APPENDIX A

SCOPING

Sub-Part 1

Meeting Minutes

Figure Eight Island Shoreline Protection Project
Scoping Meeting
Figure Eight Island, North Carolina

1. The initial scoping meeting for the Figure Eight Island Shoreline Protection Project was held on the evening of March 1, 2007 at Eaton Elementary School in Wilmington, North Carolina. The meeting was attended by individuals including elected officials, local residents, resource agencies, and representatives of the Figure Eight Island Homeowners Association (including its consultant, Coastal Planning and Engineering, CPE). Several members of the PDT also attended.

2. Attendees.

The meeting attendees that signed in at the meeting are listed below:
1. Ken Willson
2. Diane Sanders
3. Bill Raney
4. Earl Johnson
5. Steve Everhart
6. Walker Golder
7. Craig J. Kruempel
8. Vickie Savage
9. Frank Daniels
10. Patricia Roseman
11. David Webster
12. Bob Parr
13. Margo O'Mahoney
14. Frank Folger
15. Gray Sneeder
16. Matthew Stokley

3. Scoping Issues.

Following the presentation of the proposed project, the meeting attendees were divided into three groups and each group asked to provide a list of project issues.

Group 1

-How will this project affect navigation through the inlet?
-How will this project affect:
    -Primary Nursery Areas and shellfish areas (and SAVs)
    -Shorebirds (foraging habitat, ebb tide delta), piping plover critical habitat
    -Sea turtle habitat
-How will the project affect recreational boaters- during construction of the project?
-How will affect SAVs?

-Who owns the new uplands created by the project (Hutaff Island)?
-Are there hard bottoms in the vicinity of the project- if so will they be impacted?
-What are the benefits to navigation/economics of the proposed project (commercial and recreational use)?
-Inlet maintenance: How often? How will it be done? Who is responsible? Will mitigation be required?
-How will this project affect maintenance of the AIWW?- and who will pay?
-How will the new connections (inlet) to Greens Channel and Nixon Channel be determined?

Group 2

-Effects on biological destruction, ecosystem degradation, Public Trust Waters and Primary Nursery Areas
-Effects on New Hanover County-limited resources- development
-Public resources lost vs. private gain, both from a recreational and biological standpoint
-Public effect on shorebirds (nesting)
-Explore all alternatives for sand source (offshore, spoil islands, move homes, homes fall in- no action alternative)
-Cost to general public, cultural impact
-Benefits of deeper water and safety
-Boating impacts on inlet
-Storm surge impacts (hurricanes and nor'easters)
-Environmental effects on Hutaff Island.
-Impacts on channelization to meanders. Keep meanders in project inlets and channel
-Duration/frequency of maintenance dredging
-Address affects on recreational fishing and pleasure craft. Pre-vs post project, types of boats, quantify people
-Impacts to Futch Creek
    -What is scope of project
    -Extend scope of project to reach Futch Creek
    -Don't narrow scope of analysis too much
-Address potential benefits to water quality by flushing of waterway from estuarine creeks to waterway
-Extend the prestudy period
-Extend monitoring with maintenance dredging
-Look at having the channel in optimal location
-Address benthic, larval fish, SAV and intertidal areas in EIS. Wants to know is there impacts to endangered species other than sea turtles
-Would like to see holistic approach of entire project. Baseline data established for benthic, larval fish, SAV, and intertidal areas. Pre-construction vs. post construction to analyze impacts of baseline data. Secure data collection.
-Include biological recovery time
-Navigation of channel. Public use and deep water access. EIS- include economic base for recreation. Economic impact of protecting tax base.

Group 3

-Address the quality of beach fill material
-Long term management plan – (address)
-Short timeframe- completion of EIS
-Assessment of impacts on Wrightsville Beach and Hutaff Island
-Address changes to mapped tidal wetlands and intertidal mudflats
-Upland borrow sources?
-Use public funds?
-Duration of permit?
-Project performance- Identify renourishment cycle and project life.
-What happens if 50cy/ft is not sufficient?
-EIS- address cumulative impacts to include shoreline to Cape Lookout (shoreline, inlet, inlet complexes) wildlife, EFH, fisheries, etc.
-Impacts of adjacent inlets- Masons Inlet and Rich Inlet?
-Can you use public sand on Figure 8 Island?
-EIS should address alternatives that does not include Rich Inlet or are there other alternatives that meet the purpose and need without relocating Rich Inlet (i.e. shoreline protection to North End)
-Who is responsible (pay for) any long term monitoring that may be required.

Minutes
3 May 2007 PDT
Figure Eight Island Yacht Club

The first meeting of the Rich Inlet Project Delivery Team was held on Thursday, May 3, 2007 at the Figure Eight Island Yacht Club. Mickey Suggs of the US Army Corps of Engineers called the meeting to order at 10:00 a.m.

Mickey explained that the US Army Corps of Engineers (USACE) has received notice from Figure "8" Beach Homeowners' Association, Inc. of their intent to prepare a draft Environmental Impact Statement for the purpose of developing and implementing an Inlet Management Plan, repositioning the main ebb channel of Rich Inlet, and for the nourishment of the ocean beach along the northernmost threes miles of shoreline on Figure Eight Island in New Hanover County, NC.

Mickey further explained that when the USACE receives a proposal for any project, the Corps must follow a standard project development process to determine if there is a significant impact or effect on the quality of the human environment. The USACE relies on resource agencies and people who use the channel to provide public interest issues and impact concerns that should be addressed during the development, planning and implementation processes for the Environmental Impact Study (EIS). Mickey noted that it had been discussed with Figure 8 that based on the unknown factors and sensitive inlet topic; it was posed that the EIS process would be a shorter time frame. **Howard Hall** asked if the timeframe of the project was 30 years and **Mickey** responded that it has not been decided yet.

The Rich Inlet Project Delivery Team (PDT) includes a diverse group of federal and state resource and non-profit agency representatives chosen by the USACE to effectively develop and provide input for the project. **Mickey** noted that the PDT body is not a decision-making body; agencies will provide input on issues to be addressed in the Rich Inlet EIS but will not make permit decisions.

David Kellam, Administrator of Figure "8" Beach Homeowners' Association, welcomed members of the Project Delivery Team and invited introductions. Participation list is included at the end of the meeting minutes.

Tom Jarrett of Coastal Planning & Engineering, Inc. (CPE) welcomed all in attendance. He stated that the PDT meeting format is informal and open discussion is encouraged while presenters are delivering their reports. A site walk and orientation at the Rich Inlet project site will be conducted at the meeting's conclusion. **Tom** noted that Dr. Bill Cleary will be presenting affects of Rich Inlet on adjacent shorelines and inlet morphology based on extensive studies completed by him. Inlet morphology will be updated with present time studies in which CPE will be developing relationships between the morphology and inlet/shoreline responses due to channel modifications.

Tom explained that the proposed Rich Inlet project would offer modifications to the channel to hopefully offer more favorable impacts to Figure Eight Island and Hutaff Island. Material from this project would allow for nourishment of the ocean beach along the northernmost three miles of Figure Eight Island shoreline. **Mickey** commented if a project modification is deemed necessary to extend the area for nourishment from the initial three mile area to the entire ocean beach, another Notice of Intent would have to be sent out. **Tom** suggested to David to include the entire oceanfront of Figure Eight Island, which would include an additional $1^{1/2}$ mile.

A concern was raised that if the project was extended past the initial proposed three mile nourishment area, it would run into areas of the beach that already receive nourishment from Mason Inlet projects. **David Kellam** stated that the 2002 Mason Inlet project yielded nourishment to approximately one-half of the Island. More recent nourishment projects included pumping sand from a mitigation island near the AIWW to Figure Eight in 2003 and a truck haul project for the New Hanover County Mason Inlet permit in 2005. **Tom** said there may be some overlap of nourishment projects.

A NC historical ship wreck site, Wild Dayrell, has been surveyed by Tide Atlantic Research (TAR) and well documented in Rich Inlet. A buffer area around the wreck has been developed to protect and prevent impacts to the wreck. **Mickey** asked if the buffer area includes erosion buffer to the site after project completion. **Tom** answered by stating that the wreck has been exposed and covered up with the migration of Rich Inlet naturally over time and the wreck is a major constraint on where to align and reposition channel. **Tom** stated that the wreck site will be properly addressed in the EIS and Engineering design. The buffer information was coordinated with the underwater Archeological section of North Carolina State Government.

Tom discussed sand placement and estimated that 1.5 to 3 million cubic yards of material will be realized from this project. Careful design will go into connecting the new channel to Nixon Channel and the mouth of Green Channel. **Tom** explained that the ultimate goal of project is to optimize and develop a stable channel like Bogue Inlet.

Tom presented a slide overview of past Figure Eight Island projects since 1972. He showed that through these projects, the entire island has received renourishment at some point in time. Most disposal and/or nourishment have been directed to the extreme north and south ends. **Tom** also pointed out that at least 4 dredge projects have taken place in Nixon Channel.

The meeting was then turned over to Dr. Bill Cleary of the University of North Carolina at Wilmington. **Dr. Cleary** has conducted a number of studies since 1979 to identify the causes of erosion to Figure Eight Island. He stated while the causes of erosion are complex, he believes they are basically related to the changes in the adjacent inlets and the impact of recent storms.

Dr. Cleary presented a slide of the historic ebb channel location and reported that Rich Inlet is a relatively stable inlet. The channel does however move within a 1,500 foot wide corridor. Rich Inlet is a flood dominant inlet with more sediment being carried into the inlet system than is carried out. Sand accumulation in this area may cause inlet closure in the area. Placement of the channel influences both Figure Eight Island and Hutaff Island.

With the current placement of Rich Inlet and impact from numerous nor'easters and hurricanes, the north end of Figure Eight Island has become an erosion hot zone. Dramatic erosion along the northern end of Figure Eight Island has left many homes with virtually no significant storm protection in the form of a dune and beach during high tide conditions. Currently 18 homes on Figure Eight Island have artificially restored dunes formed by sandbags but the erosion spreads far south from this location. Beach nourishment only is not a viable option in the erosion hot zone areas. **Dr. Cleary** noted that the inlet hazard zones extend well beyond the inlet shoreline.

Jim Bushardt stated that Hutaff Island has significant wash over areas that occurred in the late '90's and asked if the erosion rate of Hutaff Island is impacted by the relative location of Figure Eight Island and Rich Inlet. **Dr. Cleary** explained that storm impacts and the relative location of Rich Inlet to Hutaff Island or Figure Eight Island affects erosion or accretion rates. The increase erosion on Figure Eight is due to the rapid northeasterly movement of the main channel. The repositioning and realignment of the channel has led to dramatic changes in the position of the offshore shoals and once nourished northern end of Figure Eight Island. Erosion along this shoreline segment will continue until the main channel is realigned naturally or by dredging activities.

Dr. Cleary explained that it is important to ascertain the link between oceanfront shoreline changes and the morphologic changes in the inlet system. With slides, he detailed the morphology of Ebb-Tidal Deltas including Main Ebb Channels, Mariginal Flood Channels, Swash Bars and Terminal Groins; Swash Bar Attachment Locations and Channel Orientations; Rich Inlet Shoulder Changes; Downdrift Erosion areas; Erosion Hot Spot Shoreline Positions (1938-2003); Nixon Channel Shore with Chronic Erosion since 1993 and Channel Encroachment (March 2001); Bar Build Up and Potential Breach Site; Estuarine Shorelines; and Apex of Ebb Tidal Delta Shifts.

Mickey reaffirmed that the hot spots began eroding in 2000 and the channel was located adjacent to Hutaff Island. **Dr. Cleary** explained that there is a lag effect once a channel is modified or migrates due to the amount of sand present in the system. The larger the amount of sand is present in the system, the greater effect on adjacent shorelines. **Dr. Cleary** stated that the take away point is the position and orientation of the channel controls the shape and symmetry of the ebb tidal delta which functions to control the accretion and erosion of the adjacent shorelines. He restated that in his opinion nourishment is simply not an option based on the results of his studies.

Dr. Cleary stated that chronic erosion of the estuarine shoreline on the north end of Figure Eight Island has occurred since 1983. He confirmed with David that 2 to 3 lots are located in the area of erosion. Approximately 96 meters of estuarine shoreline erosion (marsh peat) has occurred due to a seaward shift of Nixon Channel.

Steve Everhart questioned if the permit would be a 20-year permit. **Tom** explained that the answer to this question would be determined in the permitting process after the EIS is complete.
Jim Iannucci asked if the channel will become a fill channel like Bogue Inlet. **Tom** responded that filling the channel may be a recommendation based on the engineering design for the project.

Ken Willson provided an update on geotechnical investigations that have been completed by CPE within Rich Inlet. He mentioned that the preliminary investigations in February included using jet probes to look for relict flood channels. Vibracores were then collected in March in which the sediment is currently being analyzed. Portions of the native beach sand samples have been collected based on the NC Sediment Criteria Rules. Due to numerous nourishment projects on Figure Eight Island, native beach material is not present and therefore, along with coordination of the State (Jeff Warren), two transect profiles have been set-up on the southern half of Hutaff Island. **Mickey** asked what depth the vibracores were collected and **Ken** responded that the average depth of the cores was -20.6 feet NAVD. Ken reviewed the NC State Sediment Technical Standards. **Tom** mentioned that the native beach material collected on Hutaff will result in similar sized material to Figure Eight Island. Ken concluded the presentation by noting that the vibracores sediment analysis will be completed by the next PDT meeting.

Tom discussed design considerations and project evaluations being developed by CPE. The channel realignment project aims at reversing the most recent erosion trend by moving the main ebb channel approximately 1,500 feet. The morphology of the system provides a real world example of how the system would be affected by a project. A feasible design approach may include digging along the alignment to help capture the flow and help the inlet to become more stable; closure of the existing channel dike; look at variable channel widths; and connecting to the mouth of Green Channel. He noted that the three areas that will be focused on during the modeling analysis is the north end of Figure Eight Island, the areas behind Hutaff Island, and the estuarine shoreline within Rich's Inlet.

Tom stated that the key element of the design process is Dr. Cleary's analysis of the morphology of the inlet and how has the system behaved with various channel configurations. The Delft3D modeling methodology is similar to what was developed for Bogue Inlet. **Tom** explained that an alternative includes closure of the existing channel through the construction of a dike. The dike could be connected to Hutaff Island although construction would be difficult.

Fritz Rohde asked about the depth of the existing channel. **Dr. Cleary** stated that portions of the current channel may be as deep as 30-35 feet with shallower areas near the ocean. The project could yield 1.5 to 3 million cubic yards of material. Figure "8' Beach Homeowners' Association wishes to keep from placing too much material on the beach so alternatives were discussed. Fill could be placed near the shore to help build up the south side ebb delta to hasten migration on to the island and to keep it from carrying sand back in the inlet.

Michelle Duval asked if the dike was a critical element for the success of this project like in Bogue Inlet. **Tom** declared this is a good question and if the dike is deemed a critical part of this project, it could raise some concerns. This channel project is different from Bogue Inlet in that the flow out of Green Channel is smaller than at Bogue. Engineering designs will have to address this question.

Fritz Rohde wanted to know if the inlet was a flood driven system, could Green Channel completely close off. **Dr. Cleary** responded with the fact that Green Channel has always stayed open as nature has moved the inlet naturally and that it is his belief that the channel would not close off but would more likely produce the reverse effect. The realigned channel should shunt water in the channels behind Figure Eight Island better than it does in the existing location. Currently Green Channel is closing. **Dr. Cleary** asked if the Delft3D model showed infilling of Green Channel and **Tom** responded that it did not. Tom stated that based on the intent of Figure Eight Island, the inlet would be maintained on a regular timeline. Doug confirmed that the State permit recognize periodic maintenance but the original permit issued will be for a one-time only dredging and engineering event and all subsequent activities will be included as a major permit modification. Dr. Cleary added that the placement of sand in the offshore area is critical to the project and would accelerate the success and decrease the lag time of effects.

Dawn York stated that she is currently in the preliminary stages of collecting historic baseline biological resource data for the area identified within the inlet complex and adjacent shoreline habitats. She stated that she is coordinating with several PDT and agency representatives to collect accurate data. **Dawn** has been in contact with Dr. David Webster of UNC-W on endangered species monitoring for Figure Eight Island. Dr. Webster's monitoring studies include sea turtles, birds, and seabeach amaranth. He also monitors piping plovers with the assistance of Sue Campbell of NCWRC. Other biological resources to be investigated will include water quality, shellfish resources, SAV, hardbottom, and wetlands. **Dawn** noted that a Draft EFH has been developed and a Biological Assessment is in draft form.

Michelle Duval asked if a CD of the presentation and biological resources table could be made available to members of the PDT. **Tom** stated that the information will be adequately distributed to PDT members. (***As requested, a pdf of each presentation and biological resource table is provided with the meeting minutes***)

Mickey stated that the next PDT meeting may be scheduled for the end of July 2007. Members will be given a 30-day advance notice prior to future PDT meetings.

As confirmed by **David**, the Figure "8" Beach Homeowners' Association would like to start the project in the winter of 2009-2010.

At the conclusion of this meeting, Attendees recessed for lunch before gathering on the north end of Figure Eight Island for a site walk and orientation within the project zone. Areas visited on the northern end of the island included Rich, Green and Nixon Channels and erosion hot zones with sandbagged artificial dunes.

List of PDT Participants
3 May 2007

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Minutes
18 September 2007 PDT
Figure Eight Island Yacht Club

The second meeting of the Figure Eight Island Shoreline and Inlet Management Project Delivery Team was held on September 18, 2007 at the Figure Eight Island Yacht Club.

Mickey Suggs of the US Army Corps of Engineers called the meeting to order at 10:00 a.m. Introductions by all meeting attendees were made. It was noted that **Tom Jarrett** was absent. **Mickey** indicated that the majority of the meeting would include a PowerPoint presentation by **Chris Day** of Coastal Planning & Engineering (CPE) which will describe the modeling results for the proposed modification eroded areas on Figure Eight Island and Rich Inlet.

Chris began his presentation by outlining his talk into five main parts: 1) general background on why the project is necessary and goals and objectives of the project; 2) an introduction to the conceptual designs; 3) Delft 3D model; 4) a review of the various alternatives including the preferred alternative; and 5) a description of the remaining engineering tasks that need to be accomplished.

Chris described that two hotspots of erosion have been identified on the north end of Figure Eight Island. One area of concern is on the oceanfront shoreline at the northeast end, near Rich Inlet. The second area is on the northwestern (lee) side of Figure Eight Island. The likely cause of the high retreat rates near Rich Inlet is due to the northward migration and orientation of the ebb shoal of the inlet. As the ebb shoal relocates, there is greater likelihood of erosion on the northern portion of Figure Eight Island due to wave energy. **Bill Cleary** noted that the erosion hotspot on the leeward side of Figure Eight Island has developed due to the migration of the scour hole in Nixon Channel. To alleviate the ocean shoreline hotspot, it has been recommended by **Bill Cleary** that a new ebb channel should be formed perpendicular to the island. The erosion hotspot adjacent to Nixon Channel should be resolved by connecting the newly formed ebb channel to Nixon and Green Channel.

It was asked by the PDT when the erosion began and how long will it continue at its current rate of erosion. **Chris Day** responded that erosion has been occurring for approximately 14 years. It was noted that the channel could shift to its original orientation naturally, however if this did occur it could take another 15 years and, as a result the adjacent homes may be comprised during this time.

Chris Day continued to describe the technical aspects of the modeling effort. The model, Delft 3D, is produced by Delft Hydraulics Laboratory in the Netherlands. It is a wave transformation model coupled with a flow model. The major inputs for this model include wave height, bathymetry, refraction and bottom friction. The flow model simulates currents, flow rates, wind stress and sediment transport. For this project, existing wave data was used as an input for the model (new data was not collected).

A total of four alternatives were developed, three of which were incorporated into the Delft 3D model. **Alternative 1** entails extending the ebb channel to the interior salt marsh. Due to the large volume dredged, this was determined not to be economically feasible and therefore was not entered into the model.

Alternative 2 is comprised of two variations, 2a and 2b, both of which extends the dredged channel into Nixon and Green channels. **Alternative 2A** involves dredging a 17-foot deep channel approximately 0.75 miles into Nixon Channel and 0.5 miles into Green Channel. In **Alternative 2B**, the cut in Nixon Channel would be shorter- less than 0.5 miles. **Bill Cleary** expressed that Alternative 2A would provide the most stable ebb tide channel. There was concern that 2A could cut off part of Hutaff Island, but **Chris** explained that this would not be the case because the water is deeper than it appears in the presentation graphic. Alternative 2A was mentioned to be the recommended alternative at this time. There was discussion regarding channel depth in which the ebb channel would be dredged to -17 feet NAVD; the depth of Green Channel would be -14 feet below mean high water.

Alternative 3 does not include dredging into Green Channel and therefore would not provide better navigation through Green Channel. There was also discussion regarding possible environmental impacts due to flow and sand deposition. This alternative does not meet the project objects and therefore was not entered into the Delft3D model. *(Note: Since the meeting, as requested by the PDT, this alternative has been modeled without waves.)*

Alternative 4 includes Dr. Cleary's ebb channel with 2 connections – one to Nixon Channel and one towards the salt marsh. Access to Green Channel would be established via the connection that extends towards the salt marsh and an existing back channel. Alternative 4 was also split into two alternatives – 4A and 4B. The difference between the two alternatives is the length of the connection into Nixon Channel. Like Alternative 2, a question to be resolved by the model was whether a shorter connection into Nixon Channel would still provide the needed shoreline protection for the Figure 8 Island's residents.

With each of these options, a temporary diversion dike would be constructed simultaneously to cut off the existing ebb channel. Over time, this sand dike will equilibrate naturally through wave and tide dynamics following construction of the new channel. **Stuart Mossman** asked if these scenarios have been modeled without the use of the dike. **Chris Day** responded that they have not. **Stuart Mossman** responded by mentioning that we therefore may end up with two channels. A question was asked if it would be plausible to place a sheet pile structure in place rather than a sand dike. A temporary structure would not be permissible under the current legislation.

The final alternative was the "No Action" scenario. This alternative examined present conditions and three years into the future. The model results demonstrated the continuation of scouring in Nixon Channel and would cause the formation of a secondary ebb channel near Figure Eight Island.

The selected alternative includes a 500 ft wide ebb channel with an -17 ft NAVD depth (Alternative 2A). Nixon Channel would be dredged 3,800 ft long and 275 ft wide with a depth of -17' NAVD (Alternative 2A). Green Channel would be dredged 1,425 ft long and 225 ft wide with a depth of -17 ft NAVD (Alternative 2B). The closure dike would be constructed to a height +6 ft NAVD and either 100 ft or 200 ft wide, depending on further investigation.

Chris Day closed his presentation with a review of the remaining tasks to be completed. This includes the investigation for the optimum size of the closure dike. He will also perform a 5-year simulation of the recommended alternative using wave data. He will then also compare the results of the 5-year "No Action" scenario with waves to a number of parameters including erosion and deposition patterns, ebb shoal, tidal prism, and the impacted area. A final report detailing these results will be generated.

Bill Cleary expressed his concern that there has not been enough investigation into dredging longer into Green Channel. He noted that the ebb and flood flows would be restricted without opening up the channel more and the channel would eventually fill in. He referred to experiences in Masons Inlet.

Following lunch, participants engaged in open discussion. It was brought up that the there has been some changes to the State Sediment Criteria rules enacted in February 2007 (adopted by the RRC- 15A NCAC 07H.0312). These rules state that a geophysical survey would be required in the borrow area. Due to the shallow depth it was discussed that rather than conducting a geophysical survey there may be legal room to collect tighter spaced vibracores (500 ft space rather than 1000 ft). Some geophysical survey work may be completed in deeper areas. It was also noted that beach profiles will be collected on Figure Eight Island (5 to 6 profiles) and Hutaff Island (2 to 3 profiles).

Erin Hague asked if hardbottom resources have been identified near the oceanside of the proposed channel limits and the implications it may have on the design due to an associated 500 meter buffer. **Bill Cleary** confirmed that there are ephemeral low-relief hardbottom resources within the area, however they are further seaward than the base of the ebb shoal. **Bill Cleary** and **Erin Hague** asked can these areas be mapped if they are ephemeral. It was proposed by **Mickey Sugg** to run side scan sonar surveys within the proximity of the inlet and along the entire oceanfront shoreline (nearshore). **Ken Willson** noted that it would cost approximately $25,000 for a side scan survey of the whole island, versus approximately $13,000 for the northern 2 miles of the island. It was also suggested by the PDT to superimpose up-to-date bathymetry and photos to help determine where these areas may be located. The PDT noted that if there are in fact resources within the buffer, there would need to be additional discussions with the agencies to determine a course of action. **Bill Cleary** asked if these resources are significant if they are covered. Because it is ephemeral, **Mickey Suggs** asked how it can be determined significant if it cannot be seen. **Dawn York** mentioned that the EIS process would resolve these issues. **Doug Huggett** stated that the regulatory agencies would need some action taken to attempt to locate these resources. **Erin Hague** asked if hardbottom resources were not found as a result of a one-time nearshore sidescan investigation, would the agencies be satisfied with the effort. **Fritz Rohde** and others felt that would be satisfactory. **Erin Hague** then suggested establishing the 500 meter buffer and run side scan sonar in the nearshore. If any resources are potentially found, divers would be deployed to confirm. **David Kellam** asked if the entire island should be surveyed for hardbottom. **Mickey Suggs** mentioned the effort involved may be costly. **Ron Sechler** added that doing the entire area would add consistency with other ongoing projects. **Doug Huggett** agreed. **Mickey Suggs** suggested surveying the entire island now so there would be data for subsequent projects. **Erin Hague** suggested using the standard surveying techniques that is currently used in Florida and in North Topsail Beach.

Mickey Suggs concluded the discussion by stating that an aerial interpretation of habitats utilizing 2007 photos along with a nearshore side scan survey with hardbottom confirmation would be beneficial for the overall management of the island. **Ron Sechler** reiterated that the inlet environment contains Essential Fish Habitat.

Erin Hague stated that the general purpose of the project is to reduce the erosion rate on the oceanfront shoreline of the island. **Chris Day** added that approximately 70 acres of inlet habitat would be impacted by the footprint of the recommended channel alternative. **Ron Sechler** asked if alternative shoreline stabilization techniques could be utilized on the backside of the island. **Doug Huggett** answered that this would not be a likely solution due to the Ocean Hazard Area; however the backside could be nourished if necessary. **Erin Hague** stated that nourishing the backside is a short-term solution as shown by modeling results. Environmentally, it would not be a sound solution as opposed to a hardened structure. Many participants agreed that the primary purpose of the channel is for erosion control, not navigation.

Ron Sechler asked what the maintenance frequency would be for the channel. **David Kellam** answered that it would be less frequent than the schedule at Masons Inlet.

Sue Cameron asked if the project will cause erosion to the south end of Hutaff Island. The PDT noted that the stabilization of the ebb channel would equalize the beach on both islands.

The meeting was adjourned by Mickey Suggs.

List of PDT Participants			
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Figure Eight Island Shoreline and Inlet Management Project
March 19, 2008 PDT Meeting Minutes
Figure Eight Island Yacht Club

The third meeting of the Figure Eight Island Shoreline and Inlet Management Project Delivery Team was held on March 19, 2008 at the Figure Eight Island Yacht Club.

Mickey Sugg of the US Army Corps of Engineers called the meeting to order at 10 am. Introductions of PDT attendees were made. **Dr. Bill Cleary** gave a presentation on updated findings on shoreline change for Figure Eight and Hutaff Islands, and estuarine shoreline change for Nixon and Green Channels between 1938 and 2007. Rich Inlet is presented as a relatively stable inlet over time, however fluctuations in the ebb-channel since 1998 has caused erosion along Figure Eight Island. Rich Inlet has been open since about 1733. A historic inlet, Nixon Inlet, was once open in the northern portion of Figure Eight Island (around 4,000 ft south of the current Rich Inlet), and closed in the late 1800's. When Nixon Inlet closed, the island lengthened to the north causing erosion along the portion of the island in the area of the closed inlet. This indicates how important inlets are in controlling erosion and accretion along adjacent shorelines.

Fluctuations of the ebb-channel of Rich Inlet to the north since the late 1990's have caused increased erosion along the north end of Figure Eight Island. Sandbags have been placed in front of 20 homes to mitigate for this erosion. **Dr. Cleary** has been tasked with developing a predictive relationship between inlet conditions and response of the oceanfront shorelines, and determining historic changes along estuarine shorelines within the area. He describes that as the main ebb-channel moves toward Figure Eight Island and the ebb-delta moves with it, the delta provides protection from waves to the island and the portion of the island close to the inlet accretes. As the ebb-channel migrates away from Figure Eight, so does the ebb-delta leaving the northern portion of Figure Eight Island exposed to direct waves which leads to erosion. **Dr. Cleary** describes three (3) distinct periods of erosion within the inlet hazard zone on Figure Eight Island: 1938-1945; 1980-1984; and 1998-present. Erosion from 1938-1945 was caused by flood channels along Rich Inlet. Erosion from 1980-1984 was also associated with flood channels adjacent to Rich Inlet. During the most recent erosion event, erosion was associated with the northward migration of the ebb-channel. **Dr. Cleary** stressed that there is a lag between when channel migration occurs and subsequent erosion/accretion of the adjacent shorelines.

Mickey asked if CPE has projected maintenance events for the project based on sediment bypassing after channel relocation. **Tom Jarrett** stated that maintenance intervals have not yet been determined for this project. **Dr. Cleary** then described recent ebb-delta breaching events and resultant sand bypassing, and stated the inlet system has remained in the same relative configuration from 2004-2007. He stated erosion along inlet shorelines can be expected with or without a channel relocation project. **Dr. Cleary** discussed end point erosion rates for Figure Eight and Hutaff Island (1938-2007). Because previous nourishment events along Figure Eight Island haven't lasted very long, he believes nourishment alone will not solve erosion issues on Figure Eight. Shoreline change along the interior marshes of Rich Inlet was also discussed. As sandbars have migrated into Rich Inlet, and the interior channels have begun to clog, the inlet channel has been pushed towards Figure Eight Island and the Keenan home, causing erosion along the estuarine shoreline (>400 ft) which has led the homeowner to place sandbags along the shoreline. **Dr. Cleary** did not see evidence that dredging of Nixon Channel had an impact on erosion along this shoreline since erosion was relatively constant over time. He suggested that in order to best mitigate erosion along Figure Eight Island, the main ebb-channel should be relocated to the south which would move the apex of the ebb-delta to the south. This would create a breakwater effect for the front of Figure Eight Island, inducing natural accretion along the north end. Historical evidence suggests that when the ebb-channel has moved south, accretion has occurred subsequently along the north end of Figure Eight Island after a lag of several years. This is a natural process that CPE intends to mimic with the proposed channel relocation project. **Tom Jarrett** agreed that CPE was designing the channel relocation project to mimic this natural occurrence. **Dr. Cleary** said the inlet channel relocation will lead to some erosion along Hutaff Island. **Jim Bushardt** asked who would be responsible for mitigation costs associated with erosion along Hutaff Island. **Dr. Cleary** stated he did not know. **Don Ellson** asked if erosion and accretion within the interior channels were occurring independently of ebb-channel fluctuations. **Dr. Cleary** agreed that there didn't seem to be a linkage between the two events from his studies. **Howard Hall** asked if sand moving into the inlet and the lowering of Hutaff Island is related to sea level rise. **Dr. Cleary** stated that these changes were more closely related to storms and inlet closure. **Tom Campbell** stated CPE had conducted studies in Florida that indicated storms were more responsible for shoreline erosion than potential erosion due to sea-level rise. **Stuart Mossman** asked what effect moving the inlet channel would have on erosion on Nixon Channel. **Dr. Cleary** stated he didn't think there would be an effect. **Tom** indicated that moving the interior channel away from Figure Eight Island would relieve some of that erosion along Nixon Channel. **Dawn York** asked why there wasn't accretion in interior marshes as sand moved into the inlet. **Bill** stated that the sandbars in the channel are ephemeral and accretion of marshes has not been significant over the time period he studied. **Bob Parr** asked if Green or Nixon Channel would take over as the dominant channel. **Bill** said he couldn't predict that. **Chris Day** said modeling suggests that if no action is taken over next 5 years, the tidal prism in Green Channel would decrease. **Bill** agreed and concluded his presentation.

Dawn York began her presentation discussing baseline environmental data collected to date. Habitats within the vicinity of the project area include salt marsh, submerged aquatic vegetation (SAV), shellfish and bird and turtle nesting areas. The proposed resource investigation plan will provide data for determining potential project impacts. **Dawn** discussed specific resource data that has been collected to date from several sources – aerial photos, shellfish maps, SAV interpretation maps, water quality data, turtle nesting data, seabeach amaranth. **Mickey Sugg** asked if data interpreted from aerial photos would be groundtruthed by CPE, and if so, when that would occur. **Dawn** said these areas would be groundtruthed but did not have a date for field operations. Additional data needs to be collected including groundtruthing of shellfish habitat, saltmarsh areas, SAV, seabeach amaranth, and other biotic communities. **Dawn** discussed CPE's delineation of the proposed Permit Area based on primary and secondary impacts of the proposed project determined through modeling efforts. **Mickey** clarified why a Permit Area needs to be identified as a part of the NEPA process. Dawn stated that the Permit Area includes all alternatives identified, Nixon and Green Channels, and the extent of the toe of proposed fill. It was asked by the PDT what was meant by the "toe of fill." **Chris D** explained that when beach fill is placed, waves naturally rework the sediment and move some of it offshore as far as approximately -24 ft NAVD. **Howard Hall** stated that all of Hutaff Island and the north end of Figure Eight Island are critical piping plover nesting habitats. **Anne Deaton** asked where CPE would be looking for SAV. **Dawn** replied that CPE would groundtruth those areas preliminarily identified by Don Fields of NOAA through aerial photo interpretation. **Anne** asked if NOAA had mapped SAV in this area. **Dawn** said she was not aware of SAV mapped in this area. **Anne** stated most SAV areas she was aware of occurred along the AIWW. **Dawn** said that groundtruthing of SAV would be conducted in the AIWW if the Permit Area includes those areas. **Bill Cleary** asked if SAV is present in all channels or if they are located in pockets. **Dawn** stated that SAV is not pervasive in all channels. **Dawn** requested feedback from the PDT attendees for CPE's resource investigation. **Mickey** asked if attendees could receive a report with what has been collected to date. **Dawn** stated she would forward an updated summary report to the PDT for their review. **Doug Huggett** asked if the Topsail Project Permit area overlapped with the Permit area for this project. **Dawn** stated there was some overlap on Hutaff Island. **Ron Sechler** asked if waters within the permit area were outstanding resource waters. **Dawn** said that was correct including Futch Creek. **Ron** asked if CPE was including Futch Creek. **Dawn** stated the modeling results do not indicate impacts to Futch Creek leading to its exclusion from the Permit Area. **Dawn** concluded her presentation and the PDT broke for lunch.

Chris Day began the presentation on the continuing modeling effort for the project, a summary of the preferred alternative including channel design and beach fill. **Chris** explained the usefulness of the Delft3D model used as well as erosion and deposition patterns observed in model output for the project. Wave data used to drive the model was taken from a wave gauge off of Masonboro Island with a 3 year record. Tidal measurements were taken from a gauge at Johnny Mercer's Pier. Bathymetry used for the model was surveyed by Gahagan and Bryant (GBA) in 2006. **Chris** discussed 5 year results of the model *without* any project. The model predicts flood channels developing and causing erosion along the saltmarsh behind Rich Inlet similar to Dr. Cleary's predictions. **Chris** was comfortable with calibration of the model based on these results. **Chris** then discusses how CPE modeled performance of beach fill taken from Rich Inlet and placed along the oceanfront beach of Figure Eight Island. This study was conducted using a storm-induced beach change model (SBEACH). The model was calibrated based on data from Hurricane Ophelia. Results from the SBEACH model sufficiently predicted changes in the beach measured by GBA, especially in the dry beach. **Chris** then discussed CPE's analysis of alternatives, and stated wave prediction modeling would be completed for the identified preferred alternative. Alternative #1 includes 3 cuts – an ebb-channel cut similar to that suggested by Dr. Cleary, a connection cut to Green Channel, and a connecting cut to Nixon Channel. This alternative was not chosen because it did not address erosion concerns. Alternative 2a has longer connecting cuts into Green and Nixon Channels. The preferred alternative for Nixon Channel is 2a. The preferred alternative for Green Channel is 2b which does not include the extension because the model showed it didn't significantly increase performance. Modeling results showed that if no action was taken, scour holes would develop close to properties at the northern end of Beach Rd on Figure Eight Island. Alternative 2a would move these scour holes away from the properties. Modeling results for Alternative 2b indicate scour holes would exist close to properties similar to the no action alternative. Alternative #3 includes dredging of the main ebb-channel and Nixon Channel. This alternative does not address clogging in Green Channel and thus was dropped. Alternative #4 includes dredging Nixon

Channel, but was deemed not to be a hydraulically efficient alternative and could increase erosion of interior salt marshes. The preferred design depth of the channel was lowered to -19 ft to open up the bid process to more contractors. Because the channel was deepened, it was also narrowed at the bottom. Closure of the old channel would be accomplished with a closure dike to +6 ft NAVD. Approximately 1.7 million cubic yards would be dredged from all of the channels combined with the majority coming from the main ebb channel. Dredging in Nixon Channel would move the thalweg further away from private properties as recommended by Figure Eight Island Management. The proposed cross sectional area of the inlet (with the dike constructed) was designed to be the same as the existing cross-sectional area to maintain the existing tidal prism. Approximately 1.1 million cubic yards will be available for placement on Figure Eight Island. Material was designed to be placed with a dredge instead of dump trucks due to cost.

Chris then discussed beach fill options. The first includes placement of fill on the northern portion of the island from Bayberry Place to Rich Inlet. The second option includes placement along the entire length of Figure Eight Island. The second option would require the use of a booster pump or trucks to transport the fill, or use of a hopper dredge which could be cost prohibitive. Fill options were analyzed based on erosion from 1999 to 2007. Erosion rates on the north end of the island were highest, reach ~ 28 ft/year. Near the middle of the island, erosion rates are ~ 13 ft per year. Rates to the south are even lower. Beach fill option 1 includes fill placement between 90 and 190 cubic yards per linear foot. Option 2 includes 30 to 167 cubic yards per foot, due to the longer area to be filled. Larger volumes would be placed in areas with higher erosion rates. The equilibrium toe of fill is estimated to be -24 ft based on reworking by wave processes. This process will also decrease the width of the constructed berm. The berm was designed to be wider closer to Rich Inlet.

Chris then discussed modeling results of the performance of the channel with beach fill option 1, and channel options 2a and 2b. Model results after 2 years show the flood channel decreasing in flow (and moving farther away from private properties) and the ebb-delta moving south to align with the ebb-channel. **Chris** stated there would be a lag in transport of ebb-delta material similar to descriptions by Dr. Cleary. **Chris** also stated that 5-year model runs to predict impacts will be completed by CPE in the future. **Mickey** asked where material to fill the old channel would come from. **Chris** said some of that would come from the dike but that the dike design should perform better than the one designed at Bogue Inlet. **Tom J** stated some of that material may come from re-distribution of the ebb-delta. **Dr. Cleary** asked if the modeling data included predictions for Hutaff Island. **Chris** stated those results have not been modeled yet. **Doug Huggett** asked if a closure dike would be allowable if permission was not granted to place any construction material on Hutaff and encouraged close cooperation with Hutaff in this process. **Chris** said the closure dike would be required to make this work. **Chris** described primary impacts (channel, dike and beach fill) totaling 235 acres of direct impact. Future impacts were calculated by comparing modeled results without a project to modeled results with the project. Areas showing greater than a 0.5 foot difference were included within the Permit Area for the project described by Dawn. Option 2 has a larger impact area due to the greater distance of fill. Storm events were modeled for each beach fill option and with no project. Both beach fill options would provide protection to the dune system. A series of severe storms could significantly reduce beach fill. A 5-year model without a project indicated the berm could retreat landward significantly and intersect with current homes, causing the need for more sandbags. Five-year models with beach fill indicate the present location of the berm could be held even after a 10-year storm. **Mickey** asked how a 10-year storm is modeled. **Chris** explained that the USACE has published extreme wave heights for 10-year storms. CPE also considers 10-year storm surges based on data gathered from FEMA. These conditions then are entered into the model. Model results from beach fill Option 2 were not presented, but **Chris** stated the results were similar for a 10-year storm with Option 1. **Chris** stated that beach fill would provide protection from storm damage over the design life of the project. **Chris** then discussed fine adjustments to the designs that could be implemented to increase performance of the project including increasing dredging in Green Channel to mitigate clogging. Another adjustment includes lengthening the wider portion of beach fill to the south for Option 1. **Chris** then summarized the modeling results and suggested making further adjustments to the beach fill layout and perform 5-year modeling for the preferred alternatives.

Dr. Cleary asked if CPE had consulted the island managers or regulators concerning exceeding the 50 cy/linear foot fill limit. **Tom J** indicated the 50 cy/linear foot trigger has been removed from the regulations, and now any fill project over 300,000 cy is considered a large fill project which would freeze the static vegetation line. **Dr. Cleary** then asked if more fill was going to be placed at the northern end of the Island and **Chris** said that was correct. **Mickey** said that if Option 2 was chosen, cumulative impacts on the southern end of the island would have to be discussed because of fill from Mason's Inlet. He suggested an island-wide management plan be created for Figure Eight Island. **Chris** said it would be up to the homeowners to decide where the fill is placed. **Mickey** also stated that there may be need to place material on Hutaff if impacts to those resources are anticipated. **David Kellam** said that he hoped the management plan for the Mason Inlet project and the one created for the Rich Inlet Project could serve as an island wide management plan. **Chris** indicated this would be considered during the permitting process. **Stuart Mossman** suggested that Hutaff Island may like to have some beach fill if the project proposes to tie into the island with a dike. **Tom J** indicated that Hutaff Island contained piping plover habitat which may disallow fill from being placed, but monitoring would be planned to mitigate potential erosion along Hutaff Island. **Mickey** stated Hutaff Island's attorney was a part of the PDT team and is provided information. **Howard Hall** asked if the project included future placement of fill. **Chris** stated that future maintenance events had not been planned for the project, but that is something that will be considered. **Tom J** indicated the intent is to periodically maintain the alignment of the channel. **Howard** asked if a fixed interval was planned for this project. **Tom J** indicated that future events may need to be permitted on an event basis. **Doug Huggett** stated if future work was needed that a Major CAMA modification would be required as well as cumulative impacts considered. **Tom J** said that the intent is to manage the Rich Inlet channel primarily but would make estimates about future maintenance. **Jim Bushardt** asked if modeling results for the Futch Creek and ICW areas had been conducted. **Tom J** said this information would be included as a part of the engineering report. **Chris** indicated modeling does not show impacts to this area. **Doug Huggett** stated modeling done for Mason's Inlet did not accurately predict changes to interior channels. **Tom J** said the model used for this project was different and could better predict impacts. **It was** asked by the PDT if CPE was modeling salinity encroachment into Futch Creek. **Tom J.** indicated that since the tidal prism was the same there shouldn't be a change to the salinity. It was stated that dredging such a large amount of sediment from the interior channels would likely allow saltwater to intrude further into the creeks. **Tom** stated that since the cross-sectional area was designed to be the same as the existing inlet, tidal prism would not increase. **Ron** asked if estimates had been made concerning impacts to essential fish habitat areas (gain/loss), and if impacts were expected, what mitigation was planned. **He** also asked if aerial photography could be used to study existing essential fish habitat. **Ken** asked that if the cross-sectional area of the new inlet was the same of that of the old inlet, then would the habitats be the same before and after the project. **Chris** said the model being used could predict changes in water depths within the study area. **Dawn** stated it would be effective to study EFH through aerial photography before and after the project. **Tom J** said CPE expected to study impacts to EFH. **Dawn** explained some of the monitoring CPE has conducted for other projects concerning EFH. **Tom J.** suggested that the PDT has assisted in coming up with standards and guidance for characterization of EFH. **Mickey** asked whether Alternative 3 excluding Green Channel was modeled to show that it is not practical from an engineering standpoint. He said that Green Channel is an environmentally sensitive area and that dredging in this channel may not be approved by regulators unless CPE shows that the project will not work without dredging Green Channel. **Chris** said that if the channel is not dredged, the tidal prism within the channel would decrease over the next 5 years, and a cut at the mouth of the channel would facilitate some flow. **Mickey** said that analysis should be included in the body of the EIS document within the alternatives section because dredging in the vicinity of Green Channel could be a concern to regulators. **Tom J** said that the channel cuts were designed to replicate existing flow distribution into Green and Nixon Channels. **Dr. Cleary** asked that if Green Channel shoals over time (including from the AIWW), does that restrict access for larvae to get into these areas, and suggested if this area is not dredged at all, it may shut down. **Dr. Cleary** said many channels similar to this in the area are shoaling. **Anne** said that some channels have opened when others have closed. **Dr. Cleary** disagreed. **Anne** suggested that flow to Green Channel is retained through the project for ecological concerns. **Tom J** said that dredging Green Channel does not have an influence in reducing erosion on Figure Eight Island but said that the project should also be designed to maintain ecological considerations. **Dr. Cleary** said that fluctuations of the ebb-channel for Rich Inlet to the north could be associated with Nixon Channel gaining dominance over Green Channel due to shoaling. **Mickey** asked if modeling has been conducted without the proposed dike. **Chris** said they had not although the project had been modeled with a small dike which disappeared after a couple years leaving 2 channels. One of these would supply Nixon Channel and the other would supply Green Channel. **Chris** suggested it would be better to have one main ebb-channel supplying flow to both interior channels. **Mickey** and **Dawn** discussed the date for the next PDT meeting in which further discussion of the alternatives would take place.

ATTENDEES

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Figure Eight Island Inlet and Shoreline Management Project
June 10, 2008 PDT Meeting Minutes
Figure Eight Island Yacht Club

The meeting was called to order by **Mickey Sugg**. Introductions were made. Mickey stated that the agenda for the meeting would focus on discussing the alternatives for the Inlet and Shoreline Management Project followed by a presentation by CPE's coastal engineer, **Chris Day,** detailing the engineering analysis related to the Applicants Preferred Alternative. Mickey followed with a brief overview of the NEPA process and the format of the EIS document. This document will include the following sections:

1. Purpose and Needs
2. Scoping Issues
3. Alternatives
4. Effected Environment
5. Environmental Consequences
6. Cumulative Impacts

Doug Huggett stated that the EIS document will also go through state review to satisfy SEPA criteria. **Don Ellson** asked who is tasked with drafting the EIS. **Mickey** stated that CPE will write the document and will include input from the PDT.

Starting the discussion on the project alternatives, **Mickey** explained that all reasonable alternatives will be evaluated in terms of economics and technology. Each alternative will be rigorously explored and evaluated in Section 3 of the EIS. **Tom Jarrett** asked how the format of the Environmental Consequences section of the document will be developed. **Mickey** responded that it could be written by evaluating the potential impacts to various resources in response to the alternatives or by evaluating each alternative and describe the potential impacts to the resources in response. **Tom** felt that approaching it by alternatives may be best. **Mickey** stated this could be discussed further at a later time. **Stuart Mossman** asked who, aside from Figure Eight Island Homeowners Association, would be financially responsible for the evaluation of alternatives if they go beyond the immediate scope of the project. **Mickey** responded that costs for each alternative will be developed and evaluated. Specifically, **Stuart** expressed concern regarding Green Channel and stated that the water quality could be significantly affected by the project. **Mickey** added that these concerns will be addressed later as the PDT reviews each alternative.

Mickey continued by explaining that the NEPA process allows for the evaluation of all potential alternatives, including those which may have a conflict with state or federal law (i.e. terminal groin). Often, these alternatives are eliminated through the evaluation process, but they are still fully assessed for their economics, technology, etc. Furthermore, the EIS document will include the evaluation of the “Applicants Preferred alternative”. **Tom** stated that CPE has developed a “recommended preferred alternative” which will be submitted to the Figure Eight Island Homeowners Association for their review.

Stuart Mossman asked a procedural question regarding how the PDT will be presented the alternatives. **Mickey** replied that Chris Day will summarize the modeling results based on the various alternatives. **Tom** explained that CPE’s presentation will actually focus on the engineered design of the preferred alternative; therefore it would be prudent to review all current alternatives prior to the presentation.

Mickey reiterated that all alternatives will be evaluated based on the project purpose and needs. Furthermore, the applicant (with input from the contractor) determines the purpose and needs of the project. **Stuart** asked if the various purposes and needs could be listed prior to the discussions on the alternatives. **Dawn** stated that they are listed in the baseline assessment handout that was provided at the beginning of the meeting. **Mickey** asked **Tom** to list the purpose and needs. **Tom** stated that currently the purpose and needs primarily address the ocean shoreline but it has become clear that there are needs for the backside of the island as well. **David Kellam** stated that with regard to threatened buildings, there are 21 total properties imminently threatened. From Surf Court north, there are approximately 60 to 70 structures that will become threatened within the next 10 years. Along with protecting infrastructure, the purpose and needs of the project address environmental needs and other issues. **Stuart** stated that maintaining navigation through Green Channel and Nixon Channel is an important purpose of the project. **Mickey** mentioned that navigation will be evaluated as a public interest factor. **Tom** added that if navigation was defined as a specific purpose for the project, then specific dimensions of the relocated Rich Inlet will need to be established.   **Cleary** asked what constitutes as “navigable” waterways. **Mickey** responded that it is defined as what is navigable in present time. **Doug** reiterated that the definition of “navigable” is vague. **Tom** added that while this project will hopefully not negatively impact navigation, improving the navigability of the waterways in proximity to the project is not a purpose of the project. **Doug** mentioned that it is important to discuss potential environmental issues regarding Hutaff Island as well. **David** stated that the Figure Eight Homeowners Association is concerned about maintaining the vitality of the marsh and other environmental aspects which could potentially be impacted by the project. **David** continue to state that he hopes that the project will enhance various resources and potentially improve the navigability of the local waterways. **Cleary** inquired as to who determines what constitutes the impacts of navigation or any issue. **Mickey** stated that the existing depth of the channel would need to be determined and subsequently reviewed following the completion of project. **Tom** stated that the Delft3D model can predict these potential changes.

Following the initial discussions regarding issues related to the project alternatives; **Mickey** introduced the first proposed alternative as “No Action”. **Mickey** said that this alternative should refer to the future extrapolation of the conditions and maintenance activities which exist today. **Tom** mentioned that the No Action simply refers to conditions without future federal permits. **Mickey** mentioned that this is not the case for this project. **Doug** supported **Mickey’s** interpretation. **Bill Raney** asked how the removal of sandbags is taken into account for this alternative. **Mickey** answered that it would no longer be allowed and therefore would not be incorporated into the evaluation. **Doug** stated that it would not eliminate beach scraping and ICWW maintenance. **Stuart** added that the No Action alternative would cause the shoaling of Green Channel. **Tom** stated that modeling results demonstrate this assessment over the next five (5) years. **Cleary** asked if these modeling results assume the maintenance of the current inlet throat position. **Chris** stated that it appears that the inlet throat will maintain a similar position. **Cleary** responded that there is so much uncertainty and does not agree that you can put a lot of faith in the model over five (5) years. **Chris** added that a storm could alter the modeling results as well. **Mickey** stated direct, indirect, and cumulative effects will be incorporated into the evaluation. **David** noted that historically there has never been marsh grass in the middle of Green Channel, but it is present now which leads him to believe it has filled in recently. **Stuart** asked what the role of the PDT is regarding Alternatives. **Mickey** stated that it is the PDT’s role to bring up any issues they have with the presented alternatives or bring up additional alternatives. **Stuart** personally does not know all the consequences of the No Action alternative and inquired if it is the PDT’s role to comment on it. **Mickey** informed Stuart that the PDT needs to recommend what the No Action alternative includes and suggested it should include the continuation of sporadic maintenance events within Masons Inlet, Banks Channel, and Nixon Channel. The No Action alternative should also include future beach scraping, bulldozing, and the removal of sand bags. **Tom** agreed.

Mickey then introduced the second alternative which will be Abandon/Relocate. This alternative would not include any existing maintenance projects described above. **Tom** stated that the relocation of homes is not a viable option because there is a paucity of available lots which would need to be sold to the oceanfront homeowners. **Doug** felt that if relocation is not a viable alternative it needs to be justified and stated as such in the EIS document. **Bill** added that it may be more economically feasible to let the houses fall in the ocean rather than attempt to relocate. **Mickey** recommended that the Abandon/Relocate alternative be split into two: a) Abandon, b) Relocate. **Tom** explained again that there are not enough available lots on Figure Eight Island to accommodate the number of homes which would need to be relocated. He stated that the only reasonable alternative is abandon and demolish. **Mickey** said to include both Abandon and Relocate as one alternative but will be separated in the description. **Tom** expressed that he could develop a theoretical cost for the relocation effort, but in actuality, there is nowhere to move these homes to on the island. **Doug** and **Mickey** stated that the issue should be added to the discussion. **Don** asked if there is an option to create new land for these homes in the middle of the island. **Doug** stated that because that land is in state ownership, that option would not move forward.

The third alternative discussed was Beach Nourishment using "other sand sources". **Mickey** stated that these sand sources would include any borrow areas other than Rich Inlet, Nixon Channel, and Green Channel. These borrow areas would include offshore borrow areas, material from Mason's Inlet, dredge islands, and other locations to provide sand for beach nourishment. **Bill** asked if we should call this alternative "Beach Nourishment without Inlet Relocation" to discern it from the No Action alternative. **Mickey** said that in the No Action alternative, the Nixon Channel maintenance events may not be addressed because it has only been dredged a handful of times- he feels that we should address Nixon Channel in this alternative. **Tom** mentioned that it has in fact been dredged 4 or 5 times in the past. It was discussed that the material placed along the north end of Figure Eight Island via routine maintenance events does not stay in place which will bolster the need for long term protection. **David** explained that the material on nearby dredge spoil islands have acceptable but not preferred sand quality. **Tom** asked if we have technical sand quality information to address compatibility. **Bill** asked if we can include ebb shoals as a potential additional sand source. **Tom** stated that although it has been done in Florida, it is not recommended. **Mickey** said that it could be evaluated though. **Stuart** mentioned that there needs to be line drawn to decide when certain potential alternatives should not be considered. **Mickey** stated that even seemingly unfeasible alternatives can be quickly refuted in a few sentences within the EIS document. **Doug** added that the State needs to legally consider everything the public raises as a concern or a suggestion. **Dawn** asked if upland sand sources should be involved. **Chris Day** said that anything less than 150,000 cubic yards is not a feasible alternative due to problems associated with trucking in the material and the potential destruction to the roadbeds. **Mickey** was initially thinking of upland sand sources as a separate alternative, but it could be lumped in with this alternative as well. **Doug** feels that it can be lumped.

The fourth alternative discussed was the Terminal Groin. **Stuart** asked if there is an illustration depicting where specifically the terminal groin would be placed. **Tom** mentioned that there has only been preliminary work conducted on the Terminal Groin alternative and no such figure is available. **Mickey** said that the evaluation of this alternative would include a review of the various materials and construction types possible for the Terminal Groin. With regard to the wording of the proposed legislation stating that the Terminal Groin must be a temporary structure, **Tom** asked if the construction types or materials addressed in the document should reflect a temporary structure. **Mickey** stated that at this point since nothing has been passed through the legislation, all types of material for the terminal groin will be evaluated (rock, geotubes, sheetpile, etc) and environmental impacts examined. **Stuart** asked why terminal groins would be evaluated since they are not proven to function. **Chris** answered that modeling exists that can predict the functionality of terminal groins. **Tom** explained that there are several functioning terminal groins here in North Carolina alone. He went on to explain how terminal groins function and highlighted the ones at Pea Island and Fort Macon. **Mickey** asked if any environmental studies have been conducted in response to the Pea Island terminal groin. **Doug** said that Fish and Wildlife may have. **David** stated that the legislative issue may be resolved within 30 to 40 days. **Mickey** asked if the Terminal Groin alternative will require sand placement on the beach. **Tom** replied yes. The terminal groin would affect the northern most 2,000 feet of the shoreline (the fillet), therefore beach nourishment would still be needed to provide protection to the remaining portions of Figure Eight Island. **David** added that the size and magnitude of the terminal groin will dictate the effect of the terminal groin on the extent of beach protection. **Ron Sechler** asked why a terminal groin is being considering at this site. It was answered that it is being considered due to the potential legislation. **Doug** noted that is it currently illegal. **Tom** added that at this point, the engineering work that has been done for the Terminal Groin alternative has been conceptual; there has been no detailed engineering work at this point. **Ron** added that there is a large group of scientists that have concerns and would be opposed and that there would be a high level of attention on this project. **Cleary** stated that the terminal groin would only be placed in proximity to an inlet, which has not been made clear to the public. **Dawn** asked if at this point in time we should include the Terminal Groin alternative in the environmental consequences section due to scheduling. **Mickey** stated that the Terminal Groin alternative could be addressed as two sub-alternatives including a) Terminal Groin with Inlet Material for Beach Nourishment and b) Terminal Groin with Other Sand Sources for Beach Nourishment. **Doug** agreed. **Tom** added that if the legislation passes, the EIS schedule will need to be adjusted to allow for detailed analysis of this alternative. **Martina McPherson** asked if the channel will be modified as well in association with the Terminal Groin alternative. Tom answered that it most likely would be.

Following a lunch break, **Chris** gave a presentation regarding the Applicant's proposed preferred alternative which includes the relocation of Rich Inlet, the dredging of portions of Nixon Channel and a small portion of Green Channel followed by beach fill along Figure Eight Island. The presentation included a review of the erosion problems on Figure Eight Island, the project description, project performance, and project cost. **Chris** described the project design and how it will address erosion on the northern portion of the island, particularly two erosion hotspots: one on the oceanfront shoreline and the other on the estuarine shoreline.

(*The presentation is available to download from CPE's FTP site. ftp://ftp.coastalplanning.net; user name: ftpguest; password: cpeguest. See folder Figure 8 Island folder, then PDT folder)*

Doug asked what the equilibrium toe of fill represents. **Chris** responded by stating that it represents the depth of which the fill will slope offshore as it stabilizes. **Mickey** asked if the material placed on the backside closest to Nixon Channel will remain in place. **Chris** answered that it will spread out east and west as well as slumping off the shore to an extent. **Mickey** asked if the cuts created in Nixon Channel, Green Channel, and the entrance channel would performed with the intent to improve navigation. **Tom** answered that the purpose would not be for navigation; however navigation would be improved most likely as a secondary result. Maintenance events would most likely occur five (5) years post-construction. **Mickey** asked where the sand goes as it erodes from the shoreline. **Chris** answered that some of the material is bypassed into Rich Inlet. **Tom** stated that some of the material also gets transported into Banks Channel. **Cleary** said that this migration pattern can be viewed by looking at historic aerial photos. **Tom** also said that the ebb tide delta can store and release sediment as well, so some of the material can migrate into the ebb tide delta. **Mickey** stated that it will need to be explained in the EIS that the inlet is not being dredged as a simple sand source for beach fill; rather the inlet is being relocated to help control the erosion rate on the northern end of Figure Eight Island. Subsequently the dredged material will be placed on the beach as fill. **Don** asked if the dike would disperse within five (5) years. **Chris** explained that it will ultimately spread and blend into the natural environment. **Stuart** asked if the dike could be constructed utilizing geotubes. **Chris** said that geotubes would not work so close to the channel because it is too deep. **Tom** said that the new channel would be opened prior to the construction of the dike. Some of the material dredged from the new inlet would then be used to build the dike in the existing channel.

Following Chris's presentation, **Mickey** asked the PDT if they have any suggestions regarding the Applicants Preferred alternative. **David** stated that Green Channel has never been dredged and **Cleary** agreed. **Mickey** asked if we should separate this alternative into a) with dike and b) without dike due to the varying levels of environmental impacts anticipated. **Chris** felt that was an adequate statement. **Tom** agreed. **David** asked if there are environmentally beneficial construction techniques. **Mickey** answered by mentioning that this will be addressed as mitigation and minimization measures are discussed further in the process and EIS.

Following the discussions regarding the alternative, **Dawn** addressed the group and reviewed the baseline summary report and investigation plan. **Fritz** asked if we would only assess the areas that would potentially be dredged. **Dawn** stated that this effort would give a broad assessment of what biological resources currently exists within the Permit Area. **Dawn** went on and asked **Fritz** if the Division of Marine Fisheries has conducted recent research or monitoring within the Oyster Management Areas. **Fritz** responded that oyster spat counts are routinely conducted. **Dawn** mentioned that hardbottom resources will be investigated via sidescan in the nearshore environment out to the toe of fill in front of the beach fill area. **Cleary** asked how olive green siltstone would be groundtruthed. Tom mentioned that CPE will follow up with this issue.

Mickey stated that the resource agency representatives need to review the baseline assessment plan and comment on this document and recommend any additional data or groundtruthing needs. **Mickey** adjourned the meeting at 3:00 pm.

ATTENDEES

NAME	REPRESENTING	CONTACT INFORMATION
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Figure Eight Island Inlet and Shoreline Management Project
May 20, 2009 PDT Meeting Minutes
USACE - Wilmington District Office

The meeting was called to order at 10 am by **Mickey Sugg** of the USACE. Introductions were made. Mickey discussed the agenda for the meeting in which it would focus on updated baseline biological data as well as a review of project alternatives for the Figure Eight Island Inlet and Shoreline Management Project (Project). Open dialog from the attendees was encouraged. (*A list of attendees is provided at the end of the minutes*.)

Biological Resources
Dr. David Webster of UNCW prepared a presentation regarding the long-term biological monitoring results of rare, threatened, and endangered species identified on Figure Eight Island. Species include the seabeach amaranth, sea turtles, Carolina Diamondback terrapin, colonial nesting waterbirds, shorebirds, and marine mammals. Dr. Webster was unable to attend the meeting; therefore **Brad Rosov** of Coastal Planning & Engineering of North Carolina (CPE-NC) delivered the presentation. **Brad** explained that Dr. Webster's research and monitoring began primarily in 2001 along Figure Eight Island.

Since 2001, seabeach amaranth occurrences have varied greatly along the island ranging from over 700 individual plants in 2006 to 0 plants in 2008. This trend is typical of this ephemeral species. **Brad** discussed the results from the island-wide sea turtle monitoring program in which loggerhead turtles have been the only species to nest along Figure Eight Island. Since 2001, the numbers of loggerhead nests have ranged between 5 and 31. **Brad** confirmed the coordinates of these nests have been integrated into a Project GIS database, coordinated by CPE-NC, and have depicted the occurrence of these nests along the entire length of the island. **Brad** noted that while no known data was available regarding Carolina Diamondback terrapins, Dr. Webster is aware of a UNCW student investigating the terrapin's mortality associated with abandoned crab pots. The results of the long-term colonial waterbird nest monitoring included species such as: black skimmers, least terns, and common terns. These species successfully nested in 2001, however in subsequent years only least terns nested on Figure Eight Island and in more recent years no colonial waterbirds successfully nested. Brad then discussed the results from the long-term shorebird monitoring in which piping plovers have been documented as migrating through Figure Eight Island. Fall migration for piping plovers typically began in August and peaked in September. Some piping plovers were noted to winter over in the area, particularly near Mason Inlet on the south end of Figure Eight Island. Spring migration began in March and continued into May of each year. No piping plover nests were documented on Figure Eight Island since 2001. **Howard Hall** (USFWS) asked if the shorebird surveys included observations of banded birds to determine which populations of migrating piping plovers are utilizing Figure Eight Island. **Dawn York** (CPE-NC) and **David Kellam** (F8 Homeowners Association) concurred that bands have been identified and reported to the appropriate organizations, however, not many banded piping plovers have been recently observed. **Brad** also explained that the geographic scope of the data gathered in support of the Figure Eight Island Inlet and Shoreline Management Project includes areas along Hutaff Island, Figure Eight Island and the saltmarsh community behind both islands toward the Intracoastal Waterway. **Mickey** asked if Dr. Webster's monitoring effort was established as a permit condition of the Mason Inlet relocation project.

David stated the permit conditions from the Mason Inlet relocation project tied into the established biological monitoring program. **Chris Gibson** (GBA) mentioned that the long-term biological monitoring program actually goes over and above the permit conditions for the Mason Inlet relocation project. **Brad** continued to describe the nesting results for Wilson's plovers, American oystercatchers, and willets. Generally, these shorebird species do nest on the island with limited success. In addition to nesting data, Dr. Webster also assisted in the coordination and collection of marine mammal stranding data on Figure Eight Island, as reported by the UNCW Marine Mammal Stranding Network. Stranded species include several bottlenosed dolphins, two long-finned pilot whales, and two pygmy sperm whales.

The biological resource presentation continued as **Brad** discussed beach vitex, monitored by Dr. Webster. Since 2006, an eradication effort of this invasive species has been established. In summary, **Brad** stated that the recent human and natural changes to both Mason Inlet and Rich Inlet have dictated the locations of nesting colonial waterbirds and shorebirds and confirmed the north end of Wrightsville Beach is heavily used by nesting birds. **Dawn** asked David Kellam how long Dr. Webster will continue these monitoring efforts. **David** responded that he does not anticipate that it will end anytime soon. **Mickey** asked if this was a long-term contract. **David** answered that it is a yearly agreement with UNCW. **Howard** noted that the proposed Figure Eight Island Inlet and Shoreline Management Project should include biological monitoring such as the studies described above. (*Dr. Webster's presentation is available and will be distributed with these minutes)*

Brad then presented baseline data collected by CPE-NC to help establish a robust database of baseline conditions for a wide range of biological resources located within the Permit Area of the proposed project. His presentation focused on the findings from field investigations conducted in 2008 on submerged aquatic vegetation (SAV), shellfish, and marsh and fringing terrestrial habitats. **Brad** described the development of the proposed Permit Area and the smaller field investigation area used for these groundtruthing efforts. Two datasets of potential SAV occurrences were obtained by CPE-NC from Don Field (NOAA) and Dr. Wilson Freshwater (UNCW). **Mickey** asked if these were the same datasets presented in a earlier PDT meeting and **Dawn** replied yes. Of the 47 potential SAV sites groundtruthed, 3 contained SAV beds (*For the purpose of this study, an SAV bed was defined as a subtidal or intertidal area of submerged aquatic vegetation with one or more species of submergent vegetation. The bed may occur in isolated patches or cover extensive areas with the presence of above-ground leaves)*. Using high resolution 2008 aerial photography, an additional 17 SAV occurrences were delineated yielding a total of 6.9 acres of SAV within the Permit Area.

Utilizing NC DMF's historical shellfish habitat maps (1989-1991), CPE-NC identified the central location of the polygons described as "strata W", defined as "hard non-vegetated with shell". Twenty-three sites were groundtruthed and of these sites, nine (9) contained living shellfish, however none were discrete shellfish beds or oyster reefs. One (1) shellfish bed was opportunistically located during groundtruthing activities. Three (3) additional shellfish beds were then identified using high resolution 2008 aerial photography totaling 0.1 acres of shellfish beds within the Permit Area. A participant asked if CPE-NC had looked at the clam leases behind Hutaff Island. **Chris Gibson** noted that the clam leases were located outside the Permit Area, however he suggested that we confer with Sammy Corbett, a local commercial fisherman, to determine additional shellfish locations. **Rich Carpenter** (NCDMF) asked if other shellfish strata were explored. **Dawn** replied that CPE-NC has duplicated the field investigation methodology required for the Bogue Inlet Channel Erosion Response Project and have delineated the low marsh area, which essentially is the "V" strata. **Rich** noted that the majority of oysters are located in this habitat type. **Don Ellson** commented that all of the CPE slides to that point had been island-specific, and I asked whether the studies being presented included areas beyond simply Figure 8 Island itself, since previous data had covered a much wider area. **Brad** answered that the DEIS dies include data obtained from within the entire Permit Area including Hutaff Island.

Brad then described CPE-NC's effort to determine the acreages of various marsh and fringing terrestrial community types. These biotic communities were hand-digitized and delineated using high resolution aerial photography and ArcView GIS. These results will be used as baseline acreages within the Permit Area. (*Acreages of biotic communities were presented and can be reviewed in the presentation distributed with these minutes.*)

Ken Willson (CPE-NC) then reviewed the results of a recent sidescan sonar survey targeting potential hardbottom resources offshore of Figure Eight Island and Rich Inlet. Two (2) potential hardbottom communities had been previously identified by Dr. William Cleary (UNCW) offshore from Figure Eight Island. The recent sidescan survey included portions of one of these areas based on a 500-m buffer applied to Alternative 3 – Channel Relocation with Beach Nourishment. **Ken** explained that the results did not reveal any obvious high-relief hardbottom resources, however some areas were identified as "ripple scour" features which typically prove to contain unconsolidated material composed of shell hash and broken shells with a sand fraction. These features will be groundtruthed via SCUBA diving to ensure that no hardbottom resources exist within the surveyed area. **Dr. Cleary** suggested that some sporadic gorgonian stands may be located within the nearshore area and due to the ephemeral nature of these communities sidescan survey would have to be repeated. **Ken** responded that the sidescan and groundtruthing efforts should suffice as verification. **Mike Giles** (NCCF) asked **Ken** to describe the rationale for the 500-m buffer around the borrow area and asked if a the proposed dike should also contain a buffer area. **Ken** explained, according to the State rules only the areas to be dredged would need to include a buffer, not areas of disposal.
(*For reference, the NC State rule describing the 500-m buffer can be found at: http://ncrules.state.nc.us/ncac/title%2015a%20%20environment%20and%20natural%20resources/chapter%2007%20%20coastal%20management/subchapter%20h/15a%20ncac%2007h%20.0208.pdf*)

Ken continued to discuss the recent sidescan survey investigation and noted that the Wild Dayrell wreck was sidescanned and was then incorporated into the Project GIS database. The sidescan image of the wreck overlaid with the magnetic anomalies identified in the cultural resource investigation in 2006, indicating the wreck has not moved in three (3) years.

Molly Ellwood (NC WRC) asked if any benthic sampling has been conducted. **Mickey** stated that permit conditions could include pre- and post- construction monitoring for benthics. **Chris** stated that benthic infauna data has been collected along the southern portion of Figure Eight Island in response to the Mason Inlet relocation project. CPE-NC will coordinate with New

Hanover County and Jim Iannucci to acquire this data. **Jack Spruill** (PenderWatch) asked if there was a concern with box crabs, however, **Molly** indicated that this species was not a concern. **Rich** mentioned that some live bottom had been identified within Rich and Green Channel, however this was anecdotal and data does not exist. **Rich** also indicated that NCDMF has not updated shellfish maps for Rich Inlet and the data used by CPE-NC during the field investigation is the most recent. **Mickey** mentioned that due to the dredge events in Nixon Channel, these resources may no longer be present. **Chris** agreed and said that no live bottom has ever been recovered during dredging events in Nixon Channel. **Rich** also suggested that CPE-NC explore the marsh fringe for oyster habitat. **Dawn** reiterated that CPE-NC's mapping of the low marsh should suffice to determine the extent of this shellfish habitat type.

Mickey then reviewed the project alternatives. These include 1) No Action, 2) Abandon/Retreat, 3) Channel Relocation with Beach Nourishment (with or without the dike), 4) Beach Nourishment with Alternate Sources of Material (offshore borrow sites and other borrow sites), and 5) Terminal Groin with Beach Nourishment (with maintenance from various sources and without maintenance). **Mickey** reiterated that the applicant identifies the preferred alternative, not the Corps. If the applicant states that the terminal groin is their preferred alternative in the EIS and if the State denies the use of a terminal groin, the applicant may have to reapply using another preferred alternative. **Mike Giles** asked if this project was going to go to construction this upcoming winter. **David** responded that it certainly would not. Rather, the targeted timeline is the next two or three years. **Mike** asked if another PDT meeting will be held to discuss the alternatives, specifically the terminal groin alternative. **Mickey** replied that yes, more than likely another PDT meeting will be held to discuss issues and concerns. He continued by reiterating that Figure Eight Island approached the Corps on their intent to complete research on the terminal groin and since there is a push in the legislation this alternative will be evaluated more thoroughly than other projects have done in the past.

Tom Jarrett (CPE-NC) then presented detailed information regarding the project alternatives. He first discussed Alternative 4 which includes other sources of beach fill aside from material from Rich Inlet and Nixon Channel. **Tom** described that the offshore borrow areas described by Dr. Cleary appear to be impractical due to the cost of hauling the material from these locations (3-4 miles offshore). Furthermore, the characteristics of the material has not been determined. The other areas considered include material from Mason Inlet. The majority of this material is placed along the southern half of Figure Eight Island. Three (3) upland disposal sites along the Intracoastal Waterway were also investigated. The quality of this material is a bit finer than what is found on the native beach and the volume is inadequate (approx. 500,000 cubic yards) and therefore has been determined to be impractical as well. Upland sites (sand pits near Wallace, NC) were also explored. The cost of transporting the material via truck haul and the potential for damage to the bridge at Figure Eight Island would make this sand source impractical. **Molly** asked if a barge could be utilized to transport the upland material, thereby avoiding utilizing the bridge. **Chris** stated that inadequate draft of Nixon Channel would make that option impractical. **Chris** then asked if a similar truck haul methodology used for Mason Inlet could be used for the north end of Figure Eight Island. **Tom** stated that due to environmental concerns that would be an impracticable methodology. **Howard** stated that Rich Inlet and the northern 1/3 mile of Figure Eight Island is designated as Critical Wintering Habitat for Piping Plover. Referring back to the feasibility of utilizing the offshore borrow areas, **Ken**

noted that simply placing material on the beach without alleviating the erosion problem via channel relocation or a terminal groin would be futile due to the high erosion rates. **Tom** stated that the vast majority of recent nourishment efforts have been unsuccessful as the material erodes at a rate of 300,000 or 400,000 cy per year.

Tom briefly discussed the location of the two erosion hot spots on Figure Eight Island. One is located on the back side of the northern portion of the island along the Nixon Channel shoreline. The other is located on the northern oceanfront shoreline. Tom then described the various channel modification options including the various channel alignments proposed as well as the inclusion of a dike. The preferred option for Alternative 3 includes a short connection into Green Channel and Nixon Channel along with a dike. A dike is needed to ensure that the new channel becomes established within a short time period. Modeling results suggested that without the dike, the two channels would compete for flow and would take up to 4-5 years to merge into the new channel. **Molly** asked if the height of the dike was explored. **Tom** answered that it has been and following experience with the dike utilized at Bogue Inlet led to this design. Access onto the privately owned Hutaff Island was also discussed. **David** mentioned that the representatives from the Hutaff family are aware of the proposed project and mentioned that the dike could theoretically be built without accessing the island. **Steve Everhart** (NC DCM) mentioned that during the permitting phase, adjacent property owners must be notified of the proposed project and are given an opportunity to comment. **David** stated that the representatives of the Hutaff family are on the PDT, although they have not attended any of the meetings to date. **Dr. Cleary** stated that the Hutaff family should be happy with the project due to extensive erosion on the south end of Hutaff Island. **Molly** asked if the proposed channel alignment would increase shoaling into Green Channel. **Tom** replied that the connector would actually increase flow into Green Channel, thereby reducing shoaling. **Molly** asked if Green Channel was a Primary Nursery Area (PNA) and **Rich** replied that it was not. **Steve** mentioned that sand bags protecting the homes along the north end of the island must be removed rather than buried during construction. **Tom** asked if they could be buried and planted with vegetation. **Steve** confirmed that would not be permissible. **David** added that Figure Eight Island's goal would be to remove the sandbags regardless. **Mickey** stated that no fill was placed on sandbags during the construction of the Bogue Inlet project and the sand spit has naturally filled in around the bags.

Tom then asked the PDT "what do you think a terminal groin is?" **Howard** answered "a small jetty". **Jim Bushardt** (New Hanover Conservancy) stated that a terminal groin is "a low groin that ends just at the ebb on the ocean side". **Mickey** stated that in his opinion, the biggest concern with the terminal groin alternative includes a hard structure on the beach and this could potentially open the door for other structures at other locations. **Tom** responded by stating that the legislation does not allow for a proliferation of hard structures up and down the coast and as a representative of NCBIWA, would not recommend that. **Ken** added that for the purposes of this PDT meeting, the legislation should not be the focus of the discussions. Rather, we are seeking specific concerns regarding impacts to the environment and the biological resources. **Mike** asked why the term "terminal" was applied to the nomenclature of a terminal groin. **Tom** explained that it is due to the position of the groin at the terminal end of a littoral cell. In this case, the end is Rich Inlet. **Brad** then distributed a handout with a list of publications containing information regarding impacts to biological resources with respect to groins, terminal groins, and rubble structures. He encouraged the PDT to review this and submit any additional citations so this information can be included in the DEIS and other associated documents. **Howard** stated that nesting habitats on either side of the inlet should be evaluated in the DEIS. **David** stressed that he would also encourage the PDT to raise their concerns over the terminal groin alternative so that they can be addressed in full in the DEIS. He reiterated that Figure 8 Homeowners Association wants a thorough review of all alternatives and will rely on the evaluation of the ecological impacts to determine the appropriate course of action. **David** gave a brief summary of the language of the terminal groin legislation, but interjected that the focus of this meeting should not revolve around the legal issues regarding the legislation. **Howard** asked if the structure could be a navigation concern in which he then referenced boating accidents in SC due to the presence of jetties. **Mickey** said yes it could be, it is a public interest factor that would be evaluated. **Rich** asked what the size of the groin will be in which **Tom** replied we will get to that further in the presentation. **Ken** requested for all PDT members to please submit their concerns regarding the terminal groin soon so that they can be incorporated into the DEIS. **Molly** asked if the power point presentations would be made available. **Mickey** said yes.

Howard asked Tom to define the technical difference between a groin and a groin field. **Tom** showed a photo of South Beach on Bald Head Island as an example of a groin field. **David** stated that a groin field is not proposed. **Tom** explained that both tidal and wave induced currents facilitate the transport of sand into Rich Inlet which causes the high rates of erosion on the north end of Figure Eight Island. Furthermore, there is a nodal point along the stretch of beach where the sandbags are located causing erosion as well. He explained that the proposed terminal groin is not intended to manage the entire beach fill area; only the northern 3,000 feet of the island. Additionally, it does not remove the need for beach nourishment. Rather, it facilitates the feasibility for material to remain on the beach within the accretion fillet. **Mickey** asked if nourishment would only occur south of the nodal zone. **Tom** stated that it could, but in this case, the proposed plan includes material placed within the accretion fillet. Once the accretion fillet is formed, no additional accumulation of transported sand will occur. The rate of transportation would occur at its current rate. **Dawn** asked **Tom** to define what an accretion fillet is for the sake of the PDT. **Tom** then showed the Pea Island terminal groin and described where the accretion fillet is located and described its function. **Mickey** added that the size and extent of the accretion fillet is generally controlled by the length of the groin. **Tom** further described the history of the terminal groin at Pea Island and explained how it has performed. **Ken** asked if it is possible to quantify if the erosion occurring 6 miles down the coast from Pea Island is in response to the terminal groin. **Tom** answered that the erosion in that area is unrelated to the terminal groin.

Tom proceeded to show the PDT the options currently under development regarding the terminal groin alternative. The relative scale of the proposed terminal groin was shown with respect to the jetties located at Masonboro Island. The proposed terminal groin would extend approximately 330 feet seaward from mean high water. A longer terminal groin has also been considered, however, at this time, the shorter groin will suffice. Construction material would initially be sheet pile, however, if deemed to be successful and is to be made permanent, it would be buried with rock rubble. **Molly** asked what the height of the groin would be. **Tom** answered that it would be +6 NAVD, which is the natural berm elevation. It was asked if a wooden pier would be used during the construction phase of the groin. **Tom** responded by stating that typically a construction trestle would be utilized. The groin was also described to include a phased shoreline anchoring feature extending along the Nixon shoreline. This would be constructed only if the dredging in Nixon Channel and the inlet gorge failed to alleviate the erosion along the Nixon Channel shoreline. **Mickey** stated that the perpendicular feature would not be a groin, rather a seawall. **Chris** stated that it was an integral feature of the terminal groin to ensure its integrity. **Tom** explained the anchor structure was only a concept and would not necessarily be included in the alternative. **Molly** asked if there were two groins proposed, referring to the figure shown. **Tom** ensured that they were only the two options and the plan would only call for the construction of one groin. **Dawn** asked if the terminal groin did not include the shoreline anchoring portion, would the integrity of the terminal groin be held. **Tom** agreed that it would, however some scouring could potentially occur along Nixon Channel shoreline. **David** confirmed that the alternative includes placing material along this portion of the Nixon shoreline as well.

The channel dredging options for the terminal groin were discussed next. **Tom** described the three options which included three different dredging footprints within Nixon Channel extending into the inlet gorge. The purpose of this would be to remove the erosion pressure along the Nixon Channel shoreline. The three (3) dredging options varied in volume ranging from a bit over 1 million cubic yards to approximately 785,000 cy. **Howard** asked if the sheet pile in the shoreline anchoring portion of the terminal groin would extend above mean high water. **Tom** confirmed that it would, however, upon further consideration; this feature of the terminal groin may not be included in the alternative. **Howard** mentioned that section of shoreline is designated as critical habitat for piping plovers. **Tom** reviewed modeling results and suggested that option 2, the medium sized footprint, would probably be the recommended option for the terminal groin alternative. **Dr. Cleary** asked if the modeling included the impact of storms. **Tom** answered by stating that the modeling does include 5 years of various wave conditions. **Ken** mentioned that an elevated wave condition was placed into the model simulating a 20-year storm. **Tom** stated that he would confirm this. **Tom** asked Mickey if it would be best for the applicant to include the dimensions of the longest terminal groin option in the permit application. **Mickey** stated that the longest option should be included in the permit.

Mickey asked what additional modeling work needs to be done to design the terminal groin alternative. **Tom** responded the modeling has been completed. **Molly** asked if the terminal groin could cause increased erosion in response to a storm event due to reflective energy. **Tom** answered that the exposed area of the terminal groin could allow for additional reflective energy on the inlet side, but not on the south side. If the structure proves to be effective, it will be buried under stones which will have permeability. **David i**nterjected that the fillet would be filled simultaneously as the terminal groin was constructed. Tom suggested that there may be a delay of several months. It was added that the Pea Island accretion fillet filled in within 9 months to a year naturally. **Howard** reiterated that a biological monitoring program would be strongly recommended in response to this project and may need to go into formal consultation with USFWS. **David** replied that the Corps and the State would require this sort of monitoring in the permit conditions. **Howard** added that the biotic community mapping using aerial photography would be a good tool to assess change. **Rich** commented that there may be a concern with larval transport into the inlet due to the terminal groin, however he noted that he did not think it would be a major problem due to the relative small size of the structure. **Tom** confirmed with Ron Sechler (NMFS) that there were studies regarding larval transport in proximity to the terminal groin in Beaufort Inlet. A participant asked if the terminal groin would lessen the requirement for nourishment along Figure Eight Island. **Tom** confirmed that the terminal groin alternative would require roughly half as much renourishment as the channel alignment alternative.

Mickey stated that the meeting minutes would be distributed soon and the presentations would be made available as well. **David** requested that any additional data or information should be submitted to **Mickey**, while **David** would be happy to discuss any legislative issues with any participants. **Mickey** then adjourned the meeting at 2 pm.

ATTENDEES

NAME	REPRESENTING	CONTACT INFORMATION
Brad Rosov	CPE-NC	brosov@coastalplanning.net
Mickey Sugg	COE	mickey.t.sugg@saw02.usace.army.mil
Bill Cleary	UNCW	wcleary@charter.net
Dawn York	CPE-NC	dyork@coastalplanning.net
Don Ellson	Pender Watch	ellsond@bellsouth.net
Jack Spruill	Pender Watch	jsprull@aol.com
Bill Raney	FEI Homeowners Assoc.	waraney@bellsouth.net
Jim Iannucci	New Hanover County	jiannucci@nhcgov.com
Ron Sechler	NMFS	ron.sechler@noaa.gov
Howard Hall	USFWS	howard_hall@fws.gov
David Kellam	FEI Homeowners Assoc.	david@figure8homeowner.com
Molly Ellwood	NC WRC	molly.ellwood@ncwildlife.org
Ken Willson	CPE-NC	kwillson@coastalplanning.net
Mike Giles	NCCF	capefearcoastkeeper@nccoast.org
Margo O'Mahoney	FEI Homeowners Assoc.	momahoney@bizec.rr.com
Tom Jarrett	CPE-NC	tjarrett@coastalplanning.net
Fritz Rohde	NCDMF	fritz.rohde@ncmail.net
Holley Snider	NC DCM	holley.snider@ncdenr.gov
Steve Everhart	NC DCM	Steve.everhart@ncdenr.gov
Chris Gibson	GBA	clgibson@gba-inc.com
Ben Andrea	Pender County	andreab@pender-county.com
Jim Bushardt	New Hanover Conservancy	bushardt@bellsouth.net
Rich Carpenter	NC DMF	Rich.carpenter@ncdenr.gov
Jim Iannucci	New Hanover County	jiannucci@nhcgov.com
Jim Milne	Pender Watch	milnejim@elive.com

Sub-Part 2

Pertinent Correspondence

From: MANGIAMELI, Angela
To: Dawn York;
cc: Brad Rosov;
Subject: Topsail/Lea Islands
Date: Tuesday, February 05, 2008 9:48:38 AM
Attachments: sea turtle crawls.xls
Good_nests_2007_L-H.xls
seabeach amaranthus.xls

Hi Dawn,
I have compiled all the GPS for shorebird nests and seabeach amaranthus for 2007, I also made a note of nesting least terns on Lea but I don't have GPS for each nest. I have also included sea turtle nests for 2006, I don't have any data for 2007 as I think it was a slower year and their numbers sometimes cycle so we'll see what is out there in 2008. Just some background Lea and Hutaff Islands are monitored daily to every other day from May-August-early September for Piping Plovers (this Island represents the southern most point of their breeding range), American Oystercatchers and Wilson's Plovers. In addition piping plover, Wilson's plover along with least, and common terns and black skimmers nest on the southern point of Topsail Island (Sue Cameron may have that data).

Weekly shorebird surveys are conducted at 2 inlets sites: Rich Inlet and the southern portions of Hutaff Island, and Topsail Inlet and the northern portion of Lea Island and the southern portion of Topsail Island. On both ends the entire inlet system including all the shoals are surveyed and used by migrating and wintering shorebirds, especially wintering piping plover. Topsail Inlet has likely the highest concentration of wintering piping plovers in one location ~15. In addition banded birds (PIPL) are resighted throughout fall/spring migration and all of winter. Several individuals remain and winter here and use that system. Banding data is critical to understanding where these birds go and for how long they stay at which habitats and therefore to understand what habitat they require that should be protected. The shoals in the inlet and on the sound side of Topsail Island provide valuable feeding grounds while the Island itself is crucial for roosting periods. These surveys are conducted from mid-August through mid-May but not during the peak breeding season as all focus is turned towards the nesting shorebirds.

I hope this information helps please let me know if I can be of anymore assistance.

Thanks,
Angela

Angela Mangiameli
Conservation Biologist
Audubon North Carolina

7741 Market Street, Unit D
Wilmington, NC 28411-9444
Tel: 910-686-7527
Fax: 910-686-7587
amangiameli@audubon.org

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From:	Stephen Taylor
To:	Brad Rosov;
cc:	jim.m.kelley@ncmail.net;
Subject:	Re: GIS data set
Date:	Monday, May 05, 2008 10:05:21 AM
Attachments:	Stephen_Taylor.vcf

Brad,

Below is definition of a Oyster (Shellfish) and Seed Management area directly from our Rule Book. I use the words Shellfish and Oyster interchangeably in talking about Shellfish Management areas or Oyster Management areas. We only have one or two Seed Management areas in our district and they are loctated near Virginia Creek in Pender County. The text below was taken from our website: www.ncdmf.net under our Enforcement section, under downloads. I believe it started on page 39.

I am copying our Marine Patrol Captain, just in case you have any other "official" questions. I'm sure Officer Kelly would be more than happy to answer any questions pertaining to these areas.

If I can be of any more assistance, please don't hesitate to call or email me. Have a good day.

Regards,

stephen

North Carolina
Administrative Code
Title 15A
Department of Environment
and Natural Resources
Chapter 3 Marine
Fisheries
Subchapter 3K - Oysters,
clams, scallops and mussels
Section .0100 - Shellfish,
General

.0103 SHELLFISH OR SEED
MANAGEMENT AREAS
(a) The Fisheries Director
may, by proclamation,
designate Shellfish
Management Areas which
meet any of the following
criteria. The area has:
(1) Conditions of bottom
type, salinity, currents,
cover or cultch
necessary for
shellfish growth;
(2) Shellfish populations
or shellfish enhancement
projects which may
produce commercial
quantities of shellfish at
ten bushels or more per
acre;
Page 40 3K .0103 - .0104
(3) Shellfish populations
or shellfish enhancement
projects which may
produce shellfish suitable
for transplanting as seed
or for relaying from
prohibited (polluted) areas.

(b) It is unlawful to use a trawl net, long haul seine, or swipe net in any designated Shellfish or Seed Management area. These areas shall be marked with signs or buoys. Unmarked and undesignated tributaries shall be the same designation as the designated waters to which they connect or into which they flow. No unauthorized removal or relocation of any such marker shall have the effect of changing the designation of any such body of water or portion thereof, nor shall any such unauthorized removal or relocation or the absence of any marker affect the applicability of any rule pertaining to any such body of water or portion thereof.

(c) It is unlawful to take oysters or clams from any Shellfish Management Area which has been closed and posted, except that the Fisheries Director may, by proclamation, open specific areas to allow the taking of oysters or clams and may designate time, place, character, or dimensions of any method or equipment that may be employed.

(d) It is unlawful to take oysters from Seed Management Areas for planting on shellfish leases or franchises without first obtaining a Permit to Transplant Oysters from Seed Management Areas from the Fisheries Director. The procedures and requirements for obtaining permits are found in 15A NCAC

03O .0500.
History Note: Authority G.S. 113-134; 113-182; 113-221; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. March 1, 1994;
Temporary Amendment Eff. October 1, 2001;
Amended Eff. April 1, 2003.

.0104 PERMITS FOR PLANTING SHELLFISH FROM PROHIBITED/ POLLUTED AREAS

(a) It is unlawful to take oysters or clams from prohibited (polluted) public waters for planting on leases and franchises except as authorized by G.S. 113-203. Lease and franchise holders shall first obtain a permit from the Fisheries Director setting forth the time, area, and method by which such shellfish may be taken. The procedures and requirements for obtaining permits are found in 15A NCAC 03O .0500.

(b) The season for relaying clams shall be between April 1 and May 15 and the season for relaying oysters shall be for a specified six week period between the date of the statewide closure of oyster season and June 30, as determined by the Fisheries Director based on the status of oyster resources available for harvest from public bottom and market factors affecting sale of oysters from public bottom which will assist in determining the statewide closure date and manpower available to monitor the relaying activity.

(c) For areas designated by the Fisheries Director as sites where shellfish would otherwise be

destroyed in maintenance dredging operations, the season as set out in Paragraph (b) of this Rule shall not apply.
(d) The Fisheries Director, acting upon recommendations of the Division of Environmental Health, shall close and reopen by proclamation any private shellfish beds for which the owner has obtained a permit to relay oysters and clams from prohibited (polluted) public waters.
History Note: Authority G. S. 113-134; 113-182; 113-203; 113-221; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. March 1, 1996; September 1, 1991;
Temporary Amendment Eff. October 1, 2001;
Amended Eff. April 1, 2003.

Brad Rosov wrote:

Stephen,

Actually, I do have a request for you- I have a general understanding of what these OMA's represent, however I am curious if there is either a document or an "official" description of these sites and how they were determined and what their designation means? Even if you are able to write me a paragraph or two it would be helpful as I would like to be as accurate as possible as we incorporate this information into the our EIS.

Thanks again for your help with this!

Regards,
Brad

From: Stephen Taylor [mailto:Stephen.Taylor@ncmail.net]
Sent: Monday, May 05, 2008 8:35 AM
To: Brad Rosov; Mark Voss
Subject: Re: GIS data set

Thanks Mark for getting this to Brad. If I can do anything for clarification, please let me know.
stephen

Brad Rosov wrote:
I've passed this off to our GIS folks- I'll be in touch if we have any questions. Thanks again for your help...

Regards,

Brad

-----Original Message-----
From: Mark Voss [mailto:Mark.Voss@ncmail.net]
Sent: Friday, May 02, 2008 2:11 PM
To: Brad Rosov
Cc: Stephen Taylor
Subject: Re: GIS data set

-----Original Message-----
From: Mark Voss [mailto:Mark.Voss@ncmail.net]
Sent: Friday, May 02, 2008 2:11 PM
To: Brad Rosov
Cc: Stephen Taylor
Subject: Re: GIS data set

Mr. Rosov,

Attached is a ESRI shapefile of the 4 locations around the inlet. The GIS file is polygon, and has a NC State Plane projection, NAD83 datum, and meters for units. The attribute file id's more information about the data. If you have any questions, please contact me.

Have a good day,
Mark

Mark Voss
GIS Program
NC Marine Fisheries
1-800-682-2632
mark.voss@ncmail.net

Brad Rosov wrote:

Hi Mark,

Thanks for getting in contact with me. Ideally, the polygons of the areas will suit us best. I do not think we will have a problem accepting a zipped verion of the ArcView files, but I'm not the most savy computer guy. Please give it a try and if it bounces back we can look into other methods (i.e. we have an ftp site).

Thanks again for your help,

Brad Rosov
Marine Scientist
Coastal Planning & Engineering of North Carolina, Inc.
Marine Science & Biological Research Dept.
330 Shipyard Blvd.
Wilmington, NC 28412
910.791.9494 (O)
910.791.4129 (F)
www.coastalplanning.net

-----Original Message-----
From: Mark Voss [mailto:Mark.Voss@ncmail.net]

Sent: Friday, May 02, 2008 1:26 PM
To: Brad Rosov; Stephen Taylor
Subject: GIS data set

Mr. Rosov,

I was asked by Stephen Taylor to get a GIS shape file for you.

1. do you want the polygons of areas, or lat/longs in a point file?
2. Are you able to accept ArcView shape files in a .zip format? I know

some systems are not allowed to receive some attachments with certain file extensions.

Mark Voss
GIS Program
NC Marine Fisheries
1-800-682-2632
mark.voss@ncmail.net

From:
John Gerwin
To:
Brad Rosov;
cc:
Megan Demers-Schaefer; walker Golder; StaceyAnn Roach;
Subject:
Re: mason inlet
Date:
Sunday, May 18, 2008 6:19:44 PM

Brad, I'm headed to the field for a couple weeks. I"m cc'ing folks here who might be able to pinpoint these sites. Walker/Audubon NC manages Lea/Hutaff and they keep records for the most part, for that property. Figure Eight is known to have had PABU, and I presume still does. Megan can check to see if we've had any reports from that locality. As best I recall, Derb Carter/family have property on that island, and he's told me about PABU there. As for the general county references, again Megan can check. If there are particular "towns", let her know, although I guess we're looking at Wrightsville up to ~Annandale/south Topsail Island. The birds are known to occupy the ICW "shrub/scrub" habitat from Wilmington on up to Morehead City. To what extent we don't know. If there are some particular spots you want checked, let us know. I'm also cc'ing Stacey Roach here; she is doing PABU surveys for us this spring. She is planning on doing some ICW work but from Wrightsville south. Perhaps they could foray north a bit ("they" = her plus a biologist with Audubon NC via Walker). best, John
Brad Rosov wrote:

John,
I am writing to you in search of additional data regarding the painted bunting. We are now interested if any observations have been made in the proximity of Rich Inlet-either on Figure Eight Island or Lea/Huttaff Island in recent years. Really, any observations along the coast within the northern part of New Hanover County or southern Pender County would be helpful. Any ideas?

Thanks,

Brad Rosov
Marine Scientist
Coastal Planning & Engineering of North Carolina, Inc.
330 Shipyard Blvd.
Wilmington, NC 28409
(910) 791-9494
brosov@coastalplanning.net

From: Harry LeGrand, Jr.
To: Brad Rosov;
Subject: Re: Diamondback terrapin
Date: Friday, May 23, 2008 9:11:19 AM
Attachments: terrapin-lea-hutaff.pdf

Brad:
We have a lot of records for coastal New Hanover, but from Wrightsville Beach southward. There is an older, non-specific report from Lea-Hutaff, which I have attached.

As the species is reasonably widespread in coastal waters, and really isn't that rare, you should assume it is present in the project area.

Harry

Brad Rosov wrote:
>
> Hello Harry,
>
>
>
> I am working on compiling data for an EIS being developed for the
> Figure Eight Island Shoreline and Inlet Management Project. I was
> wondering if you know of any occurrences of the Carolina Diamondback
> Terrapin recorded within the project vicinity, which basically
> encompasses the majority of Figure Eight Island and Lea/Hutaff Island
> and many of the tidal creeks and marshlands behind these islands.
>
>
>
> Thanks for your help,
>
>
>
> Brad Rosov
>
> Marine Scientist
>
> Coastal Planning & Engineering of North Carolina, Inc.
>
> 330 Shipyard Blvd.
>

> Wilmington, NC 28409
>
> (910) 791-9494
>
> brosov@coastalplanning.net
>
>
>

From: Kelley, Roger
To: Brad Rosov;
Subject: Figure 8 Island
Date: Friday, July 11, 2008 12:59:00 PM

Brad,

I was given your fax where you were asking for the cumulative tax value of all homes and vacant lots on Figure 8. Below is that number:

$1,189,810,926

This is just the TAXABLE value out there.

If I you need any further info feel free to contact me.

Roger L Kelley

Tax Administrator
New Hanover County
230 Government Center Drive Suite 190
Wilmington, NC 28403
(910) 798-7368
(910) 798-7310 Fax
rkelley@nhcgov.com

From: Sugg, Mickey T SAW [Mickey.T.Sugg@saw02.usace.army.mil]
Sent: Monday, September 08, 2008 9:16 AM
To: Fritz Rohde; Ron Sechler; Howard_Hall@fws.gov; Doug Huggett; Molly Ellwood
Cc: Ken Willson; Dawn York; David Kellam
Subject: FW: Hardbottoms off Figure Eight

Attachments: Review of Cleary Data.pdf

Morning all-
CP&E has provided historic data depicting presence of HB in proximity to Figure Eight & Rich Inlet. Two PDT meetings ago, we briefly discussed the need to conduct side scan sonar for HB. At the time, I stated that they had to side scan around the inlet, but only recommended them to survey the entire ocean shoreline (since this would aid in all future island projects). Apparently, there is a big financial difference between just surveying the inlet and surveying the entire shoreline. Figure 8 is at a point in their planning schedule where they need to run the side scan and need to know where and how much.

Please note that the attachment depicts the channel relocation alternative only, and not a potential terminal groin. I am presuming that the permit area will not change if a groin becomes the preferred, but for any reason the groin does change the footprint of the permit area, we will reconsider if additional side scan is required. Not knowing the construction dimensions and overall effects of the groin, I don't think we can make that decision at this time (Ken, correct me if I am wrong).

I remain committed in requiring the inlet sonar, but at this time, I need feedback from you if they will be required to scan the ocean shoreline. If you would think about this and let me know one way or the other, then I'll pass it on to Figure 8 so they can finalize their plan.

Thanks for your time,
-Mickey

From: Ken Willson [mailto:Kwillson@coastalplanning.net]
Sent: Friday, September 05, 2008 11:10 AM
To: Sugg, Mickey T SAW
Cc: Dawn York
Subject: Hardbottoms off Figure Eight

Good morning Mickey,

Looks like we might get some wind and rain here? Please find attached a map that we have created which depicts the offshore areas identified by Dr. Cleary as historic "hardbottom". What he is referring to are areas that were identified with sidescan sonar and ground truthed by geologist. Dives confirmed the presence of exposed rock outcrops. The rock offshore Figure Eight Island was mapped as Limestone, where the rock located offshore of Rich Inlet was said to be siltstone. The siltstone is much less resistant to erosion (erodes faster) suggesting it may not be as stable a habitat for colonization as limestone.

For display purposes we have added a 500 m buffer around these rock outcrops. We have also included on the maps, the Equilibrium Toe of Fill (point to which the sand would equilibrate out to), and the boundary of the permit area as currently drawn.

Please pass this info along to interested parties as we are waiting for you to make a determination as to whether or not additional sidescan data should be collected along the shoreline within the project area and in the vicinity of the ebb tidal delta off Rich Inlet.

If you have any questions on the data please feel free to call me. I have spoken with Dr. Cleary at length about the data and actually helped him collect some of it.

Regards,

Ken Willson
Project Manager / Coastal Geologist

Coastal Planning & Engineering of North Carolina
www.coastalplanning.net
4038 Masonboro Loop Rd.
Wilmington, NC 28409
Phone (910) 791-9494
Mobile (910) 443-4471
Fax (910) 791-4129

Dawn York

From: Tom Jarrett
Sent: Tuesday, September 09, 2008 11:08 AM
To: Sugg, Mickey T SAW; Ken Willson; Dawn York; David Kellam
Subject: RE: PDT Meeting
Attachments: Inlet response to new channel.doc

Mickey,

The purpose of the channel relocation is to create a new ebb tide delta configuration that is comparable to the 1993 inlet configuration, i.e., the rebuilding of the south portion of the delta to provide wave protection to the north end. The figure in the attached shows the predicted inlet reconfiguration after 5-years following the channel realignment. The white outline is the configuration of the inlet in March 1993, which is basically the target configuration associated with the channel realignment.

The equilibrium toe of fill follows the -24-foot NAVD depth contour and represents the theorectical seaward limit of cross-shore profile adjustments with the fill assuming the fill material has the same size characteristics as the native. Obviously, the -24-foot contour protrudes seaward at the north end due to the existing ebb tide delta. In any event, the seaward protrusion of the -24-foot contour and the assumption some of the fill material may migrate to this depth would only contribute to and possibly hasten the reconfiguration of the ebb tide delta toward the target.

Our preliminary assessment of the material in Rich Inlet indicates it is coarser than the native (0.18 mm for Fig 8, 0.24 mm for Rich Inlet). Therefore, the theorectical toe of fill with the Rich Inlet material will fall short of the -24-foot depth contour. Once we have the final inlet composite characteristics, we will re-do the equilibrium toe on the drawings.

Hope this helps clarify. Pass along to Ron and Fritz if you want.

Tom

From: Sugg, Mickey T SAW [mailto:Mickey.T.Sugg@saw02.usace.army.mil]
Sent: Tue 9/9/2008 10:57 AM
To: Ken Willson; Dawn York; David Kellam; Tom Jarrett
Subject: RE: PDT Meeting

My direction is to survey the shoreline within the Permit Area. Ron was probably assuming that the entire oceanfront was being affected. But, I will add that if any aspect of the project changes, or any additional information demonstrates the need to expand the permit area along the oceanfront, then the surveying will need to encompass the expansion. This also includes any future maintenance adjustments that would affect additional shoreline.

In Ron's e-mail, he brought up an interesting point regarding the toe of equilibrium. Does it go out that far, or is that just a conceptional depiction that is not to scale?
-Mickey

From: Ken Willson [mailto:Kwillson@coastalplanning.net]
Sent: Tuesday, September 09, 2008 10:28 AM
To: Sugg, Mickey T SAW
Cc: Dawn York; Tom Jarrett
Subject: RE: PDT Meeting

So Ron says do the entire Island and Fritz says the permit area which is the north half of the island. We were basically proposing to Figure Eight to do the northern nearshore section and the Inlet (Permit Area). Are you good with that? If so we will move forward with Figure Eight to complete this work.

Ken Willson
Project Manager / Coastal Geologist

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Phone (910) 791-9494
Mobile (910) 443-4471
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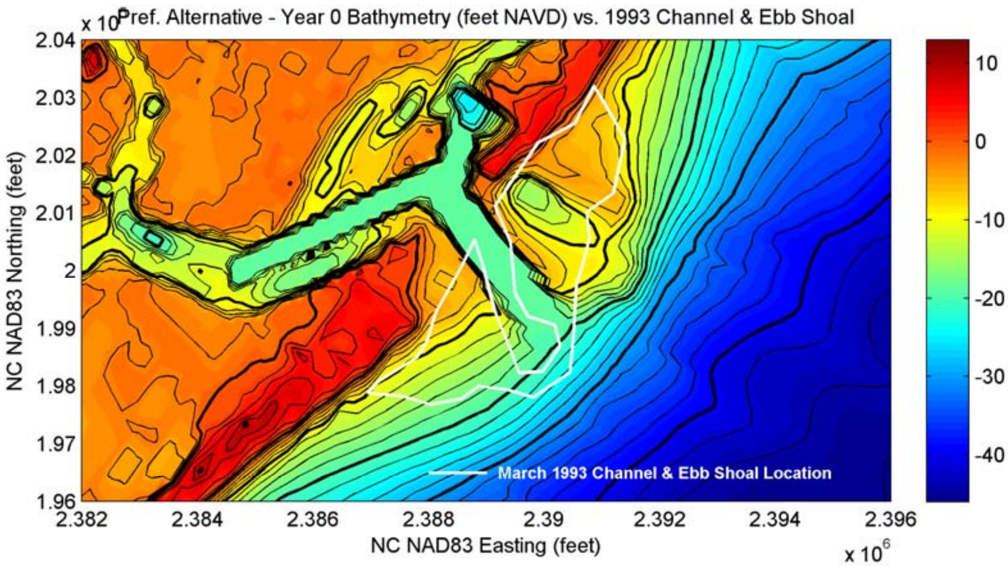
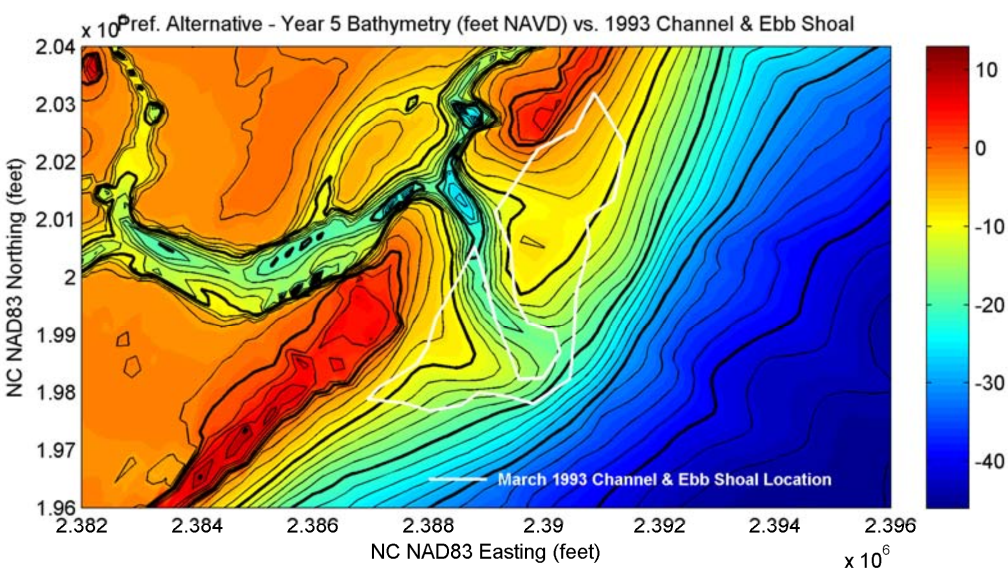


Pref. Alternative - Year 0 Bathymetry (feet NAVD) vs. 1993 Channel & Ebb Shoal
x 10^6
NC NAD83 Northing (feet)
2.04
2.03
2.02
2.01
2
1.99
1.98
1.97
1.96
2.382
2.384
2.386
2.388
2.39
2.392
2.394
2.396
NC NAD83 Easting (feet)
x 10^6
March 1993 Channel & Ebb Shoal Location
10
0
-10
-20
-30
-40



Pref. Alternative - Year 5 Bathymetry (feet NAVD) vs. 1993 Channel & Ebb Shoal
x 10^6
NC NAD83 Northing (feet)
2.04
2.03
2.02
2.01
2
1.99
1.98
1.97
1.96
2.382
2.384
2.386
2.388
2.39
2.392
2.394
2.396
NC NAD83 Easting (feet)
x 10^6
March 1993 Channel & Ebb Shoal Location
10
0
-10
-20
-30
-40

Dawn York

From: Sugg, Mickey T SAW [Mickey.T.Sugg@saw02.usace.army.mil]

Sent: Tuesday, September 09, 2008 10:58 AM

To: Ken Willson; Dawn York; David Kellam; Tom Jarrett

Subject: RE: PDT Meeting

My direction is to survey the shoreline within the Permit Area. Ron was probably assuming that the entire oceanfront was being affected. But, I will add that if any aspect of the project changes, or any additional information demonstrates the need to expand the permit area along the oceanfront, then the surveying will need to encompass the expansion. This also includes any future maintenance adjustments that would affect additional shoreline.

In Ron's e-mail, he brought up an interesting point regarding the toe of equilibrium. Does it go out that far, or is that just a conceptional depiction that is not to scale?
-Mickey

From: Ken Willson [mailto:Kwillson@coastalplanning.net]
Sent: Tuesday, September 09, 2008 10:28 AM
To: Sugg, Mickey T SAW
Cc: Dawn York; Tom Jarrett
Subject: RE: PDT Meeting

So Ron says do the entire Island and Fritz says the permit area which is the north half of the island. We were basically proposing to Figure Eight to do the northern nearshore section and the Inlet (Permit Area). Are you good with that? If so we will move forward with Figure Eight to complete this work.

Ken Willson
Project Manager / Coastal Geologist

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From: Margo O'Mahoney [momahoney@bizec.rr.com]
Sent: Thursday, July 02, 2009 3:32 PM
To: Brad Rosov
Subject: RE: Question for EIS

ok, the HOA classifies 97 lots as undeveloped.

this means that there is not a house on the lot. But, although this sounds odd, 4 lots of those 97 undeveloped lots actually have a house upon them.

that is because 4 of the houses are particularly large, and are centered on 2 adjacent lots. For HOA purposes, we count one of those lots as developed, and one as undeveloped for our annual assessment purposes....

So, to answer how many of our platted lots are "vacant" , I would say there are 93.

As far as "available" lots, not many are available, folks like to sit on them..... I just checked with our real estate broker down the hall. Of the 93 undeveloped lots, there are 16 for sale, listed either with her or with other realtors.

Of the 16 listed lots, please keep in mind that some are on the ocean, some on the sound side, some are buildable, some are not...so values range considerably... The lowest "listed" price is $800,000 and the highest is $2,400,000.

I get a mean price of $1,560,812 - based on listing price, which is a bit low right now due to the market.... also, this is not tax value.....

let me know if you need anything else...Margo

-----Original Message-----
From: Brad Rosov [mailto:Brosov@coastalplanning.net]
Sent: 7-02-09 2:13 PM
To: Margo O'Mahoney
Subject: Question for EIS

Hello Margo,

I was wondering if you may be able to provide me with a bit of information I'd like to incorporate into the Environmental Impact Statement we are developing for your beach nourishment project. I am seeking the number of available vacant lots on the island as well as their mean value. Does the F8 HOA track these figures? If not, I'll get in contact with the County…

Thanks so much- have a terrific holiday weekend!

Brad Rosov
Marine Scientist

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4038 Masonboro Loop Road
Wilmington, NC 28409
(910) 791-9494
brosov@coastalplanning.net

From: Lawrence, Richard [mailto:richard.lawrence@ncdcr.gov]
Sent: Tuesday, September 15, 2009 11:20 AM
To: Ken Willson
Cc: iimr@coastalnet.com; Henry, Nathan
Subject: RE: Proposed Cultural Resource Survey at Rich Inlet

Ken,

Nathan and I have looked over your plans and we feel that a cultural resource survey is warranted for the designated terminal groin area, both in the water and the upland area. We concur that a magnetometer survey would be the best way to examine the upland area. We base this recommendation on documented vessel losses in and around Rich Inlet and the fact that changes in the inlet may have resulted in vessel remains being buried beneath the upland areas.

Let me know if you have questions.

Richard

Richard W. Lawrence, Branch Head
Underwater Archaeology Branch
1528 Fort Fisher Blvd. South
Kure Beach, NC 28449
Phone: (910) 458-9042 ext. 204
Fax: (910) 458-4093

Please be aware that my new e-mail address is: richard.lawrence@ncdcr.gov

---

From: Ken Willson [mailto:Kwillson@coastalplanning.net]
Sent: Thursday, September 10, 2009 1:13 PM
To: Lawrence, Richard
Cc: iimr@coastalnet.com
Subject: Proposed Cultural Resource Survey at Rich Inlet

Richard,

It has been a few months since last we spoke about some questions regarding a beach nourishment project at Topsail Beach. CPENC is currently working with Gordon at TAR to plan a submerged cultural resource survey in the vicinity of Rich Inlet for a dredge and fill project. One of the questions that has arisen in our planning has to do with a proposed Terminal Groin at the north end of Figure Eight Island. The proposed design would drive steel sheet pile down to a depth of -27 ft. NAVD88 along the landward anchor section of the structure and down to -48 ft. NAVD88 along the seaward section. We were not sure of the requirements for Cultural Resource surveys for this proposed design. In the attached figure you will see the current proposed position of the structure (shown in black). We have not determined its exact placement and or length, which is why we have highlighted a corridor (orange outline) in which the final design will be confined. Our questions are whether or not a CR survey is required for the area where the structure is proposed, and specifically on the upland portion of the design? Gordon mentioned that he thought the only thing required on the terrestrial portion, if anything, would be a magnetometer survey. Please confirm if we are in the ballpark with our assumptions.

Sincere Regards,

Ken Willson
Project Manager / Coastal Geologist
Coastal Planning & Engineering of North Carolina, Inc.
4038 Masonboro Loop Rd
Wilmington, NC 28409
Office: (910) 791-9494
Cell: (910) 443-4471
Fax: (910) 791-4129

From: Lawrence, Richard [mailto:richard.lawrence@ncdcr.gov]
Sent: Wednesday, January 20, 2010 9:24 AM
To: Gordon Watts
Cc: Ken Willson
Subject: RE: Rich Inlet

Gordon,

This sounds like a reasonable approach to me and would satisfy our needs.

Richard

Richard W. Lawrence
Deputy State Archaeologist - Underwater

Office of State Archaeology
Underwater Archaeology Branch
1528 Fort Fisher Blvd. South
Kure Beach, NC 28449
Phone: (910) 458-9042 ext. 204
Fax: (910) 458-4093

Please be aware that my new e-mail address is: richard.lawrence@ncdcr.gov

---

From: Gordon Watts [mailto:iimr@coastalnet.com]
Sent: Monday, January 18, 2010 3:54 PM
To: Lawrence, Richard
Cc: Kenneth Willson
Subject: Rich Inlet

Richard,

we have been trying to find a weather/tidal window to survey Rich Inlet and the adjacent end of Figure Eight Island for Coastal Planning and Engineering (CPE). While we have carried out a mag survey of the end of Figure Eight Island getting across the bars associated with the inlet has proven to be difficult. I have attached a Hypack border file over a georeferenced aerial to show the location of Wild Dayrell, the mag survey coverage on Figure Eight and the shoals in the survey area.

After more than six weeks of waiting we have had no luck. I have attached an aerial photograph of the inlet with the proposed dredging limits identified. I would like to find out if we are able to survey what we can from the boat and walk the shoal areas with a hand held mag to identify targets and a hand held GPS to locate them, would that satisfy your requirements. We would not be able to contour the data but, we would be able to determine if there is anything that generates a magnetic anomaly in the area and define its location. We would also be able to plot our tracks across the shoals. We will continue to wait on weather and tides but if push comes to shove will this approach suffice?

Thanks for considering the approach.

Gordon

From: Webster, David [webste@uncw.edu]
Sent: Friday, January 29, 2010 9:57 AM
To: Brad Rosov
Cc: Kellam, David
Subject: RE: Figure Eight Island monitoring

Hi Brad,

Thanks for the email. I am indeed still conducting the endangered species monitoring on Figure Eight Island. This includes sea turtles on the ocean-facing beaches from 1 May until the last hatch each summer; piping plover (and other RTE colonial waterbird and shorebird species) throughout the year, focusing on the inlet areas, but also including the beaches (knot migrations for example); amaranth surveys during the summer months; and beach vitex, too. I'm hopeful that Figure Eight will keep me on the project in perpetuity, but that's not my call. They certainly understand the value of monitoring the RTE species, and we're happy to help them out.

Audubon does Hutaff Island. Contact Walker Golder (686-7527) if you need information from that side of the inlet. I believe they focus more on Piping Plovers, which nest on Hutaff (the southernmost nesting beach on the East Coast), and also other coastal bird species. I think they collect sea turtle and amaranth data, too.

Let me know if you need other information. Best, David

Wm. David Webster, Ph.D.
Associate Dean
College of Arts and Sciences
University of North Carolina Wilmington
Wilmington, NC 28403-5912
webste@uncw.edu (email)
(910) 962-3756 (phone)
(910) 962-3114 (FAX)
webste@uncw.edu/people/webste

From: Brad Rosov [mailto:Brosov@coastalplanning.net]
Sent: Friday, January 29, 2010 9:31 AM
To: Webster, David
Subject: Figure Eight Island monitoring

Hello Dr. Webster,

I am currently working on developed the EIS for the proposed Figure Eight Island Shoreline Management Plan and was wondering about the state of your long-term monitoring efforts on the island. Are you still engaged in turtle, seabeach amaranth, and bird monitoring? How long do you foresee this to continue? Finally, where, geographically do you monitor (i.e. the entire shoreline or only portions of the island… or even on Hutaff?)?

Thanks for your help!

Brad Rosov
Marine Scientist
Coastal Planning & Engineering of North Carolina, Inc.

4038 Masonboro Loop Road
Wilmington, NC 28409
(910) 791-9494
brosov@coastalplanning.net

From: Godfrey, Matthew H [matt.godfrey@ncwildlife.org]
Sent: Friday, January 29, 2010 12:23 PM
To: Brad Rosov
Subject: RE: turtle nest monitoring on Figure Eight and Hutaff

Hi Brad,
That's correct. Audubon does not do daily monitoring on Lea/Hutaff, but Webster and his group are doing daily monitoring on Figure Eight.
Matthew

From: Brad Rosov [mailto:Brosov@coastalplanning.net]
Sent: Friday, January 29, 2010 12:20 PM
To: Godfrey, Matthew H
Subject: turtle nest monitoring on Figure Eight and Hutaff

Hello Dr. Godfrey,

I am working to develop the EIS pertaining to the Figure Eight Island Shoreline Management Project and am seeking information regarding the current sea turtle nesting monitoring effort along the beaches of Figure Eight and Hutaff Islands. Am I correct in understanding that UNCW (under Dr. David Webster's direction) performs regular monitoring on Figure Eight and the Audubon Society conducts monitoring on Hutaff? Any other efforts in place?

Thanks!

Brad Rosov
Marine Scientist
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4038 Masonboro Loop Road
Wilmington, NC 28409
(910) 791-9494
brosov@coastalplanning.net

From: Tom Jarrett
Sent: Thursday, February 11, 2010 12:07 PM
To: Brad Rosov
Subject: FW: Seabeach amaranth, Figure 8, 2009

FYI

From: David Kellam
Sent: Thu 2/11/2010 11:57 AM
To: Tom Jarrett
Subject: FW: Seabeach amaranth, Figure 8, 2009
Just for your EIS notes.

David K.

From: Webster, David [mailto:webste@uncw.edu]
Sent: Thursday, February 11, 2010 11:37 AM
To: 'Dale_Suiter@fws.gov'
Cc: 'David Kellam'
Subject: RE: Seabeach amaranth, Figure 8, 2009

HI Dale,
We had no Amaranthus on Figure Eight Island this year. Maybe next year will be the charm. Best,
David

Wm. David Webster, Ph.D.
Associate Dean
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University of North Carolina Wilmington
Wilmington, NC 28403-5912
webste@uncw.edu (email)
(910) 962-3756 (phone)
(910) 962-3114 (FAX)
webste@uncw.edu/people/webste

From: Dale_Suiter@fws.gov [mailto:Dale_Suiter@fws.gov]
Sent: Thursday, February 11, 2010 11:05 AM
To: Webster, David
Subject: Seabeach amaranth, Figure 8, 2009

Hi Dr. Webster

I hope all is going well at the coast.

I'm just updating my Seabeach Amaranth spreadsheet for 2009 and noticed that I don't have any numbers for you. If you sent them in and I'm misplaced them, please forgive me. If not, just let me know how many plants you had. There is no rush, just send this in whenever you have time.

Thanks,
Dale

Dale Suiter
Endangered Species Biologist
U.S. Fish and Wildlife Service
P.O. Box 33726
Raleigh, NC 27636-3726

phone - 919-856-4520 ext. 18
fax - 919-856-4556
email - Dale_Suiter@fws.gov

From: Miller, Tancred [tancred.miller@ncdenr.gov]
Sent: Monday, February 22, 2010 4:08 PM
To: Brad Rosov
Subject: RE: Sea level rise

Correct. 4.27 is the current rate and is expected to accelerate, but we did not attempt to quantify the acceleration rate. Our projected range is 0.4m-1.4m, and we'll be planning for 1m. The Science Panel will review the numbers every 5 years, or as necessary.

From: Brad Rosov [mailto:Brosov@coastalplanning.net]
Sent: Monday, February 22, 2010 4:01 PM
To: Miller, Tancred
Subject: RE: Sea level rise

Thanks, Tancred. So, to clarify, will the 4.27mm/yr rate be amended to reflect the 1m rise by 2100?

-Brad

From: Miller, Tancred [mailto:tancred.miller@ncdenr.gov]
Sent: Monday, February 22, 2010 3:52 PM
To: Brad Rosov
Subject: RE: Sea level rise

Hi Brad,

Sorry for the delay. Yes, the CRC was advised by their Science Panel to plan for 1 meter of rise by 2100. The current rate of rise we're using is 4.27 mm/yr. Let me know if you need more detail.

Thanks,
Tancred

From: Brad Rosov [mailto:Brosov@coastalplanning.net]
Sent: Monday, February 15, 2010 10:17 AM
To: Miller, Tancred
Subject: Sea level rise

Hi Tancred,

We've met a few times up in Beaufort- I'm an old friend of John Hackney's and I've also ran into you at a few conferences over the past few years. I know that you recently convened the NC Sea Level Rise workshop and was interested in the outcome. Is the state now endorsing a position on SLR (a specific rate, etc.)? I'm drafting an EIS for Figure Eight Island and would like to incorporate SLR into the document and figured you may have some input…

Thanks a bunch,

Brad Rosov
Marine Scientist
Coastal Planning & Engineering of North Carolina, Inc.
4038 Masonboro Loop Road
Wilmington, NC 28409

(910) 791-9494
brosov@coastalplanning.net

Brad Rosov

From: Godfrey, Matthew H [matt.godfrey@ncwildlife.org]
Sent: Monday, May 10, 2010 4:51 PM
To: Brad Rosov
Subject: RE: Sea Turtles- Figure Eight Island

Hi Brad,
Sorry for the delay – in brief, there have not been any observed nests laid by the three species listed below on Figure Eight Island in the past five years.
Best,
Matthew

From: Brad Rosov [mailto:Brosov@coastalplanning.net]
Sent: Tuesday, May 04, 2010 4:55 PM
To: Matthew H. Godfrey; Godfrey, Matthew H
Subject: Sea Turtles- Figure Eight Island

Hello Dr. Godfrey,

I am working to update some information you provided us a few years ago regarding sea turtle nesting in proximity to Figure Eight Island. I currently state that there have not been any Kemp's ridley, leatherback, or hawksbill nests observed within at least the past decade, however, this was a personal communication you provided us a few years ago. Do you know if there have been any confirmed nests from these along Figure Eight or Hutaff since that time?

Thanks,

Brad Rosov
Marine Scientist
Coastal Planning & Engineering of North Carolina, Inc.
4038 Masonboro Loop Road
Wilmington, NC 28409
(910) 791-9494
brosov@coastalplanning.net

From:	Sugg, Mickey T SAW
To:	Brad Rosov
Cc:	Tom Jarrett; Ken Willson
Subject:	RE: Figure Eight Permit Area
Date:	Thursday, June 24, 2010 2:27:31 PM

I don't see this as an issue. I'm assuming the initial permit area included what you thought fell within the boundaries of the modeling. Does this change have anything to do with not dredging into Green Channel as original proposed?
-mick

Mickey Sugg, Project Manager
US Army Corps of Engineers
69 Darlington Avenue
Wilmington NC 28403-1343
(910) 251-4811 (o)
(910) 251-4025 (fax)

-----Original Message-----
From: Brad Rosov [mailto:Brosov@coastalplanning.net]
Sent: Tuesday, June 15, 2010 12:05 PM
To: Sugg, Mickey T SAW
Cc: Tom Jarrett; Ken Willson
Subject: Figure Eight Permit Area

Hello Mickey,

As we recently moved forward and completed our updated model runs, it became evident that we had a small discrepancy between the area which was modeled and the proposed Permit Area developed some time ago. I'm writing this to you to see if we can modify the Permit Area with respect to this discrepancy.

The spatial domain included within our model runs cover the area affected by Rich Inlet. This extends from Bridge Road to the midpoint between the Topsail Inlet and Rich Inlet, that applies for both the beach area and the marsh areas along the Intracoastal Waterway. The revised model was extended towards the south along the beach to Mason Inlet to cover the entire fill area and the longshore spreading zone (see the attached figure). Our proposed Permit Area was developed in coordination with you some time ago utilizing aerial photos to help "best-guess" the extent of the Permit Area in respect to areas which could be potentially impacted by the project. Looking at the attached figure, you will see that the domain of the modeled area and the permit area do not completely overlap due to a small area (64 acres) to the NE of the Permit Area not covered by the modeled area. Because this areas is rather small and seemingly out of the influence of potential impacts, I was hoping that we could modify our permit area so it is 100% contained within the area which was modeled. This would simply mean clipping that 64 acre area from the Permit Area. It will be helpful because the modeling results will be used to determine the amount of acres of various habitats within the Permit Area- something that will be impossible to do if the Permit Area includes areas not modeled!

Please let me know if this is amenable from your end.

Thanks,

Brad Rosov

Marine Scientist

Coastal Planning & Engineering of North Carolina, Inc.

4038 Masonboro Loop Rd.

Wilmington, NC 28409

910 791-9494

From: Brad Rosov <Brosov@coastalplanning.net>
Sent: Friday, July 29, 2011 8:37 AM
To: Rosov, Brad
Subject: FW: biological resource data from Figure Eight
Attachments: turtles 2008.doc; turtles 2009.docx; turtles 2010.docx

From: Webster, David [webste@uncw.edu]
Sent: Tuesday, July 05, 2011 12:06 PM
To: Brad Rosov
Cc: 'David Kellam'
Subject: RE: biological resource data from Figure Eight
Hello Brad,
Thanks for your email. I have appended three files with information pertaining to nesting sea turtles for the years 2008-2010. I have not included this summer since we are still in the middle of everything (14 nests so far, and we're only half-way through the nesting season). I'll send you the final figures for 2011 in late August, unless you need the hatching success data (which isn't completed until mid-November).
As for seabeach amaranth, there are 17 plants on the north end of Figure Eight this summer but none anywhere else. I still have one more amaranth survey to conduct (I do three surveys each summer), so I'll let you know if I find more plants. Amaranth was not found in 2008, 2009, or 2010.
I also have colonial waterbird and shorebird weekly inventory data and nesting data, but I need to condense these for easy interpretation. I will send these data to you in a couple of weeks. Best, David

Wm. David Webster, Ph.D.
Associate Dean
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webste@uncw.edu (email)
(910) 962-3756 (phone)
(910) 962-3114 (FAX)
webste@uncw.edu/people/webste

From: Brad Rosov [mailto:Brosov@coastalplanning.net]
Sent: Thursday, June 23, 2011 3:35 PM

To: Webster, David
Subject: biological resource data from Figure Eight

Hello Dr. Webster,
I am looking to update some information I have compiled regarding sea turtle nests and seabeach amaranth numbers in support of Figure Eight Island's EIS for beach nourishment. Specifically, I was hoping you might be willing to share the monitoring data you have for these critters from Figure Eight Island from 2008 til present. Also, do you have any bird data… or is that still left to Audubon?

I appreciate your help with this!

Regards,

Brad Rosov
Marine Biologist
Coastal Planning & Engineering, Inc.
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910 791-9494 direct
910 352-1555cellular
910 791-4129 fax
brad.rosov@shawgrp.com
www.coastalplanning.net

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http://www.coastalplanning.net

Rosov, Brad

From: Godfrey, Matthew H <matt.godfrey@ncwildlife.org>
Sent: Monday, August 08, 2011 6:17 AM
To: Rosov, Brad
Subject: RE: sea turtle nesting data request
Attachments: Rosov.xls

Hi Brad,
Sorry for the delay – see attached sheet. Two qualifications:
1. The monitoring at Lea-Hutaff Island for sea turtle nesting activities is limited to a few times a week, so the observed nest numbers likely underestimate the total sea turtle nesting activity on the island.
2. I don't have an electronic version of 2009 Figure Eight data, so I need to get the hard copy from storage, which will take a few more days. I think you already have received data from David Webster and/or Charlie Baker for Figure Eight, so I wanted to send you what I have now, so you can work off that.

Let me know if need anything else.
Matthew

From: Rosov, Brad [mailto:Brad.Rosov@shawgrp.com]
Sent: Monday, August 01, 2011 9:59 AM
To: Godfrey, Matthew H
Subject: sea turtle nesting data request

Hello Matthew,
Thanks for getting back to me earlier this morning. Again, we are looking for sea turtle nesting data from 2008-2010 for both Figure Eight Island and Hutaff Island. I appreciate your assistance with this.

Regards,

Brad Rosov
Marine Scientist
Coastal Planning & Engineering of North Carolina, Inc
4038 Masonboro Loop Rd.
Wilmington, NC 28409
910 791-9494 (office)
910 352-1152 (cell)
910 791-4129 (fax)

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701-5505
http://sero.nmfs.noaa.gov

May 5, 2016 F/SER47:KR/pw

(Sent via Electronic Mail)

Colonel Kevin P. Landers Sr., Commander
U.S. Army Corps of Engineers Wilmington District
69 Darlington Avenue
Wilmington, North Carolina 28403-1398

Attention: Mickey Sugg

Dear Colonel Landers:

NOAA's National Marine Fisheries Service (NMFS) has reviewed Action ID No. SAW-2006-41158, dated March 25, 2016, and the *Essential Fish Habitat (EFH) Assessment* as it pertains to the *Supplemental Environmental Impact Statement, Figure Eight Island Shoreline Management Project, Figure Eight Island, North Carolina* (SEIS), dated July 2015. The Figure Eight Beach Homeowners Association (HOA) proposes beach nourishment and installation of a terminal groin to increase beach and shoreline protection in the interest of hurricane protection, storm damage reduction, beach erosion control, and protection of public-trust natural resources for shorelines at the northern end of Figure Eight Island adjacent to Rich Inlet in New Hanover County. In the EFH Assessment, the Wilmington District has made separate affects determinations for each federally managed fishery species in the project area as well as each EFH in the project area. As the nation's federal trustee for the conservation and management of marine, estuarine, and diadromous fishery resources, the NMFS provides the following comments pursuant to authorities of the Fish and Wildlife Coordination Act and the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act).

Description of the Proposed Project

Chronic erosion along the northern sections of Figure Eight Island is linked to changes in the orientation and position of the main ebb channel through Rich Inlet. Over the past 30 years, at least 31 shoreline protection projects have attempted to reduce erosion through placing sand on the beach, re-contouring the beach to form protective berms and dunes, bulkheading, and installing sandbags. These shoreline management strategies have not been successful in providing the long-term shoreline protection sought after by the HOA, stakeholders, and coastal managers. As waterfront residential structures and properties are continually threatened by a high rate of erosion, the HOA seeks to provide protection to existing development and ensure continued use of oceanfront beaches and estuarine shorelines. The HOA seeks to construct a terminal groin 505 feet in length with a 995-foot shore anchorage section. The HOA expects the design of the groin to allow littoral transport of sand over, around, and through the structure by leaving large voids between the rocks. In addition to the groin, the HOA would nourish several areas of shoreline with material excavated from the previously permitted borrow area within Nixon Channel. The Nixon Channel beach fill would be placed along 1,400 feet of the channel, and the ocean beach fill would nourish 4,500 feet of ocean shoreline. The previously permitted area in Nixon Channel would be dredged to a depth of -9.0 feet mean low water (MLW). To achieve the management objectives, maintenance dredging of Nixon Channel and nourishment activities are expected to occur every five years over a 30-year period.

Consultation History
On September 18, 2015, the NMFS provided the Wilmington District with comments on the Draft SEIS. The NMFS indicated the Draft SEIS was not inclusive of a comprehensive assessment of EFH and recommended the Wilmington District prepare a formal EFH Assessment for the project separate from the SEIS.

Comments of EFH Assessment
The EFH Assessment reviews anticipated environmental impacts within the proposed 2,609-acre project area. The authors describe with depth, detail, and scientific support direct and indirect effects expected to occur within the estuarine and coastal habitats of the project area. Further, the authors provide detailed review of EFH for managed species that occur within the project area and habitats designated by the State of North Carolina as Primary Nursery Area. An effects determination is provided for each habitat type and for each managed fishery species. The EFH included in the assessment includes descriptions and impacts to estuarine emergent wetlands, oyster reefs and shell banks, submerged aquatic vegetation (SAV), shallow sand and mud bottoms, and live/hardbottom.

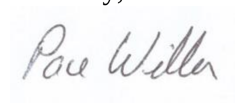
Generalized environmental impacts are expected to be temporary in nature and of short duration (days) following construction and maintenance activities. Impacts from dredging and nourishment activities include an increase in the turbidity and total suspended solids from sediments, silt, and organic materials. High concentrations of suspended solids for extended durations can impair biological productivity and ecological function by clogging fish gills, affecting recruitment of fish and invertebrates (crustaceans and invertebrates), and suppressing growth of SAV and shellfish (e.g., oysters, clams, scallops). Activities such as beach nourishment typically have more severe impacts that take longer periods of time (months and years) for ecological recovery. Ocean beach and estuarine shorelines can be extraordinarily dynamic and resilient ecosystems. These ecosystems are often able to recover quickly despite experiencing extreme disturbance events from storms and hurricanes. Nourishment activities that bury infaunal communities results in direct mortality of many forage species. These infaunal species provide important trophic linkages coupling benthic-pelagic ecosystems. Many of the organisms that utilize these habitats also provide trophic linkages between inshore and offshore populations.

The NMFS previously recommended for this project that environmental windows (seasonal restrictions) be used for timing of any in-water construction and maintenance activities to protect fish during sensitive life stages. The EFH Assessment states the construction, dredging, and maintenance schedule will include a work moratorium for April 1 through November 15 to minimize environmental impacts and provide protections for seasonal migrations of fish and protected species (i.e., sturgeon, sea turtles). The NMFS appreciates the EFH Assessment recognizing inlets serve as migratory corridors for larvae entering nursery areas and for sub-adults leaving nursery areas for maturation and spawning offshore. The results of models and literature suggest mortality associated with larval entrainment by the dredge would be minimal and localized when appropriate precautions are taken.

The NMFS believes the EFH Assessment includes a significant improvement in EFH conservation measures over those included in the SEIS. Most notably is the description of the construction practices including dredge selection, engineering for terminal groin structure, sediment compatibility for beach nourishment, water quality controls, and habitat mapping. Also, the EFH Assessment provides description of how the project integrates with monitoring requirements of the North Carolina Shoreline Management Plan, which focuses on long-term monitoring and includes measures to remove the terminal groin if adverse impacts cannot be mitigated. The NMFS believes the monitoring schedule, habitat mapping, and sediment transport and shoreline models included in the EFH Assessment will significantly improve the Figure Eight Island Shoreline Management Project. These decision-making tools address opportunities for practicable avoidance and minimization of impacts to EFH and they provide measures for adaptive management. Because of these additions, the NMFS has no EFH conservation recommendations for the project.

Thank you for the opportunity to provide these comments on the EFH Assessment, and the NMFS looks forward to further cooperation with this project that is so important for North Carolina. Please direct related questions or comments to the attention of Dr. Ken Riley at our Beaufort Field Office, 101 Pivers Island Road, Beaufort, North Carolina 28516-9722, or at (252) 728-8750.

Sincerely,



/ for

Virginia M. Fay
Assistant Regional Administrator
Habitat Conservation Division

cc: COE, Mickey.Sugg@usace.army.mil
USFWS, Pete_Benjamin@usfws.gov
NCDCM, Doug.Huggett@ncmail.net
NCDCM, Gregg.Bodnar@ncdenr.gov
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F/SER47, Ken.Riley@noaa.gov

North Carolina Department of Cultural Resources

State Historic Preservation Office

Ramona M. Bartos, Administrator

Beverly Eaves Perdue, Governor
Linda A. Carlisle, Secretary
Jeffrey J. Crow, Deputy Secretary

Office of Archives and History
Division of Historical Resources
David Brook, Director

June 25, 2012

Mickey Sugg
US Army Corps of Engineers
69 Darlington Avenue,
Wilmington, NC 28403

Re: Figure Eight Island Shoreline Management Plan, Install Terminal Groin along Rich Inlet and Beach Nourishment, SAW 2006-41158, New Hanover County, ER 12-0927

Dear Mr. Sugg:

We have reviewed the above public notice and Draft Environmental Impact Statement concerning Figure "8" Beach Homeowners Association's proposal to perform dredging and beach nourishment.

The Office of State Archaeology underwater research files have references to extensive maritime activities and shipwreck losses in the general project vicinity; therefore, much of the project area holds a high potential for containing submerged cultural resources. The report "Terrestrial and Submerged Cultural Resource Survey Rich Inlet, Figure Eight Island, North Carolina," submitted by Tidewater Atlantic Research (TAR) identifies and addresses these resources.

The remote sensing survey identified five magnetic anomalies/acoustic targets that contain signature characteristics suggestive of potentially significant cultural material. These anomalies identified as RI-1 through RI-5 in Appendix B of the above mentioned report must be avoided with the recommended 100 foot and/or 150 foot buffers. If these areas cannot be avoided additional investigations are required prior to disturbance. The wreck of the *Wild Dayrell* (0001RII) is also located in the inlet and must be avoided with the recommended 400 foot by 600 foot buffer zone as noted in the report "Location of the Remains of the Wild Dayrell in Rich Inlet, Pender County, North Carolina," submitted by TAR.

Additionally, we would like your agency, its affiliates, and all equipment operators to be aware that the possibility exists that the beach renourishment work may unearth an unknown beached shipwreck which may have been washed up on Figure 8 Island and buried over the last 450 years. In the event that such occurs, work should move to another area and the Underwater Archaeology Branch be contacted immediately (910.458.9042). A staff member will be sent to make an assessment of the wreckage and determine the proper course of action.

This caution also applies to the two areas of Rich Inlet inaccessible for TAR's survey. If during dredging operations submerged archaeological materials are encountered, such as shipwreck remains, it is the responsibility of the Army Corps of Engineers-Wilmington District to notify us immediately, pursuant to Section 106 of the National Historic Preservation Act of 1966. In addition, the area is protected by North Carolina legislation G.S. 121-22 to 28, Article 3, supported by the Abandoned Shipwreck Act of 1987 (P.L. 100-298)

Thank you for your cooperation and consideration. If you have questions concerning the above comment, please contact Renee Gledhill-Earley, environmental review coordinator, at 919/807-6579. In all future communication concerning this project, please cite the above referenced tracking number.

Sincerely,

Renee Gledhill-Earley

for Ramona M. Bartos

North Carolina Department of Cultural Resources

State Historic Preservation Office

Ramona M. Bartos, Administrator

Governor Pat McCrory
Secretary Susan Kluttz

Office of Archives and History
Deputy Secretary Kevin Cherry

August 7, 2015

Mickey Sugg
US Army Corps of Engineers
69 Darlington Avenue
Wilmington, NC 28403

Re: Figure Eight Island Shoreline Management Project, Install Terminal Groin along Rich Inlet and Beach Nourishment, New Hanover County, ER 12-0927

Dear Mr. Sugg:

We have reviewed the above public notice and Supplemental Environmental Impact Statement (SEIS) concerning Figure "8" Beach Homeowners Association's proposal to perform dredging, beach nourishment and construct a terminal groin and would like to comment.

The Office of State Archaeology underwater research files have references to extensive maritime activities and shipwreck losses in the general project vicinity; therefore, much of the project area holds a high potential for containing submerged cultural resources. Two reports cited in the SEIS identify and address some of these resources: "Location of the Remains of the *Wild Dayrell* in Rich Inlet, Pender County, North Carolina" and "Terrestrial and Submerged Cultural Resource Survey Rich Inlet, Figure Eight Island, North Carolina," both submitted by Tidewater Atlantic Research (TAR).

The remote sensing survey identified five targets that contain characteristics suggestive of potentially significant cultural material. These anomalies identified as RI-1 through RI-5 in the above mentioned report must be avoided with the recommended 100 foot and/or 150 foot buffers. If these areas cannot be avoided, additional investigations are required prior to disturbance. Of particular concern is target RI-1 (150-foot buffer) that is approximately 300 feet from the end of the proposed offload pier. The wreck of the *Wild Dayrell* (0001RII) is also located in the inlet and must be avoided with the recommended 400 foot by 600 foot buffer zone.

Our office also has concerns regarding how the placement of a terminal groin may affect the dynamics of the inlet. The resulting changes in water and sediment movement could adversely impact the unassessed targets and the stability of the *Wild Dayrell* which has been identified as culturally significant by its direct association with the American Civil War.

Additionally, we would like your agency, its affiliates, and all equipment operators to be aware that the possibility exists that the beach nourishment work may unearth an unknown beached shipwreck which may have been washed up on Figure 8 Island and buried over the last 450 years. In the event that such occurs, work should move to another area and the Underwater Archaeology Branch be contacted immediately (910.458.9042). A staff member will be sent to assess the wreckage and determine the proper course of action.

This caution also applies to the two areas of Rich Inlet inaccessible for TAR's survey. If during dredging operations submerged archaeological materials are encountered, such as shipwreck remains, it is the responsibility of the Army Corps of Engineers-Wilmington District to notify us immediately, pursuant to Section 106 of the National Historic Preservation Act of 1966. In addition, the area is protected by North Carolina legislation G.S. 121-22 to 28, Article 3, supported by the Abandoned Shipwreck Act of 1987 (P.L. 100-298)

Thank you for your cooperation and consideration. If you have questions concerning the above comment, contact Renee Gledhill-Earley, environmental review coordinator, at 919-807-6579 or environmental.review@ncdcr.gov. In all future communication concerning this project, please cite the above referenced tracking number.

Sincerely,

Renee Gledhill-Earley

for Ramona M. Bartos

cc: State Clearinghouse

Sub-Part 3

Public Notices

[Federal Register: February 26, 2007 (Volume 72, Number 37)]
[Notices]
[Page 8359-8361]
From the Federal Register Online via GPO Access [wais.access.gpo.gov]
[DOCID:fr26fe07-60]

DEPARTMENT OF DEFENSE

Department of the Army; Corps of Engineers

Intent To Prepare a Draft Environmental Impact Statement (DEIS) for the Development of an Inlet Management Plan That Includes the Repositioning and Realignment of the Main Ebb Channel of Rich Inlet and To Use the Material To Nourish Figure Eight Island, North of Wilmington, New Hanover County, NC

AGENCY: Department of the Army, U.S. Army Corps of Engineers, DoD.

ACTION: Notice of intent.

SUMMARY: The U.S. Army Corps of Engineers (COE), Wilmington District, Wilmington Regulatory Field Office has received a request for Department of the Army authorization, pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbor Act, from Figure ``8'' Beach Homeowners Association to develop a management plan for Rich Inlet that would mitigate chronic erosion on the northern portion of Figure Eight Island so as to preserve the integrity of its infrastructure, provide protection to existing development, and ensure the continued use of the oceanfront beach along the northernmost three miles of its oceanfront shoreline. Figure Eight Island is an unincorporated privately developed island located on the southeast coast of North Carolina, approximately eight miles north of Wilmington. The island is bordered to the south by Mason Inlet and Wrightsville Beach; and to the north by Rich Inlet and Lea-Hutaff Island, an undeveloped, privately-owned island.

The inlet management plan would involve the repositioning and realignment of the main ebb channel of Rich Inlet to a location closer to the north end of Figure Eight Island. The intended alignment is to be essentially perpendicular to the oceanfront shorelines of the adjacent islands. The new channel position would be periodically maintained with maintenance episodes dictated by natural shifts in the channel position that produce unfavorable shoreline responses on the north end of Figure Eight Island. While the main focus of the project is to relocate the main ebb bar channel, consideration will also be given to possible alterations in Nixon Channel and Green Channel to determine if such modification would enhance the stability of the new channel. Nixon Channel meanders along a southwesterly path on the landward

side of the north end of Figure Eight Island; connecting to the

Atlantic Intracoastal Waterway (AIWW) at a point approximately two miles west of the Rich Inlet throat. Green Channel meanders to the northeast on the landward side of Lea-Hutaff Island and intersects with the AIWW approximately 1.75 miles north of the Rich Inlet throat.

Material dredged from the inlet and channels will be placed along the central and northern portions of Figure Eight Island and, if needed, along portions of Lea-Hutaff Island. The objective of the placement of beach fill along the Figure Eight Island's shoreline is to keep the design fill density less than 50 cubic yards/foot, to avoid the placement of a permanent static vegetation line. This beach fill would be maintained through a program of periodic beach nourishment events with the material extracted from the dredging of Rich Inlet to maintain the inlet in an optimum location.

DATES: A public scoping meeting for the Draft EIS will be held at Eaton Elementary School, located at 6701 Gordon Road, on March 1, 2007 at 6 p.m. Written comments will be received until March 29, 2007.

ADDRESSES: Copies of comments and questions regarding scoping for the Draft EIS may be addressed to: U.S. Army Corps of Engineers, Wilmington District, Regulatory Division. ATTN: File Number 2006-41158-067, Post Office Box 1890, Wilmington, NC 28402-1890.

FOR FURTHER INFORMATION CONTACT: Questions about the proposed action and DEIS can be directed to Mr. Mickey Sugg, Wilmington Regulatory Field Office, telephone: (910) 251-4811.

SUPPLEMENTARY INFORMATION:

1. Project Description. The Figure Eight Beach Homeowners Association proposes to develop an inlet management plan for Rich Inlet that will produce semi-permanent positive shoreline impacts on the extreme north end of Figure Eight Island. Through a variety of investigations, it has been determined that chronic erosion problems along the northern sections of Figure Eight Island have been directly linked to changes in the orientation and position of the main ebb channel through Rich Inlet. When the main ebb channel of the inlet is oriented toward the southeast or in the direction of Figure Eight Island, and positioned close to the north end of the island, the shoreline immediately south of the inlet tends to accrete. The accretion is associated with the wave sheltering (``breakwater effect'') provided by the south side of the ebb tide delta which also moves with the channel. During periods in which the main bar channel migrates to the north toward Lea-Hutaff Island and is oriented in a southeasterly direction, the north end of Figure Eight Island erodes. The northward movement of the main ebb channel is accompanied by the northward shift of the south side of the ebb tide delta away from the north end of Figure Eight Island, thus removing the ``breakwater effect'' afforded by the south side of the ebb tide delta.

A geomorphic analysis of Rich Inlet will be performed utilizing historical aerial photographs of Rich Inlet and the adjacent shorelines. The geomorphic analysis will be used to develop alternative channel positions and alignments that will assist in determining the desired changes on the north end of Figure Eight Island. The analysis will also assist in identifying any positive and/or negative impacts associated with Lea-Hutaff Island. The position and alignment of the main ebb channel design and design alternatives will be evaluated to determine the potential effects on the adjacent shorelines and natural resources located within the study area.

2. Proposed Action. The scope of activities for the formulation of the management plan for Rich Inlet will include the following engineering and geological investigations: (1) Detailed geomorphic studies of the inlet and its impacts on the shorelines of Figure Eight Island and Lea-Hataff Island; (2) numerical model simulations of various channel alternatives including possible modifications of Nixon and Green channels; (3) geotechnical investigations to determine sediment quality in the inlet and connecting channels; (4) compatibility analysis of the inlet material with the native beach material; and (5) and analysis of the physical impacts of the project on the inlet complex (including the adjacent marshes and connecting channels) and on Figure Eight Island and Lea-Hutaff Island.

The Figure Eight Island beach fill design will consist of the disposal material from Rich Inlet channel along the island shoreline in a general template of a horizontal berm constructed to an elevation of +6.0 feet NAVD (National Geodetic Vertical Datum) with a 1V:15H seaward slope. The width of the berm, which would begin near the seaward toe of the existing dune system, will depend on the volume of material removed from Rich Inlet to construct the new channel and the slope the material assumed during placement. Another design objective is to keep the design fill density less than 50 cubic yards/foot, to avoid the placement of a permanent static vegetation line. The volume of material that would be removed to construct the new channel will depend on the final design of the channel but could range between 500,000 cubic yards and 2,000,000 cubic yards. Some of the channel material may be used to construct or maintain the dune system on portions of Figure Eight Island. Existing profiles will be analyzed to identify the range of natural beach and dune elevations, widths, and slopes. The beach fill design will include beach fill construction templates and equilibrium cross-sections to estimate the seaward limit of cross-shore spreading over the project life and the reduction in beach width due to changes in profile shape following construction.

Beach planform performance will be evaluated based on the numerical modeling for the proposed projects. The numerical model evaluation of various channel alternatives will employ a process-based numerical model known as Delft3D developed by WL Delft Hydraulics (WL Delft Hydraulics, 2005). Delft3D is an advanced 2D/3D hydrodynamic model that can simulate water level changes, currents, wave transformation, sediment transport, and bathymetric (morphological) changes in coastal environments. The model evaluations will consider short-term changes (i.e., tidal cycles and storms) to the inlet's flow pattern and morphology; as well as long-term (one to five years) changes in flow patterns and inlet morphology associated with various inlet channel alternatives. The model simulations will also be used to evaluate the importance of modifications of Nixon and/or Green Channels on the overall stability and associated impacts of the new channel.

Comprehensive geotechnical investigations of the Rich Inlet system including the inlet throat, flood tidal delta, ebb tidal delta, and feeder channels Nixon and Green Channel will be used to identify and map sand quality and quantity to be placed on the shoreline of Figure Eight Island or elsewhere as the study dictates. The proposed sand search will be completed in two phases: (1) Research and planning, and (2) jet probes and vibracore collection and analysis. Sand resources in the study area will be evaluated for compatibility with native beach sand. This evaluation is necessary to determine the potential performance of sand on the beach since the performance is highly dependent on similar sediment characteristics including mean grain size, sorting, and

composition of borrow sands and native sands.

The research and planning phase includes a comprehensive analysis of historical geophysical data, hydrographic survey data, and aerial photographs of the inlet to determine potential channel shall lag deposit sites and historic preferred channel alignment. The jet probe survey will provide preliminary qualitative information of the sediment contained in the feeder channels and the ebb tide delta of Rich inlet. Areas suspected of containing the best quality and quantity of sand resources within the preferred channel realignment corridor will be targeted for vibracore investigation.

A magnetometer survey was performed on September 3, 2006 on the wreck site of the Wild Dayrell. The Wild Dayrell is a side-wheel steamer which ran aground near in the Rich Inlet complex on February 3, 1864. The location of the Wild Dayrell and its debris field will play a major role in options associated with the location of the new inlet channel. In addition, a cultural resource study of the final borrow area and channel design will be performed using a magnetometer survey controlled by differential global positioning. Cartographic and historical research will be conducted to collect available historical data.

Natural resource studies and investigations which may be conducted in support of the plan formulation might include: (1) Identification and biological characterization of estuarine habitat types (salt march, shelfish, submerged aquatic vegetation) in a defined project area using aerial mapping and/or groundtruth investigations; (2) pre-project monitoring of threatened and endangered species and their associated habitats as determined through coordination with project stakeholders; and (3) development and/or implementation of project monitoring and mitigation plans based on the project impact assessment.

3. Issues. There are several potential environmental issues that will be addressed in the EIS. Additional issues may be identified during the scoping process. Issues initially identified as potentially significant include:

a. Potential impacts to marine biological resources (benthic organisms, passageway for fish and other marine life) and Essential Fish Habitat, particularly within Green Channel.

b. Potential impacts to threatened and endangered marine mammals, birds, fish, and plants.

c. Potential impacts to water quality.

d. Potential increase in erosion rates to adjacent Lea-Hutaff.

e. Potential impacts to Navigation, commercial and recreational.

f. Potential impacts to the long-term-management of Rich Inlet.

g. Potential impacts to private and public property.

h. Cumulative impacts of Inlet and Inlet channel relocations throughout North Carolina.

i. Cumulative impacts for using inlets as sand source in nourishment projects.

j. Potential impacts on public health and safety.

k. Potential impacts to recreational and commercial fishing.

l. The compatibility of the material for nourishment.

m. Potential impacts to cultural resources, particularly the Wild Dayrell shipwreck.

4. Alternatives. Several alternatives are being considered for the proposed project. These alternatives will be further formulated and developed during the scoping process, and an appropriate range of alternatives, including the no federal action alternative, will be considered in the EIS.

5. Scoping Process. A public scoping meeting (see DATES) will be held to receive public comment and assess public concerns regarding the appropriate scope and preparation of the Draft EIS. Participation in the public meeting by federal, state, and local agencies and other interested organizations and persons is encouraged.

The COE will also be consulting with the U.S. Fish and Wildlife Service under the Endangered Species Act and the Fish and Wildlife Coordination Act; with the National Marine Fisheries Service under the Magnuson-Stevens Act and Endangered Species Act; and with the North Carolina State Historic Preservation Office under the National Historic Preservation Act. Additionally, the EIS will assess the potential water quality impacts pursuant to Section 401 of the Clean Water Act, and will be coordinated with the North Carolina Division of Coastal Management (DCM) to determine the project's consistency with the Coastal Zone Management Act. The COE will closely work with DCM through the EIS to ensure the process complies with all State Environmental Policy Act (SEPA) requirements. It is the COE and DCM's intentions to consolidate both NEPA and SEPA processes to eliminate duplications.

6. Availability of the Draft EIS. The Draft EIS is expected to be published and circulated sometime in 2008, and a public hearing will be held after the publication of the Draft EIS.

Dated: February 12, 2007.

John E. Pulliam, Jr.,

Colonel, U.S. Army District Commander.

[FR Doc. 07-848 Filed 2-23-07; 8:45 am]

BILLING CODE 3710-GN-M

US Army Corps
Of Engineers
Wilmington District

PUBLIC NOTICE

Issue Date: February 22, 2007
Comment Deadline: March 29, 2007
Corps Action ID #: 2006-41158-065

All interested parties are herby advised that the Wilmington District, Corps of Engineers (Corps) is holding a scoping meeting for work within jurisdictional waters of the United States that is proposed by the Figure "8" Beach Homeowners Association, Inc. Specific plans and location information are described below and shown on the attached plans. This Public Notice and all attached plans are also available on the Wilmington District Web Site at www.saw.usace.army.mil/wetlands

Applicant:	Figure "8" Beach Homeowners Association, Inc. C/o: Mr. David Kellum (Administrator) 15 Bridge Road Wilmington, North Carolina 28411
AGENT (if applicable):	Coastal Planning & Engineering, Inc. C/o: Mr. Craig Kruempel 2481 N.W. Boca Raton Boulevard Boca Raton, Florida 33431

Authority

The Corps will evaluate this project pursuant to applicable procedures to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbor.

Location

The project site is located at 34-17.27, 77-43.39, within the Rich Inlet Complex (including Nixon and Green Channel) that is positioned between Figure Eight Island and Lea-Hutaff Island, and will encompass approximately 3.0 miles, or 15,840 linear feet, of ocean shoreline along the central and northern portion of Figure Eight Island, north of Wilmington, New Hanover County, North Carolina.

Existing Site Conditions

Figure Eight Island is an unincorporated privately developed island just north of Wrightsville Beach. It is bordered to the south by Mason Inlet and to the north by Rich Inlet, to the west by the Intracoastal Waterway, and to the east by the Atlantic Ocean.

Rich Inlet and Nixon Channel is the established county boundary of New Hanover and Pender. The island is a typical barrier island that has undergone a variety of natural and anthropogenic changes. The majority of the residential island has been developed; and over two decades, authorization has been granted to Figure “8” Beach Homeowners Association and to separate individual property owners to conduct various activities, such as dredging, beach bulldozing, and shoreline nourishment, within waters of the U.S.

Applicant’s Stated Purpose

The stated purpose of the project is to develop a management plan for Rich Inlet that would mitigate chronic erosion on the northern portion of Figure Eight Island so as to preserve the integrity of its infrastructure, provide protection to existing development, and ensure the continued use of the oceanfront beach along the northernmost three miles of its oceanfront shoreline.

Project Description

Figure “8” Beach Homeowners Association’s proposal to implement an inlet management plan would involve the repositioning and realignment of the main ebb channel of Rich Inlet to a location closer to the north end of Figure Eight Island. The intended alignment is to be essentially perpendicular to the oceanfront shorelines of the adjacent islands. The new channel position would be periodically maintained with maintenance episodes dictated by natural shifts in the channel position that produce unfavorable shoreline responses on the north end of Figure Eight Island. While the main focus of the project is to relocate the main ebb bar channel, consideration will also be given to possible alterations in Nixon Channel and Green Channel to determine if such modification would enhance the stability of the new channel. Nixon Channel meanders along a southwesterly path on the landward side of the north end of Figure Eight Island; connecting to the Atlantic Intracoastal Waterway (AIWW) at a point approximately two miles west of the Rich Inlet throat. Green Channel meanders to the northeast on the landward side of Lea-Hutaff Island and intersects with the AIWW approximately 1.75 miles north of the Rich Inlet throat.

Material dredged from the inlet and channels will be placed along the central and northern portions of Figure Eight Island and, if needed, along portions of Lea-Hutaff Island. The objective of the placement of beach fill along the Figure Eight Island’s shoreline is to keep the design fill density less than 50 cubic yards/foot, to avoid the placement of a permanent static vegetation line. This beach fill would be maintained through a program of periodic beach nourishment events with the material extracted from the dredging of Rich Inlet to maintain the inlet in an optimum location.

This notice is to inform interested parties that our Notice of Intent to prepare an Environmental Impact Statement (EIS) for this project will be published in the Federal Register on February 26, 2007 and once published, can be found on the Federal Register website, www.archives.gov/federal-register/ . After connecting with the website, click on Today's Federal Register, and go to the bottom of the page. Click on 2007, and then click February 26, 2007. The subject document is located under Engineers Corps. Additionally, a scheduled scoping meeting for drafting the EIS will be held at Eaton Elementary School (in the school gym), at # 6701 Gordon Road, in Wilmington (near Ogden), on March 1, 2007 at 6:00 P.M. The scoping meeting is designed to solicit comments from the public; Federal, State and local agencies and officials; and other interested parties to incorporate in the Draft EIS document. The purpose of these comments concerning public interest factors, ranging from navigation to biological resources to private and public lands, will identify issues to be addressed in the Draft EIS.

As disclosed in the Notice of Intent, any written comments pertinent to the proposed work, as outlined above, must be submitted to this office, Attention: Mickey T. Sugg, until 4:15 p.m., March 26, 2007. Question can be directed to Mr. Sugg at telephone (910) 251-4811, Wilmington Regulatory Field Office.

Distribution:

No. Cys. Mailed To

1 Mr. David Kellum, Figure "8" Beach Homeowners' Association, Inc., 15 Bridge Road, Wilmington NC 28411
1 Mr. David Ward, Ward and Smith, Post Office Box 867, New Bern NC 28563
58 Lists of addresses that requested All NC Public Notices and Addresses receiving Notices for Wilmington Field office
1 US Representative Mike McIntyre, 1605 Longworth House Office Building, Washington, DC 20515
1 Postmaster, Wilmington, NC 28401
1 Postmaster, Wilmington, NC 28405
1 Postmaster, Wilmington, NC 28409
1 Postmaster, Wilmington, NC 28411
1 Postmaster, Wrightsville Beach, NC 28480
1 Postmaster, Hampstead, NC 28443
1 Postmaster, Sneads Ferry, NC 28460
1 Postmaster, Holly Ridge, NC 28445
1 Postmaster, Surf City, NC 28445
1 Mr. Doug Huggett, DCM, NCDENR
2 Mr. Tom Mikulak, EPA, Atlanta, GA
1 Mr. Tom Jarrett, Coastal Planning & Engineering, 204 Dorchester Place, Wilmington NC 28412
1 Ms. Erin Hague, Coastal Planning & Engineering, 2481 NW Boca Raton Blvd., Boca Raton, FL 33431

1	CESAW-RG-L/ Mickey Sugg
76	TOTAL

Mr. Doug Huggett
Division of Coastal Management
North Carolina Department of
Environment and Natural Resources
400 Commerce Avenue
Morehead City, North Carolina 28557-3421

Mr. Jim Gregson
Division of Coastal Management
North Carolina Department of
Environment and Natural Resources
127 Cardinal Drive Ext.
Wilmington, North Carolina 28405-3845

Ms. Cyndi Karoly
Division of Water Quality
North Carolina Department of Environment
and Natural Resources
2321 Crabtree Boulevard, Suite 250
Raleigh, North Carolina 27609-2260

APPENDIX B

ENGINEERING REPORT

ENGINEERING REPORT
FIGURE EIGHT ISLAND INLET AND SHORELINE MANAGEMENT PROJECT

Prepared for:

Figure Eight Island Associates LLC
15 Bridge Road
Wilmington, NC 28411

Prepared by:

Coastal Planning & Engineering, Inc.

April 2016

ENGINEERING REPORT
FIGURE EIGHT ISLAND INLET AND SHORELINE MANAGEMENT PROJECT

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ENGINEERING REPORT
FIGURE EIGHT ISLAND INLET AND SHORELINE MANAGEMENT PROJECT

1.0 INTRODUCTION

Figure Eight Island is one of a number of barrier islands located along the North Carolina coast in New Hanover County. Figure Eight Island is bordered by Rich Inlet to the north and Mason Inlet to the south (Figure 1-1). The Figure "8" Beach Homeowners Association has an interest in developing a long-term Beach Protection and Management Plan that covers the 4.9 miles of oceanfront shoreline. Approximately 22,130 feet of the Figure Eight Island oceanfront shoreline is developed. Two low-lying spits extend from the developed section of the island toward the adjacent inlets. The northern spit extending towards Rich Inlet is currently ~ 2,100 feet long and the southern spit that extends toward Mason Inlet is ~ 1,500 feet. Both areas are characterized by severe shoreline change.

Rich Inlet is a relatively large inlet that separates Hutaff Island, an undeveloped barrier to the northeast, from Figure Eight Island extending to the southwest. The inlet drains an expansive marsh-filled lagoon where two large tidal creeks, Nixon and Green Channels, connect the inlet to the Atlantic Intracoastal Waterway (AIWW). Although it is relatively stable, Rich Inlet has the capability to promote considerable oceanfront shoreline changes through complex linkages to ebb channel movement and ebb-tidal delta shape changes. Currently, Figure Eight Island is confronted with serious management issues that concern inlet hazard zones and the severe recurring oceanfront erosion. Even though the inlet has been a fairly stable feature since the early 1990's, there have been substantial shoreline changes along both sides of the inlet and the adjacent oceanfront.

At least 15 known beach nourishment projects of varying size have been completed along various shoreline segments of Figure Eight Island since June of 1984 to mitigate erosion. Nourishment activities have increased since the mid to late 1990's due to changes within Mason and Rich Inlets systems and the increase in storm activity. These projects combined have placed an estimated total volume of approximately 4 million cubic yards of beach fill along the island. The island's shoreline maintenance projects have typically involved mitigation efforts along erosion hot spots along the northern and southern segments of the island.

2.0 PROBLEM IDENTIFICATION

The Homeowners Association and island residents have struggled with the continuing problems associated with Rich and Mason Inlets, including long-term chronic erosion that has been exacerbated by a series of hurricanes in the 1990's. The Association is continuing to explore inlet management and beach renourishment options to: (1) preserve the integrity of its infrastructure, (2) provide protection to the existing development, which thereby would maintain or increase property values, and (3) ensure the continued use of the oceanfront beach and its adjacent navigable waterways. Information contained in this report provides a framework for formulating a Long-Term Figure Eight Island Beach Management Strategy.

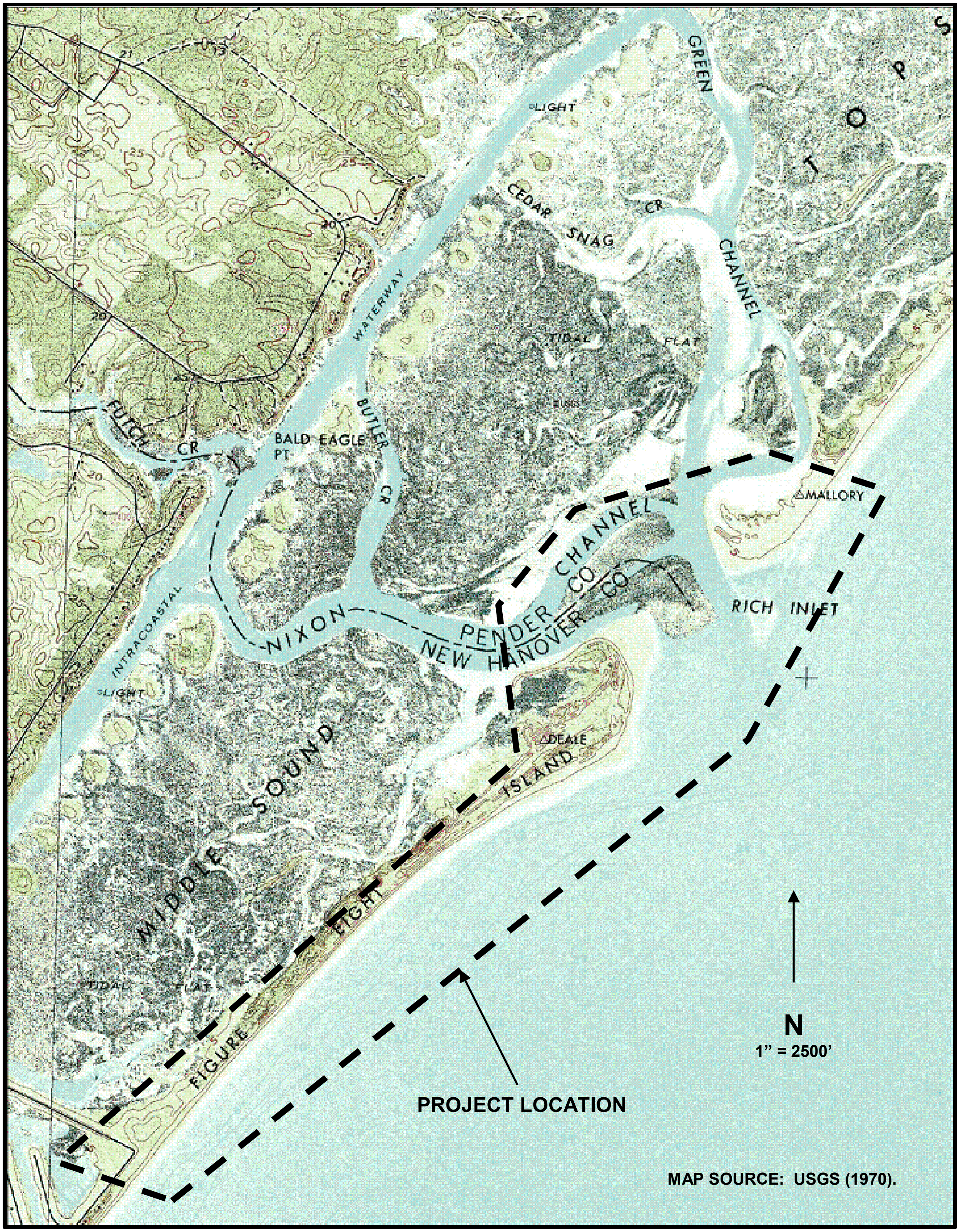


FIGURE 1-1: Figure Eight Island Project Location.

3.0 COASTAL CONSISTENCY

The consistency of this project with the Coastal Barrier Resources Act and Coastal Barrier Improvement Act of 1990 will be discussed in the Environmental Impact Statement for the project.

4.0 PHYSICAL CHARACTERISTICS OF THE PROJECT AREA

4.1 General Description

Barrier islands, such as Figure Eight Island, are composed of unconsolidated fine to medium sized quartz and shell material that is in a constant state of flux due to wind, waves, currents and storms. The oceanfront beach and the backing dunes are deposits of sand that are constantly changing their shape, and hence position with time as they respond to coastal processes.

Figure Eight Island is located within the southern coastal unit that extends from Cape Lookout to Sunset Beach, NC. The continental shelf sediment between Cape Lookout and Cape Fear is locally known as Onslow Bay. The sediment cover in Onslow Bay is generally thin as indicated by a large frequency of rock outcrops.

4.2 Tides

Ocean tides on Figure Eight Island are semi-diurnal, with a spring-neap variation of 28 days. Oceanfront tides are based on the NOAA tide gage and benchmark on Johnny Mercer's Pier in Wrightsville Beach. This benchmark is the closest oceanfront tidal benchmark established by NOAA. Tidal datums at Wrightsville Beach appear in Table 4-1. The mean tidal range is approximately 4.1 feet.

TABLE 4-1

NOAA (2003) OCEANFRONT TIDAL DATUMS
WRIGHTSVILLE BEACH, NC

TIDAL DATUM	ELEVATION (feet MLLW)	(feet NGVD)	(feet NAVD)
MEAN HIGHER HIGH WATER (MHHW)	4.64	3.01	2.05
MEAN HIGH WATER (MHW)	4.29	2.66	1.70
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	2.59	0.96	0.00
MEAN TIDE LEVEL (MTL)	2.22	0.59	-0.37
MEAN SEA LEVEL (MSL)	2.22	0.59	-0.37
NATIONAL GEODETIC VERTICAL DATUM-1929 (NGVD)	1.63	0.00	-0.96
MEAN LOW WATER (MLW)	0.15	-1.47	-2.43
MEAN LOWER LOW WATER (MLLW)	0.00	-1.63	-2.59

Additional water level measurements were collected May 25-July, 2005 by Gahagan & Bryant Associates (GBA). These measurements covered 7 different locations within Rich Inlet and the

Atlantic Intracoastal Waterway (AIWW). The locations of the 7 tide gages appear in Figure 4-1. Tidal datums based on the measurements appear in Table 4-2. The water levels measured by GBA were used to calibrate and verify the current, water level, and bathymetric change model for Rich Inlet. Tidal ranges inside the AIWW range from 3.2 to 3.6 feet. The tidal range in the throat of the inlet is approximately 3.7 feet. Tides in the AIWW lag the Wrightsville Beach tides by approximately 1 hour. Tides in the throat of Rich Inlet lag the Wrightsville Beach tides by approximately 30 minutes.

TABLE 4-2
INTERIOR TIDAL DATUMS
RICH INLET, NC

GBA Tide Gage	NC-NAD83 Easting (feet)	NC-NAD83 Northing (feet)	MHHW (feet NAVD)	MHW (feet NAVD)	MTL (feet NAVD)	MLW (feet NAVD)	MLLW (feet NAVD)
Green Channel	2388810	206816	1.9	1.3	-0.3	-2.0	-2.3
Nixon Channel	2383594	200566	2.2	1.6	-0.2	-1.9	-2.2
Inlet Throat	2388940	202433	2.2	1.7	-0.2	-2.0	-2.3
AIWW North	2387756	211356	2.0	1.5	-0.2	-1.8	-2.0
AIWW South	2378296	199045	2.3	1.7	-0.1	-1.9	-2.1
AIWW Middle	2382804	208892	2.1	1.5	-0.1	-1.8	-2.0
AIWW Figure Eight Bridge	2374595	193390	2.2	1.7	-0.1	-1.9	-2.2

NOTE: These datums are based on a limited set of water level measurements in 2005 and have not been officially certified by NOAA.

4.3 Currents

Currents were measured by GBA during a spring tidal period on June 21, 2005 (Figure 4-2) using boat-mounted Acoustic Doppler Current Profilers (ADCPs). In the throat of the inlet and Green Channel, the currents were flood-dominated. In Nixon Channel, the currents appeared to be ebb-dominated.

- In the throat of the inlet, the peak currents were 3.2 feet/second during flood and 2.7 feet/second during ebb, with a principal axis of 319º/139º.

- In Green Channel, the peak currents were 3.0 feet/second during flood and 2.0 feet/second during ebb, with a principal axis of 341º/161º.

- In Nixon Channel, the peak currents were 1.7 feet/second during flood and 1.8 feet/second during ebb, with a principal axis of 280º/100º.

The current measurements by GBA were utilized to calibrate current, water level, and bathymetric change model for Rich Inlet. Flow patterns in Rich Inlet were then analyzed using the calibrated model. A review of the flow patterns appears in the Delft3D modeling study.

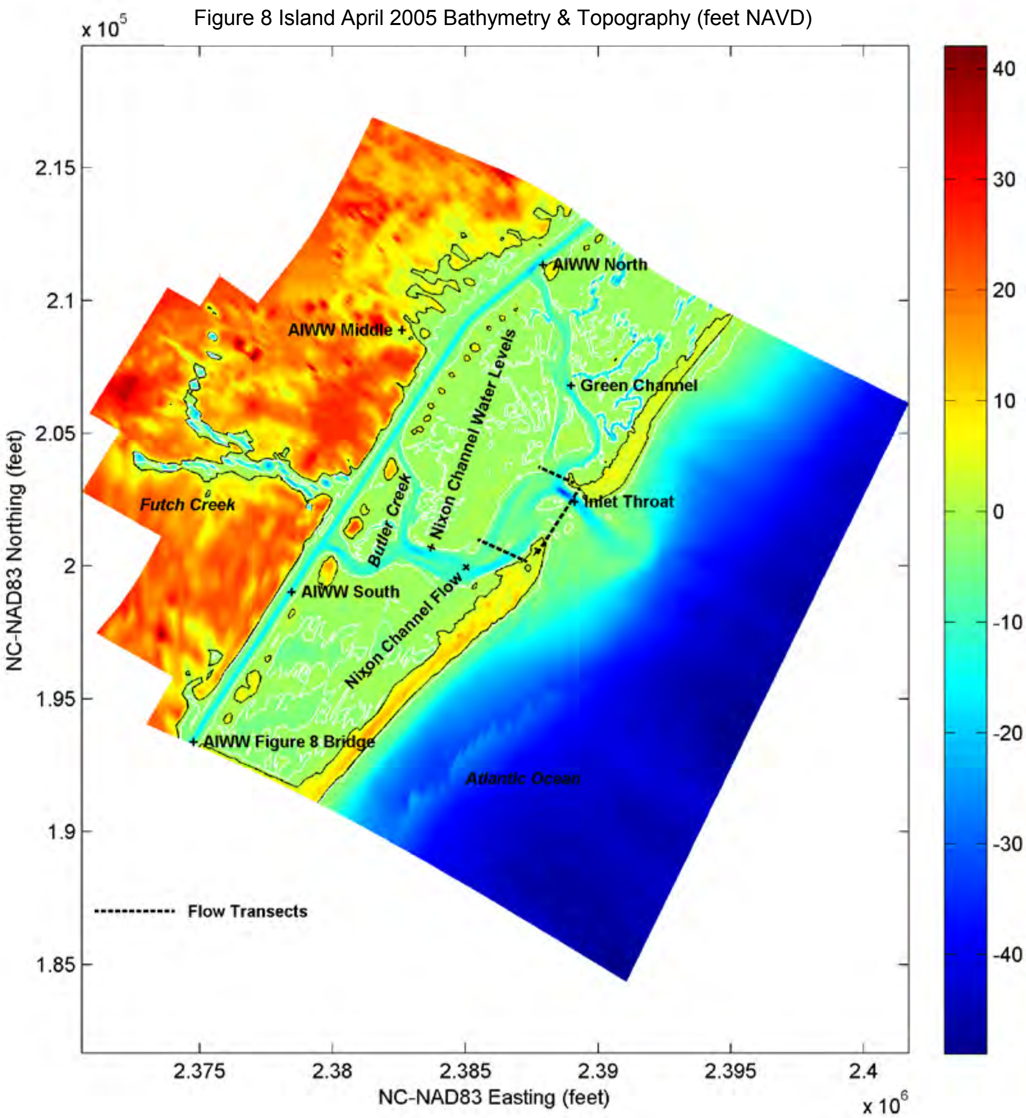


FIGURE 4-1: Tide Gage and Current (Flow) Meter Locations in Rich Inlet.

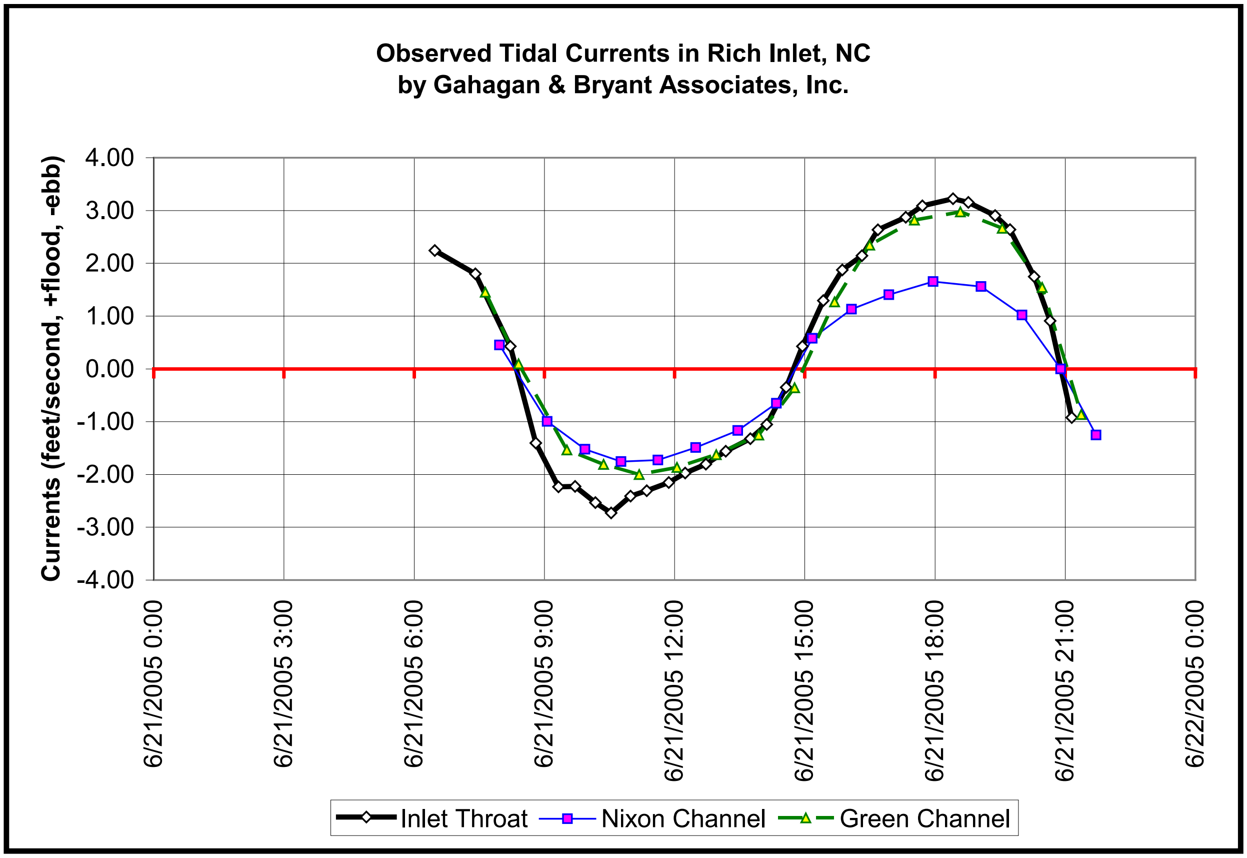


FIGURE 4-2: Tidal Currents during Spring Tide, Rich Inlet, NC.

4.4 Waves

Annual wave statistics at Figure Eight Island are based on the 2002-2005 wave observations at buoy OB3M (UNCW, 2007). The location of this gage is 34º06.133'N, 77º45.049'W at a depth of 52 feet (Figure 4-3). The root-mean-square wave height offshore is 3.3 feet, with a corresponding period and direction of 7.1 seconds and 139º (southeast). The principal direction bands are from the east-southeast and the southeast. The highest waves occur in February during the northeaster season and in August and September during hurricane season. During the summer, waves tend to approach from the south-southeast, driving the sediment transport towards the northeast. During the winter, waves tend to approach from the east-southeast, driving the sediment transport towards the southwest. Annual wave statistics appear in Tables 4-3 and 4-4 and in Figures 4-4 to 4-6.

FIGURE 4-3: Figure Eight Island, NC Wave Gages and Hindcast Stations.

TABLE 4-3

2002-2005 MONTHLY WAVE STATISTICS AT WAVE BUOY OB3M
FIGURE EIGHT ISLAND, NC

	Wave Height (feet)			Peak Wave Period (sec.)			Peak Wave Direction (deg.)		
	Mean	RMS	Max	Mean	Max	of Highest	Avg. #1*	Avg. #2**	of Highest
January	2.3	2.4	5.2	6.9	10.6	4.7	128	128	65
February	4.3	4.7	10.4	7.4	11.6	8.5	103	96	220
March	3.2	3.4	6.9	7.2	16.0	6.4	114	111	116
April	2.8	3.1	7.0	7.0	12.8	9.1	136	138	144
May	2.8	3.1	7.6	7.0	12.8	6.7	144	136	128
June	2.6	2.8	6.4	6.6	10.6	6.0	153	147	202
July	2.5	2.7	6.1	6.6	10.6	2.0	162	159	156
August	2.9	3.1	10.5	6.6	25.6	8.0	140	134	139
September	3.9	4.1	8.1	8.0	18.2	16.0	124	124	147
October	3.1	3.3	5.8	8.1	16.0	5.8	112	113	118
November	2.8	3.1	7.7	7.5	14.2	8.5	119	119	153
December	3.0	3.4	8.5	6.8	18.2	8.0	127	125	103
AVG.	3.0	3.3	10.5	7.1	25.6	8.0	134	127	139

Notes: * Average direction #1 is a simple average of the wave direction.
** Average direction #2 is the direction of the average wave energy flux.

TABLE 4-4

2002-2005 DIRECTIONAL WAVE STATISTICS AT WAVE BUOY OB3M
FIGURE EIGHT ISLAND, NC

Angle Band (deg.)	% Occur.	Wave Height (feet)			Peak Wave Period (sec.)		
		Mean	RMS	Max	Mean	Max	of Highest
0	0.3	2.8	3.1	7.7	3.6	4.9	4.9
22.5	3.4	3.3	3.7	8.8	6.7	18.2	7.5
45	1.7	3.3	3.5	6.8	4.8	9.8	5.5
67.5	5.3	3.7	4.0	8.0	5.7	16.0	6.4
90	14.0	3.4	3.7	7.9	6.9	16.0	7.5
112.5	17.8	2.9	3.2	8.6	8.1	18.2	8.0
135	17.8	2.9	3.2	10.5	8.5	18.2	8.0
157.5	15.1	2.9	3.2	8.1	7.5	18.2	16.0
180	13.3	2.8	3.0	7.9	6.5	25.6	7.5
202.5	8.6	2.6	2.8	6.4	5.3	16.0	6.0
225	1.5	2.8	3.1	10.4	4.8	16.0	8.5
247.5	0.1	2.5	2.6	3.5	4.1	7.1	7.1
270	0.1	3.2	3.5	5.9	4.7	5.5	4.7
292.5	0.1	2.8	2.9	4.1	4.8	8.5	3.6
315	0.2	3.7	3.9	6.1	4.2	6.4	6.4
337.5	0.3	2.7	2.9	6.1	5.3	18.2	5.3

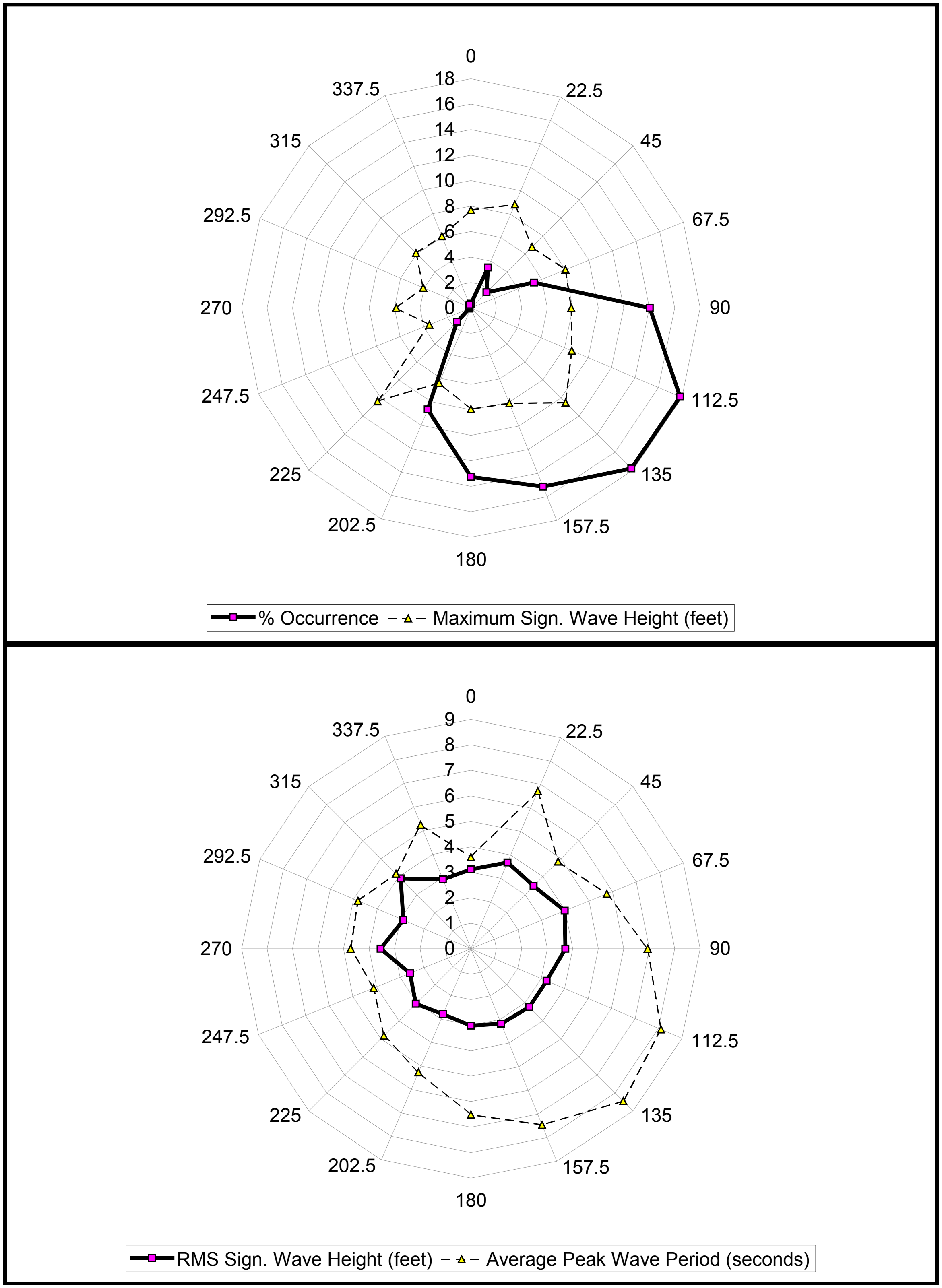
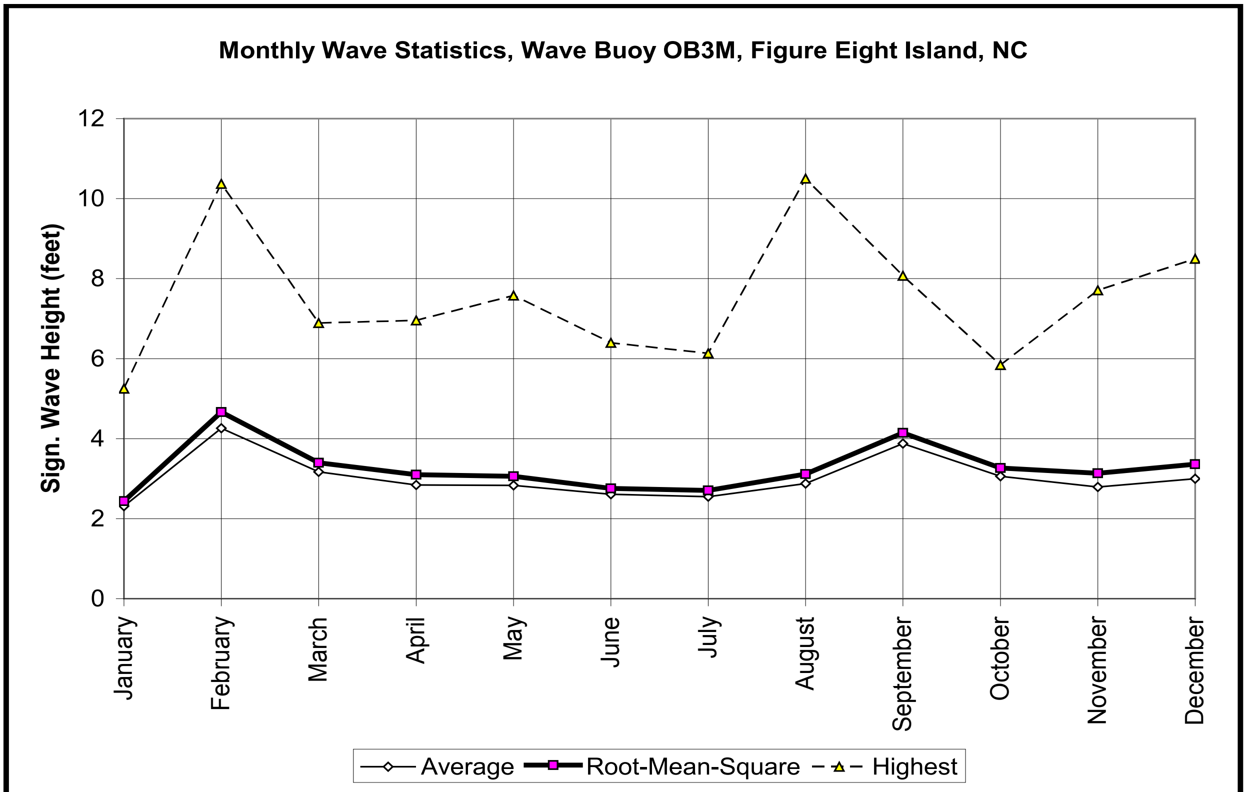


FIGURE 4-4: Directional Wave Statistics, Wave Buoy OB3M, Figure Eight Island, NC.



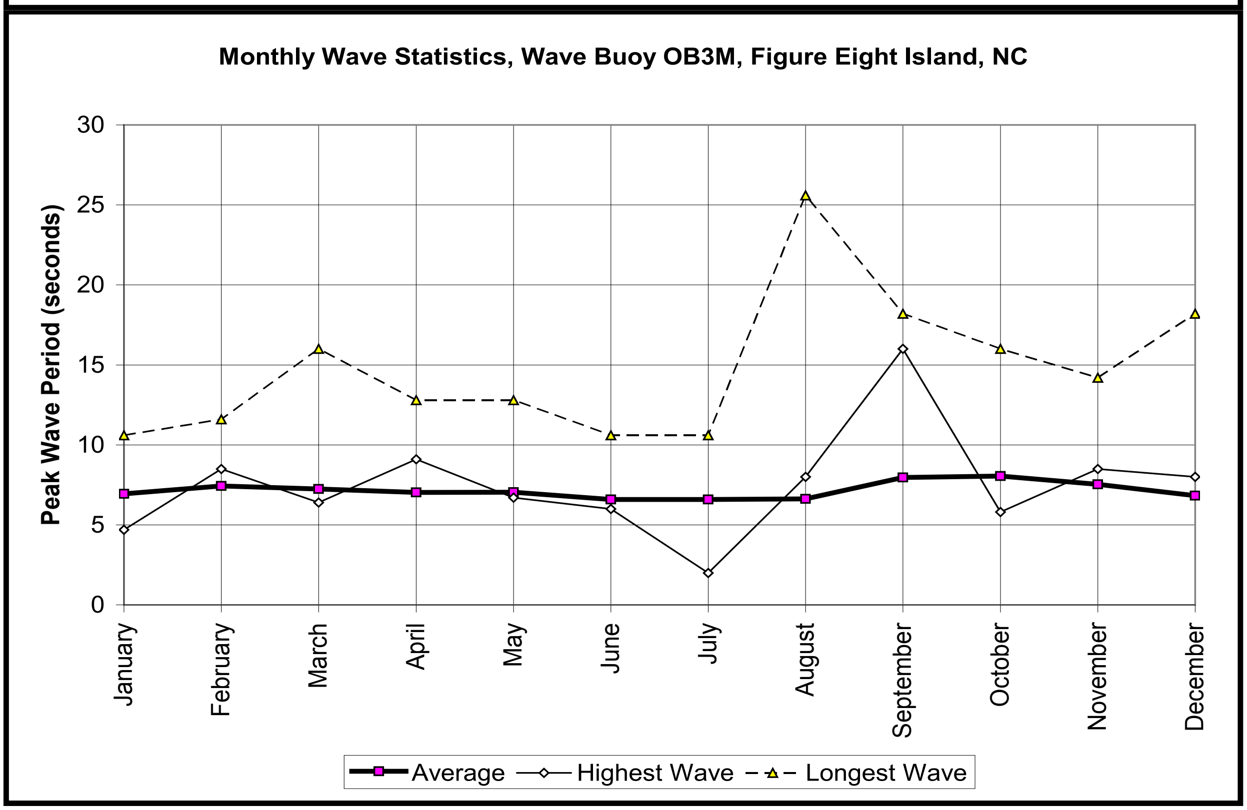


FIGURE 4-5: Monthly Wave Height and Wave Period, Figure Eight Island, NC.

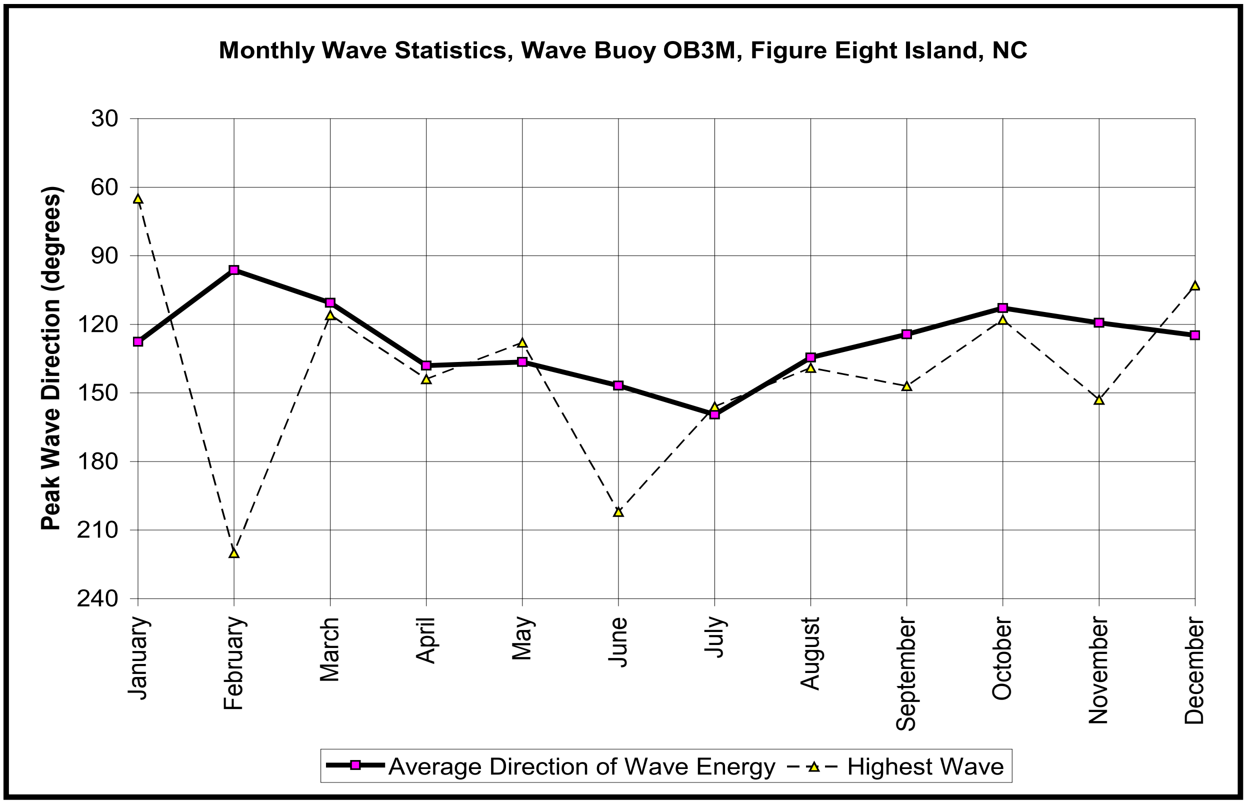


FIGURE 4-6: Monthly Wave Direction, Figure Eight Island, NC.

For numeric modeling purposes, wave conditions during storms were based on the 20 year wave hindcast record at Wave Information System (WIS) Station 296 (Figure 4-3). Wave conditions during severe storms were estimated in terms of return period. The return period represents the chance of a given wave event being exceeded in any given year. For example, the 20 year wave has a 1 on 20 chance of being exceeded in any given year. To delineate the wave height and wave period versus return period, the 20 highest wave events were taken from the wave record. A Weibull distribution was then estimated for the highest 20 wave events. The resulting wave heights and wave periods given the return period appear in Figure 4-7 and Table 4-5.

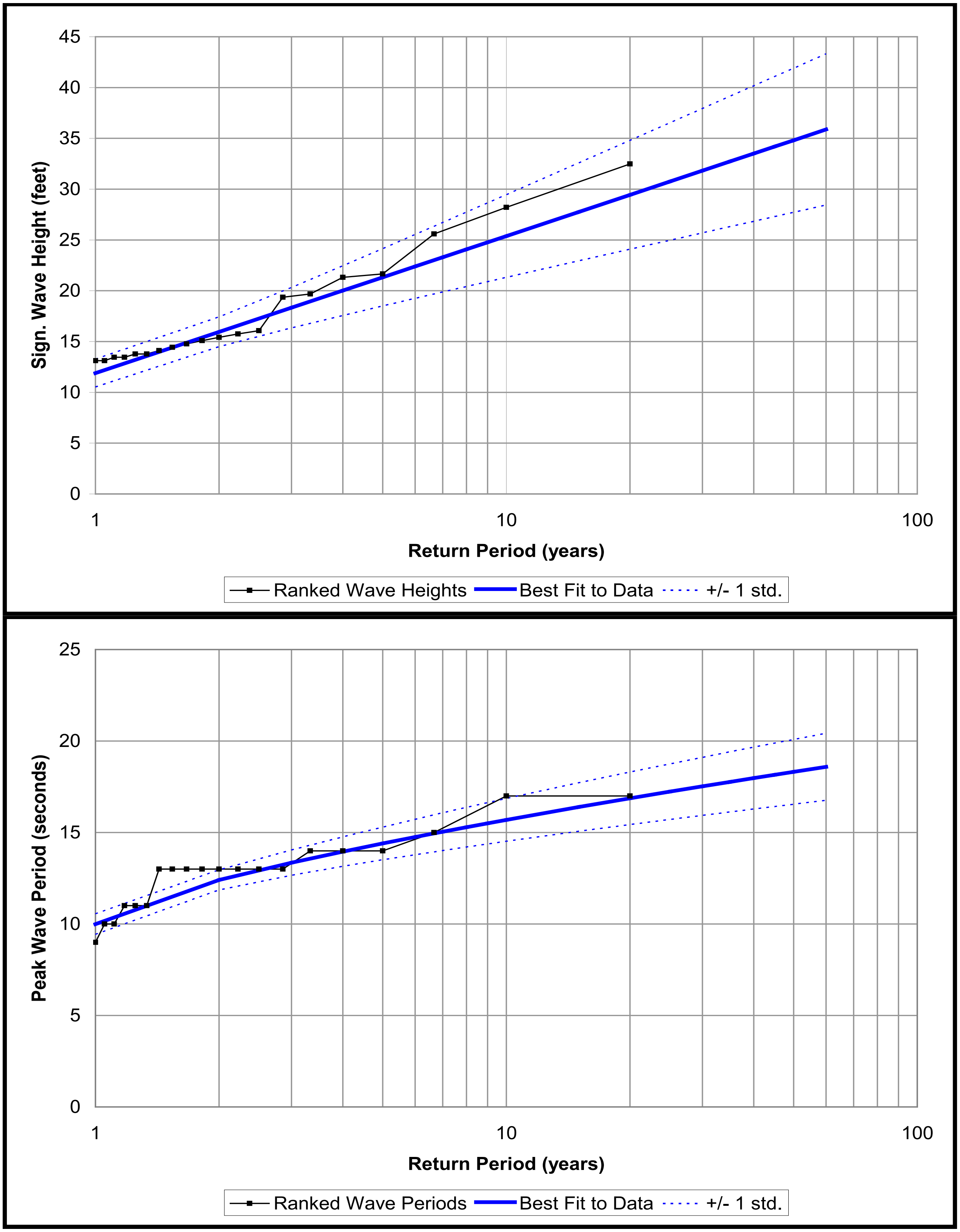


FIGURE 4-7: Storm Wave Statistics, Hindcast Station WIS296, Figure Eight Island, NC.

TABLE 4-5

1980-1999 STORM WAVE STATISTICS
HINDCAST STATION WIS296
FIGURE EIGHT ISLAND, NC

Return Period (years)	Wave Height H_{mo} (feet)	+/- σ	Wave Period T_p (sec.)	+/- σ
1	**11.9**	**1.4**	**10.0**	**0.6**
2	16.0	1.5	12.4	0.5
3	18.3	2.0	13.4	0.7
4	20.0	2.4	14.0	0.8
5	**21.3**	**2.8**	**14.4**	**0.9**
6	22.4	3.1	14.8	1.0
7	23.3	3.4	15.0	1.0
8	24.1	3.7	15.3	1.1
9	24.8	3.9	15.5	1.1
10	**25.4**	**4.1**	**15.7**	**1.2**
15	27.8	4.8	16.4	1.3
20	**29.4**	**5.4**	**16.9**	**1.4**
25	30.7	5.8	17.2	1.5
30	31.8	6.1	17.5	1.6
35	32.7	6.4	17.8	1.6
40	33.5	6.7	18.0	1.7
45	34.2	6.9	18.2	1.7
50	**34.8**	**7.1**	**18.3**	**1.8**
60	35.9	7.4	18.6	1.8

4.5 Storm Surge

Storm surge is defined as the rise of the sea surface above its astronomical tide level due to storm forces. The elevation that the storm surge reaches is known as the storm stage. The increase elevation is attributable to a variety of factors, including waves, wind shear stress, and atmospheric pressure. Storm stages are an important factor governing the performance of a beach fill during storms.

The Federal Emergency Management Agency (FEMA) released a Flood Insurance Study on April 3, 2006 for New Hanover County, North Carolina. The study detailed the storm stage elevations for 10, 50, 100, and 500 year storms. Oceanfront storm stages appear in Table 4-6 and Figure 4-8. The numerical models used in this study utilize offshore water levels as an input and calculate wave setup as an output. Accordingly, the stage values in Table 4-6 do not include wave setup. Detailed discussions of the SBEACH and Delft3D models appear in later sections of this report.

TABLE 4-6

OCEAN STORM STAGES
FIGURE EIGHT ISLAND, NC

FEMA Transect	Location	Storm Stage in feet NAVD given return period in years (excluding wave setup)			
		10	50	100	500
58	Approximately 2,430' south of intersection of Pipers Neck Rd. and Sounds Pt.	5.7	8.7	9.9	12.4
59	Approximately 645' southeast of intersection of Pipers Neck Rd. and Little Neck Rd.	5.7	8.7	9.9	12.4
60	Approximately 290' southeast of intersection of Saltmeadow Rd. and S. Beach Rd.	5.7	8.7	9.9	12.4
61	Approximately 720' northeast of intersection of S. Beach Rd. and Banks Rd.	5.7	8.7	9.9	12.4
62	Approximately 960' northeast of intersection of S. Beach Rd. and Backfin Pt.	5.7	8.7	9.9	12.4
63	Approximately 590' east of intersection of N. Beach Rd. and Bayberry Pl.	5.5	8.6	9.9	12.3
64	Approximately 1610' northeast of intersection of N. Beach Rd. and Salters Rd.	5.4	8.5	9.8	12.3
65	Approximately 1250' southwest of intersection of N. Beach Rd. and Clamdigger Point Rd.	5.3	8.5	9.8	12.3
66	Approximately 830' southeast of intersection of Surf Ct. and N. Beach Rd.	5.3	8.5	9.8	12.3
67	Approximately 520' east of intersection of N. Beach Rd. and Oyster Catcher Rd.	5.3	8.5	9.8	12.3
	Minimum Average Maximum	5.3 5.5 5.7	8.5 8.6 8.7	9.8 9.9 9.9	12.3 12.4 12.4

Source: FEMA (2006).

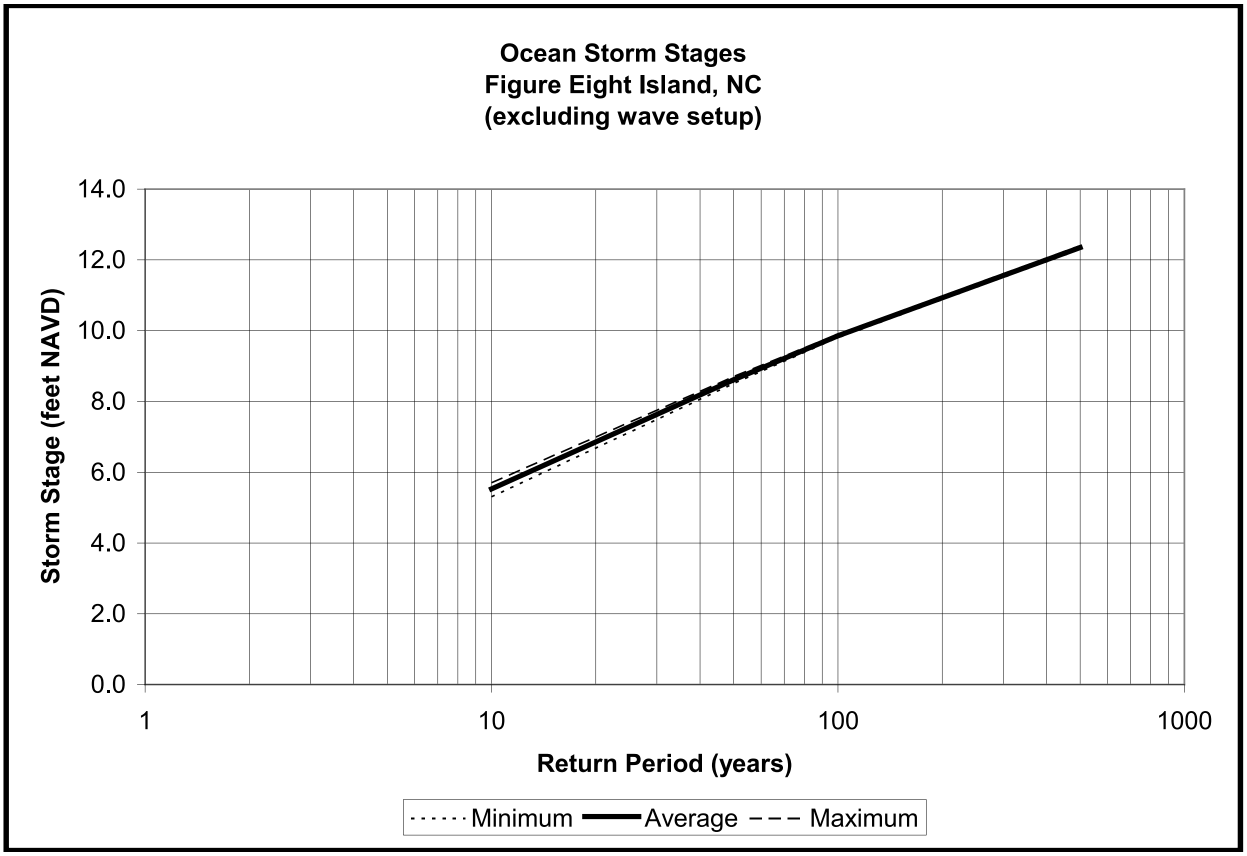


FIGURE 4-8: Ocean Storm Stages, Figure Eight Island, NC.

4.6 Depth of Closure

The depth of closure is defined as the "depth beyond which repetitive profile or topographic surveys (collected over several years) do not detect significant vertical sea bed changes. This is generally considered the seaward limit of littoral transport" (Morang and Szuwalski, 2003). The depth of closure is typically estimated by either comparing historic profiles and observing where the profiles close (pinch out and have no elevation difference) or using empirical equations, such as the ones developed by Hallermeier (1978) or Birkemeier (1985).

Historic profiles of Figure Eight Island were compared for surveys taken in October 2004, April and October 2005, and April 2006. The profiles appeared to close at an average depth of -24 feet NAVD, with closure depths ranging from -17 feet to -31 feet NGVD. This estimate was consistent with the established depth of closure for Topsail Beach (Figure 4-3), which was also -24 feet NAVD (USACE, 2006).

Empirical equations were also used to estimate the depth of closure for the project area. The Hallermeier (1978) and Birkemeier (1985) empirical equations are based on the significant wave event that is exceeded 12 hours per year (H_e and T_e). Hallermeier's equation is Equation 1, while Birkemeier's equation is shown as Equation 2.

Hallermeier's equation:

$$h_* = 2.28H_e - 68.5\left(\frac{H_e^{\ 2}}{gT_e^{\ 2}}\right) \qquad \text{[Equation 1]}$$

Birkemeier's equation:

$$h_* = 1.75H_e - 57.9\left(\frac{H_e^{\ 2}}{gT_e^{\ 2}}\right) \qquad \text{[Equation 2]}$$

The 12-hour wave event at WIS Station 296 (between 1980 and 1999) was found to have a significant wave height (H_e) of 15.8 feet and a period (T_e) of 12.5 seconds. The ACES linear wave transformation program suggests that this wave is transformed to a 21.9-foot wave near the shoreline. Application of Hallermeier's equation suggests that the depth of closure is -43.4 feet, MSL while Birkemeier's equation suggests that the depth of closure is -32.8 feet, MSL.

Based on experience, the depths of closure based on these two equations appear to be an overestimate of the depth to which sediment would be transported following a beach nourishment project. The established depth of closure for Topsail Beach (USACE, 2006) is the same as the survey-based value for Figure Eight Island. Accordingly, -24 feet NAVD has been chosen as the depth of closure for the development of this project.

4.7 Relative Sea Level Rise

The rate of sea level rise applicable to Figure Eight Island was determined from the average of sea level change rates observed at Beaufort, NC (0.0089 ft/yr), and Wilmington, NC (0.0067 ft/yr). The observed sea level trends are available from: http://tidesandcurrents.noaa.gov. The period of sea level observations used to establish these rates are 61 years for Beaufort, NC and 79 years for Wilmington, NC. The average rate of rise for these two stations is 0.0078 ft/yr.

The impacts of sea level rise on shoreline changes along Figure Eight Island due to a relative rise in sea level of 0.0078 ft/yr were based on the well-known Brunn Rule (Brunn, 1962). Per Brunn theorized that as sea level rises, the beach profile attempts to reestablish the same bottom depths relative to the surface of the sea that existed prior to the rise in sea level. The quantity of material needed to reestablish the beach profile must be derived from erosion of the shore. This theory is expressed by the equation:

$$\Delta x = ab/(e+d)$$

where:

Δx = rate of shoreline recession due to sea level rise.
e = elevation of the beach berm (+ 6 feet NAVD).
d = limiting depth between predominant nearshore and offshore material transport characteristics (-24 feet NAVD).
a = rate of sea level rise (0.0078 ft/yr)
b = distance from the initial shoreline to the limiting depth (average about 2,000 feet for Figure Eight Island).

For Figure Eight Island, the rate of shoreline erosion (Δx) associated with a sea level rise rate of 0.0078 ft/yr is equal to about 0.5 ft/year.

A recent study completed by the North Carolina Coastal Hazards Science Panel (2015) evaluated possible increases in the rate of rise of sea level due to changing climate conditions as projected by the IPCC (2013). For Beaufort, NC, the Panel estimated a possible rate of sea level to range from 0.0181 ft/year to 0.0208 ft/year for low and high greenhouse gas emissions, respectively. Similarly, the Panel projected possible rates of 0.0161 ft/year and 0.0189 ft/year for Wilmington, NC based on IPCC low and high greenhouse gas emissions. The average of these projections for application to Figure Eight Island results in possible future rates of sea level rise of between 0.0171 ft/year and 0.0199 ft/year. Inserting these rates in the Brunn Rule results in a range of possible shoreline retreat rates due to sea level rise of between 1.1 ft/year to 1.3 ft/year for the low and high greenhouse gas emission scenarios, respectively.

4.8 Native Beach Grain Size

To evaluate the materials presently on the beach, sand samples were collected in September 2007 from profiles F80+00, 10+00 (F120+00), 50+00 (F160+00), and 90+00 (F200+00) on Figure Eight Island. Due to several beach fill projects constructed along Figure Eight Island prior to sampling, these samples did not represent the "native materials" as defined by the North Carolina Technical Standards for Beach Fill Projects (15A NCAC 07H.0312). After discussion with State representatives, it was decided that sampling of the adjacent barrier island, Hutaff Island would be necessary to determine native composites. Additional samples were taken from profiles 160+00 (H1), H2, and H3 on Hutaff Island in September, 2007, along with the samples collected on Figure Eight Island. All profiles were sampled at the following locations:

- Dune
- Toe Of Dune
- Mid-Berm
- +2.0 to +3.0 feet NAVD
- Mean High Water
- Mean Tide Level
- Mean Low Water
- -6 feet NAVD
- -8.8 feet NAVD
- -11.6 feet NAVD
- -14.4 feet NAVD
- -17.2 feet NAVD
- -20 feet NAVD

The existing "beach" composites on Figure Eight Island are summarized in Table 4-7, along with the native composites on Hutaff Island. The locations of each sand sample appear in Figure 4-9.

TABLE 4-7

EXISTING BEACH COMPOSITES
FIGURE EIGHT ISLAND AND
HUTAFF ISLAND, NC

PROFILE	Mean Grain Size (mm)	Mean Grain Size (Φ)	Sorting (Φ)	% Silt	% Carbonate
F80+00	0.19	2.40	0.66	0.96	7.9
10+00 (F120+00)	0.18	2.45	0.55	1.03	5.4
50+00 (F160+00)	0.18	2.45	0.50	1.13	4.8
90+00 (F200+00)	0.18	2.47	0.46	1.04	5.9
Figure Eight Island December 2007 "Beach" Composite	**0.18**	**2.44**	**0.55**	**1.04**	**6.0**
160+00 (H1)	0.20	2.33	0.64	0.89	6.9
H2	0.19	2.41	0.59	0.97	5.9
H3	0.24	2.03	1.16	1.14	17.0
Hutaff Island December 2007 Native Composite	**0.21**	**2.26**	**0.85**	**1.00**	**9.9**

The native material on Hutaff Island is fine sand and exhibits a mean grain size of 0.21 mm, a sorting value of 0.85Φ, a carbonate content of 10%, and a low silt content of 1%. The "beach" material on Figure Eight Island is also fine sand, and exhibits a mean grain size of 0.18 mm, a sorting value of 0.55Φ, a carbonate content of 6%, and a silt content of 1%. The "beach" material on Figure Eight Island is slightly finer than the truly native material on Hutaff Island. However, the difference between the two composites is not large, and suggests that the fill placed in 2006 has mixed with the native material. A more detailed discussion of the materials presently on the beach appears in the Geotechnical Investigation for this study.

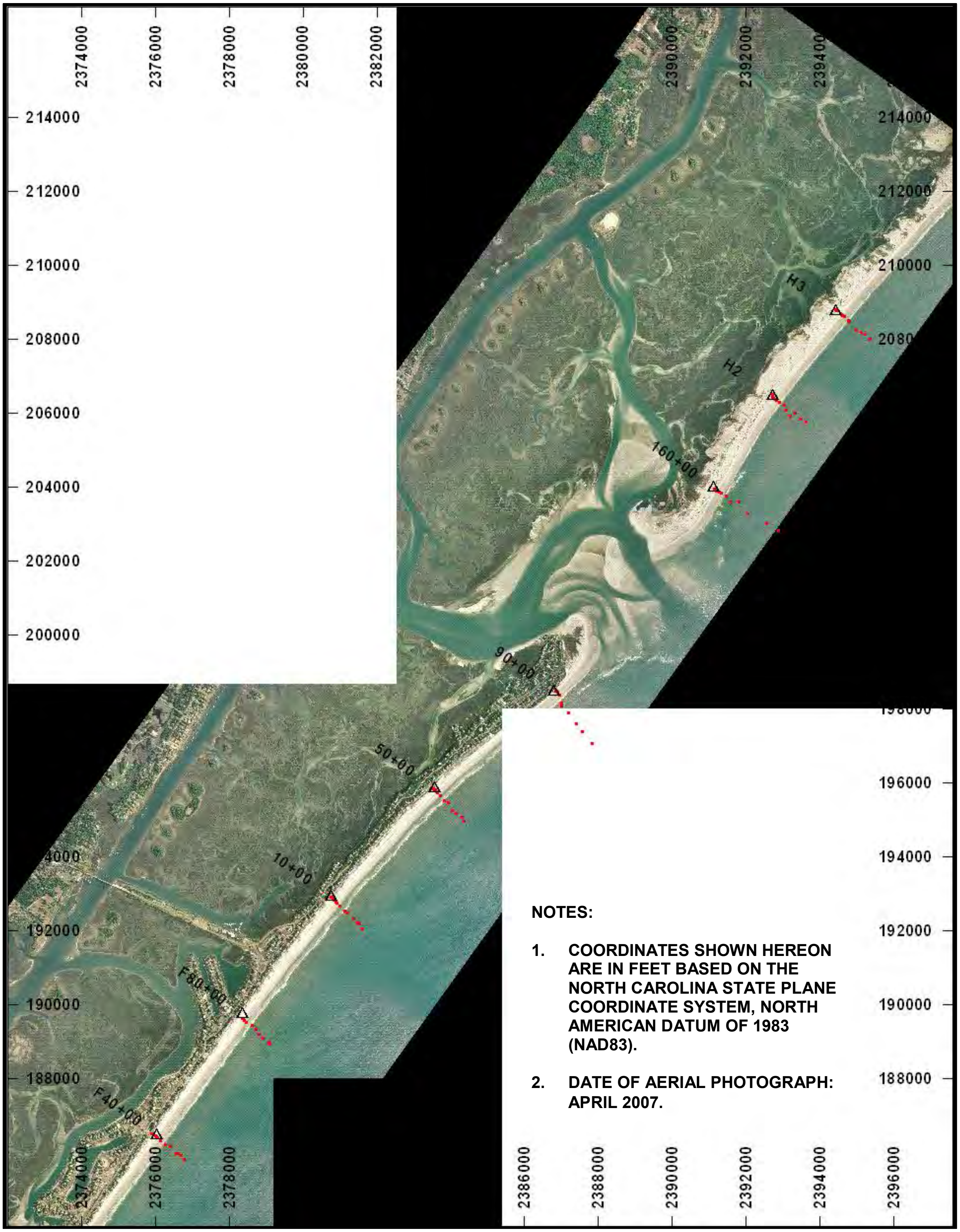


FIGURE 4-9: December 2007 Sand Samples, Figure Eight Island and Hutaff Island, NC.

4.9 Inlet Grain Size

In general, the material in Rich Inlet is fine sand. Based on the geotechnical information, the mean grain sizes of the material in the dredge cuts for Rich Inlet range from 0.18 to 0.30 mm, with sorting values ranging from 0.44 to 1.16Φ, and silt contents on the order of 1%. The composite for the dredge cuts has a mean grain size of 0.24 mm, a sorting value of 0.83Φ, and a silt content of 1%. A more detailed discussion of the materials in the dredge cuts appears in the final Geotechnical Investigation for this study.

4.10 Tidal Prism of Rich Inlet

Several estimates of the tidal prism have been developed for Rich Inlet (Table 4-8). Two sets of estimates appeared in a study by Cleary and Knierim (2003). One set was based on an Acoustic Doppler Current Profiler (ADCP) survey, and the second set was based on empirical relationships between tidal range and tidal prism.

TABLE 4-8

RICH INLET TIDAL PRISM ESTIMATES
FIGURE EIGHT ISLAND, NC

SOURCE / METHOD	TIDAL PRISM THROUGH INLET THROAT (cubic feet)					
	SPRING TIDES		AVG. TIDES		NEAP TIDES	
	FLOOD	EBB	FLOOD	EBB	FLOOD	EBB
Cleary & Knierim (2003)						
ADCP Survey	797,000,000	690,000,000	603,000,000	562,000,000	329,000,000	430,000,000
Empirical Relationships	645,000,000	652,000,000	469,000,000	434,000,000	318,000,000	247,000,000
Gahagan & Bryant (2005) Measurements	1,101,000,000	560,000,000	N/A	N/A	N/A	N/A
Delft3D Model with Waves April 2006 Conditions	N/A	N/A	653,000,000	697,000,000	N/A	N/A

Tidal prism estimates were also estimated based on a later ADCP survey by Gahagan & Bryant (2005). The depth-averaged currents (Figure 4-2) were combined with concurrent water levels and survey data (Figure 4-1) to evaluate the flow rate through the inlet throat in cubic feet per second. Flow rates were then integrated over the flood and ebb cycles shown in Figure 4-1. A final set of tidal prism estimates was based on the Delft3D modeling results. The tidal prism estimates varied widely. However, based on the values in Table 4-8, the average tidal prism was on the order of 560,000,000 cubic feet. A further discussion of the tidal prism appears in the Delft3D modeling study.

5.0 CHANNEL EVOLUTION

Erosion and accretion along relatively stable inlets such as Rich Inlet are related to complex cyclical changes in the shape of the ebb-tidal deltas. Cycles are associated with the repositioning and realignment of the ebb channel and corresponding position and size changes of the marginal flood channels and where swash bars welded onto the adjacent shorelines (FitzGerald, 1984; Cleary, 1994, 1996, and 2002; Cleary and Marden, 1999; Cleary et al., 1989).

Rich Inlet drains an extensive estuary filled with tidal marsh where two large tidal creeks, Nixon and Green Channels, connect the inlet to the Atlantic Intracoastal Waterway (AIWW). It is an example of a relatively stable inlet where the repositioning and realignment of the ebb channel leads to dramatic erosion on one or both adjacent beaches. Erosion occurs as the shape of the offshore sand shoals changes thereby affecting impact of incoming waves on the nearby beaches. Historic map and geomorphic data indicate the inlet has been a relatively stable feature over the past century. The large drainage area that includes portions of the bar-built lagoon and Pages Creek estuary enhances the inlet's stability.

A GIS-based analysis of historic aerial photographs dating from 1938 to 2003 was undertaken by Cleary and Jackson (2004) to quantify shoreline changes, their connection to the inlet's migration, and the system changes of the inlet. Cleary provided an update of this analysis which appears in Sub-Appendix A.

5.1 Historic Channel Alignment (Cleary and Jackson, 2004)

"The recent movement of the ebb (entrance) channel has been confined to a ~0.30 mile wide pathway. The ebb-tidal delta is situated on Oligocene siltstone that crops out along the ebb delta's outer margin in water depths of 30 feet. The width of the inlet throat reached a maximum of 2,673 feet in October of 1989 and a minimum of 920 feet in February of 2001. The average with the inlet throat since 1938 was 2,000 feet.

Since 1938, the position of the ebb (entrance) channel has remained within a 1,600 foot wide migration corridor, indicating that Rich Inlet has been relatively stable. Through the period from 1938 to 2003, the orientation of the ebb channel across the outer portion of the ebb-tidal delta has fluctuated between 83˚ and 181˚. Between 1938 and 1993, the ebb channel was oriented predominately in a southeasterly direction between 112˚ and 181˚ before realigning to a more easterly orientation of 103˚ in 1996. The ebb channel's alignment and position prior to the mid-1990s promoted the development of a one-mile long zone of accretion along the Figure Eight Island oceanfront immediately south of the inlet. During the period from 1993 to 1996, the ebb channel rapidly migrated 1,056 feet northeast at a rate of 308 feet per year. Between August 1996 and February 1998, the ebb channel shifted 147 feet further to the northeast before reversing its migration direction to the southwest in June 1998. Inspection of aerial photographs shows that between June 1998 and February 2002, the ebb channel migrated a distance of 588 feet to the southwest at a rate of 160 feet per year.

While the ebb channel tracked to the northeast between March 1993 and February 1998, the northern spit of Figure Eight Island elongated, dramatically reducing the inlet's width. Although the migration direction changed to the southeast in June 1998, the orientation of the ebb channel continued to be deflected in a northeasterly direction before reaching alignment of 83˚ in October 2000. A breach of the ebb-tidal delta occurred in the latter part of 2000 that resulted in a shore-normal repositioning of the ebb channel. Between February 2001 and March 2003, the outer segment of the ebb channel was continually deflected from its 156˚ alignment in early 2001 to an alignment of 190˚ by early 2003. During late 2003 and early 2004, the ebb channel was reoriented to a shore normal alignment.

Previous studies have shown that the position and orientation of the ebb channel has controlled the shape and ebb tidal delta and ultimately dictates the shoreline changes along the adjacent oceanfront shorelines of Figure Eight Island.

In order to reverse the current erosion trend and promote accretion along the northern oceanfront of Figure Eight Island, the ebb channel must assume a position that approximates the location of the ebb (entrance) channel imaged in 1980 and maintain a near shore-normal orientation of ~145 degrees. For this repositioning to occur the ebb channel must migrate ~1,300 feet to the southwest."

5.2 Location of Ebb Shoal Apex (Cleary and Jackson, 2004)

"The position and alignment of the ebb channel has controlled the symmetry of the ebb-tidal delta and its apex. The changes in the shape of the ebb-tidal delta and in the position of its apex (seaward protrusion) since 1938 are depicted in Figure [5-1]…. Changes in the position of the apex, with time, are a function of the complex interplay of ebb channel (inlet) migration and the deflection of the outer ebb channel. Storms are also thought to contribute to the observed changes in the shape of the ebb-tidal delta. Regardless of the mechanism, the position of the ebb-tidal delta's apex plays a major role in the controlling the manner in which waves impact the oceanfront shorelines in the immediate vicinity of the inlet.

The location of the apex generally coincides with the point where the ebb channel crosses the periphery of the ebb-tidal delta. Deflection of the ebb channel since 1938 has caused a shift in the position of the apex and shape change of the ebb tidal delta across a ~5,100 foot wide zone. As ebb channel migration occurred, the entire offshore shoal complex was continuously being reconfigured along the with adjacent barrier shorelines as they responded to the changes in wave approach and sand supply. The current ebb-tidal delta shape has controlled the erosion since 1997. The zone of maximum erosion along the oceanfront shorelines has generally shifted eastward through time as the ebb channel has migrated to the northeast. The northeasterly shift of the channel has not only dictated the shape of the offshore shoals that afford protection for the end of the island, but simultaneously this shift has controlled the location where large swash bar complexes attach to the shoreline.

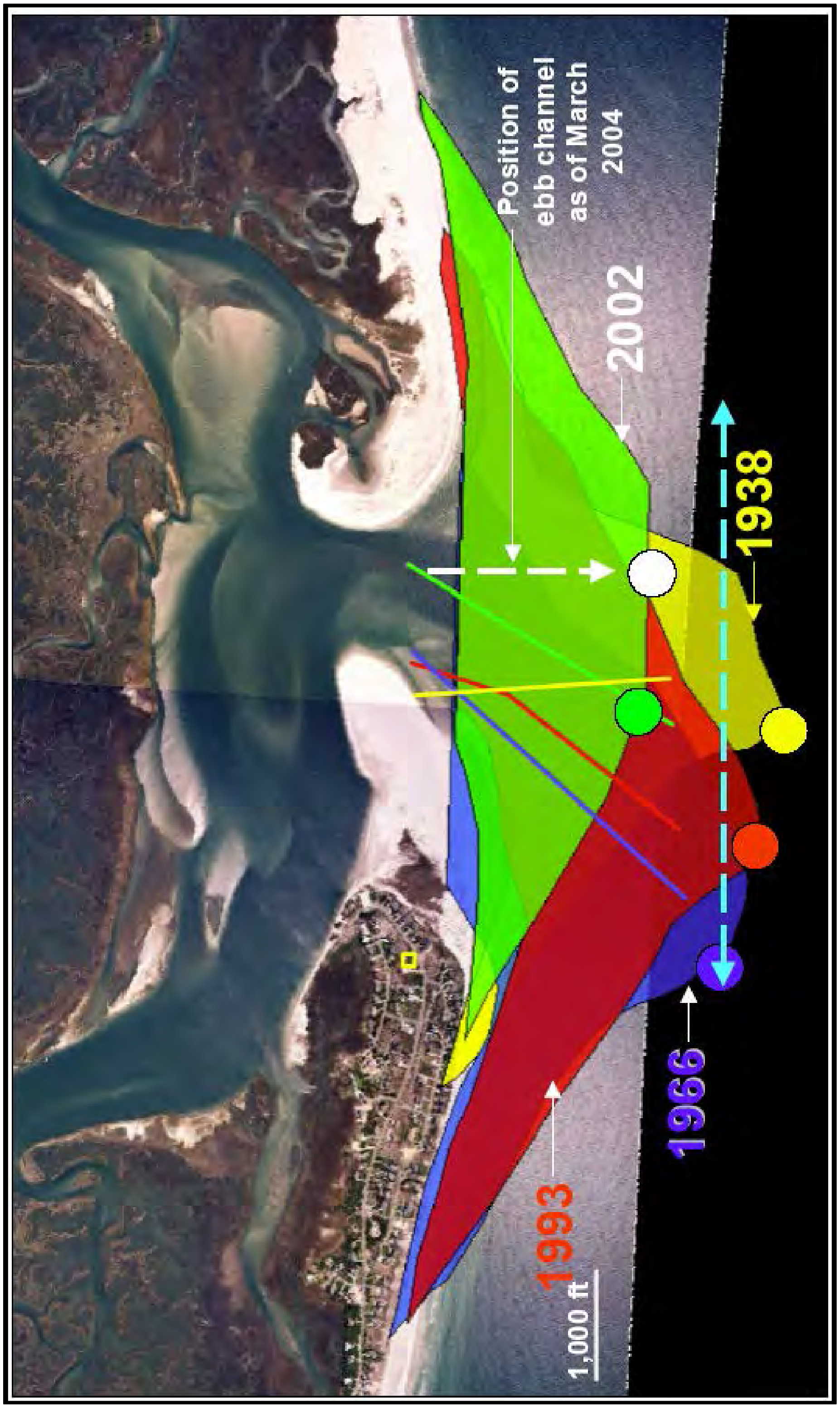


FIGURE 5-1: **Aerial photograph (March 2002) with shapes of ebb deltas (as defined by zone of breaking waves), ebb channel positions and apex of ebb deltas (colored dots). The white arrow and dot represent approximate position of the ebb channel and apex in March 2004. Dashed light blue arrow delineates the width of the zone of deflection of the ebb delta apex (dots) (Cleary and Jackson, 2004).**

A repositioning of the ebb channel toward Figure Eight Island will lead to a seaward shift and repositioning of the apex to the southwest. The consequences of this net change will reverse the erosion trend that has characterized the oceanfront since 1997.

Any future modification of the inlet should consider the ebb channel's optimum position alignment and the consequent ebb-tidal delta symmetry and related potential shoreline changes. The most felicitous ebb channel position and alignment for shoreline accretion on Figure Eight Island is a configuration where the ebb channel is shore normal and is positioned along the southern portion of its migration pathway, ~1,300 feet to 1,500 feet southwest of its current potion. Any plans that result in a substantial deviation from the above configuration will lead to increased shoreline retreat along a position of the erosion hot-spot. If and when the ebb channel attains the aforementioned position, the ebb-tidal delta will begin to reconfigure and thereby cause a southwesterly shift in large volumes of sand and in the wave sheltering effects of the offshore shoal complex. It must be understood that it is likely there will be a lag effect in terms of the movement of the ebb channel and the timing of the positive impacts along the oceanfront. The lag is primarily due to the time needed for the remobilization of the enormous volume of sediment retained in the ebb-tidal delta that currently lies northeast of the erosion hot-spot. There is a high probability that a breach across the undeveloped spit could occur that will shorten the time lag considerably. The morphology of the inlet depicted on recent photographs and observations made during recent over-flight indicate that the spit is highly vulnerable to breaching when it is narrow."

6.0 SHORELINE CHANGE ANALYSIS

The Figure Eight Island shoreline is a dynamic feature in a constant state of flux due to changes in wave energy and sediment supply. When viewed in terms of decades or on the century scale, a complex set of factors, which operate in concert, have dictated shoreline change along both the oceanfront and inlet shorelines. Under the combined influence of cumulative storm impacts, waves, and inlets, the island has generally become erosional, although certain sections of the island accrete. Sea level rise also contributes to the erosion rates along the island. However, in comparison to the other forces driving erosion, the contribution of sea level rise, which is estimated to be around -0.5 ft/yr given historic sea level trends over the past half century, is minor. Even when taking into account possible increases in the rate of sea level rise, the shoreline recession rates attributable to sea level rise would still be less than 1.3 ft/yr. Much of the northern section of Figure Eight Island is characterized by multiple sets of dune ridges that reflect the buildup of the beach that is related to the influence of Rich Inlet. The presence of large intact dunes provides protection from flooding due to increased water levels and overtopping during storms.

During the late 1990s the complex interplay between the northeasterly migration of the channel and the continuing realignment of its outer segment has resulted in a shift of the breakwater effect of the ebb-tidal delta and a repositioning of it to the northeast. Consequently, the Figure Eight Island oceanfront was no longer afforded protection from wave attack. As a result, the northern 4,500 foot segment of the oceanfront, which has a history of net accretion, began to experience severe erosion.

In the fall of 2000, an ebb delta breaching event occurred that repositioned the ebb channel and initiated a southwestward trek of the inlet and promoted erosion along the downdrift Figure Eight

Island shoreline. Between 2001 and 2003 the shoreline retreat averaged ~10 feet. In an effort to mitigate the chronic recession, 350,000 cubic yards of fill material was placed along the erosion zone and the area to the south in February and March 2001 (Cleary and Jackson, 2004). Much of the beach fill was lost by November 2001. In late 2001, erosion continued and reached critical proportions and as a last resort, large sand bags were placed along a number of the endangered homes in the area. The entirety of this shoreline stretch is now armored with a wall of sand bags. Additional fill was placed along this area in 2005 and 2006 (GBA, 2006). However, the shoreline response through March 2008 was similar to the shoreline change after the 2001 project (Figure 6-1).

FIGURE 6-1: North End of the Sandbagged Area, 4-7 Inlet Hook Road, March 18, 2008.

Oceanfront shoreline changes on Figure Eight Island since the October 1999 Light Detection and Ranging (LIDAR) survey by NOAA appear in Figure 6-2 and Table 6-1. The effect of beach fill (Table 6-2) was removed from these shoreline changes. In general, the northern and southern ends of the island erode, while the middle of the island accretes. Aside from the various beach fills, the northern end of the island (profiles 40+00 – 110+00) retreated 2 to 52 feet per year between October 1999 and April 2007. By contrast, the 3,000 foot segment on the south end of Hutaff Island advanced 15 feet/year between October 1999 and April 2005 (Table 6-3). Between April 2005 and April 2007, a large erosion loss occurred on southern Hutaff Island due to Hurricane Ophelia (October 2005) and the formation of a swash channel into Rich Inlet. Nevertheless, over the past 8 years as whole, the north end Figure Eight Island has experienced more erosion than the south end of Hutaff Island.

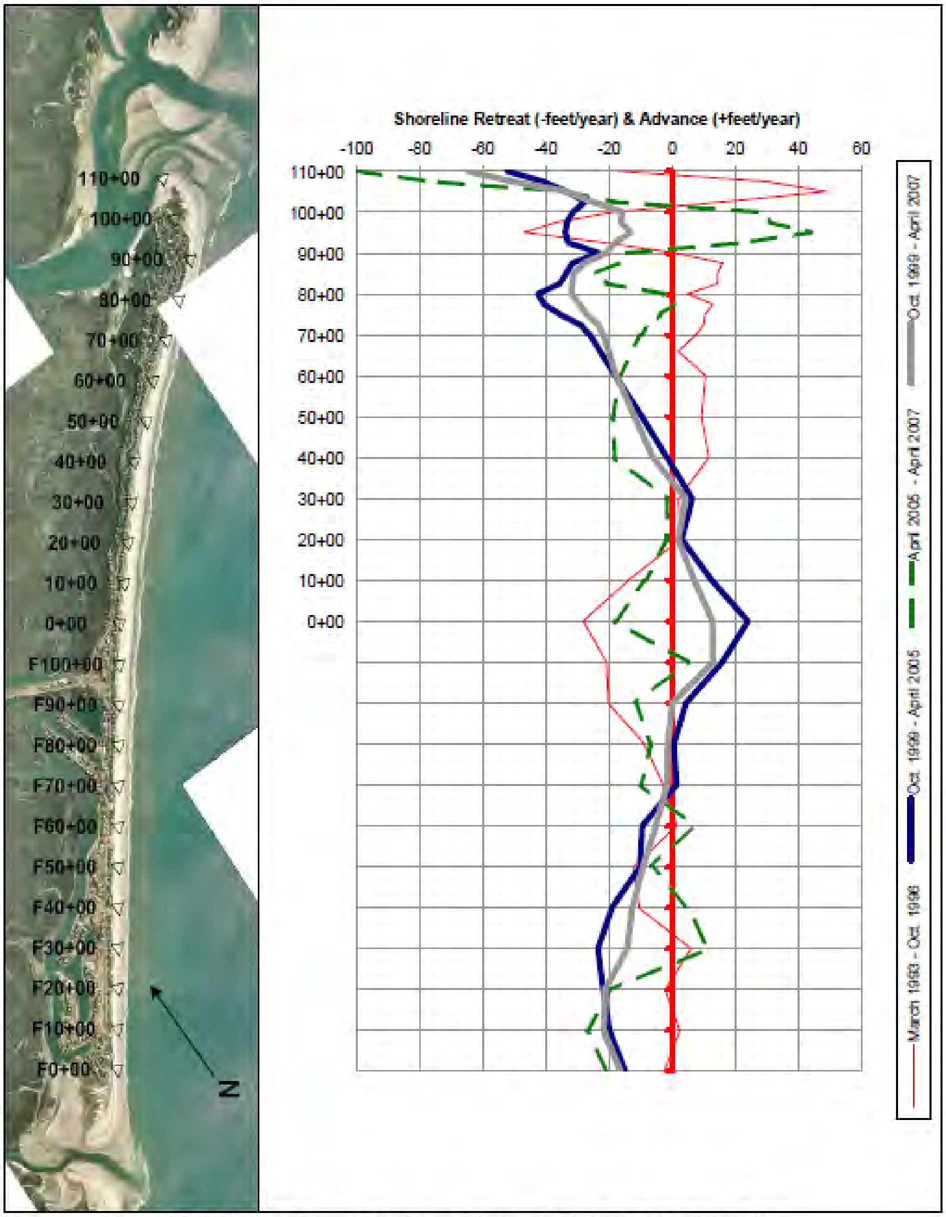


FIGURE 6-2: Ocean Shoreline Changes, Figure Eight Island, NC.

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TABLE 6-1

OCEAN SHORELINE CHANGES
(adjusted for beach fills)
FIGURE EIGHT ISLAND, NC

Profile Line	Beach Length (feet)	Shoreline Retreat (-feet/year) & Advance (+feet/year)				
		Mar 1993 to Oct 1996	Oct 1999 to Apr 2005	Apr 2005 to Apr 2007	Oct 1999 to Apr 2007	1999-2007 Worst Case
F0+00	500	-2	-14.8	-20.5	-16.3	-20.5
F10+00	1,000	2	-19.8	-27.0	-21.7	-27.0
F20+00	1,000	-2	-21.9	-19.4	-21.2	-21.9
F30+00	1,000	6	-23.5	11.3	-14.2	-23.5
F40+00	1,000	-10	-19.1	5.1	-12.7	-19.1
F50+00	1,000	-12	-10.2	-6.4	-9.2	-10.2
F60+00	1,000	1	-9.5	6.7	-5.1	-9.5
F70+00	1,000	-3	1.4	-9.8	-1.6	-9.8
F80+00	1,000	-9	0.5	-6.6	-1.4	-6.6
F90+00	1,000	-20	4.4	-11.6	0.2	-11.6
F100+00	1,000	-21	15.9	4.9	12.9	4.9
0+00	1,000	-28	24.1	-18.1	12.8	-18.1
10+00	1,000	-14	12.6	-8.5	7.0	-8.5
20+00	1,000	3	3.1	-1.4	1.9	-1.4
30+00	1,000	2	6.4	-1.7	4.2	-1.7
40+00	750	12	-1.6	-18.1	-6.0	-18.1
45+00	500	10	-5.5	-18.4	-9.0	-18.4
50+00	750	9	-9.5	-18.7	-12.0	-18.7
60+00	800	11	-17.9	-16.7	-17.6	-17.9
66+00	500	2	-22.8	-12.6	-20.1	-22.8
70+00	325	8	-26.0	-9.9	-21.7	-26.0
72+50	250	10	-29.2	-7.4	-23.4	-29.2
75+00	250	10	-35.5	-3.6	-27.0	-35.5
77+50	250	13	-40.5	0.9	-29.5	-40.5
80+00	250	5	-42.5	-2.5	-31.8	-42.5
82+50	250	14	-35.5	-20.9	-31.6	-35.5
85+00	250	14	-33.5	-24.5	-31.1	-33.5
87+50	250	16	-31.5	-17.0	-27.7	-31.5
90+00	250	1	-23.3	-14.1	-20.8	-23.3
92+50	250	-21	-32.9	22.6	-18.1	-32.9
95+00	250	-47	-33.9	44.0	-13.1	-33.9
97+50	250	-37	-33.3	30.9	-16.2	-33.3
100+00	250	-18	-31.4	27.4	-15.8	-31.4
102+50	250	16	-27.5	-18.6	-25.2	-27.5
105+00	250	49	-33.4	-33.8	-33.5	-33.8
107+50	250	30	-41.0	-77.3	-50.7	-77.3
110+00	125	-17	-52.3	-99.6	-64.9	-99.6
F0+00 to F90+00	9,000	-4	-11.9	-6.9	-10.6	-15.9
F90+00 to 45+00	6,500	-9	9.5	-7.5	5.0	-7.5
45+00 to 66+00	2,100	9	-14.1	-17.0	-14.9	-18.9
66+00 to 105+00	3,900	1	-32.0	-1.5	-23.9	-32.0

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TABLE 6-2

FIGURE EIGHT ISLAND BEACH FILLS 1993 - PRESENT

Project Date	Type of Project	Volume (c.y.)	Source	Region
February 1993	Beach Nourishment	274,000	Nixon Channel	North End*
December 1994	Beach Scraping	N/A	N/A	Island-Wide**
November 1996	Beach Scraping	N/A	N/A	Island-Wide**
January 1997	Storm Recovery	250,000	Nixon Channel	North End*
March 1998	Channel Dredging	450,000	Banks Channel and Middle Sound	Island-Wide**
March 1999 and early 2000	Beach Nourishment	785,000	Cameron Disposal Island and Banks Channel	South End
March 2001	Beach Nourishment	350,000	Nixon Channel	North End*
Jan.-Feb. 2002	Mason Inlet Relocation	390,000	Mason Inlet	South End
March 2003	Channel Dredging	50,000	Masons Inlet & AIWW	South End
March 2003	Beach Nourishment	30,000	Banks Channel & AIWW	South End
February 2005	Dredge Nourishment	183,000	Mason Inlet	South End
November 2005	Beach Nourishment	261,235	Nixon Channel	North End*
February 2006	Beach Nourishment	179,175	Banks Channel	South End
April 2006	Beach Nourishment	148,969	Mason Creek & AIWW	South End
February 2009	Beach Nourishment	295,000	Nixon Channel	North End*
Spring 2009	Channel Dredging	176,000	Mason Inlet	South End
Jan-Mar 2011	Channel Dredging	275,000	Nixon Channel	North End*
2012-2013	Mason Inlet Maintenance	237,000	Mason Inlet	South End

Sources: All projects prior to 2005 - Cleary & Jackson (2004), Chapter 5.
Spring 2005 channel dredging - Gahagan & Bryant (2005).
November 2005 and subsequent projects - Gahagan & Bryant (2006).
* The 30,000 c.y. was placed outside the active beach profile and not incorporated in the shoreline retreat rates.

TABLE 6-3

OCEAN SHORELINE CHANGES
HUTAFF ISLAND, NC

Profile Line	Beach Length (feet)	Shoreline Retreat (-feet/year) & Advance (+feet/year)			
		Mar 1993 to Oct 1996	Oct 1999 to Apr 2005	Apr 2005 to Apr 2007	Oct 1999 to Apr 2007
145+00	125	-5	-11.2	-35.6	-17.7
147+50	250	0	-4.6	-82.6	-25.4
150+00	250	-2	5.6	-109.0	-24.9
152+50	250	-3	8.5	-118.2	-25.3
155+00	250	-2	5.5	-102.1	-23.2
157+50	250	-9	10.8	-94.2	-17.2
160+00	250	-20	14.8	-82.4	-11.1
162+50	250	-26	16.2	-67.7	-6.2
165+00	250	-29	19.9	-52.7	0.5
167+50	250	-36	23.3	-40.3	6.3
170+00	250	-36	30.1	-30.5	14.0
172+50	250	-40	34.9	-35.8	16.1
175+00	125	-36	34.5	-31.9	16.8
145+00 to 175+00	3,000	-19	14.7	-70.8	-8.1

The erosional period on the north end of Figure Eight Island started in 1997. Since 1997, the main channel of Rich Inlet has moved towards its present location near Hutaff Island. However, in 1993, the main channel of the inlet was located closer to Figure Eight Island, as shown in Figure 5-4. Shoreline changes between 1993 and 1996 appear in Figure 6-2, Table 6-1, and Table 6-3. During this period, the northern half of Figure Eight Island (profiles 20+00 to 90+00 and 102+50 to 107+50) was accretional. The only erosion hotspot was located north of Inlet Hook Road (profiles 92+50 to 100+00). Conversely, the south end of Hutaff Island was erosional during this period. In general, a "comparison of the shoreline change data for Figure Eight Island and Hutaff Island for various periods since 1938 indicates that the updrift and downdrift barriers generally have opposing erosion/accretion trends. The major reversals in the accretion patterns and the onset of erosion are directly related to changes in the position of the ebb channel." (Cleary and Jackson, 2004, p. 146).

7.0 VOLUMETRIC CHANGE ANALYSIS

Volumetric changes along Figure Eight Island are based on the April 2005, April 2006, and April 2007 monitoring surveys by Gahagan & Bryant (2006, 2007). Available surveys prior to October 2004 were taken above wading depth (-4' NAVD) only, rendering them insufficient for a true volumetric change analysis.

Volume changes between April 2005 and April 2007 appear in Table 7-1 and Figure 7-1. Volume changes were computed using Beach Morphology Analysis Package Version 2.0 (BMAP, Sommerfeld, et al, 1994). The plotting routine within BMAP was utilized to evaluate the limits beyond which the apparent profile changes were dominated by survey error.

Between April 2005 and April 2007, Figure Eight Island gained 136,800 cubic yards (see Table 7-1, column 3). However, over 589,000 cubic yards of material was placed on the island (Table 6-2) between these dates. Without the beach fill, the island would have lost 452,900 cubic yards (see Table 7-1, column 5), equal to an average erosion rate of 10 c.y./year/foot. Most of the island was erosional between April 2005 and April 2007. Natural gains were limited to a few isolated areas near Bayberry Place (0+00), profiles 20+00 to 30+00, Surf Court (75+00), and Rich Inlet (105+00). The highest erosion rates occurred near Mason Inlet (INN15+00 to F20+00) and Inlet Hook Road (90+00). Moderate erosion occurred between profile 35+00 and Surf Court (70+00).

On the southern end of Hutaff Island (145+00 to 170+00), the beach lost 399,700 cubic yards. As noted earlier, this erosion was caused by Hurricane Ophelia (October 2005) and the formation of a swash channel into Rich Inlet. Based on a comparison of Tables 6-3 and 7-1, the 2005-2007 erosion patterns were not typical of the long term trend since 1999. Furthermore, they were considerably higher than the 1938-1998 erosion rates compiled by Cleary (2008).

P:\North Carolina\Figure Eight Island\Engineering\FIGURE_8_ISLAND_SEDIMENT_BUDGET.xls volume_summary 12/16/2009

TABLE 7-1

OCEANFRONT VOLUME CHANGES
APRIL 2005 - APRIL 2007
FIGURE EIGHT & HUTAFF ISLAND, NC

Profile Line	Beach Length (feet)	April 2005 - April 2007 Volume Change (c.y.) Surveyed Changes	Beach Fills	Adjusted Changes	2005-2007 Volume Change Rates (c.y./year)
INN15+00					
	100	-5,600	0	-5,600	-2,800
F-4+00					
	400	-16,400	9,300	-25,700	-12,850
F0+00					
	100	-2,700	5,300	-8,000	-4,000
F1+00					
	400	-8,000	23,400	-31,400	-15,700
F5+00					
	500	-3,200	29,200	-32,400	-16,200
F10+00					
	200	400	11,700	-11,300	-5,650
F12+00					
	200	900	11,700	-10,800	-5,400
F14+00					
	600	5,400	35,100	-29,700	-14,850
F20+00					
	400	4,800	23,400	-18,600	-9,300
F24+00					
	500	5,700	22,000	-16,300	-8,150
F29+00					
	100	1,100	2,900	-1,800	-900
F30+00					
	1,000	12,900	29,400	-16,500	-8,250
F40+00					
	1,000	18,400	29,400	-11,000	-5,500
F50+00					
	200	3,900	5,900	-2,000	-1,000
F57+00					
	800	6,800	23,500	-16,700	-8,350
F60+00					
	1,000	1,100	29,400	-28,300	-14,150
F70+00					
	1,000	6,000	29,400	-23,400	-11,700
F80+00					
	500	2,200	7,300	-5,100	-2,550
F85+00					
	500	-2,700	0	-2,700	-1,350
F90+00					

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TABLE 7-1

OCEANFRONT VOLUME CHANGES
APRIL 2005 - APRIL 2007
FIGURE EIGHT & HUTAFF ISLAND, NC

Profile Line	Beach Length (feet)	April 2005 - April 2007 Volume Change (c.y.)			2005-2007 Volume Change Rates (c.y./year)
		Surveyed Changes	Beach Fills	Adjusted Changes	
	500	-3,900	0	-3,900	-1,950
F95+00					
	500	-1,300	0	-1,300	-650
F100+00					
	1,000	5,400	0	5,400	2,700
0+00					
	500	500	0	500	250
5+00					
	500	-9,100	0	-9,100	-4,550
10+00					
	1,000	-13,000	0	-13,000	-6,500
20+00					
	1,000	3,500	0	3,500	1,750
30+00					
	500	4,200	10,900	-6,700	-3,350
35+00					
	500	7,400	21,800	-14,400	-7,200
40+00					
	500	9,000	21,800	-12,800	-6,400
45+00					
	500	9,000	21,800	-12,800	-6,400
50+00					
	1,000	15,100	43,500	-28,400	-14,200
60+00					
	600	10,300	26,100	-15,800	-7,900
66+00					

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P:\North Carolina\Figure Eight Island\Engineering\FIGURE_8_ISLAND_SEDIMENT_BUDGET.xls volume_summary 12/16/2009

TABLE 7-1

OCEANFRONT VOLUME CHANGES
APRIL 2005 - APRIL 2007
FIGURE EIGHT & HUTAFF ISLAND, NC

Profile Line	Beach Length (feet)	April 2005 - April 2007 Volume Change (c.y.) Surveyed Changes	Beach Fills	Adjusted Changes	2005-2007 Volume Change Rates (c.y./year)
	400	10,100	17,400	-7,300	-3,650
70+00					
	250	8,800	10,900	-2,100	-1,050
72+50					
	250	12,300	10,900	1,400	700
75+00					
	250	13,200	10,900	2,300	1,150
77+50					
	250	11,400	10,900	500	250
80+00					
	250	8,600	10,900	-2,300	-1,150
82+50					
	250	4,900	10,900	-6,000	-3,000
85+00					
	250	800	10,900	-10,100	-5,050
87+50					
	250	-3,600	10,900	-14,500	-7,250
90+00					
	250	-7,300	8,200	-15,500	-7,750
92+50					
	250	-10,400	2,700	-13,100	-6,550
95+00					
	250	-8,000	0	-8,000	-4,000
97+50					
	250	-200	0	-200	-100
100+00					
	250	6,000	0	6,000	3,000
102+50					
	250	10,600	0	10,600	5,300
105+00					
	250	9,300	0	9,300	4,650
107+50					
	250	2,200	0	2,200	1,100
110+00					

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TABLE 7-1

OCEANFRONT VOLUME CHANGES
APRIL 2005 - APRIL 2007
FIGURE EIGHT & HUTAFF ISLAND, NC

Profile Line	Beach Length (feet)	April 2005 - April 2007 Volume Change (c.y.)			2005-2007 Volume Change Rates (c.y./year)
		Surveyed Changes	Beach Fills	Adjusted Changes	
INN15+00 to F0+00	500	-22,000	9,300	-31,300	-15,650
F0+00 to F90+00	9,000	53,000	319,000	-266,000	-133,000
F90+00 to 45+00	6,500	2,700	54,500	-51,800	-25,900
45+00 to 66+00	2,100	34,400	91,400	-57,000	-28,500
66+00 to 105+00	3,900	57,200	115,500	-58,300	-29,150
105+00 to 110+00	500	11,500	0	11,500	5,750
FIGURE 8 ISLAND INN15+00 to 110+00	22,500	136,800	589,700	-452,900	-226,450

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TABLE 7-1

OCEANFRONT VOLUME CHANGES
APRIL 2005 - APRIL 2007
FIGURE EIGHT & HUTAFF ISLAND, NC

Profile Line	Beach Length (feet)	April 2005 - April 2007 Volume Change (c.y.) Surveyed Changes	Beach Fills	Adjusted Changes	2005-2007 Volume Change Rates (c.y./year)
145+00					
	250	-26,800	0	-26,800	-13,400
147+50					
	250	-30,500	0	-30,500	-15,250
150+00					
	250	-34,100	0	-34,100	-17,050
152+50					
	250	-37,800	0	-37,800	-18,900
155+00					
	250	-39,500	0	-39,500	-19,750
157+50					
	250	-39,100	0	-39,100	-19,550
160+00					
	250	-38,700	0	-38,700	-19,350
162+50					
	250	-38,400	0	-38,400	-19,200
165+00					
	250	-35,800	0	-35,800	-17,900
167+50					
	250	-31,100	0	-31,100	-15,550
170+00					
	250	-26,300	0	-26,300	-13,150
172+50					
	250	-21,600	0	-21,600	-10,800
175+00					
SOUTHERN HUTAFF IS. 145+00 to 175+00	3,000	-399,700	0	-399,700	-199,850

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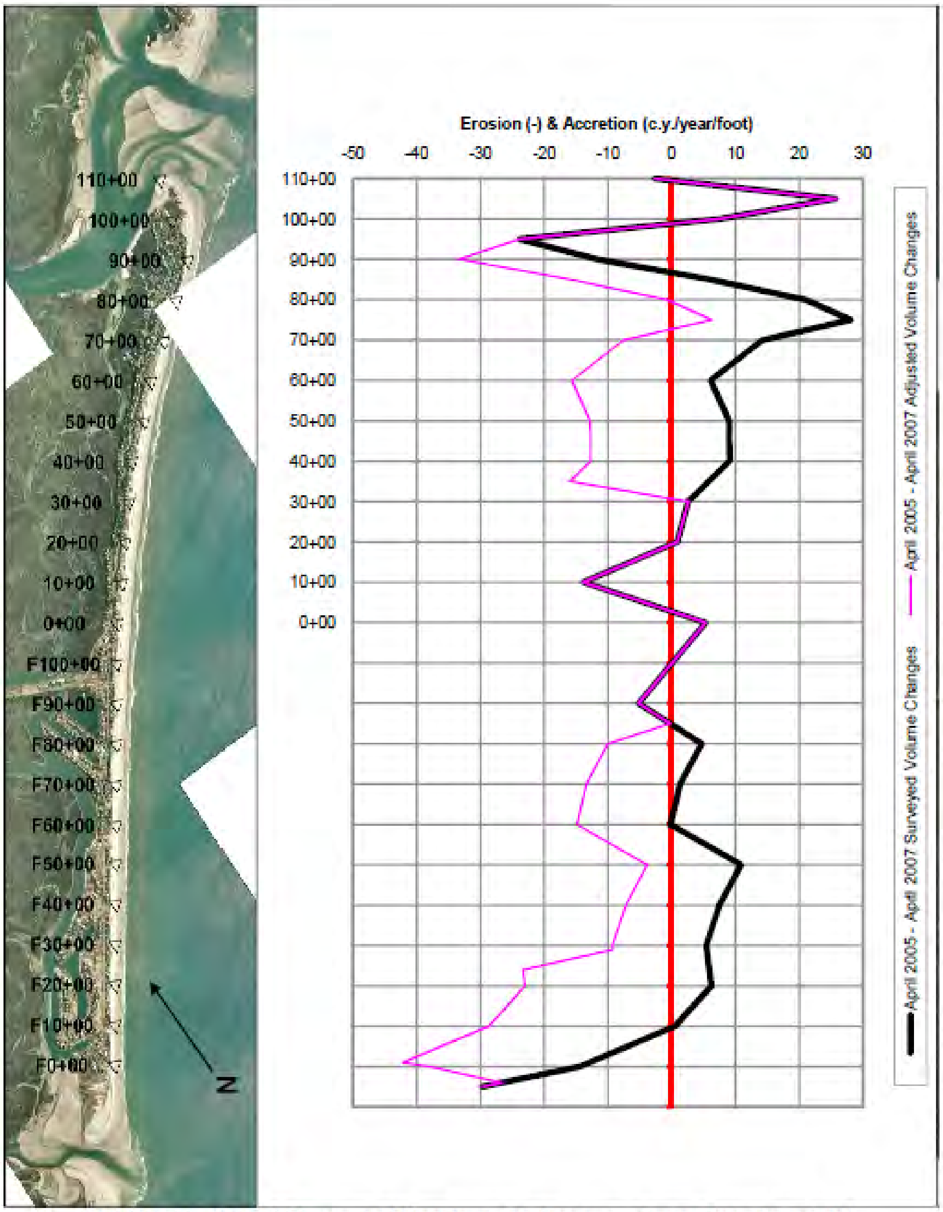

FIGURE 7-1: April 2005 - April 2007 Volumetric Changes, Figure Eight Island, NC.

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8.0 LITTORAL BUDGET

8.1 April 2005 – April 2007 Sediment Budget

Based on the volumetric changes in the previous section, two sediment budgets were developed to map the movement of material along Figure Eight Island and Rich Inlet: April 2005-April 2007 and October 1999-April 2007. For the shorter time period, changes on the oceanfront beaches were based on the erosion rates appearing in Figure 7-1 and Table 7-1. These changes were dominated by Hurricane Ophelia (September 2005) and beach nourishment operations on the northern and southern ends of the island. Volumetric changes near Rich Inlet were based on the April 2005, April 2006, and April 2007 surveys (Figures 8-1 to 8-3). To map the movement of material in Rich Inlet, the inlet and ebb shoal complex was divided into the following cells, which appear in Figure Eight-1:

- Outer Ebb Shoal.
- Existing Channel.
- Southwest Flood Channels.
- Inlet Interior.

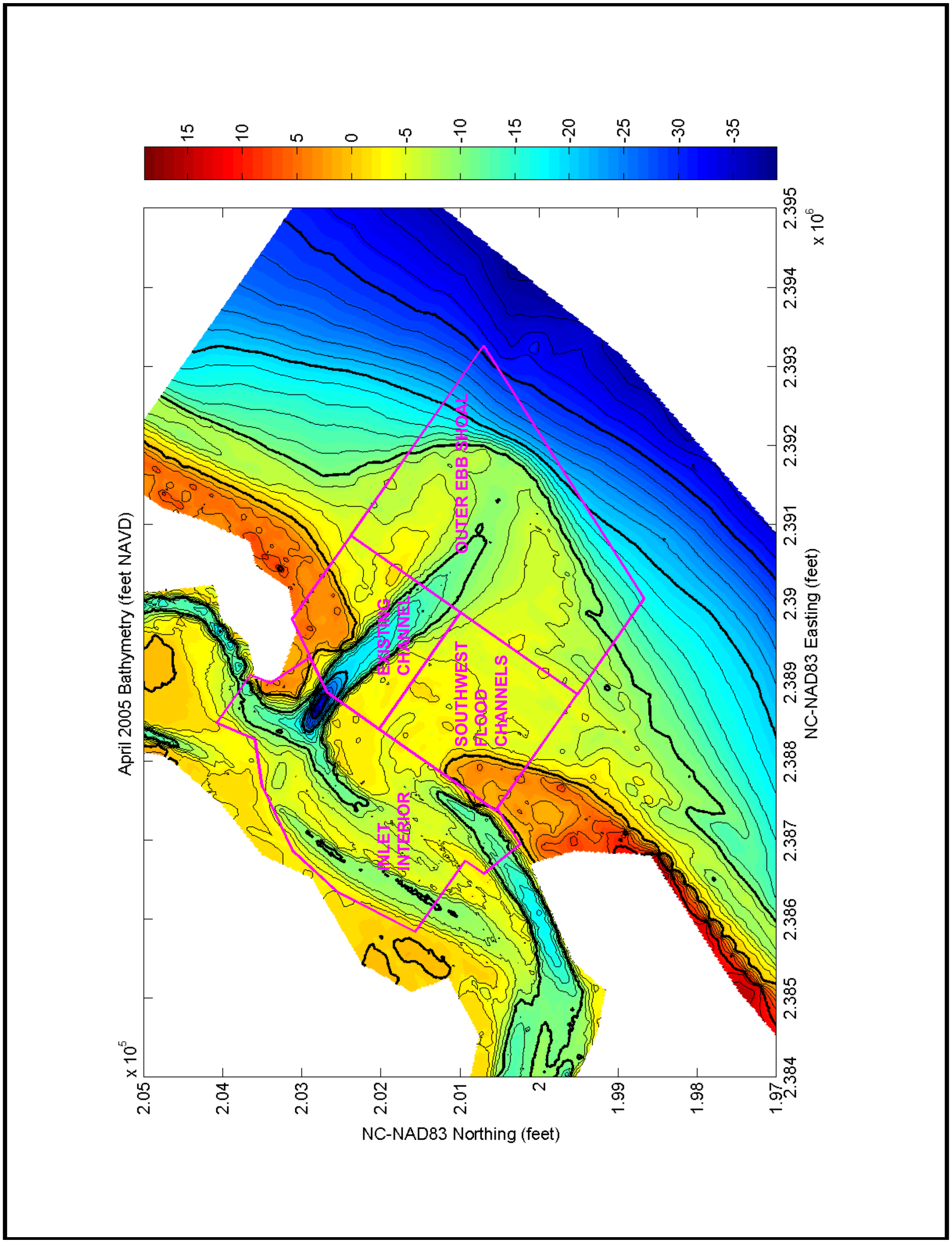


FIGURE 8-1: April 2005 Bathymetry, Figure Eight Island and Rich Inlet, NC.

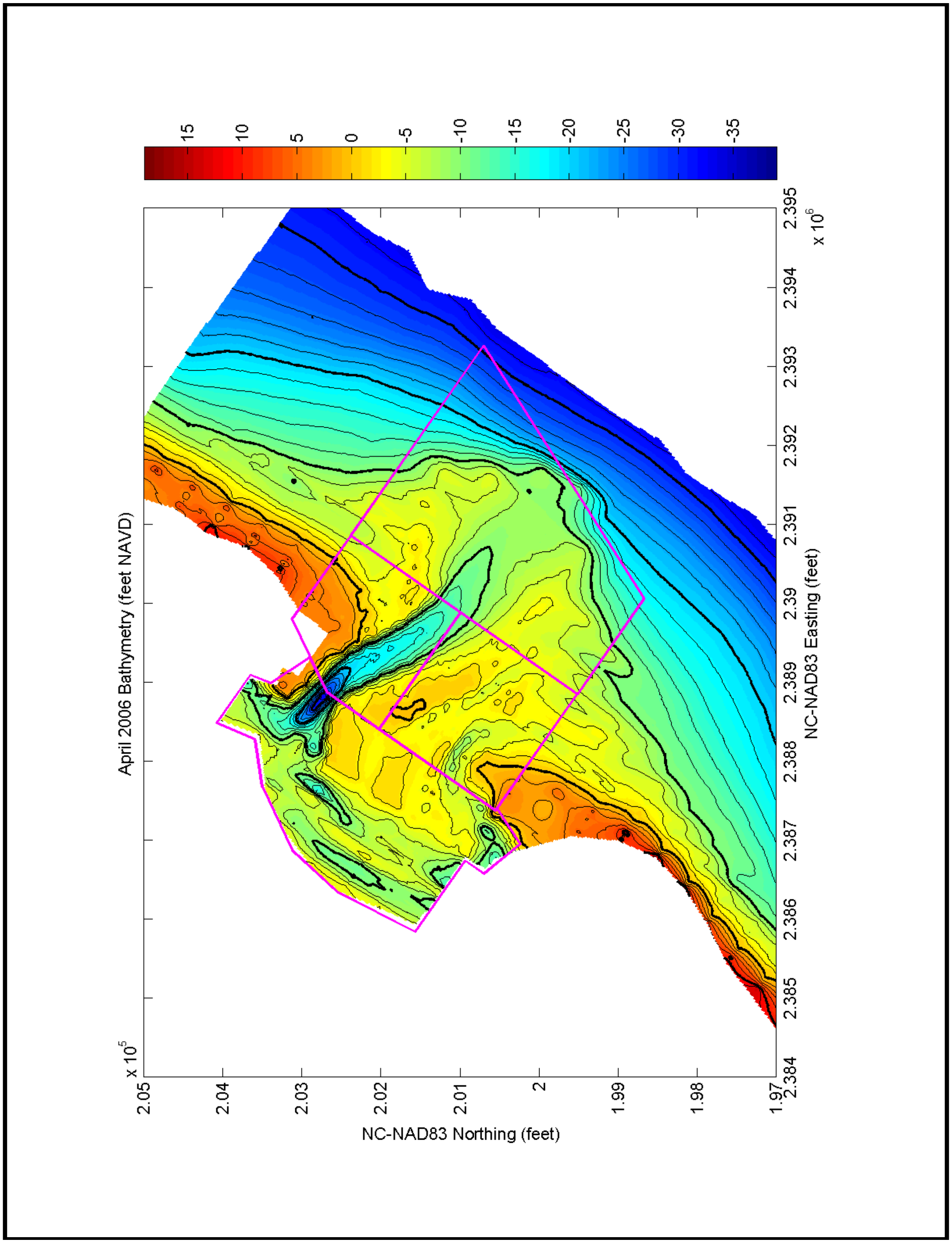


FIGURE 8-2: April 2006 Bathymetry, Figure Eight Island and Rich Inlet, NC.

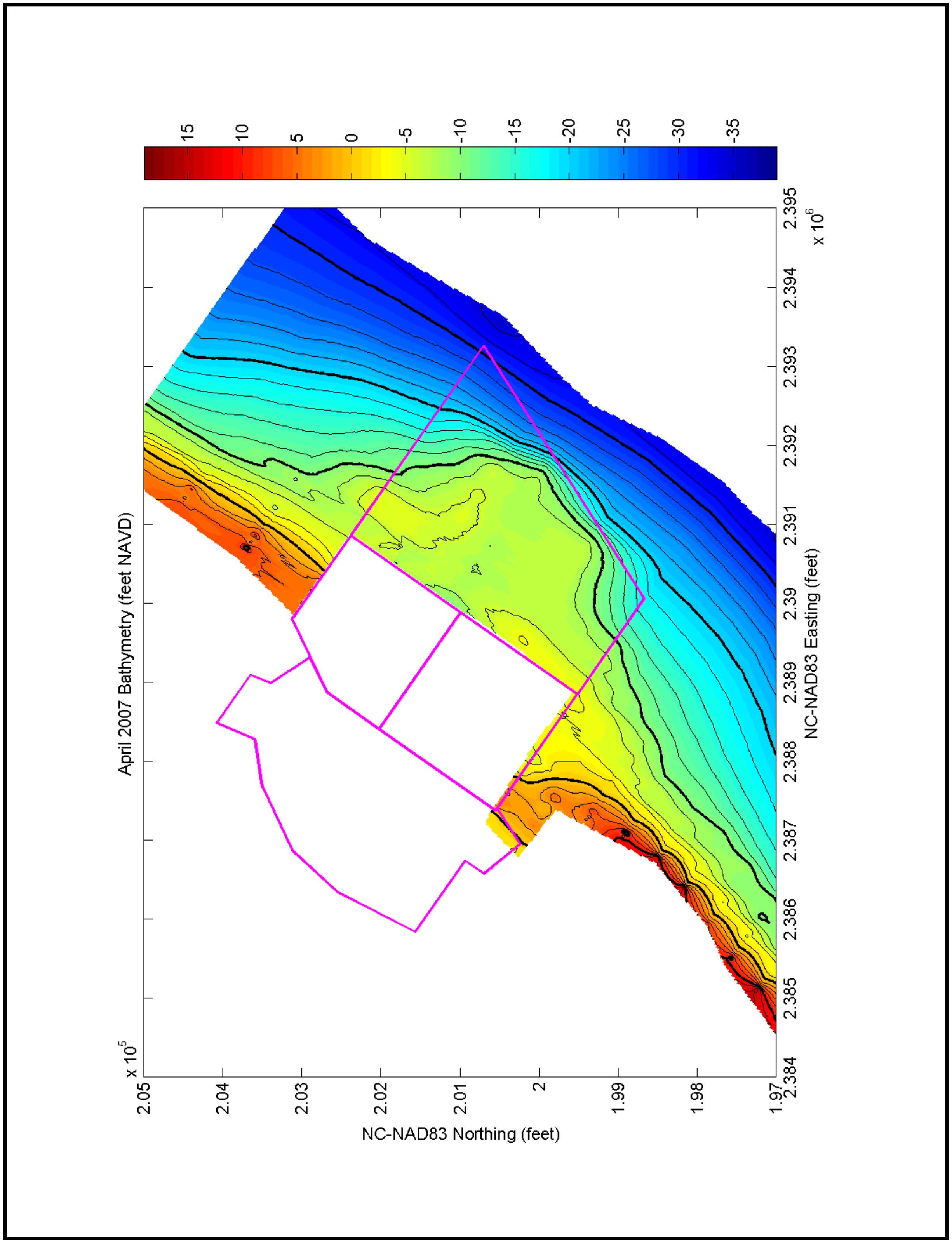


FIGURE 8-3: April 2007 Bathymetry, Figure Eight Island and Rich Inlet, NC.

The locations of these cells were based on the morphology of the inlet and the limits of the 2005, 2006, and 2007 surveys. Changes within the Outer Ebb Shoal were based on the April 2005 and April 2007 surveys. In the other inlet cells, the April 2007 survey did not provide sufficient coverage or spacing to realistically depict the bathymetry. Accordingly, changes in the other 3 inlet cells were based on the April 2005 and April 2006 surveys.

Sediment budget cells along the beach were based on the proposed beach fill layouts, discussed later in this report. South of the beach disposal area, additional cells were delineated based on the available survey data. Oceanfront sediment budget cells are listed in Table 8-1:

TABLE 8-1

OCEANFRONT SEDIMENT BUDGET CELLS
FIGURE EIGHT ISLAND, NC

Profile Lines	Beach Length (feet)	Description
INN10+00 to INN15+00	500	Undeveloped beach near Mason Inlet (1999-2007 only)
INN15+00 to F0+00	500	188 Beach Road S to 184 Beach Road S (wide lots)
F0+00 to F90+00	9,000	184 Beach Road S to 8 Beach Road S
F90+00 to 45+00	6,500	8 Beach Road S to 292 Beach Road N
45+00 to 66+00	2,100	292 Beach Road N to Surf Court
66+00 to 105+00	3,900	Surf Court to Inlet Hook Roads (Rich Inlet erosion hotspot)
105+00 to 110+00	500	Undeveloped beach near Rich Inlet
145+00 to 175+00	3,000	Southern Hutaff Island

Transport rates between the various cells in Rich Inlet were generally based on preliminary Delft3D model results between April 2005 and April 2007. Transport rates on Hutaff Island were then determined based on the observed volume changes (Table 7-1) and the amount of material entering Rich Inlet. Transport rates on Figure Eight Island were determined based on the volumetric changes in Figure 7-1. Between 2005 and 2007, a high erosion area was centered near profile 95+00 (Inlet Hook Road). Accreting areas were located on either side of this erosion hotspot, suggesting the presence of a nodal point, or the transport of material away from profile 95+00 in either direction. Based on the other observed volume changes and fill quantities on the island, transport rates along the remainder of the island were estimated.

The April 2005 – April 2007 sediment budget appears in Figure 8-4. Over the 2 year period, the south end of Hutaff Island lost 199,850 c.y./year. Most of this material went into the Rich Inlet complex, which gained 182,000 c.y./year. Within the inlet complex, the Existing Channel was the primary pathway for offshore transport of sediment, and the Southwest Flood Channels were the primary pathway for the inland transport of sediment.

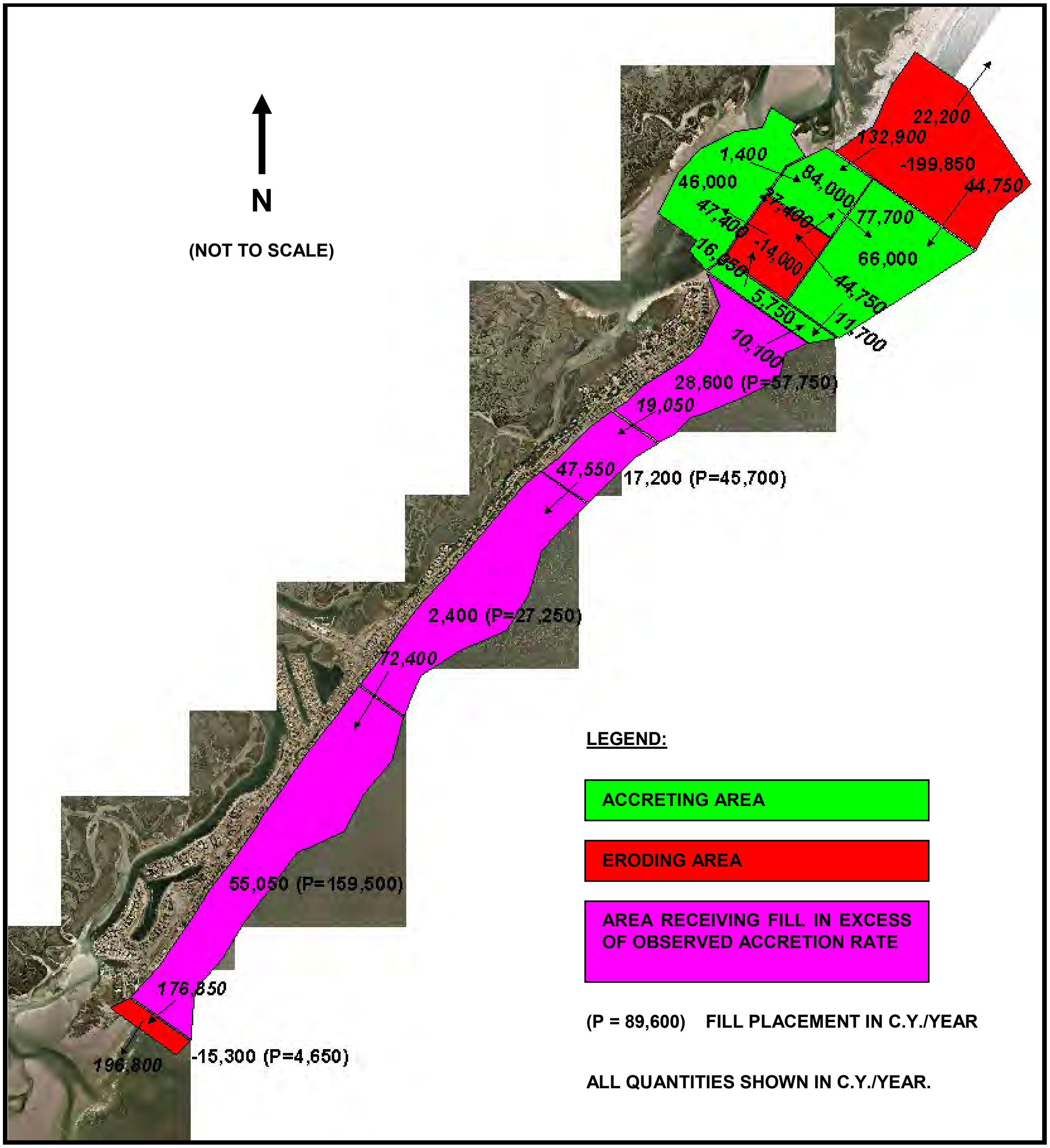


FIGURE 8-4: Figure Eight Island April 2005 – April 2007 Sediment Budget.

Along Figure Eight Island, the net transport was towards the south. Between profile 95+00 (Inlet Hook Road) and F-4+00 (south end of Beach Road), there was a consistent increase in the sediment transport rate from 0 to 196,800 c.y./year.

8.2 October 1999 – April 2007 Sediment Budget

For the longer time period, changes on the oceanfront beaches were based on the 1999-2007 shoreline changes. A detailed bathymetric survey of Rich Inlet prior to 2004 was not available. Accordingly, the inlet and ebb shoal was schematized as a single cell, with volumetric changes estimated based on sediment transport along the adjacent beaches.

The October 1999 – April 2007 sediment budget appears in Figure 8-5. During the 7½ year period, the highest rates of retreat occurred near profiles 80+00 (Comber Road) and 110+00 (Rich Inlet) (Figure 6-2). Accordingly, profile 80+00 (Comber Road) was assumed to be a nodal point, with transport of material away from the area in either direction. Given the observed shoreline changes and beach fills (Table 6-2), the estimated sediment transport was 63,200 c.y./year to northeast at profile 105+00 and 37,100 c.y./year to the southwest at profile 66+00 (Surf Court). Based on the other observed changes and fill quantities on the island, sediment transport rates along the remainder of the island were estimated.

South of profile 66+00 (Surf Court), the net sediment transport was from northeast to southwest. Between Backfin Point (F80+00) and 268 Beach Road North (35+00), there was an accreting area characterized by a decreasing rate of sediment transport. However, the direction of sediment transport was towards the southwest along this reach. South of Backfin Point (F80+00), the beaches were erosional, with an increasing rate of sediment transport towards the southwest.

The net sediment transport near Mason Inlet (INN10+00) was less than the 2005-2007 sediment budget. However, it was consistent with the migration pattern of Mason Inlet prior to 2002, which moved 2,200 feet southwest between 1985 and 2002 (Erickson, Kraus, and Carr, 2003), or approximately 129 feet/year. Based on the inlet migration rate, a +6 foot NAVD berm elevation, a -24 foot NAVD depth of closure, and a cross-shore width of 900 feet, the equivalent sediment transport would be 129,000 c.y./year. This value was close to the sediment transport rate of 142,900 c.y./year in Figure 8-5.

On the south end of Hutaff Island, the net transport rates between 1999 and 2007 were low. Transport rates at profile 175+00 were based on preliminary Delft3D model results for the 5-year, without-project scenario. Transport rates into Rich Inlet were then determined based on the observed shoreline changes between 1999 and 2007. Given the transport rates on either side of Rich Inlet, the inlet and ebb shoal gained approximately 120,600 c.y./year between October 1999 and April 2007. While the gain was 2/3 the combined value shown in Figure 8-4, it was based on erosion rates that were more representative of the study area than the 2005-2007 rates.

8.3 Summary

Based on the two sediment budgets, Rich Inlet is a sediment sink that gains 100,000 to 200,000 c.y./year. The source of this material alternates between the adjacent beaches on Figure Eight Island and the adjacent beaches on Hutaff Island. The recent source is primarily Hutaff Island.

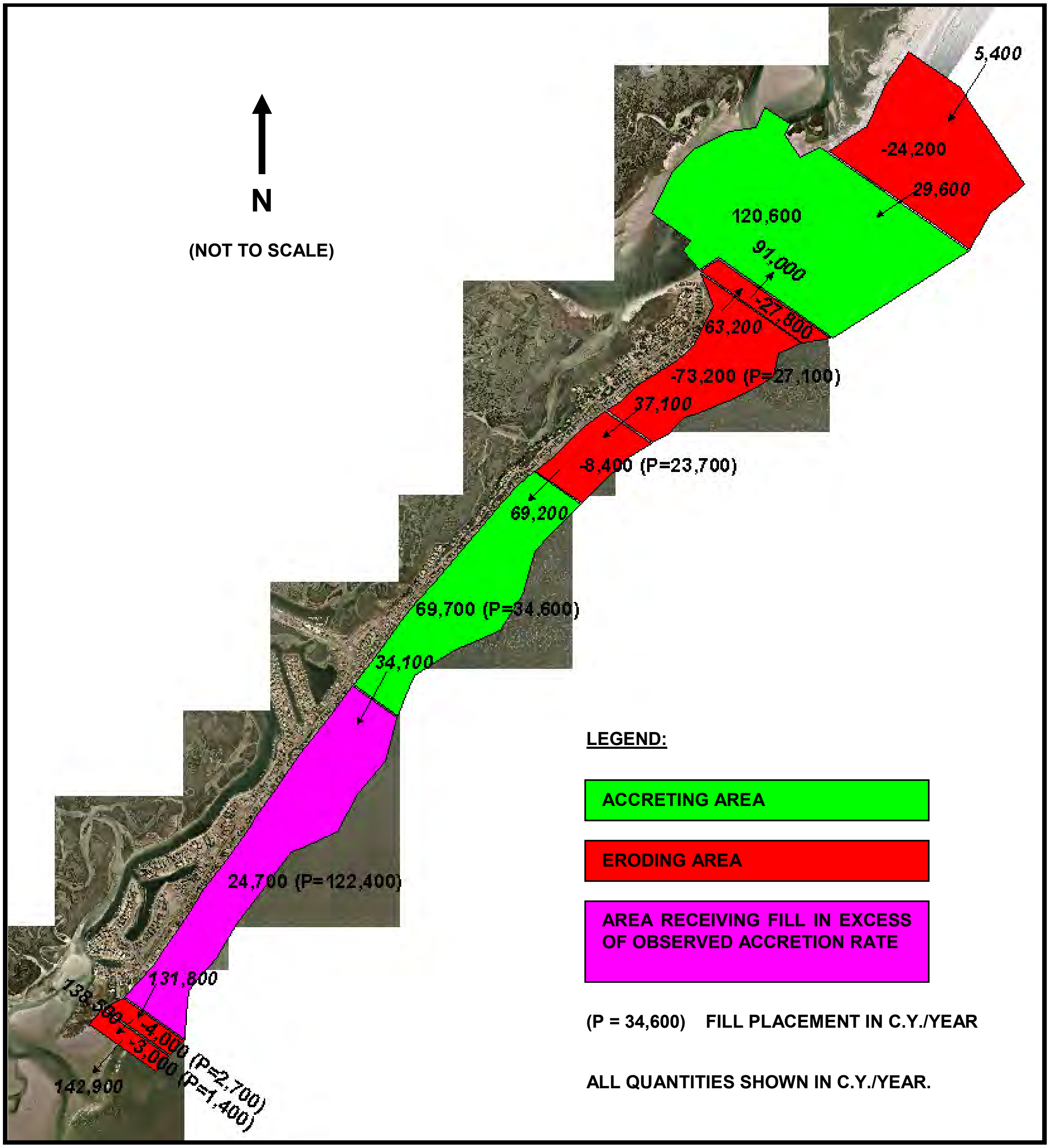


FIGURE 8-5: Figure Eight Island October 1999 – April 2007 Sediment Budget.

Near the northern end of Figure Eight Island, there is a nodal point, at which eroding sediments spread towards both the northeast and the southwest. This nodal point has shifted towards the northeast since 1999, but currently lies near Inlet Hook Road (profile 95+00). Along the rest of Figure Eight Island, the predominant sediment transport is towards the southwest. Sediment transport rates just north of Mason Inlet (profile F-4+00) vary from 142,900 to 196,800 c.y./year. Given the general erosion patterns around Rich Inlet, the northeasterly sediment transport on Topsail Island (USACE, 2006, p. 31), and the southwesterly transport near Mason Inlet, the area surrounding Rich Inlet functions as a nodal point on regional basis.

9.0 PROJECT DESIGN

The main text of the Environmental Impact Statement presents the following alternatives to address chronic erosion on Figure Eight Island:

1. Alternative 1 - No Action.

2. Alternative 2 - Abandon/Retreat.

3. Alternative 3 - Rich Inlet Management and Beach Fill.

4. Alternative 4 - Beach Fill without Management of Rich Inlet.

5. Terminal Groin Options:
   - Alternative 5C - Terminal Groin at a More Northerly Location with Beach Fill from Nixon Channel and a New Channel Connecting to Gorge of Rich Inlet

   - Alternative 5D - Terminal Groin at a More Northerly Location with Beach Fill from the Previously Permitted Area in Nixon Channel and Other Sources

The designation of the terminal groin alternatives as 5C and 5D is the result of changes made in the original terminal groin proposal presented in the Draft Environmental Impact Statement (DEIS) issued in January 2012. The terminal groin alternatives presented in the DEIS were designated as 5A and 5B and had the terminal groin positioned relatively close to the northern most homes on the north end of Figure Eight Island. During the review process for the DEIS, several of the property owners expressed concerns of the potential negative aesthetics of the structure and the possible impact on public access to the extreme north end next to Rich Inlet. As a result, the Figure "8" Beach HOA agreed to consider moving the terminal groin 420 feet north of the DEIS position. The new position of the terminal groin resulted in a new round of model investigations to evaluate the potential impacts of the new location relative to the impacts associated with the DEIS location.

Alternative 5C essentially replaces 5A in the DEIS since it would involve constructing the beach fill along the ocean shoreline and the shoreline of Nixon Channel using material obtained from maintenance of the navigation channel in Nixon Channel (previously permitted area) and a new channel connecting Nixon Channel with the gorge of Rich Inlet. For Alternative 5C, the beach fill along the ocean shoreline is slightly longer than the beach fill for 5A given the more northerly position of the terminal groin. In like manner, Alternative 5D replaces 5B presented in the DEIS. For Alternative 5D, the terminal groin is also positioned farther north and the material to construct the beach fills along the ocean shoreline and the Nixon Channel shoreline would be derived from maintenance of the previously permitted area in Nixon Channel.

The presentation of the evaluation of the terminal groin alternatives presented below is limited to the evaluation of Alternatives 5C and 5D. Model results for these alternatives as well as Alternatives 2, 3, and 4 are provided in Sub-Appendix B-1 for the 2006 initial conditions and Sub-Appendix B-2 for the 2012 initial conditions. The results of preliminary Delft3D model test performed for the DEIS using the 2006 initial conditions are provided in Sub-Appendix B. In Sub-B the nomenclature used for some of the Alternatives differ from the ones presented in this document. For example, the Alternatives designated as 5a-1, 5a-2, etc. were variations of Alternative 5A presented in the DEIS.

The evaluation of the relative impacts of the various alternatives on Rich Inlet and the adjacent shorelines was based on the results obtained from the Delft3D model. The Delft3D model is discussed in detail below. The initial conditions used in the formulation and evaluation of the alternatives was the 2006-07 conditions of Rich Inlet and the adjacent shoreline as these conditions represent the "worst case" conditions with respect to shoreline changes along the north end of Figure Eight Island. The Delft3D model was also run using conditions that existed in March 2012 as the initial condition. Simulations using the 2012 initial conditions were limited to Alternatives 2, 3, 4, and 5D.

Alternative 1 assumes that the present strategies to manage the island's shoreline in Table 6-2 will continue into the future. Alternative 2 assumes that there will be no more beach fill, dune maintenance, inlet maintenance, or sand bag placement operations. Accordingly, this alternative is the true "Without-Project" scenario. Alternative 3 implements the recommended modification of the Rich Inlet ocean bar channel proposed by Cleary (Sub-Appendix A – Rich Inlet Update), which is further detailed in this section. Dredged material from the inlet modification would be strategically placed along the north half of the island to mitigate for the erosion occurring since the late 1990s. Alternative 4 has a beach fill similar to Alternative 3 with the fill material to be taken from an offshore source as well as from maintenance of the existing navigation channel in Nixon Channel. In this regard, potential offshore sand sources have been identified by Cleary (Cleary, 2000) but have not been investigated in detail. Alternative 5 utilizes a terminal groin to create an accretion fillet on the extreme north end of Figure Eight Island and reduce erosion rates from the beach fill placed north of Bridge Road to Rich Inlet. This alternative includes beach fill material from maintenance of the previously permitted area in Nixon Channel and a new channel connector between Nixon Channel and the inlet gorge (Alternative 5C) and fill from maintenance of the previously permitted area in Nixon Channel (Alternative 5D).

9.1 Alternative 3 – Rich Inlet Management and Beach Fill

9.1.1 Channel Location

Many of the erosion problems on the northern half of Figure Eight Island are to due changes in the location and alignment of the ebb shoal and main entrance channel at Rich Inlet. Based on thorough analysis of inlet characteristics between 1938 and 2001, reported by Cleary and Jackson (2004) and an update of that analysis that includes changes between 2001 and 2007 prepared by Dr. Cleary for this report, which is provided in Sub-Appendix A, a recommended optimum channel location was developed which is shown in Figure 9-1. This channel is located in the middle of the inlet approximately 2600 feet northeast of N. Beach Road (536 block).

Based on the trends observed by Cleary and Jackson (2004) and more recently by Cleary (Sub-Appendix A), relocating the channel will also shift the ebb shoal, providing a buffer against wave-driven erosion. As noted in Section 6, the south end of Hutaff Island is eroding partly due to the formation of a swash channel. The formation of the swash channel has partially depleted the ebb shoal on the north side of Rich Inlet. On the other hand, when the north side of the ebb shoal is fully intact, the south end of Hutaff Island accretes. Given these observations, relocating the channel as shown is Figure 9-1 is a possible means of controlling erosion on the north end of Figure Eight Island without using structures.

9.1.2 Closure Dike

To ensure a successful relocation of the channel, it is necessary to close the existing channel. This task will be accomplished by building a closure dike out of the material dredged from the relocated channel. The Delft3D modeling results in a later section of this report show that without a dike, the existing channel will continue to carry the flow through Rich Inlet. The modeling results also show that the dike must be of sufficient size to remain in place for more than a few months. The closure dike at Rich Inlet will have the following dimensions:

Crest Elevation = +6 feet NAVD
Crest Width = 450 feet
Side Slopes ~ 1 vertical on 20 horizontal

9.1.3 Entrance Channel Dimensions

To establish dimensions of the ebb/entrance channel, an inlet stability analysis has been conducted. The inlet stability analysis utilizes two curves (Figure 9-2): the O'Brien curve and the Escoffier curve. The O'Brien curve is an empirical relationship between tidal prism and the cross-sectional area at the throat of the inlet. The Escoffier curve is a theoretical relationship between the tidal current velocity and the cross-sectional area. Currents at the inlet throat were measured by Gahagan & Bryant Associates, Inc. in June 2005. The most recent survey of the inlet throat was taken by Gahagan & Bryant Associates, Inc. in April 2006. As shown in Figure 9-2, the observed flood currents and cross-sectional area fall on the Escoffier curve.

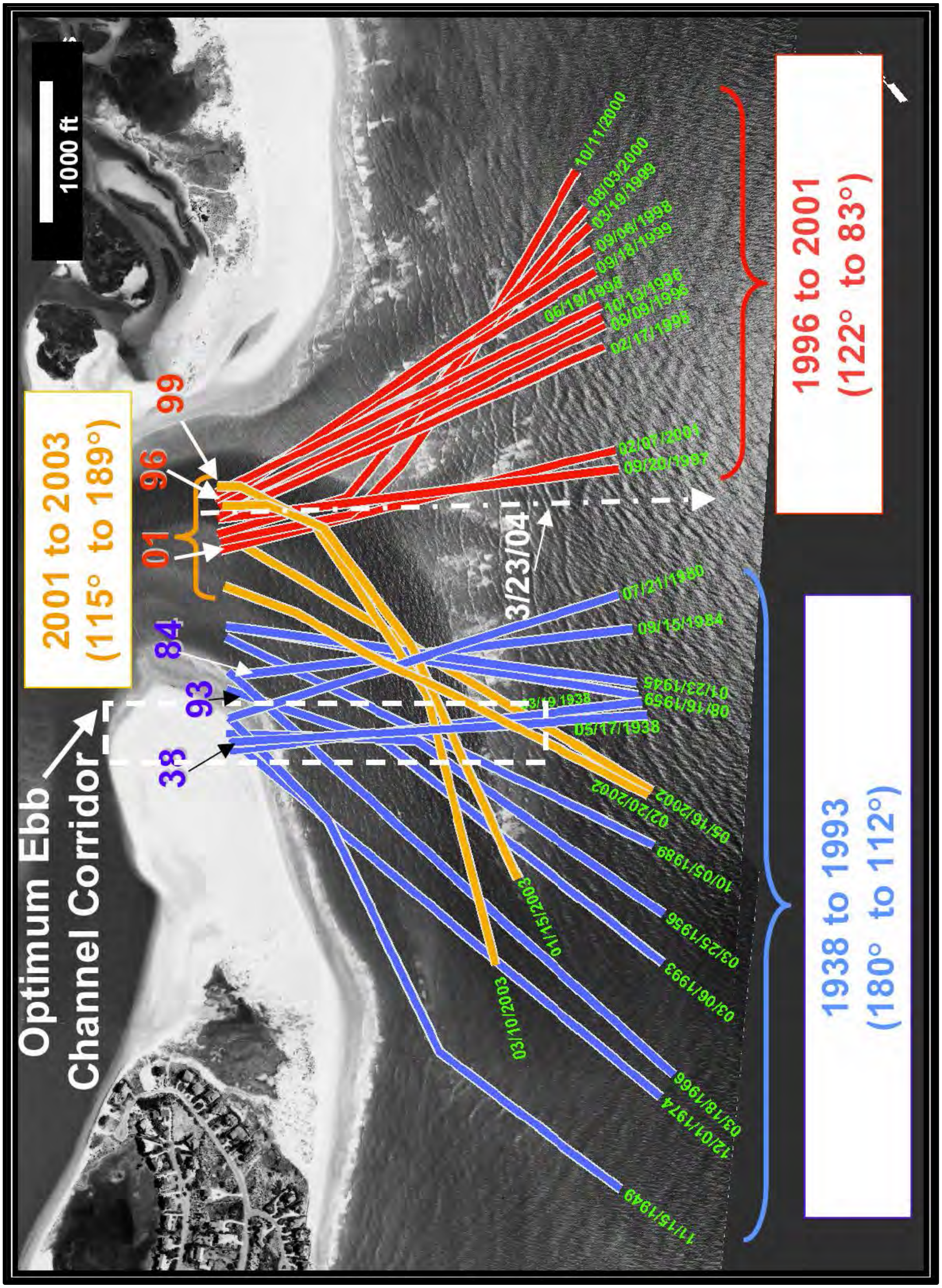


FIGURE 9-1: Rich Inlet Optimum Channel Location (Cleary and Jackson, 2004).

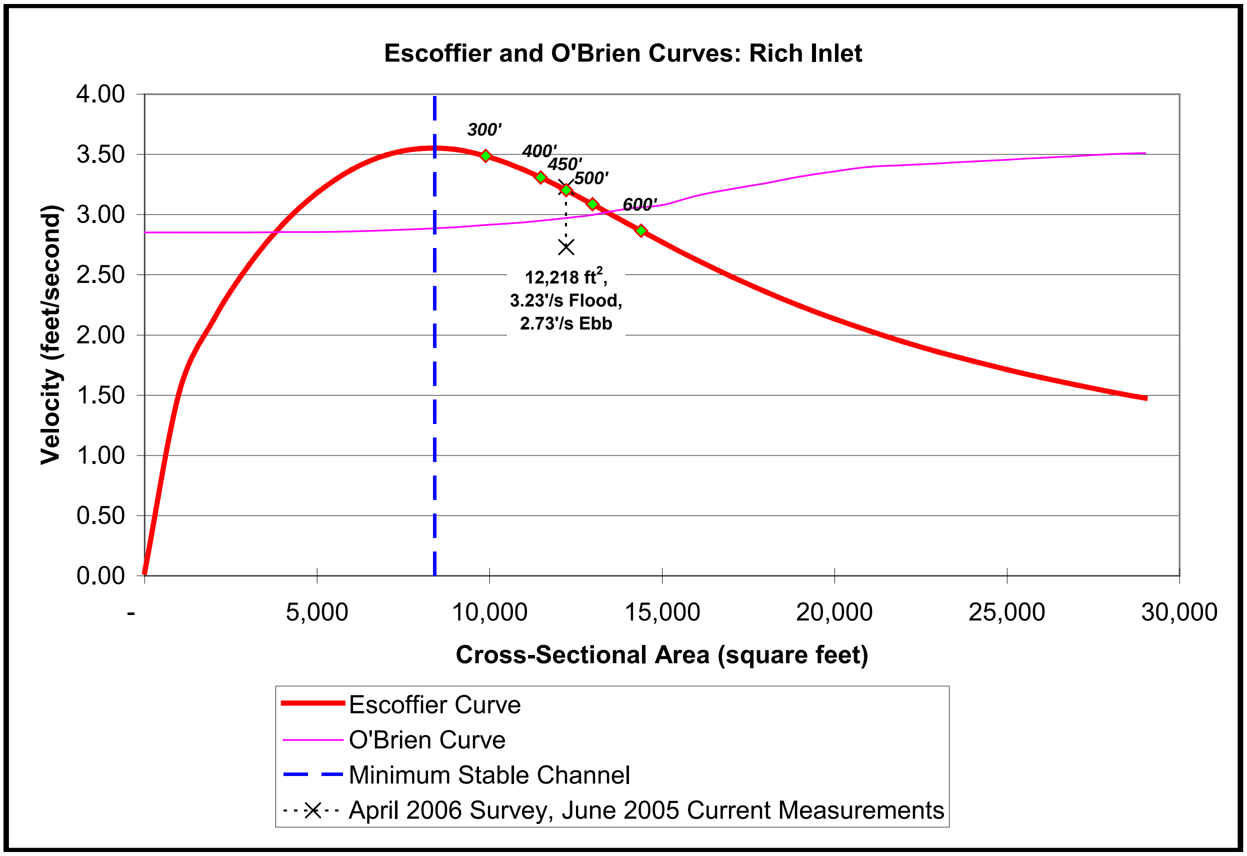


FIGURE 9-2: Inlet Stability Curves for Rich with Bottom Widths Given a Design Depth of -19 feet NAVD and Side Slopes of 1V:5H.

The O'Brien curve crosses the Escoffier curve at two points. The left point is the unstable equilibrium, which corresponds to a cross-sectional area of 3,800 square feet. Any deviation from that point immediately sets into action forces which tend to further increase or aggravate the deviation (Escoffier, 1940). If the deviation is a reduction in the cross-sectional area, the inlet closes. The right point is the stable equilibrium, which corresponds to a cross-sectional area of 13,400 square feet. Any deviation from that point immediately sets into action forces which tend to restore the channel to its initial condition (Escoffier, 1940). Between the two crossing points, the Escoffier curve peaks at a cross-sectional area of 8,400 square feet. This value represents the minimum cross-sectional area for the inlet to remain stable.

The initial designs and preliminary model simulations for Rich Inlet assumed a design depth of -17 feet NAVD. However, based on conversations with dredge contractors, a design depth of -19 feet NAVD was found to be easier and less expensive to construct. Thus, the design depth was modified to -19 feet NAVD, with side slopes of 1 vertical on 5 horizontal.

The closure dike will reduce the cross-sectional area by 8,600 square feet (Figure 9-3) which would reduce the cross-sectional area of the inlet to approximately 3,600 square feet. Based on the stability analysis presented above, this would result in an unstable inlet. For the inlet to remain stable, its cross-sectional area needs to be at least 8,400 square feet. This can be accomplished using a design cross-section with a bottom width of 300 feet. However, the 300 foot bottom width does not offer an appropriate safety factor. Furthermore, it does not restore the cross-section to present size. A bottom width of 500 to 600 feet achieves the stable equilibrium of 13,400 square feet. However, this size is not the most cost-effective, and creates a larger project footprint. A bottom width of 450 feet was selected and restores the cross-sectional to its present size. Natural forces can then be allowed to increase the cross-section.

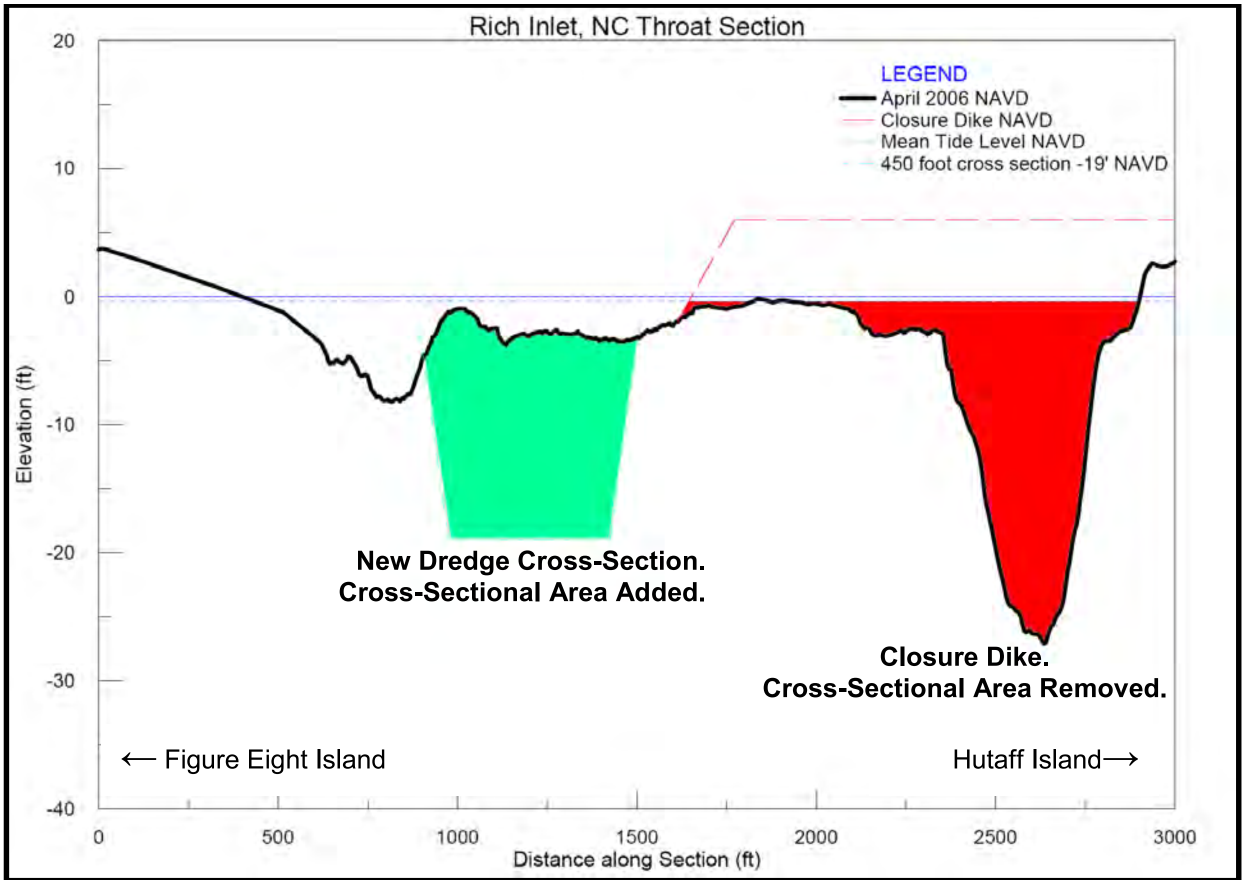


FIGURE 9-3: Cross-Section of the Inlet Throat.

9.1.4 Side Channels

Flow through Rich Inlet is carried into the Atlantic Intracoastal Waterway (AIWW) primarily through Nixon Channel and Green Channel with some flow migrating through the salt marsh area immediately north of the inlet. Nixon Channel lies to the south of the entrance channel and runs from east to west. Green Channel lies north of the entrance channel and runs from south to north. To ensure a successful relocation of the entrance channel, it is necessary to dredge connecting cuts from the entrance channel in Nixon Channel and Green Channel.

9.1.4.1 Dredging Option 1

Dredging Option 1 appears in Figure 9-4, and features an entrance channel through the middle of Rich Inlet, a connecting cut into Nixon Channel, a connecting cut into Green Channel, and a narrow extension of entrance channel towards the salt marsh bounded by Nixon Channel, Green Channel, and the Intracoastal Waterway. Although this Dredging Option provides connecting cuts in Nixon Channel and Green Channel, extension of the entrance channel is not necessary to maintain adequate flow through Nixon Channel and Green Channel. Cleary (2008) has noted that the salt marsh facing the entrance of the main channel of Rich Inlet has been eroding. Preliminary Delft3D model results have shown that much of the flow going through Green Channel is directed to and from the entrance channel through the entrance channel extension instead of the Green Channel connecting cut. This could worsen the erosion of the salt marsh and could make the Green Channel connecting cut more difficult to maintain. Finally, the extension of the entrance channel increases the project footprint and the area impacted during construction, with few added benefits. For these reasons, Dredging Option 1 has been dropped from consideration.

9.1.4.2 Dredging Option 2

Dredging Options 2A and 2B (Figure 9-5) dredge a new entrance channel through the middle of Rich Inlet. The new entrance channel is located midway between Figure Eight Island and Hutaff Island approximately 1,300 feet southwest of the existing (April 2006) channel. The length of the cut is 3,500 feet, and the bottom width is 500 feet given the old design depth of -17 feet NAVD. The new entrance channel runs along a bearing of 142° / 322° (northwest-southeast). At the northern end of the entrance channel, the dredge cut splits into two smaller channels connecting into Nixon Channel and Green Channel. The connection into Nixon Channel runs on a bearing of 64° / 244° (west-southwest to east-northeast) and has a bottom width of 275 feet given the old design depth of -17 feet NAVD. The connection into Green Channel runs on a bearing of 14° / 194° (north-northeast to south-southwest) and has a bottom width of 225 feet given the old design depth of -17 feet NAVD. Under Dredging Option 2A, the connections to Nixon Channel and Green Channel are 3,800 and 2,000 feet long, respectively. Under the shorter Dredging Option 2B, the connections to Nixon Channel and Green Channel are 1,700 and 1,400 feet long, respectively.

Dredging Options 2A and 2B provide sufficient connections from Nixon Channel and Green Channel into the entrance channel without the unnecessary dredging of Dredging Option 1. Flow into Nixon Channel and Green Channel would occur through the corresponding connecting cuts, and would not increase the erosion observed by Cleary (2008) along the interior salt marsh. At the north end of Beach Road North, seven (7) parcels face Nixon Channel (address numbers 538 to 552). The seven (7) parcels are located at Nixon Channel profiles RIN17+00 to RIN25+00. Due to the shifting of Nixon Channel, these properties are currently experiencing high rates of erosion. The high erosion rates have prompted the placement of sandbags along three (3) of the parcels. Dredging Option 2A can sufficiently address the erosion problem along this area, as detailed in the Delft3D modeling study. Dredging Option 2B cannot, since the deep section of the channel is not moved away from the threatened properties. In Green Channel, the difference in cut volume between Dredging Options 2A and 2B is 17-18%. Thus, the corresponding difference in performance would be negligible. Accordingly, if Dredging Option 2 became the Preferred Dredging Option, the design for Nixon Channel would be Dredging Option 2A, and the design for Green Channel would be Dredging Option 2B.

FIGURE 9-4: Rich Inlet Dredging Option 1 under Alternative 3.

FIGURE 9-5: Rich Inlet Dredging Options 2A and 2B under Alternative 3.

9.1.4.3 Dredging Option 3

Dredging Option 3 appears in Figures 9-6 and 9-7. This Dredging Option features only one connecting cut, which runs from the entrance channel into Nixon Channel. Because there is no connecting cut into Green Channel, it does not provide for adequate flow into Green Channel. Presently, Green Channel connects directly into the existing channel. However, if Dredging Option 3 were constructed with the closure dike across the existing channel, there would be no direct connection between Green Channel and the relocated entrance channel, as shown on the contour map in Figure 9-7. Thus, among all the Dredging Options proposed, Dredging Option 3 represents the greatest departure from the existing conditions. For this reason, Dredging Option 3 has been dropped from consideration.

9.1.4.4 Dredging Option 4

Dredging Options 4A and 4B appear in Figure 9-8. Dredging Options 4A and 4B also dredge a new entrance channel through the middle of Rich Inlet. The seaward end of the entrance channel is at the same location Dredging Options 2A and 2B, and its bearing is the same. However, its length is 4,600 feet. Along the first 3,500 feet, the bottom width is 500 feet given the old design depth of -17 feet NAVD. Along the remainder of the entrance channel, the bottom width is 300 feet given the old design depth of -17 feet NAVD. Where the 500 foot wide section ends, there is a connection into Nixon Channel. This connection runs on the same bearing as Dredging Options 2A and 2B. However, its bottom width is 200 feet given the old design depth of -17 feet NAVD. Under Dredging Options 4A and 4B, the connection to Nixon Channel is 3,800 feet and 1,700 feet long, respectively. There is no direct connection to Green Channel. All side slopes are 1 vertical on 5 horizontal.

Dredging Options 4A and 4B provide a direct connection between Nixon Channel and the entrance channel. The entrance channel ends along a natural channel that runs between Nixon Channel and Green Channel along the salt marsh. The longer entrance channel and this natural channel provide an indirect connection into Green Channel.

The difference between Dredging Options 4A and 4B is the length of the connecting cut into Nixon Channel. For reasons similar to Dredging Option 2, it is necessary to dredge the longer cut into Nixon Channel to address the erosion problem at 538-552 Beach Road North. Accordingly, Dredging Option 4B has been dropped from consideration.

9.1.4.5 Preferred Dredging Option

The two viable Dredging Options are Dredging Option 2 and Dredging Option 4A. Dredging Option 4A can reduce the erosional stresses on the north end of Figure Eight Island. However, it does not offer a direct conduit for flow between Green Channel and the entrance channel. Furthermore, it could accelerate erosion along the salt marsh area facing the entrance of the inlet. For this reason, Dredging Option 4A is not the Preferred Dredging Option. Accordingly, the Preferred Dredging Option for Rich Inlet is Dredging Option 2, with the following variations:

FIGURE 9-6: Rich Inlet Dredging Option 3 under Alternative 3.

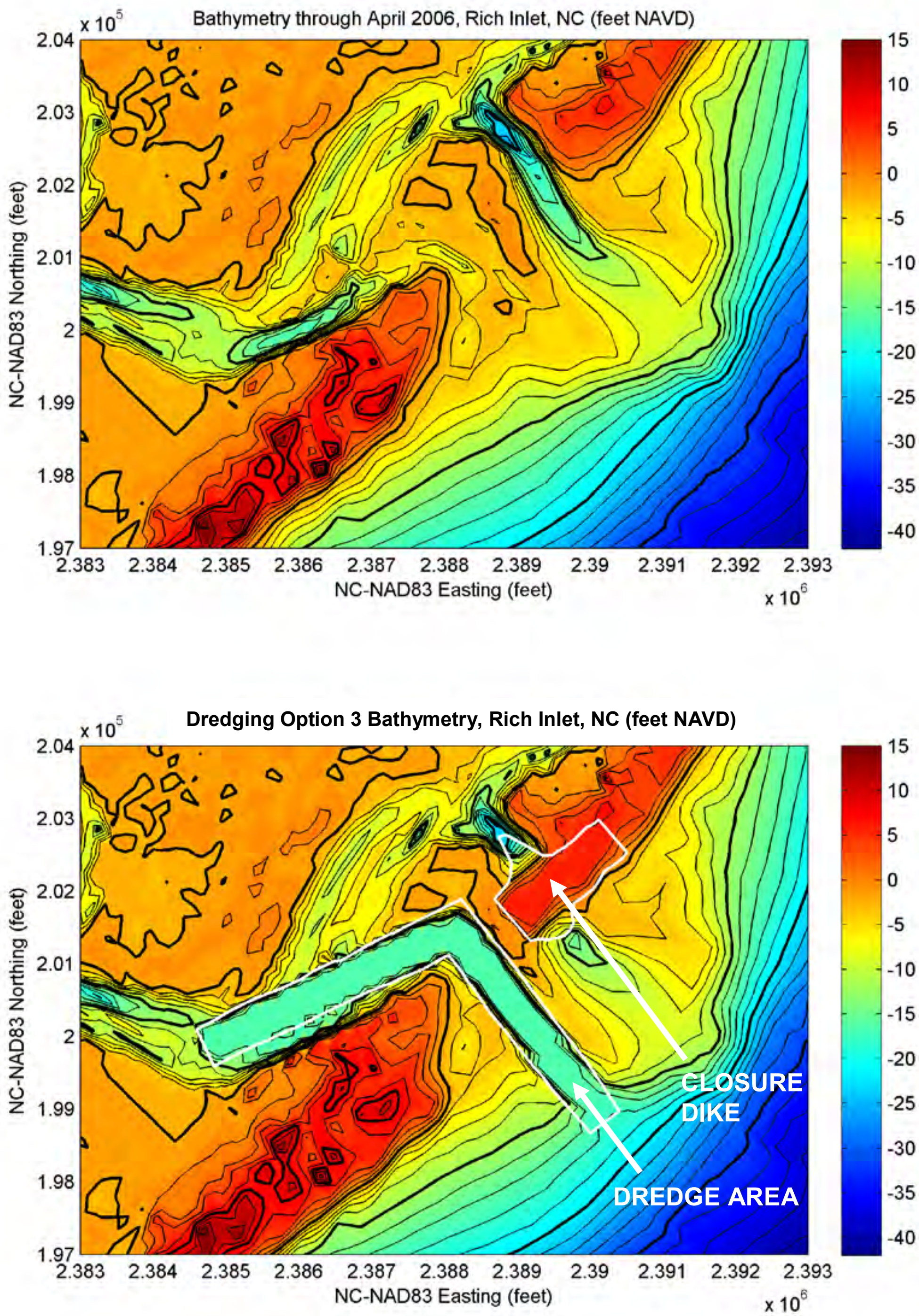


FIGURE 9-7: Bathymetric Contours Given Rich Inlet Dredging Option 3 under Alternative 3.

FIGURE 9-8: Rich Inlet Dredging Options 4A and 4B under Alternative 3.

- Dredging Option 2A inside the entrance channel and Nixon Channel.
- Dredging Option 2B inside the connection to Green Channel.

By dredging a long cut through Nixon Channel, Dredging Option 2A is able to reduce the erosion stress at 538-552 North Beach Road by shifting the flow towards the middle of the channel. Near Green Channel, the shorter Dredging Option 2B eliminates dredging in the interior of Green Channel, while maintaining a conduit for flow between Green Channel and the entrance channel.

To make the project easier to construct, the design depth was changed from -17 to -19 feet NAVD. This change allowed reduction in the bottom width from 500 to 450 feet in the entrance channel and 275 to 240 feet in the Nixon Channel cut. To improve the efficiency of the Green Channel connecting cut, the centerline of the cut was shifted slightly to the west, and the bottom width was changed to 300 feet. This change was able to ensure that the amount of flow going through Green Channel would be similar to the present conditions.

9.1.5 Channel Design Summary under Alternative 3

The Preferred Dredging Option for Rich Inlet features an entrance channel, with 2 side cuts connecting the entrance channel to Nixon Channel and Green Channel. Based on the inlet stability analysis, modeling results, and inquiries regarding feasible dredge depths, the design of Alternative 3's relocated channel in Rich Inlet may be summarized by the following:

- Dredge Depth = -19 feet NAVD + 1 foot overdepth.

- Bottom width & length:

  - Entrance Channel (inlet throat) = 450 feet x 3,500 feet.
  - Nixon Channel = 240 feet x 3,800 feet.
  - Green Channel = 300 feet x 1,400 feet.

- Dredge Volume = 1,786,500 c.y. + 156,400 c.y. overdepth based on the most recent (April 2009 to March 2012) survey = 1,942,900 c.y. total. The Nixon Channel connector contains 27,900 c.y. of clay.

- Closure Dike:

  - Crest Elevation = +6 feet NAVD + 0.5 foot tolerance.
  - Crest Width = 450 feet.
  - Side Slopes = 1 vertical on 20 horizontal (assumed).
  - Volume = 393,000 c.y. + 24,000 c.y. tolerance based on March 2012 survey = 417,000 c.y. total.

- Upland Disposal:
  - 29,700 c.y. clay from Nixon Channel

- Oceanfront Disposal Area:
  - Berm Elevation = +6 feet NAVD + 0.5 foot tolerance.
  - Construction Berm Width = varies.
  - Side Slopes:
    - 1 vertical on 5 horizontal in the dune fill area
    - 1 vertical on 10 horizontal above mean high water (+1.7’ NAVD)
    - 1 vertical on 20 horizontal (assumed) below mean high water
  - Fill Length = 12,501 feet.
  - Volume = 1,146,900 c.y. + 43,800 c.y. dune fill based on March 2012 survey = 1,190,700 c.y. total.

- Nixon Disposal Area:
  - Berm Elevation = +6 feet NAVD + 0.5 foot tolerance.
  - Construction Berm Width = varies.
  - Side Slopes:
    - 1 vertical on 5 horizontal
  - Fill Length = 1,400 feet.
  - Volume = 57,000 c.y. + 5,400 c.y. tolerance based on the 2010 before dredging and May-June 2010 LIDAR surveys = 62,400 c.y. total.

A plan view of the dredge cuts and disposal areas appear in Figures 9-8 to 9-10. Typical cross-sections appear in Figures 9-11 and 9-12.

9.1.6 Beach Fill Design under Alternative 3

Based on the 2009-2012 surveys, Alternative 3’s Preferred Dredging Option will remove approximately 1,942,900 c.y. from Rich Inlet. Filling the closure dike will require 417,000 c.y., based on the 2012 survey. Also, a pocket of clay, containing 29,700 c.y. was discovered in a section of the Nixon Channel connector which is not beach compatible and would have to be deposited in an upland disposal site located on the south side of the intersection of Nixon Channel and the AIWW. Accordingly, there will be at least 1,496,200 c.y. available to nourish the Figure Eight Island ocean shoreline north of Bridge Road and the Nixon Channel shoreline.

The following options were considered for beach disposal areas:

1. Fill along the entire length of Beach Road (F-5+00 to 105+00, 22,000 feet), and no fill along Nixon Channel.

2. Fill from the intersection of Beach Road and Bayberry Place to Rich Inlet (0+00 to 105+00, 10,500 feet), and no fill along Nixon Channel.

3. Fill from the intersection of Beach Road and Beachbay Lane to Rich Inlet (F90+00 to 105+00, 12,501 feet), with a small fill area along Nixon Channel near the north end of Beach Road (1,400 feet). This option also includes a small amount of dune fill between profiles 77+50 and 95+00 for increased storm protection.

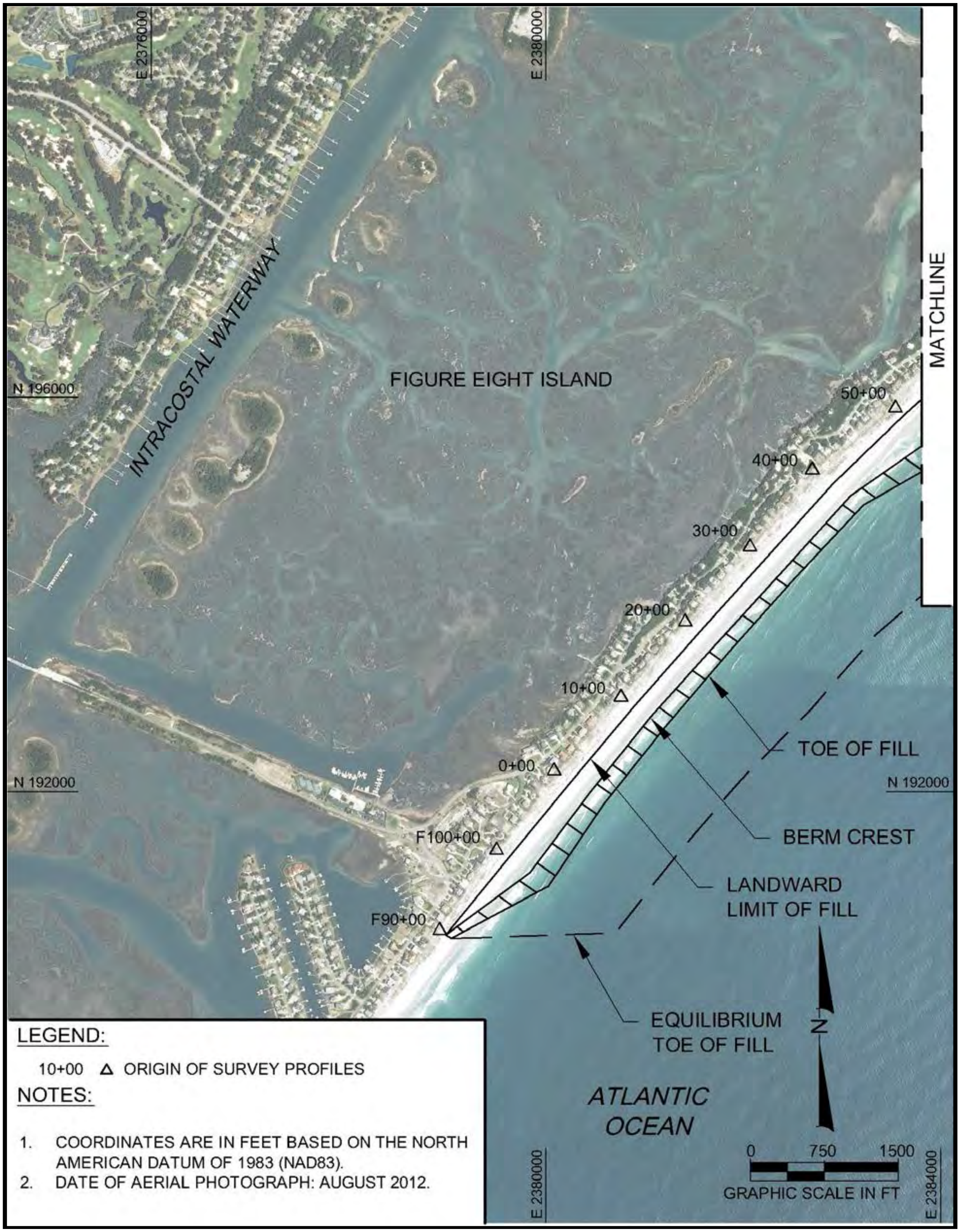


FIGURE 9-9A: Alternative 3 Preferred Dredging Option and Beach Fill Layout.

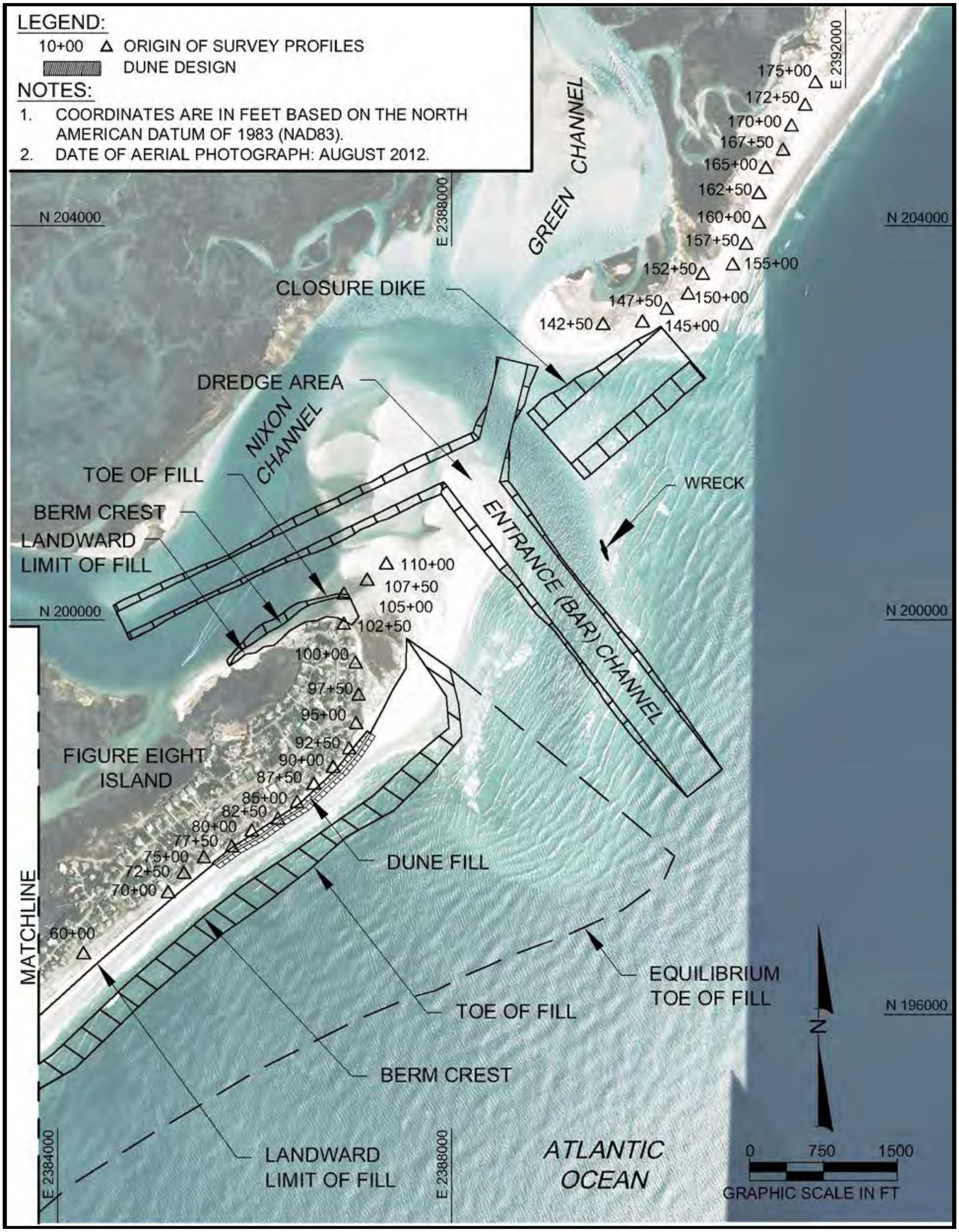


FIGURE 9-9B: Alternative 3 Preferred Dredging Option and Beach Fill Layout.

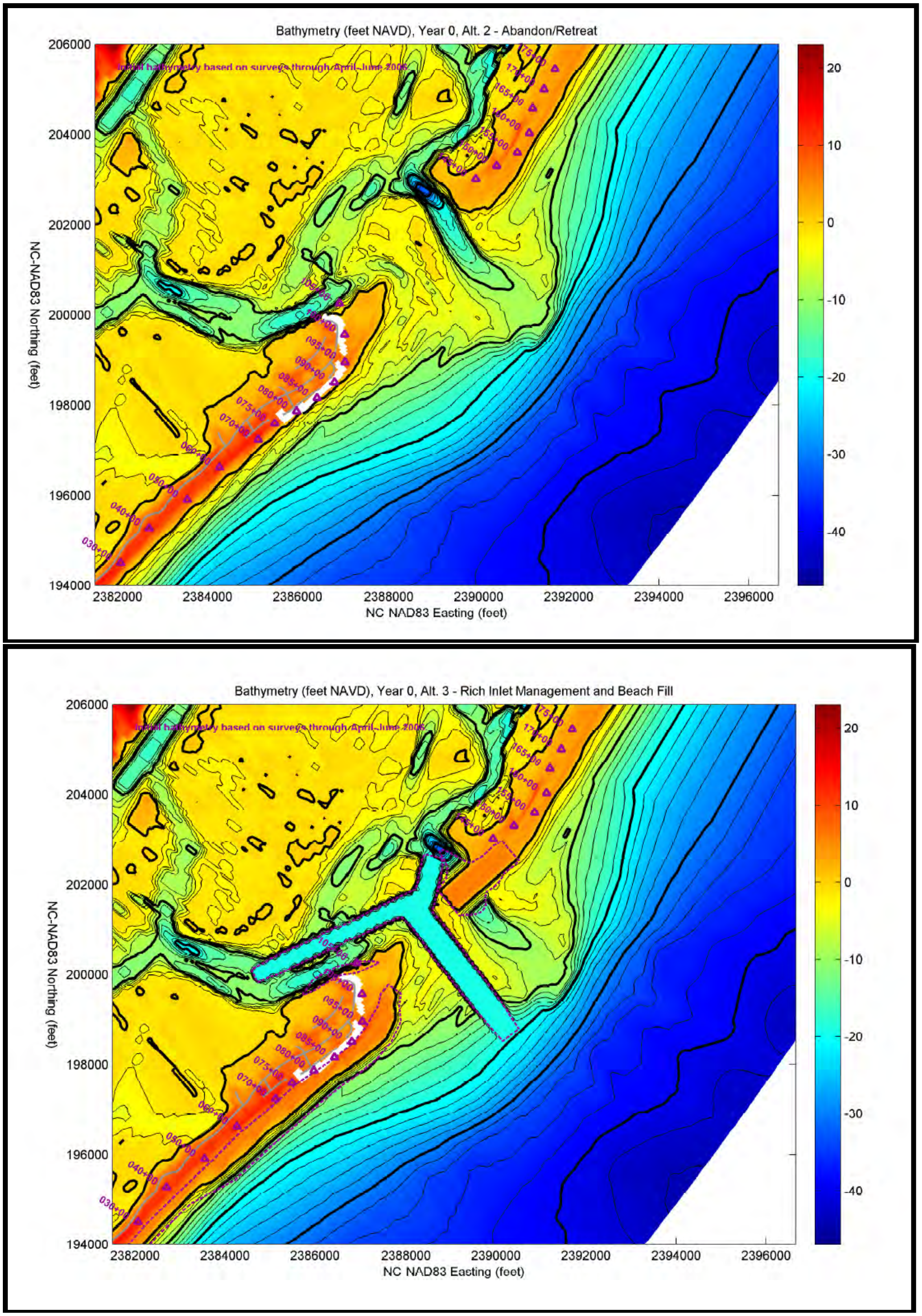
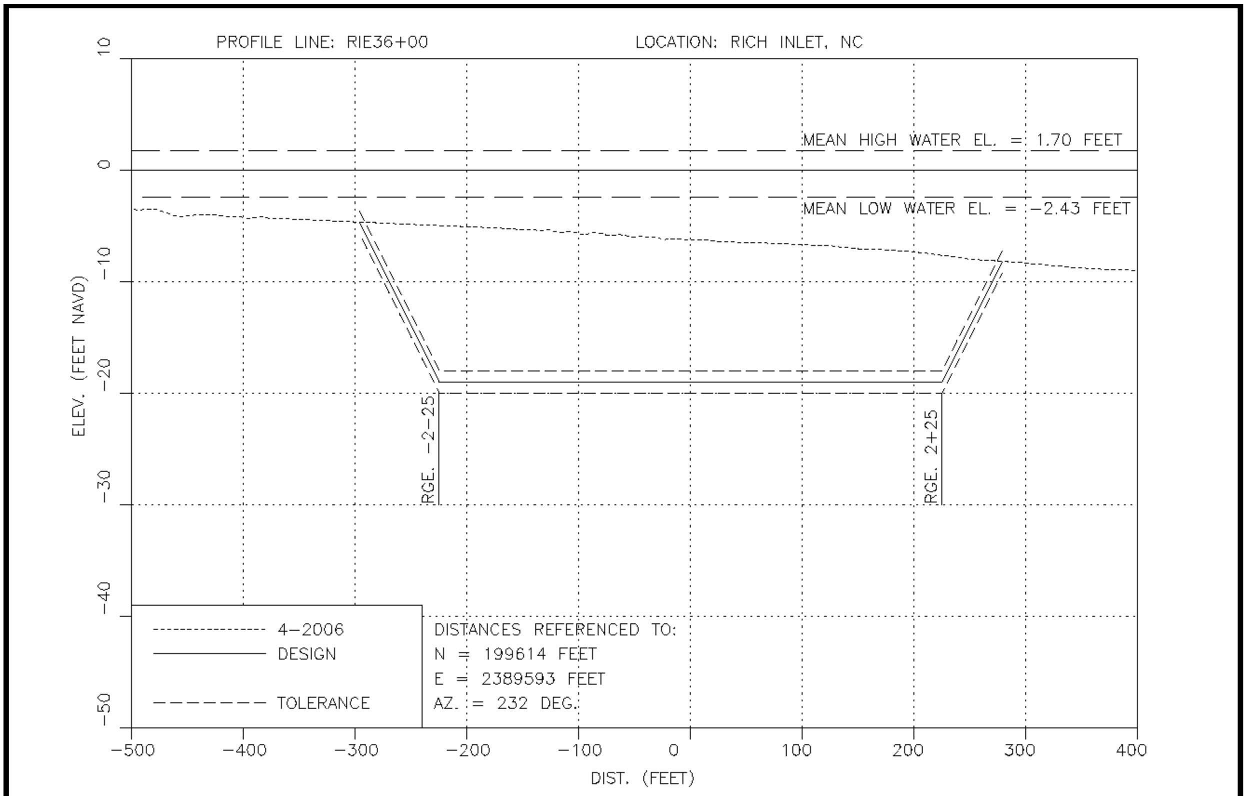


FIGURE 9-10: 2006 Bathymetric Contours and Modification Given Dredging Option No. 2 under Alternative 3.



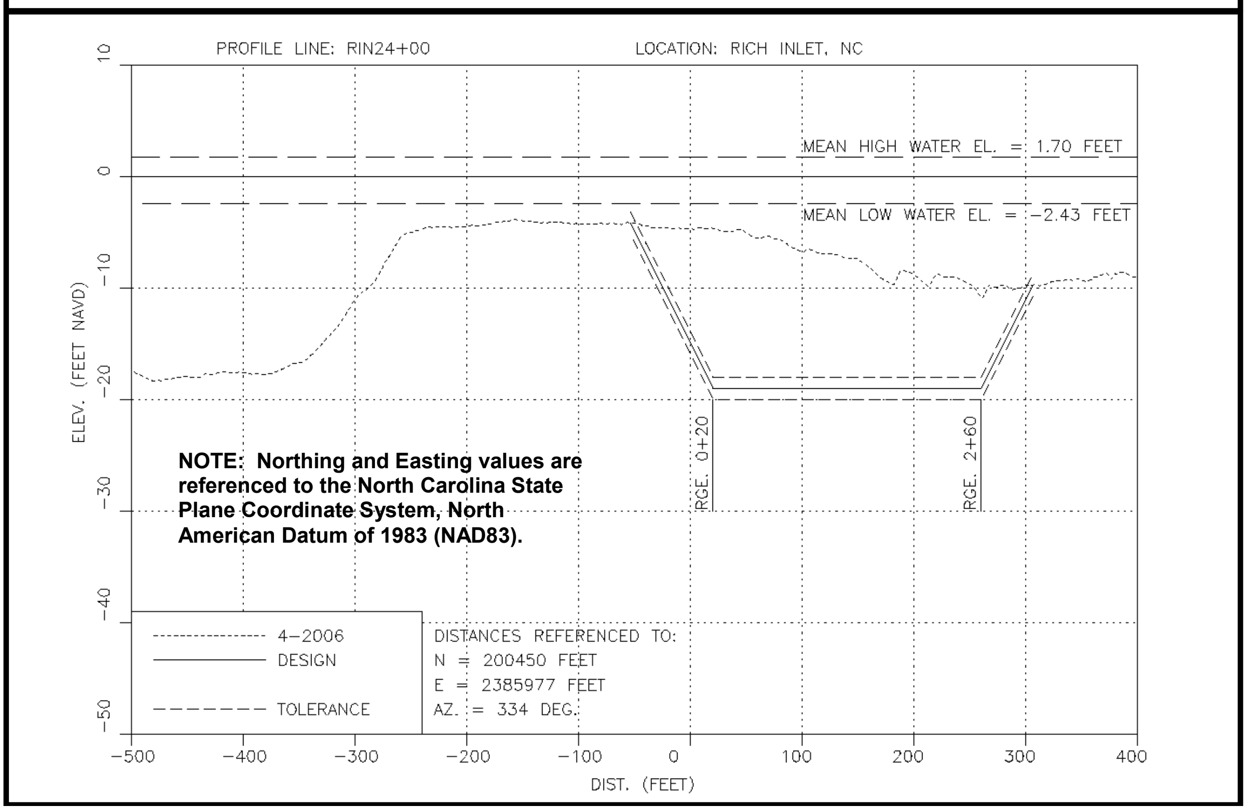


FIGURE 9-11: Typical Cross-Sections in the Entrance Channel (top) and Nixon Channel (bottom), Alternative 3.

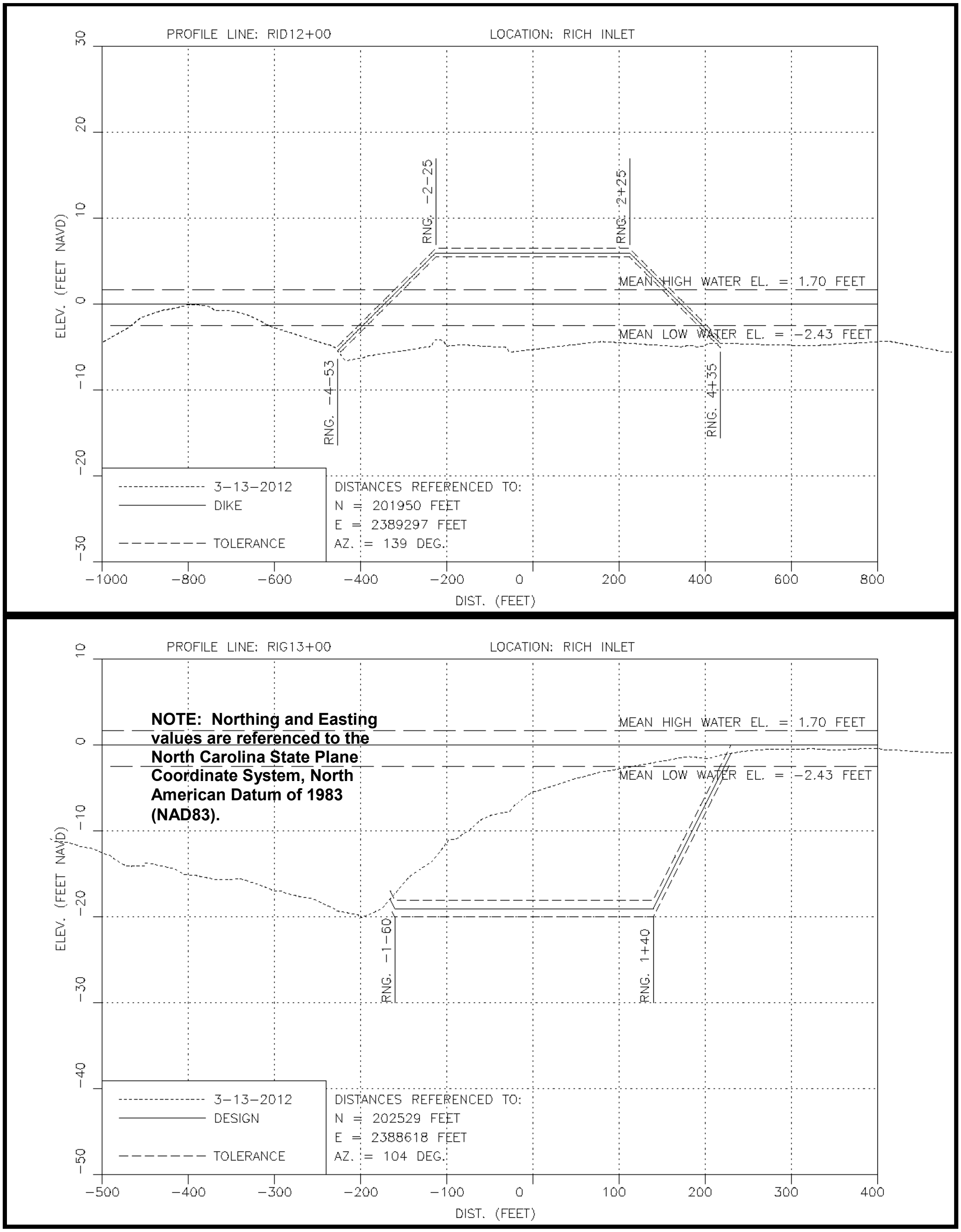


FIGURE 9-12: Typical Cross-Sections in Green Channel (top) and the Closure Dike (bottom), Alternative 3.

Alternative 3 utilizes the 3rd option above. Placing fill along the entire length of Beach Road (option 1) using a pipeline or dustpan dredge would increase the cost of dredging, especially if booster pumps were required. On the other hand, starting the fill at the intersection of Beach Road and Bayberry Place (profile 0+00) (option 2) would leave a gap in the managed shoreline between the Mason Inlet disposal area (profiles F0+00 to F100+00) (ATM, 1999) and the Rich Inlet disposal area. Finally, neither the first nor the second fill options address the high erosion area along Nixon Channel. The 3rd fill option places material along Nixon Channel to address the high erosion rates at the north end of Beach Road. In addition, it utilizes the existing maintenance program at Mason Inlet to economically manage the oceanfront shoreline as a whole. Accordingly, the 3rd fill option is the one included in Alternative 3.

9.1.6.1 Cross-Sectional Volume and Sand Compatibility

Cross-section sizes along the oceanfront shoreline are based on the "Worst Case" retreat rates in Table 6-1. The averages of those values by reach are:

- Beachbay Lane to 282 Beach Road North (F90+00 to 40+00), 9.2 feet/year.
- 302 Beach Road North to 530 Beach Road North (50+00 to 100+00), 24.8 feet/year.

The design berm elevation is +6 feet NAVD, which is approximately equal to the seaward toe of dune along the oceanfront beach fill area. The seaward limit of cross-shore spreading is assumed to be equal to the depth of closure, -24 feet NAVD.

The final quantity needed to determine the cross-section size is the overfill factor. The overfill factor indicates the proportion of fill required to compensate for differences between the grain sizes of the fill source and the existing beach. An overfill factor of 1.0 indicates that no extra fill is required. An overfill factor of 1.28 indicates that the fill volume must be increased 28% to achieve the same performance as material identical to the existing beach. Overfill factors in Table 9-1 are based on the beach composites in Table 4-7, the preliminary inlet composite for the dredge cuts, and the Shore Protection Manual (James-Krumbein) Overfill and Renourishment Factor (USACE, 1986). The higher overfill factor, based on the existing material along Figure Eight Island, is 1.044.

TABLE 9-1
OVERFILL FACTORS
FIGURE EIGHT ISLAND, NC

Composite	Mean Grain Size (mm)	Sorting (Φ)	Overfill Factor Ra
Figure Eight Island (F80+00 to 90+00)	0.18	0.55	1.044
Hutaff Island (H1 to H3)	0.21	0.85	1.000
Dredge Area (Figure 9-8)	0.24	0.83	

Based on the averaged retreat rates above, the design berm elevation (+6' NAVD), the cross-shore spreading limit (-24' NAVD), and an overfill factor of 1.044, cross-section sizes along oceanfront shoreline appear in Table 9-2. Cross-section sizes and fill volumes exclude the upper tolerance.

Cross-section sizes along the Nixon Channel shoreline are based on shoreline retreat rates between 1993 and 2005 (USGS, 1993; NOAA, 2005) (Table 9-3). Full size cross-sections extend 800 feet from profiles RIN17+00 to RIN25+00. The eastern taper section is 500 feet long, extending from profiles RIN12+00 to RIN17+00. The western taper section is 500 feet long, extending from profiles RIN25+00 to RIN30+00. The assumed cross-shore spreading limit along Nixon Channel is also -24 feet NAVD. Although this is deeper than the scour hole along the fill area, the deeper value provides a factor of safety against the high spreading losses that will occur due to the short fill length. Given the averaged retreat rate in Table 9-3, the design berm elevation (+6' NAVD), the assumed cross-shore spreading limit (-24' NAVD), and an overfill factor of 1.044, cross-section sizes along the Nixon Channel shoreline appear in Table 9-4. Cross-section sizes and fill volumes exclude the upper tolerance.

9.1.6.2 Profile Shape

The shapes of the construction templates along the beach were based on the post-construction profiles following the 2005 Bogue Inlet Channel Erosion Response Project. Beach slopes on those profiles averaged 1 vertical on 8 horizontal above wading depth, and 1 vertical on 23 horizontal below wading depth.

In the oceanfront fill area, the specified beach slope above the waterline is 1 vertical on 10 horizontal along the oceanfront fill area. For planning purposes, a beach slope of 1 vertical on 20 horizontal below the waterline is assumed. However, it should be noted that contractors are not able to control the beach slope below the waterline. Accordingly, the beach slope below the waterline is strictly an estimate based on the performance of a previous project in the region.

The design dune cross-section along Comber Road and Inlet Hook Road (profiles 77+50 to 95+00) has side slopes of 1 vertical on 5 horizontal. The crest width of the dune cross-section is 25 feet. To prevent sand from blowing into the upland properties, the dune crest elevation will be similar to the existing dune elevations along the dune fill area, which is approximately +15 feet NAVD. Overall, the dune location in Figure 9-8 is an approximation. The exact dune locations and crest elevations will be determined based on the conditions at the project site immediately prior to construction.

In the Nixon Channel fill area, the specified side slope is 1 vertical on 5 horizontal. This slope is roughly based on the existing bank slope along the scour hole. The assumed slope below the waterline is equal to the specified side slope above the waterline. Representative cross-sections along both fill areas appear in Figures 9-13 and 9-14.

TABLE 9-2

OCEANFRONT BEACH DISPOSAL AREA, ALTERNATIVE 3
BASED ON MARCH 2012 SURVEY
FIGURE EIGHT ISLAND / RICH INLET, NC

Profile Line	Fill Length (feet)	Design Retreat Rate (feet/year)	Adjusted Berm Width (feet)	Fill Distribution (c.y./foot)			Fill Volume (c.y./foot)		
				Beach	Dune	TOTAL	Beach	Dune	TOTAL
F90+00			0.0	0.0	0.0	0.0			
	1,000						26,800	0	26,800
F100+00		-9.2	46.2	53.5	0.0	53.5			
	1,001						53,600	0	53,600
0+00		-9.2	46.2	53.5	0.0	53.5			
	1,000						53,500	0	53,500
10+00		-9.2	46.2	53.5	0.0	53.5			
	1,000						53,500	0	53,500
20+00		-9.2	46.2	53.5	0.0	53.5			
	1,000						53,500	0	53,500
30+00		-9.2	46.2	53.5	0.0	53.5			
	1,000						53,500	0	53,500
40+00		-9.2	46.2	53.5	0.0	53.5			
	1,000						98,600	0	98,600
50+00		-24.8	123.8	143.6	0.0	143.6			
	1,000						143,600	0	143,600
60+00		-24.8	123.8	143.6	0.0	143.6			
	1,000						143,600	0	143,600
70+00		-24.8	123.8	143.6	0.0	143.6			

TABLE 9-2 (continued)

OCEANFRONT BEACH DISPOSAL AREA, ALTERNATIVE 3
BASED ON MARCH 2012 SURVEY
FIGURE EIGHT ISLAND / RICH INLET, NC

Profile Line	Fill Length (feet)	Design Retreat Rate (feet/year)	Adjusted Berm Width (feet)	Fill Distribution (c.y./foot) Beach	Fill Distribution (c.y./foot) Dune	Fill Distribution (c.y./foot) TOTAL	Fill Volume (c.y./foot) Beach	Fill Volume (c.y./foot) Dune	Fill Volume (c.y./foot) TOTAL
	250						35,900	0	35,900
72+50		-24.8	123.8	143.6	0.0	143.6			
	250						35,900	0	35,900
75+00		-24.8	123.8	143.6	20.1	163.6			
	250						35,900	5,400	41,300
77+50		-24.8	123.8	143.6	23.0	166.5			
	250						35,900	5,400	41,300
80+00		-24.8	123.8	143.6	20.5	164.0			
	250						35,900	5,200	41,100
82+50		-24.8	123.8	143.6	21.3	164.8			
	250						35,900	5,400	41,300
85+00		-24.8	123.8	143.6	22.1	165.7			
	250						35,900	5,600	41,500
87+50		-24.8	123.8	143.6	22.7	166.2			
	250						35,900	5,700	41,600
90+00		-24.8	123.8	143.6	23.2	166.8			

TABLE 9-2 (continued)

OCEANFRONT BEACH DISPOSAL AREA, ALTERNATIVE 3
BASED ON MARCH 2012 SURVEY
FIGURE EIGHT ISLAND / RICH INLET, NC

Profile Line	Fill Length (feet)	Design Retreat Rate (feet/year)	Adjusted Berm Width (feet)	Fill Distribution (c.y./foot)			Fill Volume (c.y./foot)		
				Beach	Dune	TOTAL	Beach	Dune	TOTAL
	250						35,900	5,700	41,600
92+50		-24.8	123.8	143.6	22.1	165.7			
	250						35,900	5,400	41,300
95+00		-24.8	123.8	143.6	21.0	164.5			
	250						35,900	0	35,900
97+50		-24.8	123.8	143.6	0.0	143.6			
	250						35,900	0	35,900
100+00		-24.8	123.8	143.6	0.0	143.6			
	250						26,900	0	26,900
102+50		-24.8	61.9	71.8	0.0	71.8			
	250						9,000	0	9,000
105+00			0.0	0.0	0.0	0.0			
Oceanfront F90+00 to 105+00	12,501			91.7	3.5	95.2	1,146,900	43,800	1,190,700

TABLE 9-3
SHORELINE CHANGES ON THE SOUTH SIDE OF NIXON CHANNEL

Profile Line	Profile Origin (NC-NAD83) Easting (feet)	Northing (feet)	Azimuth (deg.)	Shoreline Changes (feet/year) March 1993 to October 2005	October 1996 To October 2005	DESIGN
RIN12+00	2387059.4	200966.8	334.5	-N/A-	7.1	7.1
RIN13+00	2386969.2	200923.7	334.5	-N/A-	-9.3	-9.3
RIN14+00	2386879.0	200880.6	334.5	-N/A-	-14.9	-14.9
RIN15+00	2386788.7	200837.5	334.5	-N/A-	-22.5	-22.5
RIN16+00	2386698.5	200794.4	334.5	-N/A-	-N/A-	-12.8
RIN17+00	2386608.2	200751.3	334.5	-3.0	-N/A-	-3.0
RIN18+00	2386518.0	200708.2	334.5	-1.8	-N/A-	-1.8
RIN19+00	2386427.8	200665.1	334.5	-7.4	-N/A-	-7.4
RIN20+00	2386337.5	200622.0	334.5	-8.2	-N/A-	-8.2
RIN21+00	2386247.3	200578.9	334.5	-8.8	-N/A-	-8.8
RIN22+00	2386157.1	200535.8	334.5	-8.6	-N/A-	-8.6
RIN23+00	2386066.8	200492.7	334.5	-8.8	-N/A-	-8.8
RIN24+00	2385976.6	200449.6	334.5	-8.5	-N/A-	-8.5
RIN25+00	2385886.4	200406.5	334.5	-9.8	-N/A-	-9.8
RIN26+00	2385796.1	200363.4	334.5	-10.8	-N/A-	-10.8
RIN27+00	2385705.9	200320.3	334.5	-9.4	-N/A-	-9.4
RIN28+00	2385615.6	200277.2	334.5	-8.7	-N/A-	-8.7
RIN29+00	2385525.4	200234.1	334.5	-8.6	-N/A-	-8.6
RIN30+00	2385435.2	200191.0	334.5	-7.7	-N/A-	-7.7
AVERAGE						-8.6

TABLE 9-4

NIXON CHANNEL BEACH DISPOSAL AREA, ALTERNATIVE 3
BASED ON 2010 LIDAR & NIXON CHANNEL SURVEYS
FIGURE EIGHT ISLAND / RICH INLET, NC

Profile Line	Fill Length (feet)	Design Retreat Rate (feet/year)	Adjusted Berm Width (feet)	Beach Fill Distr. (c.y./foot)	Beach Fill Volume (c.y.)
RIN12+00*					
RIN13+00*					
RIN14+00*					
RIN15+00*					
RIN16+00		-8.6	34.2	39.7	
	100				4,500
RIN17+00		-8.6	42.8	49.6	
	100				5,000
RIN18+00		-8.6	42.8	49.6	
	100				5,000
RIN19+00		-8.6	42.8	49.6	
	100				5,000
RIN20+00		-8.6	42.8	49.6	
	100				5,000
RIN21+00		-8.6	42.8	49.6	
	100				5,000
RIN22+00		-8.6	42.8	49.6	
	100				5,000
RIN23+00		-8.6	42.8	49.6	
	100				5,000
RIN24+00		-8.6	42.8	49.6	
	100				5,000
RIN25+00		-8.6	42.8	49.6	
	100				4,500
RIN26+00			34.2	39.7	
	100				3,500
RIN27+00			25.7	29.8	
	100				2,500
RIN28+00			17.1	19.8	
	100				1,500
RIN29+00			8.6	9.9	
	100				500
RIN30+00			0.0	0.0	
Nixon Channel RIN16+00 to RIN30+00	1,400			40.7	57,000

*NOTE: The preliminary design included fill from profiles RIN12+00 to RIN30+00. To reduce impacts to a small tidal creek at the east end of this area, fill between profiles RIN12+00 and RIN16+00 was deleted.

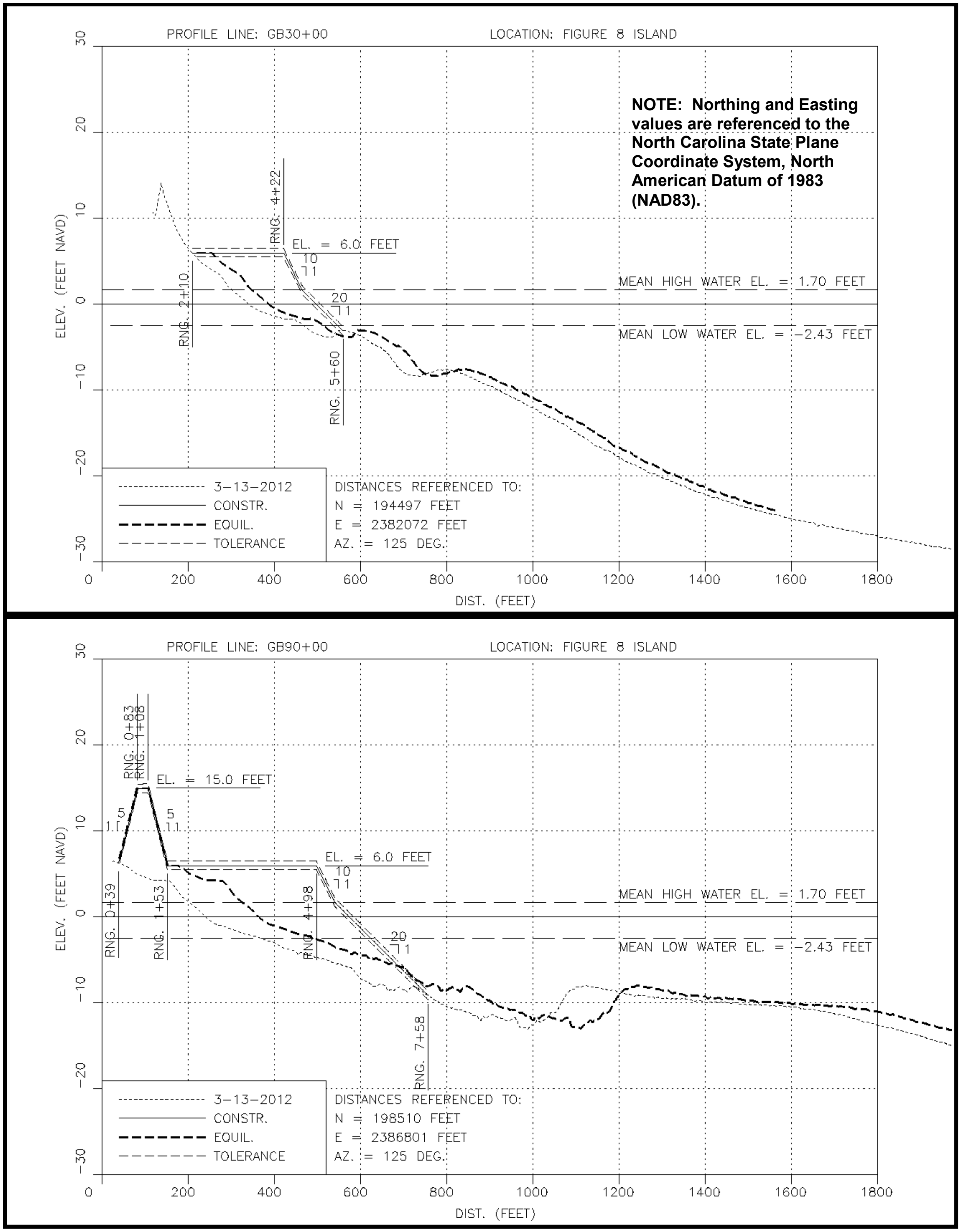


FIGURE 9-13: Representative Cross-Sections along the Oceanfront Beach Fill Area, Alternative 3.

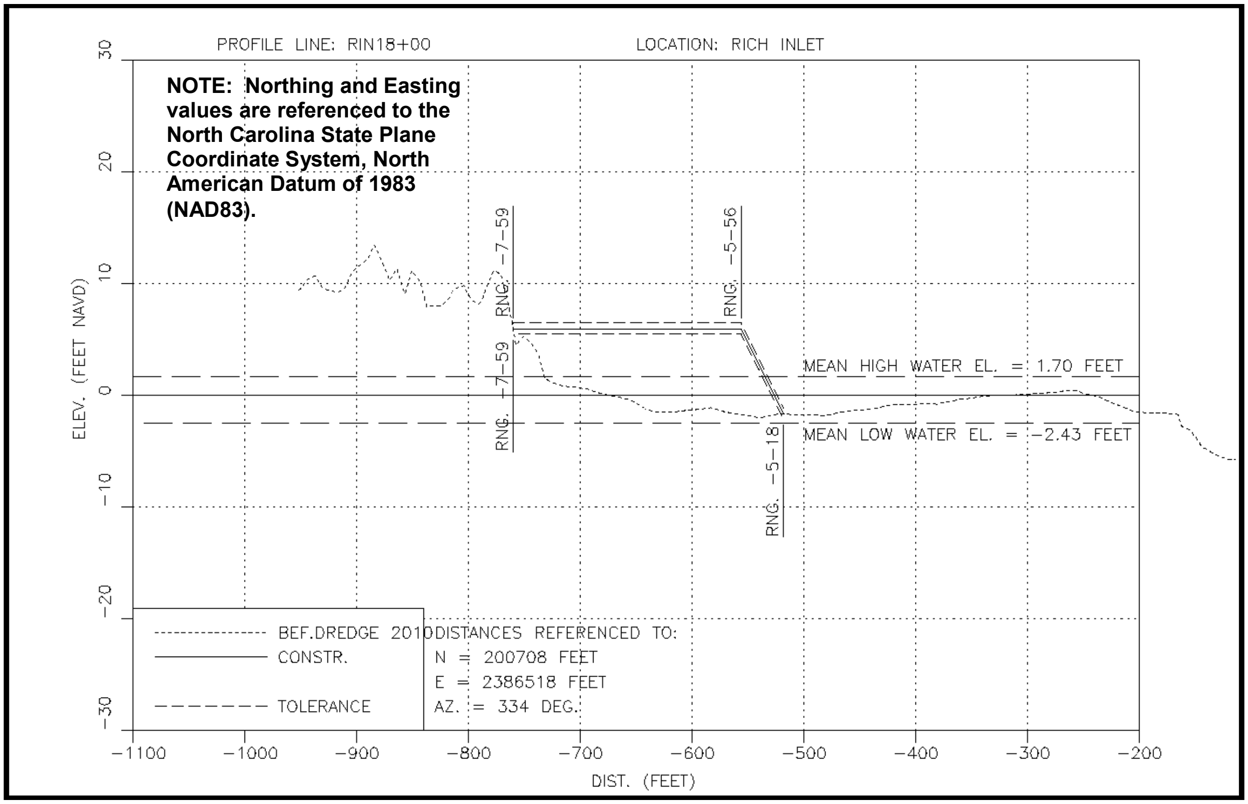


FIGURE 9-14: Representative Cross-Section along the Nixon Channel Fill Area, Alternative 3.

9.2 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. The size of the beach fill along the ocean shoreline associated with Alternative 3 was dictated by the volume of material that would be removed to move the inlet ocean bar channel to a preferred position and alignment and modify the channels leading into both Nixon and Green Channels. For Alternative 4, the size of the beach fill was based on the modeled performance of a fill between Rich Inlet and Bridge Road without any modifications to Rich Inlet. In this regard, the size of the beach fill modeled under Alternative 4 was similar to Alternative 3. However, analysis of the model results found this beach fill to be over designed for the area between stations F90+00 and 80+00 and under designed for the area north of station 80+00. As a result, the beach fill under Alternative 4 was modified to address shoreline erosion issues resulting in a smaller initial beach fill between F90+00 and 80+00 and a larger fill between 80+00 and 100+00. Since Alternative 4 does not include any modification to the Rich Inlet ocean bar channel, material to construct and maintain the beach fills would have to be obtained from other sources which are evaluated below.

Also, due to the high rates of loss from the fill obtained from the model results for the area between 80+00 and 100+00, the beach fill design for Alternative 4 was based on a four-year periodic nourishment cycle. The total initial beach fill volume along the ocean shoreline from Rich Inlet to Bridge Road would be 864,300 cubic yards based on the 2006 conditions and 911,300 based on the 2012 conditions. Design berm width and fill placement densities along the ocean shoreline are given in Table 9-5 with the fill distribution provided in Table 9-6. Beach fill placement rates and design berm widths for Alternative 4 are provided in Table 9.5 with the layout of the beach fill shown in Figures 9-15A and 9-15B. The beach fill along Nixon Channel would be the same as Alternative 3 or 57,000 cubic yards. Including the Nixon Channel beach fill, the total beach fill volume for Alternative 4 would be 921,300 cubic yards based on the 2006 conditions and 968,300 cubic yards based on the 2012 conditions.

TABLE 9-5
ALTERNATIVE 4
BEACH FILL PLACEMENT VOLUMES AND DESIGN BERM WIDTHS

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

Material to construct and maintain the beach fill under Alternative 4 would be derived from maintenance dredging of the previously permitted area in Nixon Channel, the potential offshore borrow areas identified by Dr. Cleary as described in Chapter 3 of this document, and the three northern AIWW disposal sites also discussed in Chapter 3. Due to the relative small volume available from the three AIWW disposal sites, these sites would be held in reserve and only used for periodic nourishment if the volume of material shoaling the existing permit area in Nixon Channel is insufficient to meet nourishment requirements or other concerns over the removal of the material from Nixon Channel prevent its use. Also, the relatively high rate of periodic nourishment rates for Alternative 4 indicated by the model results would require the continued use of the offshore borrow sites in order to satisfy the nourishment requirements.

Based on the Delft3D model results discussed later in this document, renourishment of the fill areas under Alternative 4 are expected to be the following:

- Oceanfront fill area:
    - Profiles 60+00 to 105+00: 764,000 cubic yards every 4 years given the 2006 initial conditions and 508,000 cubic yards every 4 years given the 2012 initial conditions.
    - Profiles F90+00 to 60+00: Deferred until deemed necessary based on future monitoring surveys.
- Nixon Channel fill area: 24,000 cubic yards every 4 years.

FIGURE 9-15A: Alternative 4 Beach Fill Layout

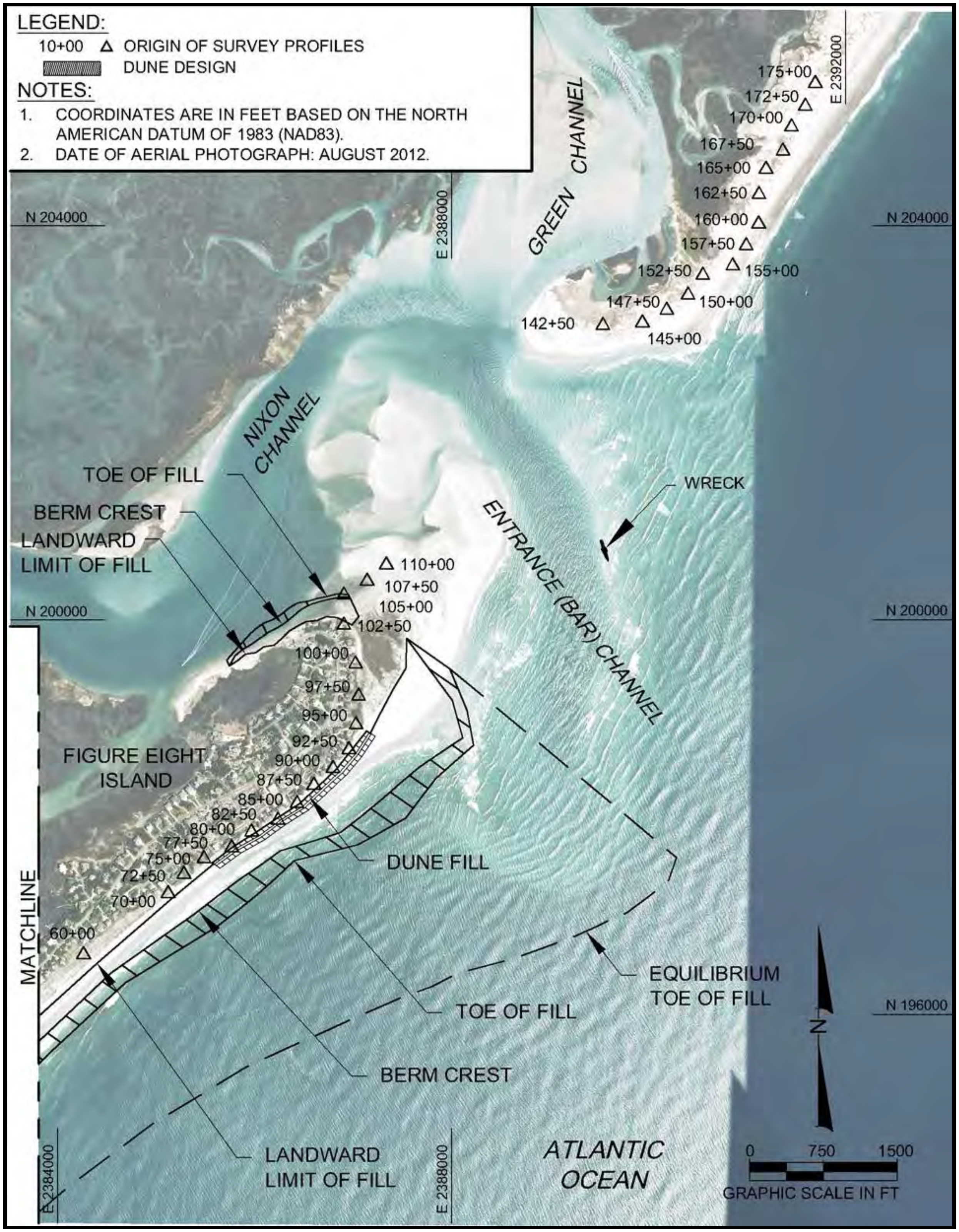


FIGURE 9-15B: Alternative 4 Beach Fill Layout

TABLE 9-6

OCEANFRONT BEACH DISPOSAL AREA, ALTERNATIVE 4
BASED ON MARCH 2012 SURVEY
FIGURE EIGHT ISLAND / RICH INLET, NC

Profile Line	Fill Length (feet)	Adjusted Berm Width (feet)	Fill Distribution (c.y./foot)			Fill Volume (c.y./foot)		
			Beach	Dune	TOTAL	Beach	Dune	TOTAL
F90+00		0.0	0.0	0.0	0.0			
	1,000					10,000	0	10,000
F100+00		17.2	20.0	0.0	20.0			
	1,001					20,000	0	20,000
0+00		17.2	20.0	0.0	20.0			
	1,000					20,000	0	20,000
10+00		17.2	20.0	0.0	20.0			
	1,000					20,000	0	20,000
20+00		17.2	20.0	0.0	20.0			
	1,000					35,000	0	35,000
30+00		43.1	50.0	0.0	50.0			
	1,000					50,000	0	50,000
40+00		43.1	50.0	0.0	50.0			
	1,000					50,000	0	50,000
50+00		43.1	50.0	0.0	50.0			
	1,000					50,000	0	50,000
60+00		43.1	50.0	0.0	50.0			
	1,000					75,000	0	75,000
70+00		86.2	100.0	0.0	100.0			

TABLE 9-6 (continued)

OCEANFRONT BEACH DISPOSAL AREA, ALTERNATIVE 4
BASED ON MARCH 2012 SURVEY
FIGURE EIGHT ISLAND / RICH INLET, NC

Profile Line	Fill Length (feet)	Adjusted Berm Width (feet)	Fill Distribution (c.y./foot)			Fill Volume (c.y./foot)		
			Beach	Dune	TOTAL	Beach	Dune	TOTAL
	250					25,000	0	25,000
72+50		86.2	100.0	0.0	100.0			
	250					25,000	0	25,000
75+00		86.2	100.0	20.1	120.1			
	250					25,000	5,400	30,400
77+50		86.2	100.0	23.0	123.0			
	250					25,000	5,400	30,400
80+00		86.2	100.0	20.5	120.5			
	250					37,500	5,200	42,700
82+50		172.4	200.0	21.3	221.3			
	250					50,000	5,400	55,400
85+00		172.4	200.0	22.1	222.1			
	250					50,000	5,600	55,600
87+50		172.4	200.0	22.7	222.7			
	250					50,000	5,700	55,700
90+00		172.4	200.0	23.2	223.2			

TABLE 9-6 (continued)

OCEANFRONT BEACH DISPOSAL AREA, ALTERNATIVE 4
BASED ON MARCH 2012 SURVEY
FIGURE EIGHT ISLAND / RICH INLET, NC

Profile Line	Fill Length (feet)	Adjusted Berm Width (feet)	Fill Distribution (c.y./foot)			Fill Volume (c.y./foot)		
			Beach	Dune	TOTAL	Beach	Dune	TOTAL
	250					50,000	5,700	55,700
92+50		172.4	200.0	22.1	222.1			
	250					50,000	5,400	55,400
95+00		172.4	200.0	21.0	221.0			
	250					50,000	0	50,000
97+50		172.4	200.0	0.0	200.0			
	250					50,000	0	50,000
100+00		172.4	200.0	0.0	200.0			
	250					37,500	0	37,500
102+50		86.2	100.0	0.0	100.0			
	250					12,500	0	12,500
105+00		0.0	0.0	0.0	0.0			
Oceanfront F90+00 to 105+00	12,501		69.4	3.5	72.9	867,500	43,800	911,300

9.3 Alternative 5C – Terminal Groin at a More Northerly Location with Beach Fill from Nixon Channel and a New Channel Connecting to Gorge of Rich Inlet

During the 2011 legislation session, the North Carolina Legislature passed Session Law 2011-387, Senate Bill 110 which allows consideration of terminal groins adjacent to tidal inlets. The legislation limited the number of terminal groins to four (4) statewide and included a number of provisions and conditions that must be met in order for the groins to be approved and permitted. In 2013, the State Legislature passed the Coastal Policy Reform Act of 2013 (SL2013-384) that modified some of the requirements included in the 2011 legislation.

The purpose of the terminal groin is to create a permanent accretion fillet immediately adjacent to the inlet by controlling tide induced or influenced sediment transport off the extreme north end of the island. In so doing, the groin and associated accretion fillet would create a relatively stable shoreline position immediately south of the inlet with an alignment comparable to the shoreline farther south. The elimination or reduction in tide induced or influenced sediment transport off the extreme north end of the island should improve the performance and longevity of beach fills placed on the northern half of Figure Eight Island but would not prevent littoral transport, i.e., wave induced sediment transport from moving past the terminal groin and into Rich Inlet. In this regard, a terminal groin would not address shoreline management problems along the entire island therefore; a shoreline management alternative that includes a terminal groin must include beach nourishment.

9.3.1 Formulation of Alternative 5C

Alternative 5C, which positions the terminal groin 420 feet north of the terminal groin position presented in the DEIS, evolved through the development of Alternative 5A. One element included in the development of Alternative 5A was consideration of three possible channel extensions from the previously permitted area in Nixon Channel to the gorge of Rich Inlet. The three channel options included:

- Dredging Option 1 – 660-740 foot wide connecting cut.
- Dredging Option 2 – 600 foot wide connecting cut.
- Dredging Option 3 – 395-416 foot wide connecting cut.

The purpose of the new channel was to:

- Facilitate navigation between the existing entrance channel and Nixon Channel.
- Provide for a straight flow pattern through Nixon Channel, to reduce the severity of erosion along the end of N. Beach Road.

Through an initial screening process involving simulations in the Delft3D model, Dredging Option 2, shown in Figure 9-16, was selected. As noted, the selected dredging option is also applicable to Alternative 5C. Dredging Option 2 provides a sufficient amount of fill material to pre-fill the groin and provide nourishment of the beach south to Bridge Road. In addition, the channel was found to be more conducive to navigation, with a depth of at least -10 feet NAVD maintained at the seaward end of Nixon Channel over the 5-year maintenance cycle. Overall, Dredging Option 2 represents the best balance of performance, cost, and impact.

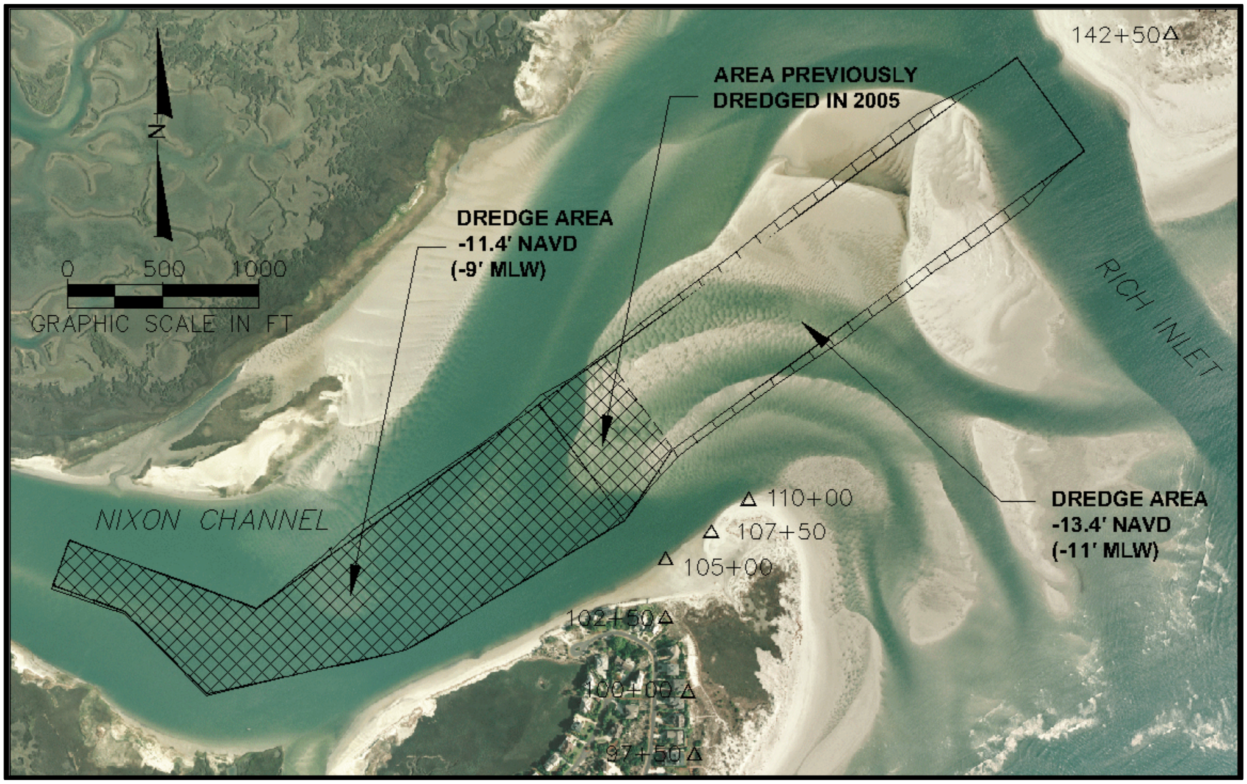


Figure 9-16. Dredging Option 2 – Alternative 5A and 5C.

Additional options for Alternative 5A involving the length of the terminal groin, its performance with and without beach fill, and orientations toward Figure Eight Island were also evaluated. The results of the Delft3D model simulations for these alternatives/options are presented graphically in Sub-Appendix B.

The model evaluations considered two possible lengths each measured from the April 2007 mean high water shoreline. The two lengths evaluated were 700 feet and 1200 feet. Based on the model results, the shorter terminal groin option was selected. Also, the model results for with the terminal groin oriented toward Figure Eight Island did not produce any significant improvement of the performance of the beach fill along the northern end of the island. Therefore, the preferred alignment of the terminal groin would be approximately perpendicular to the shoreline.

The results of the screening process for Alternative 5A, primarily the selection of the dredging option and the orientation of the terminal groin and its general overall length were incorporated into the design of Alternative 5C.

9.3.1 Description of Alternative 5C

Alternative 5C includes a 1,300-foot terminal groin located near baseline station 105+00 or in the more northerly position relative to Alternatives 5A and 5B presented in the DEIS. The terminal groin would include a 995-foot shore anchorage section extending landward of the 2007 mean high water shoreline and a 305-foot section extending seaward of the 2007 mean high water shoreline. The shore anchorage section would be constructed with sheet pile (steel or concrete) while the seaward section would be of rubblemound construction. The landward 100 feet of the shore anchorage section would include a 10-foot wide scour protection mat on both sides of the sheet pile. The beach fill for Alternative 5C would be constructed with material obtained from maintenance of the previously permitted area in Nixon Channel and construction of a new channel connecting Nixon Channel with the gorge of Rich Inlet as shown in Figure 9-16.

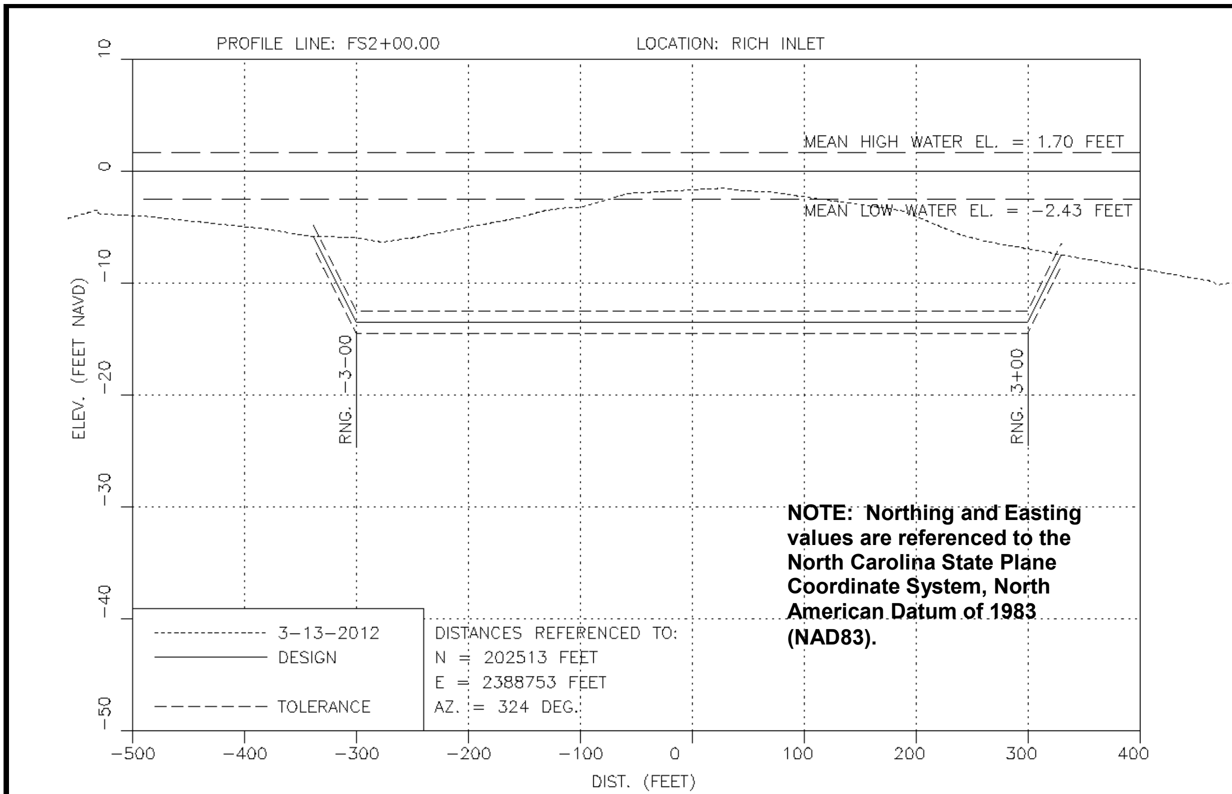
Excavation of the previously permitted area in Nixon Channel and the new channel connecting Nixon Channel with the gorge of Rich Inlet would involve the removal of 994,400 cubic yards given the 2006 initial conditions and 1,077,100 cubic yards of material for the 2012 initial conditions. An estimated 29,700 cubic yards of clay is included in this total volume. The clay material would be deposited in an upland disposal site. This would leave 964,700 cubic yards of sandy material given the 2006 conditions and 1,047,400 cubic yards of sandy material under the 2012 conditions.

9.3.2 Beach Fill Areas

Based on the most recent surveys and an allowable overdepth of one-foot, excavation of the dredge area in Figure 9-16 will provide 1,047,400 cubic yards of beach compatible material and 29,700 cubic yards of clay which would be deposited in an upland disposal site. Alternative 5C would provide a beach fill along the shoreline of Nixon Channel and along the oceanfront extending from Beachbay Lane (F90+00) to the terminal groin located near station 105+00.

Although the maintenance cycle of the project will be 5-years, a large volume is required to pre-fill the terminal groin and provide beach fill south to station F90+00. By straightening the shoreline immediately south of the terminal groin and reducing the direct impact of tidal currents along the extreme north end of the island, the terminal groin should reduce erosion rates at the island's northern end while allowing wave induced sediment transport to pass over, around, and/or through the terminal groin. Between profile 75+00 (south of Surf Court) and the terminal groin, fill distributions are based on the volume of material that would be placed to pre-fill the groin fillet. South of profile 75+00, fill distributions are based on 3 years of erosion, given the retreat rates in Tables 9-2 and 9-5, a berm elevation of +6 feet NAVD, a depth of closure equal to -24 feet NAVD, and an overfill factor of 1.044 (Table 9-1). The 3 year assumption was simply used as a means of apportioning the fill within the available volume discussed above. Based on the model results discussed later in the report, the amount of fill south of Surf Court should be sufficient for preventing erosion into the present shoreline over a 5 year period.

The fill area along the Nixon Channel shoreline contains 57,000 cubic yards. The distribution of the fill along the Nixon Channel shoreline is provided in Table 9-7.



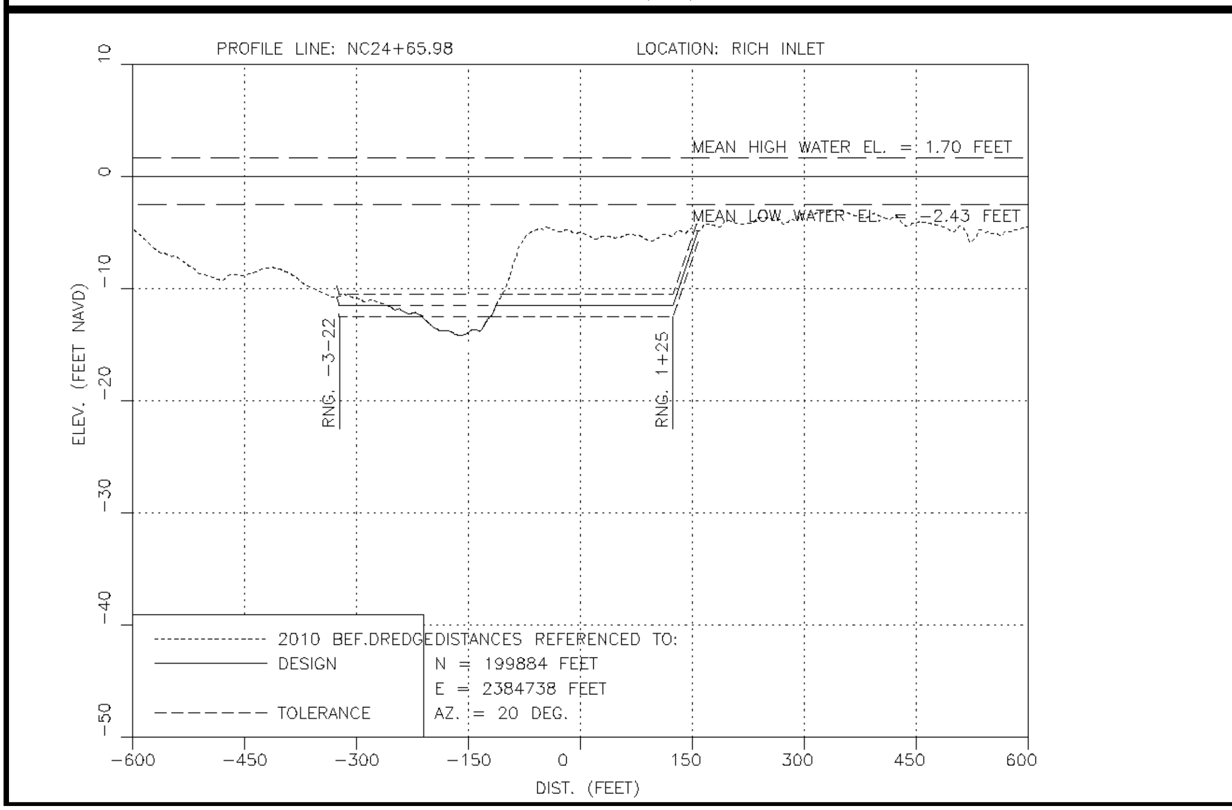


FIGURE 9-17: Representative Dredging Cross-Sections, Preferred Dredging Option (2), Alternative 5C.

TABLE 9-6

OCEANFRONT BEACH DISPOSAL AREA
ALTERNATIVE 5C
FIGURE EIGHT ISLAND / RICH INLET, NC

Profile Line	Fill Length (feet)	Design Retreat Rate (feet/year)	Adjusted Berm Width (feet)	Fill Distribution (c.y./foot)			Fill Volume (c.y.)		
				Beach	Dune	Total	Beach	Dune	Total
F90+00		-9.2	0.0	0.0	0.000	0.000			
F100+00	1,000	-9.2	36.9	42.8	0.000	42.8	21,400	0	21,400
0+00	1,001	-9.2	36.9	42.8	0.000	42.8	42,900	0	42,900
10+00	1,000	-9.2	36.9	42.8	0.000	42.8	42,800	0	42,800
20+00	1,000	-9.2	36.9	42.8	0.000	42.8	42,800	0	42,800
30+00	1,000	-9.2	36.9	42.8	0.000	42.8	42,800	0	42,800
40+00	1,000	-9.2	36.9	42.8	0.000	42.8	42,800	0	42,800
50+00	1,000	-24.8	99.0	114.9	0.000	114.9	78,800	0	78,800
60+00	1,000	-24.8	99.0	114.9	0.000	114.9	114,800	0	114,800
70+00	1,000	-24.8	99.0	114.9	0.000	114.9	114,800	0	114,800
72+50	250	-24.8	99.0	114.9	0.000	114.9	28,700	0	28,700
75+00	250	-24.8	99.0	114.9	20.1	134.9	28,700	0	28,700
77+50	250	-24.8	99.0	114.9	23.0	137.8	28,700	5,400	34,100
80+00	250	-24.8	99.0	114.9	20.5	135.3	28,700	5,400	34,100
82+50	250	-24.8	99.0	114.9	21.3	136.1	28,700	5,200	33,900
85+00	250	-24.8	99.0	114.9	22.1	136.9	28,700	5,400	34,100
87+50	250	-24.8	99.0	114.9	22.7	137.5	28,700	5,600	34,300
90+00	250	-24.8	99.0	114.9	23.2	138.1	28,700	5,700	34,400
92+50	250	-24.8	99.0	114.9	22.1	137.0	28,700	5,700	34,400
95+00	250	-24.8	99.0	114.9	21.0	135.8	28,700	5,400	34,100
97+50	250	-24.8	99.0	114.9	0.0	114.9	28,700	0	28,700
100+00	250	-24.8	99.0	114.9	0.0	114.9	28,700	0	28,700
102+50	250	-24.8	99.0	114.8	0.0	114.8	28,700	0	28,700
105+00	250	-24.8	99.0	114.8		114.8	28,700	0	28,700
Ocean front F90+00 to 105+00	12,501						945,700	43,800	989,500

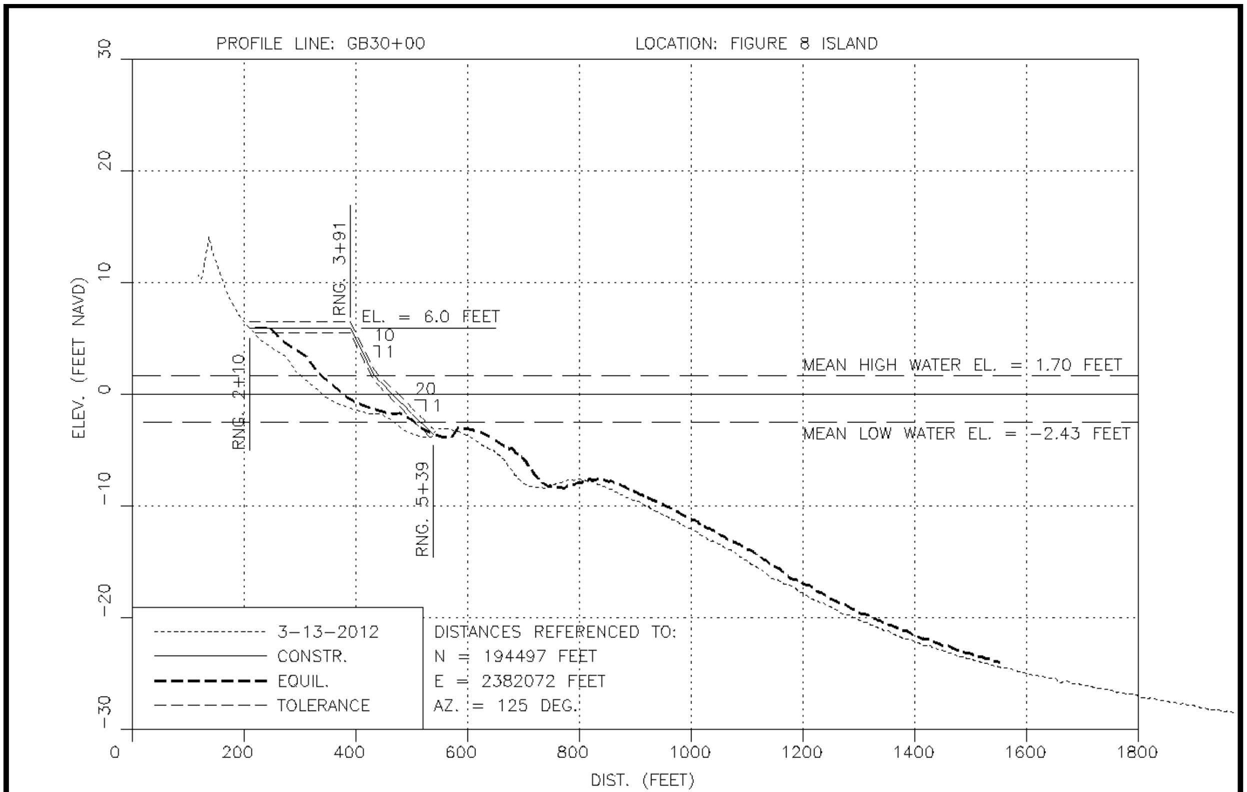
TABLE 9-7

NIXON DISPOSAL AREA
ALTERNATIVE 5C
FIGURE EIGHT ISLAND / RICH INLET, NC

Profile Line	Fill Length (feet)	Beach Fill Distribution (c.y./foot)	Beach Fill Volume (c.y.)
RIN15+00		0	0
RIN16+00	100	39.7	4,500
RIN17+00	100	49.6	5,000
RIN18+00	100	49.6	5,000
RIN19+00	100	49.6	5,000
RIN20+00	100	49.6	5,000
RIN21+00	100	49.6	5,000
RIN22+00	100	49.6	5,000
RIN23+00	100	49.6	5,000
RIN24+00	100	49.6	5,000
RIN25+00	100	49.6	4,500
RIN26+00	100	39.7	3,500
RIN27+00	100	29.8	2,500
RIN28+00	100	19.8	1,500
RIN29+00	100	10.0	500
Total	1,400		57,000

9.3.5 Profile Shape

Profile shapes along the fill area are based on the same assumptions as those of Alternative 3. Representative cross-sections appear in Figures 9-17 through 9-18.



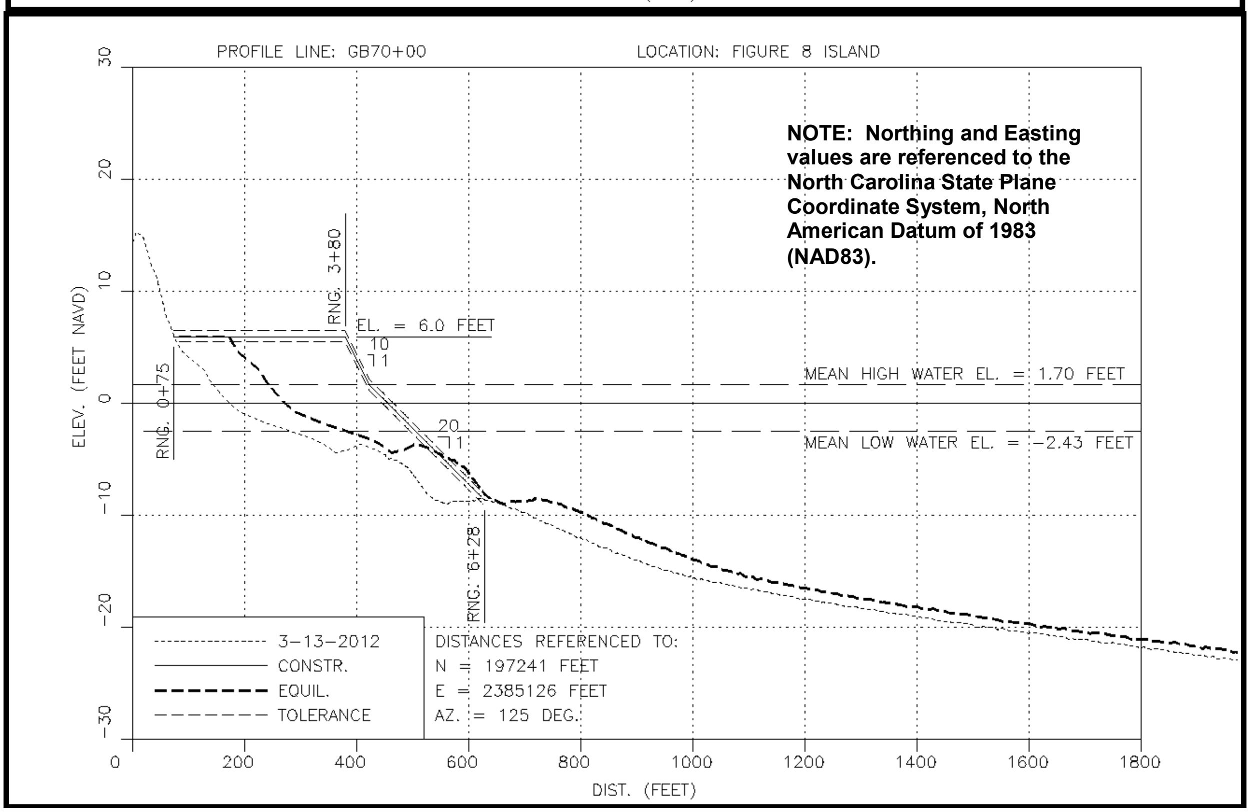
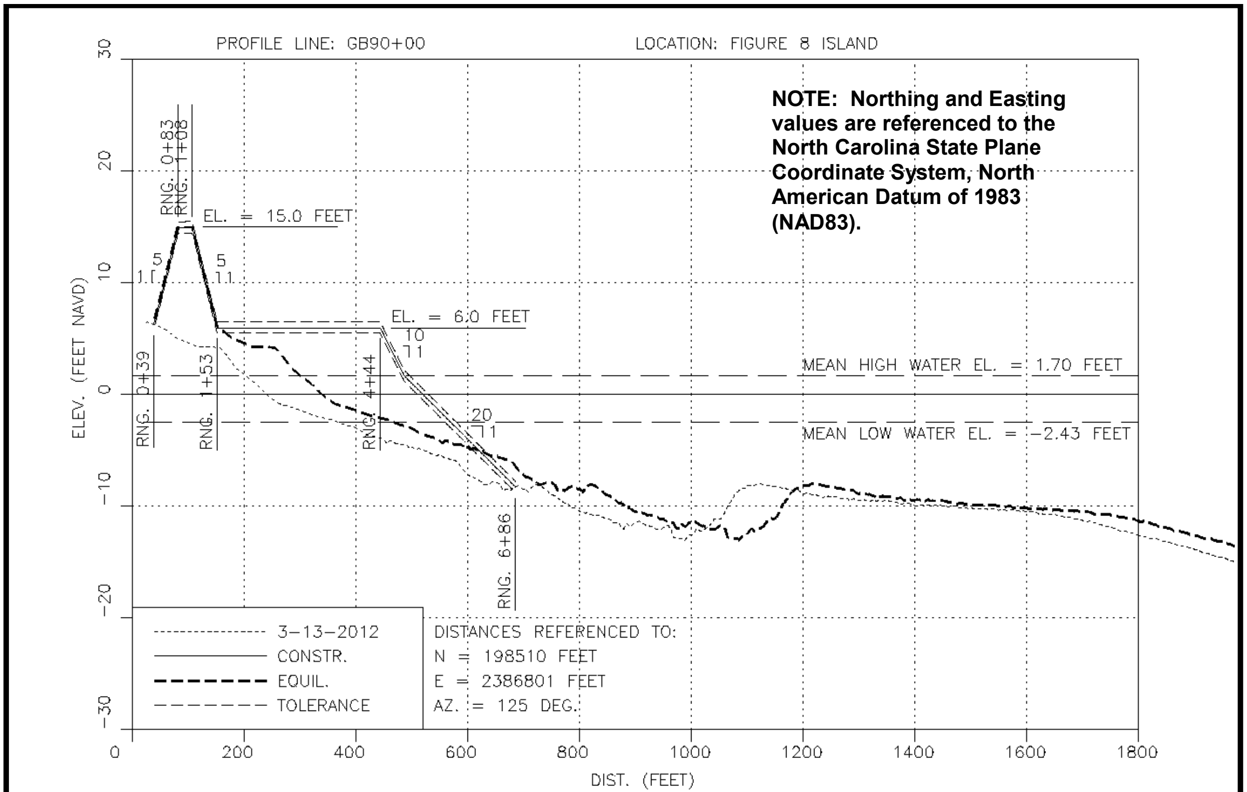


FIGURE 9-18: Representative Cross-Sections along the Oceanfront Beach Fill Area, Alternative 5C.



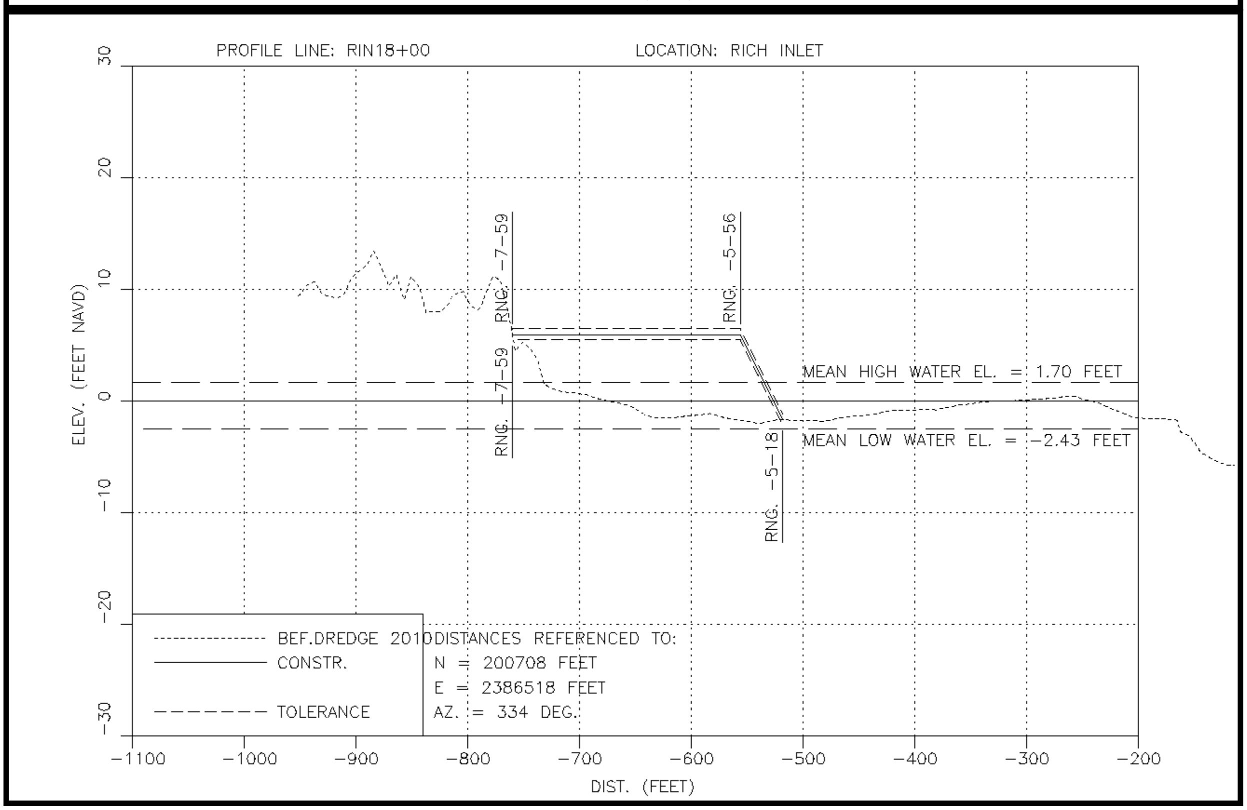


FIGURE 9-19: Representative Cross-Sections along the North End of Figure Eight Island including the Nixon Channel shoreline, Alternative 5C.

9.2.6 Design Summary for Alternative 5C

Based on the various features discussed above, the dredging and groin option for Alternative 5C can be summarized by the following:

- Terminal groin length = 1,300 feet with 305 feet extending seaward from the April 2007 shoreline and 995 feet landward of the April 2007 shoreline.

- Terminal groin footprint (bottom surface area) = 0.7 acres.

- Groin crest elevation:
    - Landward shore anchorage segment (995 feet): +1.5 feet NAVD first 795 feet landward of the April 2007 MHW shoreline and 0.5 feet NAVD last 200 feet.
    - Rubblemound segment 305 feet seaward of April 2007 MHW shoreline: +6 feet NAVD.

- Groin material: Sheet Pile (concrete or steel) for shore anchorage section and Granite quarry stone for seaward 305-foot segment. Armor stone ranging from 7.5 tons to 12.5 tons.

- Dredge cut depth in Nixon Channel and Channel Connector:
    - East section of dredge cut: -13.43 feet NAVD (-11 feet MLW) + 1 foot overdepth.
    - West section of dredge cut: -11.43 feet NAVD (-9 feet MLW) + 1 foot overdepth.

- Dredged cut bottom width:
    - East end of dredge cut: 600 feet.
    - Bending section of dredge cut: 250 to 754 feet.
    - West end of dredge cut: 250 feet.

- Dredge cut length: 6,156 feet.

- Dredge Volume = 994,400 c.y. based on the 2006 survey and 1,077,100 c.y. based on the 2012 surveys.

- Volume of clay to be deposited in upland disposal area = 29,700 c.y.

- Net volume of beach quality material (sandy material) = 907,700 c.y. for the 2006 condition and 990,400 c.y. for the 2012 condition.

- Oceanfront Disposal Area:
    - Berm Elevation = +6 feet NAVD + 0.5 foot tolerance.
    - Construction Berm Width = varies.
    - Side Slopes:
        - 1 vertical on 5 horizontal in the dune fill area
        - 1 vertical on 10 horizontal above mean high water (+1.7' NAVD)
        - 1 vertical on 20 horizontal (assumed) below mean high water

- Fill Length = 12,500 feet (Station F90+00 to 105+00).
- Volume = 850,700 c.y. based on the 2006 conditions and 933,400 c.y. for the 2012 conditions.

- Nixon Disposal Area:
  - Berm Elevation = +6 feet NAVD + 0.5 foot tolerance.
  - Construction Berm Width = varies.
  - Side Slopes:
    - 1 vertical on 5 horizontal
  - Fill Length = 1,400 feet.
  - Volume = 57,000 c.y.

A plan view of Alternative 5C as whole appears in Figures 9-20A and 9-20B.

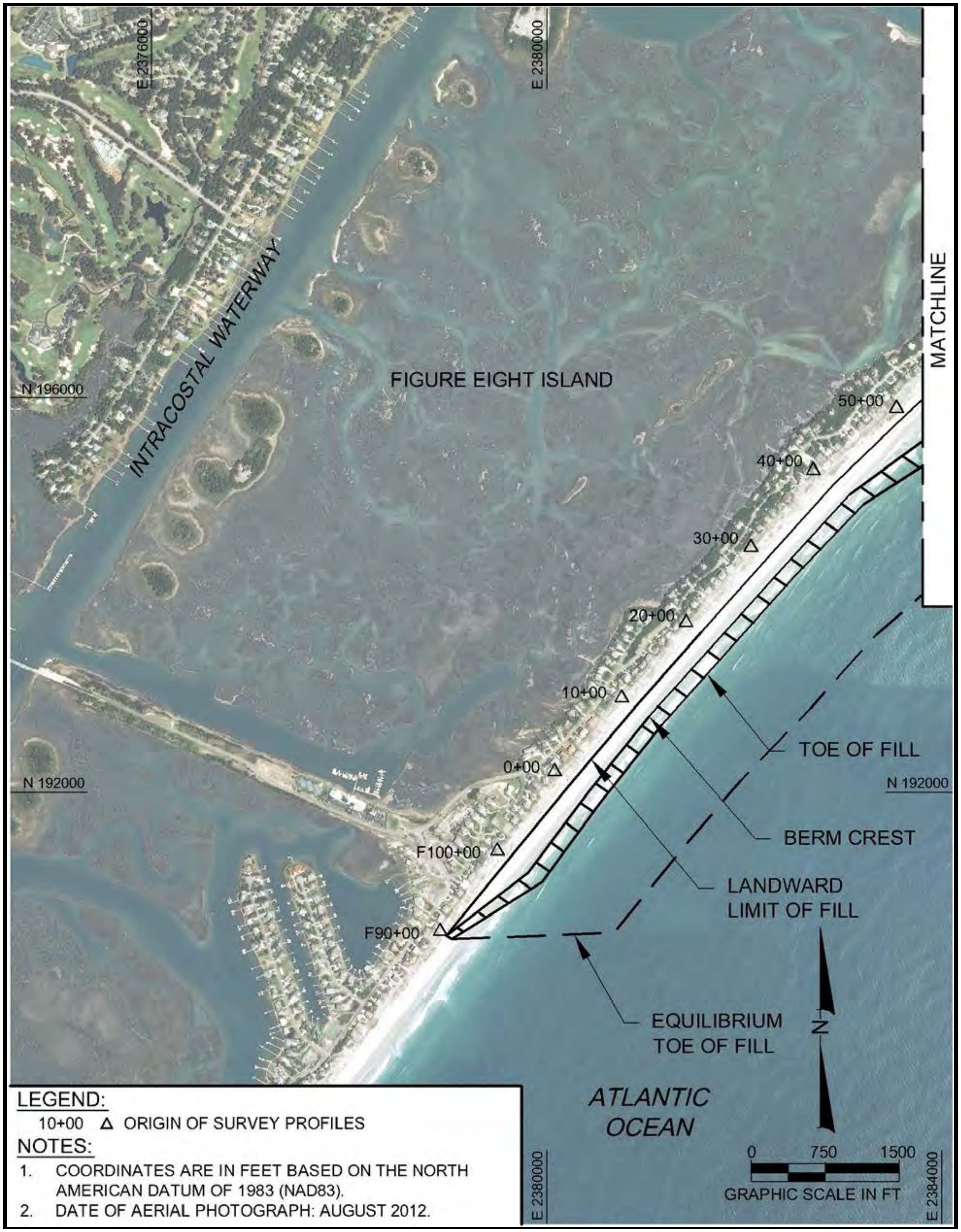


FIGURE 9-20A: Alternative 5C
Dredging and Groin Option and Beach Fill Layout.

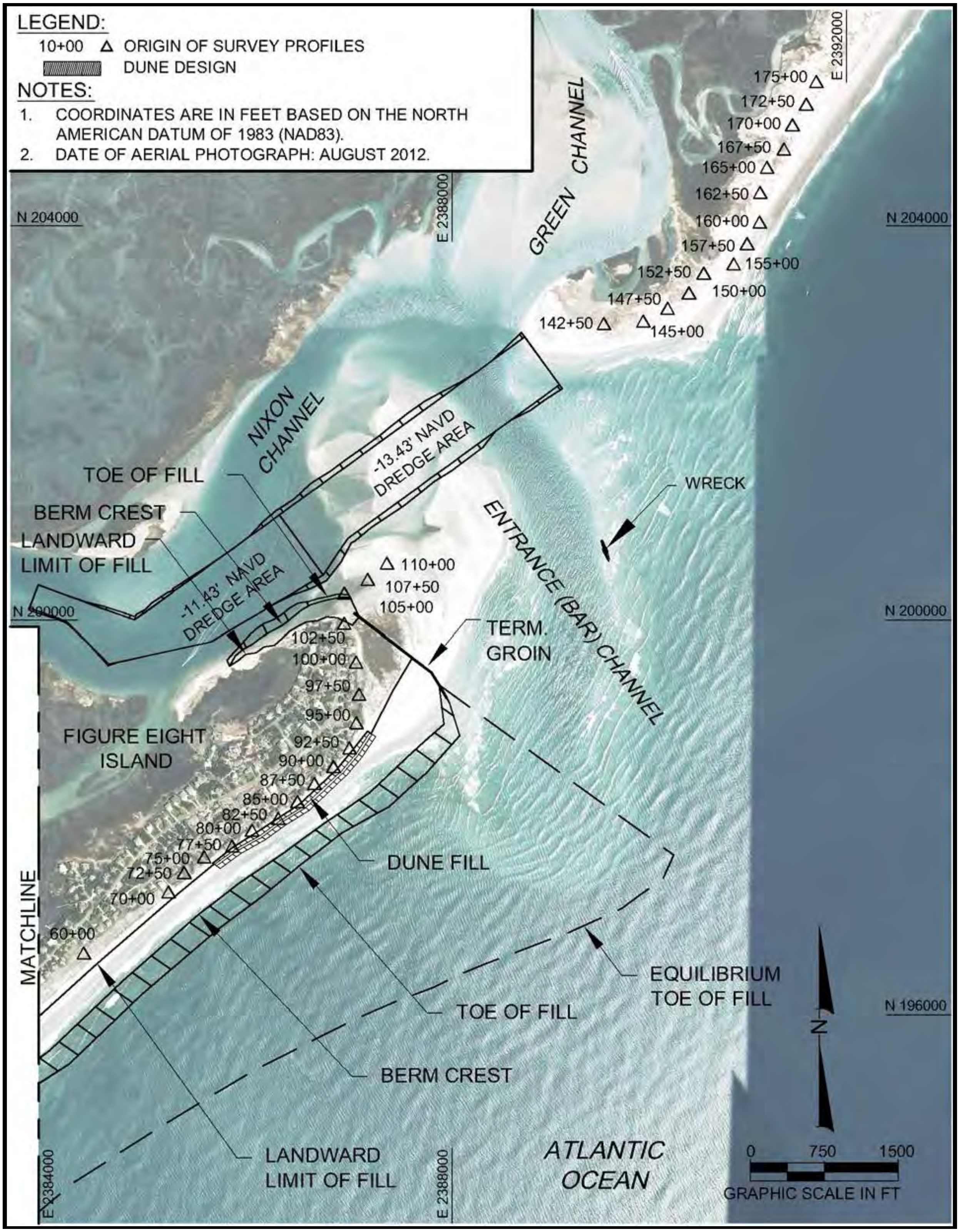


FIGURE 9-20B: Alternative 5C
Dredging and Groin Option and Beach Fill Layout.

9.4 Alternative 5D (Applicant's Preferred Alternative): Terminal Groin at a More Northerly Location with Beach Fill from the Previously Permitted Area in Nixon Channel and Other Sources

Alternative 5D includes a terminal groin in the more northerly location and the same beach fill along Nixon Channel as Alternatives 5C. The ocean shoreline beach fill for Alternative 5D would extend from station 60+00 (approximately 322 Beach Road North) to the terminal groin (station 105+00).

9.4.1 Beach Fill Design

The volume of material needed to construct the beach fill along the ocean shoreline would be 237,500 cubic yards with 57,000 cubic yards needed along the Nixon Channel shoreline resulting in a total beach fill volume of 294,500 cubic yards for Alternative 5D. Fill volumes would be the same for both the 2006 and 2012 conditions. Placement volumes and design berm widths for the ocean shoreline beach fill are provided in Table 9.8 with total volumes for the fill given in Table 9.9. Alternative 5D does not include an artificial dune in the sandbag area.

Table 9.8 Alternative 5D beach fill placement volumes and design berm widths.

Shoreline Segment (Baseline Stations)	Placement Volume (cy/lf)	Design Berm Width (ft)
60+00 to 70+00 (transition	0 to 20	0 to 17
70+00 to 77+50	20	17
77+50 to 80+00 (transition)	20 to 80	17 to 69
80+00 to 105+00 (terminal groin)	80	69

9.4.2 Alternative 5D Plan Formulation

Two terminal groin lengths were evaluated for Alternative 5D, one having the same length as Alternative 5C (1,300 feet) and the other 200-feet longer (1,500 feet). Based on the Delft3D model results, discussed below, volume losses from the beach fill with the 1,300-foot terminal groin occurred rather rapidly with only 6% of the fill placed above the -6-foot NAVD depth contour remaining at the end of the 5-year simulation. Over the whole active profile, that is from the berm crest seaward to the depth of closure (-24 ft NAVD), the entire fill was removed by the end of year 3. For the 1,500-foot structure and the same beach fill design as used in the evaluation of the 1,300-foot structure, the Delft3D model indicated the longer terminal groin was able to retain 27.5% of the fill placed above the -6-foot NAVD depth contour through year 5 of the simulation. The improved performance of the fill, particularly above the -6 foot NAVD depth contour, resulted in the selection of the 1,500-foot terminal groin for Alternative 5D.

The 1,500-foot terminal groin would include a 995-foot shore anchorage section and a seaward section that would project 505 feet seaward of the 2007 mean high water shoreline. The shore anchorage section would be constructed with either steel or concrete sheet pile while the seaward section would be of rubblemound construction. The landward 100 feet of the shore anchorage section would have a 10-foot wide stone scour protection apron on both sides.

The material to construct the beach fills would be obtained from maintenance of the previously permitted area in Nixon Channel. The plan layout for Alternative 5D is shown in Figure 9.21 with typical profiles of the ocean shoreline beach fill shown in Figures 9.22 and 9.23.

TABLE 9-9
OCEANFRONT BEACH DISPOSAL AREA
ALTERNATIVE 5D
FIGURE EIGHT ISLAND / RICH INLET, NC

Profile Line	Fill Length (feet)	Fill Distribution CY/LF	Total Volume CY
60+00	1,000	0	0
70+00	250	20	10,000
72+50	250	20	5,000
75+00	250	20	5,000
77+50	250	20	5,000
80+00	250	80	12,500
82+50	250	80	20,000
85+00	250	80	20,000
87+50	250	80	20,000
90+00	250	80	20,000
92+50	250	80	20,000
95+00	250	80	20,000
97+50	250	80	20,000
100+00	250	80	20,000
102+50	250	80	20,000
105+00	250	80	20,000
TOTAL	4,500		237,500

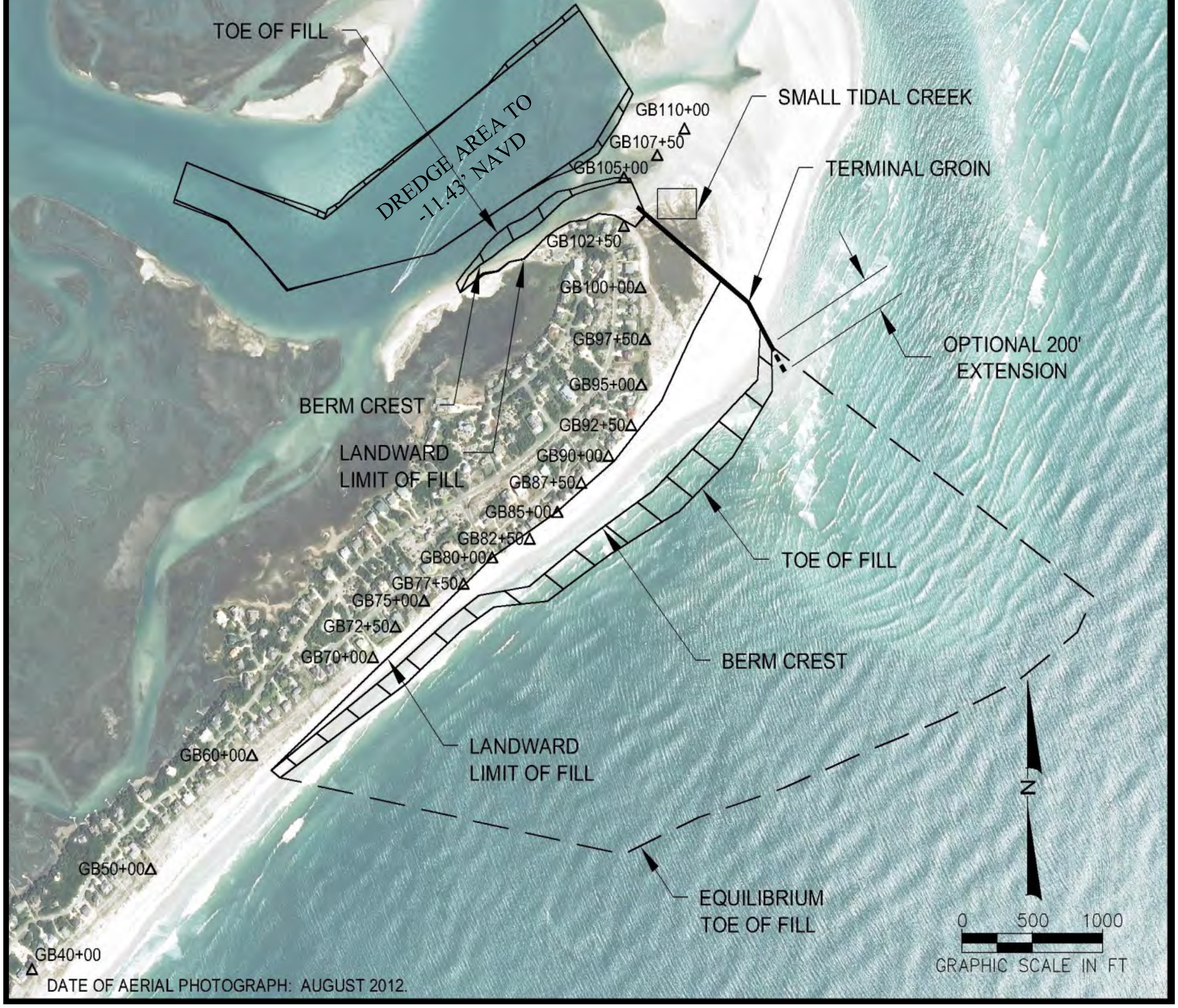
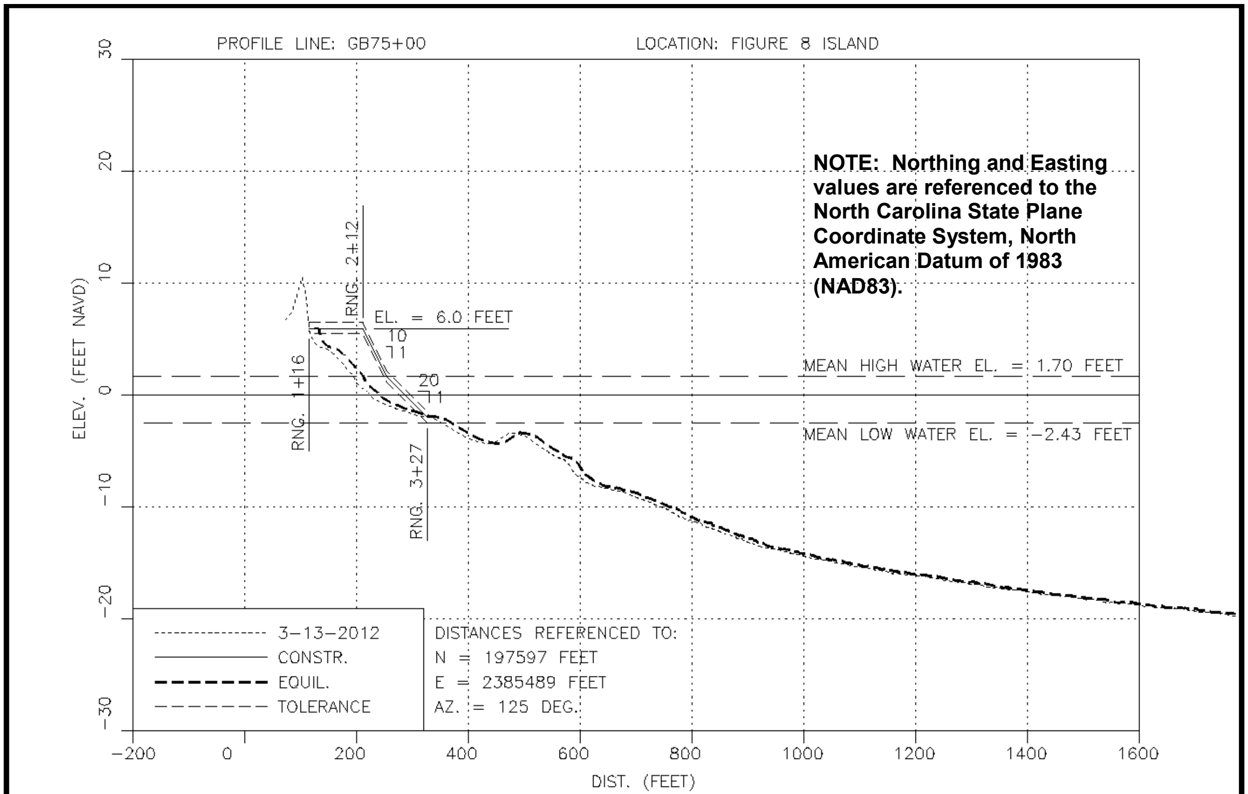


FIGURE 9-21: Alternative 5D Dredging and Groin Option and Beach Fill Layout.



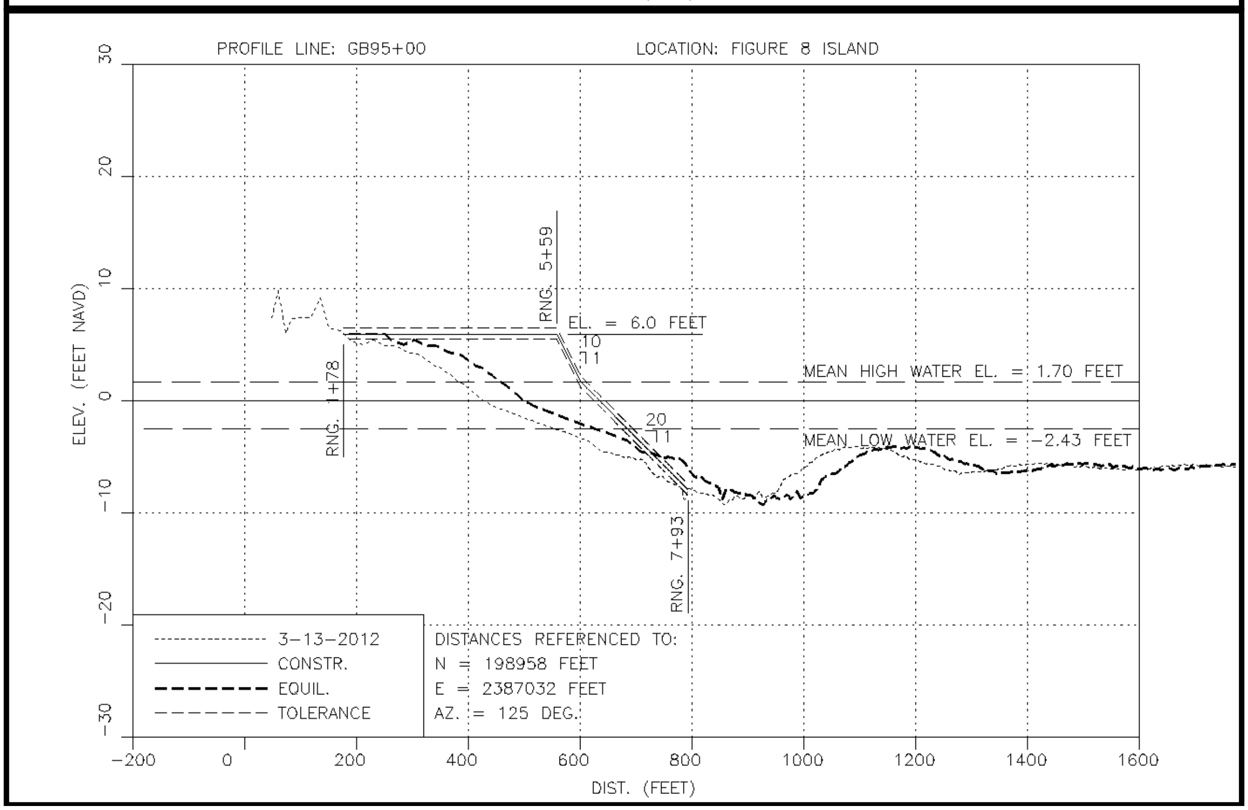


FIGURE 9-22: Representative Cross-Sections along the Oceanfront Beach Fill Area, Alternative 5D.

9.4.3 Structural Design of the Terminal Groin.

The following description of the design of the terminal groin for Alternative 5D, the Applicant's Preferred Alternative, is based on preliminary design considerations and the latest survey information which are subject to change during the preparation of detailed plans and specifications. However, the size of the structures footprint and the required construction corridor presented below are representative of the final design for Alternative 5D.

The total length of the Alternative 5D terminal groin would be 1,500 feet of which only 505 feet would project seaward of the 2007 mean high water shoreline position. The landward 995 feet of the structure would be constructed with sheet pile, either steel or concrete, and would have a top elevation of just below the elevation of the existing ground. In general, the top elevation of the sheet pile will vary from +0.5 feet NAVD for the first 200 feet on the landward end to +1.5 ft NAVD over the remaining 795 feet. The sheet pile section will begin near the Nixon Channel shoreline and end near the position of the 2007 mean high water line. To account for possible scour around the landward end of the shore anchorage section, a 10-foot wide rubble scour protection apron would be installed along both sides of the landward most 100 feet of the anchorage section. The toe apron would be installed at a depth of approximately -2 ft NAVD and would require the excavation of approximately 300 cubic yards. Material excavated for the toe apron would be used to bury the toe protection stone following placement.

A total of 22,200 square feet of sheet pile would be required for the shore anchorage section. Note the amount of sheet pile could vary based on the final design characteristics. The present preliminary design for the sheet pile would penetrate to a depth of -21 feet NAVD. Detailed design considerations would include soil borings along the alignment of the proposed structure to obtain soil characteristics as well as assumptions with regard to possible future positions of the south shoulder of Rich Inlet relative to the sheet piles. The assumed position of the south shoulder of the inlet would dictate soil and water loadings on the piles and hence dictate how deep the piles would need to be driven for stability.

The seaward 505 feet of the structure would be constructed with loose armor stone placed on top of a layer of foundation stone comprised of quarry-run material (generally 12-inch diameter or less) or possibly a wire-mesh mat filled with similar size stone. The top elevation of the rubblemound structure would not exceed +6.0 feet NAVD which is an elevation roughly equivalent to the elevation of the natural beach berm near Rich Inlet. Again, the final design of the rubblemound portion of the structure is subject to change given conditions near the time of actual construction.

The loose nature of the armor stone would be designed to facilitate the movement of littoral material through the structure. A profile of the terminal groin is shown on Figure 9-23. Figure 9-23 shows both the April 2007 profile for baseline station 105+00, which was used as a basis for the terminal groin design, and the March 2012 profile that reflects the accretion that has occurred on the north end of Figure Eight Island since 2010. A typical cross-section of the rubblemound portion is shown in Figure 9-24.

As shown on Figure 9-24, the rubblemound section of the structure would include a 25-foot wide scour protection mat along the inlet side to protect the structure against undermining should the channel through Rich Inlet migrate next to the structure. Based on this preliminary design, construction of the rubblemound portion of the terminal groin would require around 8,500 tons of armor stone, 2,900 tons of bedding stone, and 200 tons for the scour apron around the landward end of the shore anchorage section for a total of 11,600 tons of stone. Construction of the seaward portion of the terminal groin would require excavation of approximately 7,900 cubic yards to create an 82-foot wide trench to a depth of -5.5 ft NAVD. The excavated material would be returned to the trench, partially burying the structure, once construction is complete.

The concept design for the terminal groin presented here is intended to allow littoral sand transport to move over, around, and through the structure once the accretion fillet south of the terminal groin is artificially filled. This would be accomplished by setting the maximum crest elevation of the terminal groin to +6 feet NAVD, which is an elevation slightly above the natural berm elevation, and constructing the structure with large voids between adjacent stones. The relatively short length of the terminal groin seaward of the 2007 mean high water shoreline would also facilitate movement of sediment around the seaward end of the structure. The seaward 200 feet to 300 feet of the structure should be visible at all stages of the tide from both sides of the structure, however, the remaining portions of the structure would be buried below ground and would not be visible from the south side. While the north side of the rubblemound section may project a foot or two above ground, during normal weather conditions, wind-blown sand is expected to accumulate along the north side of the structure partially burying the exposed section.

The shore anchorage section would be completely below ground and would not be visible. The only time the shore anchorage section could be visible would be in the unlikely event the entire north end of the island is eroded back to the position of the sheet piles.

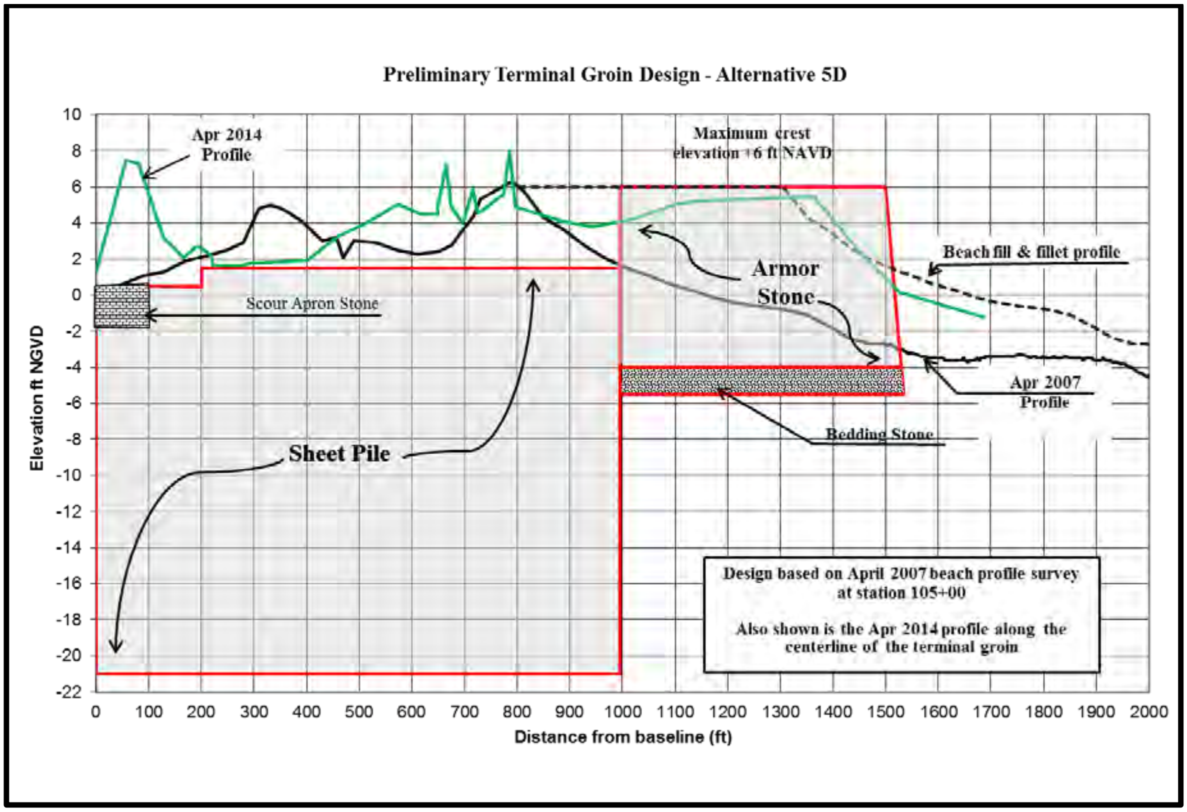


Figure 9-23. Profile of terminal groin for Alternative 5D.

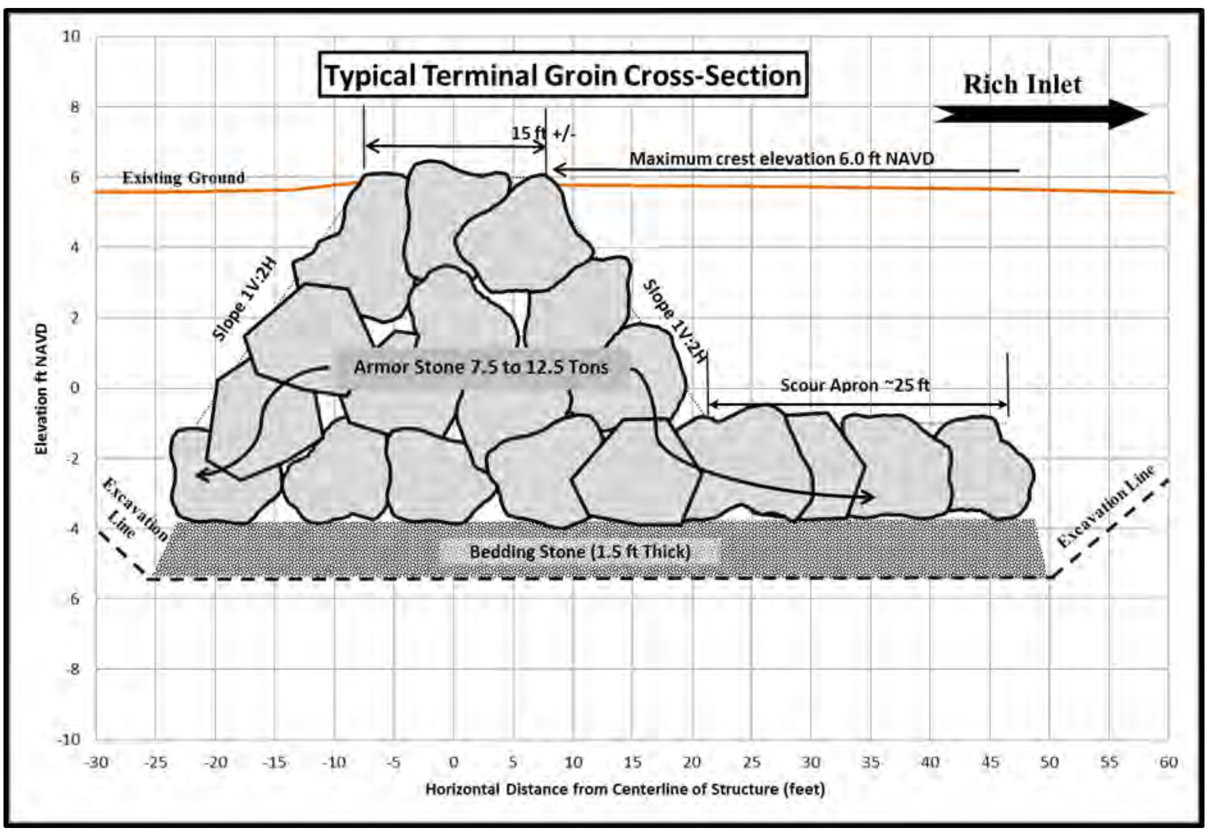


Figure 9-24. Typical terminal groin cross-section.

10.0 PROJECT PERFORMANCE DURING STORMS

Beach erosion and shoreline recession occurs during severe storm events. The performance of the project based on the Delft3D model results later in this report is based on wave cases which utilized records of both average and above-average waves between 1999 and 2007. The "second opinion" of project performance based on the GENESIS model results utilizes wave records given at 3 hour intervals between 2000 and 2009. In those results, erosion due to longshore transport variations is estimated for both average and above-average waves explicitly. Further details regarding both the Delft3D and GENESIS models appear in the sections to follow.

11.0 LONG-TERM PROJECT PERFORMANCE – DELFT3D MODEL STUDY

To evaluate the long-term performance of the various alternatives in Section 9.0, this study utilizes an advanced 2D/3D integrated modeling environment known as Delft3D (WL | Delft, 2005). Delft3D consists of two models that run together to estimate wave transformation, currents, water level changes, sediment transport, erosion, and deposition. Waves in Delft3D are simulated using SWAN (Simulating Waves Nearshore), an advanced wave transformation model that simulates breaking, shoaling, refraction, diffraction, wind stress, and bottom friction. Delft3DFLOW simulates currents, water level changes, erosion, sediment transport, erosion, and deposition based on the forcing of the tides, storm surges, waves, and winds. Delft3DFLOW and SWAN run simultaneously, exchanging wave, water level, current, and bottom depth values. Delft3D can simulate relevant coastal processes over short-term (days-storms) or long term (seasons-years) time scales.

11.1 Wave Model Calibration

Waves in the Delft3D modeling package were simulated using SWAN. Wave transformation estimates within the model utilized a spectral wave approach that treated each observed wave as a superposition of individual waves with varying frequencies and periods.

The primary inputs to the SWAN model were the bottom bathymetry, the time-dependent water levels, and the offshore waves. Additional inputs were the wave breaking coefficients, the bottom roughness scale, the diffraction coefficients, and the non-linear triad coefficients that governed wind effects. The parameter with the largest effect on the transformed wave field was the bottom roughness scale, which governed the bottom friction. Accordingly, calibration of the SWAN model was performed by examining the effect of bottom roughness on the nearshore wave height.

Several wave gages have been deployed in the region at various times, albeit separated by large distances (~ 20 to 50 miles) (Figure 11-1). Thus, the SWAN model was calibrated on a regional basis. Calibration runs were based on an easterly wave event at offshore wave gage LEJ3 (Figure 11-1) in July 2006. Concurrent wave measurements were taken at nearshore wave gage ILM1 (Figure 11-1), located on Johnny Mercer's Pier in Wrightsville Beach. The offshore waves, water levels, and wind velocities used in the model appear in Figures 11-2 to 11-4. Given the information that was available, wind velocities and water levels were assumed to be uniform over the model grid.

Calibration runs were conducted using bottom roughness scale from 0.00075 m to 0.05 m (0.2 inches to 13 inches). A reasonable agreement between the simulated and observed wave heights at gage ILM1 was achieved with a bottom roughness scale of 0.01 m (2.5 inches). The average difference between the observed and simulated wave height at gage ILM1 was -0.1 feet, with a root-mean-square difference of 0.4 feet. Matching the nearshore wave direction was more difficult. Simulated waves at gage ILM1 were more oblique to the shoreline than the observed waves. This occurred due to the tendency of the model to refract the waves parallel to the shoreline, as shown in Figure 11-5. The effect was more pronounced in the second half of the run, when there was a significant difference between wave periods at gages LEJ3 and ILM1. As shown in Figure 11-4, the prevailing winds at LEJ3 were from the northeast during the calibration period. Thus, the wind direction, combined with the bathymetry, had a large influence on the simulated wave direction. Based on the available information, a uniform wind velocity was assumed over the model grid. However, given the 48 mile distance between gages LEJ3 and ILM1, local variations in the wind speed and direction were likely during the calibration period. Overall, differences between the simulated and measured wave direction at gage ILM1 were probably due to the assumption of uniform winds.

Verification runs were based on a southerly wave event at offshore wave gage 41013 (Figure 11-1) in June 2004. Typical wave patterns during this event appear in Figure 11-6. Concurrent wave measurements were taken at nearshore wave gage OB3M (Figure 11-1). The offshore waves, water levels, and wind velocities used in the model appear in Figures 11-7 to 11-9. Similar to the calibration, wind velocities and water levels were assumed to be uniform over the model grid. The bottom roughness scale was set to 0.01 m (2.5 inches). Overall, agreement between the model results and the observations at OB3M was good. The average difference between the observed and simulated wave height at gage OB3M was +0.4 feet, with a root-mean-square difference of 0.6 feet. The average difference between the observed and simulated wave direction at gage OB3M was +1 degree. The verification showed that the SWAN model was able to accurately estimate nearshore wave heights, with reasonable approximations of the nearshore wave direction given a relatively uniform wind field. Based on the results in Figures 11-2, 11-3, 11-7 and 11-8, the calibrated SWAN model was judged to be suitable for estimating project performance.

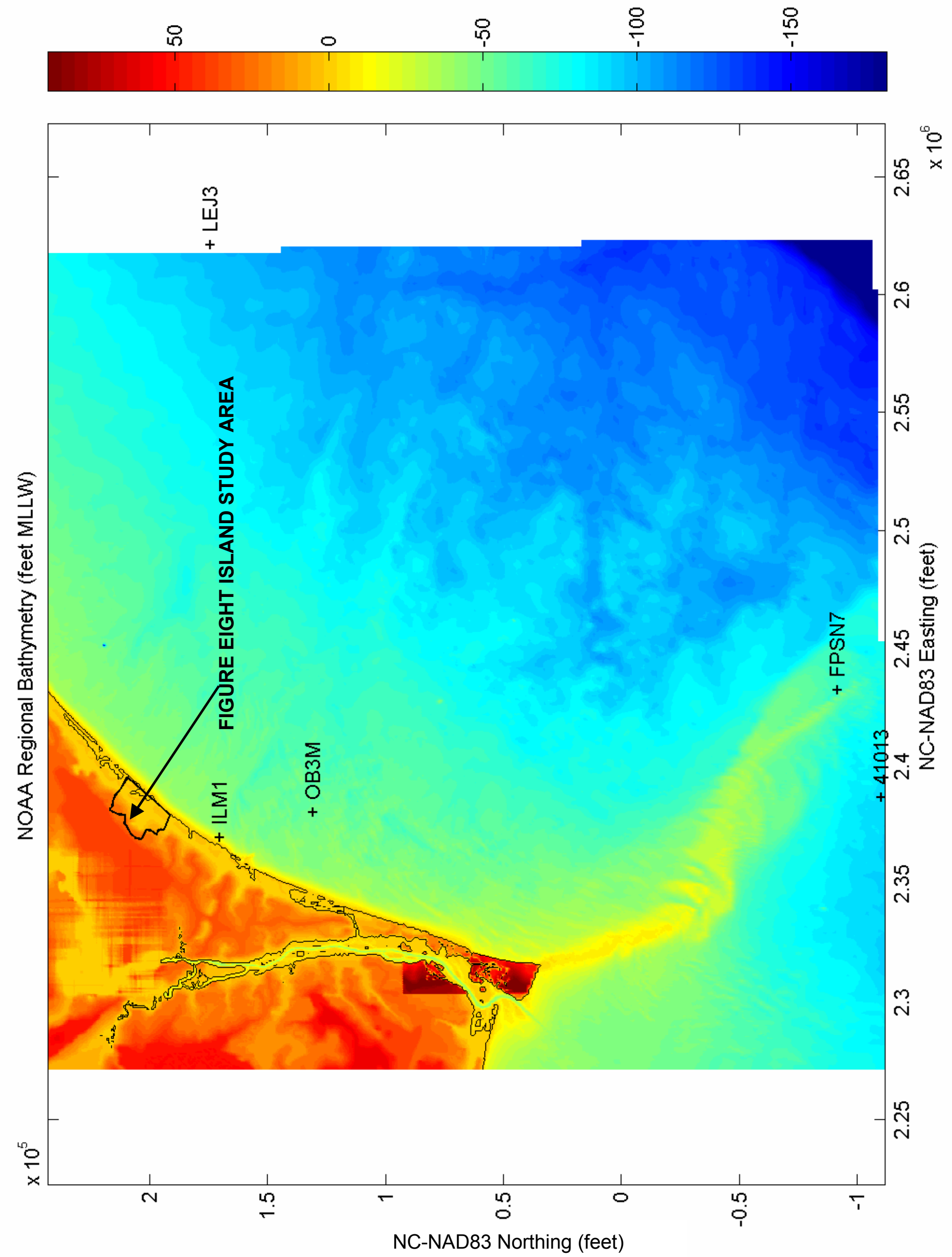
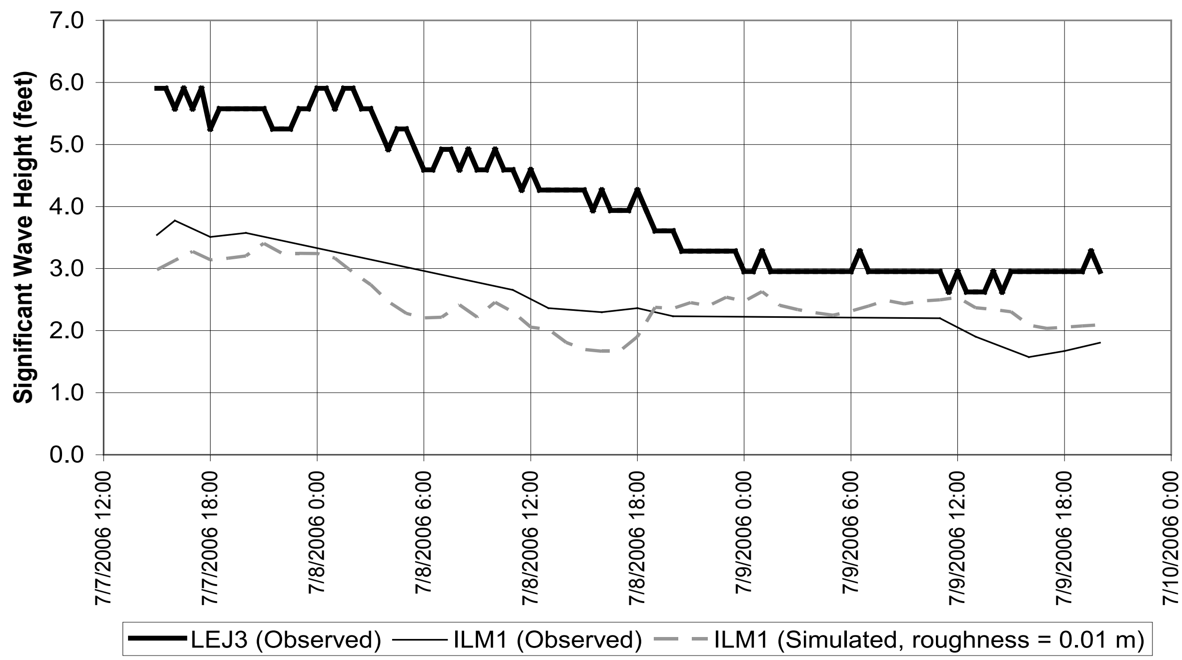


FIGURE 11-1: Wave Calibration Bathymetry based on NOAA (2006) Regional Grid, Figure Eight Island, NC.



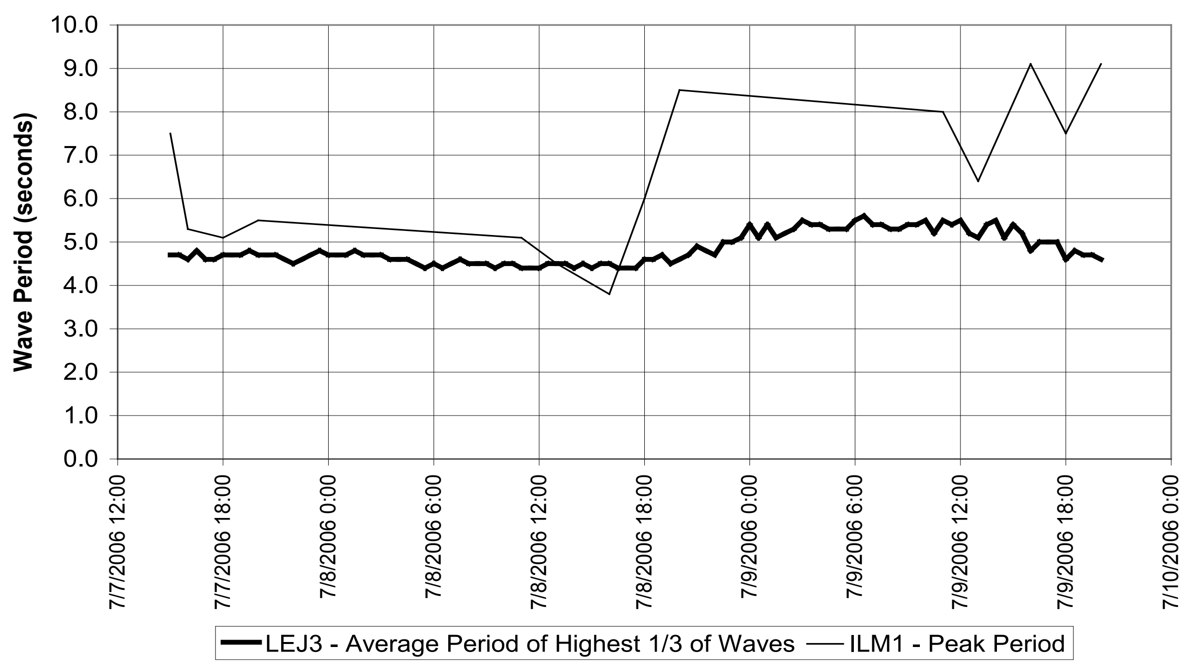


FIGURE 11-2: Delft3D-SWAN Calibration, Wave Height and Wave Period.

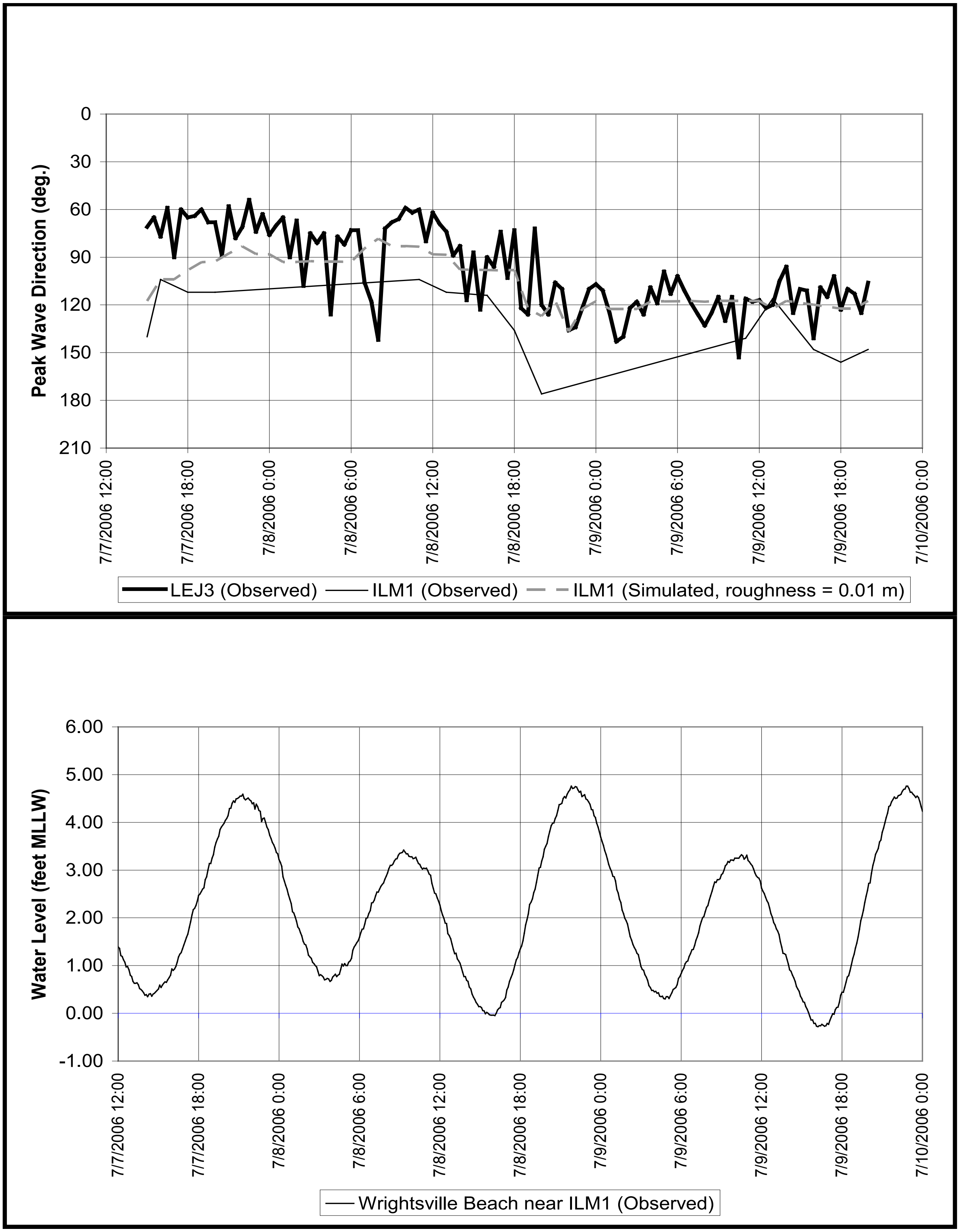


FIGURE 11-3: Delft3D-SWAN Calibration, Wave Direction and Water Level.

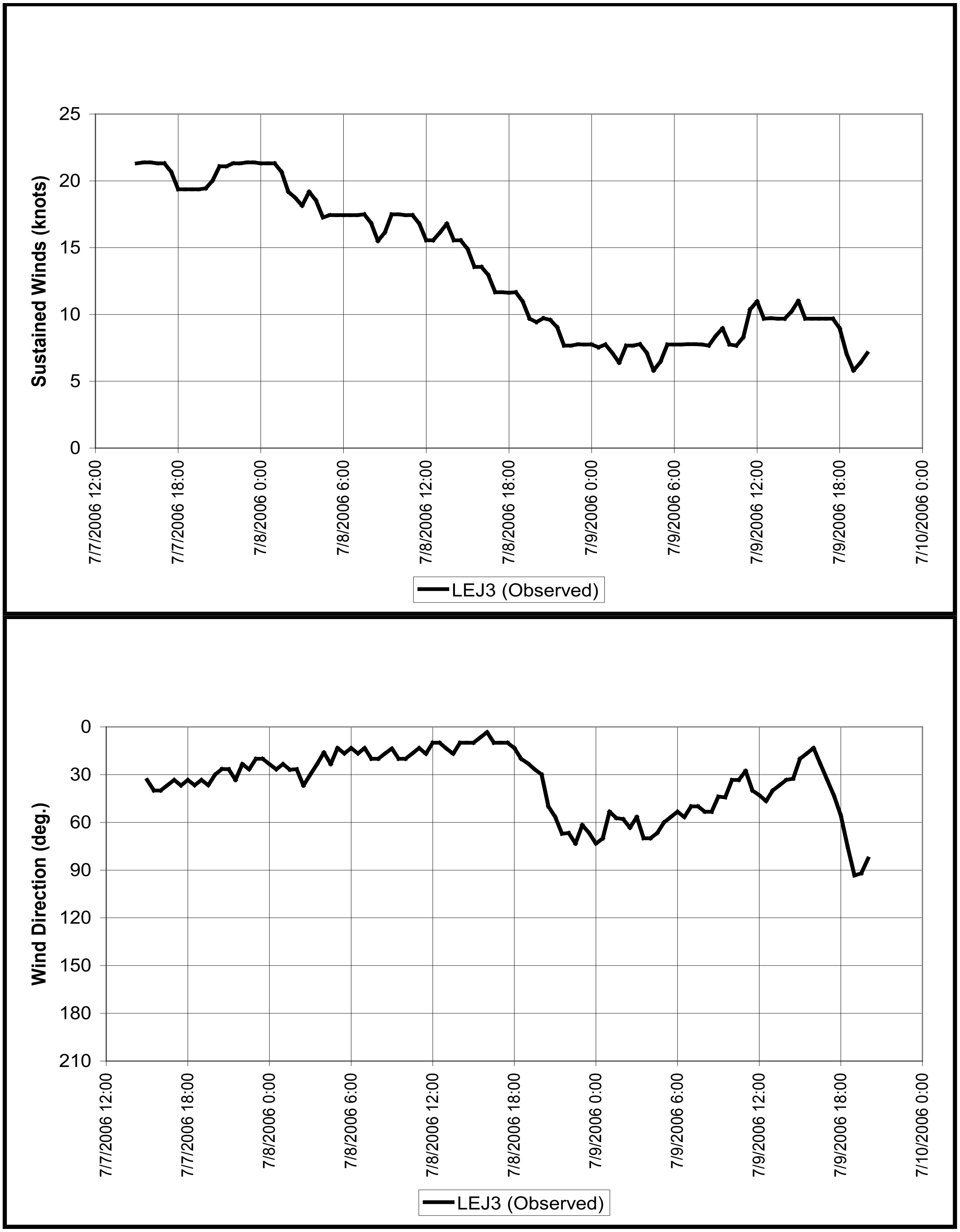


FIGURE 11-4: Delft3D-SWAN Calibration, Wind Velocity.

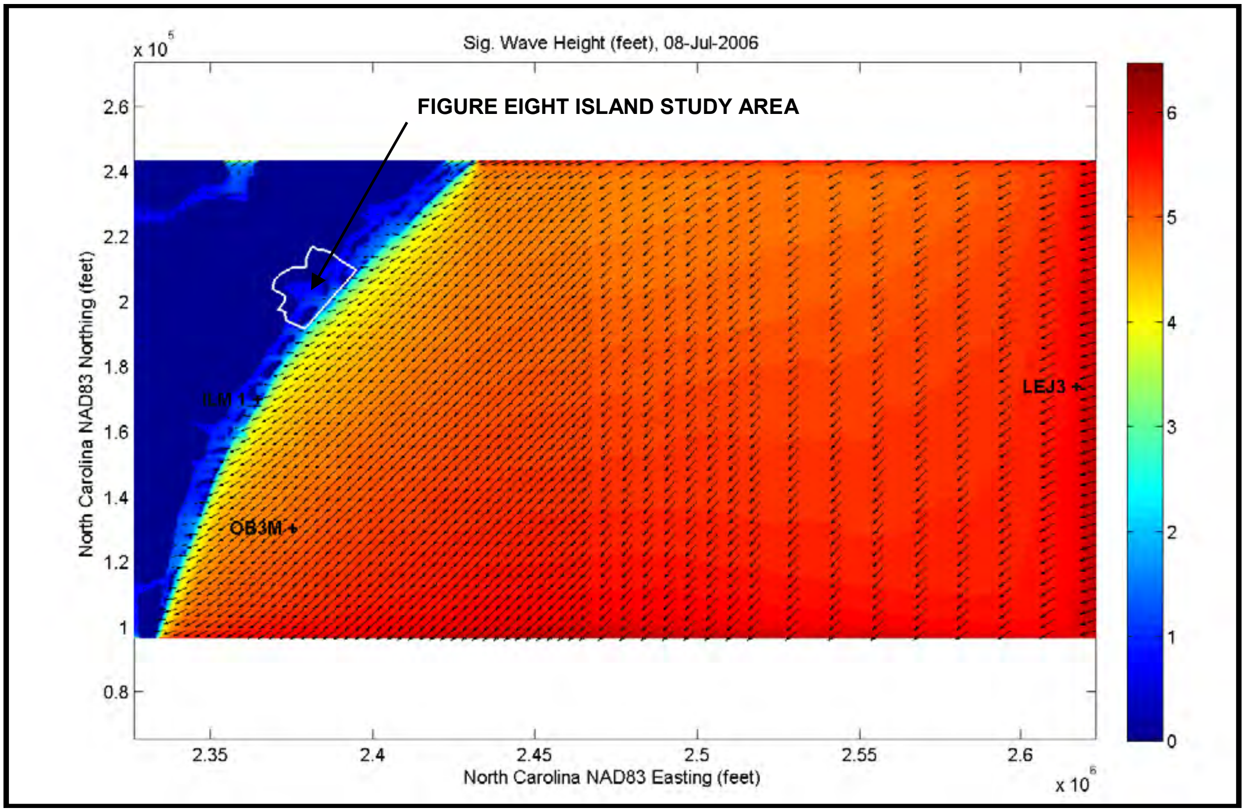


FIGURE 11-5: Typical Wave Calibration Results, Figure Eight Island, NC.

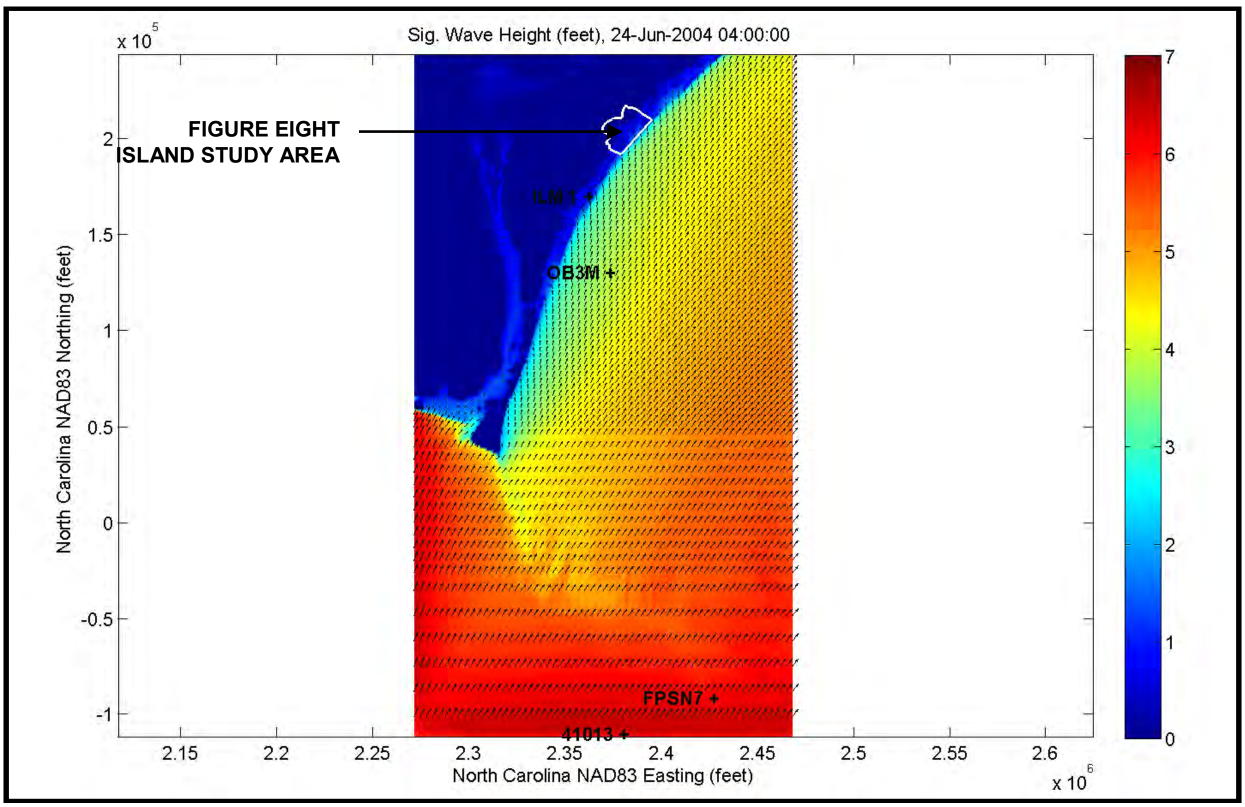


FIGURE 11-6: Typical Wave Verification Results, Figure Eight Island, NC.

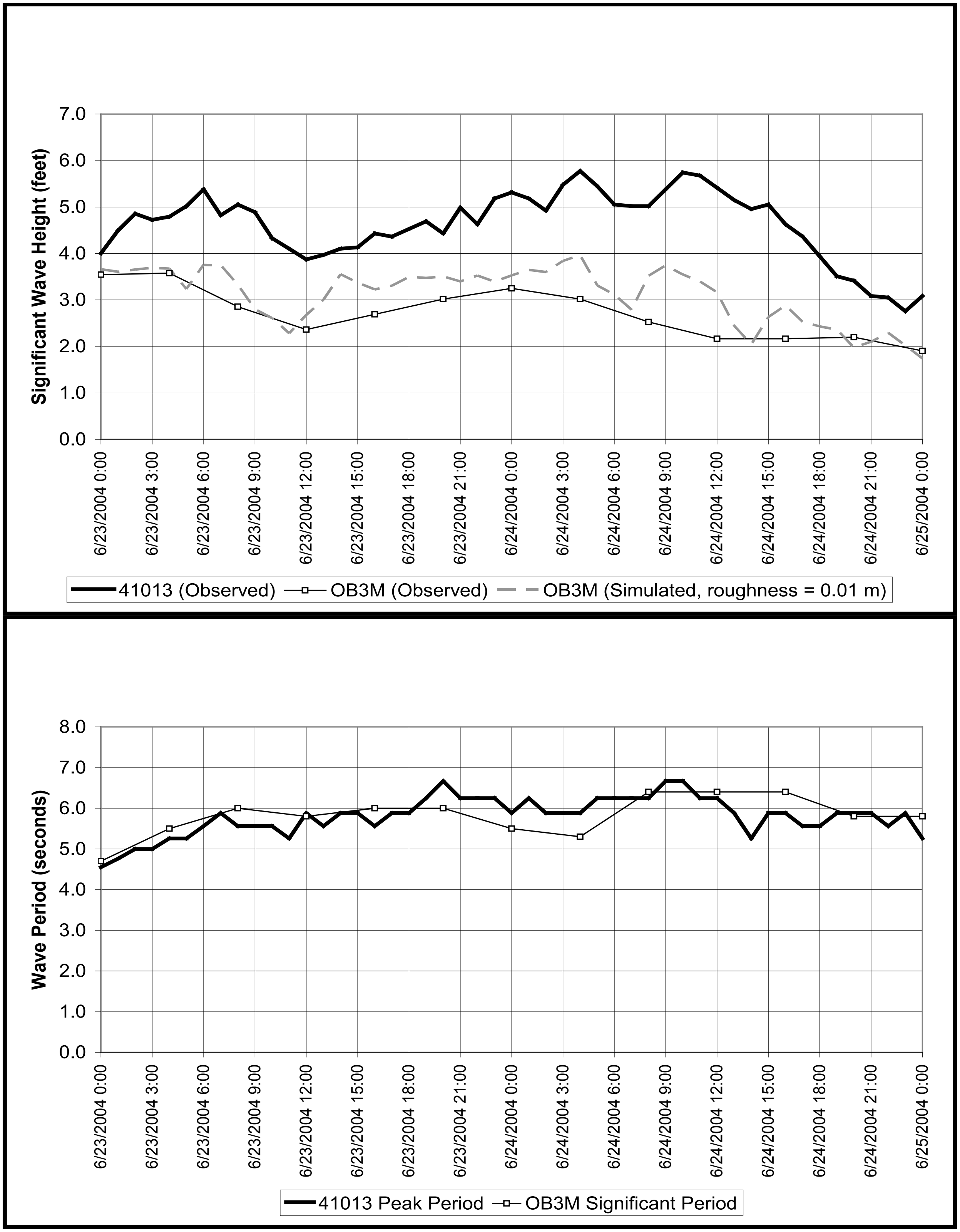


FIGURE 11-7: Delft3D-SWAN Verification, Wave Height and Wave Period.

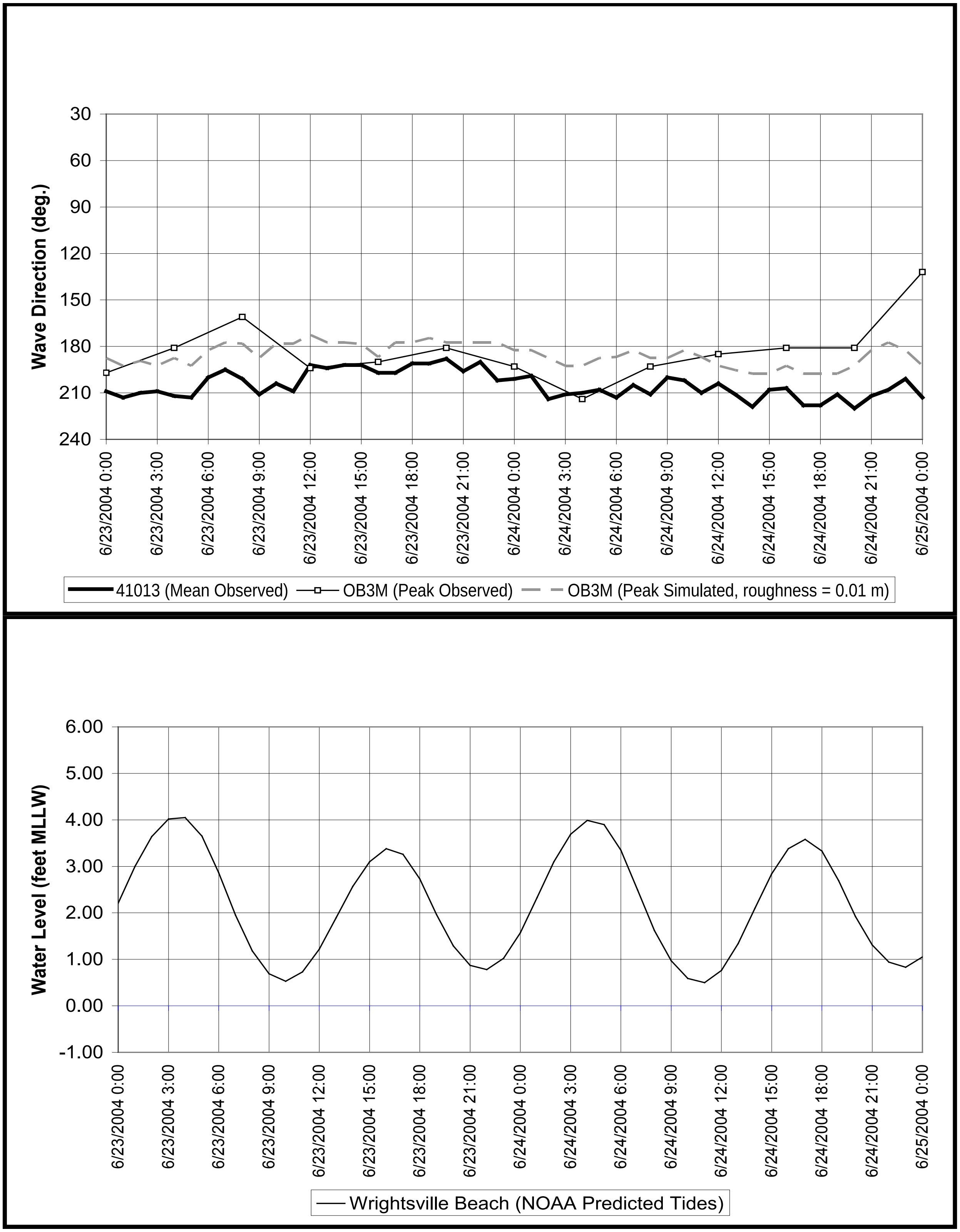
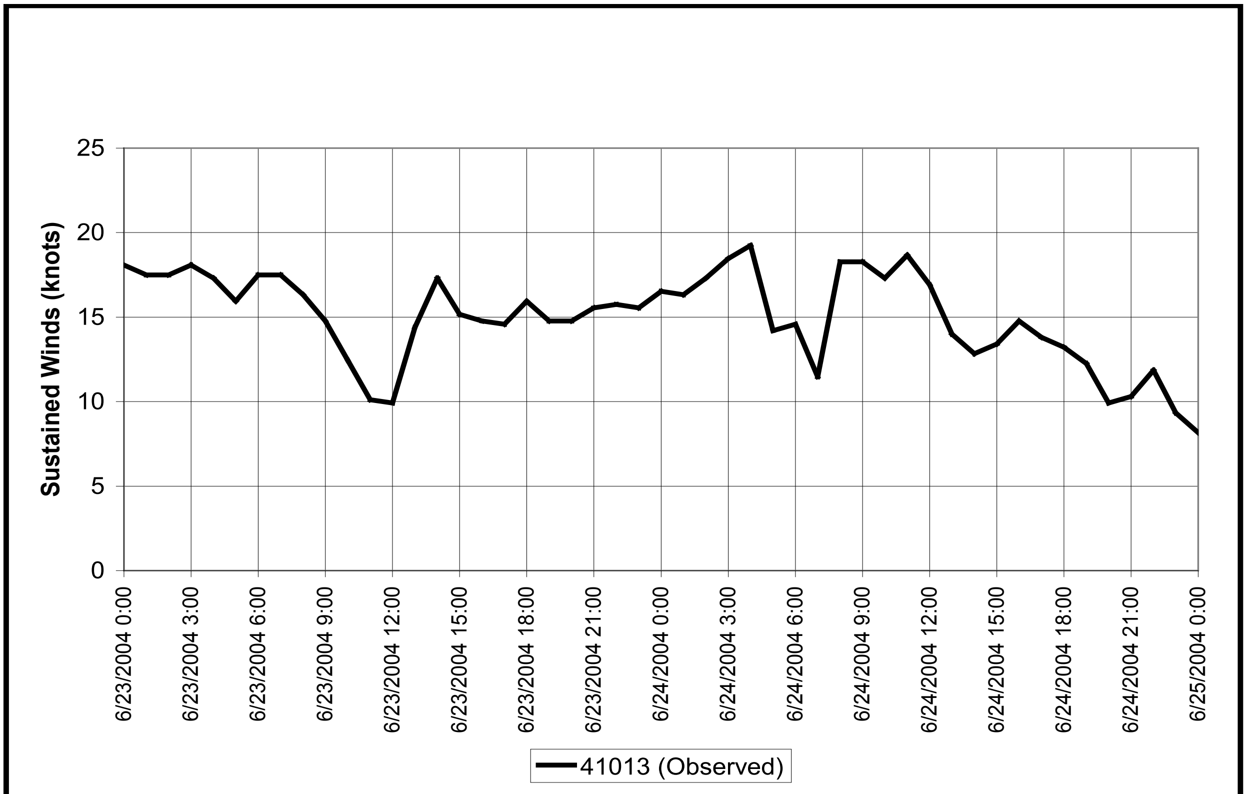


FIGURE 11-8: Delft3D-SWAN Verification, Wave Direction and Water Level.



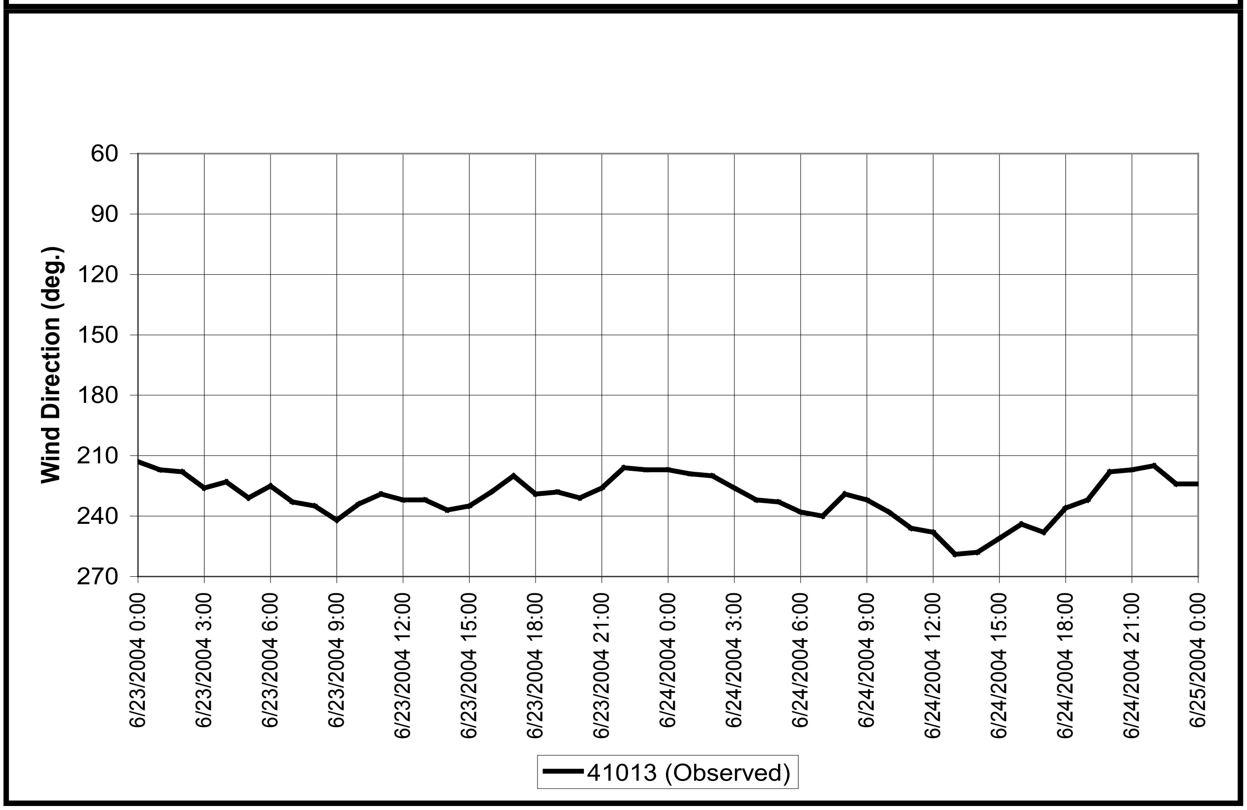


FIGURE 11-9: Delft3D-SWAN Verification, Wind Velocity.

11.2 Current and Water Level Calibration

11.2.1 Grids

Currents and water levels in the Delft3D modeling package were simulated using Delft3DFLOW. The model's currents and water levels were calibrated friction using a set of water level and current measurements provided by Gahagan & Bryant (2006) (see Section 4.3). Water levels were measured at seven (7) tide gages deployed May 25 - July 7, 2005, as shown in Figure 4-1. In addition, velocities were measured at three (3) locations on June 21, 2005 using boat-mounted Acoustic Doppler Current Profilers (ADCPs). Observed currents were reported by Gahagan & Bryant on a depth-averaged basis. The calibration run was performed using Delft3DFLOW in conjunction with SWAN, to account for the influence of both waves and tides.

Four grids were used in the flow calibration and subsequent model runs (Table 11-1 and Figures 11-10 to 11-16):

- Regional Wave Grid. The purpose of this grid was to simulate wave transformation over the region extending from Ocracoke, NC to Pawleys Island, SC. The offshore grid boundary generally followed the -500 foot NAVD depth contour. By simulating wave transformation over this area, it was possible to account for the influence of Cape Lookout and Cape Fear on the local wave patterns (Figures 11-10 through 11-12).

- Intermediate Wave Grid. The purpose of this grid (Figures 11-10, 11-11, and 11-13) was to provide more detailed wave information along the boundaries of the Local Wave Grid. This Intermediate Wave Grid extended from Surf City to Masonboro Island.

- Local Wave Grid. The purpose of this grid was to provide detailed wave information along the project area in shallow water. This grid extended from the midpoint of Hutaff Island to Mason Inlet. Wave transformation estimates along this grid were fed into the Delft3DFLOW model to estimate the wave-driven currents. Currents and water levels estimated by the Delft3DFLOW model were fed into the SWAN model to account for the influence of tidal currents and water level changes over this grid. Over the other two wave grids, tidal currents and water level changes were neglected by the SWAN model (Figures 11-10, 11-11, and 11-14).

- Flow Grid. This grid was utilized to estimate tidal currents and water level changes. Like the Local Wave Grid, this grid extended from Hutaff Island to Mason Inlet. However, to include all of the area drained by Rich Inlet, the grid was extended towards the west (Figures 11-15 and 11-16).

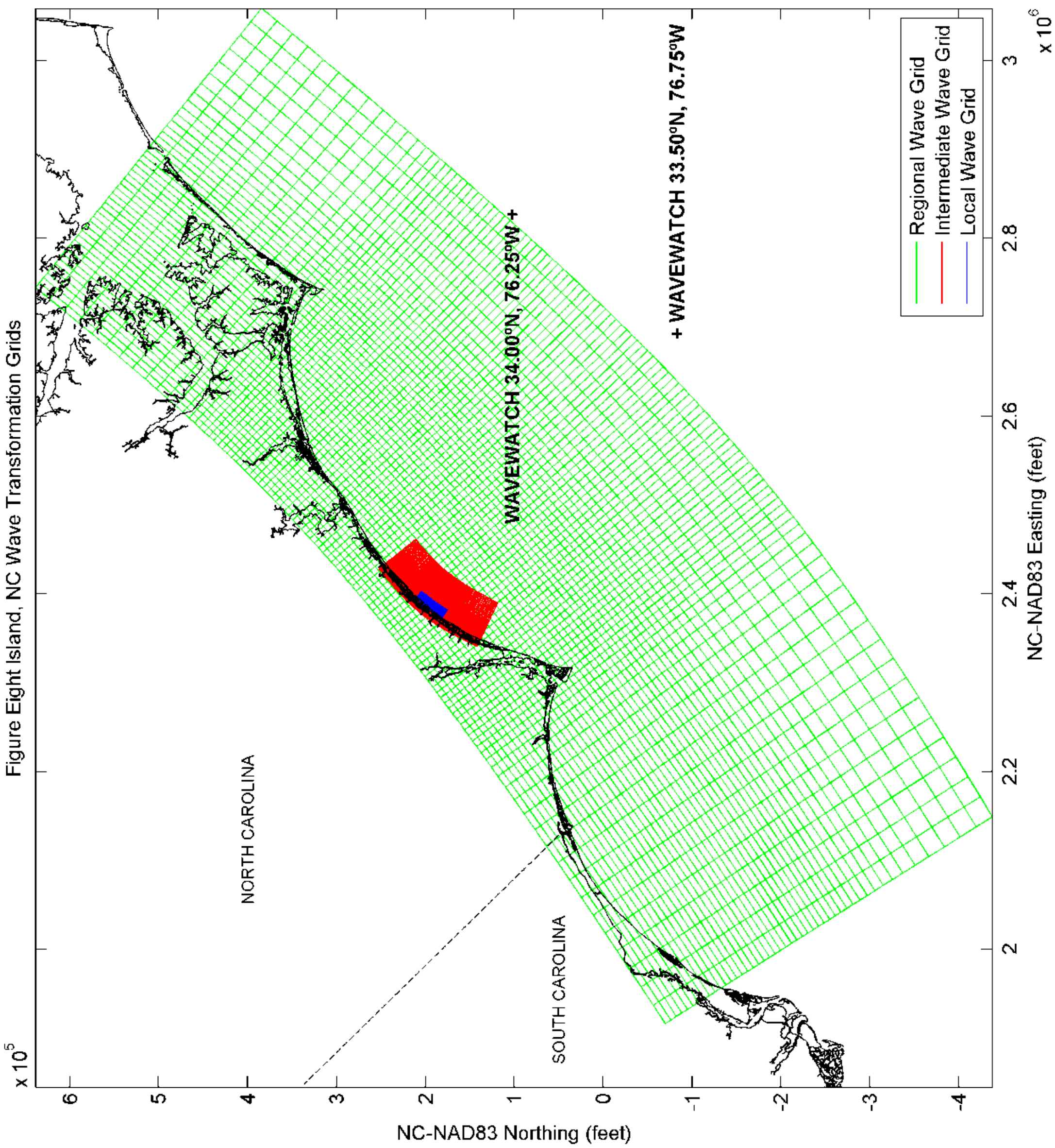


FIGURE 11-10: Wave Transformation Grids used in Delft3DFLOW Calibration and Subsequent Model Runs.

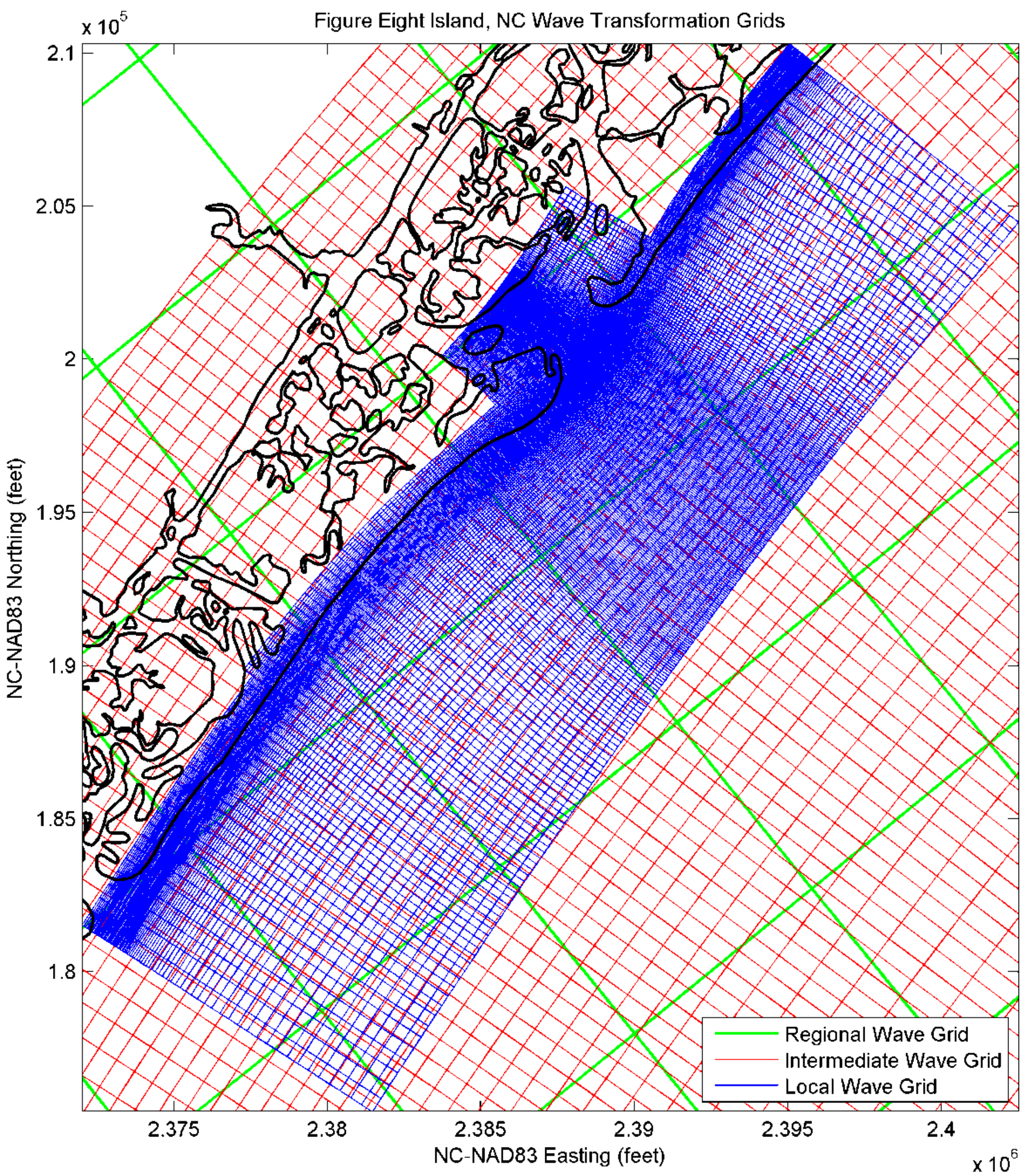


FIGURE 11-11: Wave Transformation Grids used in Delft3DFLOW Calibration and Subsequent Model Runs (closeup).

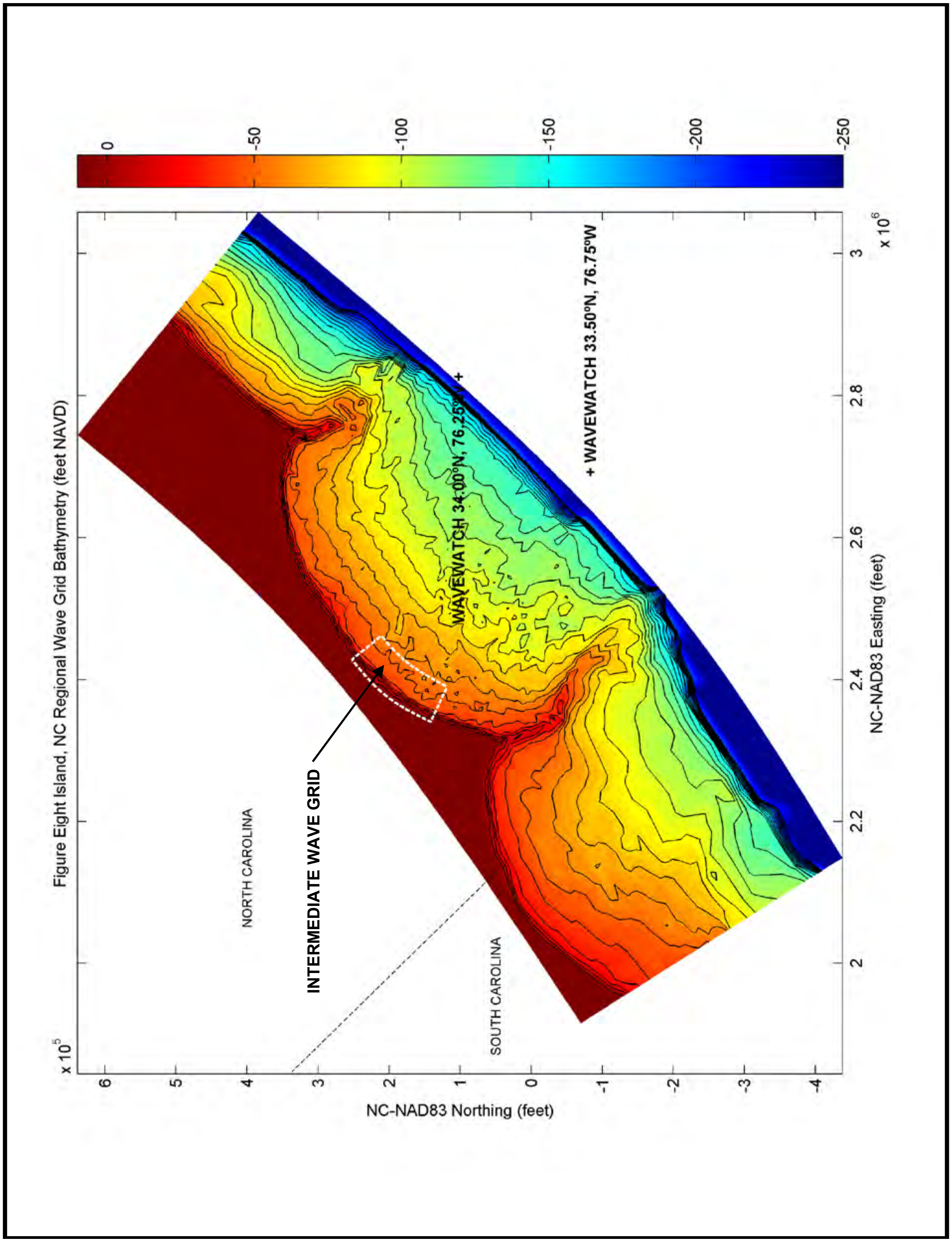


FIGURE 11-12: Bathymetry over the Regional Wave Grid.

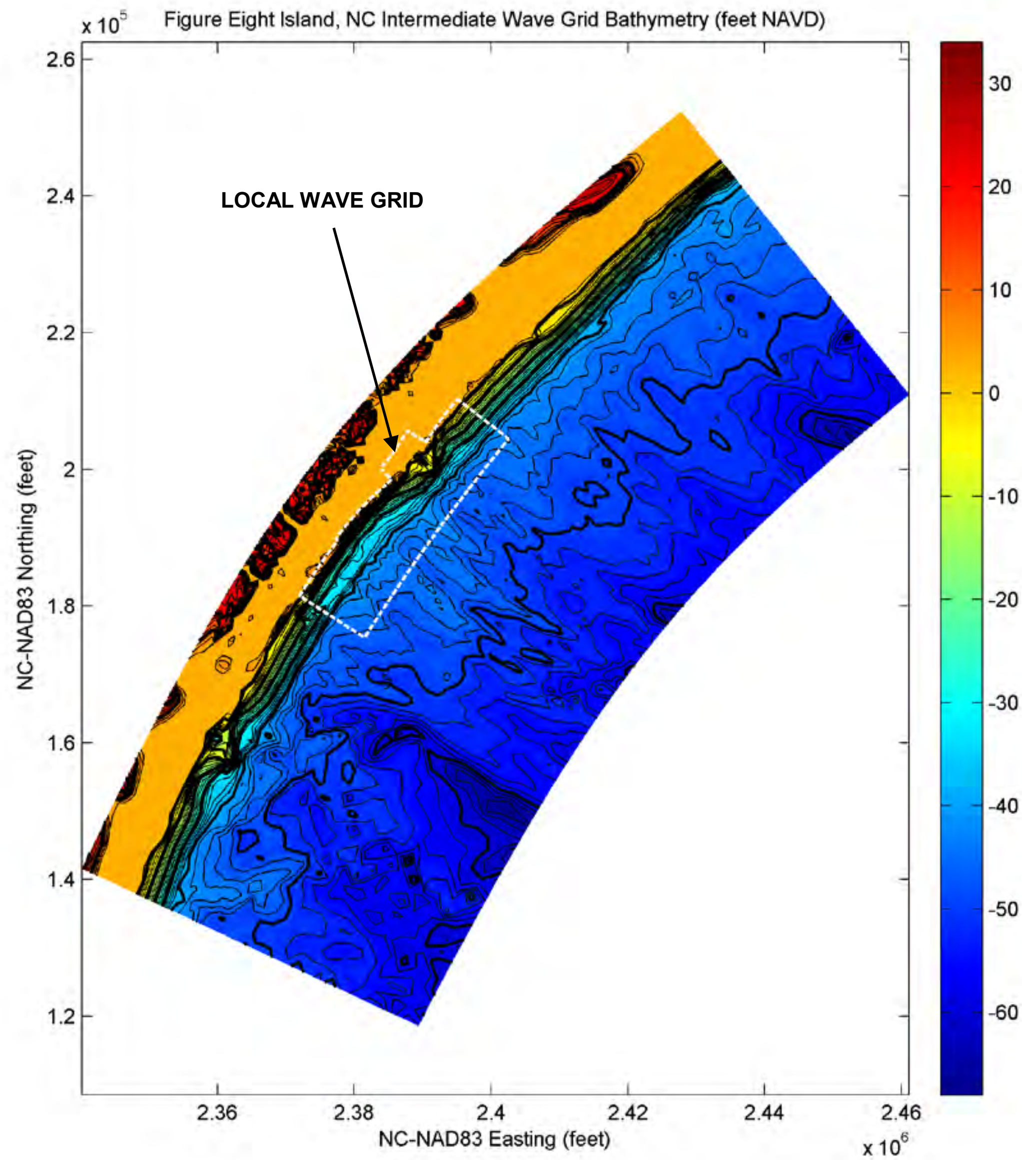


FIGURE 11-13: Bathymetry over the Intermediate Wave Grid.

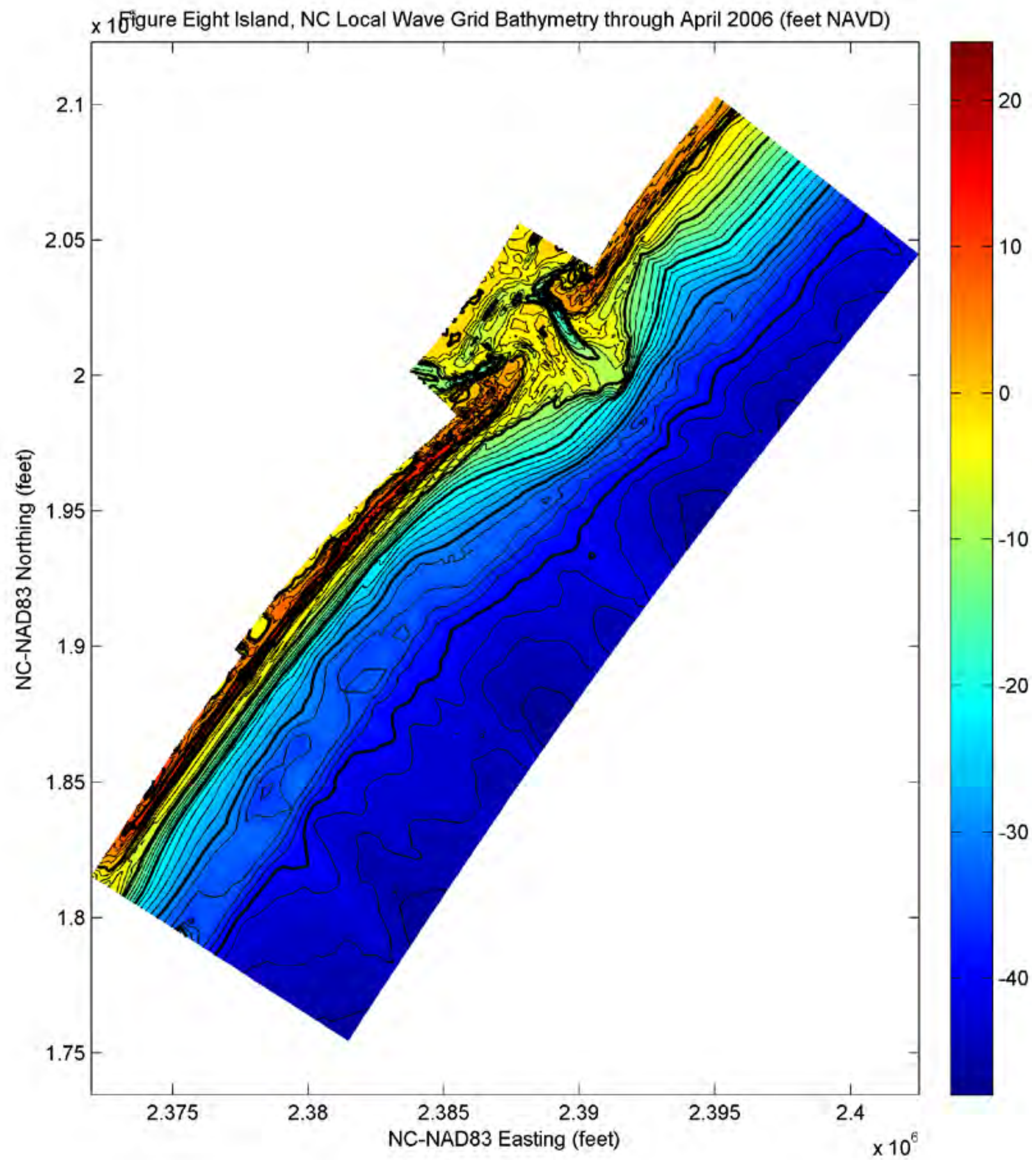


FIGURE 11-14: Bathymetry over the Local Wave Grid.

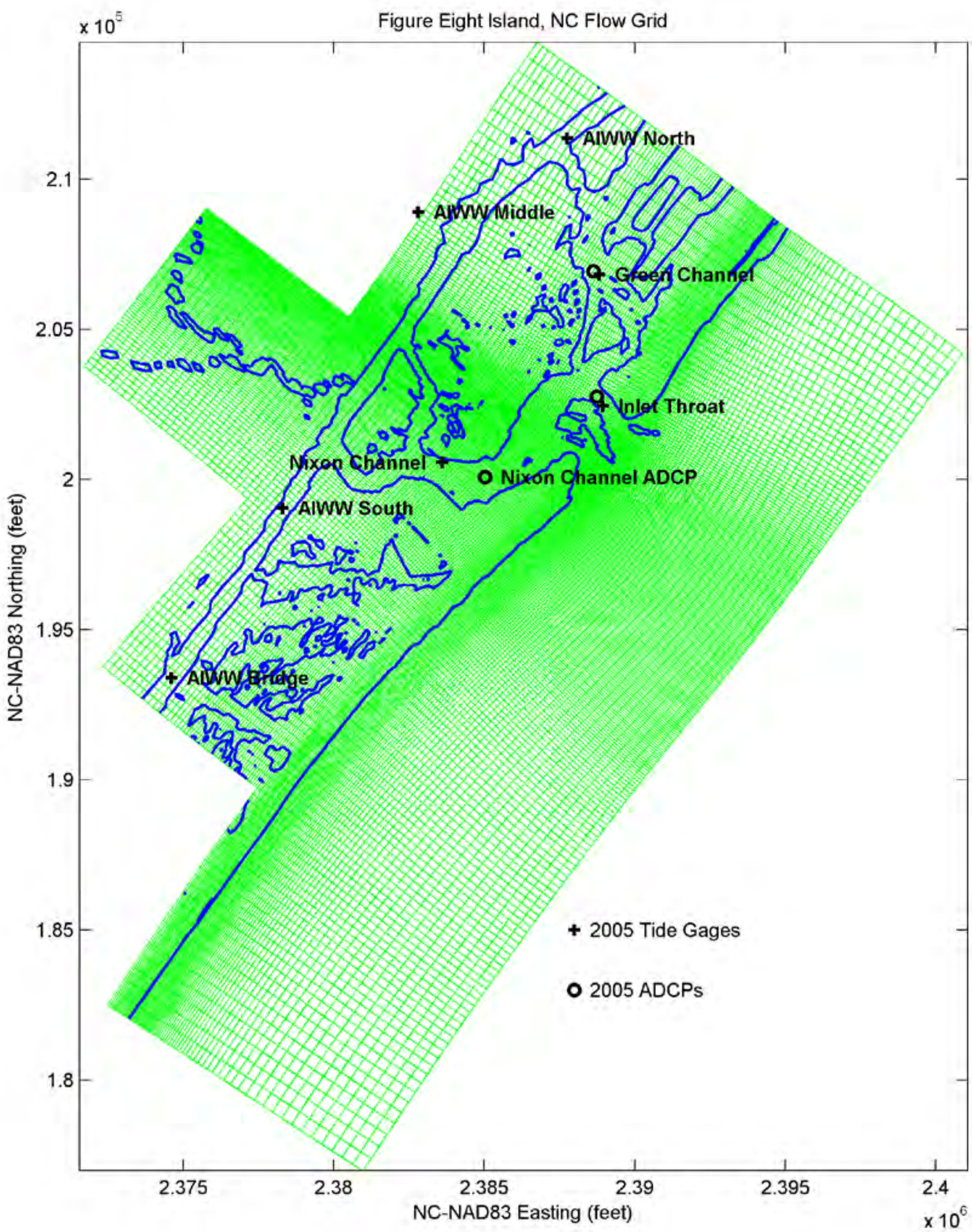


FIGURE 11-15: Flow Grid.

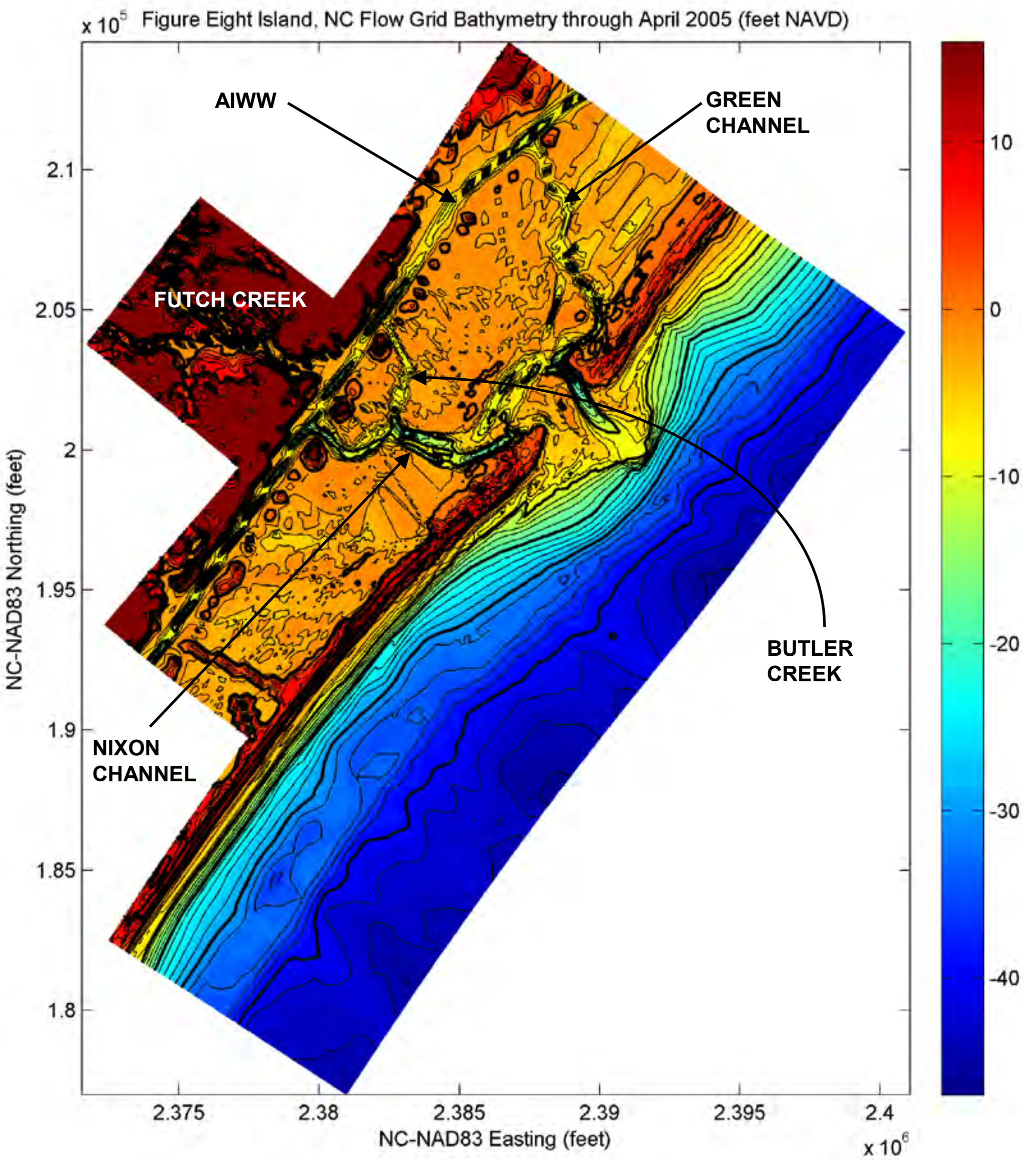


FIGURE 11-16: Bathymetry over the Flow Grid.

TABLE 11-1

GRIDS USED IN DELFT3D MODEL
FIGURE EIGHT ISLAND, NC

Grid	Longshore Grid Cells	Cross-Shore Grid Cells	Longshore Grid Spacing (feet)	Cross-Shore Grid Spacing (feet)
Regional Wave Grid	101	47	6,977 - 23,366	6,575 - 23,375
Intermediate Wave Grid	113	54	582 - 2,194	629 - 2,144
Local Wave Grid	248	93	38 - 542	40- 420
Flow Grid	248	153	33 - 575	41 - 415

Bathymetry over the Regional and Intermediate wave grids was based on the NOAA (2006) Regional Grid (Figure 11-1). Within the Flow Grid and Local Wave Grid, the bathymetry during the calibration runs was updated to depict the conditions during calibration period (May-July 2005). Accordingly, the primary data source used to fill these grids was the April 2005 survey by Gahagan & Bryant (2006). Elevations outside April 2005 survey area were estimated from:

- The October 2005 Light Detection and Ranging (LIDAR) survey of Pender County by NOAA.
- The June 2006 survey of the Mason Inlet area by Gahagan & Bryant.
- The August 2004 LIDAR survey of Pender County by NOAA.
- The March 2002 digital elevation model produced by the North Carolina Floodplain Mapping Program.
- The NOAA (2006) Regional Grid (Figure 11-1).

The 2005 bathymetry appears in Figure 11-16. The primary bathymetric features are the inlet throat, Green Channel, Nixon Channel, the AIWW, and Futch Creek. The main channel through the inlet throat and the ebb shoal ranges from -20 to -35 feet NAVD and runs from southeast to northwest. At the landward end, it splits into Green Channel, which runs from south to north, and Nixon Channel, which runs from east to west. Both channels, which end at the AIWW, are approximately 2 miles long with a typical depth of -15 feet NAVD. In Green Channel, the channel splits in two between the Inlet Throat and Green Channel tide gages. At the landward end of Nixon Channel, Butler Creek provides a secondary connection to the AIWW. Typical depths in Butler Creek are -14 feet NAVD. Futch Creek flows into the AIWW midway between Nixon Channel and Butler Creek. The marsh between Figure Eight Island and the AIWW ranges from 1 to 1.5 miles wide. Typical elevations in the marsh are on the order of 0 feet NAVD.

During the current and water level calibration, the Delft3DFLOW model was run in three-dimensional model. Five vertical layers were assumed at each grid point, with each layer equal to 20% of the water depth.

11.2.2 Model Forcing

To calibrate the currents and water levels in Delft3DFLOW, flow patterns were simulated between May 19, 2005, 8:00 PM EDT and June 30, 2005, 8:00 PM EDT. Sediment transport, erosion, and deposition were assumed to be negligible during this period. Water levels on the offshore boundary of the Flow Grid were assumed to be equal to the measured water levels by NOAA at Wrightsville Beach (see Figures 4-3 and 11-17). Waves on the offshore boundary of the Regional Wave Grid were taken from the NOAA Wavewatch forecast for the Western North Atlantic at 33.50°N, 76.75°W, -488' NAVD (see Figures 11-12, 11-17, and 11-18). Uniform wind velocities were assumed, based on measurements by NOAA at the Wrightsville Beach tide gages (see Figures 4-3 and 11-18).

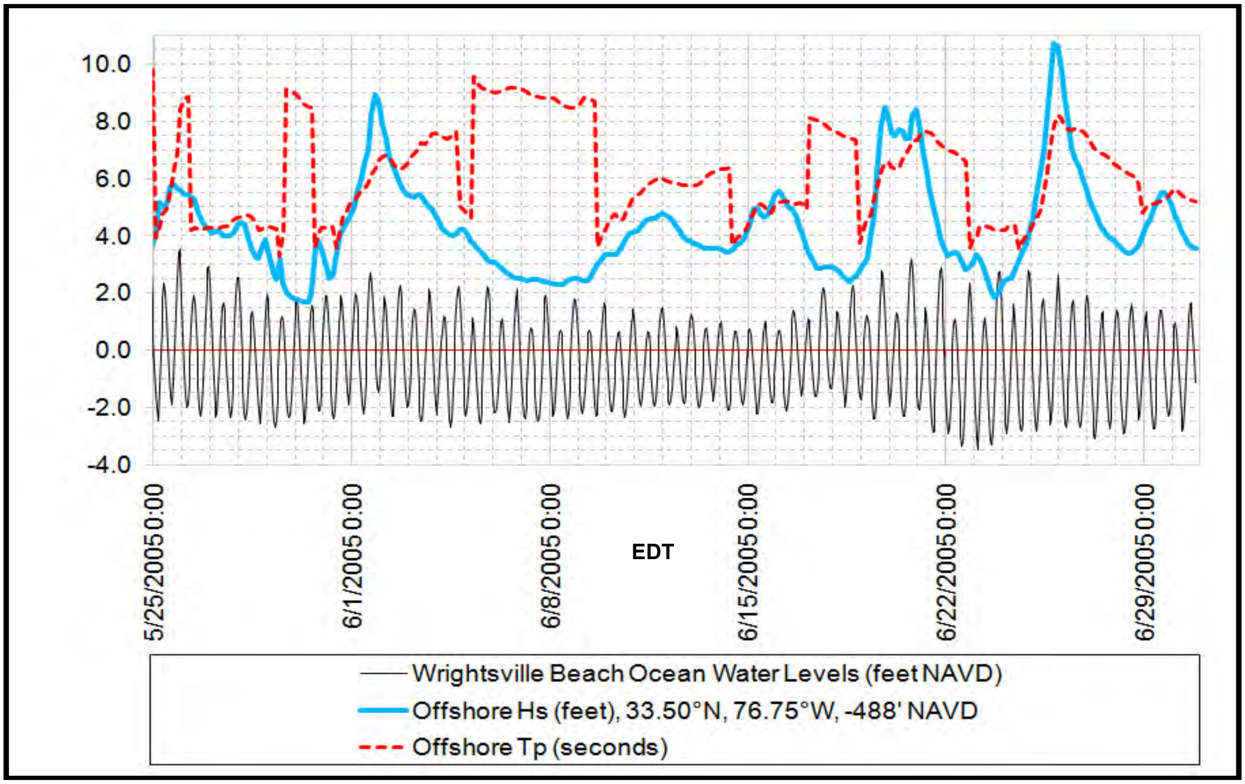


FIGURE 11-17: Offshore Waves and Water Levels during the Delft3DFLOW Calibration.

In both the SWAN and Delft3DFLOW models, the assignment of the upcoast and downcoast boundary conditions followed the standard modeling practices. On the northern and southern boundaries of the flow grid, zero gradient boundary conditions were assumed. Currents and water levels just outside the northern and southern boundaries were assumed to be equal to the corresponding values immediately inside. On the northeastern and southwestern boundaries of the Regional Wave Grid, the wave heights and directions outside the surf zone were assumed to be equal to their corresponding values on the offshore boundaries.

11.2.3 Calibration and Verification Results

To calibrate and verify the water levels and currents, Chezy's bottom friction coefficient was varied (see Figure 11-19). All other model parameters were set to their default values. Chezy's bottom friction coefficient was related to Manning's n based on the following:

Chezy's bottom friction = (Depth in meters$^{1/6}$) / (Manning's n)

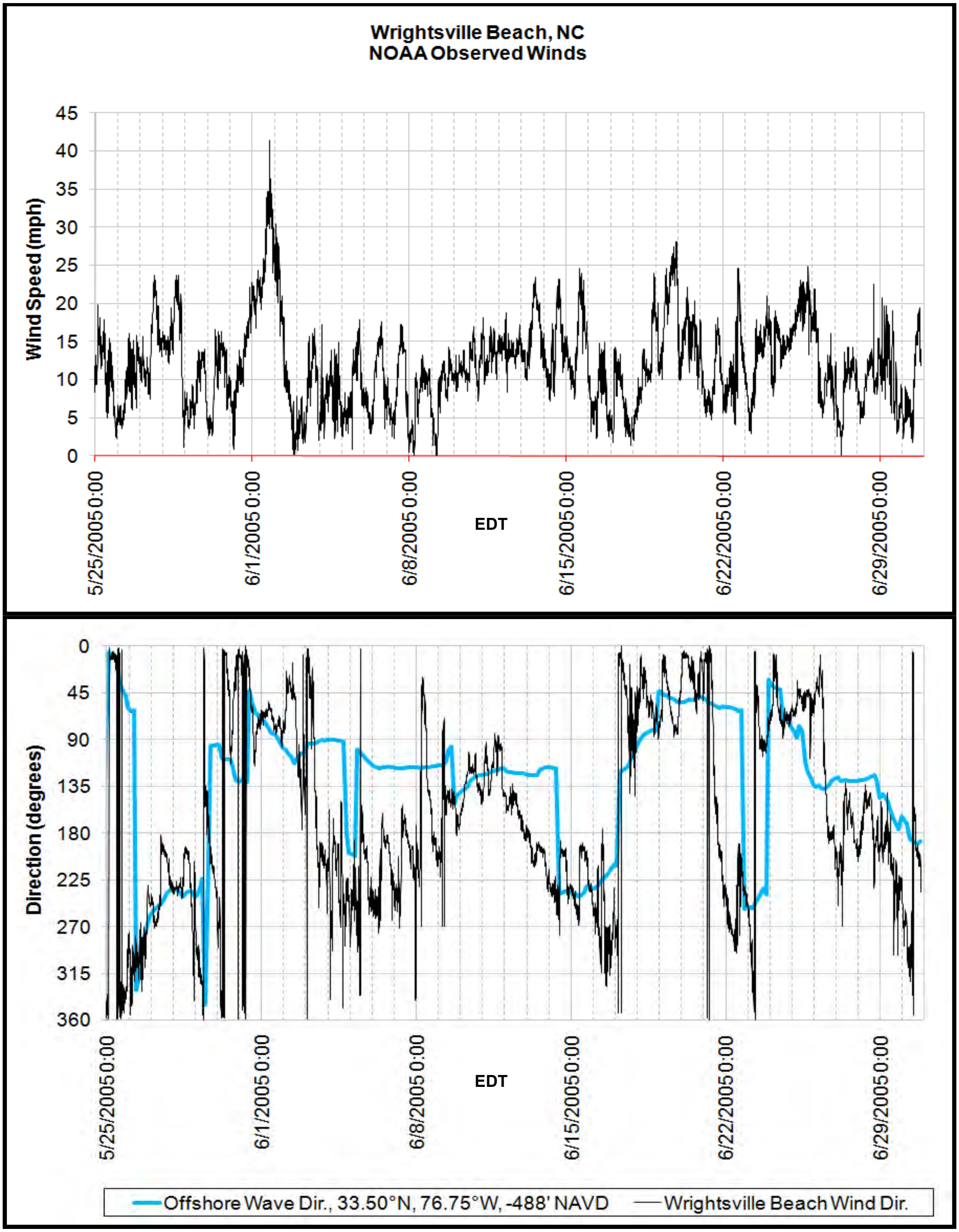


FIGURE 11-18: Wind Velocities and Offshore Waves Directions during the Delft3DFLOW Calibration.

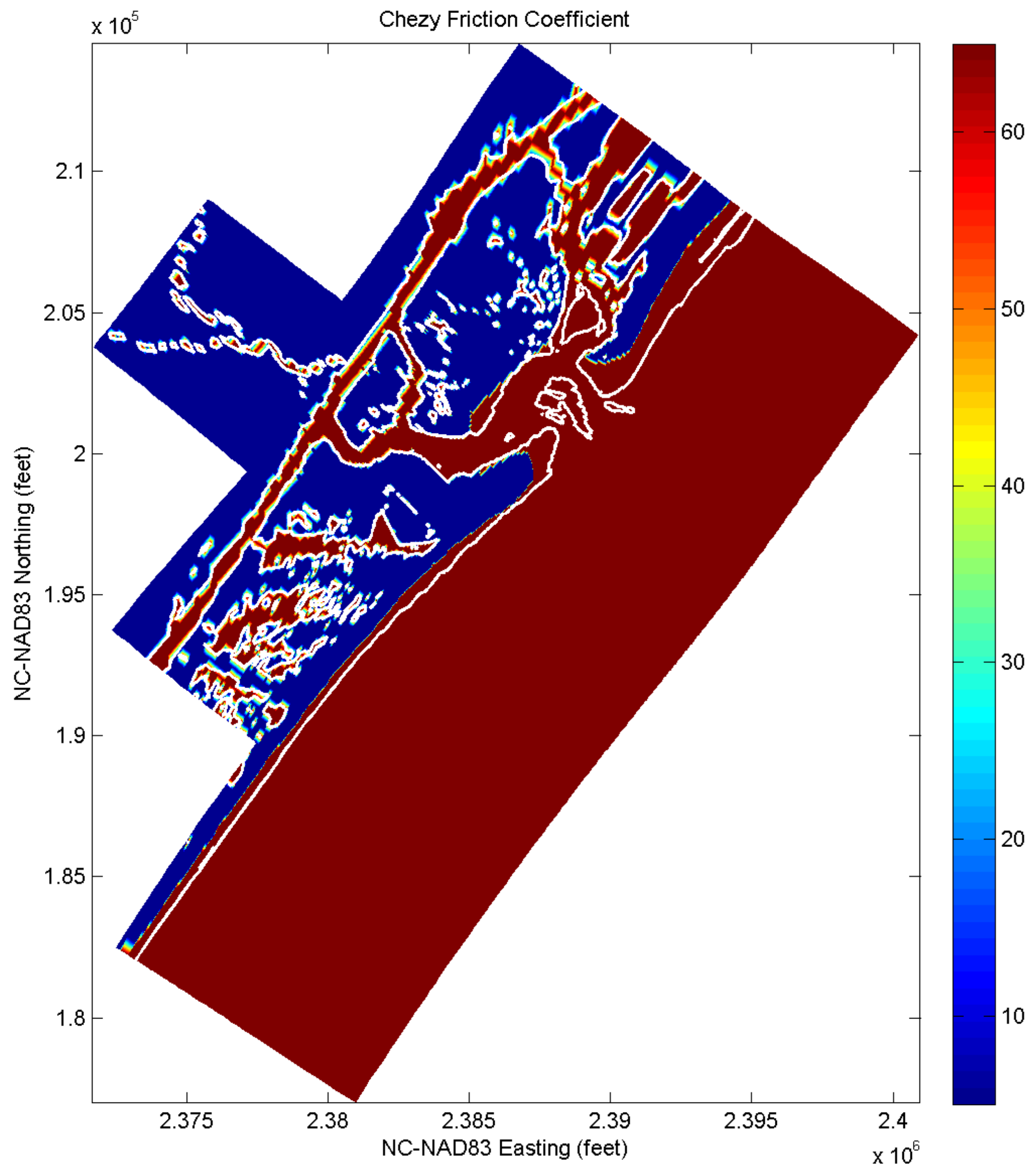


FIGURE 11-19: Final Bottom Friction Mapping for Delft3DFLOW Model.

Within the salt marsh and upland areas, the bottom friction coefficient was equal to 5. The equivalent value of Manning's n given a mean high water elevation of 1.7 feet NAVD and a bottom grade elevation of 0' NAVD would be 0.179. Elsewhere, the bottom friction coefficient was equal to 65, which was the model's default value. The equivalent value of Manning's n given a mean high water elevation of 1.7 feet NAVD and a bottom grade elevation of -15' NAVD would be 0.020.

Model results during spring tides on June 21, 2005 were used to calibrate the model. Agreement between the observed currents and the simulated currents was in the Inlet Throat and Nixon Channel was good (see Figures 11-20 to 11-21). Within Green Channel, differences between the simulated and observed currents occurred due to the location of the Green Channel ADCP (see Figures 11-15 and 11-22). This ADCP was deployed near the junction of the two forks within Green Channel and a side channel into the salt marsh. This location was characterized by complex currents in the model (see Figure 11-23). If the Green Channel ADCP had been deployed further inland, the model results would have been closer to the observations. Overall, the velocities predicted the by the model were reasonable within the areas being considered for dredging.

Simulated and observed water levels appear in Figures 11-24 to 11-26. Agreement between the measured and observed water levels was very good at all tide gages deployed by Gahagan & Bryant.

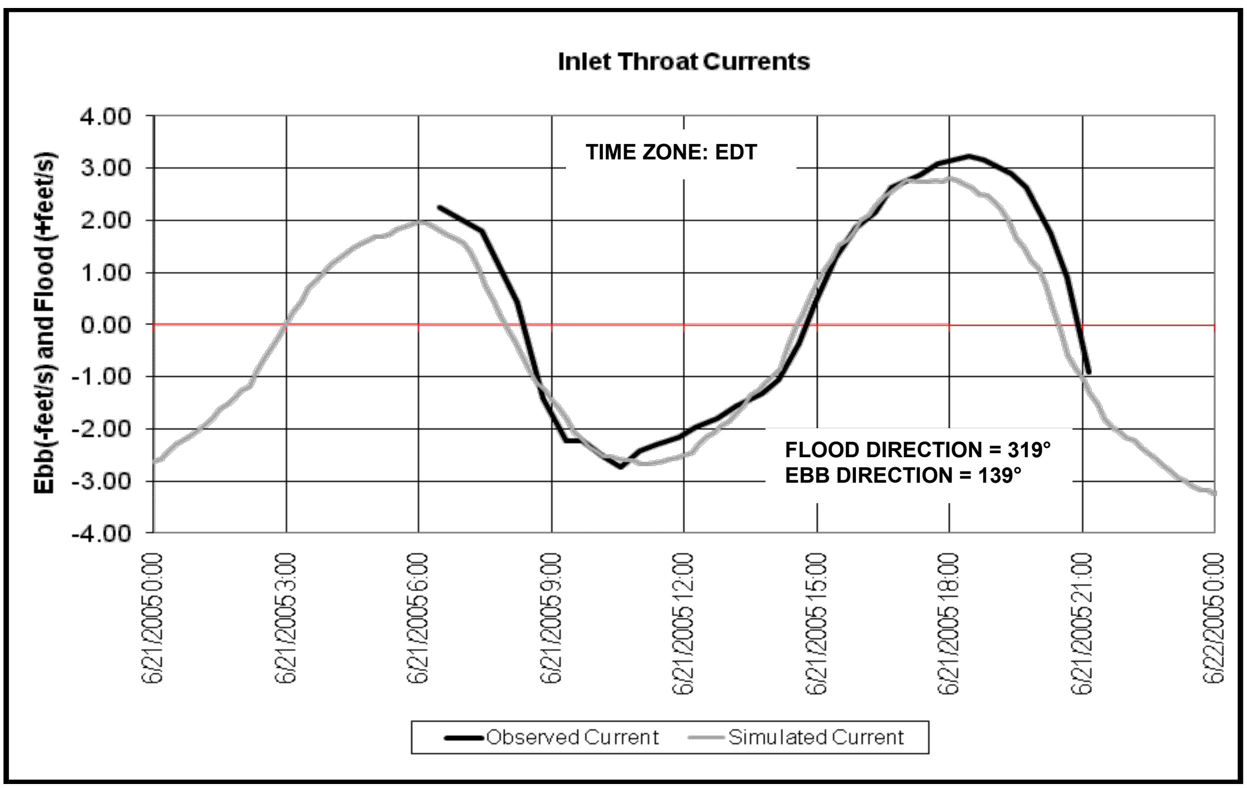


FIGURE 11-20: Simulated and Observed Currents at the Inlet Throat ADCP.

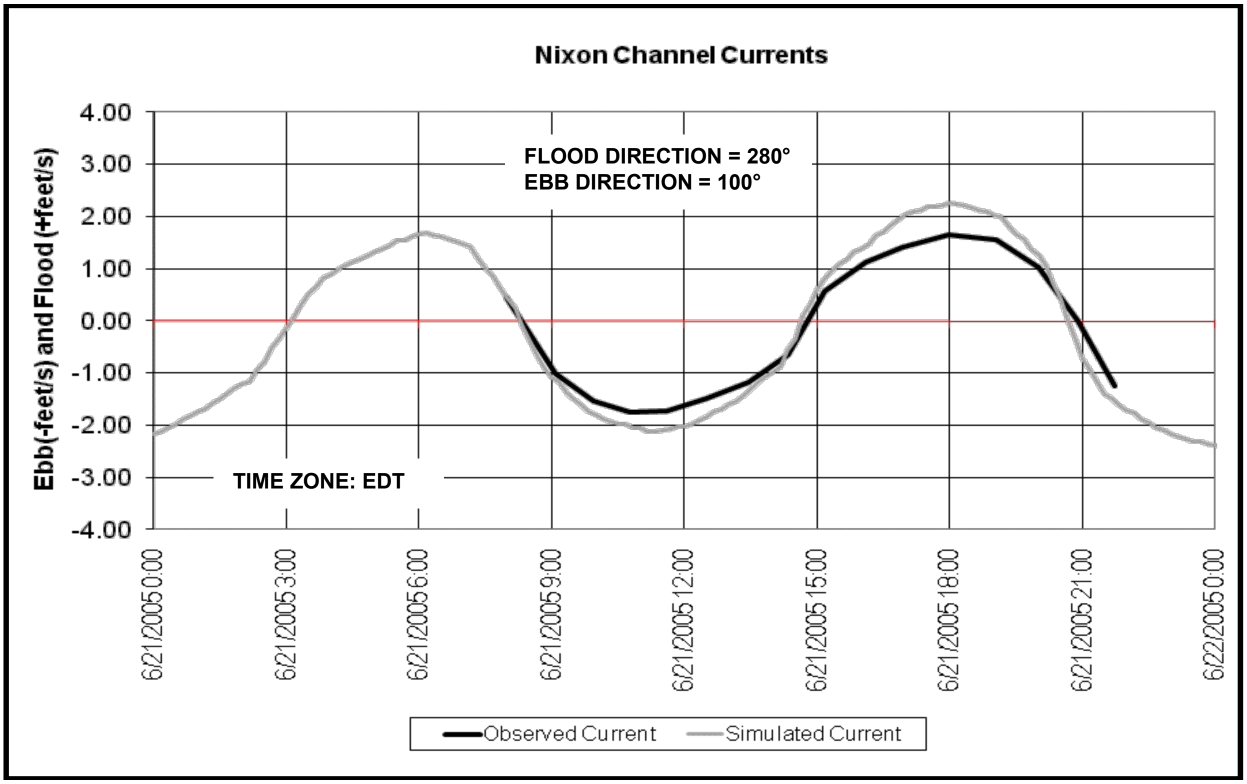


FIGURE 11-21: Simulated and Observed Currents at the Nixon Channel ADCP.

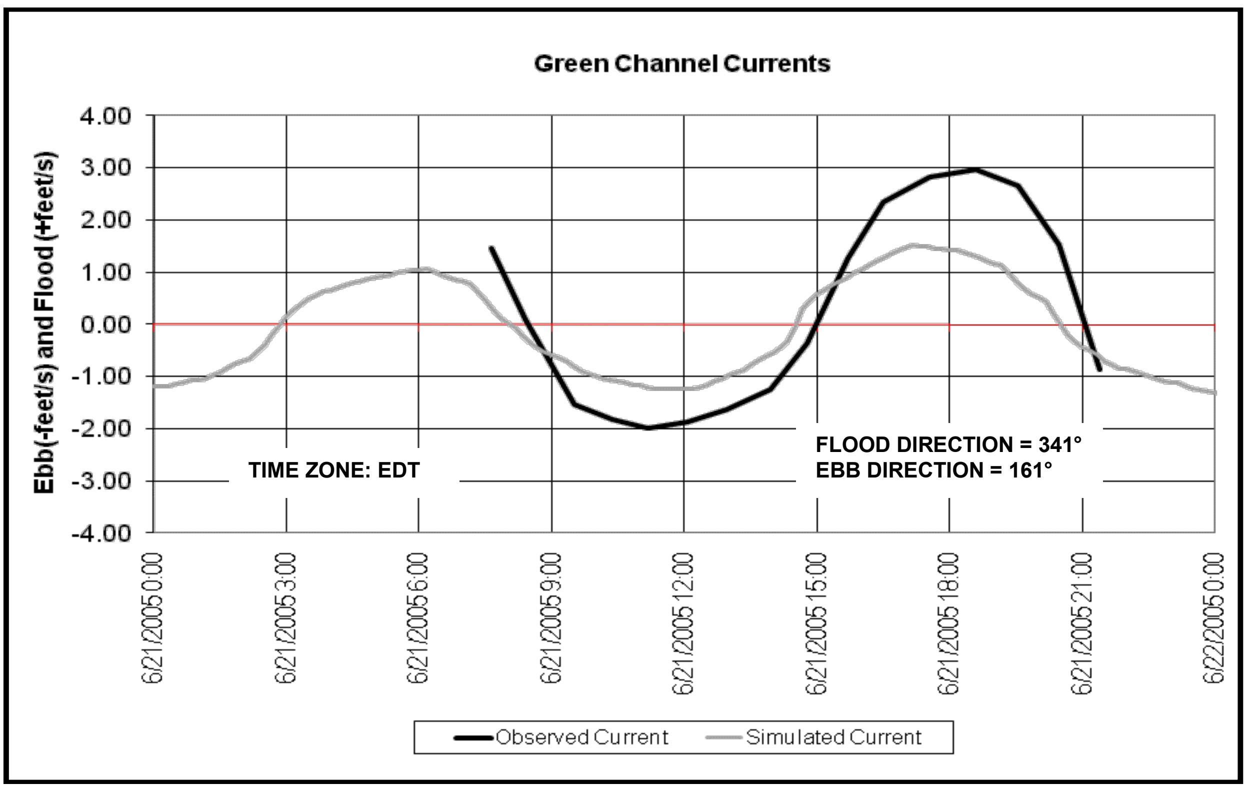


FIGURE 11-22: Simulated and Observed Currents at the Green Channel ADCP.

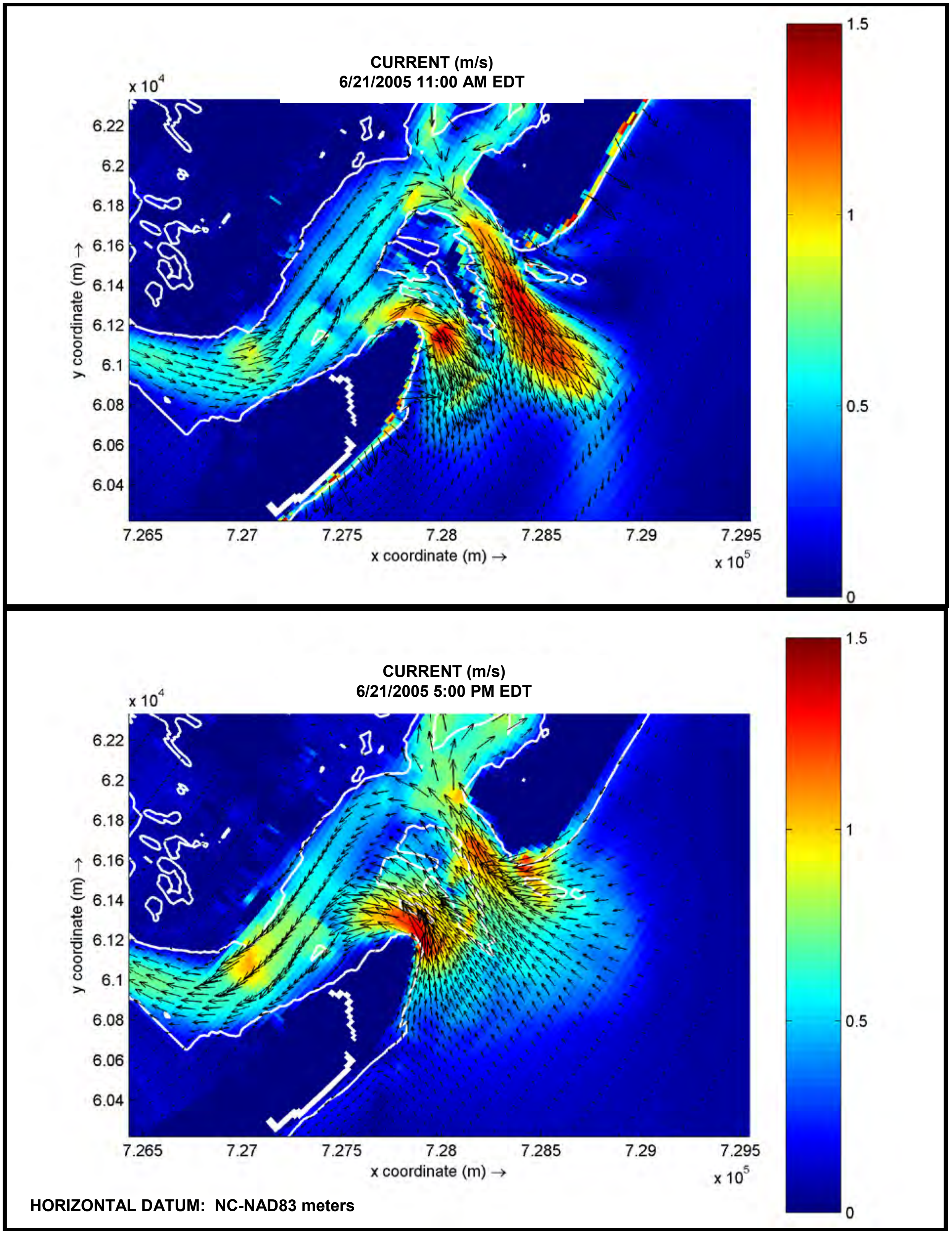


FIGURE 11-23: Typical Simulated Currents during Spring Tides.

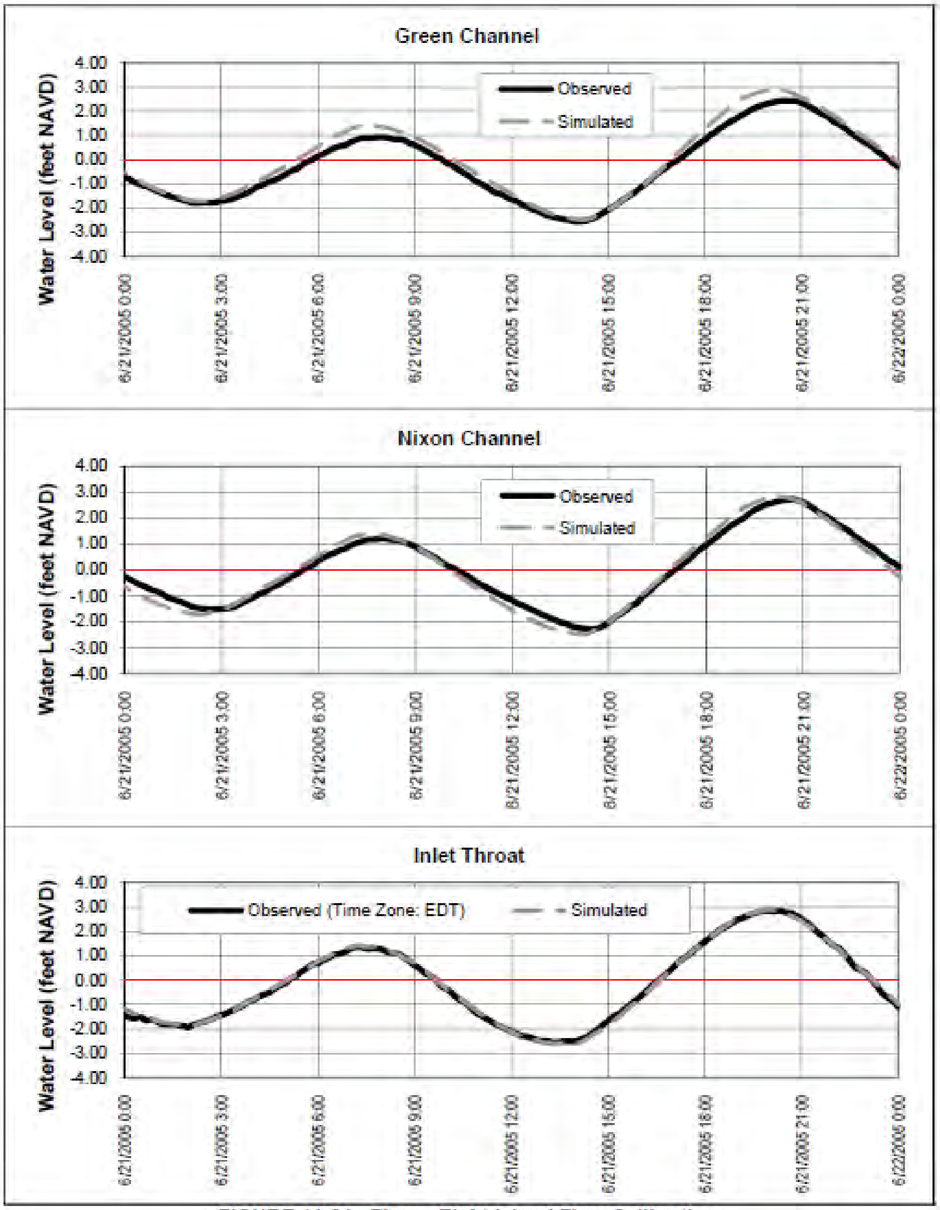


FIGURE 11-24: Figure Eight Island Flow Calibration,
Inlet Throat & Channel Tide Gage Comparisons.

COASTAL PLANNING & ENGINEERING, INC.

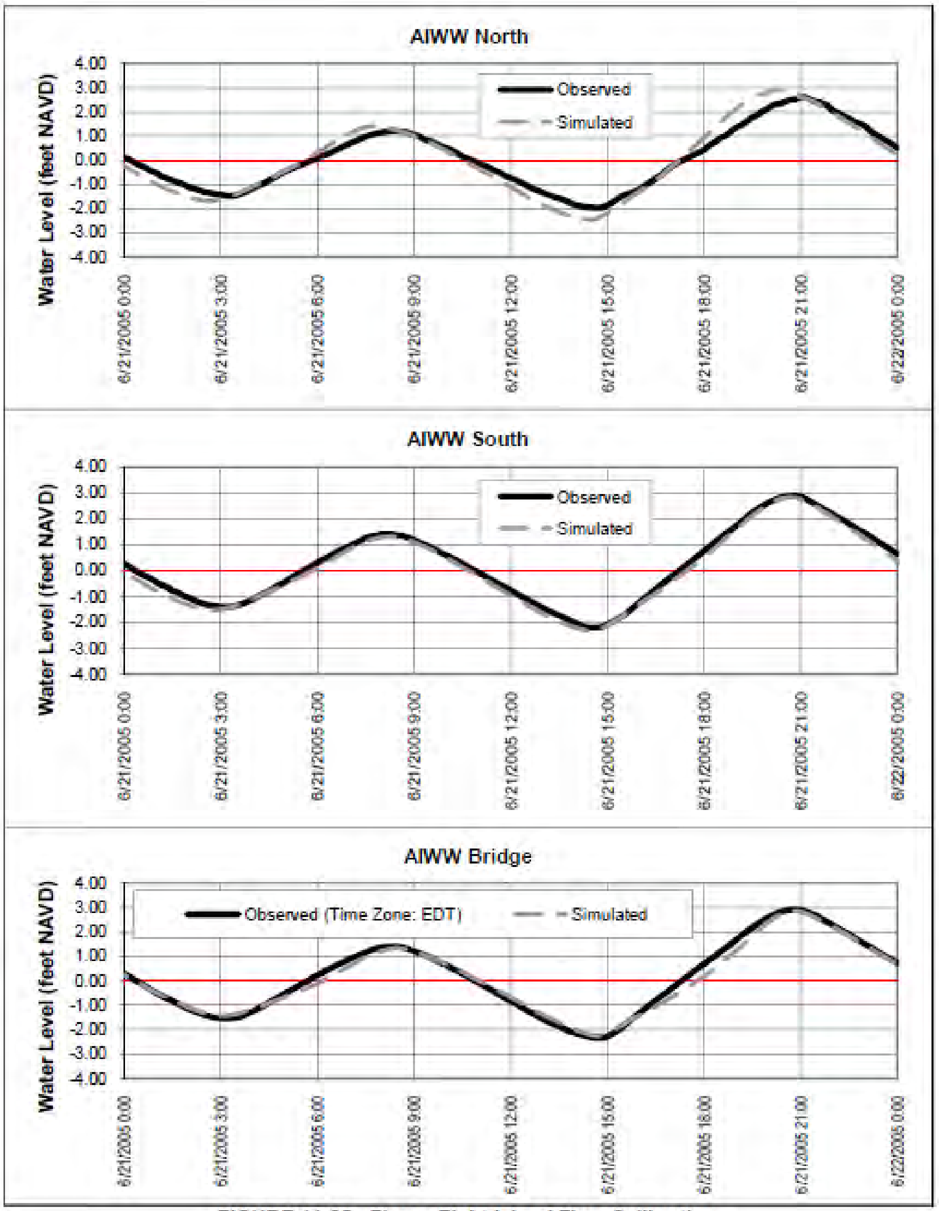


FIGURE 11-25: Figure Eight Island Flow Calibration, Atlantic Intracoastal Waterway Tide Gage Comparisons.

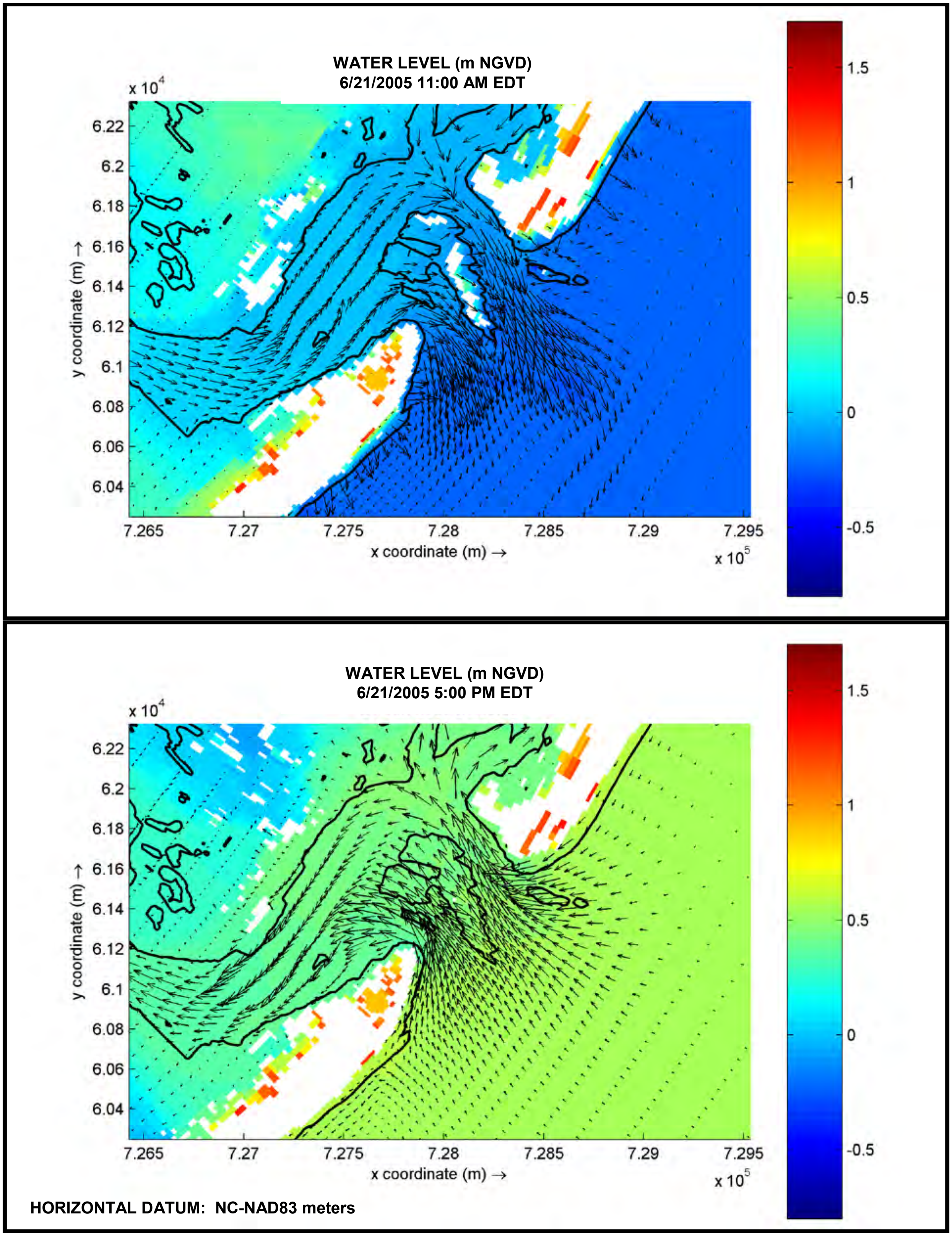


FIGURE 11-26: Typical Water Levels during Spring Tides.

Model results during neap tides on June 13, 2005 were used to verify the model (Figures 11-27 to 11-30). During neap tides, the simulated water levels agreed very well with the observed water levels. Thus, the flow model was able to predict the water levels during both neap tides and spring tides with a high level of confidence (see Table 11-2). Given the overall results from the calibration and verification periods, the flow model provided a sufficient description of the flow patterns in Rich Inlet. Accordingly, the remaining model runs in this study utilized the Delft3DFLOW model with the bottom friction values in Figure 11-19.

TABLE 11-2
DELFT3D CURRENT AND WATER LEVEL
CALIBRATION & VERIFICATION SUMMARY

ADCP	Mean Error (feet/second)	RMS Error (feet/second)
Currents, June 21, 2005 6:30 am EDT to June 21, 2005, 9:40 pm EDT:		
Inlet Throat	0.32	0.59
Nixon Channel	-0.04	0.35
Green Channel	0.28	1.03
Tide Gage	**Mean Error (feet)**	**RMS Error (feet)**
Water Levels, May 25, 2005, 10:10 am EDT to June 30, 2005, 8:00 pm EDT:		
Green Channel	0.16	0.26
Nixon Channel	-0.02	0.19
Inlet Throat	-0.08	0.18
AIWW North	-0.04	0.28
AIWW South	-0.12	0.20
AIWW Middle	-0.10	0.20
AIWW Bridge	-0.05	0.23

11.3 Erosion and Deposition Calibration

Sediment transport, erosion, and deposition in the Delft3D modeling package were simulated using Delft3DFLOW. The calibration of sediment transport, erosion, and deposition was based on the volume changes between April 2005 and the present. Parameters examined during the calibration included the following:

- The approximation of the tides.
- The delineation of the wave cases.
- The use of wind stress in both Delft3DFLOW and SWAN.
- The sediment transport parameters within Delft3DFLOW.

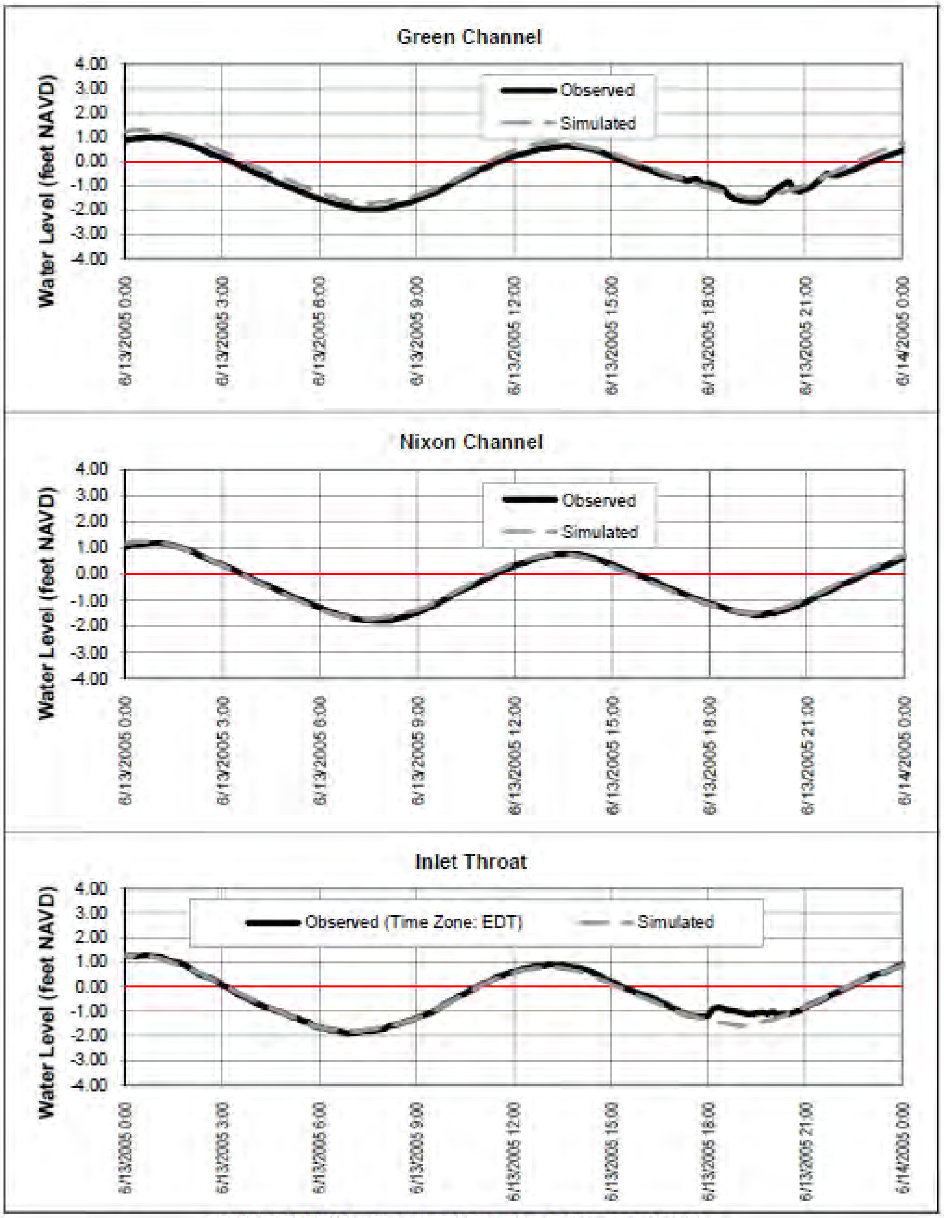


FIGURE 11-27: Figure Eight Island Flow Verification, Inlet Throat & Channel Tide Gages.

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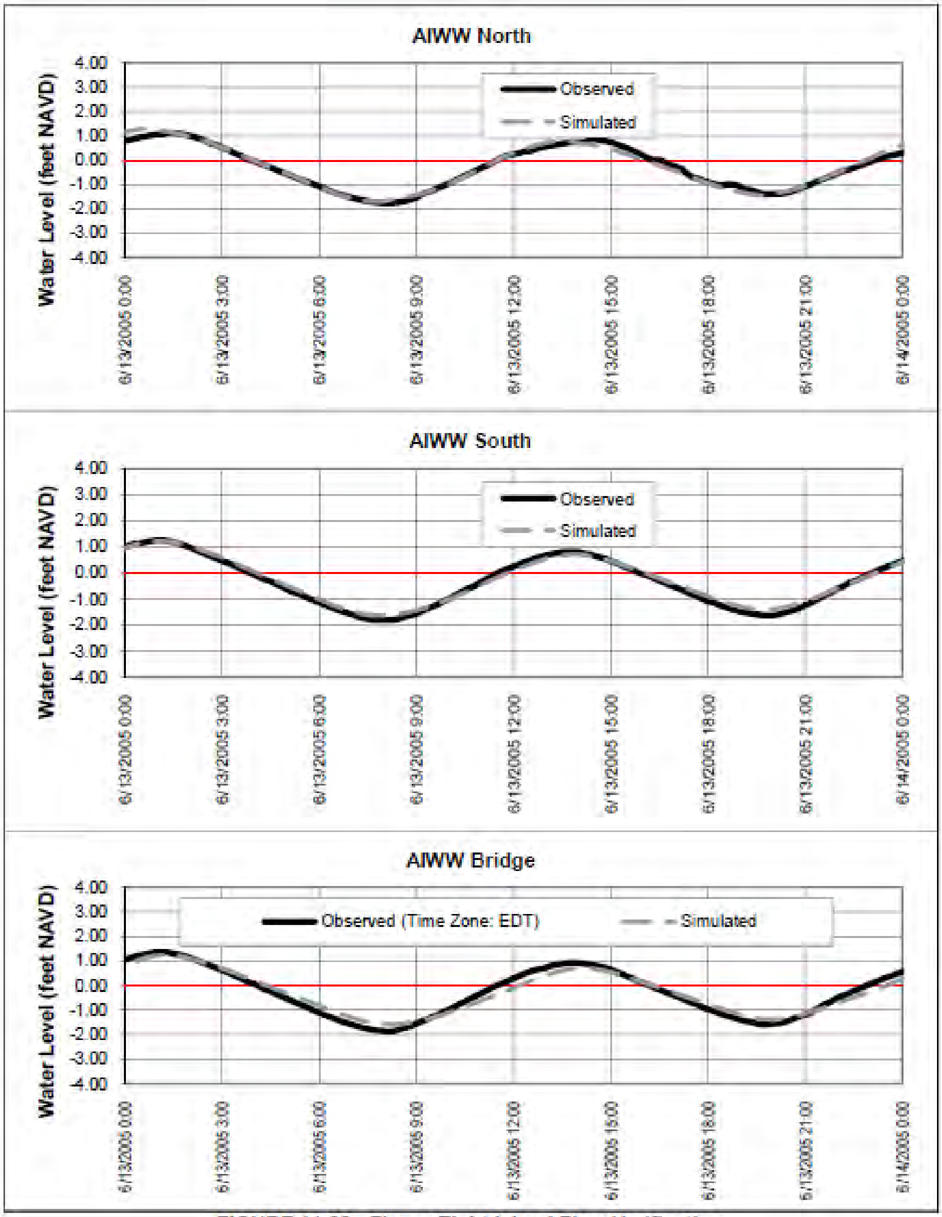

FIGURE 11-28: Figure Eight Island Flow Verification, Atlantic Intracoastal Waterway Tide Gages.

COASTAL PLANNING & ENGINEERING, INC.

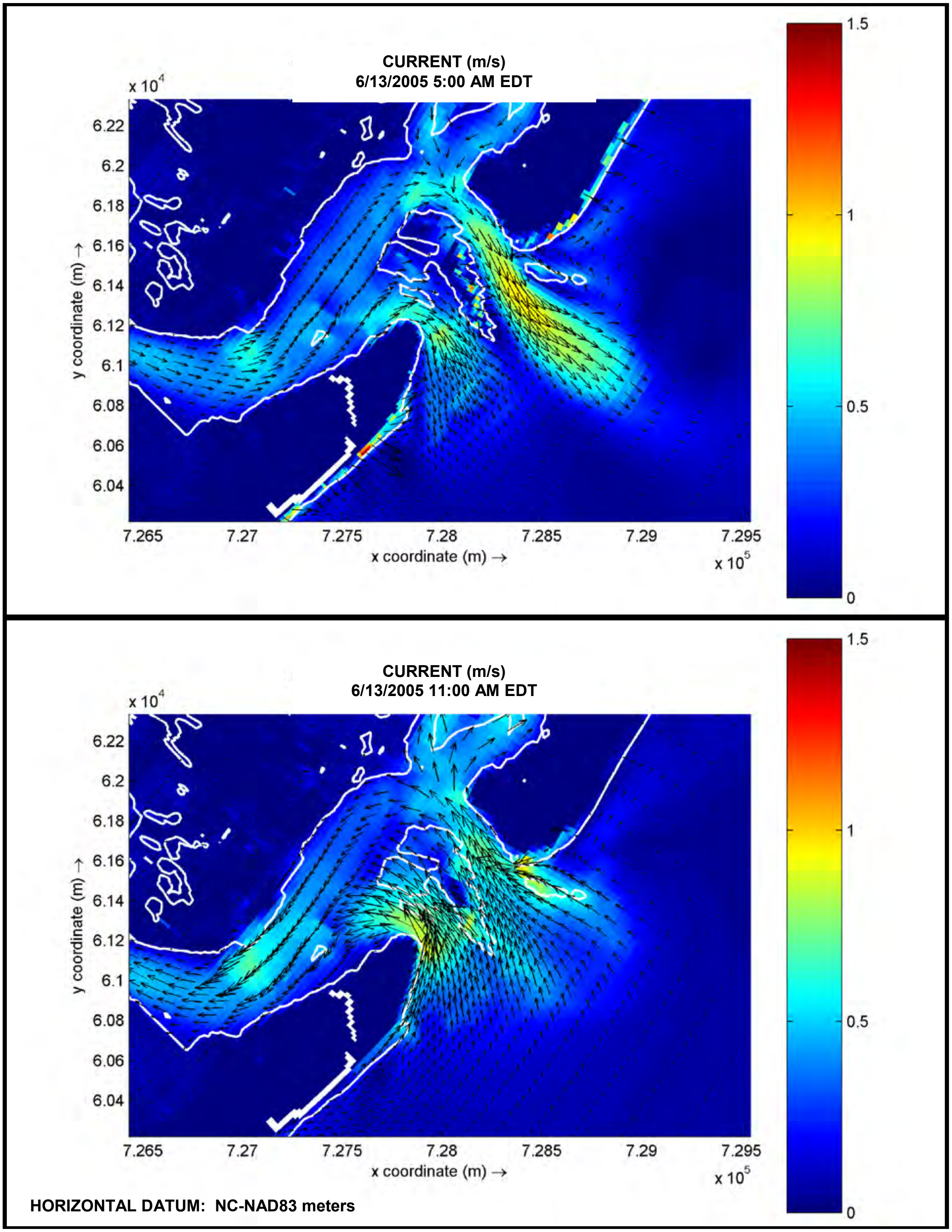

FIGURE 11-29: Typical Simulated Currents during Neap Tides.

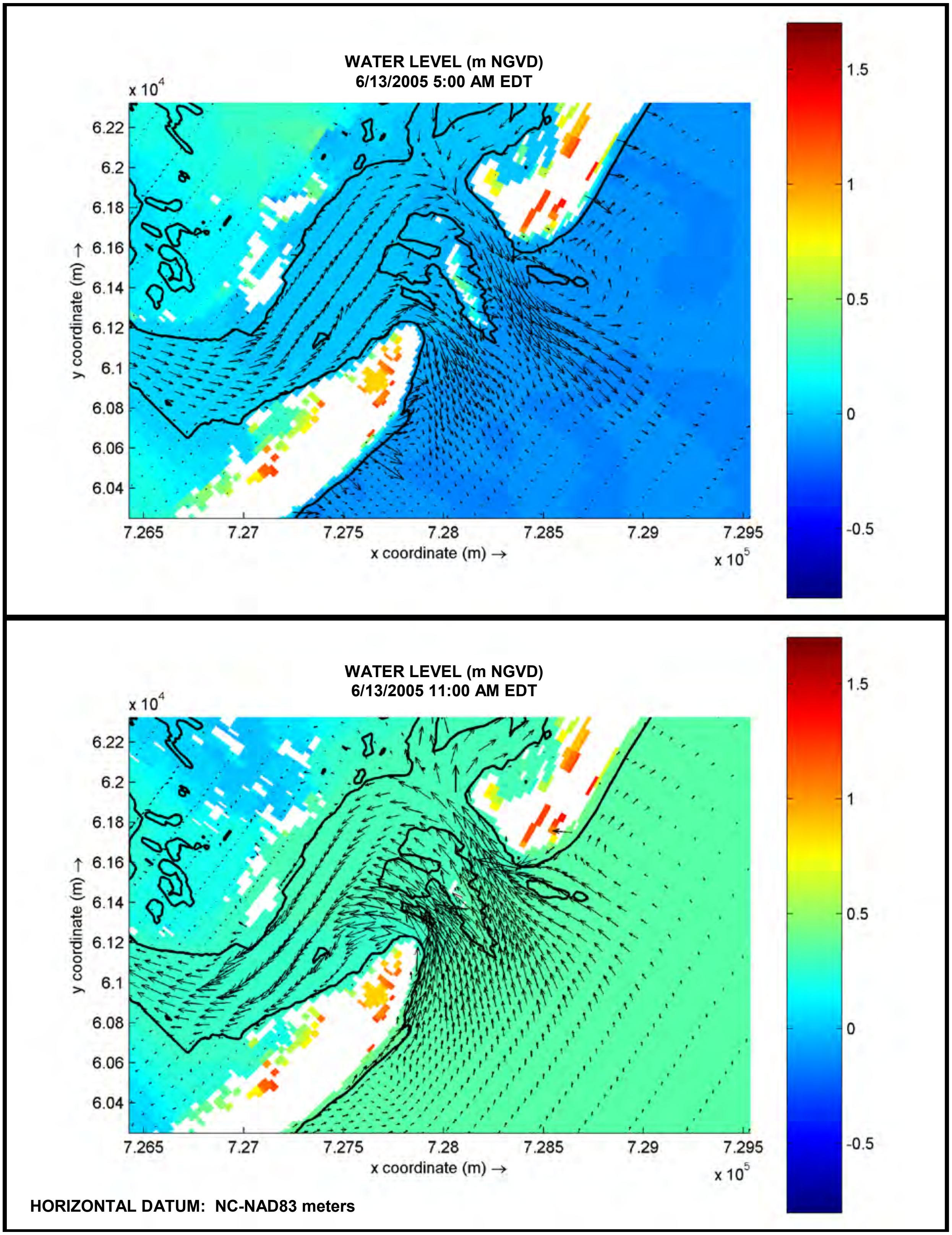

FIGURE 11-30: Typical Water Levels during Neap Tides.

11.3.1 Tides

Ideally, 2-5 years of bathymetric changes could be simulated using a 2-5 year model run. However, a 2-5 year model run using Delft3DFLOW would require 2-3 months of computational time, even under the best circumstances. To reduce the amount of computational time, a number of methods have been developed so that 5 years of bathymetric changes can be simulated using a 3-7 week model run, which can be completed in 2-7 days.

The first of these methods is the simplification of the tides. As long as a simplified tide with single harmonic produces the same residual transport as 14-15 days of predicted tides, the spring-neap tidal cycle can be approximated using a simplified tide:

$$\eta \approx \eta_o + A \cos(2\pi t/T)$$

where

η = water level
η_o = mean tide level
A = tidal amplitude
t = time
T = tidal period

To select the best simplified tide, several simulations were conducted using two methodologies (see Table 11-3):

- The Lesser (2009) approach using M2 and C1 tidal harmonics (M2C1 in Table 11-3).
- The mean tidal amplitude ± 20% and the M2 tidal period of 745 minutes (12.42 hours).

TABLE 11-3
SIMPLIFIED TIDE SCHEMES TESTED

Tide scheme	Amplitude (feet)	Period (min)
M2C1	2.16	1490
M2C1 (-20%)	1.72	1490
M2C1 (+20%)	2.59	1490
Mean	2.07	745
Mean (-20%)	1.66	745
Mean (+20%)	2.48	745

The first simulation consisted of 15 days predicted tides based on the harmonics in Table 11-4. The remaining simulations consisted of 15 days of simplified tides characterized a single amplitude and tidal period. Waves were neglected during these simulations, and default sediment transport parameters were utilized.

TABLE 11-4
TIDAL CONSTITUENTS BASED ON WATER LEVEL MEASUREMENTS
TAKEN IN THE INLET THROAT, MAY 25 – JULY 7, 2005

	Period (hours)	Amplitude (feet)	Phase (degrees)
M2	12.42	1.77	244.1
N2	12.66	0.41	243.4
K1	23.93	0.40	116.3
O1	25.82	0.18	147.9
S2	12.00	0.17	254.6
MM	661.31	0.14	331.9
MSF	354.37	0.13	290.0
M4	6.21	0.07	148.9
MU2	12.87	0.07	163.9
Q1	26.87	0.06	172.5
L2	12.19	0.04	215.6
MS4	6.10	0.04	214.7
M6	4.14	0.03	53.1
M3	8.28	0.03	190.0
MN4	6.27	0.03	75.7
NO1	24.83	0.02	170.7
2MN6	4.17	0.02	61.0
SN4	6.16	0.02	63.0

Although all 6 tidal schemes in Table 11-3 were tested, tides along the regional are semi-diurnal (see Figures 11-20, 11-21, 11-22, 11-24, 11-25, 11-27, and 11-28). Accordingly, the results of the M2C1 tests are not shown. Test results based on the 745 minute tidal schemes appear in Figures 11-30 to 11-34. The best results were achieved using the mean tidal amplitude of 2.07 feet and a tidal period of 745 minutes (12.42 hours). As shown in Figure 11-34, differences in sedimentation patterns between 15 days predicted tides and 15 days simplified tides (T = 745 minutes, A = 2.07') were small (± 1 foot) or negligible.

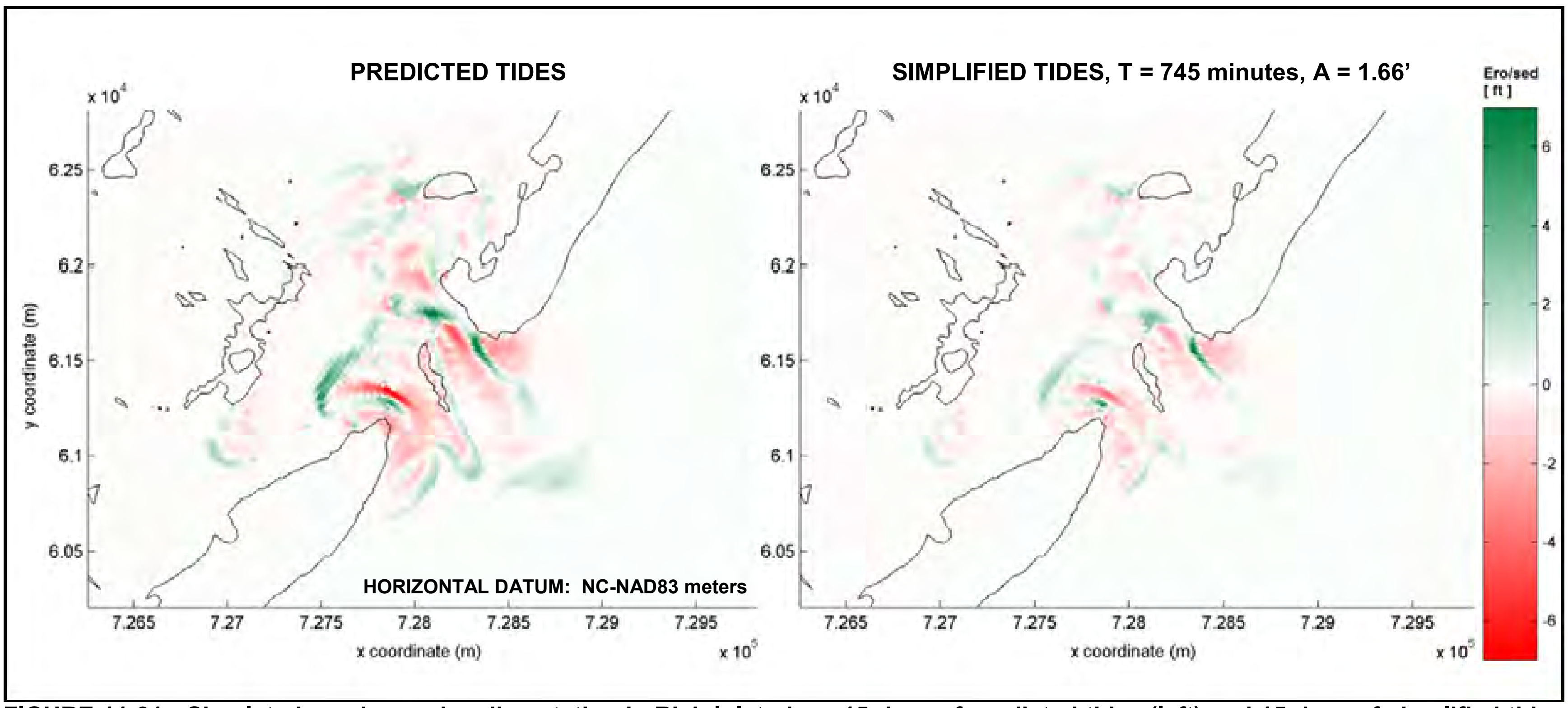

FIGURE 11-31: Simulated erosion and sedimentation in Rich Inlet given 15 days of predicted tides (left) and 15 days of simplified tides assuming T = 745 minutes (12.42 hours) and A = 1.66’ (mean – 20%) (right).

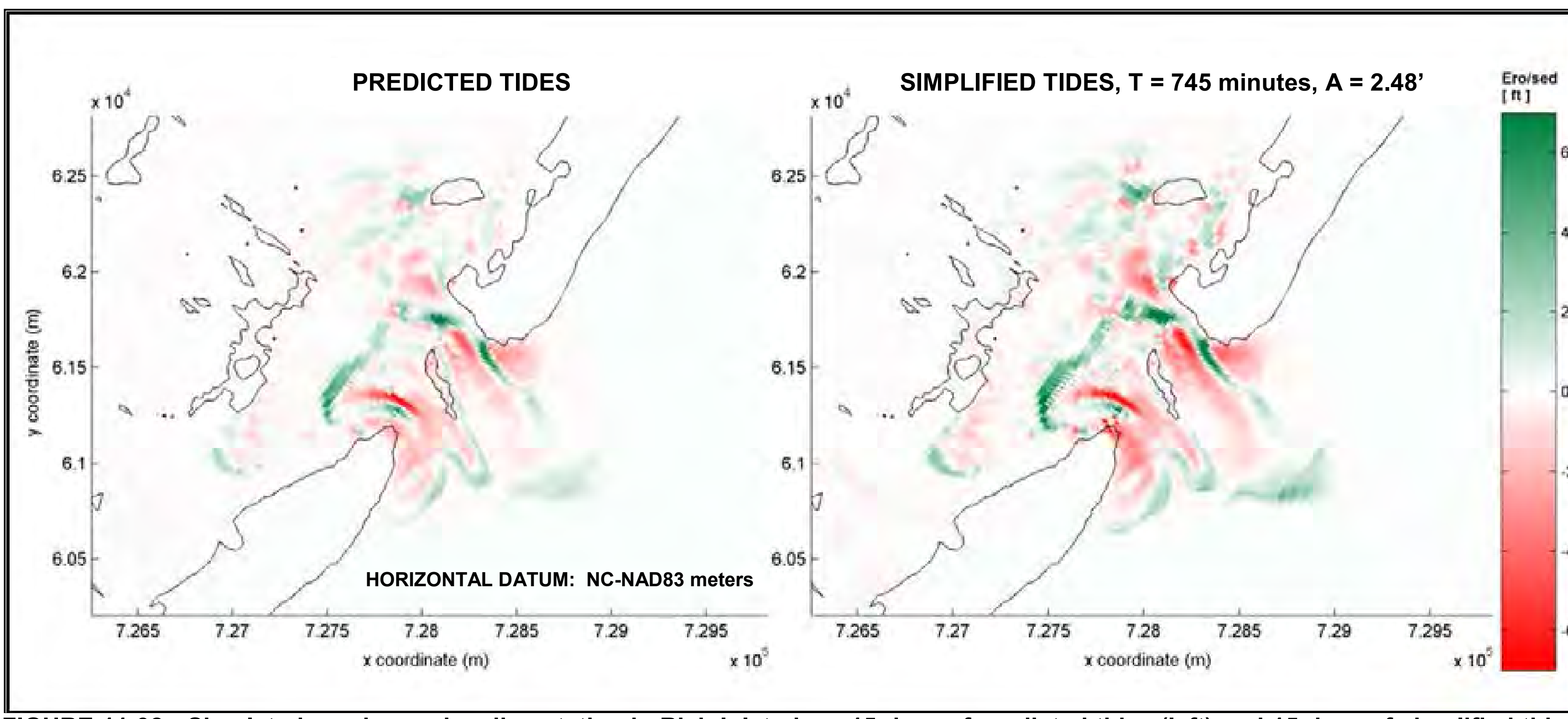

FIGURE 11-32: Simulated erosion and sedimentation in Rich Inlet given 15 days of predicted tides (left) and 15 days of simplified tides assuming T = 745 minutes (12.42 hours) and A = 2.48’ (mean + 20%) (right).

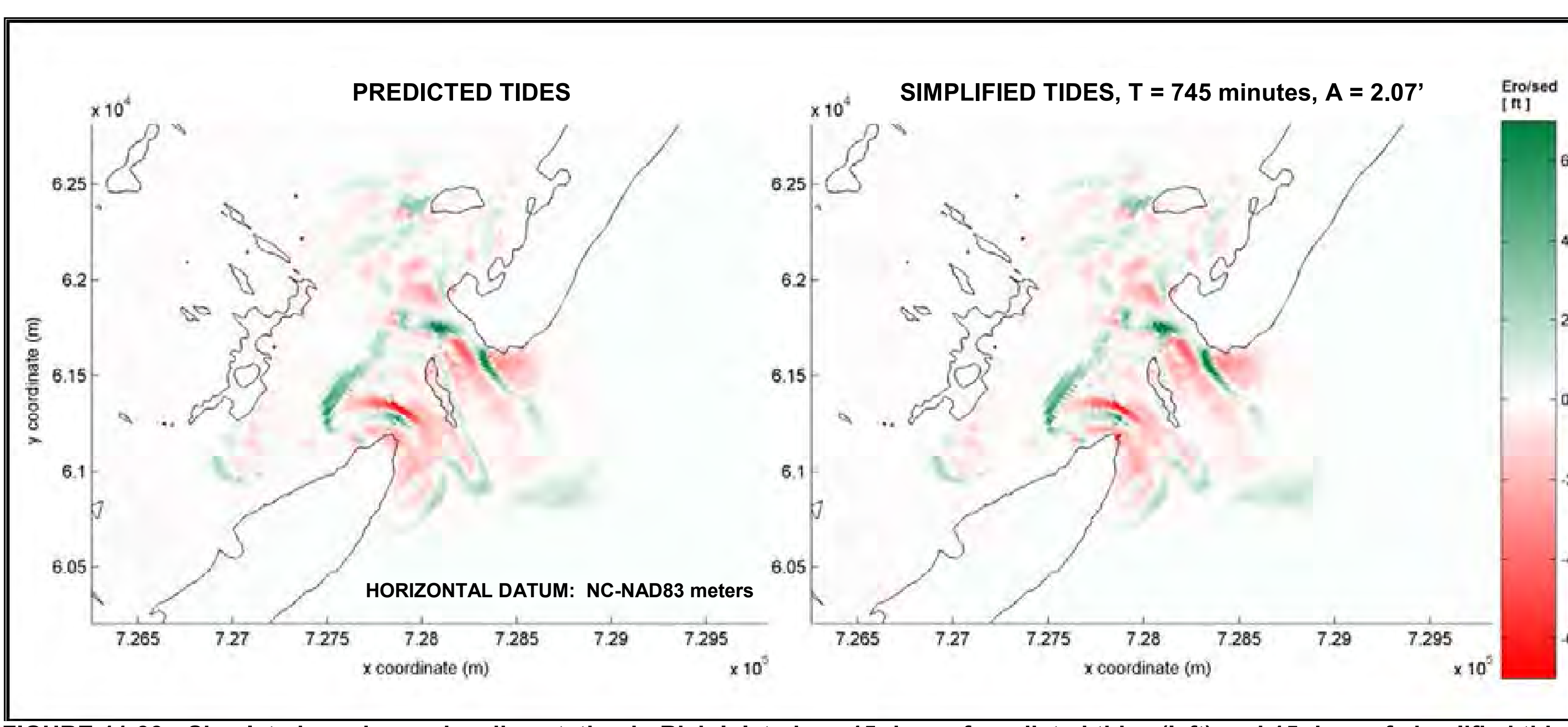

FIGURE 11-33: Simulated erosion and sedimentation in Rich Inlet given 15 days of predicted tides (left) and 15 days of simplified tides assuming T = 745 minutes (12.42 hours) and A = 2.07’ (mean) (right).

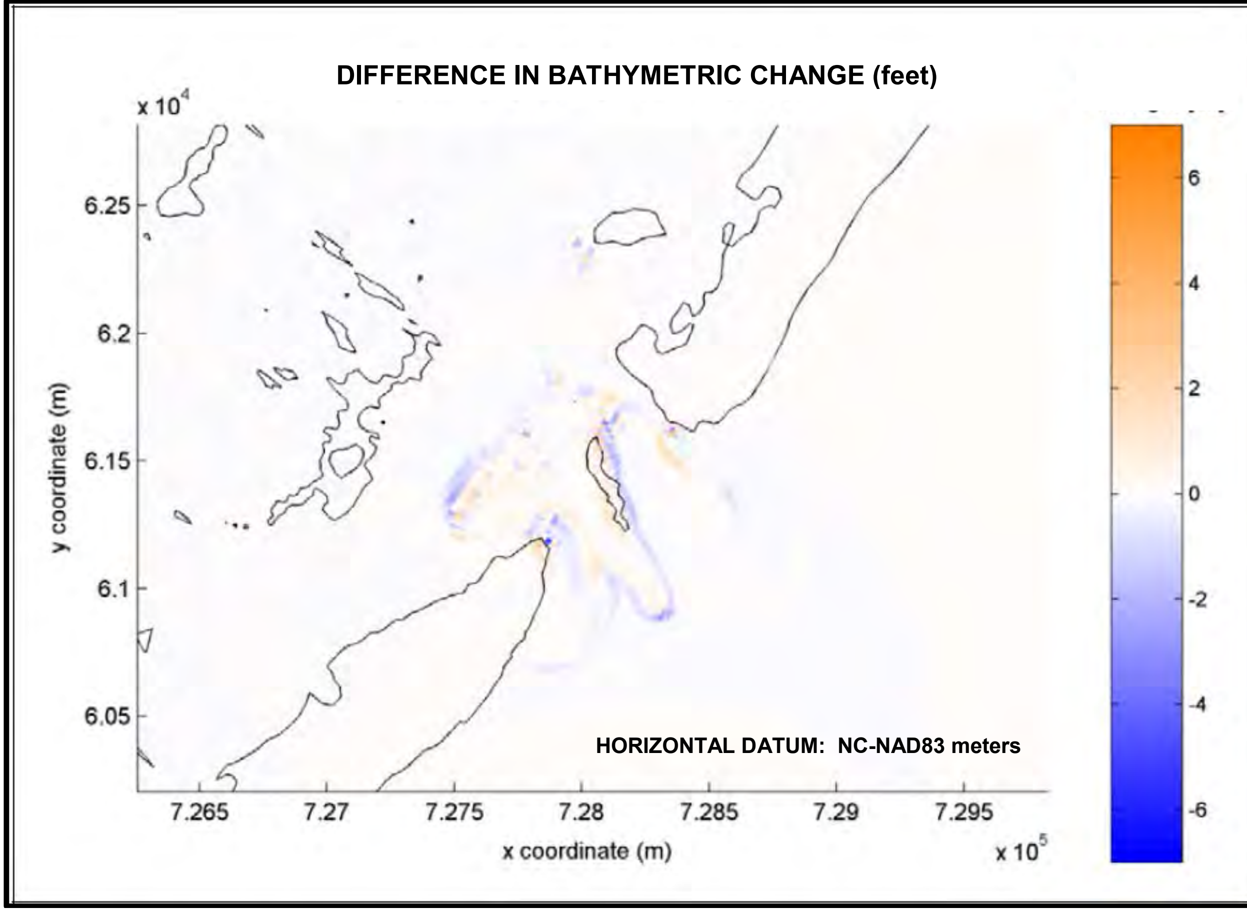

FIGURE 11-34: Differences in bathymetric change given 15 days of predicted tides versus 15 days of simplified tides assuming T = 745 minutes (12.42 hours) and A = 2.07' (mean). A difference of zero indicates that simplified tides lead to the same bathymetric changes as the predicted tides.

11.3.2 Wave Cases

The waves used to calibrate sediment transport, erosion, and deposition were based on the NOAA Global Wavewatch forecast at 34.00ºN, 76.25ºW (see Figure 11-12). The depth at site was approximately -644 feet NAVD. As noted earlier, it is not practical to simulate 2-5 years of bathymetric changes using a 2-5 year time series of offshore water levels and waves to drive the model. Instead, the Delft3D model is typically run for a shorter period of time, using 10-75 representative wave cases to approximate the general wave climate during the period of interest (i.e.: Lesser, et al., 2004; Benedet and List, 2008).

Potential wave climates for the project area were based on the forecast wave record at 34.00°N, 76.25°W between October 1999 and April 2007. All waves propagating from the landward direction bands (200° to 360° and 0° to 55°) were ignored, along with all waves smaller than 1.64 feet (0.5 m). The remaining wave records were divided into wave height and direction classes, with each wave class containing an equal amount of wave energy (in KW-Hours/m). This method, known as the Energy Flux Method, characterized each wave record based on the energy flux:

$E_p \approx 1.56\ T_p \rho g H_s^2 / 2$ (deep water assumption)

$Energy = E_p \Delta t$

Where

E_p = energy flux
T_p = peak wave period
ρ = sea water density (1025 kg/m^3)
g = gravitational acceleration (9.81 m/s^2)
H_s = significant wave height
Δt = interval between wave records (3 hours)

To simulate 1 year of sediment transport, erosion, and deposition, each wave case was run for 1 to 3 tidal cycles per year, which were characterized by a single harmonic (see previous section). Sediment transport values were then scaled by a Morphological Acceleration Factor, so that 1 to 8 weeks of the simulation would be equivalent to 1 year of erosion (i.e.: Lesser, et al., 2004; Benedet and List, 2008):

$M = T_{study\ period} / T_{model\ period}$

where

M = Morphological Acceleration Factor
$T_{study\ period}$ = (length of the study period) x (percent occurrence for each wave case)
$T_{model\ period}$ = duration of the wave case in the model simulation

Lower M values were used for the higher waves, during which the majority of the significant bathymetric changes occurred. Conversely, higher M values were used for the more frequent, but smaller waves. This schematization was consistent with the standard practices used within the Delft3D modeling community.

Based on the method above, 3 wave climates were delineated:

1. A 12-case wave climate.
2. A 20-case wave climate.
3. A 70-case wave climate that approximated the full time series of waves between October 1999 and April 2007.

To determine which wave climate would be the most appropriate, preliminary Delft3D-FLOW simulations using each wave climate were performed. Since the objective of this task was to determine how many wave cases would be necessary, sediment transport was activated within the Delft3D model, but changes to the seafloor elevation were not. Default sediment transport parameters were also utilized. These settings ensured that the sediment transport rates from each wave climate would not be biased by the erosion or deposition that would theoretically occur during the various wave cases. Average longshore sediment transport values were then extracted from the output of each simulation. Finally, sediment transport values based on the first two wave climates were compared to those of the 70-case wave climate (Figure 11-35).

Since erosion and deposition were not considered in this task, the results in Figure 11-35 were not intended to be compared to the sediment budgets in Figures 8-4 or 8-5. However, the results of the test showed that it would be possible to use a 12-case wave climate in the subsequent phases of the model calibration and the future conditions simulations. Wave cases appear in Table 11-5 and Figure 11-36.

TABLE 11-5
OCTOBER 1999 TO APRIL 2007
WAVE CLIMATE
34.00ºN, 76.25ºW, -644' NAVD

Wave Case	Hs (feet)	Tp (sec.)	Wave Dir. (deg.)	Frequency (days/year)	Tidal Cycles in Model per Year	Morph. Acceler-ation Factor	Wind Speed (mph)	Wind Dir. (deg.)
#1	4.5	7.9	64.2	21.5	2	20.7	3.6	77.1
#2	8.3	9.5	63.4	5.3	1	10.2	8.7	45.0
#3	11.8	10.2	63.6	2.4	1	4.6	19.9	45.0
#4	3.6	8.0	91.3	32.6	2	31.5	2.5	120.3
#5	6.0	8.5	89.1	11.1	1	21.5	6.1	61.7
#6	10.0	9.2	85.7	3.6	1	7.0	9.2	15.0
#7	3.2	7.5	122.1	44.7	3	28.8	4.0	166.4
#8	7.0	7.5	128.5	9.2	1	17.8	5.6	147.4
#9	14.7	9.5	130.9	1.6	1	3.2	4.7	155.4
#10	4.5	5.4	181.7	30.3	2	29.3	8.4	206.9
#11	8.4	7.0	177.8	6.6	1	12.8	13.9	232.2
#12	13.4	8.2	178.7	2.2	1	4.3	18.3	240.2

The smallest wave cases have heights in the range of 3.2 feet (1 m). The intermediate wave heights are in the range of 7.5 feet (2.3 m), and the highest waves are in the 12.5 foot (3.8 m) range. Peak wave periods vary from 5.4 to 10.1 seconds, and the wave direction varies from 63 to 181 degrees. The wind associated to the representative wave conditions was defined as the mean wind of each wave class (selected by Energy Flux Method). Each repetition of the 12 wave cases corresponded to 1 year of sediment transport, erosion, and deposition.

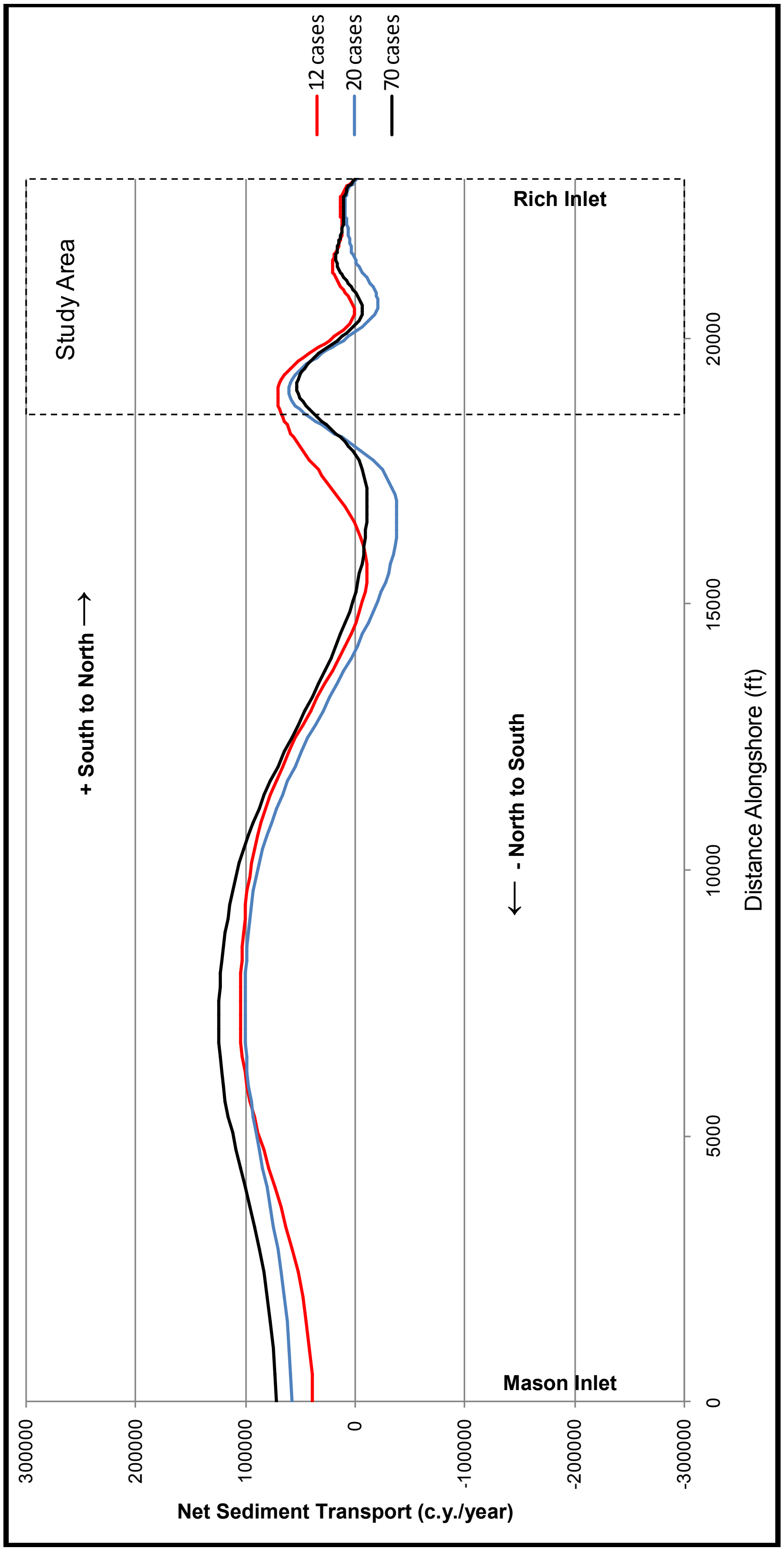

FIGURE 11-35: Theoretical Longshore Sediment Transport along Figure Eight Island Based on Wave Climates with 12, 20, and 70 Cases.

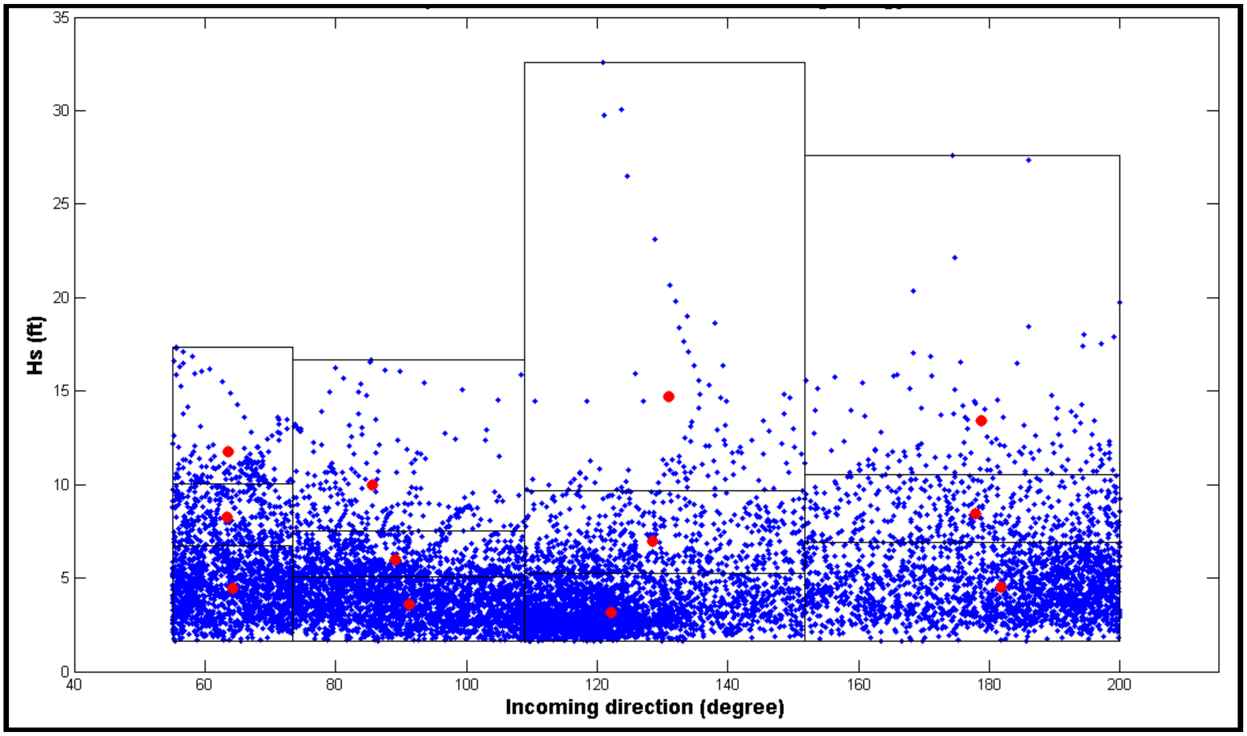

FIGURE 11-36: October 1999 To April 2007 Wave Climate, 34.00ºN, 76.25ºW, -644' NAVD, with Representative Wave Cases (red) for 12 Wave Classes (black squares).

11.3.3 Wind Stress

Both the SWAN and Delft3DFLOW models utilize wind stress formulations. In SWAN, wind stress governs the growth and generation of waves within the model grids. In Delft3DFLOW, shear stresses due to wind can be activated to partially govern the currents.

A large number of simulations were conducted how the model would perform if wind stress were:

1. Neglected in both models.
2. Considered in the Delft3DFLOW model but neglected in the SWAN model.
3. Considered in the SWAN model but neglected in the Delft3DFLOW model.
4. Considered In both models.

In each simulation, bathymetric changes were activated within Delft3DFLOW.

Sediment transport estimates given the first scenario were similar to those in Figure 11-35, which predicted net sediment transport towards the north along most of the island. While this was consistent with the two sediment budgets (Figures 8-5 and 8-4) at Rich Inlet, it was not consistent with the two sediment budgets elsewhere. Net sediment transport estimates under the second and third scenario appear in Figure 11-37. Similar to the first scenario, the direction of the net sediment transport was not consistent with the two sediment budgets. However, when

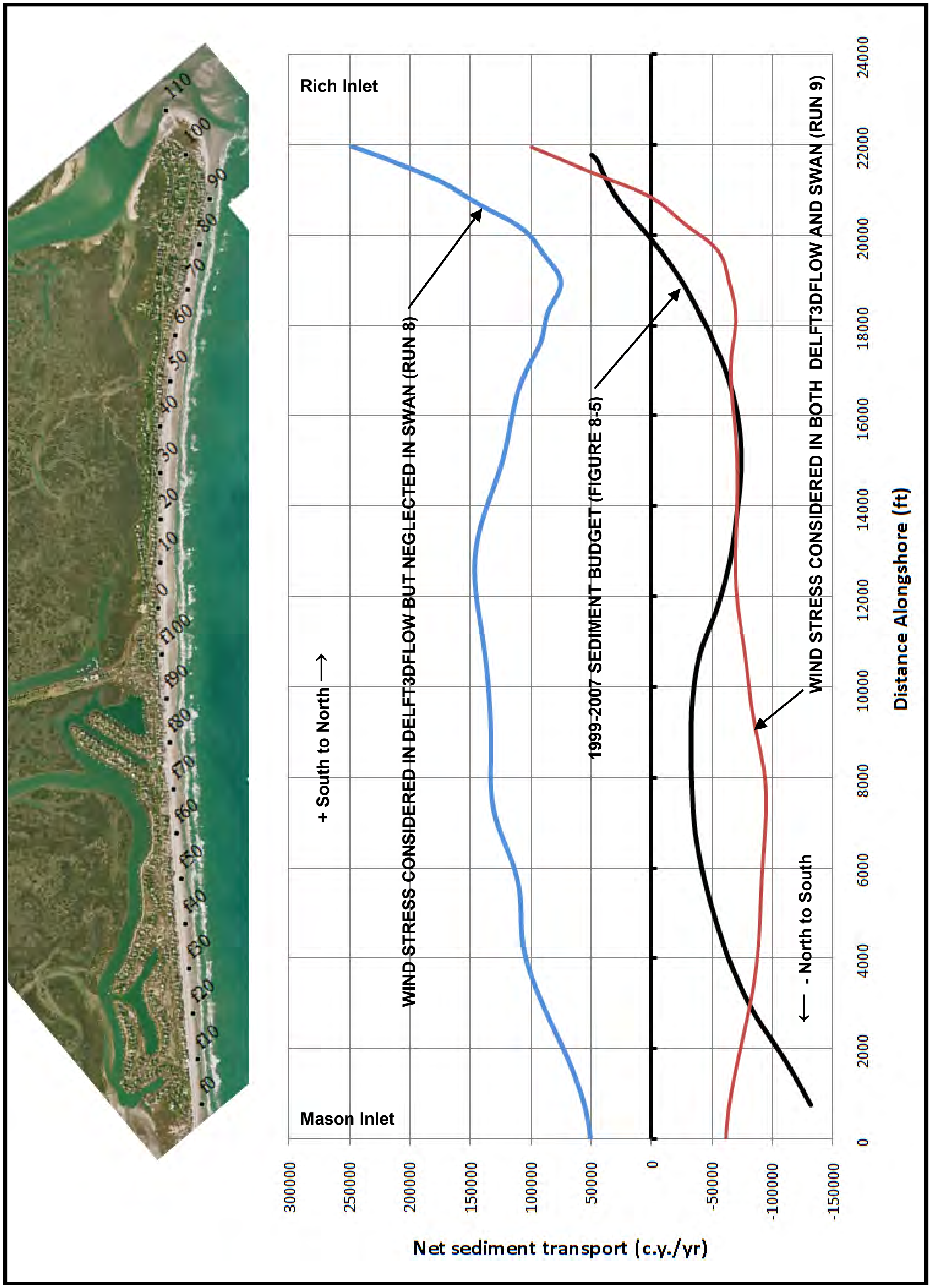

FIGURE 11-37: Sensitivity of Net Sediment Transport to the Activation of Wind Stress in Delft3DFLOW and SWAN.

wind stress was activated within both SWAN and Delft3DFLOW, the simulated sediment transport was closer to the 1999-2007 sediment budget. Subsequent simulations found that wind stress was not a critical factor in the Delft3DFLOW model, even though its application was necessary in the SWAN model. Accordingly, the final calibration run (not shown in Figure 11-37) utilized wind stress in the SWAN model but neglected wind stress in the Delft3DFLOW model. The results of the final calibration run are discussed in the next section.

11.3.4 Sediment Transport Parameters and Other Model Settings

The final phase of the calibration process considered the various sediment transport parameters in the model, along with the sequencing of the wave cases, the time step, the grid spacing, and other model settings. Over 40 calibration runs were performed during this phase. The final calibration run utilized the April 2005 survey as the primary bathymetric data source for the initial conditions, followed by the other data sources listed in Section 11.2.1. Grids were identical to those used in Figures 11-10 and 11-11. The duration of the model run was from April 2005 to April 2012.

A comparison of the simulated and observed volume changes on Figure Eight Island between April 2005 and October 2008 appear in Figure 11-38. Overall, the simulated volume changes are consistent with the observed volume changes. Both indicate a high level of erosion on the north end of the island (Surf Court to Rich Inlet, 70+00 to 110+00), mild erosion between profiles 30+00 and 70+00, and stable beaches between Backfin Point Road (F80+00) and profile 30+00. The model results do not follow the observed changes exactly. However, all of the general erosion patterns along the island's beaches are represented.

On Hutaff Island, the volume changes between April 2005 and April 2007 were anomalous due to the formation of a swash into Rich Inlet during Hurricane Ophelia in October 2005 (see Section 7.0). Since the 12 wave cases in Table 11-5 did not specifically include a Category 1 hurricane, a direct comparison of the model results to the storm-dominated changes was not appropriate. However, the model results followed the general erosion patterns on Hutaff Island between 1996 and 2000, which were characterized by accretion on the south end of the island (profiles 145+00 to 175+00) and erosion to the north (see Figure 11-39).

Net sediment transport during the final calibration run appears in Figure 11-40. In general, the sediment transport predicted by the model on the north end of Figure Eight Island is consistent with the short-term sediment budget in Figure 8-4.

Based on the results in Figures 11-38 to 11-40, the Delft3DFLOW and SWAN model provide a realistic description of the waves (Figures 11-41 and 11-42), currents (Figures 11-23 and 11-29), and erosion patterns (Figures 11-38 and 11-39) along Figure Eight Island and Hutaff Island. Accordingly, the model setup in Tables 11-5 and 11-6 was adopted to evaluate the various erosion control alternatives in Section 9.0.

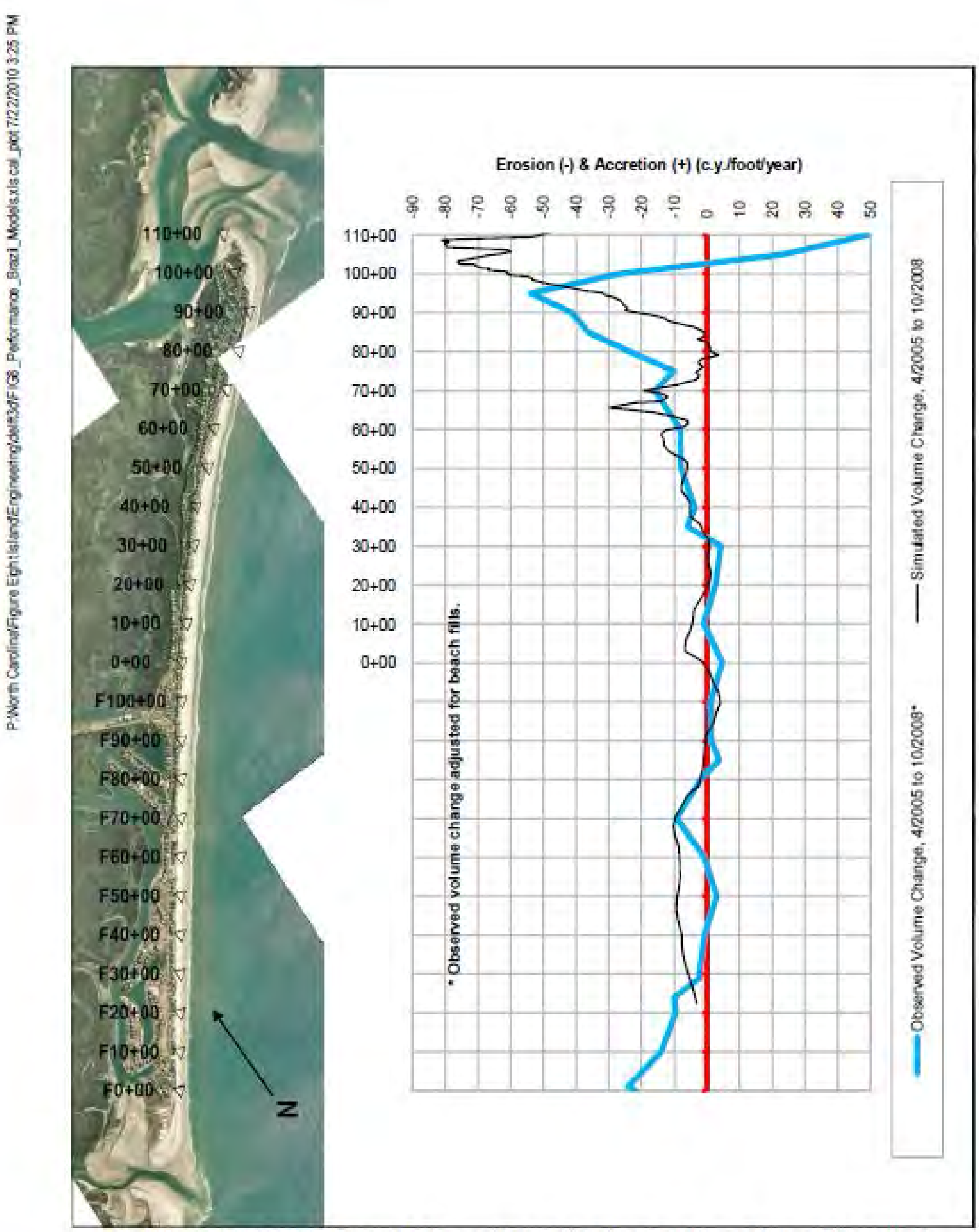

FIGURE 11-38: Delft3D Erosion & Deposition Calibration Results on Figure Eight Island.

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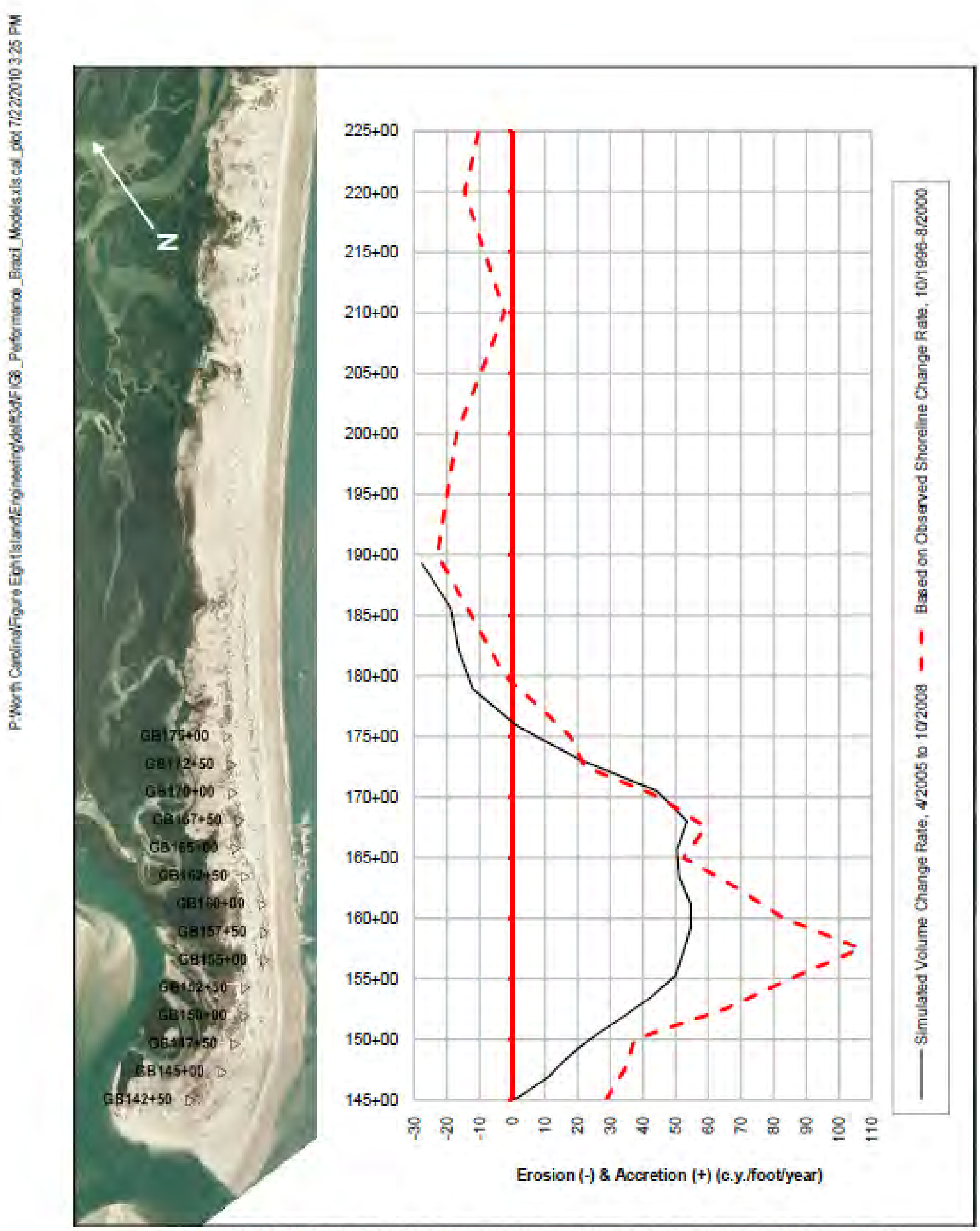


FIGURE 11-39: Delft3D Erosion & Deposition Calibration Results on Hutaff Island.

FIGURE 11-40: Comparison of the Net Longshore Sediment Transport Based on the Final Delft3D Calibration Run and the 2005-2007 Sediment Budget.

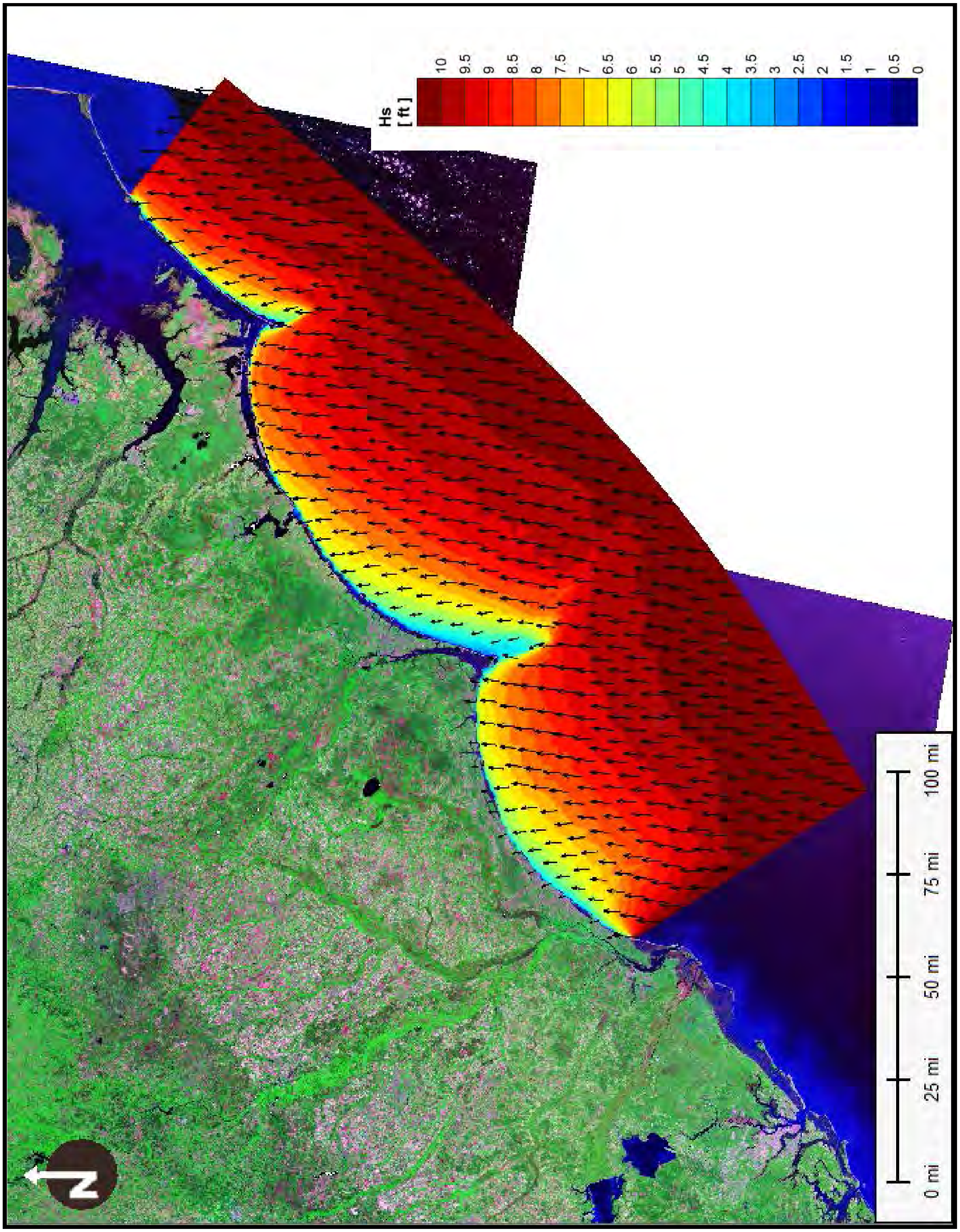


FIGURE 11-41: Typical Wave Transformation Patterns on the Regional Wave Grid (Offshore Boundary Condition - Hs: 10.3 feet; Tp: 7.3 seconds; Dir: 187 degrees).

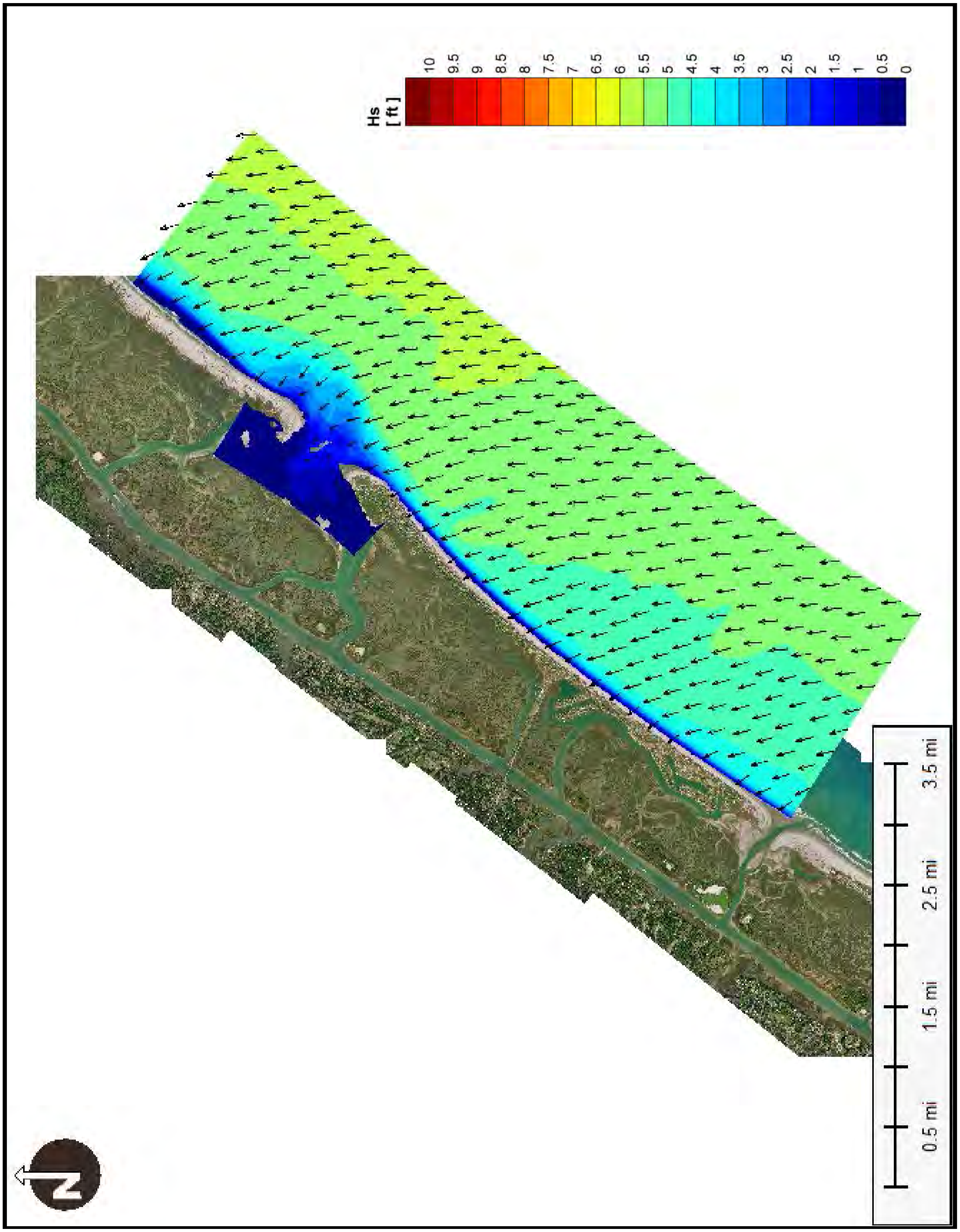


FIGURE 11-42: Typical Wave Transformation Patterns on the Local Wave Grid (Offshore Boundary Condition - Hs: 10.3 feet; Tp: 7.3 seconds; Dir: 187 degrees).

TABLE 11-6
DELFT3FLOW AND SWAN MODEL SETUP
FIGURE EIGHT ISLAND, NC

SWAN model parameters	
Gravity	9.81 m/s² (32.2 feet/s²)
Water Density	1025 kg/m³ (64 lbm/foot³)
Min. Depth for Computations	0.05 m (0.16 feet)
Spectra Type	JONSWAP
Peak Enhancement Factor	3.3
Directional Space	0 to 360 deg.
Number of Direction Bands	36
Lowest Frequency	0.05 hz
Highest Frequency	1 Hz
Number of Frequency Bands	24
Depth Induced Breaking - α_b	1
Depth Induced breaking – γ (H_b/d_b)	0.73
Bottom Friction Roughness Scale	0.01 m (0.4")
Diffraction Smoothing Coefficient	0.2
Diffraction Smoothing Steps	5
Frequency Shift	Activated
Refraction	Activated
Wind growth	Activated
Whitecapping	Activated
Quadruplets	Activated
Percent Accuracy to Accept Iteration	95%
Max. Number of Iterations	15
DELFT3DFLOW Hydrodynamic Parameters	
Number of Vertical Layers	5
Time Step	30 seconds
East Boundary Type	Water level – Harmonic
East Boundary Amplitude & Period	2.17 feet / 745 minutes
East Boundary Reflection Parameter α	0
North Boundary Type	Zero Gradient (Neumann)
South Boundary Type	Zero Gradient (Neumann)
Gravity	9.81 m/s² (32.2 feet/s²)
Water Density	1025 kg/m³ (64 lbm/foot³)
Roughness Chezy	(see Figure 11-19)
Stress Formulation Due To Wave Forces	Fredsoe
Horizontal Eddy Viscosity	5 m^2/s (52 $foot^2/s$)
3-D Turbulence Model	K-Epsilon
Advection Scheme For Momentum	Cyclic
Advection Scheme For Transport	Cyclic
Horizontal Forester Filter	Activated
Freshwater Discharges	No

TABLE 11-6 (continued)
DELFT3FLOW AND SWAN MODEL SETUP
FIGURE EIGHT ISLAND, NC

DELFT3DFLOW Sediment Transport and Morphology Parameters	
Reference Density for Hindered Setting	1600 kg/m³ (99.9 lbm/foot³)
Specific Density	2650 kg/m³ (165.4 lbm/foot³)
Dry Bed Density	1600 kg/m³ (99.9 lbm/foot³)
Median Diameter	0.3 mm
Update Bathymetry During Simulation	Yes
Spin Up Period	725 minutes
Min. Depth for Sediment Calculation	0.1 m (4")
VanRijn Reference Height Factor	1 (2")
Threshold Sediment Thickness	0.05 m
Estimated Ripple Height Factor	2
Dry Cell Erosion Factor (THETSD)	1
Multiplication Factor For Suspended Sed. Ref. Concentration (SUS)	1.4
Multiplication Factor For Bed-Load Transport Vector Magnitude (BED)	0.8
Wave-Related (Orbital Motions) Suspended Sed. Transport Factor (SUSW)	0.1
Wave-Related (Orbital Motions) Bed-Load Sed. Transport Factor (BEDW)	0.1
Horizontal Eddy Diffusivity	2 m^2/s (22 $foot^2/s$)

11.4 Future Conditions

Model results given the 1999-2007 wave cases in Table 11-5 and the "worst case" inlet survey (April 2006) are detailed in Sub-Appendix B1 and below. The model results discussed below should be interpreted in relative terms by comparing the model results for the No Action Alternative (Alternative 2) to the results obtained for the other alternatives. In this regard, all model simulations for formulation of the alternatives and evaluating impacts of the alternatives were based on "worst case" conditions that existed along the north end of Figure Eight Island in 2006-07. At that time, the bar channel of Rich Inlet had migrated to a point near the south end of Hutaff Island and the channel had assumed an alignment toward Hutaff Island. Under these inlet bar channel conditions, the north end of Figure Eight Island normally experiences severe erosion. It is these "worst case" conditions the beach and inlet management plan is addressing.

In 2010, the bar channel of Rich Inlet assumed an alignment toward the north end of Figure Eight Island which has resulted in an ephemeral build-up of material along the north end of the island. Given the historic behavior of Rich Inlet, as discussed by Dr. William J. Cleary in Sub-Appendix A of the Engineering Report (Appendix B), this condition is not expected to prevail for any substantial period of time and the channel will again swing toward Hutaff Island resulting in a renewed round of severe erosion.

If implementation of one of the management alternatives occurs within the near future, the conditions at the time of implementation will likely be similar to the conditions existing in 2012. Therefore, Delft3D model simulations were conducted using 2012 inlet and shoreline data as the initial model conditions. The model simulations with the 2012 initial conditions were run for Alternatives 2, 3, 4, and 5D.

11.4.1 Alternative 1 – No Action

Alternative 1 assumes that the present strategies to manage the island's shoreline in Table 6-2 will continue into the future. As shown in Table 6-2, dredging and fill operations around Figure Eight Island are highly variable in terms of timing and quantity, since they are dependent on decisions made by the Association, State agencies, and the Federal government. This sort of uncertainty cannot be incorporated into the Delft3D model. For this reason, Alternative 1 was not simulated.

11.4.2 Alternative 2 – Abandon/Retreat

Alternative 2 assumes that there will be no more beach fill, dune maintenance, inlet maintenance, or sand bag placement operations. Accordingly, this alternative is the true "Without-Project" scenario, and is the basis for evaluating the performance and impacts of the other alternatives. It is important to note that Alternative 2 does *not* approximate what occurred between 2006 and 2012.

In general, the model results suggest that given eroded conditions similar to those in 2006, the main channel of Rich Inlet would migrate towards the middle of the inlet (Figure 11-43 and Sub-Appendix B1). As part of this process, the flood channel on the southwestern side of the inlet, which connects Nixon Channel to the ocean, would start to close. Within Nixon Channel, the depth near the north end of Beach Road would have increased from -16 feet NAVD to -23 feet NAVD. These changes would be accompanied gains on the southern tip of Hutaff Island and severe erosion and shoreline retreat on the north end of Figure Eight Island (see Figure 11-44).

Under a scenario similar to the 2012 conditions, the model results suggest that the main channel of Rich Inlet would change its orientation from north-northwest/south-southeast to west-northwest/east-southeast (see Figure 11-45). These changes would be accompanied by losses on the southern end of Hutaff Island and gains on the sandy area on the south side of Rich Inlet (see Figure 11-46). However, losses would also occur along the beach between profiles 90+00 (Inlet Hook Road) and 105+00 due to the shifting of the ebb shoal. In addition, the south end of Green Channel could shoal in (see Figure 11-45), which is consistent with observations by Dr. William Cleary. Overall, the simulated changes around Rich Inlet given the 2012 conditions are similar to those that occurred between 1993 and 1999 (see Figure 11-47). In both cases, the channel of the inlet switches its orientation, resulting in a shifting of the ebb shoal and narrowing of the beach near Inlet Hook Road.

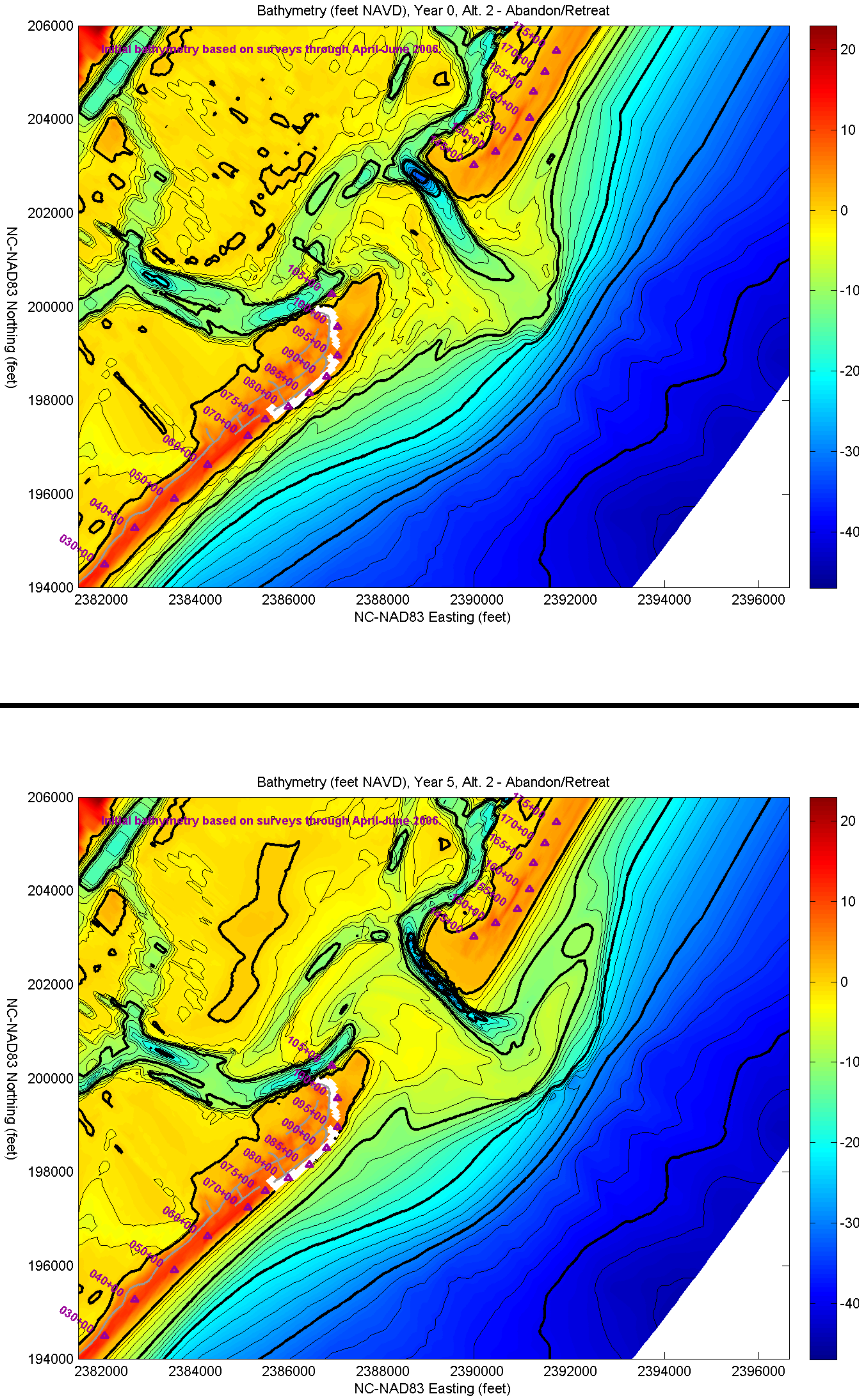


FIGURE 11-43: Delft3D Bathymetry in Rich Inlet at Years 0 and 5 for the 2006 Eroded Conditions and Alternative 2.

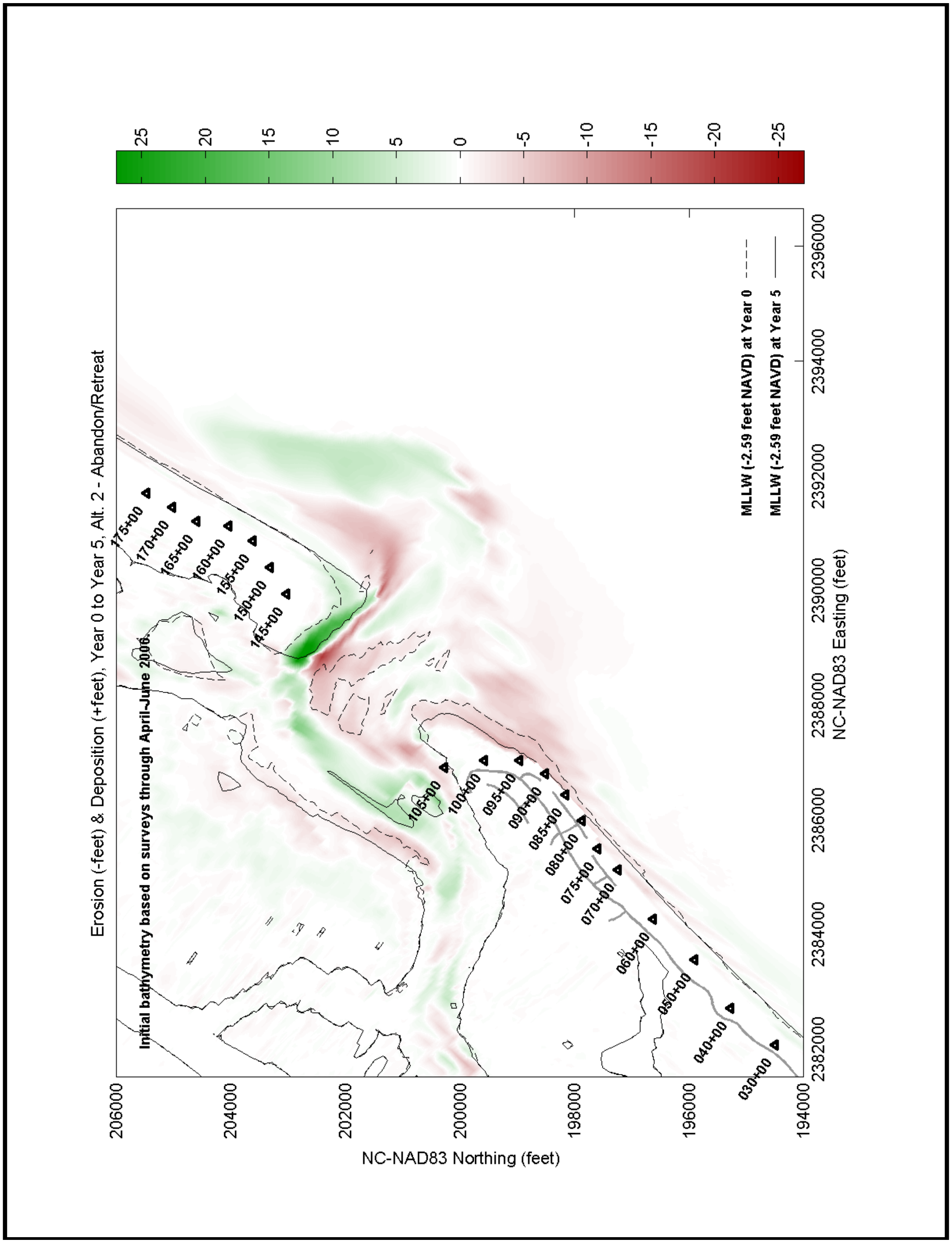


FIGURE 11-44: Delft3D Erosion and Deposition for the 2006 Eroded Conditions and Alternative 2.

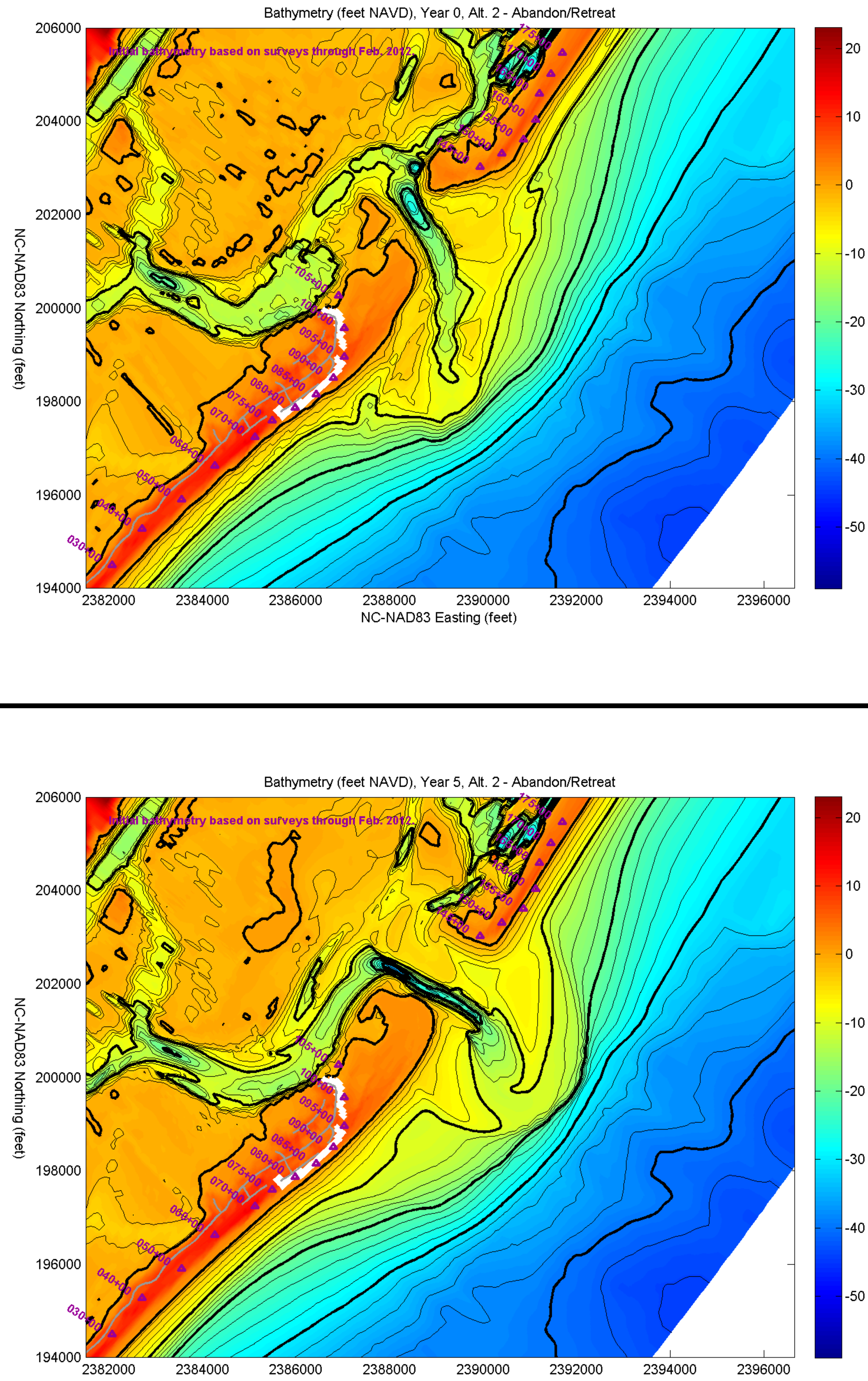


FIGURE 11-45: Delft3D Bathymetry in Rich Inlet at Years 0 and 5 for the 2012 Conditions and Alternative 2.

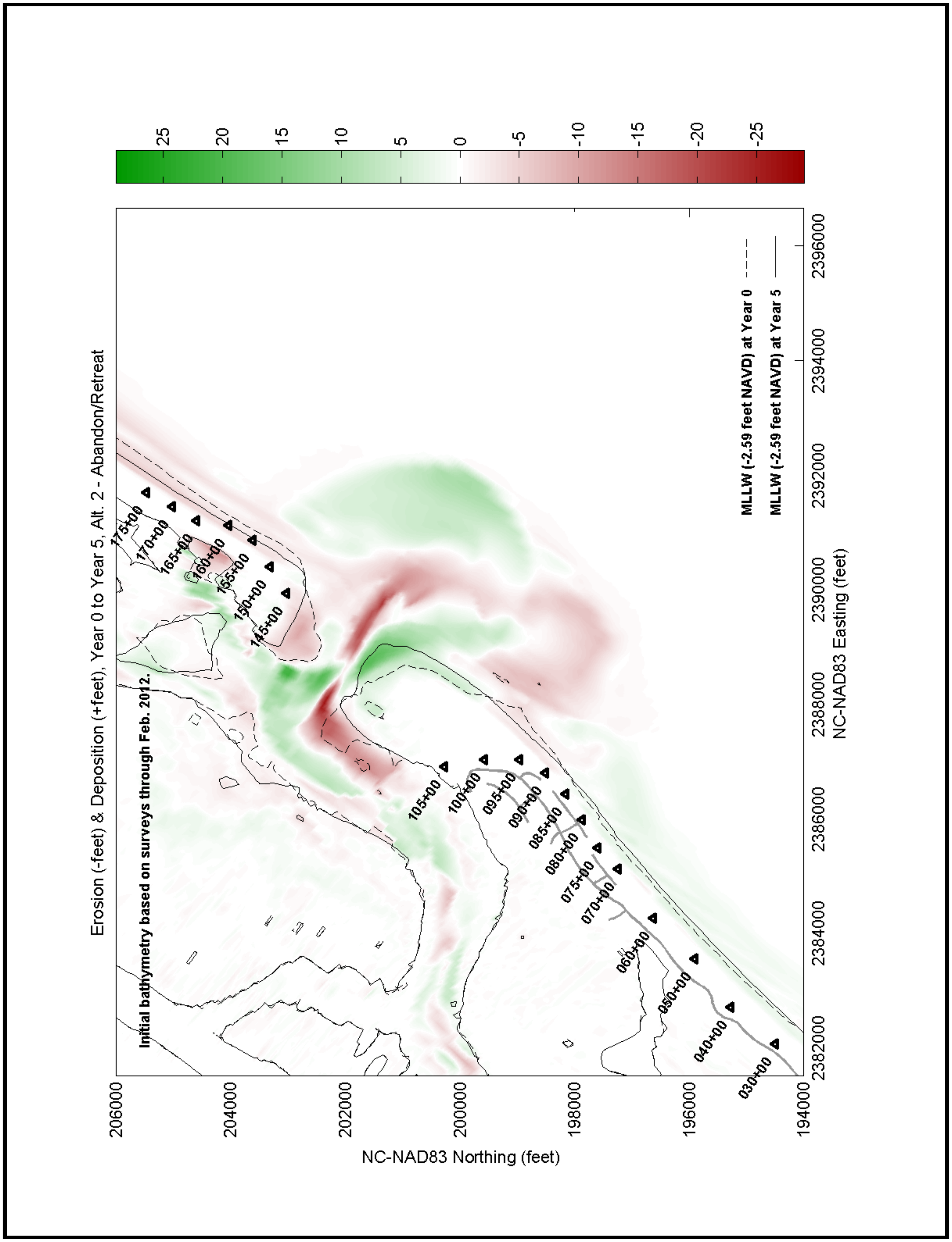


FIGURE 11-46: Delft3D Erosion and Deposition for the 2012 Conditions and Alternative 2.

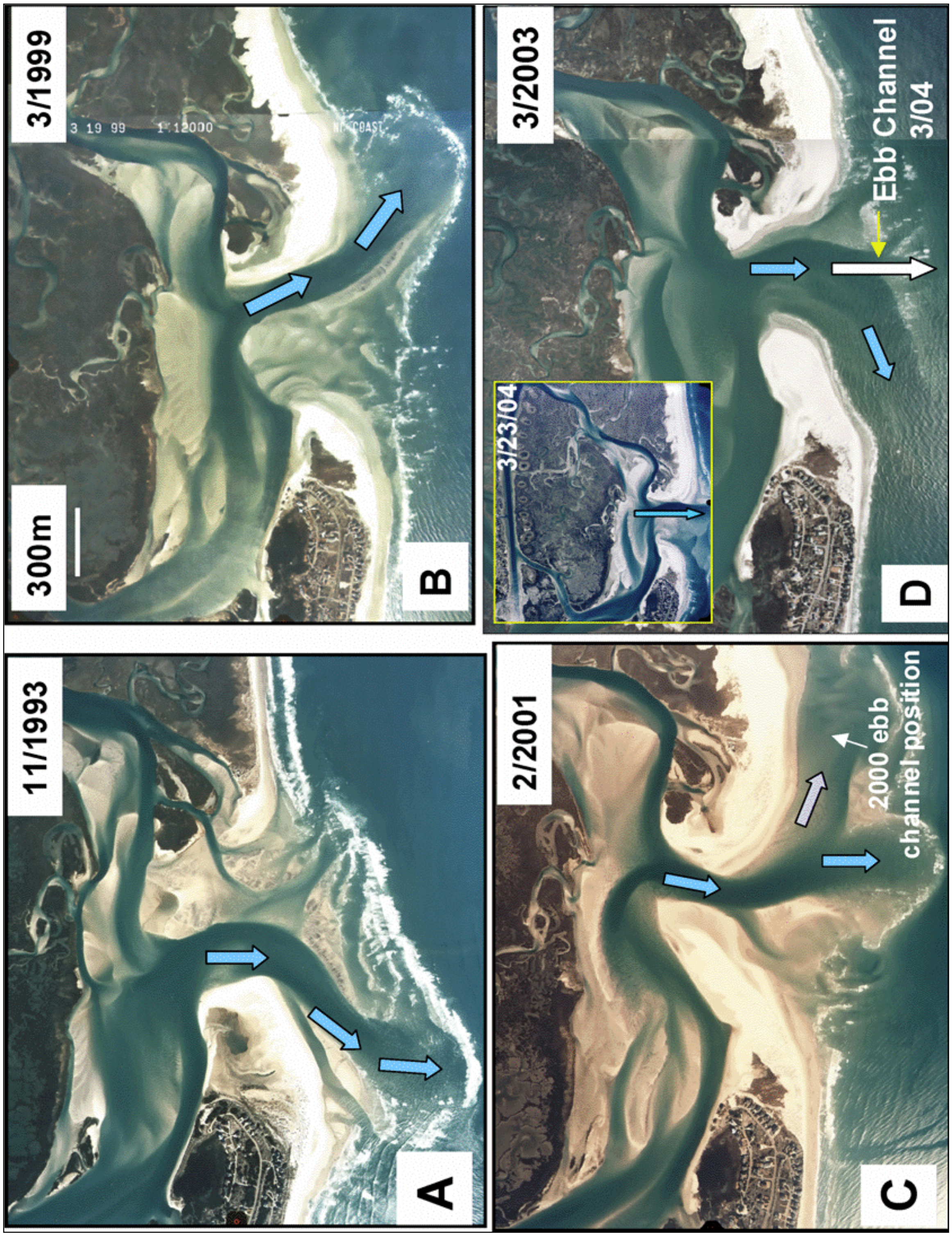


FIGURE 11-47: **Aerial photographs of Rich Inlet (11/1993-3/2004). Photographs A-D depict shoreline changes related to deflection of ebb channel (blue arrows) and subsequent repositioning and reorientation through ebb delta breaching in late 2002 (C) and late 2003 after channel deflected toward Figure Eight Island (D). Insert in D shows ebb channel as of March 2004 (Figure and caption from Cleary & Jackson, 2004).**

Simulated volume changes along the beach given the 2006 eroded conditions appear in Figure 11-48, Table 11-7, and Sub-Appendix B1. Table 11-7 also includes model indicated volume changes for the other alternatives which will be referenced in the discussion of each respective alternative. Table 11-8 provides the percent of beach fill remaining within two beach segments on Figure Eight Island for all the alternatives that include beach fill. Simulated volume changes along the beach given the 2012 conditions also appear in Sub-Appendix B2.

Model results for Alternative 3 appear in Sub-Appendix B1, Table 11-7, Table 11-8, Table 11-9, and Figures 11-48 through 11-54. Since the Delft3D-FLOW model is not able to incorporate renourishment during a model simulation, these results neglect renourishment at Year 5. It should also be noted that in the model simulations, the beach fill along Nixon Channel was based on a preliminary design with 65,000 cubic yards from profiles RIN12+00 to RIN30+00, rather than the final design with 57,000 cubic yards from profiles RIN16+00 to RIN30+00 only. Given the resolution of the Delft3D-FLOW model, the differences between the preliminary design and the final design do not have a large effect on the model results.

If Alternative 3 were constructed under eroded conditions similar to those in 2006, the straight contours of the initial dredge cut would evolve into a broad arc (see Figure 11-49). The connecting cut into Green Channel could become more constricted over time, although it would not shoal in completely. Within Nixon Channel, the depth near the north end of Beach Road would be similar to the Year 0 condition, allowing some of the fill placed along the adjacent fill area to remain in place at Year 5 (see Figure 11-50). North of profile 85+00 (13 Comber Road), erosion into the pre-construction beach face could occur (see Figure 11-50). However, the degree of erosion would be less than what would occur under the Abandon/Retreat scenario (see Figure 11-51), and the net volume changes over the active profile as a whole (Table 11-7, Figure 11-48) suggest that except for the north taper, complete loss of fill would not occur before Year 5. Refilling of the designated dredge cut would provide enough material for renourishment (see Figure 11-49 and Table 11-9). On Hutaff Island, erosion rates could increase south of profile 175+00. However, 2/3 of the closure dike that would adjoin the southern tip of the island would remain in place (see Figures 11-49 through 11-51).

If Alternative 3 were constructed under conditions similar to those in 2012, the main channel of Rich Inlet would evolve to a west-northwest/east-southeast orientation (see Figure 11-52). The connection between the entrance channel and Green Channel would remain open, fulfilling the intent of that design feature. Along Nixon Channel, much of the fill placed at Year 0 would still be remaining at Year 5 (see Figure 11-53). However, along the oceanfront, erosion into the pre-construction profile could occur by Year 5 north of profile 85+00 (13 Comber Road) (see Figure 11-53 and Sub-Appendix B1). The degree of erosion would be greater than what would occur under the Abandon/Retreat scenario (see Figure 11-54). Along Hutaff Island, project-related impacts north of profile 145+00 would be relatively small (see Figure 11-54).

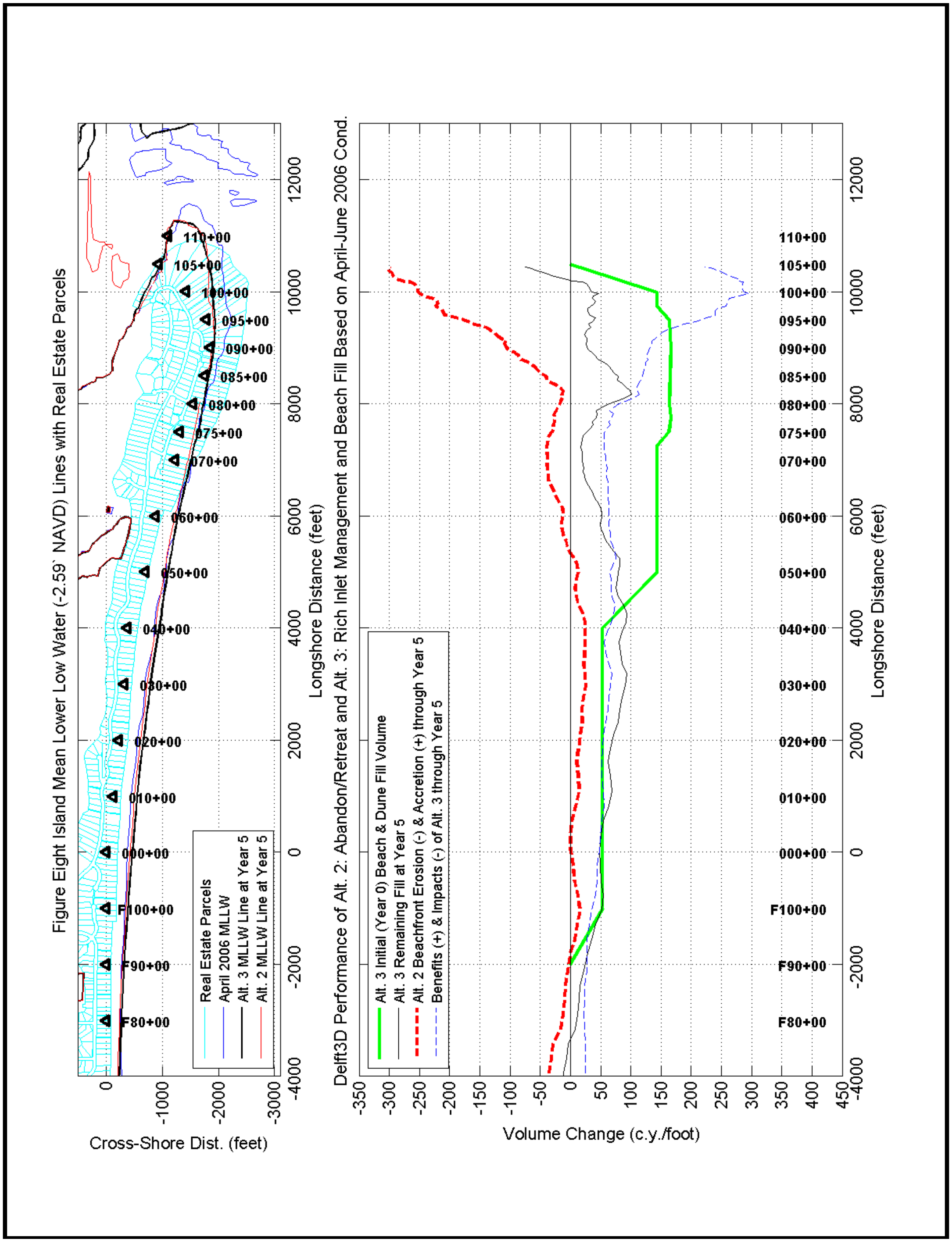


FIGURE 11-48: Delft3D Volume Changes for the 2006 Eroded Conditions and Alternatives 2 and 3.

TABLE 11-7
DELFT3D VOLUME CHANGES GIVEN THE 2006 ERODED CONDITIONS

Profile Lines	Beach Length (feet)	Volume Change (cubic yards) At the end of Year 5 of the Simulation Alt. 2	Alt. 3	Alt. 4	Alt. 5C	Alt. 5D	Alt. 5B in DEIS
FIGURE EIGHT ISLAND							
F90+00 to 60+00	8,001	+88,000	-11,000	+148,000	+102,000	+316,000	+251,000
60+00 to 105+00	4,500	-420,000	-495,000	-881,000	-467,000	-288,000	-257,000
HUTAFF ISLAND							
148+60 to 175+00	2,640	+265,000	-155,000	+285,000	-165,000	+365,000	+360,000
175+00 to 215+00	4,000	-175,000	-130,000	-150,000	-260,000	-100,000	-105,000

TABLE 11-8
DELFT3D PERCENT OF BEACH FILL REMAINING GIVEN THE 2006 ERODED CONDITIONS

Alternative	Shoreline Segment	Percent of Beach Fill Remaining After Year: 0 (Fill Volume cy)	1	2	3	4	5
2	F90+00 to 60+00	0	NA	NA	NA	NA	NA
	60+00 to 105+00	0	NA	NA	NA	NA	NA
3	F90+00 to 60+00	537,000	99.4%	108.2%	109.9%	106.7%	98.0%
	60+00 to 105+00	654,000	72.2%	60.9%	51.1%	43.3%	24.5%
4	F90+00 to 60+00	255,000	124.3%	151.4%	165.1%	168.6%	158.0%
	60+00 to 105+00	656,000	57.0%	30.5%	6.4%	-16.3%	-34.3%
5C	F90+00 to 60+00	429,000	104.4%	116.6%	121.4%	124.9%	123.8%
	60+00 to 105+00	479,000	64.3%	41.5%	25.9%	13.4%	2.5%
5D	F90+00 to 60+00	0	NA	NA	NA	NA	NA
	60+00 to 105+00	238,000	80.2%	45.0%	24.3%	10.4%	-21.2%
5B (DEIS)	F90+00 to 60+00	0	NA	NA	NA	NA	NA
	60+00 to 105+00	198,000	59.6%	33.8%	10.1%	-7.6%	-29.8%

TABLE 11-9
DELFT3D DREDGE MAINTENANCE VOLUMES
EIS ALT. 3 WITH PREFERRED DREDGING OPTION
2006 ERODED CONDITIONS

Year	Re-Dredging Volume to Design Depth (-19' NAVD) (c.y.)			
	Entrance Channel	Nixon Channel	Green Channel	TOTAL
0	0	0	0	0
1	202,000	10,000	72,000	284,000
2	430,000	20,000	173,000	623,000
3	571,000	70,000	142,000	783,000
4	641,000	103,000	132,000	876,000
5	666,000	121,000	140,000	927,000

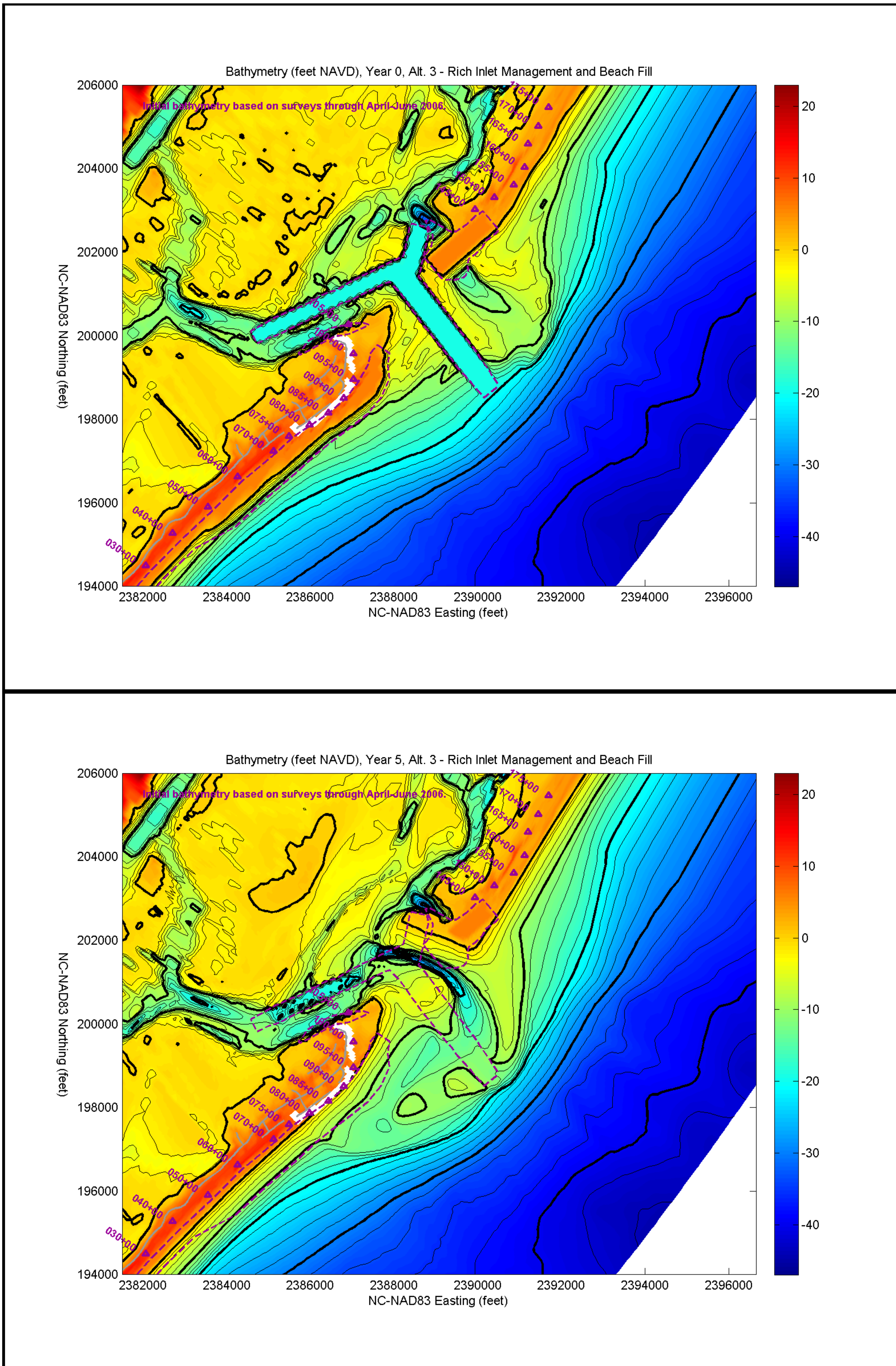


FIGURE 11-49: Delft3D Bathymetry in Rich Inlet at Years 0 and 5 for the 2006 Eroded Conditions and Alternative 3.

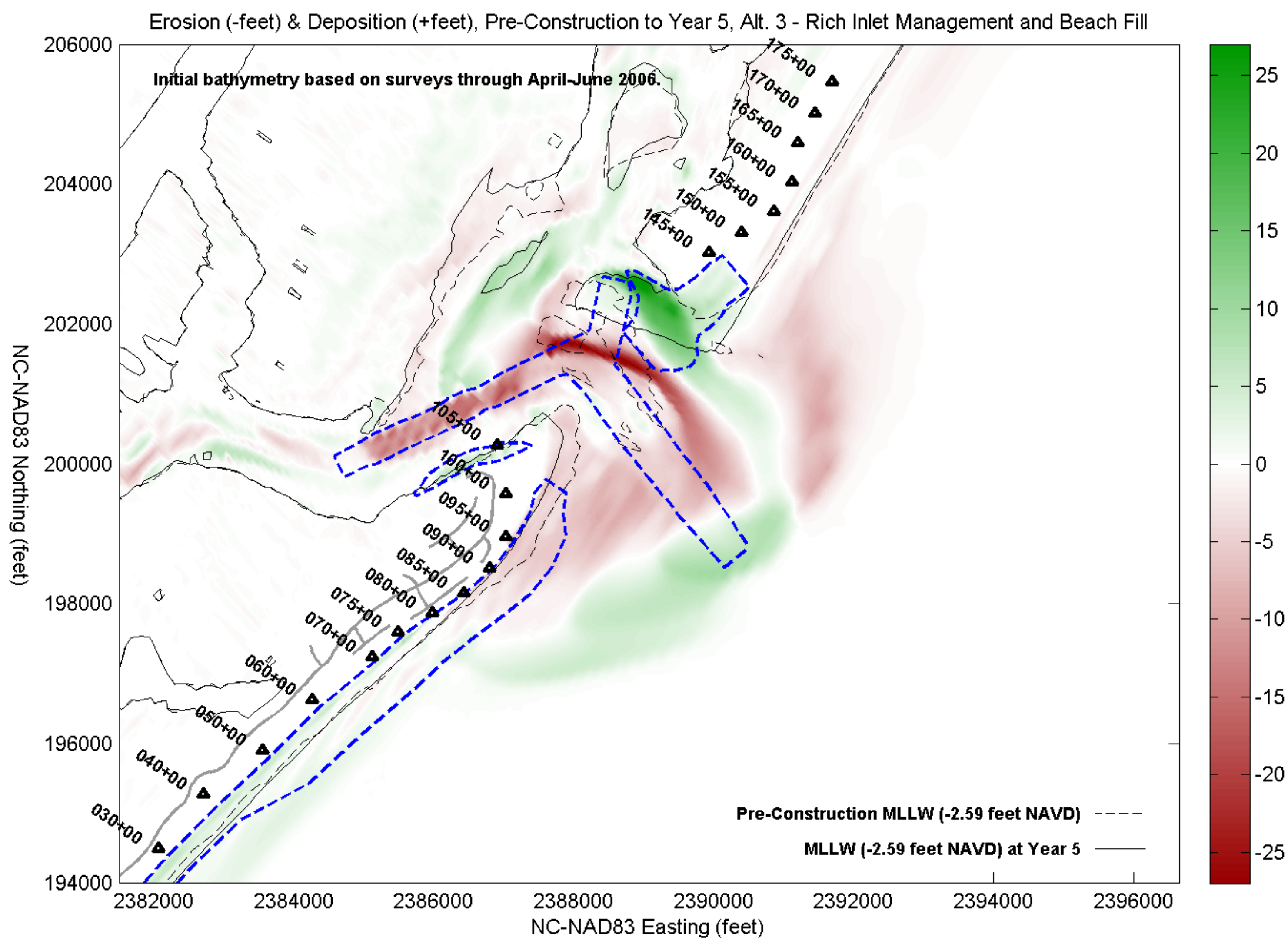


FIGURE 11-50: Delft3D Erosion and Deposition for the 2006 Eroded Conditions and Alternative 3.

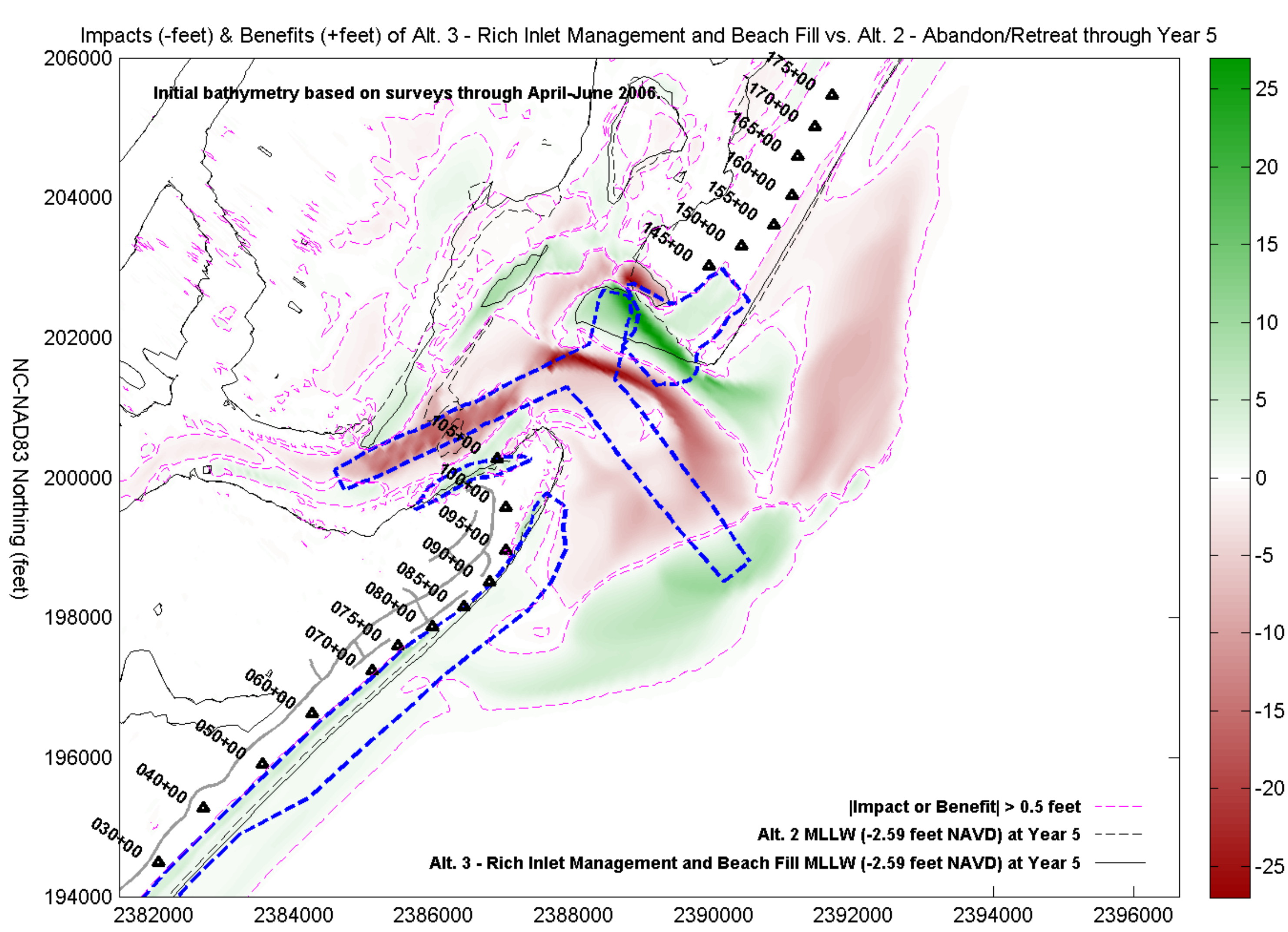
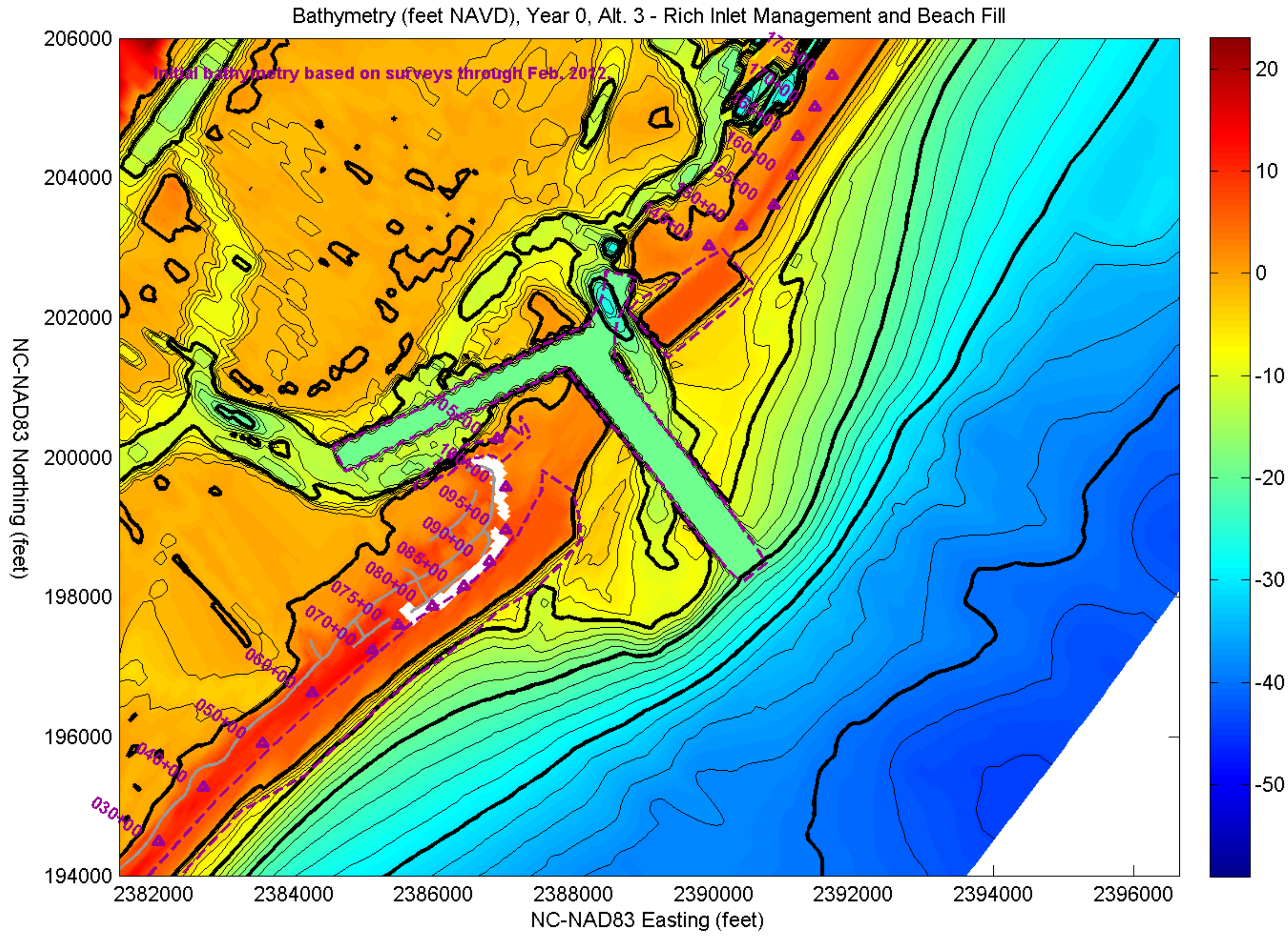


FIGURE 11-51: Impacts and Benefits of Alternative 3 Based on the Delft3D Model and the 2006 Eroded Conditions.



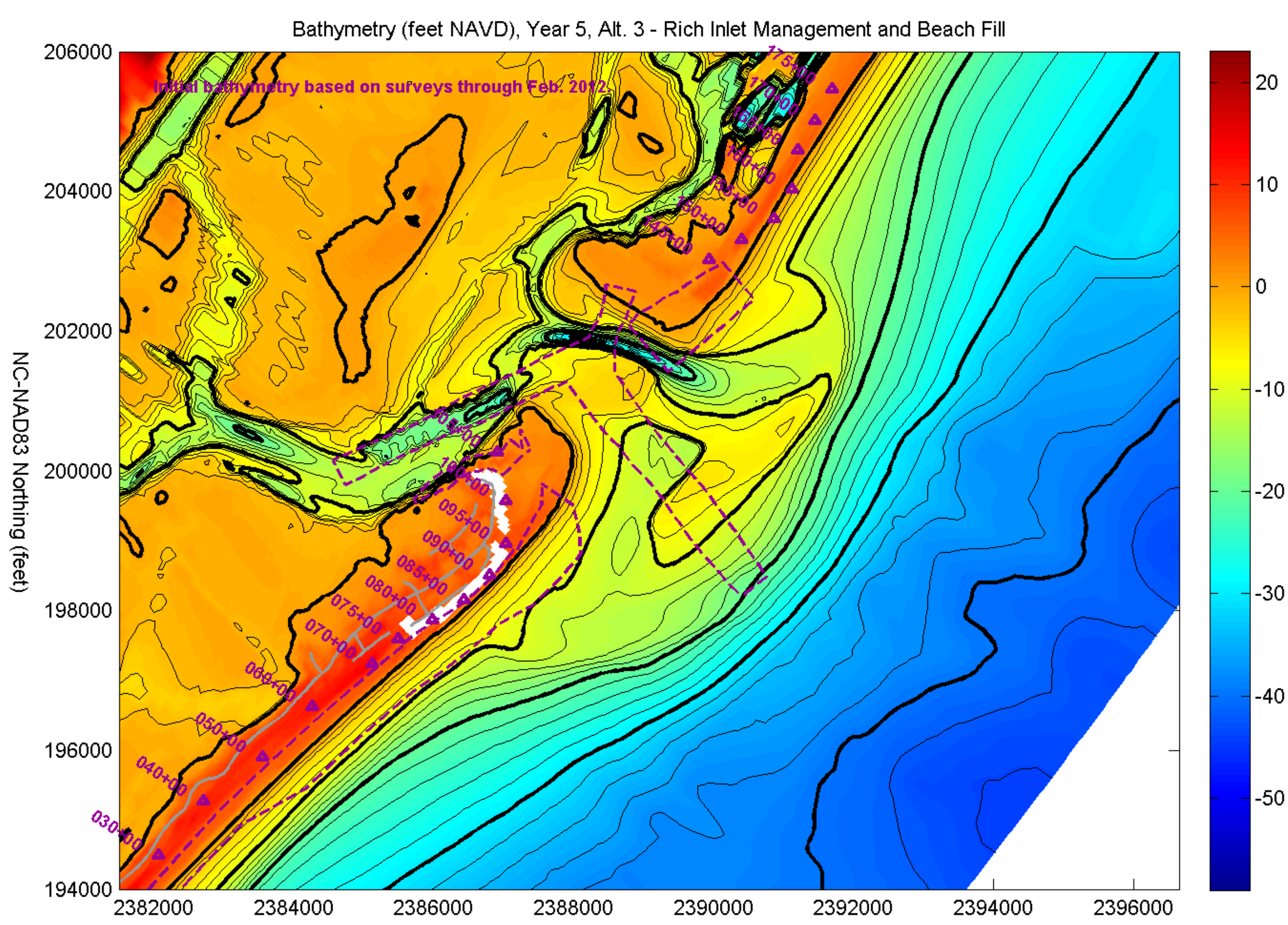


FIGURE 11-52: Delft3D Bathymetry in Rich Inlet at Years 0 and 5 for the 2012 Conditions and Alternative 3.

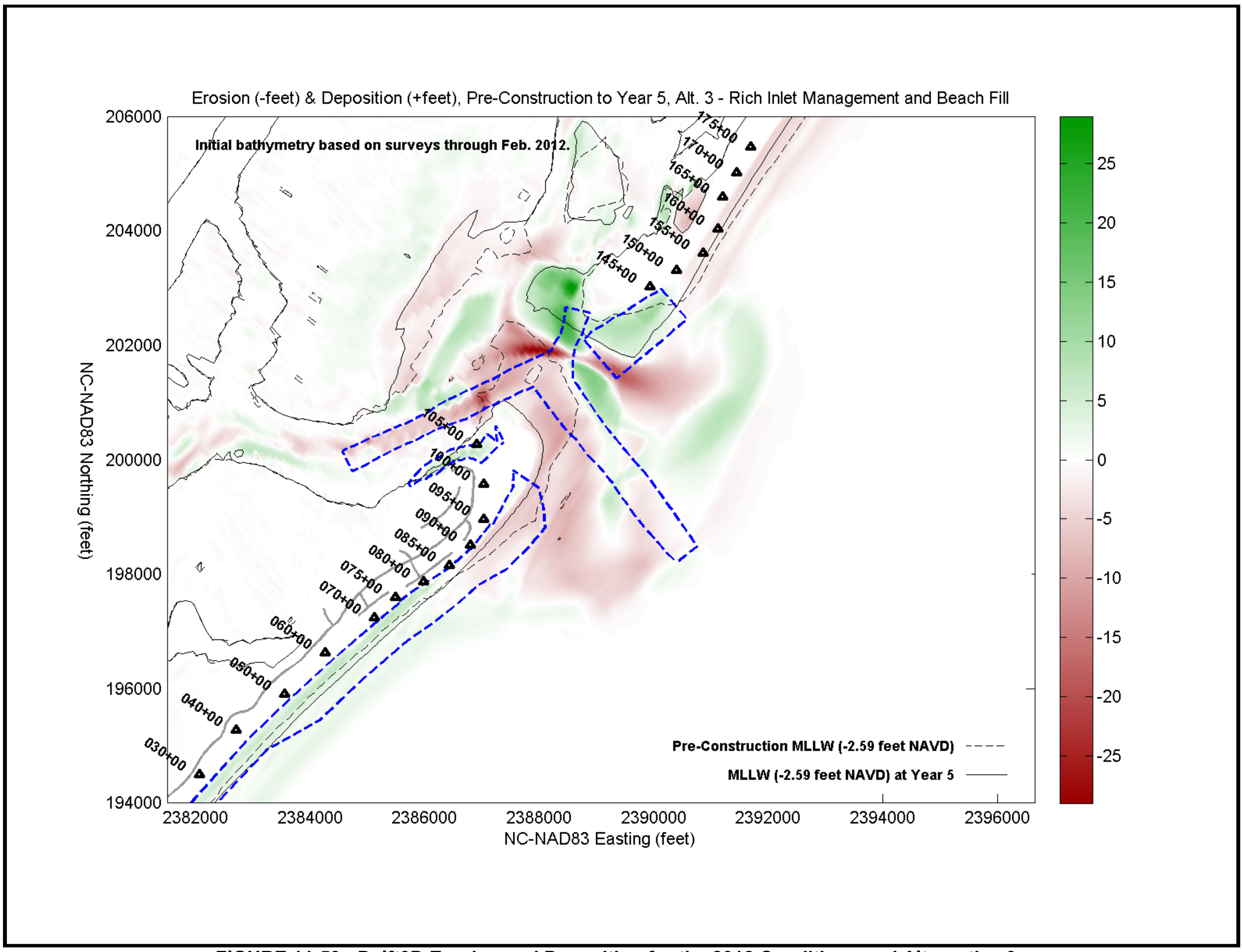


FIGURE 11-53: Delft3D Erosion and Deposition for the 2012 Conditions and Alternative 3.

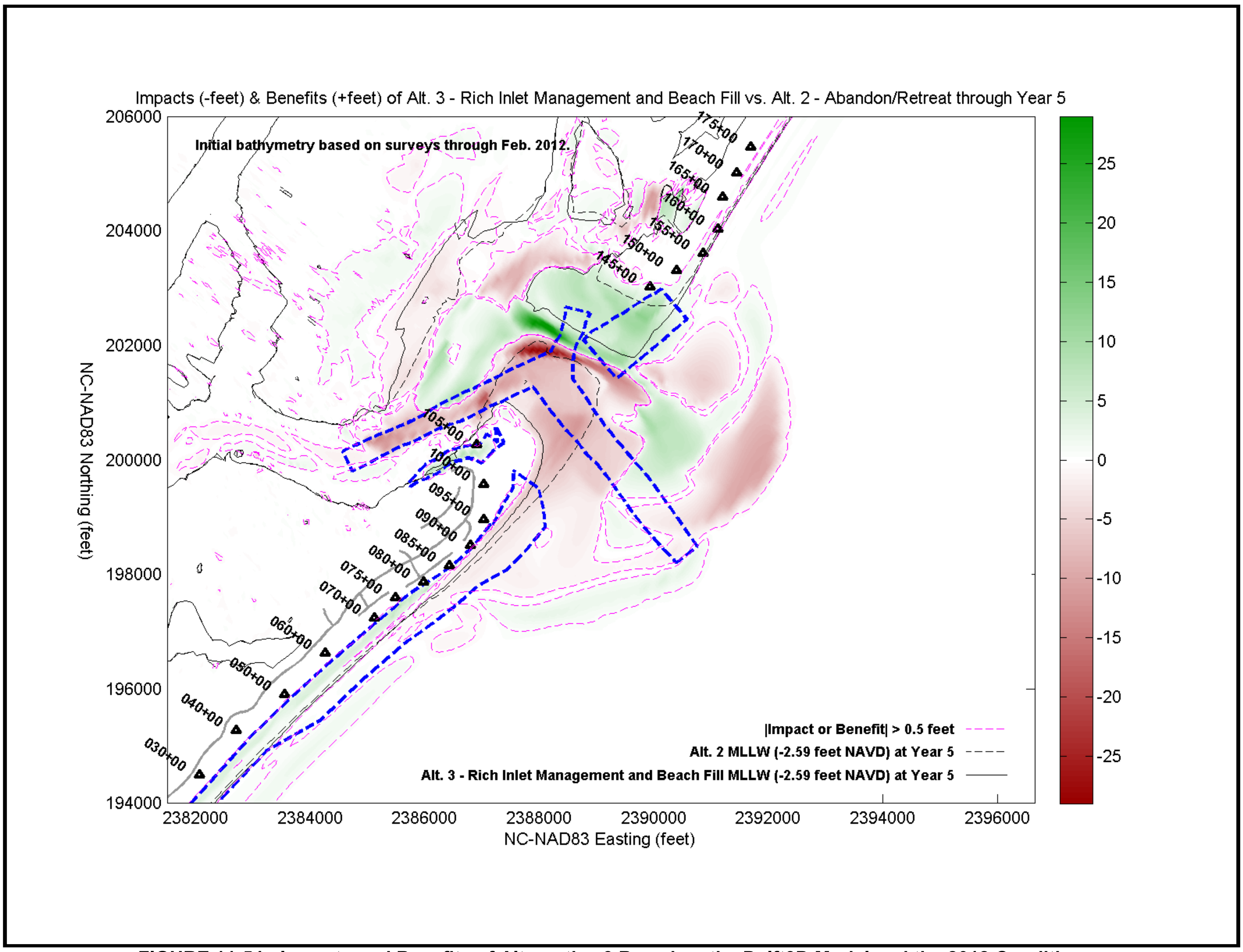


FIGURE 11-54: Impacts and Benefits of Alternative 3 Based on the Delft3D Model and the 2012 Conditions.

11.4.4 Alternative 4 – Beach Fill without Management of Rich Inlet

Model results for Alternative 4 appear in Sub-Appendix B1, Table 11-7, Table 11-8, and Figures 11-55 through 11-61. Since the Delft3D-FLOW model is not able to incorporate renourishment during a model simulation, these results neglect renourishment at Year 4. Similar to Alternative 3, the beach fill along Nixon Channel in the model simulations was based on a preliminary design with 65,000 cubic yards from profiles RIN12+00 to RIN30+00, rather than the final design with 57,000 cubic yards from profiles RIN16+00 to RIN30+00 only.

If Alternative 4 were constructed under eroded conditions similar to those in 2006, Rich Inlet would behave in a manner similar to that of the Abandon/Retreat scenario (compare Figures 11-55 and 11-43). This would also be the case if Alternative 4 were constructed under conditions similar to those in 2012 (compare Figures 11-58 and 11-46).

Volume changes given eroded conditions similar those in 2006 are summarized in Table 11-7 and Figure 11-61. Beach fill performance given Alternative 4 is provided in Table 11-8. North of profile 82+50 (8 Comber Road), erosion into the pre-construction profile would occur by Year 5 or earlier (see also Figure 11-56). The degree of erosion into the pre-construction profile would be considerably higher than that of Alternative 3 (see Table 11-7). However, erosion into pre-construction profile under Alternative 4 would be lower than the erosion obtained for the Abandon/Retreat scenario (see Table 11-7 and Figures 11-57 and 11-61).

Given conditions similar to those in 2012, erosion into pre-construction profile through Year 5 only occurs north of profile 95+00 (Inlet Hook Road) (see Figure 11-59). Since there is no dredging in Rich Inlet, negative impacts to the beach do not occur as they do under Alternative 3 (compare Figure 11-60 with Figure 11-54).

Alternatives 3 and 4 have similar fill layouts. Overall, the model results for the two alternatives suggest that given eroded conditions similar to those in 2006, Alternative 3 performs better (see Table 11-8, Figure 11-51, and Figure 11-57). However, given conditions similar to those in 2012, Alternative 4 appears to perform better than Alternative 3 (see Figure 11-54 and Figure 11-60). The differences in these results are due to the manner in which the dredge cut for Alternative 3 modifies the bathymetry in Rich Inlet, which, in turn, affects the erosion patterns on the adjacent beaches.

None of the alternatives that were simulated matched the sequence of man-made interventions that took place between 2006 and 2012. However, Alternative 4 is the most similar. The differences between Alternative 4 and the actual sequence of events between 2006 and 2012 are the following:

- Fill was placed in two successive operations towards the middle of the study period, rather than a single fill operation at the beginning of the study period.
- The amount of fill was less than the design volume for Alternative 4 (compare Tables 6-1 and 9-5).

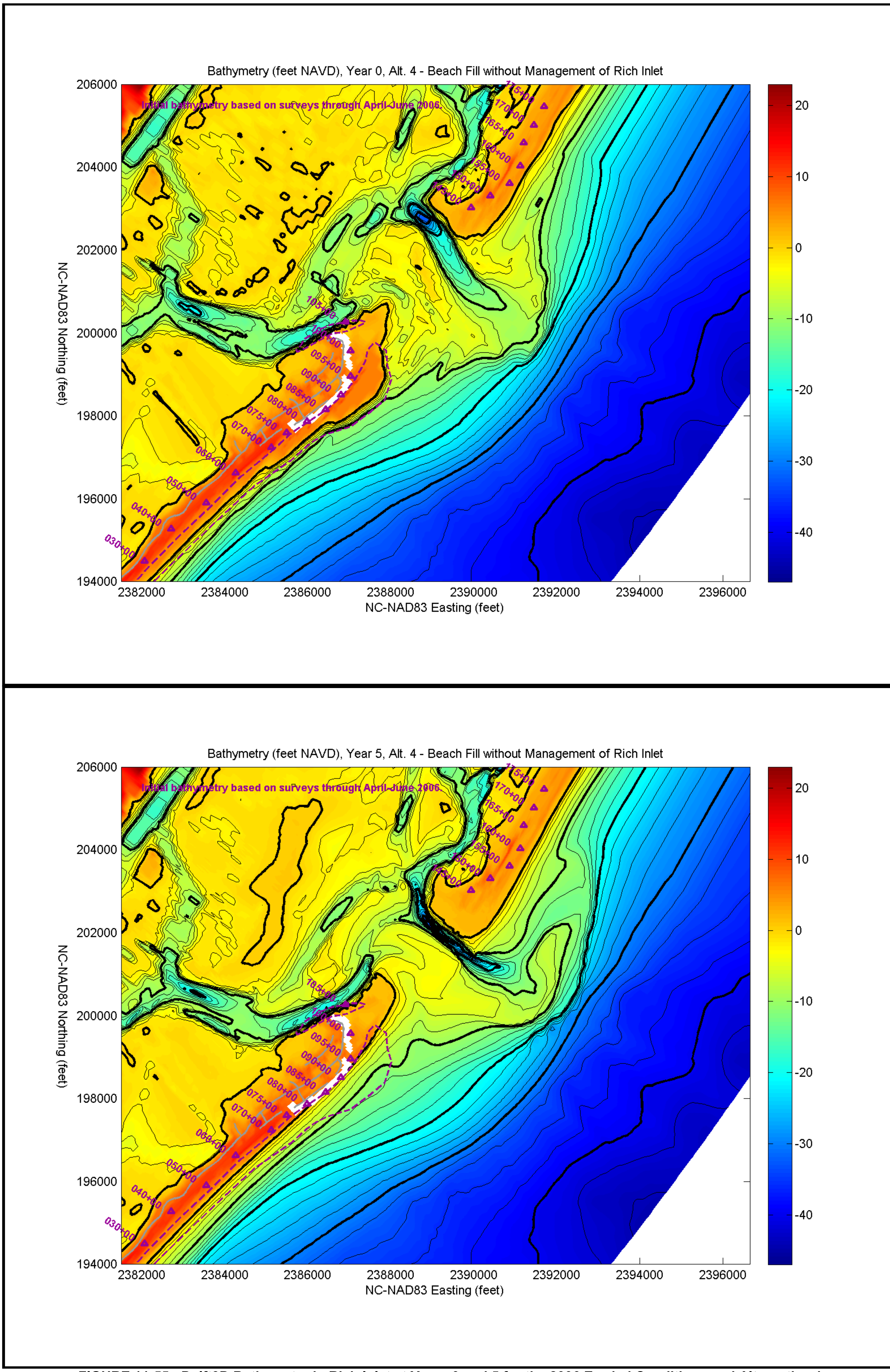


FIGURE 11-55: Delft3D Bathymetry in Rich Inlet at Years 0 and 5 for the 2006 Eroded Conditions and Alternative 4.

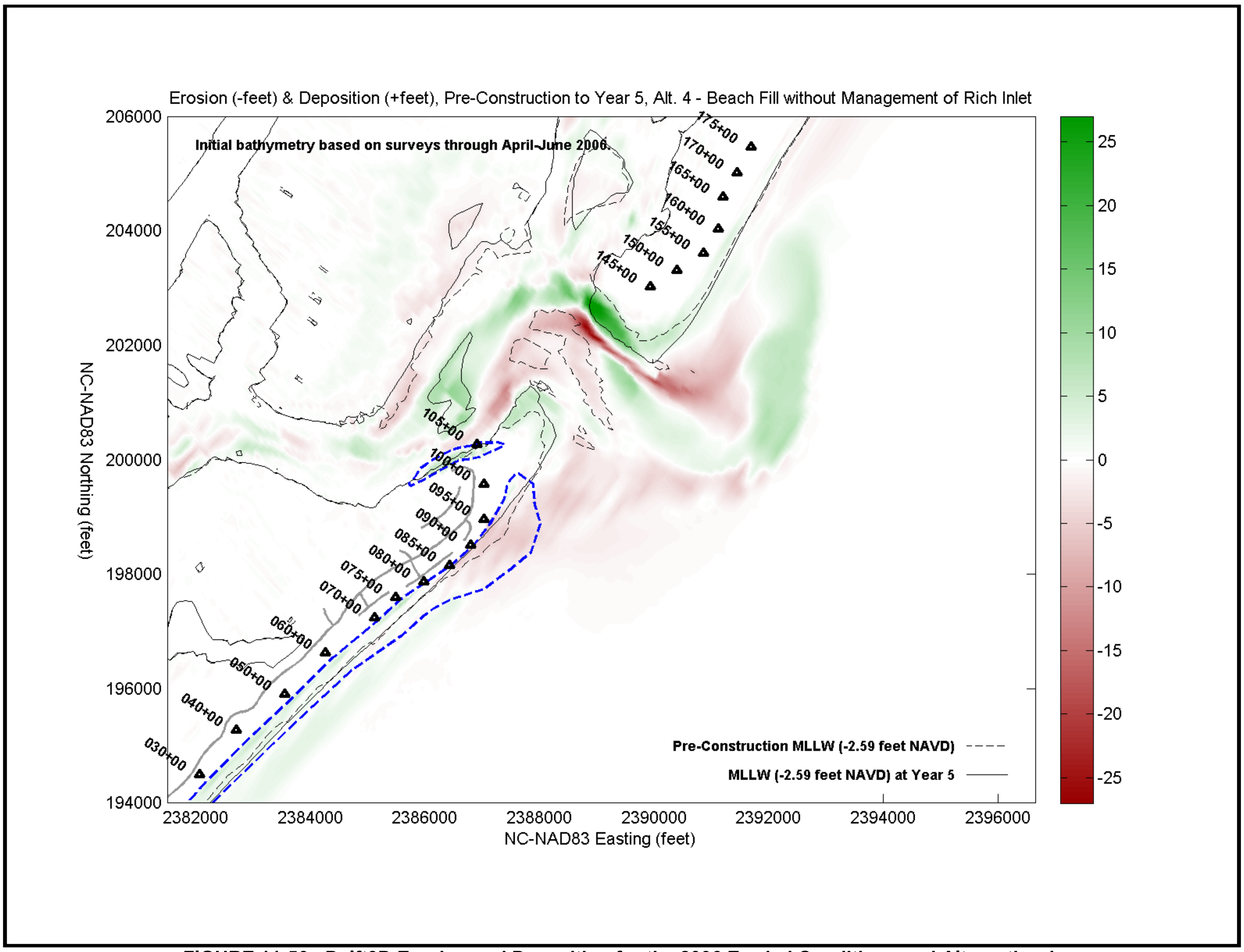


FIGURE 11-56: Delft3D Erosion and Deposition for the 2006 Eroded Conditions and Alternative 4.

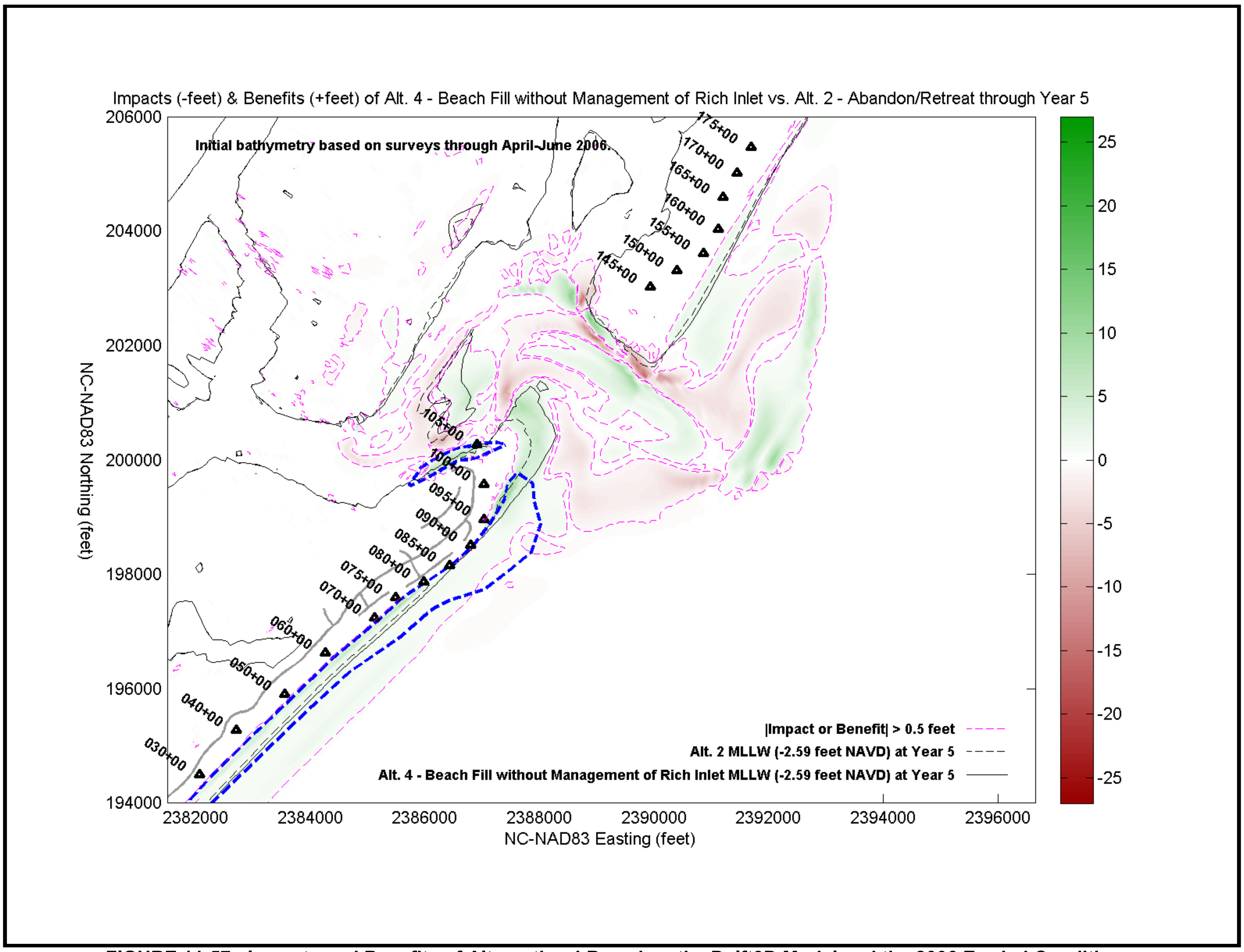


FIGURE 11-57: Impacts and Benefits of Alternative 4 Based on the Delft3D Model and the 2006 Eroded Conditions.

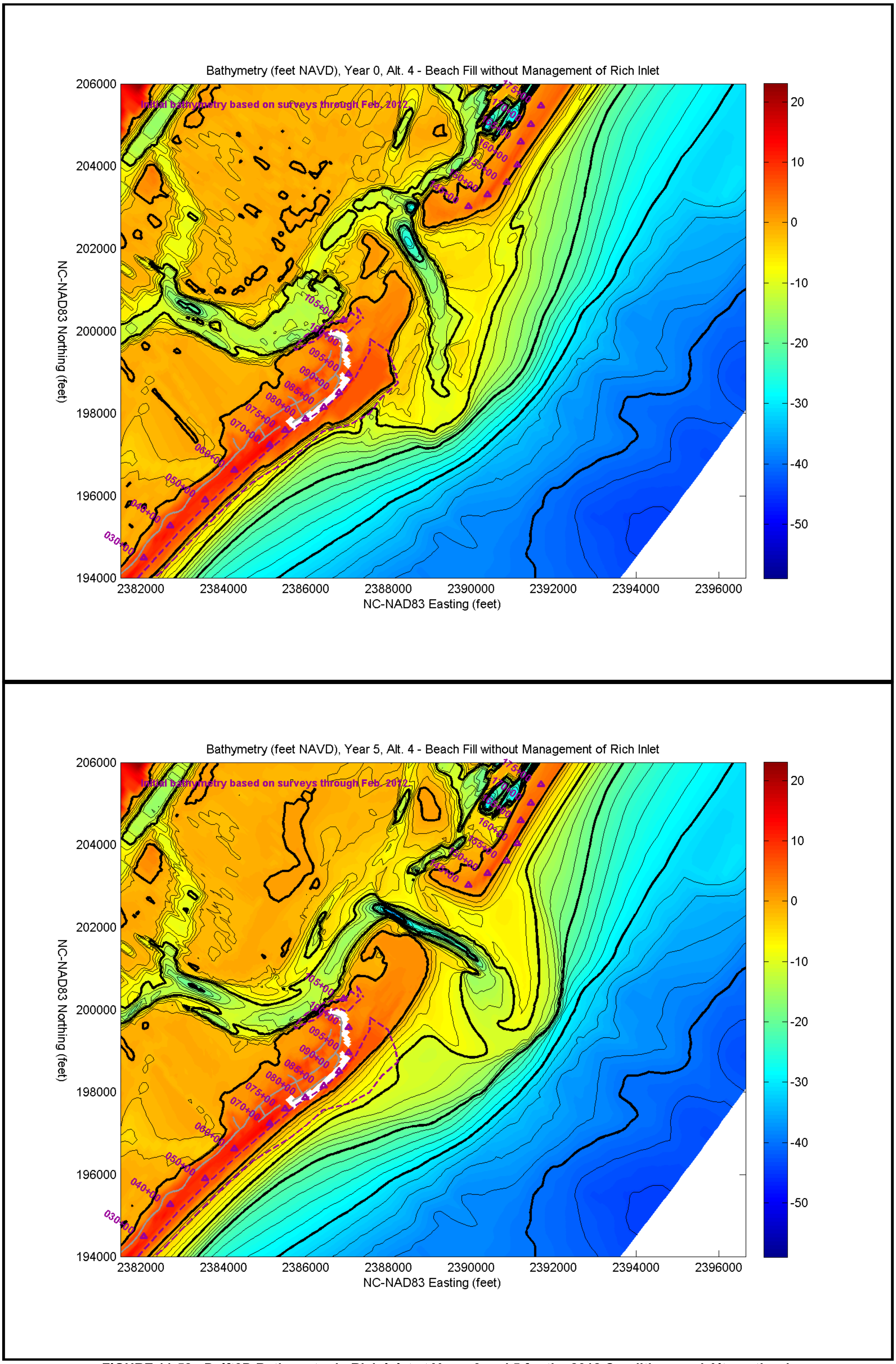


FIGURE 11-58: Delft3D Bathymetry in Rich Inlet at Years 0 and 5 for the 2012 Conditions and Alternative 4.

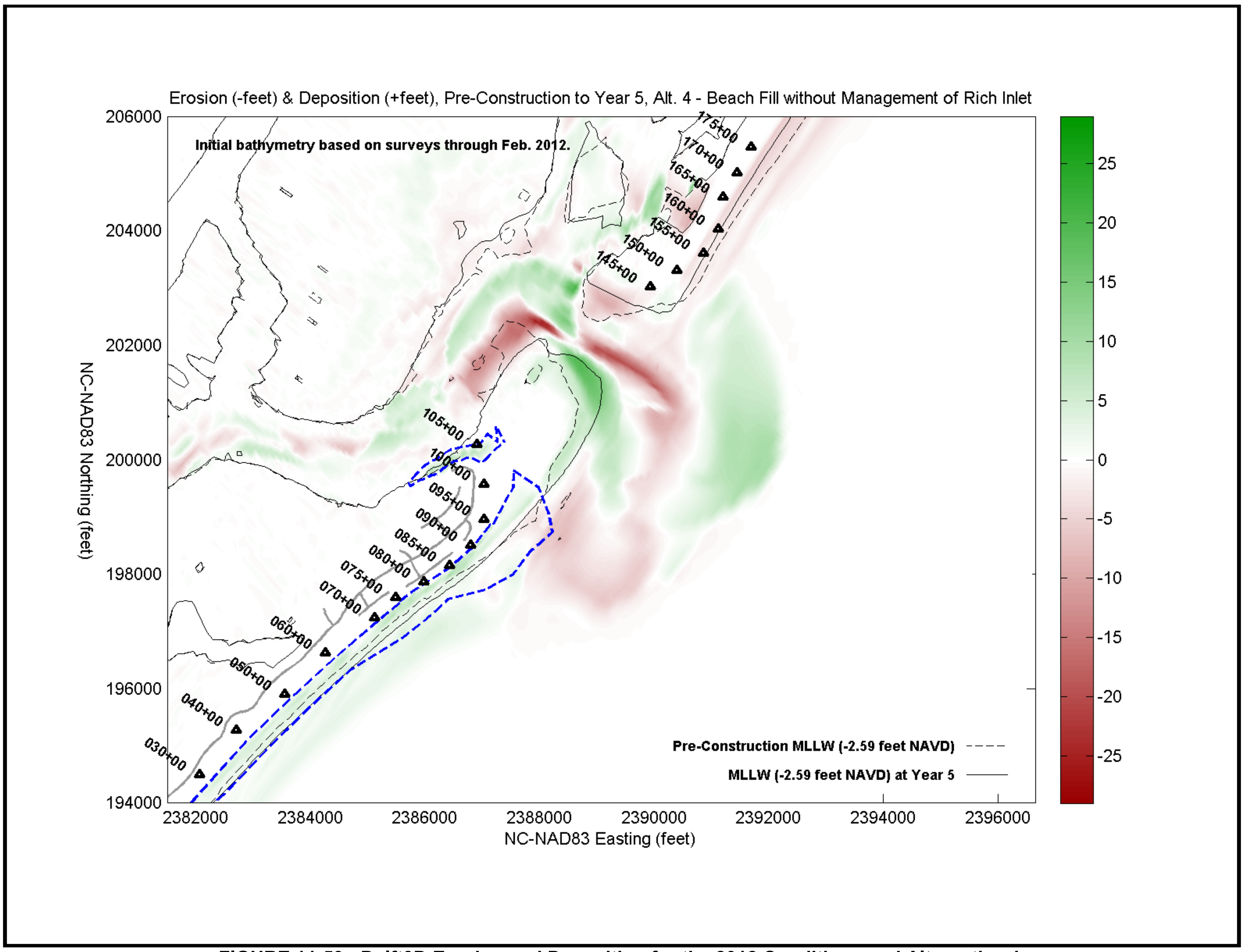


FIGURE 11-59: Delft3D Erosion and Deposition for the 2012 Conditions and Alternative 4.

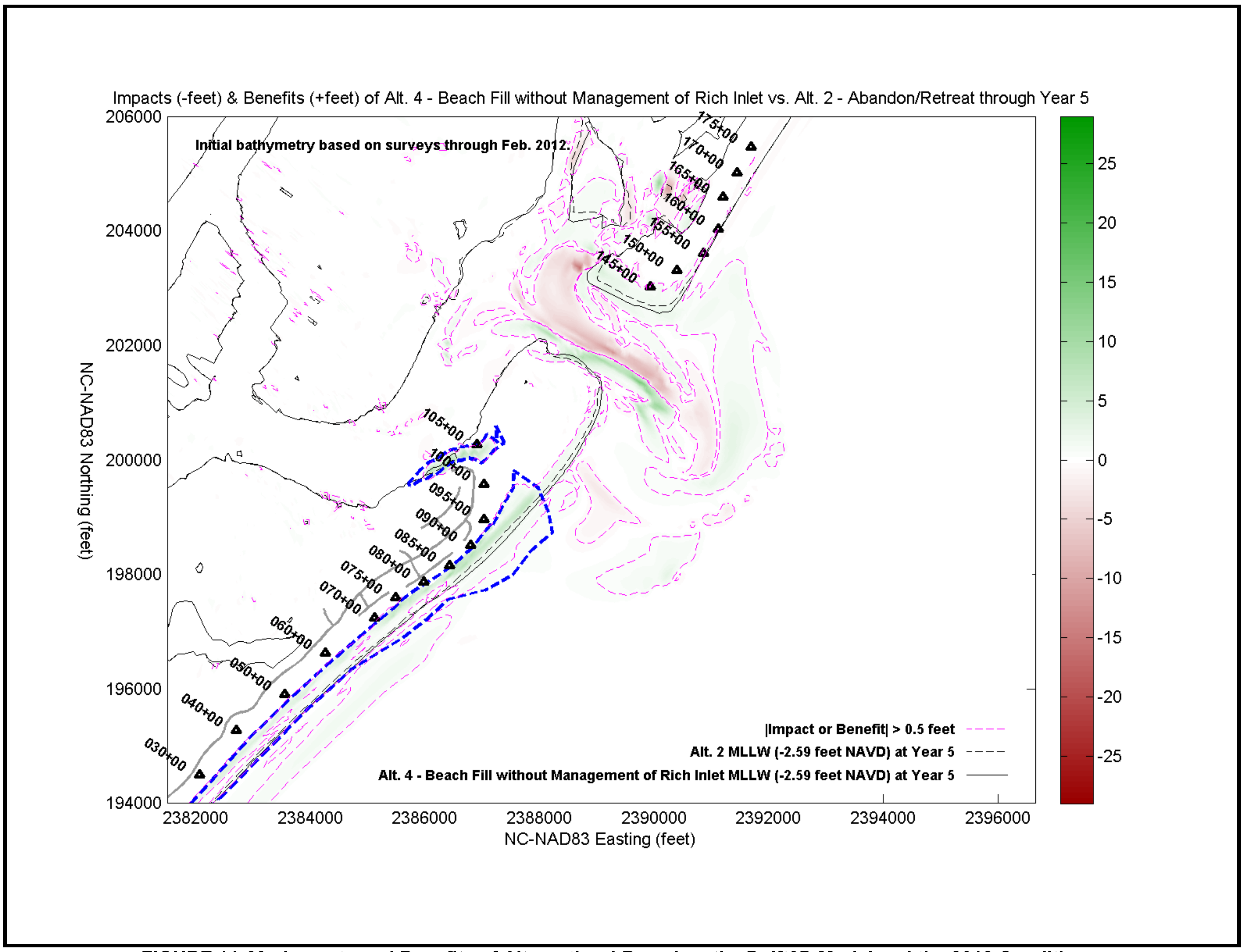


FIGURE 11-60: Impacts and Benefits of Alternative 4 Based on the Delft3D Model and the 2012 Conditions.

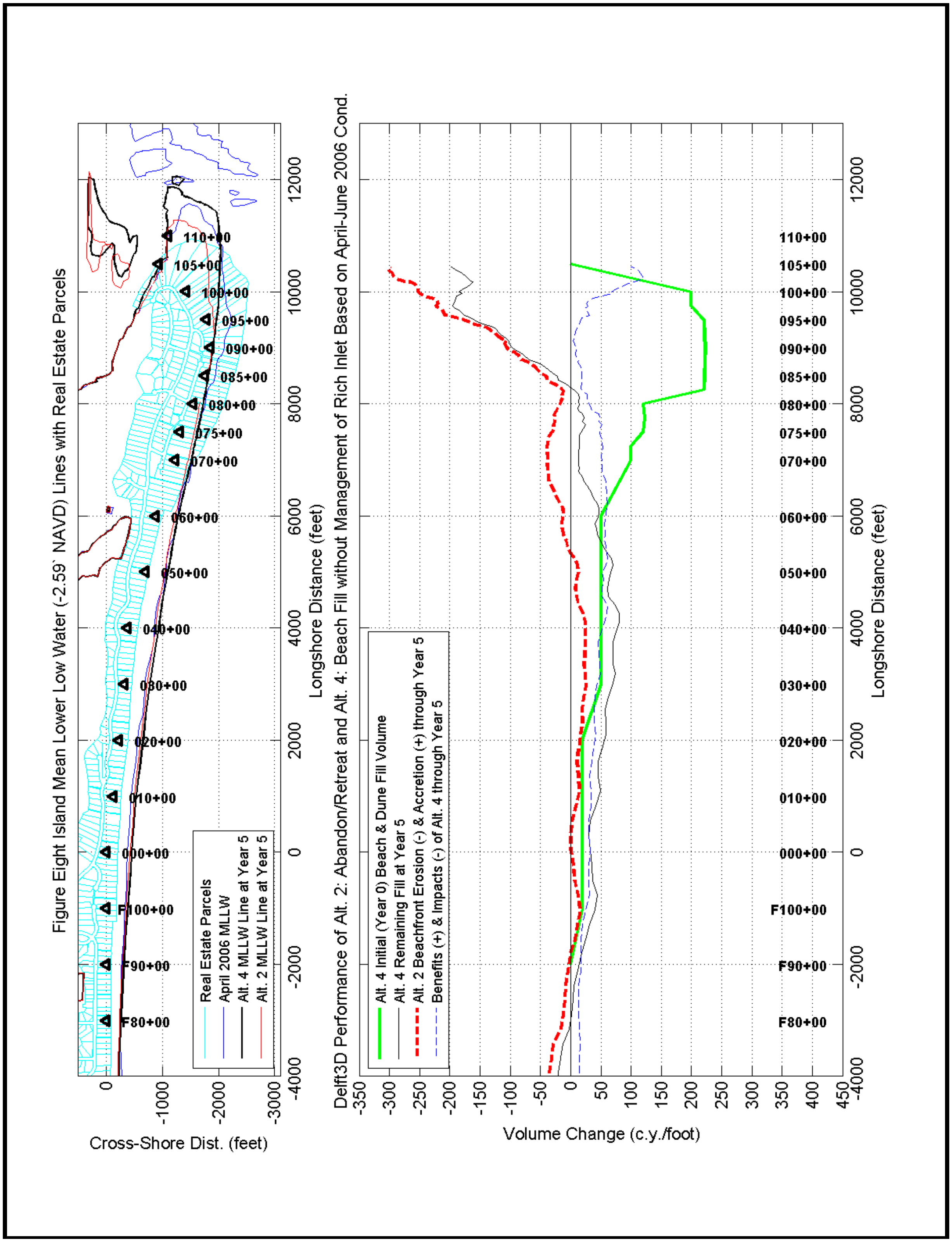


FIGURE 11-61: Delft3D Volume Changes for the 2006 Eroded Conditions and Alternatives 2 and 4.

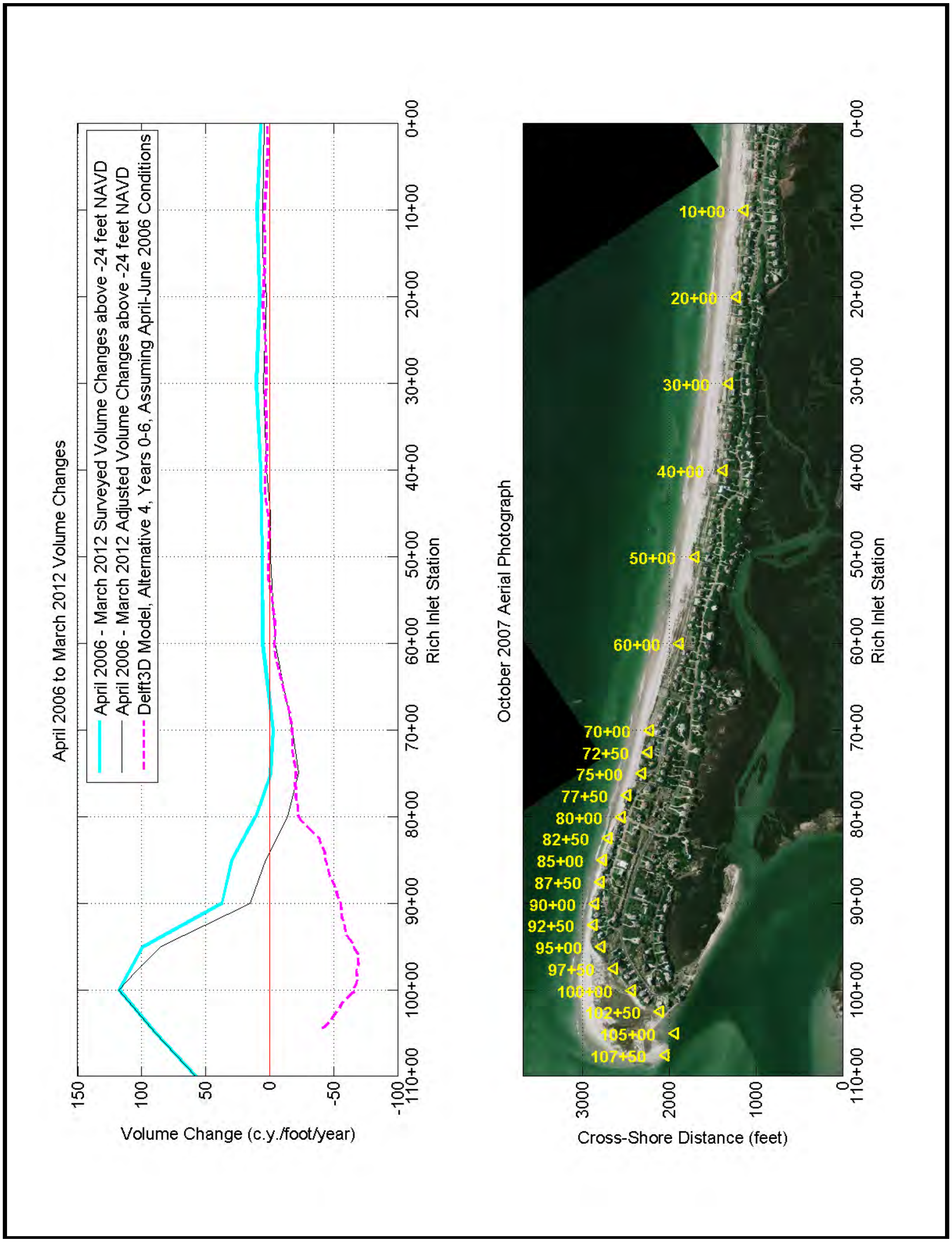


FIGURE 11-62: Comparison of Delft3D Results for Alternative 4 to Observed Volume Changes between 2006 and 2012.

Despite these differences, the model results for Alternative 4 can be used to evaluate how well the model could estimate the changes occurring from 2006 to 2012 (see Figure 11-62).

South of profile 77+50 (Comber Road), there is excellent agreement between the observed volume changes adjusted for beach fill (Figure 11-62, thin, solid line) and the model results (Figure 11-62, dashed line). North of profile 77+50, the model results suggest erosion, while the 2006 and 2012 beach surveys generally indicate accretion. It should be noted that the model was calibrated during a period of erosion along the majority of this segment (see Figure 11-38). For this reason, the model tends to estimate erosion along north of profile 77+50, rather than accretion. It should also be noted that the timing and quantity of the beach fills placed in 2009 and 2010 do not match the placement scenario of Alternative 4, in which all fill is placed at Year 0.

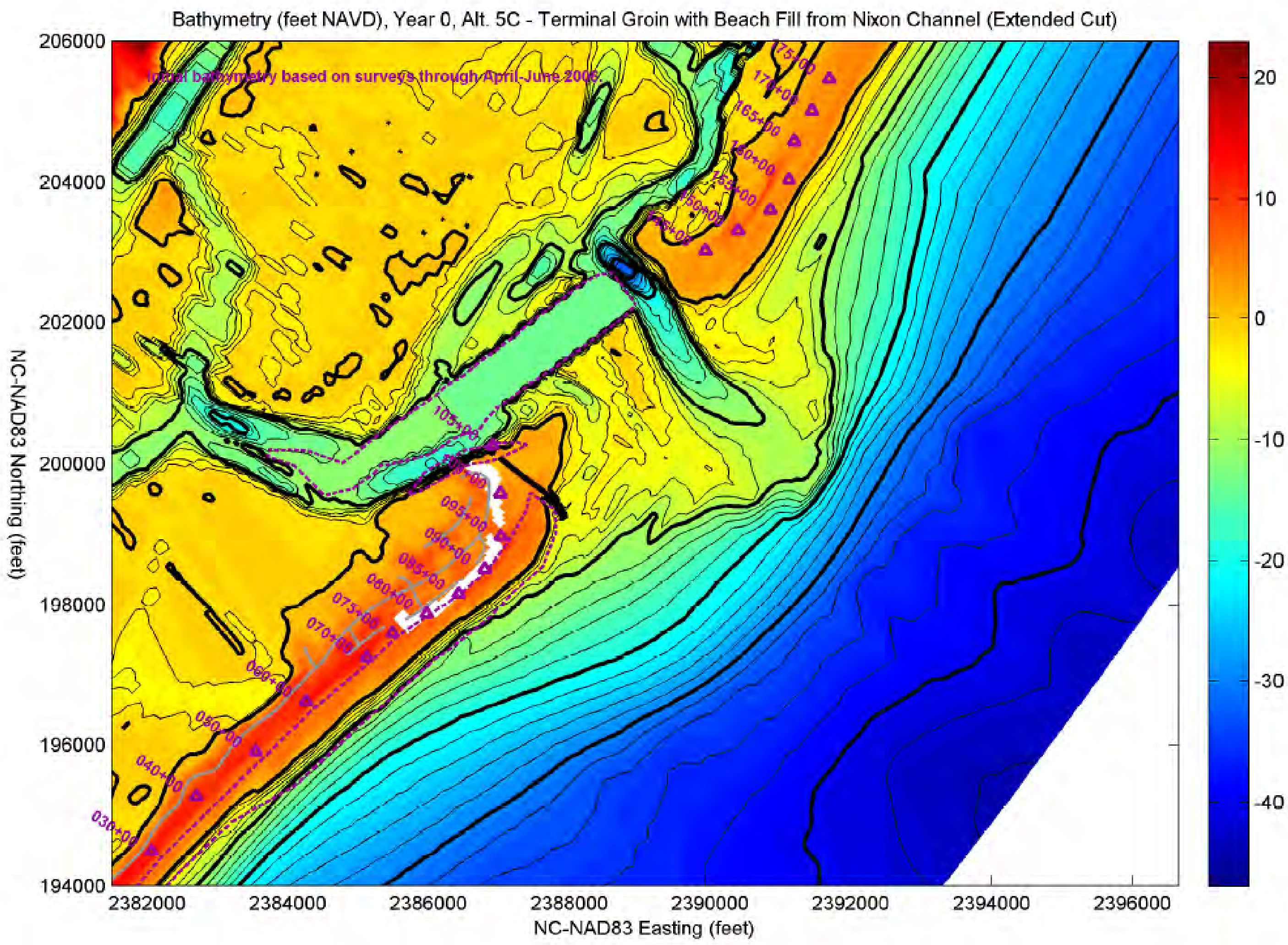
Given the results shown in Figure 11-62, the Delft3D model's estimated erosion rates on the north end of Figure Eight Island are conservative; the erosion estimates are high in comparison to the present trends. Overall, this result confirms that the model results are best used for comparisons between various alternatives, rather than absolute predictions of future volume changes.

11.4.5 Alternative 5C - Terminal Groin at a More Northerly Location with Beach Fill from Nixon Channel and a New Channel Connecting to Gorge of Rich Inlet

Model results for Alternative 5C appear in Sub-Appendix B1, Table 11-7, Table 11-8, Table 11-10, and Figures 11-63 through 11-65. Since the Delft3D-FLOW model is not able to incorporate renourishment during a model simulation, these results neglect renourishment at Year 5. Similar to Alternative 3, the beach fill along Nixon Channel in the model simulations was based on a preliminary design with 65,000 cubic yards from profiles RIN12+00 to RIN30+00, rather than the final design with 57,000 cubic yards from profiles RIN16+00 to RIN30+00 only.

TABLE 11-10
DELFT3D DREDGE MAINTENANCE VOLUMES
EIS ALT. 5C - 2006 ERODED CONDITIONS

Year	Re-Dredging Volume to Design Depth (c.y.)		
	-11' MLW (-13.43' NAVD) Cut	-9' MLW (-11.43' NAVD) Cut	TOTAL
0	0	0	0
1	129,000	7,000	136,000
2	392,000	19,000	411,000
3	382,000	42,000	424,000
4	430,000	82,000	512,000
5	365,000	122,000	487,000



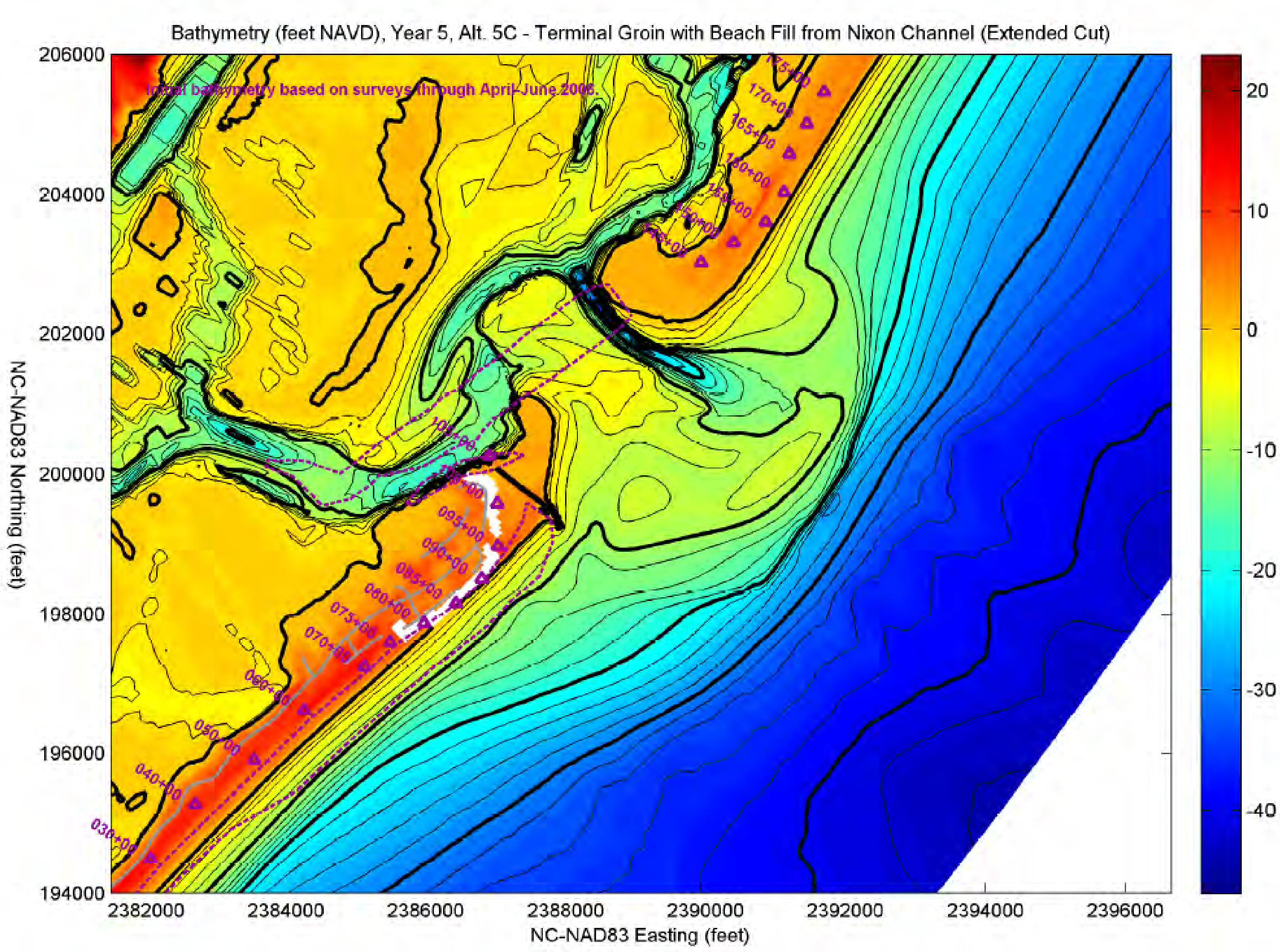


FIGURE 11-63: Delft3D Bathymetry in Rich Inlet at Years 0 and 5 for the 2006 Eroded Conditions and Alternative 5C.

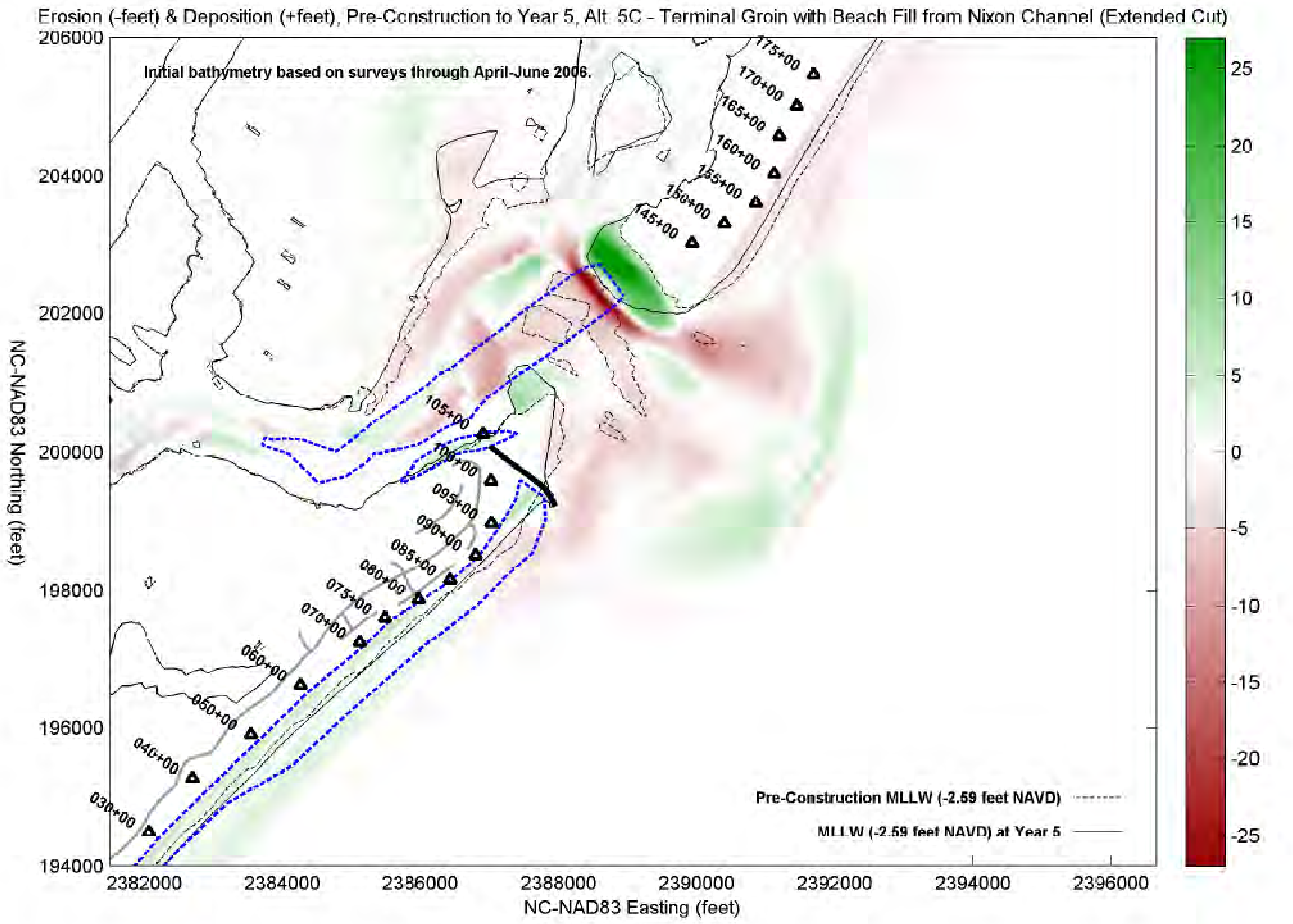


FIGURE 11-64: Delft3D Erosion and Deposition for the 2006 Eroded Conditions and Alternative 5C.

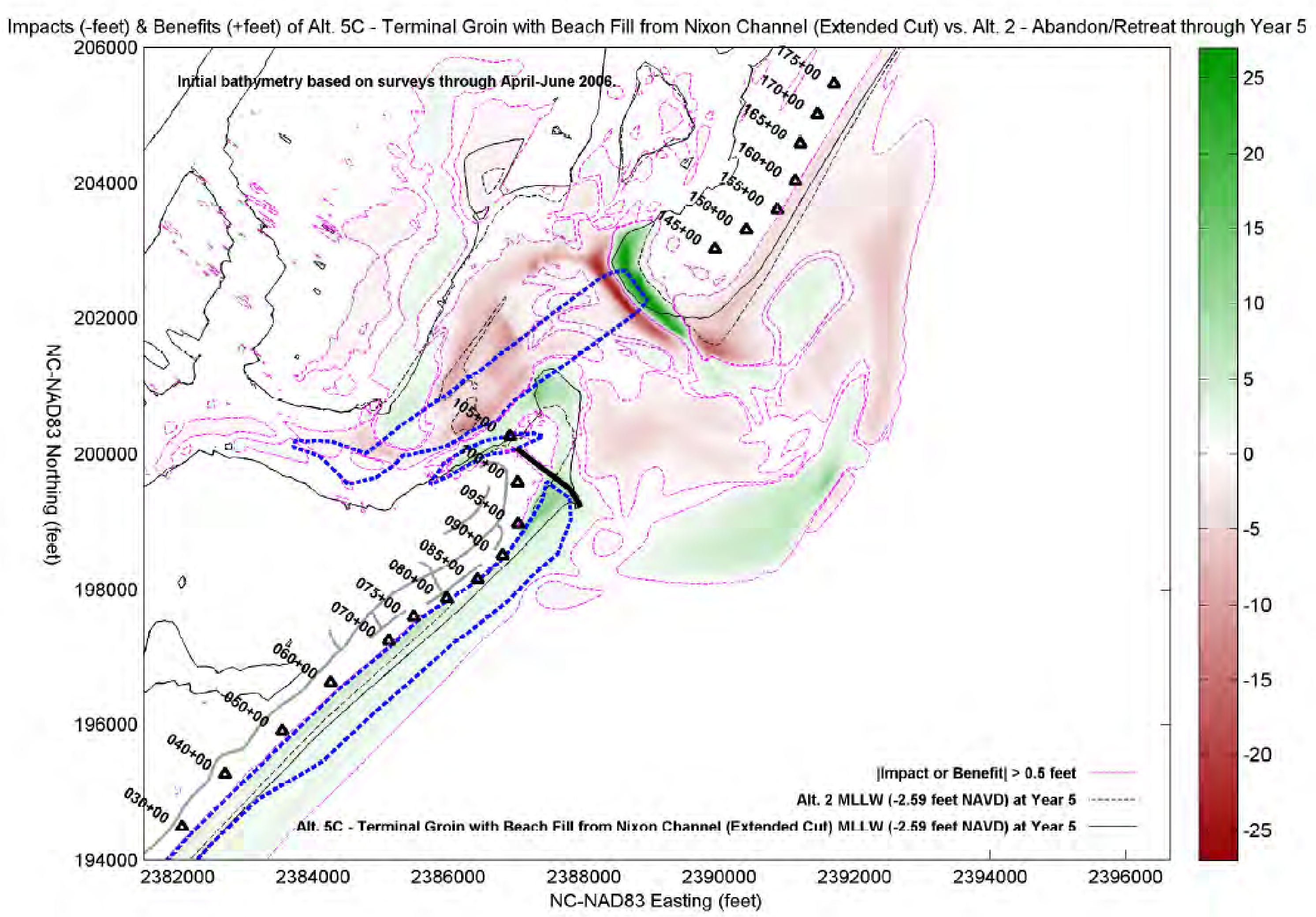


FIGURE 11-65: Impacts and Benefits of Alternative 5C Based on the Delft3D Model and the 2006 Eroded Conditions.

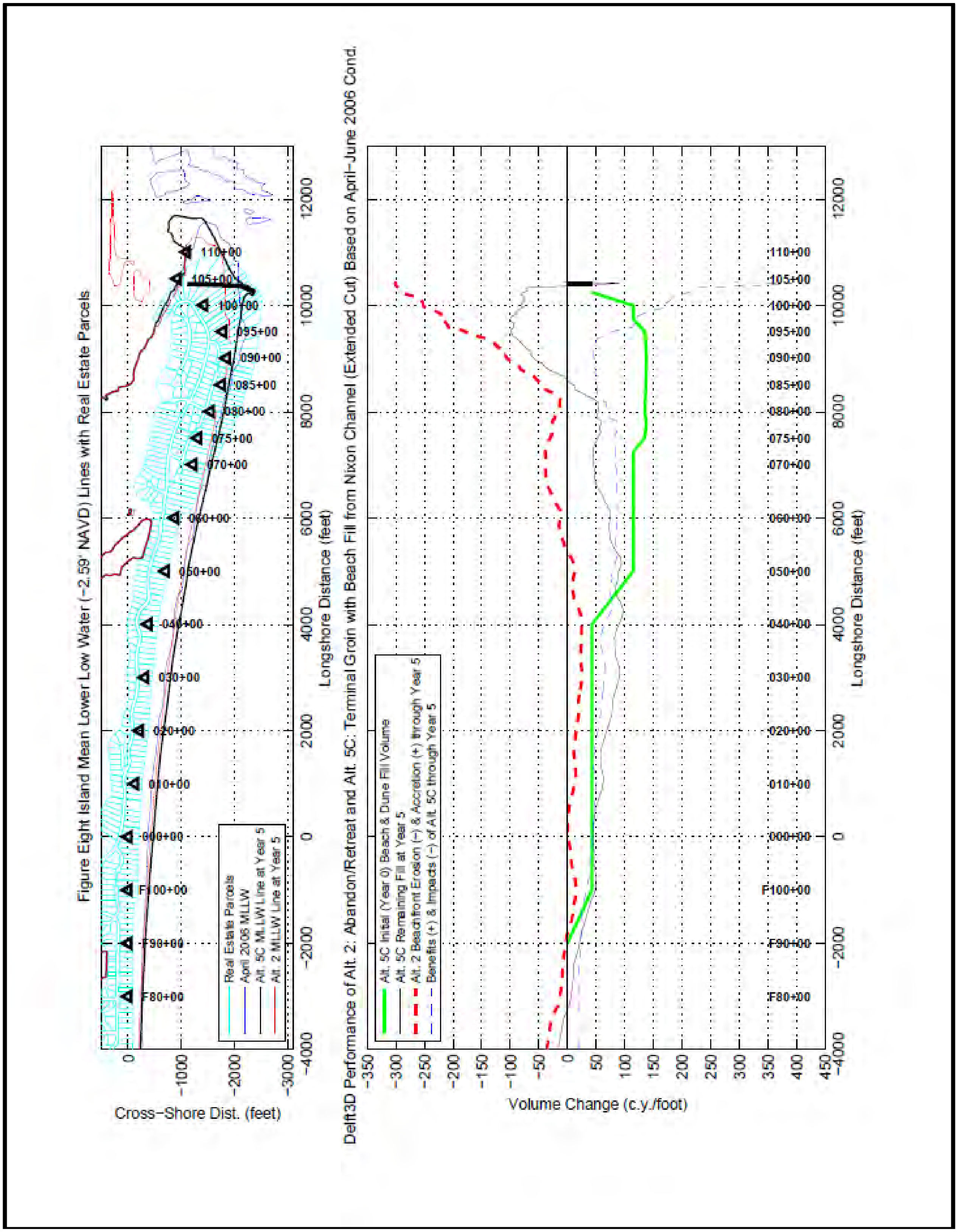


FIGURE 11-66: Delft3D Volume Changes Given the 2006 Eroded Conditions and Alternatives 2 and 5C.

The terminal groin was incorporated into the Delft3D-FLOW model by raising the grid cells along the structure to +6 feet NAVD, and setting the erodible sediment depth along those same grid cells to zero. This ensured that:

- Overtopping of the structure, if any, would be properly estimated in the Delft3D-FLOW model.

- The structure would remain in the model over the entire duration of the model run.

In the SWAN model, the terminal groin was represented as a sloped “dam” with a crest elevation of +6 feet NAVD and negligible wave reflection.

Model simulations for Alternative 5C were only conducted for the 2006 critically eroded condition. Due to the lack of support for this alternative by the Figure "8" Beach HOA, simulating Alternative 5C given the 2012 conditions was determined not to be necessary.

If Alternative 5C were constructed under eroded conditions similar to those in 2006, the main channel of Rich Inlet would have an orientation similar to that of the Abandon/Retreat scenario. However, there would be some differences in the contours of the ebb shoal, along with a more open connection between Nixon Channel and the main channel of the inlet (compare Figure 11-63 with Figure 11-45). The differences in the ebb shoal contours would be due to the beach fill material placed on the north end of Figure Eight Island and the manner in which the terminal groin would deflect the longshore transport off the north end of the island, along with dredging-related changes to the flow through Rich Inlet. The more open connection between Nixon Channel and the main channel of the inlet would be due to the extension of the 2010 cut towards the main channel of the inlet, which would migrate landward over time.

Another key difference between Alternative 5C and Alternative 2 is the development of the spit north of the terminal groin location (profile 105+00). Under Alternative 5C, the spit is longer at the end of Year 5 than it is under Alternative 2 (see Figures 11-65, 11-63, and 11-45). This result is due to the large amount of fill placed along the north end of Figure Eight Island, and suggests that with a sufficient amount of pre-filling, partial bypassing of the terminal groin would occur.

On Hutaff Island, the model results suggest that given Alternative 5C, erosion rates would be higher than those under the Abandon/Retreat scenario (see Figure 11-65 and Table 11-7). This result would be due to 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.

In terms of fill performance, the model results suggest that south of profile 85+00 (13 Comber Road), erosion into the pre-construction beach profile (see Table 11-7 and 11-64) will not occur by Year 5. North of profile 85+00, erosion into the pre-construction beach profile could occur within 5 years. However, the degree of erosion would be 2/3 less than what would occur under the Abandon/Retreat scenario (see Table 11-17). Thus, the beach fill and the terminal groin would still provide a benefit (see Figure 11-15). It is important to note that north of profile 85+00, the model results are very conservative (see Figure 11-62); the degree of erosion could be less than what the model suggests if the alternative were constructed under critically eroded conditions. Based on Table 11-9, infilling of the design cut would be just enough to renourish the project at Year 5.

11.4.6 Alternative 5D – Terminal Groin at a More Northerly Location with Beach Fill from the Previously Permitted Area in Nixon Channel and Other Sources

Model results for Alternative 5D appear in Sub-Appendix B1, Table 11-7, Table 11-8, Table 11-11, and Figures 11-67 through 11-73. This alternative constructs a 1,500 foot long terminal groin with 237,500 c.y. of fill along the oceanfront and 57,000 of c.y. of fill along the interior shoreline of Nixon Channel (see Table 9-7 and Figure 9-28). The groin was incorporated into the Delft3D-FLOW and SWAN model in the same manner as Alternative 5C. Similar to the other alternatives, renourishment at Year 5 was neglected.

TABLE 11-11

DELFT3D DREDGE MAINTENANCE VOLUMES
EIS ALT. 5D
2006 ERODED CONDITIONS

Year	Re-Dredging Volume to Design Depth (c.y.)
0	0
1	31,000
2	78,000
3	105,000
4	120,000
5	134,000

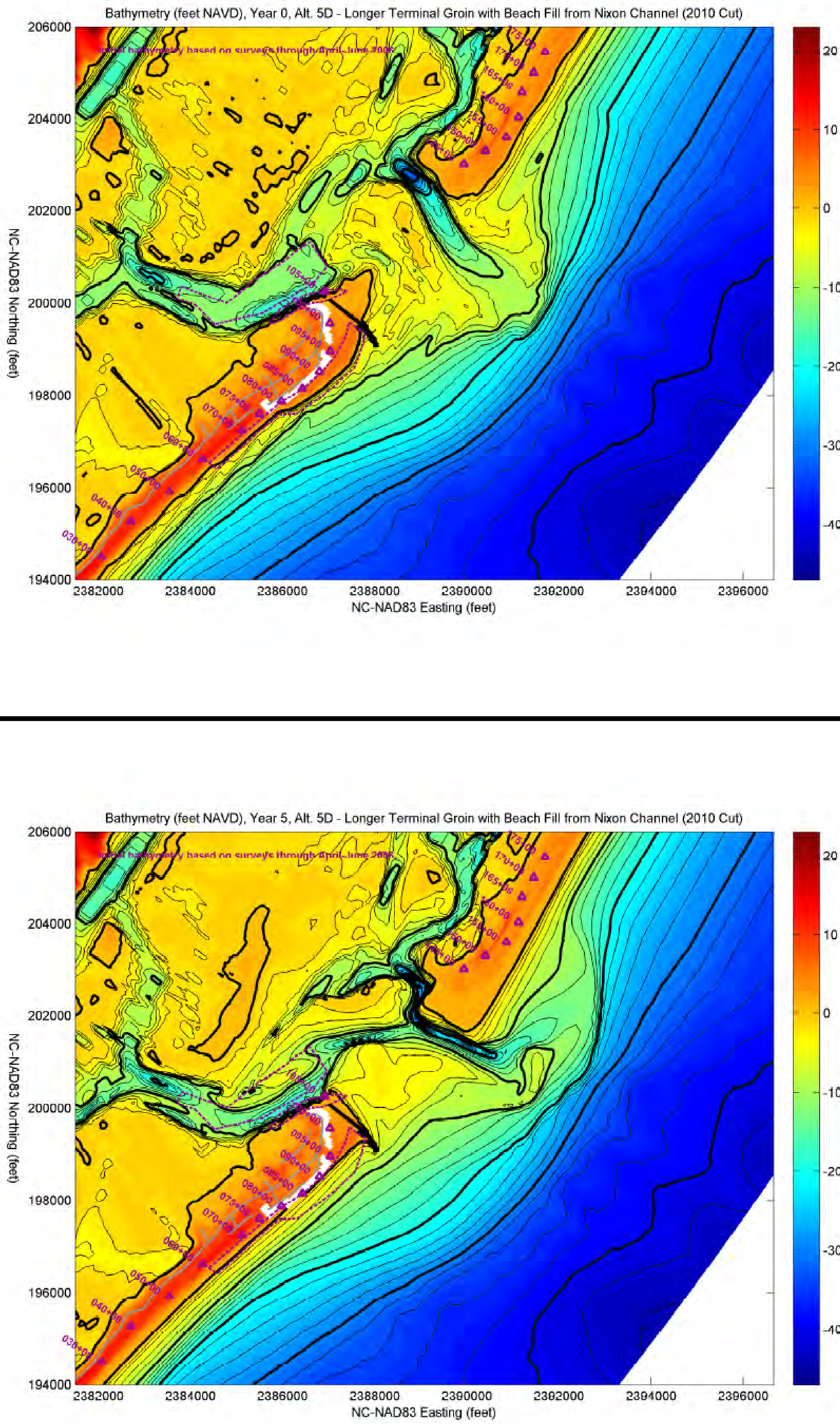


FIGURE 11-67: Delft3D Bathymetry in Rich Inlet at Years 0 and 5 for the 2006 Eroded Conditions and Alternative 5D

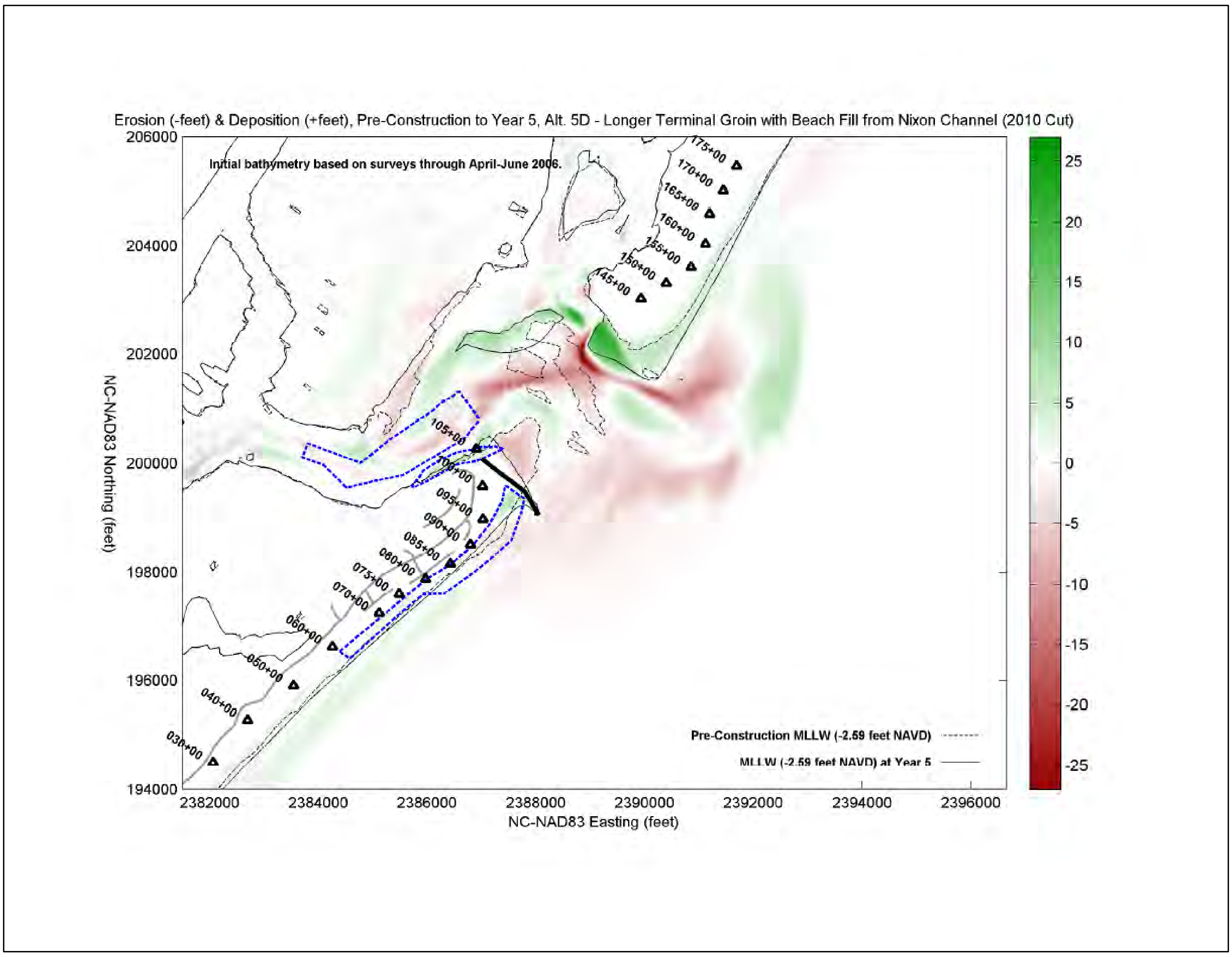


FIGURE 11-68: Delft3D Erosion and Deposition for the 2006 Eroded Conditions and Alternative 5D.

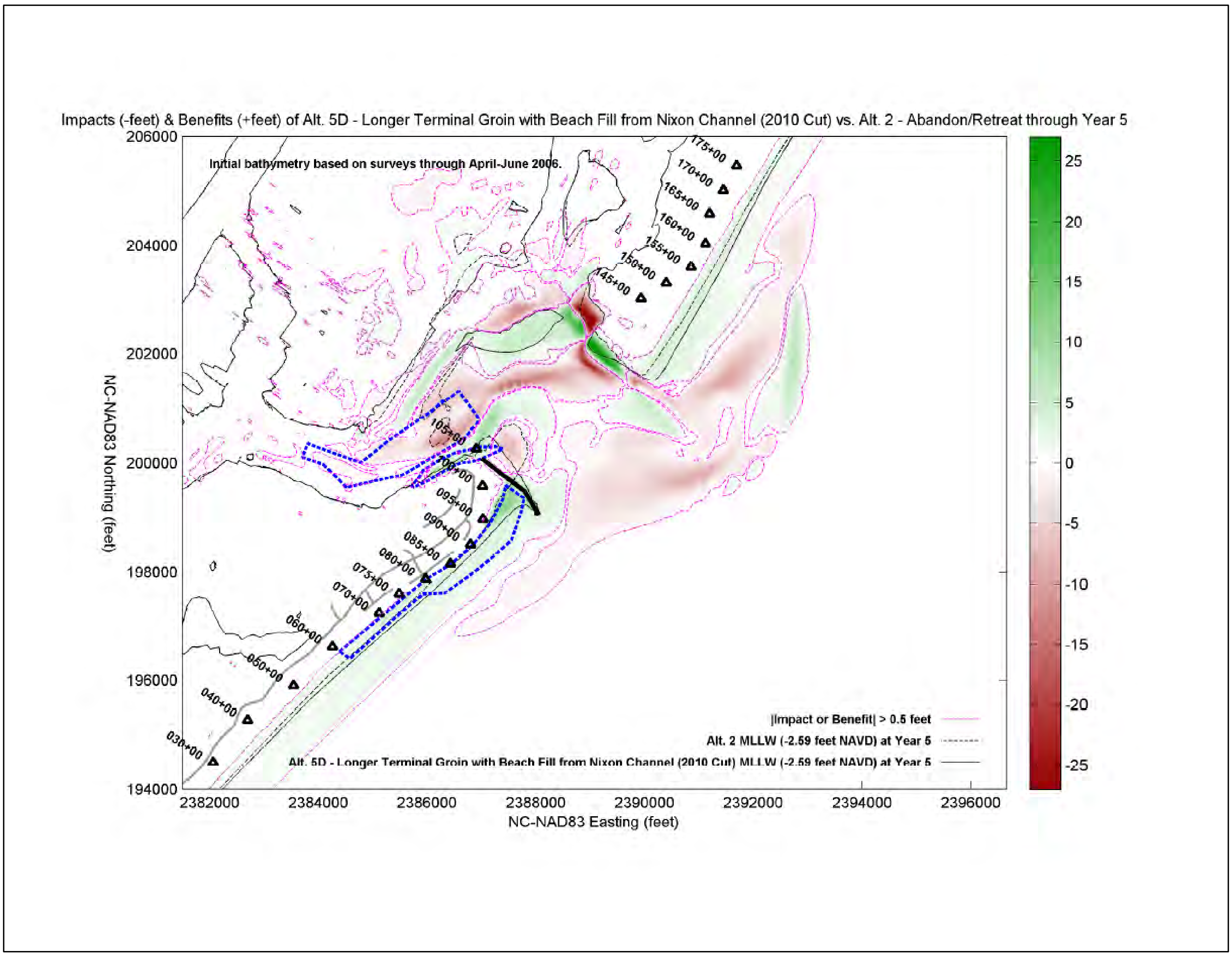
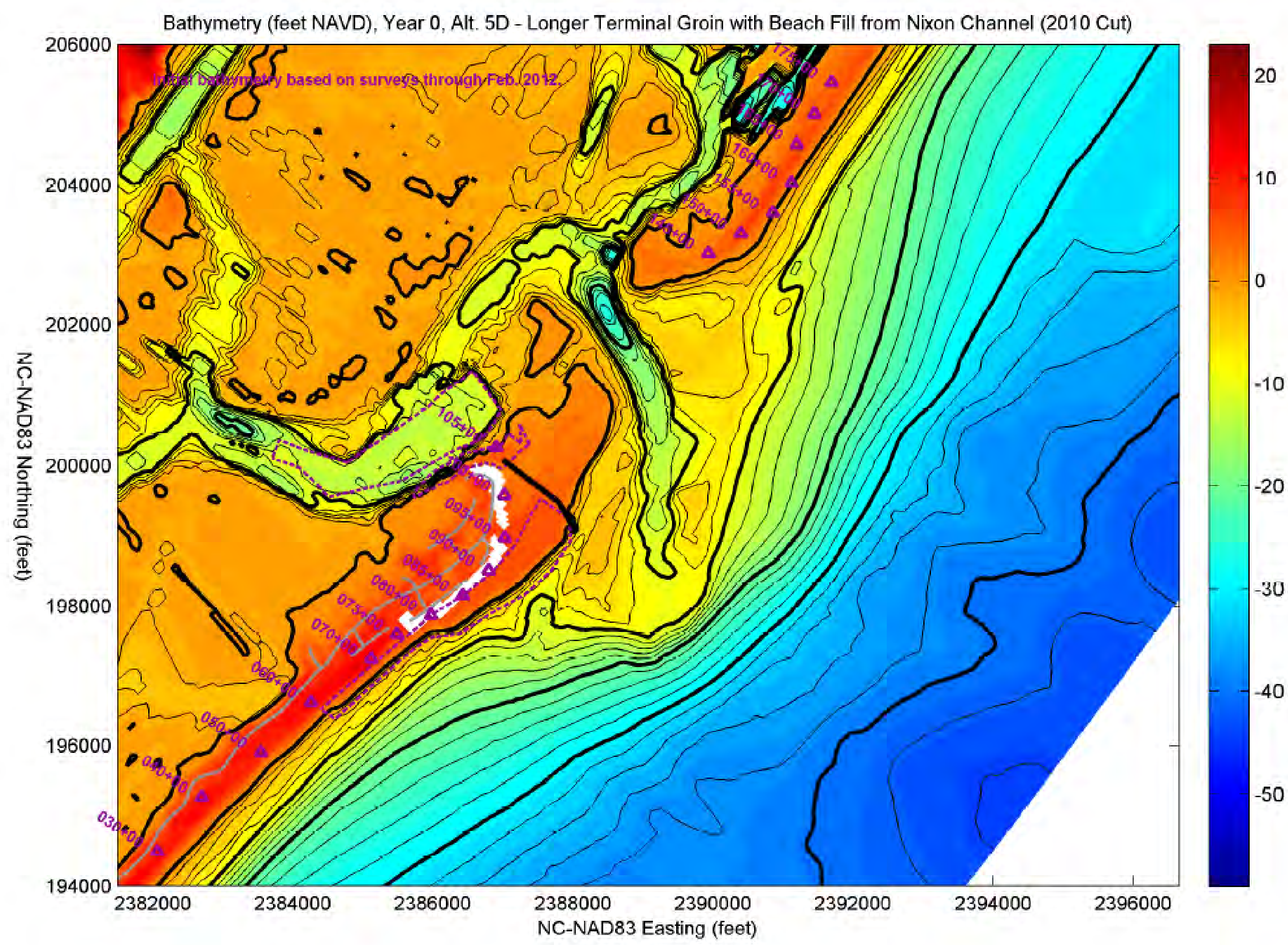


FIGURE 11-69: Impacts and Benefits of Alternative 5D Based on the Delft3D Model and the 2006 Eroded Conditions.



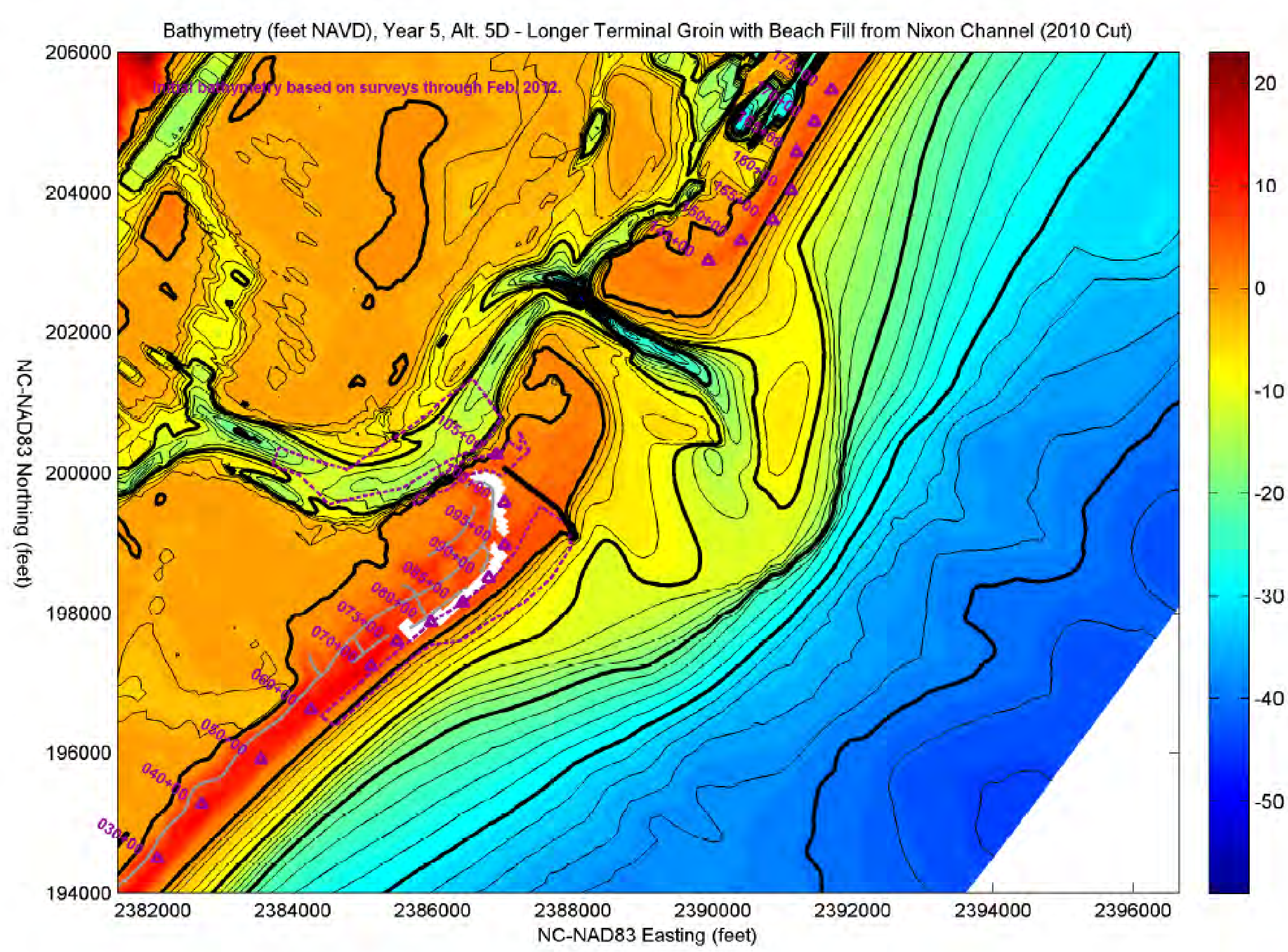


FIGURE 11-70: Delft3D Bathymetry in Rich Inlet at Years 0 and 5 for the 2012 Conditions and Alternative 5D.

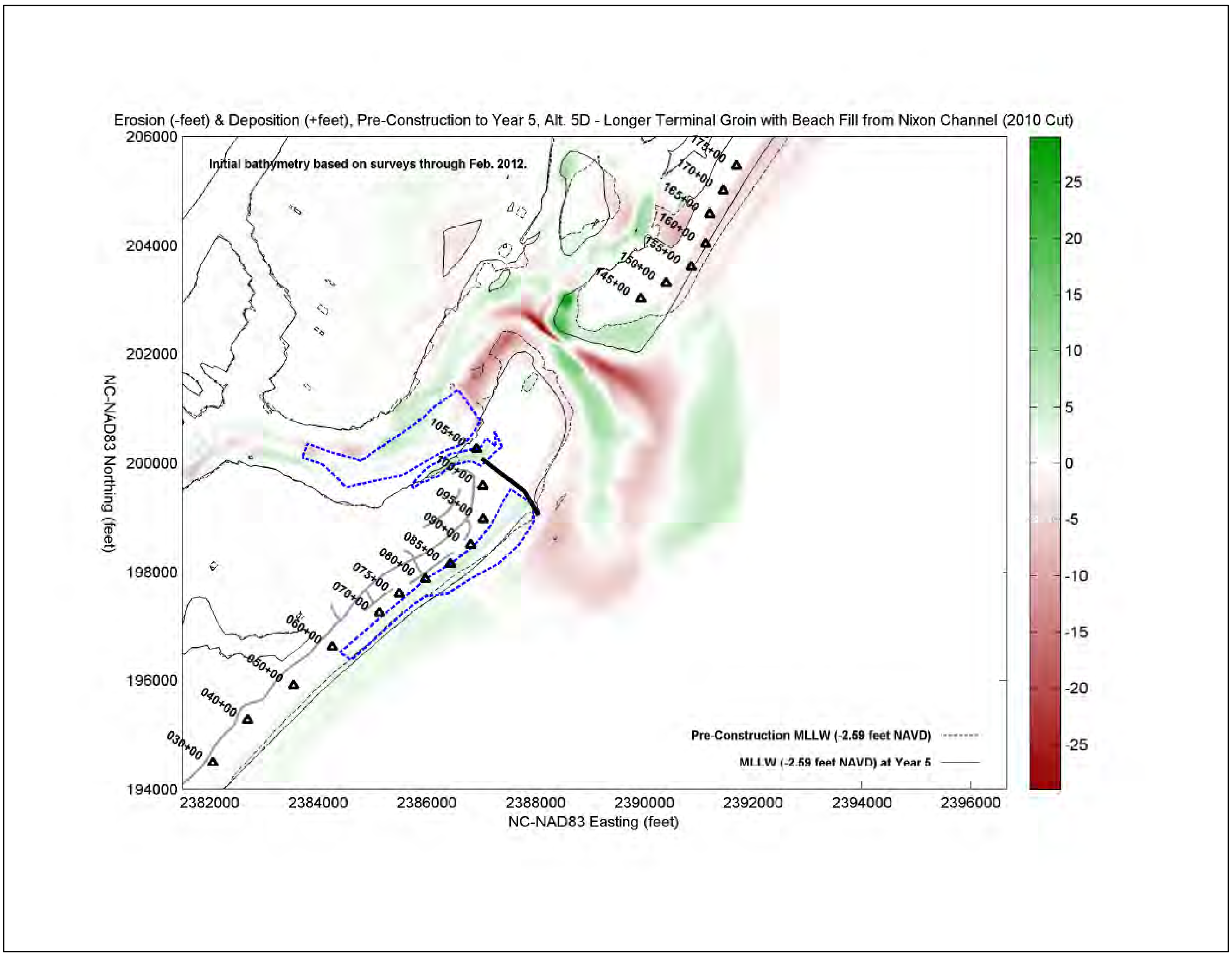


FIGURE 11-71: Delft3D Erosion and Deposition for the 2012 Conditions and Alternative 5D.

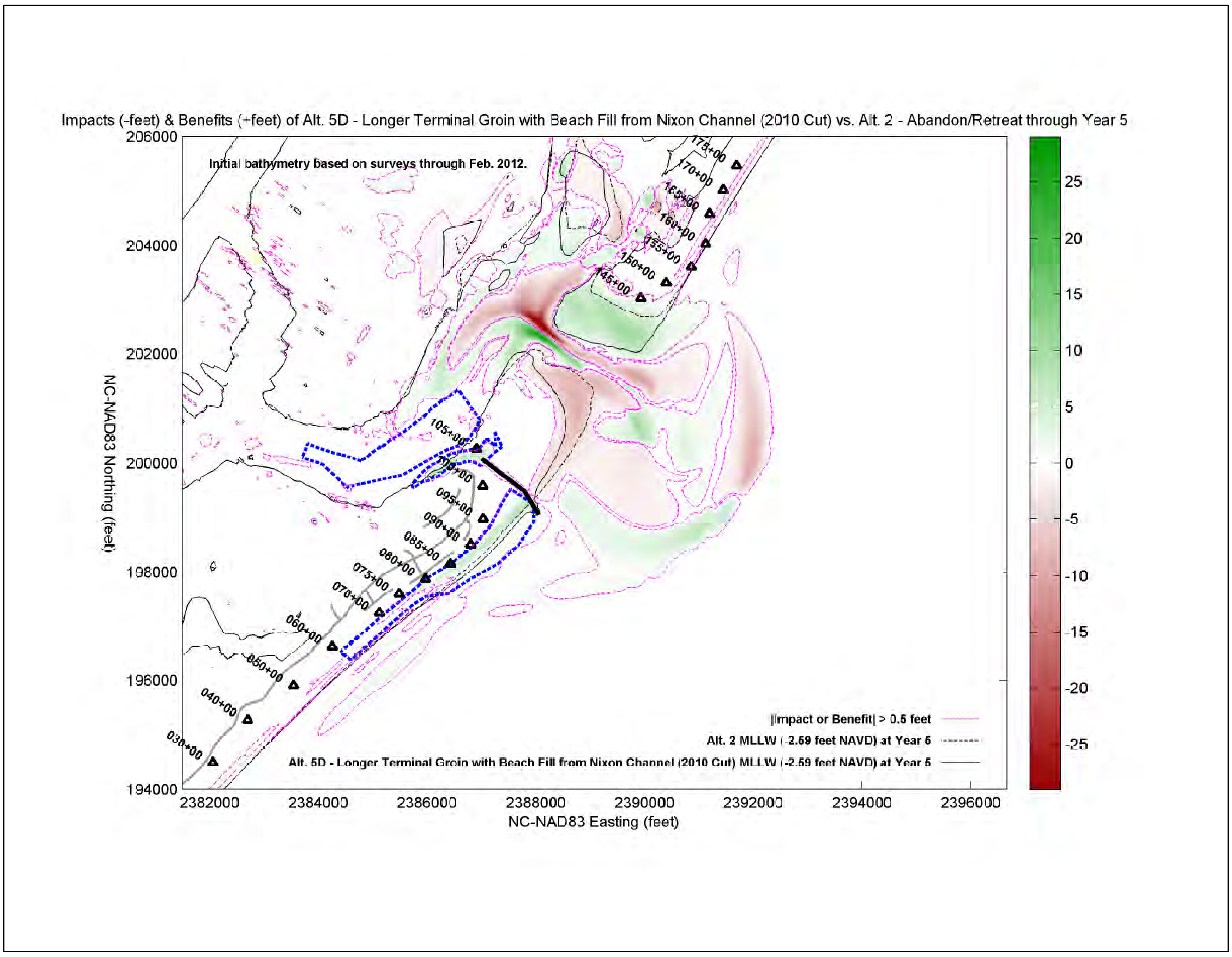


FIGURE 11-72: Impacts and Benefits of Alternative 5D Based on the Delft3D Model and the 2012 Conditions.

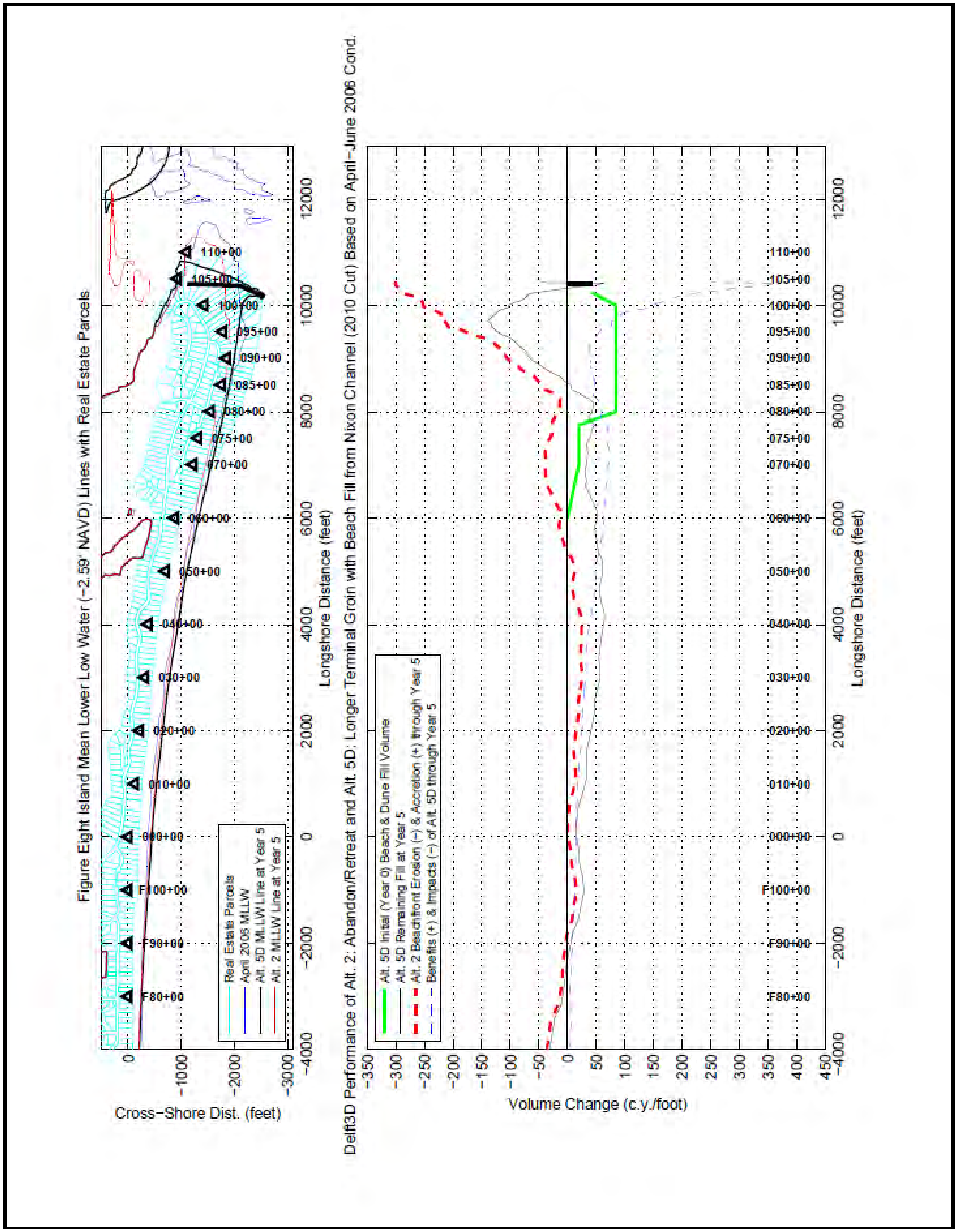


FIGURE 11-73: Delft3D Volume Changes Given the 2006 Eroded Conditions and Alternatives 2 and 5D.

If Alternative 5D were constructed under eroded conditions similar to those in 2006, most of the spit north of the terminal groin location (profile 105+00) would be lost over time (see Figure 11-67). The main channel of Rich Inlet would assume a west-northwest/east-southeast orientation, with relatively deep (> -10 feet NAVD) and continuous connections to Nixon Channel and Green Channel. Along Nixon Channel, much of the beach fill placed at Year 0 would still be in place at Year 5 (see Figure 11-68). Along the oceanfront fill area, erosion into the pre-construction profile would not occur south of profile 85+00 (13 Comber Road) over the first 5 years. North of profile 85+00, erosion into the pre-construction profile could occur if the project were built under critically eroded conditions (see Figure 11-68 and Table 11-7 and Table 11-8). However, the degree of erosion would be half of what would occur under the Abandon/Retreat scenario (see Table 11-7). Along Hutaff Island, adverse, project-related impacts would be minimal (see Figure 11-69 and Table 11-7).

Based on Table 11-11, additional sources may be needed to renourish the project at Year 5. This result is more conservative than historic filling rates might suggest. Based on the most recent dredging operations in Nixon Channel (Table 6-1), the dredge cut could refill faster than what the model suggests. Likewise, fill losses from the oceanfront may be lower than what the model suggests (see Figure 11-62). Annual monitoring will be essential for evaluating what the true renourishment needs will be and the amount of material available for beach renourishment.

If Alternative 5D were constructed under conditions similar to those in 2012, most of the spit north of the terminal groin would remain intact, except for some losses along the interior shorelines of the spit and some minor losses along its oceanfront shoreline (see Figures 11-71 and 11-72). However, the spit would be smaller in size that what would occur under the Abandon/Retreat scenario (see Figure 11-72). The main channel would have an orientation similar to the Abandon/Retreat scenario (compare Figures 11-70 and 11-45). However, it would be located somewhat further north, allowing for a more open connection with Green Channel. At the same time, Hutaff Island would be somewhat longer, even if oceanfront erosion rates north of profile 150+00 are slightly higher (see Figure 11-72). Along Nixon Channel, most of the fill placed at Year 0 would still be remaining at Year 5 (see Figure 11-71). Along the oceanfront fill area, erosion into the pre-construction profile could occur north of profile 95+00 (Inlet Hook Road) within the first 5 years (see Figure 11-71). However, south of profile 95+00, erosion into the pre-construction shoreline would be prevented.

In general, more fill is retained on the beach due to the longer groin length. Given critically eroded conditions similar to those in 2006, impacts to the spit north of the terminal groin are similar under either alternative. Given conditions similar to those in 2012, Alternative 5D reduces the surface area of the spit by roughly 25% (see Figure 11-72). Similar to the difference in performance, the difference in impact is due to the longer groin length.

11.5 Tidal Prisms & Flow Distributions

Average tidal prisms over the model simulation period appear in Table 11-12 and Figures 11-75 to 11-77. Tidal prisms are provided for the Inlet Throat, Nixon Channel, and Green Channel (Figure 11-74).

In comparison to Table 4-8, tidal prism estimates based on the Delft3D model do not exhibit a large degree of variation with respect to either time or alternative. Alternative 4, which does not include dredging in Rich Inlet, would have the least impact on tidal prism based on the model results. Alternative 3, which features the largest amount of dredging, would have the largest effect on tidal prism, with small increases in the prism through the entrance channel (0 to 7% versus Alt. 2), small increases in the prism through Nixon Channel (4 to 9% versus Alt. 2), and small decreases through Green Channel (3 to 8% versus Alt. 2). The terminal groin alternatives (5A, 5B-1, and 5B-2) also tend to increase flow in Nixon Channel and decrease flow in Green Channel versus Alternative 2, but to a lesser degree than Alternative 3. These results are due to the layouts of the design cuts. Under Alternative 3, more dredging occurs in Nixon Channel than near Green Channel. Under the terminal groin alternatives, dredging is limited to Nixon Channel. Removal of material from Nixon Channel slightly increases the flow capacity of this waterway, with less of the flow occurring through Green Channel as a result. However, in all cases, project-induced changes in the average tidal prism are 10% or less, and well within the variability shown in Table 4-8.

TABLE 11-12
TIDAL PRISM ESTIMATES GIVEN APRIL-JUNE 2006 INITIAL CONDITIONS & AVERAGE TIDES

Years after	Inlet Entrance		Nixon Channel		Green Channel	
Construction	Avg. (feet^3)	+/- σ	Avg. (feet^3)	+/- σ	Avg. (feet^3)	+/- σ
	Alternative 2 – Abandon / Retreat					
0 to 1	502,800,000	10,700,000	280,000,000	6,600,000	179,500,000	3,800,000
1 to 2	496,900,000	12,100,000	276,700,000	6,900,000	177,900,000	4,500,000
2 to 3	473,900,000	12,200,000	277,600,000	6,600,000	179,300,000	4,700,000
3 to 4	506,100,000	12,200,000	279,600,000	7,300,000	183,600,000	4,900,000
4 to 5	505,900,000	13,500,000	275,700,000	9,000,000	184,600,000	4,500,000
5 to 6	509,000,000	11,300,000	276,100,000	8,300,000	184,400,000	3,900,000
6 to 7	507,600,000	13,400,000	270,500,000	9,200,000	184,600,000	4,700,000
Years after	**Inlet Entrance**		**Nixon Channel**		**Green Channel**	
Construction	**Avg. (feet^3)**	**+/- σ**	**Avg. (feet^3)**	**+/- σ**	**Avg. (feet^3)**	**+/- σ**
	Alternative 3 – Rich Inlet Management and Beach Fill					
0 to 1	506,100,000	9,000,000	290,900,000	5,700,000	172,600,000	3,200,000
1 to 2	509,400,000	10,300,000	293,600,000	6,600,000	173,100,000	3,600,000
2 to 3	507,000,000	9,700,000	294,900,000	5,600,000	169,500,000	3,900,000
3 to 4	509,700,000	11,500,000	295,200,000	6,900,000	170,700,000	4,200,000
4 to 5	509,400,000	11,600,000	295,600,000	7,500,000	169,600,000	4,300,000
5 to 6	520,500,000	12,600,000	301,600,000	11,200,000	173,900,000	4,600,000
6 to 7	509,100,000	15,600,000	287,600,000	15,100,000	175,000,000	4,300,000
Years after	**Inlet Entrance**		**Nixon Channel**		**Green Channel**	
Construction	**Avg. (feet^3)**	**+/- σ**	**Avg. (feet^3)**	**+/- σ**	**Avg. (feet^3)**	**+/- σ**

Years after Construction	Inlet Entrance Avg. (feet^3)	+/- σ	Nixon Channel Avg. (feet^3)	+/- σ	Green Channel Avg. (feet^3)	+/- σ
	Alternative 4 – Beach Fill without Management of Rich Inlet					
0 to 1	502,300,000	11,100,000	279,600,000	6,800,000	179,500,000	3,900,000
1 to 2	496,000,000	11,600,000	275,100,000	6,600,000	178,600,000	4,600,000
2 to 3	471,300,000	11,900,000	273,700,000	6,700,000	180,900,000	4,400,000
3 to 4	503,400,000	12,100,000	278,000,000	7,100,000	183,800,000	4,700,000
4 to 5	500,700,000	12,200,000	274,300,000	7,100,000	184,100,000	4,600,000
5 to 6	504,700,000	10,600,000	276,100,000	6,400,000	184,200,000	4,000,000
6 to 7	498,800,000	11,200,000	268,300,000	6,700,000	185,200,000	4,400,000

TABLE 11-12 (continued)

TIDAL PRISM ESTIMATES GIVEN APRIL-JUNE 2006 INITIAL CONDITIONS & AVERAGE TIDES

Years after Construction	Inlet Entrance Avg. (feet^3)	+/- σ	Nixon Channel Avg. (feet^3)	+/- σ	Green Channel Avg. (feet^3)	+/- σ
	Alternative 5C - Terminal Groin with Beach Fill from Nixon Channel (Extended Cut)					
0 to 1	509,400,000	10,300,000	291,100,000	6,300,000	175,300,000	3,400,000
1 to 2	504,600,000	9,500,000	285,200,000	6,200,000	178,600,000	4,600,000
2 to 3	500,900,000	9,800,000	280,300,000	6,100,000	181,200,000	3,600,000
3 to 4	503,000,000	11,300,000	283,700,000	7,500,000	179,300,000	4,500,000
4 to 5	499,000,000	12,000,000	280,800,000	7,600,000	178,900,000	4,400,000
5 to 6	513,600,000	11,500,000	292,900,000	7,100,000	178,500,000	4,100,000
6 to 7	518,900,000	12,800,000	296,400,000	7,800,000	177,700,000	4,700,000

Years after Construction	Inlet Entrance Avg. (feet^3)	+/- σ	Nixon Channel Avg. (feet^3)	+/- σ	Green Channel Avg. (feet^3)	+/- σ
	Alternative 5D – 1300-ft Terminal Groin with Beach Fill from Nixon Channel (2010 Cut)					
0 to 1	505,200,000	10,800,000	284,100,000	6,900,000	177,600,000	3,600,000
1 to 2	501,200,000	11,900,000	282,500,000	7,000,000	175,700,000	4,400,000
2 to 3	506,700,000	12,100,000	287,800,000	6,900,000	174,900,000	4,600,000
3 to 4	514,000,000	13,600,000	291,600,000	7,700,000	177,100,000	5,300,000
4 to 5	515,300,000	12,800,000	289,600,000	7,100,000	179,600,000	5,300,000
5 to 6	519,700,000	11,500,000	290,400,000	7,000,000	181,400,000	4,500,000
6 to 7	521,600,000	11,200,000	288,500,000	6,800,000	183,600,000	4,500,000

Years after Construction	Inlet Entrance Avg. (feet^3)	+/- σ	Nixon Channel Avg. (feet^3)	+/- σ	Green Channel Avg. (feet^3)	+/- σ
	Alternative 5D – 1500-ft Terminal Groin with Beach Fill from Nixon Channel (2010 Cut)					
0 to 1	505,400,000	10,700,000	284,400,000	6,800,000	177,600,000	3,700,000
1 to 2	503,100,000	11,800,000	284,700,000	6,900,000	175,300,000	4,300,000
2 to 3	508,000,000	11,200,000	288,500,000	6,700,000	175,200,000	4,000,000
3 to 4	515,000,000	13,200,000	291,500,000	7,500,000	177,100,000	5,200,000
4 to 5	515,000,000	13,000,000	289,300,000	7,700,000	178,300,000	4,700,000
5 to 6	520,100,000	10,800,000	290,000,000	6,500,000	181,300,000	4,200,000
6 to 7	523,300,000	11,700,000	290,100,000	7,200,000	183,100,000	4,500,000

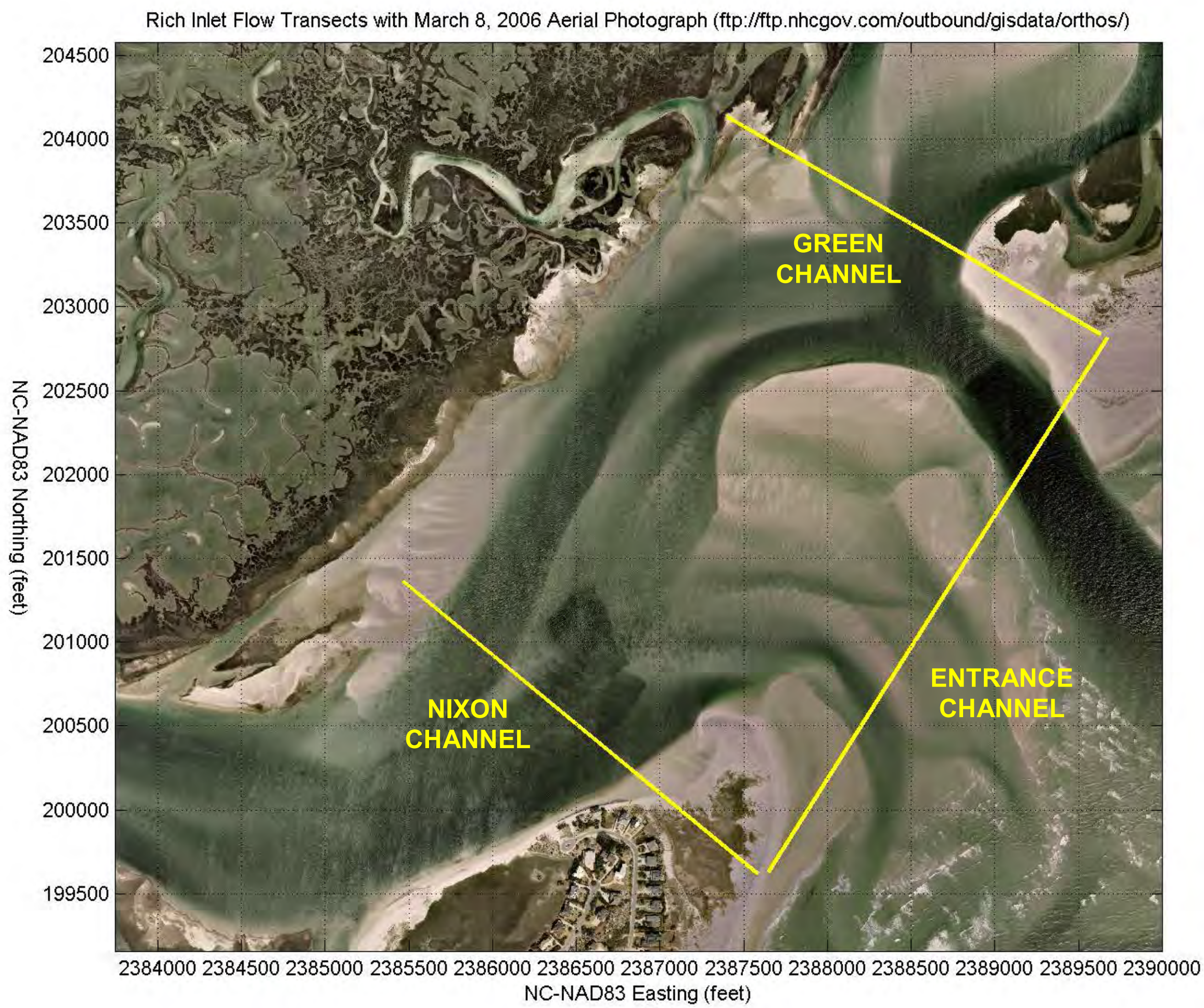


FIGURE 11-74: Rich Inlet Flow Transects.

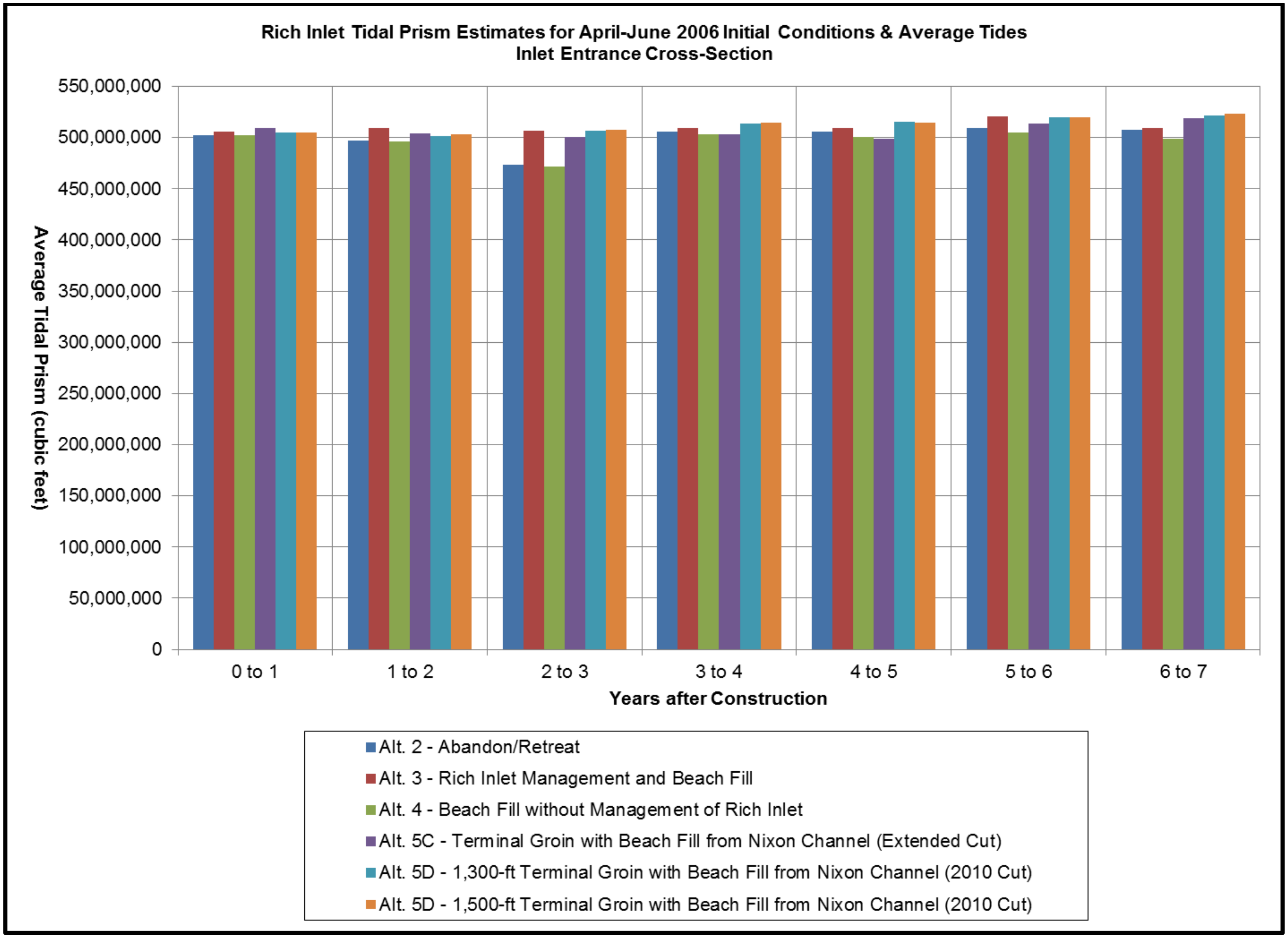


FIGURE 11-75: Tidal Prism Estimates for the Entrance Channel of Rich Inlet.

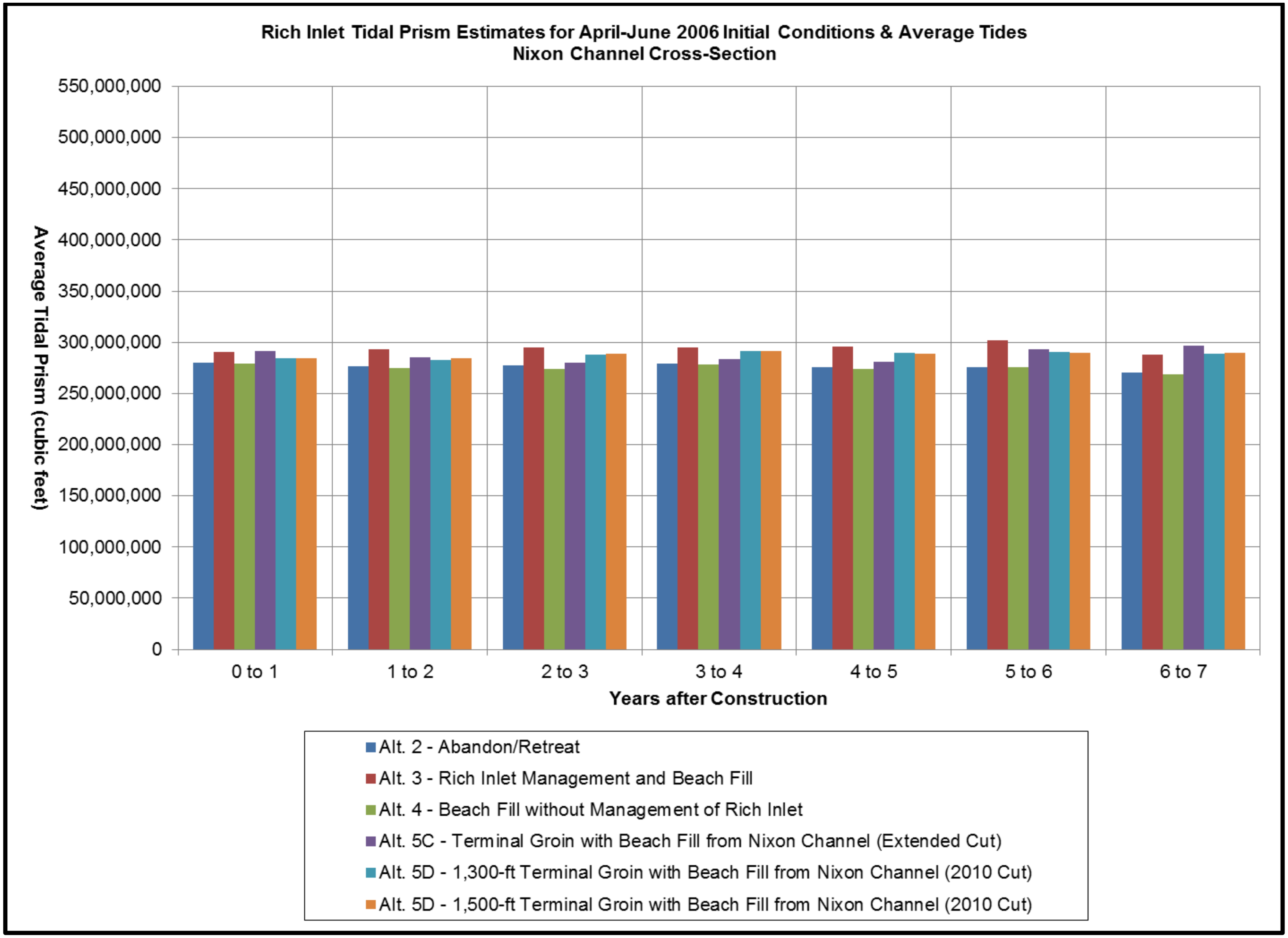


FIGURE 11-76: Tidal Prism Estimates for Nixon Channel.

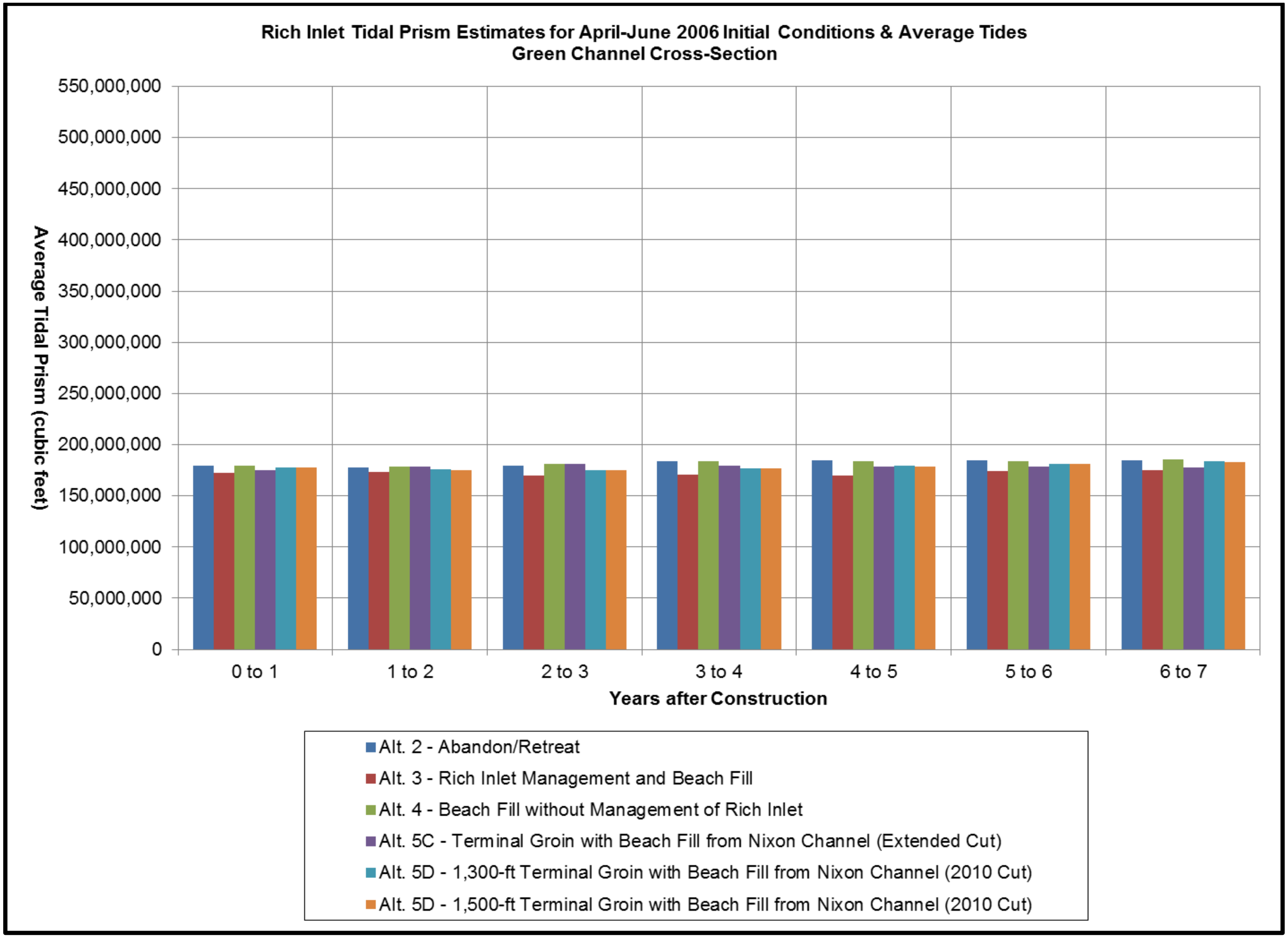


FIGURE 11-77: Tidal Prism Estimates for Green Channel.

11.6 Primary and Secondary Impact Areas

The primary impact areas are the areas falling within the beach fill templates and dredge cuts for each alternative (see Table 11-13). The secondary impact areas are based on the areas in which the vertical difference between Alternative 2 and Alternatives 3, 4, 5A, 5B-1, or 5B-2 in a given year was 0.5 feet or more (see Sub-Appendix B1 and Figures 11-51, 11-54, 11-57, 11-60, 11-65, 11-69, and 11-72). Secondary impacts include the longshore and cross-shore spreading of beach fill and the adjustment of the bottom bathymetry in Rich Inlet to the dredged conditions.

TABLE 11-13

PRIMARY IMPACT AREAS

Project Feature	Primary Impact Area (acres) Based on 2006 Critically Eroded Conditions				
	Alt. 3	Alt. 4	Alt. 5C	Alt. 5D 1300-ft	Alt. 5D 1500-ft
Oceanfront Fill Area	140.2	115.4	125.6	31.7	31.7
Nixon Channel Fill Area	7.4	7.4	7.4	7.4	7.4
Closure Dike	36.5	-N/A-	-N/A-	-N/A-	-N/A-
Dredge Cuts	92.3	-N/A-	77.6	44.7	44.7
TOTAL	276.4	122.8	210.6	83.8	83.8
Project Feature	**Primary Impact Area (acres) Based on 2012 Conditions**				
	Alt. 3	**Alt. 4**	**Alt. 5C**	**Alt. 5D 1300-ft**	**Alt. 5D 1500-ft**
Oceanfront Fill Area	146.9	119.2	127.5	40.0	40.0
Nixon Channel Fill Area	8.7	8.7	8.7	8.7	8.7
Closure Dike	29.6	-N/A-	-N/A-	-N/A-	-N/A-
Dredge Cuts	95.1	-N/A-	88.3	46.1	46.1
TOTAL	280.3	127.9	224.5	94.8	94.8

TABLE 11-14

DELFT3D SECONDARY IMPACT AREAS

Year after Construction	Secondary Impact Area (acres) Given 2006 Critically Eroded Conditions and						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5C	Alt. 5D 1300-ft	Alt. 5D 1500-ft
0	Not Simulated	0	276	123	211	84	84
1		0	875	366	732	210	266
2		0	1065	460	960	457	514
3		0	1238	569	1071	685	755
4		0	1345	690	1185	863	879
5		0	1433	813	1231	996	1055
6		0	1468	841	1329	1076	1112
7		0	1519	928	1337	1099	1147

Year after Construction	Secondary Impact Area (acres) Given 2012 Conditions and Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5C	Alt. 5D 1300-ft	Alt. 5D 1500-ft
0		0	280	128		95	95
1		0	880	298		217	216
2	Not	0	997	376	Not	370	393
3		0	1158	405		607	620
4	Simulated	0	1216	515	Simulated	756	811
5		0	1212	564		823	894
6		0	1248	632		963	1037
7		0	1307	700		1095	1207

12.0 OCEANFRONT BEACH FILL PERFORMANCE BASED ON THE GENESIS MODEL

12.1 Background

To provide a "second opinion" regarding the performance and impact of the channel modification and terminal groin alternatives, this Shoreline Management study utilizes the Generalized Model for Simulating Shoreline Change (GENESIS). GENESIS can incorporate the effects of groins, revetments, seawalls, breakwaters, and offshore bathymetry. Inputs to the model include shoreline locations, structure locations, a time series of offshore waves, and, if desired, a set of wave refraction coefficients and refracted wave angles.

GENESIS determines shoreline changes relative to a fixed baseline based on the wave-driven, longshore sediment transport. The model assumes that shoreline change is directly proportional to volume change, the profile shape is relatively constant with time, the berm elevation is uniform, and the depth of closure is uniform. As such, it is a "one-line" model that calculates shoreline position rather than bathymetric changes. The primary advantage of the GENESIS model is its ability to rapidly simulate (1-5 minutes) long-term (5-20 year) shoreline changes using a narrow grid spacing (10-50 feet).

Transport rates are calculated using the USACE (1990) formula (CERC Equation), with an additional term to account for longshore variations in the breaking wave height. To calibrate the model, three longshore transport coefficients are determined:

1. Coefficient K1 governs the transport resulting from changes in the shoreline orientation. K1 typically ranges from 0.1 to 2 and has the largest influence on the model's results (Hanson and Kraus, 1991; CPE, 2007). If GENESIS is being used with a wave transformation model that includes bottom friction, the K1 values tend to be larger.
2. Coefficient K2 governs the transport resulting from variations in the breaking wave height (Hanson and Kraus, 1991). K2 typical ranges from 0 to the value of K1.

The GENESIS baseline for Figure Eight Island appears in Figure 12-1. The baseline extends from profile F0+00 near the south end of Beach Road to profile 110+00 near Rich Inlet. The length of the baseline is 22,000 feet, with a grid spacing of 25 feet. The purpose of the long baseline is to accommodate the spreading of beach fill material given the placement of beach fill between 8 Beach Road S and Rich Inlet (profiles F90+00 to 110+00).

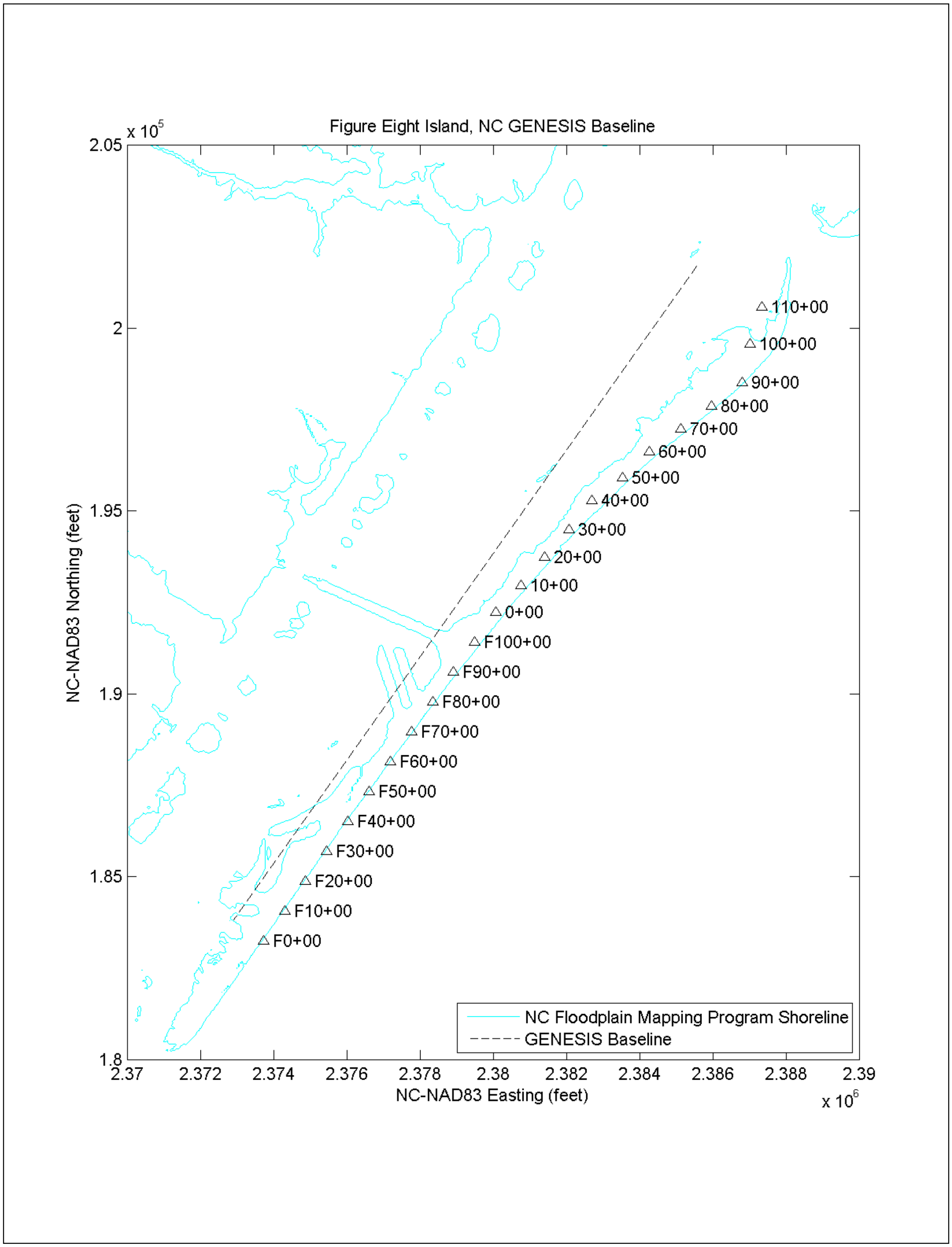


FIGURE 12-1: Figure Eight Island, NC GENESIS Baseline.

12.2 Wave Data

The wave data used in the GENESIS model was taken from the NOAA Western North Atlantic Wavewatch forecast at 34.00ºN, 76.25ºW, -644 feet NAVD (see Figure 11-12). This location was the same forecast node used in the Delft3D calibration. The record at this site extended from July 1, 1999 to December 31, 2012.

To determine the nearshore waves, the wave record was divided into the following wave height, period, and direction classes:

- Significant wave height classes: 0 to 6.4 feet, 6.4 to 10 feet, 10 to 35 feet.

- Peak wave period classes: 0-5 seconds, 5-7 seconds, 7-9 seconds, 9-11 seconds, 11-13 seconds, 13-15 seconds, 15-17 seconds, 17-23 seconds.

- Wave direction classes: 35-58°, 58-80°, 80-103°, 103-125°, 125-148°, 148-170°, 170-193°, 193-215°.

Each wave height classes contained an equal amount of wave energy in KW-Hours/m (see Section 11.3.2). The wave period and direction classes were based on typical divisions used in GENESIS modeling studies. Although the divisions above created 192 height, period, and direction classes, only 127 actually contained wave data. The average wave in each class (Table 12-1) was then transformed to the depth of closure (-24 feet NAVD) using the SWAN model. Refraction coefficients were then calculated based on the ratios of the transformed wave heights to the offshore wave heights in Table 12-1. The grids, bathymetries, and parameters used in the SWAN model were identical to those in Table 11-6 and Figures 11-10 to 11-15.

12.3 Model Calibration

The calibration of the GENESIS model was based on the shoreline and volume changes between April 2007 and October 2008. The April 2007 shoreline was used as the initial condition. A berm elevation of +6 feet NAVD was assumed, along with a closure depth of -24 feet NAVD and an average grain size of 0.18 mm (see Table 4-7). The sandbags along the north end of the island were neglected. When these were included in the model as a "seawall", their effect was grossly overstated.

To determine the values of K1 and K2, several GENESIS runs were performed using K1 values ranging from 2 to 7. The best results were achieved by setting K1 equal to 2. Changing the value of K2 from 0 to 2 led to smoother shoreline and volume changes with respect to distance. It also provided for better results when the proposed groin was included in subsequent simulations (see Hanson and Kraus, 1991, p. 53).

In general, the agreement between the simulated and observed changes was good (Figures 12-2 and 12-3).

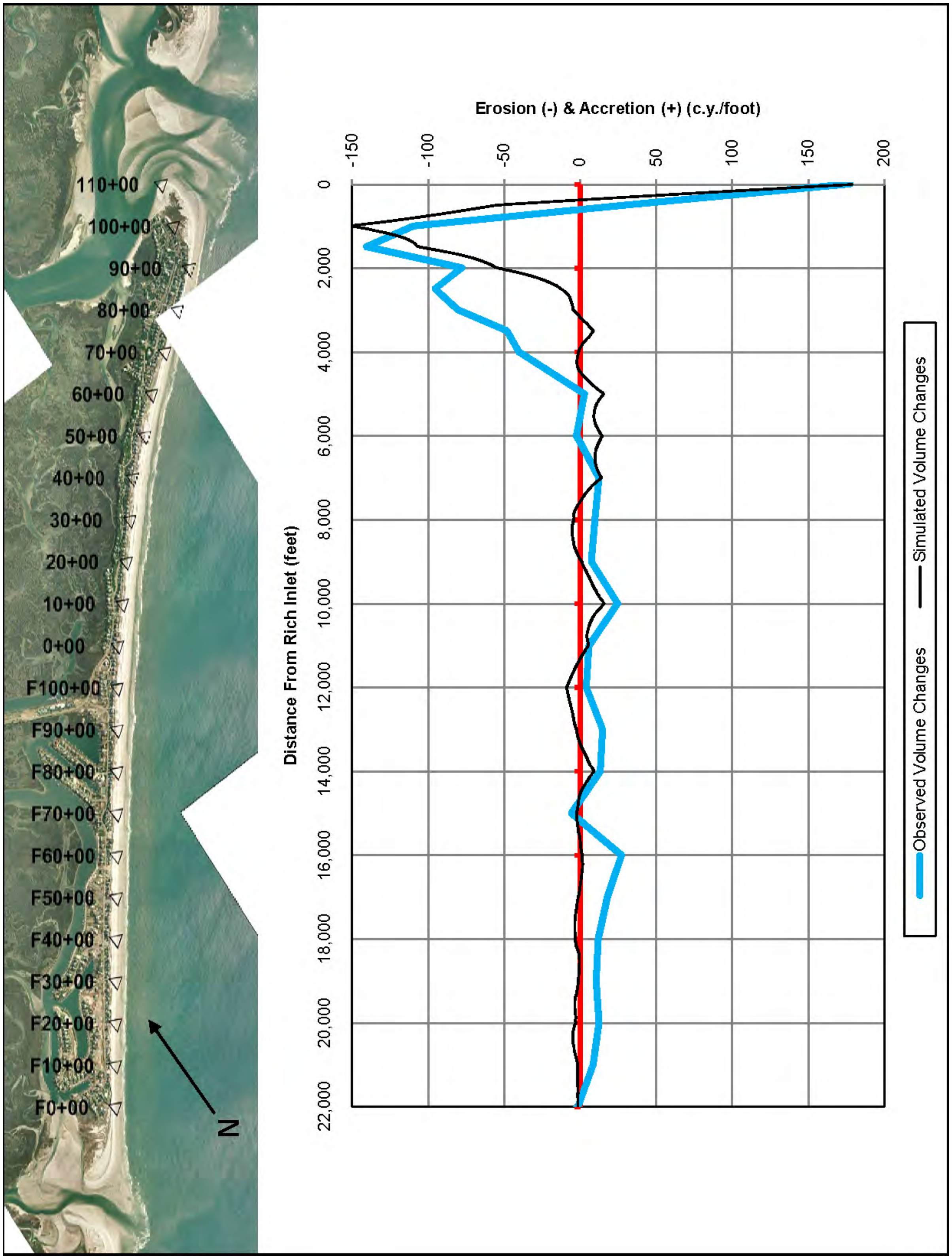


FIGURE 12-2: GENESIS Model Calibration, April 2007 to October 2008.

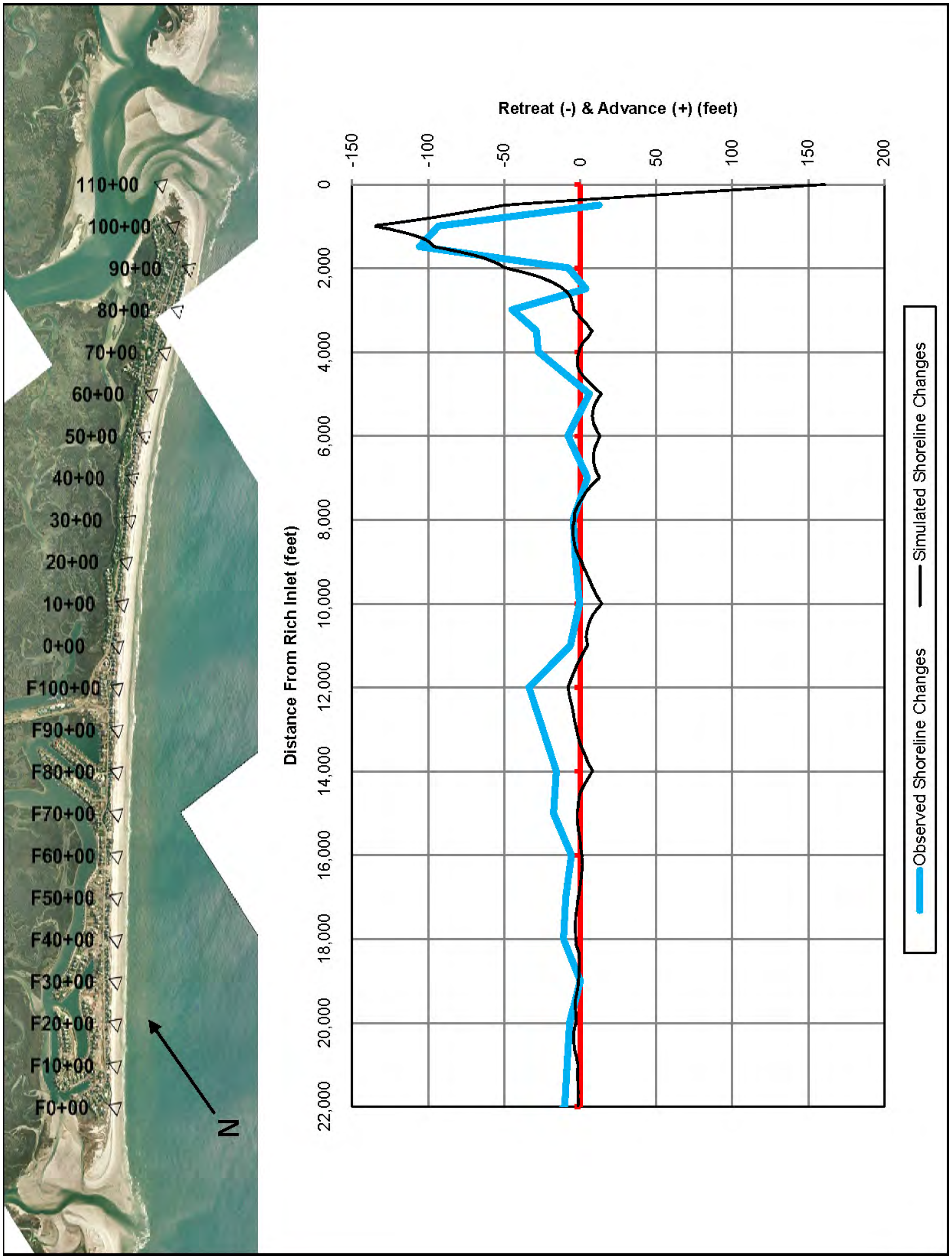


FIGURE 12-3: GENESIS Model Calibration, April 2007 to October 2008.

TABLE 12-1

WAVE CASES FOR GENESIS MODEL

Case #	Hs (feet)	Tp (sec.)	Dir. (°)
10101	4.1	4.4	46
20101	4.1	4.4	69
30101	4.1	4.4	91
40101	4.1	4.4	114
50101	4.1	4.4	136
60101	4.1	4.4	159
70101	4.1	4.4	181
80101	4.1	4.4	204
10201	4.1	6.0	46
20201	4.1	6.0	69
30201	4.1	6.0	91
40201	4.1	6.0	114
50201	4.1	6.0	136
60201	4.1	6.0	159
70201	4.1	6.0	181
80201	4.1	6.0	204
10301	4.1	8.0	46
20301	4.1	8.0	69
30301	4.1	8.0	91
40301	4.1	8.0	114
50301	4.1	8.0	136
60301	4.1	8.0	159
70301	4.1	8.0	181
80301	4.1	8.0	204
10401	4.1	9.8	46
20401	4.1	9.8	69
30401	4.1	9.8	91
40401	4.1	9.8	114
50401	4.1	9.8	136
60401	4.1	9.8	159
70401	4.1	9.8	181
10501	4.1	11.7	46
20501	4.1	11.7	69
30501	4.1	11.7	91
40501	4.1	11.7	114
50501	4.1	11.7	136
10601	4.1	13.7	46
20601	4.1	13.7	69
30601	4.1	13.7	91
40601	4.1	13.7	114
50601	4.1	13.7	136
20701	4.1	15.6	69
40701	4.1	15.6	114
50701	4.1	15.6	136
10102	7.8	4.4	46
50102	7.8	4.4	136
60102	7.8	4.4	159
70102	7.8	4.4	181
80102	7.8	4.4	204
10202	7.8	6.0	46
20202	7.8	6.0	69
30202	7.8	6.0	91
40202	7.8	6.0	114
50202	7.8	6.0	136
60202	7.8	6.0	159
70202	7.8	6.0	181
80202	7.8	6.0	204

Case #	Hs (feet)	Tp (sec.)	Dir. (°)
10302	7.8	8.0	46
20302	7.8	8.0	69
30302	7.8	8.0	91
40302	7.8	8.0	114
50302	7.8	8.0	136
60302	7.8	8.0	159
70302	7.8	8.0	181
80302	7.8	8.0	204
10402	7.8	9.8	46
20402	7.8	9.8	69
30402	7.8	9.8	91
40402	7.8	9.8	114
50402	7.8	9.8	136
60402	7.8	9.8	159
70402	7.8	9.8	181
80402	7.8	9.8	204
10502	7.8	11.7	46
20502	7.8	11.7	69
30502	7.8	11.7	91
40502	7.8	11.7	114
50502	7.8	11.7	136
60502	7.8	11.7	159
70502	7.8	11.7	181
80502	7.8	11.7	204
10602	7.8	13.7	46
20602	7.8	13.7	69
30602	7.8	13.7	91
40602	7.8	13.7	114
50602	7.8	13.7	136
60602	7.8	13.7	159
20702	7.8	15.6	69
40702	7.8	15.6	114
40802	7.8	17.4	114
10203	12.2	6.0	46
20203	12.2	6.0	69
30203	12.2	6.0	91
40203	12.2	6.0	114
50203	12.2	6.0	136
60203	12.2	6.0	159
70203	12.2	6.0	181
80203	12.2	6.0	204
10303	12.2	8.0	46
20303	12.2	8.0	69
30303	12.2	8.0	91
40303	12.2	8.0	114
50303	12.2	8.0	136
60303	12.2	8.0	159
70303	12.2	8.0	181
80303	12.2	8.0	204
10403	12.2	9.8	46
20403	12.2	9.8	69
30403	12.2	9.8	91
40403	12.2	9.8	114
50403	12.2	9.8	136
60403	12.2	9.8	159
70403	12.2	9.8	181
80403	12.2	9.8	204

TABLE 12-1 (continued)

WAVE CASES FOR GENESIS MODEL

Case #	Hs (feet)	Tp (sec.)	Dir. (°)
10503	12.2	11.7	46
20503	12.2	11.7	69
50503	12.2	11.7	136
60503	12.2	11.7	159
70503	12.2	11.7	181
20603	12.2	13.7	69
30603	12.2	13.7	91
40603	12.2	13.7	114
50603	12.2	13.7	136
60603	12.2	13.7	159
70603	12.2	13.7	181
40703	12.2	15.6	114
50703	12.2	15.6	136

The only exception was the area between Surf Court and Comber Road (profiles 65+00 to 90+00), where the model predicted a stable beach instead of an eroding beach. At all other locations, the model results were generally consistent with the observed shoreline and volume changes.

12.4 Model Verification

The verification of the GENESIS model was based on the shoreline and volume changes between April 2006 and April 2007. This period was preceded by beach fill operations on the northern and southern thirds of the island (see Table 6-2). Observed volume change patterns were characterized by an erosion hotspot on the north end of the island, stability in the middle of the island, and erosion on the southern third of the island. The April 2006 shoreline was used as the initial condition on the northern half of the island, and the June 2006 shoreline was used as the initial condition on the southern half of the island. The values of K1 and K2 were identical to those used in the final calibration run, and the existing sandbags were neglected.

Along most of Figure Eight Island, shoreline changes during the verification period were characterized by the change in the beach profile shape following the various beach fill operations (see Figure 12-5). Since this process was not included in the GENESIS model, differences between the simulated and observed shoreline changes occurred in several locations. However, on the northern and central sections of the island, agreement between the simulated and observed volume changes was good (Figure 12-4). The overall volume change patterns that occurred between April 2006 and April 2007 were reproduced by the model. On the southern third of the island (profiles F0+00 to F70+00), the GENESIS model tended to predict stable beaches instead of eroding beaches. This was due to the fact that the waves and tidal currents in Mason Inlet were not incorporated into the SWAN and GENESIS models.

Overall the calibration and verification showed that the GENESIS model is able to simulate the observed shoreline and volume changes after the beach profiles have adjusted to their equilibrium shape. During the initial adjustment period, which ranges from 1-3 years, the GENESIS model is best used as a volume change model. Based on the results presented in Figures 12-2 to 12-5, the GENESIS model is suitable for providing a “second opinion” regarding

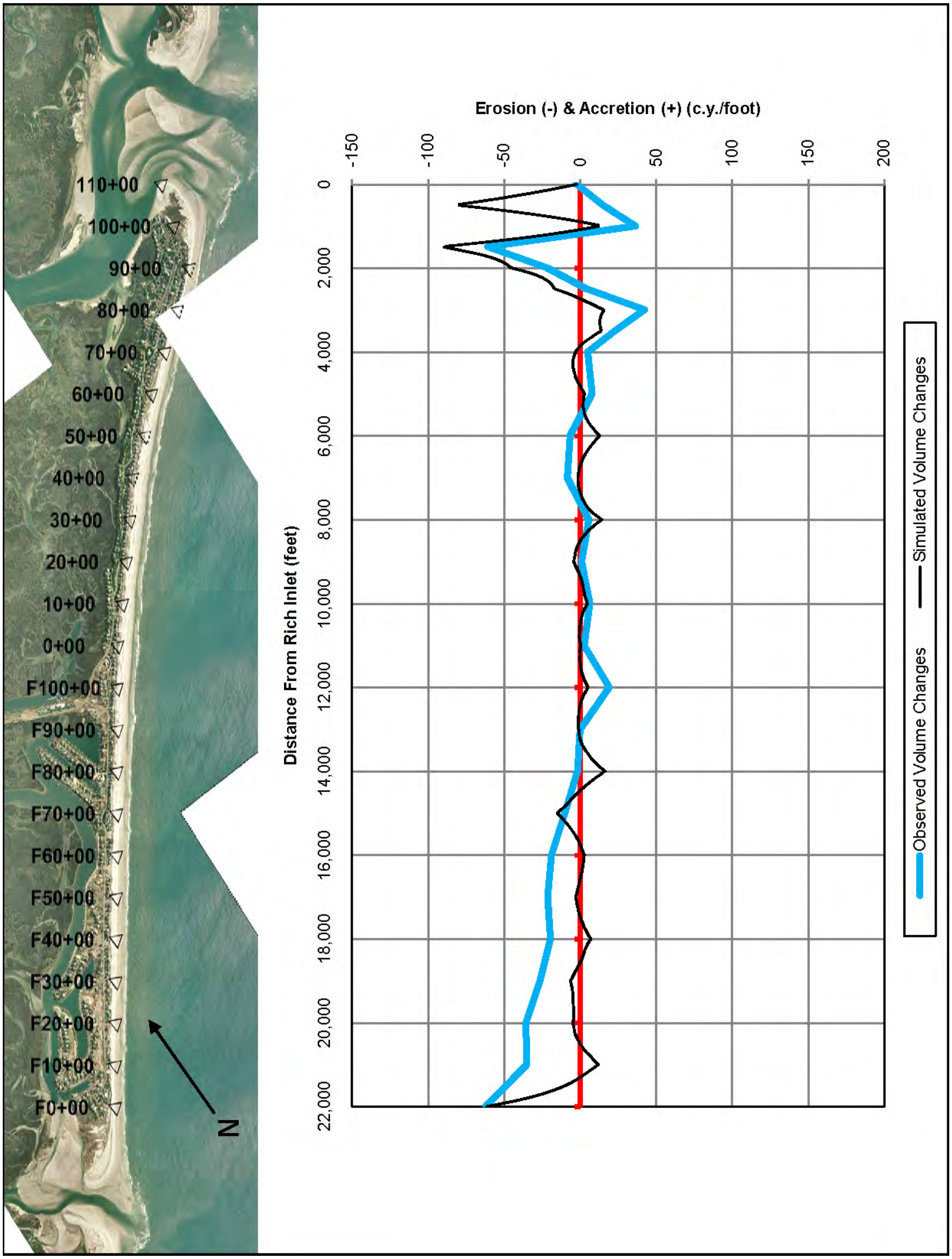


FIGURE 12-4: GENESIS Model Verification, April 2006 to April 2007.

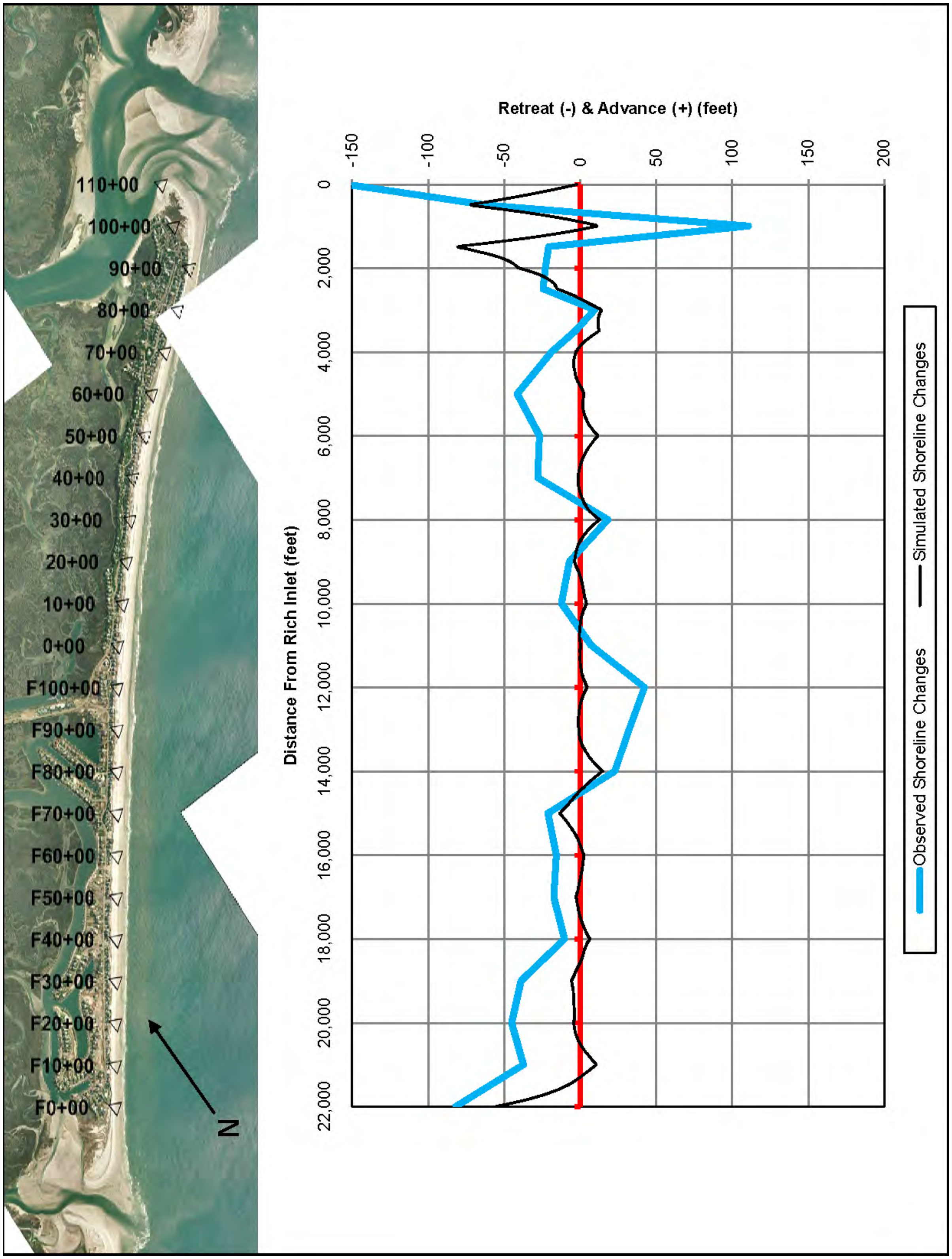


FIGURE 12-5: GENESIS Model Verification, April 2006 to April 2007.

beach fill performance over a 10 year study period on the northern and middle sections of Figure Eight Island.

12.5 Performance of the Alternatives

Using the calibrated GENESIS model, shoreline changes were estimated given the following alternatives:

- Alt. 2 - Abandon/Retreat
- Alt. 3 - Rich Inlet Management and Beach Fill
- Alt. 4 - Beach Fill without Management of Rich Inlet
- Alt. 5C - Terminal Groin with Beach Fill from Nixon Channel (Extended Cut)
- Alt. 5D – 1,300-foot Terminal Groin with Beach Fill from Nixon Channel (2010 Cut)
- Alt. 5D – 1,500 foot Terminal Groin with Beach Fill from Nixon Channel (2010 Cut)

and the following conditions:

- April 2007 critically eroded conditions.
- March 2012 conditions.

Similar to the Delft3D model results, it is important to note that once the project has been constructed, the project area will have changed relative to either set of conditions (April 2006 or March 2012). Unlike the Delft3D model, the GENESIS model is able to incorporate the effects of beach fill during the middle of a simulation. However, neither model is able to *predict* the occurrence of beach fill operations, hurricanes, tropical storms, or northeasters in future years. The GENESIS model can only estimate the effects of such events based on assumptions provided as input. These assumptions are detailed below. Given the various assumptions required to run the GENESIS model, the results in Sub-Appendix C are best suited for comparisons between alternatives. They cannot and should not be used to provide absolute predictions of the future.

12.5.1 Waves

To account for risk and uncertainty, 10 runs were performed for each scenario using random sequences of annual waves (Table 12-2). An additional run was then conducted using the actual wave sequence between 1999 and 2009, for a total of 11 runs. The 11 simulations were then averaged to provide the mean shoreline positions and confidence intervals appearing in Sub-Appendix C. To provide information regarding long-term changes, the duration of each simulation was 10 years.

TABLE 12-2

RANDOM SEQUENCES OF ANNUAL WAVES USED IN FUTURE CONDITIONS SIMULATIONS

Year of Project Life	Years from Wave Record Used in Random Wave Sequence in Run # …										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
0	2010	2005	2003	2009	2011	2004	2007	2003	2003	2005	1999
1	2011	2011	2001	2009	2012	2010	2006	2011	2010	2001	2000
2	2002	2010	2001	2003	2007	2007	2000	2002	2005	2003	2001
3	2011	2012	2010	2008	2002	2007	2004	2010	2011	2001	2002
4	2008	2008	2008	2008	2002	2011	2002	2006	2002	2002	2003
5	2001	2000	2004	2002	2003	2003	2010	2012	2003	2003	2004
6	2003	2010	2011	2001	2010	2009	2004	2001	2002	2005	2005
7	2007	2011	2000	2006	2003	2009	2006	2005	2002	2001	2006
8	2011	2008	2005	2012	2010	2005	2002	2001	2010	2011	2007
9	2012	2009	2005	2004	2003	2007	2007	2012	2007	2011	2008
10	2002	2009	2009	2007	2011	2001	2003	2000	2007	2006	2009

12.5.2 Alternatives 1 and 2

Alternative 1 assumes that the present strategies to manage the island's shoreline in Table 6-1 will continue into the future. Although the GENESIS model can incorporate the effect of beach fill during the middle of a simulation, dredging and fill operations around Figure Eight Island are highly variable in terms of timing and quantity (see Table 6-1). As such, they are difficult to predict with any degree of certainty. Since the input required to simulate Alternative 1 cannot be formulated with a sufficient degree of certainty, Alternative 1 was not simulated in the GENESIS model. Instead, Alternative 2 was used as the "Absolutely No Action" scenario by which to evaluate the other alternatives. It is important to note that Alternative 2 does *not* approximate what occurred between 2007 and 2012 (see Table 6-1).

The initial conditions for the critically eroded version of Alternative 2 were based on the April 2007 beach profile survey. Initial conditions for the 2012 scenario were based on the March 2012 survey on the northern half of Figure Eight Island and the August 2012 aerial photograph on the southern half of Figure Eight Island. In both scenarios, the effects of the existing sandbags were neglected. To account for changes in the ebb shoal between 2007 and 2012, the refraction coefficients for the 2012 scenario were updated by re-running the wave cases in Table 12-1 using the 2012 bathymetry (see Figure 11-45, top half). The refraction coefficients for the 2007 scenario were identical to the ones used in the original calibration of the GENESIS model, which were based on the 2006 bathymetries shown in Figures 11-12 through 11-14. Model results at Year 5 given Alternative 2 appear in Figures 12-6 and 12-7.

In general, the model results suggest that given eroded conditions similar to those in 2007, severe erosion would continue if the existing sandbags were removed. Oceanfront properties between profiles 80+00 and 95+00 (13 Comber Road to Inlet Hook Road) would be lost to erosion, with the further possibility of losing Inlet Hook Road itself (see Figure 12-6).

FIGURE 12-6: GENESIS Year 5 Conditions Given Alternative 2 under April 2007 Critically Eroded Conditions.

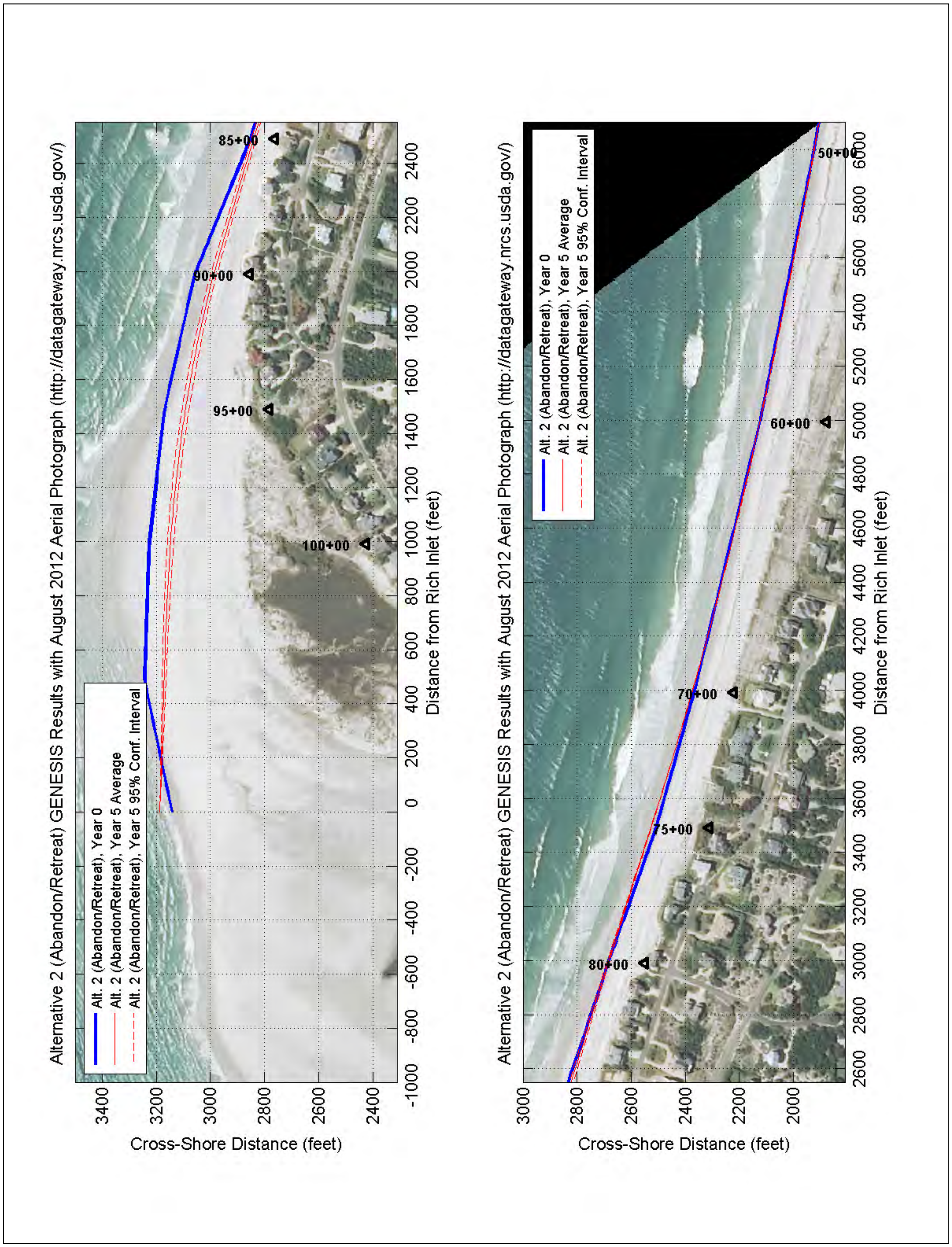


FIGURE 12-7: GENESIS Year 5 Conditions Given Alternative 2 under 2012 Conditions.

Under conditions similar to those in 2012, the model suggests that erosion could occur north of profile 80+00 (13 Comber Road) and Rich Inlet. Although this area has gained material since 2007, some of the gains have occurred due to the placement of beach fill (see Table 6-1 and Figures 6-2b and 7-1b). When the effects of beach fill are removed, the survey data suggests that an erosion hotspot still exists near the north end of Figure Eight Island (see Figures 6-2b and 7-1b). The primary difference between the model results and the survey data is not whether an erosion hotspot exists, but, rather, where it is centered. The survey data suggests that the erosion hotspot is centered between profiles 75+00 and 80+00 (see Figures 6-2b and 7-1b), while the GENESIS model results suggest that the erosion hotspot is centered further north (see Figure 12-7). Overall, the model results suggest that the existing beach would be wide enough to prevent erosion-related losses to upland properties at the north end of the island (see Figure 12-7 and Sub-Appendix C). However, given the differences between the model results in Figure 12-7 and the observed erosion patterns (Figures 6-2b and 7-1b), this finding should be confirmed using future monitoring surveys.

12.5.3 Alternative 3

Alternative 3 was incorporated into the GENESIS model by widening the 2007 and 2012 shorelines based on the "adjusted berm width" in Column 4 of Table 9-2. Since the GENESIS model did not include cross-shore transport, it was necessary to assume that the adjustment to an equilibrium beach profile shape (see Figure 9-13) would occur shortly after construction. For this reason, the "adjusted berm width" in Table 9-2 was used to develop the initial conditions, rather than beach widths based on the construction templates (see Figure 9-13). Renourishment of profiles 60+00 to 105+00 was implemented after the end of Year 5.

Preliminary simulations examined the sensitivity of the GENESIS and SWAN models to dredging in Rich Inlet. Specifically, the 2006 bathymetry (Figure 11-43, top half) was replaced with the post-construction bathymetry under Alternatives 3 and 5A (top halves of Figures 11-49 and 11-63). Using the SWAN model and the 3 different bathymetries, refraction coefficients and wave directions were computed along the -24 foot NAVD contour. Although dredging altered the wave patterns within the inlet, it did not substantially change the refraction coefficients and wave directions along the GENESIS model domain. Had the wave transformation estimates for the GENESIS model been based on the bathymetries at Years 2 or 5, inlet dredging would have altered the refraction coefficients. However, the GENESIS model would no longer be independent from the Delft3D-FLOW model. For these reasons, the refraction coefficients and nearshore wave angles for Alternatives 3, 4, 5C, and 5D with both the 1,300-ft and 1,500-ft terminal groins were the same as those for Alternative 2.

GENESIS model results for Alternative 3 appear in Figures 12-8 through 12-10. Given eroded conditions similar to those in 2007, the model suggests that by Year 5 erosion into the pre-construction shoreline will have occurred north of Comber Road (see Figures 12-8 and 12-10). This finding is consistent with the Delft3D model results (see Figure 11-48). Without the existing sandbags in place, a number of homes along Comber Road could be lost to erosion. However, the risk of loss is less than what would occur under an "absolutely no action" scenario (see Figure 12-8).

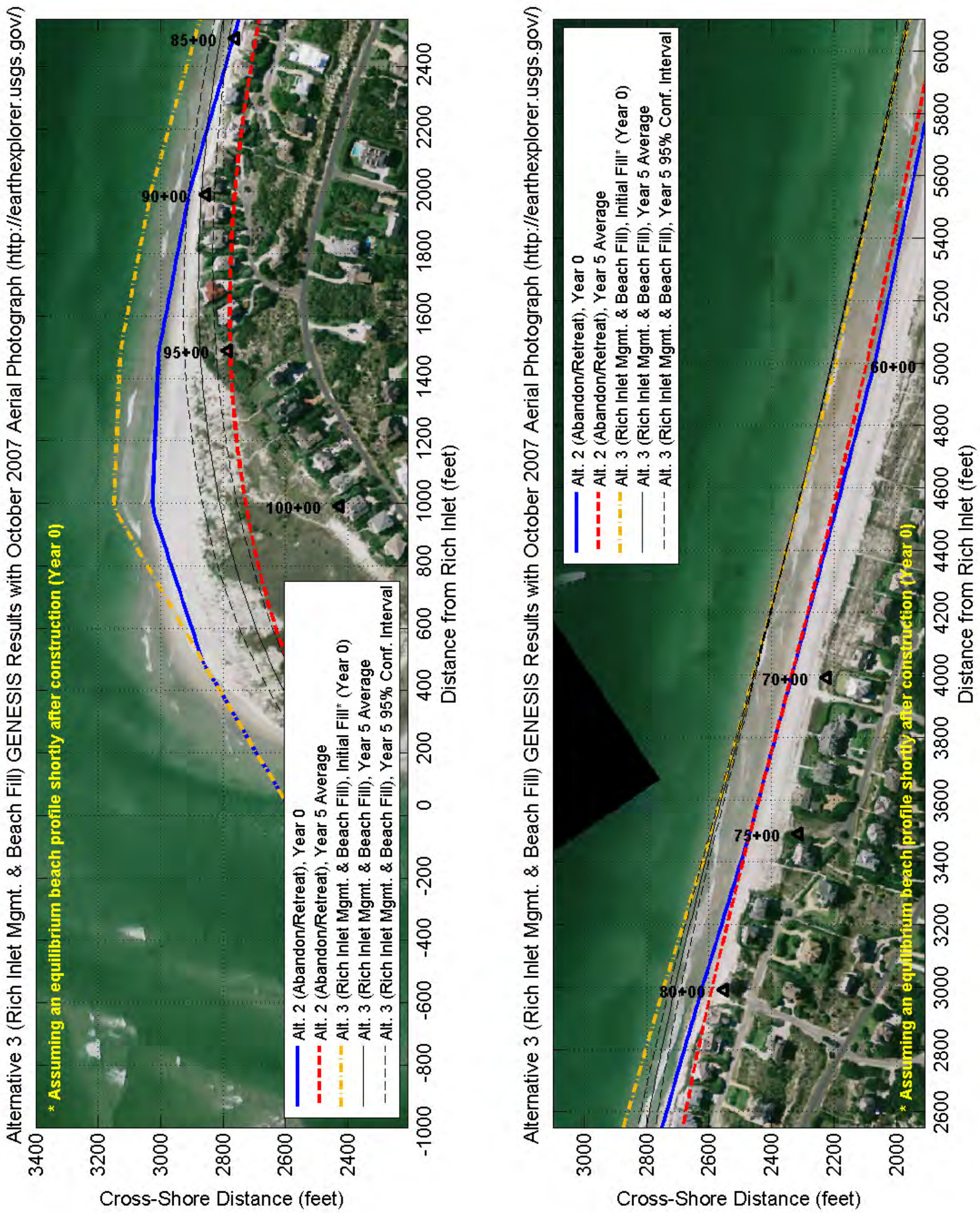


FIGURE 12-8: GENESIS Year 5 Conditions Given Alternative 3 under April 2007 Critically Eroded Conditions.

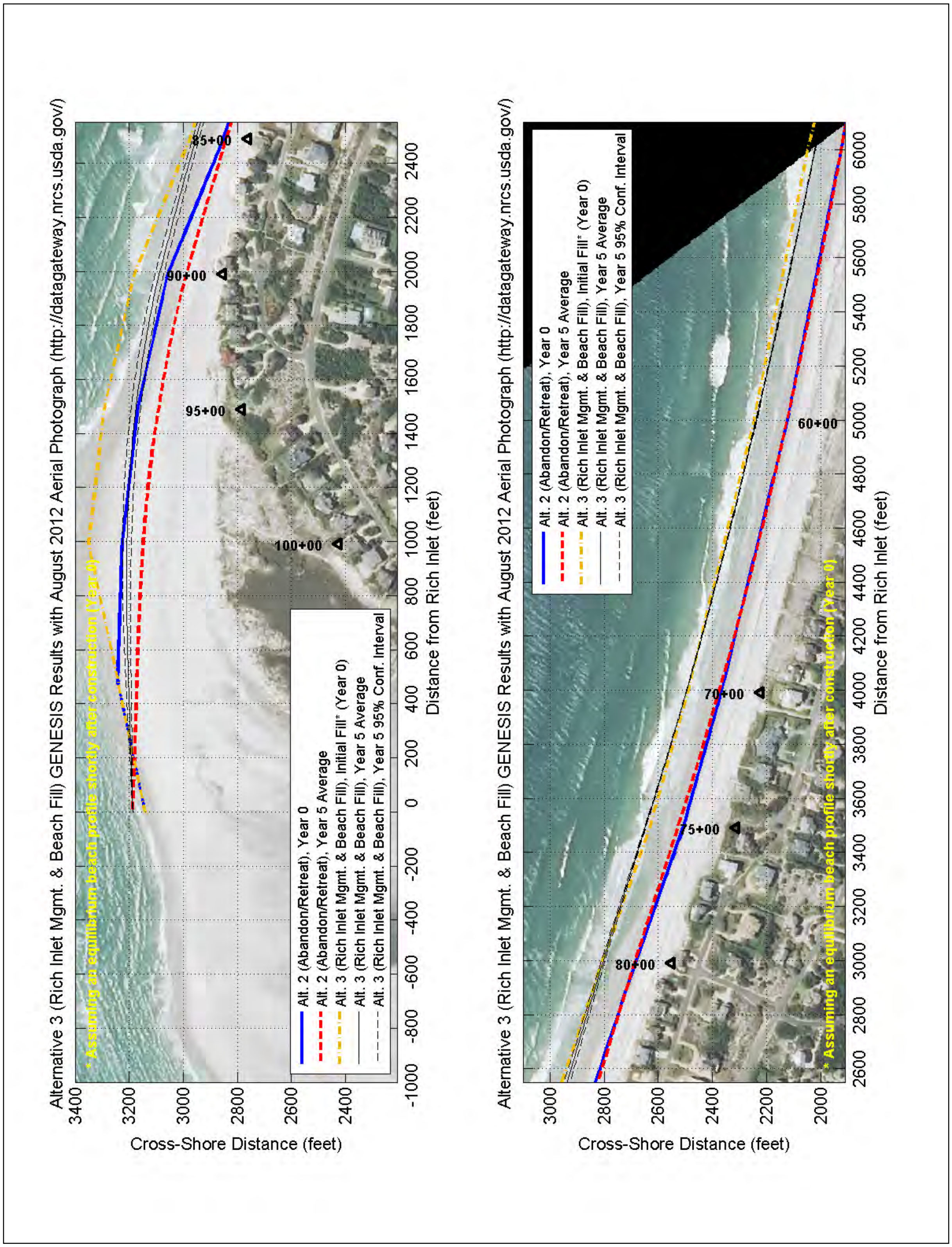


FIGURE 12-9: GENESIS Year 5 Conditions Given Alternative 3 under 2012 Conditions.

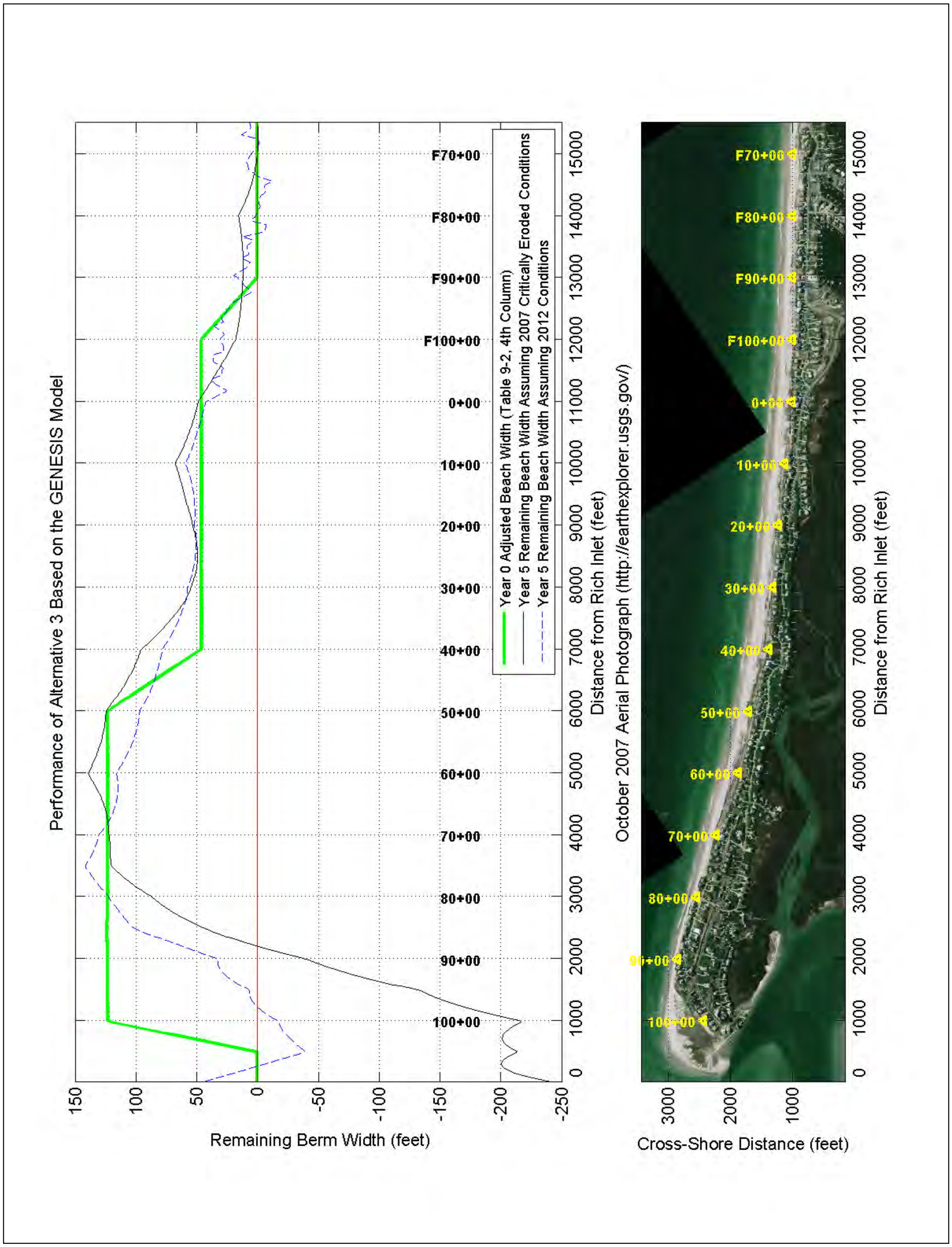


FIGURE 12-10: Remaining Beach Width Given Alternative 3 Based on the GENESIS Model.

Given conditions similar to those in 2012, the model suggests that erosion into the pre-construction shoreline over the first 5 years would be limited to the area north of profile 95+00 (see Figures 12-9 and 12-10). Given the distances between the upland buildings and the 2012 shoreline, the erosion would not pose a risk to upland development (see Figure 12-9). Along Comber Road, more erosion might occur than what the model suggests. However, given the amount of fill and the location of the 2012 shoreline, this risk appears to be manageable (see Figure 12-9).

12.5.4 Alternative 4

Alternative 4 was incorporated into the GENESIS model by widening the 2007 and 2012 shorelines based on the "adjusted berm width" in Column 3 of Table 9-5. Renourishment of profiles 60+00 to 105+00 was implemented after the end of Year 4. The effects of beach renourishment on the model results are illustrated in Figures 12-11 and 12-12, which show the results of the model at Years 4 and 5. Simulated beach widths at Year 5 are significantly greater than those at Year 4 due to the placement of fill on profiles 60+00 to 105+00 between Years 4 and 5.

GENESIS model results for Alternative 4 appear in Figures 12-11 through 12-13. Given eroded conditions similar to those in 2007, the model suggests that by Year 4, erosion into the pre-construction shoreline would occur north of profile 90+00 (see Figures 12-11 and 12-13). However, the risk of losing upland buildings due to erosion appears to be low (see Figure 12-11 and Sub-Appendix C). Given conditions similar to those in 2012, the model suggests that erosion into the pre-construction shoreline over the first 4 years would be limited to the taper sections at either end of the fill area (see Figures 12-12 and 12-13).

12.5.5 Alternative 5C

The beach fill for Alternative 5C was incorporated into the GENESIS model by widening the 2007 and 2012 shorelines based on the "adjusted berm width" in Column 3 of Table 9-6. Renourishment of profiles 60+00 to 102+50 was implemented after the end of Year 5.

As shown in Figures 12-14 and 12-15, the proposed terminal groin alignment is at an angle to the shoreline and the model's baseline. In cases such as these, the model's developers recommend that the structure be treated as a combination of an offshore breakwater and a diffracting groin (see Figure 12-16). Accordingly, the terminal groin was simulated as a diffracting groin with an effective permeability of 37% and an adjoining, offshore breakwater.

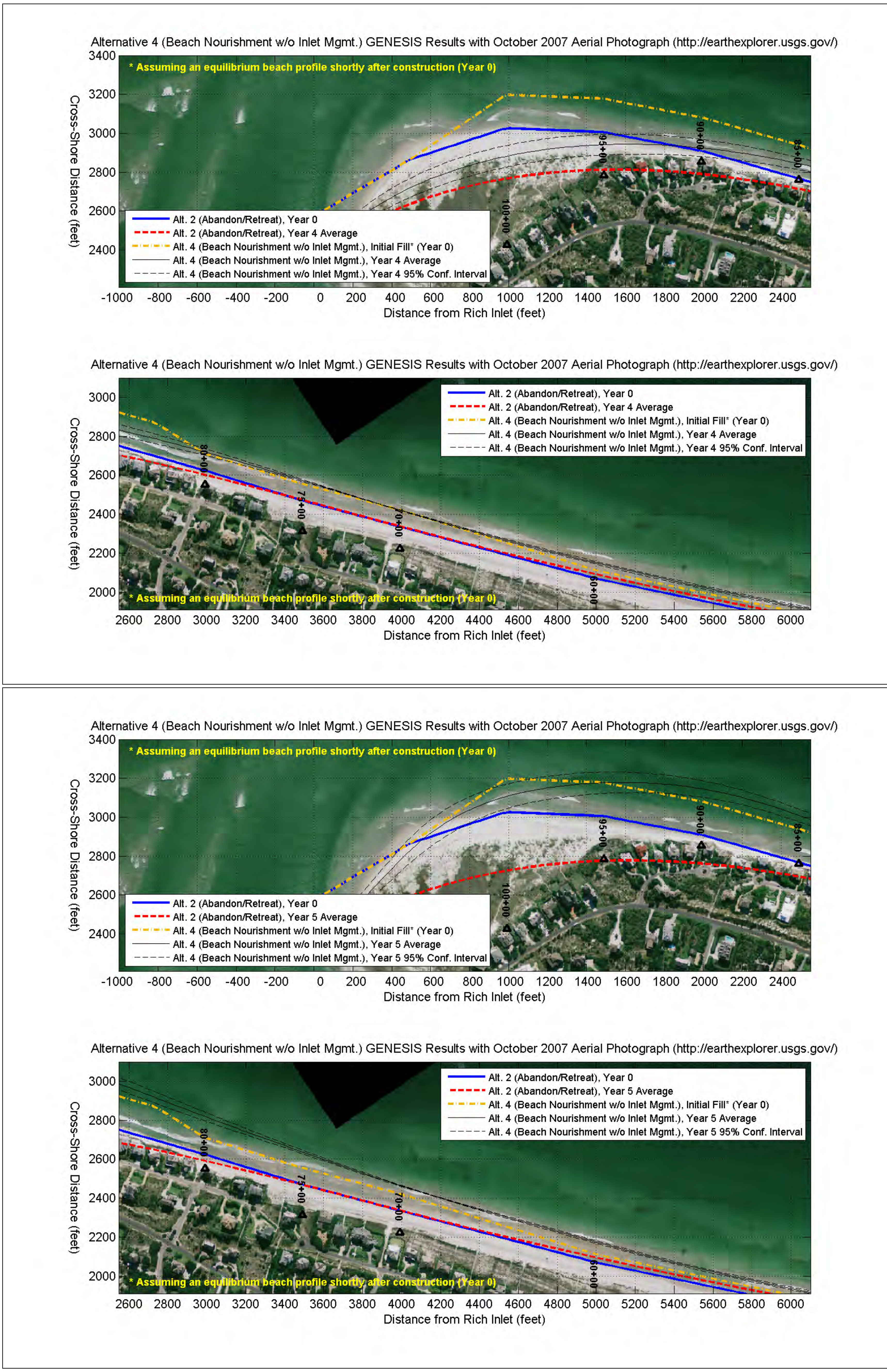


FIGURE 12-11: GENESIS Year 4 & 5 Conditions Given Alternative 4 under April 2007 Critically Eroded Conditions.

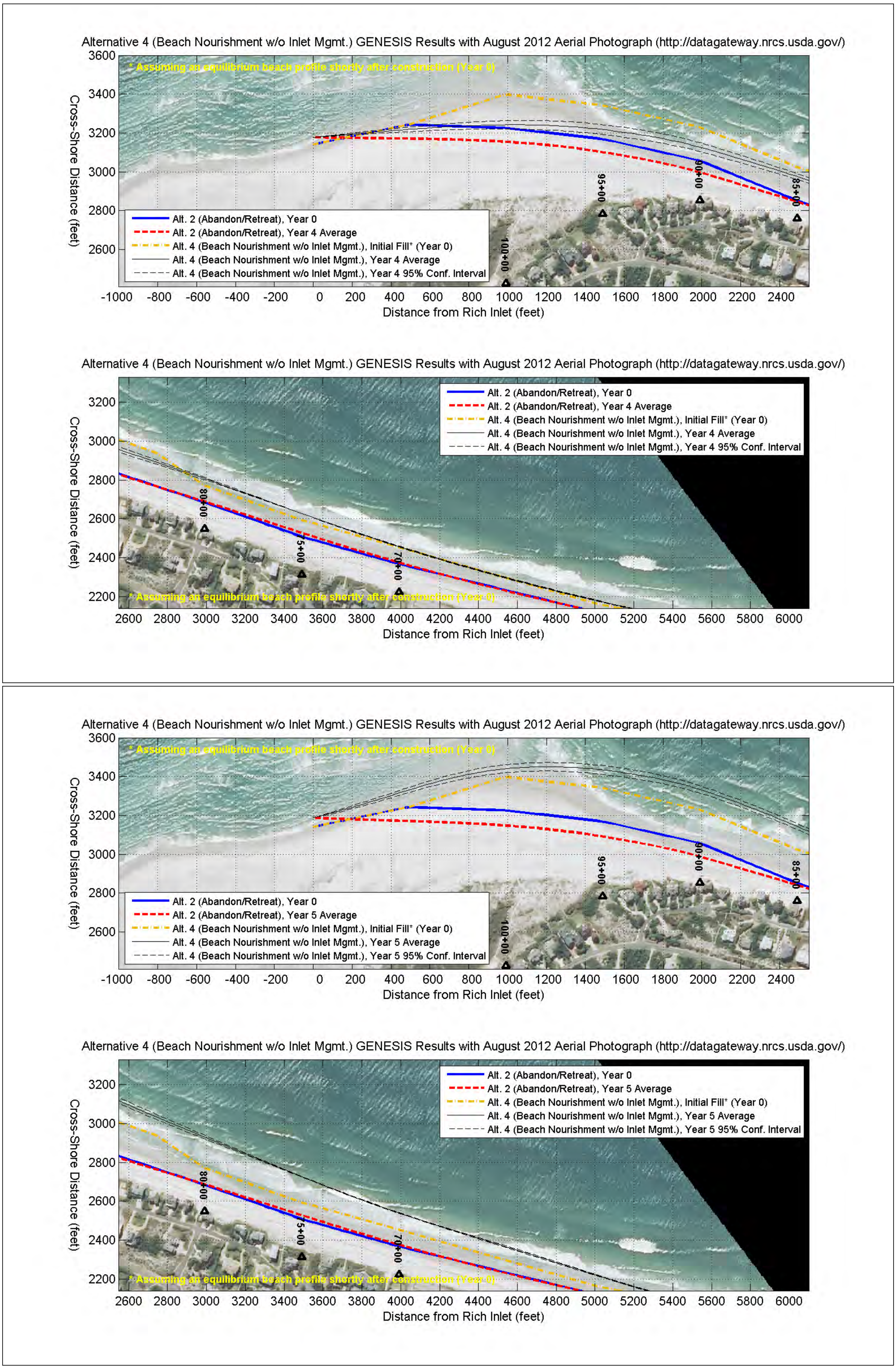


FIGURE 12-12: GENESIS Year 4 & 5 Conditions Given Alternative 4 under 2012 Conditions.

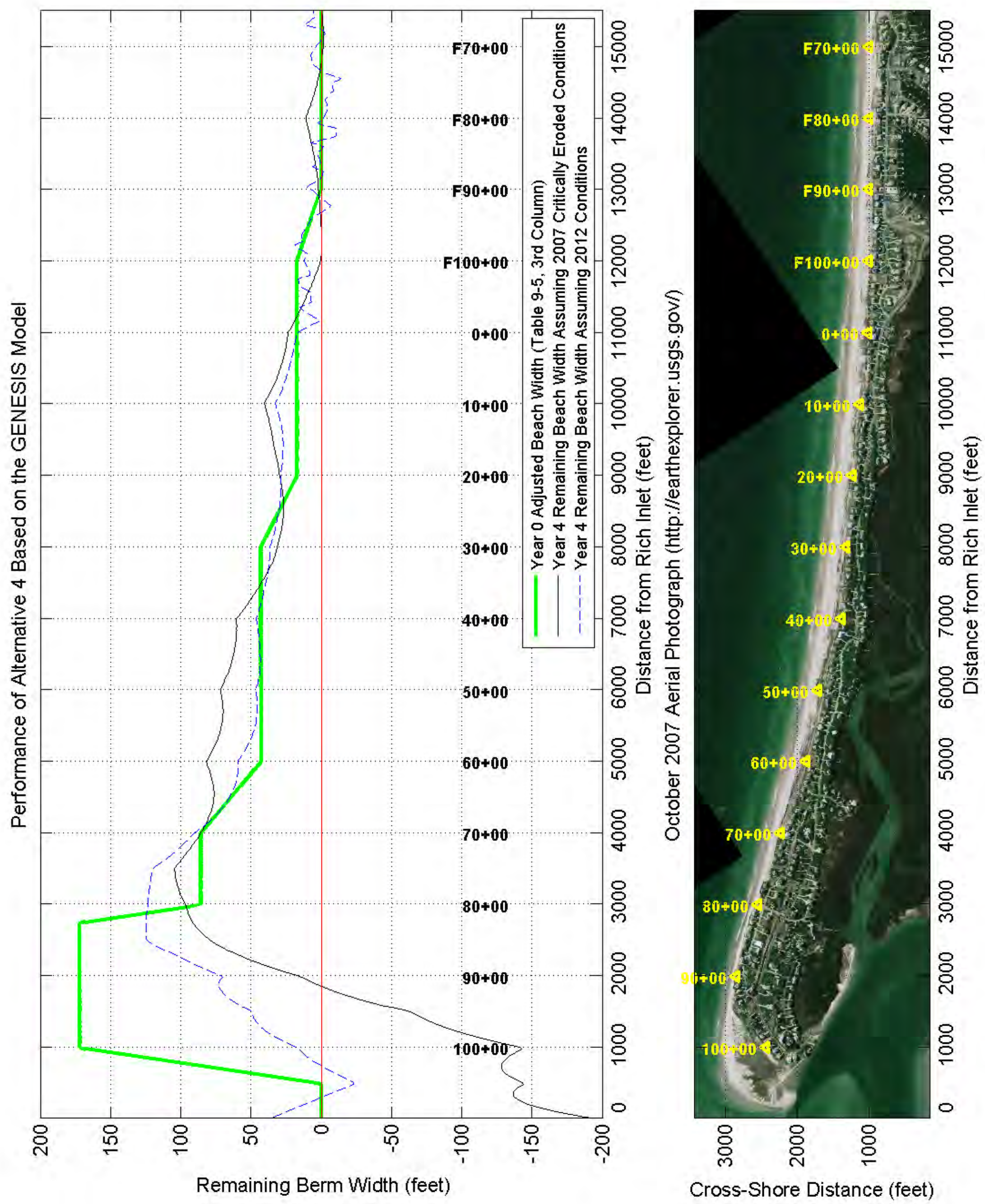


FIGURE 12-13: Remaining Beach Width Given Alternative 4 Based on the GENESIS Model.

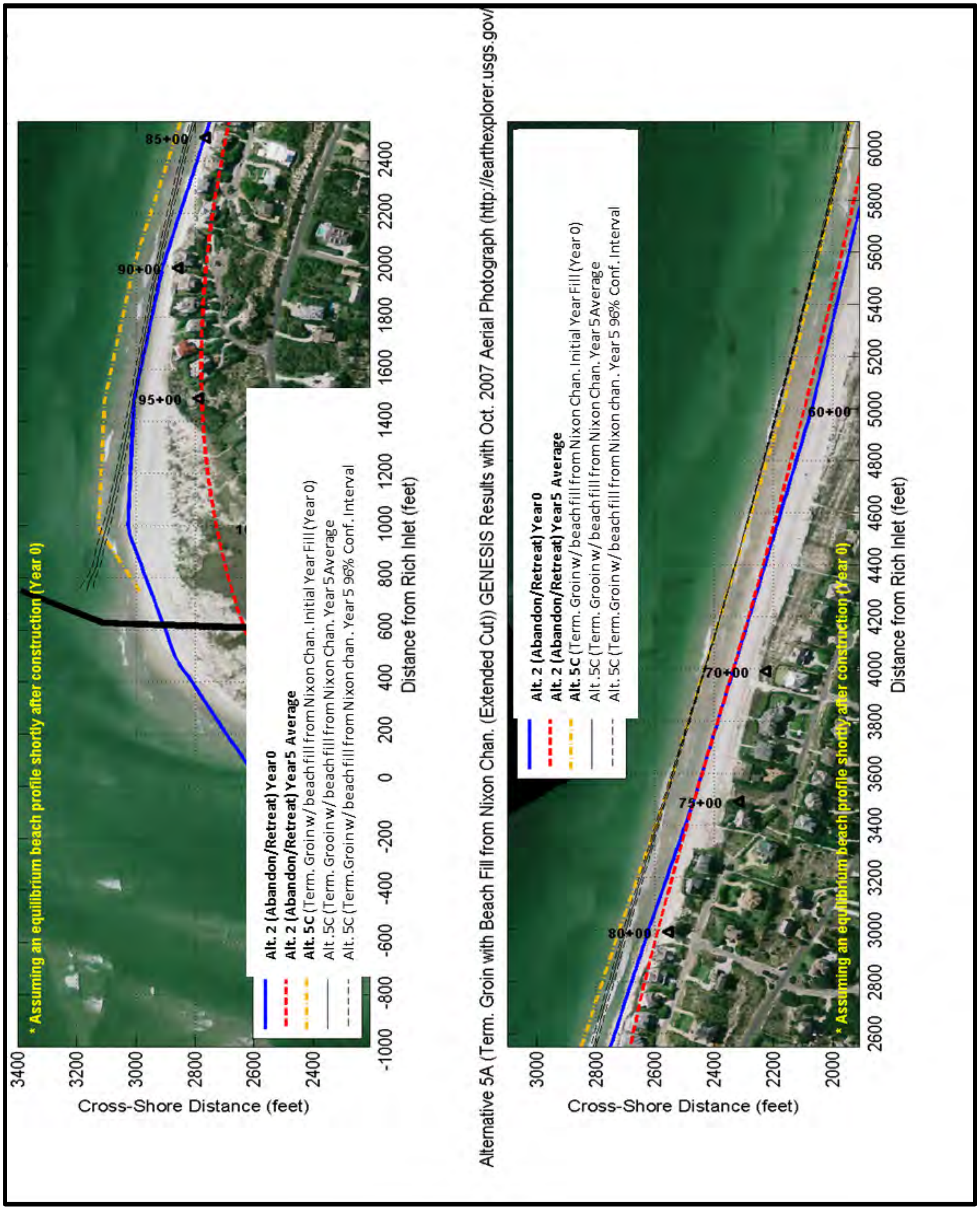


FIGURE 12-14: GENESIS Year 5 Conditions Given Alternative 5C under April 2007 Critically Eroded Conditions.

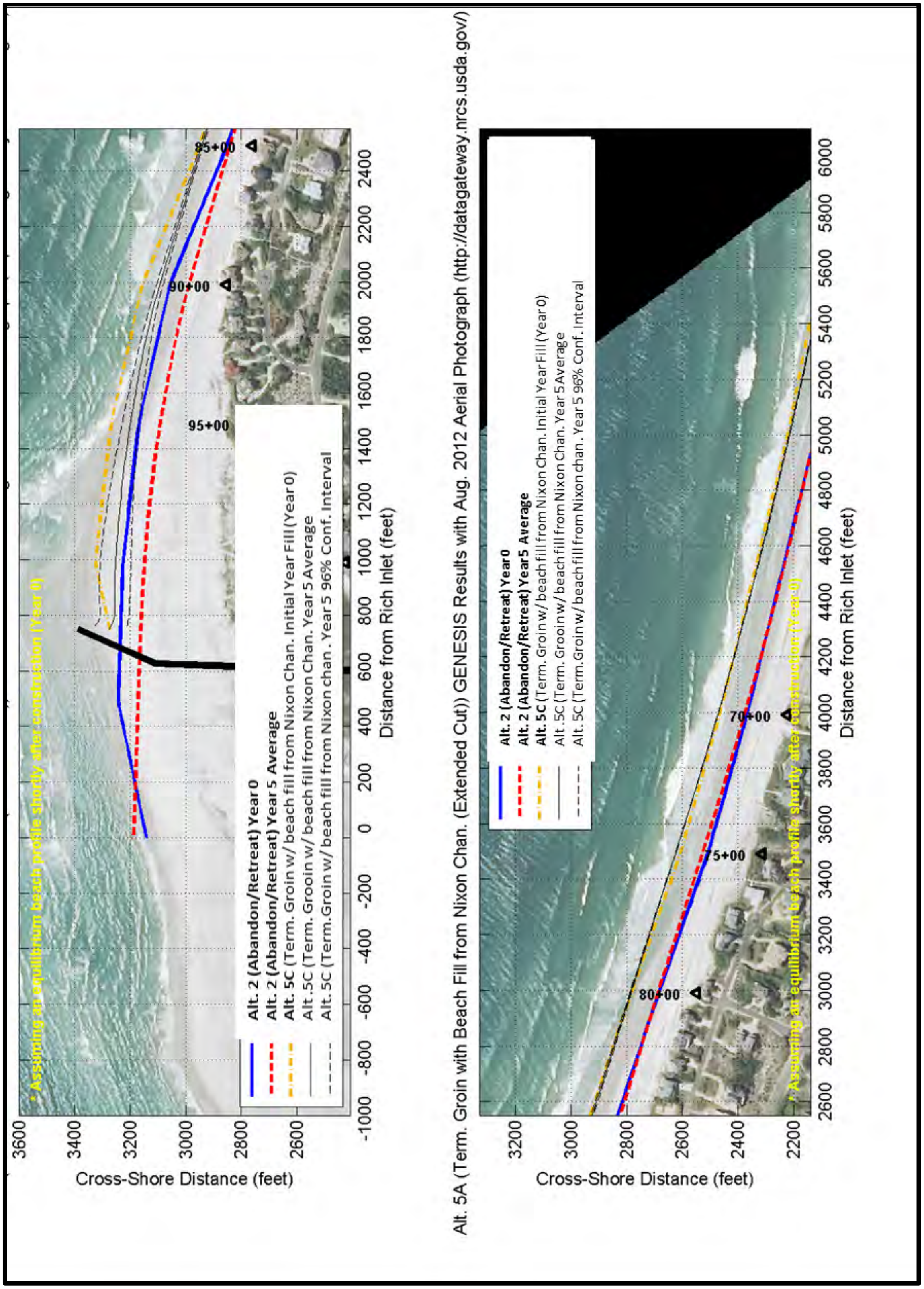


FIGURE 12-15: GENESIS Year 5 Conditions Given Alternative 5C under 2012 Conditions.

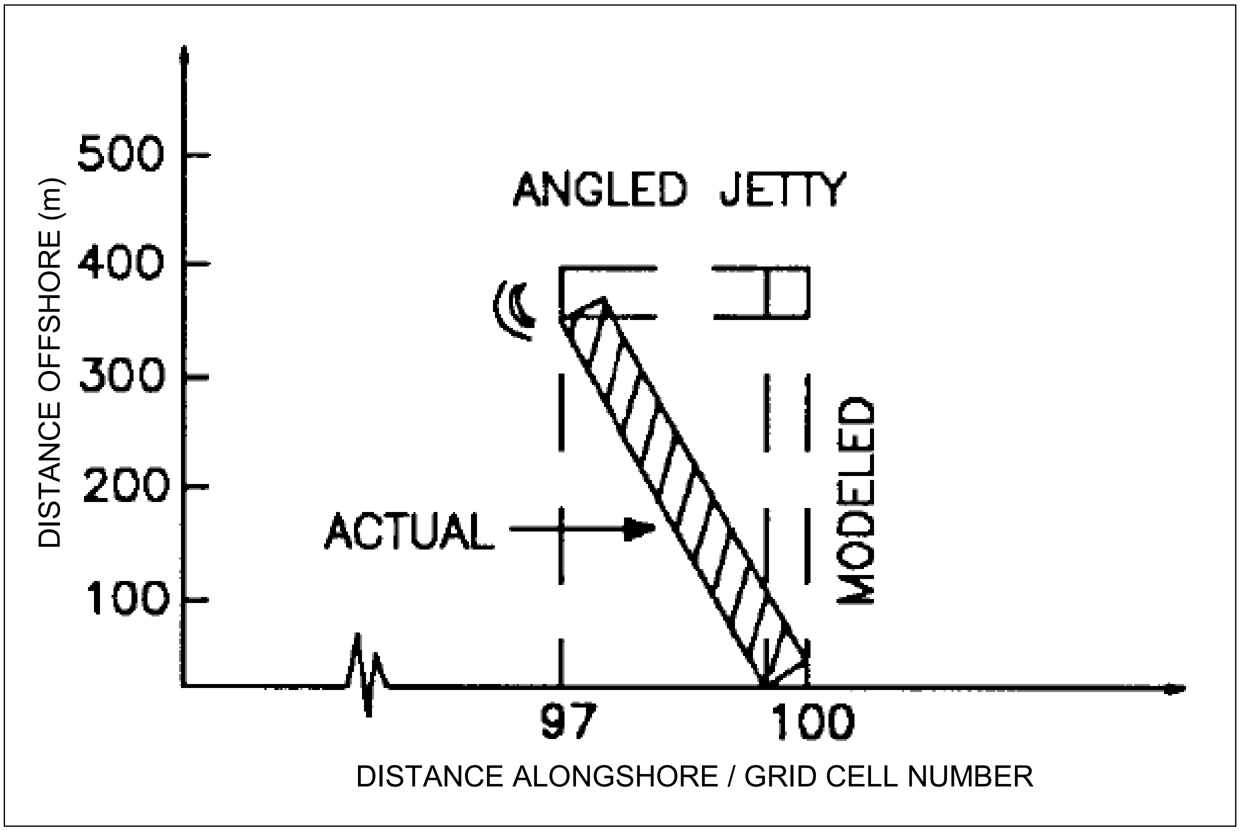


FIGURE 12-16: Recommended Representation of an Angled Groin or Jetty in the GENESIS Model (Hanson and Kraus, 1991, Figure 34, page 144).

GENESIS results for Alternative 5C appear in Figures 12-14, 12-15, and 12-17. Given eroded conditions similar to those in 2007, the GENESIS model suggests that the initial beach fill and the terminal structure will be able to prevent erosion into the pre-construction shoreline (see Figures 12-14 and 12-17). This result is more optimistic that the Delft3D model, which suggests that erosion into the pre-construction shoreline could occur by Year 5 at some locations (see Figure 11-64, Figure 11-66, and Table 11-7). However, both models suggest that Alternative 5C would provide more benefits to the project area than Alternative 3 under a critically eroded scenario, even though the initial fill volume (Table 9-6 versus 9-2) is less.

Given conditions similar to those in 2012, the GENESIS model also suggests that the initial beach fill and the terminal structure will be able to prevent erosion into the pre-construction shoreline (see Figures 12-15 and 12-17). In this case, terminal groin has a smaller effect on beach fill performance than it would under the critically eroded scenario. This is due to the fact that the wider condition of the beach results in a groin that is shorter relative to the initial shoreline.

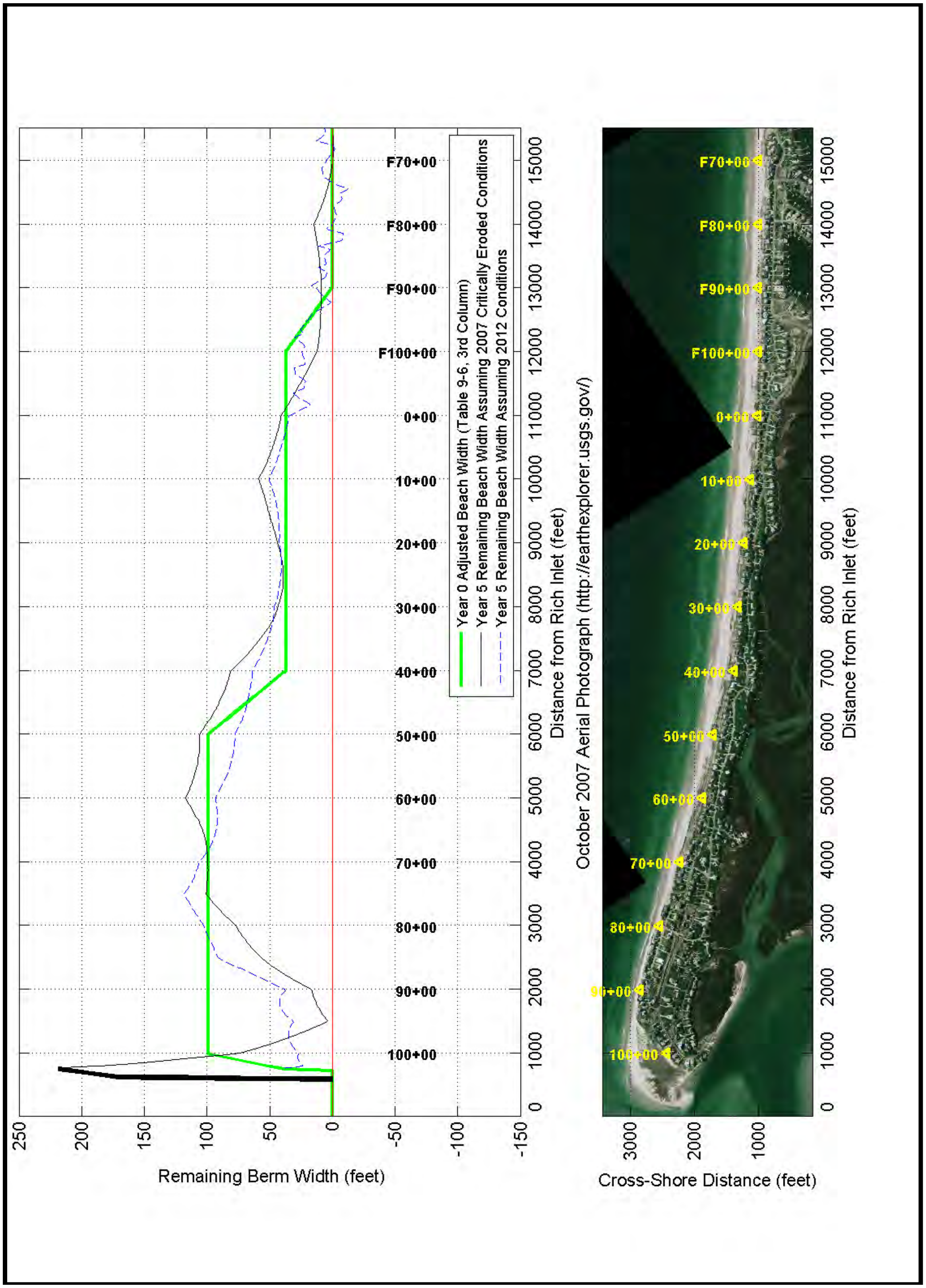


FIGURE 12-17: Remaining Beach Width Given Alternative 5C Based on the GENESIS Model.

12.5.5 Alternatives 5D-1 (1,300-ft terminal groin) and 5D-2 (1,500-ft terminal groin)

The beach fill for Alternatives 5D-1 (1.300-ft terminal groin) and 5D-2 (1,500-ft terminal groin) was incorporated into the GENESIS model by widening the 2007 and 2012 shorelines based on the "adjusted berm width" in Column 3 of Table 9-7. The terminal groins under Alternatives 5D-1 (1,300-ft) and 5D-2 (1,500-ft) were included in the GENESIS model in the same manner as they were for Alternative 5C (see Figure 12-16). For Alternative 5D-1 (1,300-ft), which included the shorter 1,300 foot groin, renourishment of profiles 60+00 to 105+00 was implemented after the end of Year 4. For Alternative 5D-2 (1,500-ft), which included the longer 1,500 foot groin, renourishment of profiles 60+00 to 105+00 was implemented after the end of Year 5. GENESIS model results for Alternatives 5D-1 (1,300-ft) and 5D-2 (1,500-ft appear in Figures 12-18 through 12-23.

In general, the GENESIS model suggests that given either alternative, there will be a limited amount of erosion into the pre-construction shoreline (see Figures 12-20 and 12-23). This is the case for both the April 2007 critically eroded scenarios and the 2012 scenarios. Under the 2012 scenarios, erosion into the pre-construction does not pose a risk to upland development (see Figures 12-19 and 12-22). Under the April 2007 critically eroded scenarios, there are 4 oceanfront homes near the south end of Inlet Hook Road (profile 90+00) that could be at risk of erosion-related damage at Year 4 or 5 (see Figures 12-18 and 12-21). However, the additional results in Sub-Appendix C suggest after the first renourishment operation, the erosion into the pre-construction shoreline over the remainder of the 10 year study period is unlikely.

A direct comparison of Alternatives 5D-1 (1,300-ft) and 5D-2 (1,500ft) appears in Figure 12-20, which shows the performance of the beach fill through Year 4. Under the 2012 scenarios, the GENESIS model suggests that Alternative 5D-2 (1,500-ft), which includes the longer 1,500 foot groin, performs slightly better than Alternative 5D-1 (1,300-ft). Under the April critically eroded scenarios, the GENESIS model suggests that Alternative 5D-1 (1,300-ft), which includes the shorter 1,300 foot groin, performs slightly better than Alternative 5D-2 (1,500-ft). Under either set of scenarios, the differences between two alternatives fall within the uncertainty ranges shown in Figures 12-18, 12-19, 12-21, and 12-22, suggesting that neither alternative is better than the other in terms of beach fill performance. This finding is somewhat contrary to the Delft3D results, which suggest that Alternative 5D-2 (1,500-ft) retains more fill on the beach (see Table 11-7).

The difference between the two models is likely due to the limitations of the GENESIS model versus the Delft3D model. The Delft3D model includes the effects of waves, tidal currents, longshore transport, cross-shore transport, and changes in the offshore bathymetry. The GENESIS model assumes that shoreline and volume changes occur due to longshore currents driven primarily by waves, and that the offshore bathymetry does not change significantly over time. Given these considerations, the Delft3D model results, which suggest that Alternative 5D-2 (1,500-ft) retains more fill on the beach (see Table 11-7), should be given more weight than the GENESIS results.

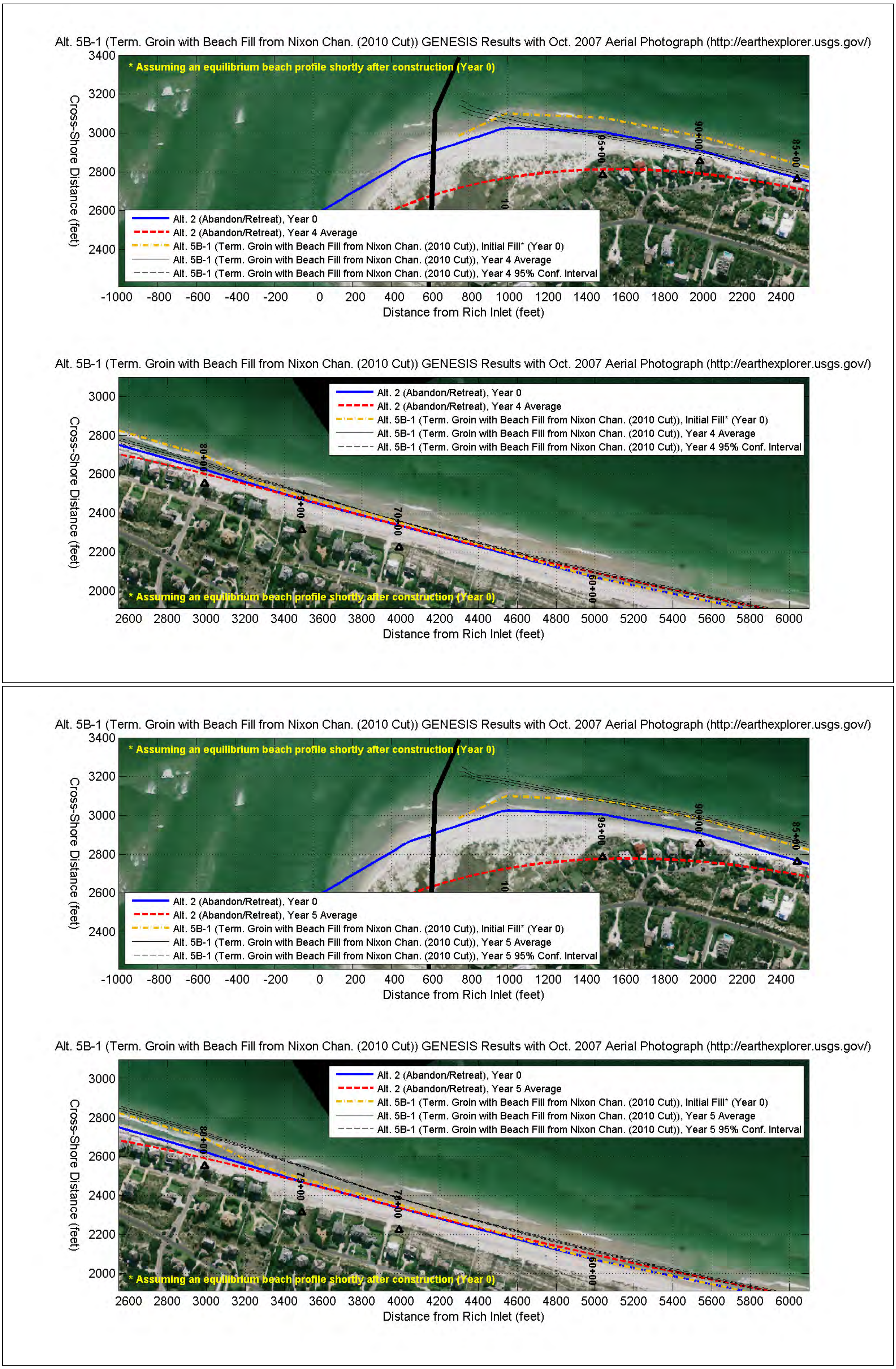


FIGURE 12-18: GENESIS Year 4 & 5 Conditions Given Alternative 5D-1 (1,300 ft) under April 2007 Critically Eroded Conditions.

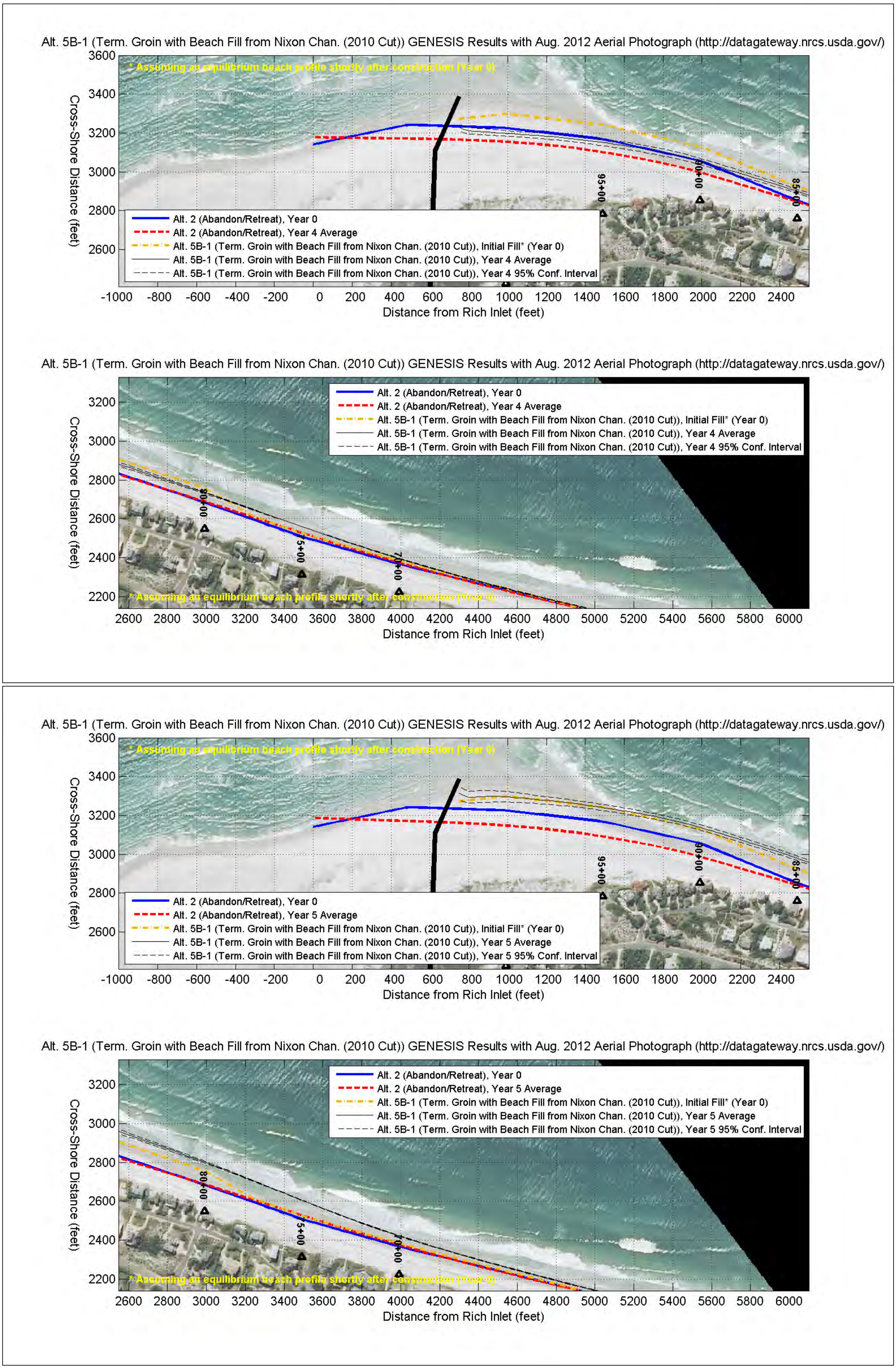


FIGURE 12-19: GENESIS Year 4 & 5 Conditions Given Alternative 5D-1 (1,300-ft) under 2012 Conditions.

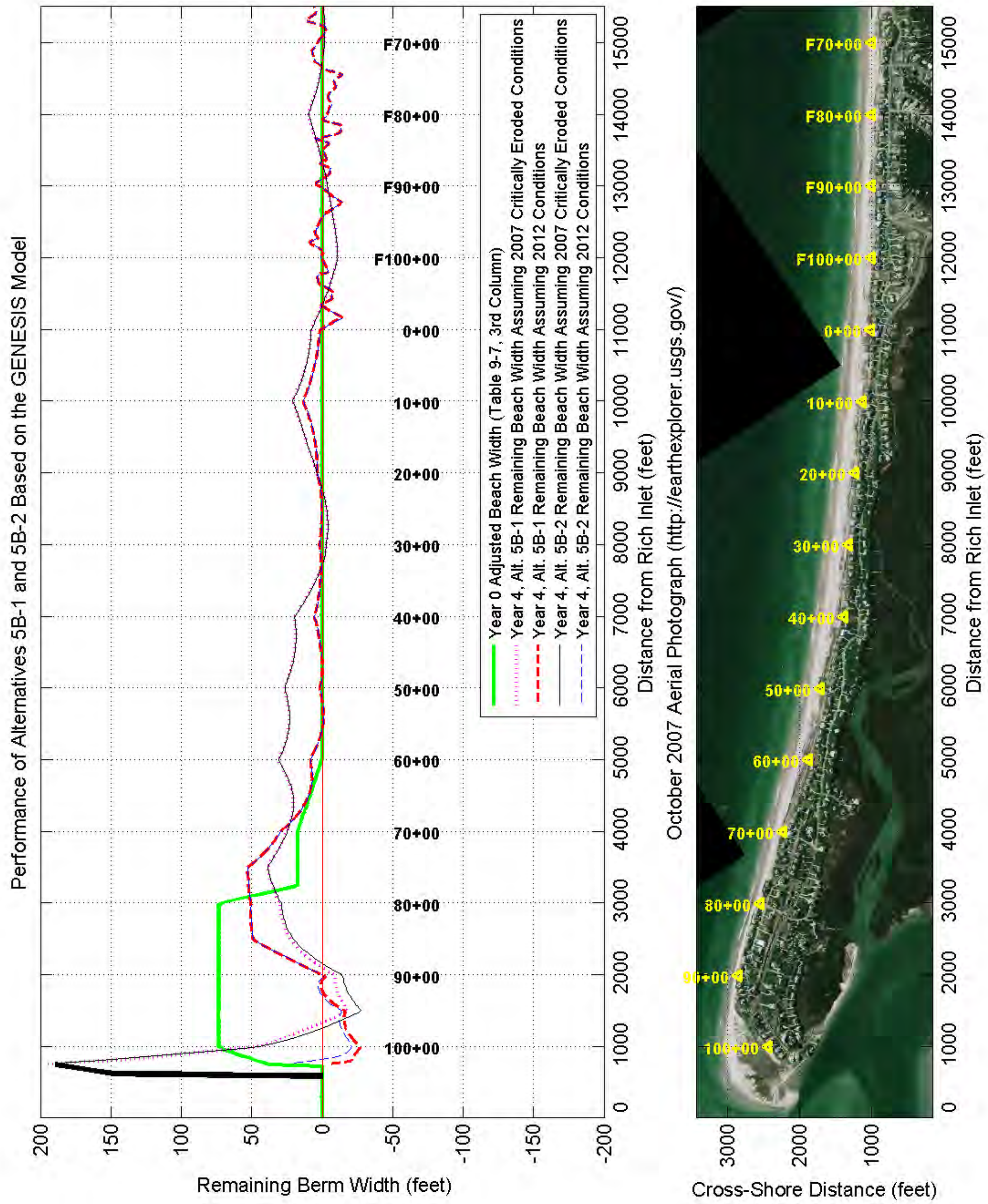


FIGURE 12-20: Remaining Beach Width at Year 4 Given Alternatives 5D-1 (1,300-ft) and 5D-2 (1,500-ft) Based on the GENESIS Model.

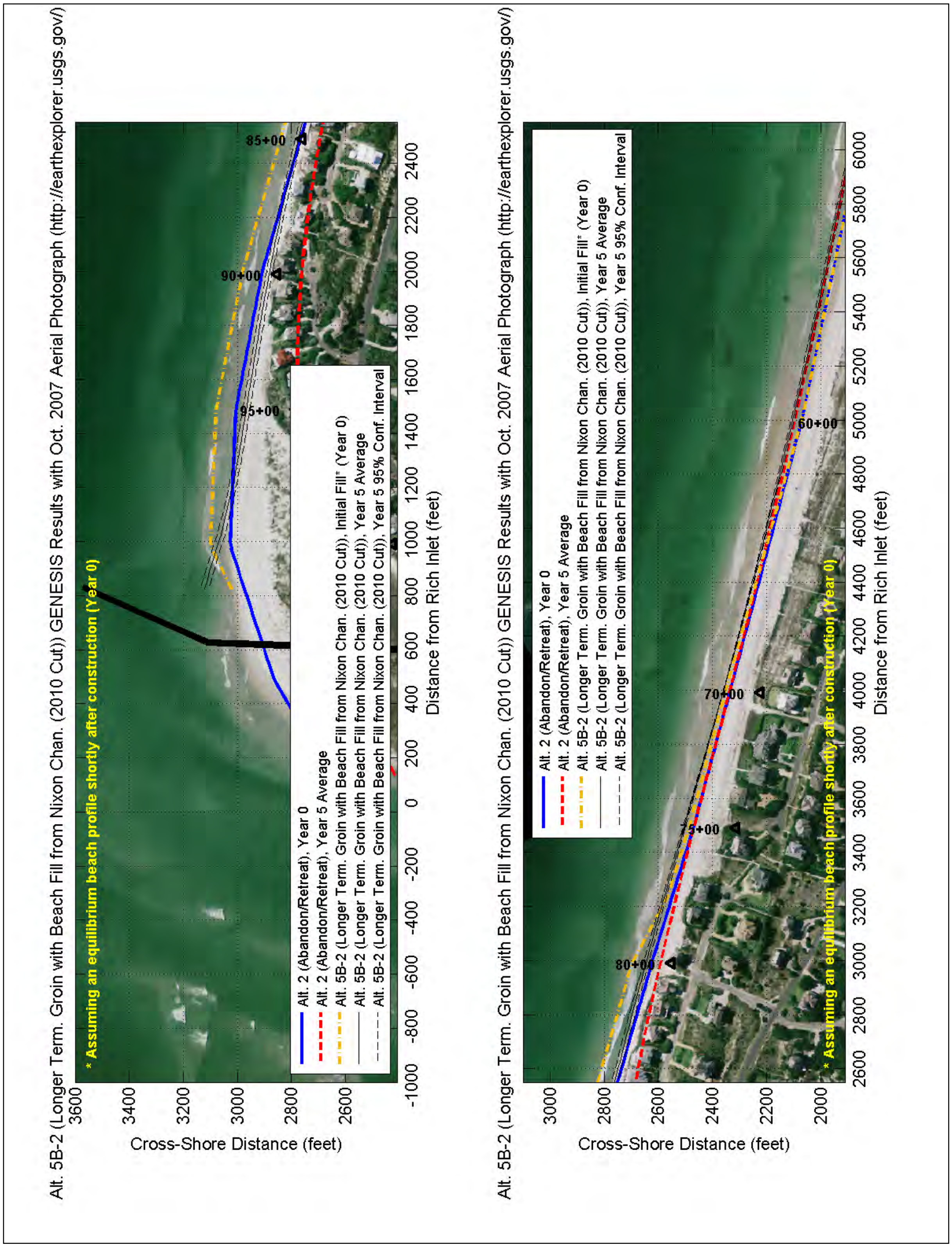


FIGURE 12-21: GENESIS Year 5 Conditions Given Alternative 5D-2 (1,500-ft) under April 2007 Critically Eroded Conditions.

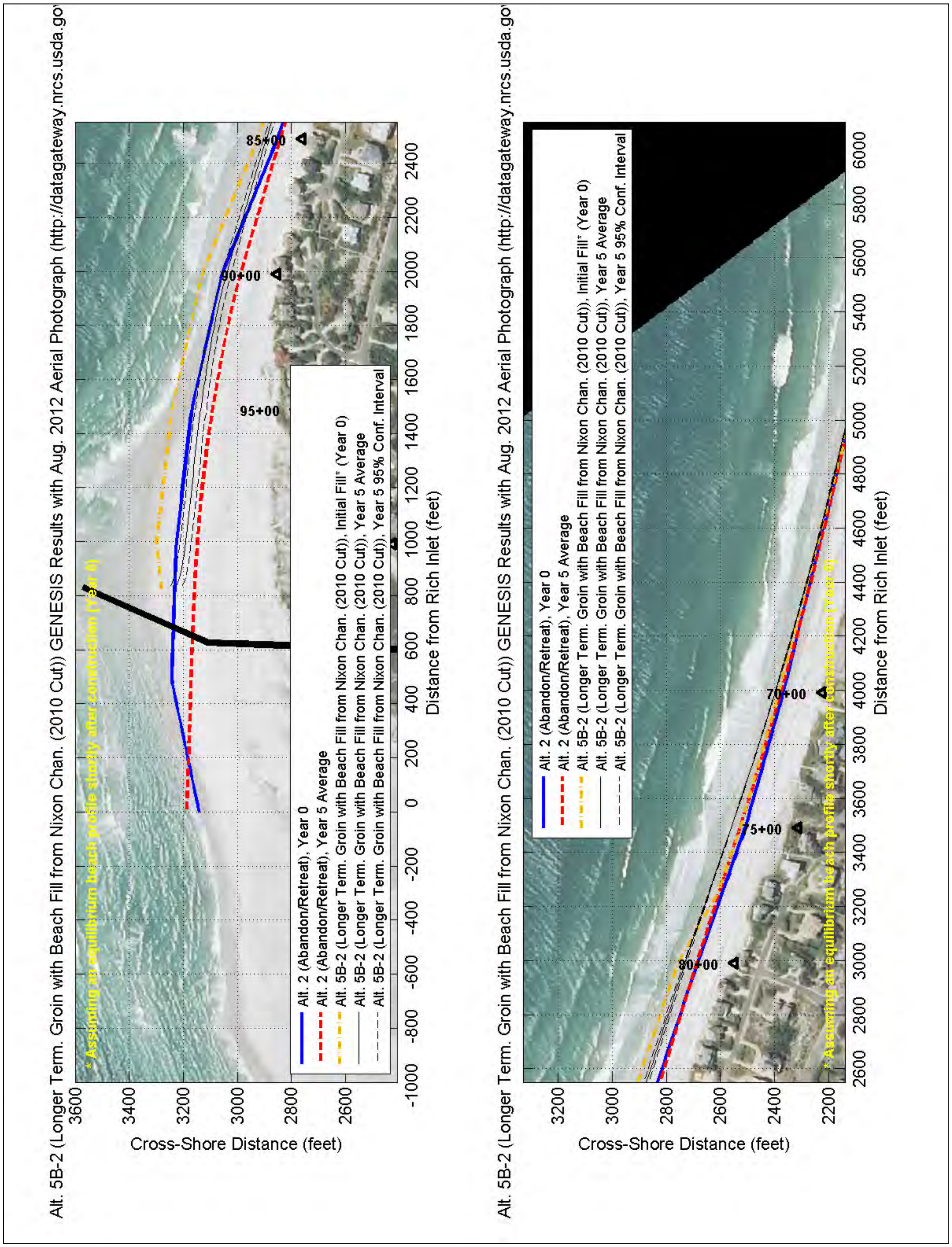


FIGURE 12-22: GENESIS Year 5 Conditions Given Alternative 5D-2 (1,500-ft) under 2012 Conditions.

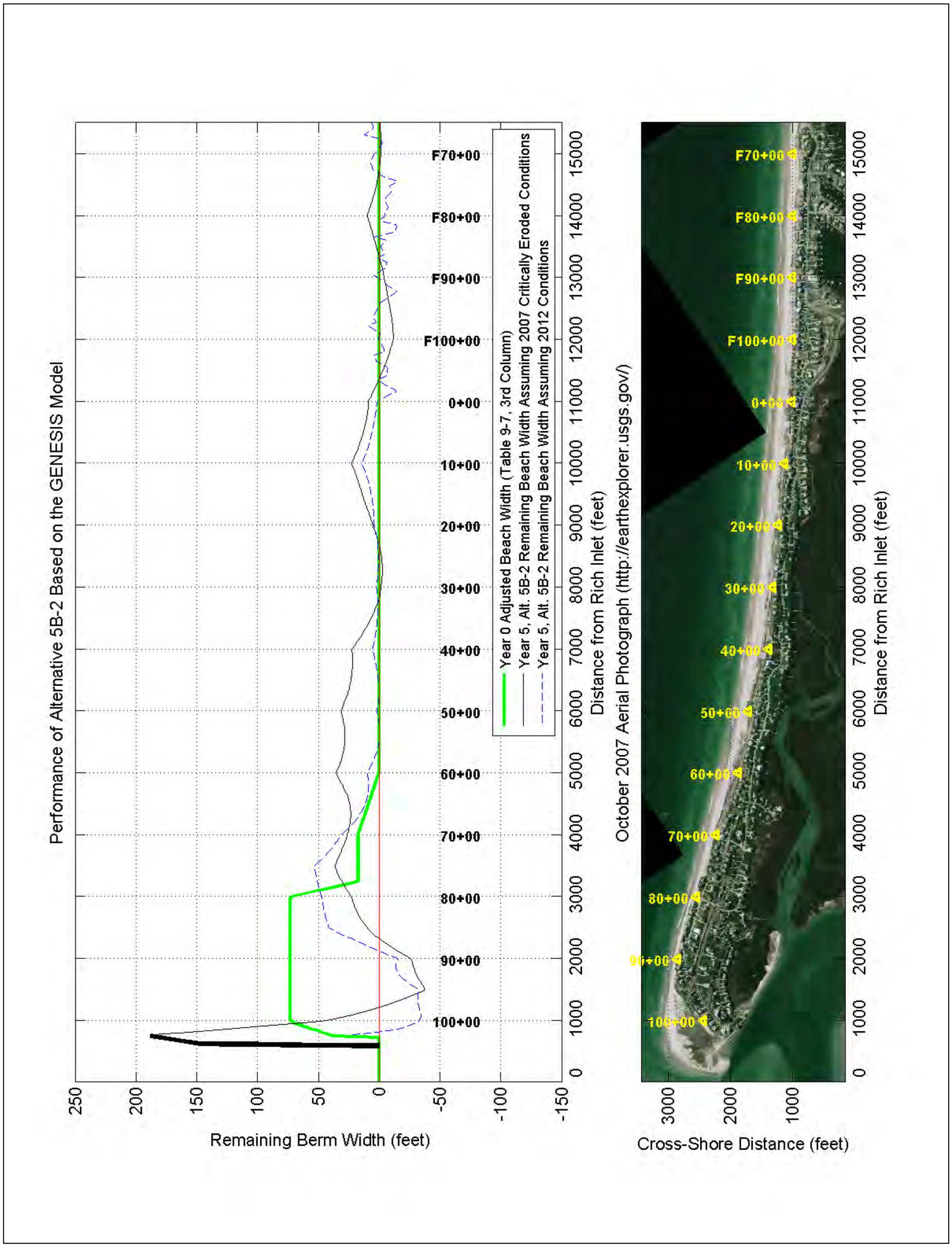


FIGURE 12-23: Remaining Beach Width at Year 5 Given Alternative 5D-2 (1,500-ft) Based on the GENESIS Model.

12.5.5 Summary

While 5-year predictions of the GENESIS and Delft3D-FLOW models differ in their details, they both suggest similar trends in the performance of Alternatives 2, 3, and 5D. The general findings of one model generally support the other. Recommendations based on the model results and the historical erosion analysis in Sections 6 and 7 appear in the final conclusions and recommendations of this report.

13.0 COST ESTIMATES

The following tables provide opinions on costs for Alternatives 3, 4, 5C, and 5D. Costs are provided for both the 2006 and 2012 conditions of Rich Inlet and Figure Eight Island.

Table 13-1a
Cost Estimate – Alternative 3
Rich Inlet Management with Beach Fill
2006 Conditions

First Cost				
Item	Unit	Quantity	Unit Cost	Cost
Beach fill from Green and Inlet Channel				
Mobilization and Demobilization	LS	1	$2,806,000	$2,806,000
Dredging (Beach Fill)	CY	1,462,900	$7.03	$10,279,000
Sub-Total (Beach Fill)				$13,085,000
Construct Dike – Upland Disposal of Clay				
Additional Mob & Demob – Pipe	LS	1	$230,000	$230,000
Modify Upland Disposal Site	Job	1	$288,000	$288,000
Dredging – Dike & Upland Disposal	CY	460,800	$7.03	$3,271,000
Sub-Total Dike & Upland Disposal				$3,789,000
Dune Vegetation	LF	1,250	$2.30	$3,000
Total Construction Cost				$16,843,000
Engineering & Design (P&S)				$150,000
Construction Oversight				$120,000
Total First Cost				**$17,113,000**
Periodic Channel Maintenance and Beach Nourishment (Every 5 years)				
Mobilization and Demobilization	LS	1	$2,806,000	$2,806,000
Dredging Entrance Channel & Beach Fill	CY	666,000	$7.03	$4,679,000
Sub-Total				$7,485,000
Engineering & Design (P&S)				$100,000
Construction Oversight				$120,000
Total Periodic Dredging Cost				**$7,705,000**

Table 13-1b
Cost Estimate – Alternative 3
Rich Inlet Management with Beach Fill
2012 Conditions

First Cost				
Item	Unit	Quantity	Unit Cost	Cost
Beach fill from Green and Inlet Channel				
Mobilization and Demobilization	LS	1	$2,806,000	$2,806,000
Dredging (Beach Fill)	CY	1,477,500	$7.03	$10,382,000
Sub-Total (Beach Fill)				$13,188,000
Construct Dike – Upland Disposal of Clay				
Additional Mob & Demob – Pipe	LS	1	$230,000	$230,000
Modify Upland Disposal Site	Job	1	$288,000	$288,000
Dredging – Dike & Upland Disposal	CY	465,400	$7.03	$3,271,000
Sub-Total Dike & Upland Disposal				$3,789,000
Dune Vegetation	LF	1,250	$2.30	$3,000
Total Construction Cost				$15,048,000
Engineering & Design (P&S)				$150,000
Construction Oversight				$120,000
Total First Cost				**$17,250,000**
Periodic Channel Maintenance and Beach Nourishment (Every 5 years)				
Mobilization and Demobilization	LS	1	$2,806,000	$2,806,000
Dredging Entrance Channel & Beach Fill	CY	666,000	$7.03	$4,679,000
Sub-Total				$7,485,000
Engineering & Design (P&S)				$100,000
Construction Oversight				$120,000
Total Periodic Dredging Cost				**$7,705,000**

Table 13-2a
Cost Estimate – Alternative 4
Beach Nourishment without Inlet Management
2006 Conditions

First Cost				
Item	Unit	Quantity	Unit Cost	Cost
Hopper Dredge – Offshore Borrow Areas				
Mobilization and Demobilization	LS	1	$2,436,000	$2,436,000
Dredging (Beach Fill)	CY	521,300	$13.30	$6,656,000
Sub-Total (Offshore Borrow Areas)				$9,092,000
18-inch Pipeline Dredge – Nixon Channel				
Mobilization and Demobilization	LS	1	$558,000	$558,000
Dredging – Nixon Channel	CY	400,000	$6.80	$2,719,000
Sub-Total Nixon Channel				$3,277,000
Dune Vegetation	LF	1,250	$2.30	$3,000
Total Construction Cost				$12,372,000
Engineering & Design (P&S)				$150,000
Construction Oversight				$170,000
Total First Cost				**$13,692,000**
Periodic Channel Maintenance and Beach Nourishment (Every 4 years)				
Hopper Dredge – Offshore Borrow Areas				
Mobilization and Demobilization	LS	1	$2,436,000	$2,436,000
Dredging (Beach Fill)	CY	328,000	$12.77	$4,188,000
Sub-Total (Offshore Borrow Areas)				$6,624,000
18-inch Pipeline Dredge – Nixon Channel				
Mobilization and Demobilization	LS	1	$558,000	$558,000
Dredging – Nixon Channel	CY	400,000	$6.80	$2,719,000
Sub-Total Nixon Channel				$3,277,000
Total Construction Cost				$9,901,000
Engineering & Design (P&S)				$100,000
Construction Oversight				$170,000
Total 4-year Nourishment Cost				**$10,171,000**

Table 13-2b
Cost Estimate – Alternative 4
Beach Nourishment without Inlet Management
2012 Conditions

First Cost				
Item	Unit	Quantity	Unit Cost	Cost
Hopper Dredge – Offshore Borrow Areas				
Mobilization and Demobilization	LS	1	$2,436,000	$2,436,000
Dredging (Beach Fill)	CY	568,300	$12.77	$7,256,000
Sub-Total (Offshore Borrow Areas)				$9,692,000
18-inch Pipeline Dredge – Nixon Channel				
Mobilization and Demobilization	LS	1	$558,000	$558,000
Dredging – Nixon Channel	CY	400,000	$6.80	$2,719,000
Sub-Total Nixon Channel				$3,277,000
Dune Vegetation	LF	1,250	$2.30	$3,000
Total Construction Cost				$11,951,000
Engineering & Design (P&S)				$150,000
Construction Oversight				$170,000
Total First Cost				**$14,292,000**
Periodic Channel Maintenance and Beach Nourishment (Every 4 years)				
Hopper Dredge – Offshore Borrow Areas				
Mobilization and Demobilization	LS	1	$2,436,000	$2,436,000
Dredging (Beach Fill)	CY	388,000	$12.77	$4,954,000
Sub-Total (Offshore Borrow Areas)				$7,390,000
18-inch Pipeline Dredge – Nixon Channel				
Mobilization and Demobilization	LS	1	$558,000	$558,000
Dredging – Nixon Channel	CY	400,000	$6.80	$2,719,000
Sub-Total Nixon Channel				$3,277,000
Total Construction Cost				$10,667,000
Engineering & Design (P&S)				$100,000
Construction Oversight				$170,000
Total 4-year Nourishment Cost				**$7,821,000**

Table 13-3a
Cost Estimate – Alternative 5C
Terminal Groin with Beach Fill from Maintenance of the Nixon Channel Navigation Channel and Connector Channel
2006 Conditions

First Cost				
Item	Unit	Quantity	Unit Cost	Cost
18-inch Pipeline – Nixon Channel & Beach Fill				
Mobilization and Demobilization	LS	1	$1,156,000	$1,156,000
Dredging (Channel & Beach Fill)	CY	994,400	$7.65	$7,605,000
Dune Vegetation	LF	1,250	$2.30	$3,000
Sub-Total (Channel & Beach Fill)				$9,396,000
Engineering & Design (P&S)				$100,000
Construction Oversight				$120,000
Total First Cost Channel & Beach Fill				**$8,984,000**
Terminal Groin				
Groin Construction	LF	1,300	$2,300	$2,990,000
Engineering & Design (P&S)				$200,000
Construction Oversight				$220,000
Total First Cost Terminal Groin				**$3,410,000**
Total First Cost Alternative 5C				**$12,394,000**
Periodic Channel Maintenance & Beach Nourishment (Every 5 years)				
Mobilization and Demobilization	LS	1	$1,156,000	$1,156,000
Dredging	CY	495,000	$7.65	$3,786,000
Total Periodic Dredging Cost				$4,942,000
Engineering & Design (P&S)				$100,000
Construction Oversight				$120,000
Total Periodic Cost (every 5 years)				**$5,162,000**

Table 13-3b
Cost Estimate – Alternative 5C
Terminal Groin with Beach Fill from Maintenance of the Nixon Channel Navigation Channel and Connector Channel
2012 Conditions

First Cost				
Item	Unit	Quantity	Unit Cost	Cost
18-inch Pipeline – Nixon Channel & Beach Fill				
Mobilization and Demobilization	LS	1	$1,156,000	$1,156,000
Dredging (Channel & Beach Fill)	CY	1,077,000	$7.65	$8,237,000
Dune Vegetation	LF	1,250	$2.30	$3,000
Sub-Total (Channel & Beach Fill)				$9,396,000
Engineering & Design (P&S)				$100,000
Construction Oversight				$120,000
Total First Cost Channel & Beach Fill				**$9,616,000**
Terminal Groin				
Groin Construction	LF	1,300	$2,300	$2,990,000
Engineering & Design (P&S)				$200,000
Construction Oversight				$220,000
Total First Cost Terminal Groin				**$3,410,000**
Total First Cost Alternative 5C				**$13,026,000**
Periodic Channel Maintenance & Beach Nourishment (Every 5 years)				
Mobilization and Demobilization	LS	1	$1,156,000	$1,156,000
Dredging	CY	495,000	$7.65	$3,786,000
Total Periodic Dredging Cost				$4,942,000
Engineering & Design (P&S)				$100,000
Construction Oversight				$120,000
Total Periodic Cost (every 5 years)				**$5,162,000**

Table 13-4a
Cost Estimate – Alternative 5D
Terminal Groin with Beach Fill From Other Sources
2006 Conditions

First Cost				
Item	Unit	Quantity	Unit Cost	Cost
18-inch Pipeline Dredge – Nixon Channel				
Mobilization and Demobilization	LS	1	$558,000	$558,000
Dredging – Nixon Channel	CY	294,500	$6.80	$2,001,000
Sub-Total Nixon Channel				$2,559,000
Engineering & Design (P&S)				$150,000
Construction Oversight				$170,000
Total Construction Beach Fill & Dune				**$2,879,000**
Terminal Groin				
Groin Construction	LF	1,500	$2,760	$4,140,000
Engineering & Design (P&S)				$200,000
Construction Oversight				$220,000
Total First Cost Terminal Groin				**$4,560,000**
Total First Cost Alternative 5D				**$7,439,000**
Periodic Channel Maintenance & Beach Nourishment (Every 5 years)				
Mobilization and Demobilization	LS	1	$558,000	$558,000
Dredging	CY	320,000	$6.80	$2,175,000
Total Periodic Dredging Cost				$2,733,000
Engineering & Design (P&S)				$100,000
Construction Oversight				$170,000
Total Periodic Cost (every 5 years)				**$3,003,000**

Table 13-4b

Cost Estimate – Alternative 5D
Terminal Groin with Beach Fill From Other Sources
2012 Conditions

First Cost				
Item	Unit	Quantity	Unit Cost	Cost
18-inch Pipeline Dredge – Nixon Channel				
Mobilization and Demobilization	LS	1	$558,000	$558,000
Dredging – Nixon Channel	CY	294,500	$6.80	$2,001,000
Sub-Total Nixon Channel				$2,559,000
Engineering & Design (P&S)				$150,000
Construction Oversight				$170,000
Total Construction Beach Fill & Dune				**$2,879,000**
Terminal Groin				
Groin Construction	LF	1,500	$2,760	$4,140,000
Engineering & Design (P&S)				$200,000
Construction Oversight				$220,000
Total First Cost Terminal Groin				**$4,560,000**
Total First Cost Alternative 5D				**$7,439,000**
Periodic Channel Maintenance & Beach Nourishment (Every 5 years)				
Mobilization and Demobilization	LS	1	$558,000	$558,000
Dredging	CY	255,000	$6.80	$1,733,000
Total Periodic Dredging Cost				$2,291,000
Engineering & Design (P&S)				$100,000
Construction Oversight				$170,000
Total Periodic Cost (every 5 years)				**$2,561,000**

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APPENDIX B
ENGINEERING REPORT

SUB-APPENDIX A

APPENDIX B
ENGINEERING REPORT

SUB-APPENDIX A

SUB-APPENDIX A

Inlet-Related Shoreline Changes: Rich Inlet, North Carolina

Update Through 2007

By

William J. Cleary

Introduction

In May 2006 a study was authorized by the Figure Eight Beach Homeowners Association, Inc. (F8BHA) to conduct a geomorphic analysis of Rich Inlet and its adjacent oceanfront and estuarine shorelines (Fig.1). The need for the investigation stemmed from a request to update existing data pertaining to the morphological history of Rich Inlet and the historic oceanfront shoreline changes (1938-2007) along 10,000 ft of Figure Eight and Hutaff Islands, as well as the estuarine feeder channel (Green and Nixon Channels) shoreline changes. The primary focus of the investigation was to provide a robust data set that could be utilized to develop a predictive relationship between inlet conditions (primarily bar channel location and orientation) and the response of the oceanfront and interior shorelines (Fig. 1). Data from this study was used in conjunction with engineering oriented investigations to better plan activities associated with the proposed ebb channel realignment effort by CPE.

Chronic erosion along the northern most portion of Figure Eight Island has been the subject of concern and debate since the early 1980s when erosion threatened several homes along Beach Road North. The deterioration of this shoreline segment reached a critical level in January 2000 when homes immediately downdrift of the inlet were threatened by the retreating shoreline. In an effort to stabilize the shoreline, concerned homeowners attempted to protect the threatened structures by emplacing large sandbags (Figs. 1 and 2 Appendix). In 2003 a variance was granted that allowed a group of homeowners to reinforce existing sand bags and increase the height of the sand bag structure (Figs. 1-3 Appendix). As of January 2008 ~ 20 lots have been armored with sand bags (Fig. 4 Appendix). Since January 2001, two nourishment projects have been completed along the northernmost portion of the island (Figs 5- 9 Appendix). The land loss in this area is a result of a number of inlet-related variables that act in concert to produce the complex erosion pattern of the oceanfront shoreline.

Figure “8” Beach Homeowners Association, Inc. (F8BHA), in an effort to support the restoration of the eroding oceanfront shoreline and to provide a long-term solution to inlet-related erosion, has contracted with Coastal Planning and Engineering of North Carolina (CPE-NC) to assist in the design of an erosion mitigation project involving realignment of the inlet's ebb channel. The relocation effort would ultimately lead to a reconfiguration of the barrier's planform along the northern end of F8I and an eventual cessation of the chronic erosion.

Subsequent to receiving the authorization to initiate the investigation, a study plan was devised to focus on the movement of the ebb channel and its linkage to ebb-tidal delta morphologic changes, the principal causes of the observed oceanfront and estuarine shoreline erosion. Figure 1 depicts the general shoreline conditions and alignment of the ebb channel in November 2008. This report presents the data from the GIS-based analysis of aerial photographs (1938-2007) that describes movement of the ebb channel and the influence it exerts on the inlet, interior and oceanfront shorelines. Figure 2 depicts the oceanfront and interior channel shoreline transects, as well as the inlet baseline that were used during the conduct of the study.

Inlet-influenced Shoreline Change

Inlets play a major role in the sediment budget as they retain large volumes of sand impounded from the littoral system (Walton and Adams, 1976). The extent to which inlets interrupt the alongshore transport and store sand depends largely upon the local hydrodynamics and the tidal prism of the specific inlet system (Nummedal, et al., 1977; Hayes, 1980; FitzGerald, 1993 and Hayes, 1994). Inlets are also important from a coastal management viewpoint because the great majority of the critical erosion zones or hot-spots that have been identified along North Carolina's coast are associated with existing inlets (Cleary, 1996 and Cleary and Marden, 1999).

Research has shown that inlets dictate the oceanfront shoreline patterns over long shoreline stretches many times the current dimensions of the adjacent inlet. The length of a shoreline reach influenced by an inlet is a function of throat size, ebb-tidal delta shape and the inlet's migration habit. Numerous studies have shown that the dynamics of inlets are site specific with each system exhibiting individualized responses to the local environmental and geological factors and the interaction of man. Therefore, effective long-term inlet management strategies and all proposed inlet modification plans require an understanding of the contemporary and historic inlet-induced shoreline changes.

Ebb-Tidal Deltas and Shoreline Change

Ebb-tidal deltas, the inlet's seaward shoals, are formed through the interaction of incident waves and tidal currents. Changes in the size or shape of ebb-tidal deltas can have a significant impact on adjacent shorelines. Regardless of size, the offshore shoals influence the ends of the adjacent barriers, acting as natural breakwaters. Waves approaching the barriers are refracted in such a manner that a region of sediment transport reversal is formed in the vicinity of the inlet (Hayes, et al., 1973; Hayes, 1994). This mechanism of transport reversal had been proposed to account for the bulbous shoreline segment immediately downdrift of some inlets. Additionally, episodes of sand bar-welding events account for a major portion of the observed progradation (FitzGerald, 1984; Cleary, 1996 Cleary, 2002 and Kana, et al., 1999). A concomitant change in the pattern of erosion or accretion on the adjacent barrier shorelines occurs when the symmetry of the ebb-tidal delta changes. Often times alternating erosion and accretion episodes produce dramatic changes in the planform of adjacent oceanfront shoreline segments (FitzGerald, 1984; FitzGerald, 1993; Cleary and Marden, 1999; Kana, et al., 1999; Gaudiano and Kana, 2001; Cleary, et al., 2000 and 2003 and Jackson et al., 2003).

Moreover, changes along shorelines bordering inlets such as Rich Inlet are related to complex and poorly understood cyclical changes in the shape of the ebb-tidal deltas. Cycles of shoreline erosion and accretion are associated with the deflection of the ebb channel and the corresponding position and size changes of the marginal flood channels and where swash bars have been welded onto the adjacent shorelines (FitzGerald, 1984; Cleary, et al., 1989; Cleary, 1994 and 1996; Cleary and Marden, 1999; Kana, et al., 1999 Cleary, et al., 2000 and 2003 and Jackson et al., 2003). The cycles involving shoreline erosion are of variable length (years to decades), and the cycle length appears to be correlated with inlet size and possibly storm climate. Additional variables governing cycles are related to interior channel hydraulics. Cycles are typically longer and more complex at larger systems. Hundreds of feet of accretion/erosion can be recorded on the adjacent shoulders subsequent to channel and ebb tidal delta shape changes. Progradation or erosion may continue for more than several decades depending upon the size of the inlet and inlet history.

General Setting

Rich's Inlet is located in the southwest portion of Onslow Bay approximately 15 miles northeast of Wilmington, NC. The inlet forms the boundary between New Hanover and Pender Counties (Fig. 1). Rich inlet is a relatively large system that separates Hutaff Island, a 9km long undeveloped barrier to the northeast, from Figure Eight Island, a private residential community to the southwest (Fig. 1). The inlet has been classified as a wave-dominated and flood-biased, transitional system (Cleary and Jackson, 2004). The inlet drains an expansive marsh-filled estuary where two large, relatively deep tidal creeks, Nixon and Green Channels, connect the inlet to the Atlantic Intra-Coastal Waterway (AIWW). It is likely its ultimate origin is related to the incision of the ancestral channel of Futch Creek that presumably controlled the location of the paleo-inlet as sea level rose during the past several thousand years. Underlying Tertiary rock units that rise within 6m of the marsh surface probably have dictated the extent of its migration pathway. Oligocene siltstone hardbottoms are common along the margin of the ebb-tidal delta in water depths of 30 ft (Cleary, 2000 and Cleary and Jackson, 2004). The inlet's relative stability is also enhanced by the expansive tidal basin drainage area, which includes Futch Creek, as well as portions of the bar-built estuary.

During the past century, Rich Inlet has been a relatively stable feature with movement of the ebb channel confined to a ~ 0.30 mile wide pathway. Despite its relative stability during the past 70 years, Rich Inlet has had the capability to promote considerable oceanfront shoreline changes through complex linkages to ebb channel movement and ebb-tidal delta shape changes. Currently, the F8BHA is confronted with a serious management issue that concerns the chronic oceanfront erosion that is characteristic of these complex inlet systems. Although the inlet was a relatively stable feature between 1938 and 1993, there have been substantial changes along both inlet shorelines and the adjacent oceanfront since the late 1990s due to the northeasterly movement of the ebb channel. During the past 15 years, the stability of the inlet has decreased with the majority of change occurring between 1993 - 1996 (Cleary and Jackson, 2004). The northeasterly movement of the ebb channel is likely due to a combination of events that have impacted the tidal basin. Although conjectural, it is hypothesized that the clogging of the feeder channels for both Old Topsail Inlet (closed 1998) to the northeast and Mason Inlet to the southwest have impacted the tidal prism by discharging through Nixon Channel, the primary feeder channel for Rich Inlet.

Methodology

Contemporary changes in the inlet, along the adjacent oceanfront and interior channel shorelines (Fig. 1), were determined through an analysis of a series of representative historic aerial photographs that date from 1938. Thirty sets of photographs were initially examined for trends; and on the basis of these observations, 10 sets of aerial photographs covering a large spatial and temporal scale (1938–2007) of Rich Inlet, adjacent Figure Eight Island and Hutaff Island were scanned to yield a resolution of 2 ft/pixel or higher. Subsequently, the images were georectified and features were digitized using ArcGIS v.9.2. Ground control points (GCPs) were selected from 1998 digital orthophotos obtained from the North Carolina Division of Coastal Management. A minimum of 15 control points for each 9”x 9” frame were used in the rectification process. The wet/dry line (shoreline), ebb delta, and ebb channel(s) of each newly produced orthophoto were digitized and projected to a common projection of North Carolina State Plane, NAD 83 datum, feet units, and GRS1980 spheroid as ArcView shapefiles.

GIS-based shoreline change analyses were performed using custom tools designed for ArcGIS v.9.x and results were stored in a digital database. The baseline and transect method was used as the primary technique to measure changes in shoreline positions across time. A baseline was constructed seaward and approximately parallel to all digitized oceanfront shorelines, and, 41 transect lines were erected perpendicular to the baseline at 500 ft spacing for purposes of measuring and calculating the various shoreline changes (Fig. 2). Likewise, 37 transects spaced at 500 ft intervals were established along a baseline paralleling portions of Nixon and Green channel's estuarine shorelines (Fig. 1). Changes in the historical shoreline position along each transect were measured and analyzed using the GIS tools, and rates-of-change were calculated using Endpoint Rate (EPR) method. The data were then exported to MS Excel for further manipulation.

In order to measure changes of inlet-associated features, a second baseline was established by constructing a line from a stable reference position on Hutaff Island extending across the inlet to Figure Eight Island. The baseline was utilized for purposes of measuring and calculating ebb channel midpoint changes, inlet width, and shoulder changes associated with ebb channel migration (Fig. 2). The inlet's minimum width (IMW) was measured across the narrowest portion of the inlet throat. The location of the mid-point and axis of the ebb channel was digitized for purposes of tracking the temporal and spatial changes in the position and orientation of the ebb channel within the inlet system. The distance from the reference position to various features that intersected the baseline was measured and recorded in the GIS database.

The surface area of ebb tidal delta was also calculated utilizing polygon shapefiles that were created by digitization of the aerial extent of shoals defined by the zone of breaking waves. The areas of each of the polygons that intersected the established inlet baseline were then determined in ArcGIS and results were stored in the GIS database. The data were then exported to MS Excel for further manipulation.

Results and Discussion

Map Evidence

Barrier islands imaged on historic maps and aerial photographs typically show evidence of unique geomorphic features that can provide clues to the barrier's response to natural processes and its evolution. Maps and aerial photographs commonly show a variety of features, including dune types, erosion scarps, overwash fans/terraces, and sections of forested ridges that vary both spatially and temporally along the island. The observed variation is related to the natural processes that are responsible for their development that occur at varying magnitudes and frequencies through time.

Various historic characteristics of Figure Eight Island, such as island length and shape, can be ascertained from NOS T-sheets, which date to 1857, as well as unpublished plane table surveys of the mid 19th century. From this investigation's perspective, the most important reason to investigate the morphologic changes observed on historic maps and surveys was to gain an understanding of how the island and various segments of the barrier have responded to storms and the vagaries of the adjacent inlets. An analysis of this sort has led to an understanding of the development of the island's planform stability.

A cursory examination of historic maps, charts and aerial photographs clearly shows that inlet-related processes have played substantial roles in altering the planform (length and shape) of the northern portion of Figure Eight Island. The first detailed map of the island illustrating the position of estuarine and oceanfront shorelines is a NOS T-sheet from 1857 (Fig. 3). This historic chart depicts the existence of a small inlet named Nixon Inlet along the northern portion of the island that played a significant role in the shape of the barrier. The former inlet was located approximately one mile south of Rich Inlet. During the mid to late 19th century, a middle-ground sand shoal or remnants of a former barrier segment separated Nixon Inlet from Rich Inlet to the northeast.

Subsequent to Nixon Inlet's closure (~ 1890s), the aforementioned feature became incorporated into Figure Eight Island. The closure of the inlet resulted in the addition of ~ 4,000 ft to the length of the shoreline at the northern end of the island by the early 1900s (Figs. 3 and 4). During the subsequent five decades, the incorporated and extended shoreline segment eroded by as much as 640 ft as the island adjusted to the position and influence of Rich Inlet (Cleary and Jackson. 2004). Between 1934 and 1993, the same shoreline reach prograded between 106 and 180 ft (Figs.3 and 5). Since the late 1990s the same area has been a chronic erosion zone (Fig. 6).

The planform changes that occurred along F8I, subsequent to the closure of Nixon Inlet in the period between 1890 and 1934, are analogous to the recent (1996 -2008) oceanfront changes that stemmed from the northeasterly migration of the ebb channel since the mid 1990s. Although the actual mechanism is different, the end result is a similar change in barrier planform and the associated erosion as the inlet shifted northward.

Aerial Photograph Data

<u>Inlet minimum width (IMW) and baseline width</u>

Rich Inlet is a relatively large inlet compared to other inlets in New Hanover and Pender Counties, NC. The parameter involving inlet width was recorded as the inlet's minimum width (IMW) and baseline width. The former parameter (IMW) was used as a standard of comparison for the photographic analysis. This parameter, by convention, is measured within the inlet throat at the narrowest distance between the wet/dry lines on the adjacent F8I and HI shoulders. The inlet's minimum width has varied considerably during the past seven decades (Fig. 7). The inlet reached its maximum IMW of 3,444 ft in March 1956 (Hurricane Hazel 1954), and its minimum IMW of 1,187 ft in May 2002. Since 1938, the inlet's average minimum width was ~ 1,909 ft.

The width of the inlet measured across the baseline (baseline width) ranged from a minimum of 1,795 ft in July 1980 to a maximum of 4, 011 ft in March 1956 ft. The difference between IMW and the baseline width ranged from a minimum of 29 ft in May 1938 to a maximum of 937 ft in September 1984. The changes recorded reflect inlet expansion and constriction associated with storms, realignment of the ebb channel, flood channel expansion and the subsequent erosion or accretion (spit development) along one or both shoulders.

Ebb channel alignment

The main tidal channel that links the ocean and the estuary and separates the adjacent islands is termed the ebb channel (Fig. 1). It is generally comprised of two channel segments. The deeper segment of the ebb channel, located between Figure Eight Island and Hutaff Island, is defined as the throat section. This relatively deep channel segment probably is confined to a relatively wide ancestral valley of Futch Creek that was incised into the underlying Oligocene units. The seaward-portion of the ebb channel, which extends across the ebb platform, is referred to as the outer bar or ebb platform channel. The azimuth of the axis of the ebb channel was measured at the point where it crosses the zone of breaking waves (terminal lobe as defined by Hayes, 1980).

The orientation (azimuth) and position of the outer channel segment has changed repeatedly over time (Fig. 8). Over the past 70 years the orientation of the seaward channel segment across the ebb platform has ranged from 84^{o} to 190^{o} but was generally aligned in an ESE to SSE orientation (Fig. 8). As a point of reference, an angle of $\sim 145^{o}$ is approximately a shore-normal alignment. The orientation of the outer bar channel is commonly a very important inlet parameter because slight changes in its alignment can have a significant impact on the erosion and accretion trends along the adjacent oceanfront and inlet shorelines, as well as the interior channel margins

The alignment of the outer portion of the ebb channel is controlled by complex wave and current interactions along the outer bar channel and swash platform that lead to the slow deflection of the channel. A second set of variables that cause the rapid realignment of the channel are storms and the interior channel hydraulics that control ebb delta breaching events. The wide fluctuations in the alignment of the ebb channel are then attributed to a sequence of ebb delta breaching events, followed by a period of time when channel deflection was the norm.

Figure 8 depicts the timing of five major ebb delta breaching events that led to a rapid realignment of the outer ebb channel segment. A sequence of aerial photographs from March 1938 to March 1956 show that the ebb channel was continually deflected toward F8I from an alignment of 123^o (March 1938) to 180^o in (November 1949). Hurricane Hazel (10/54) not only widened the inlet considerably but realigned the ebb channel. A November 1954 photograph of a portion of the inlet and a March 1956 image show the enlarged inlet and the realigned channel (152^o). Ebb channel deflection became the norm during the period between March 1956 and December 1975 when a second major breaching episode occurred that led to a reorientation of the ebb channel toward Hutaff Island (Figs. 8, 6 and 10 Appendix). By July 1980, the ebb channel azimuth was 112^o. During the following two decades, the ebb channel was once again deflected toward F8I from an alignment of 112^o (July 1980) to 162^o (March 1993). A major ebb delta breaching event likely occurred in late 1993 or early 1994 (Fig. 11 Appendix). An aerial photograph from November 1993 shows a well developed spillover channel, a remnant of an aborted breach. The subsequent photograph (5/96) depicts a reconfigured ebb delta (Fig. 12 Appendix) and a relocated and realigned ebb channel (103^o).

This juncture marked a significant period in the recent history of the inlet. The aforementioned breaching event and the subsequent changes related to the channel realignment promoted a major repositioning of the ebb tidal delta to the NE and ushered in the recent relatively rapid erosion along the F8I oceanfront (Fig. 13 Appendix). The details and mechanisms are discussed in a subsequent section of this report. During the next ~ 50 months, the outer portion of the ebb channel was deflected toward Hutaff Island (103^o to 84^o). An overflight of the inlet in August 2000 indicated the outer bar channel was deflected further NE and was highly skewed along the HI oceanfront (Fig.

8). Data from in-flight instrumentation indicated the ebb channel assumed its most ENE alignment (70^o) since 1938.

Based on available photographic information, a breaching event appeared to occurr between August 13 and December 23, 2000. The aforementioned recently realigned ebb channel (116^o) reversed its deflection direction and shifted toward F8I from February 2001 until mid 2003, when a breaching event occurred that realigned the ebb channel in an alignment of ~ 134^o. As of April 2007, the most recent aerial photograph used in the conduct of this study, the alignment was 141^o (Fig. 1). The importance of the channel's position and the direction of channel deflection/ reorientation are critical variables that govern the direction of bar by-passing events. The role of by-passing is addressed in a subsequent section of this report.

Inlet instability and ebb channel movement

Since 1938, the throat section of the channel has shifted (Fig. 14 Appendix) across a 1,550 ft wide migration pathway; and during the inlet's migration, the outer ebb channel segment has been realigned continually (Figs. 9 and 10). During the period from 1938 to 1945, the ebb channel migrated 716 ft in a northeasterly direction toward Hutaff Island (HI) at rates of ~ 104 ft/yr (Fig. 11). Over the next 11 years, between 1945 and 1956, the channel reversed its direction of migration and moved 625 ft to the southwest. Approximately 92 % (580 ft) of the migration occurred between 1945 and 1949 when the ebb channel migrated at rates approaching 120 ft/yr (Figs. 10 and 11). Between 1949 and 1956, five hurricanes impacted southeastern NC, beginning with Hurricane Barbara (August 1953) a Class # 2 storm, and ending with Hurricane Ione (September 1955), also a Class 2 storm. The most significant event was Hurricane Hazel (October 1954) a Class 4 storm, which made landfall near Calabash, NC. Numerous inlets were opened along the barriers in southeastern NC, and numerous spits were spit platforms were breached that effectively widened the inlet (Fig. 7, photo insert). The ebb channel, during the interval between 1949 and 1956, shifted SW toward F8I only a net distance of 45 ft.

During the following three years from 1956 to 1959, the ebb channel again migrated in a NE direction toward HI a distance of 625 ft, at a rate of 183 ft/yr. During the next 15 years (August 1950 to December 1974), the ebb channel migrated southwestward toward F8I a net distance of 694 ft, and in so doing, repositioned the ebb channel ~ 22ft northeast of its 1938 position (Figs. 9 and 10). Migration rates during this period of time averaged ~ 46 ft/yr. During the interval between 1974 and 1989, when the initial development of the northern portion of F8I began, the inlet shifted to the northeast a net distance of 615 ft at a time averaged rate of 25 ft/yr. The ebb channel reversed its migration direction again during the period from 1989 to 1993 and moved southwest toward Figure Eight Island a distance of ~306 ft at a rate of 87 ft /yr (Figs. 9-11).

During the remainder of the 1990s, the ebb channel again migrated toward Hutaff Island. Between March 1993 and September 1999 the channel shifted a net distance of 1,185 ft to the northeast. The great majority of the change occurred between March 1993 and August 1996 when the ebb channel shifted or more likely was reoriented during an ebb delta breaching event and ultimately was repositioned a distance of 1, 056 ft NE of its former location. Between September 1999 and February 2002, the ebb channel migrated 570 ft toward F8I at a rate of 235 ft/yr. The direction of channel migration and rate of movement has been extremely variable since February 2002 (Figs.10 and 11). Between February 2002 and March 2003, the ebb channel shifted NE toward HI at a rapid rate of 557 ft/yr. During the subsequent interval of time (March 2003 and April 2007), the ebb channel migrated to the SW and F8I a net distance of 439 ft at a time averaged rate of 107 ft/yr. The majority of the migration toward F8I occurred during the period between March 2004 and April 2007 (Fig. 10). As of April 2007, the ebb channel is positioned ~ 1,108 ft northeast of its 1938 position (Figs. 10 and 14 Appendix).

Figure Eight Island oceanfront shoreline change

Chronic erosion along the northeastern portion of F8I, along the oceanfront downdrift of Rich Inlet and along the inlet margin, has been a major concern since the early 1980s when development of the oceanfront began along the north end of the island (Fig. 10 H). The periodic deterioration and progradation of this shoreline segment is a result of a number of variables that act in concert to produce the complex erosion/accretion patterns. Several major erosion episodes of varying duration have occurred along the oceanfront in this area both prior to and subsequent to development. The mechanism that dictated the erosion was and is related to inlet process, but in each episode, the cause of the erosion, while related to Rich Inlet, was different. This section of the report describes each of the three erosion events and details the inlet-induced shoreline changes.

Shoreline changes were measured along 41 transects, established on the digitized photographs of Figure Eight Island and Hutaff Island (Fig. 2). Figures 12 and 13 depict the position of selected historic shorelines on 2007 photographs of F8I and HI for purposes of comparison and subsequent discussion. A comparison of the shoreline change data for Figure Eight Island and Hutaff Island for various periods since 1938 indicated that the barriers generally were characterized by opposing erosion/accretion trends along the immediate updrift and downdrift shoreline reaches (T11-20 on F8I and T21-31 on HI). The major reversals in the accretion patterns and the onset of erosion were directly related to inlet-induced changes.

Inspection of Figures 14 - 16 illustrates that a significant erosion episode occurred during the early 1940s prior to the development of the island. A cursory examination of historic aerial photographs that cover the period between 1938 and 1945 indicated that a major erosion episode occurred prior to the 1945 over-flight (Fig. 16). No data are available that pertain to the impacts of the Great Atlantic Storm (8/1/44) that made landfall near Southport, NC. Inspection of aerial photographs (1/23/45) of the island provides evidence of minor washover fan development and dune erosion. However, morphologic evidence indicates that the primary cause for the erosion was the configuration of the ebb and flood channels on the swash platform (Fig. 16. A-B). The position of the 1945 shoreline depicted in Figure12 is well landward of the 1938 shoreline northward of Transect 10. The details of the events leading to the mid 1940s erosion episode is unknown due to a lack of photographs; but available data indicate that the shoreline between transects 11 and 20, within the IHA, eroded an average of 142 ft (Figs. 15 and 15 Appendix). The majority of the southern segment of the oceanfront also eroded between T3 and T10 where the shoreline retreated between 4ft and 82 ft. The average zone wide erosion was 29 ft (Figs. 17 and 15 Appendix).

An examination of Figure 16 C shows that by 1949, a portion of the oceanfront shoreline prograded, and by 1956 almost the entire reach had prograded. Accretion ranged from 531 ft at T 18 near the inlet to 43 ft at T13 near the southern margin of the IHA despite the impacts of Hurricane Hazel in October 1954. The reach wise accretion averaged 241 ft (Fig. 15 Appendix). During the period between 1938 -1945, erosion also dominated the T1-T10 shoreline reach south of the IHA and averaged 142ft. During the subsequent period between 1945 and 1956, the T1-T10 reach accreted at a number of transects (T1-9) and averaged 8 ft for the entire shoreline segment.

Between 1956 and 1974, a number of events had a profound effect upon the morphology of the oceanfront shoreline. These events included the four tropical storm and hurricanes that moved through the area, the Ash Wednesday Storm of 1962, and the beach fill projects that occurred along the central and southern ends of the island between 1969 and 1973. Figure 15 shows that almost the entire northern reach of the ocean front between T11 and T19 prograded by as much as a 150 ft, despite the impacts of the above-mentioned storms. It appears that much of the shoreline progradation was due to the deflection of the ebb channel toward F8I between 1959 and the mid 1970s (Figs.16 and 10 Appendix). The average zone wide (T11-20) accretion for the period was 71 ft (Fig. 15 Appendix). In contrast to the zone nearer the inlet, the oceanfront shoreline segment to the south (T1-T9) eroded, only the shoreline in vicinity of Transect 10 accreted in a like manner to those located to the NE (Fig. I). Erosion ranged from 32 ft to 155 ft along the reach and averaged 90 ft. The significant oceanfront recession along the southern reach, (T1-10) in comparison to the progradation along the northern reach (T11-20), provides evidence relating to the positive influence of the inlet along the northern zone of F8I.

A second erosion episode began in late 1979 - early 1980. Between the onset of the erosion cycle and its end in the mid 1980s, the ebb channel migrated ~ 415 ft to the northeast (Fig. 10). The 1980 to 1984 erosion scenario developed during a period of time when large-scale ebb and flood channel reconfigurations and realignments prompted large swash bars to migrate onto the extreme northern portion of the oceanfront into the marginal flood channel and eventually into the inlet throat. During the migration and welding of the swash bars packages, severe erosion occurred in the lee of the sand bars due to secondary wave refraction around individual sand bar complexes (Fig. 16 Appendix). The effects of this scenario coupled with the effects brought about by flood channel changes led to erosion along almost the entire IHA oceanfront.

Shoreline recession during the period between 1974 and 1989 was not as dramatic as the previous erosion episode and was generally restricted to the IHA oceanfront shoreline segment between T 14 and T20 and along the inlet shoreline. Erosion along the oceanfront reached a critical stage by 1980; and by 1983, sand bags had been emplaced along a home on Inlet Hook Rd. (Figs. 16 and 17 Appendix). Subsequently, in the Spring of 1983, a small-scale nourishment project was completed along 2,000 ft of the oceanfront to mitigate the erosion (Figs. 18, 10 I and 17 Appendix). Inspection of Figures 14 and 15 shows that between 1974 and 1989 oceanfront erosion (T14 to T19) ranged from 33 to 218 ft and averaged 23 ft for IHA shoreline (Fig. 15 Appendix). Cleary and Jackson (2004) documented that the shoreline retreat between July 1980 and September 1984 averaged 171 ft and ranged from 454 ft near the inlet to 135 ft near T13.

The northeasterly migration of the channel in the late 1970s and early 1980s, and the slight deflection of its outer segment, promoted the expansion of the marginal flood channel on the southern margin of the inlet (Figs. 18 and 19). The expansion of the flood channel initiated the brief period of erosion along the inlet shoreline. During the summer of 1984, erosion was noticeable along the inlet shoreline fronting Beach Rd. North (Figs. 18 and 19.). Shoreline retreat along the inlet reach peaked in October 1984 when the HWL encroached on several of the homes along this shoreline segment. Erosion of the shoreline bordering the marginal flood channel was rapid and short-lived, and rates as high as 3.0 ft/day for a brief period of time were recorded (Cleary, 2001). By early 1985, the erosion along the inlet shoreline ceased, and rapid progradation began. Figures 18 D and 19 D depict the F8I inlet shoreline conditions in 1989.

Between 1984 and 1989, the ebb channel migrated to the northeast a net distance of 202 ft and was positioned 632 ft NE of its 1974 location (Fig. 9 and Fig. 10 Appendix.). In 1989 the channel reversed its migration direction, and by 1993, the ebb channel was located 306 ft SW of its 1989 position. Concurrently, the wide downdrift flood channel on the Figure Eight Island margin continued to infill (Figs. 9 and 19 D). The northeasterly extending F8I spit that formed in early 1985 was a major feature by 1990. The continued development of the spit led to the infilling of the majority of the marginal flood channel (Fig. 19). During the four-year period (1989-1993), the inlet shoreline and portions of the oceanfront between T16 and –T20 prograded between a minimum of 19 ft at T16, to a maximum of 299 ft at T20 (Figs 14 and 15). Erosion continued to occur along the oceanfront away from the inlet between T12-15 (Fig. 15). The IHA oceanfront shoreline (T11-T20) average accretion during this period amounted to 54 ft (Fig. 15 Appendix).

During the periods between 1974 and 1993, the southern shoreline segment (T1-10) prograded (Fig. 17). Accretion averaged 20 ft during the period from 1974 to 1989, while during the subsequent period from 1989 to 1993, accretion averaged 42 ft (Fig. 15 Appendix). The shoreline progradation recorded during each period reflected the nourishment (1983 and 1993) of the northern segment of the F8I that included the entirety of the oceanfront within the study area (Figs. 18 A-C and 19 A-C).

The erosion episodes that occurred in the early 1940s and the early 1980s appear to be more closely related and similar than the current episode that began in the late 1990s (which is subsequently described). The two earlier erosion episodes were related to marginal flood channel changes and their subsequent encroachment onto the Figure Eight Island oceanfront and inlet shorelines (Figs. 18 and 10 Appendix). In contrast, the most recent episode differs in that the erosion is generally restricted to an extensive portion of the IHA oceanfront. The current erosion is a by-product of the northeasterly migration of the ebb channel and the consequent repositioning of the ebb-tidal delta. The current erosion episode, and worst to date, was presumably initiated when the marginal flood channel began to expand between November 1992 and November 1993 (Fig. 21 A-B). The 1993 configuration of the inlet consisted of a south-southeasterly, skewed, ebb channel that was flanked by a narrow flood channel on the Figure Eight Island margin and a wide flood channel on the Hutaff Island margin. This configuration led to an ebb delta breaching event and channel reorientation that probably occurred in the later part of 1994 or early 1995 (Figs. 21 C-D and 11 Appendix). The ebb delta breaching site was likely the spillover channel imaged on the 1993 aerial photograph and the oblique photograph imaged on Figure 11 (Appendix). Alternatively, although highly unlikely, the realignment of the ebb channel to a more easterly alignment (imaged on the September 1996 photograph) may have occurred through rapid deflection of the channel.

Although the ebb channel shifted rapidly northward toward Hutaff Island between 1993 and 1996 a distance of 1,056 ft (Fig. 10 and Fig. 14 Appendix), accretion continued along the F8I oceanfront between T11-T19 and averaged ~50 ft, while the average accretion for the entire reach (including T20) was 37 ft for the three-year period. The shoreline change along the oceanfront segment south of the IHA was highly variable (Fig. 17) due most likely to manipulation of the beach profile following Hurricane Bertha in July 1996. The average change along the southern segment of the study area amounted to 3 ft of shoreline retreat (Fig.15 Appendix).

In late 1997 and early 1998 the oceanfront shoreline near the inlet began to erode slightly because the majority of the northern end of the island was no longer protected by the breakwater effect of the ebb-tidal delta (Fig. 21 and Fig. 18 Appendix). During the period from 1996 to 1998, shoreline change was highly variable along the oceanfront between T11 and T20. Shoreline retreat was prevalent near the inlet and ranged from 57 ft at T20 to 36 ft at T18, while progradation occurred along the remainder of the shoreline segment southwest of T18. Accretion along this segment between T11 and T18 varied from 20 ft to 195 ft and reflected profile manipulation following the landfall of Hurricane Fran in September 1996, as well as a beach nourishment project, completed in March 1998. The reach-wise accretion averaged 61 ft (Fig. 15 Appendix). The oceanfront segment (T1-10) south of the IHA shoreline segment prograded along its entirety due to the previously mentioned island –wide nourishment project. Accretion along the above-mentioned shoreline segment ranged from 2 ft at T1 to 103 ft at T9. The average accretion within the southern zone along F8I was 70 ft (Fig. 15 Appendix).

Regardless of the mechanism that initiated the channel migration to the northeast in the mid 1990s, the stage was set for the onset of a major and long-lasting erosion episode that continues to date along the northern end of F8I. Between 1996 and 1999, the ebb channel migrated an additional 129 ft to the northeast (Figs. 9 and 10) and was marked by a dramatic change in the orientation of the outer channel segment from 162^{o} in 1993 to 99^{o} (Figs. 8 and 9) in September 1999. As of the aforementioned date, the ebb channel was located 1,516 ft NE of its 1938 baseline position (Fig. 10 and Fig. 8 Appendix). As a consequence of the large-scale inlet changes, the ebb-tidal delta was shifted farther to the northeast, leading to a northward shift in the wave sheltering effects of the ebb delta and the concomitant exposure of the northern F8I oceanfront to wave attack. Swash bars no longer welded onto the F8I oceanfront but rather moved into the F8I marginal flood channel, and eventually the estuary and the interior feeder channels. Figures 21 C-D and 22 depict the inlet changes.

Between September 1999 and March 2002, the throat segment of the ebb channel shifted to the SW and Figure Eight Island a net distance of ~ 577 ft. In the Fall of 2000, observations made during an overflight of the inlet indicated the channel attained an alignment of ~ 70^{o} (Fig. 9) that appeared to exacerbate the erosion along the F8I oceanfront. Inspection of Figures 14 and 15 shows that significant erosion did occur along the IHA oceanfront shoreline between September 1999 and May 2002. The reach-wise average erosion amounted to 186 ft (Fig. 15 Appendix) and ranged from 5 ft at T12 to 333 ft at T20 near the inlet (Fig. 15). In contrast, accretion continued along the southern part of the study area shoreline (T1-10) where progradtion ranged from 4 ft to

40 ft (Fig. 17) and averaged 23 ft (Fig. 15 Appendix).

An ebb delta breaching event that occurred in December 2000 had a significant impact on the shape of the ebb tidal delta and the size of the ebb delta segments (Fig. 22). The breaching event, depicted by Figure 22 B – D, clearly illustrates that the shoal segment located off Hutaff Island was significantly larger than the shoal segment that fronted F8I. The updrift bar-bypassing event (Fig. 22 C) transferred more sand to the shoal segment located updrift of the ebb channel. Note the lack of swash bars and wave breaks offshore F8I in Figure 22 D and the location of swash bars south of the ebb channel. As a consequence of the ebb delta's shape and position, the F8I shoreline retreated as the barrier's planform was altered that ultimately led to shoreline armoring (Figs. 21 D and 22 and Figs 1-4 Appendix). The frequent overtopping of the sand bags and subsequent slumping of the bags prompted the placement of beach fill along the amore shoreline in order to mitigate the failure of the bags and provide storm-protection for the threatened homes (Figs. 5 and 6).

Since March 2003, the throat segment of ebb channel has reversed its migration direction and shifted to the SW and toward Figure Eight Island a net distance of 439 ft (Figs. 9, 10 and Fig. 14 Appendix). During the most recent period of channel migration, the alignment of the seaward segment of the ebb channel has varied between 134^{o} and 141^{o} (Figs. 8 and 9). The period between April 2003 and October 2004 was characterized by an ebb delta-breaching event in late 2003 that led to the repositioning and realignment of the outer ebb channel (190^{o} to134^{o}). Figure 24 depicts the pre- and post- breaching configurations of the ebb delta. The above-mentioned ebb delta breaching event differed significantly from the late December 2000 event in that the recent breaching event led to downdrift bar-bypassing. The event led to reconfiguration of the ebb delta (Fig. 24 C and D) and to an expansion of the F8I marginal channel. Concurrent with flood channel expansion, the F8I spit that extended into the throat eroded dramatically (Fig. 24 B and C). Also, the newly expanded marginal flood channel functioned as a corridor for the landward transport of large swash bars that formed on the southern portion of the swash platform. Figure 23 C and D depict the landward movement of swash bar packets into the estuary and Nixon Channel. Since 2004, the general configuration of the ebb delta has changed slightly (Fig. 25). However, the inlet has widened (Fig. 7) to its most expansive dimension (2,836 ft [IMW = 2,511 ft]) since 1956. Other noticeable changes relate to the erosion of the F8I and HI spits and the development of a large lobe of sediment within the estuary and the seaward portion of Nixon Channel (Fig. 25 D).

During the period from 2002 to 2007, erosion was the norm along the oceanfront shoreline within the IHA (T11 - T20) despite the incremental shoreline armoring with sand bags and the placement of 250,000 cy of beach fill along the northernmost 6,100 ft of the island in March 2001. An additional nourishment project was completed along the IHA oceanfront shoreline in early January 2006. Figures 7 and 8 (Appendix) show that the protection provided by the beach fill was short-lived. Figures 14 and 15 depict the shoreline changes along this segment of the oceanfront. Only a small shoreline segment between T18 (13 ft) and T19 (36 ft) accreted. Along the remainder of the IHA oceanfront, the erosion ranged from 23 ft (T20) to 88 ft (T14). The average erosion for the reach was 44 ft (Fig. 15 Appendix). The southern segment of the F8I oceanfront between T1 and T10 also eroded, but to a much greater degree than the northern part of the oceanfront due to aforementioned shoreline armoring (Fig. 17). The shoreline retreat within this zone averaged 47 ft (Fig. 15 Appendix) and ranged from a minimum of 26 ft at T1 to 79 ft at T9 (Fig. 17). Figure 9 (Appendix) depicts the shoreline conditions as of February 2008.

Hutaff Island oceanfront shoreline change

The oceanfront transects utilized in determining the shoreline changes along Hutaff Island between 1938 and 2007 are depicted on Figures 2 and 13. Inspection of historical aerial photographs and a comparison of Figures 12 and 13 shows that the F8I and HI oceanfront shorelines had contrasting and often opposing shoreline change trends. The major reversals in the progradation of the shoreline reach nearest the inlet and the onset of erosion in the area are directly related to changes in the position of the ebb channel. Figures 19 to 21 (Appendix) show that Hutaff Island is a washover-dominated barrier, whose susceptibility to increased overwash penetration has increased over time. Figure 22 and Figure 26 (Appendix) depict the general conditions of the barrier in January 2008.

Figures 27 and 28 illustrate the cumulative changes along Hutaff Island between T21 to T31 and T32 to T41. A comparison of the Figures 14 and 27 shows the previously mentioned opposing trends in accretion and erosion, particularly for those transects close to the inlet. It is also evident that Rich Inlet directly influenced a shorter portion of the oceanfront shoreline along Hutaff Island (Fig.27). During the period 1938 to1945 the shoreline segment between T21 –T24 prograded due to the shift of the inlet toward HI (Figs. 27 and 29 and Figs. 10 and 27 Appendix). Accretion along the zone of the inlet's influence (T21-T24) ranged from 14 ft to 371 ft, while the remainder of the HI oceanfront between T 25-T31 eroded 38 ft - 69 ft (Figs. 27 and 29). The zone –wide average progradation amounted to 37 ft (Fig. 23 (Appendix). Figure 30 shows that erosion was prevalent along the northern HI oceanfront segment between T32 and T41 where shoreline retreat ranged from 35 ft to 62 ft (Fig. 30). The average shoreline erosion along the northern reach (T33- T41) of HI was 45 ft (Fig. 23).

During the subsequent 48 years (1945-1993), shoreline erosion dominated the southernmost reach of Hutaff Island (Figs. 27 and 29 and Figs. 24 and 25 Appendix). Between 1945 and 1956 erosion ranged from a maximum of 453 ft at T21 to 22 ft at T31 and averaged 103 ft (Fig. 23). Presumably the majority of the shoreline retreat was related to the impacts of Hurricane Hazel in October 1954 (Fig. 29). During the following period from 1956 to 1974, which was marked by the Ash Wednesday Storm of 1962, shoreline retreat ranged from 239 ft at T22 to 167 ft at T31 (Fig. 29). The reach-wise average erosion of 201 ft was approximately double that of the preceding period (Fig. 23 Appendix). During the following 15 years (1974 to 1989) the ebb channel migrated 615 ft to the NE and (toward Hutaff Island). Ultimately the reconfigured ebb delta promoted progradation that was limited to the shoreline segment (T21-T23) adjacent to the inlet (Figs. 27 and 29 and Fig 24 Appendix). Accretion along this 1,550 ft shoreline segment ranged from 3ft to 79 ft (Fig. 29). The remainder of the zone was characterized by erosion that ranged from a minimum of 29 ft at T24 nearest the inlet, to a maximum of 169 at T31 at the northern limit of the reach (Fig 29). The average erosion for the entire reach between T21 and T31 was 53 ft, which amounted to ~ 26 % of the average retreat for previous period (Fig. 23 Appendix). Figures 27 and 29 illustrate that during the interval between 1945 and 1989, the northern shoreline segment (T32 - T41) of Hutaff Island was characterized by chronic and continuous erosion. The cumulative shoreline erosion for the reach ranged from a minimum of 335 ft at T32 to 406 ft at T37 (Figs. 28 and 30). The average shoreline retreat (Fig. 23 Appendix) for the period between 1945 and 1989 ranged from 39 ft (1945-1956) to 184 ft (1974 -1989).

Shoreline erosion continued during the period from 1989 to 1993 along the reach (T21 to T31) adjacent to the inlet (Figs. 27 and 29). During this interval, the ebb channel shifted to the SW a distance of 306 ft, while the outer segment of the ebb channel was deflecting toward F8I. As a consequence, the marginal flood channel on the HI margin expanded (Figs. 20 and 21); and as consequence, the oceanfront near the inlet eroded as much as 180 ft (Figs. 27 and 29). The remainder of the shoreline segment from T22 to T30 also eroded. Oceanfront retreat along this zone ranged from 24ft at T30 to 129 ft at T22 (Fig. 23 Appendix). Accretion during this interval was restricted to T31 at the northern limit of the reach where 476 ft of progradation occurred. The zone wide shoreline retreat averaged 58 ft (Fig. 23 Appendix).

Figures 28 and 30 illustrate that the HI shoreline segment between T32 and T41 along the northern portion of the study area was dominated by progradation during the aforementioned interval. During the 1980s, Old Topsail Inlet located between Huttaf and Lea Island was a viable SW migrating inlet that impacted the planform (curvature) of the adjacent barriers (Fig. 26 Appendix). It is beyond the scope of this report to describe the details of the inlet-related shoreline changes as the inlet migrated toward Hutaff Island. It is suffice to mention that shoreline accretion was likely due to inlet processes related to the location of the migrating inlet as it approached its closure zone. Progradation of the shoreline segment between T36 and T41 ranged from 2 to 44 ft (Figs. 28 and 30).

Southward toward T32, shoreline change was highly variable. The average shoreline change for the reach delineated by T31 and T41 was 15 ft (Fig. 23 Appendix).

The period between 1993 and 1996 was marked by the rapid shift of Rich Inlet toward HI and the consequent repositioning of the ebb channel 1,056 ft NE of its previous location. The ebb delta breaching mechanism in late 1994 also realigned the ebb channel from 162^o to103^o. The newly realigned ebb channel ultimately led to a reconfiguration of the ebb delta, which in turn promoted extensive progradation along the southern portion of HI (Figs. 27 and 29). Accretion occurred along the entire shoreline segment with the exception of the oceanfront in vicinity of T31. Progradation ranged from a maximum of 199 ft at T21 near Rich Inlet to a minimum of 12 ft at T26. The average shoreline progradation for the reach was 57 ft (Fig. 23 Appendix). Shoreline progradation also characterized the oceanfront segment between T32 and T41 where the average shoreline was 33 ft (Fig. 23 Appendix). Erosion within this zone was restricted to the shoreline in vicinity of T32 where shoreline retreat amounted to 11 ft, despite the landfall of Hurricane Bertha in the area on 5 July 1996 (Figs. 28 and 30). The oceanfront shoreline buildup that occurred north of T26 was likely due to the onshore movement of portions of the sand contained in the collapsing ebb delta of Old Topsail Inlet during its closure phase (Fig. 30 and Fig. 26 Appendix).

During the next period of time from August 1996 to June 1998, Hurricane Fran (9/96) made landfall in southeastern NC. The hurricane, a high Class III storm, produced a storm surge of 8-9 ft in the F8I - HI area. Not surprisingly, erosion was the norm along the oceanfront to the northeast of the inlet-related accretion, zone where shoreline progradation (Fig. 29) ranged from 46 ft (T22) to 116 ft (T21). Shoreline retreat along the oceanfront between T24 and T31 ranged from a minimum of 13 ft to a maximum of 73 ft. The reach-wise average shoreline amounted to 19 ft (Fig. 23 Appendix). The impact of Hurricane Fran appeared to have been greater along the shoreline segment between T32 and T41 where the entire oceanfront segment retreated between 16 ft and 95 ft (Figs. 28 and 30). The average shoreline recession for the oceanfront reach between T31-T41 was 54 ft (Fig. 23 Appendix). The closure of Old Topsail Inlet during this period of time may have contributed to the shoreline retreat as the barrier (Lea and Hutaff Islands) segments near the inlet realigned in accordance with the new contiguous island planform (Fig. 25).

During the subsequent period of study (June 1998 to May 2002), Hurricanes Bonnie (August 1998) and Floyd (September 1999) made landfall in the area. These moderate intensity storms overtopped much of Hutaff Island, transporting significant volumes of sand across the barrier in the form of washover terraces (Figs. 19 C and 26 C-D Appendix). As previously mentioned, an ebb delta breaching event occurred in December 2000 that eventually by-passed a large bar-packet to the area northeast of the ebb channel offshore HI (Fig. 23). This event had a significant impact on the shoreline changes following Hurricane Floyd (9/99). Inspection of Figures 27 and 29 indicate that net erosion was common along HI, except along the shoreline reach immediately updrift of Rich Inlet. This shoreline segment, located between T22 and T27, prograded between 49 ft and 247 ft. By contrast the shoreline segments (T28-T31) and (T32-T41) were characterized by net oceanfront retreat (Figs. 27 and 30). Erosion along the southern shoreline segment ranged from 30 ft -56 ft, while along the northern segment, the shoreline retreated between 16 ft and 138 ft (Figs. 29 and 30). The average progradation for HI shoreline segment near the inlet was 52 ft compared to 78 ft of shoreline erosion for the northern shoreline segment (Fig. 23 Appendix)).

The aerial photographs comprising Figures 22 - 24 depict the changes in the ebb channel's position and alignment prior to and subsequent to the ebb delta breaching event of mid 2003. Since February 2002, the ebb channel had shifted ~165 ft toward Figure Eight Island while the outer bar channel segment was deflected from 156^{o} to 190^{o} and as a consequence of ebb delta breaching was eventually aligned almost shore-normal (141^{o}) as of April 2007 (Figs. 24 and 25). As consequence of these ebb channel-related changes, the marginal flood channel along HI has expanded since 2004 as the throat of the inlet widened (Fig. 7) from 1,187 ft (2002) to 2,511 ft (2007). These inlet-related changes have been responsible for the erosion along the southern 4,000 ft of Hutaff Island (Fig. 29 and Figs. 25 and 27 Appendix). The shoreline segment that comprised the aforementioned reach eroded between 22 ft (T27) to 112 ft (T25), while the remaining portion of the oceanfront between TT28 and T31 prograded between 15 ft and 36 ft (Figs. 27 and 29). By contrast, the northern oceanfront segment of HI (T32-T41) retreated between 16 ft and 47 ft. Shoreline accretion (22 ft) was restricted to a small portion of the oceanfront in vicinity of T32 (Figs. 28 and 30). The average shoreline erosion for HI between 2002 and 2007 ranged from 35 ft along the southern portion of the barrier to 59 ft along the northern segment of the island (Fig. 23 Appendix).

Net Oceanfront Shoreline Changes

Utilizing the data depicted in Figures 26 and 27 (Appendix), three periods of varying durations were selected for comparisons of the net shoreline changes along Figure Eight and Hutaff Islands. The data are presented in Figure 31. A comparison of the net shoreline change data for Figure Eight Island oceanfront zone and a comparable zone along Hutaff Island for various periods since 1938 indicates that the updrift and downdrift barriers generally had opposing patterns of net change particularly near the inlet.

An inspection of Figure 31 shows that between 1938 and 2007, the southern zone (T21 –T30) along Hutaff Island shoreline was characterized by net erosion that ranged from 121 ft at T21 to 419 ft a T30. In contrast to the zone-wise erosion along Hutaff Island, only the extreme northern end of F8I nearest the inlet (T19 and 20) eroded from 40 to 208 ft, while the remainder of the northern zone along F8I (T11 and T20) prograded from a minimum of 52 ft (T18) to a maximum of 147 ft (T14). Figure 32 shows that the average net change along the F8I oceanfront zone downdrift of the inlet prograded an average of 70 ft, while the Hutaff Island oceanfront retreated an average of 307 ft. When comparing the net shoreline changes within the zones farther from the inlet, the data show that Hutaff Island's northern oceanfront zone (T31 to T41) eroded from 435 ft to 570 ft, while the southern oceanfront zone (T1-T8) along F8I eroded, but at a significantly lesser amount. Along the aforementioned zone, the erosion ranged from 2 to 15 ft while the northernmost segment (T9 to T10) prograded between 22 ft and 79 ft.

The zone-wide average net change for Hutaff Island's northern zone amounted 521 ft of shoreline retreat, compared to an average net accretion of 3 ft along the southern zone of Figure Eight Island (Fig. 32).

A comparison of the oceanfront change trends for the period between 1938 and 1996 shows that the Figure Eight Island and Hutaff Island oceanfront shorelines were characterized by dramatically different accretion and erosion trends for the period (Fig. 8-13). Between 1938 and 1996, erosion was the norm along the southern zone of Hutaff Island; shoreline retreat ranged from 184 ft to 361ft. The average shoreline loss within the zone for the period was 317 ft. In contrast to the significant erosion along Hutaff Island, the Figure Eight Island zone adjacent to the inlet prograded along its entirety. Accretion ranged between 120 ft at T11 to 379 ft in vicinity of T18; the 5,000 ft long oceanfront zone downdrift of the inlet prograded an average of 239 ft (Figs. 31 and 32).

Figure 31, which depicts the shoreline changes for the period between 1996 and 2007, shows that chronic erosion was commonplace along the entirety of the downdrift former accretion zone. Shoreline retreat along the northern zone of F8I ranged from a minimum of 5 ft at T1 to a maximum of 414 ft at T20 along the spit near the inlet. In contrast, progradation was the norm along the southern portion (T21 to T25) of the Hutaff Island oceanfront zone immediately updrift of the inlet. Progradation along the shoreline segment varied from 46 ft at T 22 to 85 ft in vicinity of T24. Shoreline retreat characterized the remainder (T26 to T30) of the HI southern oceanfront zone where erosion ranged from 15 to 64 ft. The zone-wide average shoreline progradation was 11ft (Fig. 32).

During the most recent period of study (1996 to 2007), a dramatic difference in the shoreline change patterns was recorded for the F8I and HI oceanfront zones located farther from Rich Inlet. Zone-wide shoreline recession was prevalent along the northern portion of HI where erosion ranged from a minimum of 69 ft in vicinity of T31 at the southern boundary of the zone to a maximum of 231 ft in vicinity of T41, the northernmost transect within the study area along Hutaff Island. The average zone-wide shoreline retreat amounted to 146 ft (Fig. 32). By comparison, the southern oceanfront zone along F8I was a shoreline reach where net progradation varied from 15 to 69 ft. The average zone-wide accretion was 47 ft. The difference in the zone-wide change trends along southern zone along F8I and the northern zone along HI is attributed to the placement of substantial amounts of beach fill along the northern portion of the F8I during period.

Figure Eight Island oceanfront shoreline change rates

From a management perspective, it is important to know and understand the factors that control the short-term spatial and temporal variability of shoreline change rates, particularly along oceanfront segments influenced by inlets. Both the short-term accretion and erosion rates within IHAs are usually significantly higher than adjacent shoreline reaches outside the direct influence of inlet-related processes. It is apparent from the inspection of the various data sets dealing with the recent shift of the ebb channel to the northeast, that the planform of the oceanfront shoreline segment between T1 and T20 will likely undergo increased erosion as the northern portion of F8I adjusts to the inlet's position. It is important to bear in mind that the oceanfront changes related to the movement of the channel lag behind the timing of the channel shift and the associated reconfiguration of the ebb delta. The time lag is more pronounced for larger inlets, and for Rich Inlet, the lag appears to have been several years. It was difficult to determine the exact lag duration due to the impact of four hurricanes in the mid to late 1990s, subsequent beach fill operations and profile manipulations.

Figure 28 (Appendix) illustrates the shoreline change rates for Figure Eight and Hutaff Islands for nine periods between 1938 and 2007. Shoreline change rates along the oceanfront within the Inlet Hazard Area (T11-20) for the nine time periods were extremely variable due to the above mentioned factors. During the first erosion episode (1938-1945) related to inlet changes, the erosion rates along the oceanfront ranged from a minimum of 2 ft/yr at T13 to a maximum of 71 ft/yr at T20 near the inlet. Along the remainder of the oceanfront shoreline south of the IHA, change rates varied from +2 ft/yr at T12 to -11 ft/yr at T8 (Fig. 28 Appendix). Erosion within the IHA and along the southern shoreline segment may be, in part, related to the Great Atlantic Storm of 1944. During the following period between 1945 and 1956, accretion was the norm within the majority of the IHA, where rates ranged from 48 ft/yr (T18) to 4 ft/yr (T13). The relatively high accretion rates recorded are surprising, considering the number of hurricanes that impacted southeastern NC during the early 1950s, particularly Hurricane Hazel (10/54). By comparison, the shoreline segment to the SW was characterized by varying rates of accretion and erosion that ranged from +3 ft/yr to -3 ft/yr.

During the second erosion episode (1983) that was related to the encroachment of the flood channel along the northern portion of F8I, net erosion was restricted to the oceanfront between T14 and T19, where erosion rates reached a maximum of 15 ft/yr at T15 (Fig. 28 Appendix). During this interval, a small (90,000 cy) nourishment project (1983) was completed along a 2,000 ft segment south of the inlet (Cleary and Jackson, 2004). The placement of beach fill (~ 45 cy/ft) along the shoreline segment between T14 and T18 likely masked the effect of the erosion episode.

A major change in the inlet /oceanfront linkage occurred during the period between March 1993 and August 1996 when an ebb delta breaching event occurred (12/94) that resulted in the repositioning of the ebb channel 1,056 ft to the NE of its 1993 position (Fig. 21 B-C). During this 41 month period, the ebb tidal delta was reconfigured in accordance with the new position of the ebb channel and the ESE alignment (106^{o}) of the outer bar channel segment. Approximately 22 months (March 1993) prior to the ebb delta breaching event in December 1994, a beach fill project was completed that placed ~274,000 cy along a 4,500 ft segment of the oceanfront between T1 and T20. The segment of the oceanfront where shoreline retreat was a concern was located between T1 and T14-15. During the nourishment operation, the ebb channel was highly skewed toward F8I (Fig. 21 B) that resulted in natural accretion along the shoreline segment between T15 and T20. The alignment of the ebb channel in 1993 and the associated progradation augmented the artificial shoreline restoration. Figure 28 (Appendix) illustrates that during the period between March 1993 and August 1996, the majority of the higher rates of progradation were recorded for the oceanfront segment between T11 and T19. Erosion was restricted to isolated segments nearest the inlet (T20) and along the southern portion of the study are a between T3 and T9. Hurricane Bertha (July 13, 1996), which made landfall slightly north of the island, caused minor beach and dune erosion along a portion of the oceanfront (Fig. 29 B Appendix). The aforementioned erosion along the southern segment of the oceanfront is attributed to the impacts of the storm.

Several key events in the history of the area occurred during the following period between August 1996 and June 1998, one of which was the continued northeasterly track of the ebb channel. Inspection of oblique and vertical aerial photographs from early 1998 suggests that the much of the wave sheltering protection afforded by the ebb delta, as well as the zone of swash bar attachment, continued to shift to the northeast. As a consequence, shoreline retreat ensued. The landfall of Hurricane Fran on September 9, 1996 had significant impact on the island along the island particularly the central and southern segments of F8I (Cleary and Jackson, 2004). Dune recession and overwash were common along much of the northern end of the island (Fig. 29 D Appendix), although remnants of dune ridges remained along the shoreline segment between T16 and T19. Figure 29 C (Appendix) shows that the HWL remained ~ 250-300 ft seaward of the homes.

In January 1997 an emergency nourishment project, involving an unknown volume of material, was undertaken to restore the dunes and beach that had been eroded during the summer of 1996. Approximately one year later in March 1998, an island-wide nourishment project was completed that placed ~ 450,000 cy along the shoreline. The distribution of the beach fill in terms of cy/ft per reach is unknown, or if the entire oceanfront (~29,000 ft) was nourished with such a small volume of material. The net shoreline change rates for the period between August 8, 1996 and June 19, 1998 reflect the beach fill operations. Accretion rates for the period ranged from 1 ft/yr at T1 to 105 ft/yr in vicinity of T14. Net shoreline retreat was restricted to a small segment of the oceanfront between T18 and T20, where the erosion rates ranged from 18 ft/yr to 31 ft/yr (Fig. 28 Appendix)).

Two storms with significantly elevated water levels (Hurricanes Bonnie [8/26/98] and Fran [9/16/99]) occurred during the period from March 1998 to May 2002 that impacted the oceanfront shoreline (Figs. 28 D-E Appendix). During the above period, a number of mitigation projects were completed that included the January 1999 beach "bulldozing" operation for the repair of the 1997 Post-Fran beach fill project, placement of sand bags along threatened homes in early 2000 (Fig. 1 A-B Appendix), and lastly the placement of ~ 350,000 cy of material along the northern 9,000 ft of the oceanfront (Figs. 5 and 6 Appendix). Figure 28 A (Appendix) depicts shoreline change rates and shows that shoreline retreat was commonplace along the northern segment of the oceanfront between T11 and T20 where erosion rates ranged from a minimum of 1 ft/yr at T12 to a maximum of 85 ft/yr along the shoreline in vicinity of T20 near the inlet. The longevity of the previously mentioned fill project along much northern shoreline reach was minimal (Fig. 6 Appendix). In contrast to the above, the shoreline reach (T1-T10) to the south prograded slightly, at rates ranging from 1 ft/yr to 10 ft/yr.

The most recent period in this study that covered the interval from May 2002 to April 2007 was marked by a number of storm events of both tropical and extra-tropical nature. The passage of two Hurricanes; Isabell (9/18/03) and Ophelia (9/14/05) in the area, generated high winds, waves and higher water levels that caused minor erosion along the oceanfront (Fig. 30 Appendix). Tropical Storm Ernesto (9/1/06) also caused minor erosion along portions of F8I. Several nor'easters also impacted the F8I shoreline most notably the winter storm of December 2002/January 2003 that caused severe overtopping of the sand bags along most of the armored shoreline segment. Overtopping by the increased wave activity and higher water levels led to the failure of most of the sand bags and erosion of the fill landward of the "wall", as well as scarping of the upland (Figs. 1-3 Appendix). The F8BHOA was granted a variance in the summer of 2003 to reinforce the sand bags and increase the elevation of the bags to prevent future overtopping. During construction, ~30,000 cy of fill was placed behind the sand bag wall. Figure 4 (Appendix) depicts the extent of the sand bags in 2003 and as of January 2008. Figure 28 (Appendix) shows that as a collective result of the storms and the shape and position of the ebb delta, erosion has been prevalent along almost the entire oceanfront. Erosion rates varied from a minimum of 1 ft/yr at T17 to a maximum of 18 ft/yr at T12 and T14. Only the shoreline reach located between 18 and T19 prograded at rates from 3 to 7 ft/yr.

Hutaff Island oceanfront shoreline change rates

The events that control the shoreline change rates along the Hutaff Island shoreline are natural since no nourishment activities have occurred on this undeveloped island, all of which is situated in an IHA. Variations in the shoreline change rates are of function of storm impacts, the movement of Rich Inlet's ebb channel along its migration pathway and the migration and closure of Old Topsail Inlet formerly located ~1300 ft north of Transect 41 (Figs. 13, 26 and Figs. 21 and 22 Appendix). The shoreline change trends along the oceanfront shoreline segment (T21-T25) near Rich Inlet are generally the reverse of those along Figure Eight Island for the same periods. During the period from May 1938 to January 1945, the shoreline segment near the inlet (T21-T24 progarded at rates that ranged from 4 ft/yr to 55 ft/yr, while the remainder of the HI oceanfront retreat at rates ranging from 5 to 9 ft/yr. The shoreline change trend was reversed during the following period (January 23, 1945 to March 25, 1956) when the entire oceanfront along Hutaff Island retreated at rates that varied from 1 to 41 ft/yr. The highest rates of erosion (7 -41 ft/yr) were recorded near the inlet as might be expected. The island-wide shoreline retreat was due to the impact of the numerous storms of the 1950s (Fig. 19 Appendix).

The subsequent period from March 1956 to December 1974 was marked by the impact of the 1962 Ash Wednesday Storm, a Class V nor'easter that produced massive washover terraces and breached the island in vicinity of Old Sidbury Inlet (Fig. 20 [insert]). Island-wide erosion occurred during the above period at time averaged rates that ranged from 8ft/yr to 13 ft/yr. Between 1974 to 1989 the ebb channel shifted 615 ft toward Hutaff Island as the spit on the F8I margin elongated to the NE. Consequently, the shoreline between T21 and T23 along Hutaff Island prograded at rates as high as 5 ft/yr. Although no significant storms occurred during the period, the entire oceanfront shoreline continued to retreat at relatively rapid rates that varied from 12-14 ft/yr along the oceanfront 2,000 ft SW of Old Topsail Inlet to 2-9 ft/yr along the southern segment (T24-T230) near Rich Inlet.

The SW migration of the ebb channel between October 1989 and March 1993 had a significant impact on the shoreline of HI during a relatively storm-free period. Repositioning of the channel 615 ft to the SW and a slight realignment (156^o to 162^o) of the outer bar channel segment initiated an erosion episode along much of the southern segment of HI. Erosion rates were particularly high along the oceanfront reach between T21 to T24 where retreat rates ranged from 17 to 53 ft/yr (Fig. 31 Appendix). Along the northern segment of the study area, shoreline progradation was the norm and accretion rates varied from 1 to 14 ft/yr. The exception to this pattern was the shoreline in vicinity of T 35, where minor erosion occurred at rate of 2 ft/yr. It is thought that the accretion along the northern segment of the oceanfront was related to the infilling of the tidal basin that feeds Old Topsail Inlet. Aerial photographs show that by early 1993, the inlet had narrowed considerably and the areal extent of the ebb delta was extremely limited. It is hypothesized that when the tidal prism decreased material derived from the reorganized ebb delta was transferred to the adjacent shoreline.

Hurricane Bertha that made landfall slightly west of Bald Head Island marked the beginning of a three-year period of increased storm activity in southeastern NC. The Class I hurricane caused dune recession along the length and isolated washover fan development along the length of the island. Post-storm aerial photographs also showed that a scarped dune line existed along the oceanfront along the shoreline in the study area. Figure 31 (Appendix) that depicts the shoreline change rates for the period from March 1993 to August 1996 shows a significant reversal in the shoreline change rates along the majority of the HI oceanfront where progradation rates varied from 1 to 58 ft/yr. The highest rates of accretion occurred along the reach between T21 and T24 where the rates of progradation ranged from 14 ft/yr to 58 ft/yr at T21 nearest the inlet. During the above period, the northern portion of the HI shoreline also prograded at rates that varied from 1 to 23 ft/yr. The reversal of the erosion trend is likely attributed to changes brought about by post-storm reworking of the upper part of the beach profile where sand from the eroded and scarped dunes accumulated. Along the inlet-influenced shoreline reach, the high rates of accretion may be attributed to the above scenario as well as the landward movement of swash bars during the storm's elevated water level (5.9ft).

During the following period between August 1996 and June 1998, Hurricane Fran, (September 6 , 1996) a Class III storm, made landfall near Cape Fear. As a result, the island was located in the quadrant where the storm surge (9.5 ft) had a particularly devastating impact on majority of the Hutaff Island (Fig. 31 Appendix). The elevated water level and the high waves overtopped the low-relief island causing erosion of the dunes and grasslands and as a result massive washover terraces formed along most of the island. Erosion rates varied from 51 ft in T35 along the northern segment of the study area to 6 ft/yr at T24 near Rich Inlet. The shoreline reach between T21 and T23 near the inlet was the only segment that prograded during the period. Along this short segment of the oceanfront, accretion rates varied form a minimum of 25 ft/yr to 62 ft/yr (Fig. 31 Appendix).

Two hurricanes (Bonnie [8/26/98] and Floyd [9/1699) made landfall in the area during the period from June 1998 to May 2002. Hurricane Bonnie made landfall to the northeast along Topsail Island. Storm surge associated with the Class II hurricane reached an elevation of 7.9 ft along Topsail Beach and as a result the majority of the island was overtopped that led to the development of massive washover terraces that extended well into the back barrier area. Hurricane Floyd also made landfall (9/16/99) along Topsail Island. Much of the extremely low-relief barrier was inundated by the hurricane's 8.2 ft high storm surge that led to extensive overwash that penetrated well into the tidal marsh and intertidal channels within the estuary (Fig. 25 C Appendix). The combined effects of both hurricanes led to shoreline retreat along the northern portion of the oceanfront (T28-T41) where erosion rates ranged from 5 to 35 ft/yr. Along the southern shoreline segment between T22 and T27 the shoreline prograded at rates that varied from 13 to 68 ft/yr. The only oceanfront reach along the southern shoreline segment that retreated was located in vicinity of Rich Inlet (T21) that eroded at a rate of 7 ft/yr (Fig. 31 Appendix).

Figures 20 B and 21A (Appendix) depict the washover dominated topography conditions of the Hutaff Island during the beginning of the period from May 2002 to April 2007. Hurricane Ophelia (September 15, 2005), whose western eye-wall skirted the coast in the southeastern NC, as it tracked northward, caused minor beach erosion and breaches in the re-developing dune line (Fig. 21 B Appendix). Figure 31 (Appendix) illustrates the shoreline change rates for the period between May 2002 and April 2007. Inspection of the above-mentioned figure shows that erosion was prevalent along much of the oceanfront shoreline. Erosion rates along the northern segment of the oceanfront varied from 3 to 10 ft/yr, while along the southern segment, where erosion was more severe ranged from 4 to 23 ft/yr. Shoreline progradation during this period was limited to the oceanfront segment between T28 to T33 where accretion rates varied from 3 ft/yr to 7 ft/yr.

The relatively high shoreline retreat rates along the southern oceanfront segment during the above period of time are attributed to the changes that occurred in the Rich Inlet system. Two ebb delta breaching events, the first that occurred in late 2000 (Fig. 23 C) and the second, in mid 2003 (Fig. 24 A), had a significant impact on the shoreline changes along the updrift oceanfront (Fig. 31 Appendix). As a result of the first breaching event the ebb channel was repositioned ~ 600 ft toward HI and in effect repositioned the zone of swash bar attachment farter to the NE along HI. Figures 23 D and 21 A (Appendix) depict the updift by-passed shoal segment and the landward movement of a large swash bar complex, portions of which eventually welded onto HI by mid 2003 (Fig. 24 A). As a consequence of the second ebb delta breaching episode, the ebb channel was eventually shifted toward F8I a distance of ~ 440 ft. The bar by-passing direction in this instance was downdrift (Figs. 24 and 25). Subsequent to the transport of the much of the by-passed bar segment into the estuary the inlet widened considerably.

During the period when the ebb channel shifted to the southwest and the inlet expanded, the updrift marginal flood channel expanded and impinged on the HI oceanfront near the inlet (Fig. 25). The above events initially led to high rates of progradation along HI and eventually to moderate rates of erosion. Figures 26 and 22 (Appendix) depict the erosion along the oceanfront near the inlet and the revegetation of the embryo dunes to the northeast on Hutaff Island as of January 20, 2008. For purposes of comparison, the reader is referred to Figure 26 that depicts the portions of the study on January 2002 and Figure 1 that illustrates the inlet and Huttaf Island on November 9, 2008.

Long-term oceanfront shoreline change rates

Recent studies have suggested that a minimum of 10 years of relatively continuous historic shoreline data are needed to interpret short-term trends, and a minimum of 50 years of data are needed for deciphering long-term trends (Camfield and Morang, 1996). The dataset for Figure Eight Island that covers the period from 1939 to 2007 provided only snapshots in time of the shoreline position(s) representing the cumulative effects of natural and/or anthropogenic factors influencing change. This section of the report focuses on two major aspects of oceanfront shoreline change along Figure Eight Island and Hutaff Island: long-and short-term (1938-2007 island-wide and zone-wide changes, which facilitate the determination and presentation of erosion and accretion trends. Since recent studies (Cleary, 2001 and Cleary and Jackson, 2004) have documented that Rich Inlet plays a pivotal role in shoreline change along these barriers, this section of the report also focuses on the changes (discussed elsewhere in this report) and rates of change that occurred during two periods of varying length from May 1938 to August 1996 and from August 1998 to April 2007. The two aforementioned periods were defined on the basis of the position of the ebb channel, the corresponding ebb delta shape changes and the related shoulder changes that extended along the adjacent oceanfront shorelines for a distance of 3-5,000 ft. Understanding the causes of the shoreline rate changes during the above periods of time is germane to this investigation in terms of relating the rate changes to vagaries of Rich Inlet since the mid 1990s and the proposed relocation of the ebb channel.

The results from area-wide shoreline change rate analyses were based on changes recorded along transects depicted in Figure 2. The shoreline change rates for the three periods for the entire ~ 20,000 ft long oceanfront within the area are depicted in Figure 33. The data presented in Figure 31 for the period May 1938 to April 2007 illustrate that Figure Eight Island and Hutaff Island have contrasting long-term rates of change. Inspection of the data indicate that the F8I oceanfront segment nearest the inlet (T19 and T20) eroded at rates that ranged from 1 to 3 ft/yr while the remainder of the northern shoreline zone between T10 and T18 prograded since 1938; rates ranged from 1 to 2 ft/yr. By comparison, the southern portion of the F8I oceanfront shoreline, between T1 and T9, retreated at rates that varied slightly from 0.3 to 0.21 ft/yr, and hence were recorded as zero for purposes of convenience. By contrast, the Hutaff Island shoreline eroded along its entirety (T21 to T41). Rates ranged from a maximum of 8 ft/yr for the shoreline segment in vicinity of T40 along the northern zone of HI, to a minimum rate of 2 ft/yr along the shoreline reach adjacent to Rich Inlet (T21).

The earliest period, which extended from May 1938 to August 1996, reflected an interval when the ebb channel migrated 1,056 ft to the NE. As of August 1996, the ebb channel was positioned 1,387ft northeast of its 1938 position (Figs.10 and 14 in Appendix). In addition to the repositioning of the ebb channel, the outer bar segment was deflected toward Hutaff Island along an alignment of 103^{o}, and as a consequence, the ebb-tidal delta was dramatically reconfigured. The position and shape changes resulted in the shift of the ebb delta's wave-sheltering effect away from F8I setting the stage for the current erosion episode (Fig. 21 B-C).

Data presented in Figure 33 for the period May 1938 to August 1996 (Post-Bertha/Pre-Fran) illustrate that the northern zone (T10 – T20) prograded at higher time-averaged accretion rates that ranged from 1 to 7 ft/yr. The influence of the Rich Inlet is evident when a comparison is made of the shoreline change rates for the aforementioned zone to that of the southern oceanfront (T1-T9) where the zone- wide erosion rate was 1 ft/yr. During this period the Hutaff Island oceanfront zone (T21- 30) near the inlet was characterized by net erosion. Shoreline retreat rates varied from 3 ft/yr to 6 ft/yr. The lower erosion rates (3 to 5ft/yr) recorded was for the shoreline segment adjacent to the inlet. The remainder of the HI shoreline between T24 and T41 eroded at a rate of 6 ft/yr.

During the most recent period of study from August 1996 to April 2007, the ebb channel migrated a net distance of 278 ft toward Figure Eight Island, while the alignment of the outer bar channel segment varied from 103^{o} to 190^{o} (Fig. 8). As of April 2007, the ebb channel was aligned in near shore-normal fashion and positioned 1,108 ft to the northeast of its 1938 position. The influence of the position of the ebb channel mentioned above is evident upon inspection of data presented for the period in Figure 33. During the recent period, chronic erosion was prevalent along the majority of the northern zone (T10-20) along F8I where erosion was significantly higher than the previous period (1993-1996). Erosion rates along the oceanfront shoreline between T12 to T21 varied from a minimum of 1 ft/yr in vicinity of T13 to a maximum rate of 39 ft/yr along the shoreline segment nearest the inlet (T20). The erosion rates would have been much higher if it had not been for the construction of the armoring of much of the shoreline segment between T15 and T20 and the placement of beach fill along the oceanfront. By contrast, the southern segment of the F8I oceanfront prograded slightly at rates that ranged from 1 to 6 ft/yr. The accretion along the southern zone reflected the aforementioned nourishment projects.

The shoreline rates of change data for Hutaff Island depicted on Figure 31 for the above period show that aside from the shoreline segment (T21-T25) near Rich Inlet the remainder of the southern oceanfront zone, as well as the entirety of the oceanfront along the northern zone, eroded at rates that varied from 1 to 22 ft/yr. It is interesting to note that erosion rates increased in a northeasterly direction from a minimum of 1 ft/yr in vicinity of T26 to 22 ft /yr at T41 near Old Topsail Inlet's closure zone (Fig. 33). By contrast, the adjacent HI shoreline segment to the southwest, from T21 to T25, was characterized by progradation that varied from 4 to 8ft/yr along the 2,550 ft long reach.

The positive shoreline change rates were related to the position of the ebb channel and the associated swash bar attachments located along the oceanfront protected and nourished by the ebb delta (Fig. 25). Historically, the entirety of Hutaff Island has been a chronically eroding, overwash-dominated barrier both prior to and subsequent to the closure of Old Topsail Inlet in early 1998 (McGinnis and Cleary, 2003 and Doughty et al., 2006). The oceanfront shoreline erosion is related to the complex interaction of a number of variables, including the three inlets that have impacted the barrier. The current barrier, named Hutaff Island, is actually a 3.75 mile long island composed of two former barrier segments that were joined when Old Topsail Inlet closed in early 1998 (Fig. 25). In 1938 the former Hutaff Island was ~3.1 miles long, and by late 1997 it was shortened to a length of 1.85 miles due to the migration of Old Topsail Inlet. Prior to inlet closure, Lea Island formerly located to the NE of Old Topsail Inlet was also decreasing in length as New Topsail Inlet eroded the northern portion of the barrier as it migrated to the southwest.

As of 2007, Hutaff Island was 3.6 miles long, of which the northernmost 1.1 miles of the island represents the southern portion (spit) of Lea Island. The changes in lengths of Hutaff and Lea Islands, and hence the positioning of the three inlets that have historically impacted the islands are germane to this study. The chronic erosion and the high rates of erosion are attributed to the island planform changes that occurred concomitant with migration of both New and Old Topsail Inlets from 1938 to1998 and with New Topsail Inlet during the past nine years. As closure of Old Topsail Inlet occurred, storm events augmented the inlet-induced shoreline retreat. Because Rich Inlet is currently positioned only a short distance (1,108 ft) NE of its 1938 position, its impact on the entire barrier's planform is significantly less than the two unstable inlets. It is beyond the scope of this report to provide the details of these changes since the closure zone lies outside the study area.

Green and Nixon Channel Shoreline Changes

The oceanfront along Figure Eight Island and Hutaff Island are not the only areas to experience shoreline erosion associated with the ebb channel and inlet configuration changes. The marsh and sandy shoreline segments that comprise the estuarine portion of the Rich Inlet system also have been impacted by morphologic changes in the inlet system (Figs. 34 and 35). In order to assess the role of the ebb channel changes and associated shoal changes on the interior channel margins of Green and Nixon Channel, a series of 37 transects spaced were established along a baseline paralleling portions of the estuarine shoreline (Fig. 36). Figure 36 illustrates the various shoreline positions (marsh scarp or HWL on sandy shoreline segments) between 1938 and 2007. The complex pattern of shoreline change, which generally involved retreat along this 8,000 ft long channel margin complex, is primarily due to the influx of sand into the estuary via the ebb and marginal flood channels and the subsequent transport of the material along the channel (bed forms) and its margins (Figs. 35, 36 and Fig. 33 Appendix).

The historic position and alignment of the ebb channel within the variably wide inlet and the associated width of the marginal flood channels appear to have played a significant role in the changes recorded. The reader is referred to various images in Figures 20-26 and 33 (Appendix) that depict the changes in the flood-tidal delta lobes, and their position within Green and Nixon Channels, as well as their impact on the adjacent tidal marsh. Figure 37 depicts the shoreline changes that have occurred along the external channel margins of Green and Nixon Channels for four periods between 1938 and 2007 while the net changes are illustrated by Figure 38. Inspection of Figure 37 shows that erosion was the norm along that the majority of the external (seaward) margin of the Green and Nixon Channels with the exception of the estuarine shoreline segment near the near the inlet (T11-T14) along back barrier of Hutaff Island. Shoreline erosion along the Green Channel margin ranged from 24 ft in vicinity of T14 to 106 ft at T17. In contrast the estuarine shoreline-reach between T11 and T14 prograded from a minimum of 339 ft at T14 to a maximum of 1,278 ft at T11. The average shoreline erosion for this estuarine shoreline segment was 36 ft (Fig. 39). During this interval, the entirety of the Nixon Channel seaward margin (T1-10) eroded from a minimum of 11 ft at T10 near the inlet to a maximum of 270 ft at T5 (Figs. C and D). The average shoreline change between 1938 and 1993 along the Nixon Channel seaward margin amounted to -127 ft (Fig. 39).

The subsequent period from 1993 to 1996 was an important interval in terms of the morphologic changes in the inlet system when the ebb channel shifted toward Hutaff Island 1,056 ft (Fig. 21). During this period, erosion dominated the channel margins and ranged from 8 ft to 177 ft along the Nixon Channel seaward margin. The Green Channel margin also eroded and the shoreline retreat ranged from 1 to 162 ft, minor accretion occurred along the shoreline in vicinity of T16 and T18 (10-14 ft) (Fig. 37). Shoreline change rates varied from 2.5 to 51.9 ft/yr along the Nixon Channel seaward margin, while rates of change varied from -47 ft/yr at T15 to + 4 ft/yr at T18 (Figs. 33 and 34 Appendix). The average shoreline erosion for estuarine channel margin segments ranged from 64 ft for Nixon Channel shoreline to 62 ft for the Green Channel shoreline (Fig. 34 Appendix).

During the subsequent 4.6 years (August 1996 to February 2001), the ebb channel migrated a net distance of 187 ft to the southwest. Figures 21 and 23 illustrate the general configuration of the inlet channels and shoulders during this period of time. The shoreline change along the Nixon Channel's external (seaward) margin was highly variable. Progradation was the norm along the landward segment (T1-T5); accretion ranged from 1-75 ft while erosion was dominant along the seaward segment and ranged from 5 ft to 30 ft. Erosion was also the norm, but of a greater magnitude along the entirety of the seaward margin of Green Channel. The estuarine shoreline retreat ranged from 36 ft to 329 ft (Fig. 37). Shoreline change rates for the Nixon Channel margin varied from +16 ft/yr at T4 to -52 ft/r at T10, while change rates along the Green Channel margin varied from -8 ft/yr to -72 ft/yr (Fig. 34 Appendix). During the aforementioned period of time (1996-2001), the Nixon Channel seaward margin prograded an average of 17 ft while the Green Channel shoreline along Hutaff Island by contrast eroded an average of 132 ft (Fig. 35 Appendix).

An examination of Figures 37-39 shows that between 2001 and 2007, shoreline retreat was prevalent along the entirety of both Nixon and Green Channel's seaward margin. The estuarine shoreline along Nixon Channel eroded from a minimum of 2 ft in vicinity of T10 to a maximum of 156 ft at T9 near the inlet (Fig. 37). The average erosion along Nixon Channel shoreline amounted to 74 ft. The Huttaf Island estuarine shoreline along Green Channel eroded a minimum of 10 ft at T18 along its landward portion to a maximum of 272 ft nearer the inlet along the former accretion zone. The average shoreline loss was 104 ft (Fig. 35 Appendix). Shoreline erosion rates varied considerably along both of the channel's margins, and ranged from less than 1 ft/yr at T10 (Nixon Channel) to 45 ft/yr at T13 (Green Channel) along the Hutaff Island shoreline near the inlet (Fig. 34 Appendix).

Inspection of Figures 37-39 clearly shows that the only estuarine shoreline reach that prograded during the period of study (1938-2007) was located along the Green Channel margin adjacent to the inlet. The reach between T11 and T13 that accreted between 385 ft and 952 ft reflects the historic re-development of the Hutaff Island spit complex that occurred several times since 1938 (Figs. 16 and 41 Appendix). The most recent episode of spit re-development occurred in the mid 1990s (Fig. 36 Appendix). It was difficult to determine from the available data if the increased rates of erosion along the seaward margins of Nixon and Green Channels are solely related to the dramatic repositioning of the ebb channel in the period from 1993 to 1996. Figure 36 (Appendix), that depicts the time averaged erosion rates for the periods 5/17/38 - 3/6/93 and 3/6/93 - 4/1/07, shows that the erosion rates were generally higher for the Nixon Channel seaward margin, particularly along the segment near the inlet (T7 - T10) where average erosion rates were as high as 18 ft/yr. The erosion along the majority of the Green Channel margin was significantly greater, particularly near the inlet where erosion rate reached a maximum of 44 ft/yr (Fig. 36 Appendix). The minimum erosion rate of 3 ft/yr was recorded along the landward segment of the channel (T17-T18).

The above-mentioned increased erosion along the Nixon Channel T7 - T9 shoreline segment (Fig. 37 and Fig. 32 Appendix) has led to the development of a high hazard zone where shoreline retreat has become a serious management issue. Figures 18 A-B, 19 B and Figure 41 (Appendix) illustrate the condition of the estuarine shoreline and adjacent uplands in the area. The presence of a series of shrub thickets in the early

1980s attests to the historic stability of the upland area prior to 1980. Figure 14 (Appendix) that depicts the cumulative migration of the ebb channel shows that the channel shifted 1,516 ft to the NE by September 1999 (Fig. 21). Further movement of the ebb channel to the NE in 1999, coupled with the change in the orientation of the outer bar channel, promoted the development of an expansive flood channel on the Figure Eight Island shoulder (Fig. 23 A). By 2001, the rapid elongation of a spit (Fig. 23 C) within the inlet throat led to the constriction of the inlet (1,889 ft [1993] to 1,200 ft [2001]). As the spit elongated, sand from the landward migrating swash bars was transported landward within the narrowing flood channel and eventually into the estuary forming extensive flood-tidal delta lobes that clogged portions of Nixon Channel (Fig. 23 C). Many lobate sand bodies formed and migrated through the interior channel system.

A significant amount of sediment within the sand lobes that comprised the flood-tidal delta continued to be reworked by the ebb and flood currents and eventually transported southwestward along Nixon Channel and eventually into the AIWW. At a distance of ~ 1,600 - 2,400ft southwest of the inlet throat, the landward migrating sand bodies frequently shoaled portions of Nixon Channel. Periodically, the migrating sandy bed forms prompted the thalweg, located on the southeast margin of the channel, to encroach on the Figure Eight Island estuarine shoreline. As a consequence of this shoaling, the shoreline along the developed portion of the island eroded (Figs. 41, 42 and Fig. 38 Appendix).

Figure 43 illustrates the changes that have occurred along the estuarine shoreline between T7 and T10 for four periods since 1938. During the period (1938-1993) prior to the development of this portion of Figure Eight Island shoreline erosion occurred and ranged from 48 ft (T8) to 145 ft (T9). Erosion rates during the period from 1938 to1993 were relatively low and ranged from ~1.0 ft/yr at T8 to 2.6 ft/yr at T9 (Fig. 43 C). During the subsequent period from March 1993 to August 1996, shoreline retreat continued ranging from 58 ft to 61 ft. During this 3.4 year period, erosion rates increased substantially to 17 ft/yr at T8 and to 18.0 ft/yr at T9. During the period of inlet constriction (1996-2001), the shoreline in vicinity of T8 prograded 11 ft, while the adjacent shoreline segment near T9 eroded 30 ft. Rates of shoreline change varied from 2.5 ft/yr at T8 to -7 ft/yr at T9. Figure 43 B shows that by February 2001, the cumulative erosion along this reach varied from 99 ft (T8) to 236 ft (T9).

Following the ebb delta breaching event in December 2000, the inlet widened from 1,187 ft (2002) to 2,511 ft (2007). During the period from February 2001 to April 2007, the F8I spit has continued to erode as the inlet expanded. Figure 38 depicts the eroded spit and the encroachment of the HWL upon the structures along the shoreline. As of April 2007, the ebb channel was positioned ~ 70 ft to the southwest of its February 2001 location and 1,109 ft northeast of its May 1938 position (Fig. 14 Appendix). As a consequence of the concurrent expansion of the flood channel on the F8I margin, sandy bed forms enter the estuary across a wide corridor (Figs. 24 C-D, 25, 34A and 35 A). Figures 26 and Fig. 32 Appendix) depict the configuration of the inlet as of January 20, 2008.

Although conjectural, it appears that the position of the ebb channel, has caused the location of the sand lobes to shift northward in the estuary within Nixon Channel and along the interior marsh shoreline (Fig. 25). In general and as a consequence, the channel thalweg and flow have been directed toward the seaward margin of Nixon Channel resulting in continued erosion of the developed segment of the estuarine shoreline (Fig. 32 and 38 Appendix). Erosion along this reach during the period from 2001 to 2007 ranged from 53 ft to 156 ft, while erosion rates have varied from 9 ft/yr at T8 to 25 ft/yr at T9. Figures 43 D, 44 and Figure 39 (Appendix) depict the retreating shoreline and the exposure of a large peat bed along portions of the channel margin. Since 1938, the cumulative land loss along this reach, between T8 and T9, ranged from 147 to 392 ft (Fig. 43 B). Erosion in this area is likely to continue for a period of time if the ebb channel remains in its current location. However, if the developing estuarine spit (Figs. 1 and 26) elongates landward along the channel's seaward margin progradation may occur if and when the thalweg is shifted toward the center of the channel.

Figure 45 depicts the net shoreline changes that occurred during various periods between 1938 and 2007, while Figure 46 illustrates the cumulative changes along the Nixon and Green Channel interior (landward) margins (Fig. 36). Inspection of the above figures clearly shows that during the period from 1938 to 1996 erosion was prevalent along much of the interior margin of the channels with the exception of the shoreline segments near the area where the channels bifurcate (Figs. 36 and 45). Between the zones of progradation (T19 to T21- T37), erosion ranged from a minimum of 15 ft (T32) to a maximum of 182 ft (T31). The time averaged erosion rates ranged ~ 1 ft/yr to ~ 3 ft/yr (Fig 37 Appendix). Progradation of the Nixon Channel interior margin (T19-21) ranged from 34 ft to 188 ft while the Green Channel margin in vicinity of T37 prograded 62 ft. During the following period (1993-1996) that was marked by a dramatic shift of the ebb channel toward Huttaf Island, the shoreline changes along interior shoreline were highly variable. Accretion occurred in vicinity of five widely-spaced transect locations (Fig. 45) and in part likely reflects the influence of Hurricane Bertha's elevated water level and increased wave swash that overtopped the adjacent marsh, particularly immediately landward of the inlet throat. Erosion during this period ranged from 5 ft to 105 ft. Shoreline change rates were generally greater along the Green Channel margin where accretion rates amounted to ~14 ft/yr while erosion rates were as high as ~31 ft/yr (Fig. 37 Appendix).

During the subsequent period from 1996 to 2001, shoreline progradation was prevalent along the Nixon Channel interior channel margin and ranged from 4 ft to 57 ft. The greatest amount of shoreline accretion occurred along the Green Channel margin in between T35 and T37 where as much as 262 ft of shoreline progradation occurred (Fig. 45). Accretion rates varied along the entire interior channel margin from a minimum of 1 ft/yr to a maximum of ~58 ft/yr. The rapid buildup and erosion of the shoreline was likely attributed to storm-induced changes related to Hurricanes Fran (9/96) Bonnie (8/98) and Floyd (9/99) that reworked the bed forms that were located within the channels and attached to the channel margins.

The distribution of the sand bodies within the interior channels and along their margins has changed considerably since 2001 (Figs. 1, 23 C, 24 B-D, 25 and 26).

Inspection of the aerial photographs depicted in the aforementioned figures indicates that the position and alignment of the ebb channel and the associated flood ramp location plays a critical role in distribution of the bed forms and the erosion and accretion that occurred along the interior margins. Figures 25, 26 and Figure 32 (Appendix) depict the recent evolution of the large sand body along the Nixon Channel interior margin, as well as the flushing and deepening of the small channel adjacent to the Green Channel interior margin. Since 2001, erosion that ranged from 10 to 29 ft has occurred along a major portion of the interior margin of Nixon Channel segment between T22 and T27. Shoreline retreat ranged from 10 ft to 29 ft. Slightly landward along the channel margin accretion has occurred that ranged from 21ft to 82 ft (Fig. 45). In contrast to the variable shoreline changes in Nixon Channel, the Green Channel interior margin has eroded along its entirety due to the flushing of the channel adjacent to the landward bank (Figs. 1, 26 and 36). As a consequence of the above scenario, shoreline retreat along the interior margin ranged from 20 ft to 213 ft near the bifurcation of Green Channel (Fig. 45) at rates ranging from ~ 1 ft/yr to ~35 ft/yr (Fig. 37 Appendix).

The positions of the shorelines depicted in Figure 36 show that the largest amount of net accretion along the interior margins of Nixon and Green Channels occurred where the feeder channels narrow and eventually bifurcate. The greatest amount of progradation occurred along the Nixon Channel margin where net shoreline accretion ranged from 9 ft to 207 ft (T19-22). Figure 41 shows that the Nixon Channel shoreline segment between T19 and T21 is the reach where net progradation has occurred during the periods from 1938 to 1993 and from 1993 to 2007. Inspection of Figure 40 (Appendix) shows that the majority of the remaining shoreline segments eroded during both periods. The only shoreline segment that has continuously accreted since 1938 is located in vicinity of T21 is (Fig. 46).

The only interior margin segment within Green Channel where net accretion (67 ft) occurred was the short reach near T 37. The maximum accretion for the T37 shoreline segment as well as adjacent segment (T36) occurred in 2001 when the progradation varied from 83 to 280 ft. Figure 47, which illustrates the net shoreline changes along the interior channel margin shows that the remainder of the interior margin eroded from a minimum of 37 ft at T36 (Green Channel) to a maximum of 313 ft at T31 located landward of the current position of the ebb channel (Figs.1 and 26). Figure 41 depicts the time averaged erosion rates for the periods 5/17/38-3/6/93 and 3/6/93 - 4/1/07. The higher shoreline change rates for the period between 1993 and 2001 may reflect the difference in length of time that comprises the two periods. More likely the increased rates are related to the migration of the ebb channel to the NE and the consequent repositioning of the flood ramp where the divergence of the flood flow occurs. Since the current position of the channel is close to its most northeasterly location since 1938 it seems reasonable to assign a more significant indirect role to the migration of the ebb channel as the variable that triggers the erosion. Inspection of the data indicated that the highest erosion rates were recorded for the segment of the Green Channel margin (T31-T35) immediately north of the flood ramp position (Figs. 45 and 47).

The impact of ebb-tidal delta changes on the oceanfront shorelines

The shape of the ebb delta and its seaward boundary was interpreted from aerial photographs (1938-2007) on the basis of the location of the outer zone of waves breaking on the seaward perimeter of the ebb-tidal delta platform. Noting the “point” where the breaking waves become essentially parallel to the adjacent oceanfront shorelines identified the landward limit of the ebb-tidal delta. This exercise provided information on the changes in the size and shape of the ebb-tidal delta related to the migration, deflection and repositioning of the ebb channel as a result of breaching events. The location of the apex of the ebb delta generally coincides with the “point” where the ebb channel crosses the periphery of the ebb-tidal delta. Figure 48 illustrates this concept and depicts the ebb channel position, orientation and the general shape of the ebb-tidal for representative years. Deflection of the ebb channel since 1938 has caused a shift in the position of the apex and shape change of the ebb tidal delta across a variably wide zone. Although the throat segment of the ebb channel has shifted within a 1,550 ft wide migration pathway (Figs. 9,14 and 48), the outer bar channel segment has been re-positioned continuously along a 6,000 ft wide zone that straddles the inlet (Fig. 9). As changes in the position of the occurred, the entire offshore shoal complex was continuously being reconfigured along with the adjacent barrier shorelines as they responded to the changes in wave approach and sand supply.

Inspection of historic aerial photographs dating from 1938 to 2007 illustrates that the size (surface area), position and shape of the ebb-tidal delta have changed considerably since 1938 (Figs. 43 and 44). Figures 49 and 45 (Appendix), which illustrate the changes in the apparent surface area of the ebb delta since 1938, show that the surface area of the ebb-tidal delta ranged from a maximum of ~13.7 million ft^2 (3,380 Ac) in August 1959 to a minimum of 7.0 million ft^2 (1,737 Ac) in September 1984. The average surface area of the ebb-tidal delta since 1938 was 10.2 million ft^2. The wide range of values may reflect slight errors involved in the methodology, but the data do provide a means of assessing the relationship of ebb delta shape changes, the evolution of the inlet morphology and oceanfront shoreline changes.

In addition to significant changes in the total area of the ebb delta there were also substantial area gains and losses of the northern and southern segments of the ebb delta (Fig. 49). The apparent surface area of the northern ebb delta segment (HI) varied fro a minimum of 1.3 M ft^2 in February 1998 to a maximum surface area of 6.6 M ft^2 in March 1993. The average area of the northern segment between 1938 and 2007 was 4.5 M ft^2 compared to 5.7 M ft^2 for the southern segment (Fig. 49). The surface area of the shoal segment south of the ebb channel during the above period varied from 3.6 M ft^2 to 8.3 M ft^2. During the majority of the time between 1938 and 1993, the area of the southern segment (F8I) was generally larger. The surface area ranged from 4.5 M ft^2 in December 1974 to 8.3 M ft^2 in August 1959 while the average surface area during the period was 6.0 M ft^2. Since 1993, when the ebb channel shifted a maximum distance of 1,217 ft to the northeast, the area of the southern segment ranged from 3.6 M ft^2 in March 2003 to 8.3 M ft^2 in August 1996, following an ebb delta breaching event. The average size of the southern segment that had shifted northward and away from Figure Eight Island was 5.3 M ft^2.

Figures 49 and Figure 45 and 46 (appendix) illustrate the impacts of the major ebb delta breaching events on the apparent surface areas of the northern and southern bar segments. The four major breaching events that were recognized: late 1975 (Figs. 43 C, 44 C [Appendix], 21 B-C, and 24 A). The resulting segment gains or losses were a function of the direction of bar-bypassing in each of the above events. The December 1975 event realigned the ebb channel from a SSE orientation to ESE alignment resulting in downdrift by-passing of the bar segment toward F8I. As a consequence, the southern segment of the ebb delta enlarged from 4.5 M ft^2 to 6.9 M ft^2 while the northern segment decreased in apparent size from 5.3 M ft^2 to 1.8 M ft^2 (Fig. 49). A similar event occurred in early-mid 1994 (Fig. 11 Appendix) that culminated in a 1,056 ft northeasterly shift of the ebb channel (Figs. 45 and 46) and a significant increase in the size of the southern segment that amounted to 2.3 M ft^2 of additional area. In contrast, due to the realignment of the ebb channel, the northern segment lost 4.6 M ft^2 and as a result its total area decreased to 1.4 M ft^2.

Two additional but smaller scale events occurred in late 2000 and mid 2003. The late 2000 ebb delta breaching episode realigned the ebb channel from ~85^o to ~120^o and thereby bypassed the segmented bar updrift (north of the newly aligned ebb channel). Figure 23 B-D depicts the pre- and post-breaching event configurations of the ebb delta. The addition of the by-passed material increased the apparent surface area of the northern segment fronting Hutaff Island from 1.3 M ft^2 to 5.7 M ft^2 while the area of the southern segment decreased in size from 6.1 M ft^2 to 3.7 M ft^2 (Fig. 49). The most recent breaching event occurred in mid 2003 at a time when the ebb channel was highly skewed toward F8I (Fig. 24 B and 43 D[Appendix]). The breaching site and the new position of the ebb channel were located ~2450 ft to the northeast (Fig. 9). The deflected outer bar segment of the ebb channel was realigned from 190^o to ~135^o and as consequence of the reorientation, downdrift bar by-passing occurred. The transfer of material southward increased the area of the southern segment from 3.6 M ft^2 to 5.2 M ft^2.

Inspection of the images depicted in Figs. 23-26 shows that since 1996, regardless of the size of the ebb delta's southern segment, it provided little or no protection for the

Figure Eight Island oceanfront along the former accretion zone (T11-T20) because the great majority of the southern bar segment fronted the flood channel within the inlet and periodically the F8I spit. Only during the transition period between (early 1995 and early 1997) when the entire ebb delta was reconfiguring, did the southern shoal segment provide any natural nourishment via swash bar attachment along F8I. Subsequent to the complete reorganization of the ebb delta and the consequent removal of the wave sheltering effect, shoreline erosion has been commonplace along the F8I oceanfront. The natural lag in the timing of the chronic erosion was augmented by the previously mentioned nourishment projects.

The apparent surface area changes of the ebb delta cannot be correlated with the cumulative ebb channel changes although the average size of the outer bar and its segments are smaller since 1993 when the ebb channel dramatically shifted to the northeast. During the period from 1938 to 1993, the average size of the ebb delta was ~ 10.9 M ft^2 and since 1993 the average size has decreased to ~ 8.7 M ft^2. During the above period, the ebb channel migrated within a 715 ft wide zone within the inlet while the ebb delta apex (defined by the "point" where the ebb channel crosses the outer bar periphery) shifted across a 3,615 ft wide front (Figs 9 and 50). The reader must recall that the position of the apex is primarily controlled by the alignment of the outer bar channel segment as well as the throat position of the ebb channel. Inspection of Figure 50 shows for example that as of December 1974 the ebb channel's position was nearly approximately the same as the 1938 ebb channel position (Fig. 9) but the apex was located 2,120 ft to the southwest of the location of the apex in 1938. The rapid changes in the position of the apex are usually due to deflection but on occasion ebb delta breaching dramatically reorients the ebb channel. The southwesterly movement of the apex from 1956 to 1974 was due to defection while the rapid shift in the apex position between 1993 and 1996 was related to a channel relocation associated with a breaching event.

Figure 50 illustrates that progradation along the Figure Eight Island oceanfront between T11 and T20 continued beyond 1993 when the apex and ebb channel dramatically shifted to the northeast. The maximum shoreline progradation (300 ft) along F8I was attained in June 1998. The continued shoreline accretion that occurred during the previously mentioned transition period was related to the reconfiguration of the entire ebb delta, particularly the southern segment offshore F8I. How much of the shoreline progradation is due the post-storm nourishment activities between 1993 and 1998 is unknown. Since 1998 when the channel and the apex of the ebb delta shifted to the southwest, erosion has been the norm despite additional nourishment projects.

The northward shift of the ebb channel and the reconfiguration of the ebb delta since 1993 have promoted minor accretion along the Hutaff Island oceanfront (T21`-30) that slightly altered the long-term cumulative shoreline erosion (Figs. 56 and 47 [Appendix]). The period and cumulative shoreline changes for the oceanfront segment between T21 and T30 are depicted by Figs. 27 and 29. Inspection of the data presented for the three periods between 1993 and 2007 illustrate that majority of the shoreline segment between T21 and T25 prograded significantly particularly during the period from 1998-2002, when the oceanfront progradation ranged from 50ft to 247 ft. The beginning of the above period marked the time when the ebb channel and the apex of the ebb delta reached their northeastern most positions. Inspection of the various shoreline change data for the HI oceanfront near the inlet indicates that the direct influence of the inlet is limited to a maximum shoreline length of 3,500 ft extending between T21-T6. In comparison, the data (Figs. 14, 15, 51 and Fig. 47 [Appendix]) clearly indicate that the inlet-influenced zone along the F8I oceanfront extends ~ 5000 ft southwest of the inlet (~T10 - T20).

Figure 48 (Appendix) depicts the cumulative shoreline changes for the entire study area shoreline between T1 on F8I and T41 on HI. Inspection of the data presented for the period from 1938 to 2007 shows dramatic differences in the shoreline changes along the barriers adjacent to Rich Inlet. The data presented also clearly illustrates the historic positive influence on the shoreline zone that extends between T10 and T18 where cumulative shoreline changes range from a minimum accretion of 22 ft in vicinity of T10 to a maximum progradation of 143 ft at T14. The shoreline buildup within this zone is directly related to the ebb channel's position between 1938 and 1993 and the fluctuating position of the ebb delta's apex across the 3,615 ft offshore front. The ebb tidal delta for a period of ~ 55 years provided the oceanfront a variable breakwater effect and concurrently facilitated the periodic nourishment of the shoreline during swash bar attachment episodes.

Impact of Channel Relocation

The overall goal of this study was to develop an understanding of the relationship between the inlet's temporal and spatial morphologic changes and the changes that occurred along the adjacent oceanfront and interior shorelines since 1938. A secondary goal was to then utilize this understanding to better predict the response of the Figure Eight and Hutaff Island oceanfront and interior shorelines to the proposed channel relocation effort. The detailed analysis of the historic changes that have taken place since 1938, clearly show that the movement of the inlet's ebb channel and the attendant ebb-tidal delta position and shape changes are the primary factors that dictate the erosion and accretion trends along the inlet and oceanfront shorelines of both barriers. The historic progradation of a portion of the Figure Eight Island oceanfront (T11-T20) as well as the current chronic erosion episode are directly related to the migration and deflection/reorientation of the ebb channel.

During the past 70 years, the inlet has shifted within a 1,550 ft wide migration zone and as the inlet moved along its migration corridor, the repositioning and realignment of the ebb channel promoted several major periods of oceanfront and inlet shoreline erosion (Fig.14). Since development began along the northern end of the island in the late 1970s, there have been two distinct erosion episodes. The first and relatively short-lived episode that occurred in the early 1980s involved erosion of the inlet shoreline as well as a portion of the oceanfront nearest the inlet. The second and more severe episode that began in the late 1990s continues to date and involves the entirety of the northern oceanfront.

Figure 52 depicts various historic shoreline positions since 1938 within the Inlet Hazard Area along Figure Eight Island. When development of the northern end (T15-T19) of the island began in the late 1970s, the IHA shoreline had naturally prograded to one of its most seaward positions (Fig. 52). Figure 10 A-F (Appendix) shows that the developed area was characterized by a series of well developed and vegetated dune ridges and a relatively wide recreational beach. Development in this area (T15 -19) established a fixed construction line within a shoreline zone with a high hazard potential. Since the mid 1970s, the shoreline has been in a state of flux (Fig. 14 and Fig. 10 [Appendix]) and as a result has retreated periodically toward the construction line that is nearly coincident with the 1938 shoreline position.

During the subsequent two decades (1974 to 1998), shoreline recession along the zone between T11 and T17 was mitigated by both natural and anthropogenic means (nourishment). However, since 1998 the chronic oceanfront erosion could not be mitigated either by nourishment, that was extremely short-lived, or by natural nourishment derived from swash bar attachment. Since 1974, the shoreline reach between T13 and T20 has retreated landward from a minimum of 81 ft in vicinity of T14 to a maximum of 368 ft at T18 (Fig. 49 Appendix). Erosion along the reach since 1974 has averaged 218 ft and has exceeded 50 % of the 36.6 year net progradation that occurred along the reach between 1938 and 1980. The 2007 HWL position has encroached on the late 1970s building line and near the northern end of the oceanfront is positioned landward of the 1938 shoreline position (Fig. 52). As the planform of the former accretion zone continues to change, the HWL will continue to retreat landward beyond the 1938 shoreline position. Without question, shoreline retreat is inevitable unless the ebb channel is relocated naturally or otherwise.

The position and alignment of the ebb channel have controlled the symmetry of the ebb-tidal delta and its apex. The changes in the shape of the ebb-tidal delta and in the position of its apex (seaward protrusion) since 1938 are depicted in Figure 48. Changes in the position of the apex above are a function of the complex interplay of ebb channel (inlet) migration and the deflection of the outer ebb channel. Storms are also thought to contribute to the observed changes in the shape of the ebb-tidal delta. Regardless of the mechanism, the position and shape of the ebb-tidal delta played a major role in controlling the manner in which waves impact the F8I oceanfront shoreline in the immediate vicinity of the inlet.

During the period from 1938 to the mid 1990s, the configuration of the inlet and its offshore shoals promoted long-term progradation of the F8I oceanfront; however, since 1996 the position and shape of the ebb-tidal delta have dictated chronic erosion. The zone of maximum erosion along the oceanfront shorelines has generally shifted eastward through time as the ebb channel has migrated to the northeast. The northeasterly shift of the channel has not only dictated the shape of the offshore shoals that afford protection for northern end of the island, but simultaneously has controlled the location where large swash bar complexes attach to the F8I shoreline. A repositioning of the ebb channel toward Figure Eight Island will eventually lead to a repositioning of the ebb delta to the southwest. The consequences of this change will reverse the erosion trend that has characterized the oceanfront since the late 1990s.

Any future modification of the inlet should consider the ebb channel's optimum position, alignment and the consequent ebb-tidal delta symmetry and related potential shoreline changes. The most felicitous ebb channel position and alignment for shoreline accretion on Figure Eight Island is a configuration where the ebb channel is shore normal and is positioned along the southern portion of its migration pathway, ~ 1,300 ft -1,500 ft southwest of its 2007 position (Figs. 1, 9 and 48). If and when the ebb channel attains the aforementioned position, the ebb-tidal delta will begin to reconfigure and thereby cause a southwesterly shift in large volumes of sand and in the wave-sheltering effects of the offshore shoal complex. It must be understood that it is likely there will be a lag effect in terms of the movement of the ebb delta and the timing of the positive impacts along the oceanfront. The lag is primarily due to the time needed for the remobilization of the enormous volume of sediment retained in the ebb-tidal delta that currently lies northeast of the erosion hot-spot.

The proposed channel relocation effort would mimic natural historic ebb delta breaching events previously described; a minimum of four major events have occurred since 1938. The data coupled with an inspection of historic aerial photographs suggests there is a felicitous inlet (ebb channel) configuration that provides mutual benefits, although of a disproportionate nature, for both shoulders and oceanfront shoreline segments that flank the inlet. The proposed channel relocation site falls within this optimum zone (Fig. 53), and its throat position is similar to that of the 1993 ebb channel while the alignment of the outer bar channel segment is nearly shore-normal (~145^{o}). Relocation of the ebb channel to this location will alter the sediment transport patterns dramatically on both margins of the floodway and shoulders and ultimately result in the significant reconfiguration of the ebb tidal delta. After an initial period of adjustment, the apex of the ebb delta is predicted to shift ~1,200 ft in a southwestward direction.

The channel relocation will reduce the areal extent of the southern segment of the ebb delta, while gradually increasing the size of reconfigured northern ebb shoal segment. The reconfiguration of the ebb delta that fronts a portion of Hutaff Island and the inlet's floodway, will eventually lead to infilling and abandonment of the existing ebb channel along the northeastern margin of the inlet. The abandonment of the old channel will be greatly enhanced by construction of the proposed dike across the channel. The cessation of ebb tidal flow within the channel would accelerate the reconfiguration of the fronting ebb delta segment. The relatively rapid landward transport of the materials comprising the abandoned shoal segment would augment the littoral transport and eventually promote spit growth within the flood channel on the HI shoulder as infilling of the seaward portion of the former ebb channel occurs. It is estimated that the new position of the ebb channel in effect will promote the lengthening of HI by as much as 1,500 ft thru spit elongation.

Figure 53 illustrates the respective historic positions of the ebb channel, both within the throat and across the outer barb and the optimum channel relocation corridor. Based upon the centerline position of the relocation corridor, it is estimated that the apex of the ebb delta will be positioned ~ 350 ft northeast of the point where the 1989 ebb channel intersects the seaward margin of corridor's polygon and ~1,200 southwest of the 2007 position of the apex. Given sufficient time, the oceanfront shoreline along Hutaff Island will erode and recede to a position that is approximated by a line located between the 1989 and 1993 shorelines depicted on Figure 55. The amount of erosion is predicted to range from 35ft along the shoreline between T25 and T27 to ~ 260 ft along the shoreline reach in vicinity of T21 nearest the inlet. Shoreline progradation will occur along the southwesterly extending spit and is estimated to range from 500 ft to 800 ft.

The southwestward repositioning of the ebb channel and the associated reconfiguration of the ebb-tidal delta will have the opposite effect on the Figure Eight Island shoulder. The movement of the ebb delta's apex farther to the southwest will likely lead to a seaward movement of the ebb delta's smaller, southern segment's outer margin (zone of breaking waves). This seaward extension of the swash platform will have a positive influence on the adjacent Figure Eight Island oceanfront by altering the wave refraction patterns and ultimately leading to a reversal of the historic shoreline change trend. It is anticipated that oceanfront shoreline progradation will range from ~35 ft along the oceanfront in vicinity of T10 to as much as 480 ft along the northeastern extremity of the shoreline near T20 (Fig. 52).

It is likely that if the newly reconfigured flood channel of the F8I margin expands, there will be inlet shoreline erosion as the channel system evolves. The new position of the ebb channel and the configuration of the floodway will promote progradation along the Nixon Channel seaward margin, as the recurved estuarine spit elongates westward along the external shoreline.

Summary

The primary focus of this investigation was to develop a predictive relationship between bar channel location and orientation and the response of the oceanfront shorelines on Figure Eight and Hutaff Islands. Chronic erosion along the northern end of the Figure Eight Island is a result of a number of inlet-related variables that act in concert to produce the complex shoreline change patterns. In an effort to support the restoration of the eroding oceanfront shoreline, and to provide a long-term solution to inlet-related erosion, the F8BHOA has contracted with CPE of NC to finalize the design of a recommended project for relocation of the ebb channel.

The morphology of the northern segment of the island, as imaged on historic aerial photographs and maps, suggests that the accretionary wedge, located downdrift of Rich Inlet, began to develop in the late nineteenth century with the closure of Nixon Inlet. The forested dune ridges along the north central portion of the island represent the remnants of the accretionary wedge related to former Nixon Inlet. The subsequent evolution of the accretion zone since the late nineteenth century was related to the historic relative stability of Rich Inlet until 1993. The periodic erosion/accretion episodes that occurred were related to the ebb delta shape changes that were ultimately dictated by the inter-relationships between the position and alignment of the ebb channel and the associated adjustments in the marginal flood channels.

Although the oceanfront along the northern portion of Figure Eight Island has experienced several periods of erosion since 1938, net progradation has characterized the past seven decades of oceanfront shoreline change (Fig. 31). Between 1938 and 2007 the shoreline within the Inlet Hazard Area, between T10 and T 20, prograded an average of 70 ft (Fig. 32). The great majority of the natural oceanfront progradation occurred periodically between 1938 and 1996, when the ebb channel was positioned within ~715 ft of its 1938 position (Fig. 14 Appendix). The coast-wise extent of the shoreline buildup varied and depended upon the proximity of the ebb channel, its alignment and the location of the zone of swash bar attachment. Between 1938 and 1996, the shoreline segment between T10 and T 20 prograded an average of 239 ft (Fig. 32). Subsequent to the ebb delta breaching event in 1994, which repositioned the ebb channel 1,056 ft to the northeast, the ebb delta and the F8I oceanfront entered a transition period when the system was adjusting to the new position and alignment of the channel. The reconfiguration of the ebb delta that was likely completed by late 1998 marked the onset of major island planform changes and the chronic erosion that currently exists along the

Figure Eight Island oceanfront between T11 and T20. Since 1996, the net oceanfront change along the shoreline segment between T11 and T20, ranged from 5 ft to 414 ft. The zone-wide oceanfront erosion for the period averaged 169 ft (Fig. 32).

Marked differences are evident when one compares the Figure Eight Island and Hutaff Island shoreline change trends for the above-mentioned periods. Oceanfront shoreline erosion has been the norm both in a temporal and spatial sense. Oceanfront progradation only occurred along a 2,000 long segment, between T21 and 25, during the period from 1996 to 2007, when the ebb channel was positioned close to Huttaf Island. During the above period, shoreline accretion ranged from 46 ft to 85 ft and averaged 11 ft for the oceanfront zone between T21 and T30 (Figs. 31 and 32).

Inspection of historic aerial photographs and observations made during frequent overflights of the estuary since 1972 shows that changes within and along the interior channels that feed Rich Inlet are highly variable. During the past seven decades, net erosion along the seaward margin of Nixon Channel has ranged from 134 ft to 392 ft and averaged 248 ft while most of the seaward margin of Green Channel (T11 - T18) has eroded from a minimum of 139 ft to a maximum of 306 ft. Only the shoreline segment between T11 and T13 has prograded during the period from 1938 to 2007. Progradation for the short shoreline segment near the inlet averaged 743 ft in comparison to the net erosion along the remainder of the Green Channel margin that averaged 196 ft. The maximum accretion along the Green Channel shoreline occurred during the period from 1938 to 1996 when the shoreline segment between T11 and T14 prograded an average of 972 ft (Fig. 37). The shoreline buildup occurred during a period when the ebb channel was positioned in excess of a 1,000 ft to the southwest. By comparison, only the more landward segment (T1 - T5) along the Nixon Channel seaward margin prograded an average of 44 ft during the period from 1996 to 2001. During all other periods, the channel margin eroded. The shoreline changes in vicinity of the Nixon Channel erosion hot-spot (T7-T9) accelerated rapidly during the combined period from1993 to 2007 when the erosion increased to 1.7 to 2.1 times greater than 1938-1996 shoreline losses (48 ft - 145 ft) in the short span of 14.1 years (Fig. 43).

Along the landward margin of the Nixon and Green Channels, net progradation occurred at only 13 % of the 37 shoreline segments located along the interior margin. The greatest amount of accretion occurred along the Nixon Channel shoreline between T 19 and T22 where progradation averaged 141 ft and ranged from 9 ft to 207 ft. Only the shoreline in vicinity of T37 in Green Channel accreted (67 ft). The remainder of the channel margin (T 23 to T36) eroded an average of 124 ft; shoreline retreat ranged from 37 ft to 313 ft.

A variety of concerns have been raised about the impacts of the proposed relocation of the ebb channel. Concerns focus on the impacts the channel relocation effort will have on the Hutaff Island oceanfront shoreline and the interior channels, particularly Green Channel. Relocation of the ebb channel to its optimum position of 1,400 ft to the southwest of its 2007 position, will alter the sediment transport patterns and lead to a reconfiguration of the ebb-tidal delta. The consequences will involve a 1,200ft southwestward shift of the apex of the ebb delta and a repositioning of the marginal flood channels. Given sufficient time, the oceanfront along Hutaff Island will erode (80-260 ft) ft) to a position that is approximated by the position of a line located between the 1989 and 1993 shorelines (Fig. 54). Inlet-induced erosion will be restricted to 3,500 ft zone near the inlet. The construction of the elevated sand dike within the existing ebb channel will divert the flow to the relocated ebb channel and at the same time enhance the development of a southwesterly elongating spit. Concomitant with the readjustment of the flood channel and oceanfront recession, Hutaff Island will lengthen as the recurved spit extends into the estuary and Green Channel. The spit with time will assume the shape and curvature similar to the existing feature (Fig. 1). Nixon Channel's seaward (external) shoreline will likely prograde near the inlet as flood-tidal currents transport sand along the margin.

The southwestward repositioning of the ebb channel will have a contrasting impact on the Figure Eight Island oceanfront. The shift of the ebb delta to the southwest will have a positive influence on the adjacent Figure Eight Island shoreline within the

IHA. It is anticipated that progradation on F8I will be substantial (45 - 480 ft) along a segment from T10 to T20 and beyond to the southern portion of the existing spit. It is difficult to predict if shoreline recession will continue along the Nixon Channel erosion hot-spot. It is likely, although not a certainty, that as the flood channel along the F8I margin adjusts to the new position of the ebb channel, the recurving spit will continue to extend toward and the along the seaward (external) margin of Nixon Channel. Should this scenario unfold, the extending spit will envelop the chronic erosion zone and thereby increase the potential for additional progradation.

It is important to understand that there will be a lag effect in terms of the movement of the ebb delta and the timing of the impacts along the oceanfront shorelines. The response lag is primarily due to the time needed for the remobilization of the enormous volume of sediment retained in the ebb-tidal delta. The eventual reconfiguration and repositioning of the ebb-tidal delta will shift the outer bar's wave-sheltering effect and the zone of swash bar attachment to the southwest. Given sufficient time natural progradation will again occur along the Figure Eight island oceanfront.

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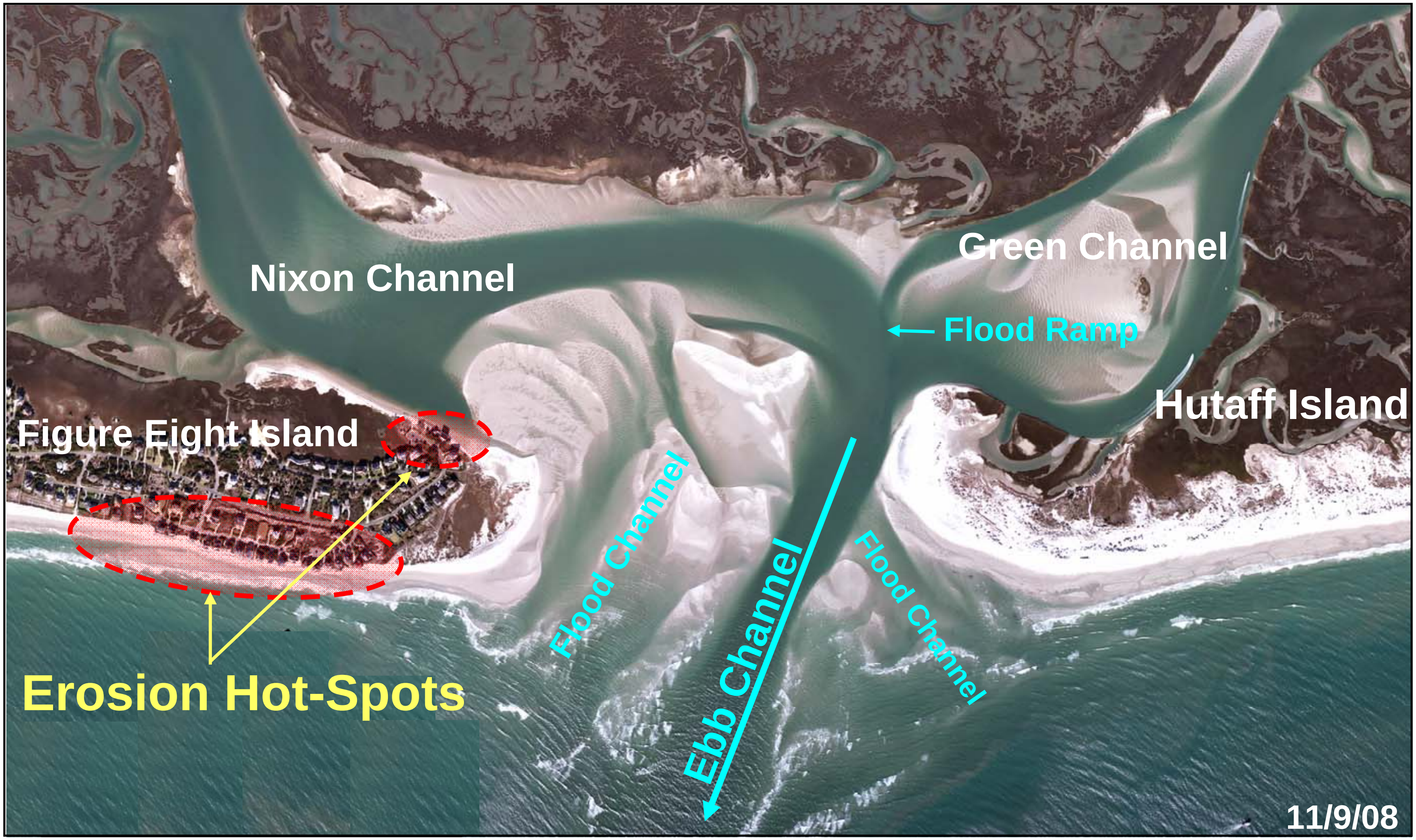

Figure 1. Aerial photograph of Rich Inlet, Figure Eight Island and Hutaff Island depicting conditions as of 11/9/08. Note the expansive marginal flood channel located on the F8I margin that acts as a corridor for the transport of large volumes of sand into the estuary and interior channels. Also note the developing spit along the F8I inlet shoreline. Photograph courtesy of GBA- Wilmington, NC.

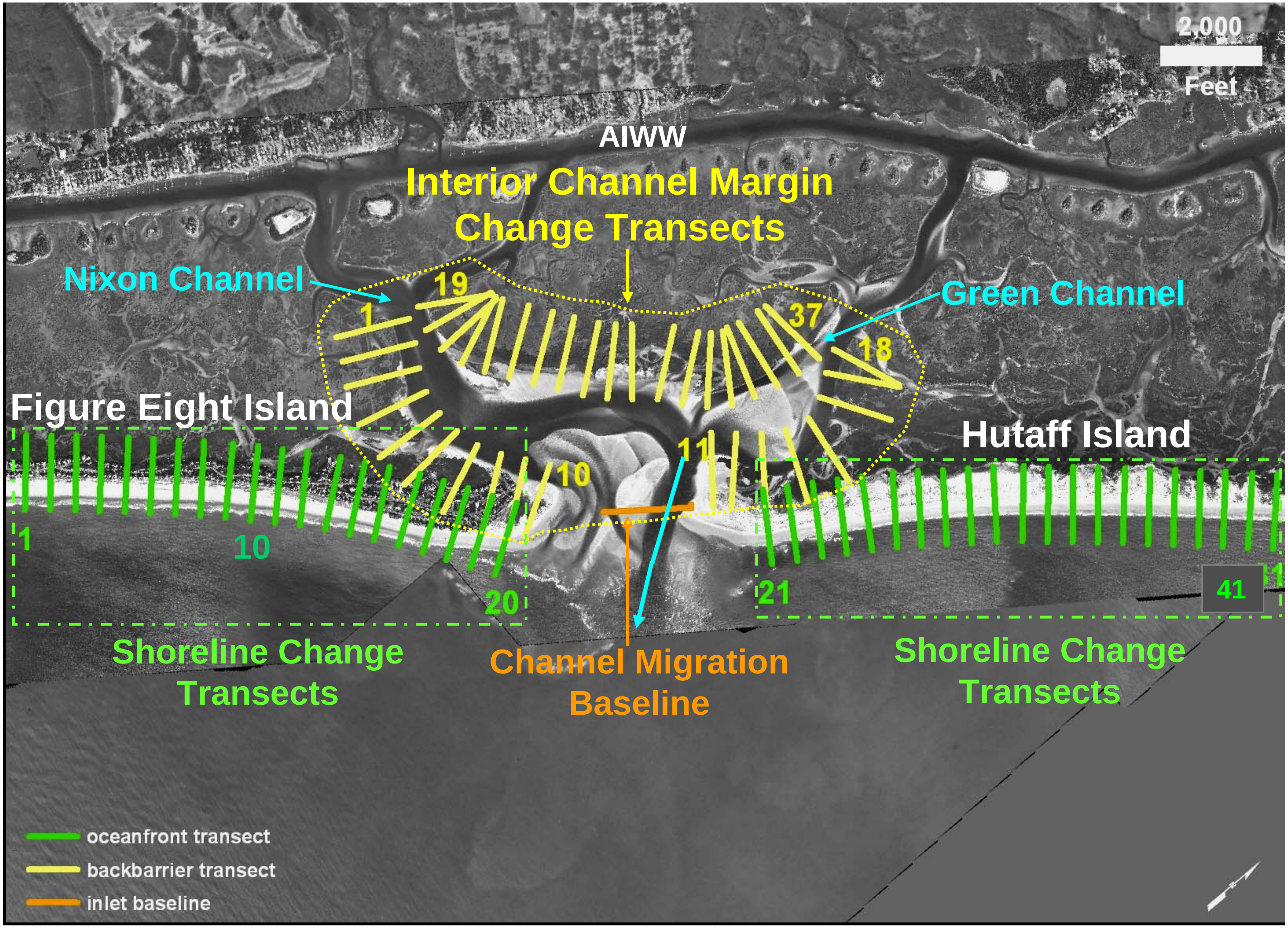

Figure 2. Aerial mosaic (2006) depicting the ebb channel baseline position and the estuarine and oceanfront shoreline transect locations.

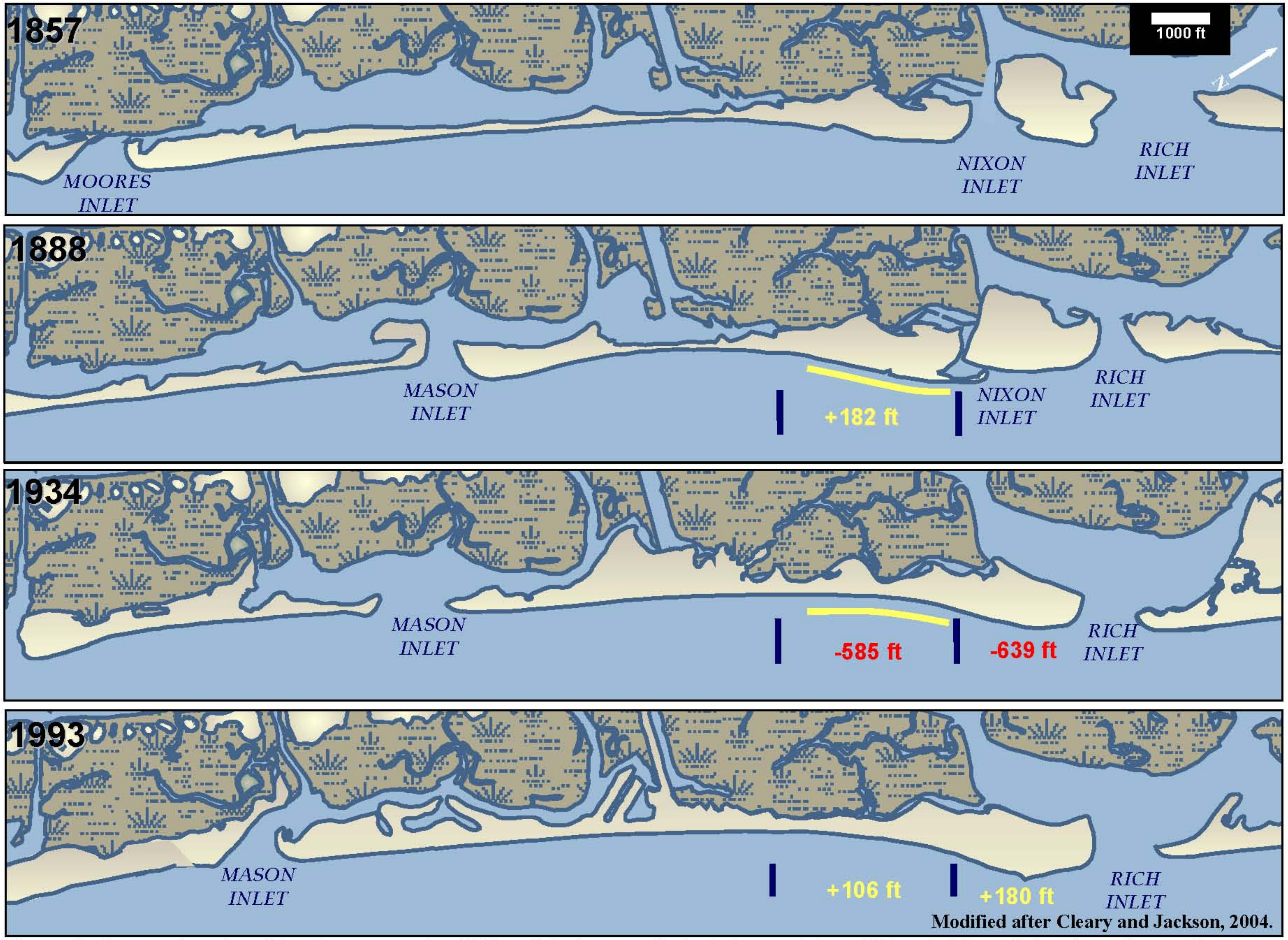

Figure 3. Cartoon based on historic maps and a 1993 aerial photograph depicting position of historic Nixon Inlet along the northern portion of F8I. Note the large bulbous shape of the shoreline (yellow line) with the northward extending spit imaged on the1888 map. By 1934 the incorporated shoreline segment eroded an average of 585 ft while the shoreline reach nearest the inlet eroded an average of 639 ft since inlet closure. Since 1934 the two reaches have prograded an average than ranged from 106 to 180 ft.

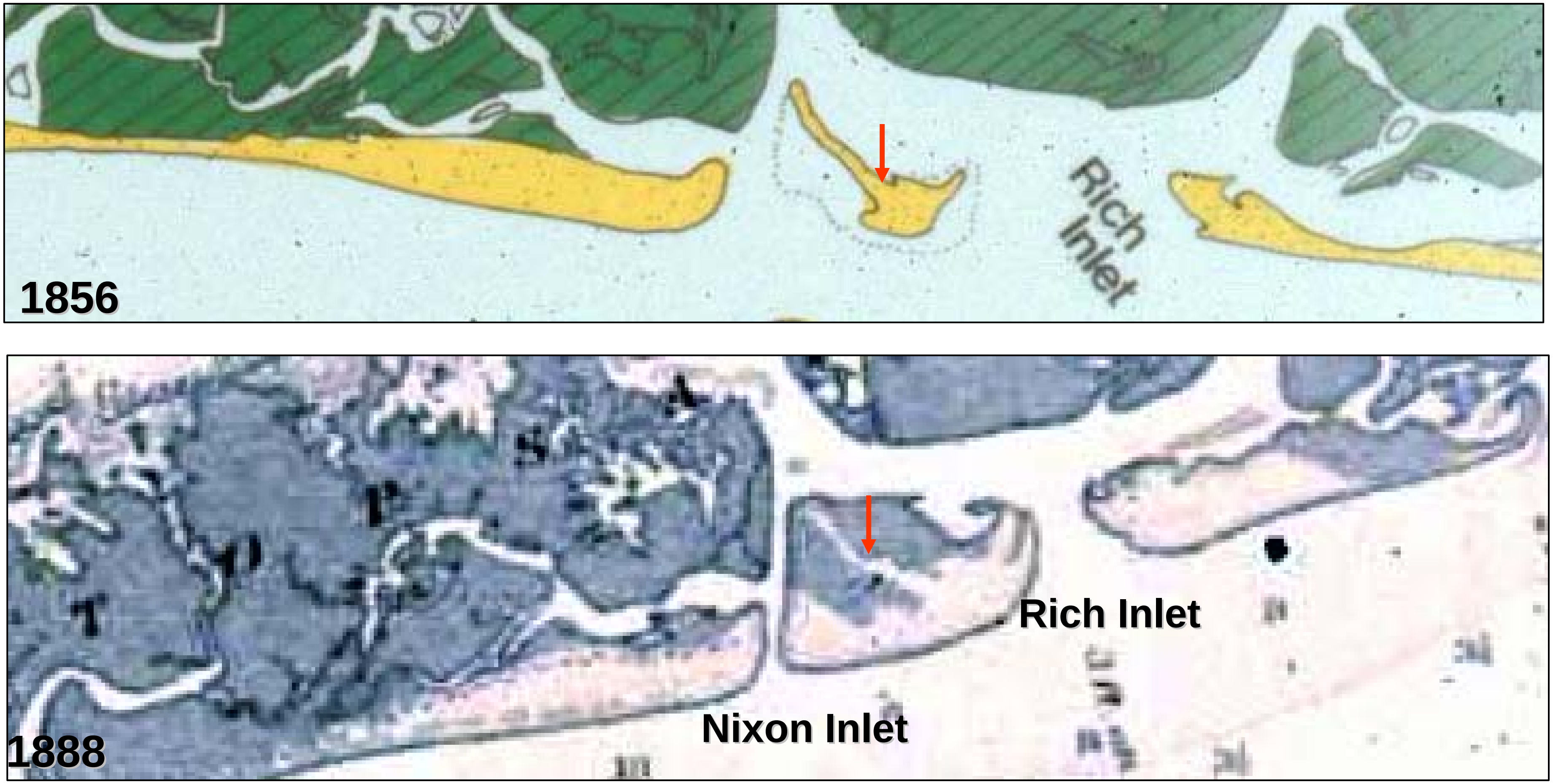

Figure 4. Cartoon depicting position of historic Nixon and Rich inlets along the northern portion of F8I in 1856 and 1888. Arrows delineate morphologic features imaged on an 1938 aerial photograph.

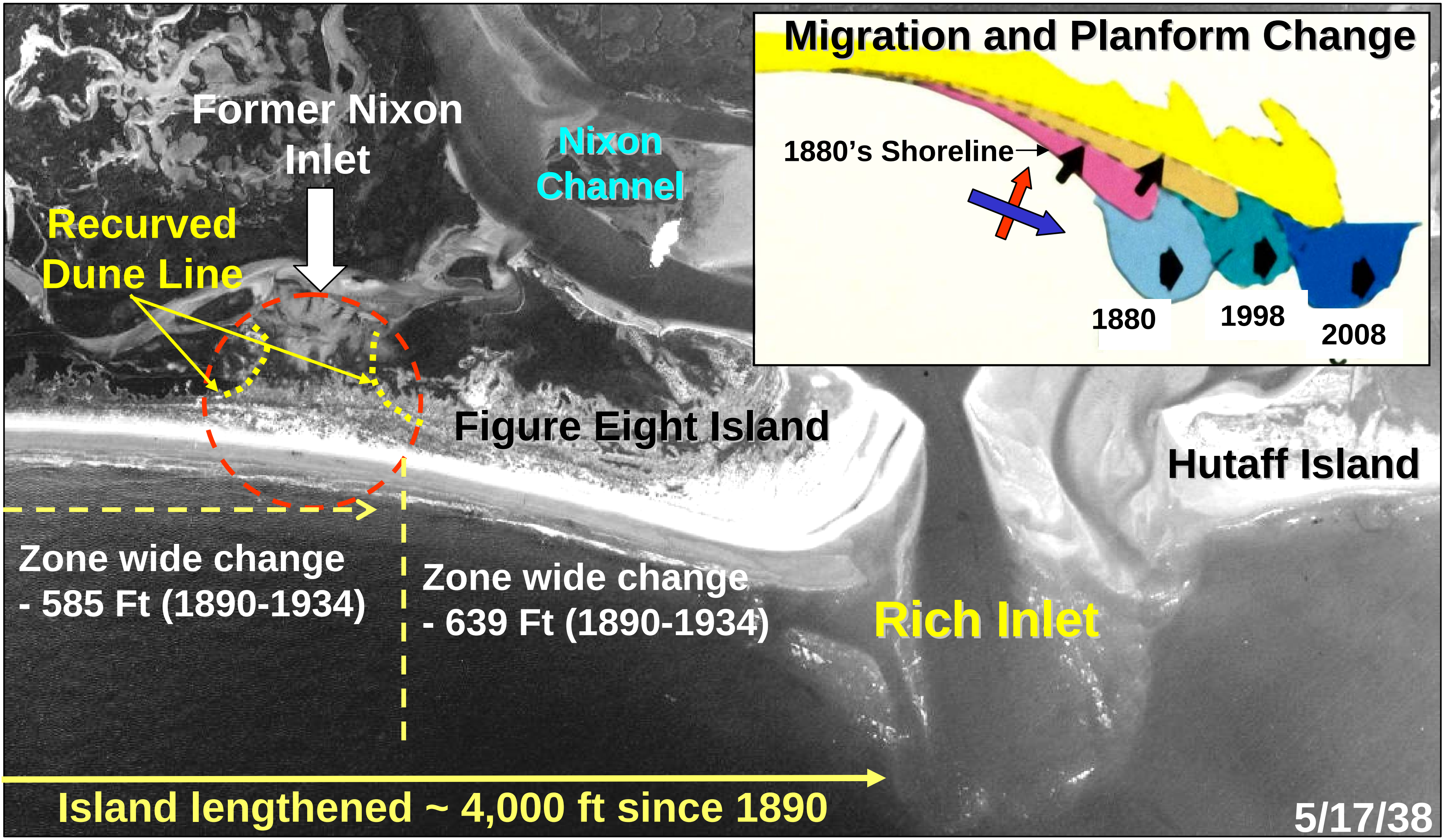

Figure 5. Historic aerial photograph (1938) depicting the historic late 19th C. position of Nixon Inlet and the inlet shoreline features. Insert depicts shoreline planform changes that occurred subsequent to the closure of Nixon Inlet and the attendant lengthening of F8I. Shoreline erosion along the northern portion of the island averaged 585 to 639 ft. See Figure 4 for morphologic features preserved and indentified on 1938 photograph. Modified after Cleary and Jackson 2004.

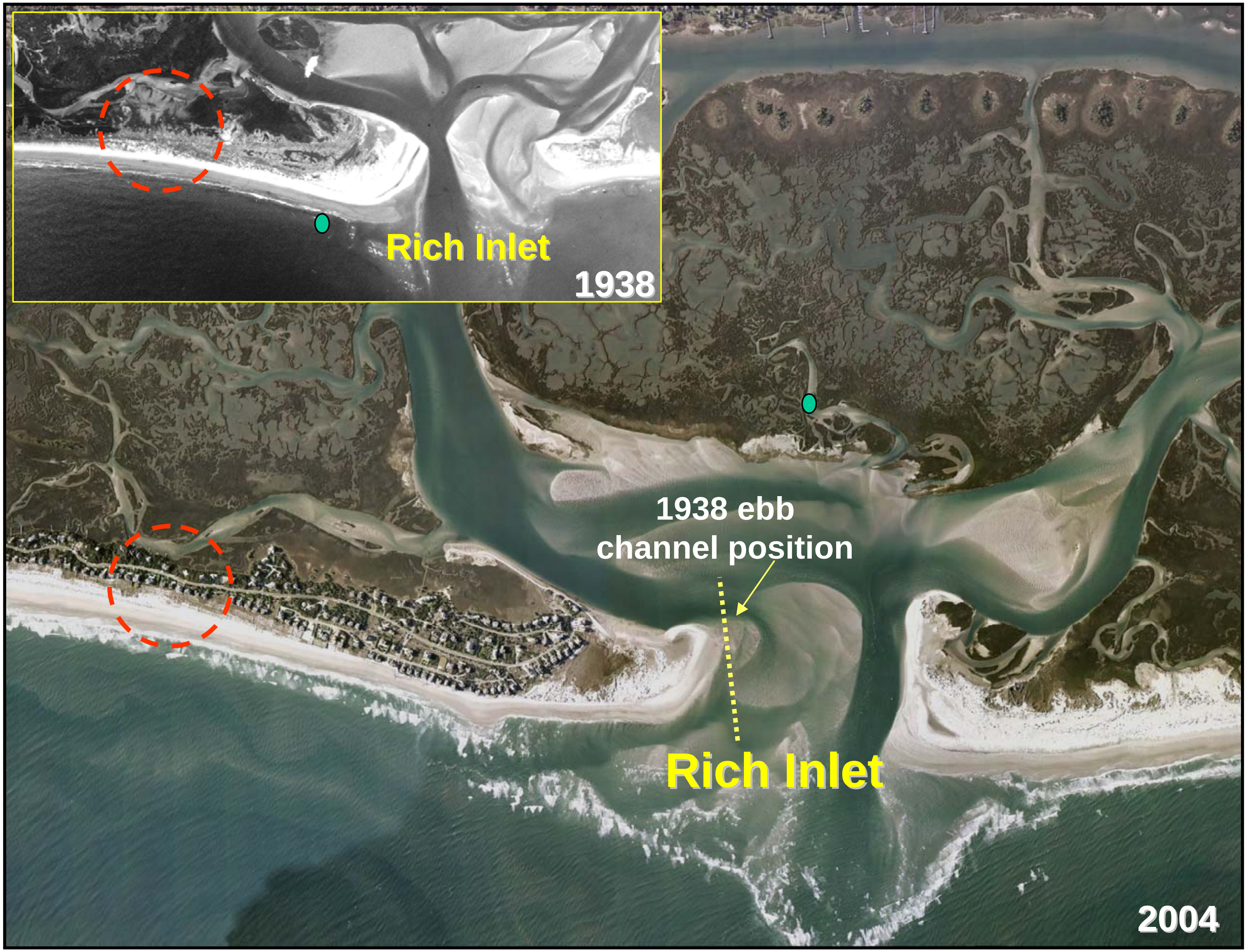

Figure 6. Recent aerial photograph (2004) depicting the location of historic Nixon Inlet and the shoreline conditions downdrift of Rich Inlet. Insert is a 1938 photograph of the area and the location of Nixon Inlet and the bulbous shape of the shoreline downdrfit of Rich Inlet**.**

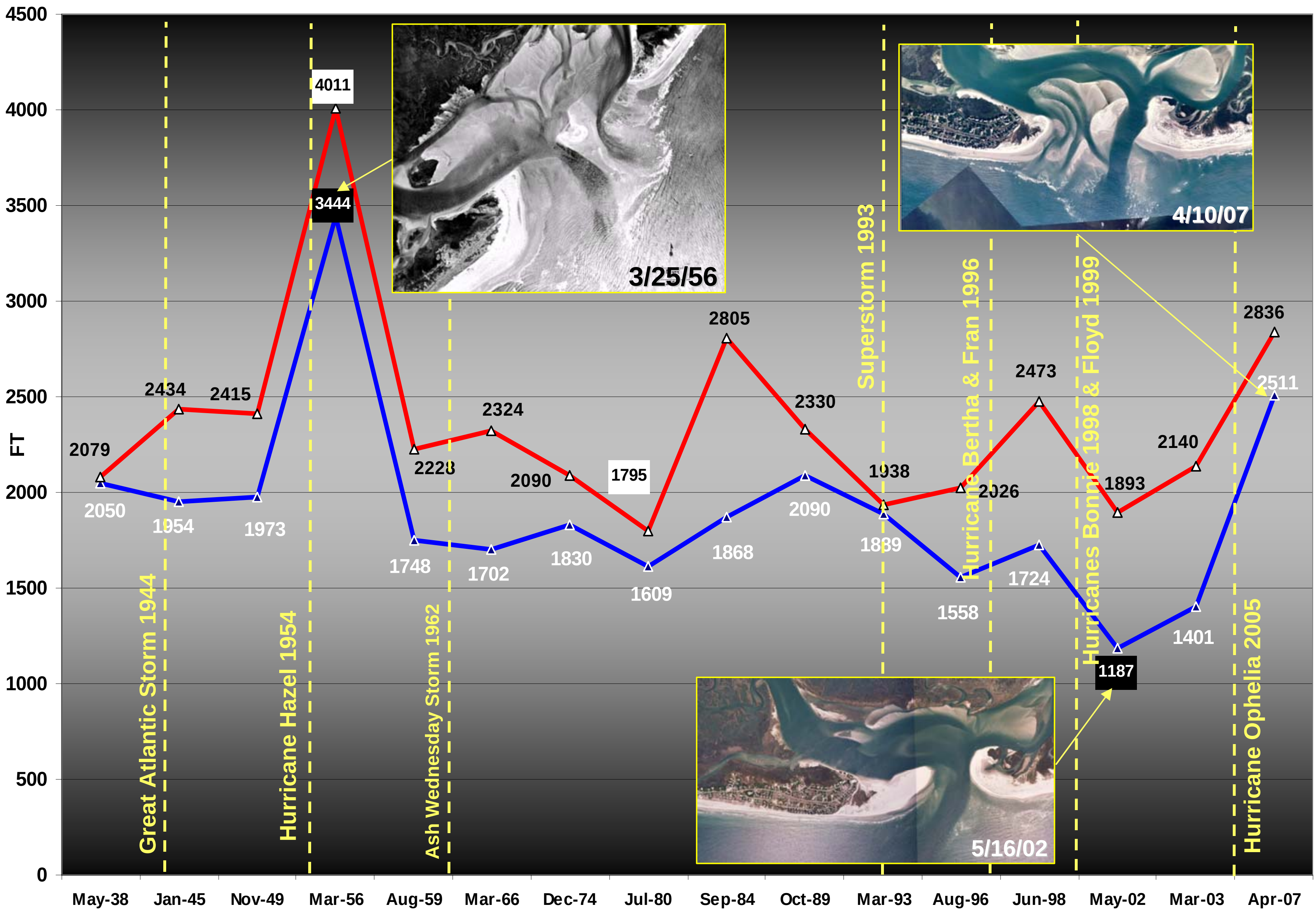

Figure 7. Line graphs depicting the inlet's minimum width (IMW) and baseline width since 1938. See Figure 2 for location of inlet baseline. The inserts are historical aerial photographs that depict the current (2007) and minimum (2002) IMW as well as the storm-related widening of the inlet (3/25/56) due to Hurricane Hazel in October 1954.

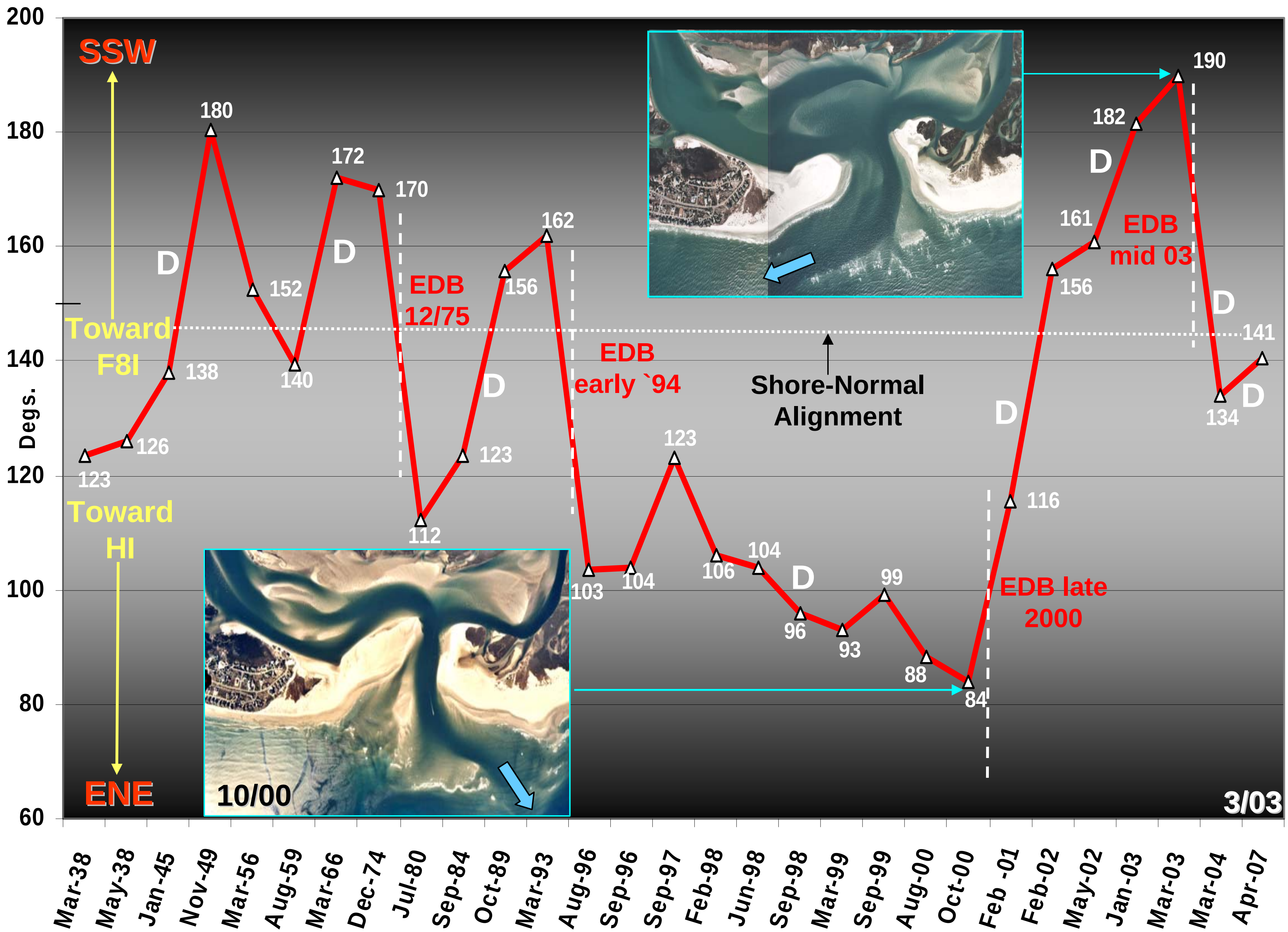

Figure 8. Line graph depicting the orientation (azimuth) of the outer portion of the ebb channel since 1938. The inserts are historical aerial photographs that depict the maximum (2003) and minimum (2000) azimuths of the ebb channel. Ebb delta breaching events that occurred between 1938 and 2007 are labeled "EDB" while channel deflection is labeled by a white colored "D".

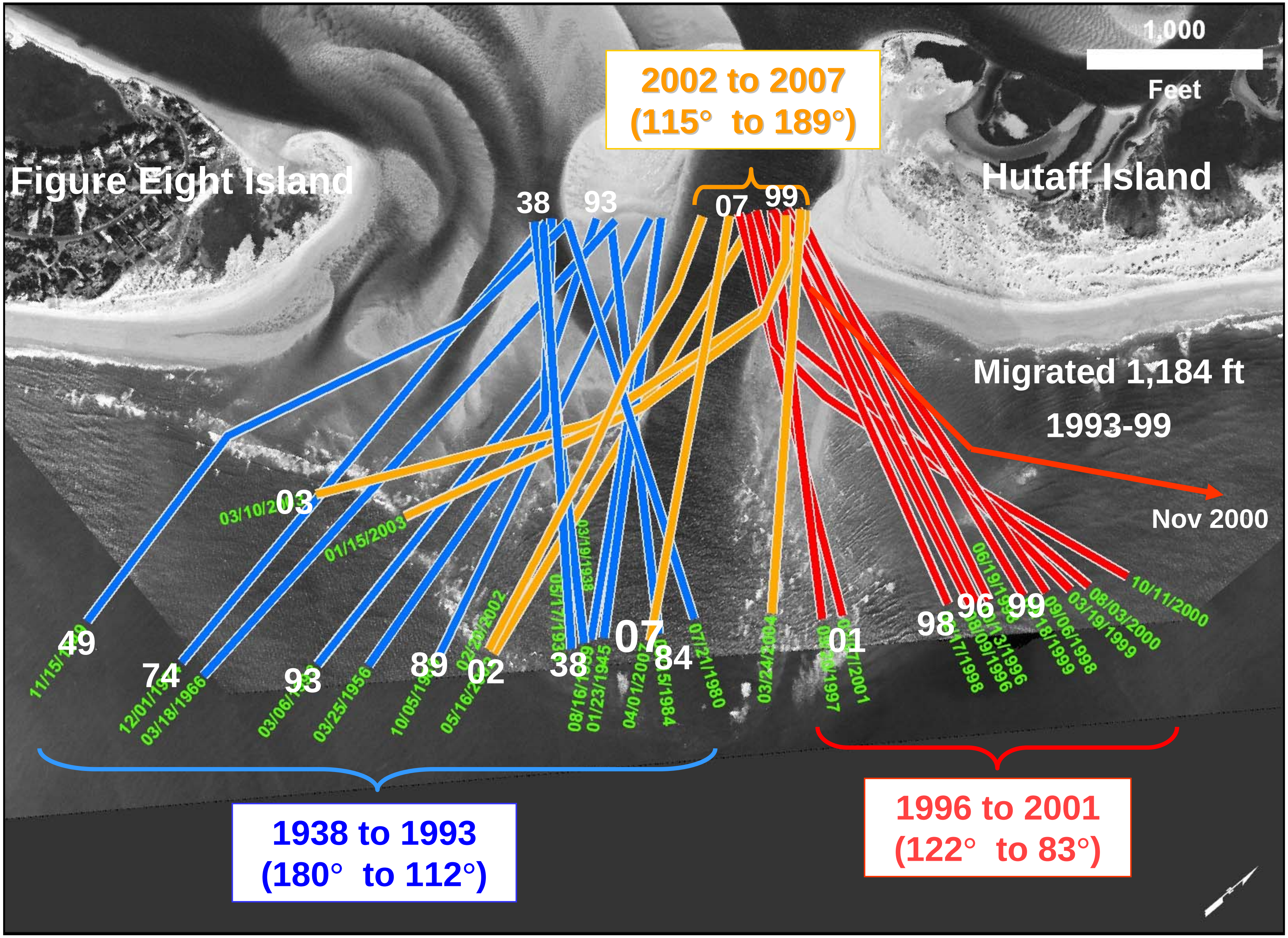

Figure 9. Aerial photograph mosaic (2006) depicting position of the ebb channel between 1938 and 2007. During the mid 1990s the ebb channel shifted to the NE ~1,184 ft and has remained in same general location. Note the changing alignment of outer portion of the ebb channel.

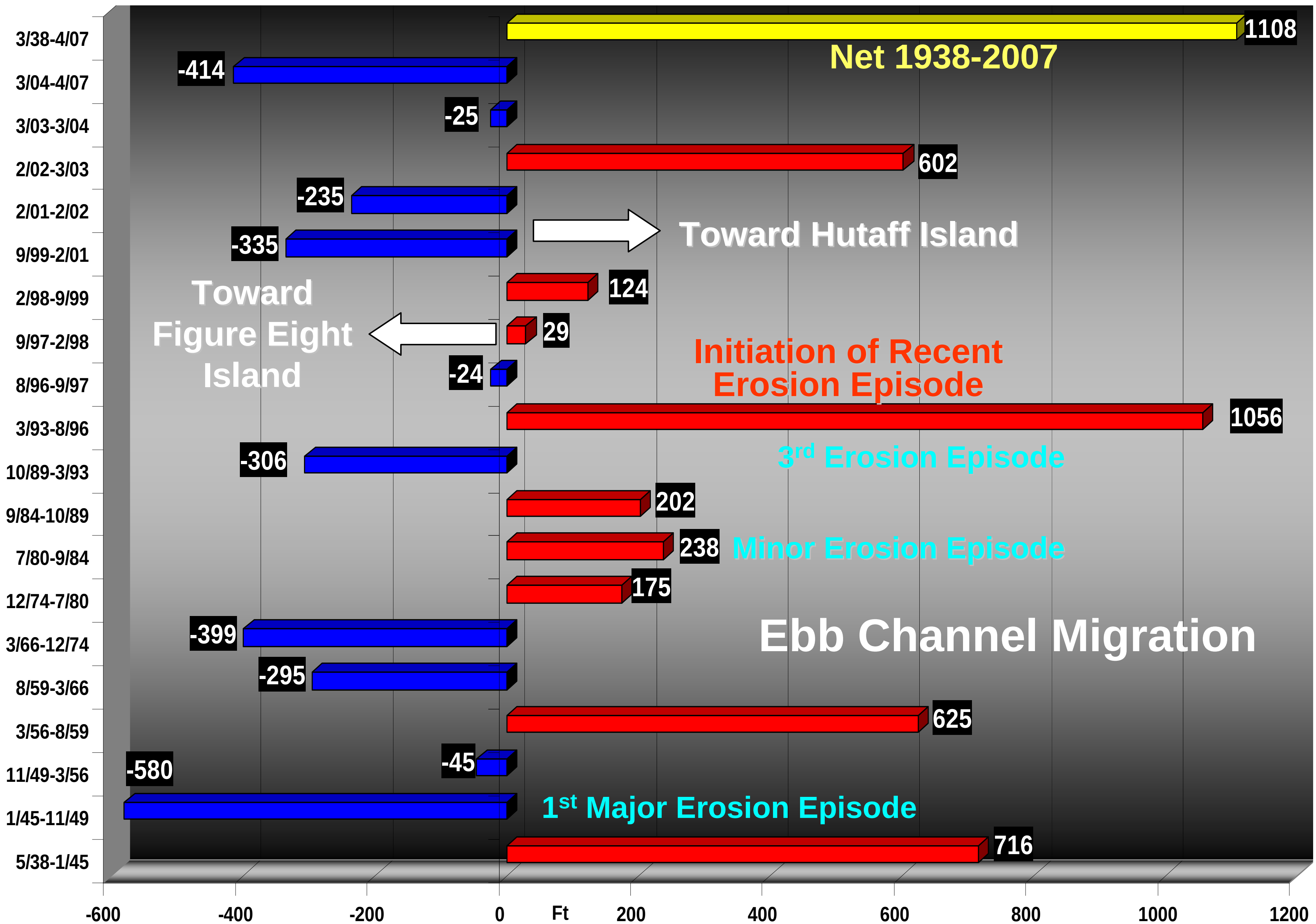

Figure 10. Bar graph depicting migration of Rich's Inlet ebb channel (throat segment) between March 1938 and April 2007.

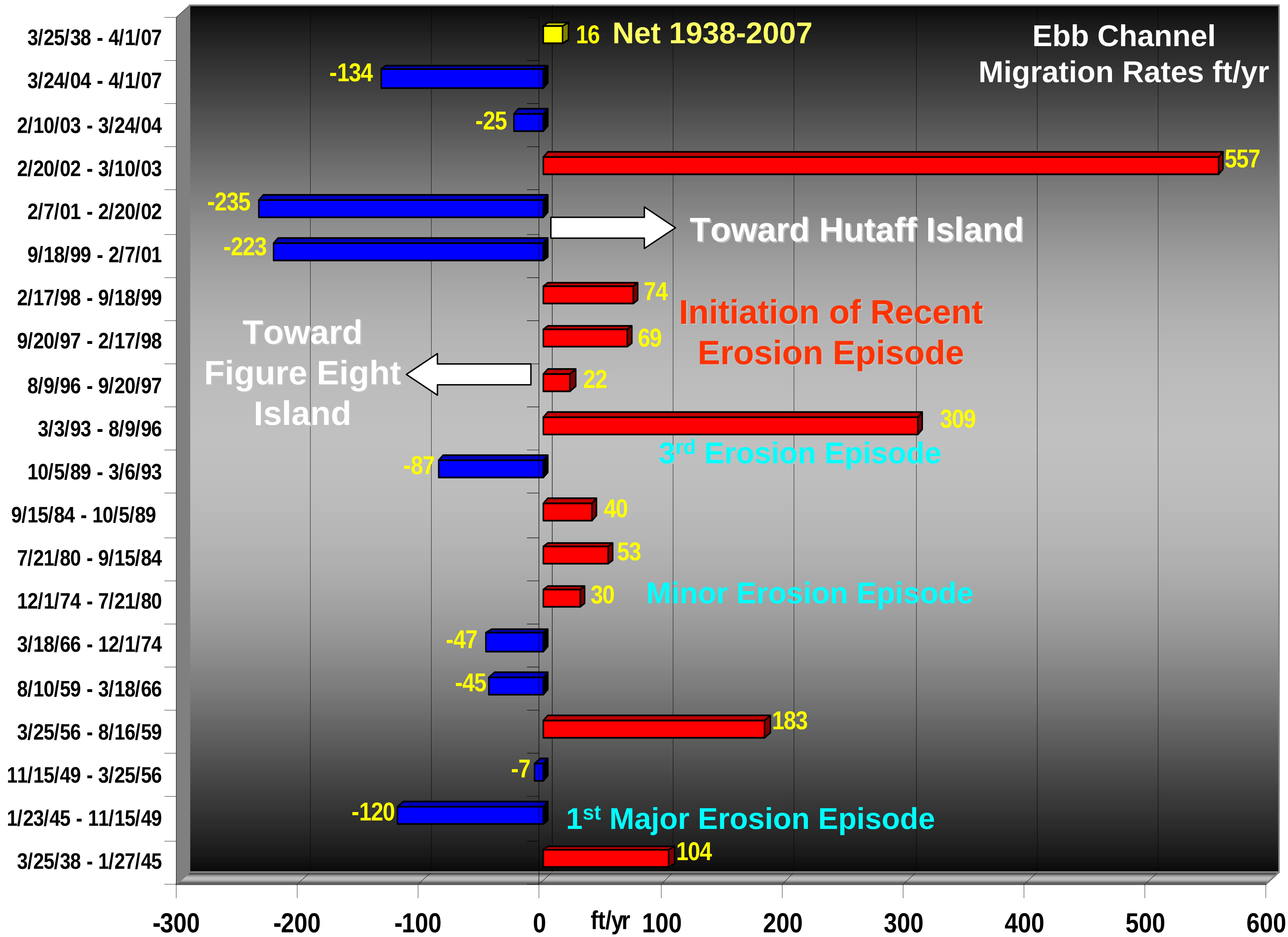

Figure 11. Graph depicting ebb channel migration rates for various time intervals between 1938 and 2007.

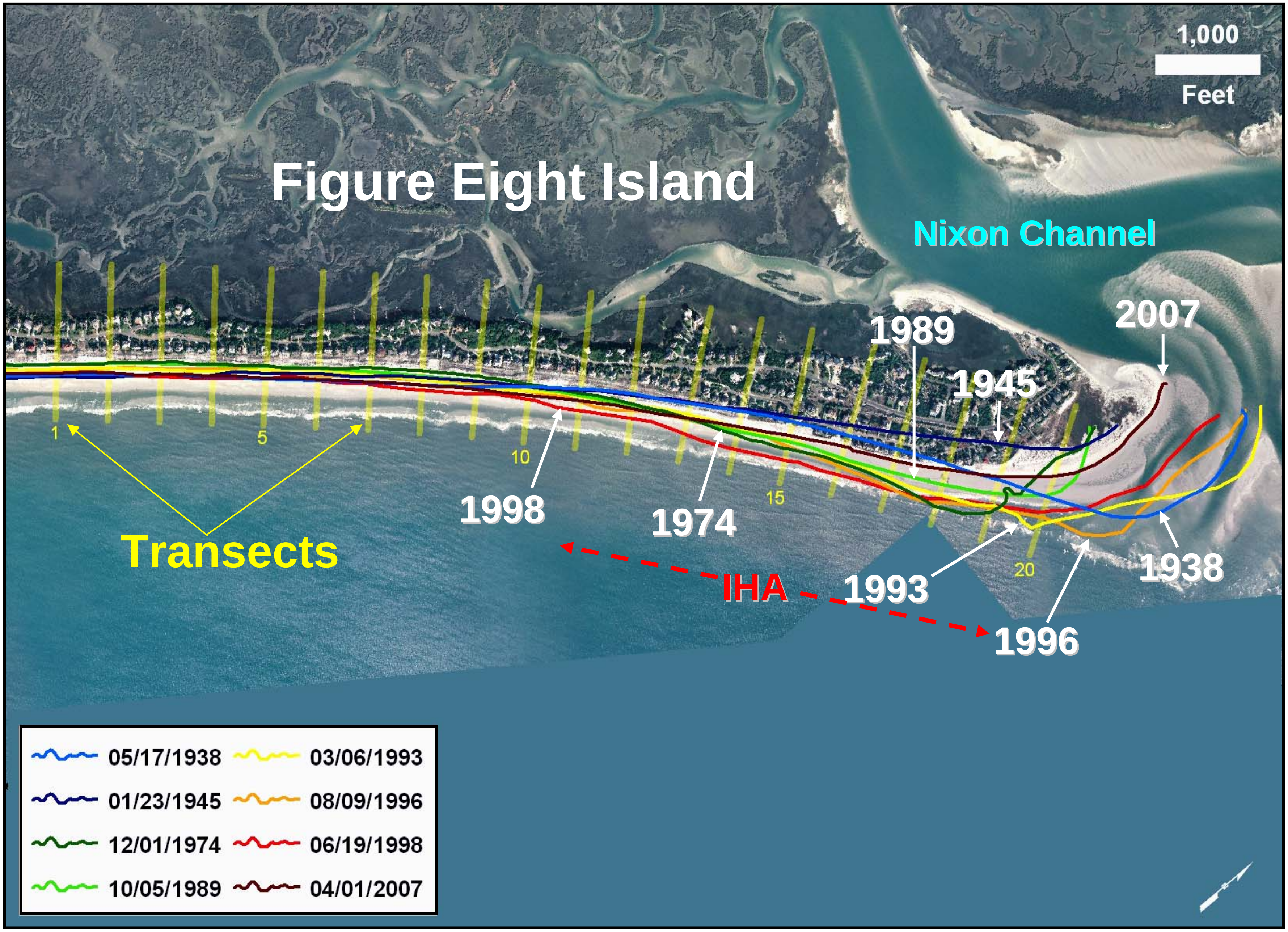

Figure 12. Aerial photograph (2007) depicting selected (8) shoreline positions along F8I since 1938 and transect locations (T1-20). The F8I Rich Inlet IHA includes the shoreline reach between Transects 11 and 20. Note that the 1945 shoreline position is the most landward positioned shoreline. Also note a significant number of homes lie seaward of the 1945 shoreline position

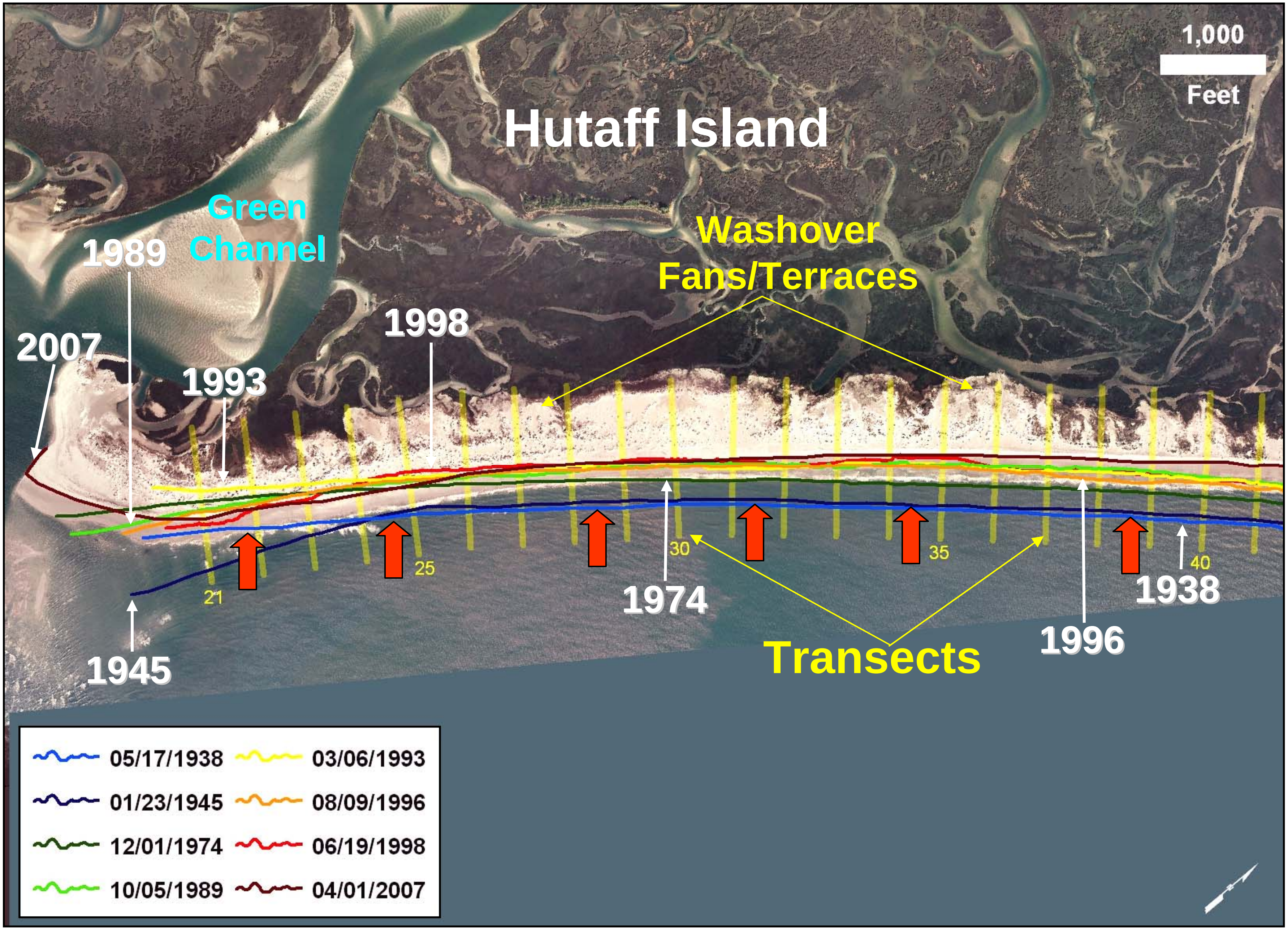

Figure 13. Aerial photograph (2007) depicting selected (8) shoreline positions along HI since 1938 and transect locations (T21-41). The entirety of Hutaff Island is included within an IHA. For purposes of comparison and discussion this study has designated the Rich Inlet zone of influence to include the shoreline reach between Transect 21 and 30. Note that the relative positions of the 1938 and 1945 shorelines along the barrier. Also note the continuous retreat of the shoreline since 1938 north of T 26.

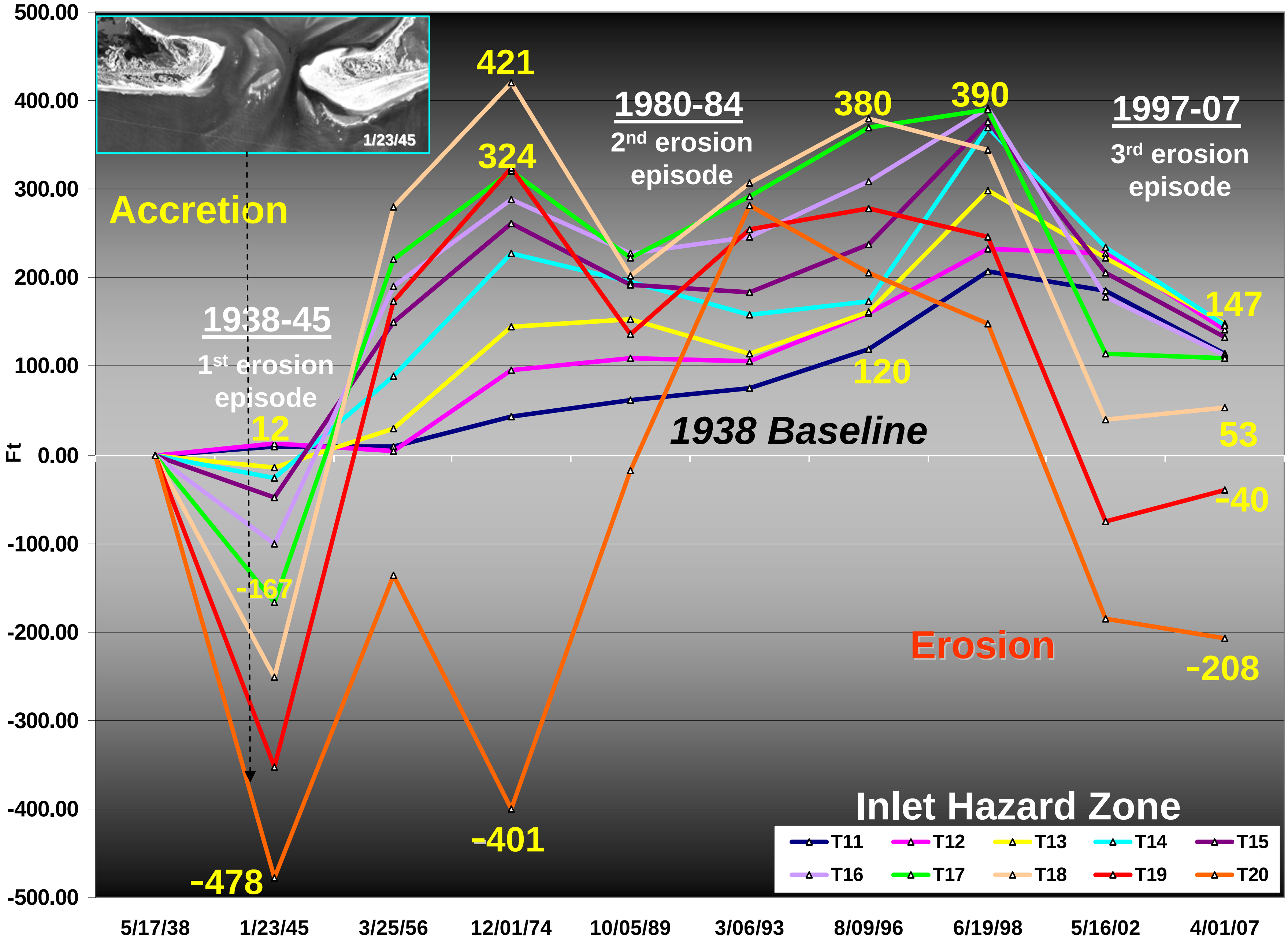

Figure 14. Graph depicting the cumulative shoreline change along transects located within the IHA (T11 to T20) on F8I. Photograph inserts depict condition of the shoreline during the 1st erosion episode.

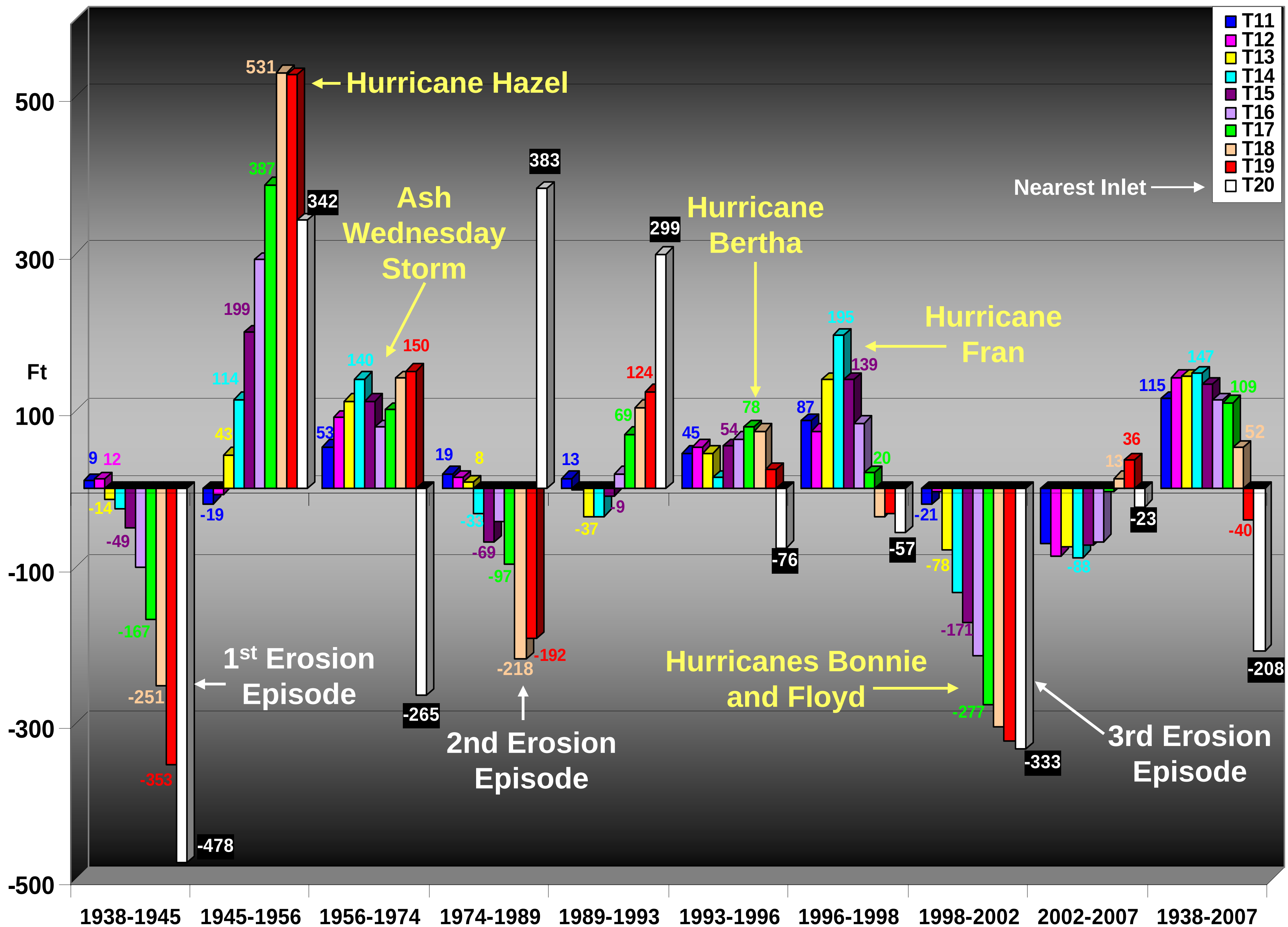

Figure 15. Bar graph depicting short-term shoreline changes along the oceanfront between the T11 and T 20 from 1938 to 2007. The oceanfront shoreline segment lies within the F8I portion of the Rich Inlet IHA.

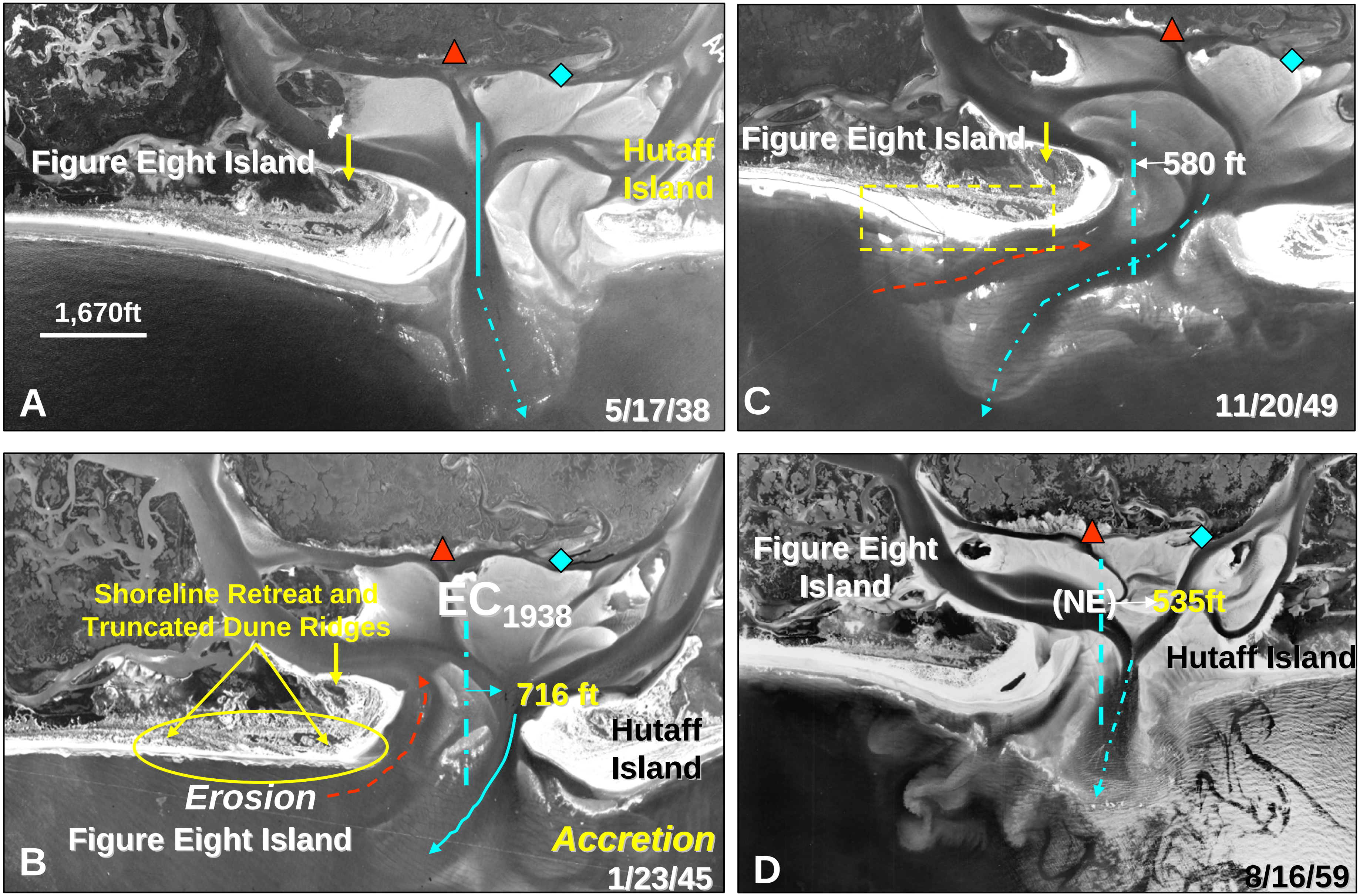

Figure 16. Historic aerial photographs (1938 –1959) illustrating shoreline changes along F8I downdrift of Rich Inlet. **A**. View (517/38) of the north end of F8I showing accretion zone downdrift of Rich Inlet. **B**. View (1/23/45) of the erosion along the accretion zone. Note truncated dune ridges and the encroachment of the flood channel due to the skewed ebb channel. Also note the progradation of the HI shoreline. **C**. View (11/20/49) depicting the skewed ebb channel and the buildup of the shoreline in the lee of the flood channel. Note the erosion of the HI oceanfront. **D**. View (8/16/59) showing progradation of the F8I oceanfront and inlet margin accretion (spit buildup). The erosion of HI is due to the NE shift of the ebb channel and development of the flood channel. Red triangle and light blue diamond are reference points.

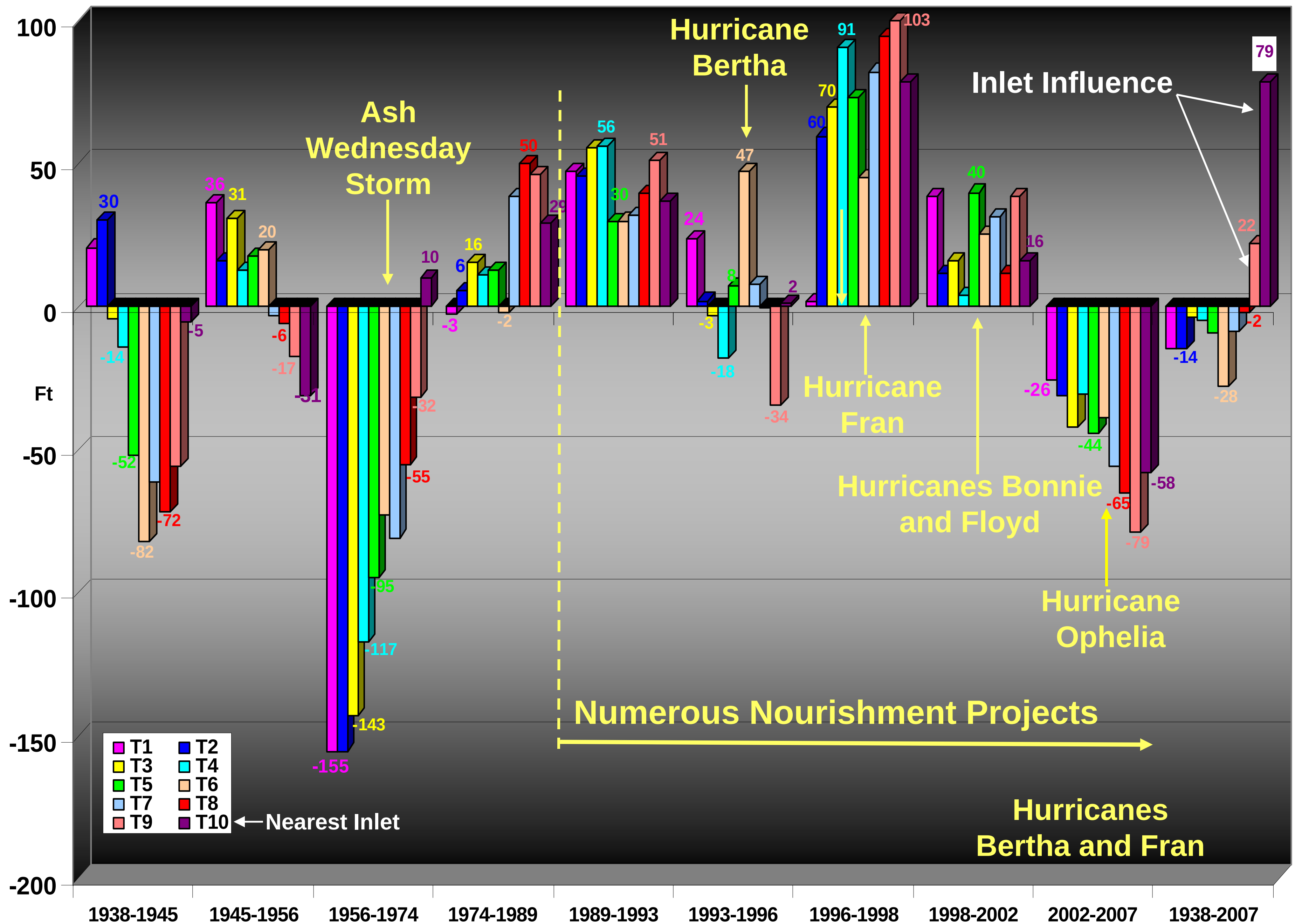

Figure 17. Bar graph depicting short-term shoreline changes from 1938 to 2007 along F8I between the T1 –T 10 the reach that lies outside the IHA.

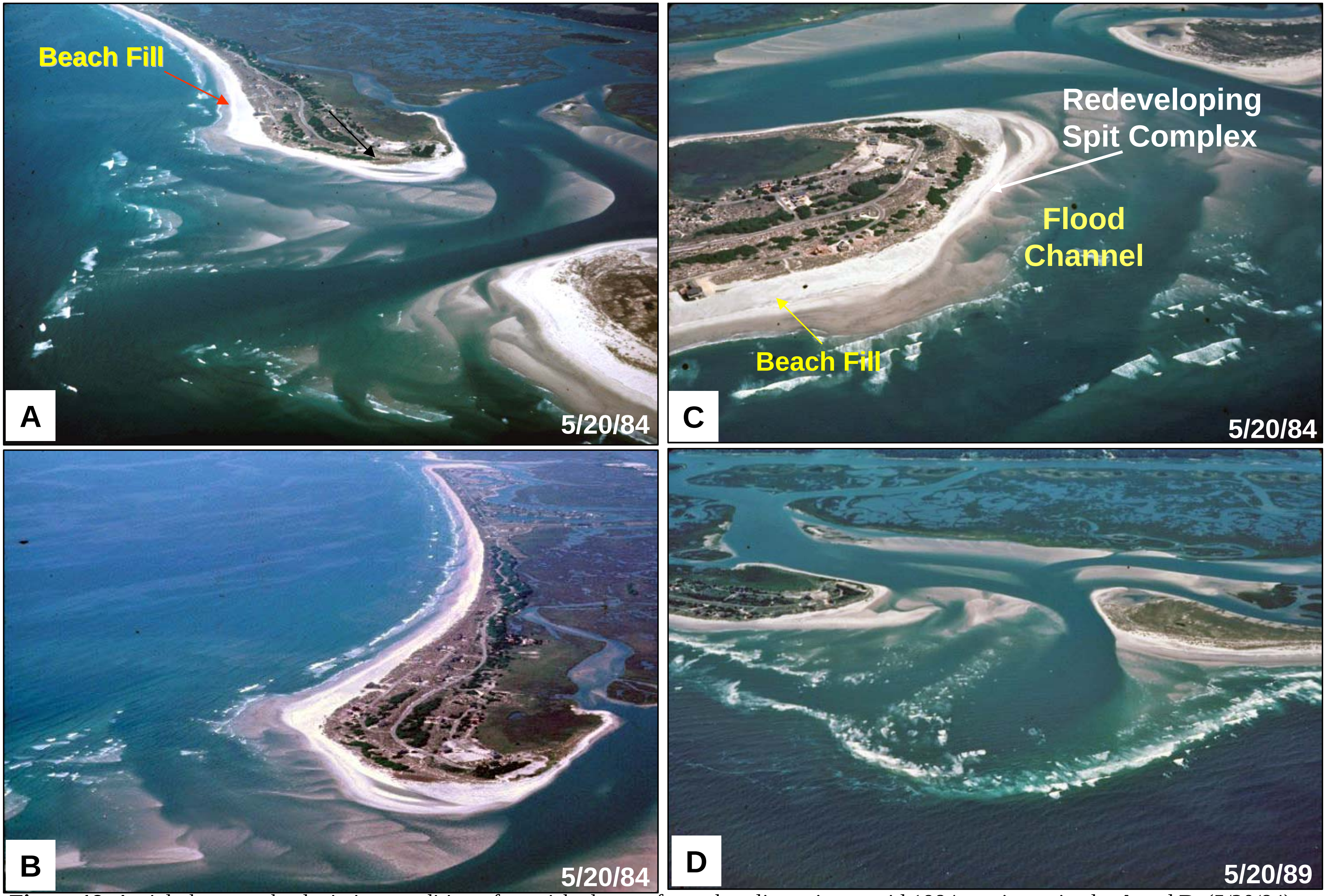

Figure 18. Aerial photographs depicting condition of nourished oceanfront shoreline prior to mid 1984 erosion episode. **A**.and **B**. (5/20/84). Views of nourished shoreline segment and swash bar welding onto F8I. **C**. View (5/20/84) showing the onset of erosion of redeveloping inlet shoreline **D**. Landward view (5/20/89) of Rich Inlet showing spit development along scarped inlet shoreline. Note lack of shrub line along scarp line.

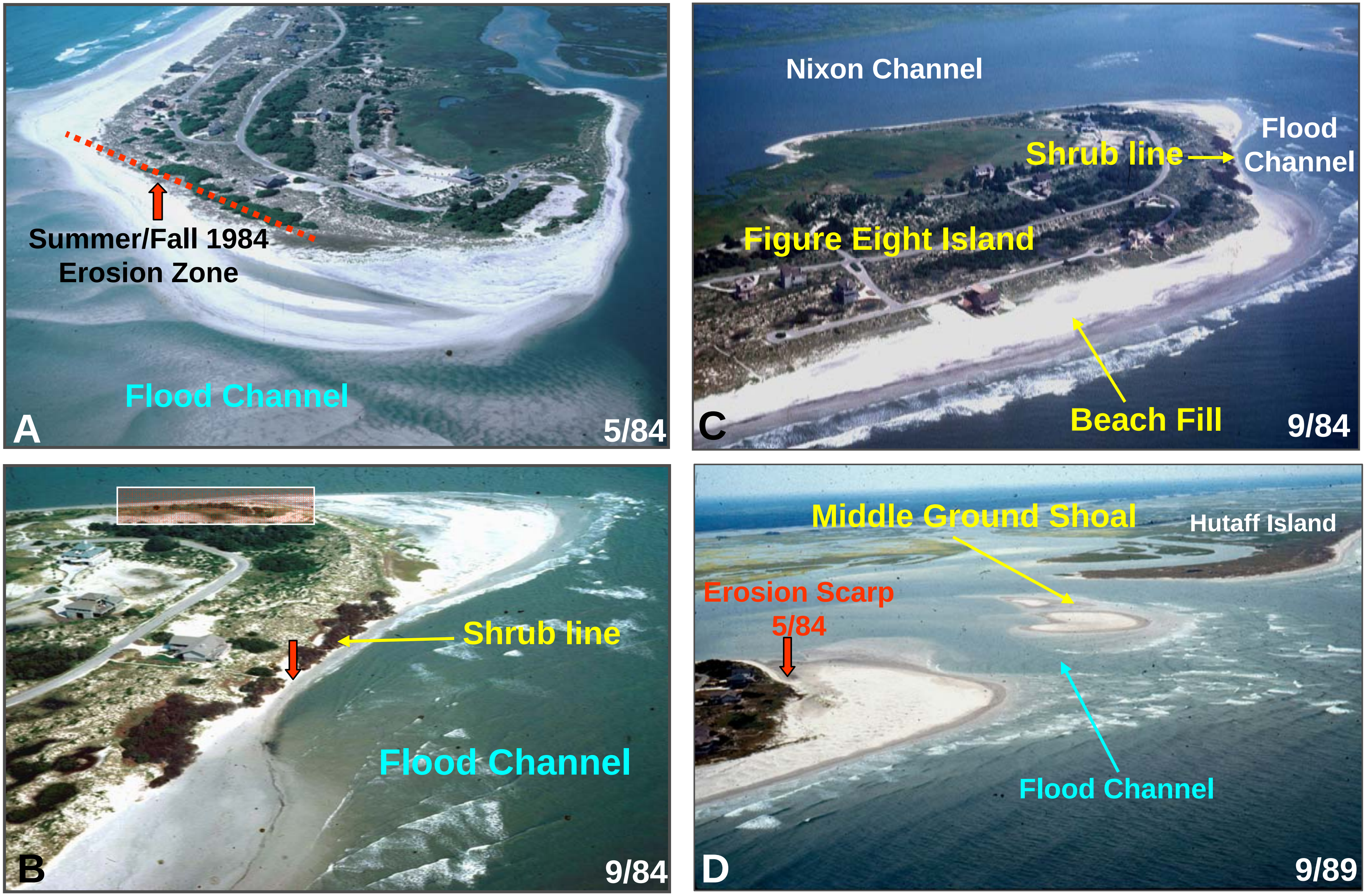

Figure 19. Oblique aerial photographs of F8I and Rich's Inlet shoreline during 1984**. A.** Seaward view of the inlet shoreline depicting the redeveloping spit, ridge and swale features, and the intact shrub line. **B.** Oblique aerial photograph depicting very rapid erosion of the inlet shoreline and dying shrub thickets. Compare to **"A". C.** Landward view (9/84) of eroded and scalloped inlet shoreline. **D.** Landward view (9/89) of rebuilt and elongating inlet shoreline spit. Note the occluded channel adjacent to the scarped uplands and the lack of shrubs. By 1993 the spit had enlarged considerably and the flood channel had infilled while the mid-inlet shoal became incorporated into the barrier.

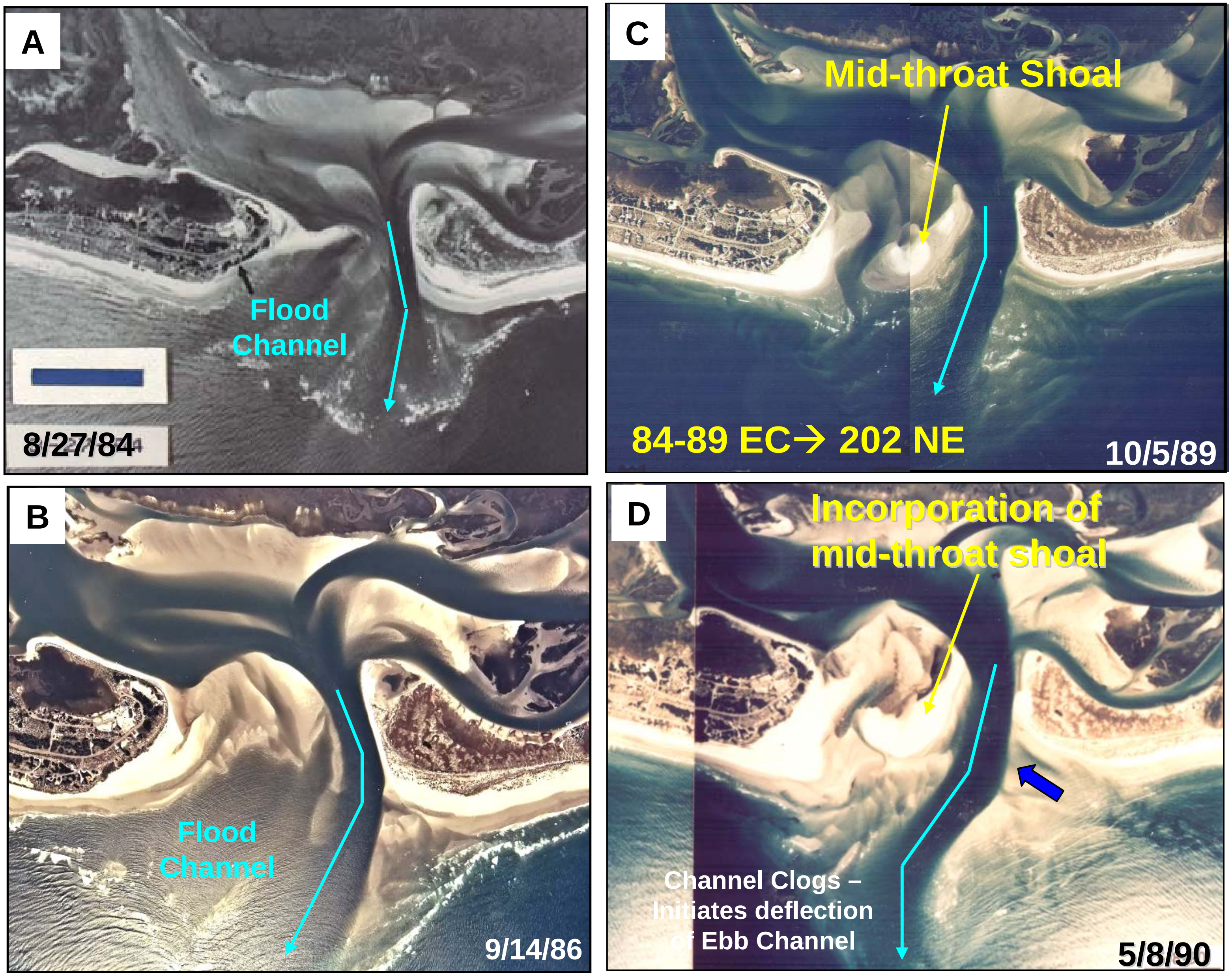

Figure 20. Aerial photographs (8/84- 5/90) of flood channel changes along F8I margin. **A.** View (8/27/84) of erosion along F8I shoreline. Note position of ebb channel. B. View (9/14/86) of redeveloped spit along F8I inlet margin. **C.** View (10/5/89) of mid throat shoal and northward developing spit. **D.** View (5/8/90) of nearly infilled flood channel. Note narrow inlet and initial incorporation of mid throat shoal

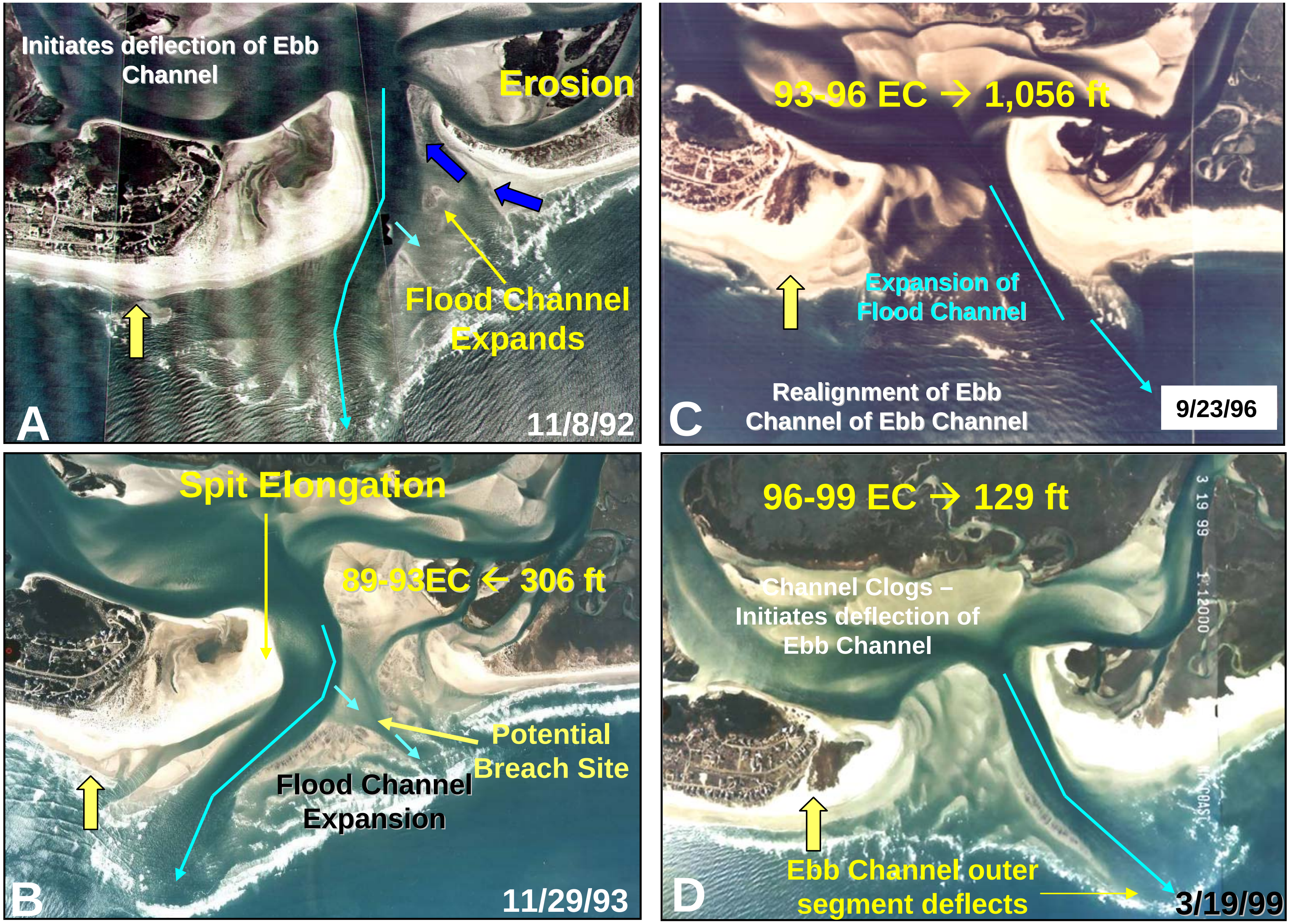

Figure 21. Aerial photographs of Rich Inlet (11/92-3/99). Photographs depict oceanfront shoreline changes related to ebb delta breaching and ebb channel deflection (**A-D**), spit development/erosion on F8I inlet margin and changes in the symmetry of the ebb-tidal delta (**A-D**). Note the change in the wave-sheltering effect with channel shift to NE **(B-D)**.

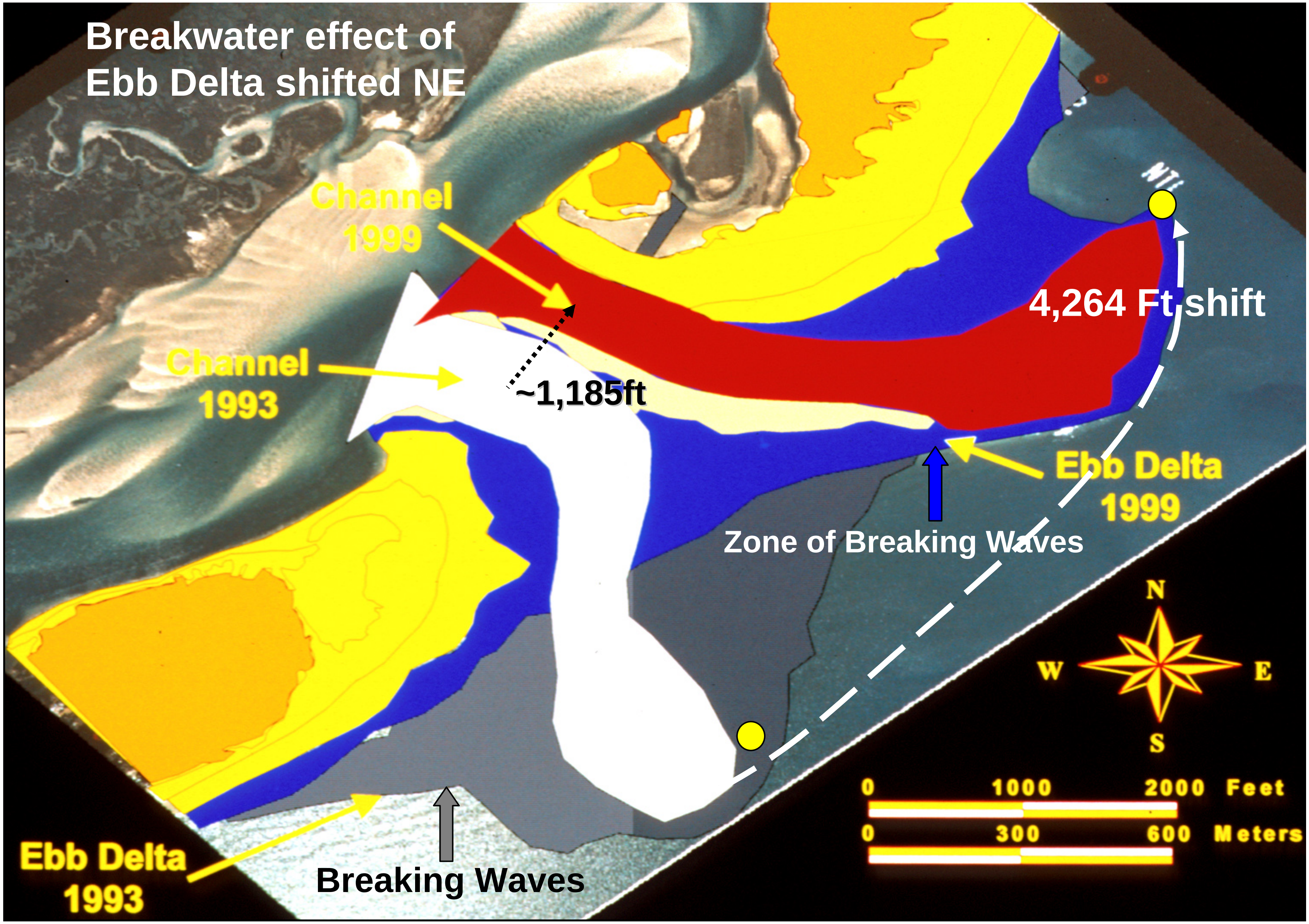

Figure 22. Cartoon illustrating the effects of ebb channel repositioning and outer channel realignment on the F8I oceanfront shoreline. The image shows the superposition of the 1993 and 1996 zone of breaking waves along the ebb-tidal delta and the location of the throat segment of the ebb channel. A NE shift of the ebb delta exposed the F8I oceanfront to incident waves. In this configuration swash bars no longer attached to the F8I oceanfront but rather moved into the flood channel and eventually the estuary and interior channels.

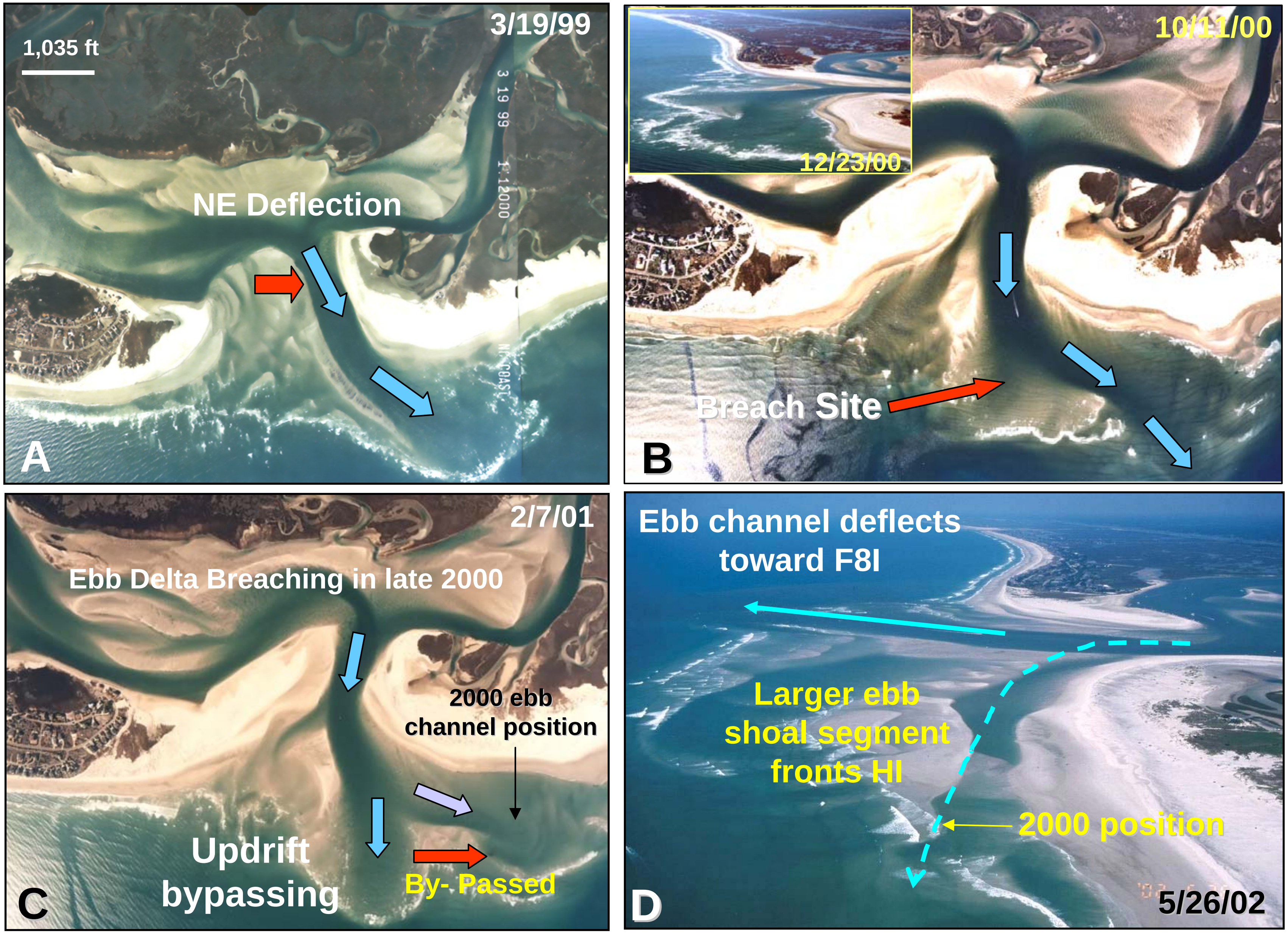

Figure 23. Aerial photographs (1999-2002) depicting the effects of ebb channel repositioning, realignment and bar by-passing. **A.** Image (3/19/99) depicts post-breaching deflection of ebb channel to NE**. B.** View (10/11/00) of ebb delta prior to beaching showing near breach. Insert shows breach. **C.** Photograph (2/7/01) depicts recent ebb delta breaching event (Dec 2000) and the large sand package in the process of being by-passed updrift. **D**. Southward view of ebb channel shifting southward and the larger ebb delta segment located NE of the channel fronting HI. Note the lack of any significant breakwater effect offshore F8I.

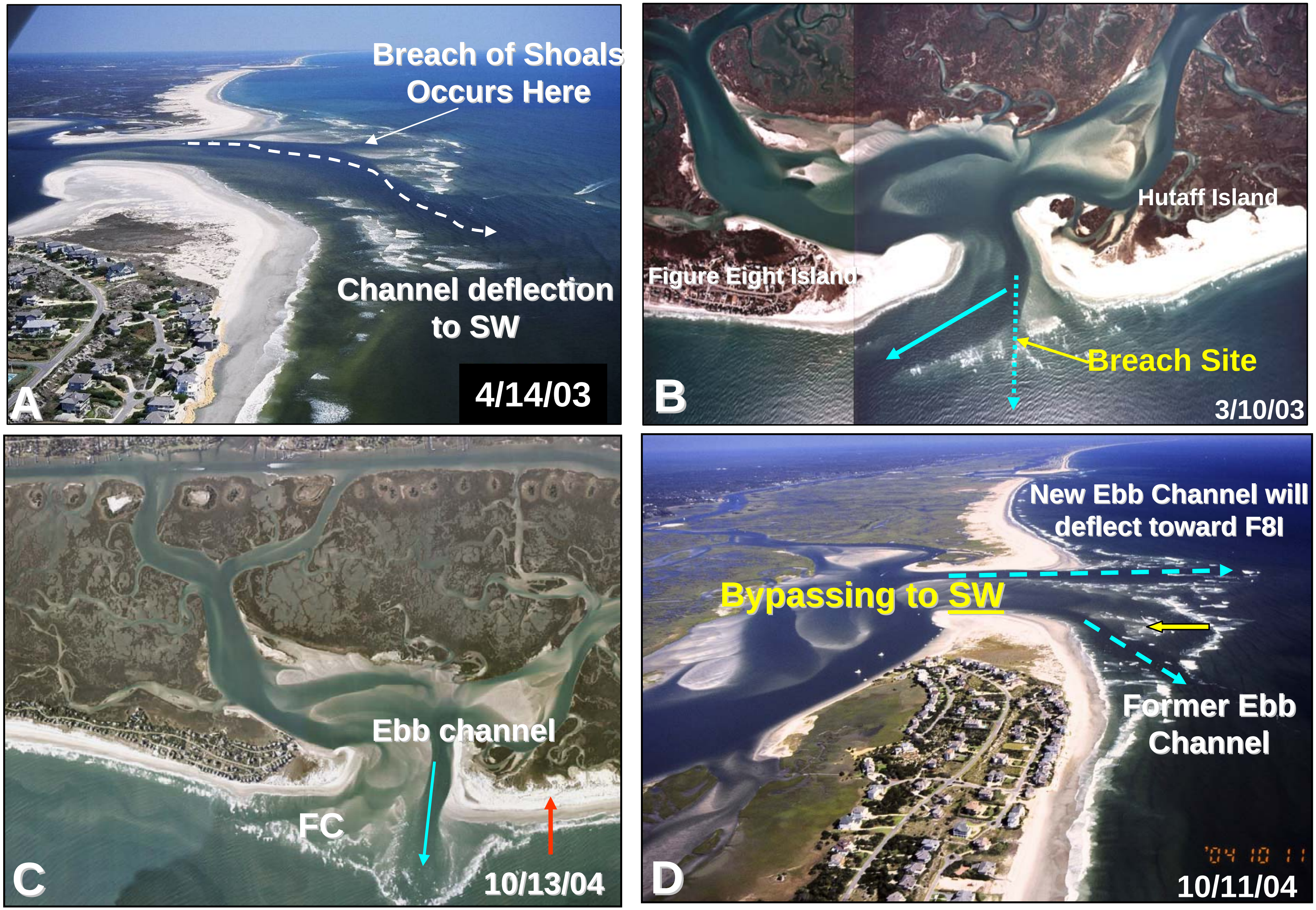

Figure 24. Aerial photographs (4/14/03- 10/11/04) depicting an ebb delta breaching event and SW bar by-passing event. **A.** Oblique image(4/14/03) showing channel aligned toward F8I. **B.** Photograph (3/10/03) depicting breach site note configuration of elongating spit. **C.** Image (10/13/04) illustrating realigned shore-normal ebb channel expanded flood channel adjacent to F8I. Note change in F8I spit. **D.** Oblique photograph depicting a NE view of former and new position of ebb channel. Ebb shoal segment depicted in **"**A and B**"** was by-passed to the SW.

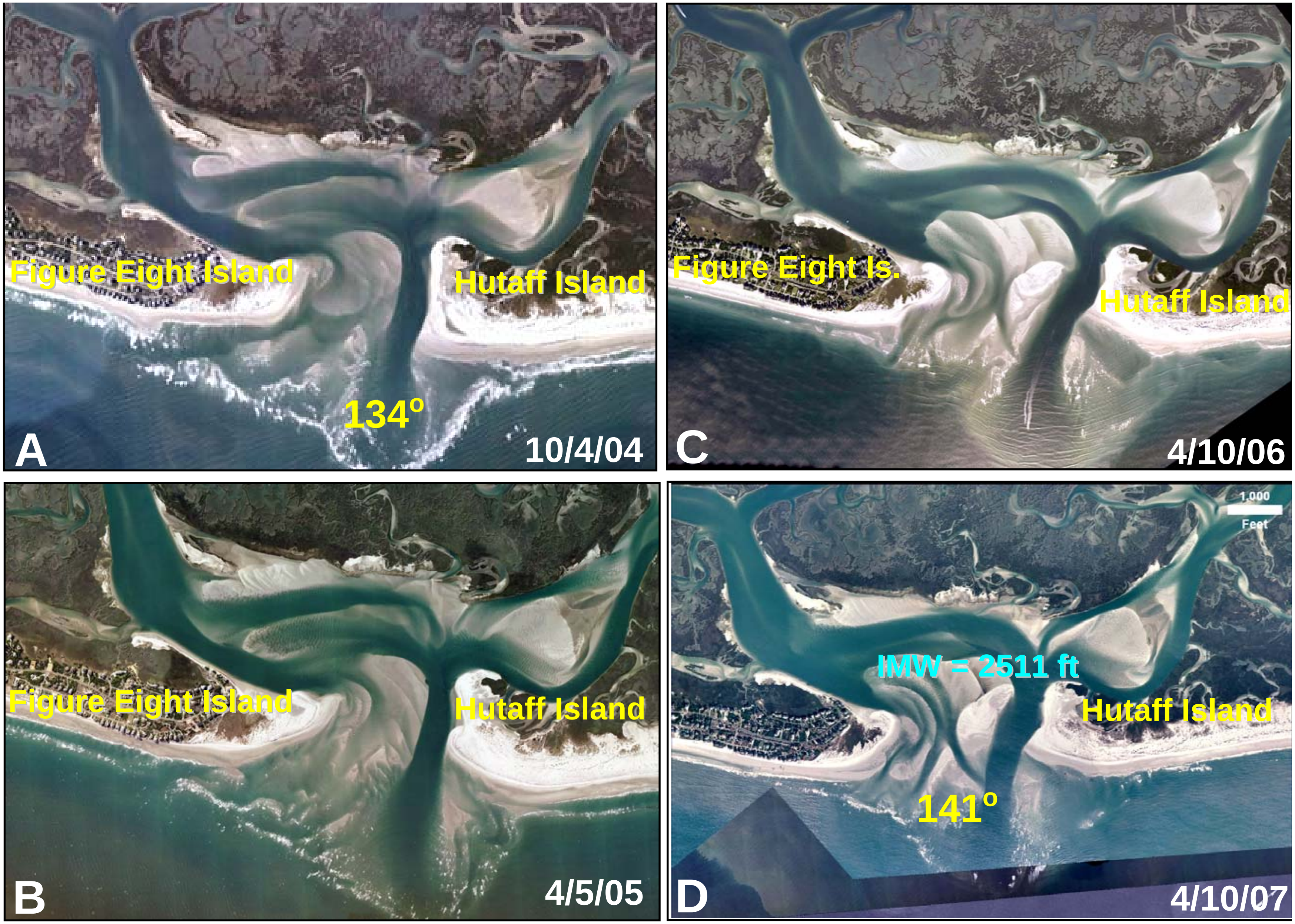

Figure 25. Aerial photographs (**A.** 10/4/04, **B.** 4/5/05, **C.** 4/10/06 and **D.** 4/10/07) depicting recent shoreline and inlet changes. Note the alignment of the ebb channel has remained fairly constant since 2004 while the ebb channel has shifted ~ 415 ft toward F8I (SW) since 2004.

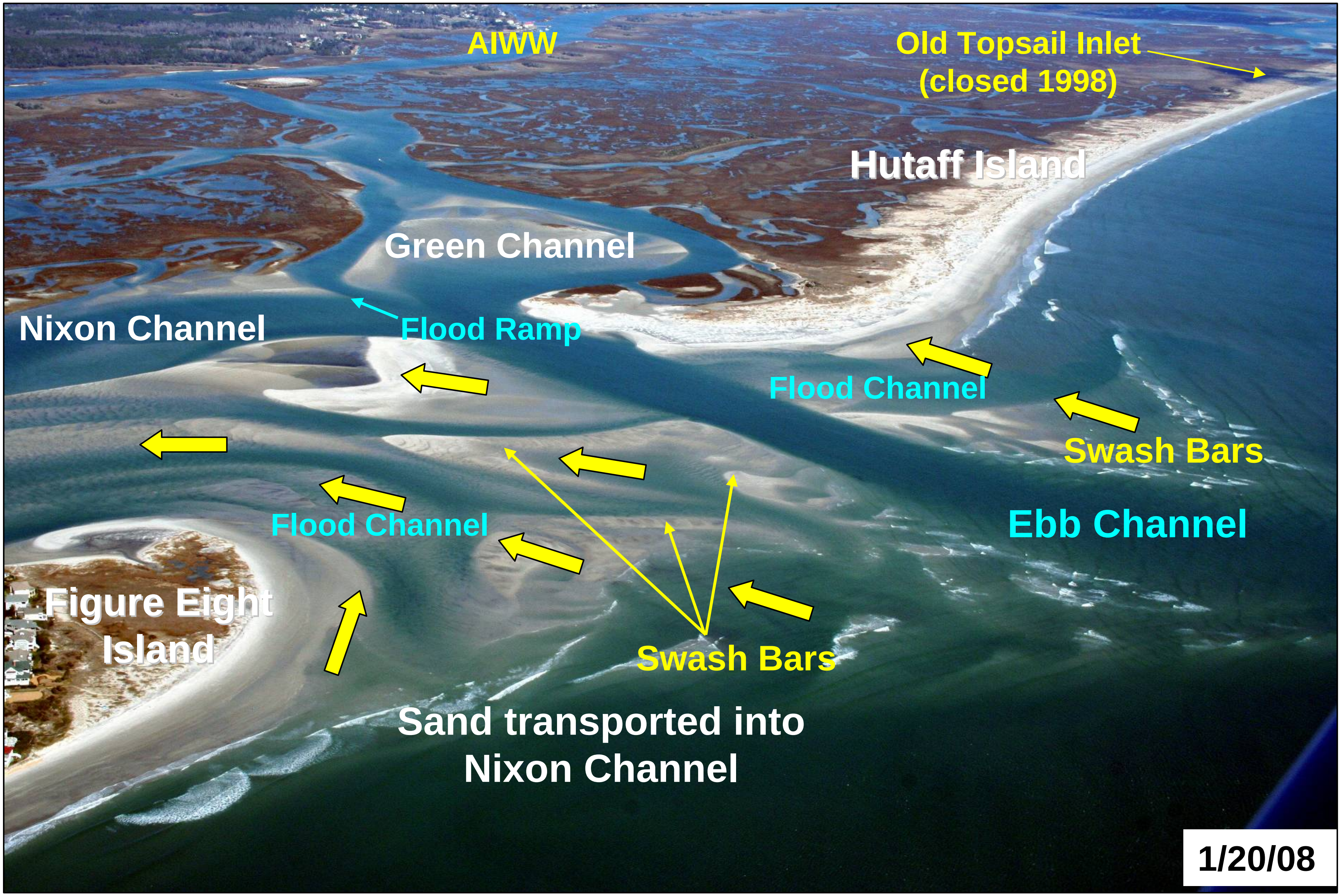

Figure 26. Oblique aerial photograph (1/20/08) of Rich Inlet and portions of the interior channels. Note the asymmetrically shaped ebb tidal delta and the location and alignment of the ebb channel. The wide marginal flood channel that abuts F8I is the major corridor for the transport of large volumes of sand into the estuary and Nixon Channel. Swash bars that formerly attached along F8I currently migrate through the flood channel. Note the attachment of swash bars along HI.

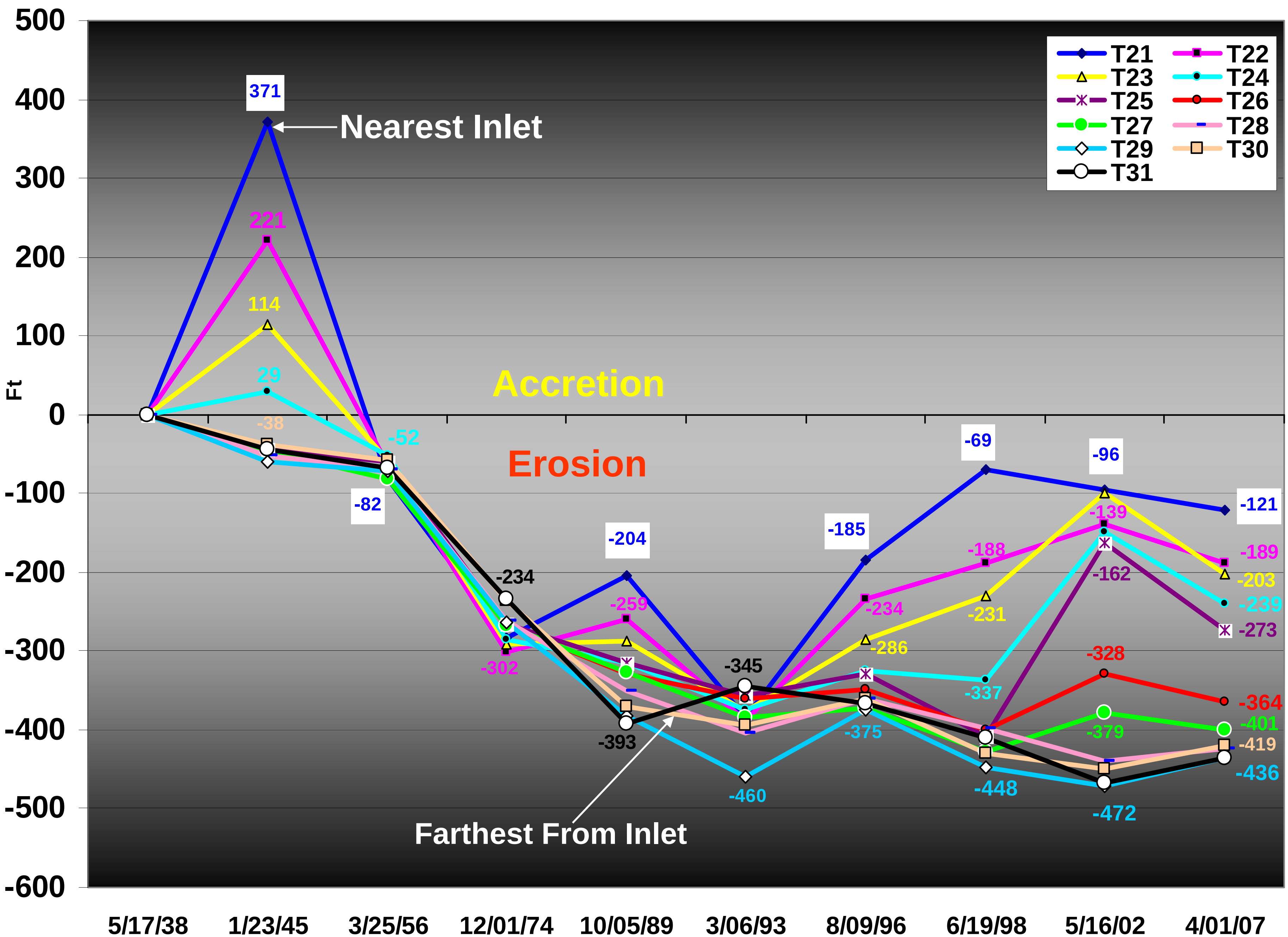

Figure 27. Graph depicting cumulative shoreline changes between 1938 and 2007 along transects T21 to T31 on HI. Note the shoreline at all transects has been characterized by net erosion that ranged from 121 to 436 ft. See Figure 13 for transect locations.

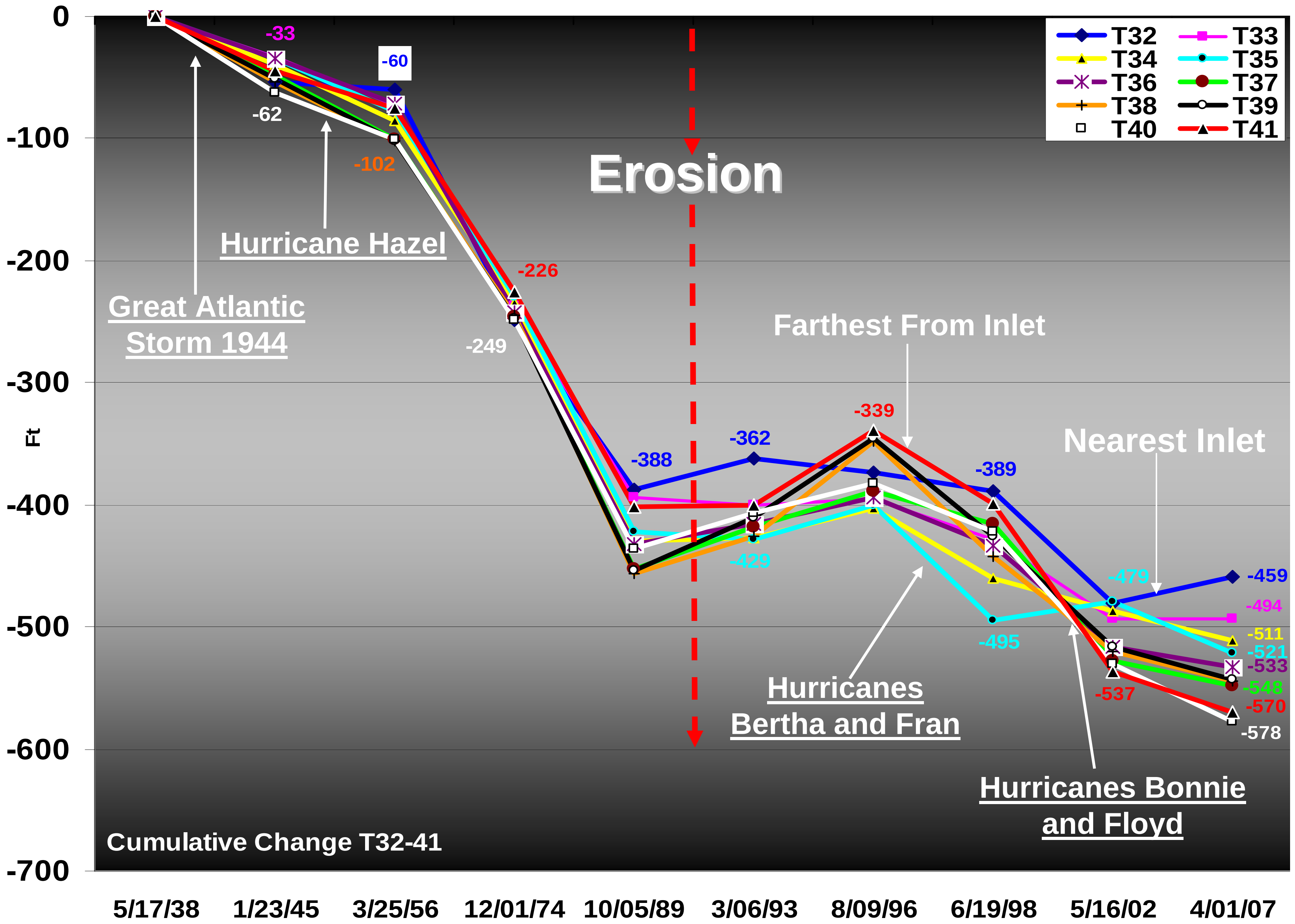

Figure 28. Graph depicting cumulative shoreline changes between 1938 and 2007 along transects T32 to T41on HI. Note the shoreline at all transects has been characterized by net erosion that ranged from 459 to578 ft. See Figure 13 for transect locations.

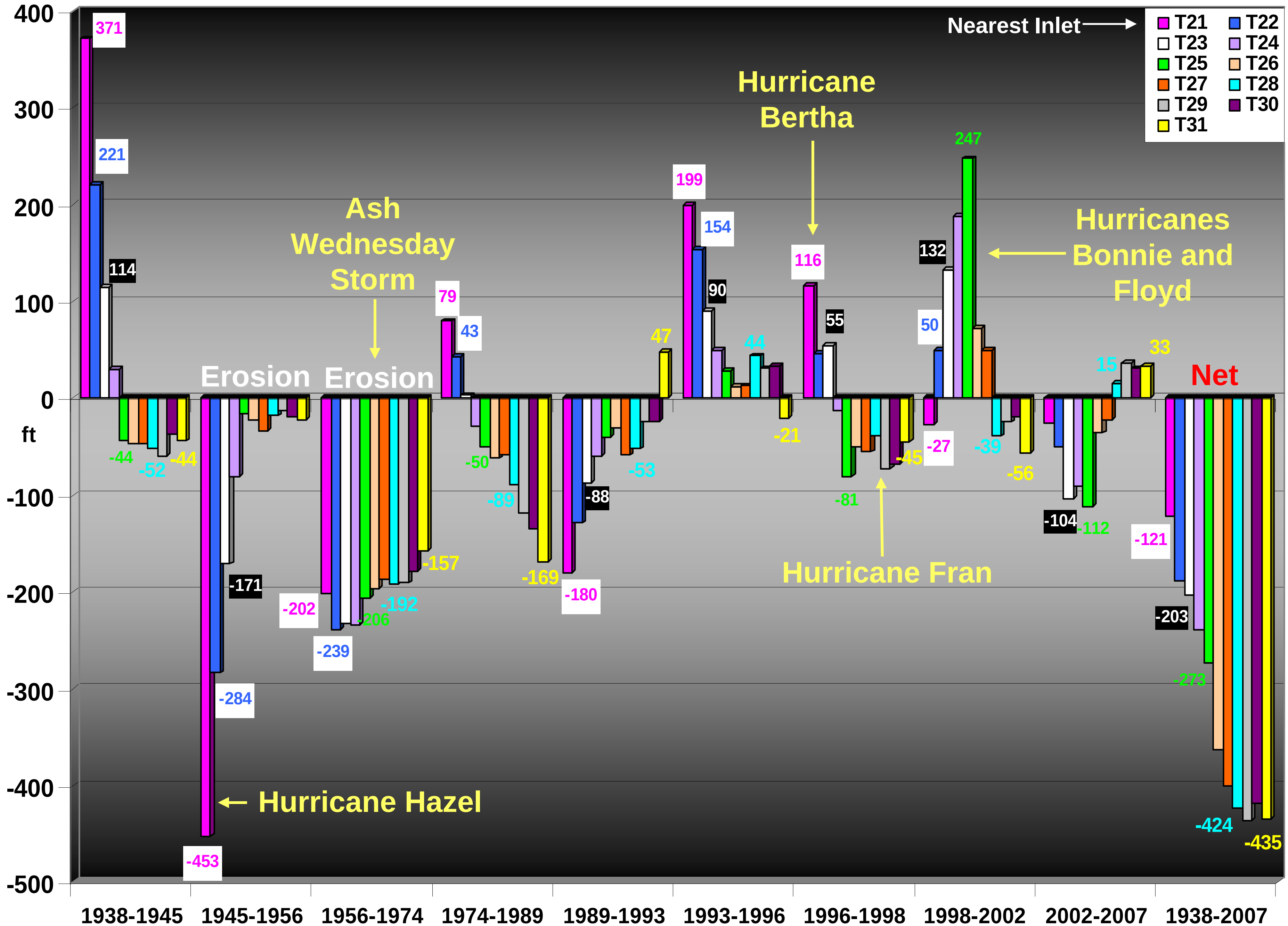

Figure 29. Bar graph depicting short-term shoreline changes along the HI oceanfront between the T21 and T 31 from 1938 to 2007. The entirety of the HI oceanfront shoreline lies within an IHA. Periods of accretion are inlet-related.

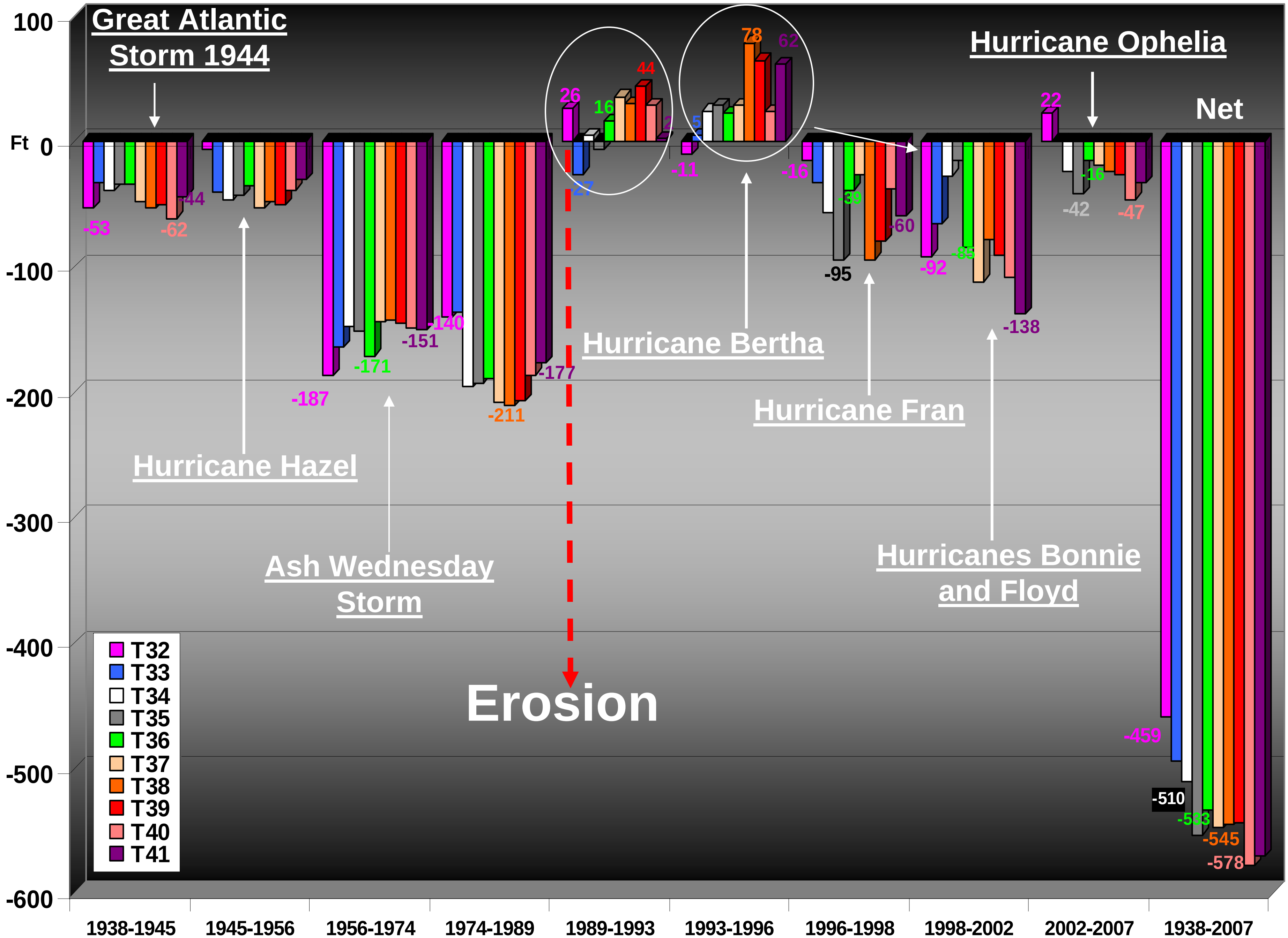

Figure 30. Bar graph depicting short-term shoreline changes along the HI oceanfront between the T32 and T 41 from 1938 to 2007.

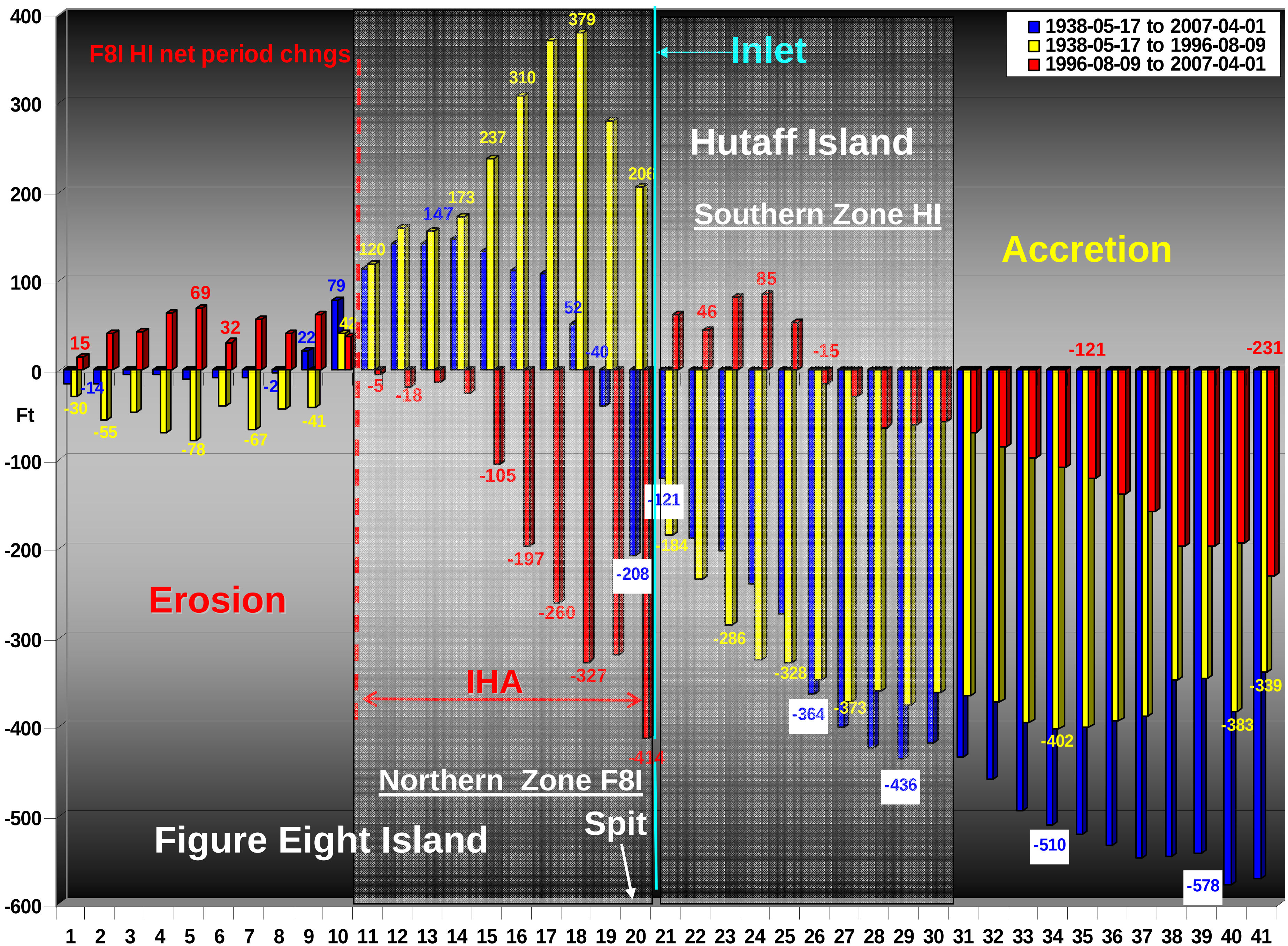

Figure 31. Graph depicting the net shoreline changes along the F8I and HI oceanfront for selected periods of time between 1938 and 2007. A contrasting pattern of shoreline change characterizes F8I (Transects 1-20) and HI (Transects 21 - 41).

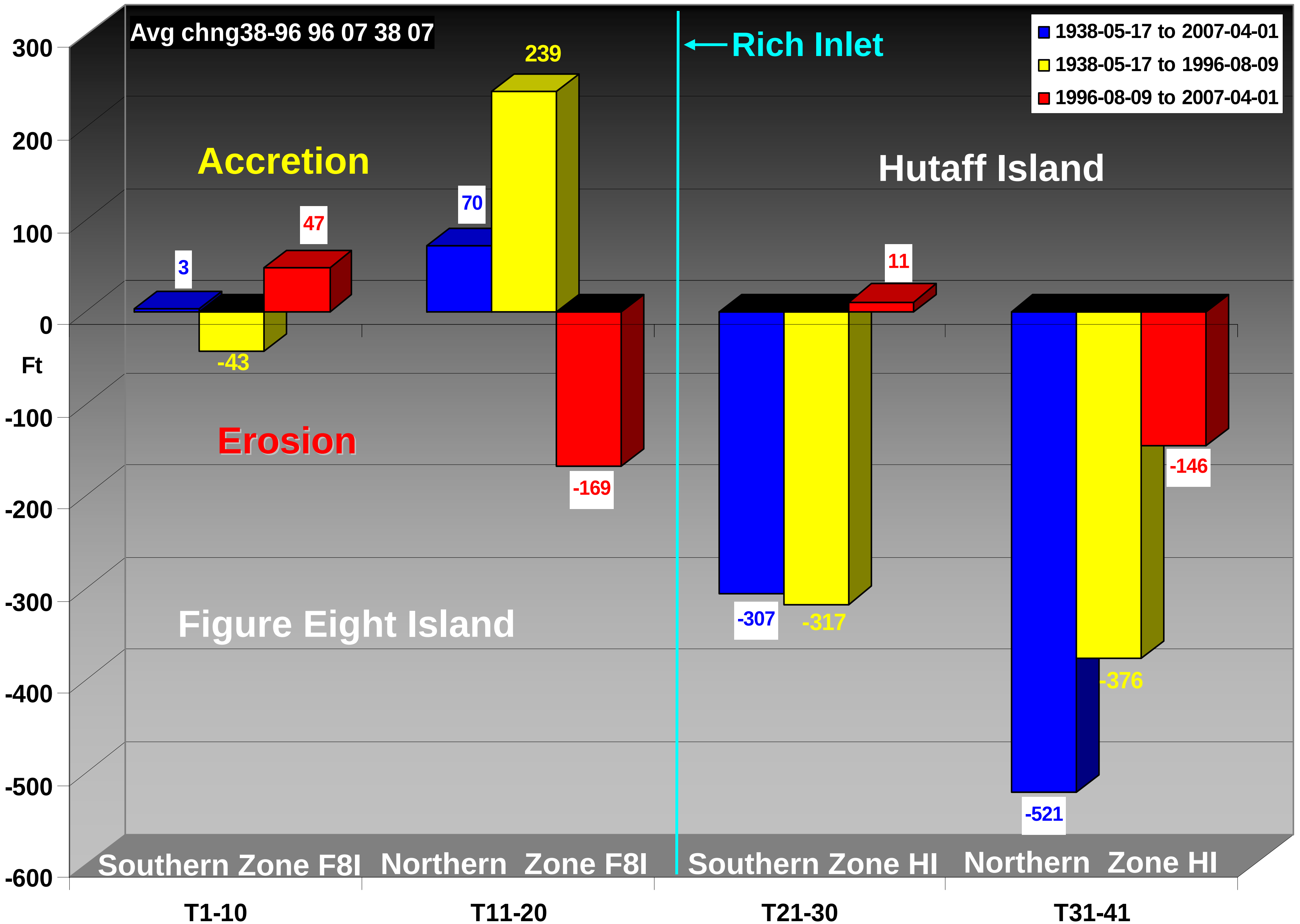

Figure 32. Graph depicting the average net shoreline changes along the F8I and HI oceanfront zones (T1-10, T11-20, T21-31 and T32-41) for selected periods of time between 1938 and 2007. A contrasting pattern of shoreline change characterizes F8I (Transects 1-20) and HI (Transects 21 - 41).

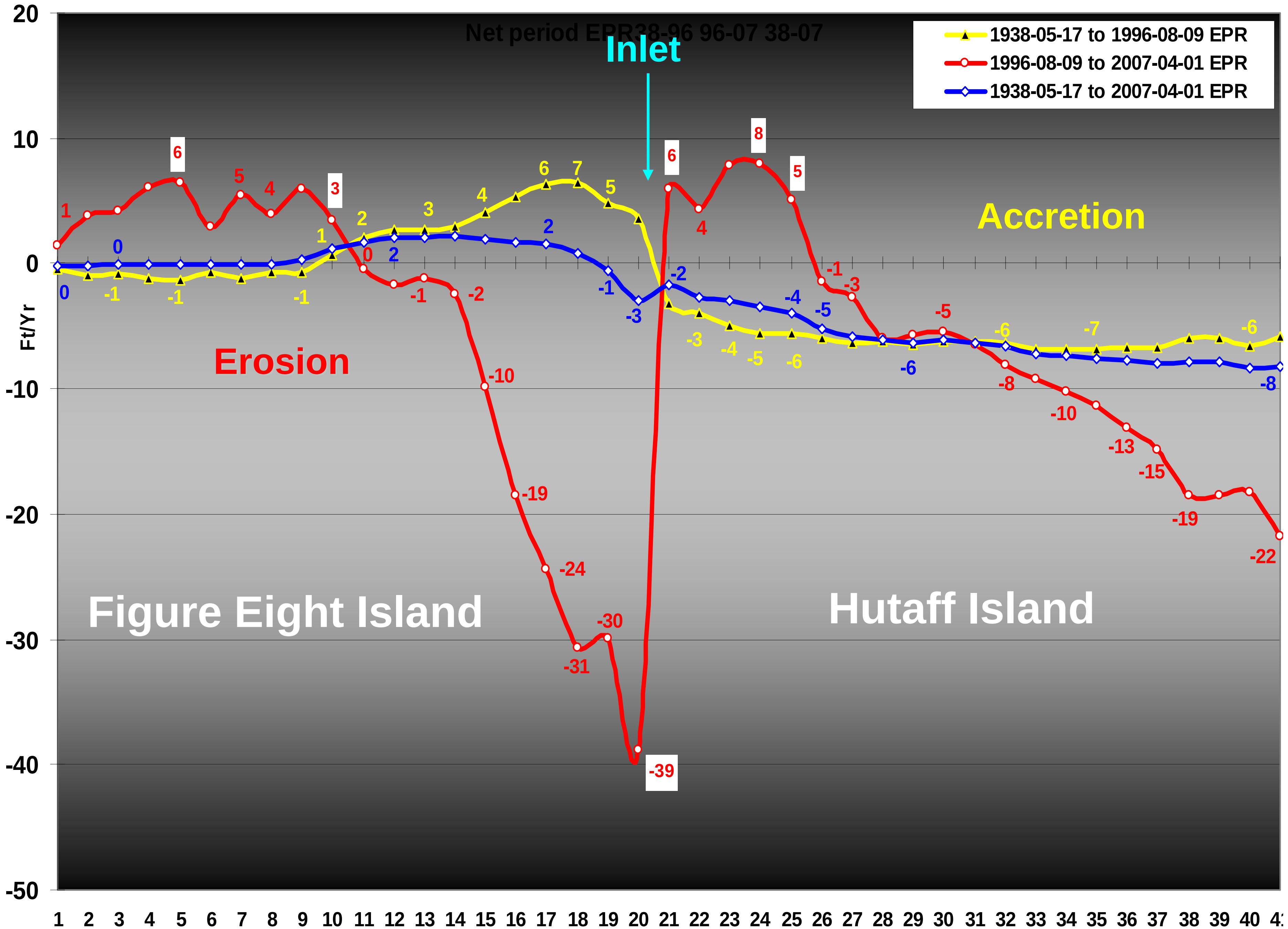

Figure 33. Graph depicting the shoreline change rates (end-point rate) for all transects along F8I and HI for various periods of time between 1938 and 2007.

Figure 34. Oblique aerial photograph (10/11/04) illustrating the oceanfront conditions along northern end of F8I, the interior channels and location of the estuarine erosion hot-spot (light blue dashed line box).

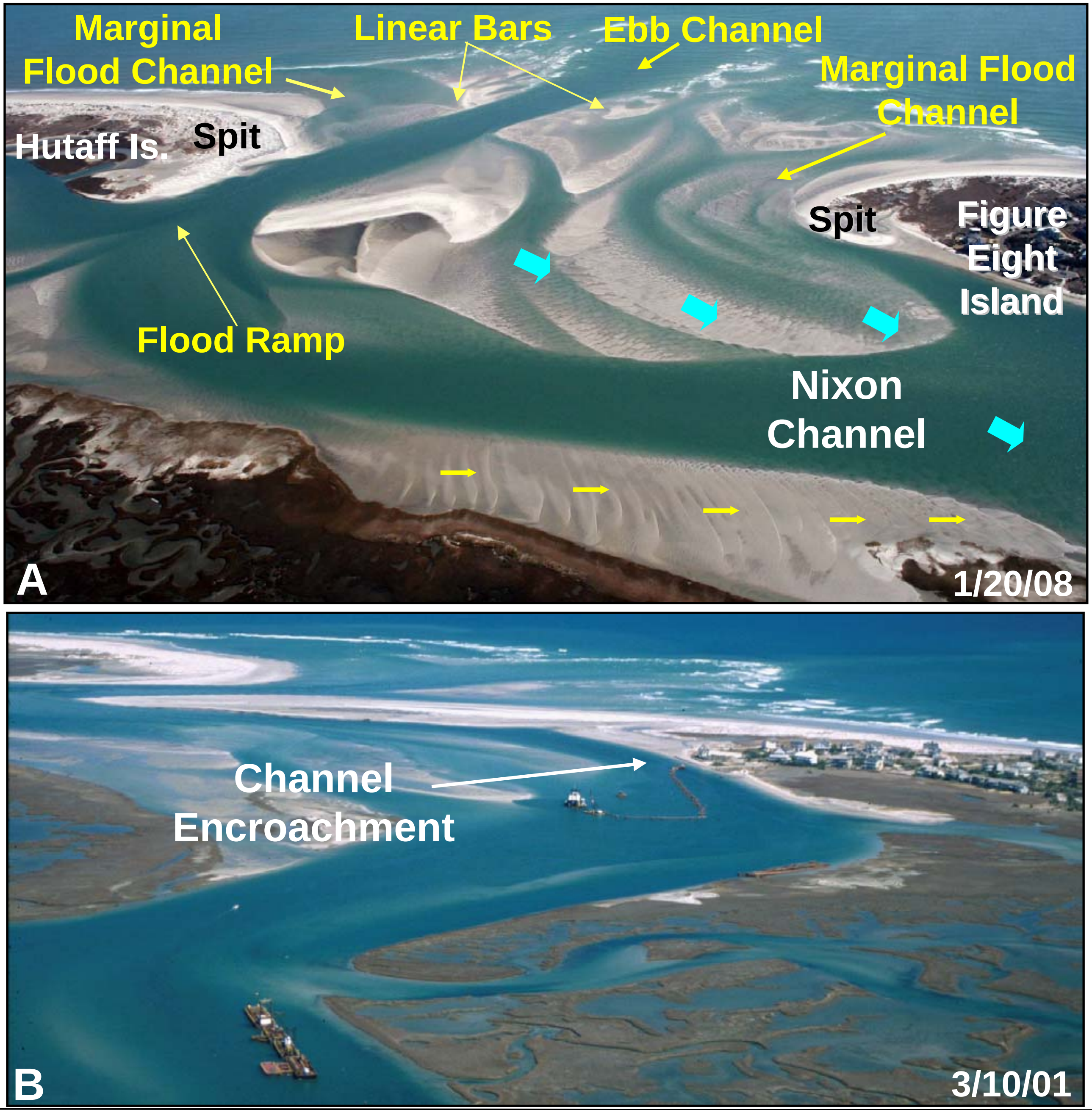

Figure 35. Aerial photographs depicting migration of bed forms (sand bars) and subsequent shoaling of the navigation channel. **A.** Seaward view (1/20/08) of the ebb and flood deltas and the multitude of bed forms. The majority of the sand packages are moving into Nixon Channel. **B.** Seaward view (3/10/01) of Nixon Channel depicting dredging operations associated with the 2001 nourishment project.

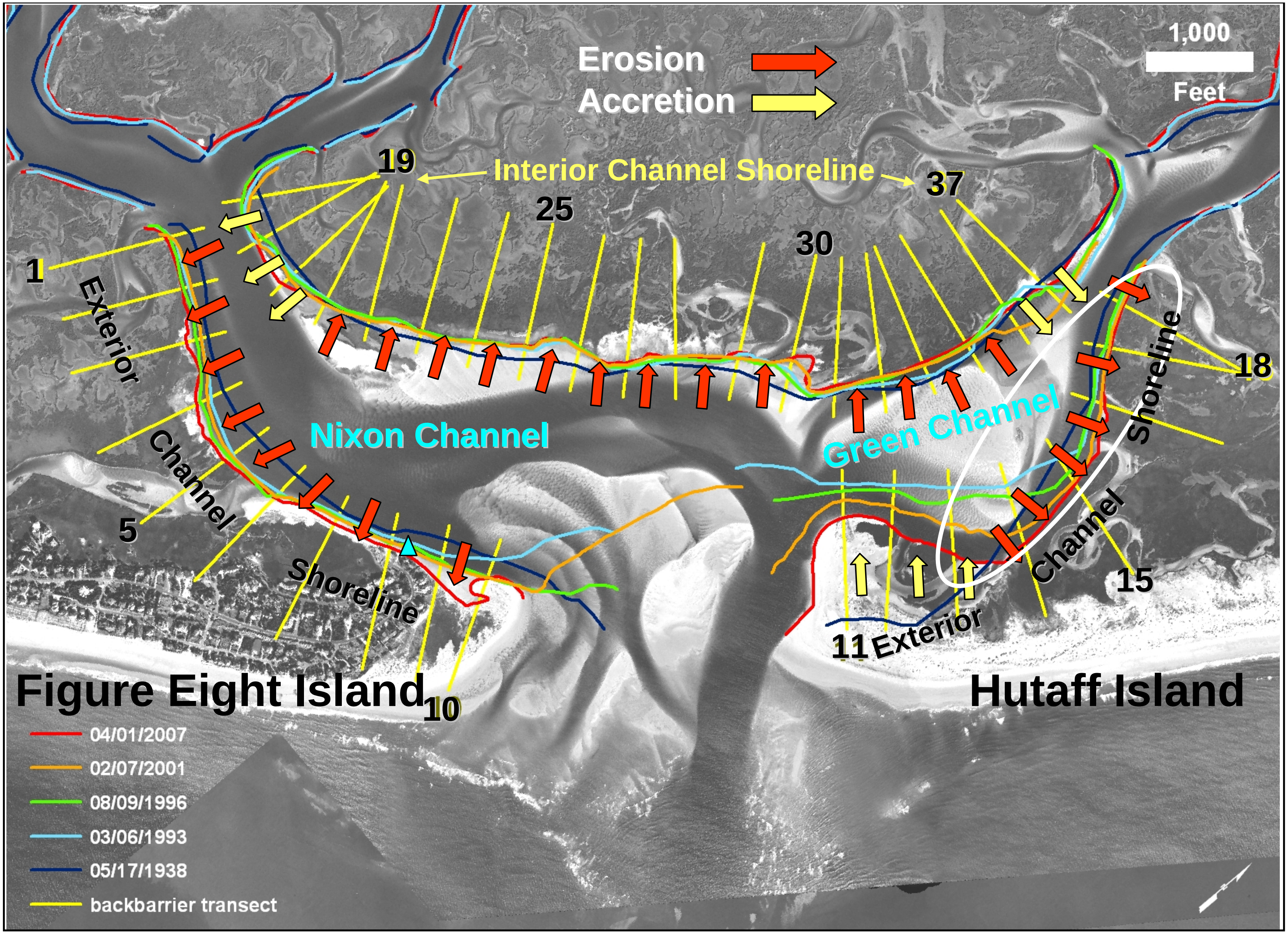

Figure 36. Aerial photograph (2007) depicting the location of transects along the margins of Green and Nixon Channels and the positions of the estuarine channel margins (selected years 1938-2007). Red colored arrows denote erosion while yellow arrows denote accretion.

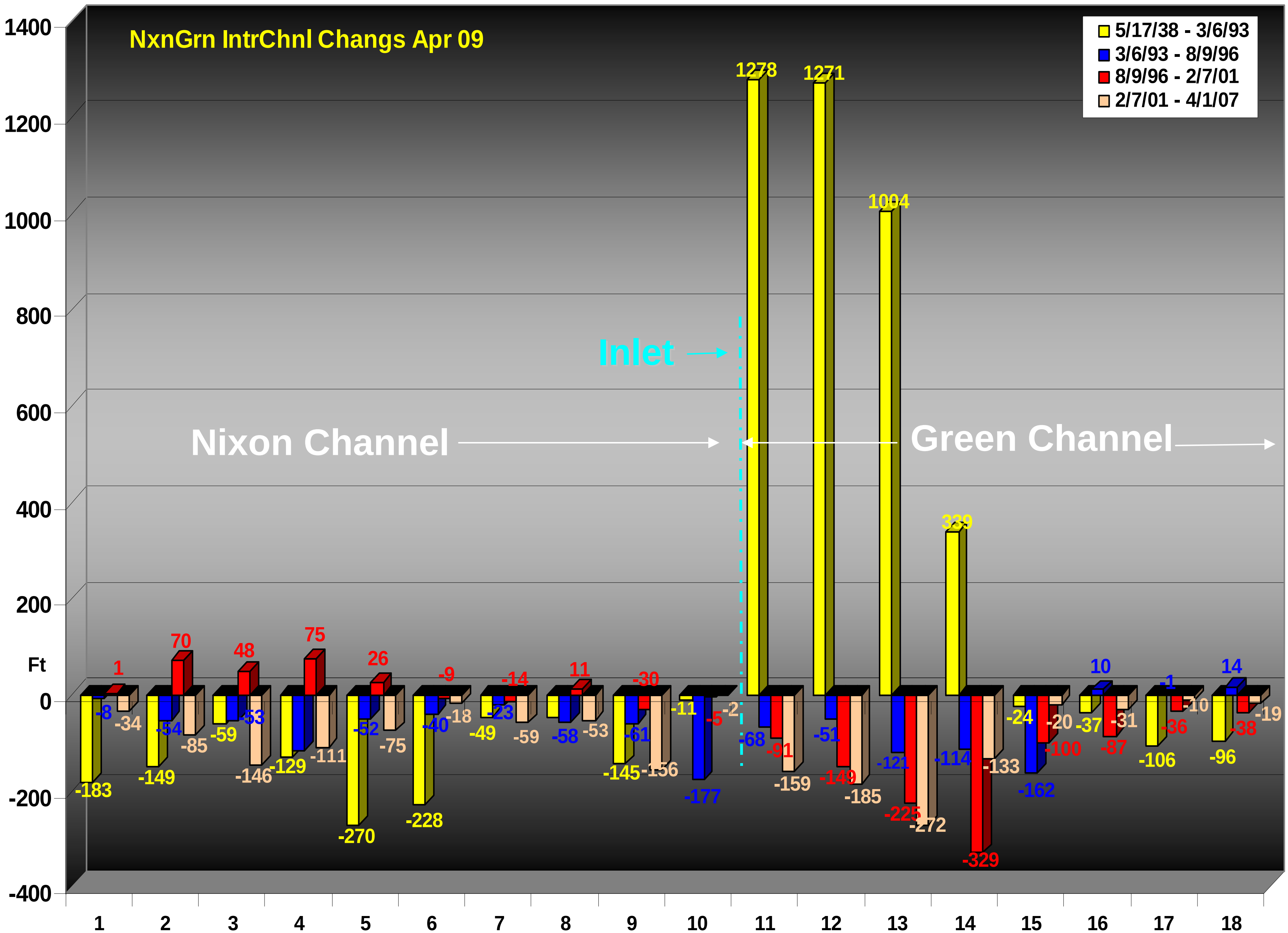

Figure 37. Bar graph illustrating net shoreline changes for various periods between 1938 and 2007 along the external (seaward) channel margin from T1 to T18. See Figure 36 for transect locations.

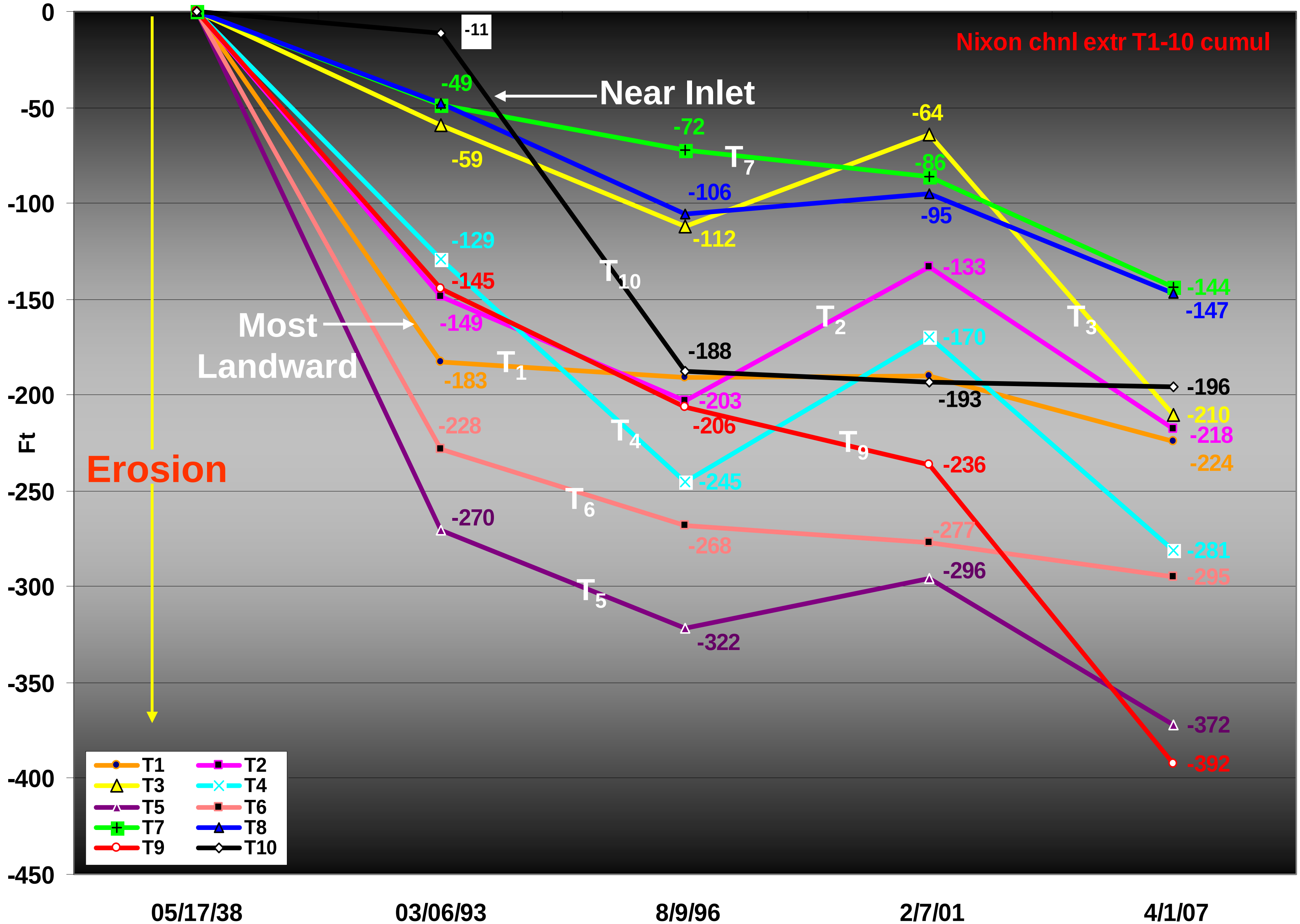

Figure 38. Graph depicting the cumulative shoreline change along the Nixon Channel exterior (seaward) margin. Note X axis is not to scale. See Figure 36 for location of transects along F8I channel margin.

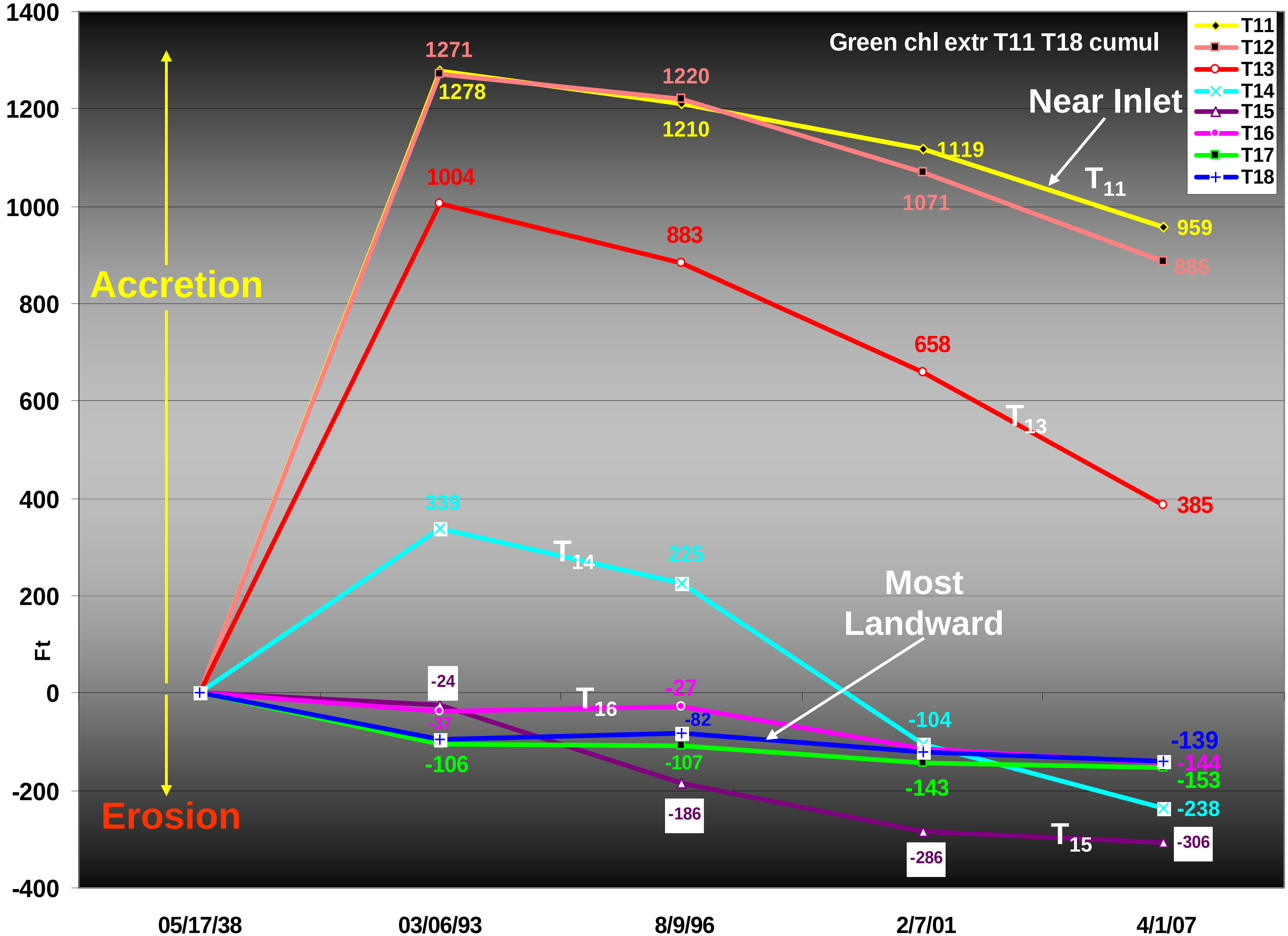

Figure 39. Graph depicting the cumulative shoreline change along the Green Channel exterior (seaward) margin. Note X axis is not to scale. See Figure 36 for location of transects along HI channel margin.

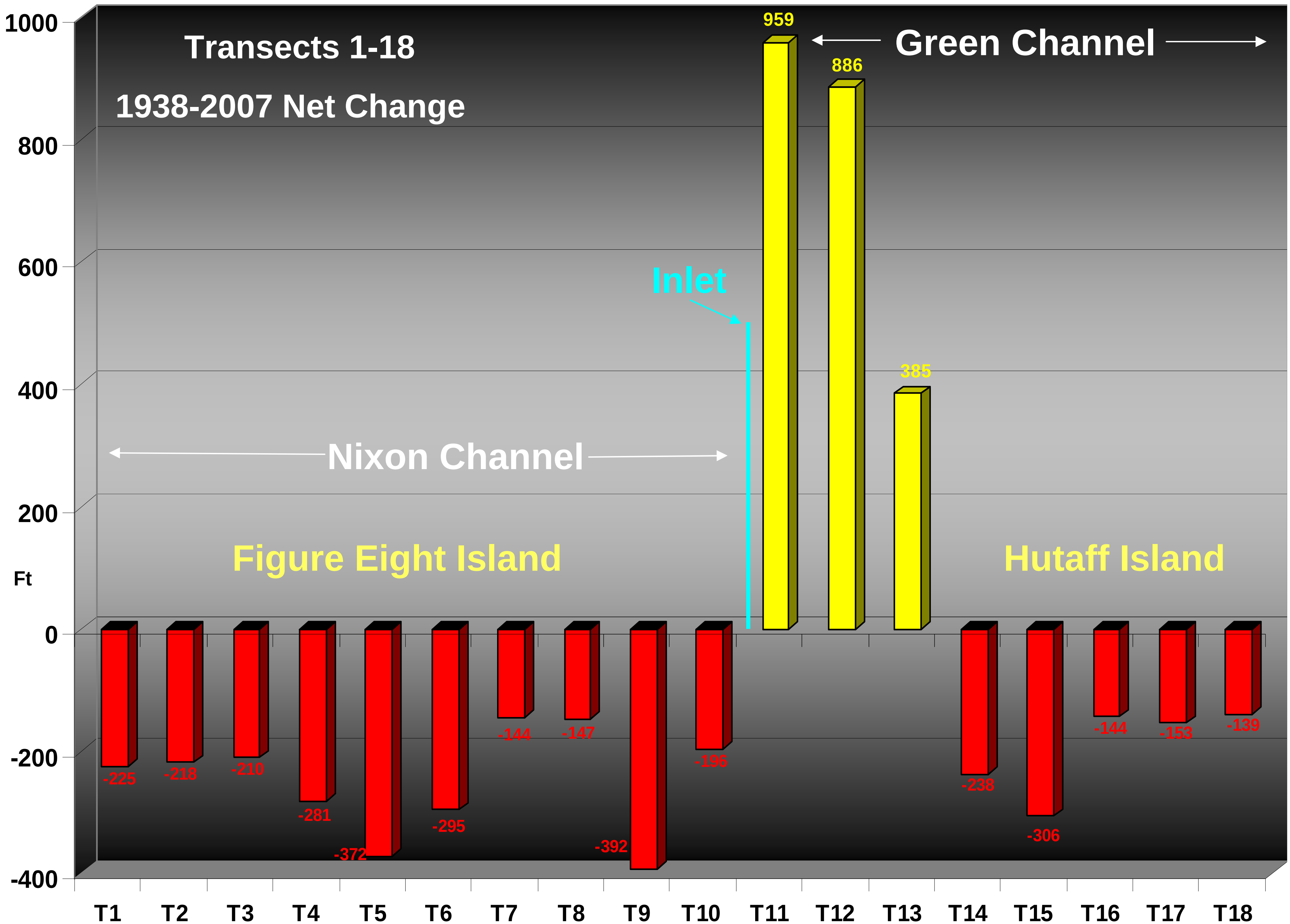

Figure 40. Bar graph depicting net shoreline change along external (seaward) margin (T1-T18) of Green and Nixon Channels from 1938-2007.

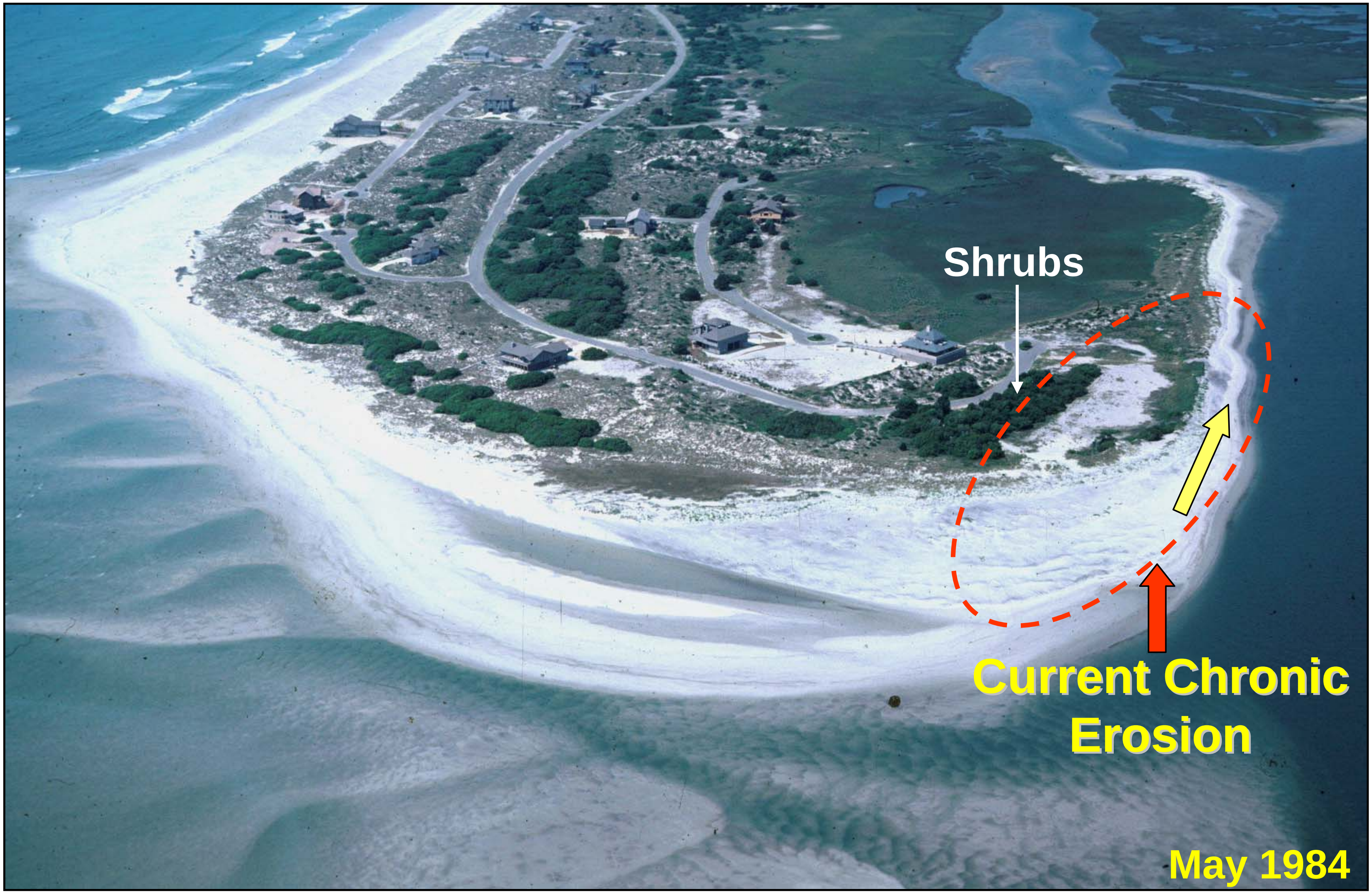

Figure 41. Oblique photograph (5/84) of the current erosion hot-spot along Nixon Channel. Note the relatively wide estuarine beach, dune field and shrubs. Also note the incipient spit development (yellow arrow).

Figure 42. Photographs depicting erosion and shoreline retreat along Nixon Channel shoreline between 9/99 and 2/08. **A.** Seaward view (9/99) of eroding channel margin shoreline. Thin veneer of sand mantles offshore peat subcrop. **B.** Seaward view (11/02) of peat exposure and shrub stumps. **C.** Seaward view (10/06) of peat exposure and sand accumulation due to wave swash. **D.** Seaward view (2/08) of newly emplaced sand bags.

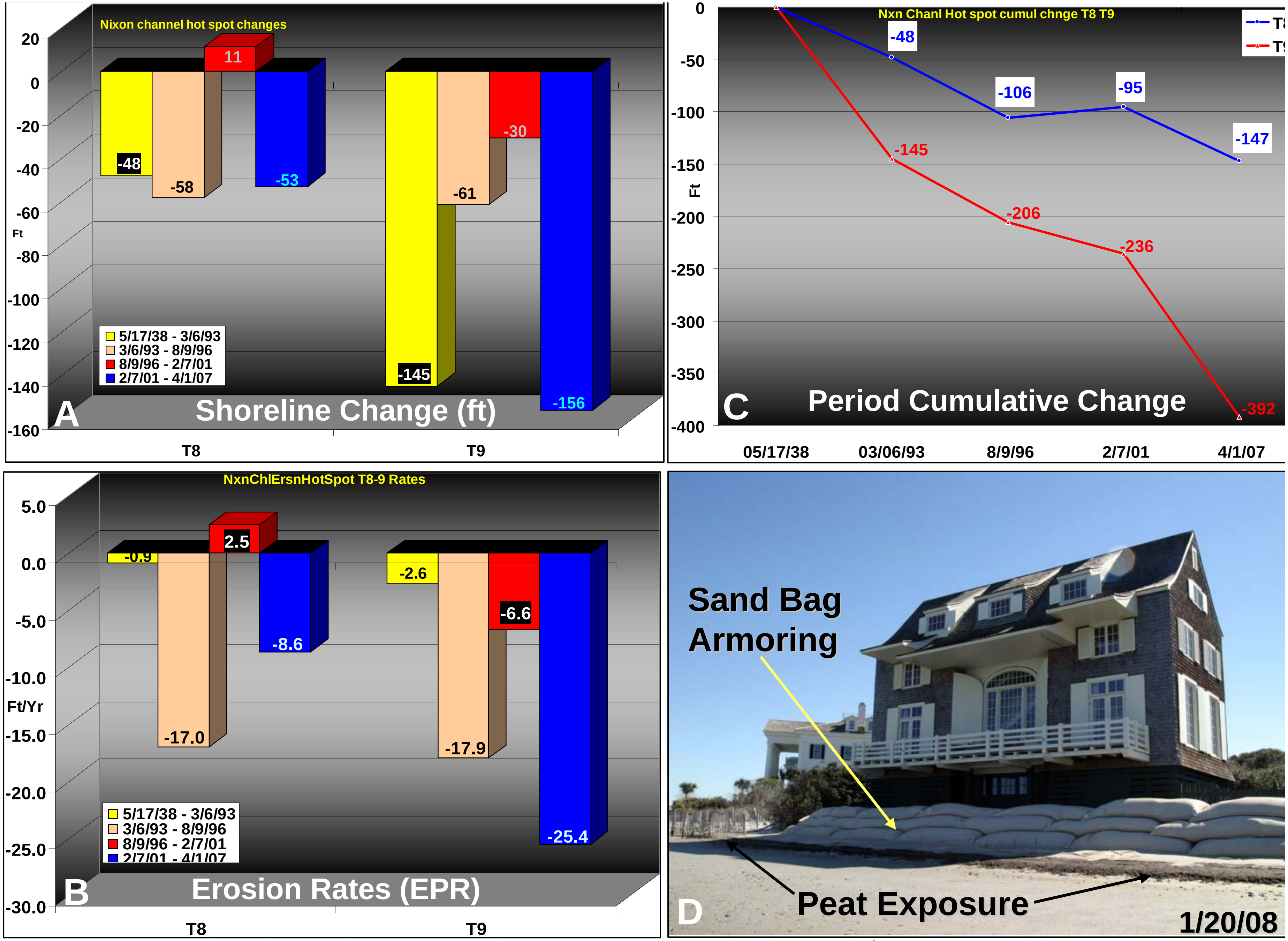

Figure 43. Estuarine channel erosion hot-spot (T8-9) along Nixon Channel. **A.** Shoreline graph for various periods between 1938-2007. **B.** Graph depicting T8-9 erosion rates (EPR). **C**. Graph of cumulative shoreline changes. **D**. Photograph (1/20/08) depicting armored shoreline and extensive peat exposure along low tide beach.

Figure 44. Photographs depicting erosion along a portion of the Nixon Channel shoreline. **A.** Landward view (5/3/07) illustrating erosion of the upland area. **B.** Landward view (5/3/07) of peat exposure along intertidal beach, stranded walkover and slumping of "sod". **C.** Seaward view (2/19/08) of retreating shoreline imaged in "A" and "B". **D.** Landward view (2/19/08) of structure in " A" and "C" and small scarp (red arrow) that extends toward adjacent home that is fronted by sand bags and a peat exposure.

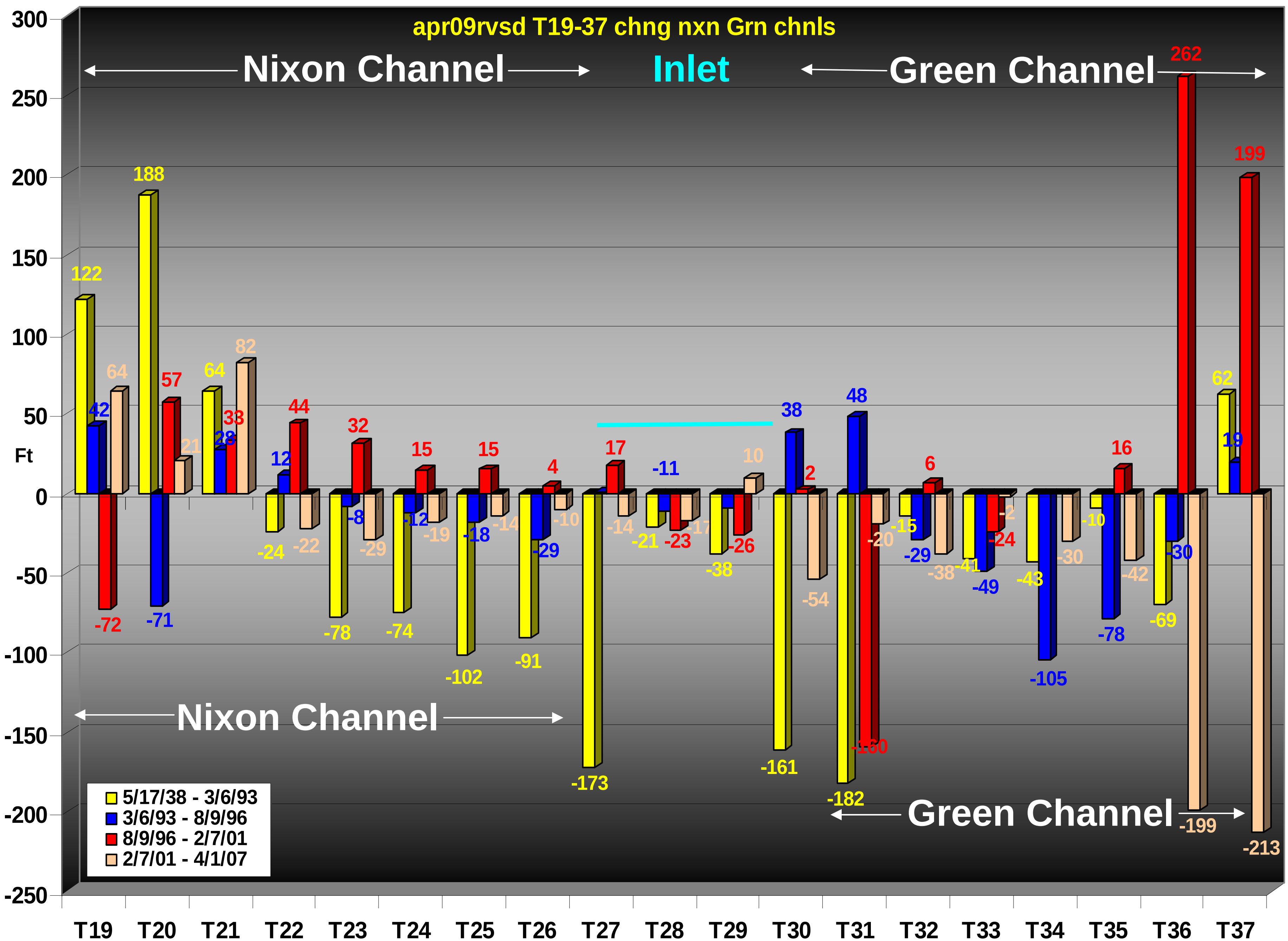

Figure 45. Bar graph illustrating net shoreline changes for various periods between 1938 and 2007 along the internal (landward) channel margin from T19 to T37. See Figure 36 for transect locations.

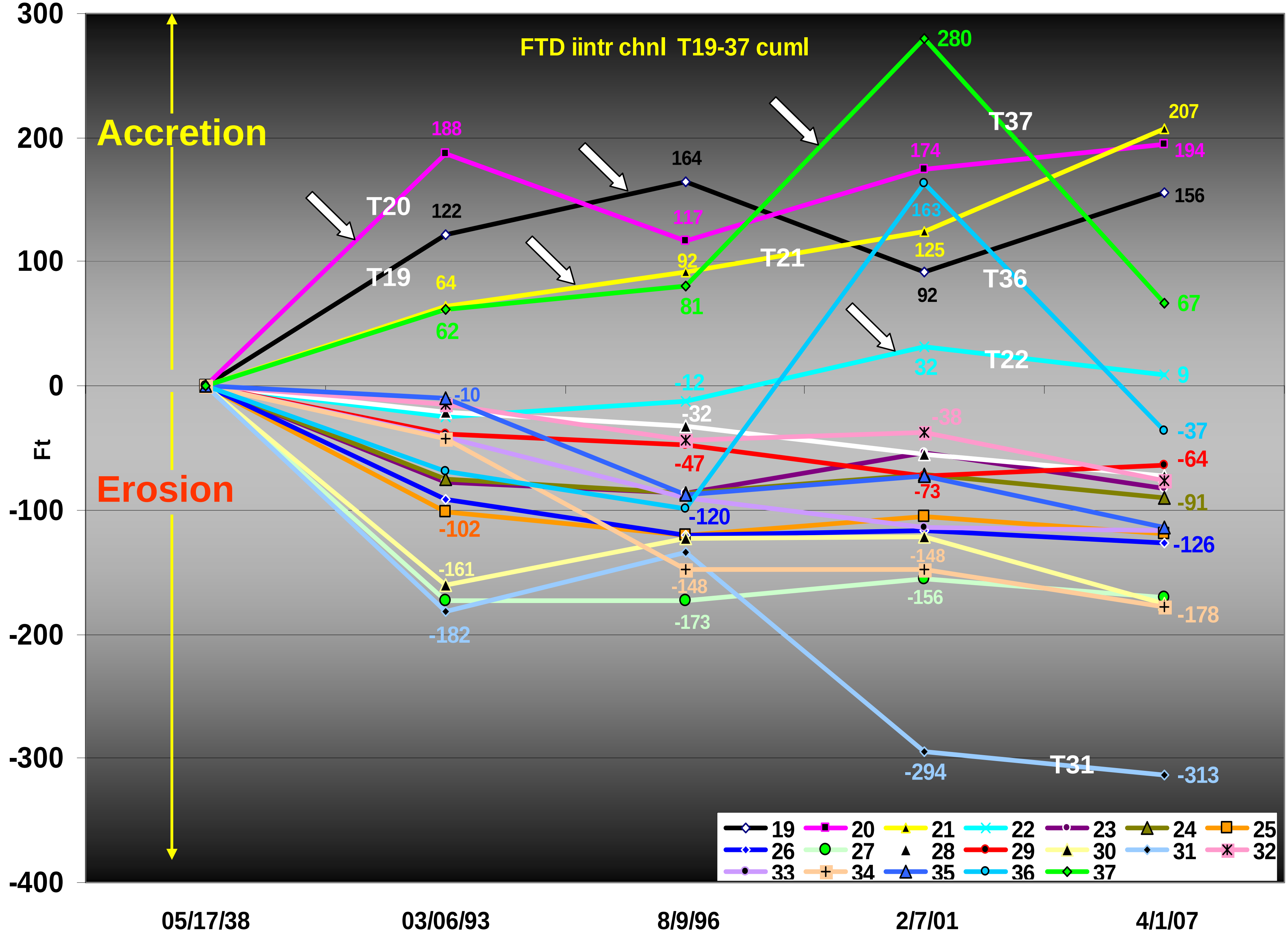

Figure 46. Graph depicting the cumulative shoreline change along Green and Nixon Channel's interior (landward) margin. Note X axis is not to scale. See Figure 36 for location of transects along flood tidal delta margin. White arrows represent transects where net accretion has occurred.

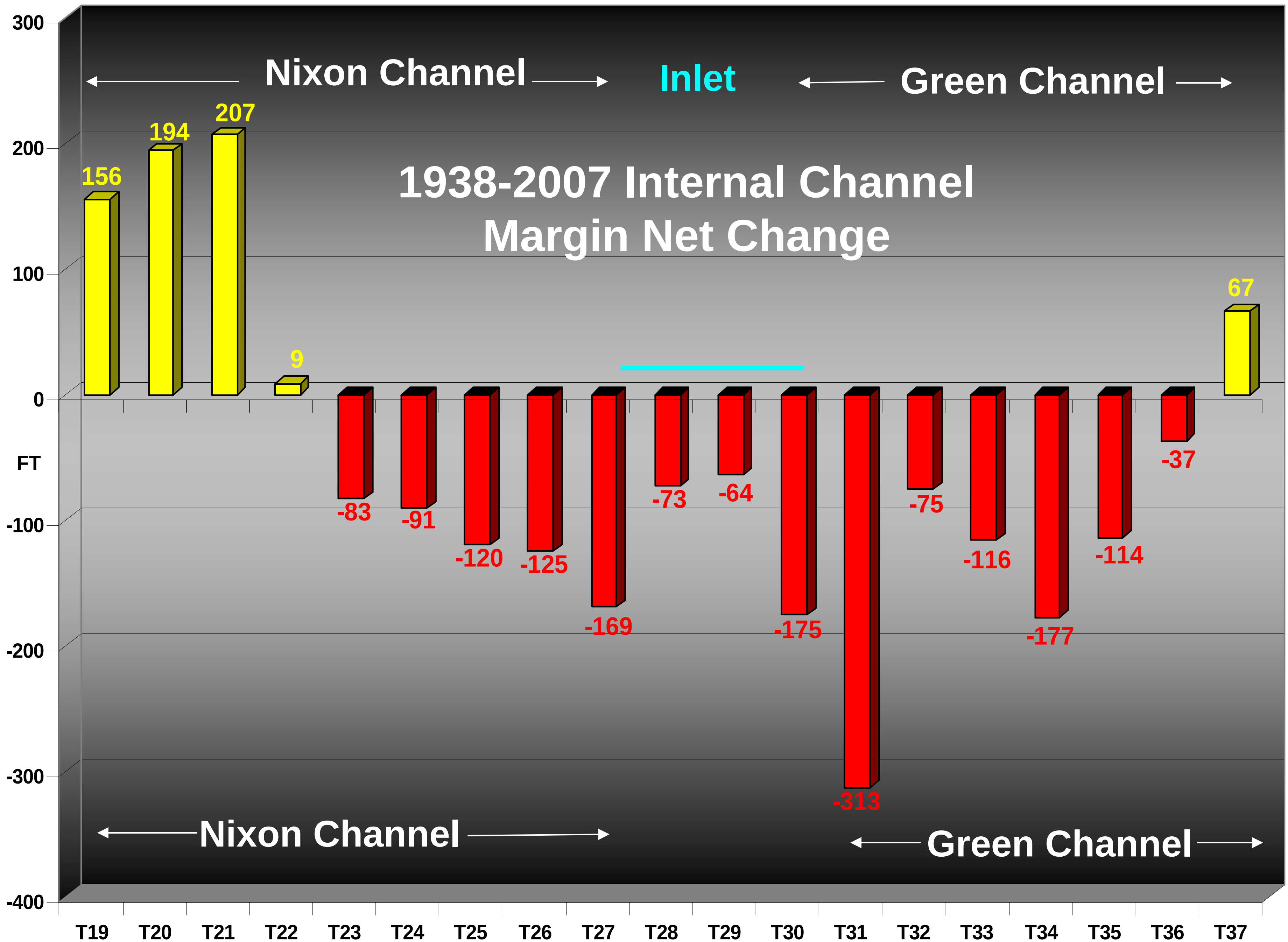

Figure 47. Bar graph illustrating net shoreline change along the internal channel margin reach between T19 and T37 during the period from 1938-2007. See Figure 36 for transect locations

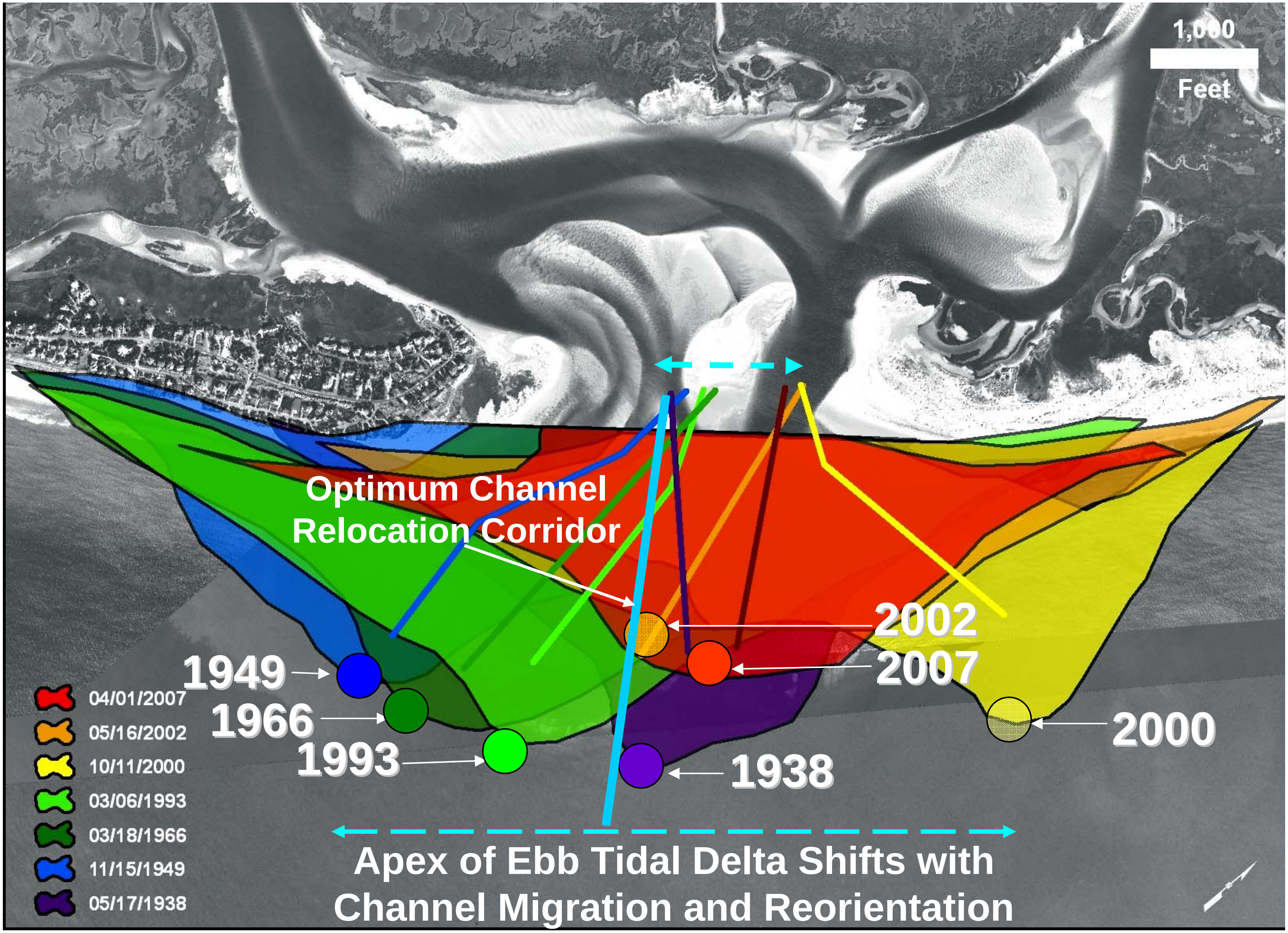

Figure 48. Aerial photograph (2007) of Rich Inlet depicting the shapes of various ebb tidal deltas and ebb channel positions for selected years between 1938 and 2007.Colored circles represent the ebb delta apex.

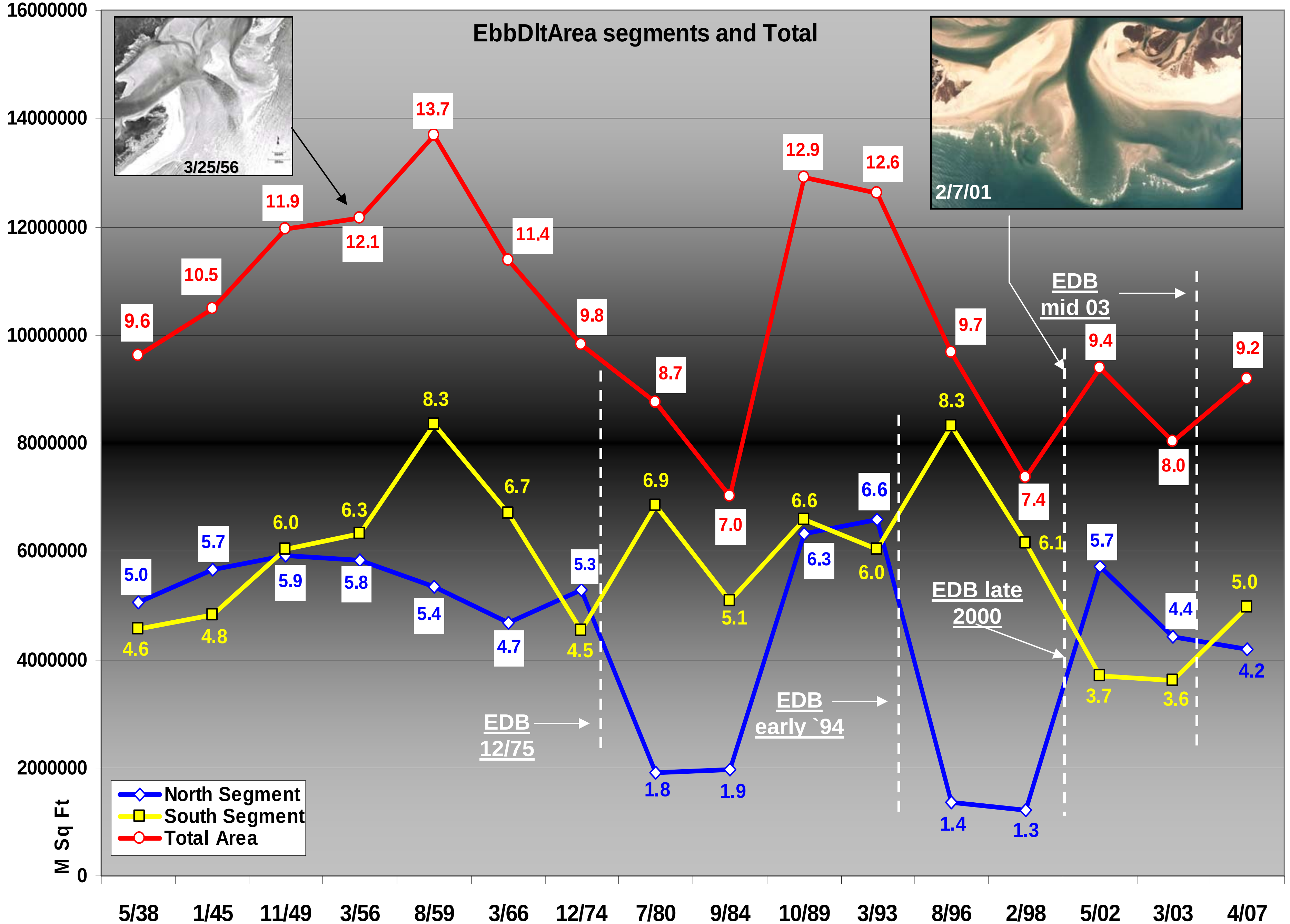

Figure 49. Graph depicting the area of the ebb delta segments (A [North] and B [South]) and total ebb-tidal area in millions of square feet (Sq. Ft.) since 1938. Ebb delta breaching events (EDB) are referenced by dashed white colored lines.

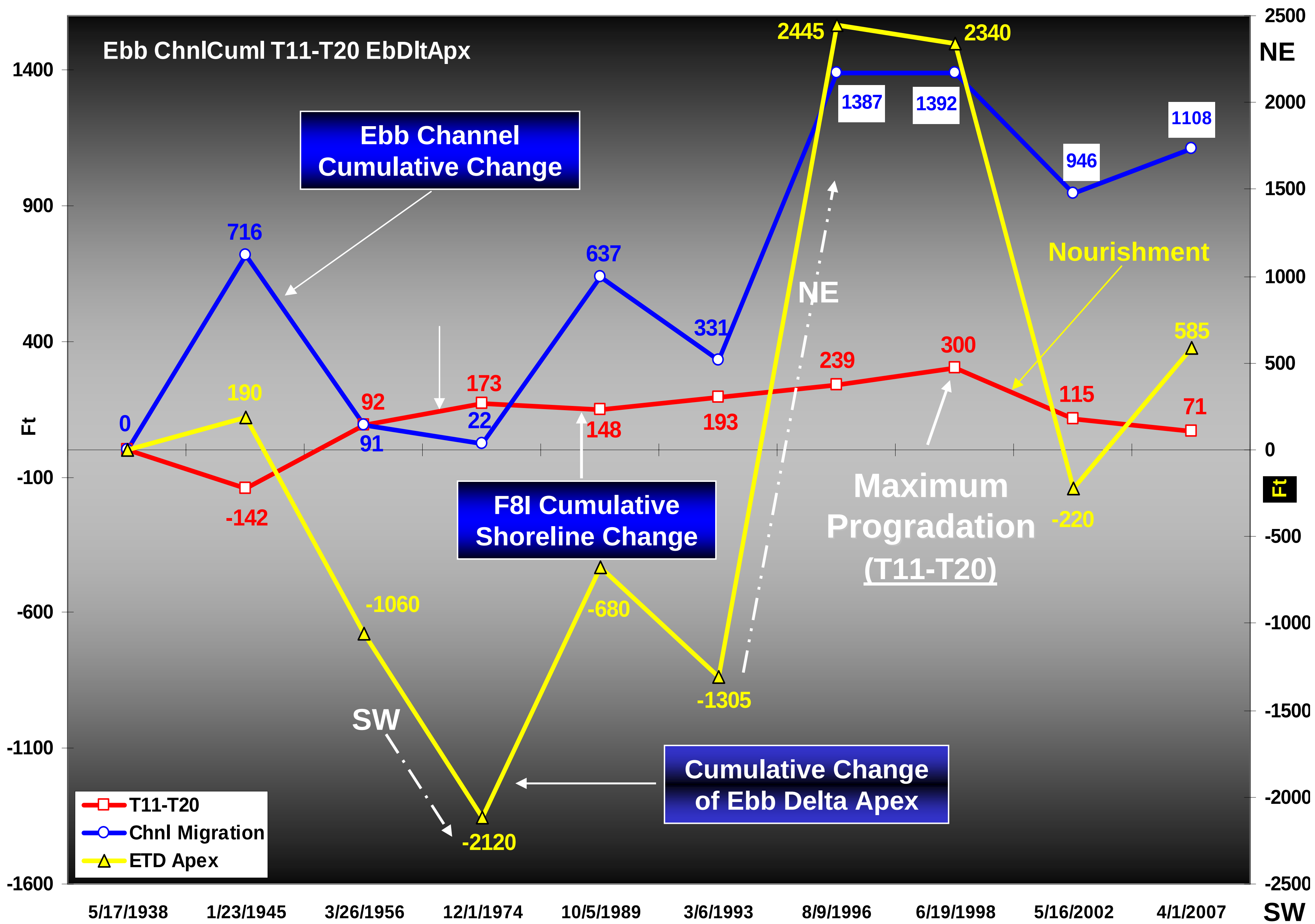

Figure 50. Line graph depicting cumulative migration of the ebb channel, cumulative shoreline change (Avg. T11-20) on Figure Eight Island and cumulative change of the ebb delta apex between 1938 2007.

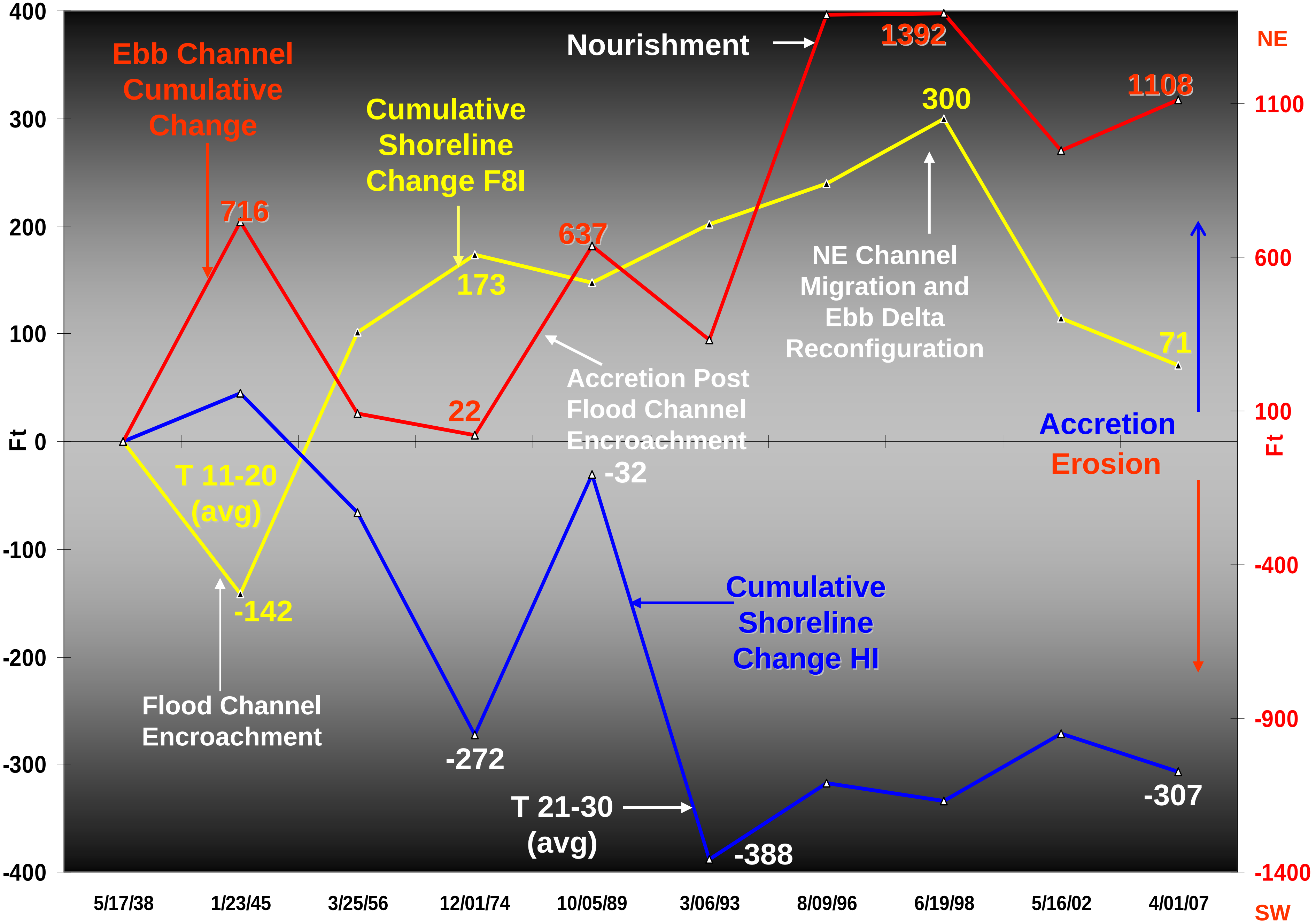

Figure 51. Graph comparing F8I and HI cumulative average oceanfront shoreline change (inlet-influenced reach) and ebb channel mid-point migration.

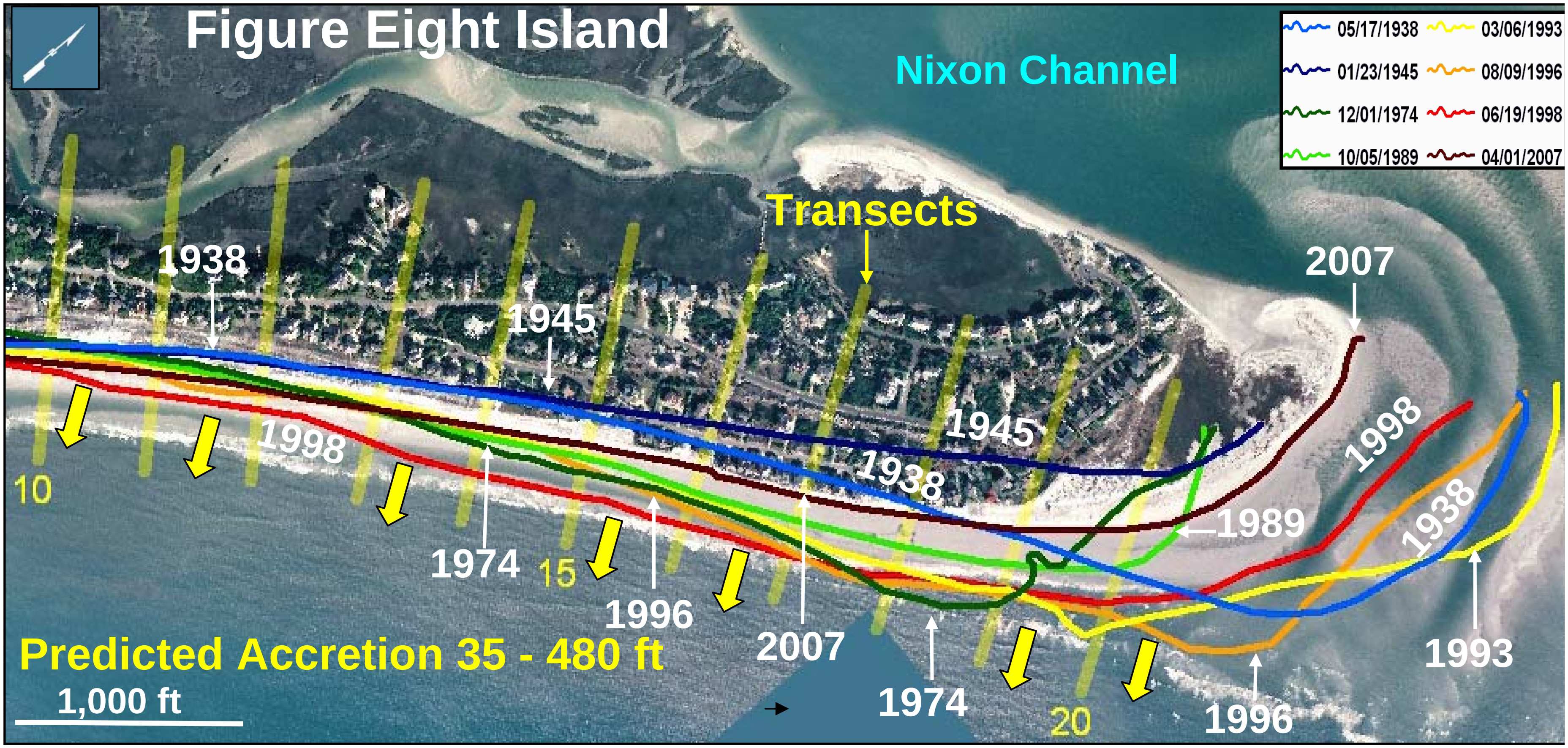

Figure 52. Map depicting the various positions of the historic shorelines within the Inlet Hazard Area (IHA) along the Figure Eight Island oceanfront between 1938 and 2007. Note the position of the 1945 shoreline. Base aerial photograph dates from 2007.

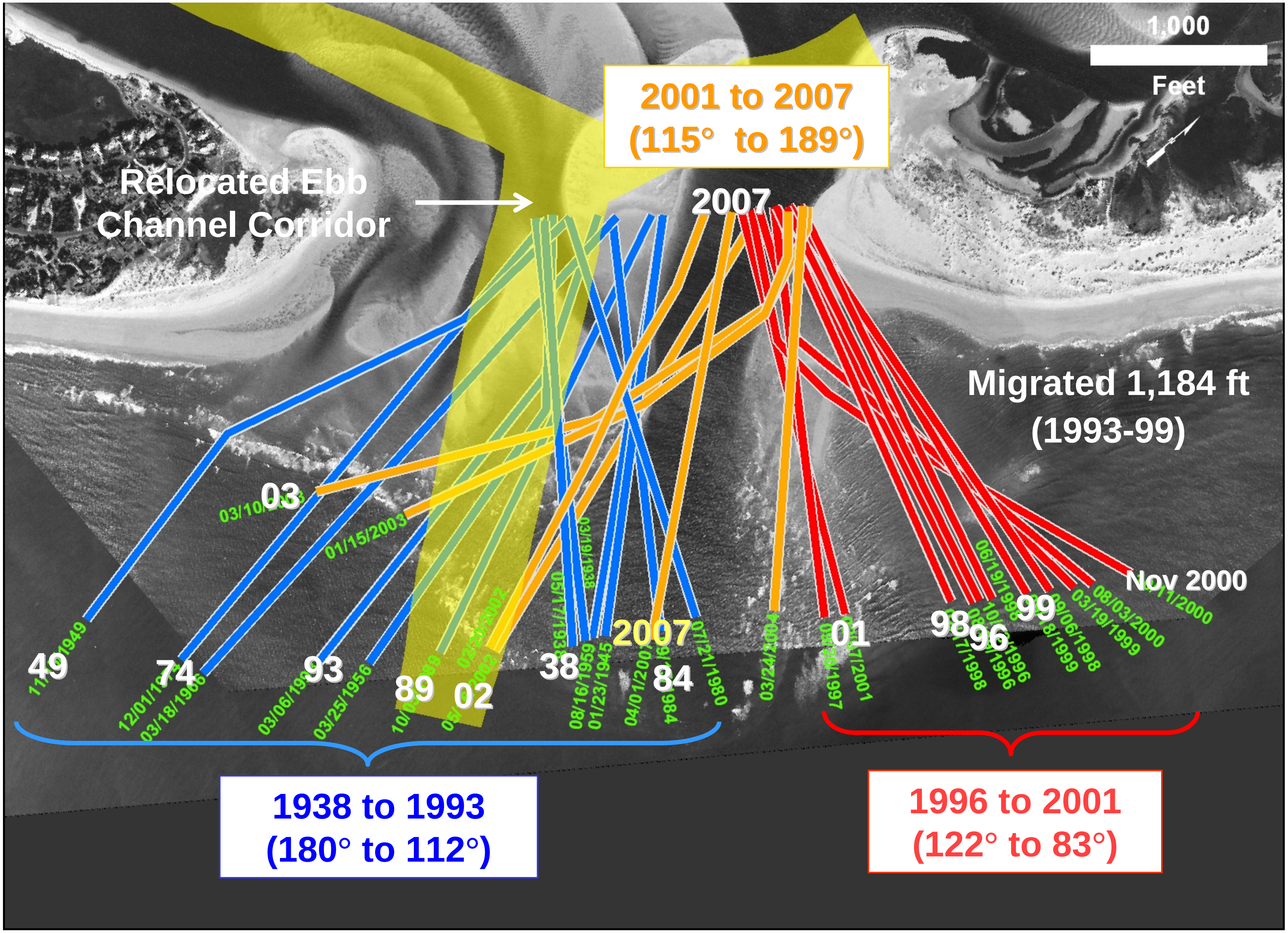

Figure 53. Aerial photograph mosaic (2006) depicting position and alignment of the ebb channel between 1938 and 2007. The yellow polygon represents the proposed ebb channel relocation corridor. The proposed channel relocation site represents the most advantageous position and alignment that will promote accretion along the F8I oceanfront shoreline.

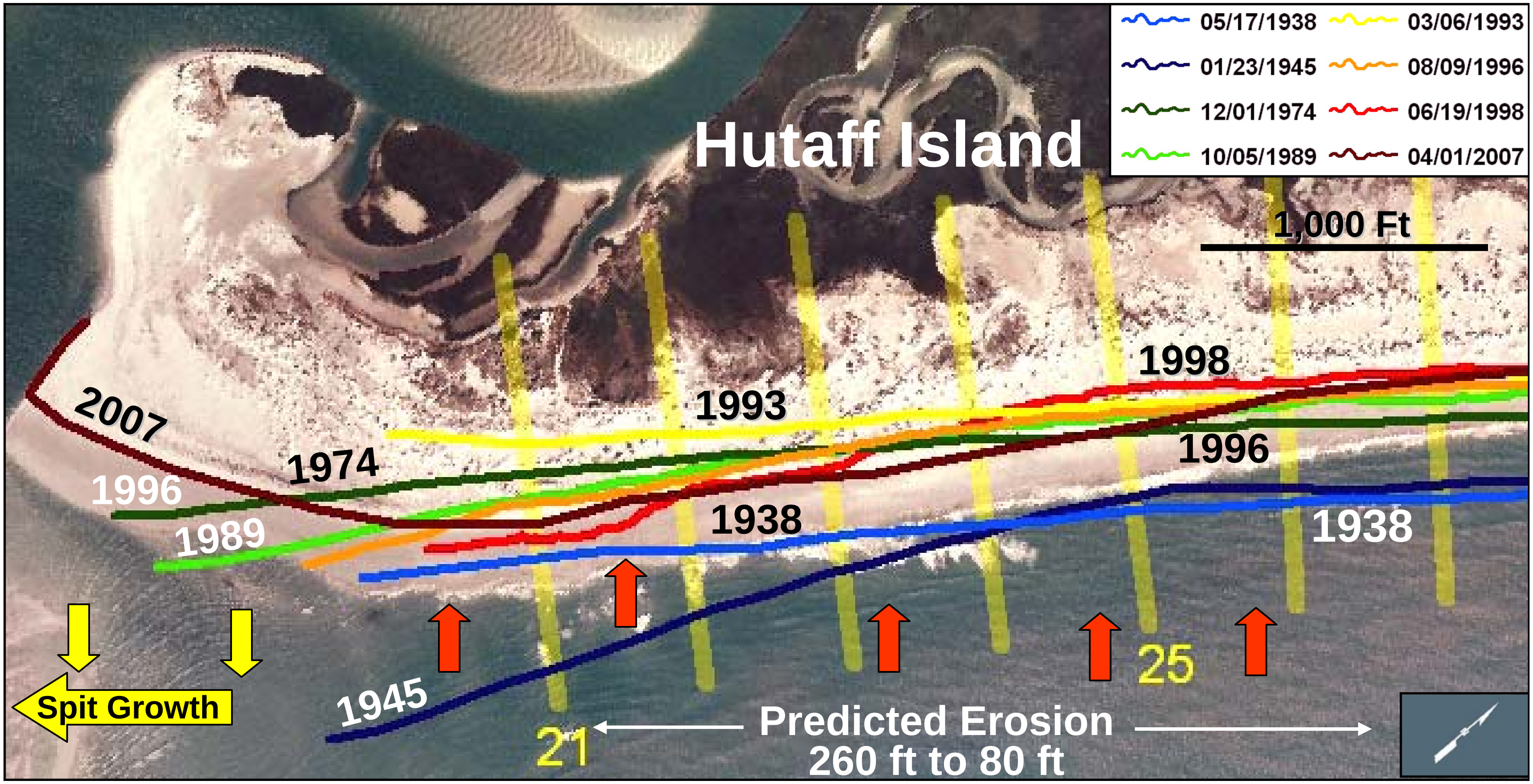

Figure 54. Map depicting the various positions of historic shorelines along the Hutaff Island oceanfront between 1938 and 2007. Note the position of 1945 shoreline. Channel relocation will induce erosion along the shoreline segment between T21 –T27 and concurrently will promote island lengthening thru spit growth. Base aerial photograph dates from 2007.