turbidity and TSS section above, levels are expected to be lower or similar to natural conditions and any suspended particulates would settle out of the water column rapidly. This should not have any appreciable effects on larvae migrating through the inlet complex. Overall, any indirect or cumulative impacts are anticipated to be minimal.

PUBLIC SAFETY

Direct and Indirect Impacts: During the construction of Alternative 3, public safety will be temporarily impacted due to the usage of heavy machinery within Rich Inlet, Nixon Channel and Green Channel, and along the oceanfront shoreline of Figure Eight Island. The implementation of Alternative 3 will alleviate the erosional pressure along of the northern 3.8 km (2.4 mi) of Figure Eight Island thereby protecting the nineteen (19) imminently threatened homes on the island. Without the threat of these homes being damaged or demolished, public safety will be positively indirectly impacted due to the avoidance of hazardous conditions caused by continued erosion including the exposure of utilities and leaking septic tanks. Furthermore, the sandbags, which could pose a public safety hazard due to their size and orientation to the eroded shoreline, may be removed and replaced with a nourished beach tapered from a developed dune ridge. Although the specific methodology has not been determined, the mesh sandbags would most likely be removed through mechanical means with use of a backhoe after being cut open to remove the sand. Public safety hazards would increase on Hutaff Island with the use of heavy machinery during the construction of the dike and dredging within the inlet. This risk would be low since there are no residences on Hutaff Island and access is only by boat. Furthermore, construction will take place within the dredging window of November 16th through March 31st when public use, both in-water and on the beach, of Nixon Channel, Green Channel, Rich Inlet, and Hutaff Island is at its lowest peak.

Cumulative Impacts: Public safety within Rich Inlet, along the oceanfront shoreline of Figure Eight Island, and the Nixon Channel shoreline may be temporarily impacted during each maintenance event scheduled approximately every five (5) years. Maintenance of the Nixon and Green Channel connectors should only be needed on an infrequent basis. When and if maintenance of these two channels are needed, the safety issues would be the same as discussed above for initial construction of Alternative 3. No significant adverse impacts are anticipated along Hutaff Island as the construction of the closure dike is a one-time event.

AESTHETIC RESOURCES

Direct Impacts: Temporary negative impacts to aesthetic resources will result from the implementation of Alternative 3 due to the visual presence of heavy machinery within the natural settings of Nixon Channel, Green channel, Rich Inlet and the oceanfront shorelines of Figure Eight Island and Hutaff Island. This activity would generally take place over a 3-4 month period, but would take place during the winter months when the majority of the residence and/or guests are not present on the island and use of surrounding waterways are at their lowest. Following completion of the construction phase of Alternative 3, the aesthetic resources will be as they were prior to construction. Currently 19 structures on the ocean shoreline and one (1) structure on the Nixon Channel shoreline have sandbags. The expected stabilization of the shoreline along the north end of Figure Eight Island combined with periodic nourishment of the shoreline south of Rich Inlet to Bridge Road should allow the removal of the existing sandbag revetments. With the removal of the sandbags along the northern portion of Figure Eight Island, the aesthetic quality of the island is expected to improve.

Indirect and Cumulative Impacts: Cumulative impacts will occur due to the anticipated on-going maintenance of Rich Inlet with the placement of dredged material on Figure Eight Island. These events will occur no more than once every five (5) year cycle. However, no dike construction will occur during a maintenance event. Also, maintenance of the Nixon and Green Channel connectors would only be needed on an infrequent basis. Due to the time length in between maintenance events, cumulative effects are expected to be minimal.

RECREATIONAL RESOURCES

Direct Impacts: Figure Eight Island is a private island with limited public access. General public access is restricted to boat access only. However, the shorelines and shoals of Nixon Channel, Green Channel, Rich Inlet, and the northern spit of Figure Eight Island are heavily used by the general public, especially during the summer months. An assessment of boat usage within proximity to Rich Inlet, as shown in Table 4.14, indicates that the majority of recreational boaters congregate along the banks of Hutaff Island, in the open water behind the inlet, and within any open exposed shoals. Many boaters also utilize the northern spit of Figure Eight Island as an area to anchor and access the island. The recreational opportunities along the ocean shoreline are primarily utilized by the private homeowners and guests to the island. Recreational opportunities such as beachcombing, sunbathing, surfing, fishing, and walking along the beach will be temporarily affected during the construction activities associated with Alternative 3. However, all construction activities will be limited to working within a window when recreational use is at its lowest during the year. Even during construction, complete access will not be restricted to these areas. Some exposed shoals that could be used for anchoring boats and sunbathing will be removed by dredging to a depth of -19 foot NAVD. Some of these areas are likely to be offset with the placement of the channel dike.

Indirect and Cumulative Impacts: In regards to the removal of exposed shoals associated with the dredging, the Delft3D model showed that the newly constructed bar channel underwent adjustments as shoals that were removed ultimately were reformed or created in new locations overtime. This is not unlike natural conditions in the sense that severe storms can breach ocean bar shoals to create a new channel; and overtime, the inlet adjusts by reshoaling at other locations within the inlet complex. As previously stated, Delft3D model results show that of the 909,000 cy of material removed from the bar channel, 629,000 cy is anticipated to infill by year 5, based on 2006 conditions. This deficit may leave fewer shallow and intertidal areas for anchoring boats on the sound side, or backside, of the inlet. Even with this potential reduction of shoals, this is not expected to have an appreciable effect on boat usages within the inlet complex. Recreational boat users frequently find new locations as shoals are constantly shifting.

For Figure Eight Island shoreline usages, recreational resources and opportunities are expected to benefit immediately following construction due to the increased size and extent of the nourished beaches along the oceanfront and Nixon Channel shoreline. As the closure dike welds to Hutaff Island, the dry beach community that forms will offer additional area for surf fishing, bird watching, and other recreational opportunities.

NAVIGATION

Direct Impacts: Navigation will be temporarily impacted due to the presence of the dredge and pipeline during the implementation of Alternative 3. The dredging involved with Alternative 3 will effectively close the present entrance channel. At no time will complete restriction of navigation occur in Nixon Channel during dredge operations. Restrictions will be determined by the USCG and will be limited to the areas where the dredge and the pipelines are located. Directly after the dredging of all channels, navigation within Rich Inlet and the flood tide delta (sound side) will be expected to greatly increase due to the newly created channel depth of -19 feet NAVD.

Indirect and Cumulative Impacts: The 5-year Delft3D model simulation resulted in the evolution of the “Y” shaped dredge cut to a more curved shape and both sides of the entrance channel assumed a more gradual slope. As part of this process, the interior portions of the bar channel migrated toward Hutaff Island while the outer portion assumed an orientation toward the north end of Figure Eight Island. The initial increase in navigation benefits as seen immediately following construction would be maintained to a certain level over the next 5 years until the next maintenance event. At no time would the depths within the dredged areas be projected to decrease to pre-project conditions. Sometime after year 5 following construction, the bar channel could breach the ebb tide delta and become aligned parallel to the shoreline on the south end of Hutaff Island. However, such a breach of the ebb tide delta will probably not occur since the model indicated the channel would have migrated out of the original construction corridor by the end of year 5 prompting a maintenance event to restore the preferred position and alignment of the bar channel.

At the end of the 5-year Delft3D model simulation under the 2006 shoreline conditions, the channel leading from Nixon Channel to the inlet gorge maintained a depth of 10 feet or greater and a width of approximately 100 feet both of which are adequate for the size vessel that normally uses Rich Inlet. On the Hutaff Island side of the inlet, the closure dike across the existing entrance channel gradually eroded and morphed into a recurved sand spit that projected into the mouth of Green Channel. Even so, the model results at the end of the 5-year model simulation indicated a channel with a depth of approximately 8 feet between the inlet gorge and the mouth of Green Channel during the entire 5-year simulation period. As stated earlier, maintenance dredging within Nixon and Green Channels will likely be infrequent over the 30-year study period. Whether maintenance would occur or not within these two channels, the historic hydrodynamics within the ebb tide delta has not resulted in a closing or prohibition of boat usage. For Rich Inlet, navigational use would only improve if maintenance events occurred once every five (5) years over the 30-year period. Therefore, navigation would be expected to be maintained throughout the entire inlet complex as a result of Alternative 3.

INFRASTRUCTURE

Direct Impacts: The results of Dr. Cleary's geomorphological analysis (provided in Sub-Appendix A of Appendix B) indicated that when the bar channel of Rich Inlet is orientated toward Figure Eight Island, the north end of the island tends to accrete whereas when the channel is aligned toward Hutaff Island, the north end of Figure Eight Island erodes. Under Alternative 3, the main ocean bar channel would be relocated to a position and alignment that would produce favorable shoreline changes on the extreme north end of Figure Eight Island. This southerly alignment, along with the nourishment of 12,500 linear feet of oceanfront shoreline and 1,400 linear feet of Nixon Channel shoreline, would provide additional protection for the existing infrastructure immediately following construction. This additional protection would be most beneficial for those 19 homes along the ocean shoreline and one home along the Nixon Channel shoreline currently containing sandbags.

Indirect, and Cumulative Impacts: Alternative 3 is expected to benefit the infrastructure on Figure Eight Island due to the long-term protection from erosion over the 30-year study period. The beach nourishment plan for Alternative 3 would include the use of approximately 1.2M cubic yards of material as beach fill along 12,500 linear feet of the Figure Eight Island shoreline. This would serve to protect the homes and infrastructure along the oceanfront shoreline of the island from the intersection of Beach Road and Beachbay Lane to Rich Inlet (F90+00 to 105+00). The design width of the oceanfront dry beach, following anticipated adjustments in response to wave action, will vary along the length of the 12,500 foot fill area. Within the area where the sandbags are present and erosion rates are highest, the design width of the dry beach will be 124 feet. The remaining areas will average 46 feet, including the existing dry beach. In addition, the alternative includes a small fill area (1,400 feet) along Nixon Channel near the north end of Beach Road which would expand the existing shoreline by approximately 50 feet. These two locations will be renourished approximately every five years providing the long term protection.

The modeled performance of the beach fill along the ocean shoreline at the end of Year 5 of the simulation indicated the southern 8,000 feet of the fill should remain fairly stable and only need periodic nourishment on an infrequent basis. Erosion of the 4,500 feet of fill north of station 60+00 to Rich Inlet removed most of the fill by the end of Year 5 of the simulation. While erosion did not encroach into the pre-project upland area, this 4,500-foot section would need to be renourished about every five (5) years. This would normally be accomplished using material removed to restore the preferred position of the bar channel in Rich Inlet.

SOLID WASTE

Direct, Indirect, and Cumulative Impacts: Both short and long-term benefits are expected from the reduction of solid waste with the implementation of Alternative 3. This alternative will provide protection along portions of Figure Eight Island thereby decreasing the risk of damage to residential buildings and infrastructure. This would alleviate the potential of increased amount of solid waste through demolition.

NOISE POLLUTION

Direct Impacts: The relocation of Rich Inlet, dredging of the connector channels, construction of the closure dike, and the placement of beach compatible material on the oceanfront and backbarrier shoreline would temporarily raise the noise level during the 2.5 month construction period due to the use of heavy machinery. On the oceanfront side, this would be short-term since the equipment would be constantly relocating as work moves down the beach. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. Also, dredging and beach placement would occur during times when residents and visitors are less likely to be present.

Indirect and Cumulative Impacts: No indirect or cumulative impacts pertaining to noise pollution are anticipated due to the time of year and the low frequency of beach nourishment events, which is a maximum of once every five (5) years and up to 6 separate events over the 30-year study period.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: Alternative 3 is expected to reduce the potential loss of homes and infrastructure on the north end of Figure Eight Island and along Nixon Channel shoreline. While some homes may be subject to damage during severe storm events, the level of damage would not necessarily result in the property owners moving or demolishing their homes. Thus, the existing tax base would be maintained.

Alternative 3 would preserve the existing tax value. However, since the width of the beach along the north end of Figure Eight Island would vary from a maximum immediately following beach nourishment to a minimum at the end of the 5-year nourishment cycle, some of the threatened 40 structures north of 302 Bridge Road North could still be subjected to some storm damage. This could lead to the eventual abandonment and/or demolition of some of the structures which would in turn reduce the tax value on Figure Eight Island. Since abandonment and/or demolition of these homes would be determined by the affected property owners, they were assumed to remain in place throughout the 30-year analysis period with no impact on the existing tax base.

Implementation of Alternative 3 will benefit the local economy of New Hanover County. If the current erosion rates were to continue, the damage or destruction of imminently threatened homes would decrease the local tax revenue on Figure Eight Island. Therefore, the protection of these homes from erosion provided by the implementation of Alternative 3 will provide a positive direct, indirect, and cumulative economic benefit. Table 5.21 depicts the average annual economic impact associated with Alternative 3 based on 2006 shoreline conditions. Over the thirty year planning period, the total implementation cost for Alternative 3 would be about $63.3 million in current dollars. This total cost includes $17.1 million for initial construction of the new channels, sand dike, and beach fills and $46.2 million for maintaining the channel every five (5) years with disposal of the dredged material along both the ocean shoreline of Figure Eight Island north of Bridge Road and along the Nixon Channel shoreline.

Table 5.21- Summary of Average Annual Economic Impact of Alternative 3

Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
0	0	$2,564,000	$2,564,000

D. IMPACTS ASSOCIATED WITH ALTERNATIVE 4: BEACH NOURISHMENT WITHOUT INLET MANAGEMENT

Alternative 4 would include a beach fill along the ocean shoreline between Rich Inlet and Bridge Road and a fill along the Nixon Channel shoreline immediately behind the north end of Figure Eight Island and periodic nourishment to maintain the fills. For Alternative 4, the size of the beach fill was reduced relative to Alternative 3 with design of the fill dictated by shore protection needs not the distribution of a given volume of material from a new channel as was the case under Alternative 3. The beach fill for Alternative 4 would vary in width from 17 to 43 feet from stations F90+00 to 60+00 and then increase in width to 86 feet at station 70+00 and then 172 feet in width north of station 82+50 to Rich Inlet. Since Alternative 4 does not include any modification to the Rich Inlet ocean bar channel, material to construct and maintain the beach fills would be obtained from Nixon Channel, three upland disposal islands, and the offshore borrow sites. Due to the finite volume of material available in the AIWW disposal sites (total of approximately 527,000 cubic yards), this material would be held in reserve for possible use in rebuilding dunes damaged by coastal storms.

ESTUARINE HABITATS

Salt Marsh Communities

Direct and Indirect Impacts: Like Alternative 1, Dr. Cleary's shoreline analysis suggests that portions of shoreline behind Rich Inlet which contain salt marsh habitat have experienced erosion in response to the development of this large flood tide delta. While the erosion rates in this area are significantly greater than the pre-1993 rates, this increase cannot be directly attributable to dredging in Nixon Channel due to the influence of the migrating sand lobes into Nixon Channel associated with the morphological changes that have occurred to Rich Inlet since 1993. Regardless, these periods of salt marsh erosion along the shoreline would be expected to continue so long as the flood tide delta directs the majority of the flow close to the eroding shoreline (Cleary, pers. comm.). Additional erosion of salt marshes has been occurring along the Nixon Channel shoreline. This erosion appears to be related to movement of the Nixon Channel thalweg toward the island. Recent photographs have shown exposure of high marsh peat and shrub stumps along the estuarine shoreline in this location which have helped validate this process (Cleary, pers. comm.). Due to the dynamic nature of the inlet system and the proximity of the salt marsh resources to the evolving shoreline, direct and indirect impacts to salt marshes are expected to continue.

Salt marsh communities are present in proximity to the three disposal islands, as previously described in Chapter 4. However, extraction of beach fill material from these sites are not expected to have any impact on these marsh resources. This is due to the utilization of proper construction practices for stabilization and preventive measures, such as silt fencing, to protect these resources.

The area where fill would be placed along the Nixon Channel shoreline would terminate south of the small tidal creek that serves to feed the area of high marsh along the northern end of Figure Eight Island. As such, no significant adverse impacts are anticipated to this high marsh area.

Although primary nursery areas (PNAs) are located within the Permit Area, no PNA will be directly impacted by beach fill activity. PNAs are generally defined as being located in the upper portions of creeks and bays. These are usually shallow areas with soft, muddy bottoms surrounded by marshes and wetlands. Low salinity and the abundance of food in these areas are ideal for young fish and shellfish. The 1,400 foot section of estuarine shoreline along Nixon Channel where beach fill is proposed for Alternatives 4 is characterized by high salinity water with a sandy bottom.

Cumulative Impacts: Similar to as described for Alternative 1, beyond the existing natural processes of erosion and development, no cumulative impacts are anticipated with Alternative 4.

Submerged Aquatic Vegetation

Direct, Indirect, and Cumulative Impacts: The three confirmed occurrences of SAV are specifically found within tidal creeks along the edge of salt marshes west of Green and Nixon Channels. As with Alternative 1 and 3, these areas are outside of the dredging footprint of Nixon Channel for Alternative 4 and any potential indirect impacts are expected to be minimal.

As described in Chapter 4, there are seventeen potential SAV areas close to the three disposal islands. Should these sites be utilized, proper construction methods, such as silt fencing and proper placement of pipes, will be implemented to reduce any potential direct or indirect affects to SAVs. Additionally, dredging would occur within the confined disposal island and this would reduce the likelihood of impacts associated with the burial of SAV resources. In addition, dredging will occur during the dredging window between November 16th and March 31st, which is when biological activity is low and SAV resources are less abundant within the Permit Area. Furthermore, negative cumulative impacts are not expected to be incurred as SAVs are expected to migrate to their preferred depth should sea levels rise over the next 30 years as currently predicted.

Shellfish Habitat

Direct and Indirect Impacts: The dredging of material from Nixon Channel is predicted to cause a short term increase in turbidity and TSS. Due to the low silt percentage and the well-sorted sand within Nixon Channel, the turbidity levels are expected to remain below the state standard outside the immediate area of dredging. As stated above for SAV resources, there are also potential shellfish beds close to the three disposal islands that could be used as a contingency borrow site. Should these sites be utilized, proper construction methods, such as silt fencing and placement of pipes, will be implemented to reduce any potential direct or indirect effects to these shellfish resources. Additionally, dredging would occur within the confined disposal island and this would reduce the likelihood of impacts associated with the burial of shellfish beds.

Cumulative Effects: Turbidity levels are predicted to remain localized and below the state standard, as shown by Cleary and Knierim (2001) following dredging within Nixon Channel. Salinity throughout the inlet complex will remain unchanged as the waterways within the inlet complex are expected to provide the similar tidal prism as existing conditions. Therefore, cumulative impacts to shellfish habitat under Alternative 4 are not expected.

UPLAND HAMMOCK

Direct, Indirect, and Cumulative Impacts: The upland hammocks present atop of the AIWW man-made dredge disposal islands that could be utilized to repair storm damaged dunes under Alternative 4 would be removed during excavation of the islands. Some colonial waterbirds such as green herons and yellow-crowned night herons utilize vegetated, upland environments similar to those present on the dredge disposal islands. These three colonial waterbird groups prefer trees, shrubs, and grass lands for nesting and, as a result, may utilize the upland hammocks identified within the Permit Area. It would be expected that this dredging would force these birds to relocate to other suitable habitat, such as proximate upland hammocks that line the AIWW atop other dredge disposal islands.

INLET DUNES AND DRY BEACHES

(NOTE: In the discussion for these habitat types, we have defined the north side where beach nourishment stops as the "inlet" and the south side where beach nourishment starts as "oceanfront". See OCEANFRONT DRY BEACHES AND DUNES further below for discussion addressing the south side where beach nourishment starts.)

Direct Impacts: Alternative 4 encompasses approximately the same fill footprint along the shoreline of Nixon Channel as Alternative 3. Approximately 57,000 cubic yards of material will cover approximately 0.6 acres of inlet dry beach under the 2006 shoreline conditions, but will create approximately 1.2 acres of that habitat. This results in a net gain of 0.6 acres. No areas of inlet dry beach, inlet dune, or overwash habitat would be removed during the dredging from within the Nixon Channel borrow area.

The expansion of this shoreline footprint will increase the dry beach and provide additional resting, and potential nesting, habitat for shorebirds, including the piping plover. As stated previously under Alternative 3, Audubon North Carolina bird survey data revealed that piping plovers frequented the Nixon Channel shoreline to forage during the 2010 season. The increase of inlet dry beach is expected to enhance their foraging ability. Additionally, the Nixon Channel shoreline also contains a small amount, less than 300 linear feet, of low lying inlet dunes; and the placement of fill material at the foot, and expanding outward, of this dune system will provide additional protection to this habitat.

Indirect Impacts: For Alternative 4, effects on inlet dunes and dry beach habitats depend on how the inlet bar channel behaves. As shown by Dr. Cleary's geomorphic analysis of Rich Inlet, the habitats associated with the inlet undergo significant changes in response to the reorientation of the ebb tide delta. Although the relative position of the inlet has been stable over the past century, fluctuations in orientation of the main ebb-channel have forced subsequent periods of erosion and accretion on the adjacent shorelines of Figure Eight and Hutaff Islands (Cleary, 2009). As depicted through the 5-year Delft3D model simulation for Alternative 4, the sand spit projecting off the north end of Figure Eight Island into Rich Inlet initially elongated but stabilized by the end of Year 2 with some slight erosion occurring between Year 4 and 5 of the simulation. The initial elongation of the sand spit appeared to be due to sand transported to the north from the oceanfront beach fill. Under the 2006 shoreline conditions, these morphological changes to the inlet dunes and dry beaches indicated a net increase of approximately 4.1 acres of habitat along the spit on Figure Eight Island and Hutaff Island over the 5-year period. This net gain includes the approximate net loss of approximately 0.8 acres of inlet dry beach that was initially created along the Nixon Channel shoreline. Although this type of response of the sand spit may result in a decrease in the dry beach, it should result in the increase of intertidal habitat for foraging/resting shorebirds on the Figure Eight Island side of the inlet, as well as potentially providing additional inlet dry beach nesting habitat for sea turtles on the inlet oceanside of the island. Monitoring data has shown turtles nesting in this vicinity and the movement of beach fill into the inlet under Alternative 4 may increase nesting opportunity within the inlet dry beach. This potential decreases following the initial construction, as much of the beach material has eroded between Years 2 and 3, which results in less sediment feeding the oceanside inlet dry beach. The Audubon North Carolina bird survey data shows bird use within the inlet dry beach and overwash areas of Rich Inlet. The effects of Alternative 4 on that use should provide some indirect protection to inlet dunes and expand dry beaches and the natural resources that utilize them.

During the same 5-year simulation time period, the Delft3D model results also indicated accretion of inlet dunes and dry beaches on the southern portion of Hutaff Island. This accretion of an estimated 57,000 cubic yards of material (as per Delft3D model results) on the southern end of Hutaff Island is expected to augment the habitat gains indicated on Figure Eight Island thereby increasing the resting and nesting habitat for shorebirds.

Similar to Alternative 2, Delft3D modeling results suggests an increase of less than 5 acres of inlet dunes and dry beaches under Alternative 4.

Cumulative Impacts: Alternative 4 includes beach renourishment once every four (4) years. For the 30-year review period, this could include up to a maximum of seven (7) separate periodic nourishment events. During each nourishment cycle, transport of material into the inlet will continue as was shown in the 5-year simulation. This material will add to the inlet dry beach and overwash areas in the spit of Figure Eight Island and help support foraging and nesting habitat for bird species, including piping plover. However, the initial increase is short-term as described in the indirect discussion. The additional benefits along Nixon Channel are also expected to be short-term. As described in the indirect discussion of Alternative 3, Audubon North Carolina bird survey data consistently showed piping plover use from 2008-2012 within the inlet dry beach and overwash areas on both shoulders of Rich Inlet. This occurred during a short period where the bar channel started shifting from a central location to more of a southerly position. Under Alternative 4, after the 2-year period of the beach fill migrating into the inlet, the shifting and changing of inlet dry beach and overwash habitats will be contingent mostly on the orientation of the bar channel. As shown in the bird survey data, piping plover and other shorebirds are expected to adjust to the shifting and continue to use these habitats for foraging, resting, and nesting. Cumulative impacts over the 30-year study period are not anticipated with the implementation of Alternative 4.

INTERTIDAL FLATS AND SHOALS

(<u>NOTE</u>: In the discussion for these habitat types, we have defined the north side where beach nourishment stops as the "inlet" and the south side where beach nourishment starts as "oceanfront".)

Direct Impacts: Intertidal flats and shoals have developed in a dynamic inlet system and therefore tend to be ephemeral in nature, especially with regard to dynamic island formations within the inlet. Because the previously permitted dredging area in Nixon Channel associated with Alternative 4 does not include intertidal flats or shoal areas, this alternative is not expected to have direct impacts on those habitats. Therefore, beyond existing natural processes, no additional direct impacts are anticipated with Alternative 4.

Indirect and Cumulative Impacts: Due to maintenance dredging-related increases in suspended sediment and turbidity (which could be transported to the interior of the inlet complex during flood stages of the tidal cycle); minor secondary impacts could be introduced. The intertidal flat biotic community's density and abundance may fluctuate over time, but overall would be expected to remain persistent. During flood stages of the tidal cycle, dredged material that remains in suspension could be transported into the interior portions of the inlet complex and settle on the intertidal flats and shoals. However, the material shoaling the Nixon channel has a low silt content, and is fairly coarse, will result in only minor and ephemeral increases in both suspended sediment and turbidity.

A portion of the 864,300 cubic yards of beach fill placed along Figure Eight Island's oceanfront shoreline could be transported in a northern direction and enter into the inlet. As shown in Figure 5.51, the 5-year Delft3D model estimated that an additional 180,200 cubic yards of material would be transported into the inlet as a result of Alternative 4. This influx of material was shown to occur mostly by Year 2, and then diminished for the remaining three years. This sediment could result in the formation of approximately 0-5 acres of additional intertidal flats and shoals, especially in the middle shoal area of the inlet, or the flood tide delta. Although the area of dry beach is reduced, the conversion into intertidal habitat is expected to provide some benefit bird species using the area for foraging and resting. As shown by Audubon North Carolina bird surveys, this flood tide delta in its natural state was frequently used as foraging habitat by piping plover from 2008-2011. Exact numbers and location of their use varied during this time, which is expected due to the constant shifting. In that 4-year period, the bar channel migrated slightly from a central location to a southerly position. Like inlet dunes and dry beaches, effects on intertidal flat and shoal habitats depend on the orientation of the ebb-tide channel and how it behaves. The formation and reformation of these habitats are dynamic and ever changing, especially during certain time periods and responding to storm events. The Audubon North Carolina data for piping plover during this period suggested that the number of birds appear to have adjusted to the geomorphic shifting of these habitats. Of the seven landscape types where piping plovers were observed foraging within their 2.9km^2 study area in the Rich Inlet complex (including the north end of Figure Eight Island and south end of Hutaff Island, the intertidal flats and shoals was highly utilized for foraging piping plovers (Addison and McIver, 2014).

With the implementation of Alternative 4, there is expected to be a slight increase of intertidal flats and shoals within a 2-year period of oceanfront beach nourishment. After that initial increase, the habitats natural shift and change will be contingent mostly on the orientation of the bar channel. As shown in the bird survey data, piping plover and other shorebirds are expected to adjust to the shifting and should continue to use these habitats for foraging, resting, and nesting. Cumulative impacts to intertidal flats and shoals over the 30-year study period are not anticipated with the implementation of Alternative 4.

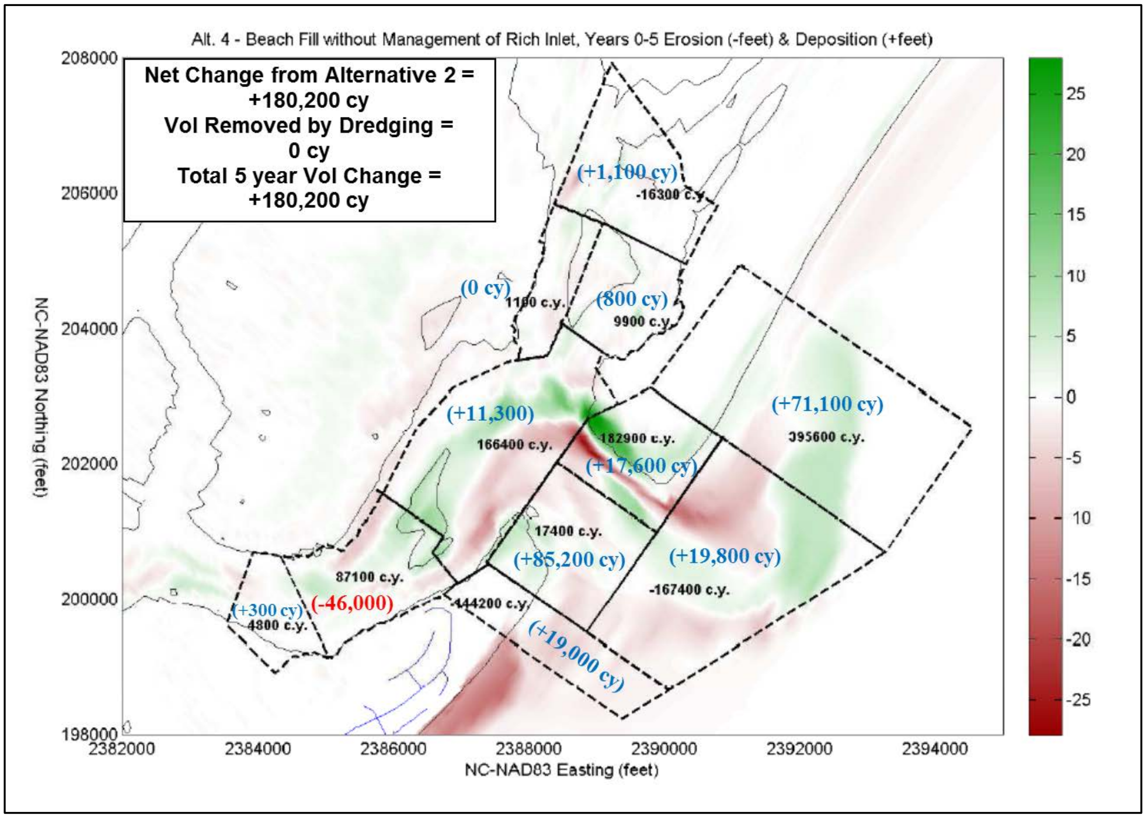

Figure 5.51. Modeled volume changes in discrete areas within the Permit Area for Alternative 4. Values in blue and red indicate an increase or decrease in material volume, respectively, compared to the baseline conditions shown in Alternative 2.

OCEANFRONT DRY BEACH AND DUNE HABITATS

(NOTE: In the discussion for these habitat types, we have defined the north side where beach nourishment stops as the "inlet" and the south side where beach nourishment starts as "oceanfront".)

Oceanfront Dune Communities

Direct Impacts: Similar to Alternative 3, a dune with a crest elevation of 4.6 m (15.0 ft.) NAVD would be constructed in the area from baseline station 77+50 to 95+00 or in the area presently devoid of a dune and where homes are presently protected by sandbag revetments for Alternative 4. The footprint of this artificial dune would encompass approximately 4.6 acres which would result in a positive impact to this habitat. This stabilization measure will allow for long-term growth and development of dune vegetation and provide habitat for roosting, foraging and nesting shorebirds. The dune communities located on Hutaff Island are not expected to be directly affected by the implementation of Alternative 4 since all beach fill is occurring on Figure Eight Island.

Indirect and Cumulative Impacts: As described previously, the orientation of the inlet bar channel plays an important role regarding the shoreline erosion rates on both Figure Eight and Hutaff Islands. Since 2010, the inlet has reoriented itself to the southeast providing an environment favorable for accretion on Figure Eight Island's northern oceanfront shoreline. So long as the inlet bar maintains this orientation, the oceanfront dune communities on Figure Eight Island would be expected to persist or increase in size while the contrary would be expected on the southern oceanfront shoreline on Hutaff Island. This scenario could change, however, should the inlet bar reorient itself as it has done in the recent past.

As concluded by the results of the 5-year Delft3D simulation, beach renourishment would be needed along the oceanfront shoreline of Figure Eight Island every four (4) years under Alternative 4, which totals up to a maximum of seven (7) separate periodic nourishment events over the 30-year study period. Approximately 764,000 cubic yards of material is expected to be dredged and placed on the island each maintenance cycle. Consequently, the project will serve to provide long-term protection of the oceanfront dunes along the northern portion of Figure Eight Island within the 30-year study period. This continual dune protection will result in the protection of the nesting, foraging, and resting habitat for wildlife utilization. Although the physical location of the dune system for Hutaff Island may change as natural overwashing and other storm-induced events might occur, the dune communities on the island are expected to remain intact with minimal long-term impacts as a result of Alternative 4.

Oceanfront Dry Beach Communities

Direct Impacts: The beach nourishment plan included in Alternative 4 would benefit the dry beach communities along 12,500 linear feet of the Figure Eight Island oceanfront shoreline through the expansion of the dry beach habitat. Beach nourishment would restore the dry beach habitat along from the intersection of Beach Road and Beachbay Lane to Rich Inlet (F90+00 to 105+00, 12,500 feet). The construction of Alternative 4 is expected to result in a footprint of approximately 45-50 acres of dry beach habitat along the oceanfront shoreline on Figure Eight Island as a result of fill placement. Included within this footprint is approximately 29 acres of existing dry beach habitat. Approximately 15-20 acres of additional advanced fill will be placed creating new dry beach habitat. Impacts include the pumping of dredge material via pipeline along the oceanfront, which contains dry beach habitat, and pushing the material to the target elevations and location via bulldozers. The width of the oceanfront dry beach will vary along the length of the 12,500 foot fill area. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be 172 feet. The width in the remaining areas will vary from 17 feet between stations F90+00 and 20+00, 43 feet from 30+00 to 60+00, 86 feet from 70+00 to 80+00, and 172 feet from 82+50 to 105+00, including the existing dry beach. Like Alternative 3, this increased dry beach area under Alternative 4 will serve to benefit seabeach amaranth, nesting sea turtles, and resting and nesting birds. Some negative effects from covering the existing dry beach include the immediate mortality of macro invertebrates such as ghost crabs and with the potential of sand compaction from heavy equipment. However, these communities are expected to recover within the order of months to more than one year (National Research Council, 1995; Carter and Floyd, 2008) allowing several years of recovery time prior to any subsequent renourishment event. With the use of compatible material, the recovery is expected to be shorter.

While widening the beach itself is beneficial under Alternative 4, using suitable material for successful nesting is essential in providing natural conditions. The composition, color, and grain size of the beach sand can affect the incubation time, sex, and hatching success of turtle hatchlings (Deaton et al., 2010). Physical characteristics such as density, compaction, shear resistance, moisture content, slope, sand color, grain size, grain shape, sand mineral content, and gas exchange may affect the success of sea turtle nests (Nelson and Dickerson 1988, Crain et al. 1995). The fill placed upon Figure Eight Island will conform to the State sediment criteria rules and therefore is not expected to be a detriment to nesting success of sea turtles. Since the beach fill activity for Alternative 4 is similar in nature to Alternative 3, reference Alternative 3 discussion regarding the benefits and potential detriments of beach nourishment in oceanfront dry beach habitat for nesting sea turtles.

Indirect and Cumulative Impacts: As discussed in the Shoreline Change section on page 187, volumetric losses from the beach fill for Alternative 4 on Figure Eight Island between stations 60+00 and 105+00 averaged 191,000 cubic yards/year over four years while the area south of station 60+00 accreted at a rate of 44,000 cubic yards/year over that same four year period. Changes indicated by Delft3D modeling along the southern 2,640 feet of Hutaff Island were essentially dictated by the location of the bar channel, and subject to the resulting natural processes, and were, therefore, the same as the changes computed for Alternative 2.

Based on the historical geomorphological and modeling analysis, the amount of any change along the oceanfront dry beaches on either island within a 4 year period, or over a longer timeframe, is strongly contingent on the location or positioning of the ebb tide channel. As determined and previously discussed, a southerly directed bar channel reduces the erosion along the northern portions of Figure Eight Island, while the southern dry beaches of Hutaff Island experiences greater erosion. The opposite effect occurs when the bar channel is situated in a more northerly direction, which favors ocean dry beach habitat more on Hutaff Island.

In general, the performance of the fill as indicated by the model results will enhance the dry beach area available to wildlife, including seabeach amaranth, sea turtles, shorebirds, as well as recreational space for residents and visitors on Figure Eight Island as described above for Alternative 3. According to Greene (2002), beach nourishment can benefit endangered and threatened sea turtles by restoring habitat along eroded beaches. Some studies have found no significant difference between nourished and non-nourished beaches in the number of eggs per nest, as well as, hatching and emergence success (Nelson *et al.*, 1985; Ryder, 1991). Other projects have shown increased numbers of nests, hatchlings, and survival rate of young turtles (Raymond, 1984). The increase in dry beach on Figure Eight Island and on Hutaff

Island is also expected to positively affect the shorebirds, water birds and colonial birds that utilize this habitat. Therefore, Alternative 4 is expected to provide benefits to birds and turtles for foraging and nesting as well as recreational space for residents and visitors on Figure Eight Island.

WET BEACH COMMUNITIES

Direct Impacts: The implementation of Alternative 4 will cause short-term impacts to approximately 10-15 acres of the wet beach community. These communities will be buried with up to seven feet of dredged fill material along 12,500 linear feet of oceanfront shoreline and 1,400 linear feet of Nixon Channel Shoreline. However, once the fill is placed, an additional 10-15 acres of wet beach habitat will be formed and, therefore, there will be no net change in wet beach habitat acreage.

Bird survey data provided by Audubon North Carolina showed piping plovers foraging along the Nixon Channel shoreline in 2010. The addition of beach fill along the oceanfront shoreline and Nixon Channel shoreline could directly impact infaunal organisms used as prey for shorebirds and other predators. These impacts are considered to be short-term because studies have demonstrated rapid recovery times for organisms inhabiting wet beaches. As mentioned in Chapter 4, Nelson (1985) indicates that organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels. Also, as previously stated, with the use of beach compatible material, infaunal organisms are expected to recruit in the newly formed wet beaches at a quicker rate, reducing the recovery period. In conjunction with compatible beach fill, the nourishment activity will occur during the winter months, between November 16 and March 31. This construction period is when biological activity and the onshore benthic populations within the wet beach habitat are at its lowest. This will, in turn, help reduce the potential affects to bird and fish species that prey upon the benthic community and cause any impacts to be short-term in nature.

Indirect Impacts: As indicated by 5-year Delft3D modeling, indirect impacts of approximately 5-10 acres of wet beach habitat along the ocean shoreline of Figure Eight Island would be anticipated as a result of the gradual shifting of the marine intertidal beach habitat. The gradual shifting occurs when the wet beach is displaced seaward after the nourishment takes place and is shown to continue as the intertidal zone equilibrates and adjust to the constructed beach. This may affect shorebirds, crustacean, and fish foraging on the infaunal community, which could also impact recreational fishing. However, this shifting would occur over a 4-year period and would allow for the gradual adjustment of the infaunal organisms. The slow rate of transition is expected to minimally affect shorebirds, crustaceans, and fish foraging. For Alternative 4, it is also anticipated that beach nourishment will occur during the winter months or seasonal period when some of the infaunal community has migrated further offshore and their populations on the wet beach are lower. This in turn will also minimize any potential impacts upon recreational fishing. Furthermore, impacts under Alternative 4 will be reduced due to the fact that the material utilized for beach fill will be compatible with native material, thereby resulting in a shorter recovery time period for infaunal communities.

Cumulative Impacts: Renourishment activity under Alternative 4 could take place at a maximum of once every four (4) years, or up to seven (7) times over the 30-year study period. Each individual renourishment event would duplicate the impacts in the indirect description above. With up to seven (7) separate renourishment activities over 30 years beach placement along 12,500 linear feet of Figure Eight Island and 1,400 feet along the Nixon Channel shoreline could potentially affect the diversity and abundance of infaunal populations. These effects could be cumulative if the communities do not recover to pre-construction levels between nourishment events. One factor to consider in evaluating the population recovery is the adaptability of the infaunal community. As researched, organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels (Nelson, 1985). Other studies reported by Maurer (National Research Council, 1995) supported the burial capabilities of nearshore species, which found that these species were capable of burrowing through sand up to 40 cm. As stated above, Nelson (1985) has demonstrated the adaptability and rapid recovery for organisms residing in the marine intertidal zone. With a minimal four year period between any maintenance events, there is expected to be ample time for any species to recover due to their resilience in this environment; and with the reason stated in the Indirect Impacts discussion above, any cumulative impacts to these resources are expected to be non-appreciable over the 30-year study period for Alternative 4.

MARINE HABITATS

Softbottom Communities

Direct Impacts: The activities associated with Alternative 4 would result in direct impacts to approximately 25 acres of softbottom community every four (4) years due to the dredging within the previously permitted Nixon Channel borrow area and placement of fill along the Nixon Channel shoreline and oceanfront shoreline. The estimated volume required to initially nourish the oceanfront shoreline and the Nixon Channel shoreline is 921,300 cy based on the 2006 conditions. It is acknowledged that under current existing conditions, Figure Eight Island is not as severely eroded as it was in 2006. However, in order to provide uniformity, the results of modeling based upon the 2006 conditions are being considered across the alternatives . The previously permitted borrow area within Nixon Channel is estimated to contain approximately 400,000 to 500,000 cubic yards of material to be dredged. To supplement this, an additional 527,000 cubic would be obtained from the offshore borrow sites. The AIWW dredged material sites will likely only be used to reconstruct dunes damaged by storms, because of their limited capacity.

Excavating the previously permitted borrow area in Nixon Channel would cause an immediate removal of infaunal and non-motile epibenthic organisms from the softbottom community. Adjacent infaunal communities residing in the softbottom habitat would directly and possibly indirectly be impacted by increased levels of turbidity, immediate removal, and immediate burial of infaunal biota during dredging operations. The dredging footprint for Nixon Channel is approximately 25 acres and will consist of excavating the existing depth to a depth of –9 feet MLW. Based upon documented shoaling rates in the Nixon Channel area, the previously permitted site should supply around 400,000-500,000 cy every four (4) years. Construction of the beach would result in the direct deposition of material from mean low water (MLW) to the construction toe-of-fill, which will cover softbottom habitat resulting in immediate mortality. Overall nourishment and Nixon Channel dredging impacts to the infaunal community will be similar to those described in Alternative 3 with the exception of a lesser dredging footprint for Alternative 4. Some of the impacts associated with Alternative 4 should be reduced by a winter dredging timeframe and with the presence of adjacent foraging softbottom communities located in the ebb tide delta and in undisturbed flood tide areas of Green and Nixon Channels. More information regarding infaunal impacts related to dredging can be found under the section entitled “General Environmental Consequences Related to Dredging” above.

Because the beaches along Hutaff Island will not receive disposal material, impacts to softbottom resources outside of natural shifting processes on or around Hutaff Island in response to Alternative 4 are not anticipated.

Indirect Impacts: For the oceanfront beach placement, the slope of the fill would adjust and equilibrate seaward. The adjusted fill along the entire beach fill area will merge with the existing profile at a depth of -24 feet NAVD. Consequently, softbottom habitats will be covered with various depths of sediment during this adjustment period, which could affect the foraging behavior of some fish species. The degree of infaunal mortality with the covering would be contingent on the amount of material and the rate of adjustment. It should be reiterated that the material placed along the shoreline that would equilibrate seaward meets the State’s sediment criteria requirements as being compatible to the native sediment. Using compatible material will help reduce the time of recovery, thus minimizing any affects to foraging fish species. As described in Alternative 3, the adaptive nature of the infaunal species will minimize these impacts associated with Alternative 4.

Cumulative Impacts: Removal of material from the offshore borrow areas will result in the direct mortality of all organisms present within the benthic community located within the borrow areas. Although the recruitment pattern is altered, the recovery of species after sediment removal is relatively quick, depending upon the opportunistic nature of the species (Deaton et al., 2010; Posey and Alphin, 2002). At dredge sites monitored off the coast of New Jersey, infaunal assemblages recovered within one year after disturbance, while biomass and taxonomic richness took 1.5 to 2.5 years to recover (Deaton et al., 2010). Many of the infaunal organisms found within the offshore borrow areas are considered to be resilient, and the temporal spacing of approximately four years between periodic maintenance events, if the site is used in consecutive events, the time between each event should allow for a full recovery of these infaunal communities within this softbottom habitat. Therefore, cumulative impacts are not anticipated if dredging occurred within the offshore borrow sites.

As previously discussed in Alternative 3, dredging within the previously permitted area of Nixon Channel is not expected to result in cumulative impacts to the infaunal communities or in the feeding behaviors of fish species. The infill rate of the dredged footprint, as displayed in the modeling, should be at a rate where the recovery of infaunal communities would occur within the 4-year cycle and prior to any subsequent event. Due to the finite volume of material in the AIWW dredge material disposal islands, the borrow sources would only be used to rebuild dunes following severe storm events.

For oceanfront softbottom habitats, impacts will occur as described above in the direct and indirect discussion at a maximum of once every four (4) years for each maintenance nourishment event. These affects could be repeated up to a maximum of seven (7) times over a 30-year study period. For the reasons stated in the discussions, especially the noted resilience and recovery time of the infaunal community, long-term impacts are not anticipated.

Cumulative effects to softbottom habitats from dredging or beach fill activities are not expected with the implementation of Alternative 4.

WATER QUALITY

Turbidity and TSS

Direct and Indirect Impacts: For Alternative 4, the dredging within Nixon Channel, prospective offshore borrow areas, and the placement of material on the oceanfront and estuarine shoreline will result in the suspension of silt and fine fractions in the water column. Although this occurs, the duration of suspended particulates and turbidity for these projects are generally short-lived. During a 2001 monitoring effort, measurements for turbidity and TSS were taken before, during, and after the dredging within Nixon Channel and the associated placement of beach fill along the oceanfront shoreline of Figure Eight Island. Results showed that both parameters increased at the point of discharge on the oceanfront shoreline, however, these values (44.0 mg/l and 301.0 mg/l for turbidity and TSS, respectively) returned to ambient conditions rapidly (Cleary and Knierim, 2001). In a 2005 monitoring effort in Bogue Inlet, turbidity levels during the pumping of sediment for the construction of the closure dike revealed that turbidity levels never exceeded the State standard of 25 NTUs with the highest observation of 16.4 NTU. The low sit/clay content of the material within the areas being dredged should result in relatively low concentrations of suspended sediment outside the immediate area of deposition. The low concentration of suspended sediment indicates that turbidities are likely to remain low during dredging and placement of material on the beaches. Therefore, any negative impacts related to turbidity and TSS are expected to be short-term and similar to those discussed for Alternative 1. Natural conditions support fluctuating turbidity levels in the nearshore and offshore water column of the Permit Area.

Cumulative Impacts: Renourishment of the Figure Eight Island beach are anticipated to occur approximately every four (4) years and each maintenance event will take approximately eight (8) weeks to complete, pending weather and working conditions. This totals up to a maximum of seven (7) events over the 30-year study period. With a minimum 4-year maintenance period between events, any negative effects from a single maintenance event is not expected to carry over to any effects of subsequent events due to the documented short-term nature of impacts. Based on this and the factors stated above, no cumulative impacts regarding suspended particulates and turbidity are expected.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: The average tidal prism of Rich Inlet obtained from the Delft3D simulations for Alternative 4 was 500.6 million cubic feet or about 99.5% of the tidal prism of baseline conditions at year 0 for Alternative 2. This relatively small difference is within the accuracy of the Delft3D model and is deemed not to be significant. Flow distribution through Nixon Channel and Green Channel was also essentially identical to the distribution indicated for Alternative 2 with Nixon Channel carrying 55.3% of the flow and Green Channel 36.3%. Under Alternative 4, the only conditional change that has the potential to effect the tidal prism is when a dredging event, associated with the periodic beach nourishment, occurs within the 25 acre previously permitted area in Nixon Channel. This dredging footprint, which historically ranges from 30,000 to 200,000 cubic yards, is of such a small amount as to effect the prism within the inlet complex; consequently, should result in minimal hydrodynamic or salinity level changes in either short- or long-term conditions. Given the 5-year model results of Alternative 4 in comparison with the results under natural conditions of baseline conditions at year 0 for Alternative 2, hydrodynamics and salinity are not expected to be impacted in response to Alternative 4.

Larval Transport

Direct Impacts: As stated above under the discussion on softbottom communities, the dredging and beach fill operations associated with Alternative 4 are not anticipated to significantly impact larval transport into Rich Inlet. Larvae of some fish species are expected, however, to be entrained within the dredge while operating in Nixon Channel. These include the larvae of winter and early spring spawners such as spot, Atlantic croaker, southern and summer flounders, menhaden. However, because the peak of juvenile settlement generally occurs within the estuary in spring through early summer (Ross and Epperly 1985), these impacts are anticipated to be limited. Furthermore, due to the relatively small volume of water pumped through the dredge compared to the volume included within the tidal prism, impacts to many species of fish larvae are expected to be minimal.

Indirect and Cumulative Impacts: With Alternative 4, maintenance dredging within Nixon Channel could occur up to a maximum of once every four (4) years during the winter months (between November 16-March 31) when larval transport is at its lowest. With potential dredging events spaced at every four (4) years, this is also expected to reduce any potential cumulative impacts. Any indirect or cumulative impacts are anticipated to be minimal.

PUBLIC SAFETY

Direct and Indirect Impacts: During the construction of Alternative 4, public safety will be temporarily impacted due to the usage of heavy machinery within Nixon Channel and along the oceanfront shoreline of Figure Eight Island. In the event the upland dredged material disposal sites adjacent to the AIWW are used for post-storm dune repair, pipelines would be extended from the upland sites to the Nixon Channel shoreline and the ocean shoreline. The implementation of Alternative 4 will provide beach fill along the northern 3.8 km (2.4 mi) of ocean shoreline and 0.4 km (.27 mi) of the Nixon Channel shoreline of Figure Eight Island thereby adding protection to the current nineteen (19) ocean front homes and one soundside home that are imminently threatened on the island. Without the threat of these homes being damaged or demolished, public safety would increase due to the avoidance of hazardous conditions caused by continued erosion including the exposure of utilities and leaking septic tanks. Furthermore, the sandbags, which could pose a public safety hazard due to their size and orientation to the eroded shoreline, may be removed and replaced with a nourished beach tapered from a developed dune ridge. Although the specific methodology has not been determined, the mesh sandbags may be removed through mechanical means with use of a backhoe after being cut open to remove the sand. Construction will take place within the dredging window of November 16th through March 31st when public use of Nixon Channel and Figure Eight Island is at its lowest peak. No public safety impacts would be incurred on Hutaff Island.

Cumulative Impacts: Public safety within Nixon Channel and along the oceanfront shoreline of Figure Eight Island will be temporarily impacted during each maintenance event scheduled approximately every four (4) years. These impacts will be similar in nature as those described above. No significant adverse impacts are anticipated along Hutaff Island.

AESTHETIC RESOURCES

Direct Impacts: Temporary negative impacts to aesthetic resources will result from Alternative 4 due to the visual presence of heavy machinery within the natural settings of Nixon Channel and portions of its shoreline as well as the oceanfront shoreline of Figure Eight Island. This activity would generally take place over a 3-4 month period, but would take place during the winter months when the majority of the residence and/or guests are not present on the island and use of surrounding waterways are at their lowest. Following completion of the construction phase of Alternative 4, the aesthetic resources will be as they were prior to construction. Currently 19 structures along the ocean shoreline and one structure on the Nixon Channel shoreline have sandbags. Maintenance of the beach fill along the north end of Figure Eight Island should provide the level of protection to allow the existing sandbag revetments to be removed. With the removal of the sandbags along the northern portion of Figure Eight Island, the aesthetic quality of the island is expected to improve.

Indirect and Cumulative Impacts: Cumulative impacts to aesthetic resources will occur due to the anticipated dredging within Nixon Channel and usage of the material contained within the upland dredge disposal islands for nourishment events occurring every four (4) years on Figure Eight Island. Due to the time length in between maintenance events, cumulative effects are expected to be minimal.

RECREATIONAL RESOURCES

Direct Impacts: For Alternative 4, direct impacts to recreational resources are anticipated to be similar as those described under Alternative 3. An assessment of boat usage within proximity to Rich Inlet, as shown in Table 4.14, indicates that the majority of recreational boaters congregate along the banks of Hutaff Island, in the open water behind the inlet, and within any open exposed shoals. Recreational opportunities such as beachcombing, sunbathing, surfing, fishing, and walking along the beach will be temporarily affected during the construction activities associated with Alternative 4. However, all construction activities will be limited to working within a window when recreational use is at its lowest during the year. Even during construction, complete access will not be restricted to these areas.

Indirect and Cumulative Impacts: Delft3D modeling suggested that an influx of 180,200 cys of material would be transported into the Permit Area following the 5-year simulation. This could serve to increase the intertidal shoals which are often used as recreational areas for boaters. Immediately following construction, recreational resources and opportunities along the northern portion of Figure Eight Island are expected to benefit from the increased size and extent of the nourished beaches along the oceanfront shoreline and Nixon Channel shoreline. This will offer additional area for surf fishing, bird watching, and other recreational opportunities. However, recreational activities will be interrupted every four (4) years during maintenance dredging and beach fill operations. Cumulative impacts to recreation are expected to be minimal since dredging and filling activities are generally taking place during winter months when recreational activities are at their lowest levels and Figure Eight Island residents are not present. Effects from Alternative 4 on Hutaff Island are also expected to be non-appreciable.

NAVIGATION

Direct, Indirect, and Cumulative Impacts: The initial construction followed by periodic maintenance dredging in Nixon Channel benefit navigation due to a maintained depth created by on-going dredging activities. During the dredging, however, navigation will be temporarily directly impacted due to the presence of pipelines within the waterway. Even if dredging within Nixon Channel does not occur, this is not expected to reduce the navigational use of this channel. At no time will complete restriction of navigation occur in Nixon Channel during dredge operations. Navigation will also be temporarily restricted within the areas between the offshore borrow area and the disposal areas along the oceanfront shoreline and Nixon Channel shoreline. Restrictions will be determined by the USCG and will be limited to the areas where the dredge and the pipelines are located. These restrictions will be imposed during every maintenance event, which is scheduled for every four (4) years. Both the initial and subsequent dredging activities will occur during the winter months when Nixon, Green, and Rich Inlet channels are less frequently used by boaters.

INFRASTRUCTURE

Direct Impacts: As described previously, Dr. Cleary's assessment of Rich Inlet indicated that when the bar channel is orientated toward Figure Eight Island, the north end of the island tends to accrete whereas when the channel is aligned toward Hutaff Island, the north end of Figure Eight Island erodes. Under Alternative 4, the main ocean bar channel would continue to naturally migrate to the north or south. Currently, the bar channel is positioned in a favorable orientation leading to beneficial accretion on the north end of Figure Eight Island since about 2010.

This alternative includes the placement of approximately 864,300 cubic yards of dredged material along 12,500 linear feet in the northern portion of Figure Eight Island's oceanfront shoreline. This would serve to protect the homes and infrastructure along the oceanfront shoreline of the island from the intersection of Beach Road and Beachbay Lane to Rich Inlet (F90+00 to 105+00). The width of the oceanfront dry beach will vary along the length of the 12,500 foot fill area. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be 172 feet. The width in the remaining areas will vary from 17 feet between stations F90+00 and 20+00, 43 feet from 30+00 to 60+00, 86 feet from 70+00 to 80+00, and 172 feet from 82+50 to 105+00, including the existing dry beach (Table 5.12). Also, approximately 57,000 cubic yards of material would be placed along 1,400 linear feet of Nixon Channel shoreline. This shoreline would increase to approximately 50 feet in width. Both oceanfront and Nixon Channel shorelines would receive additional benefit to protect the existing infrastructure immediately following construction.

Indirect, and Cumulative Impacts: Alternative 4 is expected to benefit a number of homes and infrastructure on Figure Eight Island due to the long-term protection from erosion. The 5-year model simulation of the oceanfront beach fill indicated that the volumetric changes from the oceanfront beach fill for Alternative 4 between stations F90+00 and 60+00 averaged a gain of 30,000 cubic yards/year over the 5-year Delft3D model simulation period. Therefore, the infrastructure within this segment was afforded protection. The Delft3D model simulation for the beach fill area north of station 80+00, however, showed that erosion had progressed into the pre-nourished beach profile by Year 4 of the simulation. Therefore, the infrastructure in this area would be left vulnerable by Year 4, in which a subsequent renourishment event would be implemented. Plans under Alternative 4 include a maintenance beach fill once every four (4) years and up to a maximum of seven (7) separate periodic nourishment events within a 30-year study period. The simulated performance of the fill between 60+00 and 105+00 mimics what has been observed following 6 previous beach nourishment attempts on the north end of Figure Eight Island. The 1,400 foot segment of Nixon Channel shoreline maintained over the Delft3D model simulation indicating that the homes and infrastructure in that area would remain relatively protected with the addition of the 50-foot wide beach fill.

SOLID WASTE

Direct, Indirect, and Cumulative Impacts: Implementation of Alternative 4 will result in similar positive affects to solid waste as those described under Alternative 3.

NOISE POLLUTION

Direct Impacts: Dredging within Nixon Channel and the offshore borrow areas along with the utilization of material from within the upland dredge disposal sites, which are included in Alternative 4, would temporarily raise the noise level in the areas of the dredge and the discharge point on the beach. This impact would be short-term since the equipment would be constantly relocating as work moves down the beach. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. Also, dredging and beach placement would occur during times when residents and visitors are less likely to be present.

Indirect and Cumulative Impacts: No indirect or cumulative impacts pertaining to air and noise pollution are anticipated.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: Construction of Alternative 4 would be accomplished by removing 400,000-500,000 cubic yards from the existing permit area in Nixon Channel and the balance; 576,300 cubic yards from the offshore borrow areas identified by Dr. Cleary Over the thirty year planning period, the total implementation cost for Alternative 4, based on the April 2012 survey conditions, would be about $69.0 million in current dollars. This total cost includes $13.3 million for initial construction of the beach fills along the ocean and Nixon Channel shorelines, $1.0 million for geotechnical investigations and permitting offshore borrow area, and $54.7 million to nourish the beach fills every four (4) years. The equivalent average annual costs for initial construction and future maintenance over a 30 year period would be 2,780,000/year. Table 5.22 depicts the average annual economic impact associated with Alternative 4 based on 2006 shoreline conditions.

Table 5.22- Summary of Average Annual Economic Impact of Alternative 4

Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
0	0	3,259,000	3,259,000

E. IMPACTS ASSOCIATED WITH ALTERNATIVE 5A: TERMINAL GROIN WITH BEACH FILL FROM NIXON CHANNEL NAVIGATION CHANNEL AND A NEW CONNECTOR CHANNEL

A 1,600-foot long terminal groin, with 700 feet being seaward of the MHW line, would be constructed at the extreme north end of Figure Eight Island to control both wave and tidal current induced shoreline changes immediately south of Rich Inlet (Figures 3.12a and 3.12b in Chapter 3). The 900-foot section landward of the MHW line would act as a shore anchor to protect against possible flanking of the landward end of the structure. The shore anchorage section would extend back from the 2007 MHW shoreline and terminate near the Nixon Channel shoreline (Figure 3.12a in Chapter 3).

Alternative 5A would include beach fill in the same two areas as Alternative 3, one fronting Nixon Channel and a second covering the ocean shoreline from Beachbay Lane (F90+00) to the terminal groin located at station 100+00. Material used for beach nourishment will be obtained from dredging the previously permitted area in Nixon Channel to -11.4 ft. NAVD (the depth permitted in the past within that area) and a new connector channel, which would be dredged to -13.4 ft. NAVD. The purpose of the new channel connector is to concentrate ebb flows away from the eroding portion of the Nixon Channel shoreline. Construction of the new channel connector and reestablishing the previously permitted dimensions in Nixon Channel would require the excavation of 994,400 cubic yards of material based upon the 2006 shoreline position and take approximately 4.5 months to construct. As stated in Appendix B, Delft3D modeling results suggest that erosion into the pre-construction beach face would be prevented along most of the fill area over 5 years. Therefore, it is anticipated that maintenance dredging would be conducted at a minimum of every five (5) years.

ESTUARINE HABITATS

Salt Marsh Communities

Direct Impacts: The salt marsh resources within Alternative 5A are located primarily along the sound sides of Figure Eight, the extreme northern tip of Figure Eight Island, Hutaff, and the marsh islands southeast from the Atlantic Intracoastal Waterway (AIWW). During construction of the terminal groin at Figure Eight Island, an approximate 600-foot by 50-foot (or 0.7 acre) salt marsh area located within the designated working corridor on the northern tip of Figure Eight Island will be temporarily impacted by the use of heavy machinery. Impacts include using the corridor as a travelway for transporting equipment and materials and with the direct installation of sheet pilings for the groin structure. These activities are expected to affect this salt marsh community in the following manner: damaging or removing coastal vegetation, compacting the marsh substrate, and disrupting the surface circulation flow of water. Several measures will be taken to reduce these impacts to the salt marsh: 1) Activity will be limited to the 50 foot width included in the construction corridor at this location, 2) Logging mats or other surface type mats will be utilized to reduce the compaction of the substrate, and 3) The entire length of the sheet pile will be greater than 0.5 feet below grade (or, below the ground-level) over the area that spans salt marsh habitat. As a result, the sheet pile will not disrupt surface flow. Although damage or removal of vegetation is anticipated, impacted salt marsh plant communities are expected to, and known to, revegetate quickly. The salt marsh habitat in this area is primarily comprised of *Spartina patens* (salt meadow cordgrass) and *Salicornia virginica* (glasswort) unlike much of the *Spartina alterniflora* (smooth cordgrass) dominated salt marsh located behind the inlet complex. The construction of the offloading dock or pier to be used for transporting building material, such as the rock and possible sheet piling, onto the site will constructed in a manner to minimize any direct impacts to the ephemeral salt marsh near the anchor section along Nixon Channel shoreline. The placement will avoid these resources if possible and will be elevated to reduce any potential impact from shading.

Additionally, salt marsh is present along the perimeter of the disposal island located in proximity of the AIWW that will be used when dredging the connector channel. A lens of non-beach compatible material has been identified within a small portion of the proposed connector channel for Alternative 5A. When encountered, this material would be pumped to the disposal area where erosion control measures, including improvements to the dike surrounding the upland disposal area, will be implemented to prevent erosion into the adjacent salt marsh areas. Also, any placement of an outfall pipe within the disposal island would be oriented such that the effluent would avoid impacting the coastal marsh.

Although primary nursery areas (PNAs) are located within the Permit Area, no PNA will be directly impacted by beach fill activity. PNAs are generally defined as being located in the estuarine system, including portions of rivers, creeks and bays (see Chapter 4). These are usually shallow areas with soft, muddy bottoms surrounded by marshes and wetlands. Low salinity and the abundance of food in these areas are ideal for young fish and shellfish. The 1,400 foot section of estuarine shoreline along Nixon Channel where beach fill is proposed for Alternatives 5A is characterized by high salinity water with a sandy bottom.

Indirect Impacts: The construction of the terminal groin under Alternative 5A will include a shore anchorage section constructed of steel or concrete sheet pile which will extend through the salt meadow cordgrass and saltwater-dominated wetlands. This tidally influenced area is fed by a tidal finger that connects into Nixon Channel. The shore anchorage portion has been designed to avoid the tidal finger such that the tidal exchange within the wetlands will not be disrupted. Furthermore, the sheet pile would be constructed below grade to ensure that the surface water is able to spread across the wetland area during high tides and is able to drain completely as the tide ebbs. In addition to the potential for impacts to the wetlands in response to altered hydrology of the surface waters, there were some concerns that the groundwater flow could be impeded and cause “mounding” of water on one side of the structure. As described by Nat Wilson, a hydrologist with NCDENR’s Groundwater Management Branch of the Water Resources Management Section, “ground water flow on a barrier island tends to be towards the ocean and ICWW or sound from the center of the island -- perpendicular to the length of the island. The shallow ground water is moving down gradient from highest head beneath the topographic highs towards the ocean and ICWW” (Wilson, pers. comm.) (Figure 5.52). Because the structure is oriented in basically the same direction as the ground water flow, the structure should not impede the movement of the ground water. Therefore, the structure should not cause indirect impacts to the functionality of the wetlands adjacent to the shore anchorage section.

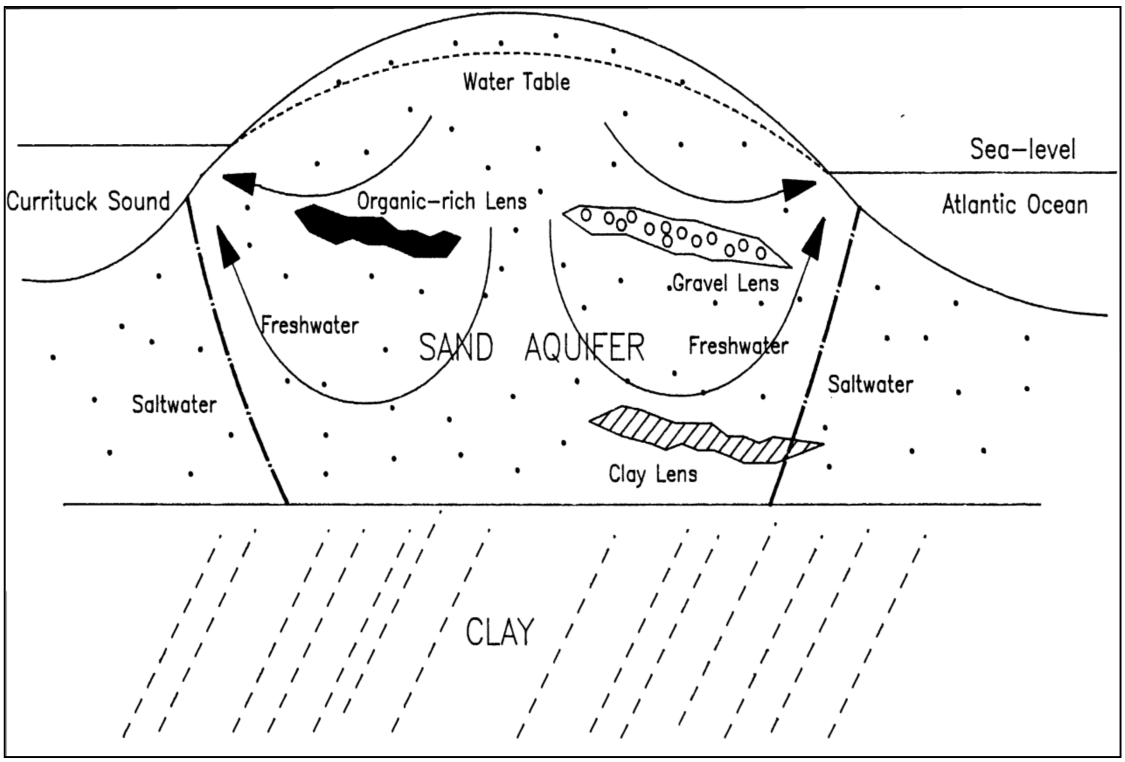

Figure 5.52. Schematic cross section showing groundwater flow patterns through the surficial aquifer on a North Carolina barrier island (NCDWR, 1991).

Following the dredging within Nixon Channel and the connector channel, modeling results suggest that the primary flow will adjust from its current alignment along its southern bank to the middle of the channel, which should reduce the erosional stress along the salt marsh near the north end of Beach Road (see Chapter 3). This, along with the placement of 57,000 cubic yards of beach fill, will reduce the potential for the erosion of the salt marsh in this area.

Along the salt marsh shoreline facing the entrance of Rich Inlet, currents are expected to be reduced slightly as flow is shifted from the back channel into the new dredge cuts thereby reducing potential salt marsh erosion at that location. The majority of the salt marsh resources located within the permit area is located at a considerable distance from the proposed project. With the exception of the construction corridor for the terminal groin along the northern portion of the island, no additional or indirect impacts to salt marsh are anticipated. The fill placed along Nixon Channel terminates south of the creek that serves to feed this area of high marsh along the northern end of Figure Eight Island. As such, no indirect impacts are anticipated to this high marsh area.

One terminal groin structure evaluated in the 2010 DENR report was the 1,525 foot-long terminal groin that was constructed in 2004 at the southern terminus of Amelia Island. The primary purpose of the groin at Amelia Island was to help stabilize the eroding shoreline and consequently protect the maritime forest and natural communities, including salt marsh habitats in proximity to the structure (DC&A 2003). Similar to the terminal groin design as described for Alternative 5A, this groin was constructed as a rubble mound structure. Downdrift erosion was prevented due to the low profile of the structure which allowed for material to wash over the groin, as the design calls for at Figure Eight Island. The terminal groin at Amelia Island, however, was also designed to be "leaky" and allow for material to pass through the structure as well. This "leaky" design concept has also been adopted for the Figure Eight Island terminal groin. Based on a preliminary evaluation of aerial photographs pre- and post-construction of the Amelia Island terminal groin, no significant changes have been observed in the salt marsh communities in response to the construction of the terminal groin (Olsen Associates, Inc. 2008). However, these inferences have not been verified. Although the results from individual projects vary due to specific environmental and physical conditions, the salt marsh at that location doesn't appear to have been negatively impacted by the terminal structure, as noted in the 2010 DENR terminal groin report. Due to these similarities, the results from the Amelia Island project can provide some assurances that the indirect impacts to the salt marsh communities in response to the construction of the terminal groin described for Alternative 5A are not likely to occur. However, the dynamic nature of the inlet system and the proximity of the salt marsh resources to the evolving shoreline, both positive and negative direct or indirect impacts to salt marshes are expected to continue.

For the disposal island, no secondary impacts to salt marsh resources are anticipated. This is due to the preventive measures that will be taken to decrease the potential for erosion and to the strategic location and placement of any outfall structure that will direct the effluent away from marsh areas.

Cumulative Impacts: Alternative 5A includes the maintenance of Nixon Channel and the connector channel at a minimum every five (5) years, or up to six (6) separate maintenance events over a 30-year study period. Also, some maintenance of the rubblemound portion of the terminal groin may be required. In this regard, the frequency of storm conditions exceeding the design conditions cannot be predicted with any degree of certainty. Therefore, maintenance of the terminal groin was based on the assumption that an average of 1% of the stone would need to be repaired every year. This does not mean maintenance would be needed every year, rather, over the 30-year planning period; the equivalent annual cost for maintenance of the terminal groin would be equal to 1% of the initial construction cost of the rubblemound portion of the structure. Any necessary maintenance activity for the terminal groin is expected to take advantage of using non-salt marsh areas, or uplands, as a travelway to transport equipment and materials. If access into the marsh areas is required, the same measures used for initial construction, i.e., a narrow/limited corridor and mats, will be implemented. Maintenance of the structure is not expected to have any cumulative impacts on the salt marsh on the north end of Figure Eight Island. No cumulative impacts to the salt marshes are expected because the deepening of Nixon Channel and associated placement of material along the Nixon Channel shoreline which is expected to reduce erosion pressure in proximity to salt marsh resources. It should also be noted that the subject salt marsh community area at this location appears to experience transitional periods of not having salt marsh, making the determination for salt marsh cumulative impacts in this area difficult. This can be observed in a November 30, 1989 aerial photo. Cumulative impacts to other salt marsh communities within Alternative 5A are not expected.

Submerged Aquatic Vegetation

Direct and Indirect Impacts: As discussed previously, SAV resources are found away from the throat of Rich Inlet in areas that are protected from naturally induced changes in water quality such as turbidity and TSS. Dredging within Nixon Channel and the connector channel as associated with Alternative 5A are predicted to cause a short term increase in turbidity and TSS levels during construction operations; however it is expected that the levels will remain within the State standard of 25 NTUs. The well-sorted sands with low silt content within the majority of these dredged areas are expected to keep turbidity and TSS levels below the state standard outside the immediate area of construction. However, a lens of non-beach compatible material has been identified within a small portion of the proposed connector channel. This material would be pumped to an upland disposal area located in proximity to the AIWW where erosion control measures, including improvements to the dike surrounding the upland disposal area, will be implemented to control material from eroding into known or unknown SAV habitats. Any placement of an outfall pipe within the disposal island would be oriented such that the effluent would not directly impact existing SAV beds as no known SAV resources have been identified in proximity to the disposal island.

Since dredging Nixon Channel and the connecting channel is not expected to significantly alter the tidal flow through the inlet, the salinity within the permit area is expected to maintain its existing condition and therefore SAVs are not anticipated to be impacted (see Appendix B). Furthermore, dredging activity would occur during winter months when SAV resources are biologically less active. There are no anticipated SAV impacts due to changes in water quality with the implementation of Alternative 5A.

Cumulative Effects: Turbidity and TSS levels are predicted to remain localized and below the state standard soon after all channel maintenance events, as observed following dredging in Nixon Channel in 2001. The highest weekly average of turbidity and TSS recorded at the discharge site was 44.0 mg/l and 301.0 mg/l, respectively, during this monitoring (Cleary and Knierim, 2001). Maintenance events, scheduled for every five (5) years, will be restricted to within the original dredge footprint and will occur during the winter months when SAV resources are biologically inactive. Cumulative impacts to SAV under Alternative 5A are not expected.

<u>*Shellfish Habitat*</u>

Direct and Indirect Impacts: No shellfish beds are present within the footprint of the channels to be dredged. The dredging of material from Nixon Channel and the connector channel is predicted to cause a short term increase in turbidity and sedimentation levels. Due to the low silt percentage and the well-sorted sands in the majority of the areas to be dredged, the turbidity levels are expected to remain below the state standard outside the immediate area of dredging. However, a lens of non-beach compatible material has been identified within a small portion of the proposed connector channel. This material would be pumped to an upland disposal area located in proximity to the AIWW where erosion control measures, including improvements to the dike surrounding the upland disposal area, will be implemented to control material from eroding into adjacent shellfish resources. If deemed necessary, silt fencing would be placed around the disposal area and an outfall pipe would be placed within the disposal island and oriented such that the effluent would not directly impact existing shellfish resources. Therefore, these resources are not anticipated to be impacted by activities related to Alternative 5A.

Cumulative Effects: Turbidity levels are predicted to remain localized and below the state standard, as shown by Cleary and Knierim (2001) following dredging within Nixon Channel. Salinity throughout the inlet complex will remain unchanged as the waterways within the inlet complex are expected to provide the similar tidal prism as existing conditions. Therefore, cumulative impacts to shellfish habitat under Alternative 5A are not expected.

UPLAND HAMMOCK

Direct, Indirect, and Cumulative Impacts: Generally, the activities associated with Alternative 5A are not expected to cause any direct, indirect, or cumulative impacts to the upland hammock resources located within the Permit Area due to the distance and relative elevation of the resource from the proposed activities. However, a lens of non-beach compatible material has been identified within a small portion of the proposed connector channel. This material would be pumped to an upland disposal area located in proximity to the AIWW. Erosion control measures, including improvements to the dike surrounding the upland disposal area, will be implemented to control material from eroding into adjacent areas. Upland hammock habitat does exist along portions of the dredge disposal island and the disposal material is expected to remain confined within the settling pond, not affecting the hammock habitat. No upland hammock habitat is located within the footprint of the terminal groin structure or associated construction corridor.

Upland hammocks within the permit area may be threatened by potential sea level rise overtime. According to the International Panel on Climate Change, global mean sea level rose at an average rate of about 1.7 ± 0.5 mm/year during the twentieth century (IPCC, 2007). Recent climate research has documented global warming during the twentieth century, and has predicted either continued or accelerated global warming for the twenty-first century and possibly beyond (IPCC, 2007). This rate, which is difficult to predict, is anticipated to increase over the next 100 years. Rahmstorf (2007) predicts that global sea level in 2100 may rise 0.5 m (1.6 ft.) to 1.4 m (4.6 ft.) above the 1990 level. As stipulated by North Carolina HB 819, the State has directed that only "historic rates of sea-level rise may be extrapolated to estimate future rates of rise but shall not include scenarios of accelerated rates of sea-level rise unless such rates are from statistically significant, peer-reviewed data and are consistent with historic trends". If any rise is validated, the increase in sea level could result in potential cumulative impacts to coastal upland hammocks present in the permit area. With Alternative 5A, there was virtually no difference in the average tidal prism versus baseline conditions at year 0 for Alternative 2. The average tidal prism for Alternative 5A was 503.4 million cubic feet compared to 502.9 million cubic feet for Alternative 2, a 0.6% difference. Flow distribution patterns for Alternative 5A were also the same as Alternative 2 with 56.5% of the flow through Nixon Channel and 35.5% through Green Channel. Changes to the tidal prism within the inlet complex, including Nixon and Green Channels, due to construction of Alternative 5A were minimal over the 5-year simulation (refer to Appendix B - Engineering Analysis). Outside of natural effects from sea level rise, no project impacts to upland hammocks are anticipated.

INLET DUNES AND DRY BEACHES

(<u>NOTE</u>: In the discussion for these habitat types at the terminal groin location, we have defined the north side of the structure as the "inlet" and the southern side as "oceanfront". See OCEANFRONT DRY BEACHES AND DUNES further below for discussion addressing the south side of the groin structure.)

Direct Impacts: Under the 2006 shoreline conditions, approximately 0-5 acres of direct impact are expected to the inlet dunes and dry beaches on Figure Eight Island with the implementation of Alternative 5A. No direct impacts are expected to take place within inlet overwash habitat areas with this alternative. The impact area includes portions of the construction corridor, the footprint of the terminal groin, and the placement of dredge material along the shoreline of Nixon Channel. The direct impacts associated with the construction corridor would be considered temporary because it's expected that the elevations will remain the same and that any disrupted vegetation would return shortly after completion of the groin structure. The direct impacts associated with the construction corridor and the footprint of the terminal groin within the inlet dunes and dry beaches will encompass approximately 0.6 and 0.1 acres, respectively. Work consists of excavating the inlet dune area both on the Nixon Channel side and the oceanside in order to install the rubble/rock material for the structure. Once the structure is in place, the excavated dune material will be placed over the rock groin and reformed to pre-construction conditions to the maximum extent possible. The dune areas will be sand fenced and vegetated to restore and stabilize the inlet dunes. The installation of the groin structure along the inlet dry beach area, which is adjacent to the inlet dune, is likely to directly remove any seabeach amaranth vegetation, via excavation, that would be in its dormant stage. As shown in Chapter 4, a population of these plant species have been inventoried in the vicinity of the structures footprint & construction corridor.

Other biological resources such as resting shorebirds, particularly overwintering piping plover, using inlet dry beach habitat may be displaced within the construction limits during work activities. These shorebirds, if present during construction, could be temporarily disturbed by the noise associated with the nearby staging, storage, and transportation of equipment, materials, supplies, and workers on the beach in support of project construction. Bulldozers are typically used to achieve the design height and berm width for the proposed beach fill sections, and additional heavy machinery will be utilized to construct the terminal groin, which are likely to be on-going during most of the daylight hours. This may likely cause the shorebirds within the area to seek out and use alternative habitat areas outside of the direct influence of project activity. The noise associated with the construction – such as operation of heavy machinery and pile driving - may stress bird populations using the dry beach, whether in the construction limits or the surrounding areas, by causing them to spend more time responding to the disturbance rather than foraging and resting, or force them to vacate the area altogether. The presence and operation of this equipment may also directly injure or kill the birds if not previously spotted, or force them to alter their normal feeding or roosting behavior. Additionally, rocks that will be used to construct the rubble mound portion of the groin will be stockpiled in an area adjacent to the groin, which will encompass dry beach. With the potential for during construction impacts to shorebirds, it is expected that the winter work timeframe, the availability of other supporting dry beach habitat (totally approximately 215 acres) in the inlet, and the adaptability of the shorebirds will help in reducing those effects. For their ability to adjust to the presence of construction, other inlet projects have demonstrated the continual use by shorebirds, including piping plover, while work was on-going. For example and as described in Alternative 3, in the recent ebb tide channel relocation project in New River Inlet, during-construction bird monitoring was conducted within the approximate 2.5 month construction period between November 2012 and February 2013, when some wintering birds such as overwintering piping plover, would likely be present. The results of the monitoring showed the constant presence of shorebirds throughout the inlet complex, including several sightings of piping plovers (Coastal Planning & Engineering, 2013). During construction surveys showed an average of 1,840 individuals for a variety of species per survey. In another bar channel relocation project in Bogue Inlet, the 2005 during construction bird monitoring also showed the continued use of the inlet complex while dredging and a dike construction in the inlet were on-going from January to April, 2005. Shorebirds, including piping plover, were observed during the monitoring efforts for both projects appeared to adjust to the presence of construction equipment and noise and are of the same species found in Rich Inlet. The same continued use and inhabitation for Rich Inlet complex is expected throughout the entire construction period.

For Alternative 5A, the placement of 57,000 cubic yards along the Nixon Channel shoreline, which creates approximately 1.2 acres of new dry beach, will cover a small portion of the native dry beach. This area contains approximately 0.6 acres of inlet dry beaches. The expansion of this shoreline footprint will increase the total area of dry beach and provide additional resting, and potential nesting, habitat for shorebirds. Shorebirds, including piping plover, have been sighted along this shoreline, but mostly foraging in the intertidal zone at low tide. The addition of this inlet dry beach habitat will serve to expand the area for resting birds during their feeding activity. The Nixon Channel shoreline also contains a small amount, less than 300 linear feet, of low lying inlet dunes and the placement of fill material at the foot, and expanding outward, of this dune system will provide additional protection to this habitat.

As shown in Chapter 4, turtle nests have been found on the oceanside along the northern end of Figure Eight Island. With the ten years of data (2001-2010), nest locations were documented in 2003 and 2004 within proximity of the terminal groin structure construction corridor and footprint. The construction and design of the structure has the potential to affect sea turtle nesting capabilities. Construction could result in compaction of the dry beach reducing the success for nesting; and the terminal groin is expected to be approximately 1-3 feet above surface elevation which would impede migration or crawling along the dry beach.

While negative impacts are anticipated to the inlet dry beach, the adjacent oceanfront dry beach on the south side of the structure will be expanded. This oceanfront dry beach will be constructed with the use of compatible beach material. According to the modeling, under the 2006 conditions, it is anticipated that direct impacts would occur to inlet dry beach on the Figure Eight side of the inlet, but no significant adverse impacts would be incurred within those habitats on the Hutaff side. However, the erosion and accretion experienced on both sides of the inlet is largely determined by the position of the bar channel in Rich Inlet. As stated previously, the position of the channel is subject to periodic relocations.

Indirect Impacts: The construction corridor under Alternative 5A will be kept open for an undetermined amount of time for any necessary maintenance or potential for structure removal. Future maintenance of the terminal groin is expected to be limited to the rubblemound portion of the structure. This maintenance activity, which is expected to be primarily limited to the portion of the groin below the mean high water line, could involve the replacement of displaced stones or perhaps replacement of stones that could not be recovered. The frequency of this maintenance activity and use of the construction corridor would depend of the severity of storms and would likely be infrequent, if at all, due to the known low maintenance of other existing groin structures. As a general comparison, the terminal groin structures at Pea Island and Fort Macon have not required maintenance since their original construction in 1991 and 1965, respectively.

For inlet dune, dry beach, and overwash habitat changes, the degree of indirect impacts would largely be contingent on the location of the ebb tide bar channel. The geomorphic analysis of Rich Inlet has shown that these habitats undergo significant changes in response to the reorientation of the bar channel under natural conditions. As previously discussed, the analysis has shown that when the inlet bar channel maintains a central to northerly position toward Hutaff Island the northern spit of Figure Eight Island undergoes erosion while the southern spit of Hutaff accretes. The opposite occurs when the bar channel shifts southward toward Figure Eight Island. The island accretes while Hutaff experiences erosion. In the Delft3D model simulations, the bar channel was located central to northward during the 2006 shoreline condition runs and the model results showed that the shoreline of the sandy spit on the north end of Figure Eight Island receded and became juxtaposed to the terminal groin. As a result, this area of erosion appears to have converted most of the inlet dry beach and overwash habitat to intertidal and subtidal habitats on the north side of the terminal groin, which would benefit fishery resources that would likely forage and rest in the converted habitat types, but would negatively affect shorebird resting and nesting habitat.

The loss of inlet dry beach and overwash during the conversion is approximately 12 acres. The predicted loss of the sand spit on the north end of Figure Eight Island under Alternative 5A may be partially due to sediment sloughing off the end of the island and depositing in the rather large channel that would be constructed to connect Nixon Channel with the gorge of Rich Inlet. When the channel gorge is positioned next to the terminal groin, the amount of accretion or development of inlet dry beach and overwash habitat used by shorebirds, especially piping plovers, on the north side of the structure are expected to be limited. In limiting the formation of these habitats on the southern inlet shoulder of Figure Eight Island, the conditions for promoting roosting and potential nesting habitat would be less than naturally occurring levels at this location. For piping plover, this area of the island is designated as critical habitat under Unit NC-11 and is a significant area for the recovery of the bird’s population. The reduction of Unit NC-11 within the Figure Eight Island spit is expected to limit piping plover’s use within the 5-year modeling period under 2006 shoreline conditions. It is expected that the initial beach fill and maintenance of dry beach along Nixon Channel shoreline and within the oceanfront fillet will provide some benefit to shorebird's, including piping plover, resting and nesting behavior at those locations. Also, even if the channel does assume a position next to the terminal groin, that position is not expected to be permanent.

Under the erosive 2006 shoreline conditions for Alternative 5A, the seaward end of the terminal groin would ends in a water depth of about -3 feet NAVD88. Overtime, the landward portions of the terminal groin will likely become covered in sand and possibly vegetated while the seaward most 300 to 400 feet of the structure could be periodically exposed depending on antecedent sea and weather conditions. The littoral processes impacting the outer portion of the ocean bar and the position and alignment of the bar channel are expected to continue as in the past, and as would the primary mode of sediment bypassing around Rich Inlet. As demonstrated by the morphological history of Rich Inlet developed by Dr. William Cleary and reported in Sub-Appendix A of Appendix B, sediment bypassing around Rich Inlet occurs through the process of channel migration and subsequent channel breaching (a process also known as bar bypassing) and Alternative 5A groin structure would not prohibit this process. The Deftl3D 5-year model simulation indicated a loss of approximately 86% of the oceanfront fill during the first 4 years of the simulation, with much of this eroded material being transported into the inlet area. The sediment passed the terminal groin as a result of overtopping, leaking through it, or simply being transported around it. The bypassing of littoral sediment around Rich Inlet would continue to occur and could result in some inlet dry beach and overwash habitat redevelopment on the Figure Eight Island spit over time allowing for natural resources including seabeach amaranth and shorebirds, like piping plover, to continue to persist in this area. Even with this influx of material, the inlet dune, dry beach, and overwash areas on the north side of the structure continued to erode, according to the modeling. The 5-year model for Alternative 5A results suggested that much of what was initially inlet dunes along the spit area were converted to intertidal and subtidal habitat (Figures 5.22-5.27).

For the Hutaff Island spit, the Delft3D model results for Alternative 5A indicated that the southern tip of the Island would undergo accretion between year 0 and year 5. This accretion would lead to the development of additional inlet dry beach and dune and overwash communities (See Figures 5.22-5.27), which would also expand Critical Habitat Unit NC-11 for piping plover and benefit the bird's resting and nesting ability during the 5-year modeling period. Because Hutaff Island is unpopulated and access is restricted to boats, the increased dry beach and overwash habitat on the southern tip of the island is valuable for nesting and resting wildlife, particularly with shorebirds like the piping plover. Like the Figure Eight side of the inlet, Hutaff's southern spit has been shown by the Audubon North Carolina 5-year survey data to be heavily used for foraging and roosting by piping plover. As shown by research, wintering plovers on the Atlantic coast prefer wide beaches in the vicinity of inlets (Nicholls and Baldassarre, 1990; Wilkinson and Spinks, 1994). Along with accretion of inlet dry beach and inlet dunes on Hutaff Island, model results also indicate that inlet dry beach habitat was created and maintained within the flood tide delta area beyond the convergence of the connector channel and the inlet channel.

Even though the 5-year model suggested that inlet dry beach and dunes are anticipated to accrete on Hutaff Island, the accretion does not appear to fully compensate for the loss on the northern portion of Figure Eight Island. In total, a net of approximately 0-5 acres of inlet dunes and dry beaches may be lost as a result of the implementation of Alternative 5A.

Cumulative Impacts: Alternative 5A includes maintenance of the beach fill segments once every five (5) years resulting in a maximum of six (6) separate events over the course of the 30-year project. Continued periodic nourishment of the north end of Figure Eight Island should result in the continuation of sediment transport past the terminal groin and into Rich Inlet during a 4-year period. After the indirect 5-year initial loss when the structure is completed, it is unknown and difficult to discern what the extent and/or magnitude of long-term and cumulative effects from Alternative 5A will have on inlet dry beaches and overwash habitat throughout the inlet. It is anticipated that the majority of the losses will occur on Figure Eight Island spit, which would limit shorebirds nesting capabilities and seabeach amaranth species in that area. This limitation includes the reduction of Unit NC-11 Critical Habitat for piping plover. With the south shoulder of Rich Inlet fixed in place by the terminal groin, the southward growth of Hutaff Island would be limited by tidal currents flowing through Rich Inlet. As a result, substantial southward movement of the Hutaff sand spit is not anticipated beyond that which would occur during the first 5 years following the installation of the terminal groin. Impacts to inlet dry beaches and overwash habitats, including the shorebirds that utilize them, are expected within the inlet complex over a 30-year study period; however, the extent of those impacts are unknown. It is anticipated that, at some point in time, the loss of habitat as a result of the terminal groin will equilibrate and begin to shift under the natural influence of the bar channel positioning and continue to be present within the inlet complex. With the structure being short in nature and only extended slightly seaward of the MHW line, this should assist in reducing long-term impacts on these habitat types.

INTERTIDAL FLATS AND SHOALS
(NOTE: In the discussion for these habitat types at the terminal groin location, we have defined the north side of the structure as the "inlet" and the southern side as "oceanfront".)

Direct Impacts: The dredging activities associated with Alternative 5A would directly impact approximately 25-30 acres of the approximate 206 acres of intertidal flats and shoals found within the Permit Area through direct excavation of these resources. This includes the removal of 994,400cubic yards of material from the previously dredged area within Nixon Channel and the new connector channel. Specifically, the footprint of the area to be dredged for the connector channel is characterized by abundant intertidal habitat, which would be converted to the alternate habitat type of subtidal. Infaunal species residing within the material taken from the intertidal flats and shoals would be immediately eliminated during the dredging operation.

Similar to Alternative 3, the removal of this habitat may impact fish species which utilize flats and shoals as foraging grounds, refuge, nursery grounds, and spawning habitat. Several different fish species inhabit the intertidal flats and shoals and the water column within these areas. As reported by USACE (1984), species that utilize these habitats include red drum, spotted seatrout, bluefish, Atlantic croaker, kingfish, and mullet. These species forage upon many of the benthic organisms that reside within intertidal flats and shoals. With the direct removal of 25-30 acres of these potential foraging areas, this would reduce available prey or food sources and could change feeding behavior within the inlet complex. However, due to the winter time construction, many of these species will be located offshore and will not be utilizing the nearshore or inlet intertidal flats and shoal areas during the construction period. For any fish species that may be present, it is expected that their mobility will provide them the opportunity to temporarily relocate to the roughly 180 acres of adjacent similar habitats while dredging and terminal groin construction is taking place.

For Alternative 5A, the direct removal of the infaunal species present within the intertidal flats and shoals to be dredged may also have an effect on shorebirds, including the endangered piping plover and its critical habitat. As previously stated, the infaunal community is a major food source for shorebirds and the disturbance of that food source may act as a stressor. The Audubon North Carolina survey data, as previously described above, revealed that piping plover were foraging for food within the flood tide delta habitat where the connector channel is proposed to be dredged. Additionally, the presence of construction activity in association with the groin and beach nourishment placement may also stress shorebirds specifically along the intertidal flats in the northern portion of Figure Eight Island.

Even with these anticipated project stressors, with the utilization of appropriate conservation measures, the direct effects on the bird resources are expected to be minimal, however, a portion of piping plover critical habitat would be expected to be fundamentally altered. Conservation measures that will serve to minimize effects to the various bird species include construction taking place between November 16th and March 31st when some of the migratory species will not be present. In addition, all onshore activity will be restricted to a designated construction corridor no wider than 200 feet. And for those species that will be present during construction, it is expected that they will utilize the remaining undisturbed ~180 acres of intertidal flats and shoals located outside the dredging footprint and outside of any onshore construction area. It is also anticipated that any stress levels from land and/or in-water construction, which will be limited to a specific area, will be non-appreciable based on the during-construction monitoring results for New River Inlet and Bogue Inlet projects as discussed in "Inlet dunes and Dry Beaches" and in Alternative 3. The bird species in Rich Inlet, which are the same species found in New River and Bogue Inlets, are expected to adjust and adapt to the presence of construction equipment and noise, and are expected to continue to inhabit the inlet complex throughout the entire construction period of Alternative 5A.

Indirect Impacts: The direct removal of approximately 994,400 cubic yards of material from Nixon Channel and the connector channel will result in a sediment deficit within the inlet complex system and, in turn, cause a direct impact to foraging shorebirds including piping plover. This deficit would also reduce the amount of Unit NC-11 critical habitat for piping plover within this portion of Rich Inlet. Although 57,000 cubic yards of material will be placed along the adjacent Nixon Channel shoreline, the majority of the amount (932,100 cubic yards) will be pumped onto the oceanfront shoreline for the construction of the terminal groin accretion fillet and beach fill. Note, the difference between the total volume of material needed for the beach fills and the volume to be excavated is due to tolerances allowed for both the excavation and fills.

The shoaling or infilling rate within the inlet complex is expected to increase following the implementation of Alternative 5A due to the -11.43 to -13.43 foot depth NAVD subtidal area that will be created. Based on the results of the Delft3D model simulation for Alternative 5A, the rate of shoaling of the existing dredged area in Nixon Channel was fairly steady during the five-year simulation while the proposed channel connector experienced rapid shoaling over the first two years. Shoaling of the proposed connector channel moderated between years 3 and 4 of the simulation, with the model predicting minor scouring during the last year of the simulation. During the first few years, it is expected that foraging fish may experience a reduction of prey as the benthic infaunal communities recover in the dredged area shoals.

Although the Delft3D model was simulated for Alternative 5A to assess shoreline changes, the model was not utilized to assess the volumes of erosion and deposition within discrete cells within the inlet complex. This exercise, however, was performed for Alternative 5C which included the same dredging area within Nixon Channel and the connector channel as

Alternative 5A. The only difference between the two alternatives is that Alternative 5A includes a groin design located approximately 420 feet south and contains a slightly longer effective length in comparison to the groin designed for Alternative 5C. As such, the results from Alternative 5C could be used as a proxy for Alternative 5A. The model volume changes in discrete areas within the inlet complex after 5-years for Alternative 5C are provided in Figure 5.58. These results for Alternative 5C, which is similar to Alternative 5A, suggest that after the 5-year modeling period, 852,600 cubic yards of material would be transported back into the inlet. This sediment accumulation will help reform or develop some of the intertidal flats and shoals in the inlet flood tide delta area that was dredged. The reformation of these habitats should help reduce the potential change of fish behavior using the area for foraging, refuge, nursery grounds, and/or spawning. In addition, it would help to maintain some of the piping plover foraging areas located in the critical habitat unit. However, considering that 1,077,000 cubic yards was removed during dredging under the 2006 conditions, this would result in a net decrease of 224,500 cubic yards in the inlet area over the 5-year period. This outcome could cause less intertidal flats and shoals habitat areas compared to pre-construction conditions. As stated previously, the accuracy of the model volume changes are ±10,000 cubic yards within each discrete area.

Volume model results showed that much of the sediment accumulation occurred in the middle ground shoal area immediately behind the inlet and in Nixon Channel. It's within this middle ground shoal area where the dredging of the connector channel will take place. Since the dredging will take place within parts of the natural sediment accumulation point, it is expected that relatively rapid shoaling, or in-filling, of the dredged areas would tend to reform intertidal flat and shoal habitats. Delft3D model results suggest that approximately 500,000 cubic yards of material will collect in the excavated areas within two years, helping to restore, in a short period, some of the initial lost foraging habitat. Following this initial two year adjustment, shoaling decreased with the channel actually experiencing some scour during the last year of the simulation. Between Year 4 and 5 of the simulation, the intertidal flats extending beyond the sand spit on Figure Eight Island began to recede on the Figure Eight Island side. By the end of Year 4 of the simulation, over 86% of the fill placed between baseline station 60+00 and the terminal groin had been lost. Therefore, the rate of northward transport of the fill material diminished by Year 4 which could have contributed to the erosion of the sand spit and the intertidal areas that are associated with it. Because of the anticipated net reduction of the extent of intertidal flats and shoals shown in the 5-year modeling period, negative impacts to the fish and bird species utilizing these habitats within the inlet complex would be anticipated overall, despite the addition of intertidal areas from the dry beach and overwash conversion on the northern spit on Figure Eight Island.

Another area of significant volume change affecting intertidal flats and shoal areas occurred off the south end of Hutaff Island. Initially, the intertidal flats and shoals off Hutaff Island decreased following the construction of Alternative 5A. However, by Year 5, these resources began to reform to a similar extent as its pre-construction reach. The volume change appeared to be contingent on the alignment of the inlet bar channel which was to the southwest through Year 3 of the simulation. From Year 4 to Year 5, the bar channel began to assume a more northeasterly alignment and some of the initial volume loss north of the inlet was restored. During the periods of time when the intertidal flats and shoals were relatively less abundant in this location, birds and fish would be indirectly impacted due to less foraging habitat. However, there would be an abundance of intertidal flats and shoals that remained within the inlet complex, which birds and fish could utilize to forage. Model results showed that the southern spit of Hutaff Island accumulated material as well as in the inlet interior (see Figure 5.53).

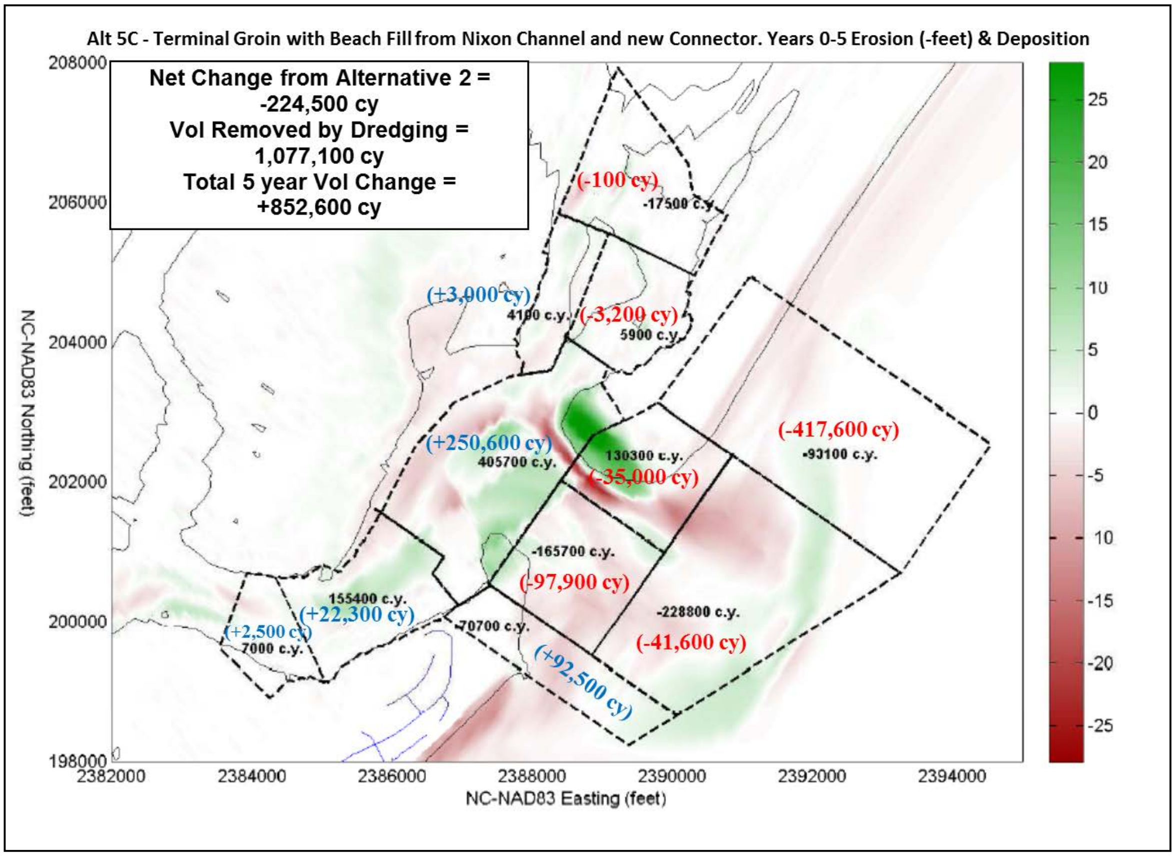

Figure 5.53. Modeled volume changes in discrete areas within the Permit Area for Alternative 5C (applicable for Alternative 5A). Values in blue and red indicate an increase or decrease in material volume, respectively, compared to the baseline conditions shown at year 0 for Alternative 2.

Under Alternative 5A, the direct mortality of the macroinfaunal population in the dredged intertidal flats and shoals may have an indirect impact on bird and fish species that forage on these communities. As discussed in Alternative 3, it is anticipated that some benthos will repopulate the dredged area within a short period of time, but there will be a time lag for the area to repopulate to its pre-construction community diversity and total numbers. In this recovery period, some individual bird and/or fish species may have to adjust their foraging habits and temporarily use other areas. For fish resources, studies of dredging and disposal effects on nearshore and estuarine fish populations have reported rapid recovery or minimal effects following the removal of benthic organisms associated with dredging (Courtenay *et al.*, 1980; de Groot, 1979a; de Groot, 1979b; Posey and Alphin, 2000). These minimal effects are anticipated in part also due to the winter time construction when biological activity is lowest. Topographic changes in response to dredging within both inshore and offshore borrow areas have also shown to benefit certain fish by creating refuge or forage areas (Lalancette, 1984). The unconsolidated and unvegetated communities that remain in the inlet complex would continue to redistribute as they lack structure and are dynamic in nature.

As demonstrated in the Deflt3D modeling of the shoreline, results showed that much of the inlet dry beach, overwash, and dune system on the north side of the terminal groin structure appears to be converted into intertidal flats and shoal habitat over the 5-year modeling period. The conversion will produce approximately 2-3 acres of this habitat, which provide foraging areas for both fish and bird species. Over the five (5) year modeling period, the change is expected to continue to provide feeding and foraging for several bird species, including the piping plover. However, there will likely be an overall net reduction of approximately 0-5 acres of intertidal flats and shoals within the project area due to the net deficit of approximately 224,000 cubic yards of material within the inlet system.

For Rich Inlet, intertidal flats and shoal habitat are a valuable feeding resource for both migrating and residential bird and fish species. With a net deficit in sediment volumes over a 5-year period, this habitat may not recover to pre-construction conditions and could potentially affect the feeding behavior of the bird and fish species utilizing them. The magnitude and extent of impacts would be contingent on how quickly intertidal flats and shoals reform or shift elsewhere. It is anticipated that some material of the formed accretion fillet and beach fill will continue to be transported through the structure back into the inlet, as demonstrated in the volume modeling results and through observations of other terminal groins structures such as Pea Island and Fort Macon. Additionally, the Delft3D 5-year shoreline modeling revealed that some of the inlet dry beach, overwash, and dune habitat on the north side of the groin structure will be converted to intertidal flats and shoals. This conversion is expected within the first year. The continuation of sediment input into the inlet system and the habitat conversion north of the terminal groin structure should help sustain the continued presence of intertidal flats and shoals over a 5-year period.

Cumulative Impacts: For Alternative 5A, the Delft3D shoreline modeling under the 2006 conditions has shown the need for beach renourishment once every five (5) years with the material coming from the previously dredged Nixon Channel and the new connector channel. This could potentially total up to six (6) individual maintenance events within the 30-year study period. Each maintenance episode is expected to impact intertidal flats and shoal habitat as described in the indirect impact assessment above. It should be noted that the intertidal flats and shoals in the inlet are not fixed stationary habitats, but are considered to be ephemeral and dynamic. Consequently, bird resources are known to adjust to these changes.

As discussed in the indirect impact section, a net decrease of 224,500 cubic yards of sediment over the 5-year period was shown under the 2006 conditions, which may result in less habitat than pre-construction conditions. If beach fill maintenance is needed once every five (5) years and all six (6) dredging and renourishment activities were conducted, then some cumulative sediment deficit could be expected over the 30-year study period. It is difficult to estimate what this total would be and to what degree the deficit would have on forming and reforming intertidal flats and shoal habitats over 30 years. Model results suggested that beach fill needs for renourishment or maintenance events would be less than the initial construction amount. The required amount is estimated to be approximately 487,000 cubic yards, which is approximately half of the original amount dredged. Similar to above, rapid in-filling of the dredging footprint will initially occur and moderate overtime. With a minimum of 5-years between dredging events, infaunal organisms residing within the intertidal flats and shoals are expected to be sustained and not affected overtime by periodic dredging events. Within the 30-year study period, fish and shorebird populations utilizing intertidal flat and shoal resources within the inlet complex may be affected cumulatively due to the slight sediment deficit in the inlet which could limit the formation of intertidal flats and shoals. Under Alternative 5A, the magnitude and extent of cumulative impacts would be contingent on how quickly intertidal flats and shoals will reform or shift elsewhere.

The overall effects of the initial sediment deficit is not known. However, one can reference the 24-year old terminal groin in Oregon Inlet, which is approximately 975 linear feet longer than Alternative 5A structure, to obtain a general understanding of long term impacts to intertidal flats and shoals around the groin structure. As described by USFWS (2008), habitat behind the terminal groin on Pea Island has undergone succession over the 20 years due to wind and water-borne sand. Since the piping plover is primarily a winter resident at Oregon Inlet, which is also a designated area as Critical Habitat for piping plover, the major threat to this species in the vicinity of the inlet is the degradation of intertidal foraging habitat (USACE 2001). The construction of the terminal groin resulted in natural formation of a 50-acre fillet located on the downdrift side; thus, restoring and stabilizing the tip of Pea Island (Dennis and Miller 1993). This provided valuable habitat for piping plovers and other shorebirds for a number of years following the creation of a vernal pool or mud flat by the North Carolina Department of Transportation (NCDOT). However, in more recent years the presence of the terminal groin, as well as other actions such as dredging and nourishment, has modified habitat important to piping plovers by eliminating intertidal flats on the downshore side of the structure and allowing encroachment of vegetation in the stabilized areas. This stabilization of the northern tip of Pea Island has changed some of the inlet dynamics as it pertains to piping plover habitats. Despite this, piping plovers have continued to utilize portions of Pea Island as an area for foraging activity. Although only limited data of piping populations are available prior to the construction of the terminal groin, post-construction data demonstrates the variability in annual counts. Populations of piping plovers on Pea Island have been relatively low prior to 2000. Between the years 1986 and 1999, an average of 2 piping plovers were observed per year with an annual range of 0 to 8 individuals. During this time the intertidal pool created soon after the construction of the groin had been modified and became vegetated. Although this specific area adjacent to the groin was no longer valuable habitat for piping plovers, other intertidal flats and shoals located along Pea Island in proximity to the inlet provided this important habitat in subsequent years. In 2000, observations on Pea Island increased sharply to 87 individuals. Annual observations subsequently declined to 33 individuals in 2001, and increased sharply to 307 individuals in 2002. Pea Island observations declined steadily over the next three years, reaching a low of 4 individuals in 2005. Annual observations increased to 19 individuals in 2006; however, no piping plovers were reported from Pea Island during 2007 or 2008. In 2009, a total of 40 individuals were observed on Pea Island (NCDENR, 2010). Piping plover observations have also been made on the northern side of Oregon Inlet along Bodie Island (part of the Cape Hatteras National Seashore) since 1965 (Schweitzer, pers. comm.). Over the past 20-25 years, the Bodie Island spit extending into the inlet has grown considerably in size. As such, this area has continued to provide habitat for shorebirds, including the piping plover. Compared to an average of 2 piping plovers observed per year between 1986 and 1999 on Pea Island, over 11 piping plovers were observed on Bodie Island per year with a maximum of 39 individuals observed in 1995. This helps to demonstrate that despite the construction of the terminal groin on the south side of Oregon Inlet, bird use continued on both sides of the inlet.

Another example, which is much more severe in its modification to an inlet's dynamics, is the jetty at Masonboro Inlet. This inlet is located approximately 9.5 miles south of Rich Inlet and is between Wrightsville Beach and Masonboro Island. The north jetty, which includes a low weir section to allow sediment to deposit in a sediment trap on the inlet side of the structure, was completed in 1966 while the south jetty was completed in 1982. The majority of the inlet, including the flood tide delta, is subject to routine dredging. This jetty structure differs from a terminal groin in that the jetties, which are intended to control shoaling of the navigation channel, are much longer than a terminal groin. For the Masonboro Inlet jetty, both jetties are over 3,400 linear feet long, and the inlet's modifications differ greatly from its natural conditions. Even with these inlet modifications that have drastically reduced piping plover habitat, the birds continue to utilize the inlet. In the Audubon North Carolina bird surveys, the results included piping plover data at Masonboro Inlet from July 2009- May 2012. The data showed that the birds did use the inlet during this timeframe for foraging and roosting, but as expected, with much less frequency and numbers than Rich Inlet. Most of the use occurred on the southern spit of Wrightsville Beach which is frequented by beach goers.

In addition, many boaters utilize the shoals as an area to anchor and recreate. Although the inlet is anticipated to maintain extensive shoals, the net decrease of 224,500 cubic yards of sediment in the inlet could reduce the net amount of intertidal flats and shoals. As such, boaters using these resources may flush out and disturb the migratory birds utilizing the habitat for foraging. During peak summer months, it can be expected that any available shoals would be used since Rich Inlet area is known to experience a continuous high volume of boaters and people in the summer. After the initial post-construction effects on the north side of the terminal groin equilibrate, it is anticipated that the presence of intertidal flat and shoal habitats will be largely dictated by the migration and position of the inlet bar channel over the 30-year study period.

OCEANFRONT DRY BEACH AND DUNE HABITATS

(<u>NOTE</u>: In the discussion for these habitat types at the terminal groin location, we have defined the south side of the structure as the "oceanfront" and the northern side as "inlet".)

Oceanfront Dune Communities

Direct Impacts: Similar to Alternative 3 and 4, Alternative 5A includes a dune with a crest elevation of 4.6 m (15.0 ft.) NAVD that would be constructed in the area from baseline station 77+50 to 95+00 or in the area presently devoid of a dune and where homes are presently protected by sandbag revetments. The footprint of this artificial dune would encompass approximately 4.6 acres which would result in a positive impact to this habitat. This stabilization measure will allow for long term growth and development of dune vegetation and provide habitat for roosting, foraging and nesting shorebirds. The dune communities located on Hutaff Island are not expected to be directly impacted by the implementation of Alternative 5A.

Indirect and Cumulative Impacts: The orientation of the inlet has been proven to play an important role regarding shoreline erosion rates within the Permit Area. When the inlet channel is positioned in a southerly orientation, the oceanfront dunes on Figure Eight Island would be expected to persist or increase in size while the contrary would be expected on the southern oceanfront shoreline on Hutaff Island. The opposite is true for both islands when the bar channel is located in a more northerly position. In comparing a 2010 aerial to the January 2015 aerial image (Figure 5.54), the inlet bar channel appears to have shifted from the south to a more central location; and if the shifting continues northward, the oceanfront of Figure Eight Island is anticipated to undergo erosive conditions affecting oceanfront dunes while Hutaff's oceanfront experiences accretion.

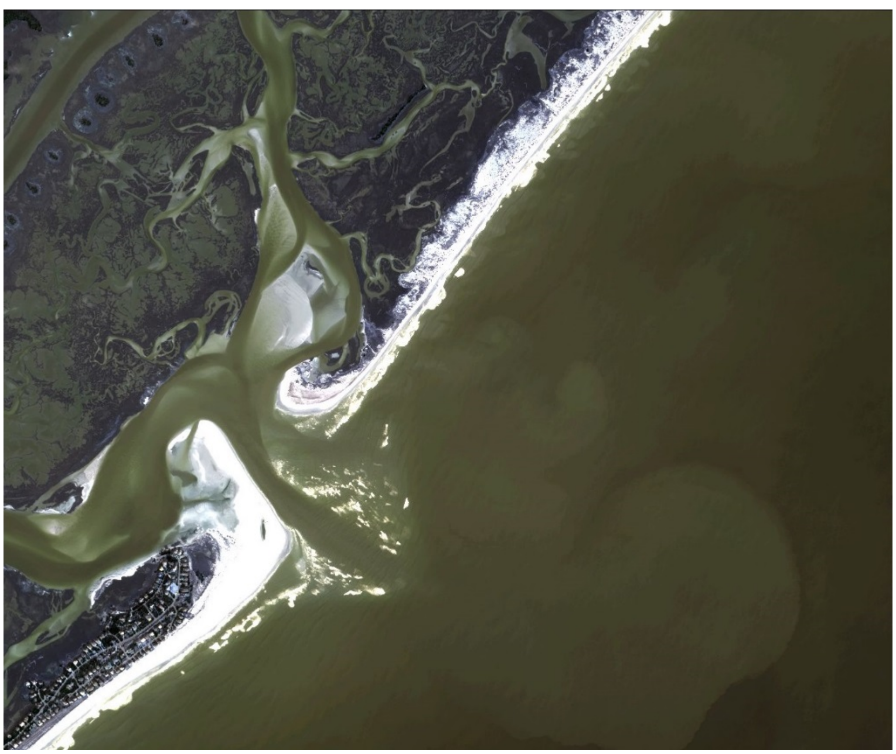

Figure 5.54. January 2015 aerial photo of Rich Inlet (Photo from National Agricultural Imagery Program)

Alternative 5A includes renourishment at a minimum of every five (5) years, and up to six (6) separate events within the 30-year study period. With the terminal groin structure in place and the subsequent maintenance events, the project will serve to provide long-term protection of the oceanfront dune system; consequently, resulting in cumulative impacts on Figure Eight Island that are beneficial to dune habitat. This should allow the establishment of a vegetated community to be maintained which provides habitat for resting birds and other wildlife. Although overwashing of dunes can result in the formation of important habitat for a variety of shorebirds on the backside of barrier islands, the dunes along Figure Eight Island are located in front of residential development and therefore overwashing are not expected. The dune communities located on Hutaff Island would be expected to migrate westward as natural processes including transgression will influence the environment. Although the physical location of the dune system may change as overwashing and other storm-induced events influence the environment, impacts to the dune communities at Hutaff Island in response to Alternative 5A are expected to be minimal.

Oceanfront Dry Beach Communities

Direct Impacts: Fill placement associated with Alternative 5A would include the placement of dry beach habitat along the oceanfront shoreline from the intersection of Beach Road and Beachbay Lane to the terminal groin located along the northern portion of the ocean shoreline of Figure Eight Island. Direct impacts to the dry beach will be incurred during the initial fill placement and the construction of the terminal groin. The impacts associated with the construction of the terminal groin were described previously under the inlet dunes and dry beach section above. The fill placement area would encompass approximately 45-50 acres of dry beach habitat including the burial of approximately 29 acres of existing dry beach. Alternative 5A would include the placement of approximately 15-20 additional acres of dry beach along the oceanfront on Figure Eight Island.

The width of the oceanfront dry beach immediately following construction will vary along the length of the 12,250 foot fill area. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be approximately 106 feet. The remaining areas will have a width of 40 feet, based on 2006 conditions. This area will become beneficial habitat for resting colonial waterbirds. In particular, the development of the fillet area within approximately 750 feet of the structure would create a dry beach habitat that could be used by shorebirds which may somewhat offset the anticipated reduction of inlet dry beach and overwash areas on the north, or inlet, side of the terminal groin.

Direct impacts to the oceanfront dry beach will also include the mortality of crustaceans including ghost crabs, however, these communities are expected to recover within the order of months to more than one year (National Research Council, 1995; Carter and Floyd, 2008). This reduction in dry beach habitat will initially reduce available habitat for seabeach amaranth, sea turtles, and shorebirds, including the piping plover, however the increased beach width as a result of nourishment will compensate for this loss.

The composition, color, and grain size of the beach sand can affect the incubation time, sex, and hatching success of turtle hatchlings (Deaton et al., 2010). Physical characteristics such as density, compaction, shear resistance, moisture content, slope, sand color, grain size, grain shape, sand mineral content, and gas exchange may affect the success of sea turtle nests (Nelson and Dickerson 1988, Crain et al. 1995). The fill placed upon Figure Eight Island will conform to the State sediment criteria rules and therefore is not expected to impact the nesting success of sea turtles. Because the material utilized for the nourishment will meet State Sediment Criteria, the widened dry beach is expected to increase sea turtles nesting habitat with native compatible material. The proposed project would be conducted during the winter and, therefore, would not impact potential nesting activity by birds or turtles.

As discussed in Alternative 3, negative effects to sea turtle nesting from the fill are not anticipated due to the compatible quality of material used to expand the dry beach area on Figure Eight Island. Higher temperatures may significantly reduce incubation periods and contribute to a higher incidence of late-stage embryonic mortality (Ernest 2001). Nest temperature also influences sex determination in hatchlings, with warmer temperatures producing more females and cooler temperatures producing more males (Wibbels 2004). Consequently, dark sediments may alter hatchling sex ratios. Investigations of beach nourishment effects on hatching success have reported variable results; including positive effects (Broadwell 1991, Ehrhart and Holloway-Adkins 2000), negative effects (Ehrhart 1995, and no effect (Raymond 1984, Nelson et al. 1987, Broadwell 1991, Ryder 1993, Steinitz et. al. 1998, Herren 1999, Brock et al. 2009). The variation in findings has been attributed to differences in the physical attributes of individual projects, the extent of erosion on the pre-nourishment beach, and construction techniques (Brock et al. 2009). As stated above, the grain size, color, and other attributes of the material placed along the northern portion of Figure Eight Island as part of Alternative 5A will comply to the State sediment criteria which will help reduce potential impacts. Reference the discussion in Alternative 3 regarding the benefits and potential detriments of beach in oceanfront dry beach habitat for nesting turtles.

Indirect Impacts: Like Alternative 2, the Delft3D 5-year model simulation for Alternative 5A indicated that erosion is expected to occur on the north side of the terminal groin potentially affecting the habitat for nesting turtles, seabeach amaranth, and shorebirds. The placement location of the groin structure is situated near the transition point from oceanfront dry beach to inlet dry beach habitats. Along the ocean shoreline south of the terminal groin, the shoreline should become more stable which should assist in maintaining wildlife habitat for seabeach amaranth, nesting sea turtles, and shorebirds and reduce the frequency for beach nourishment. For the most part, the volume loss identified from the northern 2,000 feet of shoreline on Figure Eight Island occurred offshore as a relatively wide dry sand beach remained south of the terminal groin through the 5-year model simulation. For Hutaff Island, the oceanfront dry beach along the southern 2,640 feet of the island eroded over the 5-year modeling period for Alternative 5A with the rate of accretion being about 43% less than determined for baseline conditions at year 0 for Alternative 2. However, most of the volume loss from this area was offshore and was associated with the reconfiguration of the north side of the ebb tide delta of Rich Inlet.

The ocean shoreline of Figure Eight Island under Alternative 5A experienced accretion south of baseline station 60+00 to station F90+00. Between station 60+00 and station 100+00 (terminal groin location), most of the beach fill from within the pre-nourished profile out to a depth of -24 feet NAVD (depth of closure) was lost by the end of Year 5 of the simulation. However, 15.9% of the fill above the -6 ft. NAVD contour remained after 5 years. The majority of these losses were observed in the offshore area as the retention of the fill above -6 ft. NAVD would continue to provide a dry sand beach for the entire 5 year period and would provide erosion protection for the artificial dune included between stations 77+50 and 95+00.

Based on the bird surveys conducted by Audubon North Carolina, piping plover utilized this oceanfront of Hutaff mostly during the 2008-2010 survey period. The birds were mostly observed foraging, which would assumable be along the wet beach but possibly using the dry beach for resting during foraging. As stated above, the model revealed that most of the volume loss from this area was offshore and was associated with the reconfiguration of the north side of the ebb tide delta of Rich Inlet. The erosion along the oceanfront dry beach is not expected to interrupt the foraging and roosting behaviors of the piping plover.

As disclosed in Chapter 4 and described above under the Inlet Dry Beach discussion, data from monitoring sea turtle nests show recorded nest sites within the proximity of the groin structure. Out of the ten years of data (from 2001-2010), nest were found near this location in 2003 and 2004. The sporadic nesting at the spit of Figure Eight Island is likely due to the movement of the ebb tide channel, or bar channel, which could either provide favorable or unfavorable habitat and successful nesting for sea turtles. The construction of the terminal groin is expected to limit any nesting habitat, and/or decrease the success of nesting, on the inlet side of the structure due to projected erosion. Like all other terminal groin alternatives, the structure itself could impede adult turtles migrating to nesting sites or hatchlings crawling back to the ocean.

Hard structures such as terminal groins can indirectly affect nesting sea turtles and hatchlings. The type of effect is dependent on structure design, which can be shore parallel, shore perpendicular, long, short, high, low, permeable, or impermeable. The proposed structure will be a shore-perpendicular terminal groin with a 900-ft shore anchorage section and 700 linear foot rubble mound portion extending seaward of the 2007 shoreline. Direct affects from this type of groin may include: (1) prevention of access to suitable nesting sites, (2) abandonment of nesting attempts due to interaction with the structure, and (3) interference with proper nest cavity construction and nest covering. Mosier (2000) demonstrated that hard structures such as seawalls on the beach can physically block a nesting female from accessing a more suitable higher elevation nesting environment. In the study of three nesting beaches on the east coast of Florida, 86% of nesting females that encountered a hard structure during emergence returned to the water without nesting as a result of the inability to access higher elevation nesting habitat (Mosier, 2000). According to Lucas *et. al*. (2004), in a study designed to assess sea turtle response to beach attributes (i.e. hard structures), turtles emerged onto portions of the beach where anthropogenic structures threatened to block access to optimal nesting habitat; however, upon encountering the structures, turtles abandoned the nesting sequence. This study indicated that only the most seaward structures affected sea turtle nesting. Depending on the design of shore perpendicular structures the structure may act as an impediment or a trap (Foote *et. al*., 2002) to nesting females and/or hatchlings (Davis *et. al*., 2002). The constructed fillet is expected to extend close to the terminus of the 700 foot seaward component of the proposed terminal groin designed for Alternative 5A. Therefore, effects of the structure would be expected to be minimal on nesting sea turtles and emerging hatchlings.

Cumulative Impacts: Based on the historical geomorpholoic and modeling analysis, the amount of any change along the oceanfront dry beaches on both Figure Eight Island and Hutaff Island within a five year period, or over a longer timeframe, is strongly contingent on the location or positioning of the ebb tide channel. As determined and previously discussed, a southerly directed bar channel reduces the erosion along the northern portions of Figure Eight Island, while the southern dry beaches of Hutaff Island experiences greater erosion. The opposite effect occurs when the bar channel is situated in a more northerly direction, which favors ocean dry beach habitat more on Hutaff Island. With periodic maintenance nourishment scheduled every five (5) years over the 30-year study period for Alternative 5A, the dry sand beach and dunes along the north end of Figure Eight Island's oceanfront would be preserved.

Habitat for resting colonial waterbirds, nesting shorebirds, and nesting sea turtles along the ocean dry beach is expected to be maintained at the location of the terminal groin fillet for approximately 1,500 linear feet. The remaining 11,000 linear feet should be maintained with supplemental beach renourishment cycles via maintenance dredging within Nixon Channel and the connector channel every five (5) years. Maintaining the dry beach along the oceanfront shoreline will help ensure that bird and sea turtle habitat will persist. Maintenance of the rubblemound portion of the terminal groin should be infrequent, if at all, and would depend on the frequency of severe storms that exceed the design conditions for the armor stone. If maintenance of the rubblemound portion is needed, this could involve simply recovering and replacing displaced stones or adding stone to replace the ones that could not be located on site. Any maintenance work within the dry beach area would be restricted within a designated corridor in order to limit any potential impacts.

WET BEACH COMMUNITIES

Direct Impacts: For Alternative 5A, the addition of beach fill to Figure Eight Island is expected to impact approximately 10-15 acres of the wet beach community along the oceanfront shoreline and Nixon Channel shoreline, immediately burying the infaunal community. Also, the construction of the terminal groin will cover, or convert to rubble, approximately 0.3 acres of wet beach habitat located on both the oceanfront shoreline and the Nixon Channel shoreline, permanently burying the infaunal community within this area as well. Once the beach fill is placed, approximately 10-15 acres of new wet beach habitat will be created resulting in no net change in wet beach acreage.

Areas where fill will exceed 40 cm are expected to experience higher rates of infaunal mortality. As mentioned in Chapter 4, Nelson (1985) indicates that organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels. Furthermore, dredging will occur during the winter months while biological activity is reduced and the population of infaunal organisms are more likely to have migrated, in part, offshore. Although the wet beach infauna can adapt to fluctuations in the natural environment, the addition of sediment to the wet beach would have immediate yet short-term and minimal negative impacts to foraging fish and birds. As previously stated in the section earlier in the chapter entitled "General Environmental Consequences Related to Beach Fill", infaunal organisms are expected to recruit in the newly formed wet beaches at a quicker rate when using beach compatible material, which reduces the recovery period. In conjunction with compatible beach fill, the nourishment activity will occur during the winter months, between November 16 and March 31. This construction period is when biological activity and the onshore benthic populations within the wet beach habitat are at its lowest. This will, in turn, help reduce the potential affects to bird and fish species that prey upon the benthic community and cause any impacts to be short-term in nature. Direct impacts, outside the footprint of the groin structure, within the wet beach habitat along the oceanfront and Nixon Channel shorelines will be similar to those described in Alternative 3 and 4.

Indirect Impacts: For Alternative 5A, the Delft3D model results suggested that secondary impacts of approximately 5-10 acres of marine intertidal habitat occurred along the oceanfront shoreline of Figure Eight Island while the fill placement equilibrated over the 5 year simulation. This may affect shorebird, crustacean and fish foraging, and recreational fishing through a temporary reduction in bait species during and immediately after construction. Impacts should be reduced due to the fact that the material utilized for beach fill will be compatible with native material, thereby reducing to the recovery period for infaunal communities.

The ability for infaunal species to repopulate disturbed wet beach habitat in proximity to a shoreline stabilizing structure was demonstrated following the construction of the rubble weir jetty structures at Murrells Inlet, South Carolina. These structures, constructed in the late 1970's, includes a 3,347 foot jetty extending into the ocean with a 1,348 foot weir section on the north side of the inlet. The southern jetty includes a 3,317 foot structure that extends into the ocean without a weir system. The macrobenthic communities of the intertidal and nearshore subtidal environments were sampled during the construction of the jetties and once again five (5) years later. Comparison of species abundance between years and among localities (updrift and downdrift) suggested no widespread impacts to macrobenthic fauna were attributable to jetty construction (Knott et al, 1984). Although the physical conditions are not identical at both locations, a similar response would be anticipated following the construction of the terminal groin on Figure Eight Island.

Cumulative Impacts: As a result of the dredging and renourishment activity at a minimum every five (5) years, or six (6) separate events of the 30-year study period, negative effects could occur if the diversity and abundance of infaunal populations do not recover between nourishment events. However organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels (Nelson, 1985). Alternative 5A is not expected to result in long-term cumulative impacts to wet beach habitat due to the adaptability of benthic communities, sufficient period between maintenance events for recovery, and the use of compatible material. This habitat will continue to provide foraging areas for small fish and bird species.

MARINE HABITATS

Softbottom Communities

Direct Impacts: The activities associated with Alternative 5A, would result in direct impacts to approximately 80-90 acres of softbottom community within the dredging footprint in Nixon Channel and the connector channel as well as the fill footprint of construction associated with the terminal groin. The targeted excavation depths are -19 NAVD in Nixon Channel and between -11.43 and -13.43 NAVD in the connector channel.

Excavating the channels will cause an immediate negative impact by removing infaunal and non-motile epibenthic organisms from the softbottom community. Some of the impacts should be reduced by a winter dredging timeframe and with the presence of adjacent foraging softbottom communities located in the ebb tide delta and in undisturbed areas within the inlet complex. Although the recruitment pattern is altered, the recovery of infaunal species after sediment removal is relatively quick, depending upon the opportunistic nature of the species (Deaton et al., 2010; Posey and Alphin, 2002). More information regarding infaunal impacts related to dredging can be found under the section entitled "General Environmental Consequences Related to Dredging" above. Adjacent infaunal communities residing in the softbottom habitat would directly and possibly indirectly be impacted by increased levels of turbidity, immediate removal, and immediate burial of infaunal biota during dredging operations.

Within the 700 foot long footprint of the 75-foot wide terminal groin extending beyond mean high water, approximately 1.2 acres of nearshore softbottom will be permanently removed. An additional 3.2 acres would be temporarily directly impacted due to the utilization of the construction corridor. It is not known to what the full effects of this will be on the fishery resource, but with the softbottom habitat surrounding the footprint of the structure, the fishery resource should be capable of locating food sources and foraging within nearby areas.

Indirect Impacts: Construction of the beach would result in the direct deposition of material from the dune or berm crest seaward to the construction toe-of-fill, which covers softbottom habitat. Over time, the slope of the fill would adjust and equilibrate seaward. Softbottom habitats located seaward of the toe of fill would be indirectly impacted during equilibration time frame, which is expected to occur over a 12 month time frame. Burial depths during the adjustment period will vary. Studies reported by Maurer (National Research Council, 1995) supported the burial capabilities of nearshore species, which found that these species were capable of burrowing through sand up to 40 cm. As described above, the resilient nature of the infaunal species will limit the indirect impacts. Recolonization of these infaunal species typically tends to occur within the order of several months. Softbottom communities may also change with natural shifting patterns of sediment erosion or deposition (Deaton et al., 2010). It should be reiterated that the material placed over the softbottom habitat meets the State's sediment criteria language and is therefore considered to be compatible with the native sediment.

As described in Alternative 3, the results from an infaunal monitoring following the Bogue Inlet Channel Relocation Project revealed that colonization of opportunistic species within the dredging footprint occurred immediately after construction ceased, and subsequently followed a predictive succession of changes over time. The results demonstrated that all diversity index values were considerably reduced at the main ebb habitat 1-year post-construction. However, the disturbance was considered abated as diversity subsequently increased by two-years post-construction and continued to increase by three-years post-construction (Carter and Floyd, 2008). The inferences from this study can be applied to this proposed project as the areas to be dredged are similar in physical nature.

As discussed in Chapter 3, the dredging within Nixon Channel and the connector channel will remove a net volume of 994,400cy based on the April 2006 survey conditions. The net removal of this volume of material combined with the volume changes in the inlet complex over the 5-year Delft3D simulation would leave a net deficit of approximately 224,500 cubic yards of material in the sound areas immediately behind Rich Inlet relative to baseline conditions at year 0 for Alternative 2. Despite this sediment deficit, infaunal communities would be expected to repopulate the benthos.

Cumulative Impacts: Alternative 5A is expected to undergo the indirect impacts discussed above each time a maintenance event occurs which is projected to be once every five (5) years, or a maximum of six (6) separate events over the 30-year study period. With a minimum five years between any maintenance events within Nixon Channel and the connector channel, softbottom communities should have sufficient time to recover as described in the indirect impacts above. This is due to the resilient nature of the constituents of softbottom habitat and the time it takes for full recovery.

The fishery resources using the inlet complex for foraging would be affected during, and immediately after, each maintenance dredging event. It is uncertain what the magnitude and severity of removing the softbottom community would be on the feeding behaviors of migrating fish. However, the presence of adjacent softbottom communities within the ebb tide delta and in undisturbed within the inlet complex would continue to provide a food source. These other foraging habitat areas, along with winter-time dredging, will help in reducing the magnitude and severity of any cumulative effects. Therefore, cumulative impacts should be kept to a minimum.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts: Although no natural hardbottom communities have been observed within the Permit Area, it is anticipated that the construction of the terminal groin may provide an artificial hardbottom habitat. The physical structure of the proposed groin is expected to create habitat which may provide a foraging site and shelter for fishes, including bluefish, in the surf zone (Hay and Sutherland, 1988). Juvenile black sea bass, for example, use a variety of man-made habitats including artificial reefs, shipwrecks, bridge abutments, piers, pilings, jetties, groins, submerged pipes and culverts, navigation aids, anchorages, rip-rap barriers, fish and lobster traps, and rough bottom along the sides of navigation channels (NOAA, 2007b). Although this may be beneficial to some species, Chapman and Bulleri (2003) have concluded that creating rocky habitat has led to the introduction of non-native invasive species within the vicinity of a hard structure. These structures are often associated with higher fish abundances and species richness than in other surf zone communities (Peters and Nelson 1987; Clark et al. 1996). Some functions associated with hardbottom communities are anticipated with the construction of the terminal groin.

WATER QUALITY

Turbidity and TSS

Direct and Indirect Impacts: The direct impacts with regards to turbidity and TSS would be expected to be similar as those described for Alternatives 3 and 4. The dredging within Nixon Channel and the connector channel will result in the suspension of silt and fine fractions in the water column. Although this occurs, the duration of suspended particulates and turbidity for these projects are generally short-lived. During a 2001 monitoring effort, measurements for turbidity and TSS levels returned to ambient conditions rapidly soon after dredging ceased. For the higher silt/clay content within the dredging footprint of Rich Inlet, the material will be deposited within an existing confined disposal island. The material will be discharged within the diked island and the silts/clays will settle prior to the effluent being returned to open water. Effects from the increase of turbidity and TSS could impair fish that are present during the time of operations. However, any potential impact is expected to be short-term due to the time of dredging and beach nourishing (when biological activity is at its lowest), the content of the material being dredged, documented measurements from similar projects, type of dredge plant, and the ability of fish to avoid higher concentrated areas.

Cumulative Impacts: Dredging within Nixon Channel and the connector channel along with the beach fill activities are anticipated to occur at a maximum once every five (5) years, which could total up to six (6) separate events over the 30-year study period. Each maintenance event will take approximately eight (8) weeks to complete, pending weather and working conditions. After each dredging, there will be adjustment within the -11.43 to -

13.34 foot NAVD channel and in-filling is expected within months. The adjustment or equilibration period of infilling may increase turbidity and/or TSS levels, but should not exceed dredging levels. Also, it should be acknowledged that levels can increase dramatically during times of storms. With a maintenance interval scheduled for approximately every five (5) years, a total of up to six (6) maintenance events could occur over the 30-year study period. Any negative effects from a single maintenance event is not expected to affect subsequent events due to the documented short-term nature of impacts. Based on this and the factors stated above, no cumulative impacts regarding suspended particulates and turbidity are expected.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: The average tidal prism for Alternative 5A was essentially the same as the baseline conditions represented in year 0 of Alternative 2, as was the distribution of flow through Nixon and Green Channels. Therefore, Alternative 5A would not cause any change in the existing hydrodynamics of Rich Inlet including salinity levels. It is known that the natural conditions within a tidal inlet are highly dynamic and that the tidal prism may become altered as conditions change. Following the dredging of Nixon Channel and the connector channel into the inlet gorge, the hydrology within the inlet complex will also be altered from its current state, however by year 5 of the simulated model run, the flow through Nixon Channel for Alternative 5A was 5% greater than what is indicated for the baseline conditions. Furthermore, the minor changes to the tidal prism in Nixon Channel due to construction of Alternative 5A are generally smaller than those of Alternative 3 due to the smaller dredge cuts. These relatively small changes in tidal prism will allow for the tidal exchange to continue within Rich Inlet, Nixon Channel, and Green Channel thereby maintaining the existing state of hydrodynamic and salinity (see Chapter 3 for more detail). Any migrational effects on fishery resources from this change is expected to be non-appreciable.

Larval Transport

Direct, Indirect, and Cumulative Impacts: Perpendicular coastal structures, particularly long jetties, can potentially interfere with the passage of larvae and early juvenile fish, such as bluefish, from offshore spawning grounds into estuarine nursery areas. Successful transport of larvae from fish spawning on the continental shelf through the inlet is dependent on along-shore transport processes which occur within a narrow zone parallel to the shoreline (Blanton et al. 1999; Churchill et al. 1999; Hare et al. 1999). Obstacles such as jetties adjacent to inlets may block the natural passage for larvae into inlets and reduce recruitment success (Kapolnai, et al. 1996; Churchill et al. 1997; Blanton et al. 1999). Miller (1992) and Settle (NMFS, unpub. data), estimated that successful passage of winter-spawned, estuarine-dependent larvae through Oregon Inlet could be reduced 60-100% while reviewing the potential impacts of a previously proposed dual jetty system at Oregon Inlet, which would be a structure bordering both sides of an inlet.

The 2001 Fish and Wildlife Coordination Act Report concluded that the Oregon Inlet project should not be constructed because of, among other concerns, the impact of jetties on larval fish passage (USACE, 1999). Although there are conflicting opinions on the magnitude of fisheries impacts of a dual jetty system at Oregon Inlet, it was postulated that the construction of the Oregon Inlet structures could prevent some portion of ocean-spawned larvae from reaching estuarine nursery areas (USACE, 1999). Construction or lengthening of jetties, particularly where inlets occur infrequently along the coast (such as Oregon Inlet), could lower successful fish recruitment and fishery productivity (Kapolnai et al. 1996; Churchill et al. 1997; Blanton et al. 1999).

Limited research is available to determine the long-term consequences of terminal groins on larval transport and recruitment and the process of larval transport through inlets. The most relevant and recent research is presented in the Terminal Groin Study, Final Report, prepared by Moffatt & Nichol in March of 2010 for the Coastal Resource Commission. The report concludes "In terms of larval transport, a terminal groin may reduce unrestricted access into inlet systems" (NCDENR, 2010). However, the report also states "As noted in the Physical Assessment Section, once a beach protrudes to near the end of the structure, either by natural longshore transport or through beach nourishment, wave processes transport sand around and over the groins into the tidal inlet. The same sand by-passing action would also affect the by-pass of estuarine dependent larval forms" (NCDENR, 2010).

More recently, a numerical modeling effort was conducted by Olsen Associates, Inc. examining the potential impacts to tidal hydraulics and transport of fish larvae in response to the construction of a terminal groin. The effort also modeled a beach fill only alternative for comparison. The groin structure is planned at Bald Head Island along the north side of the Cape Fear River Inlet, or the mouth of the Cape Fear River, south of Wilmington. Using the Delft3D particle tracking model, it was determined that a terminal groin at that location would have no far-reaching effects on the tidal hydraulics of the inlet; consequently, resulting in non-appreciable impacts to larval transport and no appreciable limiting influence on the ability of particles (i.e. hypothetical larval fish) to enter the estuary. Differences in tidal flows were shown to be minor and localized within the general vicinity of the structure. These predicted minimal alterations to tidal flows were not expected to meaningfully hamper the ability of fish larvae to reach the inlet from the nearshore waters proximate to Bald Head (Olsen Associates, Inc. 2012). Although inlet conditions vary between Rich Inlet and Cape Fear River Inlet, the terminal groin structure at Figure Eight Island is expected to have similar non-appreciable effects on larval transport. The structure at Rich Inlet will be approximately 700 linear feet seaward of the April 2007 mean high tide line, leaving 900 linear feet as a landward anchor. The length of the groin, along with the accompanying fillet and downshore beach fill, will minimally protrude into the nearshore larval transport zone. This is also depicted in the Delft3D bathymetry modeling results presented in Appendix B.

As described in Chapter 3, the fillet of the terminal groin will be artificially filled with beach compatible material immediately following construction which will effectively extend the dry beach shoreline seaward approaching the end of the terminal groin. Therefore, unlike the concerns associated with the previously proposed approximate 2,500 linear foot dual jetties at Oregon Inlet, the proposed single terminal groin a Figure Eight Island would not act as a direct impediment to longshore transport of larvae into the inlet. Once the beach protrudes to near the end of the structure, either by natural longshore transport or through beach nourishment, wave processes transport sand around and over the groin into the tidal inlet. The same sand by-passing action would also resemble the by-pass of estuarine dependent larval forms thereby reducing any impacts to bluefish and other species. In this regard, fish and other motile organisms will be expected to pass by the structure as they migrate along the shoreline which is expected to extend near the seaward terminus of the groin.

Research of larval transport at Beaufort Inlet North Carolina conducted by Forward et al. (1999) assessed whether larvae used selective tidal stream transport for ingress through the inlet and for movement into the estuary. If larvae entered the estuary equally (number per m^3) in all areas, then the percentage of total larval abundance should be equal (33%) at the three sampling sites in the Beaufort Inlet (East side, Center, West side). For Atlantic menhaden, spot and pinfish, the percentage of larvae collected on the East side of the inlet in the middle of the flood tide at night ranged from 64 to 92%. The flounder species were slightly lower with the percentage collected on the East side ranging from 40 to 67%. Thus, these species predominately entered the Beaufort Inlet on the East Side. The exception to this situation was Atlantic croaker larvae, which had the greatest percentage (54 to 56%) collected at the center of the inlet (Forward, et al., 1999). Rich inlet, with a longshore current from north to south, would likely have similar larval transport for ingress through the inlet with the greatest numbers entering the inlet from the north side. Therefore, with the terminal groin positioned on the south side of the inlet, in conjunction with the above described minimal protrusion of the terminal groin, the impact to larval transport into Rich Inlet is expected to be minimal.

It should be noted that the construction of the terminal groin under the 2006 erosive conditions would result in 700 linear feet of the structure's footprint being below the MHW line without the installation of the fillet. With the fillet in place, the structure would expect to be less.. Therefore, the structure and the accompanying fillet would have minimal interaction with larvae in the water. Should the shoreline recede in subsequent years, the fillet that would form and be maintained along the south side of the groin would extend to the seaward extent of the structure. In this regard, larvae would not be anticipated to interact with the groin and therefore impacts would not be expected.

The periodic dredging and beach fill operations associated with Alternative 5A are not anticipated to significantly impact larval transport into Rich Inlet. Furthermore, should the groin be constructed while the shoreline condition on the north end of Figure Eight Island includes a large dry beach as it appears in 2014, the seaward end of structure would terminate prior to reaching the ocean. As such, the groin and the fillet would not interact with larval transport. Additionally, as discussed in the Turbidity and TSS section above, levels are expected to be lower or similar to natural conditions and any suspended particulates would settle out of the water column rapidly. This should not have any appreciable effects on larvae migrating through the inlet complex.

Along with larval and juvenile fish, the structure has the potential to interfere with adult fish. Fish, including mullet that migrate over the nearshore softbottom habitat, may be impeded when they encounter the terminal groin. A study conducted at Murrells Inlet examined the movement of fish and plankton across the weir jetty (Knott et al., 1984). These data suggest that few swimming organisms were moving across the weir during the study. Further evidence supporting the hypothesis that the weir is a barrier to free swimming species came from visual observations. Visible schools of fishes, including menhaden and mullet, were never observed passing directly over the weir. The crest of the weir remained visible at the surface of the water even at high tide, and its location was marked by the turbulence from passing waves (USACE, 1981). Although the jetty at Murrells Inlet acted as a barrier for fish migration, the physical nature of the proposed structure at Figure Eight Island is not a jetty construction design and is much shorter in length. Furthermore, the accretion fillet is expected to fill seaward and would therefore reduce the exposed area of the groin. In this regard, fish and other motile organisms will be expected to pass by the structure as they migrate along the shoreline which is expected to extend near the seaward terminus of the groin. Therefore, migrating fish may be only minimally impacted by the presence of the terminal groin. Following consultation with the NMFS's Habitat Conservation Division, it was determined that the proposed terminal groin would not

PUBLIC SAFETY

Direct, Indirect, and Cumulative Impacts: During the construction of Alternative 5A, construction hazards will increase due to the usage of heavy machinery within Nixon Channel and along the oceanfront shoreline of Figure Eight Island during beach nourishment activities and the construction of the terminal groin. Safety precautions, such as access restriction and use of USCG navigation rules will be undertaken to reduce this risk. Also, construction will take place within the dredging window of November 16th through March 31st when public use, both in-water and on the beach, of Nixon Channel, Green Channel, Rich Inlet, and Hutaff Island is at its lowest peak. After the initial construction and beach fill, maintenance dredging and nourishment events could occur up to once every five (5) years, and up to a maximum of six (6) separate events over the 30-year study period. For Figure Eight Island, the implementation of Alternative 5A will alleviate the erosional pressure along of the northern 3.8 km (2.4 mi) of the ocean shoreline on Figure Eight Island and the 0.4 km (.26 mi) of along the Nixon Channel shoreline thereby providing long-term protection for the nineteen (19) oceanfront and one soundside structure that are threatened. Without the threat of these homes being damaged or demolished, public safety should increase due to the avoidance of hazardous conditions caused by continued erosion including the exposure of utilities and leaking septic tanks. Furthermore, the sandbags, which could pose a public safety hazard due to their size and orientation to the eroded shoreline, may be removed through mechanical means and replaced with a nourished beach tapered from a developed dune ridge.

The proposed crest elevation of the groin will be below the existing topography along the landward portion of the structure. Along the seaward portion, the crest elevation will be at or below +6 feet NAVD which is the natural elevation of the beach berm near Rich Inlet. While most of the structure will be below ground level, the seaward 300 feet to 400 feet could be periodically exposed in response to antecedent wave and tide conditions. The relatively short seaward length of the structure would not pose a safety hazard to boaters. Also, with most of the structure below or less than a foot above ground level, the structure would not pose a safety hazard to pedestrians. No public safety hazards are anticipated in proximity to Hutaff Island.

AESTHETIC RESOURCES

Direct Impacts: Temporary impacts to aesthetic resources will result from the implementation of Alternative 5A due to the usage of heavy machinery within Rich Inlet and on the oceanfront shoreline of Figure Eight Island due to the construction of the terminal groin and the dredge and beach fill operation. This activity would generally take place over a 3-4 month period, but would occur during the winter months when the majority of the residence and/or guests are not present on the island and use of surrounding waterways are at their lowest. Following completion of the construction phase of Alternative 5A, the aesthetic resources will be as they were prior to construction with the exception of the terminal groin at the northern portion of Figure Eight Island. The landward portion of the terminal groin would include a design with the sheet pile primarily below the existing ground elevation limiting impacts to the aesthetics. Any material removed to construct the foundation of the terminal groin will be back filled with some of the material used to cover the structure. Also, the area disturbed by the construction activities will be restored to near pre-construction conditions by grading and planting of native plants. As a result, portions of the rubble mound structure, in particular the most seaward 400 feet, would be visible particularly following certain wave and tide conditions. This may result in long-term disruptive vistas for the northern Figure Eight Island residents and/or those visiting that end of the island for an unobstructive view of the inlet area. The terminal groin and the dredge and fill operation will occur during the winter months when the number of residents on the island are at their lowest. Therefore, while the aesthetic resources may be temporarily impacted, less people will notice the disruption. The north end of Figure Eight Island south of the terminal groin is expected to become stable enough to allow the removal of the sandbag revetments. The removal of the sandbags along the northern portion of Figure Eight Island will improve the aesthetic quality of the island.

Indirect and Cumulative Impacts: Indirect and cumulative impacts will occur due to the anticipated on-going maintenance of Nixon Channel along with the placement of dredged material on Figure Eight Island. These events will occur at a maximum once every five (5) years and up to six (6) separate beach maintenance events over the 30-year study period.

Due to the length of time in between maintenance events, cumulative effects are expected to be minimal with the implementation of Alternative 5A.

RECREATIONAL RESOURCES

Direct Impacts: Figure Eight Island is a private island with limited public access. General public access is restricted to boat access only. However, the shorelines and shoals of Nixon Channel, Green Channel, Rich Inlet, and the northern spit of Figure Eight Island are heavily used by the general public, especially during the summer months (see Table 4.14). The recreational opportunities along the ocean shoreline are primarily utilized by the private homeowners and guests to the island. Recreational opportunities such as beachcombing, sunbathing, surfing, fishing, and walking along the beach will be temporarily impacted during the construction activities associated with Alternative 5A. However, all construction activities will be limited to working within a window when recreational use is at its lowest during the year. Even during construction, complete access will not be restricted in these areas. The beach fill along 1,400 linear feet of the Nixon Channel shoreline will immediately create a wider dry beach for the boaters and other recreational use. Some exposed shoals that could be used for anchoring boats and sunbathing will be removed by dredging the connector channel to a depth of -11.43 to -13.43 feet NAVD.

After completion of the structure, there may be some minor impediment for walking the beach, or access to, along the northern tip of Figure Eight Island. Portions of the rubble mound structure are projected to be approximately 1-3 feet above the beach grade and could hinder access for certain persons.

Indirect and Cumulative Impacts: Following construction, recreational resources are expected to benefit from Alternative 5A due to the increased size and extent of the oceanfront nourished beach and the nourished shoreline of Nixon Channel. Along the terminal groin, fin fish will likely be attracted to rubble structures due to their increased structural complexity which provides shelter from predators (Hay and Sutherland, 1988). The presence of fish along the terminal groin may increase recreational fishing opportunities resulting in beneficial uses. Macroalgae and sessile invertebrates including sponges and tunicates will also utilize the structure as habitat. The flora and fauna will provide snorkeling opportunities along the length of the structure as well. With the deepening of Nixon and connector channels, recreational boating is expected to increase, but should level off as the channels reform overtime to the original depths. Boaters utilizing the intertidal areas for recreational opportunities will be limited to use the existing shoals and flats which would initially be reduced following the excavation of the connector channel. Once these areas undergo some reform, however, the extent of the recreational opportunities upon these areas will increase. With the potential of maintenance events, this expected cycle of use would continue before and after each event for the life of the project. Due to the anticipated erosion along the northern portion of Figure Eight Island coupled with accretion on the southern portion of Hutaff Island, some recreational opportunities may increase on Hutaff and decrease on Figure Eight Island. Within the 30-year study period, recreational resources are expected to be maintained with overall minimal changes.

NAVIGATION

Direct and Indirect Impacts: For Alternative 5A, the initial construction including the deepening of the connector channel followed by periodic maintenance dredging in Nixon Channel will benefit navigation due to a maintained depth created by on-going dredging activities. The initial dredging depth of the connector channel will be approximately -11.43 to -13.43 feet NAVD. During the dredging, however, navigation will be temporarily directly impacted due to the presence of pipelines within Nixon Channel and the connector channel. At no time will complete restriction of navigation occur in Nixon Channel during dredge operations. There will be some minor negative impacts to navigation in Nixon Channel due to the presence of barges used to transport the stone for construction of the terminal groin. The barges would be moored in relatively deep water next to an offloading pier. Restrictions will be determined by the USCG and will be limited to the areas where the dredge and the pipelines are located. These restrictions will be imposed during every maintenance event, which is scheduled approximately every five (5) years.

Cumulative Impacts: Following the dredging of Nixon Channel and the connector channel, Delft3D modeling results suggest that the entrance of Rich Inlet will behave in a similar manner to natural conditions over the next 5 years. The dredged area will be expected to shoal, however they will remain navigable in between maintenance events. The terminal groin will be clearly visible; therefore it should not pose a threat to boats. Any recommended markings on the terminal groin as suggested by the US Coast Guard will be implemented to assure the safety of vessels. Following the construction of Alternative 5A, boaters should find navigation within the back side of Figure Eight Island and the newly constructed connector channel easier to navigate after initial dredging and after each maintenance event, which is anticipated to occur at a minimum every five (5) years. Therefore, navigation is expected to be positive over the long-term. As stated earlier, maintenance dredging within Nixon Channel and the connector channel would occur approximately once every five (5) years and up to six (6) separate occurrences over the 30 year study period. Whether maintenance would occur or not within these two channels, historic hydrodynamics within the ebb tide delta has not resulted in closing or prohibiting boat usage. It is anticipated that navigational use would only improve if maintenance events occurred once every five years (5) over the 30-year period. Therefore, navigation would be expected to be maintained throughout the entire inlet complex as a result of Alternative 5A.

INFRASTRUCTURE

Direct, Indirect, and Cumulative Impacts: As described previously, Dr. Cleary's assessment of Rich Inlet indicated that when the bar channel is orientated toward Figure Eight Island, the north end of the island tends to accrete whereas when the channel is aligned toward Hutaff Island, the north end of Figure Eight Island erodes. Under

Alternative 5A, the main ocean bar channel would continue to naturally migrate to the north or south. Currently, the bar channel is positioned in a favorable orientation leading to beneficial accretion on the north end of Figure Eight Island since about 2010.

Alternative 5A is expected to benefit the infrastructure on Figure Eight Island due to the short-term and long-term protection from erosion. The beach nourishment plan in Alternative 5A would include the use of approximately 907,700 cubic yards of material as beach fill along 12,250 linear feet of the Figure Eight Island shoreline. This would serve to protect the homes and infrastructure along the oceanfront shoreline of the island from the intersection of Beach Road and Beachbay Lane to the location of the terminal groin. The width of the oceanfront dry beach will vary along the length of the 12,250 foot fill area. Furthermore, the installation of the terminal groin will result in a wider beach within the accretion fillet which will protect the infrastructure as well. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be 106 feet based off 2006 conditions. The remaining areas will vary between 106 to 40 feet wide. In addition, the alternative includes a small fill area comprised of 57,000 cubic yards spanning 1,400 feet along the Nixon Channel shoreline near the north end of Beach Road resulting in the creation of a 50-foot beach berm. These two locations will be renourished at a minimum every five (5) years over the 30-year study period.

SOLID WASTE

Direct, Indirect, and Cumulative Impacts: This alternative will provide protection along portions of Figure Eight Island thereby decreasing the risk of damage to residential buildings and infrastructure. This would alleviate the potential of increased amount of solid waste through demolition. Implementation of Alternative 5A is expected to benefit the pubic by not contributing to additional solid waste.

NOISE POLLUTION

Direct Impacts: The dredging of the Nixon Channel and the connector channel, the placement of beach compatible material on the oceanfront and estuarine shoreline, and construction of the terminal groin would temporarily raise the noise level in the areas due to the use of heavy machinery. Total time of construction for Alternative 5A is estimated to be approximately 4.5 months. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. The noise pollution would be short-term since the equipment would be constantly relocating as work moves down the beach. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. Also, dredging and beach placement would occur during times when residents and visitors are less likely to be present.

Indirect and Cumulative Impacts: No indirect or cumulative impacts pertaining to noise pollution are anticipated with Alternative 5A due to the low frequency of beach nourishment events and the time of year.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: Implementation of Alternative 5A is expected to benefit the local economy of New Hanover County. If the historic erosion rates were to continue, based upon the periodic shifting of the bar channel, the damage or destruction of imminently threatened homes would decrease the local tax revenue on Figure Eight Island. As depicted in Table 5.23, the average annual equivalent cost for constructing and maintaining Alternative 5A would be $1,890,000 for 2006 conditions. Over the 30-year planning period, the total implementation cost for Alternative 5A in current dollars would be $43.68 million, based upon the 2006 conditions.

Table 5.23 Summary of Average Annual Economic Impact of Alternative 5A

	Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
2006 Conditions	$0	$0	$1,890,000	$1,890,000

No structures or buildable lots are expected to be lost under Alternative 5A, but again, repetitive storm damage could eventually lead to the demolition of some of the threatened structures. The protection of the homes and infrastructure is expected to provide a short and long-term benefit on the economy.

F. IMPACTS ASSOCIATED WITH ALTERNATIVE 5B: TERMINAL GROIN WITH BEACH FILL FROM NIXON CHANNEL AND OTHER SOURCES

For Alternative 5B, the terminal groin would have the same design as that described for Alternative 5A as well as the beach fill along Nixon Channel as described in Alternatives 3, 4, and 5A. The oceanfront nourishment footprint for Alternative 5B would differ from previous alternatives and encompasses a shorter placement distance, which extends approximately 4,250 linear feet from the terminal groin south to baseline station 60+00. Maintenance events would be scheduled every five (5) years over the 30-year study period.

The material to construct the beach fills for Alternative 5B would be derived from maintenance of the previously permitted area in Nixon Channel. The three northern disposal areas situated adjacent to the AIWW would provide a supplemental source of beach nourishment material. These disposal islands would be used in the event that shoaling of the Nixon Channel permit area does not provide enough material to maintain the beach south of the terminal groin or if it is needed to respond to damages associated with coastal storms. Alternative 5B would not include a new channel connecting Nixon Channel to the inlet gorge.

The initial beach fill for Alternative 5B, which would be constructed to a crest elevation of 1.8 m (6.0 ft.) NAVD, would be limited to the area between stations 60+00 and 100+00 (terminal groin). In this regard, the area between the terminal groin and station 80+00, which lies within the estimated limits of the accretion fillet that would form next to the terminal groin, would be pre-filled by placing material at a rate of 80 cubic yards/linear foot. This would widen the entire fillet area by an average of approximately 69 feet. South of station 80+00, the placement rate would be reduced to 20 cubic yards/linear foot to station 70+00 and then transition to 0 cubic yards/linear foot at station 60+00. Table 3.7 in Chapter 3 provides a summary of the placement rates and design berm widths for Alternative 5B.

The total volume of beach fill along the ocean shoreline would be 197,500 cubic yards. The Nixon Channel beach fill would require 57,000 cubic yards bringing the total beach fill volume to 254,500 cubic yards.

ESTUARINE HABITATS

Salt Marsh Communities

Direct Impacts: Temporary impacts during the construction of the groin for Alternative 5B are expected to be the same as those described for Alternative 5A. During construction of the terminal groin at Figure Eight Island, a 600-foot by 50-foot (or 0.7 acre) salt marsh area located within the designated working corridor on the northern tip of Figure Eight Island will be temporarily impacted by the use of heavy machinery. Impacts include using the corridor as a travelway for transporting equipment and materials and with the direct installation of sheet pilings for the groin structure. For Alternative 5B, the affects from construction and travel within this habitat and the implemented precautionary measures to reduce impacts will be the same as those described in Alternative 5A. As mentioned under Alternative 5A, the construction of the offloading dock or pier to be used for transporting building material, such as the rock and possible sheet piling, onto the site will constructed in a manner to minimize any direct impacts to the ephemeral salt marsh near the anchor section along Nixon Channel shoreline. The placement will avoid these resources if possible and will be elevated to reduce any potential impact from shading.

Salt marsh communities are present in proximity to the three disposal islands located along the AIWW, as previously described in Chapter 4. Like Alternative 4, extraction of beach fill material from these sites are not expected to have any impact on these marsh resources. This is due to the utilization of proper construction practices for stabilization and preventive measures, such as silt fencing, that would be utilized to protect these resources.

In addition, the fill placed along Nixon Channel terminates south of the small tidal creek that serves to feed the area of high marsh along the northern end of Figure Eight Island. As such, no significant adverse impacts are anticipated to this high marsh area.

Although primary nursery areas (PNAs) are located within the Permit Area, no PNA will be directly impacted by beach fill activity. PNAs are generally defined as being located in the upper portions of creeks and bays. These are usually shallow areas with soft, muddy bottoms surrounded by marshes and wetlands. Low salinity and the abundance of food in these areas are ideal for young fish and shellfish. The 1,400 foot section of estuarine shoreline along Nixon Channel where beach fill is proposed for Alternatives 5B is characterized by high salinity water with a sandy bottom.

Indirect Impacts: As described for Alternative 5A, there were some concerns with Alternative 5B that the terminal groin could impede groundwater flow and cause "mounding" of water on one side of the structure. As described by Nat Wilson, a hydrologist with NCDENR's Groundwater Management Branch of the Water Resources Management Section, "ground water flow on a barrier island tends to be towards the ocean and ICWW or sound from the center of the island -- perpendicular to the length of the island. The shallow ground water moves down a gradient from highest head beneath the topographic highs towards the ocean and ICWW" (Wilson, pers. comm.) (Figure 5.39). Because the structure is oriented in basically the same direction as the ground water flow, the water should continue to move relatively unimpeded and therefore not cause indirect impacts to the functionality of the coastal wetlands adjacent to the shore anchorage section. Also similar to Alternative 5A, the top of the sheet pile anchor through the salt marsh for Alternative 5B will be below grade as to not interfere or disrupt tidal exchange.

Because Alternative 5B does not involve dredging the connector channel from Nixon Channel to the inlet gorge, flow within Nixon Channel will not be adjusted from its current alignment along its southern bank to the middle of the channel. Therefore, the erosional stress along the salt marsh near the north end of Beach Road (see Chapter 3) will be expected to continue along with the development of salt marsh just further east. However, the placement of 57,000 cubic yards of beach fill will be expected to reduce the potential for the erosion of the salt marsh in this area. The fill placed along Nixon Channel terminates south of the creek that serves to feed the area of high marsh along this northern end of Figure Eight Island. As such, no significant adverse impacts are anticipated to this high marsh area.

As discussed for Alternative 5A, the evaluation of the Amelia Island project provides a cursory review of the unlikelihood that the terminal groin will affect the surrounding salt marsh complexes. Like Alternative 5A, some assurances are given that the indirect impacts to the salt marsh communities in response to the construction of the terminal groin are not expected under Alternative 5B.

For the disposal island, no secondary impacts to salt marsh resources are anticipated for Alternative 5B. This is due to the preventive measures that will be taken to decrease the potential for erosion and to the strategic location and placement of any outfall structure that will direct the effluent away from marsh areas.

Cumulative Impacts: Alternative 5B includes the maintenance of the previously permitted area in Nixon Channel at a maximum once every five (5) years with this material used to nourish the Nixon Channel shoreline and Figure Eight Island oceanfront. Within the 30-year study period, the dredging and beach fill maintenance event could occur up to six (6) separate times. If the material from the dredged disposal islands are not used during the initial beach construction, the three islands may be incorporated in future maintenance events contingent on needs. Structural maintenance of the shore anchorage portion of the terminal groin is not anticipated, and maintenance of the rubblemound portion should be minimal based on the documented performance of both the Fort Macon and Pea Island terminal groins. Any necessary maintenance activity for the terminal groin is expected to take advantage of using non-salt marsh areas, or uplands, as a travelway to transport equipment and materials. If access into the marsh areas is required, the same measures described in Alternative 5A, using a narrow/limited corridor and mats, will be implemented. Maintenance of the structure is not expected to have any cumulative impacts on the salt marsh on the north end of Figure Eight Island. Additionally, no cumulative impacts to the salt marshes are expected because the deepening of Nixon Channel and associated renourishment of the Nixon Channel shoreline is expected to reduce erosion pressure in proximity to salt marsh resources. It should also be noted that the subject salt marsh community area and tidal finger at this location appear to experience transitional periods of not having salt marsh, making the determination for salt marsh cumulative impacts in this area difficult. This can be observed in a November 30, 1989 aerial photo. Cumulative impacts to other salt marsh communities within the permit area are not expected for Alternative 5B.

Submerged Aquatic Vegetation

Direct and Indirect Impacts: As discussed previously, SAV resources are found away from the throat of Rich Inlet in areas that are protected from naturally induced changes in water quality such as turbidity and TSS. Dredging within Nixon Channel are predicted to cause a short term increase in turbidity and TSS levels during construction operations; however it is expected that the levels will remain within the State standard of 25 NTUs as shown in Cleary and Knierim's 2001 report and Bogue Inlet Project, as described under Alternative 3 and 5A.

Since dredging within Nixon Channel is not expected to significantly alter the tidal flow through the inlet, the salinity within the permit area is expected to maintain its existing condition and therefore SAVs are not anticipated to be impacted by a change in salinity (see Appendix B). Should the dredged material disposal sites be utilized under Alternative 5B, SAVs would not be expected to be impacted due to the utilization of proper construction methods, including silt fencing. This would reduce the likelihood of impacts associated with the burial of SAV resources. In addition, dredging will occur during the dredging window between November 16th and March 31st, which is when biological activity is low and SAV resources are less abundant within the Permit Area. Therefore, there are no anticipated SAV impacts for Alternative 5B due to changes in water quality.

Cumulative Effects: Similar to Alternatives 4 and 5A, cumulative impacts to SAV under Alternative 5B are not expected.

Shellfish Habitat

Direct and Indirect Impacts: The dredging of material from Nixon Channel is predicted to cause a short term increase in turbidity and TSS. Due to the low silt percentage of material found within Nixon Channel, the turbidity levels are expected to remain below the state standard outside the immediate area of dredging.

As stated above for SAV resources, there are also potential shellfish beds within proximity to the three disposal islands that could be used as a contingency borrow site. Should these sites be utilized, proper construction methods, such as silt fencing and placement location of pipes, will be implemented to reduce any potential direct or indirect affects to these shellfish resources. Additionally, dredging would occur within the confined disposal island and this would reduce the likelihood of impacts associated with the burial of shellfish beds.

Cumulative Effects: As described previously for Alternatives 4 and 5A, cumulative impacts to shellfish habitat under Alternative 5B are not expected.

UPLAND HAMMOCK

Direct, Indirect, and Cumulative Impacts: Upland hammocks within the permit area may be threatened by potential sea level rise overtime. According to the International Panel on Climate Change, global mean sea level rose at an average rate of about 1.7 ± 0.5 mm/year during the twentieth century (IPCC, 2007). Recent climate research has documented global warming during the twentieth century, and has predicted either continued or accelerated global warming for the twenty-first century and possibly beyond (IPCC, 2007). This rate, which is difficult to predict, is anticipated to increase over the next 100 years. Rahmstorf (2007) predicts that global sea level in 2100 may rise 0.5 m (1.6 ft.) to 1.4 m (4.6 ft.) above the 1990 level. If any rise is validated, the increase in sea level could result in potential cumulative impacts to coastal upland hammocks present in the permit area.

The upland hammocks present atop of the AIWW dredge disposal islands that could be utilized as a contingency for the nourishment activities associated with Alternative 5B would be removed during excavation of the islands. Some colonial waterbirds such as green herons and yellow-crowned night herons utilize vegetated, upland environments similar to those present on the dredge disposal islands. These three colonial waterbird groups prefer trees, shrubs, and grass lands for nesting and, as a result, may utilize the upland hammocks identified within the Permit Area. It would be expected that these birds would relocate to other proximate upland hammocks that line the AIWW. Impacts to upland hammocks under Alternative 5A are expected to be non-appreciable.

INLET DUNES AND DRY BEACHES

(<u>NOTE</u>: In the discussion for these habitat types at the terminal groin location, we have defined the south side of the structure as the "oceanfront" and the northern side as "inlet")

Direct Impacts: Under the 2006 shoreline conditions, approximately 0-5 acres of direct impacts are expected in inlet dunes, dry beaches, and overwash habitats on Figure Eight

Island with the implementation of Alternative 5B. No direct impacts will take place within these inlet habitat types on Hutaff Island or in overwash habitat areas on either of the islands under this alternative. Similar to those described for Alternative 5A, the impact area includes portions of the construction corridor, the footprint of the terminal groin, and the placement of dredge material along the shoreline of Nixon Channel. The impacts associated with the beach fill and the construction corridor would be considered temporary while the impacts associated with the footprint of the terminal groin would be permanent. The direct impacts associated with the construction corridor and the footprint of the terminal groin within the inlet dunes and dry beaches will encompass approximately 0.6 and 0.1 acres, respectively. Work consists of excavating the inlet dune area both on the Nixon Channel side and the oceanside in order to install the rubble/rock material for the structure. Once the structure is in place, the excavated dune material will be placed over the rock groin and reformed to pre-construction conditions to the maximum extent possible. The dune areas will be sand fenced and vegetated to restore and stabilize the inlet dunes. Biological resources such as resting shorebirds will be displaced during the construction, but it is expected that the adjacent and surrounding dune habitat on Figure Eight and Hutaff Islands can support those resources while work activity is undertaken for Alternative 5B. The installation of the groin structure along the inlet dry beach area, which is adjacent to the inlet dune, is likely to directly remove any seabeach amaranth vegetation, via excavation, that would be in its dormant stage. As shown in Chapter 4, a population of these plant species have been inventoried in the vicinity of the structures footprint & construction corridor.

The placement of 57,000 cubic yards along the Nixon Channel shoreline, which encompasses approximately 1.2 acres of newly created inlet dry beach, will cover a small portion of the native dry beach. This area has and continues to experience high erosion rates and contains approximately 0.6 acres of inlet dry beaches. The expansion of this shoreline footprint will have the same beneficial effect to shorebirds as discussed in Alternatives 3, 4, and 5A.

As stated under Alternative 5A, turtle nest locations were documented in 2003 and 2004 within proximity of the proposed terminal groin construction corridor and footprint. The construction and design of the structure for Alternative 5B has the same potential to affect sea turtle nesting capabilities as described in Alternative 5A. Construction activities associated with Alternative 5B will not coincide with sea turtle nesting season.

Although direct impacts would occur to inlet dry beach on the Figure Eight side of the inlet, no significant adverse impacts are anticipated within those habitats on the Hutaff side. Any negative impacts to the inlet dry beach is expected to be offset with the expansion of the adjacent oceanfront dry beach on the south side of the structure. This oceanfront dry beach will be constructed with the use of compatible beach material and should minimize any direct impacts within inlet dry beaches under Alternative 5B.

As stated under Alternative 5A, any piping plovers present within the permit area would be temporarily disturbed by the noise associated with the nearby staging, storage, and transportation of equipment, materials, supplies, and workers on the beach in support of project construction which is scheduled to occur between November 16 and March 31. Bulldozers may be used to achieve the design height and berm width for the proposed beach fill sections, and additional heavy machinery will be utilized to construct the terminal groin. Furthermore, rocks that will be used to construct the rubble mound portion of the groin will be stockpiled in an area adjacent to the groin. This would likely cause piping plovers within the area to seek out and use alternative habitat areas outside of the influence of project activity. The presence and operation of this equipment may also directly injure or kill the birds if not previously spotted, or force them to alter their normal feeding or roosting behavior. Noise associated with the construction – such as operation of heavy machinery and pile driving - may stress the piping plovers by causing them to spend more time responding to the disturbance than foraging and resting, or force them to vacate the area. Any piping plovers utilizing the sand spit at the north end of Figure Eight Island may also be disturbed by noise associated with construction activities. With the potential for during construction impacts to shorebirds, it is expected that the winter work timeframe, the availability of other supporting dry beach habitat (totally approximately 215 acres) in the inlet, and the adaptability of the shorebirds will help in reducing those effects. Due to the distance from the project activities, any plovers within these areas will not likely be directly impacted by project activity.

Indirect Impacts: The construction corridor for Alternative 5B will be kept open for an undetermined amount of time for any unseen maintenance or potential for structure removal. If the structure remains, it is expected that the landward portions of the terminal groin will become covered in sand and possibly vegetated while the seaward most 300 to 400 feet of the structure could be periodically exposed depending of antecedent sea and weather conditions. As stated under Alternative 5A, due to the fact that much of the groin would be covered in sand and not extend far into open water, bypassing of littoral sediment around Rich Inlet would be expected to continue to occur and could result in the redevelopment of the Figure Eight Island spit over time allowing for natural resources including seabeach amaranth to continue to persist in this area. See Alternative 5A for additional discussion on the future maintenance of the terminal groin.

When using the 2006 shoreline conditions, the results of the Delft3D 5-year simulation showed that less than half of the sand spit located north of the terminal groin on Figure Eight Island remained at the end of Year 5. Much like Alternative 5A, most of the spit had morphed into a intertidal and subtidal habitat. The loss of approximately 15 acres of inlet dry beaches and inlet dunes in this area would result in a loss of resting and nesting habitat for shorebirds, including critical habitat for the endangered piping plover. This loss includes the approximately 0.8 acres of inlet dry beach that was initially created with the fill placement along the Nixon Channel shoreline. Like Alternative 5A, it is expected that some of the sediment eroding from the oceanfront beach fill will continue to be transported into the inlet at some undetermined rate over the 5-year simulation period. However, the approximate 197,500 cubic yards of oceanfront fill for Alternative 5B is expected to provide only a minimal influx of material into the inlet. At the end of Year 5, the remaining spit area on the north side of the terminal groin was estimated to be approximately 3.7 acres.

For piping plover, this area of the island is designated as critical habitat under Unit NC-11 and is a significant area for the recovery of the bird's population. The reduction of Unit NC-11 within the Figure Eight Island spit is expected to limit piping plover's use within the 5-year modeling period under 2006 shoreline conditions.

Under Alternative 5B, the southern 2,640 feet of Hutaff Island accreted at a rate of 72,000 cubic yards/year (see Figures 5.28 through 5.33). The spit on the south end of Hutaff Island propagated south during the first three years of the model simulation and then stabilized. At the end of year 5, the spit at Hutaff Island had gained approximately 12 acres of inlet dry beach and overwash habitat which would expand Critical Habitat Unit NC-11 for piping plover and benefit the bird's resting and nesting ability. Because Hutaff Island is unpopulated and access is restricted by boats only, the increased habitat on the southern tip of the island is valuable for resting, nesting, and foraging wildlife.

Even though the newly formed inlet dunes, dry beach and overwash areas are shown on Hutaff Island, it doesn't appear to fully compensate for the loss on the northern portion of Figure Eight Island. In total, a net loss of approximately 0-5 acres of these habitat types are expected within the 5-year simulation as a result of the implementation of Alternative 5B.

Cumulative Impacts: Alternative 5B includes maintenance of the beach fill segments every 5 years resulting in a maximum of 6 events over the course of the 30-year project. It is expected that some of the beach fill will continue to migrate into the inlet after each event, but the amount is not anticipated to have an appreciable benefit to the sustaining of inlet dry beach and overwash habitat within the Figure Eight Island spit. Long-term impacts to inlet dry beaches and overwash areas, including the shorebirds that utilize them, are expected within the inlet complex under Alternative 5B. However, the extent of those impacts are unknown. After the initial post-construction effects on the north side of the terminal groin equilibrate, it is anticipated that the presence of inlet dry beach and overwash habitat will be largely dictated by the migration and position of the inlet bar channel over the 30-year study period. Continued periodic nourishment of the north end of Figure Eight Island should result in the continuation of some sediment transport past the terminal groin and into Rich Inlet. This should mitigate for some of the additional loss of inlet dry sand beach and inlet dune habitat and could eventually result in the recreation of a portion of the sand spit on the north end of Figure Eight Island.

INTERTIDAL FLATS AND SHOALS

(NOTE: In the discussion for these habitat types at the terminal groin location, we have defined the south side of the structure as the "oceanfront" and the northern side as "inlet")

Direct Impacts: The dredging area associated with Alternative 5B does not include intertidal flat and shoal habitat, therefore, no direct impacts will occur. The groin and beach nourishment construction activity may stress shorebirds, including the endangered piping plover, from foraging along the intertidal flats that are located close to the construction area. However, as shown with the channel relocation project in New River Inlet discussed in Alternative 3 and 5A, during-construction bird monitoring revealed continual bird use of the inlet resources as dredging and inlet beach activity was in operation. As with that project, construction for Alternative 5B will take place between November 16th and March 31st when some migratory bird species are not present and bird populations are at their lowest.

The use of mechanical equipment will be restricted within a specific construction corridor for the construction of the terminal groin which should help in reducing any potential stresses on the birds that may be foraging and/or resting in the area. In addition, these birds would be expected to temporarily relocate to available nearby intertidal flats and shoals on the north side of the inlet. It is also anticipated that any stress levels from land and/or in-water construction, which will be limited to a specific area, will be non-appreciable based on the during-construction monitoring results for New River Inlet and Bogue Inlet projects as discussed in "Inlet dunes and Dry Beaches" and in Alternative 3. The bird species in Rich Inlet, which are the same species found in New River and Bogue Inlets, are expected to adjust and adapt to the presence of construction equipment and noise, and are expected to continue to inhabit the inlet complex throughout the entire construction period of Alternative 5C. Direct impacts to shorebirds utilizing these habitats should be minimal under Alternative 5B.

Indirect Impacts: For Alternative 5B, the direct removal of approximately 254,500 cubic yards of material from Nixon Channel will result in a sediment deficit within the inlet complex system and, in turn, cause a direct impact to foraging shorebirds including piping plover. This deficit would also reduce the amount of Unit NC-11 critical habitat for piping plover within this portion of Rich Inlet. Although 57,000 cubic yards of material will be placed along the adjacent Nixon Channel shoreline, the majority of the amount (197,500 cubic yards) will be pumped onto the oceanfront shoreline for the construction of the terminal groin accretion fillet and beach fill. Note, the difference between the total volume of material needed for the beach fills and the volume to be excavated is due to tolerances allowed for both the excavation and fills.

The dredged area within Nixon Channel is anticipated to shoal in at a relatively constant rate over the five-year period between maintenance events. Although the Delft3D model was simulated for Alternative 5B to assess shoreline changes, the model was not utilized to assess the volumes of erosion and deposition within discrete cells within the inlet complex. This exercise, however, was performed for Alternative 5D which included the same dredging area within Nixon Channel as Alternative 5B. The only difference between the two alternatives is that Alternative 5B includes a groin design located 420 feet south and contains a slightly longer structure. As such, the results from Alternative 5D could be used as a proxy for Alternative 5B. As described for Alternative 5D and illustrated in Figure 5.55, the overall net change in volume compared to the baseline conditions of Alternative 2 was a decrease of 449,700 cubic yards. Out of this amount, 289,500 cubic yards was artificially removed by dredging from the previously permitted area in Nixon Channel. This leaves a 160,200 cubic yard net loss from the inlet complex, which, in relative terms, would be a similar deficit for Alternative 5B over a 5-year period. Again, the accuracy of the model volume changes are ±10,000 cubic yards within each discrete area. The largest volume decrease was measured in the offshore bar directly seaward of the inlet throat. But, losses were also noted within the flood tide delta, or middle shoal, and along the Figure Eight shoulder of the inlet. These two locations exhibit an abundance of intertidal flats and shoal habitat areas where foraging and roosting of piping plover have been documented by Audubon NC bird surveys. With this projected overall net decrease in the 5-year simulated period, there may be less inlet flats and/or shoals than pre-construction conditions.

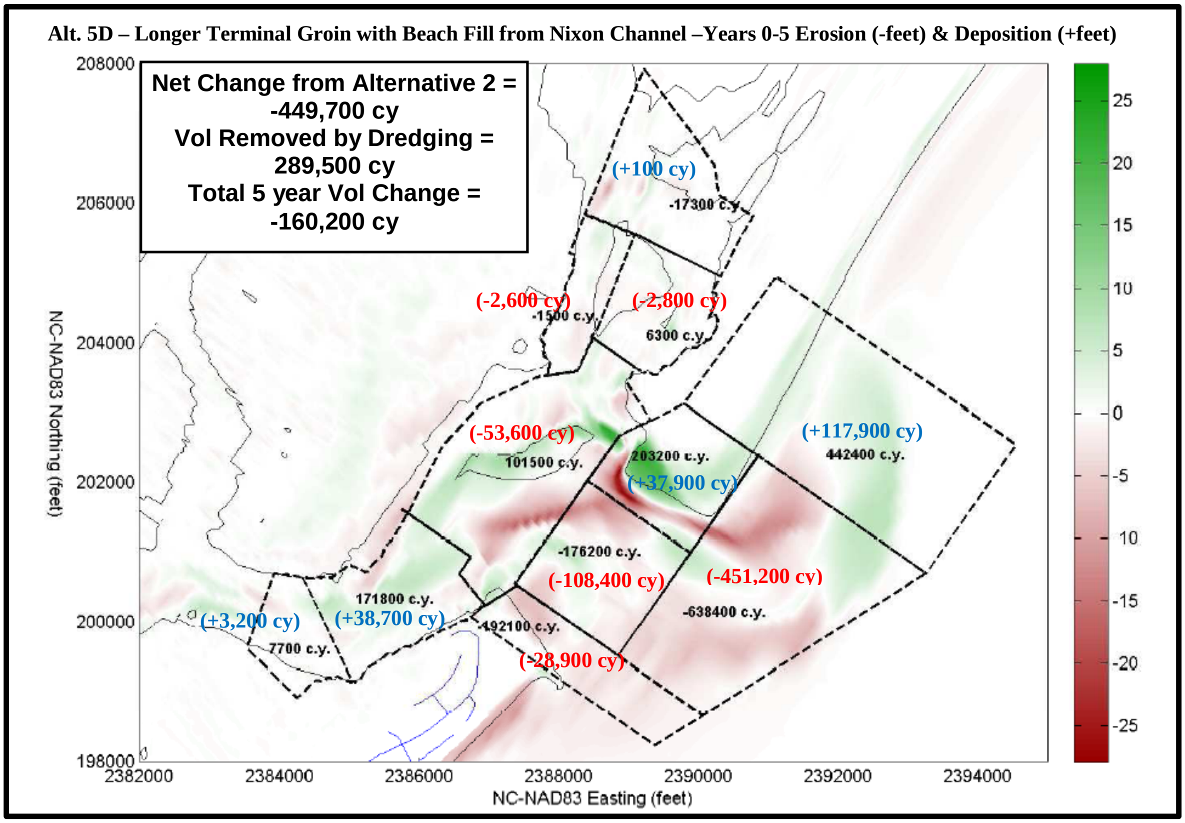

Figure 5.55. Modeled volume changes in discrete areas within the Permit Area for Alternative 5D (Applicable for Alternative 5B). Values in blue and red indicate an increase or decrease in material volume, respectively, compared to the baseline conditions shown in Alternative 2.

The overall effects of the initial sediment deficit on intertidal flats and shoal habitats within the inlet is not known for Alternative 5B. However, as described in Alternative 5A, one can reference the 23-year old terminal groin in Oregon Inlet to obtain a general understanding of impacts to these areas around the groin structure and to what effects it has on shorebirds, especially piping plover (see Intertidal Flats and Shoals under Alternative 5A for more information). It can be expected that the sediment deficit under Alternative 5B would potentially reduce the amount of material available for intertidal flats and shoal redevelopment within the inlet complex. This could potentially affect piping plover, and other shorebirds, as well as fishery resources that utilize these shoals for foraging. In addition, many boaters who utilize the shoals as an area to anchor and recreate could be impacted as a result in the reduction of intertidal habitat located within the inlet. In response, boaters may flush out and disturb the migratory birds utilizing the limited habitat for foraging.

As previously stated, some of the Figure Eight Island sand spit located north of the terminal groin remained at the end of Year 5 of the Delft3D simulation. However, most of the dry beach and overwash area within the spit had morphed into intertidal and subtidal habitats. The initial stability of the dry beach and overwash in the sand spit appeared to be associated with material eroded from the beach fill south of the terminal groin passing over and around the terminal groin. The model indicated relatively high rates of sediment loss from the oceanfront fill during the first 3 years of the simulation with this eroded material being transported past the terminal groin and onto the sand spit. The influx of this sediment should initially reduce the rate of dry beach and overwash conversion to intertidal and submerged flats and shoals on the Figure Eight Island spit. But after the third year, the conversion would increase and produce approximately 4-5 acres of intertidal flats and shoal habitats which would help to maintain some of the piping plover foraging areas located in the critical habitat unit.

Despite the potential changes, the intertidal flats and shoals within the inlet complex are expected to continue to exist under the 2006 shoreline conditions with the implementation of Alternative 5B. Deltf3D model results suggest that shoaling increased in some locations and decreased in others. Specifically, the intertidal shoals in proximity to the area dredged within Nixon Channel and along the ebb tide delta were initially reduced. The reduction of these resources in proximity to Nixon Channel could be attributed to material in-filling the newly dredged area. For Rich Inlet, intertidal flats and shoal habitat are a valuable feeding resource for both migrating and residential bird and fish species. With a net deficit in sediment volumes over a 5-year period, this habitat may not recover to pre-construction conditions and could potentially affect the feeding behavior of the bird and fish species utilizing them. Like Alternative 5A, the magnitude and extent of impacts would be contingent on how quickly intertidal flats and shoals will reform or shift elsewhere for Alternative 5B. As mentioned, it is anticipated that some material of the formed accretion fillet and beach fill will continue to be transported long-term through sand bypassing the structure back into the inlet as demonstrated in the volume modeling results and through observations of other terminal groins structures such as Pea Island and Fort Macon. This may help minimize any decrease of habitat size or amounts. Since Alternative 5B proposes a maintenance event every five years, it should provide an influx of sediment into the inlet by transporting through and around the groin. These factors should assist in reducing any long-term impacts on many species and piping plover critical habitat.

Delft3D model results from Alternative 5B suggests the tidal prism could decreased by an amount similar to that indicated by the Delft3D model results for the baseline conditions of Alternative 2. With the tidal prism remaining relatively unchanged after dredging and the installation of the groin structure, sediment movement and distribution within the 5-year simulation will be minimally affected within the inlet which should not impact the development and redevelopment of intertidal flats and shoals.

Cumulative Impacts: For Alternative 5B, the Delft3D shoreline modeling under the 2006 conditions has shown the need for beach renourishment once every 5 years with the material coming from the previously permitted area in Nixon Channel. This could potentially total up to 6 individual maintenance events within the 30-year study period. Each maintenance episode is expected to impact intertidal flats and shoal habitat as described in the indirect impact assessment above. One exception would be the north side of the terminal groin where no additional conversion to the habitat is expected. However, this inlet side of the groin structure is expected to be periodically fed by sediment transporting from the oceanfront after each renourishment event as demonstrated in the volume modeling results and through observations of other terminal groins structures such as Pea Island and Fort Macon. The intertidal flats and shoals in the inlet are not fixed stationary habitats, but are considered to be ephemeral and dynamic; consequently, bird resources are known to adjust to these changes.

The additional dredging of ~300,000 cubic yards of sediment in Nixon Channel every 5 years, if needed, is expected to result in a minor deficit, but it is unknown to what extent that would cumulatively have on the development and redevelopment of intertidal flats and/or shoals. In turn, fish and shorebird populations utilizing intertidal flat and shoal resources within the inlet complex may be cumulatively impacted due to the slight sediment deficit in the inlet which could limit the formation of intertidal flats and shoals. The magnitude and extent of cumulative impacts would be contingent on how quickly intertidal flats and shoals will reform or shift elsewhere. After the initial post-construction effects on the north side of the terminal groin equilibrate, it is anticipated that the presence of intertidal flat and shoal habitats will be largely dictated by the migration and position of the inlet bar channel over the 30-year study period.

In addition, many boaters utilize the shoals as an area to anchor and recreate. Without extensive shoals, boaters may flush out and disturb the migratory birds utilizing the habitat for foraging. During peak summer months, it can be expected that any available shoals would be used since Rich Inlet area is known to experience a continuous high volume of boaters and people in the summer.

OCEANFRONT DRY BEACH AND DUNE HABITATS

(<u>NOTE</u>: In the discussion for these habitat types at the terminal groin location, we have defined the south side of the structure as the "oceanfront" and the northern side as "inlet")

<u>*Oceanfront Dune Communities*</u>

Direct and Indirect Impacts: The placement of approximately 254,500 cubic yards of beach compatible material along Figure Eight Island is expected to help stabilize the dune system and provide long term storm protection. Although the construction of dunes is not a part of the plan for Alternative 5B, the beach fill is intended to provide direct and indirect benefits to the coastal dune communities as it allows for growth and development of dune vegetation thereby providing habitat for roosting, foraging and nesting shorebirds. On Hutaff Island, approximately 0.3 acres of coastal dune communities are expected to be indirectly affected by the implementation of Alternative 5B within the first year following construction, as concluded by the Delft3D modeling effort. This 0.3 acres of impact is considered to be negligible due to the compensation occurring with beach nourishment along Figure Eight Island to help stabilize the dune system and provide short and long-term storm protection within the 5-year simulation. In general, only minimal negative impacts are anticipated to the oceanfront dune communities within the Permit Area.

Cumulative Impacts: Like all the alternatives, the orientation of the inlet bar channel has been proven to play an important role regarding shoreline erosion rates along the oceanfront of Figure Eight and Hutaff Islands. When the inlet channel is positioned in a southerly orientation, the oceanfront dunes on Figure Eight Island would be expected to persist or increase in size while the contrary would be expected on the southern oceanfront shoreline on Hutaff Island. The opposite is true for both islands when the bar channel is located in a more northerly position. Currently, the inlet bar channel appears to be shifting from the south to a more central location; and if the shifting continues northward, the oceanfront of Figure Eight Island is anticipated to undergo erosive conditions affecting oceanfront dunes while Hutaff's oceanfront experiences accretion.

The implementation of Alternative 5B includes a renourishment cycle of a maximum once every five (5) years, which includes the placement of approximately 285,000 cys of material along the northern section of Figure Eight Island (255,000 along the ocean front shoreline and 30,000 along the Nixon Channel shoreline). Over the 30-year study period, the renourishment or maintenance could occur up to six (6) separate events. Consequently, the project will serve to provide long-term protection of the dunes on Figure Eight Island and should benefit any resources using that habitat. The magnitude and extent of the protection would depend largely of the position of the inlet bar channel. No cumulative impacts are anticipated as the direct impacts as described above are expected to be temporary in nature. Although overwashing of dunes can result in the formation of important habitat for a variety of shorebirds, the dunes along Figure Eight Island are located in front of residential development and therefore overwashing events would not provide this effect.

The dune communities located on Hutaff Island would be expected to migrate westward as natural processes influence the environment, but the dune communities are expected to remain intact. Also, the south tip of Hutaff Island could grow and project farther south into Rich Inlet creating additional dry sand beach an opportunities for natural dune development. However, if the predicted increased rates of sea level rise is validated, the long term viability of dunes within the permit could be impacted as the potential of detrimental storm surge could increase.

Oceanfront Dry Beach Communities

Direct Impacts: Fill placement associated with Alternative 5B would include the placement of dry beach habitat along the oceanfront shoreline from 322 Beach Road North to the terminal groin located along the northern portion of the ocean shoreline of Figure Eight Island. Direct impacts to the dry beach will be incurred during the initial fill placement and the construction of the terminal groin. The impacts associated with the construction of the terminal groin were described previously under the inlet dunes and dry beach section above. The fill placement area would encompass approximately 10-15 acres of dry beach habitat including the burial of approximately 10 acres of existing dry beach. Alternative 5A would include the placement of approximately 4 additional acres of dry beach along the oceanfront on Figure Eight Island.

The effects of the groin construction to the dry beach habitat will initially reduce available nesting habitat for sea turtles and shorebirds, including the piping plover, and cover seabeach amaranth; however, the increased beach width as a result of nourishment will compensate for this impact. The width of the oceanfront dry beach immediately following construction will vary along the length of the fill area between 80 feet in proximity to the terminal groin to 20 feet at station 70+00 based on 2006 conditions. The development of the fillet area closest to the structure would create a dry beach habitat that could be used by shorebirds, especially in light of the reduction of inlet dry beach and overwash areas on the north, or inlet, side of the terminal groin. This dry beach will encompass approximately 5 acres of potential habitat use.

The direct effects of the beach fill activity within the oceanfront dry beach community for Alternative 5B will be similar to that of Alternatives 3, 4, and 5A. The physical characteristics of the dry beach are highly critical for sea turtle nesting success and the composition of the fill material for Alternative 5B is expected to be compatible with the current native sediment. Reference the discussion in Alternative 3 and 5A regarding the benefits and potential detriments of beach nourishment in oceanfront dry beach habitat for nesting turtles.

Indirect Impacts: Like Alternative 5A, the Delft3D 5-year model simulation for Alternative 5B indicated erosion is expected to occur on the north side of the terminal groin potentially affecting the habitat for nesting turtles, seabeach amaranth, and shorebirds. The placement location of the groin structure is situated near the transition point from oceanfront dry beach to inlet dry beach habitats. Any potential affects to resources utilizing oceanfront dry beach on the north side of the structure is expected to be compensated by the development of this habitat on the south side of the groin. The increased area of dry beach on the south side of the groin as a result of nourishment as well as the retention of sediment within the accretion fillet will result in positive indirect impacts including the increased habitat for nesting sea turtles, resting and nesting shorebirds, and seabeach amaranth. The width of the oceanfront dry beach immediately following construction will vary along the length of the 4,250 foot fill area. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be increased by 69 feet. The width of dry sand beach south of station 80+00 will be increased by 17 feet. This area will become beneficial habitat for resting colonial waterbirds. Also, because the material utilized for the nourishment will meet State Sediment Criteria, the widened dry beach is expected to increase sea turtles nesting habitat.

The southern 2,640 feet of Hutaff Island accreted under Alternative 5B at a rate slightly greater than indicated for the baseline conditions reflected in Alternative 2. However, the difference in the accretion rates are deemed to not be significant. Farther north between stations 175+00 and 215+00, volume losses under Alternative 5B were essentially the same as Alternative 2. Any accretion in this area is expected to continue providing a stable oceanfront dry beach habitat for nesting turtles, shorebirds, and seabeach amaranth.

Simulation of Alternative 5B in the Delft3D model indicated the beach fill area (station 60+00 to the terminal groin) would lose an average of 51,000 cubic yards/year over the 5-year simulation period. As was the case for Alternative 5A, the segment south of station 60+00 to F90+00 was stable to accretionary with the area actually gaining material at a rate of 50,000 cubic yards/year. Beginning in year 4 of the simulation and continuing into year 5, erosion began to affect the pre-nourishment profile primarily north of station 80+00. Given these model results, periodic nourishment of the beach fill under Alternative 5B would be needed about every 5 years. Based on the model indicated loss rate of 51,000 cubic yards/year, the 5-year periodic nourishment requirement would be 255,000 cubic yards. While the volume changes mention above cover the entire active profile out to -24 feet NAVD, some of the fill placed above the -6-foot NAVD contour was still in place after 5 years. The retention of sediment above -6 feet NAVD would provide protection to the pre-nourished upland area. The net increase in dry beach habitat will benefit nesting sea turtles, seabeach amaranth, and shorebirds. Based on the bird surveys conducted by Audubon North Carolina, piping plover utilized this oceanfront of Hutaff mostly during the 2008-2010 survey period. The birds were mostly observed foraging, which would assumedly be along the wet beach but possibly using the dry beach for resting during foraging. The model revealed that most of the volume loss from this area was offshore and was associated with the reconfiguration of the north side of the ebb tide delta of Rich Inlet. The erosion along the oceanfront dry beach is not expected to interrupt the foraging and roosting behaviors of the piping plover

Hard structures such as terminal groins can indirectly affect nesting sea turtles and hatchlings. The structure for Alternative 5B will have the same potential affect as described in Alternative 5A. But with the constructed fillet extending close to the terminus of the 700 foot seaward component of the proposed terminal groin, the effects of the structure would be expected to be minimal to nesting sea turtles and emerging hatchlings.

Cumulative Impacts: With the maintenance of the oceanfront dry beach, habitat for resting colonial waterbirds, nesting shorebirds, seabeach amaranth, and nesting sea turtles is expected to be maintained long-term at the location of the terminal groin fillet for approximately 1,250 linear feet. The remaining 3,000 linear feet of the fill area would be maintained with supplemental beach renourishment cycles via maintenance dredging within Nixon Channel and possibly utilization of material from the upland dredge disposal islands. These renourishment events are expected to occur within a minimum of every five (5) years with a total of six maintenance events over the 30-year study period. Maintaining the dry beach along the oceanfront shoreline will help ensure that bird and sea turtle habitat will persist.

As with Alternative 5A, maintenance of the rubblemound portion of the terminal groin for Alternative 5B should be infrequent and would depend on the frequency of severe storms that exceed the design conditions for the armor stone. If maintenance of the rubblemound portion is needed, this could involve simply recovering and replacing displaced stones or adding stone to replace the ones that could not be located on site. Any maintenance work within the dry beach area would be restricted within a designated corridor in order to limit any potential impacts.

WET BEACH COMMUNITIES

Direct Impacts: The addition of beach fill to Figure Eight Island is expected to impact less than 5 acres of the wet beach community along the oceanfront shoreline and Nixon Channel shoreline, immediately burying the infaunal community. The construction of the terminal groin will permanently remove approximately 0.3 acres of wet beach habitat on the oceanfront side and the Nixon Channel side, causing the mortality of the infaunal community within its footprint as well. Once the beach fill is placed, approximately 10-15 acres of new wet beach habitat will be created resulting in no net change in wet beach acreage.

Although the wet beach infauna can adapt to fluctuations in the natural environment, the addition of sediment to the wet beach would have immediate yet short-term and minimal negative impacts to foraging fish and birds. Impacts to the wet beach communities, including the loss of prey (infaunal resources) for foraging fish and birds are expected to be similar to those described for Alternative 5A.

Indirect Impacts: For Alternative 5B, the Delft3D model results suggested that secondary impacts of less than 5 acres of marine intertidal habitat will occur along the ocean shoreline of Figure Eight Island while the fill placement equilibrates. This may affect shorebird, crustacean and fish foraging, and recreational fishing through a temporary reduction in bait species during and immediately after construction. Impacts should be reduced due to the fact that the material utilized for beach fill will be compatible with native material, thereby reducing the recovery period for infaunal communities. Indirect impacts and minimization to those impacts for oceanfront and Nixon Channel shoreline are similar to those described in Alternatives 3, 4, and 5A.

As discussed under Alternative 5A, the ability for infaunal species to repopulate disturbed wet beach habitat in proximity to a shoreline stabilizing structure was demonstrated following the construction of the rubble weir jetty structures at Murrells Inlet, South Carolina. The macrobenthic communities of the intertidal and nearshore subtidal environments were sampled during the construction of the jetties and once again five (5) years later. Comparison of species abundance between years and among localities (updrift and downdrift) suggested no widespread impacts to macrobenthic fauna were attributable to jetty construction (Knott et al, 1984). Although the physical conditions are not identical at both locations, a similar response would be anticipated following the construction of the terminal groin on Figure Eight Island.

Cumulative Impacts: As a result of the dredging and renourishment activity at a minimum every five (5) years, or six (6) separate events over the 30-year study period, negative effects could occur if the diversity and abundance of infaunal populations do not recover between nourishment events. However, organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels (Nelson, 1985). Alternative 5B is not expected to result in long-term cumulative impacts to wet beach habitat due to the adaptability of benthic communities, sufficient period between maintenance events for recovery, and the use of compatible material. This habitat will continue to provide foraging areas for small fish and bird species.

MARINE HABITATS

<u>*Softbottom Communities*</u>

Direct Impacts: The activities associated with Alternative 5B would result in a direct impact to approximately 25-30 acres of softbottom community within the dredging footprint in Nixon Channel and within the construction footprint of the terminal groin.

The dredging within Nixon Channel will take the current channel elevations to a depth of -11.4 ft. NAVD. This excavation will cause an immediate negative impact by removing infaunal and non-motile epibenthic organisms from the softbottom community. As described above for wet beach communities, the resilient nature of the infaunal species will limit the direct impacts. Recolonization of these infaunal species typically tends to occur within the order of several months, especially with the use of material that is compatible with native sediment and meets the State's sediment criteria rules. For the reasons explained in Alternative 5A, direct impacts should be minimized with the implementation of Alternative 5B.

For the 1,600-foot long structure, approximately 700 feet will extend seaward beyond the mean low water under the 2006 shoreline conditions. This section, which is 75-feet wide, will permanently cover approximately 1.2 acres of nearshore softbottom community. The anchor section of the rock structure will extend approximately 50 feet waterward of the mean low water in Nixon Channel and cover approximately 0.02 acres of softbottom habitat. An additional 0.06 acres would be temporarily impacted due to the utilization of the construction corridor. It is not known to what the full effects of this permanent covering will be on the fishery resource, but with the softbottom habitat surrounding the footprint of the structure for Alternative 5B, the fishery resource should be capable of locating food sources and foraging within nearby areas.

Indirect Impacts: Construction of the beach would result in the direct deposition of material from the sandbag revetments or the seaward toe of the existing dune seaward to the construction toe-of-fill. Over time, the slope of the fill would adjust and equilibrate seaward and consequently cover softbottom habitats located seaward of the toe of fill. Similar to Alternatives 3, 4, and 5A, the degree of infaunal mortality associated with the covering would be contingent on the amount of material and the rate of adjustment. Studies have shown that many infaunal organisms that utilize this softbottom habitat are capable of burrowing through sand up to 40 cm, and thus can survive being covered by limited amounts of material (National Research Council, 1995). Softbottom communities may also change with natural shifting patterns of sediment erosion or deposition (Deaton et al., 2010). It should be reiterated that the material placed over the softbottom habitat meets the State's sediment criteria language and is therefore considered to be compatible to the native sediment.

For Alternative 5B, the removal of material from the Nixon Channel borrow area would leave a net deficit of approximately 160,200 cubic yards of material from the inlet complex over the 5-year simulated period, which is further discussed in Chapter 3. Infaunal communities located within Nixon Channel and surrounding areas would be expected to repopulate the benthos despite the sediment deficit. As described under Alternatives 3 and 5A, the results from an infaunal monitoring following the Bogue Inlet Channel Relocation Project demonstrated the successional recolonization and continued increase of recovery overtime within an inlet complex that underwent extensive dredging. Reference the discussion in Alternative 3 for the findings and the verification of infaunal recovery in that monitoring.

Negative impacts to foraging fish and invertebrates include the temporary loss of prey from the dredged softbottom habitat within Nixon Channel and from the time period of adjustment for nearshore infaunal communities that are covered. For softbottom habitat permanently covered by the terminal groin footprint, this loss of potential foraging habitat is minimal due to the abundance of infaunal food source in the adjacent areas. The overall effects to fish feeding behavior is expected to be non-appreciable.

Additionally, fish, including mullet that migrate over the nearshore softbottom habitat, may be impeded when they encounter the terminal groin. Data from a study conducted at Murrells Inlet, SC suggested that few swimming organisms moved across the weir. Although the jetty at Murrells Inlet acted as a barrier for fish migration, the physical nature of the proposed structure at Figure Eight Island is much shorter in length. Furthermore, the accretion fillet is expected to fill seaward and would therefore reduce the exposed area of the groin. In this regard, fish and other motile organisms will be expected to pass by the structure as they migrate along the shoreline which is expected to extend near the seaward terminus of the groin. Therefore, migrating fish may be only minimally impacted by the presence of the terminal groin.

Cumulative Impacts: Alternative 5B is expected to undergo the indirect impacts discussed above each time a maintenance event occurs which is projected to be every five (5) years, equating to six (6) separate events over the 30-year study period. The nature of cumulative impacts for dredging and renourishement events are expected to be similar as those described for Alternatives 3,4, and 5A with the exception that the footprint of the fill area is considerably smaller and the magnitude of impacts is anticipated to be less. Like Alternative 5A, cumulative effects associated with the footprint of the structure are anticipated to be minimal.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts: Although no natural hardbottom communities have been observed within the Permit Area, it is anticipated that the construction of the terminal groin under Alternative 5B may provide an artificial hardbottom habitat. The physical structure of the proposed groin is expected to create habitat which may provide a foraging site and shelter for fishes, including bluefish, in the surf zone (Hay and Sutherland, 1988). These effects are expected to be the same as those described above under Alternative 5A.

WATER QUALITY

Turbidity and TSS

Direct and Indirect Impacts: With the implementation of Alternative 5B, the dredging within Nixon Channel and the placement of material on the oceanfront and estuarine shoreline will result in the suspension of silt and fine fractions in the water column, similar to that of Alternative 4. Although this occurs, the duration of suspended particulates and turbidity for these projects are generally short-lived. During a 2001 monitoring effort, measurements for turbidity and TSS were taken before, during, and after the dredging within Nixon Channel and the associated placement of beach fill along the oceanfront shoreline of Figure Eight Island. Results showed that both parameters increased at the point of discharge on the oceanfront shoreline, however, these values (44.0 mg/l and 301.0 mg/l for turbidity and TSS, respectively) returned to ambient conditions rapidly (Cleary and Knierim, 2001). The low sit/clay content of the material within the area being dredged should result in relatively low concentrations of suspended sediment outside the immediate area of deposition. The low concentration of suspended sediment indicates that turbidities are likely to remain low during dredging and placement of material on the beaches. Therefore, any negative impacts related to turbidity and TSS are expected to be short-term and similar to those discussed for Alternative 1. Natural conditions support fluctuating turbidity levels in the nearshore and offshore water column of the Permit Area and work under Alternative 5B is not expected to exceed natural conditions.

Cumulative Impacts: Dredging within Nixon Channel and the placement of beach fill activities are anticipated to occur at a maximum once every five (5) years, which could total up to six (6) separate maintenance events over the 30-year study period. Each maintenance event will take approximately eight (8) weeks to complete, pending weather and working conditions. After each dredging, the dredged are in Nixon Channel will begin to shoal with sediment transported into the area through Rich Inlet. The adjustment or equilibration period of infilling may increase turbidity and/or TSS levels, but should not exceed dredging levels. Also, it should be acknowledged that levels can increase dramatically during times of storms. Due to factors described above, no cumulative impacts regarding suspended particulates and turbidity are expected.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: Under Alternative 5B, the Delft3D model simulation displayed some change within the tidal prism over the 5-year period, but the results of that change were considered minor. The average tidal prism of Rich Inlet under Alternative 5B was 509.3 million cubic feet which was only 1.3% larger than the average tidal prism for the baseline conditions exhibited in Year 0 of Alternative 2. This relatively small difference is within the accuracy of the model and considered to be insignificant. Based on the modeling, Alternative 5B would not cause any change in the existing hydrodynamics or salinity levels of Rich Inlet. Flow distribution through Nixon and Green Channels was also basically the same as the baseline conditions, with Nixon Channel carrying 56.5% and Green Channel 34.7%. The relatively small difference in tidal prism and flow distribution will allow for the tidal exchange to continue within Rich Inlet, Nixon Channel, and Green Channel thereby maintaining baseline hydrodynamics and salinity levels. (see Chapter 3 for more detail). Any migrational affects to fishery resources from this change in the inlet is expected to be non-appreciable.

Larval Transport

Direct, Indirect, and Cumulative Impacts: There is potential for direct impacts to fish larvae within the water column under Alternative 5B during the dredging of Nixon Channel. Larvae could be entrained within the dredge while operating in the flood tide delta where fish larvae would be migrating. This potential forentrainment is low due to the time of year dredging and to the relatively small volume of water pumped through the dredge compared to the volume within the tidal prism See Alternative 5A for further discussion on direct impacts.

Like all the terminal groin alternatives, the structure of Alternative 5B has the short and long-term potential to interfere with the passage of larvae and early juvenile fish from offshore spawning grounds into estuarine nursery areas. These structures can disrupt along-shore transport processes within the narrow zone paralleling the shoreline which larvae are dependent upon. Restricting access into the estuarine habitat behind Figure Eight and Hutaff Island could affect certain fish species. Although research is limited on long-term terminal groin affects to larval transport, the following has been used in order to make the determination that Alternative 5B is not likely to have an effect: 1) reference to a numerical model for Bald Head Island terminal groin project, 2) larval transport entering from the north side, or Hutaff side, of Rich Inlet, 3) the fillet will extend to the end of the structure allowing sand by-passing to continue and allowing nearshore transport for larvae to enter into Rich Inlet, 4) minimal change to the tidal prism and inlet hydrodynamics, and 5) recent shoreline conditions have been such that the terminal groin could have been constructed in the dry, disclosing the fact that the structure would not protrude any further seaward than periods of natural conditions. For further description on these reasons, reference discussion in Alternative 5A larval transport.

Although the terminal groin is shown to have minimal changes to the inlet hydrodynamics, there is a potential that fish, including mullet that migrate along the nearshore oceanfront, may be impeded when they encounter the structure. This was shown at the jetty in Murrells Inlet, which is described under Alternative 5A. The potential for fish impediment is greatly lessened than that of the Murrells Inlet jetty due to the shorter length and design differences for the terminal groin under Alternative 5B. Furthermore, the accretion fillet is expected to fill seaward and would reduce the exposed area of the groin. As stated previously, the conditions of the shoreline from 2010-2012 period were as such that the terminal groin could almost be completely constructed shoreward, or beachward, of the mean high water line. In this regard, fish and other motile organisms will be expected to pass by the structure as they migrate along the shoreline which is expected to extend near the seaward terminus of the groin. Therefore, migrating fish may be only minimally impacted by the presence of the terminal groin. It should be noted that the construction of the terminal groin under the 2006 erosive conditions would result in 700 linear feet of the structure's footprint being below the MHW line without the installation of the fillet. With the fillet in place, the structure would expect to be less.. Therefore, the structure and the accompanying fillet would have minimal interaction with larvae in the water even if constructed during a period of erosive conditions.

PUBLIC SAFETY

Direct, Indirect, and Cumulative Impacts: During the initial and long-term maintenance construction of Alternative 5B, some hazards, both on land and in the water, will increase due to the usage of heavy machinery within the Permit Area during the dredge operation, beach nourishment, and the terminal groin construction. Safety precautions, such as access restriction and use of USCG navigation rules will be undertaken to reduce this risk. Also, construction will take place within the dredging window of November 16th through March 31st when public use, both in-water and on the beach, of Nixon Channel, Green Channel, Rich Inlet, and Hutaff Island is at its lowest peak. Effects on public safety for Alternative 5B are similar to those in Alternative 5A, and see Alternative 5A discussion for further details on impacts, precautionary measures, and potential benefits.

No public safety hazards are anticipated in proximity to Hutaff Island.

AESTHETIC RESOURCES

Direct Impacts: Temporary impacts to aesthetic resources will result from the implementation of Alternative 5B, similar to those described above for Alternative 5A, due to the usage of heavy machinery within Rich Inlet and on the oceanfront shoreline of Figure Eight Island due to the construction of the terminal groin and the dredge and beach fill operation. This activity would generally take place over a 3-4 month period, but would occur during the winter months when the majority of the residence and/or guests are not present on the island and use of surrounding waterways are at their lowest. The area disturbed by the construction activities will be restored to near pre-construction conditions by grading and planting of native plants. As a result, portions of the rubble mound structure, in particular the most seaward 400 feet, would be visible particularly following certain wave and tide conditions. The terminal groin and the dredge and fill operation will occur during the winter month when the number of residents on the island are at their lowest. Therefore, while the aesthetic resources may be temporarily impacted, less people will notice the disruption. The north end of Figure Eight Island south of the terminal groin is expected to become stable enough to allow the removal of the sandbag revetments. The removal of the sandbags along the northern portion of Figure Eight Island will improve the aesthetic quality of the island.

No impacts to the aesthetic resources are anticipated within proximity to Hutaff Island.

Indirect and Cumulative Impacts: Indirect and cumulative impacts will occur due to the anticipated on-going maintenance of Nixon Channel along with the placement of dredged material on Figure Eight Island. These events will occur no more than once every five (5) years, and this cycle could result up to a total of six (6) separate maintenance events over the 30-year study period. Due to the length of time in between maintenance events, cumulative effects for aesthetic resources are expected to be minimal.

RECREATIONAL RESOURCES

Direct Impacts: Impacts to recreational resources are anticipated to be minimal for Alternative 5B and similar to those discussed for Alternative 5A. The recreational opportunities along the ocean shoreline are primarily utilized by the private homeowners and guests to the island. Recreational opportunities will be temporarily impacted during the construction activities associated with Alternative 5B. However, all construction activities will be limited to working within a window when recreational use is at its lowest during the year. Even during construction, complete access will not be restricted in these areas. The beach fill along 1,400 linear feet of the Nixon Channel shoreline will immediately create a wider dry beach for the boaters and other recreational use.

After completion of the structure, there may be some minor impediment for walking the beach, or access to, along the northern tip of Figure Eight Island. The structure is projected to be approximately 1-3 feet above the beach grade and could hinder access for certain persons.

Indirect and Cumulative Impacts: Following construction, recreational resources are expected to benefit from Alternative 5B due to the increased size and extent of the oceanfront nourished beach and the nourished shoreline of Nixon Channel. Along the terminal groin, fin fish will likely be attracted to rubble structures due to their increased structural complexity which provides shelter from predators (Hay and Sutherland, 1988). The presence of fish along the terminal groin may increase recreational fishing opportunities resulting in beneficial uses. Macroalgae and sessile invertebrates including sponges and tunicates will also utilize the structure as habitat. The flora and fauna will provide snorkeling opportunities along the length of the structure as well. Due to the anticipated erosion along the northern portion of Figure Eight Island coupled with accretion on the southern portion of Hutaff Island, some recreational opportunities may increase on Hutaff and decrease on Figure Eight Island.

NAVIGATION

Direct Impacts: Navigation is anticipated to be improved within the surrounding waters of Rich Inlet with the implementation for Alternative 5B. Benefits to navigation are similar to those discussed for Alternative 5A, with the exception that the connector channel will not be dredged. The initial construction followed by periodic maintenance dredging in Nixon Channel will benefit navigation due to a maintained depth created by on-going dredging activities. During the dredging, however, navigation will be temporarily directly impacted due to the presence of pipelines within Nixon Channel. At no time will complete restriction of navigation occur in Nixon Channel during dredge operations. There will be some minor negative impacts to navigation in Nixon Channel due to the presence of barges used to transport the stone for construction of the terminal groin. Restrictions will be determined by the USCG and will be limited to the areas where the dredge and the pipelines are located. These restrictions will be imposed during every maintenance event, which is scheduled approximately every five (5) years.

Indirect and Cumulative Impacts: Following the dredging of Nixon Channel, Delft3D modeling results suggest that the entrance of Rich Inlet will behave in a similar manner to natural conditions over the next 5 years. The dredged area in Nixon Channel will be expected to shoal, however is expected to remain navigable in between maintenance events. The terminal groin will be clearly visible; therefore it should not pose a threat to boats. Any recommended markings on the terminal groin as suggested by the US Coast Guard will be implemented to ensure the safety of vessels. Following the construction of Alternative 5B, boaters should find navigation within the back side of Figure Eight Island easier to navigate after initial dredging and after each maintenance event, which is anticipated to occur at a minimum every five (5) years. This enhancement of navigation should continue over the 30-year study period. Therefore, navigation is expected to be positive over the long-term.

INFRASTRUCTURE

Direct, Indirect, and Cumulative Impacts: Alternative 5B is expected to benefit the infrastructure on Figure Eight Island due to the long-term protection from erosion. The beach nourishment plan included in Alternative 5B would include the use of approximately 197,500 cys of material as beach fill between stations 60+00 and 100+00 on Figure Eight Island's oceanfront shoreline and an additional 57,000 cys placed along the Nixon Channel shoreline. The width of the oceanfront dry beach will vary along the length of fill area while the Nixon Channel beach fill will result in the create of a 50-foot beach berm. Furthermore, the installation of the terminal groin will result in a wider beach within the accretion fillet which will protect the infrastructure as well. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be 69 feet based off 2006 shoreline conditions. The remaining areas will vary between 17 and 69 feet.

SOLID WASTE

Direct, Indirect, and Cumulative Impacts: Impacts to solid waste are anticipated to be similar to those discussed for Alternative 5A. This alternative will provide protection along portions of Figure Eight Island thereby decreasing the risk of damage to residential buildings and infrastructure. This would alleviate the potential of increased amount of solid waste through demolition.

NOISE POLLUTION

Direct Impacts, Indirect, and Cumulative Impacts: Impacts to noise pollution are anticipated to be minimal and similar to those discussed for Alternative 5A.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: Initial construction costs for the terminal groin would be $4,836,000 which is the same as Alternative 5A. The initial costs of the beach fills along the Nixon Channel and ocean shoreline using material from the Nixon Channel permit area would be $2,607,000 resulting in a total cost for initial construction (beach fills and terminal groin) of $7,443,000. No structures or land would be lost under Alternative 5B, but repetitive storm damage could eventually lead to the demolition of some of the threatened structures.

Over the 30-year planning period, the total cost for Alternative 5B in current dollars would be about $24.76 million. As depicted in Table 5.24, the average annual equivalent cost for constructing and maintaining Alternative 5B would be $1,056,000. Included in this annual cost is an average of $25,000 for maintenance of the terminal groin.

Table 5.24. Summary of Average Annual Economic Impact of Alternative 5B

	Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
2006 Conditions	$0	$0	$1,056,000	$1,056,000

G. IMPACTS ASSOCIATED WITH ALTERNATIVE 5C: TERMINAL GROIN AT A MORE NORTHERLY LOCATION WITH BEACH FILL FROM NIXON CHANNEL AND A NEW CONNECTOR CHANNEL

A 1,300-foot long terminal groin, with 305 feet being seaward of the 2007 MHW line, would be constructed at the extreme north end of Figure Eight Island to control both wave and tidal current induced shoreline changes immediately south of Rich Inlet (Figures 3.13a and 3.13b in Chapter 3). The 995-foot section landward of the MHW line would act as a shore anchor to protect against possible flanking of the landward end of the structure. The shore anchorage section would extend back from the 2007 MHW oceanfront shoreline and terminate near the Nixon Channel shoreline (Figure 3.13a in Chapter 3). The main difference between this option and Alternative 5A is that Alternative 5C will be located approximately 420 feet northward, or closer to the throat or gorge of Rich Inlet and will be approximately 395 linear feet shorter seaward of the MHW. The configuration also differs in the fact that the 995-foot section runs at a slight angle across the northern section of Figure Eight Island and turns slightly for the remaining 305 feet seaward of the MHW line.

Alternative 5C would include beach fill in the same two general areas and the same amount as Alternative 5A; one fronting Nixon Channel and a second covering the ocean shoreline from Beachbay Lane (F90+00) to the terminal groin located at station 105+00. Material used for beach nourishment will be obtained from dredging the previously permitted area in Nixon Channel to -11.4 ft. NAVD (the depth permitted in the past within that area) and a new connector channel, which would be dredged to -13.4 ft. NAVD. The purpose of the new channel connector is to concentrate ebb flows away from the eroding portion of the Nixon Channel shoreline. Construction of the new channel connector and reestablishing the previously permitted dimensions in Nixon Channel would require the excavation of 1,077,100 cubic yards of material and take approximately 4.5 months to construct. As stated in Appendix B, Delft3D modeling results suggest that erosion into the pre-construction beach face would be prevented along most of the fill area over 5 years. Therefore, it is anticipated that maintenance dredging would be conducted at a maximum of every five (5) years.

ESTUARINE HABITATS

Salt Marsh Communities

Direct Impacts: During construction of the terminal groin for Alternative 5C, work will directly be conducted within the salt marsh community located on the northern tip of Figure Eight Island. Like Alternative 5A and 5B, activity in this area involves the installation of sheet pilings at a depth of about 0.5 feet below grade and will be outside the boundary of the small tidal finger that feeds into Nixon Channel. However, unlike those alternatives, the structure's anchor in Alternative 5C would cross a shorter distance through the salt marsh. The designated working corridor used by heavy machinery in the salt marsh is approximately 303-foot by 50-foot (or 0.35 acre). Alternative 5C will implement the same precautionary and minimization measures to reduce salt marsh impacts on Figure Eight Island and along the perimeter of the Disposal Islands as described in Alternative 5A. As mentioned under Alternative 5A, the construction of the offloading dock or pier to be used for transporting building material, such as the rock and possible sheet piling, onto the site will constructed in a manner to minimize any direct impacts to the ephemeral salt marsh near the anchor section along Nixon Channel shoreline. The placement will avoid these resources if possible and will be elevated to reduce any potential impact from shading. Reference 5A for further discussion on these measures and description to direct impacts to salt marsh communities.

Although primary nursery areas (PNAs) are located within the Permit Area, no PNA will be directly impacted by beach fill activity. PNAs are generally defined as being located in the upper portions of creeks and bays. These are usually shallow areas with soft, muddy bottoms surrounded by marshes and wetlands. Low salinity and the abundance of food in these areas are ideal for young fish and shellfish. The 1,400 foot section of estuarine shoreline along Nixon Channel where beach fill is proposed for Alternatives 5C is characterized by high salinity water with a sandy bottom.

Indirect and Cumulative Impacts: Under Alternative 5C, the tidal exchange in and around the subsurface sheet piles are not expected to be interrupted or normal flow patterns impeded for the reasons described in Alternative 5A. Also as explained in Alternative 5A, structural maintenance of the terminal groin should be minimal and infrequent. Any necessary maintenance would use existing uplands or non-coastal wetlands for access to transport equipment and materials. If conditions were such that the salt marsh is to be used, the same measures outlined for the initial construction of the groin would be implemented to reduce impacts. For further explanation on indirect and cumulative effects associated with salt marsh communities associated with Alternative 5C, see Alternative 5A for discussion points for all areas within the inlet complex and disposal islands.

<u>Submerged Aquatic Vegetation</u>

Direct, Indirect, and Cumulative Impacts: As discussed previously, SAV resources are found away from the throat of Rich Inlet in areas that are protected from naturally induced changes in water quality such as turbidity and TSS. Dredging within Nixon Channel and the connector channel are predicted to cause a short term increase in turbidity and TSS levels during construction operations; however it is expected that the levels will remain within the State standard of 25 NTUs as shown in Cleary and Knierim’s 2001 report, as described under Alternative 5A.

Since dredging within Nixon Channel and the connector channel is not expected to significantly alter the tidal flow through the inlet, the salinity within the permit area is expected to maintain its existing condition and therefore SAVs are not anticipated to be impacted by a change in salinity (see Appendix B). Should the dredged disposal sites be utilized, SAVs would not be expected to be impacted due to the utilization of proper construction methods, including silt fencing. This would reduce the likelihood of impacts associated with the burial of SAV resources. In addition, dredging will occur during the dredging window between November 16th and March 31st, which is when biological activity is low and SAV resources are less abundant within the Permit Area. Therefore, there are no anticipated SAV impacts due to changes in water quality or potential habitat areas. Maintenance events, scheduled for every five (5) years during the 30-year study period, will be restricted to within the original dredge footprint and will occur during the winter months when SAV resources are biologically inactive. Cumulative impacts to SAV under Alternative 5C are not expected.

Shellfish Habitat

Direct, Indirect, and Cumulative Impacts: No shellfish beds are present within the footprint of the channels to be dredged. The dredging of material from Nixon Channel and the connector channel is predicted to cause a short term increase in turbidity and sedimentation levels. Potential impacts and implemented measures to minimize those impacts to shellfish habitat are the same as those described for Alternative 5A. Reference the discussion in Alternative 5A.

UPLAND HAMMOCK

Direct, Indirect, and Cumulative Impacts: Impacts to the upland hammocks for Alternative 5C are anticipated to be similar to those described for Alternative 5A which include the potential impacts associated with the disposal of incompatible material. Outside of natural effects from potential sea level rise, no project impacts to upland hammocks, including those habitats on the disposal islands, are anticipated with Alternative 5C. See Alternative 5A for additional details regarding upland hammocks.

INLET DUNES AND DRY BEACHES

(NOTE: In the discussion for these habitat types at the terminal groin location, we have defined the south side of the structure as the "oceanfront" and the northern side as "inlet". Under Alternative 5C, we acknowledge that this structure extends approximately 420 feet closer to the inlet than Alternatives 5A and 5B, and removes that area as inlet dunes and dry beaches for this alternative. See OCEANFRONT DRY BEACHES AND DUNES further below for discussion addressing the south side of the groin structure.)

Direct Impacts: Approximately 0-5 acres of direct impact to the inlet dunes and dry beaches on Figure Eight Island with the implementation of Alternative 5C are anticipated. Like Alternatives 5A and 5B, much of the direct impacts to these resources will occur with the installation and the footprint of the terminal groin structure. Alternative 5C will impact approximately 0.9 acres of inlet dunes and 0.2 acres of dry beach, which is an additional 0.3 acres more for dune habitat and 0.1 acres more for dry beach than Alternatives 5A and 5B. Work consists of excavating the inlet dune area both on the Nixon Channel side and the oceanside in order to install the rubble/rock material for the structure. Once the structure is in place, the excavated dune material will be placed over the rock groin and reformed to pre-construction conditions to the maximum extent possible. The direct impacts associated with the construction corridor would be considered temporary because it's expected that the elevations will remain the same and that any disrupted vegetation would return shortly after completion of the groin structure. The dune areas will be sand fenced and vegetated to restore and stabilize the inlet dunes. Biological resources such as resting shorebirds will be displaced during the construction, but it is expected that the adjacent and surrounding dune habitat on Figure Eight and Hutaff Islands can support those resources while work activity is undertaken. The installation of the groin structure along the inlet dry beach area, which is adjacent to the inlet dune, is likely to directly remove any seabeach amaranth vegetation, via excavation, that would be in its dormant stage. As shown in Chapter 4, a population of these plant species have been inventoried in the vicinity of the structures footprint & construction corridor

For Alternative 5C, the placement of 57,000 cubic yards along the Nixon Channel shoreline, which creates approximately 1.2 acres of dry beach, will cover a small portion of the native dry beach. This area has and continues to experience high erosion rates and contains approximately 0.6 acres of inlet dry beaches. Like Alternatives 3, 4, 5A, and 5B, the expansion of this shoreline footprint will increase the dry beach and provide additional resting, and potential nesting, habitat for shorebirds. See those alternatives for further details.

As shown in Chapter 4, turtle nests have been found on the oceanside along the northern end of Figure Eight Island. With the ten years of data (2001-2010), nest locations were documented in 2003 and 2004 within proximity of the terminal groin structure construction corridor and footprint. The construction and design of the structure has the potential to affect sea turtle nesting capabilities. Construction could result in compaction of the dry beach reducing the success for nesting; and the terminal groin is expected to be approximately 1-3 feet above surface elevation which would impede migration or crawling along the dry beach in the vicinity of the structure.

Any negative impacts to the inlet dry beach is expected to be offset with the expansion of the adjacent oceanfront dry beach on the south side of the structure. This oceanfront dry beach will be constructed with the use of compatible beach material and should minimize any direct impacts within inlet dry beaches. Although direct impacts would occur to inlet dry beach on the Figure Eight side of the inlet, no significant adverse impacts would be incurred within those habitats on the Hutaff side.

As stated under Alternative 5A, any piping plovers present within the permit area would be temporarily disturbed by the noise associated with the nearby staging, storage, and transportation of equipment, materials, supplies, and workers on the beach in support of project construction which is scheduled to occur between November 16 and March 31. Bulldozers may be used to achieve the design height and berm width for the proposed beach fill sections, and additional heavy machinery will be utilized to construct the terminal groin. Furthermore, rocks that will be used to construct the rubble mound portion of the groin will be stockpiled in an area adjacent to the groin. This would likely cause piping plovers within the area to seek out and use alternative habitat areas outside of the influence of project activity. The presence and operation of this equipment may also directly injure or kill the birds if not previously spotted, or force them to alter their normal feeding or roosting behavior. Noise associated with the construction – such as operation of heavy machinery and pile driving - may stress the piping plovers by causing them to spend more time responding to the disturbance than foraging and resting, or force them to vacate the area. Any piping plovers utilizing the sand spit at the north end of Figure Eight Island may also be disturbed by noise associated with construction activities. With the potential for during construction impacts to shorebirds, it is expected that the winter work timeframe, the availability of other supporting dry beach habitat (totally approximately 215 acres) in the inlet, and the adaptability of the shorebirds will help in reducing those effects. Due to the distance from the project activities, any plovers within these areas will not likely be directly or indirectly impacted by project activity.

Indirect Impacts: As described for Alternatives 5A and 5B, the construction corridor for Alternative 5C will be kept open for an undetermined amount of time for any unseen maintenance or potential for structure removal. Future maintenance of the terminal groin is expected to be limited to the rubblemound portion of the structure. The frequency of this maintenance activity would depend of the severity of storms and would likely not be needed every year. As a general comparison, the terminal groin structures at Pea Island and Fort Macon have not required maintenance since their original construction in 1991 and 1965, respectively. With the high possibility of little to no maintenance occurring, it is expected that the majority of the landward portions of the terminal groin, particularly within the dune system, will be covered with sand and vegetated and be maintained as a ninlet dune and dry beach system over the 30-year study period.

Under the 2006 shoreline conditions, the 5-year Delft3D model simulation for Alternative 5C showed that the sandy spit on the north end of Figure Eight Island was maintained and actually gained approximately 2.0 acres of dry beach and possibly overwash areas (Figure 5.39). The bypassing of littoral sediment around Rich Inlet would continue to occur and could result in some inlet dry beach and overwash habitat redevelopment on the Figure Eight Island spit over time allowing for natural resources including seabeach amaranth and shorebirds, like piping plover, to continue to persist in this area. Like Alternative 5A and 5B terminal groins, the model for Alternative 5C indicated relatively high rates of sediment loss from the oceanfront fill during the first 4 years of the simulation with this eroded material being transported past the structure as a result of overtopping, leaking through it, or simply being transported around it. While this sediment influx from the beach fill initially fed the spit and maintained the inlet's extensive intertidal shoals, over 58.4% of the fill between baseline station 60+00 and the terminal groin had been lost by the end of Year 2 with much of the material bypassing the groin. Losses from the fill moderated slightly over the next 3 years, however, by the end of year 5, only 2.5% of the initial fill volume remained on the beach profile above the -24-foot depth of closure. The gain of inlet dry beach and overwash habitat in this area within the 5-year modeling period would result in an increase of nesting habitat for shorebirds including the endangered piping plover and it's designated critical habitat. The loss of the approximate 0.8 acres of dry beach habitat initially created along Nixon Channel shoreline is included in this habitat increase. As stated under Alternative 5A, due to the fact that much of the groin would be covered in sand and not extend far into open water, bypassing of littoral sediment around Rich Inlet would be expected to continue to occur and could result in the redevelopment of the Figure Eight Island spit over time allowing for natural resources including seabeach amaranth to continue to persist in this area.

The model results also indicates the southern tip of Hutaff Island would be expected to accrete between year 0 and year 5 of the Delft3D model. This accretion would lead to the development of additional inlet dry beach, dune, and overwash communities (see Figures 5.34-5.39). Because Hutaff Island is unpopulated and access is restricted by boats only, the increased dry beach and overwash habitat on the southern tip of the island may be considered more valuable for nesting and resting wildlife, particularly with shorebirds like the piping plover. Like the Figure Eight side of the inlet, Hutaff's southern spit has been shown by the Audubon North Carolina 5-year survey data to be heavily used for foraging and roosting by piping plover. As stated for Alternative 5A, when the channel gorge is positioned next to the terminal groin, the amount of accretion or development of inlet dry beach and overwash habitat used by the piping plovers on the north side of the structure could be limited. In limiting the formation of these habitats on the southern inlet shoulder of Figure Eight Island, the conditions for promoting roosting and potential nesting habitat would be less than naturally occurring levels at this location. The initial beach fill and maintenance of dry beach along Nixon Channel shoreline and within the oceanfront fillet is expected to benefit piping plover's resting and nesting behavior at those locations.

In the maintaining of inlet dry beach and overwash areas for Alternative 5C over the 5-year modeling period, this will continue to provide areas for boaters to anchor and recreate on both shoulders of the inlet.

Cumulative Impacts: Even though the 5-year modeling results show a slight gain of habitat within the inlet complex, it is very likely that, at some point within the 30-year study period, erosion will occur on the north side of the structure as exhibited within most terminal groin structures. It is uncertain to what the magnitude and extent of any impacts to inlet dune, dry beach, and overwash habitats that may take place after the 5-year model simulation. With maintenance events occurring up to a maximum of once every five (5) years, or six (6) times over the 30-year study period, the cycle of beach fill sediment entering into the inlet will reoccur with the majority of influx being within the first two years of the event. This influx helps show that material continues to be transported past the terminal groin as a result of overtopping, leaking through it, or simply being transported around it. With on-going input of sediment, some of the inlet dry beach and overwash areas just north of the groin structure should continue to persist. In addition, the spit on the northern end, or Hutaff side, of Rich Inlet is expected to provide long-term inlet dune, dry beach, and overwash habitat regardless of any potential effects from the groin structure. Although the extent of potential cumulative impacts over the 30-year study period is unknown, the presence of inlet dry beaches and overwash habitats are expected to continue overtime and to provide foraging, nesting, and resting areas for piping plover and other shorebirds that utilize them. It is anticipated that if the reduction of these habitats occur due to the presence of the terminal groin structure, the rate of that reduction will equilibrate at some point in time and the shifting of inlet dune, inlet dry beach, and overwash habitats will become more influenced by the natural movement and positioning of the bar channel. The continuation of this habitat on Hutaff Island will help minimize the potential of cumulative impacts on Figure Eight Island over the 30-year study period.

INTERTIDAL FLATS AND SHOALS

(NOTE: In the discussion for these habitat types at the terminal groin location, we have defined the south side of the structure as the "oceanfront" and the northern side as "inlet". Under Alternative 5C, we acknowledge that this structure extends approximately 420 feet closer to the inlet than Alternatives 5A and 5B. See OCEANFRONT DRY BEACHES AND DUNES further below for discussion addressing the south side of the groin structure.)

Direct Impacts: The dredging activities associated with Alternative 5C are similar to those described under Alternative 5A and would directly impact approximately 25-30 acres of the approximate 206 acres of intertidal flats and shoals found within the Permit Area through direct excavation of these resources. This includes the removal of 994,400 cubic yards of material from the previously dredged area within Nixon Channel and the new connector channel. Specifically, the footprint of the area to be dredged for the connector channel is characterized by abundant intertidal habitat, which would be converted to the alternate habitat type of subtidal. Infaunal species residing within the material taken from the intertidal flats and shoals would be immediately eliminated during the dredging operation. However, research has shown that recovery of benthos would be expected to occur within several months.

For Alternative 5C, the removal of this habitat may impact fish species which utilize flats and shoals as foraging grounds, refuge, nursery grounds, and spawning habitat, as well as shorebirds, including piping plover, which use the critical habitat found within this area for resting, foraging, and nesting Measures that will reduce potential affects to fish and bird species include the following: 1) winter dredging season, 2) restricted construction corridor, 3) adaptability of species, and 4) the use of adjacent undisturbed intertidal flats and shoals. For those species that will be present during construction, it is expected that they will utilize the remaining undisturbed ~180 acres of intertidal flats and shoals located outside the dredging footprint and outside of any onshore construction area. It is also anticipated that any stress levels from land and/or in-water construction, which will be limited to a specific area, will be non-appreciable based on the during-construction monitoring results for New River Inlet and Bogue Inlet projects as discussed in "Inlet dunes and Dry Beaches" and in Alternative 3. The bird species in Rich Inlet, which are the same species found in New River and Bogue Inlets, are expected to adjust and adapt to the presence of construction equipment and noise, and are expected to continue to inhabit the inlet complex throughout the entire construction period of Alternative 5C. For these reasons, as further referenced in the Alternative 5A direct impact discussion, Alternative 5C project affects to both fishery and bird resources are expected to be minimal.

Indirect Impacts: The direct removal of approximately 994,400 cubic yards of material from Nixon Channel and the connector channel will result in an immediate sediment deficit within the inlet complex system. Although 57,000 cubic yards of material will be placed along the adjacent Nixon Channel shoreline, the majority of the amount (932,100 cubic yards) will be pumped onto the oceanfront shoreline for the construction of the terminal groin accretion fillet and beach fill. Note, the difference between the total volume of material needed for the beach fills and the volume to be excavated is due to tolerances allowed for both the excavation and fills.

Model volume changes in discrete areas within the inlet complex after 5-years for Alternative 5C are provided in Figure 5.56. The shoaling or infilling rate within the inlet complex is expected to increase following the implementation of Alternative 5C due to the -11.43 to -13.43 foot depth NAVD subtidal area that will be created. Based on the results of the Delft3D model simulation, the rate of shoaling of the previously permitted area in Nixon Channel was fairly steady during the five-year simulation while the proposed channel connector experienced rapid shoaling over the first two years. Shoaling of the proposed connector moderated between years 3 and 4 of the simulation with the model predicting minor scouring during the last year of the simulation. The model results show approximately 852,600 cubic yards of material being transported back into the inlet system. This sediment accumulation will help reform or develop some of the intertidal flats and shoals in the inlet flood tide delta area that was dredged. The reformation of these habitats should help reduce the potential change of fish behavior using the area for foraging, refuge, nursery grounds, and/or spawning. Even with the accumulation of this material, the model results reveal an overall net decrease of 224,500 cubic yards of the original amount of sediment removed the initial dredging. As stated previously, the accuracy of the model volume changes are ±10,000 cubic yards within each discrete area. The model results showed that much of the sediment accumulation occurred in the middle ground shoal area immediately behind the inlet and in Nixon Channel. It's within this middle ground shoal area where the dredging will take place. Delft3D model results suggest that approximately 500,000 cubic yards of material will collect within the areas excavated in Nixon channel and the connector channel within two years. During the first few years, it is expected that foraging fish may experience a reduction of prey as the benthic infaunal communities recover in the dredged area shoals. Because of the anticipated net reduction of the extent of intertidal flats and shoals shown in the 5-year modeling period, negative impacts to the fish and bird species utilizing these habitats within the inlet complex would be anticipated overall despite the addition of intertidal areas resulting from the eroding northern spit on Figure Eight Island.

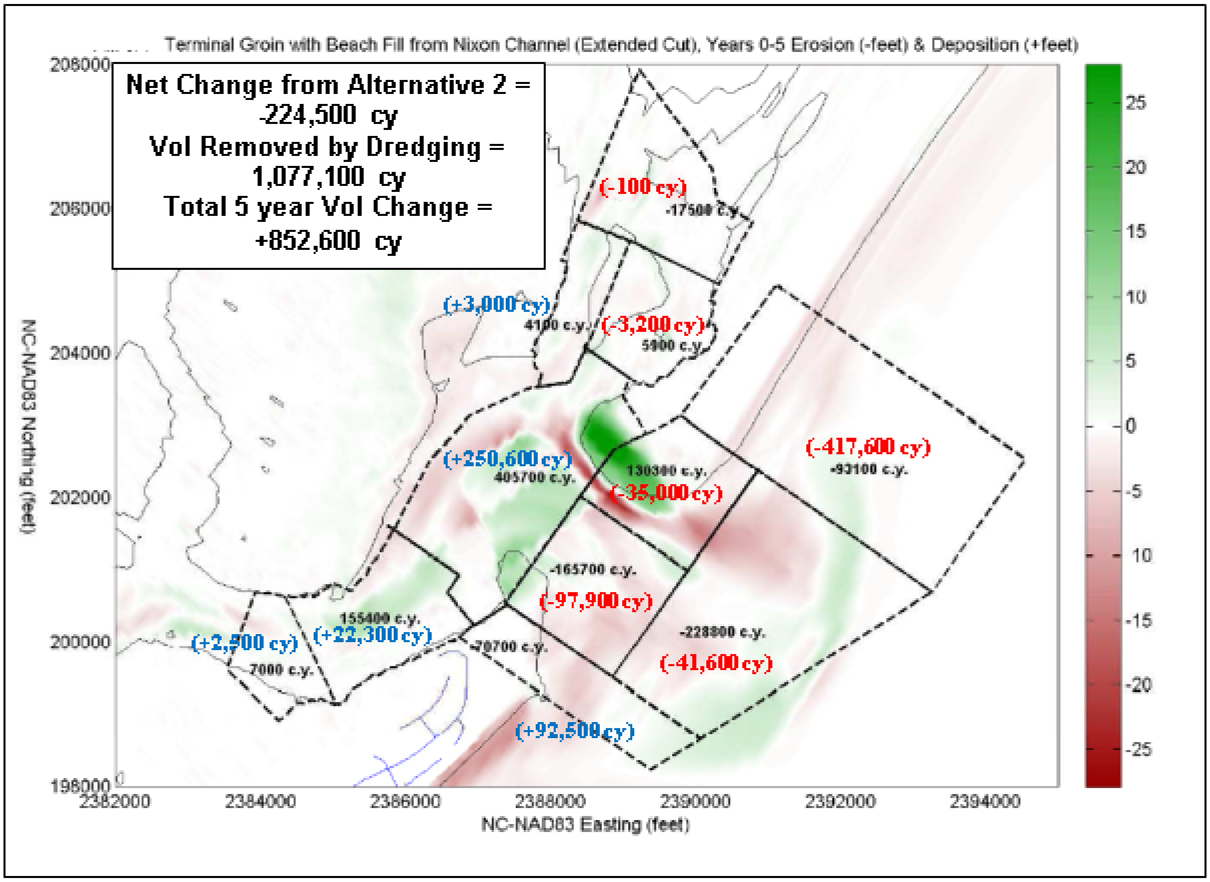

Figure 5.56. Modeled volume changes in discrete areas within the Permit Area for Alternative 5C. Values in green and red indicate an increase or decrease in material volume, respectively, compared to baseline conditions at year 0 for Alternative 2.

A review of the Delft3D model outputs for Alternative 5C (Figures 5.34-5.39) suggested that the intertidal flats and shoals on the north side of Figure Eight Island may have demonstrated a slightly higher indirect impacts to the intertidal flats and shoals compared to those depicted by the model results for Alternatives 5A and 5B. This, in turn, could cause a reduction in the amount of Unit NC-11 critical habitat for piping plovers within this portion of Rich Inlet. On the other hand, model results suggested slightly less of an impact on the Hutaff Island side of Rich Inlet. It is anticipated , however, that some material of the formed accretion fillet and beach fill will continue to be transported beyond the structure back into the inlet as demonstrated in the modeling results and through observations of other terminal groins structures such as Pea Island and Fort Macon and as described in Alternative 5A. The intertidal flats and shoals within the inlet complex, including the middle shoal ground area, will continue to receive some sediment input through the sand bypassing, helping to sustain the continued presence of intertidal flats and shoals.

For Rich Inlet, intertidal flats and shoals are a valuable feeding source for shorebirds including the endangered piping plover. The Audubon North Carolina survey data, as previously described above, revealed that piping plover were foraging for food within the flood tide delta habitat where the connector channel is proposed to be dredged. The Delft3D model simulations for Alternative 5C suggest that the intertidal flats and shoals may not be as abundant compared to Alternatives 5A and 5B and therefore may not provide the same benefit for foraging birds. Additionally, the presence of construction activity in association with the groin and beach nourishment placement may also stress shorebirds specifically along the intertidal flats in the northern portion of Figure Eight Island.

The direct mortality of the macroinfaunal population in the dredged intertidal flats and shoals may also have an indirect impact on bird and fish species that forage on these communities. It is anticipated that some benthic organism will populate the dredged area within a short period of time, but there will be a time lag for when the area repopulate to its pre-construction community diversity and total numbers. In this recovery period, some individual bird and/or fish species may have to adjust to their foraging habits and temporarily use other areas. For fish resources, studies of dredging and disposal effects on nearshore and estuarine fish populations have reported rapid recovery or minimal effects following the removal of benthic organisms associated with dredging (Courtenay *et al.*, 1980; de Groot, 1979a; de Groot, 1979b; Posey and Alphin, 2000). These minimal effects are anticipated in part also due to the winter time construction when biological activity is lowest. Topographic changes in response to dredging within both inshore and offshore borrow areas have also shown to benefit certain fish by creating refuge or forage areas (Lalancette, 1984). The unconsolidated and unvegetated communities that remain in the inlet complex would continue to redistribute as they lack structure and are dynamic in nature.

Cumulative Impacts: While the overall effects of the initial sediment deficit is not known for Alternative 5C, it is expected that bird use for most species, including the piping plover, will continue over the 30-year study period. One can reference the 23-year old terminal groin in Oregon Inlet to obtain a general understanding of impacts to intertidal flats and shoals around the groin structure beyond the 5-year simulation period. Despite changes over the last 23 years, presence of piping plover within Oregon Inlet has persisted on both sides of the inlet's shoulder. Similar circumstances are expected in Rich Inlet, but with a higher concentration of bird use due to a smaller groin structure and an expected lesser impact. Reference discussion in Alternative 5A for further details.

Maintenance dredging under Alternative 5C could occur up to six (6) events over a 30-year period. Similar to Alternative 5A, this would result in a reoccurrence of shifting intertidal flat and shoal habitats that are used by fish species for foraging. The majority of the shifting will occur within two years after the maintenance event and then gradually leveling off until the next event would be take place. It is difficult to estimate what this total would be and to what degree the deficit would have on forming and reforming intertidal flats and shoal habitats over 30 years. With an expected short-recovery period for the benthic community and the presence of surrounding undisturbed foraging areas, the fish species are expected to adjust to the shifting of this habitat. Cumulative affects to the feeding behavior or food source should be non-appreciable.

The cumulative impacts to the intertidal flats and shoals are similar to those described for Alternative 5A.

OCEANFRONT DRY BEACH AND DUNE HABITATS

(NOTE: In the discussion for these habitat types at the terminal groin location, we have defined the south side of the structure as the "oceanfront" and the northern side as "inlet". Under Alternative 5C, we acknowledge that this structure extends approximately 420 feet closer to the inlet than Alternatives 5A and 5B, and includes more oceanfront dry beach and dune habitat for this alternative.)

Oceanfront Dune Communities

Direct Impacts: Beach nourishment under Alternative 5C is expected to help stabilize the dune system, repair portions of the dunes, and provide long-term protection along the Figure Eight Island. Similar to Alternative 3, 4, and 5A, a dune with a crest elevation of 4.6 m (15.0 ft.) NAVD would be constructed in the area from baseline station 77+50 to 95+00 or in the area presently devoid of a dune and where homes are presently protected by sandbag revetments. The footprint of this artificial dune would encompass approximately 4.6 acres which would result in a positive impact to this habitat. This stabilization measure will allow for long term growth and development of dune vegetation and provide habitat for roosting, foraging and nesting shorebirds. The dune communities located on Hutaff Island are not expected to be directly impacted by the implementation of Alternative 5C.

Indirect and Cumulative Impacts: The orientation of the inlet has been proven to play an important role regarding shoreline erosion rates within the Permit Area. When the inlet channel is positioned in a southerly orientation, the oceanfront dunes on Figure Eight Island would be expected to persist or increase in size while the contrary would be expected on the southern oceanfront shoreline on Hutaff Island. The opposite is true for both islands when the bar channel is located in a more northerly position. Currently, the inlet bar channel appears to be shifting from the south to a more central location; and if the shifting continues northward, the oceanfront of Figure Eight Island is anticipated to undergo erosive conditions affecting oceanfront dunes while Hutaff's oceanfront experiences accretion.

Similar to Alternative 5A, Alternative 5C includes renourishment at a minimum of every five (5) years. With the terminal groin structure in place and the subsequent maintenance events, the project will serve to provide long-term protection of the oceanfront dune system; consequently, resulting in cumulative impacts on Figure Eight Island that are beneficial to dune habitat. This should allow the establishment of a vegetated community to be maintained which provides habitat for resting birds and other wildlife. Although the physical location of the dune system may change as overwashing and other storm-induced events influence the environment, impacts to the dune communities at Hutaff Island in response to Alternative 5C are expected to be minimal. For further details concerning cumulative impacts to Alternative 5C, reference discussion in Alternative 5A.

<u>*Oceanfront Dry Beach Communities*</u>

Direct Impacts: With Alternative 5C, the terminal groin structure is located approximately 420 linear feet closer to the inlet throat than Alternative 5A and 5B; and like Alternative 5A and 5B will include the construction of a fillet, or beach fill, south of the structure. The beach fill on Figure Eight Island associated with Alternative 5C would encompass approximately 45-50 acres of oceanfront dry beach habitat from the intersection of Beach Road and Beachbay Lane to the terminal groin location. This includes the burial of approximately 29 acres of existing dry beach and the creation of 15-20 additional acres. The impacts associated with the construction of the terminal groin were described previously under the inlet dunes and dry beach section above.

The nourishment associated with Alternative 5C will provide additional dry beach habitat that will benefit nesting sea turtles, sea beach amaranth, and bird resources. The benefits and impacts associated with this 12,250 foot fill area on Figure Eight Island are anticipated to be the same as those described for Alternative 5A. In particular, the development of the fillet area within approximately 750 feet of the structure would create a dry beach habitat that could be used by shorebirds which may offset the anticipated reduction of inlet dry beach and overwash areas on the north, or inlet, side of the terminal groin. The dry beach habitat in this portion of the fillet will encompass approximately 5 acres of potential habitat use.

Direct impacts to the oceanfront dry beach will also include the mortality of crustaceans including ghost crabs, however, these communities are expected to recover within the order of months to more than one year (National Research Council, 1995; Carter and Floyd, 2008). This reduction in dry beach habitat will initially reduce available habitat for seabeach amaranth, sea turtles, and shorebirds, including the piping plover, however the increased beach width as a result of nourishment will compensate for this loss. Some factors, as described for the other project alternatives involving beach fill, will reduce some of these temporary impacts. These include the utilization of fill material conforming to the State sediment criteria and wintertime construction.

As discussed in Alternative 3, negative effects to sea turtle nesting from the fill are not anticipated due to the compatible quality of material used to expand the dry beach area on Figure Eight Island. As stated previously, the grain size, color, and other attributes of the material placed along the northern portion of Figure Eight Island as part of Alternative 5C will be compatible to the native composition and will comply to the State sediment criteria which will help reduce potential impacts.

No direct impacts will occur within oceanfront dry beach habitats on Hutaff Island.

Indirect Impacts: The placement location of the groin structure is situated near the transition point from oceanfront dry beach to inlet dry beach habitats, however 420 feet closer to the inlet throat than Alternatives 5A and 5B. Along the oceanfront, the 5-year simulation of Alternative 5C in the Delft3D model under 2006 conditions indicated the beach area between stations F90+00 and 30+00 would accrete while the segment between stations 30+00 and 60+00 would only experience minor losses and would not require periodic nourishment. As a result, periodic nourishment for Alternative 5C would be required primarily between stations 60+00 and 105+00. Even though model results indicate the area south of station 60+00 may not need periodic nourishment, that area would continue to be monitored and nourishment provided future conditions warrant. The Delft3D model simulated losses from the section of the shoreline between station 60+00 and the terminal groin (station 105+00) averaged 93,000 cy/year over the five year simulation period. Assuming periodic maintenance of the previously permitted area in Nixon Channel and the proposed connecting channel is accomplished every five years, the nourishment requirement for the ocean shoreline would be 465,000 cy. The stabilization of this oceanfront shoreline should assist in maintaining wildlife habitat for seabeach amaranth, nesting sea turtles, and shorebirds. For the most part, the volume loss identified from the northern 2,000 feet of shoreline on Figure Eight Island occurred offshore as a relatively wide dry sand beach remained south of the terminal groin through the 5-year model simulation.

The southern 2,640 feet of Hutaff Island eroded under Alternative 5C compared to accretion under baseline conditions at year 0 for Alternative 2. This result would be due to the effect of the terminal groin on the sediment transport off the north end of Figure Eight Island, changes in the flow through Rich Inlet associated with the design cut, and the resulting changes in the development of the ebb shoal. Based on the bird surveys conducted by Audubon North Carolina, piping plover utilized this oceanfront of Hutaff mostly during the 2008-2010 survey period. The birds were mostly observed foraging, which would assumedly be along the wet beach but possibly using the dry beach for resting during foraging. The model revealed that most of the volume loss from this area was offshore and was associated with the reconfiguration of the north side of the ebb tide delta of Rich Inlet. The erosion along the oceanfront dry beach is not expected to interrupt the foraging and roosting behaviors of the piping plover.

As disclosed in Chapter 4 and described in Alternative 5A Inlet Dry Beach discussion, data from monitoring sea turtle nests show recorded nest sites within the proximity of groin structure. Out of the ten years of date (from 2001-2010), nest were found near this location in 2003 and 2004. The sporadic nesting at the spit of Figure Eight Island is likely due to the movement of the ebb tide channel, or bar channel, which could either provide favorable or unfavorable habitat and successful nesting for sea turtles. The construction of the terminal groin is expected to limit any nesting habitat, and/or decrease the success of nesting, on the inlet side of the structure due to projected erosion. Like all other terminal groin alternatives, the structure itself could impede adult turtles migrating to nesting sites or hatchlings crawling back to the ocean. See Alternative 5A for further description of structural impacts on nesting sea turtles and hatchlings. With Alternative 5C, the structure is less likely to act as an impediment or obstacle since the footprint of the groin structure is located closer to the inlet throat or gorge.

Cumulative Impacts: Based on the historical geomorphologic and modeling analysis, the amount of any change along the oceanfront dry beaches on both Figure Eight Island and Hutaff Island within a five year period, or over a longer timeframe, is strongly contingent on the location or positioning of the ebb tide channel. However, with periodic maintenance nourishment scheduled every five (5) years for Alternative 5C over the 30-year study period, the dry sand beach and dunes along the north end of Figure Eight Island's oceanfront would be preserved.

Habitat for resting colonial waterbirds, nesting shorebirds, and nesting sea turtles along the ocean dry beach is expected to be maintained at the location of the terminal groin fillet for approximately 1,500 linear feet. The remaining 11,000 linear feet should be maintained with supplemental beach renourishment cycles via maintenance dredging within Nixon Channel and the connector channel every five (5) years encompassing up to six (6) separate events over the 30-year study period. Maintaining the dry beach along the oceanfront shoreline will help ensure that bird and sea turtle habitat will persist.

Maintenance of the rubblemound portion of the terminal groin should be infrequent, if at all, and would depend on the frequency of severe storms that exceed the design conditions for the armor stone. If maintenance of the rubblemound portion is needed, this could involve simply recovering and replacing displaced stones or adding stone to replace the ones that could not be located on site. Any maintenance work within the dry beach area would be restricted within a designated corridor in order to limit any potential impacts.

WET BEACH COMMUNITIES

Direct Impacts: For Alternative 5C, the addition of beach fill to Figure Eight Island is expected to impact 10-15 acres of the wet beach community along the oceanfront shoreline and Nixon Channel shoreline, immediately burying the infaunal community. Once the beach fill is placed, approximately 10-15 acres of new wet beach habitat will be created resulting in no net change in wet beach acreage. Also, the construction of the terminal groin will cover, or convert to rubble, approximately 0.3 acres of wet beach habitat located on both the oceanfront shoreline and the Nixon Channel shoreline, permanently burying the infaunal community within this area as well. This covering with fill and rubble would result in mortality for most of the beach and Nixon Channel footprint. The mortality of any present benthic organisms could disrupt feeding habits or decrease food source for fish and bird species. With the timing of nourishment, reduced biological activity, possibly offshore migration of some benthic organisms, and adjacent undisturbed habitats, the immediate impact to the resource of wet beach habitat is expected to be minimal. Direct impacts to the wet beach community are anticipated to be the same as those described for Alternative 5A.

Indirect and Cumulative: Delft3D model results suggested that secondary impacts of approximately 5-10 acres of marine intertidal habitat occurred along the oceanfront shoreline of Figure Eight Island while the fill placement equilibrated over the 5 year simulation. This may affect shorebird, crustacean and fish foraging, and recreational fishing through a temporary reduction in bait species during and immediately after construction. Impacts should be reduced due to the fact that the material utilized for beach fill will be compatible with native material, thereby reducing to the recovery period for infaunal communities. Besides the footprint of the structure, indirect impacts and minimization to those impacts for oceanfront and Nixon Channel shoreline are similar to those described in Alternative 5A.

The infaunal communities and macrobenthic biota located both updrift and downdrift of the newly constructed terminal groin would be expected to recover within an order of several years, as demonstrated by a study at Murrells Inlet, South Carolina and previously discussed under Alternative 5A. Although the physical conditions are not identical at both locations, a similar response would be anticipated following the construction of the terminal groin on Figure Eight Island.

As a result of the dredging and renourishment activity at a minimum every five (5) years over the 30-year study period, negative effects could occur if the diversity and abundance of infaunal populations do not recover between nourishment events. However organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels (Nelson, 1985). Alternative 5C is not expected to result in long-term cumulative impacts to wet beach habitat due to the adaptability of benthic communities, sufficient period between maintenance events for recovery, and the use of compatible material. This habitat will continue to provide foraging areas for small fish and bird species.

MARINE HABITATS

Softbottom Communities

Direct Impacts: The activities associated with Alternative 5C, would result in direct impacts to approximately 80-90 acres of softbottom community within the dredging footprint in Nixon Channel and the connector channel as well as the fill footprint of construction associated with the terminal groin. The targeted excavation depths are -19 NAVD in Nixon Channel and between -11.43 and -13.43 NAVD in the connector channel. This would remove the infaunal community residing in the softbottom or substrate habitat and could, in turn, affect the feeding behavior of fish species that use the areas for foraging. Impacts to the softbottom communities and the fish species utilizing these habitats are anticipated to be similar to those described for Alternative 5A; however, due to the fact that the proposed groin is 300 feet shorter seaward for Alternative 5C, these impacts are slightly less.

Of the 305-foot long by 75-foot section of the terminal groin extending beyond mean high water, approximately 0.5 acres of nearshore softbottom will be permanently removed. An additional 1.4 acres would be temporarily directly impacted due to the utilization of the construction corridor. It is not known to what the full effects of this will be on the fishery resource, but with the softbottom habitat surrounding the footprint of the structure, the fishery resource should be capable of locating food sources and foraging within nearby areas.

Some of the impacts to the fishery resource should be reduced by a winter dredging timeframe and with the presence of adjacent foraging softbottom communities located in the ebb tide delta and in undisturbed areas within the inlet complex. Although the recruitment pattern is altered, the recovery of infaunal species after sediment removal is relatively quick, depending upon the opportunistic nature of the species (Deaton et al., 2010; Posey and Alphin, 2002). More information regarding infaunal impacts related to dredging can be found under the section entitled "General Environmental Consequences Related to Dredging" above. Adjacent infaunal communities residing in the softbottom habitat would directly and possibly indirectly be impacted by increased levels of turbidity, immediate removal, and immediate burial of infaunal biota during dredging operations.

Indirect Impacts: The channel dredging, terminal groin construction and shoreline nourishment activities affecting softbottom communities will be similar to those actions described in Alternative 5A. The Alternative 5C activities will indirectly, or could potentially, impact the infaunal community and feeding behaviors for fish species. The following factors are expected to reduce or minimize any impacts on the infaunal and fish communities that use softbottom habitat: 1) Short recovery period in the infaunal community, 2) Quick recolonization of opportunistic species, 3) resilience of inhabiting a harsh environment, and 4) availability of food source and habitat in adjacent areas. Affects to softbottom habitat under Alternative 5C is expected to be minimal and short-term. For further detailed description of these impacts, reference the discussion in Alternative 5A.

Cumulative Impacts: Under Alternative 5C, maintenance dredging and nourishment is expected to occur at the most once every five (5) years and up to six (6) separate events over the 30-year study period. Similar to what was described for Alternative 5A and above in the indirect discussion, softbottom communities should have sufficient time to fully recover between each maintenance event over a long period of time, reducing any long-term appreciable effects on the foraging behavior of fish. Cumulative impacts are expected to be kept to a minimum.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts: No hardbottom habitat is located within the structural footprint of Alternative 5C that will extend seaward of the mean high tide line or within the toe of equilibrium for the beach fill placed along the oceanfront. Therefore impacts are not anticipated. However, like all the terminal groin alternatives, the structure is expected to provide an artificial hardbottom habitat that should benefit those fishery resources which use the habitat for foraging and cover from predators. For further discussion on these benefits, see Alternative 5A.

WATER QUALITY

Turbidity and TSS

Direct, Indirect, and Cumulative Impacts: When Alternative 5C is implemented, turbidity and TSS levels will increase during the dredging of the channels and the discharge of fill material along both Nixon Channel and the Figure Eight Island oceanfront shorelines. Any increase in levels is expected to be within the State standards. Impacts to water quality from dredging and fill placement will be similar to those described for Alternative 5A. See discussion in Alternative 5A for further details.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: Alternative 5C will result in minimal change to the tidal prism of Rich Inlet, Nixon Channel, and Green Channel. Salinity composition and levels should be unaffected. At the end of the Delft3D 5-year modeling, the hydrodynamics of the Rich Inlet complex is essentially the same, with a slight 5% increase in flow, as the baseline conditions represented in year 0 for Alternative 2. Maintenance dredging is expected up to a maximum of once every five (5) years and up to six (6) separate events over the 30-year study period. Although there may be a slight 5% increase in flow after the initial dredging, this is not expected to cumulatively increase with each event over time due to the reduction in the amount of material being dredged during the maintenance events. For further discussion on Alternative 5C affects to Hydrodynamics and Salinity, see Alternative 5A.

Larval Transport

Direct, Indirect, and Cumulative Impacts: There is potential for direct impacts to fish larvae within the water column under Alternative 5C during the dredging of Nixon Channel and the connector channel. Larvae could be entrained within the dredge while operating in the flood tide delta where fish larvae would be migrating. This potential of entrainment is low due to the time of year dredging and to the relatively small volume of water pumped through the dredge compared to the volume within the tidal prism. See Alternative 5A for further discussion on these direct impacts.

Like all the terminal groin alternatives, the structure of Alternative 5C has the potential to interfere with the passage of larvae and early juvenile fish from offshore spawning grounds into estuarine nursery areas, however, the portion of the structure extending beyond the MHW line, based on the 2006 shoreline conditions, would be approximately 300 feet less than the groin designed for Alternatives 5A and 5B. As such, it should be noted that the construction of the terminal groin under the 2006 erosive conditions would result in 400 linear feet of the structure's footprint being below the MHW line without the installation of the fillet. With the fillet in place, the structure would expect to be less. Therefore, the structure and the accompanying fillet would have minimal interaction with larvae in the water even if constructed during a period of erosive conditions. In general, however, these structures can disrupt along-shore transport processes within the narrow zone paralleling the shoreline which larvae are dependent upon. Restricting access into the estuarine habitat behind Figure Eight and Hutaff Island could affect certain fish species. Although research is limited on long-term terminal groin affects to larval transport, the following has been used in order to make the determination that Alternative 5C is not likely to have an effect: 1) reference to a numerical model for Bald Head Island terminal groin project, 2) larval transport entering from the north side, or Hutaff side, of Rich Inlet, 3) the fillet will extend to the end of the structure allowing sand by-passing to continue and allowing nearshore transport for larvae to enter into Rich Inlet, and 4) recent shoreline conditions have been such that the terminal groin could have been constructed in the dry, disclosing the fact that the structure would not protrude any further seaward than periods of natural conditions. For further description on these reasons, reference discussion in Alternative 5A larval transport.

Along with larval and juvenile fish, the structure has the potential to interfere with adult fish. Fish, including mullet that migrate over the nearshore softbottom habitat, may be impeded when they encounter the terminal groin. As described under Alternative 5A and cited in Knott, et al, 1984, although the jetty at Murrells Inlet acted as a barrier for fish migration, the physical nature of the proposed structure at Figure Eight Island differs in that it is not designed as a jetty and is comparatively much shorter in length. Furthermore, the accretion fillet is expected to fill seaward and would therefore reduce the exposed area of the groin. In this regard, fish and other motile organisms will be expected to pass by the structure as they migrate along the shoreline which is expected to extend near the seaward terminus of the groin. Therefore, migrating fish may be only minimally impacted by the presence of the terminal groin.

PUBLIC SAFETY

Direct, Indirect, and Cumulative Impacts: During the initial and long-term maintenance construction of Alternative 5C, some hazards, both on land and in the water, will increase due to the usage of heavy machinery within the Permit Area during the dredge operation, beach nourishment, and the terminal groin construction. Safety precautions, such as access restriction and use of USCG navigation rules will be undertaken to reduce this risk. Also, construction will take place within the dredging window of November 16th through March 31st when public use, both in-water and on the beach, of Nixon Channel, Green Channel, Rich Inlet, and Hutaff Island is at its lowest peak. After the initial construction and beach fill, maintenance dredging and nourishment events could occur up to once every 5 years, and up to a maximum of six (6) separate events over the 30-year study period. For Figure Eight Island, the implementation of Alternative 5C will alleviate the erosional pressure along of the northern 3.8 km (2.4 mi) of the ocean shoreline on Figure Eight Island and the 0.4 km (.26 mi) of along the Nixon Channel shoreline thereby providing long-term protection for the nineteen (19) oceanfront and one soundside structure that are imminently threatened. Effects on public safety for Alternative 5C are similar to those in Alternative 5A, and see Alternative 5A discussion for further details on impacts, precautionary measures, and potential benefits.

No public safety hazards are anticipated in proximity to Hutaff Island.

AESTHETIC RESOURCES

Direct Impacts: Temporary impacts will result from the implementation of Alternative 5C due to the usage of heavy machinery while constructing the terminal groin, dredging the channels, and nourishing the oceanfront and Nixon Channel shorelines. Following completion of the construction phase of Alternative 5C, the aesthetic resources will be as they were prior to construction with the exception of the terminal groin at the northern portion of Figure Eight Island. The landward portion of the terminal groin would include a design with the sheet pile primarily below the existing ground elevation limiting impacts to the aesthetics. Also, the area disturbed by the construction activities will be restored to near pre-construction conditions by grading and planting of native plants. Portions of the rubble mound structure, in particular the most seaward 200 feet, would be visible particularly following certain wave and tide conditions. This may result in long-term disruptive vistas for the northern Figure Eight Island residents and/or those visiting that end of the island for an unobstructive view of the inlet area. The winter-time construction will also limit the impacts to aesthetics as less people will notice the disruption due to less tourism during that time of the year. The north end of Figure Eight Island south of the terminal groin is expected to become stable enough to allow the removal of the sandbag revetments. The removal of the sandbags along the northern portion of Figure Eight Island will improve the aesthetic quality of the island. See Alternative 5A for additional discussions.

Indirect and Cumulative Impacts: Indirect and cumulative impacts under Alternative 5C will occur due to the anticipated on-going maintenance of Nixon Channel along with the placement of dredged material on Figure Eight Island. These events will occur at a maximum once every five (5) years and up to six (6) separate beach maintenance over the 30-year study period. Due to the length of time in between maintenance events, cumulative effects are expected to be minimal with the implementation of Alternative 5C.

RECREATIONAL RESOURCES

Direct Impacts: For Alternative 5C, impacts to recreational resources are similar to those described under Alternative 5A. General public access is restricted to boat access only. However, the shorelines and shoals of Nixon Channel, Green Channel, Rich Inlet, and the northern spit of Figure Eight Island are heavily used by the general public, especially during the summer months (see Table 4.14). Recreational opportunities such as beachcombing, sunbathing, surfing, fishing, and walking along the beach will be temporarily impacted during the construction activities associated with Alternative 5C. However, all construction activities will be limited to working within a window when recreational use is at its lowest during the year. Even during construction, complete access will not be restricted in these areas. The beach fill along 1,400 linear feet of the Nixon Channel shoreline will immediately create a wider dry beach for the boaters and other recreational use.

After completion of the structure, there may be some minor impediment for walking the beach, or access to, along the northern tip of Figure Eight Island. Portions of the rubble mound structure are projected to be approximately 1-3 feet above the beach grade and could hinder access for certain persons.

Indirect and Cumulative Impacts: Following construction, recreational resources are expected to benefit from Alternative 5C due to the increased size and extent of the oceanfront nourished beach and the nourished shoreline of Nixon Channel. However, as shown in the Delft3-D 5-year modeling simulation, Figure Eight Island will experience erosion along the northern portion of the island while accretion is anticipated on the southern portion of Hutaff Island. Within this 5-year period of shifting, some recreational opportunities may decrease on Figure Eight Island while Hutaff Island experiences an increase in opportunities. With the potential of maintenance events once every five (5) years and up to six (6) separate events over the 30-year study period, this expected cycle of use would continue before and after each event for the life of the project. As mentioned in Alternative 5A, the removal of shoals within the dredging footprint may limit areas for boaters to anchor. However, this is expected to be short-term due to the reformation of shoals in the flood tide delta and to the availability of other anchoring locations within the Rich Inlet complex. Along the terminal groin, fin fish will likely be attracted to rubble structures due to their increased structural complexity which provides shelter from predators (Hay and Sutherland, 1988) leading to recreational fishing and snorkeling opportunities. As mentioned in Alternative 5A, within the 30-year study period, recreational resources are expected to be maintained with overall minimal changes.

NAVIGATION

Direct, Indirect, and Cumulative Impacts: Like Alternative 5A, the initial construction including the deepening of the connector channel followed by periodic maintenance dredging in Nixon Channel will benefit navigation due to a maintained depth created by on-going dredging activities under Alternative 5C. The initial dredging depth of the connector channel will be approximately -11.43 to -13.43 feet NAVD. During the dredging, however, navigation will be temporarily impacted due to the presence of pipelines within Nixon Channel. At no time will complete restriction of navigation occur in Nixon Channel during dredge operations. There will be some minor negative impacts to navigation in Nixon Channel due to the presence of barges used to transport the stone for construction of the terminal groin. The barges would be moored in relatively deep water next to an offloading pier. Restrictions will be determined by the USCG and will be limited to the areas where the dredge and the pipelines are located. These restrictions will be imposed during every maintenance event, which is scheduled approximately every five (5) years.

Cumulative Impacts: Following the dredging of Nixon Channel, Delft3D modeling results suggest that the entrance of Rich Inlet will behave in a similar manner to natural conditions over the next 5 years. The dredged area will be expected to shoal, however it will remain navigable in between maintenance events. The terminal groin will be clearly visible;

therefore it should not pose a threat to boats. Any recommended markings on the terminal groin as suggested by the US Coast Guard will be implemented to ensure the safety of vessels. Following the construction of Alternative 5C, boaters should find navigation within the back side of Figure Eight Island channel easier to navigate after initial dredging and after each maintenance event, which is anticipated to occur at a maximum every five (5) years and up to six (6) separate occurrences over the 30-year study period. Alternative 5C is expected to benefit navigational use within the Rich Inlet complex over the long-term.

INFRASTRUCTURE

Direct, Indirect, and Cumulative Impacts: Alternative 5C is expected to benefit the infrastructure on Figure Eight Island due to the short-term and long-term protection from erosion. The nourishment plan in Alternative 5C would use approximately 907,700 cubic yards of material as beach fill along 12,250 linear feet of the Figure Eight Island shoreline and 57,000 cubic yards of material along 1,400 linear feet of Nixon Channel shoreline. This would serve to protect the homes and infrastructure along the oceanfront shoreline of the island from the intersection of Beach Road and Beachbay Lane to the location of the terminal groin and the homes at the north end of Beach Road near Nixon Channel. The width of the oceanfront dry beach will vary along the length of the 12,250 foot fill area. Furthermore, the installation of the terminal groin will result in a wider beach within the accretion fillet which will protect the infrastructure as well. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will approximately 91 feet. South of station 50+00, the width of the fill will be around 34 feet. The Nixon Channel shoreline will be expanded to approximately 50 feet wide and will produce approximately 1.2 acres of additional dry beach to protect the homes in that areas. These two locations will be renourished up to once every five (5) years and potentially up to six (6) separate events over the 30-year study period.

SOLID WASTE

Direct, Indirect, and Cumulative Impacts: This alternative will provide protection along portions of Figure Eight Island thereby decreasing the risk of damage to residential buildings and infrastructure. This would alleviate the potential of increased amount of solid waste through demolition. Implementation of Alternative 5C is expected to benefit the pubic by not contributing to additional solid waste.

NOISE POLLUTION

Direct Impacts, Indirect, and Cumulative Impacts: Impacts to noise pollution are anticipated to be minimal and similar to those discussed for Alternative 5A. With a total construction period estimated at 4.5 months, the noise pollution would be short-term since the equipment would be constantly relocating as work moves down the beach. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. Also, dredging and beach placement would occur during times when residents and visitors are less likely to be present. No indirect or cumulative impacts pertaining to noise pollution are anticipated with Alternative 5C due to the low frequency of beach nourishment events and the time of year.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: Implementation of Alternative 5C is expected to benefit the local economy of New Hanover County. If the current erosion rates were to continue, the damage or destruction of imminently threatened homes would decrease the local tax revenue on Figure Eight Island.

Construction of the new channel would involve the removal of 994,400 cubic yards based on the 2006 survey with an excavation cost of $8,984,000.

The initial construction cost of the 1,300-foot terminal groin for Alternative 5C is estimated to be $3,410,000 which includes engineering and design and construction oversight. The total initial construction cost of Alternative 5C given the 2006 survey condition would be $12,394,000. The initial construction of Alternative 5C is expected to take approximately 4.5 months.

Periodic nourishment of the beach fills in Nixon Channel and the ocean shoreline using material obtained from maintenance of the existing Nixon Channel permit area as well as the new channel connector would cost $5,162,000 every five (5) years. Maintenance of the rubblemound portion of the terminal groin could average $15,000/year.

The average annual equivalent cost for constructing and maintaining Alternative 5C would be $1,831,000 based on the 2006 conditions (Table 5.25). Over the 30-year planning period, the total implementation cost for Alternative 5C in current dollars would be approximately $43.80 million. See Appendix B and Appendix G for more information regarding cost.

Table 5.25 Summary of Average Annual Economic Impact of Alternative 5C

	Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
2006 Conditions	$0	$0	$1,831,000	$1,831,000

No structures or buildable lots are expected to be lost under Alternative 5C, but again, repetitive storm damage could eventually lead to the demolition of some of the threatened structures. The protection of the homes and infrastructure is expected to provide a short and long-term benefit on the economy.

H. IMPACTS ASSOCIATED WITH ALTERNATIVE 5D (APPLICANT'S PREFERRED ALTERNATIVE): TERMINAL GROIN AT A MORE NORTHERLY

LOCATION WITH BEACH FILL FROM NIXON CHANNEL AND OTHER SOURCES

The terminal groin for Alternative 5D would follow the same general alignment as the terminal groin under Alternative 5C but would extend 200 feet farther seaward of the 2007 MHW shoreline. The terminal groin for 5D would have the same shore anchorage section as Alternative 5C. Thus, the total length of the Alternative 5D terminal groin would be 1,500 feet. Like Alternative 5B, the beach fill for Alternative 5D along the ocean shoreline would extend from the terminal groin south to baseline station 60+00, and no additional dune system will be constructed. Based on the modeled performance of the beach south of station 60+00, no initial fill would be needed to be placed south of station 60+00 to Bridge Road, however, this area would be included in future shoreline monitoring programs and could be nourished in the future should conditions warrant. Alternative 5D also includes the same beach fill along 1,400 feet of Nixon Channel as included in Alternatives 3, 4, 5A, 5B, and 5C.

The material to construct the beach fills for Alternative 5D would be derived from maintenance of the previously permitted area in Nixon Channel. The three northern disposal islands situated adjacent to the AIWW would provide a supplemental source of beach nourishment material. These disposal islands would be used in the event that shoaling of the Nixon Channel permit area does not provide enough material to maintain the beach south of the terminal groin or if it is needed to respond to damages associated with coastal storms. Alternative 5D would not include a connector channel from Nixon Channel to the inlet gorge.

The initial beach fill for Alternative 5D, which would be constructed to a crest elevation of 1.8 m (6.0 ft.) NAVD, would be limited to the area between stations 60+00 and 105+00 (terminal groin). In this regard, the area between the terminal groin and station 80+00, which lies within the estimated limits of the accretion fillet that would form next to the terminal groin, would be pre-filled by placing material at a rate of 80 cubic yards/linear foot. This would widen the entire fillet area by an average of approximately 69 feet. South of station 80+00, the placement rate would be reduced to 20 cubic yards/linear foot to station 70+00 and then transition to 0 cubic yards/linear foot at station 60+00. Table 3.9 in Chapter 3 provides a summary of the placement rates and design berm widths for Alternative 5D.

The total volume of initial beach fill along the ocean shoreline, including the dune fill, would be 237,500 cubic yards. The Nixon Channel beach fill would require 57,000 cubic yards bringing the total beach fill volume to 294,500 cubic yards.

ESTUARINE HABITATS

Salt Marsh Communities

Direct Impacts: Like Alternative 5C, a 300-foot by 50-foot (or 0.34 acre) salt marsh area located within the designated working corridor on the northern tip of Figure Eight Island will be temporarily impacted during the installation of Alternative 5D terminal groin's anchor. Activity in this area involves the installation of sheet pilings at a depth of approximately 0.5 feet below grade and will be outside the boundary of the small tidal finger that feeds into Nixon Channel. The installation methods for the sheet pilings, the use of the corridor within this marsh community, precautionary measures to reduce impacts, and impacts associated with Alternative 5D in this area will be the same as the other terminal groin alternatives described above (5A, 5B, and 5C). The removal of material from the three (3) disposal islands will not directly impact any of the surrounding tidal marsh. Additionally, preventive measures will be incorporated during extraction operations on these islands to keep sediment or any other material from eroding into these marsh areas. See description in Alternative 5B for further discussion concerning the disposal island and Alternative 5A, 5B, and 5C for further details concerning the subject issues for the marsh resources on Figure Eight Island spit. As mentioned under Alternative 5A, the construction of the offloading dock or pier to be used for transporting building material, such as the rock and possible sheet piling, onto the site will constructed in a manner to minimize any direct impacts to the ephemeral salt marsh near the anchor section along Nixon Channel shoreline. The placement will avoid these resources if possible and will be elevated to reduce any potential impact from shading.

In addition, the fill placed along Nixon Channel terminates south of the small tidal creek that serves to feed the area of high marsh along the northern end of Figure Eight Island. As such, no significant impacts are anticipated to this high marsh area.

Although primary nursery areas (PNAs) are located within the Permit Area, no PNA will be directly impacted by beach fill activity. PNAs are generally defined as being located in the estuarine system, including portions of rivers, creeks and bays (see Chapter 4). These are usually shallow areas with soft, muddy bottoms surrounded by marshes and wetlands. Low salinity and the abundance of food in these areas are ideal for young fish and shellfish. The 1,400 foot section of estuarine shoreline along Nixon Channel where beach fill is proposed for Alternatives 5D is characterized by high salinity water with a sandy bottom.

Indirect and cumulative Impacts: For Alternative 5D, the stretch of sheet piling through the salt marsh community is not expected to interrupt tidal exchange within the salt marsh area or groundwater flows either in the short- or long-term as described in Alternative 5A. Maintenance of the terminal groin structure, especially within the salt marsh habitat, is not anticipated for the reasons disclosed in Alternative 5A. If required, then precautionary measures described in Alternative 5A will be implemented. See Alternative 5A discussion of Amelia Island for a cursory review of the unlikelihood of terminal groin structure's affecting surrounding salt marsh communities.

Alternative 5D does not include the construction of a connector channel; consequently, flow within Nixon Channel will not be adjusted from its current alignment along its southern bank to the middle channel. With this continuing flow at this location, erosional stress along the salt marsh near the north end of Beach Road will be the same. The initial placement of 57,000 cubic yards of beach fill at this location should help reduce some of that stress on the marsh community, and long-term maintenance placement of material, which could occur up to six (6) separate events over the 30-year study period, is expected to continue reducing this stress.

The use of the disposal islands for nourishment needs is not expected to impact surrounding salt marsh communities under Alternative 5D. Precautionary measures implemented during sand extraction, as explained in Alternative 5B, will minimize the potential for any secondary or cumulative effects.

Any indirect or cumulative impacts, or potential impacts, for Alternative 5D will be similar to those described in Alternative 5A.

Submerged Aquatic Vegetation

Direct, Indirect, and Cumulative Impacts: As discussed previously, SAV resources are found away from the throat of Rich Inlet in areas that are protected from naturally induced changes in water quality such as turbidity and TSS. Dredging within Nixon Channel is predicted to cause a short term increase in turbidity and TSS levels during construction operations; however it is expected that the levels will remain within the State standard of 25 NTUs as shown in Cleary and Knierim's 2001 report and Bogue Inlet Project, as described under Alternative 3 and 5A.

Since dredging within Nixon Channel is not expected to significantly alter the tidal flow through the inlet, the salinity within the permit area is expected to maintain its existing condition and therefore SAVs are not anticipated to be impacted by a change in salinity (see Appendix B). Should the disposal sites be utilized, SAVs would not be expected to be impacted due to the utilization of proper construction methods, including silt fencing. This would reduce the likelihood of impacts associated with the burial of SAV resources. In addition, dredging will occur during the dredging window between November 16th and March 31st, which is when biological activity is low and SAV resources are less abundant within the Permit Area. Therefore, there are no anticipated SAV impacts due to changes in water quality or potential habitat areas. Maintenance events, scheduled for every five (5) years during the 30-year study period, will be restricted to the original dredge footprint and will occur during the winter months when SAV resources are biologically inactive. Similar to Alternatives 4 and 5A, any cumulative impacts to SAV under Alternative 5D are not expected to be adverse.

Shellfish Habitat

Direct and Indirect Impacts: For Alternative 5D, no shellfish beds are present within the footprint of the channel to be dredged. However, the dredging of material from Nixon Channel is predicted to cause a short term increase in turbidity and TSS. Due to the low silt percentage and the well-sorted within Nixon Channel, the turbidity levels are expected to remain below the state standard outside the immediate area of dredging. Using proper construction practices, the removal of material from the three upland dredge disposal islands should not cause direct or indirect impacts to shellfish resources within proximity of the islands or pipelines. See Alternative 5A for further details.

As stated above for SAV resources, there are also potential shellfish beds within proximity to the three disposal islands that could be used as a contingency borrow site. Should these sites be utilized, proper construction methods, such as silt fencing and placement location of pipes, will be implemented to reduce any potential direct or indirect affects to these shellfish resources. Additionally, dredging would occur within the confined disposal island and this would reduce the likelihood of impacts associated with the burial of shellfish beds.

Cumulative Effects: As described previously for Alternatives 4 and 5A, cumulative impacts to shellfish habitat under Alternative 5D are not expected.

UPLAND HAMMOCK

Direct, Indirect, and Cumulative Impacts: Upland hammocks within the permit area may be threatened by potential sea level rise overtime. If any rise in sea level is validated, the increase could result in potential cumulative impacts to coastal upland hammocks present in the permit area.

The upland hammocks present atop of the AIWW dredge disposal islands that could be utilized as a contingency for the nourishment activities associated with Alternative 5D would be removed during excavation of the islands. Some colonial waterbirds such as green herons and yellow-crowned night herons utilize vegetated, upland environments similar to those present on the dredge disposal islands. These three colonial waterbird groups prefer trees, shrubs, and grass lands for nesting and, as a result, may utilize the upland hammocks identified within the Permit Area. It would be expected that these birds would relocate to other proximate upland hammocks that line the AIWW.

As with Alternatives 5A, 5B, and 5C, impacts to upland hammocks under Alternative 5D are expected to be non-appreciable.

INLET DUNES AND DRY BEACHES

(<u>NOTE</u>: In the discussion for these habitat types at the terminal groin location, we have defined the south side of the structure as the "oceanfront" and the northern side as "inlet". Under Alternative 5D, we acknowledge that this structure extends approximately 420 feet closer to the inlet than Alternatives 5A and 5B, and removes that area as inlet dunes and dry beaches for this alternative. See OCEANFRONT DRY BEACHES AND DUNES further below for discussion addressing the south side of the groin structure.)

Direct Impacts: The impacts to the inlet dunes and dry beach habitat are expected to be the same during the construction of the terminal groin for Alternative 5D as described for Alternative 5C. Like the other terminal groin alternatives, much of the direct impacts to inlet dunes and dry beaches will occur with the installation and within the footprint of the terminal groin structure and the construction corridor. Alternative 5D will impact approximately 0.9 acres of inlet dunes and 0.2 acres of dry beach. Work consists of excavating the inlet dune area both on the Nixon Channel side and the oceanside in order to install the rubble/rock material for the structure. Once the structure is in place, the excavated dune material will be placed over the rock groin and reformed to pre-construction conditions to the maximum extent possible. The dune areas will be sand fenced and vegetated to restore and stabilize the inlet dunes. Biological resources such as resting shorebirds will be displaced during the construction, but it is expected that the adjacent and surrounding dune habitat on Figure Eight and Hutaff Islands can temporarily support those resources while work activity is undertaken for Alternative 5D. The installation of the groin structure along the inlet dry beach area, which is adjacent to the inlet dune, is likely to directly remove any seabeach amaranth vegetation, via excavation, that would be in its dormant stage. As shown in Chapter 4, a population of these plant species have been inventoried in the vicinity of the structures footprint & construction corridor.

The placement of 57,000 cubic yards of dredged material along the Nixon Channel shoreline, which encompasses approximately 1.2 acres of newly created dry beach, will cover a small portion of the native dry beach. This area has historically experienced high erosion rates and contained approximately 0.6 acres of inlet dry beaches under the 2006 conditions. The expansion of this shoreline footprint would have the same beneficial effect on shorebirds as discussed in Alternatives 3, 4, 5A, 5B, and 5C. See Alternatives 3, 4, and 5A for discussion on those benefits.

As shown in Chapter 4 and described in Alternative 5A, turtle nests have been found on the oceanside along the northern end of Figure Eight Island and in the proximity of the groin structure, including the footprint and construction corridor. The construction and design of the structure for Alternative 5D has the same potential to affect sea turtle nesting capabilities as described in Alternative 5C. Reference the discussion in Alternative 5C. To minimize any potential impacts, construction activities associated with Alternative 5D will be scheduled so that it does not coincide with sea turtle nesting season.

While the negative impacts to the inlet dry beach near and north of the structure are expected, there will be an expansion of the adjacent oceanfront dry beach on the south side of the structure. This oceanfront dry beach will be constructed with the use of compatible beach material. Although direct impacts would occur to inlet dry beach on the Figure Eight side of the inlet, no significant adverse impacts are anticipated within those habitats on the Hutaff side.

As stated under Alternative 5A, any piping plovers present within the permit area would be temporarily disturbed by the noise associated with the nearby staging, storage, and transportation of equipment, materials, supplies, and workers on the beach in support of project construction which is scheduled to occur between November 16 and March 31 to minimize the potential impact. Bulldozers may be used to achieve the design height and berm width for the proposed beach fill sections, and additional heavy machinery will be utilized to construct the terminal groin. Furthermore, rocks that will be used to construct the rubble mound portion of the groin will be stockpiled in an area adjacent to the groin. This would likely cause piping plovers within the area to seek out and use alternative habitat areas outside of the influence of project activity. The presence and operation of this equipment may also directly injure or kill the birds if not previously spotted, or force them to alter their normal feeding or roosting behavior. Noise associated with the construction – such as operation of heavy machinery and pile driving - may stress the piping plovers by causing them to spend more time responding to the disturbance than foraging and resting, or force them to vacate the area.

Any piping plovers utilizing the sand spit at the north end of Figure Eight Island may also be disturbed by noise associated with construction activities. With the potential for during construction impacts to shorebirds, it is expected that the winter work timeframe, the availability of other supporting dry beach habitat (totally approximately 215 acres) in the inlet, and the adaptability of the shorebirds will help in reducing those effects. Due to the distance from the project activities, any plovers within these other areas will not likely be directly or indirectly impacted by project activity. In regards to their ability to adjust to the presence of construction, other inlet projects have demonstrated the continual use by shorebirds, including piping plover, while work was on-going. For example and as described in Alternative 3, in the recent ebb tide channel relocation project in New River Inlet, during-construction bird monitoring was conducted within the approximate 2.5 month construction period between November 2012 and February 2013, when some wintering birds such as overwintering piping plover, would likely be present. The results of the monitoring showed the constant presence of shorebirds throughout the inlet complex, including several sightings of piping plovers (Coastal Planning & Engineering, 2013). During construction surveys showed an average of 1,840 individuals for a variety of species per survey. In another bar channel relocation project in Bogue Inlet, the 2005 during construction bird monitoring also showed the continued use of the inlet complex while dredging and a dike construction in the inlet were on-going from January to April, 2005. Shorebirds, including piping plover, were observed during the monitoring efforts for both projects appeared to adjust to the presence of construction equipment and noise and are of the same species found in Rich Inlet. The same continued use and inhabitation by avifauna and other species found in the Rich Inlet complex is expected throughout the entire construction period.

Indirect Impacts: Similar to all other groin alternatives, the construction corridor for Alternative 5D will be kept open for an undetermined amount of time for any unseen maintenance or potential for structure removal. If the structure remains, it is expected that the landward portions of the terminal groin will become covered in sand and possibly vegetated while the seaward most 200 to 300 feet of the structure could be periodically exposed depending of antecedent sea and weather conditions. See Alternative 5A for additional discussion on the future maintenance of the terminal groin.

Since the terminal groin will terminate in relativity shallow water, it should not exert any substantial influence on processes occurring seaward of the end of the structure. For example, under the 2006 eroded condition on the north end of Figure Eight Island, the seaward end of the terminal groin would have ended in a water depth of about -3 feet NAVD88. As a result, the littoral processes impacting the outer portion of the ocean bar and the position and alignment of the bar channel would continue as in the past as would the primary mode of sediment bypassing around Rich Inlet. As demonstrated by the morphological history of Rich Inlet developed by Dr. William Cleary and reported in Sub-Appendix A of Appendix B, sediment bypassing around Rich Inlet occurs through the process of channel migration and subsequent channel breaching (a process also known as bar bypassing). Therefore, the bypassing of littoral sediment around Rich Inlet would continue to occur and could result in the redevelopment of the Figure Eight Island spit over time allowing for natural resources including seabeach amaranth to continue to persist in this area.

When using the 2006 shoreline conditions, the results of the Delft3D 5-year simulation showed a small percentage of the sand spit located north of the terminal groin on Figure Eight Island remained at the end of Year 5. Much like Alternative 5A and 5B, most of the spit had morphed into a intertidal and subtidal habitat. The loss of approximately 12 acres of inlet dry beaches, inlet dunes, and overwash in this area would result in a decline of nesting and roosting habitat for shorebirds, including the endangered piping plover, and decrease of habitat for seabeach amaranth. This loss includes the approximate 0.6 acres of inlet dry beach that was initially created with the fill placement along the Nixon Channel shoreline. As demonstrated in the Audubon North Carolina bird surveys, piping plover used the northern spit of Figure Eight Island for foraging and roosting, especially on the backside, or soundside, of the spit, which is a part of Unit NC-11 Critical Habitat for piping plover. The reduction of inlet dry beach and overwash areas would likely affect the resting and nesting behavior of shorebirds and could limit piping plover's use of its Rich's Inlet critical habitat unit during the 5-year modeling period.. The decrease of inlet dry beach would also reduce the potential for seabeach amaranth to sustain a population at this location. The magnitude and extent of these effects are unknown. Like Alternative 5A, it is expected that some of the sediment eroding from the oceanfront beach fill will continue to be transported into the inlet at some undetermined rate over the 5-year simulation period. In the area between stations 60+00 and 105+00, 21.2% of the initial beach fill volume remained after the 5-year Delft3D model simulation based on 2006 conditions. Much of this material was transported to the north through and around the groin. This sediment influx would help minimize for some extent of the habitat loss and any resulting affects that may occur on the bird resources.

The response along Hutaff Island to Alternative 5D was basically the same as observed under Alternative 5B model simulation. Under Alternative 5D, the southern 2,640 feet of Hutaff Island accreted at a rate of 72,000 cubic yards/year (see Figures 5.40 through 5.45). The spit on the south end of Hutaff Island propagated south during the first three years of the model simulation and then stabilized. This extension of inlet dry beach would increase the amount of habitat with piping plover's Unit NC-11 Critical Habitat, helping to offset some of the loss occurring within the Figure Eight Island spit. As shown in the Audubon North Carolina bird survey, this southern spit was heavily used by piping plovers for the entire 2008-2012 survey period. Noted behavior during this time comprised of both foraging and roosting. With the spit increasing over the 5-year simulation when compared to the baseline conditions of Alternative 2, piping plover and other bird species will continue to utilize that area with a possible increase of use due to additional overwash and dry beach habitat. Because Hutaff Island is unpopulated and access is restricted by boats only, the increased habitat on the southern tip of the island is considered valuable for nesting and foraging wildlife.

For the middle shoal area of the inlet flood tide delta, the Delft3D 5-year model simulation showed a slight increase in overwash habitat when compared to the baseline conditions of Alternative 2. This increase appears to be approximately 0-2 acres and is expected to provide some roosting habitat for piping plover and other shorebirds. The Audubon North Carolina bird surveys show piping plovers using this middle shoal area from 2008 to 2011 for foraging. This additional overwash would provide resting, or roosting, areas for bird species during their feeding activity.

When the channel gorge is positioned next to the terminal groin, the amount of accretion or development of inlet dry beach and overwash habitat used by shorebirds, including piping plovers, on the north side of the structure would be limited. In limiting the formation of these habitats on the southern inlet shoulder of Figure Eight Island, the conditions for promoting roosting and potential nesting habitat would be less than naturally occurring levels at this location. Again, this limitation would reduce Unit NC-11 for piping plover along this spit. The initial beach fill and maintenance of dry beach along Nixon Channel shoreline and within the oceanfront fillet is expected to benefit piping plover's, and other shorebirds, resting and nesting behavior at those locations. Also, even if the channel does assume a position next to the terminal groin, that position is not expected to be permanent.

On the inlet shoulder of Hutaff Island, the inlet dry beach and overwash habitat is expected to undergo periods of fluctuation over the long-term, but is expected to be somewhat consistent with levels demonstrated in natural conditions. The fluctuation of shorebird habitat, including piping plover, on Hutaff Island is anticipated to be largely influenced by natural conditions and the positioning of the bar channel rather than by the proposed project. Even though newly formed inlet dune, dry beach, and overwash areas are shown on Hutaff Island and the middle shoal area, this formation, along with sediment input from the oceanfront, doesn't fully compensate for the loss on the northern portion of Figure Eight Island. In total for the 5-year simulation period, a net loss of approximately 0-5 acres of these habitat types are anticipated as a result of the implementation of Alternative 5D. This deficit of habitat is likely to affect the foraging and roosting behavior of shorebirds.

In addition, the overall loss of inlet dune, dry beach, and overwash areas will reduce the amount of boat use for recreation. As a result of the aerial imagery assessment discussed in Alternative 2 the northern spit of Figure Eight Island is frequently used by boaters. The loss of dry beach and overwash areas will limit the space for anchoring and the use of Figure Eight shoreline for recreation.

Cumulative Impacts: Alternative 5D includes maintenance of the beach fill segments every five (5) years resulting in a maximum of six (6) events over the course of the 30-year project. It is expected that some of the beach fill will continue to migrate over, through, and/or around the groin structure into the inlet after each event. However, the amount is not anticipated to have an appreciable long-term benefit to the sustaining of inlet dry beach and overwash habitat within Figure Eight Island spit. Like Alternative 5A and 5B, long-term impacts to inlet dry beaches and overwash areas, including the shorebirds that utilize them, are expected within the inlet complex under Alternative 5D. After the initial loss of habitat during the 5-year period described above, the extent and magnitude of habitat loss and the impacts on the bird resource are unknown. After the initial post-construction effects on the north side of the terminal groin equilibrate, it is anticipated that the presence of inlet dry beach and overwash habitat will be largely dictated by the migration and position of the inlet bar channel over the 30-year study period as it has been shown to do in the past.

The spit on the northern end, or Hutaff side, of Rich Inlet is expected to provide long-term inlet dune, dry beach, and overwash habitat beyond the 5-year modeling period regardless of the potential effects from the groin structure on the south side of the inlet. Although the extent of potential cumulative impacts over the 30-year study period is unknown, the presence of inlet dry beaches and overwash habitats within Rich Inlet are expected to continue overtime and to provide foraging, nesting, and resting areas for piping plover and other shorebirds that utilize them. This can be seen when observing the changes over the last 24 years at Oregon Inlet terminal groin, which is a much longer structure than Alternative 5D (see discussion in Alternative 5A Intertidal Flats and Shoals). It is anticipated that, if the reduction of these habitats occur due to the presence of the terminal groin structure, the rate of that reduction will equilibrate at some point in time and the shifting of inlet dune, inlet dry beach, and overwash habitats on Hutaff Island and the middle shoal will become more influenced by the natural movement and positioning of the bar channel.

INTERTIDAL FLATS AND SHOALS

(<u>NOTE</u>: In the discussion for these habitat types at the terminal groin location, we have defined the south side of the structure as the "oceanfront" and the northern side as "inlet". Under Alternative 5D, we acknowledge that this structure extends approximately 420 feet closer to the inlet than Alternatives 5A and 5B, and removes that area as inlet dunes and dry beaches for this alternative. See OCEANFRONTDRY BEACHES AND DUNES further below for discussion addressing the south side of the groin structure.)

Direct Impacts: Under Alternative 5D, the groin and beach nourishment construction activity may stress shorebirds, including the endangered piping plover, from foraging along the intertidal flats that are located in close proximity of the construction area. However, as shown with the channel relocation project in New River Inlet and Bogue Inlet discussed in Alternative 3 and 5A, during-construction bird monitoring revealed continual bird use of the inlet resources as dredging and inlet beach activity was in operation. As with these projects, construction for Alternative 5D will take place between November 16th and March 31st when some migratory bird species are not present and bird populations are at their lowest.

The use of mechanical equipment will be restricted within a specific construction corridor for the construction of the terminal groin which should help in reducing any potential stresses on the birds that may be foraging and/or resting in the area. In addition, these birds would be expected to temporarily relocate to available nearby intertidal flats and shoals on the north side of the inlet. Direct impacts to shorebirds utilizing these habitats should be minimal under Alternative 5D.

The dredging area associated with Alternative 5D does not include intertidal flat and shoal habitat, therefore, no direct impacts will occur. However, there are potential effects on the fishery resources that may be migrating through the area and/or utilizing adjacent intertidal flats and shoals. Several different fish species inhabit these areas and forage on many of the benthic organisms that reside within the intertidal flats and shoals. For any fish species that may be present, it is expected that their mobility will provide them the opportunity to temporarily relocate to surrounding habitats while the dredging is taking place. Additionally, the winter time dredging will occur when many of these species are likely offshore and not utilizing the nearshore or inlet intertidal flats and shoals.

Indirect Impacts: For Alternative 5D, model sediment volume changes in discrete areas within the inlet complex after 5-years are provided in Figure 5.56. The overall net change in volume for Alternative 5D compared to the baseline conditions at year 0 for Alternative 2 was -160,200 cubic yards. This net loss included the 294,500 cubic yards artificially removed by dredging in the Nixon Channel borrow area with material placed along the oceanfront and Nixon Channel shorelines on Figure Eight Island. The largest volume decrease was measured in the offshore bar directly seaward of the inlet throat. But, losses were also noted within the flood tide delta, or middle shoal area, and along the Figure Eight shoulder of the inlet, which are both included in the piping plover's critical habitat boundary of Unit NC-11. These latter two locations exhibit an abundance of intertidal flats and shoal habitat areas where foraging and roosting of piping plover have been documented by Audubon NC bird surveys. It is also expected that these locations are used by various fish species for feeding and/or temporary refuge from predators. With this projected net decrease in sediment volume within the system, there may be less inlet flats and/or shoals than pre-construction conditions in certain areas, but there also may be more of these habitats in other areas. For instance, the Figure Eight shoulder of the inlet is showing a decrease in volume; however, the majority of that loss occurs within the 12 acre conversion of inlet dune, dry beach, and overwash areas to intertidal flats and submerged sand flats and shoal habitats at that location. The Defltt3D 5-year simulation revealed an increase of approximately 4-5 acres of intertidal flats and shoals within the northern spit of Figure Eight Island due to this conversion. Although this conversion would reduce the roosting and potential nesting habitat for shorebirds, like piping plover, it would increase the foraging areas within the northern spit of Figure Eight Island. By year 5 of the Delft3D model simulations, the spit on the south end of Hutaff Island propagated south during the first three years of the model simulation and then stabilized. This extension of inlet dry beach would increase the amount of habitat with piping plover's Unit NC-11 Critical Habitat, helping to offset some of the loss occurring within the Figure Eight Island spit. This would be a short-term benefit for roosting and nesting potentials on the north side of the inlet where documented use for foraging and roosting has been consistent. Additionally the increase of intertidal flats would provide additional feeding and shelter areas for a variety of fishery resources.

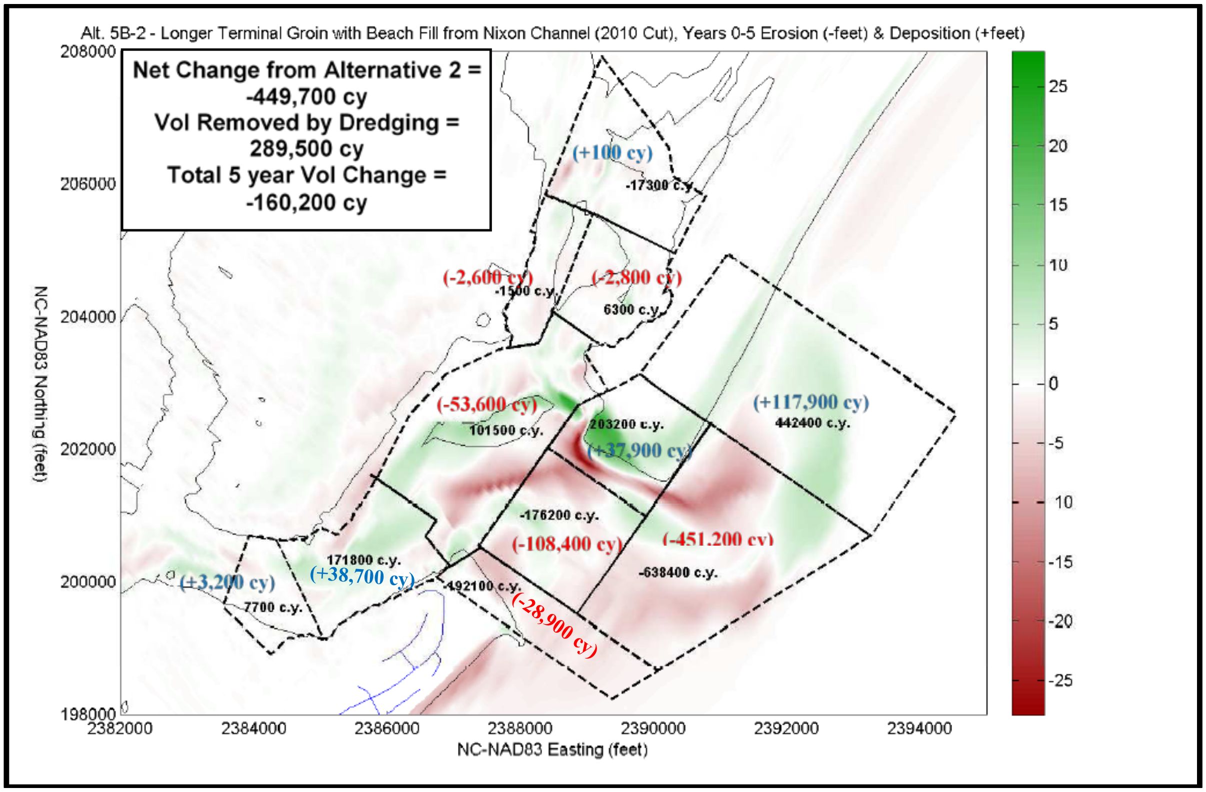

Figure 5.56. Model volume changes in discrete areas within the Permit Area for Alternative 5D. Values in green and red indicate an increase or decrease in material volume, respectively, compared to Alternative 2.

The initial stability of the dry beach and overwash in the sand spit on the north side of the terminal groin appeared to be associated with material eroded from the oceanfront beach fill passing over and around the structure. The model indicated relatively high rates of sediment loss from the oceanfront fill during the first 3 years of the simulation with this eroded material being transported past the terminal groin and onto the sand spit. The low-profile of the proposed terminal groin is intended to promote the transportation of material over the structure during periods of relatively high wave conditions and storms. In addition, material will be transported through the structure due to spaces between stones and the lack of a solid "core" built within the groin. The influx of this sediment around, over, and through the structure initially reduced the rate of dry beach and overwash conversion to intertidal and submerged flats and shoals located north, or downdrift, of the structure. However, the conversion increased after the third year and produced approximately 4-5 acres of intertidal flats and shoal habitats. At the end of the 5-year simulation, the overall conversion provided foraging areas for the birds on the northern end of Figure Eight Island.

Despite the potential sediment reduction under Alternative 5D, the intertidal flats and shoals within the inlet complex continued to exist within the 5-year model simulation under the 2006 shoreline conditions. Like Alternative 5B, Delft3D model results suggest that shoaling increased in some locations and decreased in others. Specifically, the intertidal shoals in proximity to the area dredged within Nixon Channel and along the ebb tide delta were initially reduced. The reduction of these resources in proximity to Nixon Channel could be attributed to material in-filling the newly dredged area. The intertidal flats and shoals within the inlet complex, including the middle shoal ground area, would be expected to continue to receive some sediment input through the sand bypassing, helping to sustain the continued presence of intertidal flats and shoals.

The tidal prism is anticipated to only change marginally compared to baseline conditions of Alternative 2. With the tidal prism remaining relatively unchanged after dredging and the installation of the groin structure, sediment movement and distribution within the 5-year simulation will be minimally affected within the inlet which should not impact the development and redevelopment of intertidal flats and shoals.

Cumulative Impacts: For Alternative 5D, the Delft3D shoreline modeling under the 2006 conditions has shown the need for beach renourishment once every five (5) years with the material coming from the previously dredged Nixon Channel. This could potentially total up to 6 individual maintenance events within the 30-year study period. Each maintenance episode is expected to impact intertidal flats and shoal habitat as described in the indirect impact assessment above. One exception would be the north side of the terminal groin where no additional conversion to the habitat is expected. However, this inlet side of the groin structure is expected to be periodically fed by sediment transporting from the oceanfront after each renourishment event as demonstrated in the volume modeling results and through long-term observations of other terminal groins structures such as Pea Island and Fort Macon. Even without maintenance events, sediment transport is expected to continue into the inlet under natural conditions but at a lesser rate. It should be noted that inlet intertidal flats and shoals are not fixed stationary habitats, and are considered to be ephemeral and dynamic in natural conditions. Consequently, bird resources are known to adjust to these changes.

For each maintenance event every five (5) years, approximately 320,000 cubic yards of sediment would be dredged from Nixon Channel to nourish both the ocean and Nixon Channel shoreline beach fill areas. Each dredging event is expected to result in a minor deficit of sediment and it is unknown to what extent that would cumulatively have on the development and redevelopment of intertidal flats and/or shoals. The magnitude and extent of impacts would be contingent on how quickly intertidal flats and shoals will reform or shift elsewhere and this, in turn, would help in knowing how fish and shorebird populations utilizing these resources would adjust. It can be expected that the sediment deficit under Alternative 5D would potentially reduce the amount of material available for intertidal flats and shoal redevelopment within the inlet complex. This could potentially affect piping plover, and other shorebirds, as well as fishery resources that utilize these shoals for foraging.

The overall effects of the initial sediment deficit on intertidal flats and shoal habitats within the inlet is not known for Alternative 5D. However, as described in Alternative 5A, one can reference the 23-year old terminal groin in Oregon Inlet to obtain a general understanding of impacts to these areas around the groin structure and to what effects it has on shorebirds, especially piping plover (see Intertidal Flats and Shoals under Alternative 5A for more information).

After the initial post-construction effects on the north side of the terminal groin equilibrate, it is anticipated that the presence of intertidal flat and shoal habitats will be largely dictated by the migration and position of the inlet bar channel over the 30-year study period. For Rich Inlet, it is anticipated that some material within the formed accretion fillet and beach fill will continue to be transported beyond the structure back into the inlet over the long term as demonstrated in the modeling results and through observations of other terminal groins structures such as Pea Island (Oregon Inlet) and Fort Macon.

In addition, many boaters utilize the shoals as an area to anchor and recreate. Without extensive shoals, boaters may flush out and disturb the migratory birds utilizing the habitat for foraging. During peak summer months, it can be expected that any available shoals would be used since Rich Inlet area is known to experience a continuous high volume of boaters and people in the summer.

OCEANFRONT DRY BEACH AND DUNE HABITATS

(<u>NOTE</u>: In the discussion for these habitat types at the terminal groin location, we have defined the south side of the structure as the "oceanfront" and the northern side as "inlet". Under Alternative 5D, we acknowledge that this structure extends approximately 420 feet closer to the inlet than Alternatives 5A and 5B, and includes more oceanfront dry beach and dune habitat for this alternative.)

<u>Oceanfront Dune Communities</u>

Direct and Indirect Impacts: With Alternative 5D, the placement of approximately 264,500 cubic yards of beach compatible material along 4,250 linear feet of Figure Eight Island is expected to help stabilize the dune system and provide long term storm protection. Although the construction of dunes is not a part of the plan for Alternative 5D, the beach fill is intended to provide direct and indirect benefits to the coastal dune communities as it allows for growth and development of dune vegetation thereby providing habitat for roosting, foraging and nesting shorebirds. On Hutaff Island, approximately 0.3 acres of coastal dune communities are expected to be indirectly affected by the implementation of Alternative 5D within the first year following construction, as concluded by the Delft3D modeling effort. In general, only minimal or negligible negative impacts are anticipated to the oceanfront dune communities within the Permit Area.

Cumulative Impacts: Like all the alternatives, the orientation of the inlet bar channel has been proven to play an important role regarding shoreline erosion rates along the oceanfront of Figure Eight and Hutaff Islands. When the inlet channel is positioned in a southerly orientation, the oceanfront dunes on Figure Eight Island would be expected to persist or increase in size while the contrary would be expected on the southern oceanfront shoreline on Hutaff Island. The opposite is true for both islands when the bar channel is located in a more northerly position. Currently, the inlet bar channel appears to be shifting from the south to a more central location; and if the shifting continues northward, the oceanfront of Figure Eight Island is anticipated to undergo erosive conditions affecting oceanfront dunes while Hutaff's oceanfront experiences accretion.

The implementation of Alternative 5D includes a renourishment cycle of a maximum once every five (5) years, which includes the placement of approximately 290,000 cys of material along the Figure Eight Island's oceanfront shoreline and 30,000 cubic yards along the Nixon Channel shoreline. Over the 30-year study period, the renourishment or maintenance could occur up to six (6) separate events. Consequently, the project will serve to provide long-term protection of the dunes on Figure Eight Island and should benefit any resources using that habitat. The magnitude and extent of the protection would depend largely of the position of the inlet bar channel. Like Alternative 5B, no cumulative impacts are anticipated as the direct impacts as described above are expected to be temporary in nature. Although overwashing of dunes can result in the formation of important habitat for a variety of shorebirds, the dunes along Figure Eight Island are located in front of residential development and therefore overwashing events would not provide this effect.

The dune communities located on Hutaff Island would be expected to migrate westward as natural processes influence the environment, but the dune communities are expected to remain intact. Also, the south tip of Hutaff Island could grow and project farther south into Rich Inlet creating additional dry sand beach an opportunities for natural dune development. However, if the predicted increased rates of sea level rise is validated, the long term viability of dunes within the permit could be impacted as the potential of detrimental storm surge could increase.

<u>Oceanfront Dry Beach Communities</u>

Direct Impacts: The groin structure for Alternative 5D is positioned and located the same as Alternative 5C, with the exception that it is 200 feet longer below mean high water. But unlike that option, Alternative 5D (similar to Alternative 5B) does not include a dune construction plan. The beach fill footprint for Alternative 5D is the same as Alternative 5B and would encompass approximately 10-15 acres of the dry beach habitat. This includes approximately 10 acres of existing dry beach habitat and the creation of approximately 4 additional acres. The difference between the two alternatives is that Alternative 5D is 420 feet closer to the inlet and will require more beach fill for the initial placement, which includes a total of 264,500 cubic yards of material. The direct impacts to the dry beach will be incurred during the beach nourishment activity and the construction of the terminal groin. The impacts associated with the construction of the terminal groin were described previously under the inlet dunes and dry beach section above. The effects of the groin construction to the dry beach habitat will initially reduce available nesting habitat for sea turtles and shorebirds, including the piping plover, and cover seabeach amaranth habitat; however the renourishment will result in increased beach width. Some factors, as described for the other project alternatives involving beach fill, will reduce some of these temporary impacts. These include the utilization of fill material conforming to the State sediment criteria and wintertime construction.

Direct impacts to the oceanfront dry beach will also include the mortality of crustaceans including ghost crabs, however, these communities are expected to recover within the order of months to more than one year (National Research Council, 1995; Carter and Floyd, 2008).

The width of the oceanfront dry beach immediately following construction will vary along the length of the fill area between 69 feet in proximity to the terminal groin to 17 feet at station 70+00 based on 2006 conditions. The development of the fillet area closest to the structure would create additional dry beach habitat that could be used by shorebirds. This dry beach will encompass approximately 5 acres of potential habitat use.

The direct effects of the beach fill activity within the oceanfront dry beach community for Alternative 5D will be similar to that of Alternatives 3, 4, 5A, and 5C. The physical characteristics of the dry beach, such as grain size, color, and composition, are highly critical for sea turtle nesting success and the composition of the fill material for Alternative 5D is expected to be compatible with the current native sediment. Also, construction will take place within the dredging window of November 16^{th} through March 31^{st} which is outside of the sea turtle nesting season. Reference the discussion in Alternative 3 and 5A regarding the benefits and potential detriments of beach nourishment in oceanfront dry beach habitat for nesting turtles. Therefore, no permanent significant adverse impacts are anticipated.

No significant direct impacts are associated within oceanfront dry beach habitats on Hutaff Island.

Indirect Impacts: As discussed for Alternative 5B, the Delft3D 5-year model simulation for Alternative 5D indicated erosion is expected to occur on the north side of the terminal groin potentially affecting the habitat for nesting turtles, seabeach amaranth, and shorebirds. The location of the groin structure is situated near the transition point from oceanfront dry beach to inlet dry beach habitats, but is 420 feet closer to the inlet throat than Alternative 5B. The increased area of dry beach on the south side of the groin as a result of nourishment as well as the retention of sediment within the accretion fillet will result in positive indirect impacts including the increased habitat for nesting sea turtles, resting and nesting shorebirds, and seabeach amaranth. The width of the oceanfront dry beach immediately following construction will vary along the length of the 4,250 foot fill area. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be increased by 69 feet. The width of dry sand beach south of station 80+00 will be increased by 17 feet. This area will become beneficial habitat for resting colonial waterbirds. Also, because the material utilized for the nourishment will meet State Sediment Criteria, the widened dry beach is expected to increase sea turtles nesting habitat.

For the 2006 condition under Alternative 5D, the southern 2,640 feet of Hutaff Island accreted at a rate of 72,000 cubic yards/year from the baseline conditions established in Alternative 2. The response along Hutaff Island to Alternative 5D was basically the same as observed under Alternative 5B which is not surprising since the only difference in the two alternatives was the location of the terminal groin. Any accretion in this area is expected to continue providing a stable oceanfront dry beach habitat for nesting turtles, shorebirds, and seabeach amaranth.

Simulation of Alternative 5D in the Delft3D model indicated the beach fill area (station 60+00 to the terminal groin) would lose an average of 58,000 cubic yards/year over the 5-year simulation period. As was the case for the other terminal groin alternatives, the segment south of station 60+00 to F90+00 was stable to accretionary to slightly accretionary. Given these model results, periodic nourishment of the beach fill under Alternative 5B would be needed about every five (5) years. Based on the model indicated loss rate of 58,000 cubic yards/year, the 5-year periodic nourishment requirement would be 290,000 cubic yards along Figure Eight Island's oceanfront shoreline. While the volume changes mention above cover the entire active profile out to -24 feet NAVD, some of the fill placed above the -6-foot NAVD contour was still in place after 5 years. The retention of sediment above -6 feet NAVD would provide protection to the pre-nourished upland area. The net increase in dry beach habitat will benefit nesting sea turtles, seabeach amaranth, and shorebirds. Based on the bird surveys conducted by Audubon North Carolina, piping plover utilized this oceanfront of Hutaff mostly during the 2008-2010 survey period. The birds were mostly observed foraging, which would assumedly be along the wet beach but possibly using the dry beach for resting during foraging. The erosion along the oceanfront dry beach is not expected to interrupt the foraging and roosting behaviors of the piping plover.

Hard structures such as terminal groins can indirectly affect nesting sea turtles and hatchlings. The structure for Alternative 5D will have the same potential affect as described in all of the other groin alternatives, particularly with 5C due to their same location. With the constructed fillet extending close to the terminus of the 505-foot seaward component of the proposed terminal groin, the effects of the structure would be expected to be minimal to nesting sea turtles and emerging hatchlings.

Cumulative Impacts: With the maintenance of the oceanfront dry beach, habitat for resting colonial waterbirds, nesting shorebirds, seabeach amaranth, and nesting sea turtles is expected to be maintained at the location of the terminal groin fillet for approximately 1,250 linear feet. The remaining 3,000 linear feet of the fill area would be maintained with supplemental beach renourishment cycles via maintenance dredging within Nixon Channel and possibly utilization of material from the upland dredge disposal islands. These renourishment events are expected to occur within a minimum of every five (5) years with a total of six (6) maintenance events over the 30-year study period. Maintaining the dry beach along the oceanfront shoreline will help ensure that bird and sea turtle habitat will persist. Based on the historical geomorphological and modeling analysis, the amount of any change to the oceanfront dry beach of Hutaff and Figure Eight Islands is strongly contingent on the location or positioning of the ebb tide bar channel. This is expected to be even more so once the initial shifting equilibrates after the installation of the groin structure.

As with Alternative 5A, maintenance of the rubblemound portion of the terminal groin should be infrequent and would depend on the frequency of severe storms that exceed the design conditions for the armor stone. If maintenance of the rubblemound portion is needed, this could involve simply recovering and replacing displaced stones or adding stone to replace the ones that could not be located on site. Any maintenance work within the dry beach area would be restricted within a designated corridor in order to limit any potential impacts.

WET BEACH COMMUNITIES

Direct Impacts: For Alternative 5D, the impacts to the wet beach communities, including the fish and bird resources that use them, would be anticipated to be similar to those described under Alternative 5B due to similar nourishment footprints. This impact encompasses less than 5 acres of the wet beach community along the oceanfront shoreline and Nixon Channel shoreline, immediately burying the infaunal community, a valuable food source for fish and birds. Of this amount, the construction of the terminal groin will permanently cover approximately 0.3 acres of wet beach community within its footprint. Once the beach fill is placed, approximately less than 5 acres of new wet beach habitat will be created resulting in no net change in wet beach acreage. Impacts to the wet beach communities, including the loss of prey (infaunal resources) for foraging fish and birds, are expected to be similar to those described for the other terminal groin alternatives.

Indirect Impacts: For Alternative 5D, the Delft3D model results suggested that secondary impacts of less than 5 acres of marine intertidal habitat will occur along the ocean shoreline of Figure Eight Island while the fill placement equilibrates. This may affect shorebird, crustacean and fish foraging, and recreational fishing through a temporary reduction in bait species during and immediately after construction. Impacts should be reduced due to the fact that the material utilized for beach fill will be compatible with native material, thereby reducing the recovery period for infaunal communities which will allow for a continued prey source for higher trophic species such as shorebirds and fish. Indirect impacts and minimization to those impacts for oceanfront and Nixon Channel shoreline are similar to those described in Alternatives 5A and 5B.

As discussed under the other terminal groin alternatives, the ability for infaunal species to repopulate disturbed wet beach habitat in proximity to a shoreline stabilizing structure was demonstrated following the construction of the rubble weir jetty structures at Murrells Inlet, South Carolina. The macrobenthic communities of the intertidal and nearshore subtidal environments were sampled during the construction of the jetties and once again five (5) years later. Comparison of species abundance between years and among localities (updrift and downdrift) suggested no widespread impacts to macrobenthic fauna were attributable to jetty construction (Knott et al, 1984). Although the physical conditions are not identical at both locations, a similar response would be anticipated following the construction of the terminal groin on Figure Eight Island.

Cumulative Impacts: As a result of the dredging and renourishment activity at a minimum every five (5) years, or six (6) separate events over the 30-year study period, negative effects could occur if the diversity and abundance of infaunal populations do not recover between nourishment events. However, organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels (Nelson, 1985). Alternative 5D is not expected to result in long-term impacts to wet beach habitat due to the adaptability of benthic communities, sufficient period between maintenance events for recovery, and the use of compatible material. This habitat will continue to provide foraging areas for small fish and bird species on a long-term basis.

MARINE HABITATS

Softbottom Communities

Direct Impacts: The activities associated with Alternative 5D would be similar to those described for Alternative 5B result in a direct impact to approximately 25-30 acres of softbottom community within the dredging footprint in Nixon Channel and within the construction footprint of the terminal groin. For the reasons explained in Alternative 5A and 5B, direct impacts should be minimized with the implementation of Alternative 5D.

For the 1,500-foot long structure, approximately 505 feet will extend seaward beyond the mean low water under the 2006 shoreline conditions. This section, which is 75-feet wide, will permanently cover approximately 0.9 acres of nearshore softbottom community. An additional 1.5 acres would be temporarily impacted due to the utilization of the construction corridor. It is not known to what the full effects of this permanent covering will be on the fishery resource, but with the available softbottom habitat surrounding the footprint of the structure for Alternative 5D, the fishery resource should be capable of locating food sources and foraging within nearby areas.

Indirect Impacts: Construction of the beach would result in the direct deposition of material from the dune or berm crest seaward to the construction toe-of-fill. Over time, the slope of the fill would adjust and equilibrate seaward and consequently cover softbottom habitats located seaward of the toe of fill. Similar to Alternatives 3, 4, and all the terminal groin alternatives, the degree of infaunal mortality associated with the covering would be contingent on the amount of material and the rate of adjustment. Studies have shown that many infaunal organisms that utilize this softbottom habitat are capable of burrowing through sand up to 40 cm, and thus can survive being covered by limited amounts of material (National Research Council, 1995). Softbottom communities may also change with natural shifting patterns of sediment erosion or deposition (Deaton et al., 2010). It should be reiterated that the material placed over the softbottom habitat meets the State's sediment criteria language and is therefore considered to be compatible to the native sediment. As discussed in Chapter 3 and the Intertidal Flats and Shoal Indirect discussion above, the removal of material from the Nixon Channel borrow area would leave a net deficit of approximately 160,200 cubic yards of material from the inlet complex for Alternative 5B over a 5-year period. Despite this sediment deficit, infaunal communities would be expected to repopulate the benthos.

For Alternative 5D, the removal of material from the Nixon Channel borrow area would leave a net deficit of approximately 160,200 cubic yards of material from the inlet complex over the 5-year simulated period, which is further discussed in Chapter 3. Infaunal communities located within Nixon Channel and surrounding areas would be expected to repopulate the benthos despite the sediment deficit. As described previously, the results from an infaunal monitoring following the Bogue Inlet Channel Relocation Project demonstrated the successional recolonization and continued increase of recovery overtime within an inlet complex that underwent extensive dredging. Reference the discussion in Alternative 3 for the findings and the verification of infaunal recovery in that monitoring.

Negative impacts to foraging fish and invertebrates include the temporary loss of prey from the dredged softbottom habitat within Nixon Channel and from the time period of adjustment for nearshore infaunal communities that are covered. For softbottom habitat permanently covered by the terminal groin footprint, this loss of potential foraging habitat is minimal due to the abundance of infaunal food source in the adjacent areas. The overall effects to fish feeding behavior is expected to be non-appreciable.

Additionally, fish, including mullet that migrate over the nearshore softbottom habitat, may be impeded when they encounter the terminal groin. Data from a study conducted at Murrells Inlet, SC suggested that few swimming organisms moved across the weir. Although the jetty at Murrells Inlet acted as a barrier for fish migration, the physical nature of the proposed structure at Figure Eight Island is much shorter in length. Furthermore, the accretion fillet is expected to fill seaward and would therefore reduce the exposed area of the groin. In this regard, fish and other motile organisms will be expected to pass by the structure as they migrate along the shoreline which is expected to extend near the seaward terminus of the groin. Therefore, migrating fish may be only minimally impacted by the presence of the terminal groin.

Cumulative Impacts: Alternative 5D is expected to undergo the indirect impacts discussed above each time a maintenance event occurs which is projected to be every five (5) years equating to six (6) separate events over the 30-year study period. The nature of cumulative impacts for dredging and renourishment events are expected to be similar as those described for Alternatives 3,4, and all of the terminal groin alternatives with the exception that the footprint of the fill area is considerably smaller and the magnitude of impacts is anticipated to be less. Like all the terminal groin alternatives, cumulative effects within the softbottom community associated with the footprint of the structure are anticipated to be minimal.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts: Although no natural hardbottom communities have been observed within the Permit Area, it is anticipated that the construction of the terminal groin under Alternative 5D may provide an artificial hardbottom habitat. The physical structure of the proposed groin is expected to create habitat which may provide a foraging site and shelter for fishes, including bluefish, in the surf zone (Hay and Sutherland, 1988). The presence of some fish attracted to the groin structure may predate upon sea turtle hatchlings. These effects are expected to be the same as those described above under Alternative 5A.

WATER QUALITY

Turbidity and TSS

Direct, Indirect, and Cumulative Impacts: The impacts of turbidity and TSS within Rich Inlet complex, along the oceanfront shoreline, and surrounding the (3) disposal islands are expected to be minimal and short-term as described for Alternative 5A, 5B, and 5C. This includes results from the dredging of the previously permitted Nixon Channel borrow area, the placement of the dredged material on the oceanfront beach and Nixon Channel shoreline, and the construction of the terminal groin structure. For further details see discussions in Alternative 5A and 5B.As previously discussed, natural conditions support fluctuating turbidity levels in the nearshore and offshore water column of the Permit Area and work under Alternative 5D is not expected to exceed natural conditions.

Dredging within Nixon Channel and the placement of beach fill activities are anticipated to occur at a maximum once every five (5) years, which could total up to six (6) separate maintenance events over the 30-year study period. Each maintenance event will take approximately eight (8) weeks to complete, pending weather and working conditions. After each dredging, there will be adjustment within the dredged area in Nixon Channel and in-filling is expected within months. The adjustment or equilibration period of infilling may increase turbidity and/or TSS levels, but should not exceed dredging levels. Also, it should be acknowledged that levels can increase dramatically during times of storms. Due to factors described above, no significant adverse cumulative impacts regarding suspended particulates and turbidity are expected.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: Under Alternative 5D, the Delft3D model simulation displayed some change within the tidal prism over the 5-year period, but the results of that change were considered minor. The impacts of hydrodynamics and salinity are expected to be minimal as described above for Alternative 5A, 5B, and 5C. The average tidal prism of Rich Inlet under Alternative 5D was slightly larger and within the margin of error within the model than the average tidal prism for the baseline conditions exhibited at year 0 for Alternative 2. Based on the modeling, Alternative 5D, like the other terminal groin alternatives, is not anticipated to cause any change in the existing hydrodynamics of Rich Inlet including salinity levels. Flow distribution through Nixon and Green Channels was also basically the same as described for Alternative 2 baseline conditions (see Chapter 3 for more detail). Any migrational effects on fishery resources from this change in the inlet is expected to be non-appreciable.

<u>*Larval Transport*</u>

Direct, Indirect, and Cumulative Impacts: There is potential for direct impacts to fish larvae within the water column under Alternative 5D during the dredging of Nixon Channel. Larvae could be entrained within the dredge while operating in the flood tide delta where fish larvae would be migrating. This potential of entrainment is low due to the time of year dredging and to the relatively small volume of water pumped through the dredge compared to the volume within the tidal prism See Alternative 5A for further discussion on these direct impacts.

Like all the terminal groin alternatives, the structure of Alternative 5D has the short and long-term potential to interfere with the passage of larvae and early juvenile fish from offshore spawning grounds into estuarine nursery areas, however, the portion of the structure extending beyond the MHW line, based on the 2006 shoreline conditions, would be approximately 100 feet less than the groin designed for Alternatives 5A and 5B but 200 feet longer than the groin designed for Alternative 5C. It should be noted that the construction of the terminal groin under the 2006 erosive conditions would result in 600 linear feet of the structure's footprint being below the MHW line without the installation of the fillet. With the fillet in place, the structure would expect to be less. Therefore, the structure and the accompanying fillet would have minimal interaction with larvae in the water. In general, however, these structures can disrupt along-shore transport processes within the narrow zone paralleling the shoreline which larvae are dependent upon. Restricting access into the estuarine habitat behind Figure Eight and Hutaff Island could affect certain fish species. Although research is limited on long-term terminal groin affects to larval transport, the following has been used in order to make the determination that Alternative 5D is not likely to have a significant adverse effect: 1) reference to a numerical model for Bald Head Island terminal groin project, 2) larval transport entering from the north side, or Hutaff side, of Rich Inlet, 3) the fillet will extend to the end of the structure allowing sand by-passing to continue and allowing nearshore transport for larvae to enter into Rich Inlet, 4) minimal change to the tidal prism and inlet hydrodynamics, and 5) recent shoreline conditions have been such that the terminal groin could have been constructed in the dry, disclosing the fact that the structure would not protrude any further seaward than periods of natural conditions. For further description on these reasons, reference discussion in Alternative 5A larval transport.

Although the terminal groin is shown to have minimal changes to the inlet hydrodynamics, there is a potential that fish, like mullet, migrating along the nearshore oceanfront may be impeded when they encounter the structure. This was shown at the jetty in Murrells Inlet, which is described under Alternative 5A. The potential for fish impediment is greatly lessened than that of the Murrells Inlet jetty due to the shorter length and design differences for the terminal groin under Alternative 5D. Furthermore, the accretion fillet is expected to fill seaward and would reduce the exposed area of the groin. As stated previously, the conditions of the shoreline from 2010-2012 period were as such that the terminal groin could almost be completely constructed shoreward, or beachward, of the mean high water line. In this regard, fish and other motile organisms will be expected to pass by the structure as they migrate along the shoreline which is expected to extend near the seaward terminus of the groin. Therefore, migrating fish may be only minimally impacted by the presence of the terminal groin. Following consultation with the NMFS's Habitat Conservation Division, it was determined that the proposed terminal groin would not affect the essential fish habitat including larval transport (see letter from NMFS in Appendix A, Sub-Appendix 2).

PUBLIC SAFETY

Direct, Indirect, and Cumulative Impacts: During the initial and long-term maintenance construction of Alternative 5D, some hazards, both on land and in the water, will increase due to the usage of heavy machinery within the Permit Area during the dredge operation, beach nourishment, and the terminal groin construction. Safety precautions, such as access restriction and use of USCG navigation rules will be undertaken to reduce this risk. Also, construction will take place within the dredging window of November 16th through March 31st when public use, both in-water and on the beach, of Nixon Channel, Green Channel, Rich Inlet, and Hutaff Island is at its lowest peak. Effects on public safety for Alternative 5D are similar to those described for the other terminal groin alternatives. See Alternative 5A discussion for further details on impacts, precautionary measures, and potential benefits to public safety.

No significant public safety hazards are anticipated in proximity to Hutaff Island.

AESTHETIC RESOURCES

Direct Impacts:
Temporary impacts will result from the implementation of Alternative 5D due to the usage of heavy machinery while constructing the terminal groin, dredging the channels, and nourishing the oceanfront and Nixon Channel shorelines. Following completion of the construction phase of Alternative 5D, the aesthetic resources will be as they were prior to construction with the exception of the terminal groin at the northern portion of Figure Eight Island. The landward portion of the terminal groin would include a design with the sheet pile primarily below the existing ground elevation limiting impacts to the aesthetics. Also, the area disturbed by the construction activities will be restored to near pre-construction

conditions by grading and planting of native plants. Portions of the rubble mound structure, in particular the most seaward 200 feet, would be visible particularly following certain wave and tide conditions. This may result in long-term disruptive vistas for the northern Figure Eight Island residents and/or those visiting that end of the island for an unobstructive view of the inlet area. The winter-time construction will also limit the impacts to aesthetics as less people will notice the disruption due to less tourism during that time of the year. The north end of Figure Eight Island south of the terminal groin is expected to become stable enough to allow the removal of the sandbag revetments. The removal of the sandbags along the northern portion of Figure Eight Island will improve the aesthetic quality of the island. See Alternative 5A for additional discussions.

No significant adverse impacts to the aesthetic resources are anticipated within proximity to Hutaff Island.

Indirect and Cumulative Impacts: Indirect and cumulative impacts under Alternative 5D will occur due to the anticipated on-going maintenance of Nixon Channel along with the placement of dredged material on Figure Eight Island. These events will occur at a maximum once every five (5) years and up to six (6) separate beach maintenance over the 30-year study period. Due to the length of time in between maintenance events, cumulative effects are expected to be minimal.

RECREATIONAL RESOURCES

Direct Impacts: Impacts to recreational resources for Alternative 5D are anticipated to be minimal and similar to those discussed for Alternative 5B. The recreational opportunities along the ocean shoreline are primarily utilized by the private homeowners and guests to the island. Recreational opportunities will be temporarily impacted during the construction activities associated with Alternative 5D. However, all construction activities will be limited to working within a window when recreational use is at its lowest during the year. Even during construction, complete access will not be restricted in these areas. The beach fill along 1,400 linear feet of the Nixon Channel shoreline will immediately create a wider dry beach for the boaters and other recreational use.

After completion of the structure, there may be some minor impediment for walking the beach, or access to, along the northern tip of Figure Eight Island. Portions of the rubble mound structure are projected to be approximately 1-3 feet above the beach grade and could hinder access for certain persons.

Indirect and Cumulative Impacts: Following construction and similar to the other groin structure alternatives, recreational resources are expected to benefit from Alternative 5D due to the increased size and extent of the oceanfront nourished beach and the nourished shoreline of Nixon Channel. Along the terminal groin, fin fish will likely be attracted to rubble structures due to their increased structural complexity which provides shelter from predators (Hay and Sutherland, 1988). Due to the anticipated erosion along the northern portion of Figure Eight Island coupled with accretion on the southern portion of Hutaff

Island, some recreational opportunities may increase on Hutaff and decrease on Figure Eight Island.

NAVIGATION

Direct Impacts: Under Alternative 5D, impacts to navigation are anticipated to be minimal and similar to those discussed for Alternative 5B. Restrictions will be determined by the USCG and will be limited to the areas where the dredge and the pipelines are located. These restrictions will be imposed during every maintenance event, which is scheduled approximately every five (5) years.

Indirect and Cumulative Impacts: Following the dredging of Nixon Channel, Delft3D modeling results suggest that the entrance of Rich Inlet will behave in a similar manner to natural conditions over the next 5 years. The dredged area will be expected to shoal, however it is expected to remain navigable in between maintenance events. The terminal groin will be clearly visible; therefore it should not pose a threat to boats. Any recommended markings on the terminal groin as suggested by the US Coast Guard will be implemented to ensure the safety of vessels. Following the construction of Alternative 5D, boaters should find navigation within the Nixon Channel borrow area easier to navigate after initial dredging and after each maintenance event, which is anticipated to occur at a minimum every five (5) years. This enhancement of navigation should continue over the 30-year study period. Therefore, navigation is expected to be positive over the long-term.

INFRASTRUCTURE

Direct, Indirect, and Cumulative Impacts: Impacts to infrastructure are anticipated to be minimal and similar to those discussed for Alternatives 5A, 5B, and 5C. Alternative 5D is expected to benefit the infrastructure on Figure Eight Island due to the long-term protection from erosion. The beach nourishment plan included in Alternative 5D would include the use of approximately 264,500 cys of material as beach fill between stations 60+00 and 105+00 on Figure Eight Island's oceanfront shoreline and an additional 57,000 cys placed along the Nixon Channel shoreline. The width of the oceanfront dry beach will vary along the length of fill area while the Nixon Channel beach fill will result in the creation of a 50-foot beach berm and will produce approximately 1.2 acres of additional dry beach to protect the homes in that areas. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be 69 feet. These two locations will be renourished up to once every five (5) years and potentially up to six (6) separate events over the 30-year study period. The installation of the terminal groin will also result in a wider beach within the accretion fillet which will protect infrastructure on Figure Eight Island as well.

SOLID WASTE

Direct, Indirect, and Cumulative Impacts: Impacts to solid waste are anticipated to be similar to those discussed for Alternatives 5A, 5B, and 5C. Alternative 5D will provide protection along portions of Figure Eight Island thereby decreasing the risk of damage to residential buildings and infrastructure. This would alleviate the potential of increased amount of solid waste through demolition.

NOISE POLLUTION

Direct Impacts, Indirect, and Cumulative Impacts: Impacts to noise pollution are anticipated to be minimal and similar to those discussed for Alternative 5A, 5B, and 5C. See also the discussion on the potential impacts of noise contained in the section on Inlet Dunes and Dry Beaches above. For further description on noise impacts associated with Alternative 5D, see the Noise Pollution section for those alternatives.

ECONOMICS

Direct, Indirect, and Cumulative Impacts:
Implementation of Alternative 5D is expected to positively impact the local economy of New Hanover County. Initial construction costs for the terminal groin would be $4,560,000 while construction of the beach fill would cost approximately $2,879,000. No structures or land would be lost under Alternative 5D, but repetitive storm damage could eventually lead to the demolition of some of the threatened structures.

Over the 30-year planning period, the total cost for Alternative 5D in current dollars would be approximately $26.18 million under 2006 conditions. As depicted in Table 5.26, the average annual equivalent cost for constructing and maintaining Alternative 5D would be $1,098,000. Included in this annual cost is an average of $25,000 for maintenance of the terminal groin.

Table 5.26. Summary of Average Annual Economic Impact of Alternative 5D

	Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
2006 Conditions	$0	$0	$1,098,000	$1,098,000

Chapter 6 AVOIDANCE AND MINIMIZATION

The following describes actions and measures incorporated into the design of the Applicant's Preferred Alternative – Alternative 5D to avoid and/or minimize direct, indirect, and cumulative effects to the resources and the public uses found within the Permit Area.

1. How will Alternative 5D (Applicant's Preferred Alternative) construction practices avoid and minimize environmental impacts?

Construction Schedule

In order to protect certain threatened and endangered species and other bird and fish species that utilize Rich Inlet complex and the ocean shorelines of Hutaff and Figure Eight Islands, all construction activities are scheduled to occur between November 16 and March 31. The timing of construction activities was specifically scheduled to occur outside of the sea turtle nesting season, the West Indian manatee summer occurrence in North Carolina, the piping plover (and other shorebirds) migratory and breeding seasons, the seabeach amaranth flowering period, and when most biological activities are at their lowest. Working during this time frame is expected to minimize any potential adverse impacts to offshore, nearshore, intertidal, and beach biological resources to the maximum extent possible.

Also, the construction of the rubble mound portion of the terminal groin as well as the sand placement and dredge operations will be conducted outside of primary invertebrate production and recruitment periods (spring and fall) which will limit impacts to amphipods, polychaetes, crabs and clams.

Construction work during the November 16-March 31 time frame will occur at the lowest peak of public use. Both residential and visitor use on Figure Eight Island are at its minimal and boater use within Rich Inlet and the surrounding waters being infrequent. With public presence on both islands and in adjacent waters at its lowest, impacts to navigational and recreational uses are anticipated to be non-apprecible. This would also reduce any public safety concerns.

Terminal Groin Structure

Two terminal groin designs were considered for the Applicant's Preferred Alternative. One option, Alternative 5C, included a 1,300-foot terminal groin with a 305-foot section extending seaward of the 2007 mean high water shoreline and the other design, Alternative 5D, consisted of a 1,500-foot long structure with a 505-foot section extending seaward of the 2007 mean high water shoreline. Both design lengths of the terminal groin were evaluated through the use of the Delft3D model using 2006 baseline conditions; and the 1,500-foot long option was further modeled using the 2012 baseline conditions. After assessing all the modeling results, Figure "8" Beach HOA Board determined that Alternative 5D would be the preferred and best option to serve their purpose and need for long-term protection of the island.

The Applicant's Preferred Alternative includes a combination of both the rubble mound and sheet pile design. The structure's anchor is being constructed in a manner to reduce any impacts to the salt marsh community located in the northern spit of Figure Eight Island. For the 995-foot long sheet piled anchor section, the sheets will be driven in a manner that the tops will be approximately 0.5 feet below the surface elevation of the salt marsh area. Leaving this 0.5 foot space is expected to provide continued tidal exchange and not interrupt normal flow patterns. Additionally, the rubble scour protection apron for the anchor was minimized to a width of 10 feet in ordere to reduce impacts to the marsh community while still supporting the integrity of the structure. For the seaward 505-foot section of the groin, a rubble mound design was selected over sheet piles. This will provide some spacing in the "leaky" structure to allow some sediment to migrate through and not eliminate sediment bypass into the inlet. The rubble design is also expected to provide habitat for sessile benthic organisms as well as crustaceans and fin fish, increasing beneficial use to the marine environment more than that of sheet piles. These design considerations have been incorporated into the structure specifically as an effort to address the avoidance and mimimization of impacts to marine and estuarine life.

During the construction of the groin, a construction corridor varying in width from 50 feet to 200 feet will be established around the footprint of the structure and all construction activity will be required to remain within the corridor. This will ensure that the environmental impacts will be kept to a minimum within the construction area. As stated in Chapter 5, a portion of the shore anchorage component of the terminal groin will be constructed within an area of high marsh habitat. In order to minimize temporary direct impacts to these resources, the orientation of the groin will be designed such that it will span the shortest distance through the wetlands totaling 303 feet (Figure 6.1) and the construction corridor will be reduced to 50 feet. In addition, the construction corridor for this portion of the groin will be located to the south of the creek that meanders from Nixon Channel into the wetland such that tidal exchange will continue. Furthermore, the top of the sheet pile structure will be installed below grade which will also allow for the continuation of proper tidal exchange. Finally, the location for the unloading of the rubble mound material from the barge will be situated along the Nixon Channel shoreline in an area containing minimal vegetation.

Beach Fill along Nixon Channel Shoreline

For Alternative 5D, the initial placement of 57,000 cubic yards of material encompassed a length of 1,800 linear feet along the Nixon Channel shoreline terminating near the end of the Figure Eight Island spit. With this design, material would have covered the mouth of the small tidal creek that feeds the salt marsh community, eventually choking off the tidal influence. The shoreline footprint was modified and shortened the length of placement to 1,400 linear feet in order to avoid impacting the tidal finger and indirectly affecting the marsh community located in this area.

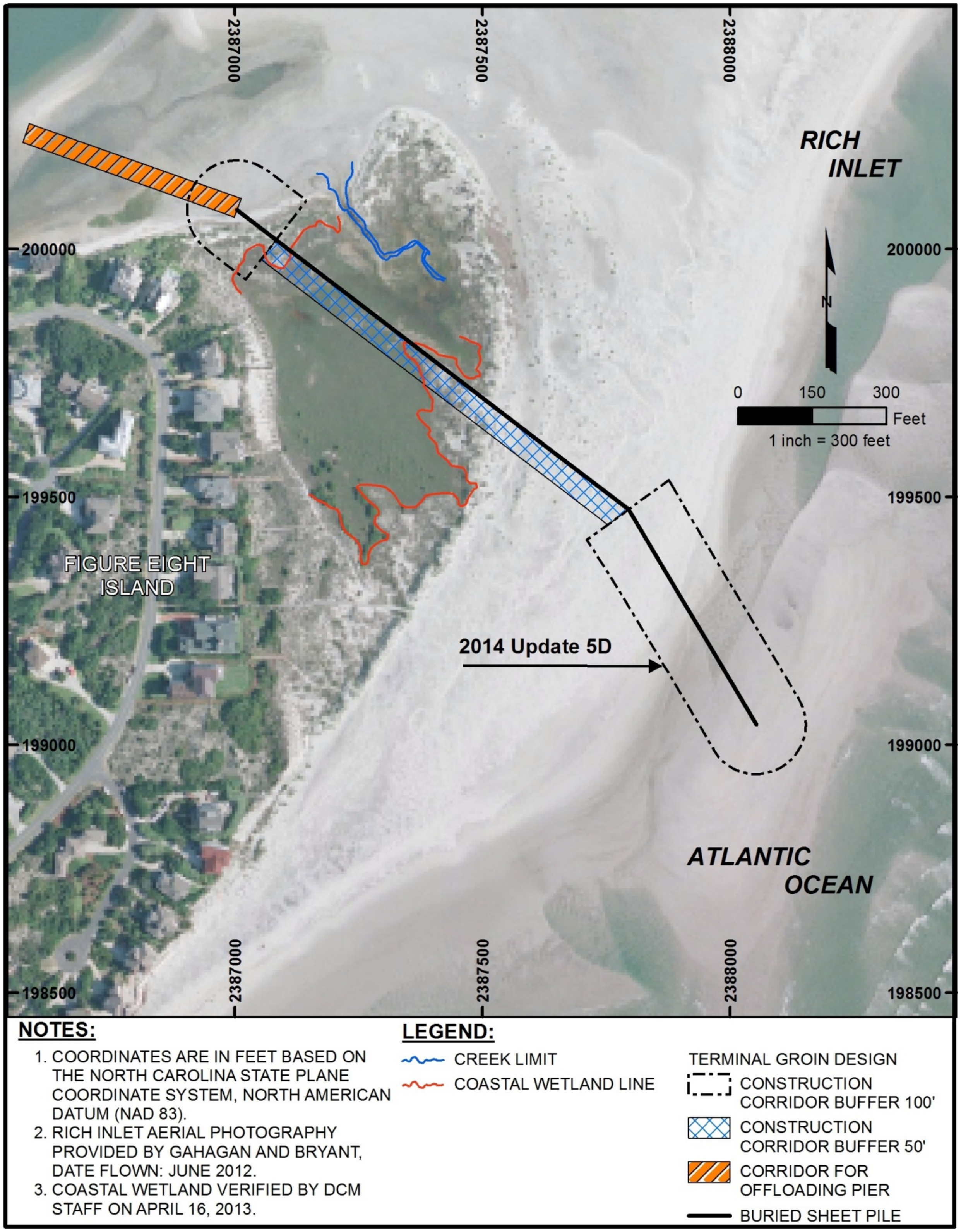

Figure 6.1. Location of the shore anchorage section of the terminal groin spanning areas of high marsh

Dredge Type

A hydraulic cutterhead is proposed for dredging the proposed borrow area within Nixon Channel. A cutterhead dredge uses a rotating cutter assembly at the end of a ladder arm to excavate bottom material, which is then drawn into the suction arm and pumped to the shoreline. On the beach, pipelines will transport the sediment to the designated beach fill area. Bulldozers will be used to construct seaward shore parallel dikes to contain the material on the beach, and to shape the beach to the appropriate construction cross-section template. During construction, the contractor will utilize surveying techniques for compliance with the designed berm width, height, and slope.

Compared to similar types of dredging methodologies, a cutterhead dredge creates minimal disturbance to the seafloor resulting in lower sedimentation and turbidity levels. Anchor (2003) conducted a literature review of suspended sediments from dredging activities. This report concluded that the use of a hydraulic dredge (i.e., cutter suction) limits the possibilities for resuspension of sediment to the point of extraction. Also, since the sediment is suctioned into the dredge head, the sediment cannot directly enter into the middle or upper water column.

No incidences of sea turtle takes from a hydraulic dredge have been identified during the research and development of this document. Therefore, the use and methods involved with this type of machinery reduces or eliminates the likelihood of an incidental take.

Dredge Positioning

DREDGEPAK® or similar navigation and positioning software will be used by the contractor to accurately track the dredge location. The software will provide real-time dredge positioning and digging functions to allow color display of dredge shape, physical feature data as found in background Computer Aided Design (CAD) charts and color contour matrix files from hydrographic data collection software described above on a Cathode Ray Tube (CRT) display. The software shall also provide a display of theoretical volume quantities removed during actual dredging operations.

Dredge anchors shall not be placed any further than 61 m (200 ft) from the edge of the areas to be dredged. The dredge contractor will be required to verify the location of the anchors with real time positioning each and every time the anchors are relocated.

Sediment Compatibility

The North Carolina Coastal Resources Commission adopted State Sediment Criteria Rule Language (15A NCAC 07H .0312) for borrow material aimed at preventing the disposal of an inordinate amount of coarse material (primarily shell and shell hash) on the beach (NCDCM, 2007) and is summarized in Chapter 4. The native material on Figure Eight Island contains an average gravel content of 0.05% and an average granular content of 0.26%; the upper limit of gravel and granular that could be placed on the beach is 5.05% and 5.26%, respectively (Table 6.1). Based on a native silt average of 1.04% at Figure Eight Island, the allowable silt content of material to be placed on the beach is 6.04% (Table 6.1). Based on a native calcium carbonate percentage of 6.0%, the allowable calcium carbonate % of material to be placed on the beach would be limited to 21.0% (Table 6.1). The rule language has been adhered to during the planning and development of the Figure Eight Island Shoreline Management Project, which reduces the potential for negative effects of beach nourishment (See Appendix D –Geotechnical Report).

Table 6.1. Characteristics of the native beach and borrow area material

	% Silt	% Carbonate	% Granular	% Gravel	Mean Grain Size (mm)
State Standard Allowance (1)	5	15	5	5	
Figure Eight Native Beach	1.04	6.0	0.26	0.05	0.18
State Standard Cutoff	6.04	21.0	5.26	5.05	
Hutaff Island Native Beach (2)	1.0	9.9	1.15	0.33	0.21
State Standard Limit	6.0	24.9	6.15	5.33	
Nixon Channel Borrow Area	1.25	8.12	0.77	0.52	0.22

(1) Allowances above native beach material.
(2) Characteristics of the native beach material on Hutaff Island adopted as representative of the native beach material on Figure Eight Island.

As noted above, the Sediment Criteria Rule provides beneficial guidelines for both grain size and percent weigh of calcium carbonate (NCDCM, 2007) which is intended to minimize compaction which could otherwise impact nesting sea turtles and bentic macroinfauna populations. Aside from these beneficial guidelines, other important characteristics such as organic content, heavy mineral content, and color are not addressed. These aspects of the beach fill will be considered during nourishment construction to reduce the effects of compaction and unsuitable material. A monitoring program will be developed that will ensure the material is compatible in composition and nature to the native material. See the section entitled "Construction Observations" below for more detail regarding this monitoring program which will be designed to ensure that only compatible material will be placed on the oceanfront and Nixon Channel shorelines. This quality management protocol is likely to reduce any potential direct, indirect, and/or cumulative impacts to fish and bird resources by shortening the recovery time of the benthic community food source. It is also expected to benefit sea turtle nest construction and incubation of the eggs and to not interrupt any of their nesting habits.

Pipeline Observations

In order to minimize impacts on wintering piping plover, the pipeline alignment will be designed to avoid potential piping plover wintering habitat. The alignment will be coordinated with, and approved by, the USACE and NC DCM. As-built positions of the pipeline will be recorded using GPS technology and included in the final construction observation report.

In order to avoid impacts associated with the transport of fill material to the disposal sites, the Figure "8" Beach HOA will negotiate with the dredging contractor to monitor and assess the pipeline during construction. This will serve to avoid leaking of sediment material from the pipeline couplings, other equipment, or other pipeline leaks that may result in sediment plumes, siltation and/or elevated turbidity levels. The Figure "8" Beach HOA, along with their Engineer, will coordinate with the dredgers and have in place a mechanism to cease dredge and fill activities in the event that a substantial leak is detected (leaks resulting in turbidity that exceed state water quality standards or sedimentation). Operations may resume upon appropriate repair of affected couplings or other equipment.

2. What are the monitoring initiatives being developed?

Several monitoring initiatives have been implemented along Figure Eight Island as part of permit conditions for previously implemented beach nourishment projects. A description of existing and proposed monitoring initiatives in support of the Figure Eight Island Shoreline Management Project is included below.

Construction Observations

Several initiatives will be undertaken by Figure "8" Beach HOA, the Engineer, or his duly authorized representative to monitor construction practices. Construction observation and contract administration will be periodically performed during periods of active construction. Most observations will be during daylight hours; however, random nighttime observations may be conducted. The Figure "8" Beach HOA, the Engineer, or his duly authorized representative will provide onsite observation by an individual with training or experience in beach nourishment and construction observation and testing, and that is knowledgeable of the project design and permit conditions. The project manager, a coastal engineer, will coordinate with the field observer. Multiple daily observations of the pumpout location will be made by the Figure "8" Beach HOA, the Engineer, or his duly authorized representative for QA/QC of the material being placed on the beach. Information pertaining to the quality of the material will periodically be submitted to the USACE and NC DCM for verification. If incompatible material is placed on the beach, the USACE and NC DCM will be contacted immediately to determine appropriate actions.

Material Color

The Figure "8" Beach HOA, the Engineer, or their duly authorized representative, will collect a representative sub-surface (6 in below grade) grab sediment sample from each 100-ft long (along the shoreline) section of the constructed beach to visually assess grain size, wet Munsell color, granular, gravel, and silt content. Each sample will be archived with the date, time, and location of the sample. Samples will be collected during beach observations. The sample will be visually compared to the acceptable sand criteria (Table 6.1). If determined necessary by the Engineer, or his duly authorized representative, quantitative assessments of the sand will be conducted for grain size, wet Munsell color, and content of gravel, granular and silt. A record of these sand evaluations will be provided within the Engineer’s daily inspection reports and submitted to USACE and NC DCM for verification.

Escarpments
Visual surveys of escarpments will be made along the beach fill area immediately after completion of construction. Escarpments in the newly placed beach fill that exceed 18 inches for greater than 100 ft shall be graded to match adjacent grades on the beach. The decision for escarpment removal will be determined upon consultation with USACE and NC DCM. Removal of any escarpments during the sea turtle hatching season (May 1 through November 15) shall be coordinated with the North Carolina Wildlife Resources Commission (NCWRC), USFWS, and the USACE – Wilmington District.

Water Quality
The inlet, nearshore and offshore water columns are classified as SA and High Quality Water (HQW) under the North Carolina State water quality standards. This classification requires that work within the water column shall not cause turbidity levels to exceed 25 NTU or background (ambient) conditions that are above 25 NTU.

Dredge and fill operations are expected to temporarily elevate turbidity levels in the water column at the borrow area and fill sites. Higher turbidity levels are likely to be found in the discharge zone (nearshore swash zone) during periods of active construction. The use of a cutter suction dredge will minimize the area of disturbance since this type of dredge involves suction for the extraction of sediment.

Turbidity monitoring during construction will be managed by the contractor. The contractor will be responsible for notifying the construction engineer in the event that turbidity levels exceed the State water quality standards.

Bird Monitoring

The University of North Carolina at Wilmington (UNCW), under the direction of Dr. David Webster, conducts shorebird and colonial waterbird monitoring throughout the year along the beachfront of Figure Eight Island and the areas surrounding Mason and Rich Inlet. In addition, Audubon North Carolina has monitored the Rich Inlet complex which includes Figure Eight Island's northern spit since 2008. These monitoring efforts are expected to continue for the foreseeable future (Webster, pers. comm.). It is anticipated that bird monitoring efforts will occur prior to construction of the groin and continue for at least two years thereafter. Annual monitoring reports will be submitted to the USACE and NC DCM for determining project impacts to endangered and threatened bird species.

Seabeach Amaranth (*Amaranthus pumilus*)

Since 2002, UNCW has conducted regular monitoring, paid by Figure "8" Beach HOA, along the entire beachfront of Figure Eight Island for the presence of seabeach amaranth. This monitoring is anticipated to continue for the foreseeable future (Webster, pers. comm.). Audubon North Carolina also reports upon the occurrence of seabeach amaranth along the beachfront on Hutaff Island (Mangiameli, pers. comm., 2008). The annual monitoring report will be submitted to the USACE and NC DCM for determining project impacts to seabeach amaranth.

Sea Turtles

Since 2001, sea turtle nesting activity has been monitored on a daily basis throughout the nesting season along the Figure Eight Island beachfront by UNCW under the direction of Dr. David Webster (Godfrey, pers. comm.). This monitoring, paid by the Figure "8" Beach HOA, begins on approximately May 1 and continues through the last hatch date each year. Audubon North Carolina performs a similar monitoring effort throughout nesting season on Hutaff Island, however, this monitoring is not conducted on a daily basis. The annual monitoring report will be submitted to the USACE and NC DCM for determining project impacts to sea turtles. Dr. Matthew Godfrey of the NCWRC expressed the difficulties in reporting sea turtle population and nesting trends since the availability of observers and consistency in data collection can contribute to the unreliability of the data (Godfrey, pers. comm.). With the continuation of UNCW's monitoring along Figure Eight Island, the data collection will be more reliable and provide accurate information that aids with the assessment of turtle nesting conditions along the northern end of Figure Eight.

West Indian Manatee (*Trichechus manatus*)

Inwater activity associated with Alternative 5D will occur outside the period when *T. manatus* are likely to be present, which is June to October. Although the manatee should be absent during dredge and fill operations, precautions will be taken by the contractor to further reduce the risk of impacting the West Indian manatee. The dredging contractor will adhere to the precautionary guidelines established by the USFWS – Raleigh Office for construction activities in North Carolina waters and will have these guidelines on the dredging plant at all times. Refer to the *Guidelines for Avoiding Impacts to the West Indian Manatee*.

Aerial Habitat Mapping

Purpose and Goals
It is anticipated that the implementation of the proposed project has the potential to impact certain biological resources and habitats found within the proposed Permit Area, particularly within the complex of Rich Inlet. These include resources such as the salt marsh within the Figure Eight Island spit, inlet dry beach, intertidal flats and shoal communities, SAV, and shellfish habitats found within the area to be investigated. Determining the baseline conditions of the resources prior to construction is a fundamental step in quantifying changes in response to the implementation of Alternative 5D. Existing data and newly acquired data were utilized to delineate and characterize habitats and select species within the proposed Permit Area (Figure 4.1). Data gathered from these efforts provided the baseline conditions of a number of biological resources as reported in Chapter 4 of this document.

In an effort to understand any potential habitat changes resulting from Alternative 5D, plans are to continue the aerial photo delineation or mapping of the habitats with the Permit Area. The effort will not focus on the entire Permit Area, but will target the Rich Inlet complex as depicted in Figure 6.2. The mapping is confined to this area since habitat changes resulting from Alternative 5D are expected at this location. It is acknowledged that the data in Figure 4.1 within the Rich Inlet complex has somewhat changed from its initial collection due to the ongoing natural shifting that occurs in inlet systems. With the expectation of a continual shift of resources, an updated mapping of the habitat baseline conditions will be performed within a time period closer to the construction of Alternative 5D. Following the completion of Alternative 5D, subsequent habitat mapping efforts will be conducted on an annual basis for 3 years. Each post-construction habitat map will be compared to the updated baseline conditions. An assessment will be conducted to determine what changes have occurred and to what extent. This evaluation will also help to determine if the project attributed to any of those changes.

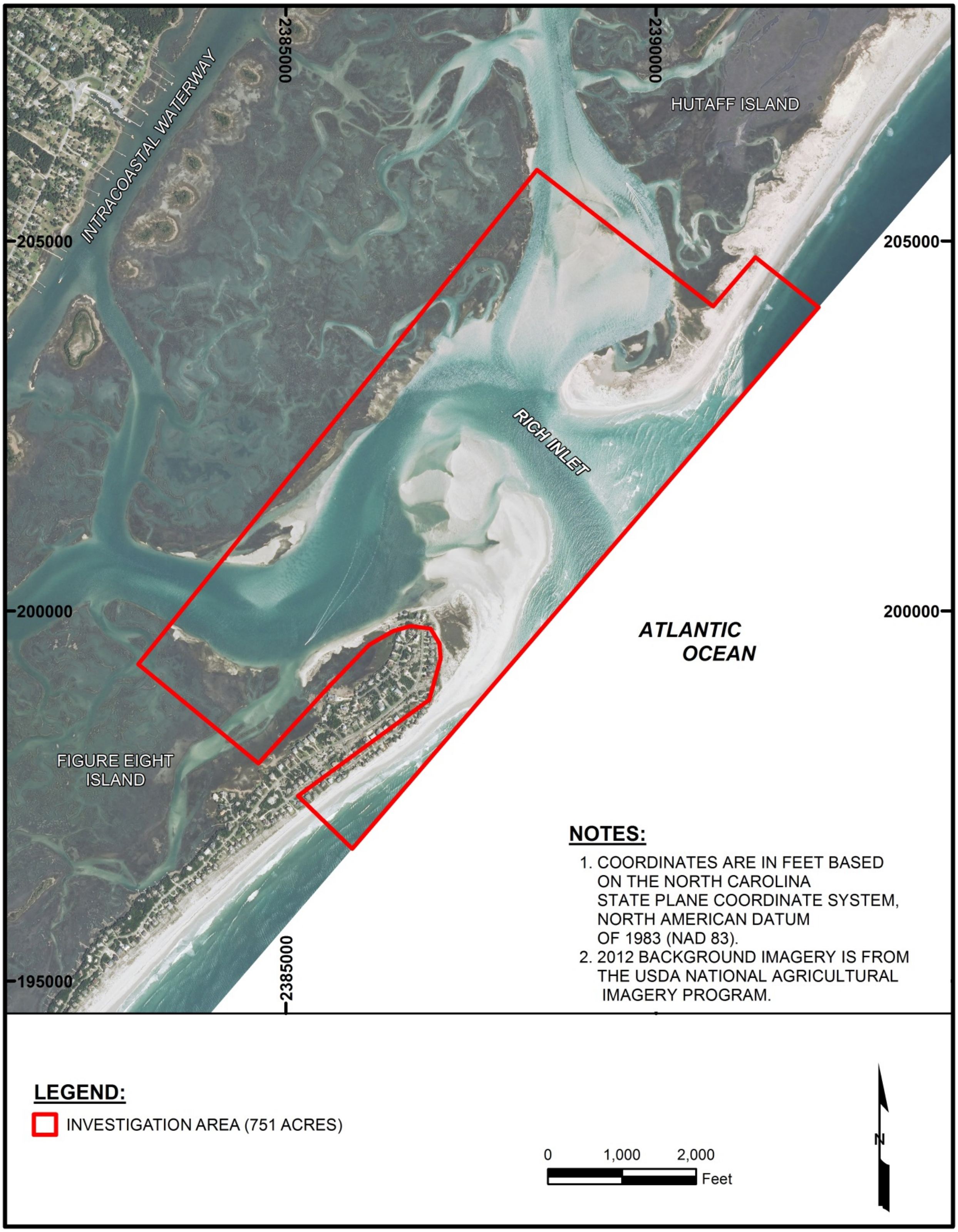

Figure 6.2. Rich Inlet habitat mapping boundary

Monitoring Schedule
Photographic interpretation of biotic communities and groundtruthing investigations within the proposed habitat mapping area was completed in April 2009 utilizing high resolution aerial photography acquired in 2008. Pre-construction investigations will further update the 2009 effort and will be conducted within a time period closer to any implementation of Alternative 5D.

The acquisition of high resolution aerial photographs, ground-truth investigations, and identification of biotic communities will be conducted within the Proposed Habitat Mapping Area between 1 September and 30 November in the 3 years following construction of the proposed project. All surveys will be compared to the most recent pre-construction conditions.

Monitoring Parameters

Aerial Photography:
Cartographic aerial photography will include the acquisition of ortho-rectified color digital imagery of the 751 acre Rich Inlet Habitat Mapping area. Resolution of the acquired imagery will be sufficient to accurately delineate and map habitats and features of environmental significance within the survey area. The aerial platform from which the imagery is acquired will have an onboard GPS that will provide an accurate basis for product correction. NMFS will be consulted regarding the performance specifications on the imagery prior to finalizing the plan by the Figure "8" Beach HOA and authorizing a contract.

In compliance with State and Federal agency requests, digital image acquisition will be scheduled, to the greatest extent possible, to coincide with good weather conditions and an ebb tide that may provide for increased accuracy of habitat interpretation. Considering the weather-dependent nature of this activity, every effort will be made to accomplish this task under optimum conditions.

Aerial imagery analysis conducted pre- and post-construction will be used to monitor any changes in SAV distribution. Aerial imagery will be collected in accordance with NOAA's Coastal Services Center 2001 *Guidance for Benthic Habitat Mapping – An Aerial Photographic Approach* (Finkbeiner et al., 2001). Aerial photographs include the acquisition of ortho-rectified color digital imagery of the Rich Inlet Habitat Mapping area. Resolution of the acquired imagery will be sufficient (<0.6 m [2 ft]) to accurately delineate and map habitats and features of environmental significance within the survey area. An emphasis will be placed on those marine and estuarine habitats located immediately within and adjacent to the Rich Inlet Habitat Mapping area. The aerial platform from which the imagery is acquired will include an onboard Global Positioning System (GPS) that will provide an accurate basis for product correction.

Submerged Aquatic Vegetation:
Resource maps depicting SAV communities along coastal North Carolina do not show SAV communities occurring within the Rich Inlet Habitat Mapping area. However, the pre-construction field investigations performed by CPE-NC confirmed the presence of SAV resources.

Post-construction assessment of SAV resources will be conducted using the same methodology as the pre-construction survey. Areas identified from aerial photography as potential SAV resources within the Rich Inlet Habitat Mapping area and areas confirmed to contain SAV from the pre-construction assessment will be visually groundtruthed. Coordinates of these sites will be obtained and a Global Positioning System (GPS) will be utilized to navigate to each location. Snorkeling will be conducted to locate and map SAV resources. Should the visibility in the water be poor, snorkelers will utilize both visual cues and tactile cues to assess the presence or absence of SAV resources. The extent of identified SAV beds will be determined by following the boundary of the bed while periodically recording GPS coordinates. These coordinates will be converted to a Geographic Information System (GIS) shapefile using ArcView 9.3 software and overlaid on high resolution aerial photography. The boundaries of the mapped SAV beds will then refined through visual interpretation of the aerial photos. Additional SAV resources within the Rich Inlet Habitat Mapping area may be extrapolated from areas with similar color signature in the updated high resolution (<2 feet) geo-referenced aerial photography. Once the SAV beds are digitized, acreages will be determined by utilizing the Xtools area calculation function in ArcView.

Shellfish Resources:
The NCDMF shellfish habitat maps contain 23 individual polygons representing the W stratum within the limited area in the Rich Inlet Habitat Mapping area. Pre-construction field investigations were conducted on 15, 17, and 22 September 2008 by CPE-NC staff biologists to visually groundtruth these potential shellfish areas within the Rich Inlet Habitat Mapping area that may receive impacts due to project-related activities. Coordinates of the center point of these polygons were obtained and GPS was utilized to navigate to each location. Water clarity was generally poor with visibility less than 2 ft; therefore snorkelers utilized both visual cues and tactile cues to assess the presence or absence of shellfish resources. A description of the benthic conditions was recorded at each location. The spatial extents of discrete shellfish beds were determined by following the boundary while periodically recording GPS coordinates. These coordinates were then converted to a Geographic Information System (GIS) shapefile using ArcView 9.3 software and overlaid upon high resolution aerial photography. The boundaries of the mapped shellfish beds were then refined through visual interpretation of the aerial photos. Additional shellfish resources within the entire Permit Area were then identified via extrapolation of areas with similar color signature in the 2008 high resolution (<2 feet) geo-referenced aerial photography. Once the shellfish beds were digitized, acreages were determined by utilizing the Xtools area calculation function in ArcView.

Salt Marsh, Intertidal Shoals, Supratidal Shoals, and Subtidal Communities:
Visual interpretations of biotic community types were digitally mapped using ArcView 9.3 software over high-resolution georeferenced digital multispectral aerial photographs as part of the initial pre-construction assessment of biotic communities. The methods employed for interpretation of aerial photography included visual analysis of color variations in the photographs to delineate habitats (dark areas = submerged land; white areas = sediment exposed above high tide line). Resolution of this imagery (< 2 feet) allowed for adequate delineation of the habitats and features within the Rich Inlet Habitat Mapping area. Following the development of the preliminary biotic community mapping within the Rich Inlet Habitat Mapping area via

visual interpretation, field investigations were conducted to groundtruth the initial delineations. Sites selected for groundtruthing were determined by identifying areas that were difficult to classify from the aerial photography. These locations were visited via boat and the biotic community type (as identified through aerial photographic interpretation) was then verified. Based on the results of the field investigations, the preliminary habitat map was revised as necessary and acreages were determined.

Reporting
The final product from each post-construction assessment will include a report describing the biotic community map derived from the methods explained above. This report will summarize the acreage of each habitat identified and will compare the acreages to previous investigations (pre-construction and any post-construction efforts that may have occurred). Results of these mapping efforts will be incorporated into the Global Information System (GIS) database developed for this project. Acreages of each habitat type present within the permit area will be provided in a report to the USACE – Wilmington District, NMFS, USFWS, NCWRC, and NCDCM by January 1st of each year.

Shoreline Management Plan

Introduction
Legislation passed by the NC General Assembly in June 2011(SB 110) and in 2013 (SB 151) authorized the permitting of terminal groins at four (4) inlets in North Carolina with the requirement to provide a plan for managing inlet and the estuarine and ocean shorelines likely to be under the influence of the inlet. This legislation requires the management plan to include the following:

(1) A monitoring plan.
(2) A baseline for assessing adverse impacts and thresholds for when adverse impact must be mitigated.
(3) A description of mitigation measures to address adverse impacts.
(4) A plan to modify or remove the terminal groin if adverse impacts cannot be mitigated.

In 2015, Session Law 2015-241, HB 97 was passed and increased the number of terminal groin structures in North Carolina that could be permitted from four to six. This legislation specified that the two additional terminal groin permits may only be issued for structures located on the sides of New River Inlet in Onslow County and Bogue Inlet in Carteret and Onslow County.

The following sections describe the historic shoreline change information used to develop past shoreline trends along both Figure Eight Island and Hutaff Island. The historic data will also be used to determine the variability of past shoreline behavior. The past shoreline changes establishes the basis on which to develop expected future trends in shoreline behavior in the absence of any changes in shoreline erosion response measures along Figure Eight Island. The expected future trends in shoreline behavior will form the basis of establishing shoreline change thresholds that would be used to determine if mitigation is required to offset adverse shoreline impacts of the proposed terminal groin.

The development of the shoreline change thresholds is followed by a description of the monitoring plan that would be used to identify adverse impacts and proposed mitigation measures, including possible removal of the terminal groin.

Shoreline Change Information.
The basis for establishing the shoreline change thresholds is the history of shoreline changes that have occurred under existing conditions that were determined by Dr. William Cleary as reported in Sub Appendix A of Appendix C. Dr. Cleary used ten (10) sets of georectified aerial photographs taken between March 1938 and April 2007 and measured changes in the position of the wet/dry line at each transect shown on Figure 6.3. The transects covered the ocean shoreline of Figure Eight Island 9,500 feet south of Rich Inlet and 10,000 feet north of Rich Inlet on Hutaff Island. Transect spacing was 500 feet along both shorelines. The time interval between various sets of aerial photographs ranged from 1.5 years to 18.7 years. As shown by the transect location on Figure 6.2, the analysis did not include the extreme northern tip of Figure Eight Island or the extreme southern tip of Hutaff Island as the sand spits that characterize these two areas are ephemeral and shorelines simply did not exist in these areas on all sets of aerial photographs.

As a matter of reference, on Figure Eight Island, Transect 1 corresponds approximately to baseline station 5+00 while Transect 20 is located at approximately baseline station 100+00, as shown in Figures 3.14a and 3.14b in Chapter 3. On Hutaff Island, Transect 21 is located at approximately baseline station 150+00 and Transect 41 is approximately equal to baseline station 160+00.

The area covered by the shoreline change analysis on Figure Eight Island extends about 4,500 feet southwest of the proposed new Inlet Hazard Area for Rich Inlet being considered by the Coastal Resources Commission. On Hutaff Island, all of which is included in the proposed new Inlet Hazard Area, the shoreline change analysis extended to a point just south of the location of the former Old Topsail Inlet which closed sometime between 1996 and 1998.

The measured shoreline changes along Figure Eight Island reported by Dr. Cleary were adjusted for the impacts of numerous beach fills that occurred during his period of analysis (March 1938 to April 2007). This adjustment was made by determining the average density of each beach fill, expressed as cubic yards/lineal foot of beach, and translating this placement density into an effective fill width. For example, if the measured shoreline change during a time increment at a particular transect was -35 feet and the effective width of beach fills placed on this transect during the time increment was 40 feet, the adjusted shoreline change during the period would be -75 feet.

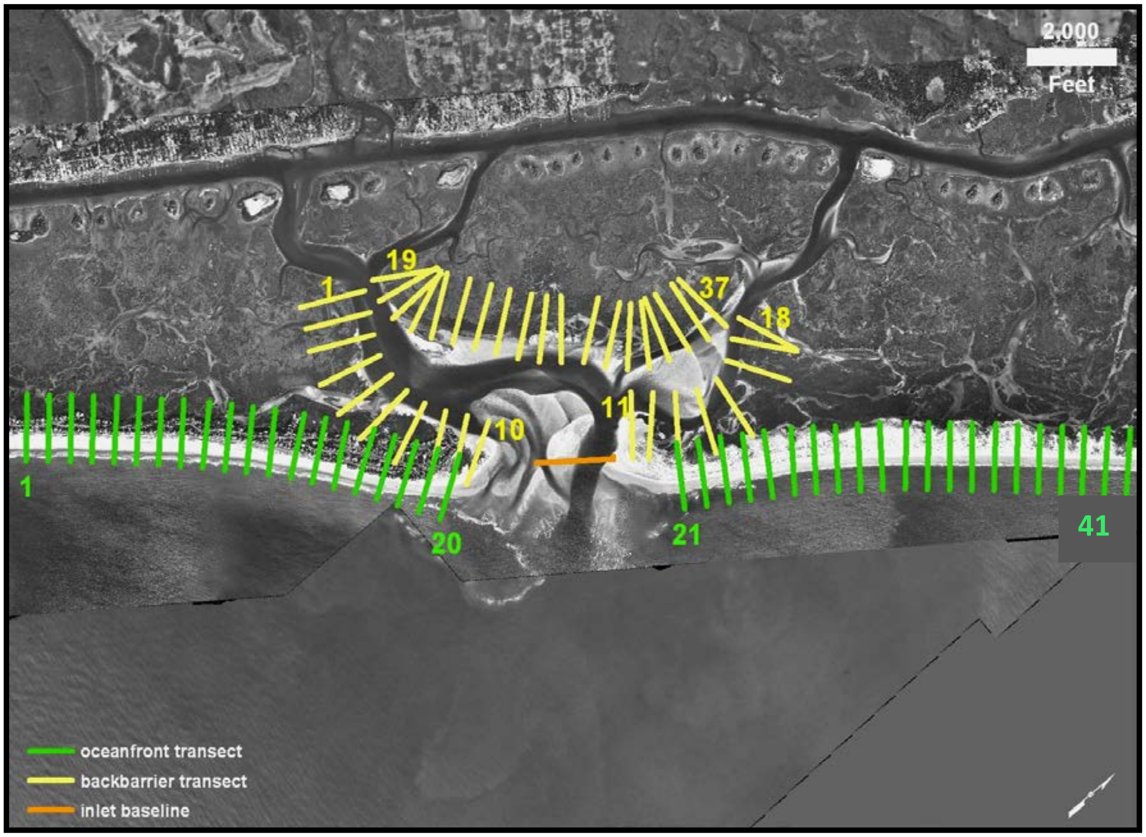

Figure 6.3. Shoreline transects.

Cumulative shoreline changes were developed for each transect along the ocean shorelines of Figure Eight Island and Hutaff Island (green transects on Figure 6.2). These cumulative plots are provided in Attachment 1. Transects were grouped based on similar shoreline change characteristics and average cumulative changes computed for each group. Transect 20, which is located immediately south of Rich Inlet, did not display shoreline change characteristics similar to transects immediately to its south and was therefore treated as a one-transect group. The table in Attachment 1 provides the average cumulative changes for the transect groups and the shoreline change rates determined for each time increment between the 10 sets of aerial photographs. Average cumulative changes for each transect group on Figure Eight Island and Hutaff Island are provided on Figures 6.4 and 6.5 for Figure Eight Island and Hutaff Island, respectively.

Methods to monitor shoreline changes on the estuarine side of Figure Eight Island and Hutaff Island (yellow transects 1-37 in Figure 6.3) would be similar to the ones conducted for Bogue Inlet and Mason Inlet. However, DCM did not seek guidance on how to monitor the estuarine areas.

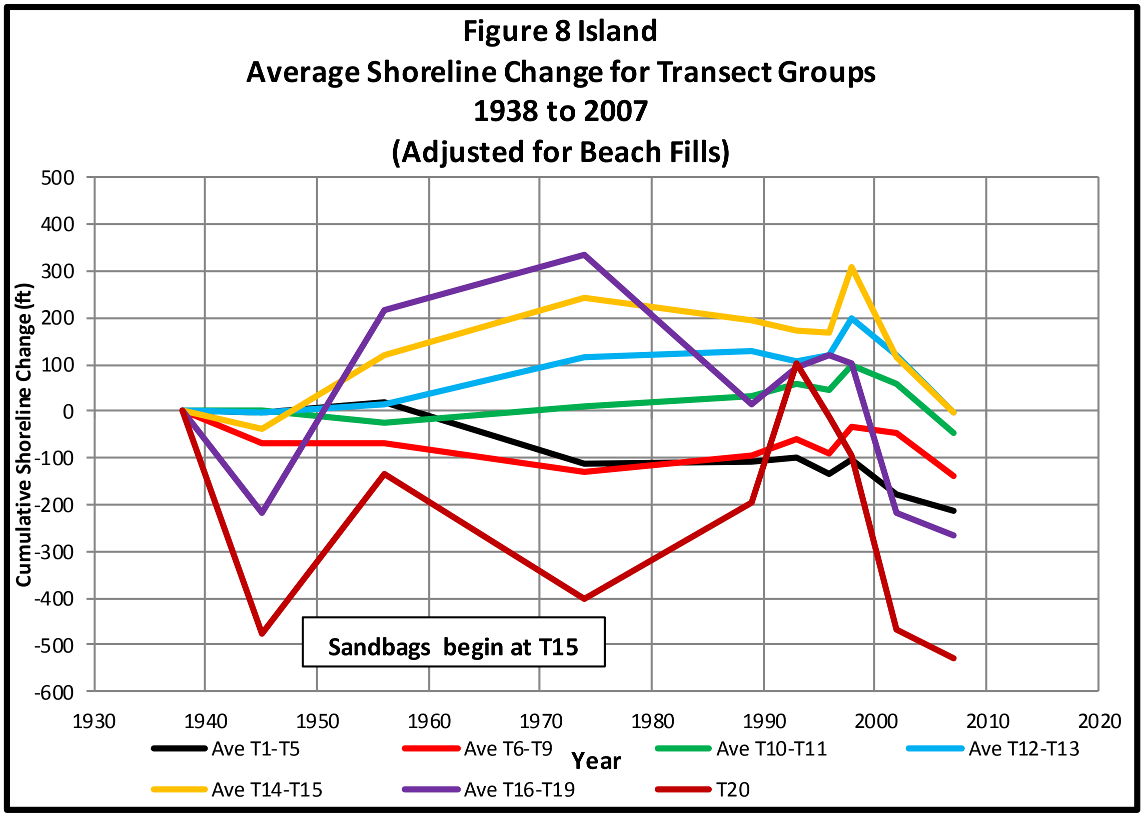

Figure 6.4. Cumulative shoreline changes between 1938 and 2007 for transect groups on Figure Eight Island.

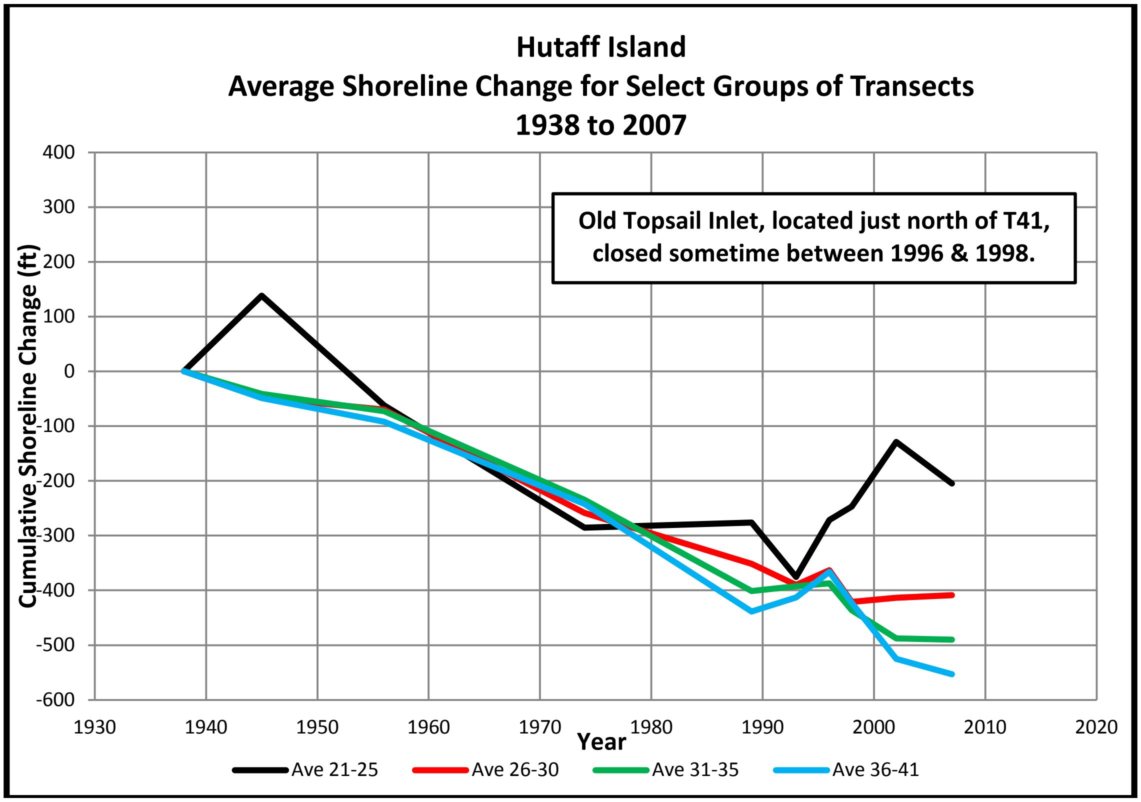

Figure 6.5. Cumulative shoreline changes between 1938 and 2007 for transect groups on Hutaff Island.

<u>Evaluation of Shoreline Changes</u>.
Linear regression shoreline change rates were determined for each transect group for the 1938 to 2007 time period as well as the time period between 1974 and 2007. In 1974, the bar channel of Rich Inlet began to migrate northeast or toward Hutaff Island with this migration continuing until 1999 (Sub Appendix A of Appendix C). During subsequent time periods between 1999 and 2007, the bar channel shifted back and forth between Figure Eight Island and Hutaff Island but generally maintained a position closer to Hutaff Island. This persistent position of the bar channel closer to Hutaff Island resulted in distinct differences in shoreline behavior during the 1974-2007 time period for the transects on Figure Eight Island closest to Rich Inlet and to a lesser extent on Hutaff Island. Also, the frequent movement of the bar channel during the 1974-2007 time period produced a rather wide range of shoreline responses, particularly on the extreme north end of Figure Eight Island.

The following figures (Figures 6.6 to 6.15) provide plots of the average cumulative changes in the shoreline position for each group of transects on Figure Eight and Hutaff Islands. The figures include linear regression trends through the data for the complete record from 1938 to 2007 and the more recent time period 1974 to 2007 that included significant impacts of shifts in the position and alignment of the Rich Inlet ocean bar channel.

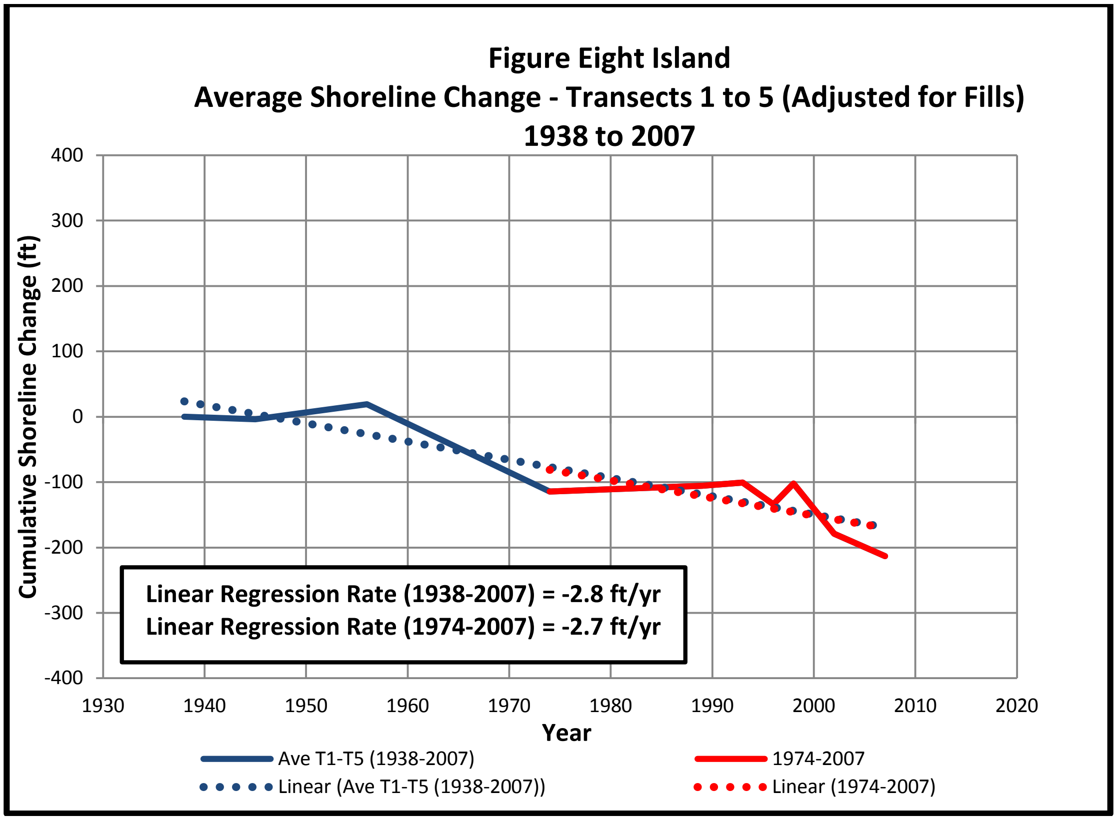

Figure 6.6. Figure Eight Island 1938-2007 average shoreline change for transects 1-5.

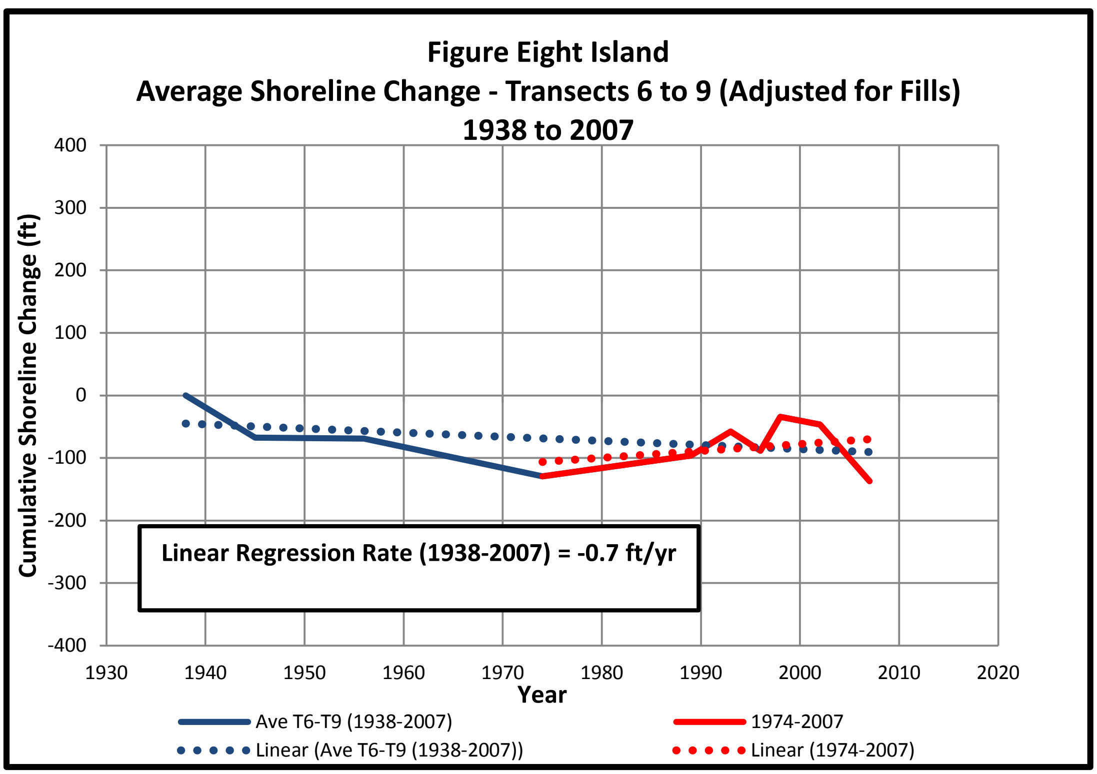

Figure 6.7. Figure Eight Island average shoreline change for transects 6-9.

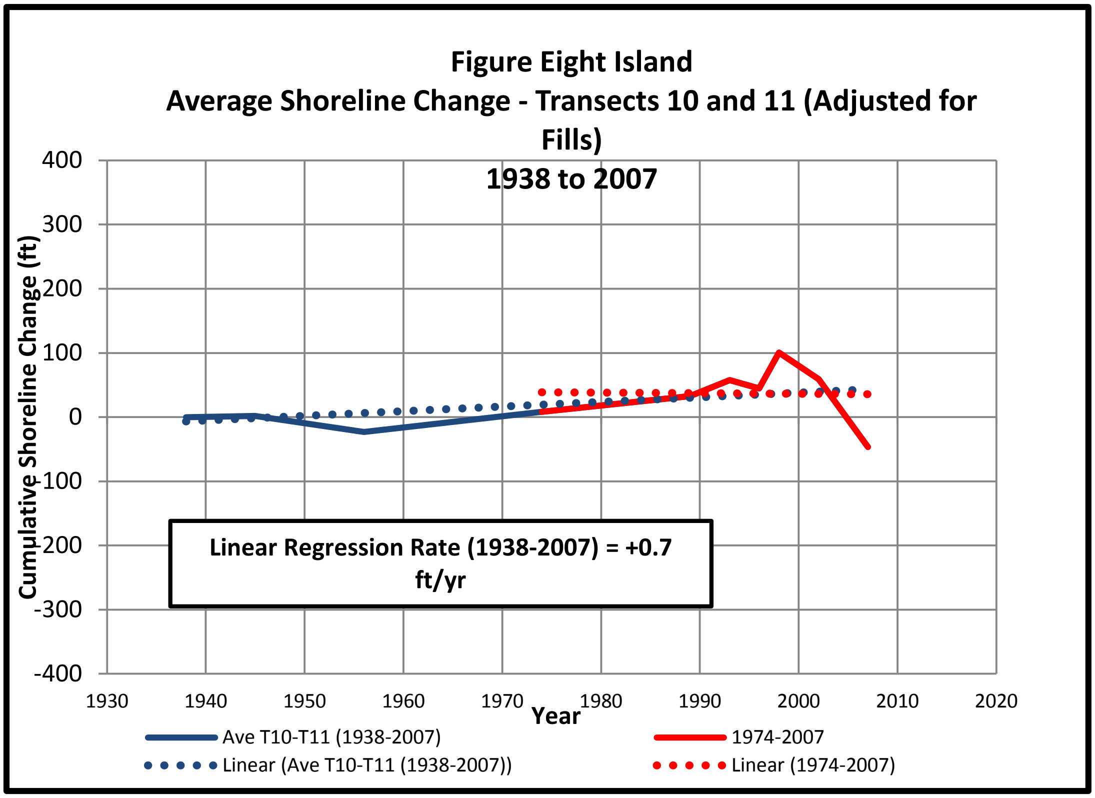

Figure 6.8. Figure Eight Island average shoreline change for transects 10-11.

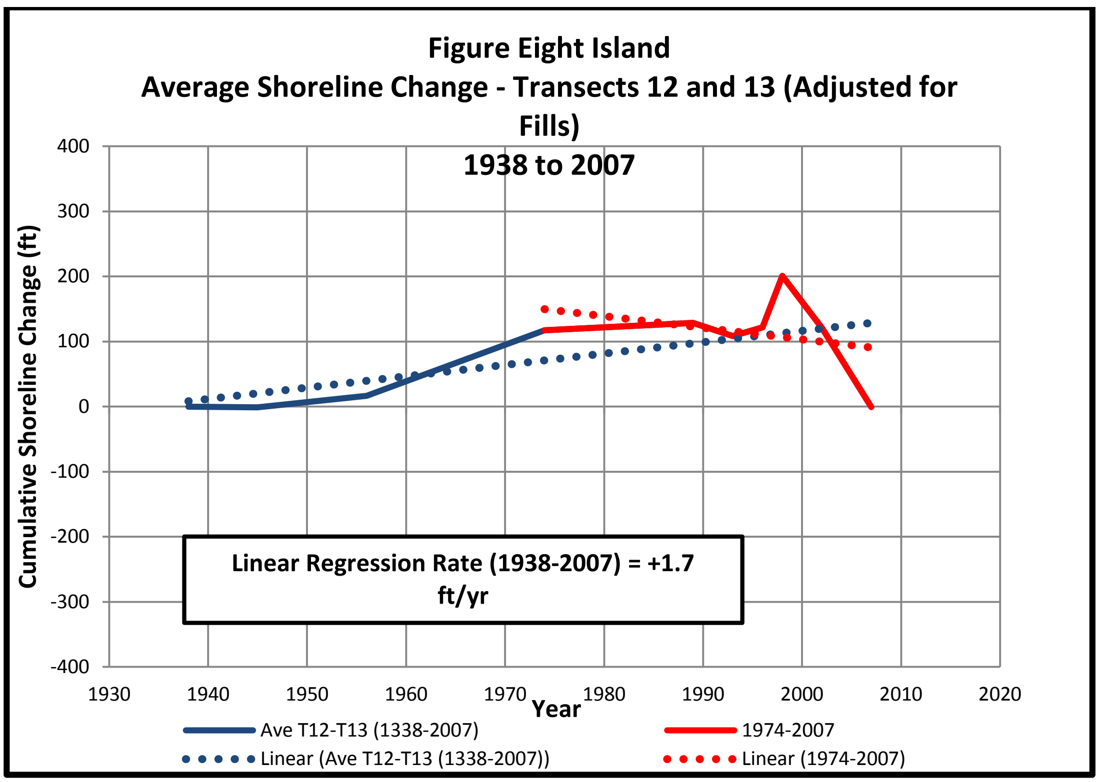

Figure 6.9. Figure Eight Island average shoreline change for transects 12-13.

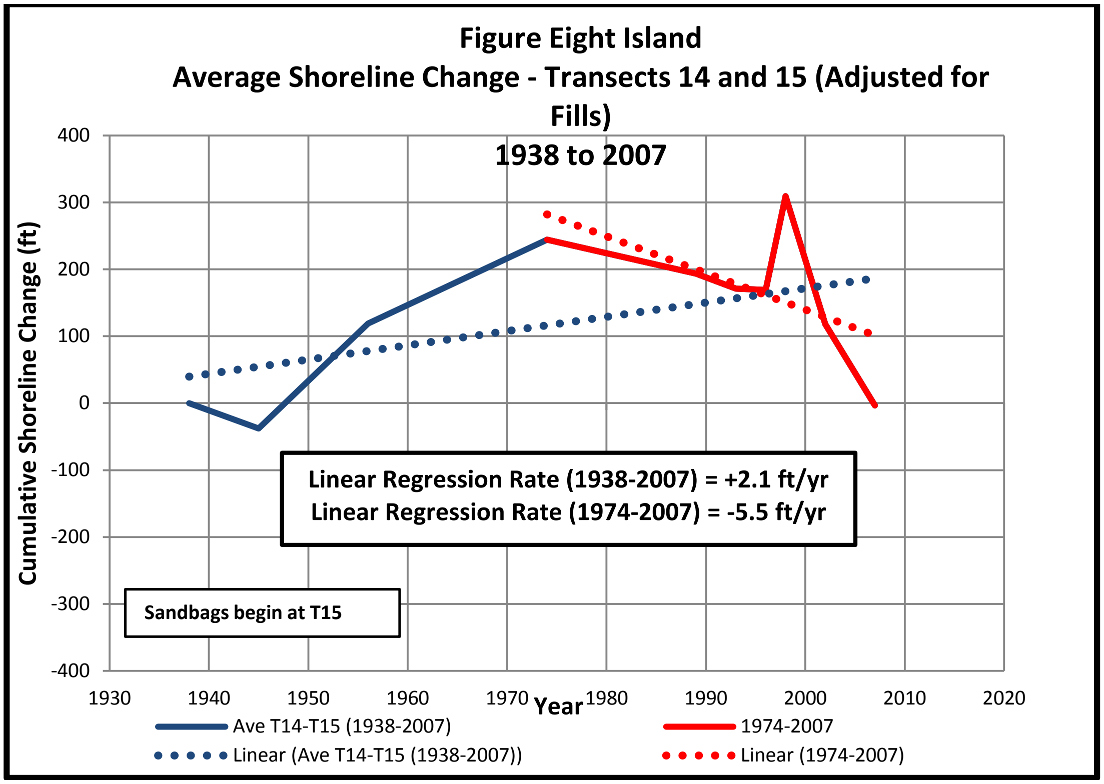

Figure 6.10. Figure Eight Island average shoreline change for transects 14-15.

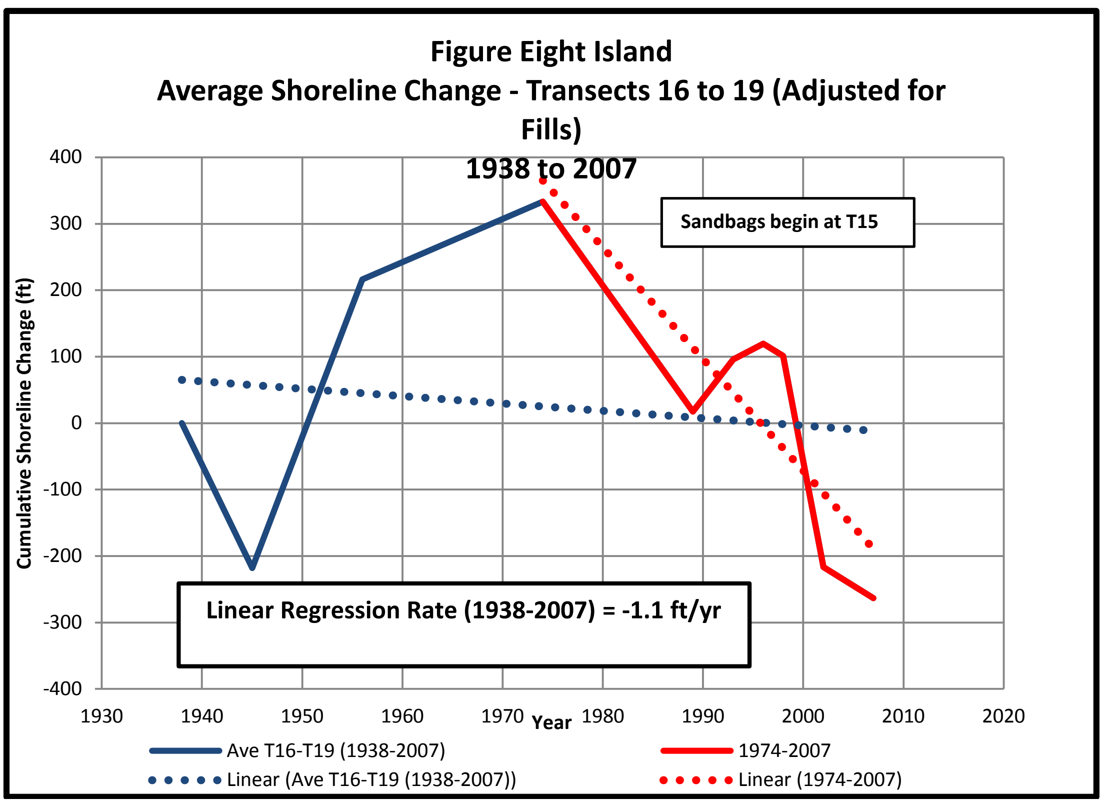

Figure 6.11. Figure Eight Island shoreline change for transects 16-19.

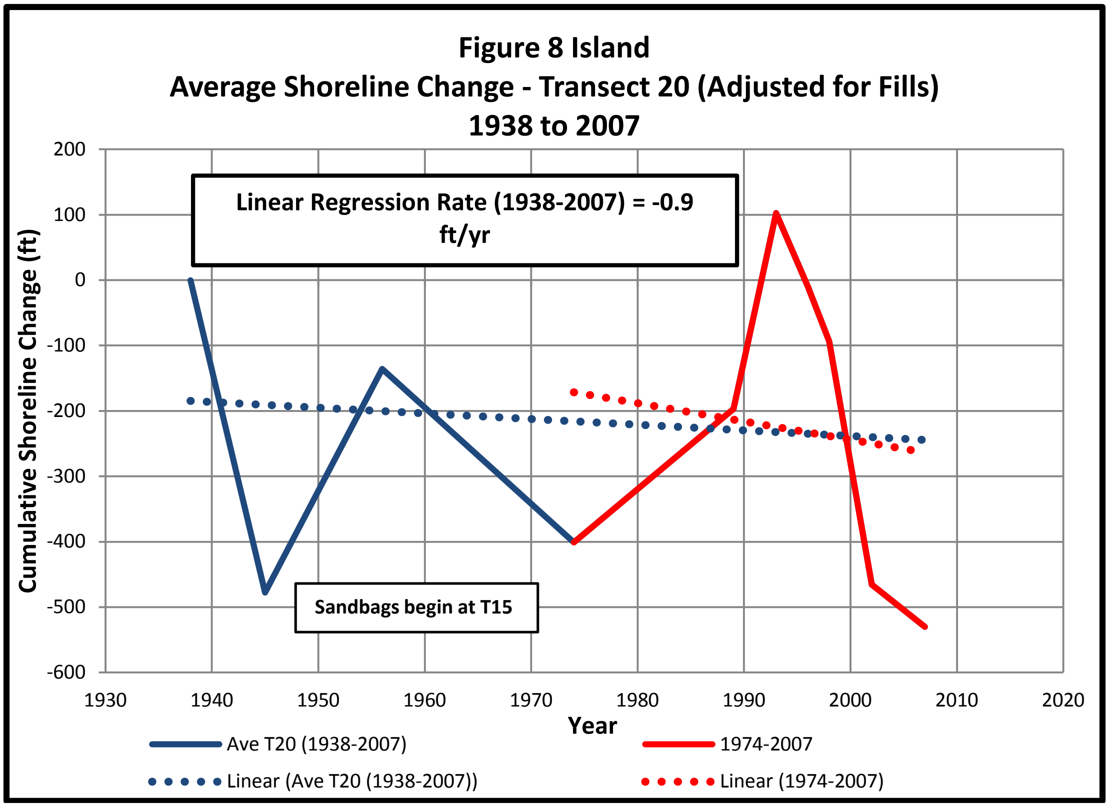

Figure 6.12. Figure Eight Island shoreline change for transect 20.

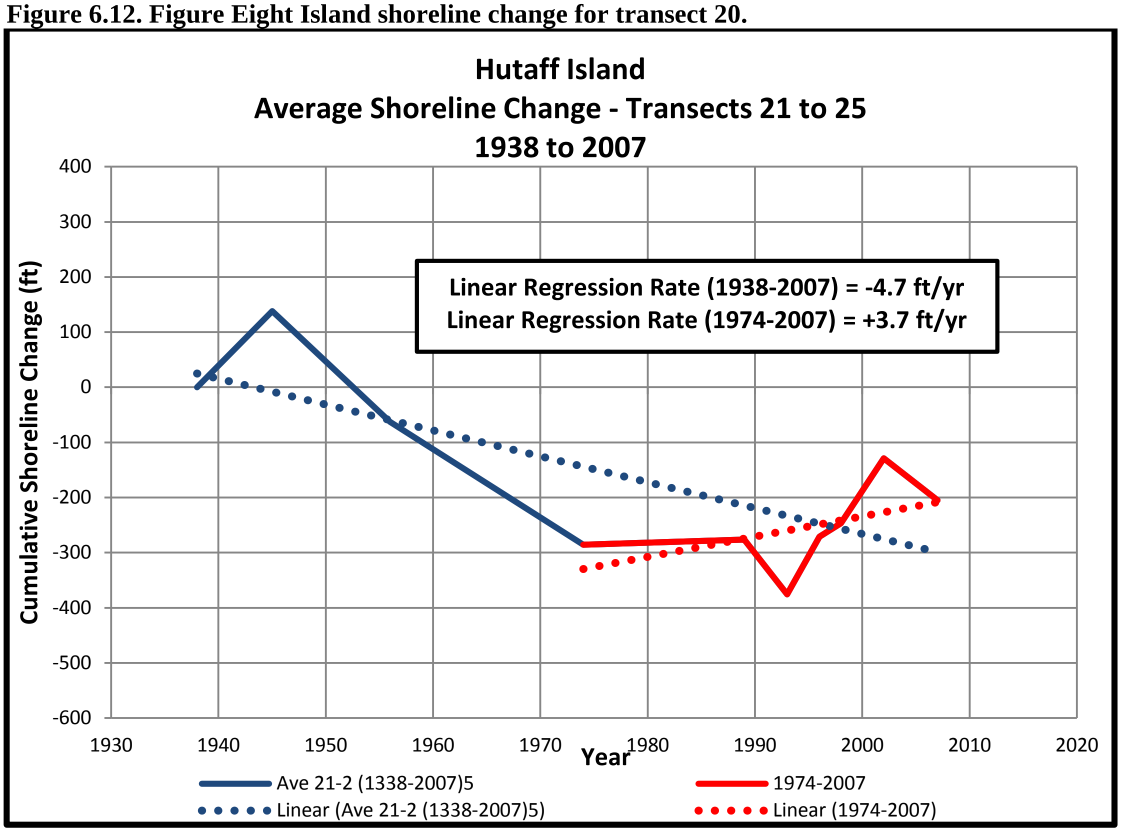

Figure 6.13. Hutaff Island average shoreline change for transects 21 to 25.

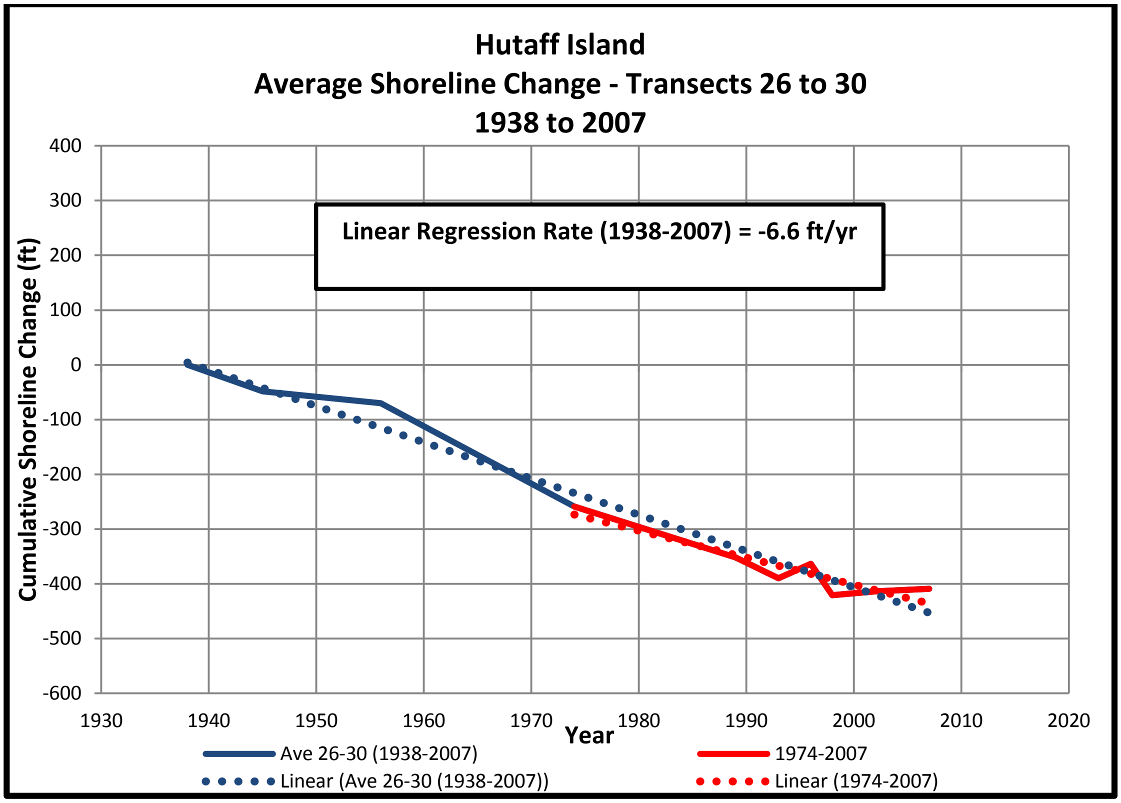

Figure 6.14. Hutaff Island average shoreline change for transects 26 to 30.

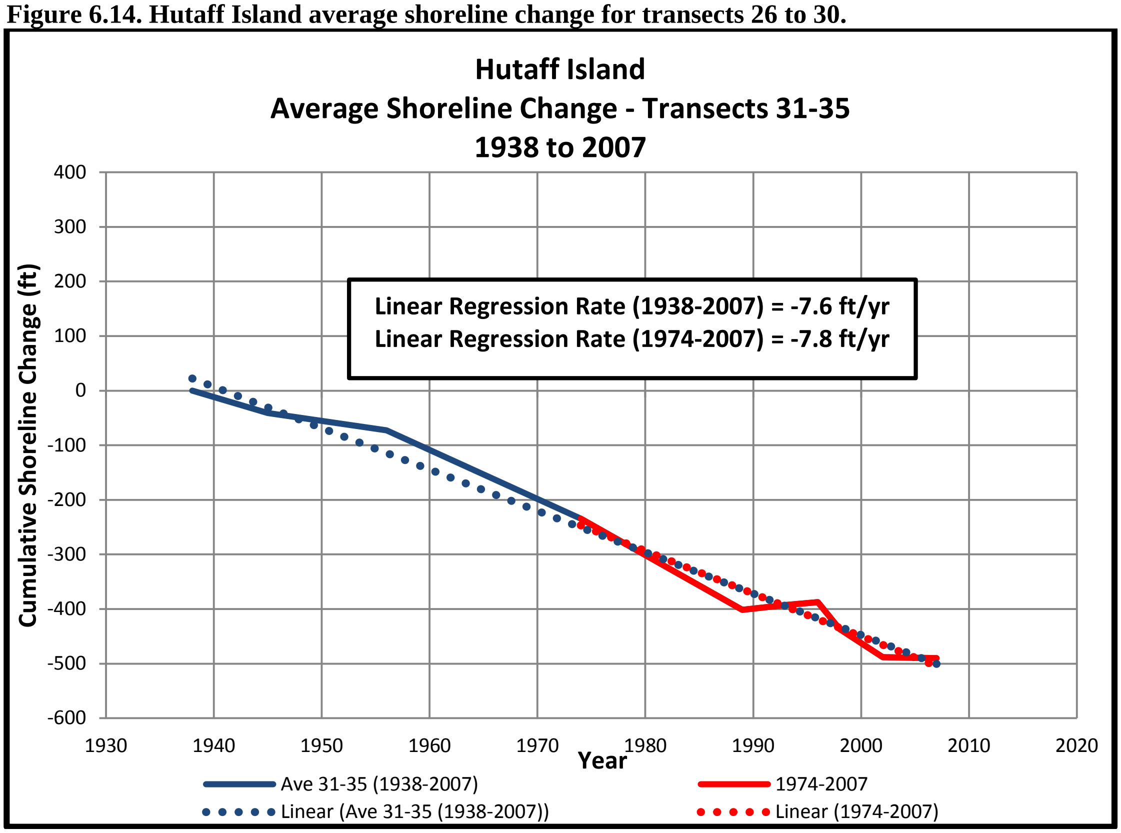

Figure 6.15. Hutaff Island average shoreline change for transects 31 to 35.

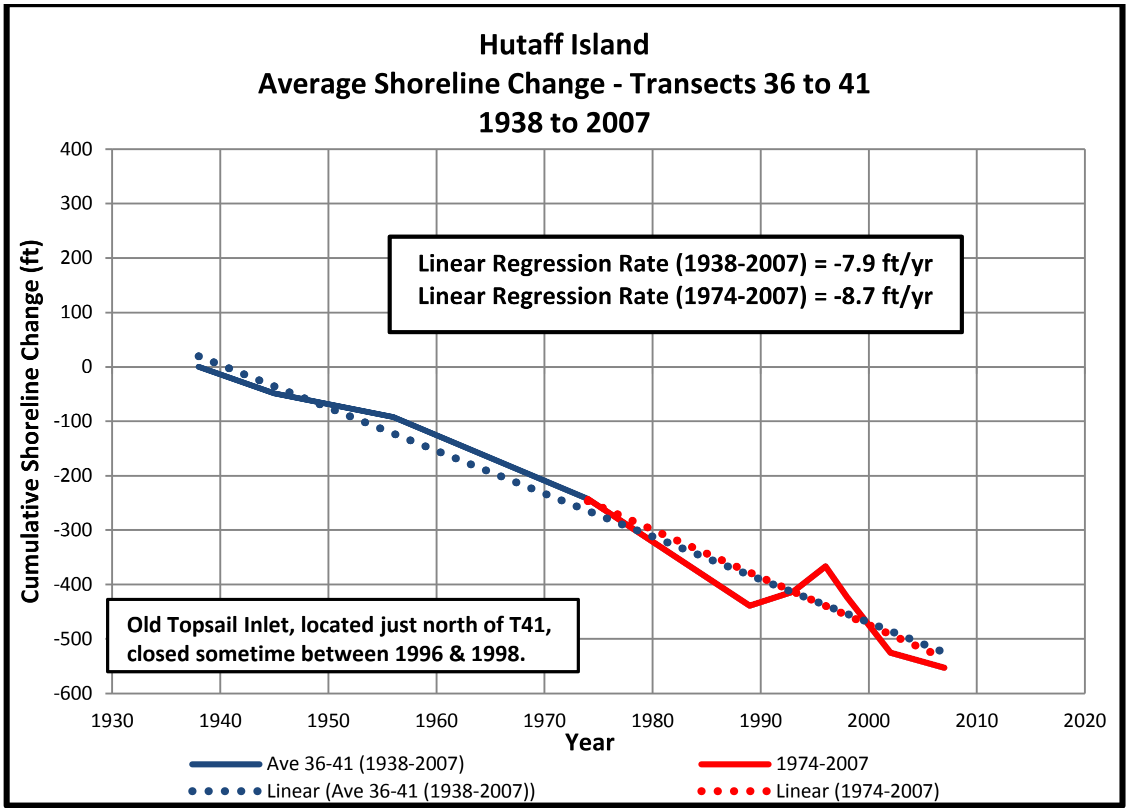

Figure 6.16. Hutaff Island shoreline change for transects 36 to 41.

A summary of the linear regression change rates for the two time periods, 1938-2007 and 1974-2007, for each transect group on Figure Eight Island and Hutaff Island is provided in Table 6.2. Also included in Table 6.2 is the maximum shoreline recession rate computed for each transect group, the time period the maximum rate occurred, the duration of the maximum rate, and the percent of time the two linear regression rates were exceeded.

Table 6.2. Summary of shoreline changes on Figure Eight Island and Hutaff Island.

Transect Group	Shoreline Length in Transect Group (ft)	Linear Regression Rate (ft/yr)		Maximum Shoreline Change			Percent of Time Linear Regression Rate Exceeded	
		1938-2007	1974-2007	Rate (ft/yr)	Time Period	Duration (yrs)	1938-2007	1974-2007
Figure Eight Island								
1-5	2,000	-2.8	-2.7	-19.2	1998-2002	4.01	45.3%	38.8%
6-9	2,000	-0.7	+1.1	-17.1	2002-2007	5.11	55.2%	38.8%
10-11	1,000	+0.7	-0.1	-20.7	2002-2007	5.11	34.4%	38.8%
12-13	1,000	+1.7	-1.8	-23.7	2002-2007	5.11	49.6%	38.7%
14-15	1,000	+2.1	-5.5	-47.7	1998-2002	4.01	54.5%	38.7%
16-19	2,000	-1.1	-16.8	-79.3	1998-2002	4.01	46.8%	58.3%
20	500	-0.9	-2.8	-92.8	1998-2002	4.01	57.4%	43.5%
Hutaff Island								
21-25	1,500	-4.7	+3.7	-29.1	1989-1993	3.41	55.6%	26.3%
26-30	2,000	-6.6	-4.9	-37.7	1996-1998	1.52	44.1%	61.2%
31-35	2,000	-7.6	-7.8	-32.3	1996-1998	1.52	56.6%	63.0%

36-41	2,500	-7.9	-8.7	-37.0	1996-1998	1.52	56.6%	63.0%

The linear regression rates developed for each transect group do not adequately represent the highly variable nature of the behavior of the shorelines over short time intervals. As shown in Table 6.2, the long-term linear regression rates for the 1938-2007 time period were exceeded around 45% to almost 60% of the time while the 1974-2007 rates were exceeded approximately 40% to 60% of the time. Therefore, the shoreline change thresholds developed for Figure Eight Island and Hutaff Island take into account the highly variable nature of shoreline behavior.

Shoreline Change Threshold Development.
In the absence of any new shoreline management initiatives on Figure Eight Island or significant changes in the rate of relative sea level rise, the behavior of the shorelines on both Figure Eight Island and Hutaff Island would be expected to exhibit characteristics similar that which has occurred in the past. This would include continuation of long-term trends, short-term fluctuations in the rates due to storms, and the impacts of changes in the morphology of Rich Inlet. The purpose of the shoreline change thresholds is to provide a basis for determining if the installation of a terminal groin on the north end of Figure Eight Island has an adverse impact on the behavior of the adjacent shorelines. If the shoreline change thresholds are exceeded, the Figure “8” Beach HOA would be responsible for taking mitigative and/or corrective measure to offset the negative impacts. Given the past variability in the behavior of the shoreline on both sides of Rich Inlet as demonstrated above, the shoreline change thresholds presented below include conditions that would reduce the possibility of premature reaction to short-term shoreline changes yet still provide a reasonable basis for determining if negative impacts are occurring. However, since the thresholds would not totally eliminate possible misinterpretations of the cause of excessive negative shoreline impacts, there will be some risk that the permit applicant may be required to mitigate for shoreline impacts that are not totally related to the installation of the terminal groin.

Given the influence Rich Inlet has on the behavior of the ocean shorelines of Figure Eight Island and Hutaff Island, and the recent tendency for the inlet’s ocean bar channel to be situated near the south end of Hutaff Island, the measured shoreline changes for the 1974 to 2007 time period were used to establish the shoreline change thresholds. Specifically, the expected future changes in the shoreline within each transect group are based on the 1974-2007 linear regression shoreline change rates with allowances included to account for past variability in shoreline behavior over shorter time increments.

Expected Future Shoreline Changes.
The expected future shoreline changes within each transect group in the absence of any impacts associated with the terminal groin are defined by the linear regression rate computed for the 1974-2007 time period. For example, the linear regression shoreline change rate for transect group T1-T5 on Figure Eight Island is -2.7 feet/year and the expected change in the shoreline position after 30 years would be a recession of 81 feet. Given the variability in the behavior of the shorelines, an allowable variation in the shoreline change, or threshold boundaries, was based on 90% confidence limits associated with the 1974-2007 linear regression rate. The 90% confidence limit refers to the likelihood future shoreline changes for each transect group will be within the specified confidence interval, i.e. 90%. For transect group T1-T5, the computed 90%

confidence interval for the shoreline change rate has an upper limit of +0.1 foot/year and a lower limit of -5.5 feet/year. Therefore in this example, the future change in the shoreline position for transect group T1-T5 would be expected to fall within a range of 3 feet of accretion to 165 feet of erosion at the end of 30 years with a 90% degree of confidence. The 90% confidence limits for the 1974-2007 linear regression shoreline change rates for all transect on Figure Eight Island and Hutaff Island are provided in Table 6.3.

Table 6.3. 90% Confidence intervals for the 1974-2007 linear regression shoreline change rates for each transect group on Figure Eight Island and Hutaff Island.

Transect Group	1974-2007 Linear Regression Rate & 90% Confidence Limits		
	Upper Limit ft/yr	Linear Regression Rate ft/yr	Lower Limit ft/yr
Figure Eight Island			
T1-T5	+0.1	-2.7	-5.5
T6-T9	+4.3	+1.1	-2,1
T10-T11	+3.8	-0.1	-4.0
T12-T13	+3.0	-1.8	-6.5
T14-T15	+1.2	-5.5	-12.2
T16-T19	-7.9	-16.8	-25.6
T20	+22.2	-0.4	-23.0
Hutaff Island			
T21-T25	+9.2	+3.7	-1.8
T26-T30	-3.1	-4.9	-6.7
T31-T35	-5.8	-7.8	-9.8
T36-T41	-5.0	-8.7	-12.5

The linear regression shoreline change rate for each transect group was used to project expected shoreline changes within each transect group over a 30-year period following the installation of a terminal groin on the north end of Figure Eight Island. These expected shoreline changes are provided on Figures 6.17 to 6.27. An envelope covering a range of possible variations in the shoreline changes was also determined using the upper and lower 90% confidence limits for the shoreline change rates given in Table 6.3. The resulting expected shoreline changes along with the 90% upper and lower limits of these expected changes are plotted on Figures 6.17 to 6.27. In each of these plots, future shoreline changes begin with the construction of the terminal groin and extend 30 years into the future.

Following the construction of the terminal groin, cumulative shoreline changes within each transect group would be determined based on the results of the shoreline monitoring program described below. The post-construction shoreline changes would be compared to the expected future shoreline change based on the pre-project shoreline change rates. As an example of how measured shoreline changes post-terminal groin construction would be compared to the expected shoreline change and the 90% confidence interval, the shoreline changes observed on Figure Eight Island and Hutaff Island between 1974 to 2007 were used to develop theoretical observed shoreline changes within each transect group following construction of the terminal groin. These "observed" shoreline changes are superimposed on Figures 6.17 to 6.27.

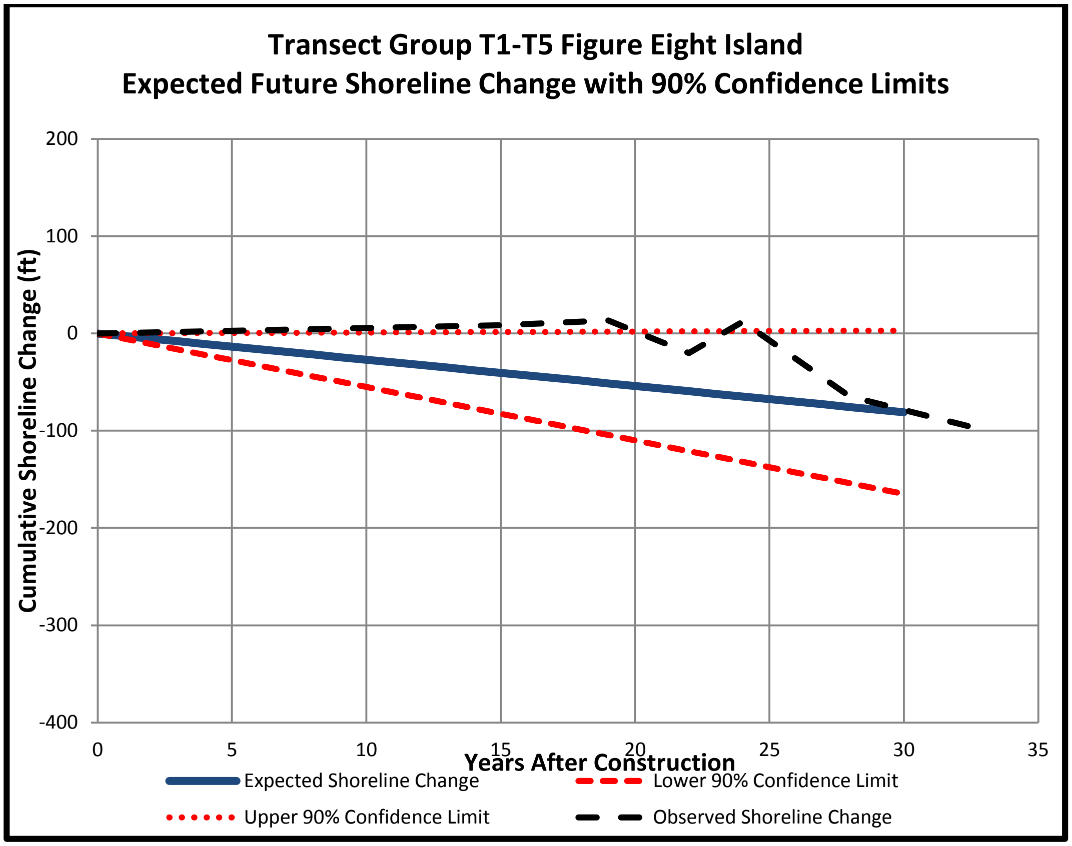

Figure 6.17. Transect Group T1-T5, Figure Eight Island – Expected future shoreline change.

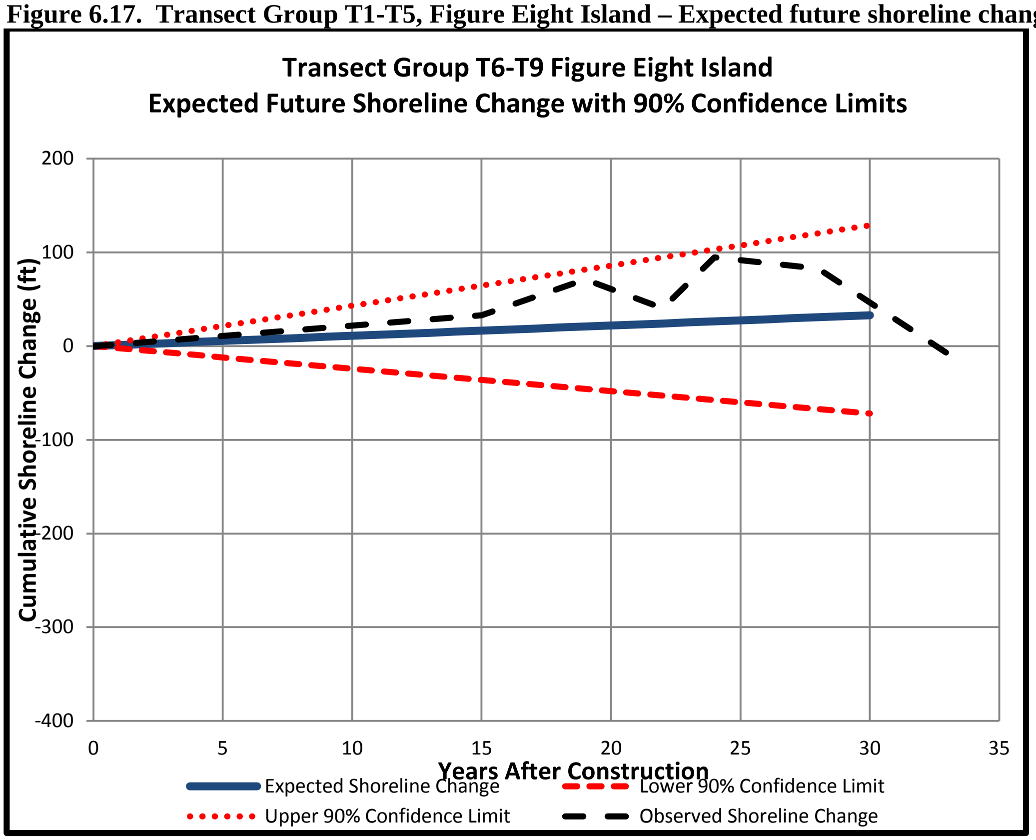

Figure 6.18. Transect Group T6-T9, Figure Eight Island – Expected future shoreline change.

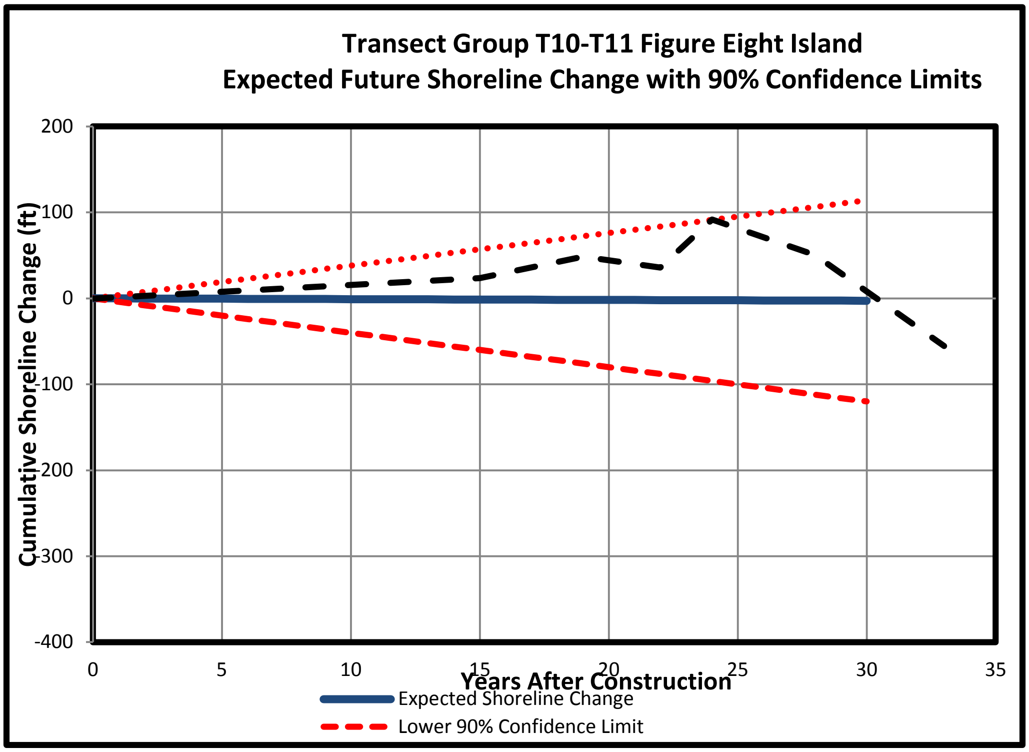

Figure 6.19. Transect Group T10-T11, Figure Eight Island – Expected future shoreline change.

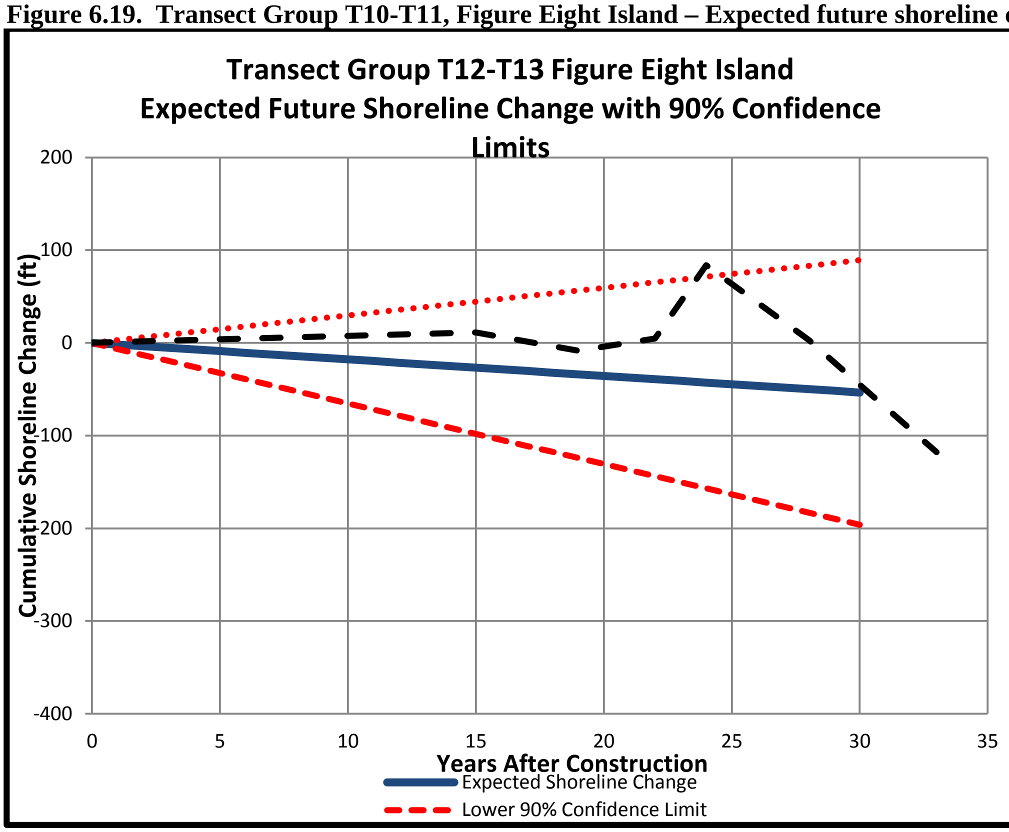

Figure 6.20. Transect Group T12-T13, Figure Eight Island – Expected future shoreline change.

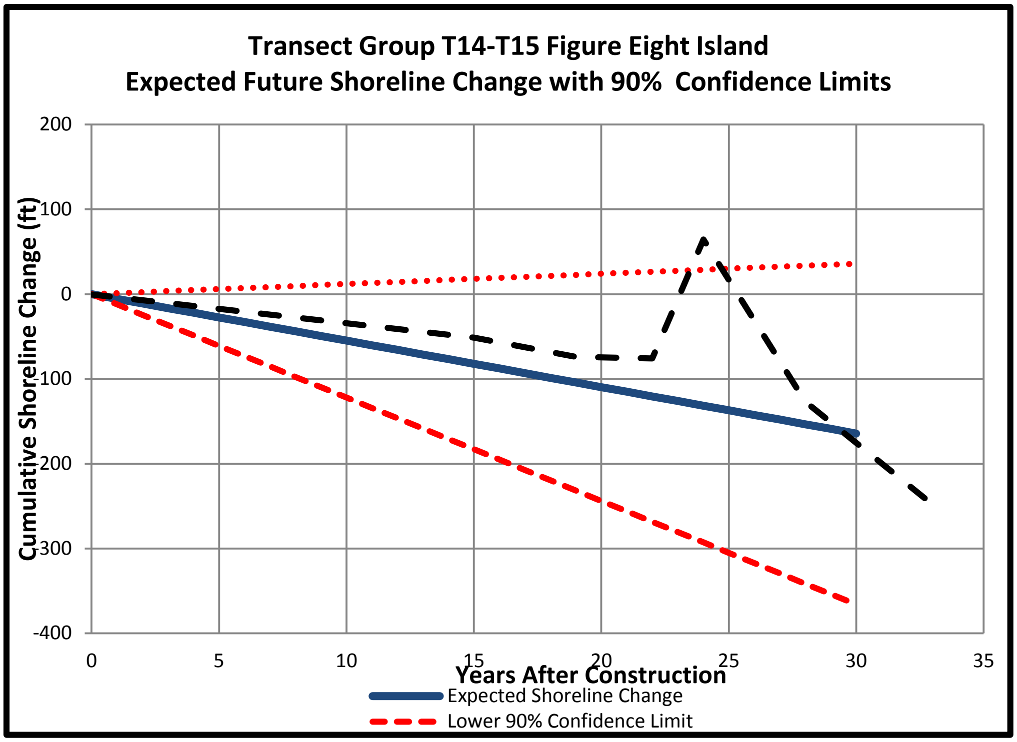

Figure 6.21. Transect Group T14-T15, Figure Eight Island – Expected future shoreline change.

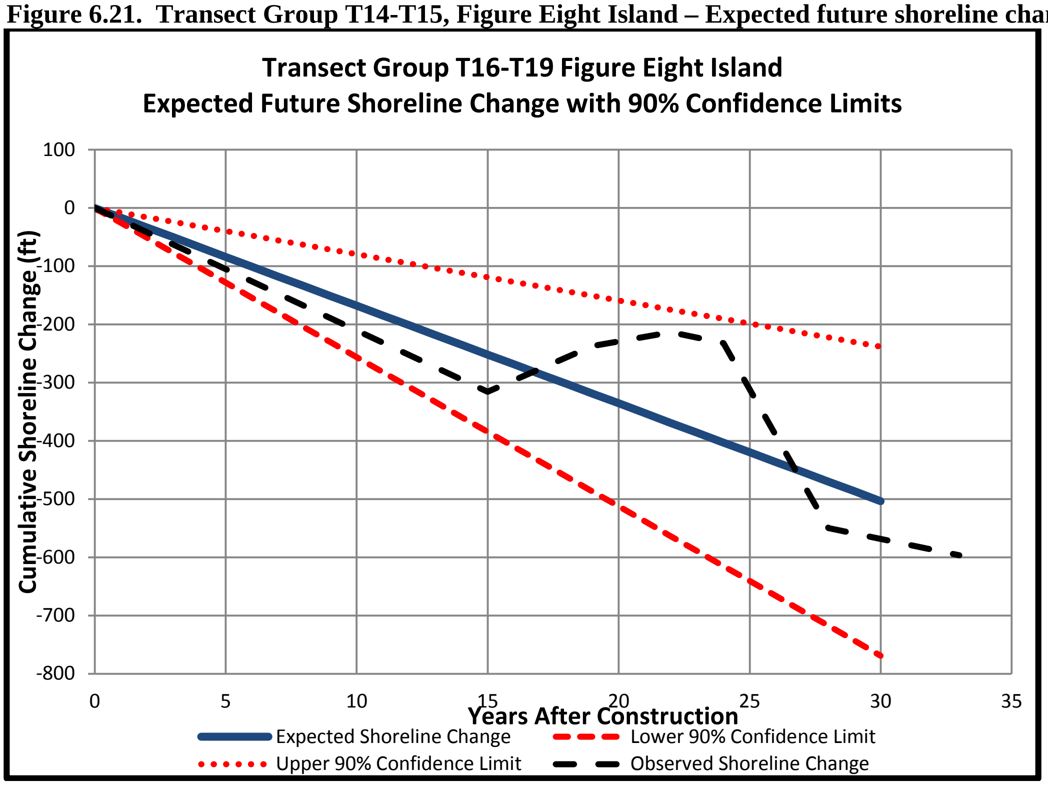

Figure 6.22. Transect Group T16-T19, Figure Eight Island – Expected future shoreline change.

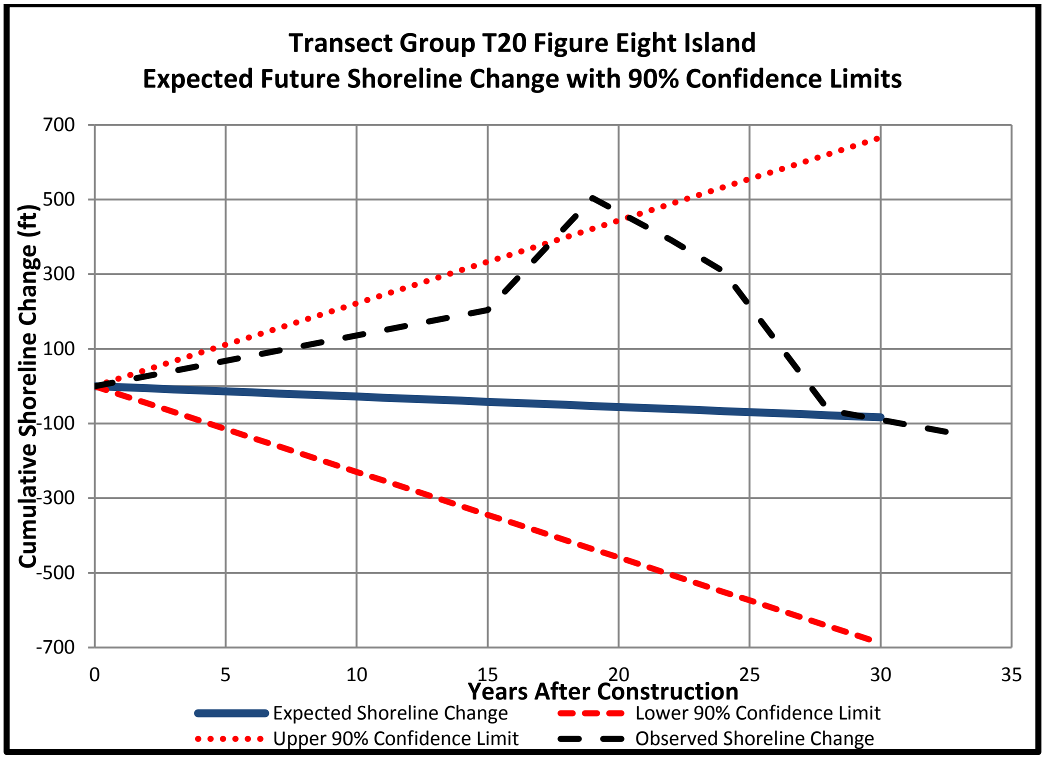

Figure 6.23. Transect Group T20, Figure Eight Island – Expected future shoreline change.

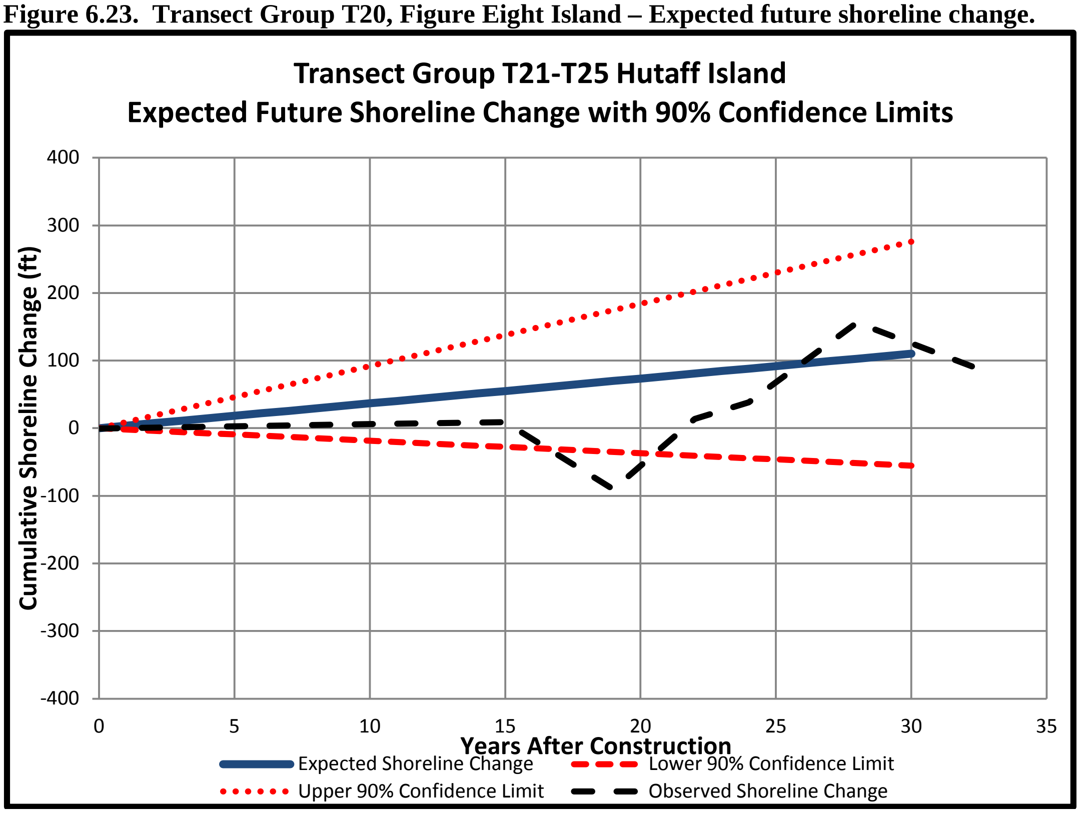

Figure 6.24. Transect Group T21-T25, Hutaff Island – Expected future shoreline change.

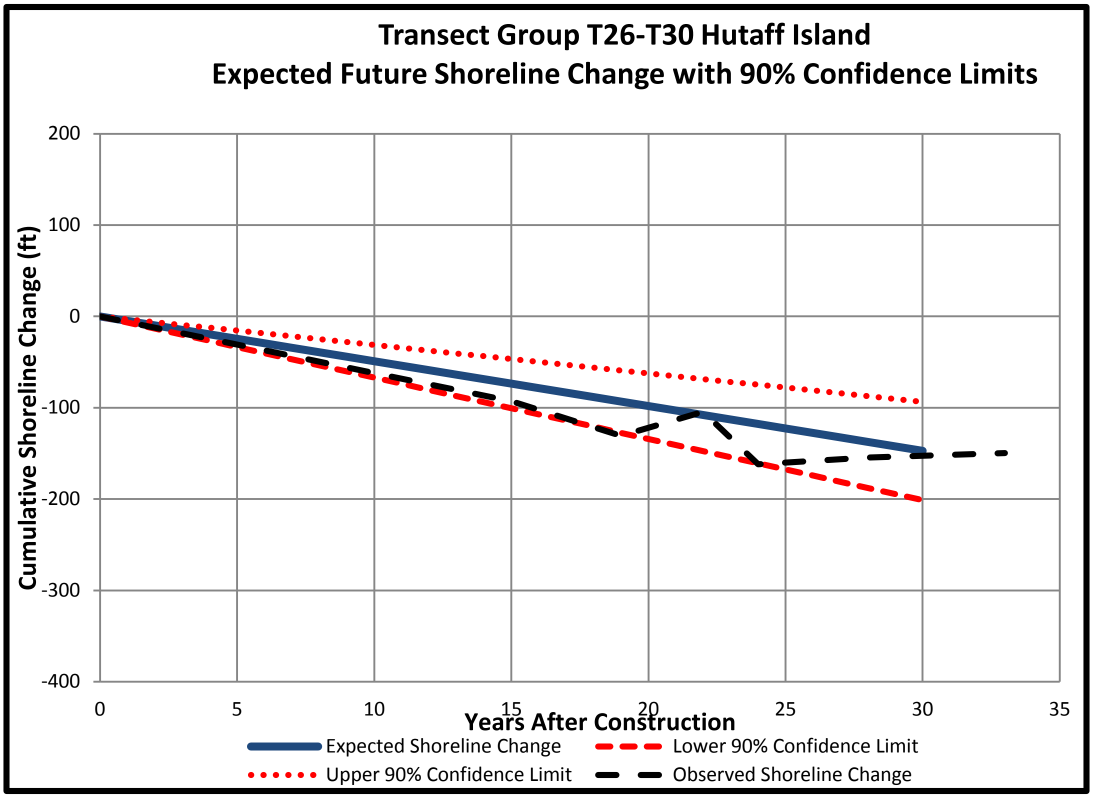

Figure 6.25. Transect Group T26-T30, Hutaff Island – Expected future shoreline change.

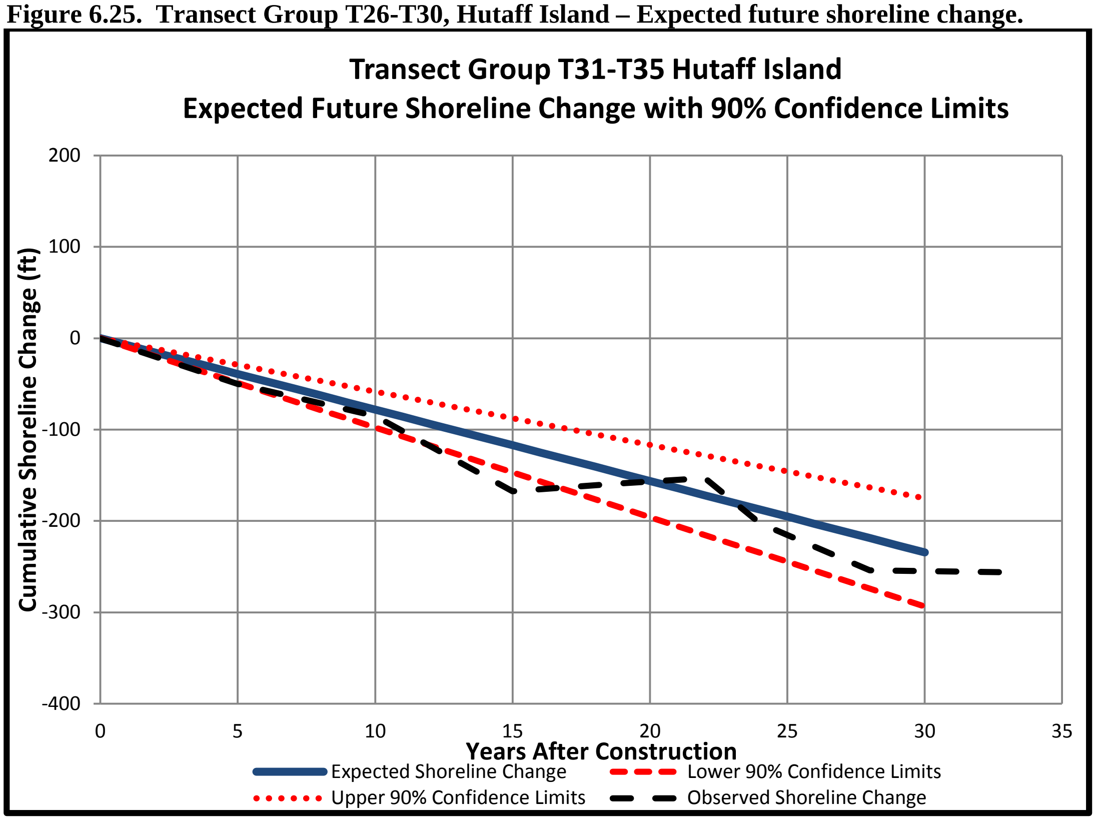

Figure 6.26. Transect Group T31-T35, Hutaff Island – Expected future shoreline change.

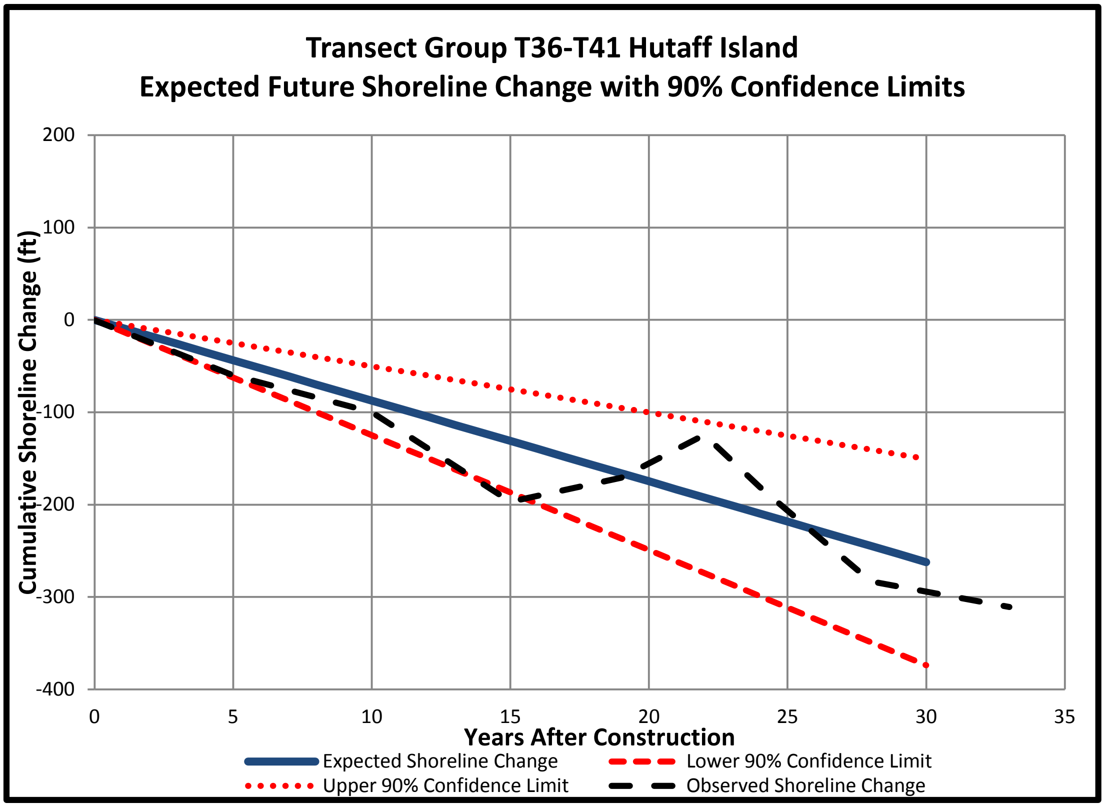

Figure 6.27. Transect Group T36-T41, Hutaff Island – Expected future shoreline change.

Response Trigger.

Should the cumulative shoreline changes within two adjacent transect groups exceed the lower 90% confidence limit, as is the case for transect groups T31-T35 and T36-T41on Hutaff Island used in the examples on Figures 6.17 to 6.27, the shoreline behavior would be deemed to have exceeded the shoreline change threshold for those two transect groups. However, given the known variability in the shoreline behavior, a verification period of two (2) years would follow to determine if the observed shoreline changes continue to exceed the lower 90% confidence limit in both transect groups. If the lower 90% shoreline change confidence limit continues to be exceeded for the entire 2-year confirmation period, then mitigative measures would be in order. If, however, the shoreline recovers and the cumulative shoreline change within either transect group becoming less than the lower 90% confidence limit any time during the 2-year confirmation period, the threshold would be re-set and no mitigation would be required. The two-year verification period has been generally applied to other projects in which shoreline change thresholds have been adopted in order to determine if and/or when a project produces negative impacts. For example, a similar verification period was used for the Pea Island/Oregon Inlet terminal groin and the Fort Fisher revetement (near Carolina Beach, NC). In general, the two year confirmation period is associated with observed post-storm behavior of beaches along the NC coast and has been used by the USACE for monitoring the effects of the Fort Fisher revetment as well as the impacts of the Shallotte Inlet Borrow Area in proximity to Ocean Isle Beach and Holden Beach.

Should the mean high water shoreline encroach within 40 feet of an ocean front structure, road, or other infrastructure on Figure Eight Island, plans would begin immediately to counter the erosion through the use of beach nourishment. Note the use of 40 feet is double the distance used by the NC Division of Coastal Management to determine when a structure becomes imminently threatened. Material to provide the mitigation beach fill would be obtained from the Nixon Channel borrow area.

On the Hutaff Island side of Rich Inlet no man-made structures or infrastructure exists. Therefore, the response trigger associated with shoreline change rates described above would dictate when mitigation is requires. The primary mitigation effort on Hutaff Island would be through beach nourishment. Material for the mitigation beach fill would also be obtained from the Nixon Channel borrow area.

Monitoring Plan.
Post-construction change analysis in the shorelines of Figure Eight Island and Hutaff Island would be accomplished twice a year for at least two years post-construction. At the end of two years, the monitoring analysis would be reassessed by the federal and state permitting agencies and a decision made as to whether or not to continue twice yearly surveys or decrease the coverage to once a year.

Shoreline changes would be measured from georectified aerial photographs with a scale of 1 inch = 200 feet. The shoreline would be defined by the wet/dry line on the photographs and measurements would be made at each of the same transects used to develop the shoreline change thresholds. Annual monitoring reports will be prepared and will include the aerial photographs, shoreline change results for each transect, average changes for each transect group, and plots of the cumulative post-construction shoreline changes superimposed on the shoreline change threshold curves. The report will identify if any of the thresholds for the transect groups have been exceeded and will indicate if a confirmation period has been initiated or if the shoreline change thresholds have been exceeded beyond a confirmation period. The monitoring reports will be provided to both the federal and state permitting agencies.

The aerial photographic analysis of shoreline changes will be supplemented by a continuation of the existing profile survey monitoring program being conducted by the Figure "8" Beach HOA. The existing profile monitoring program is conducted once a year and covers all of Figure Eight Island and the south end of Hutaff Island. Profile spacing is generally 1,000 feet, however, closer profile stationing of 250 feet is used for the north end of Figure Eight Island between baseline station 70+00 and Rich Inlet. The beach profiles extend from the dune seaward to approximately the 30-foot depth contour. The survey monitoring program also includes perpendicular and horizontal transects in Rich Inlet.

Mitigation Measures.
The general response for mitigating shoreline erosion impacts that exceed the shoreline change thresholds would be in the form of beach nourishment. The beach profile surveys described above would be used to determine the volume of material required to restore the post-construction shoreline change to a condition above the shoreline change threshold. Material

needed to restore the shoreline would be derived from the existing permit area in Nixon Channel or possible the three northern upland disposal sites situated adjacent to the AIWW.

In the event the negative impacts of the terminal groin cannot be mitigated with beach nourishment or possible modifications to the design of the terminal groin, the terminal groin would be removed. Removal would entail the extraction of the sheet pile from the shore anchorage section and the complete removal of all stone, including bedding, underlayer, and armor stone as well as the entire structure seaward of the MHW line. All of the terminal groin construction materials would be transported off the island and placed in an appropriate storage site. The terminal groin material, particularly the sheet pile and stone, would have some salvage value; however the opinion on the cost for removal of the terminal groin, excluding any salvage value, is $3.2 million.

Attachment 1
Shoreline Change Thresholds

Table A-1

Figure Eight Island Shoreline Change Information

	Mar-38	Jan-45	Mar-56	Dec-74	Oct-89	Mar-93	Aug-96	Feb-98	Feb-02	Apr-07
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T1 - T5 (2,000 ft)										
T1 incremental change		21	36	-155	-3	47	24	2	39	-26
fill width during time increment		0	0	0	0	42	36	27	99	0
T1 Incr. change adjusted for fill	0	21	36	-155	-3	5	-12	-25	-60	-26
T1 change since 1938		21	57	-98	-101	-96	-108	-133	-193	-219
T2 incremental change		30	16	-155	6	46	2	60	12	-31
fill width during time increment		0	0	0	0	42	36	27	99	0
T2 Incr. change adjusted for fill	0	30	16	-155	6	4	-34	33	-87	-31
T2 change since 1938		30	47	-109	-103	-100	-133	-101	-188	-218
T3 incremental change		-4	31	-143	16	56	-3	70	16	-42
fill width during time increment		0	0	0	0	42	36	27	99	0
T3 Incr. change adjusted for fill	0	-4	31	-143	16	14	-39	43	-83	-42
T3 change since 1938		-4	27	-116	-100	-87	-126	-83	-166	-208
T4 incremental change		-14	13	-117	11	56	-18	91	4	-30
fill width during time increment		0	0	0	0	42	36	27	99	0
T4 Incr. change adjusted for fill	0	-14	13	-117	11	14	-54	64	-95	-30
T4 change since 1938		-14	-1	-119	-108	-94	-148	-84	-179	-209
T5 incremental change		-52	18	-95	13	30	8	73	40	-44
fill width during time increment		0	0	0	0	42	36	27	99	0
T5 Incr. change adjusted for fill	0	-52	18	-95	13	-12	-28	46	-59	-44
T5 change since 1938		-52	-34	-129	-116	-128	-156	-110	-169	-213
Averages for T1 - T5										
Incremental Change		**-4**	**23**	**-133**	**9**	**47**	**3**	**59**	**22**	**-35**
fill width during time increment		**0**	**0**	**0**	**0**	**42**	**36**	**27**	**99**	**0**
Incremental change adjusted for fill	**0**	**-4**	**23**	**-133**	**9**	**5**	**-33**	**32**	**-77**	**-35**
Change since 1938-fill adjusted		**-4**	**19**	**-114**	**-106**	**-101**	**-134**	**-102**	**-179**	**-213**
Average incremental rate (ft/yr)		**-0.6**	**2.0**	**-7.1**	**0.6**	**1.5**	**-9.7**	**21.1**	**-19.2**	**-6.8**

Table A-1

Figure Eight Island Shoreline Change Information

	Mar-38	Jan-45	Mar-56	Dec-74	Oct-89	Mar-93	Aug-96	Feb-98	Feb-02	Apr-07
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T6 - T9 (2,000 ft)										
T6 incremental change		-82	20	-73	-2	30	47	45	25	-39
fill width during time increment		0	0	0	0	0	36	27	39	0
T6 Incr. change adjusted for fill		-82	20	-73	-2	30	11	18	-14	-39
T6 change since 1938	0	-82	-62	-135	-137	-107	-96	-77	-91	-130
T7 incremental change		-61	-3	-81	39	32	8	82	32	-56
fill width during time increment		0	0	0	0	0	36	27	39	41
T7 Incr. change adjusted for fill		-61	-3	-81	39	32	-28	55	-7	-97
T7 change since 1938	0	-61	-64	-145	-106	-74	-103	-47	-55	-151
T8 incremental change		-72	-6	-55	50	40	0	95	12	-65
fill width during time increment		0	0	0	0	0	36	27	39	41
T8 Incr. change adjusted for fill		-72	-6	-55	50	40	-36	68	-27	-106
T8 change since 1938	0	-72	-78	-133	-83	-43	-80	-12	-39	-145
T9 incremental change		-56	-17	-32	47	51	-34	103	39	-79
fill width during time increment		0	0	0	0	0	36	27	39	41
T9 Incr. change adjusted for fill		-56	-17	-32	47	51	-70	76	0	-120
T9 change since 1938	0	-56	-73	-104	-58	-7	-77	-1	-1	-121
Averages for T6 - T9										
Incremental Change		**-68**	**-2**	**-60**	**33**	**38**	**5**	**81**	**27**	**-60**
fill width during time increment		**0**	**0**	**0**	**0**	**0**	**36**	**27**	**39**	**31**
Incremental change adjusted for fill		**-68**	**-2**	**-60**	**33**	**38**	**-31**	**54**	**-12**	**-90**
Change since 1938-fill adjusted	**0**	**-68**	**-69**	**-129**	**-96**	**-58**	**-89**	**-34**	**-46**	**-137**
Average incremental rate (ft/yr)		**-9.9**	**-0.1**	**-3.2**	**2.2**	**11.2**	**-9.0**	**35.7**	**-3.0**	**-17.7**
T10 - T11 (1,000 ft)										
T10 incremental change		-5	-31	10	29	37	2	79	16	-58
fill width during time increment		0	0	0	0	0	36	27	39	41
T10 Incr. change adjusted for fill		-5	-31	10	29	37	-34	52	-23	-99
T10 change since 1938	0	-5	-36	-26	3	40	6	57	35	-64
T11 incremental change		9	-19	53	19	13	45	87	-21	-71
fill width during time increment		0	0	0	0	0	36	27	39	41
T11 Incr. change adjusted for fill		9	-19	53	19	13	9	60	-60	-112

T11 change since 1938	0	9	-10	43	62	75	84	144	84	-28
Averages for T10 - T11										
Incremental Change		**2**	**-25**	**32**	**24**	**25**	**23**	**83**	**-2**	**-65**
fill width during time increment		**0**	**0**	**0**	**0**	**0**	**36**	**27**	**39**	**41**
Incremental change adjusted for fill		**2**	**-25**	**32**	**24**	**25**	**-13**	**56**	**-41**	**-106**
Change since 1938-fill adjusted	**0**	**2**	**-23**	**9**	**33**	**58**	**45**	**101**	**59**	**-46**
Average incremental rate (ft/yr)		**0.3**	**-2.3**	**1.7**	**1.6**	**7.3**	**-3.7**	**36.6**	**-10.3**	**-20.7**

Table A-1

Figure Eight Island Shoreline Change Information

	Mar-38	**Jan-45**	**Mar-56**	**Dec-74**	**Oct-89**	**Mar-93**	**Aug-96**	**Feb-98**	**Feb-02**	**Apr-07**
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T12 - T13 (1,000 ft)										
T12 incremental change		12	-8	90	14	-2	53	73	-5	-86
fill width during time increment		0	0	0	0	0	36	27	39	41
T12 Incr. change adjusted for fill		12	-8	90	14	-2	17	46	-44	-127
T12 change since 1938	0	12	4	95	109	106	124	170	126	-1
T13 incremental change		-14	43	112	8	-37	45	139	-78	-74
fill width during time increment		0	0	0	0	0	36	27	39	41
T13 Incr. change adjusted for fill		-14	43	112	8	-37	9	112	-117	-115
T13 change since 1938	0	-14	29	140	148	111	120	232	115	0
Averages for T12 - T13										
Incremental Change		**-1**	**18**	**101**	**11**	**-20**	**49**	**106**	**-41**	**-80**
fill width during time increment		**0**	**0**	**0**	**0**	**0**	**36**	**27**	**39**	**41**
Incremental change adjusted for fill		**-1**	**18**	**101**	**11**	**-20**	**13**	**79**	**-80**	**-121**
Change since 1938-fill adjusted	**0**	**-1**	**17**	**117**	**128**	**109**	**122**	**201**	**121**	**-1**
Average incremental rate (ft/yr)		**-0.2**	**1.6**	**5.4**	**0.7**	**-5.8**	**3.9**	**51.7**	**-20.0**	**-23.7**
T14 - T15 (1,000 ft)										
T14 incremental change		-26	114	140	-33	-36	14	195	-134	-88
fill width during time increment		0	0	0	0	0	36	27	39	41
T14 Incr. change adjusted for fill		-26	114	140	-33	-36	-22	168	-173	-129
T14 change since 1938	0	-26	88	228	195	159	137	306	133	4
T15 incremental change		-49	199	111	-69	-9	54	139	-171	-73
fill width during time increment		0	0	0	0	0	36	27	39	41
T15 Incr. change adjusted for fill		-49	199	111	-69	-9	18	112	-210	-114
T15 change since 1938	0	-49	150	261	192	183	201	313	103	-10

Averages for T14 - T15										
Incremental Change		**-38**	**157**	**125**	**-51**	**-23**	**34**	**167**	**-152**	**-80**
fill width during time increment		**0**	**0**	**0**	**0**	**0**	**36**	**27**	**39**	**41**
Incremental change adjusted for fill		**-38**	**157**	**125**	**-51**	**-23**	**-2**	**140**	**-191**	**-121**
Change since 1938-fill adjusted	0	-38	119	245	194	171	169	310	118	-3
Average incremental rate (ft/yr)		**-5.5**	**14.0**	**6.7**	**-3.4**	**-6.6**	**-0.5**	**91.9**	**-47.7**	**-23.7**

Table A-1

Figure Eight Island Shoreline Change Information

	Mar-38	**Jan-45**	**Mar-56**	**Dec-74**	**Oct-89**	**Mar-93**	**Aug-96**	**Feb-98**	**Feb-02**	**Apr-07**
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T16 - T19 (2,000 ft)										
T16 incremental change		-101	292	78	-42	19	63	83	-213	-68
fill width during time increment		0	0	0	179	0	36	27	39	41
T16 Incr. change adjusted for fill		-101	292	78	-221	19	27	56	-252	-109
T16 change since 1938	0	-101	191	269	48	67	95	151	-101	-210
T17 incremental change		-167	387	100	-97	69	78	20	-277	-4
fill width during time increment		0	0	0	179	0	36	27	39	41
T17 Incr. change adjusted for fill		-167	387	100	-276	69	42	-7	-316	-45
T17 change since 1938	0	-167	220	320	44	113	155	148	-168	-213
T18 incremental change		-251	531	140	-218	103	73	-36	-304	13
fill width during time increment		0	0	0	179	0	36	27	39	41
T18 Incr. change adjusted for fill		-251	531	140	-397	103	37	-63	-343	-28
T18 change since 1938	0	-251	280	420	24	127	164	101	-241	-270
T19 incremental change		-353	528	150	-192	124	24	-33	-322	36
fill width during time increment		0	0	0	179	0	36	27	39	41
T19 Incr. change adjusted for fill		-353	528	150	-371	124	-12	-60	-361	-5
T19 change since 1938	0	-353	174	324	-47	77	65	5	-357	-362
Averages for T16 - T19										
Incremental Change		**-218**	**434**	**117**	**-137**	**79**	**60**	**9**	**-279**	**-6**
fill width during time increment		**0**	**0**	**0**	**179**	**0**	**36**	**27**	**39**	**41**
Incremental change adjusted for fill		**-218**	**434**	**117**	**-316**	**79**	**24**	**-18**	**-318**	**-47**
Change since 1938-fill adjusted	**0**	**-218**	**216**	**333**	**17**	**96**	**120**	**101**	**-217**	**-264**

Average incremental rate (ft/yr)		**-31.9**	**38.9**	**6.3**	**-21.3**	**23.1**	**6.9**	**-12.1**	**-79.3**	**-9.2**
T20 (500 ft)										
T20 incremental change		**-478**	**342**	**-265**	**383**	**299**	**-76**	**-57**	**-333**	**-23**
fill width during time increment		**0**	**0**	**0**	**179**	**0**	**36**	**27**	**39**	**41**
T20 Incr. change adjusted for fill		**-478**	**342**	**-265**	**204**	**299**	**-112**	**-84**	**-372**	**-64**
T20 change since 1938	**0**	**-478**	**-136**	**-401**	**-197**	**103**	**-9**	**-94**	**-466**	**-530**
Average incremental rate (ft/yr)		**-69.9**	**30.6**	**-14.2**	**13.7**	**87.8**	**-32.6**	**-55.3**	**-92.8**	**-12.6**

Table A-1

Hutaff Island Shoreline Change Information

	Mar-38	**Jan-45**	**Mar-56**	**Dec-74**	**Oct-89**	**Mar-93**	**Aug-96**	**Feb-98**	**Feb-02**	**Apr-07**
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T21 - T25 (2,000 ft)										
T21 incremental change		371	-453	-202	79	-180	199	116	-27	-25
T21 change since 1938	0	371	-82	-283	-204	-384	-184	-69	-96	-121
T22 incremental change		221	-284	-239	43	-129	154	46	50	-50
T22 change since 1938	0	221	-63	-301	-259	-388	-234	-188	-138	-188
T23 incremental change		114	-171	-233	3	-88	90	55	132	-104
T23 change since 1938	0	114	-57	-290	-288	-375	-286	-231	-99	-203
T24 incremental change		29	-81	-234	-29	-60	50	-13	188	-90
T24 change since 1938	0	29	-52	-286	-314	-374	-324	-337	-149	-239
T25 incremental change		-44	-16	-206	-50	-40	28	-81	247	-112
T25 change since 1938	0	-44	-60	-266	-316	-356	-328	-409	-162	-273
Averages for T21 - T25										
Incremental change		**138**	**-201**	**-223**	**9**	**-99**	**104**	**25**	**118**	**-76**
Cumulative change since 1938	**0**	**138**	**-63**	**-285**	**-276**	**-375**	**-271**	**-247**	**-129**	**-205**
Average incremental rate (ft/yr)		**20.2**	**-18.0**	**-11.9**	**0.6**	**-29.1**	**30.3**	**16.1**	**29.4**	**-14.9**
T26 - T30 (2,500 ft)										
T26 incremental change		-47	-23	-197	-62	-31	12	-51	72	-36
T26 change since 1938	0	-47	-70	-266	-328	-360	-348	-399	-327	-364
T27 incremental change		-47	-34	-186	-59	-59	13	-56	49	-22
T27 change since 1938	0	-47	-81	-268	-327	-386	-373	-429	-379	-401
T28 incremental change		-52	-18	-192	-89	-53	44	-40	-39	15

T28 change since 1938	0	-52	-70	-262	-351	-404	-360	-399	-439	-424
T29 incremental change		-59	-13	-191	-119	-24	31	-73	-25	36
T29 change since 1938	0	-59	-72	-263	-382	-406	-375	-448	-472	-436
T30 incremental change		-38	-19	-179	-135	-24	33	-68	-20	31
T30 change since 1938	0	-38	-57	-236	-370	-394	-361	-430	-450	-419
Averages for T26 - T30										
Incremental change		**-48**	**-21**	**-189**	**-93**	**-38**	**26**	**-57**	**7**	**5**
Change since 1938	**0**	**-48**	**-70**	**-259**	**-352**	**-390**	**-363**	**-421**	**-414**	**-409**
Average incremental rate (ft/yr)		**-7.1**	**-1.9**	**-10.1**	**-6.3**	**-11.2**	**7.7**	**-37.7**	**1.8**	**0.9**

Table A-1

Hutaff Island Shoreline Change Information

	Mar-38	**Jan-45**	**Mar-56**	**Dec-74**	**Oct-89**	**Mar-93**	**Aug-96**	**Feb-98**	**Feb-02**	**Apr-07**
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T31 - T35 (2,500 ft)										
T31 incremental change		-44	-22	-157	-169	47	-21	-45	-56	33
T31 change since 1938	0	-44	-67	-224	-393	-345	-366	-411	-468	-435
T32 incremental change		-53	-7	-187	-140	26	-11	-16	-92	22
T32 change since 1938	0	-53	-60	-248	-388	-362	-373	-389	-481	-459
T33 incremental change		-33	-40	-164	-137	-27	5	-32	-66	0
T33 change since 1938	0	-33	-73	-237	-374	-400	-395	-428	-494	-494
T34 incremental change		-40	-47	-148	-196	4	24	-57	-28	-24
T34 change since 1938	0	-40	-86	-234	-430	-426	-402	-459	-486	-510
T35 incremental change		-35	-43	-152	-193	-7	29	-95	-16	-42
T35 change since 1938	0	-35	-78	-230	-422	-429	-400	-495	-511	-553
Averages for T31 - T35										
Incremental change		**-41**	**-32**	**-162**	**-167**	**9**	**5**	**-49**	**-51**	**-2**
Change since 1938	**0**	**-41**	**-73**	**-234**	**-401**	**-393**	**-387**	**-436**	**-488**	**-490**
Average incremental rate (ft/yr)		**-6.0**	**-2.8**	**-8.7**	**-11.3**	**2.6**	**1.5**	**-32.3**	**-12.8**	**-0.4**
T36 - T41 (3,000 ft)										
T36 incremental change		-35	-36	-171	-190	16	22	-39	-85	-16
T36 change since 1938	0	-35	-71	-242	-432	-416	-394	-433	-518	-533
T37 incremental change		-48	-54	-144	-208	36	29	-27	-112	-20
T37 change since 1938	0	-48	-101	-246	-454	-418	-389	-416	-528	-548

T38 incremental change		-54	-48	-143	-211	30	78	-94	-79	-25
T38 change since 1938	0	-54	-102	-245	-456	-426	-348	-442	-521	-545
T39 incremental change		-51	-51	-145	-207	44	65	-80	-91	-26
T39 change since 1938	0	-51	-102	-247	-454	-410	-346	-426	-517	-543
T40 incremental change		-62	-39	-149	-186	29	24	-39	-109	-47
T40 change since 1938	0	-62	-101	-249	-436	-407	-383	-422	-531	-578
T41 incremental change		-44	-31	-151	-177	2	62	-60	-138	-34
T41 change since 1938	0	-44	-75	-226	-402	-400	-339	-399	-537	-570
Averages for T36 - T41										
Incremental change		**-49**	**-43**	**-150**	**-196**	**26**	**46**	**-56**	**-102**	**-28**
Change since 1938	**0**	**-49**	**-92**	**-242**	**-439**	**-413**	**-366**	**-423**	**-525**	**-553**
Average incremental rate (ft/yr)		**-7.1**	**-3.9**	**-8.1**	**-13.2**	**7.6**	**13.5**	**-37.0**	**-25.5**	**-5.4**

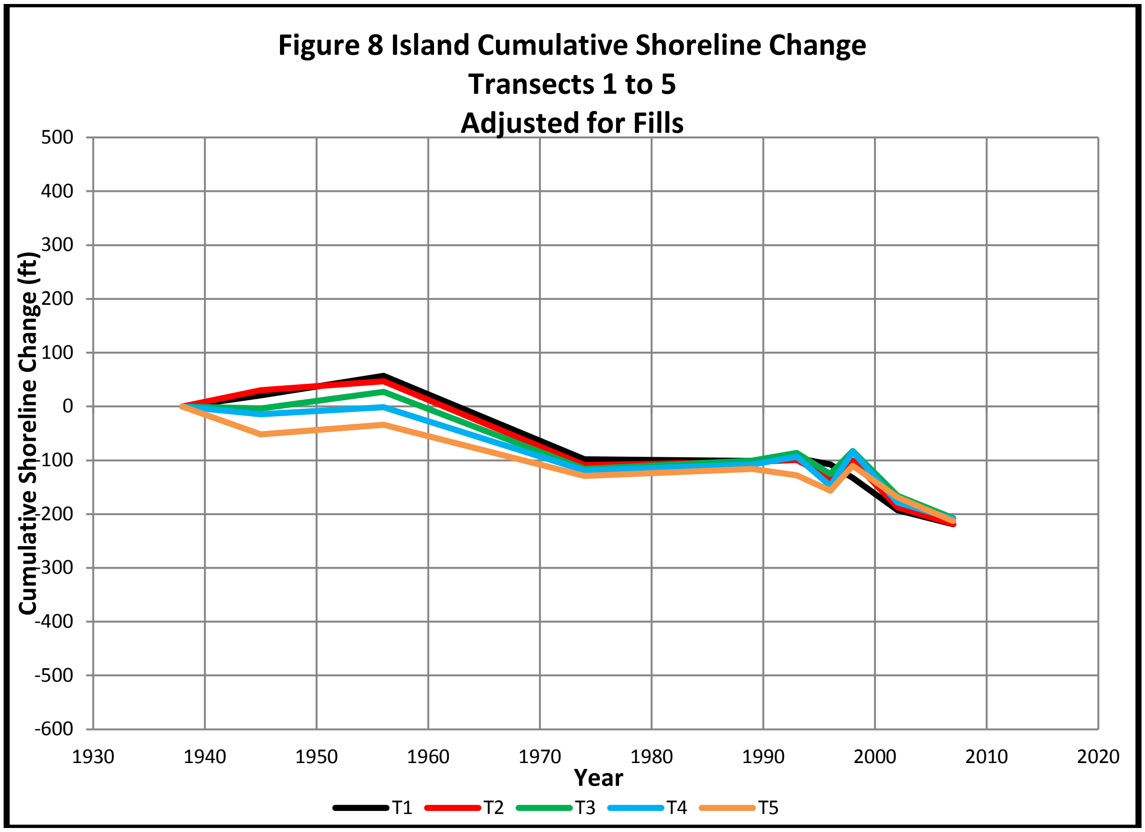

Figure A-1. Cumulative shoreline change Transects 1 to 5.

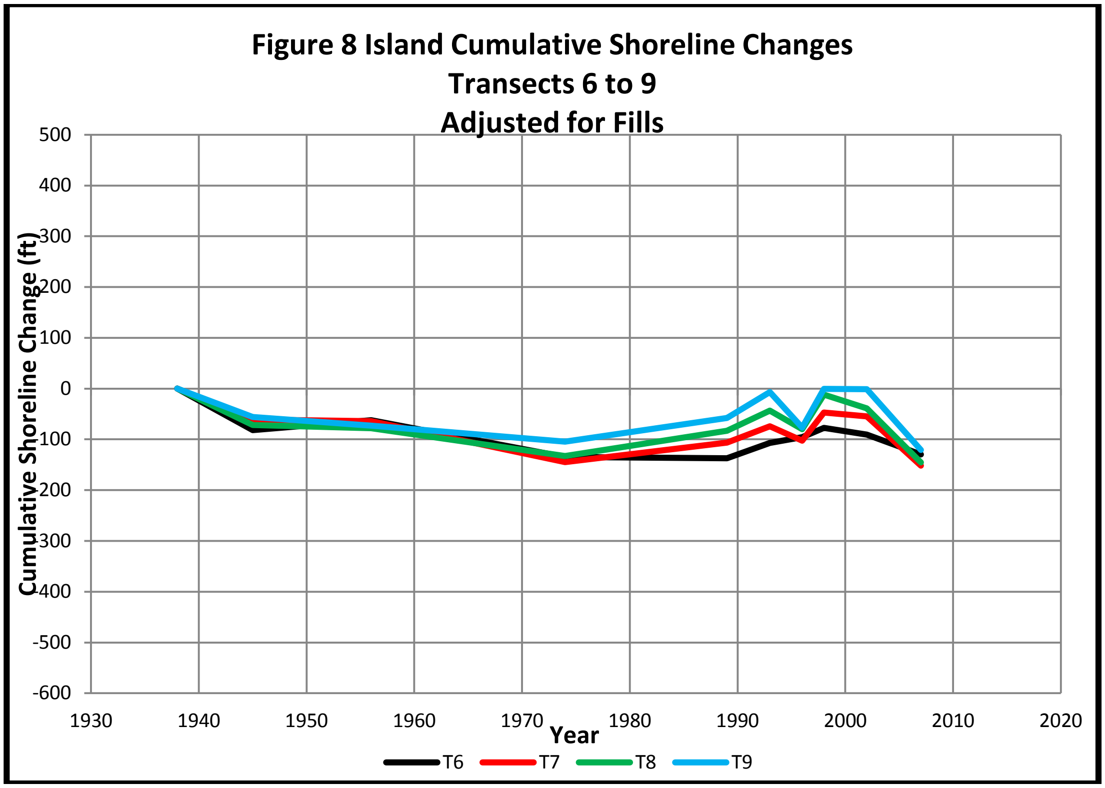

Figure A-2. Cumulative shoreline changes Transects 6 to 9.

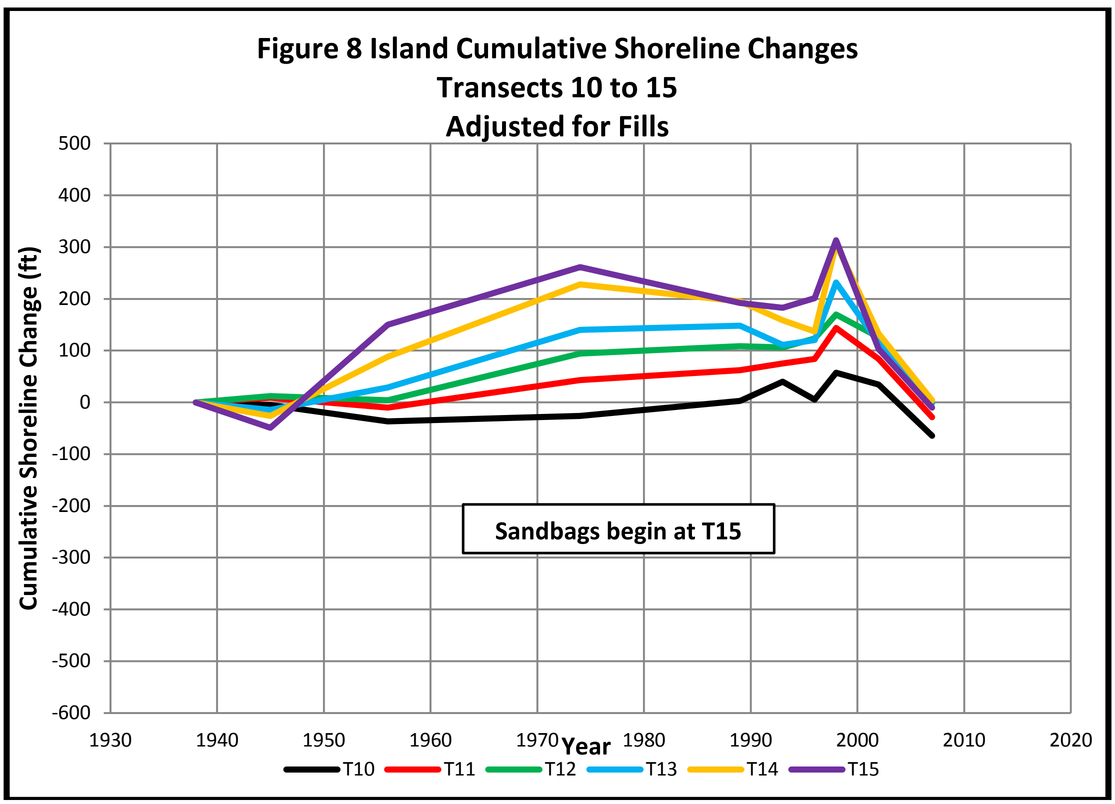

Figure A-3. Cumulative shoreline changes Transects 10 to 15.

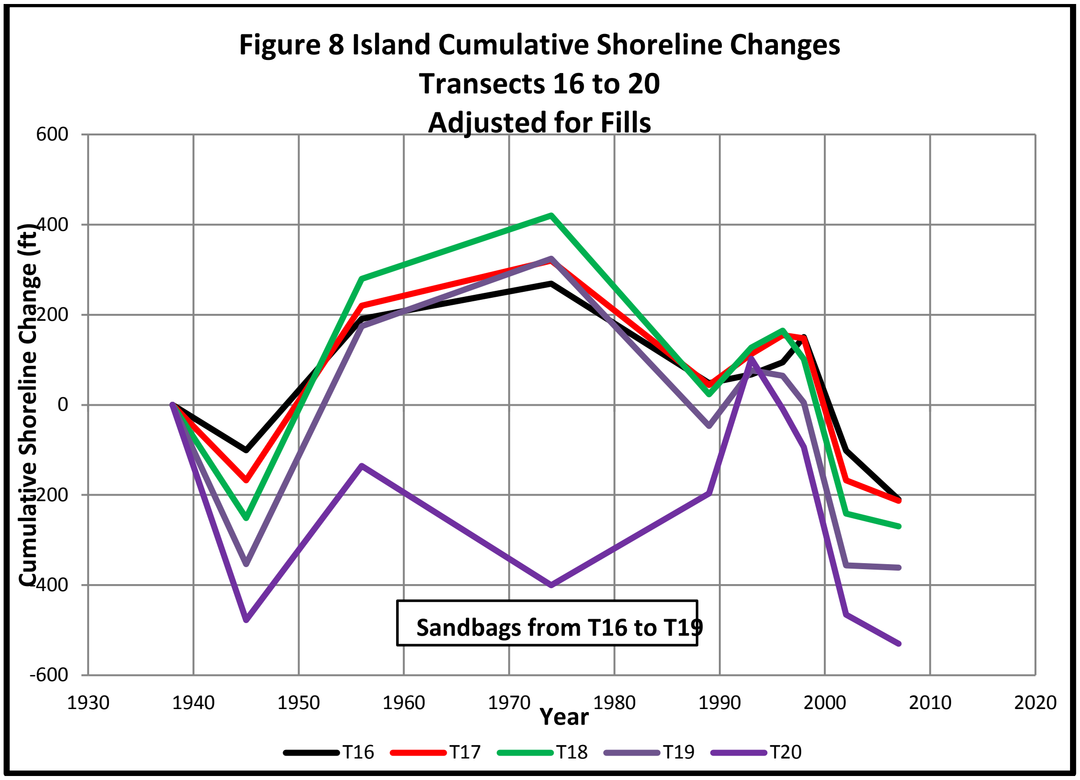

Figure A-4. Cumulative shoreline changes Transects 16 to 20.

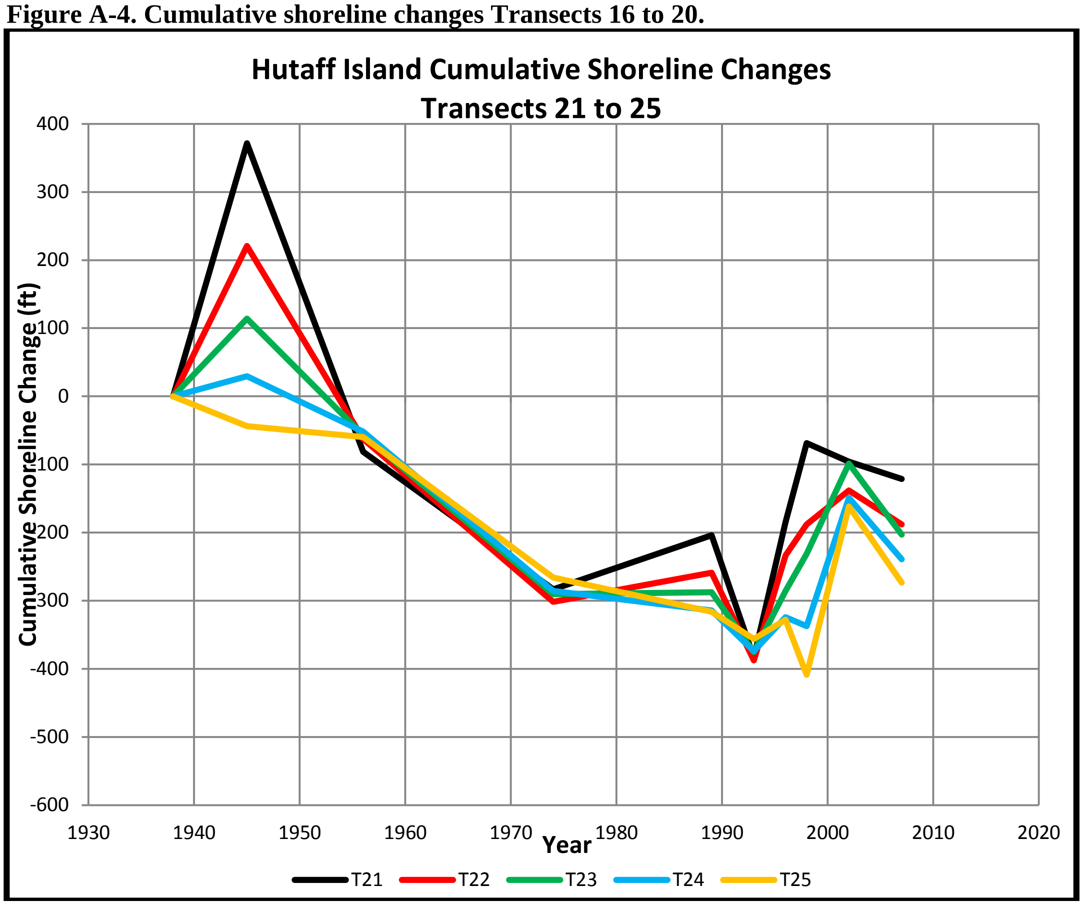

Figure A-5. Cumulative shoreline changes Transects 21 to 25.

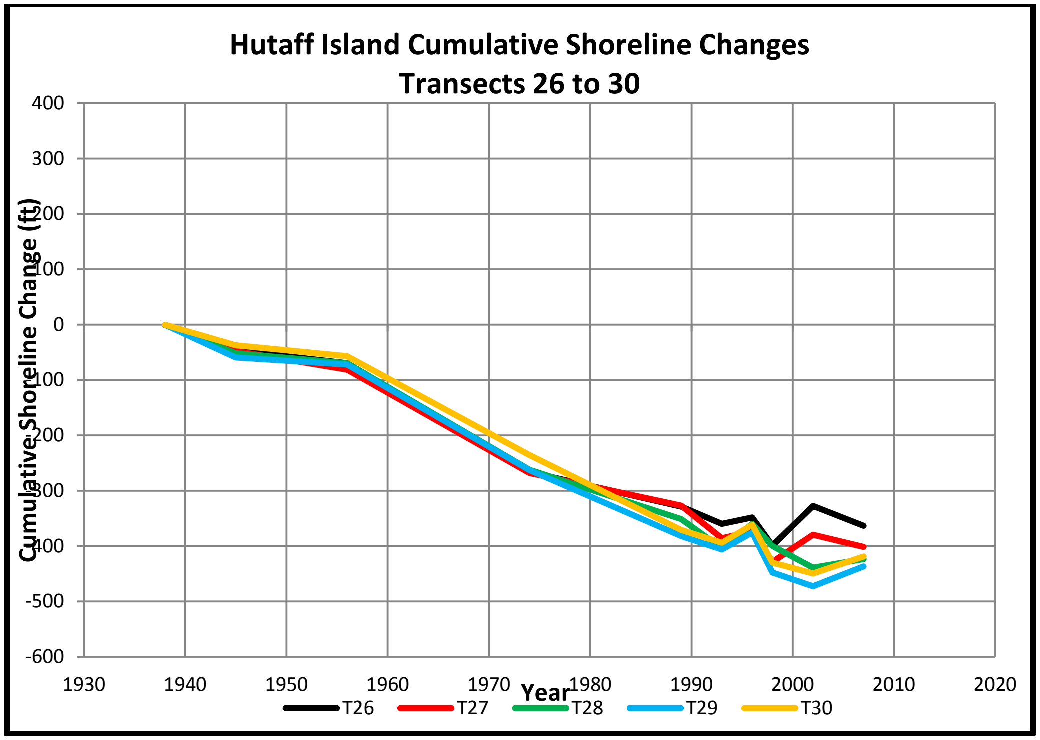

Figure A-6. Cumulative shoreline changes Transects 26 to 30.

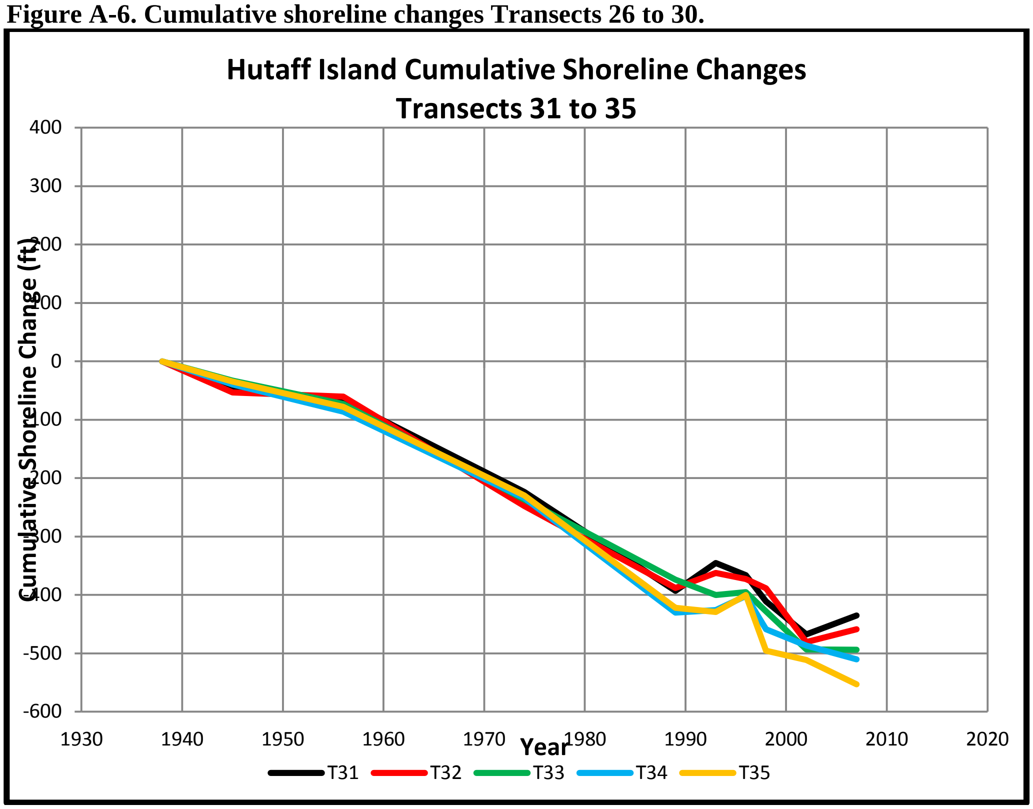

Figure A-7. Cumulative shoreline changes Transects 31to 35.

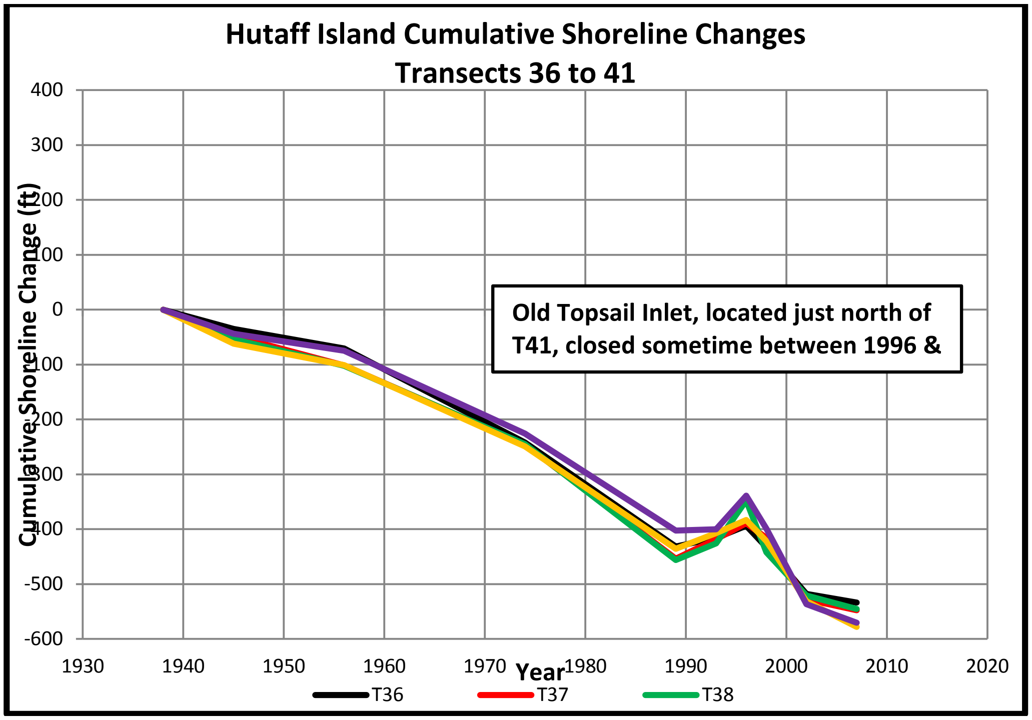

Figure A-8. Cumulative shoreline changes Transects 36 to 41.

Other Mitigation Measures

At this time, no specific mitigation measures have been identified to compensate for potential adverse impacts to biological resources, with the exception of removing the terminal groin. At the completion of all the monitoring events, the results will be utilized to discern if any affects to the biological resources have occurred and to what degree those impacts are having on the resource. All monitoring results will be coordinated with the appropriate Federal and State resource agencies to assist in this determination and to help develop any mitigative measures that are necessary.

3. How does the construction of the terminal groin relate to SB 110 and SB 151?

Senate Bill 110 and the amended terminal groin construction law in SB 151 contains a number of stipulations that the applicant must abide by to ensure that the Preferred Alternative is implemented within the law. Many aspects of the legislations are discussed in various sections of this EIS. Section 1. G.S. 113A-115-1(e)(6) of the legislation requires the applicant to provide financial assurance that is adequate to cover the cost of (a) long-term maintenance and monitoring of the terminal groin, (b) carry out mitigation measures provided in the inlet management plan, and (c) modify or remove the terminal groin if negative impacts cannot be mitigated. These financial assurances are addressed below.

The cost of monitoring the performance of the terminal groin and assessing impacts to the adjacent shorelines and inlet environment totals $480,000. This includes the acquisition of high resolution aerial photos of the inlet and adjacent shorelines, computation of shoreline change rates from the aerial photos, analysis of beach profile surveys along both Figure Eight Island and

Hutaff Island, comparison of measured shoreline change rates to erosion thresholds, and measurements of changes in various habitats within the Permit Area. It is proposed that this monitoring will occur twice a year for the first two years following construction of the groin and, depending on the performance of the groin, it may be reassessed to determine if it would be appropriate to change to once a year thereafter for a total of 30 years. Depending on the performance of the structure, this long-term monitoring may be curtailed prior to the end of the 30-year period.

Maintenance of the terminal groin would depend on the number of times the design conditions for the structure would be exceeded over the 30-year planning period. Since this cannot be predicted with any degree of certainty, maintenance of the structure was based on an assumption that an average of 1% of the armor stone would have to be replaced every year. Given this assumption, maintenance of the Alternative 5A terminal groin would average $25,000 per year. Note this does not mean maintenance of the structure would be needed every year. Over the course of the 30-year evaluation period, maintenance of the structure may only be needed two or three times with the average annual equivalent cost of these future repairs equal to $25,000 per year. It should be noted that the documented performance of both the Fort Macon and Pea Island terminal groins which have not required any maintenance since their initial construction.

Mitigation measures to address shoreline changes along Figure Eight Island and Hutaff Island that exceed the erosion thresholds would involve the placement of beach fill. Since the applicant's preferred alternative for Figure Eight Island includes periodic nourishment approximately every 5 years at an estimated cost of $2,561,000 for each operation, no additional shoreline mitigation is anticipated for Figure Eight Island. Mitigation beach fill for Hutaff Island is not anticipated due to the lack of private property and structures on the island.

Should removal of the terminal groin become necessary, the estimated cost for removal of the structure is estimated to be approximately $3.2 million.

In summary, the financial assurances will be based upon:

- -$480,000 for shoreline monitoring
- -$25,000 for maintenance
- -$2,561,000 for beach nourishment on Figure Eight Island
- -$3,200,000 for the removal of the terminal groin

Based on these costs, the total amount of financial assurances provided by the Figure 8 Beach Homeowners Association will be $6,266,000. The instrument type or form of financial assurance has yet to be determined.

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