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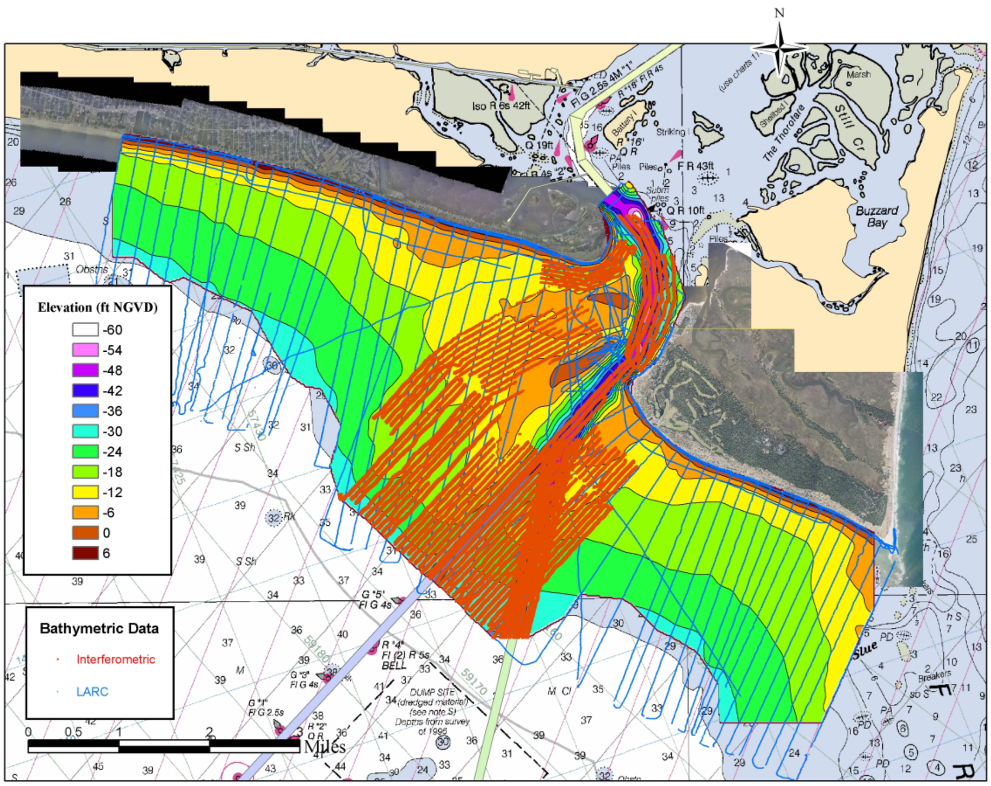
Wilmington District

PHYSICAL MONITORING WILMINGTON HARBOR NAVIGATION PROJECT REPORT 7: October 2008 – September 2009



AUGUST 2010

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EXECUTIVE SUMMARY

The mouth of the Cape Fear River and Wilmington Harbor entrance channel are located in eastern Brunswick County, near Cape Fear, about 25 miles south of Wilmington, North Carolina. The river mouth, which is approximately one mile in width, is bordered on the east by Bald Head Island and to the west by Oak Island/Caswell Beach. Bald Head Island is a barrier island beach stretching from the river entrance to Cape Fear. The south-facing beach covers about three miles and is commonly referred to as South Beach. Likewise, the approximately 1.5-mile portion of the island that borders along the river is called West Beach. Oak Island/Caswell Beach is part of a barrier island that covers about 13 miles extending from Lockwoods Folly Inlet on the western end to the Cape Fear River on the east. The eastern half of this island, which consists of a portion of Oak Island, Caswell Beach and Fort Caswell, falls within the project monitoring area.

The comprehensive Wilmington Harbor-96 Act Project consists of channel improvements extending from the ocean entrance upstream to just above the Northeast Cape Fear River railroad bridge in Wilmington, some 37 miles. The improvements, pertinent to this study, consist of deepening the ocean bar channel and entrance channel from the authorized depth of 40 feet to 44 feet, beginning at a point approximately 6.7 miles offshore through the Battery Island Channel located 2.9 miles upstream. Continuing from Battery Island Channel to the Cape Fear Memorial Bridge, 24.3 miles, the authorized channel is deepened from 38 feet to 42 feet.

This physical monitoring program for the Wilmington Harbor navigation channel-deepening project is examining the response of adjacent beaches, entrance channel shoaling patterns, and the ebb tide delta to the channel deepening and realignment for which construction began in December 2000. The present monitoring program involves five elements: beach profile surveys, channel and ebb tide delta surveys, wave and current measurements, aerial photography; and data analysis/reporting.

This report is the seventh in a series and serves to update the monitoring program with data collected October 2008 through November 2009. The initial report published in July 2004 covered the period of August 2000 (pre-construction survey) through June 2003. The second, third, fourth, fifth, and sixth reports covered the periods of; June 2003 to June 2004, June 2004 to August 2005, September 2005 to September 2006, October 2006 to September 2007, and October 2007 to September 2008 respectively. The remaining reports are scheduled to be prepared on an annual basis.

Beach profile surveys are the primary data source and are collected along both Bald Head Island and Oak Island/Caswell Beach. The beach surveys consist of specified transects, or profiles, taken generally perpendicular to the trend of the shoreline. Bald Head Island profiles include 58 stations along about 22,000 feet of shoreline. Oak Island/Caswell Beach profiles include 62 stations along about 31,000 feet of shoreline. Beach profile surveys are taken semi-annually. Bathymetric portions of these profiles from offshore through the surf zone and over the shoal areas that border each side of the Cape Fear entrance channel, and those near Frying Pan Shoals are typically collected with the US Army

Engineer Research and Development Center's Lighter Amphibious Re-supply Cargo (LARC) survey system. The LARC vehicle transits through the water, across shoals, through the surf zone up to the base of the beach dunes.

Channel and ebb tide delta surveys are collected using a Submetrix Interferometric (SI) System. This system collects swath bathymetry and side scan sonar from a hull-mounted transducer and covers about a 19 square mile area encompassing the channel and outer limits of the extensive ebb tide delta. These surveys are taken at the same time as the LARC survey.

Wave data are collected by three bottom-mounted wave gauges consisting of an Acoustic Doppler Current Profiler (ADCP) meter and a pressure gauge. The gauges are located just offshore of Oak and Bald Head Islands plus in the offshore waters about 11 miles from the coast.

Currents are also measured along specified transects across the mouth of the Cape Fear River and near the new channel realignment using a downward-looking, shipboard-mounted current profiler. Current measurements are collected over a complete tidal cycle and are scheduled at the same time as the ebb tide delta surveys.

Aerial photography of the project area is obtained through the Civil Works Imagery Monitoring Program in conjunction with the National Geospatial-Intelligence Agency (NGA). The NGA has contracted with two satellite imagery providers, DigitalGlobe and GeoEye, to obtain requested imagery from one of five active satellites. Image resolution ranges from 1.4 to 3 foot resolution depending on the satellite tasked. Six images were obtained for use in the current monitoring report including May 2008, November 2008, and January, March, August, and November 2009.

Data collected over the present monitoring period of October 2008 through November 2009 have included: two complete beach profile surveys (January 2009 and May 2009), one ebb shoal survey (January 2009), one entrance channel current measurement (April 2009), and near continuous wave measurements.

Results to Date

Significant observations through the current monitoring period are summarized below in bulleted format. The paragraphs following the bulleted items provide further explanation of the results to date.

- Dredging of the navigation channel occurred between February and April 2009 with nearly 1,064,000 cubic yards of material being placed on the adjacent beaches of Oak Island / Caswell Beach.
- Shoreline offset along Oak Island/Caswell Beach increased an average of 66 feet over the last year due to beach placement of dredged material and is on the average 140 feet more seaward than it was at the start of the project 8.7 years ago.

- Most of the initial beach disposal material (1,181,800 cubic yards) remains along Oak Island/Caswell Beach. A combination of this material with the 2009 placement and diffused material from the nearby Sea Turtle Habitat project leaves the beach with 2,411,800 cubic yards more than the August 2000 pre-construction condition.
- Comparing long-term shoreline change rates with those of the 8.7-year monitoring period show Oak Island presently experiencing high rates of accretion versus historic minor erosion due largely to the disposal of sediment from the project.
- Bald Head Island experienced overall shoreline losses over the last year as the 2007 beach disposal continued to erode along South Beach. When comparisons are made over the 8.7-year monitoring period accretion is most prevalent along Bald Head Island; however, an area of chronic shoreline recession remains present along a 3,400 foot section in the south-western corner of the island.
- The section of Bald Head Island where material was placed in 2007 has lost more material through May 2009 (-1,052,500 cubic yards) than was placed (978,500 cubic yards).
- Overall, Bald Head Island has more material on the beach than the pre-construction condition in August 2000 (+118,000 cubic yards); however, the western end of the island has lost 758,000 cubic yards between stations 45 and 106.
- Comparing long-term shoreline change rates with those of the 8.7-year monitoring period show Bald Head Island is presently experiencing less erosion overall. However, the post-construction rates are higher along the western end of South Beach and this area has expanded further east since Report 6.
- Village of Bald Head reconstructed a geo-textile groin field following the placement of the January 2005 beach fill along about 6,500 feet of shoreline within the problem area at the western end of South Beach. The groin field began to show signs of deterioration as early as November 2008 resulting in significant shoreline erosion by January 2009 along the western end of South Beach, just prior to the most recent dredging event. However, it continued to have a positive overall effect in retaining the beach thru the May 2009 survey, particularly within the upper portions of the beach profile. The groin field did continue to deteriorate and was essentially non-functional by the end of this monitoring period (September 2009).
- Village of Bald Head and the Wilmington District have entered in a legal settlement agreement which requires bi-monthly channel surveys to monitor the minimum navigable width along the channel reaches of Smith Island, Bald Head Shoal Reach 1 and Bald Head Shoal Reach 2. Results indicate that the channel width did fall below the 500 foot threshold limit in November 2008; however, no action was required due to the temporal proximity to the planned dredging in February 2009.
- All widths within the navigation channel were greater than 500 feet as of June 2009, with the minimum width within the channel being 605 feet.
- Rate of spit growth into Baldhead Shoal Channel decreased following the 2005 dredging versus the 2001-02 dredging and reduced even further following the 2007 dredging. For the period following the February-April 2009 dredging event the

progression of the groin field failure, which began as early as November 2008, escalated erosion into the channel closer to the rate observed following the initial dredging.

- Overall change in ebb and nearshore bathymetry included moderate changes within Jay Bird Shoals, growth of the western portions of Bald Head Shoal, and infilling of the old channel bed (aided by dredged material disposal)
- Current measurements taken before and after project channel dredging show similar overall flow regimes, except for consistently higher peak velocities measured with the after project condition
- The initial 6-year cycle of the sand management plan has been completed. A re-evaluation of the plan including modifications to placement quantities, locations, and frequency will be made over the next monitoring period and recommendations will be made as part of Monitoring Report 8.

Discussion of Results

Beach profile surveys were compared for the beaches on either side of the entrance channel. In each case comparisons were made from the current surveys to the last survey as reported in Report 6 (July 2008) and with respect to the initial pre-project condition established with the survey of August/September 2000. Comparisons were analyzed to determine the overall condition of the beach with respect to both changes in shoreline and profile volumes. Shoreline and volumetric changes were computed over the current period (from July 2008 to May 2009) and for the entire period (from August/September 2000 to May 2009).

For Oak Island/Caswell Beach, the shoreline change measured over the last year has been greatly influenced by the disposal activity between February and April 2009 which resulted in an overall accreting beach. The disposal occurred in two zones along Oak Island between Profiles 60 and 95 (123,400 cubic yards) and Profiles 120 and 260 (941,000 cubic yards). Prior to the placement, the shoreline was generally receding, particularly within the western half of the monitoring area. The placement of material within these zones advanced the shoreline between 80 and 180 feet. When considering the shoreline changes along Oak Island with respect to the pre-construction position in August 2000, the beach width has increased an average of 140 feet. In fact, with the exception of a few profile locations along the eastern tip of the island, all other lines have shown an increase in beach width relative to the August 2000 shoreline position. The shoreline position along the island just prior to the 2009 beach disposal was largely accretionary when compared to the pre-construction position as well. The average shoreline increase of 69 feet prior to the 2009 disposal is reflective of the relative stability of this section of the beach as a whole.

In terms of volume change, Oak Island/Caswell Beach has shown mostly accretion over the current monitoring period due in most part to the disposal activity discussed above. The only exceptions were a zone extending between Profiles 10 & 45 on the eastern tip of the island and Profile 300 on the far western end of the island, which lost minor amounts of material. When considering all profile lines, a net gain of 1,130,098 cubic yards was computed since the last report, between July 2008 and May 2009. This gain reverses the general overall trend of losses that had been observed over the last several years. The overall volume response has been positive when considering the measurements over the entire 8.7-year monitoring period. As such, all reported volume changes are positive with the exception of four isolated profiles on the eastern tip of the island which show small losses. All other areas are very healthy with respect to volumetric gains relating back to August 2000 base condition. Specifically, by the end of the period, an excess of 2,411,837 cubic yards of material remains on Oak Island above the August 2000 pre-project condition. This quantity actually reflects a modest net gain above the sum of the fill volumes placed in 2001 and 2009 of about 204,693 cubic yards. This surplus above the placed quantity is believed to be the result of the eastward spreading of a separate beach fill (Sea Turtle Habitat Project in 2001) placed just beyond the boundary of the project area. The alongshore distribution of material basically follows the shoreline response where net gains are seen along most of the island.

Since the last reporting, most of the profile locations along Bald Head Island have been erosional. The profile locations found to be accretionary occurred along a short section of west beach and a portion of the spit (Profiles 28 to 36) and along the eastern end of South Beach (Profiles 182 to 194), as well as a few intermittent profiles spread throughout the monitoring area. The largest retreats were measured along a 1,100 ft section of South Beach in the vicinity of the spit (Profiles 40 to 47). Specifically, the peak recession measured at the end of the period was 254 feet (Profile 43) and the average loss in this area was 208 feet. These losses represent some of the largest losses along the island since the initiation of the monitoring program. The area covering Profiles 32 through 45 which defines the spit had an average loss of 128 feet over the current period, while the area along West Beach (Profiles 0 thru 28) lost an average of 3 feet. When considering the overall area bounded by the limits of the 2007 fill (between Profiles 45 to 170), the shoreline was found to have eroded an average of 52 feet. The average loss for the entire monitoring area since Monitoring Report 6 is 40 feet.

Shoreline change patterns as measured over the last 8.7-year period, i.e., since the monitoring was initiated, are generally positive when measuring relative to the September 2000 base survey. For example, all lines along South Beach, extending eastward from Profile 78 are largely accretional, with the May 2009 shorelines being an average of 127 feet seaward of their September 2000 positions. In contrast, the western portion of South Beach is once again developing a highly erosional pattern as documented in prior reports. As of May 2009, the shoreline was found to be landward of the base position between Profiles 40 and 73, an area nearly 1,100 feet larger than the erosive area reported in Monitoring Report 6. The average shoreline loss over this 3,380 foot reach was 155 feet, with a peak recession of 331 feet occurring at Profile 43. Extending westward from this erosional reach is a 400 foot zone dominated by large accretions within the limits of the Bald Head spit. Here the shoreline is on the order of 230 feet wider than in 2000. For West Beach (Profiles 0 thru 28), located immediately along the river channel, the shoreline has shown an average loss of about 25 feet when compared to the base condition. When considering all locations along

Bald Head Island (Profiles 0 to Profile 218), the shoreline is presently on the average 48 feet more seaward than it was in 2000.

In terms of volumetric change from the last survey (July 2008) of Report 6 to the present, Bald Head Island is dominated by losses throughout the monitoring area. Every profile within the monitoring area showed volumetric losses when compared to the July 2008 condition. In summing the changes over the entire monitoring area, the losses total to approximately 937,000 cubic yards of material. Of this, 49% was lost between Profiles 32 and 61 on the west end of South Beach. The zones along South Beach which received dredged material (Profiles 44 to 91 and 110 to 170) during the April 2007 placement were found to have lost nearly 614,000 cubic yards of sand. Cumulatively, since the fill was placed in 2007, this area has lost 1,052,500 cubic yards of sand which exceeds the 978,500 cubic yards placed.

When analyzing the total volumetric profile changes since the beginning of the monitoring in August 2000, Bald Head Island is split between areas of gains and losses over the last 8.7 years. The most substantial increases are found along the eastern half of South Beach and in the vicinity of the spit. Elsewhere, there are two areas which have recorded net overall losses for the entire period. One is located at the extreme eastern end of South Beach, where some losses have occurred near the cape. The other, which is of greater concern, is along the westernmost portion South Beach extending into the spit area between Profiles 45 to 106. This reach, which has expanded from 2,500 feet to nearly 6,100 feet since Monitoring Report 6, has been the site of chronic erosion in the past. Volumetrically this represents net loss of about 758,000 cubic yards. Aside from these areas of erosion, only Profiles 8 and 16 along West Beach shows a minor net loss of material compared with the base year condition. As a result of this overall response in the profiles, the net volume change is a modest gain of 118,000 cubic yards as of May 2009 with respect to the beginning of the monitoring in 2000.

Rates of shoreline change were likewise computed over the monitoring period. These rates were compared with long-term shoreline change rates computed from the North Carolina Division of Coastal Management (NCDCM) shoreline data based on a 62-year period of record (1938-2000). Although the monitoring period spans a relatively shorter time period of about 8.7 years to date, it is of interest to compare these trends with established long-term shoreline response for the area.

Shoreline change rates computed over the initial 8.7-year period show that for Oak Island/Caswell Beach substantial accretion is present over most of the island largely reflecting the influence of the 2001 and 2009 beach fills. Although these positive rates have been found to moderate since the fill placement, they remain in sharp contrast to the long-term trend. Overall, the shoreline change rate averaged over the entire monitoring area was about +16.3 feet per year for the 8.7-year period. By comparison the long-term NCDCM rate over the entire reach was –1.1 feet per year.

For Bald Head Island, the comparison of the long-term rates with the rates computed since 2000 show that most of the island is eroding less over the initial 8.7-year monitoring period. However, notwithstanding this overall positive response, the post-construction erosion rates continue to be greater along the western corner of South Beach. A direct comparison of the pre- and post-construction shoreline change rates show that only three profile lines are eroding at a higher rate during the post-construction period. These lines are located at the western end of South Beach (Profiles 53, 57 and 61). Adjacent Profiles 66 and 69 are presently eroding but at a lower rate as compared to the pre-construction condition. All other lines are accreting in direct contrast to the long-term erosion experienced along the remaining areas of South Beach. Most of this response is attributable to the beach fill placements and possibly to the positive effect of the rehabilitated groin field.

In March 2005, the Village of Bald Head and the Wilmington District entered into an agreement to conduct bi-monthly navigation channel surveys within the channel locations along the island. These surveys are intended to document the channel shoaling and to record the navigable channel width throughout the area. The threshold deemed to be a minimum acceptable channel width is 500 feet at the -42 feet mean low water (MLW) elevation. As of 2009, 27 condition surveys have been accomplished, five of which occurred over the present reporting period (February 2009, April 2009, June 2009, August 2009 and November 2009). The three most recent surveys are post-dredging settlement surveys, which follow the Feb-April 2009 channel dredging operation. The 2009 dredging event increased the navigable width measured at -42' MLW so that every profile within the navigation channel exceeds the minimum required navigable width of 500 feet. Widths within the channel as of November 2009 ranged from a minimum of 577 feet at station 18+00 to a maximum of 996 feet at station 5+00. The width at station 23+00, which has historically been a location of increased shoaling, had a navigable width of 690 feet as of November 2009.

The navigation channel surveys have also been used to analyze the rate of shoaling along Reach 1 in the immediate vicinity of the Bald Head spit. Following the initial placement of fill 2001-02 (1.8 million cubic yards), the area of the spit was found to have enlarged volumetrically to at least twice as large as previously observed. The same area of growth was monitored following the two subsequent dredging events (i.e. 2004-05 (1.2 million cubic yards and 2007 (1.0 million cubic yards). The comparison showed that the rate of growth was slower following both the second event and third events. Specifically, the initial rate was about 16,500 cubic yards per month. An analysis of all settlement surveys for the second dredging event, January 2005 through March 2007, showed that the spit growth had slowed to about 9,900 cubic yards per month, i.e., a 40 % reduction in the shoaling rate. Analysis for the third monitoring period, April 2007 through February 2009, shows that the growth rate has continued to decrease from the previous two dredging cycles and is now at a rate of 8,950 cubic yards per month. This is a 46% reduction in the shoaling rate versus the initial dredging operation and a 10% reduction when compared to the second dredge cycle. Calculation of the shoaling rate following the most recent dredging event in February-April 2009 revealed that the growth rate has increased to 13,500 cubic yards per month. This represents a 51% increase over the computed rate from the previous dredge cycle. However, this rate remains lower than the initial rate by nearly 18%. The recent increase in shoaling rates within the channel is most likely associated with the failure of the Bald Head Island groin field and the subsequent loss of material that had been retained within the field.

In prior reports the effectiveness of the reconstructed groins was analyzed by comparing the response of the 2001 beach fill (without the groins) to the 2006 beach fill (with the groins). The analysis revealed that the new groin field had an apparent positive effect in retaining the beach, particularly within the upper portions of the beach profile. This is reflected in the positive response with respect to shoreline change and changes in the onshore volumes. Changes of this nature would be expected given the cross-shore extent of the groins having a length of about 300 feet, and with the shoreward end of the groins terminating at elevations of about -2 feet or above. For the present report, this analysis was updated to include a similar comparison with the third beach fill for which about 22 months of monitoring data are now available. Comparisons were made over similar 22 to 24 month periods following each respective fill event. The results indicate that the groins have continued to have a positive effect on retaining the fill. Specifically, the average retreat within the area of the groin field approximately 22 to 24 months after each fill event was 164 feet for the first fill with no groin field in place, 94 feet after the second fill with the newly constructed groin field in place and 80 feet following the third event with the groin field in place. In contrast to this general response, the shoreline loss during the third fill continues to be much greater in the western end of the groin field, when compared to the prior two cycles. Shoreline retreats of over 250 feet are measured for the third 22 to 24 month period versus about 200 feet and 100 feet for the first and second fills. This accelerated erosion appears to be due to the western end of the groin field being damaged and as a result, not functioning properly.

Aerial photography of Bald Head Island obtained during the current monitoring period covers a longer timeline than the profile surveys from which volumetric changes within the groin field are measured. Photography for the island was obtained for May 2008, November 2008, and January, March, August, and November of 2009. Digitized shorelines from this photography were used to separately quantify shoreline impacts related to the failure of the groin field. The photography revealed that the majority of the groin field had progressively failed from the west toward the east. This failure and the resulting loss of the sand contained within the groin field coupled with the down drift erosion associated with the groin field adjusting to its new western limits have produced shoreline erosion to its most landward point since the initiation of the monitoring program. The photography also shows, in the November 2009 image, the initial stages of a reconstruction of the groin field within the same general area as the 2005 construction. This new groin field is being constructed as part of the locally funded beach nourishment project undertaken by the Village of Bald Head Island in 2009/2010.

Detailed bathymetric surveys were made of the ebb and nearshore shoals in the vicinity of the entrance channel to assess any changes associated with the entrance channel deepening and realignment. Aside from the direct changes resulting from dredging the new channel, the major overall changes in morphology of the ebb and nearshore shoals since the start of the monitoring have included changes along Jay Bird Shoals, Bald Head Shoals, and within the vicinity of the old channel bed. The changes within Jay Bird Shoals have been somewhat complex with some portions shoaling and some portions scouring. Generally, the outer portions have shown a generalized lowering but a moderate amount of shoaling has occurred within the northernmost area of Jay Bird Shoals just off the tip of Oak Island.

Adjacent to this shoal is a scour feature associated with a flood channel just offshore of Oak Island although the most recent surveys have shown this feature to have become more stable, and little change is noted in this area when the January 2009 survey is compared with the January 2008 survey. On the other side of the channel, Bald Head Shoal has shown significant gains extending off of the southwestern corner of Bald Head Island. Additionally, the old channel bed has also accreted since the beginning of the monitoring period, as this area is used as a disposal site for other dredging operations in the river. In general, the offshore area, with the exception of the old and new channels, have remained relatively stable since the last monitoring report with only minor shoaling noted west of the channel.

To date currents have been measured on nine occasions, with the initial occurring before the channel improvements and the remaining eight after the deepening. Currents are measured over a complete tidal cycle along transects across the mouth of the entrance channel and along the seaward portion of the ebb tide delta near the intersection of the old and new channel alignments. Comparison of current measurements taken before and after the channel dredging show very similar flow regimes and are consistent with the minimal change seen in the overall bathymetry of the ebb tide delta. Of interest, however, is that with each of the post-dredging measurements, the maximum velocities are found to be greater than those of initial current survey. This was evident with both the inlet and offshore transects.

Sand Management Considerations.

Operation of the project involves the implementation of a Sand Management Plan. Under this plan, disposal of beach compatible sediment is to occur on the beaches adjacent to the Cape Fear River entrance every 2 years. The distribution is such that disposal is to occur in a 2 to 1 ratio with two-thirds of the material going to Bald Head Island and the remaining one-third to Oak Island/Caswell Beach. This sediment ratio is accomplished by having the first two maintenance cycles (i.e. years 2 and 4) place sediment on Bald Head with the last cycle going to Oak Island/Caswell. Thus a complete operation and maintenance cycle will take 6-years to accomplish.

The first maintenance dredging was accomplished between November 2004 and January 2005. In accordance with the sand management plan, the beach compatible material dredged during the first cycle was placed along Bald Head Island. The Corps of Engineers and the Village of Bald Head worked jointly to develop this disposal plan. Approximately 1,217,500 cubic yards of beach quality sediment were placed along the most critically eroding portions of South Beach. This work was coupled with the replacement of geo-textile groins by the Village of Bald Head under a private permit action, with the intent of reducing the erosion of the in-place fill. The groin reconstruction took place over the period of March-May 2005. The second maintenance cycle occurred February-April 2007 and involved disposal of material along Bald Head Island as scheduled. This operation amounted to an additional 978,500 cubic yards placed along South Beach. The most recent maintenance dredging involved placement of beach compatible sediments along Oak Island/Caswell Beach. During this work, the third maintenance cycle, approximately 1,064,400 cubic yards were placed between February and April 2009. With the completion of this maintenance dredging, the first overall 2 to 1 sand management cycle has been accomplished (i.e. through the 6-year cycle).

In accordance with the sand management plan, an assessment is to be made following the completion of the first full cycle regarding the effectiveness of the current sand distribution scheme and determine if changes are warranted. To properly evaluate the present sand sharing ratio, an additional two years of monitoring data will be evaluated following the Oak Island/Caswell disposal, thereby assessing a full disposal cycle. The results of the reevaluation will be contained in the next monitoring report. Aside from the analysis of the physical data collected to date, the reassessment will also include the results of a numerical modeling effort which is presently underway. The modeling study uses the Corps' Coastal Modeling System (CMS) to estimate circulation, wave transformation, sediment transport and morphology changes within the Cape Fear region. This involves a wave transformation model, (CMS-WAVE) and a current/sediment transport model (CMS-FLOW). In the mean time, plans are being made for the next disposal operation on Bald Head Island in 2011 as originally scheduled; assuming funds are available for this purpose.

PHYSICAL MONITORING
WILMINGTON HARBOR NAVIGATION PROJECT
REPORT 7

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PHYSICAL MONITORING
WILMINGTON HARBOR NAVIGATION PROJECT

REPORT 7

Part 1 INTRODUCTION

Purpose

Wilmington Harbor navigation project covers over 37 miles of channel improvements extending from the mouth of the Cape Fear River to Wilmington, N.C. and the Northeast Cape Fear River. Improvements consist of a general deepening of the river by 4-ft from the mouth to the North Carolina State Port facilities, numerous improvements to turns and bends in the channel, a passing lane and implementation of environmental mitigation features. This document is the seventh in a series of monitoring reports that focuses on the navigation improvements in the immediate vicinity of the Cape Fear ocean entrance channel and covers the period of October 2008 through September 2009. Monitoring Reports 1, 2, 3, 4, 5 and 6 were published in August 2004, February 2005, May 2006, May 2007, April 2008, and June 2009 respectively, and covered the first eight years of monitoring (USACE 2004, USACE 2005, USACE 2006, USACE 2007, USACE 2008, and USACE 2009). The monitoring program is designed to meet two main objectives: (1) to document the response of the adjacent beaches to the deepening and alignment changes of the entrance channel and (2) to use the results of the program to effectively implement the project's sand management plan.

Project Description

Location. The mouth of the Cape Fear River and Wilmington Harbor entrance channel are located in eastern Brunswick County, near Cape Fear, about 25 miles south of Wilmington. Cape Fear is the southernmost of three large capes that predominate the North Carolina coastal plan-form. Frying Pan Shoals extend southeastward from the cape some 20 miles into the Atlantic Ocean. The river mouth, which is approximately one mile in width, is bordered on the east by Bald Head Island and to the west by Oak Island/Caswell Beach as shown in Figure 1.1. Bald Head Island is a barrier beach stretching from the river entrance to Cape Fear. The south-facing beach covers about three miles and is commonly referred to as South Beach. Likewise, the approximately 1.5-mile portion of the island that borders along the river is called West Beach and the reach extending northward from the point at Cape Fear, facing east toward the Atlantic Ocean, is termed East Beach. Oak Island/Caswell Beach is part of a barrier island that covers about 13 miles extending from Lockwoods Folly Inlet on the western end to the Cape Fear River on the east. The eastern half of this island which consists of a portion of Oak Island, Caswell Beach and Fort Caswell, falls within the project monitoring area.

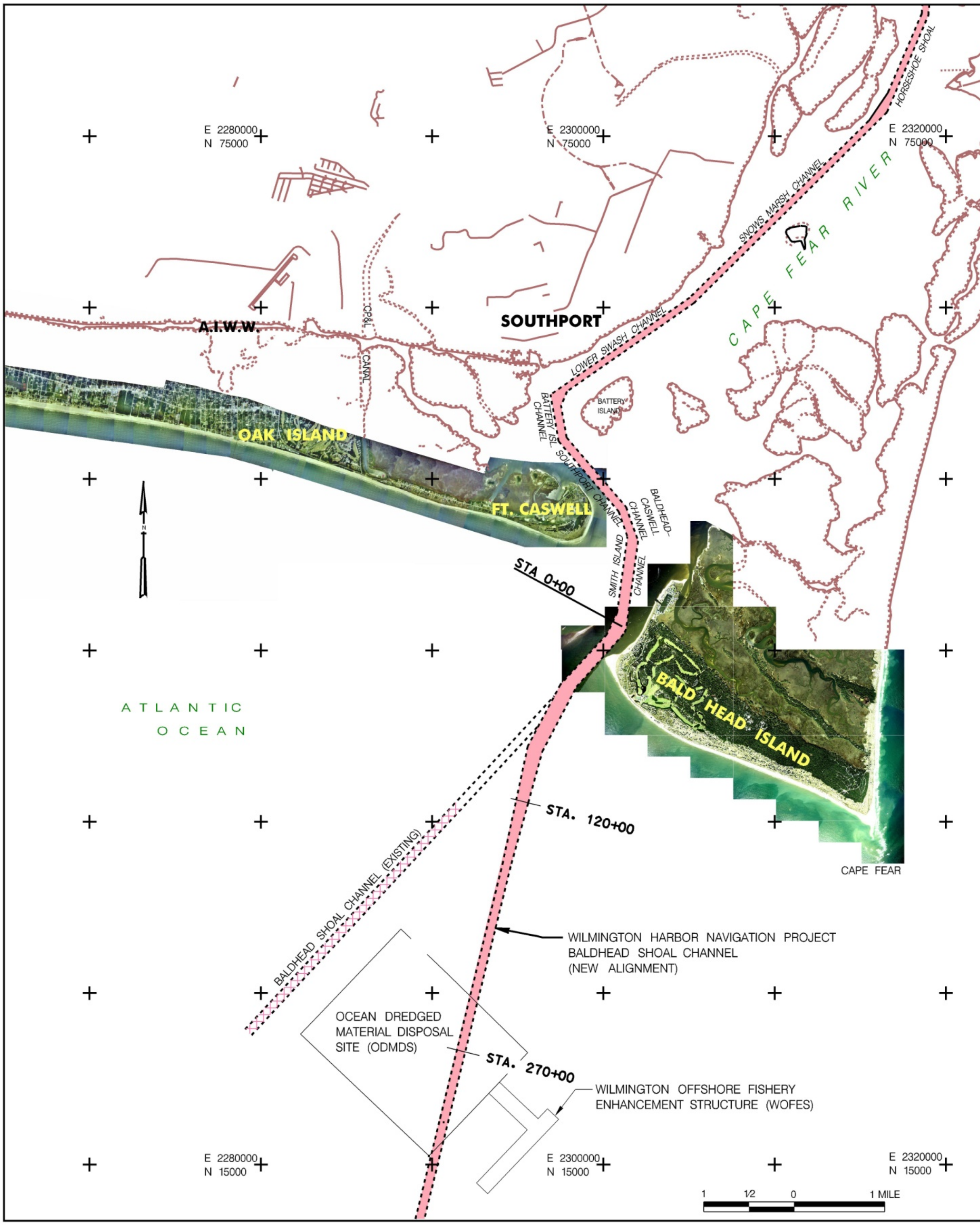


Figure 1.1 Project Location Map

Federal Channel Realignment and Deepening. With the signing of the Energy and Water Appropriations Bill on October 13, 1998 three separate projects (Wilmington Harbor – Northeast Cape Fear River project, Wilmington Harbor – Channel Widening Project, and Cape Fear – Northeast Cape Fear rivers project) were combined into one known as the Wilmington Harbor, NC – 96 Act project. This comprehensive project, with a total estimated cost of $440 million, consists of channel improvements extending from the ocean entrance upstream to just above the Northeast Cape Fear River railroad bridge in Wilmington, some 37 miles. The improvements consist of deepening the ocean bar channel and entrance channel from the authorized depth of 40 feet to 44 feet, beginning at a point approximately 6.7 miles offshore through the Battery Island Channel located 2.9 miles upstream. Continuing from Battery Island Channel to the Cape Fear Memorial Bridge, 24.3 miles, the authorized channel is deepened from 38 feet to 42 feet.

This stretch includes a new passing lane and numerous turn and bend improvements, plus channel widening and enlargement of the anchorage basin at the state port facility. The final 2.2 mile stretch of the river spanning along the Wilmington waterfront and beyond, includes deepening the channel from 32 feet to 38 feet to just above the Hilton Railroad Bridge and from 25 feet to 34 feet to the upstream limits of the project.

The entrance channel improvements, which are most relevant to the monitoring effort, are shown on Figure 1.2. In addition to the 4-foot deepening, the channel was realigned from a southwesterly orientation to a more south-southwest orientation. This 30-degree southern shift in alignment of the Baldhead Shoal Channel was recommended based on achieving significant cost savings (approximately $39 million) by avoiding the removal of rock that existed along the former alignment. The new channel also was widened from 500-feet to as much as 900-feet to accommodate safe ship navigation in the vicinity of the intersection of the old and new alignments.

Construction Activity. The realignment and deepening of the entrance channels were accomplished under two dredging contracts. One contract involved dredging of the seaward most portion of the Baldhead Shoal channel covering the outer 4.5 miles of the new alignment (station 120+00 seaward). Material dredged from this portion of the new channel consisted of fine silts and sands that were deemed unsuitable for beach disposal. This material was placed in the designated offshore disposal site. Work began in December 2000 and was completed in April 2001 by Great Lakes Dredge and Dock at a cost of $13.6 million.

The second contract covered the remaining portions of the entrance channels beginning at the inner section of the Baldhead Shoal Channel through the Snows Marsh reach, a distance of about 9.5 miles. Most of the material dredged from this portion of the river was suitable for beach disposal and was placed on the Brunswick County Beaches. This contract was undertaken by Bean-Stuyvesant for a cost of $64.7 million. Beach disposal began in February 2001 and was completed in April 2002, with the dredging of portions of the channel containing non-compatible beach material continuing until December 2002. Beaches receiving the compatible sand included Bald Head Island, Caswell Beach/eastern Oak Island, western Oak Island and Holden Beach. The Baldhead Island and Caswell Beach/East Oak Island portions were determined to be least costly beach disposal alternatives and material was placed at 100% Federal expense. The other beach placement activities where accomplished under Section 933 authority of the Water Resources Development Act of 1986 where the local government covered the added cost of pumping material to their respective beaches.

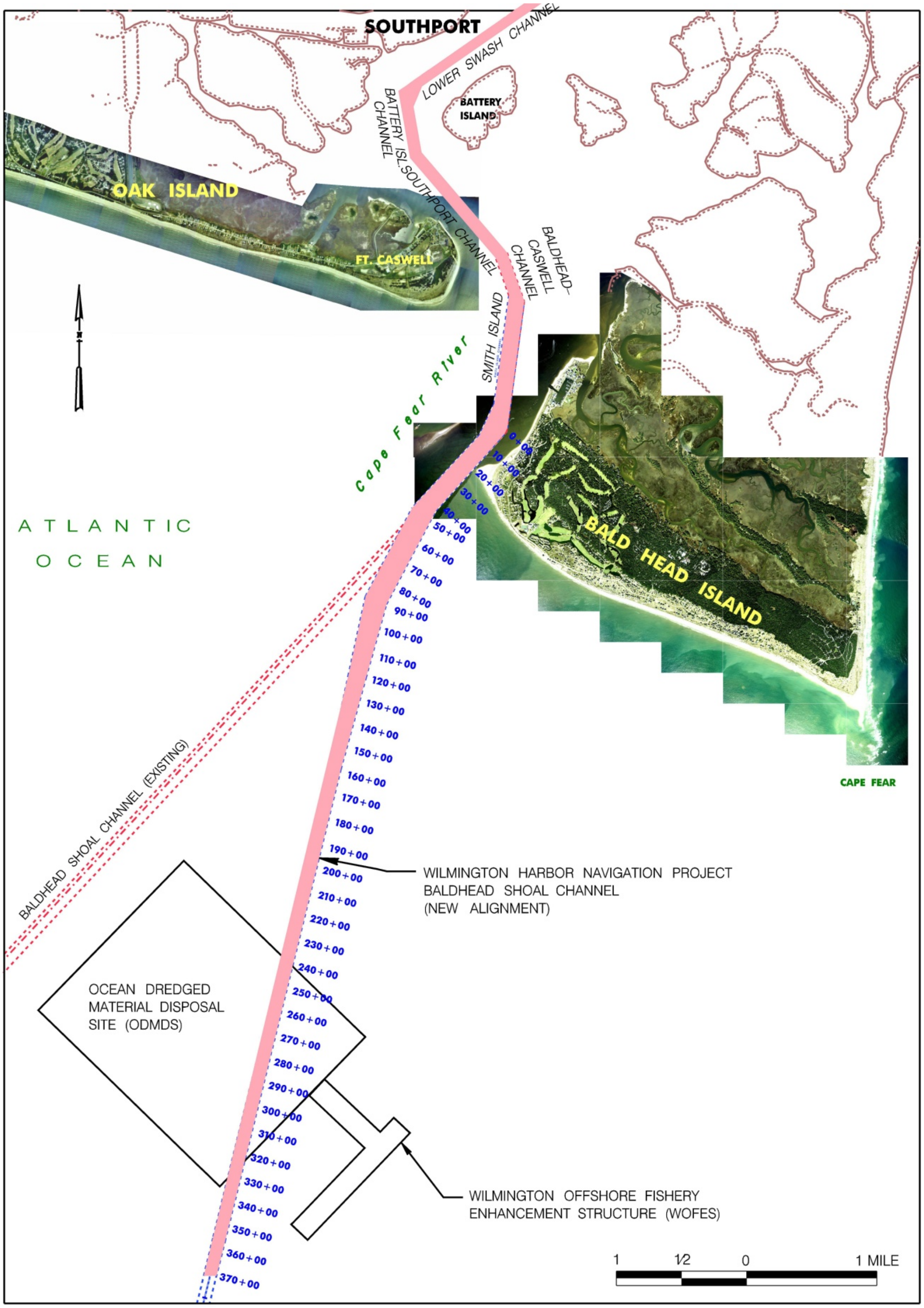


Figure 1.2 Realignment of the Federal Navigation Channel at the Cape Fear River Entrance

Overall, on the order of 5 million cubic yards of sediment (in-place beach volume measurement) were placed on the Brunswick County beaches under this contract for the initial deepening. Table 1.1 summarizes the distribution of volume of material between the beach communities along with placement dates and various other pertinent factors.

TABLE 1.1 WILMINGTON HARBOR BEACH DISPOSAL OPERATIONS

LOCATION	APPROX BL STA	PLACEMENT LIMITS NORTHING (ft, NAD83)	EASTING (ft, NAD83)	PLACEMENT DATES START mm/dd/yyyy	STOP mm/dd/yyyy	BEACH VOLUME (INPLACE) (cy)	DREDGE
(INITIAL CONSTRUCTION)							
BALD HEAD ISLAND	41+60	43,692.25	2,300,542.01	2/23/2001		1,849,000	*Stuyvesant & Merridian*
	205+50	35,750.21	2,314,236.42		7/4/2001		
OAK ISLAND EAST (CASWELL)	60+00	52,126.62	2,295,138.57	7/5/2001		133,200	*Merridian*
	80+00	52,847.44	2,292,954.85				
OAK ISLAND EAST	121+00	53,711.05	2,289,255.43			1,048,600	*Merridian*
	294+00	58,418.34	2,272,322.77		8/12/2001		
OAK ISLAND WEST	415+00	60,332.24	2,260,537.66	8/13/2001		1,269,800	*Merridian*
	665+50	59,778.68	2,235,486.44		4/25/2002		*Eagle*
HOLDEN BEACH	84+00	60,092.96	2,222,254.95	12/9/2001		501,400	*Eagle*
	195+00	58,820.26	2,211,433.72		2/20/2002		
(FIRST MAINTENANCE CYCLE)							
BALD HEAD ISLAND	46+00	43,836.00	2,300,813.68	11/12/2004		1,217,500	*Illinois*
	130+00	39,051.42	2,307,196.47		1/25/2005		
(SECOND MAINTENANCE CYCLE)							
BALD HEAD ISLAND	44+00	42,243.24	2,301,716.03	2/28/2007		398,500	*Illinois*
	91+00	40,550.81	2,303,601.67				
	110+00	39,771.16	2,305,333.49			580,000	*Illinois*
	170+00	37,552.01	2,310,903.49		4/30/2007		
(THIRD MAINTENANCE CYCLE)							
CASWELL BEACH/OAK ISLAND	60+00	52,733.39	2,295,144.60	2/8/2009		123,400	*Illinois*
	95+00	53,605.88	2,291,753.90				
	120+00	54,349.03	2,289,368.51			941,000	*Illinois*
	260+00	58,047.07	2,275,885.90		4/24/2009		

<u>Maintenance Dredging.</u> Subsequent to the initial construction, plans were made to implement two dredging operations to remove localized "high-spots" remaining within the authorized channel limits. These two dredging contracts involved removal of unsuitable beach material along the outer channel termed "Clean Sweep I" and the removal of beach compatible material along the inner channel reaches termed "Clean Sweep II". Clean Sweep I contract was awarded in September 2003 and was completed in January 2004. The beach disposal operation of Clean Sweep II was completed in 2005. With the timing of Clean Sweep II coming approximately two years after completion of the initial construction, this operation is considered as the first maintenance dredging of the new channel. In accordance with the sand management plan described below, the beach compatible sediments dredged during the first two cycles are designated for disposal along Bald Head Island with the third cycle going to Caswell Beach/Oak Island. As such, approximately 1,217,500 cubic yards of beach fill were placed along Bald Head Island between November 2004 and January 2005 as

indicated above in Table 1.1. This was followed two years later by the second maintenance cycle, with an additional 978,500 cubic yards placed along Bald Head Island, over the period of February-April 2007. The most recent maintenance dredging involved placement of beach compatible sediments along Oak Island/Caswell Beach. During this work, the third maintenance cycle, approximately 1,064,400 cubic yards were placed between February and April 2009

Sand Management Plan. A sand management plan developed for the Wilmington Harbor 96 Act project (USACE 2000) addressed the disposal of beach quality sand during both the construction and maintenance phases of the project. The future maintenance includes the periodic disposal of littoral material removed from the ocean entrance channel on the beaches adjacent to the Cape Fear River Entrance. The goal of the sand management plan is to make the best use of littoral sediments during maintenance of the project and return beach compatible material back to the adjacent beaches. This is in keeping with the state of North Carolina policy to insure that beach quality sand is not removed from the active beach system.

The results of wave transformation/sediment transport analysis conducted by the U.S. Army Corps of Engineers Coastal and Hydraulics Lab (Thompson, Lin, & Jones 1999) for the Wilmington District found that the distribution of sediment transport at the Cape Fear entrance was such that two-thirds of the material comes from Bald Head Island and one-third is derived from Oak Island/Caswell Beach. In order to maintain the sediment balance on both islands, littoral material removed from the entrance channel is placed back on the beach from whence it came in the same distribution. Accordingly, two out of every three cubic yards of littoral shoal material removed from the entrance channel is placed back on Bald Head Island and the remaining cubic yards placed on east Oak Island/Caswell Beach. Maintenance of the channel takes place biennially. In order to accomplish this two-to-one distribution, the littoral shoal material removed from the entrance channel for maintenance is placed on Bald Head Island in years 2 and 4 following the construction of the new ocean entrance channel and on Caswell Beach-Oak Island during year 6. Accordingly, one full maintenance cycle takes 6 years to complete.

Each maintenance operation involves the removal and disposal of approximately 1,000,000 cubic yards of beach material. The disposal locations on each island are based on the measured beach response during the operation of the project as determined by the monitoring program. The overall disposal lengths include 16,000 feet on Bald Head Island and 25,000 feet along Oak Island/Caswell Beach. The 16,000-foot reach on Bald Head Island includes approximately 14,000 feet of South Beach and 2,000 feet of West Beach. The disposal boundary on Oak Island/Caswell Beach, nearest to the Cape Fear River entrance, falls along the eastern town limits of Caswell Beach (located approximately 2,500 feet west of the river entrance) and extends westward along Oak Island. Actual disposal locations fall within the above limits, but may not cover the entire area on any given operation.

The disposal operation along Oak Island / Caswell Beach during the February-April 2009 dredging event concluded the initial 6-year maintenance cycle following the initial harbor deepening. Evolution of the fill material along both Oak and Bald Head Island will continue to be monitored throughout 2010. These data will be used to evaluate the efficacy of the current sand management plan and will be used in conjunction with the entire monitoring data set to establish a long term sand management plan that maximizes beneficial use of the dredged materials.

Monitoring Program

Scope. The monitoring program is designed to measure the response of the adjacent beaches, shoaling patterns in the entrance channel, and changes in the ebb tide delta of the entrance channel beginning immediately before initial construction and continuing throughout the operation and maintenance of the project. The results of this monitoring program will be used to make necessary adjustments in the beach disposal location for the littoral material removed from the entrance channel and to document the response of the adjacent beaches to the deepening and alignment changes of the entrance channel.

Program Elements. The present monitoring program consists of five basic elements namely; beach profile surveys, channel and ebb tide delta surveys, wave and current measurements, aerial photography, and data analysis/reporting. The data collection effort is a large undertaking and involves numerous entities including the Corps of Engineers, private contractors, and academia. The Wilmington District manages the program and is responsible for project coordination, funding, data analysis and report preparation. The majority of the data collection is accomplished by the U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Field Research Facility (FRF) located in Duck, North Carolina. The FRF is responsible for obtaining the beach profile surveys, ebb shoal surveys, wave and current measurements, and associated data reduction, quality control, and analysis. The wave/current gauges are operated by Evans Hamilton, Inc (EHI) through the FRF and the detailed ebb tide delta and shipboard current surveys have been performed by the Virginia Institute of Marine Science, through EHI and more recently by the FRF. Some of the beach profile surveys and aerial photography are also obtained by the Wilmington District through the use of private companies. The beach profiles have been surveyed by McKim & Creed Engineering and Greenhorne & O'Mara (subcontract with Geodynamics); whereas, the aerial photos have been provided under contract with Barton Aerial Technologies, Inc. and Nova Digital Systems, Inc. Additional aerial photography has recently been acquired through the Civil Works Imagery Monitoring Program. This program contracts with two satellite providers, DigitalGlobe and GeoEye, to obtain satellite imagery of varying resolution and can be obtained at more frequent intervals than traditional aerial photography. The basic program elements are described in the following paragraphs.

Beach Profile Surveys. The beach profile surveys serve as the backbone of the monitoring program and are taken along Bald Head Island and Oak Island/ Caswell Beach. The beach surveys consist of specified transects, or profiles, taken generally perpendicular to the trend of the shoreline. For Bald Head Island, the beach profiles begin at the entrance to the Bald Head Island marina on West Beach, and extend all the way to Cape Point, located at the eastern end of South Beach as shown in Figure 1.3. The location of these profile stations were selected to coincide with existing beach profile stations currently being monitored by the Village of Bald Head Island, which are spaced at an interval of approximately 400 feet. The total shoreline distance covered along Bald Head Island is about 22,000 feet and includes a total of 58 beach profile stations. For the Oak Island/Caswell Beach portion, beach profile stations were established at approximately 500-foot intervals, beginning near the Cape Fear River Entrance and extending west along Caswell Beach/Oak Island, as shown in Figure 1.4. This coverage includes approximately 5,000 feet of shoreline fronting the North Carolina Baptist Assembly grounds at Fort Caswell (2,500 feet along the inlet shoulder and 2,500 feet along the ocean-front) plus 26,000 feet along Oak Island extending west of the Baptist Assembly property. The beach profile stations extend 1000 feet westward of the designated disposal limit on Oak Island and encompass a total shoreline length of 31,000 feet. A total of 62 profile lines comprise this shoreline reach. The profile locations follow along an existing baseline established by the Corps of Engineers that had designated profile stations at 1,000 foot intervals. The monitoring plan added intermediate lines at 500-feet and utilized the pre-existing 1,000 foot stations so that prior surveys could be incorporated into the program as necessary.

The designated assigned profile numbers as shown on the figures are correlated to their respective location along the established baseline for each transect location. For example, Profile 310 on Oak Island (the last line) corresponds with baseline Station 310+08.91, and is approximately 31,000 feet from the inlet entrance.

The beach profile surveys are taken semi-annually. At the start of the program, the surveys were scheduled to coincide with the spring (April-May) and fall (October-November) seasons. During the spring survey all profiles are surveyed with coverage over the onshore portion of the beach. The onshore survey coverage extends from the landward limit of the profile line (a stable point beyond the back toe of the dune) seaward to wading depth. During the fall the onshore coverage is repeated; however, the coverage of every other line is extended offshore to a seaward distance of 15,000 feet or to a depth of 25 feet. Beginning in 2005, both the fall and spring surveys were designated to have the same coverage with both having onshore and offshore profile lines. This revised coverage is expected to continue as long as funds are available. The survey data are reported with respect to the National Geodetic Vertical Datum (NGVD) 1929 and North American Datum (NAD) 1983 horizontal datum.

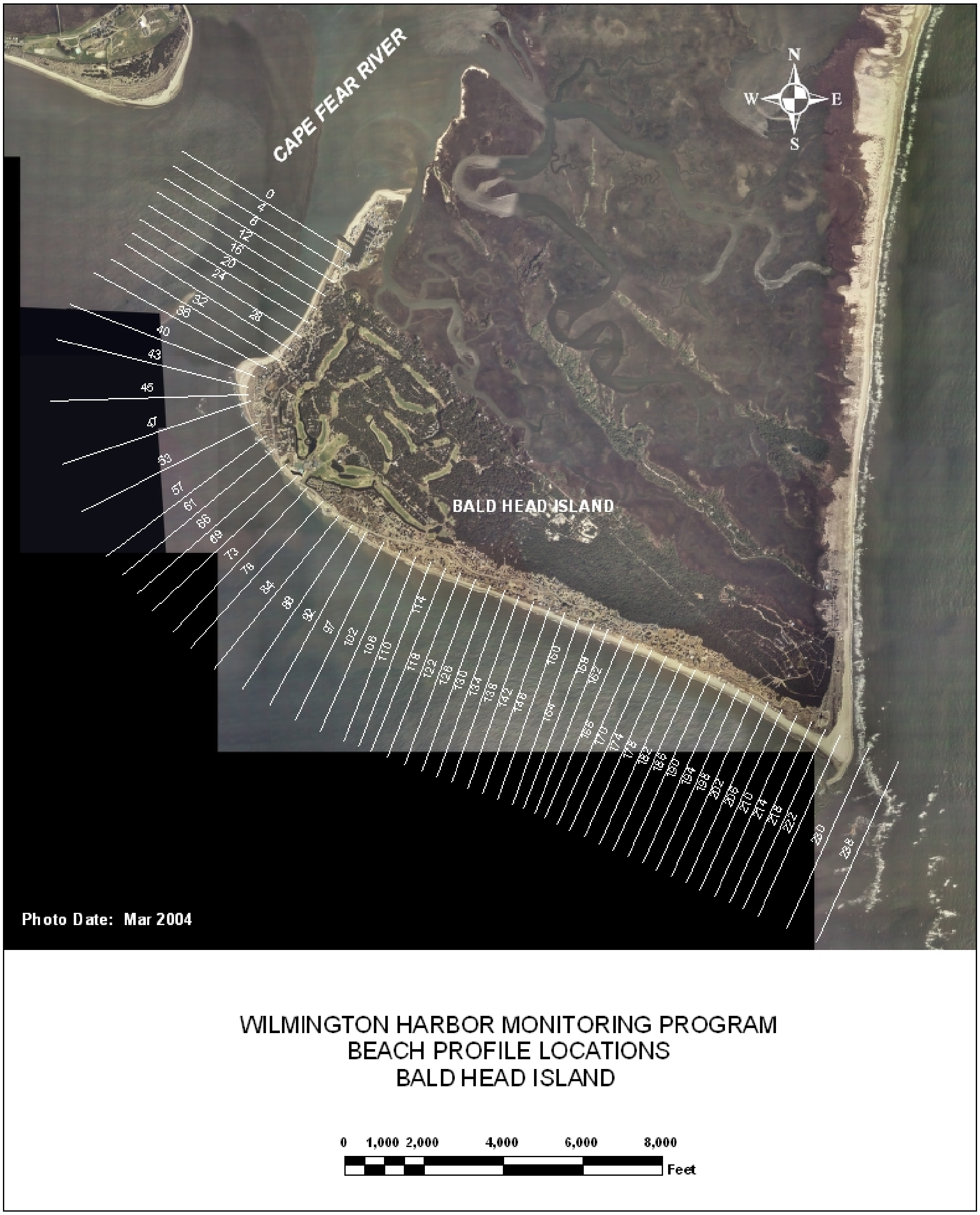


Figure 1.3 Bald Head Island Beach Profile Locations

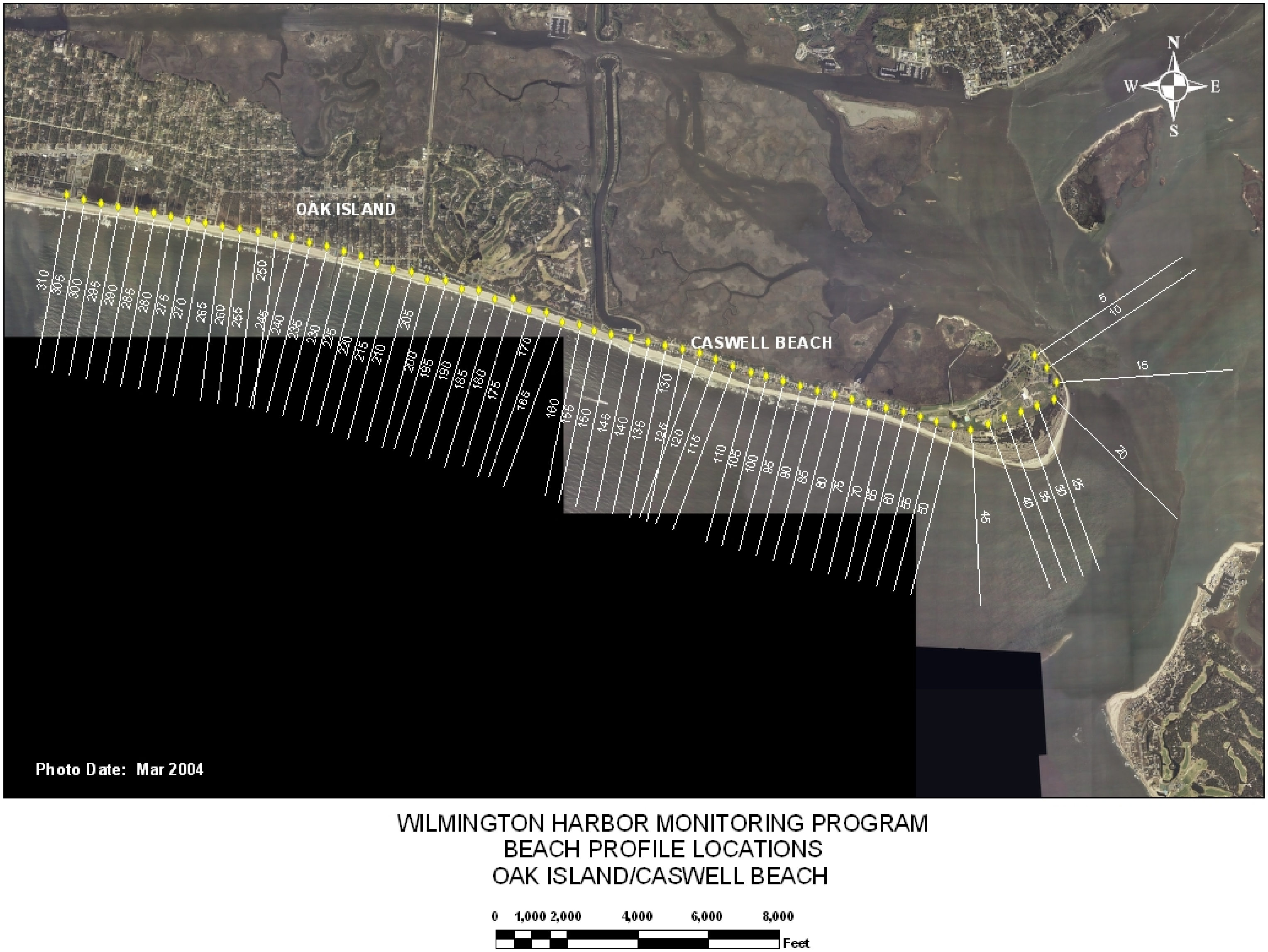


Figure 1.4 Oak Island/Caswell Beach Profile Locations

The most difficult areas to obtain accurate bathymetric surveys are through the surfzone and over the shoal areas that border each side of the Cape Fear entrance channel, and those near Frying Pan Shoals. Access to these locations is very difficult for conventional watercraft due to breaking waves and shallow depths. Under the present monitoring effort these access problems are largely eliminated through the use of the FRF's Lighter Amphibious Re-supply Cargo (LARC) survey system. The LARC vehicle, shown in Figure 1.5, is uniquely designed to transit through the water, across shoals, and through the surf zone up to the base of the beach dunes. The LARC is equipped with a Trimble Real-Time Kinematic Global Positioning Satellite (RTK-GPS) survey system for accurate horizontal and vertical positioning of the vehicle and a Knudsen Echosounder to measure depth while traversing the profile lines.

Figure 1.5 FRF Hydro-LARC Survey System

Channel and Ebb Tide Delta Surveys. The Corps of Engineers routinely surveys the condition of the ocean entrance channel from the Smith Island Range seaward to the Bald Head Shoal Range about once every three months. The area covered by these surveys includes the entire width of the authorized channel and some limited areas adjacent to the channel but outside the channel prism lines. Additional surveys are obtained in association with the numerous dredging contracts that will continue during the future maintenance of the channel.

The realignment of the seaward portion of the Bald Head Shoal Range is expected to be accompanied by a reconfiguration in the shape of the ebb tide delta. The major change expected is the reorientation of the western portion of the ebb tide delta with the reoriented delta essentially paralleling the alignment of the new channel. To monitor these changes, detailed surveys of the offshore area encompassing the entire ebb tide delta are accomplished on an annual basis. The surveys are scheduled to coincide with the offshore beach profile surveys so that the coverage can be combined where applicable. The general extent of the ebb delta surveys is indicated on Figure 1.6.

The bathymetric data over the ebb shoal area are collected using a very detailed and accurate Submetrix Interferometric (SI) System. This system collects swath bathymetry and sidescan sonar from a hull-mounted transducer. Horizontal and vertical accuracy, when coupled with RTK-GPS and a motion sensor is 15-20 cm (6-8 inches). Unlike traditional multi-beam systems, the SI maintains a swath width of 8-10 times the water depth and simultaneously collects both depth and seabed reflection properties. This system performs particularly well in shallow waters, ranging from 2-20 meters (6 to 66 feet) and produces swath soundings at 2 meter (6 foot) grid spacing.

Wave and Current Measurements. Wave and current measurements are also included as an integral part of the monitoring program. Three bottom-mounted gauges have been positioned in the project area in the ocean as shown in Figure 1.7. One gauge is located immediately offshore of Bald Head Island in 19 feet of water, the second is located just offshore of Oak Island (23 feet water depth), with the third positioned in 42 feet of water 11 miles offshore. The outer gauge was positioned to measure wave and water level data seaward of the navigation channel and ebb shoal influence. The nearshore gauges provide data in the vicinity of the navigation channel, nearshore shoals and adjacent beaches. A fourth gage was temporarily deployed just inside the entrance channel of the river where it was periodically moved to three locations in 2000-2001. All gauges consist of a combination of an Acoustic Doppler Current Profiler (ADCP) meter and a pressure gauge. This combination is capable of producing measurements of wave height, period and direction, water level (tide and surges) as well as currents over the water column. Water temperature near the bottom is also recorded. The sensors are mounted in a steel framed pod for protection from trawlers and are self-recording. Data are recorded at 3-hour intervals; except for the Oak Island gauge which is presently hard-wired to shore and reports on an hourly basis.

In addition to fixed bottom mounted gauges described above, currents are also measured along specified transects across the mouth of the Cape Fear River and near the new channel realignment. These measurements are recorded using a downward-looking, shipboard-mounted current profiler, which operates along the two closed loops as shown in Figure 1.8. The vessel navigates along the tracks over a complete tidal cycle to capture both ebb and flood flows as well as the entire tidal prism. Current surveys are accomplished annually corresponding with the ebb tide delta survey.

Aerial Photography. Vertical color aerial photographs have been obtained yearly generally near the time of the spring profile survey. The nominal scale of the historic

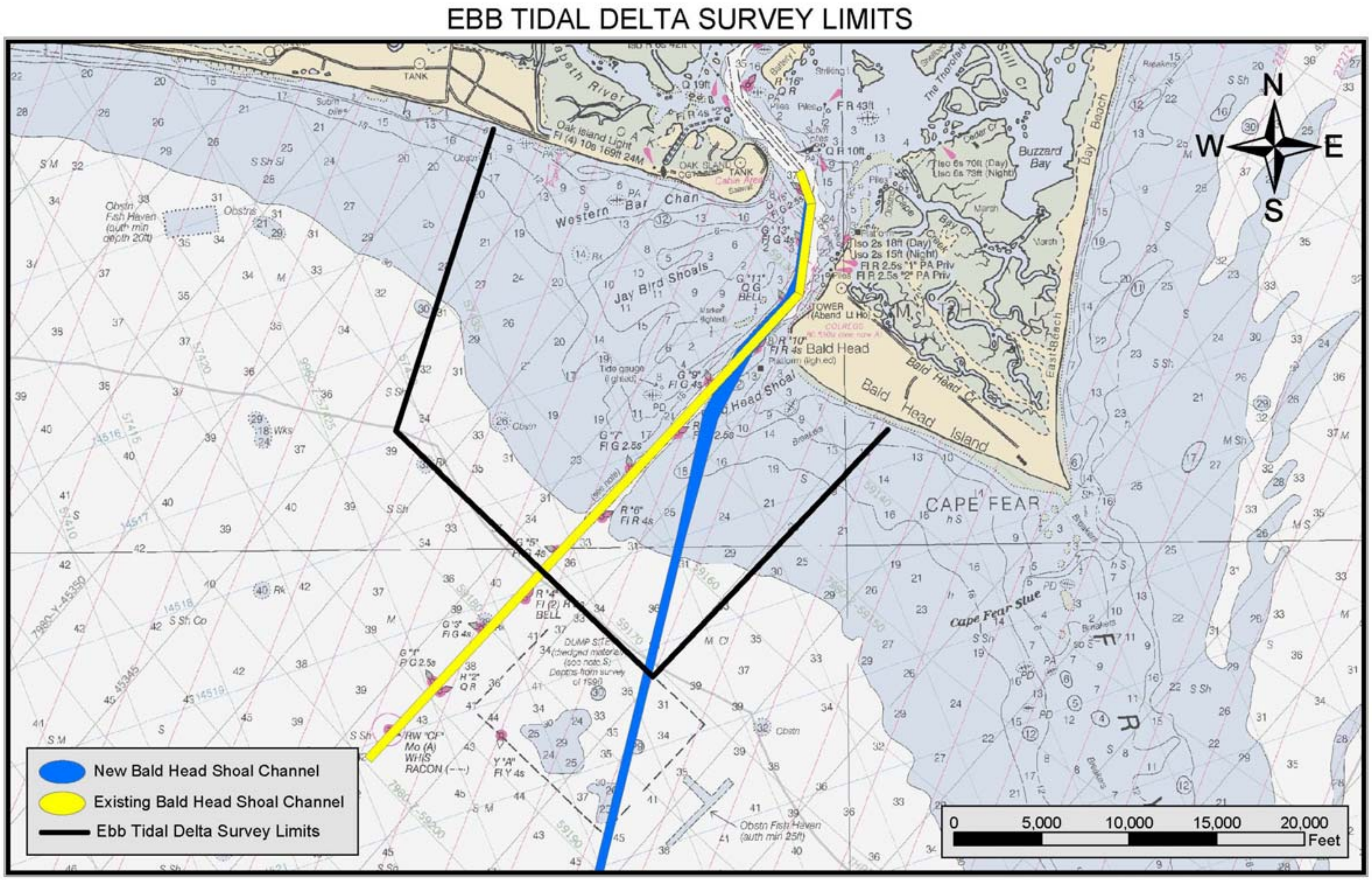


Figure 1.6 Entrance Channel and Ebb Tide Delta Survey Coverage

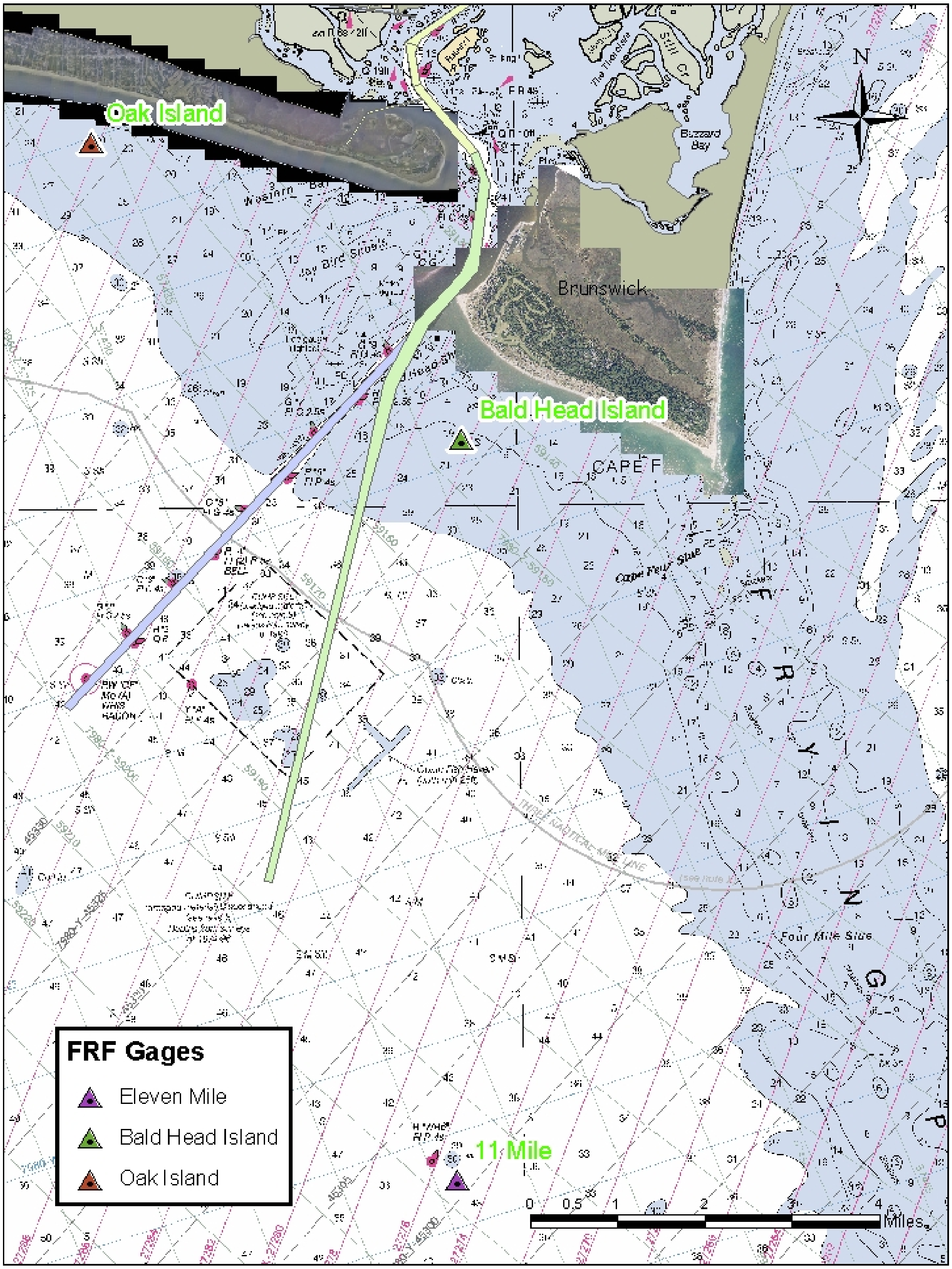


Figure 1.7 Wave and Current Gauge Locations

Ship-Board Current Profile Track Lines

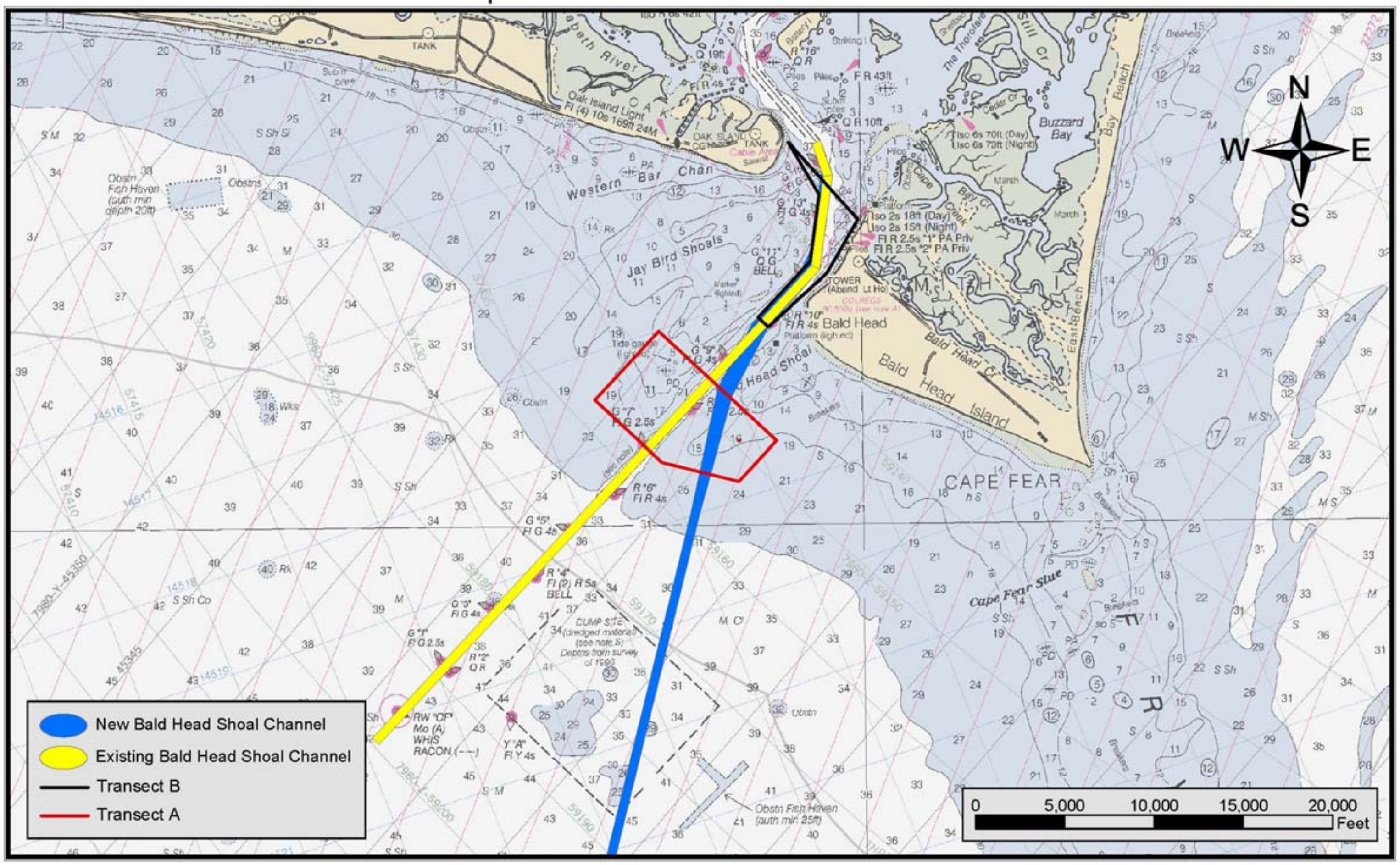


Figure 1.8 Shipboard Current Profile Locations

photography ranges from 1 inch equals 1000 feet over the entire project area to1 inch equals 500 feet for the Wilmington Harbor monitoring area. Recent imagery of the monitoring area has been obtained through the National Geospatial Intelligence Agency (NGA). The NGA is the Department of Defense executive agent for commercial satellite imagery acquisition. Through the existing NGA contracts with DigitalGlobe and GoeEye, the USACE is able to request imagery through one of five satellites with image resolution ranging from 1.4 to 3 foot resolution depending on availability and usage requirements. The ability to acquire satellite imagery has improved our monitoring effort by providing the ability to use imagery that correlates to specific events while lowering the overall cost of the monitoring effort.

Data Analysis and Reporting. Reports summarizing the monitoring activity are scheduled for preparation on an annual basis. Each report includes an analysis of the observed changes and trends along the adjacent beaches and a comparison to expected or historical trends. The reports also include an assessment of the shoaling patterns in the ocean entrance channel, temporal changes in the ebb tide delta and an analysis of the wave and current measurements. All reports are provided to the Village of Bald Head Island, the Town of Caswell Beach, the Town of Oak Island, and interested parties for their review and comment.

Bald Head Island Monitoring Survey Program.

In addition to the federal activity, a monitoring program is also being implemented by the Village of Bald Head Island. The Village has contracted with Olsen Associates to provide coastal engineering services for this program. Table 1.2 is a listing of the dates and coverage for the Village of Bald Head Island monitoring surveys. In 2005 following a beach disposal activity, the locals reconstructed a groin-field project along the western portion of South Beach (see Part 2 for discussion of this project and others undertaken by the Village of Bald Head). As a condition of the CAMA permit, the Village is required to submit an annual survey monitoring report to the NC Division of Coastal Management assessing the performance/impacts of the groin field.

Further, beginning in January 2005, the Corps of Engineers has agreed, as part of a legal settlement agreement, to initiate bi-monthly condition surveys of the channel along Bald Head Island. These surveys cover the Smith Island Range plus Bald Head Shoal Ranges 1 & 2. These surveys are being utilized to monitor the condition of the channel, the navigable channel width, and the relationship with the stability of Bald Head Island. The details of this effort and results to date are given in Part 4 of this report.

Table 1.2 Village of Bald Head Island Beach Profile Surveys

Date of Survey	Range of Stations	On Shore	Off Shore
1996 - Sep	20 to 166	X	
1997 - Mar	20 to 166	X	
1997 - Jun	20 to 162	X	
1997 - Sep	24 to 162	X	
1998 - Mar	20 to 162	X	
1998 - Jun	20 to 162	X	
1998 - Sep	20 to 158	X	
1998 - Dec	24 to 166	X	
1999 - Mar	24 to 166	X	
1999 - Nov	0 to 218	X	X
2000 - Nov	0 to 214	X	X
2001 - Aug	8 to 210	X	X
2002 - Jul	8 to 210	X	X
2002 - Dec	0 to 222	X	X
2003-May	0 to 218	X	X
2003-Oct	0 to 218	X	X
2004-Apr	0 to 218	X	X
2004-Oct	0 to 218	X	X
2005-Apr	0 to 218	X	X
2005-Nov	0 to 218	X	X
2006-Apr	0 to 218	X	X
2006-Nov	0 to 218	X	X
2007-Jun	0 to 218	X	X
2007-Nov	0 to 218	X	X
2008-May	0 to 218	X	X

Activities to Date. Figure 1.9 gives a time line activity chart that summarizes all tasks undertaken to date associated with the physical monitoring program. Data collection for the Wilmington Harbor monitoring program began in August 2000 prior to the dredging of the entrance channel. This report covers the monitoring activity through the May 2009 beach survey and therefore spans an initial period of 8.7 years. Table 1.3 lists all the monitoring surveys to date. Since the initiation of the program there have been 17 onshore beach profile surveys, 15 offshore beach profile surveys and 9 surveys of the ebb tide delta. Additional surveys of portions of the beach were also conducted before, during and after placement of the various beach disposals associated with the dredging contracts.

Table 1.3 Wilmington Harbor Monitoring Surveys

Survey Date	Onshore Profiles	Offshore Profiles	Ebb Shoal
Aug-Sep 2000	X	X	X
Oct 2001		X	
Nov-Dec 2001	X		
Dec 01-Jan 02			X
June 2002	X		
Nov-Dec 2002		X	
Jan 2003			X
Jan-Feb 2003	X		
June 2003	X		
Dec 03-Jan 04	X		
Jan 04		X	X
June 2004	X	X[1]	
Feb 2005	X	X	
Mar 2005			X
Aug 2005	X	X	
Mar 2006	X	X	
Apr 2006			X
Oct 2006	X	X	
Jan 2007			X
Jan 2007	X	X	
Jul 2007	X	X	
Jan 2008	X	X	X
Jul 2008	X	X	
Jan 2009	X	X	X
May 2009	X	X	

[1/] Bald Head Only

With respect to the wave/current meters, all four instruments were initially deployed in September 2000. All three ocean gauges have been maintained over the entire monitoring period, but have undergone periods of downtime do to servicing and other problems. The river gauge was in operation from September 2000 through September 2001 as it was cycled between three sites near the river entrance. The shipboard current measurements were taken on eight occasions beginning with the initial October 2000 data collection effort as shown in the listing in Table 1.4. Additionally, aerial photographs were taken on fourteen occasions to date as given in Table 1.5 including those provided by the Village of Bald Head. The most recent photography for the current monitoring period was flown on March 22, 2009 and August 8, 2009.

Table 1.4 Wilmington Harbor Shipboard Current Measurements

October 2000
April 2002
March 2003
January 2004
March 2006
February/March 2007
March 2008
April 2009

Table 1.5 Wilmington Harbor Aerial Photography

October 11, 2000
February 7, 2001
May 16, 2002
March 10, 2003
August 15, 2003
June 1, 2004
April 24, 2006
October, 2006*
May 20, 2007*
May 13, 2008*
Nov 18, 2008
Jan 14, 2009*
Mar 22, 2009
Aug 8, 2009
Nov 16, 2009
*Provided by BHI

Also included on the activity chart (Figure 1.9) are the dredging periods for the entrance channel and associated beach disposal time frames. As discussed earlier in this report, this initial construction was accomplished under two contracts. One contract, commonly known as Ocean Bar I, covered the outer bar channel, (Bald Head Shoal-Outer Reach). The second, Ocean Bar II, covered Bald Head Shoal-Inner channel plus the lower river channel ranges of Smith Island, Bald Head-Caswell, Southport, Battery Island, Lower Swash, and Snows Marsh. Dredging on Ocean Bar I began in December 2000 and was completed April 2001, with all the material being removed and deposited in the designated ocean disposal site. Ocean Bar II work involved removal of beach compatible sediments as well as fine silts and clays designated for offshore disposal. Dredging of Ocean Bar II commenced February 2001 with disposal on Bald Head Island. The Bald Head placement was completed in early July 2001 and the disposal was then initiated on Eastern Oak Island/Caswell Beach. This segment was finished in August 2001 followed by completion of the Oak Island West beach disposal in April 2002. The overall Ocean Bar II contract, including the dredging of non-suitable beach material was completed in December 2002.

Subsequently, the first maintenance cycle along the realigned/deepened channel was undertaken approximately two years following the initial construction. This cycle included the Clean Sweep I dredging over the period of September 2003 through January 2004, plus the Clean Sweep II contract completed during January 2005. The latter contract involved beach disposal activity between November 2004 and January 2005 along Bald Head Island. The second maintenance cycle was completed over the February-April 2007 time period with disposal again going to Bald Head Island. The third maintenance cycle involved placement along Oak Island/Caswell Beach, which was done over the period of February-April 2009.

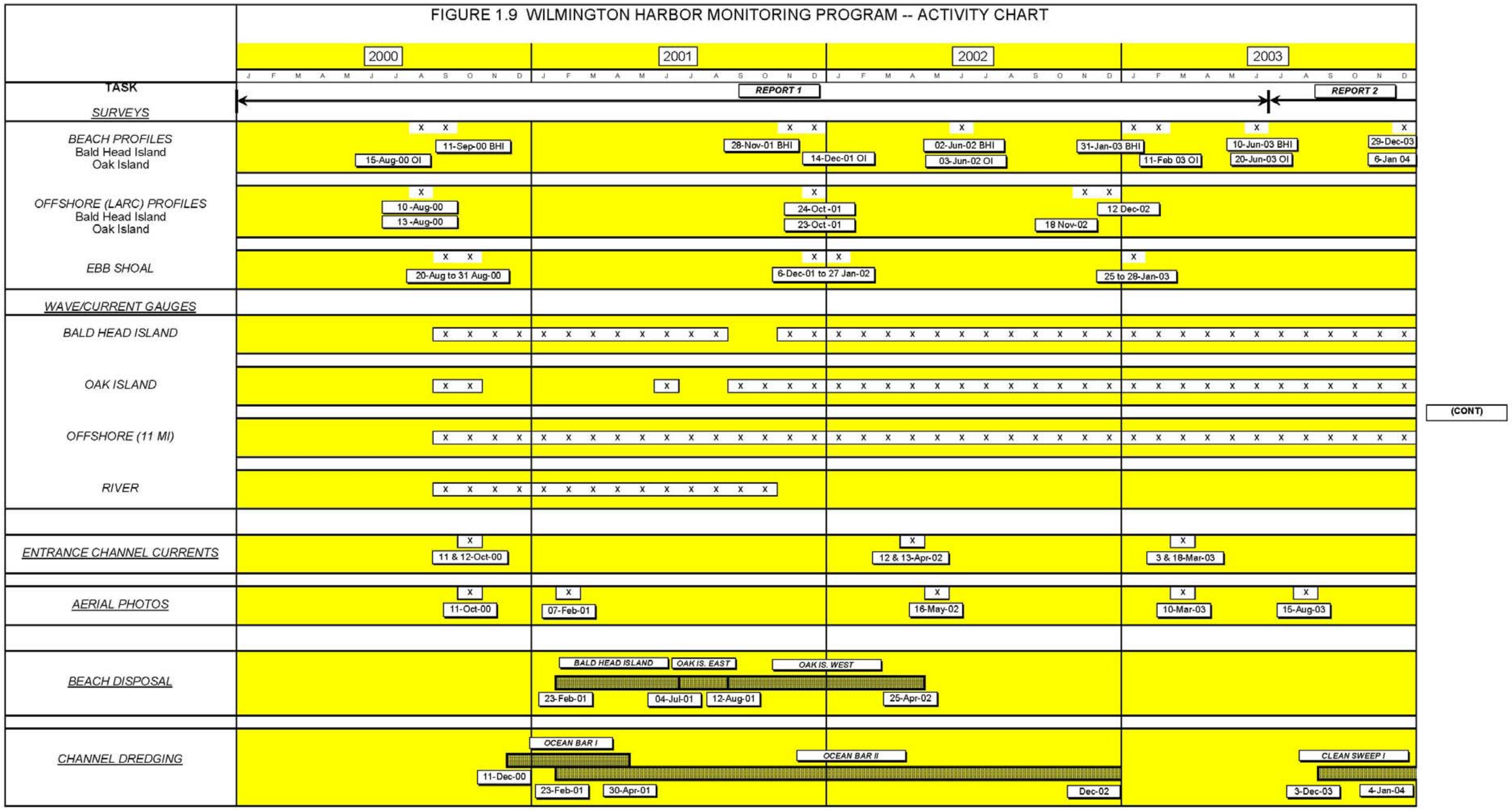
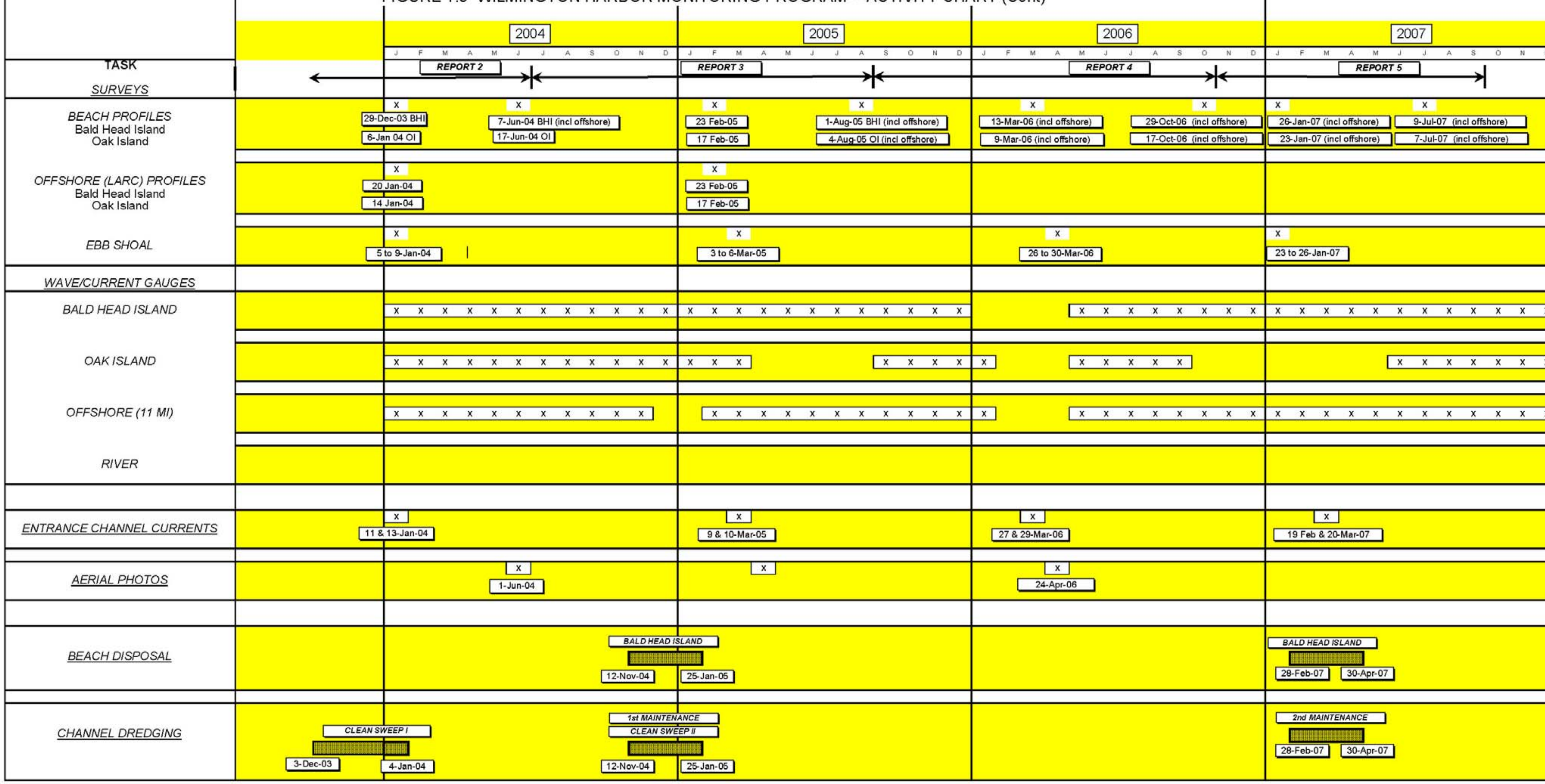


FIGURE 1.9 WILMINGTON HARBOR MONITORING PROGRAM -- ACTIVITY CHART

FIGURE 1.9 WILMINGTON HARBOR MONITORING PROGRAM -- ACTIVITY CHART (Cont)



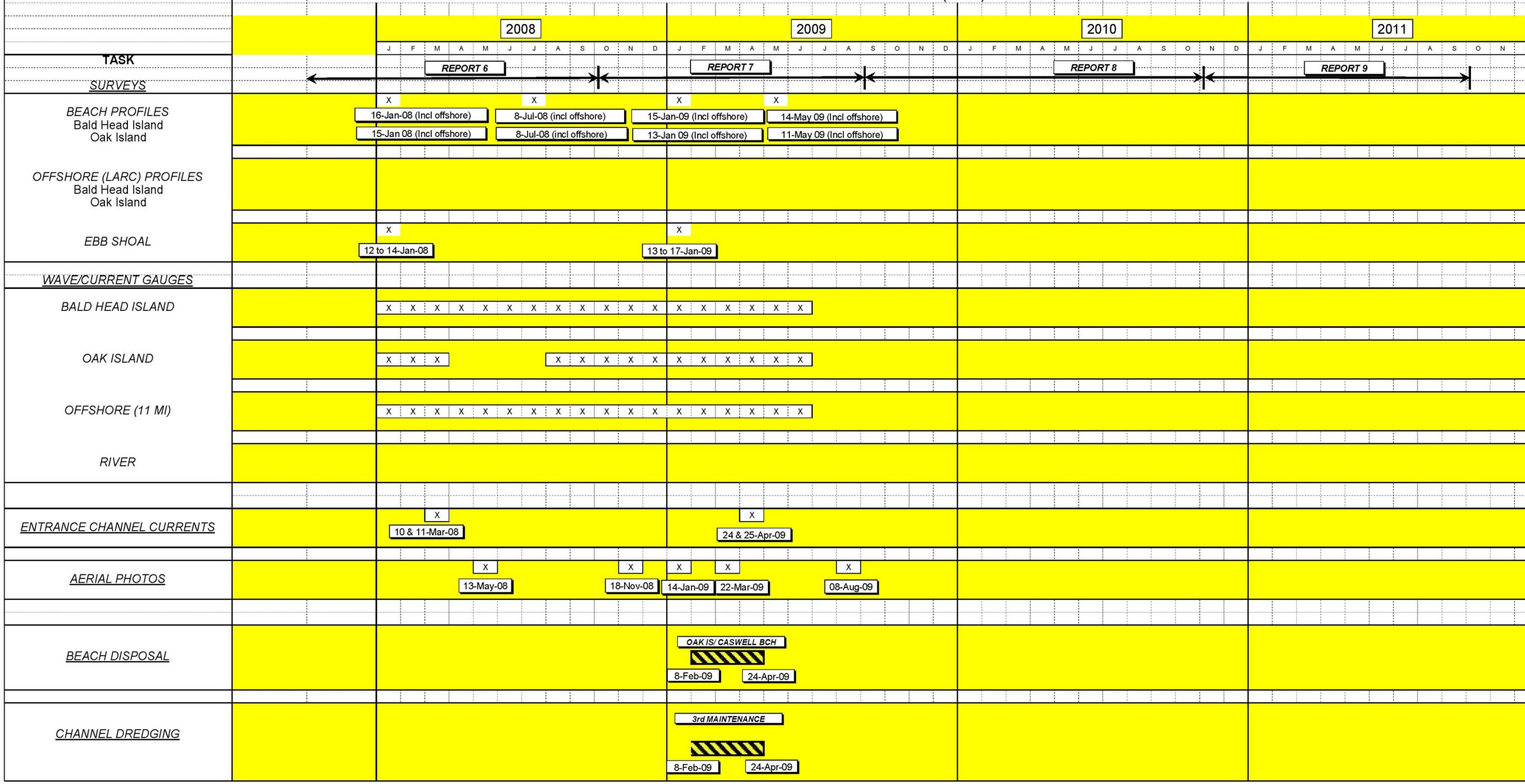


FIGURE 1.9 WILMINGTON HARBOR MONITORING PROGRAM -- ACTIVITY CHART (Cont)

Part 2 BACKGROUND INFORMATION

Shoreline Change Rates

State Erosion Rates. Rates of shoreline change have been calculated for the entire coastline of North Carolina by the NC Division of Coastal Management (NCDCM). These data are used for planning and regulatory purposes in establishing construction setback distances along the ocean front shoreline. The shoreline changes are representative of long-term average annual rates based on the comparison of shoreline locations interpreted from historic aerial photos. The shoreline position is recorded from a common shore parallel baseline along fixed transects that run at right angles to the base line. Transects are spaced every 50-meters (164 feet) along the coastline and are grouped in individual base maps consisting of 72 transects each. Each base map covers about 3.6 km (2.2 miles) of coastline. In reporting the shoreline change data, the NCDCM uses the end point method that compares the earliest shoreline position with most recent position and divides the shoreline change by the time interval between the two dates. An alongshore average is then used to smooth out smaller perturbations along the coast. This running average uses 17 adjacent transects consisting of eight transects on either side of the transect of interest.

For this study NCDCM shoreline position data were combined with the initial monitoring survey of Aug/Sep 2000, taken immediately prior to the channel deepening and realignment. The NCDCM data included shoreline positions taken from aerial photos dated 1-Apr 38, 16-Aug 59, 8-Dec 80, 25-Aug 86 and 1-Sep 92. Average annual shoreline change rates were computed by taking a least-squares fit of all the shoreline positions spanning the dates 1938 through 2000. A running alongshore average, as noted above, was then computed from the least squares fit data. The final computations represent long-term shoreline change rates for the monitoring area spanning more than 62 years before the new channel work was initiated. These long-term pre-construction rates are given in Figure 2.1 for Oak Island/Caswell Beach and in Figure 2.2 for Bald Head Island. Later in Part 4 of this report, these computed rates are compared to the rates calculated over the monitoring period to date (i.e. the post-construction period).

Oak Island/Caswell Beach Shoreline Change Rates. Figure 2.1 covers about 6 miles of coastline along Oak Island/Caswell Beach just west of the Cape Fear entrance. The trend in long-term shoreline change rates show a general erosion pattern along the western two-thirds of the area and accretion along the remaining third nearest the river entrance. The erosion rates range from 2 feet per year at the western end of the study area, to a maximum erosion of nearly 6 feet per year, which occurs near the boundary line between Oak Island and Caswell Beach. The erosion then diminishes moving eastward from the peak eventually turning accretionary at a point about 2000 feet to the east of the CP&L canal area. From this point eastward, the beach has historically been stable showing rates of accretion ranging from 1 to 2 feet per year to a maximum of more than 30 feet per year along the tip of Fort Caswell.

Bald Head Island Shoreline Change Rates. As shown on Figure 2.2, the long-term trend in shoreline change for Bald Head Island is one of erosion. The erosional pattern along the 3-mile extent of South Beach shows relatively higher erosion both at the western and eastern ends with more stability along the central reach. The pattern holds true except for a few transects nearest the river entrance that are found to be accretionary at the southwestern tip of Bald Head. Proceeding eastward from this stable area is an erosion zone covering about one mile where the rates range from –2 feet per year to a maximum of –6.6 feet per year. The rates then range from –2 to –3 feet per year average along the central portions of South Beach. Eastward beyond this relatively more stable reach the rates gradually increase towards Cape Fear reaching a maximum erosion rate of about 20 feet per year.

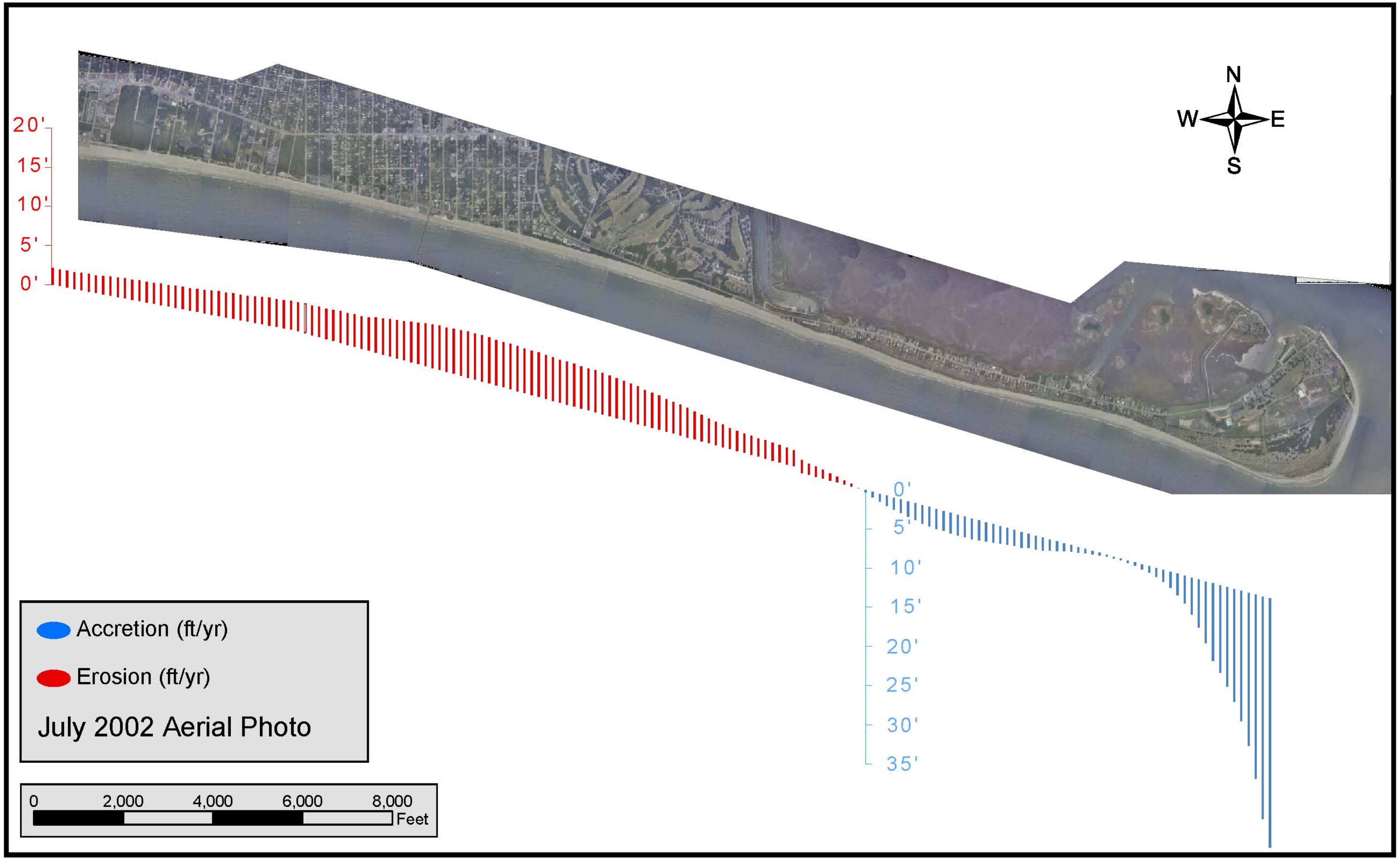


Figure 2.1 Long-Term Average Annual Shoreline Change Rates (1938-2000) Oak Island/Caswell Beach

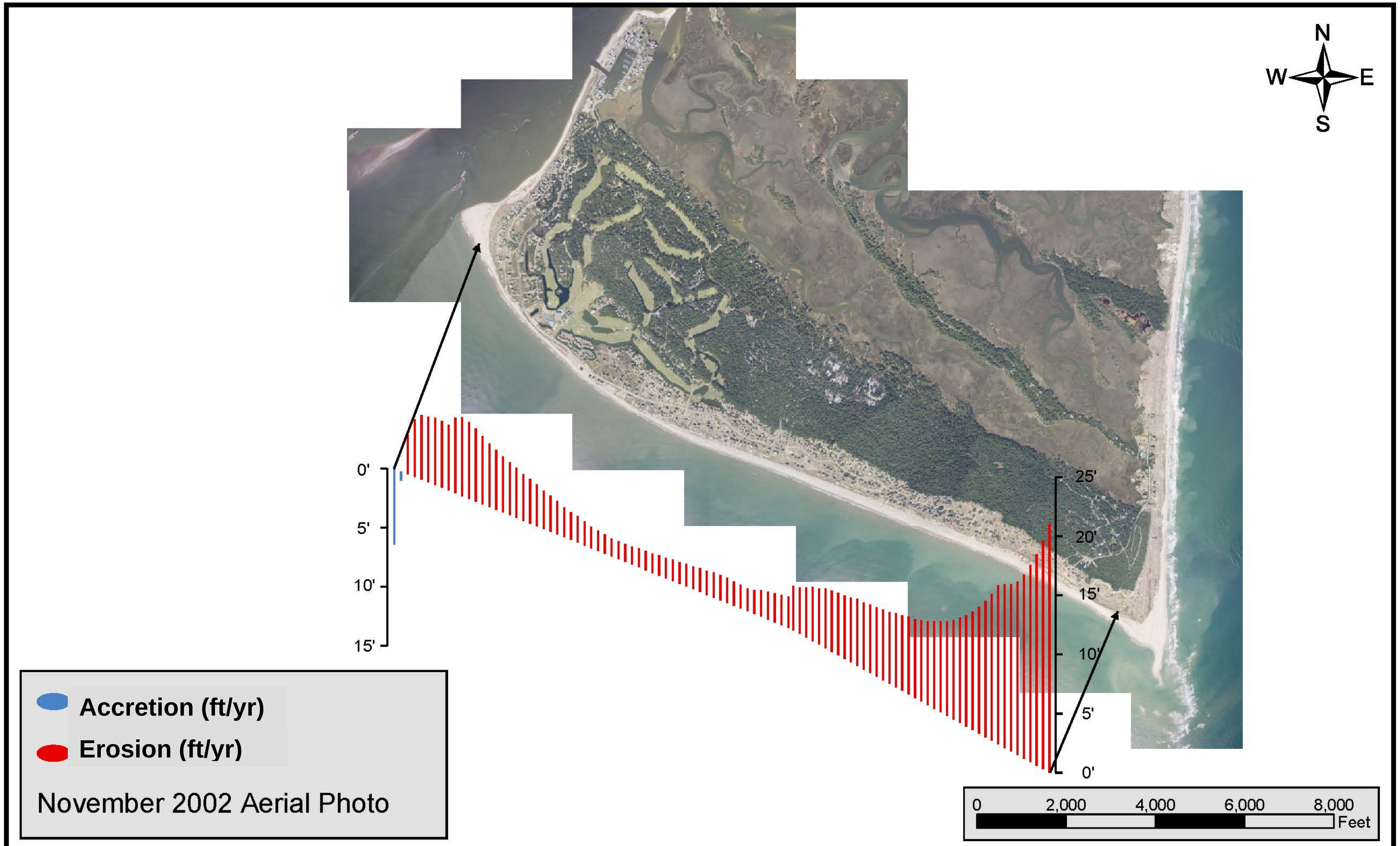


Figure 2.2 Long-Term Average Annual Shoreline Change Rates (1938-2000) Bald Head Island

Erosion Control Activities at Bald Head Island

To combat the erosion that Bald Head Island has been experiencing since the early 1970's, there have been a number of erosion control activities undertaken including beach disposal projects, groin field construction/rehabilitation and sand bag placement. These operations have concentrated on the south-western portion of Bald Head Island where erosion problems have been most acute.

Three beach disposals of approximately 360,000 cubic yards in 1991, 650,000 cubic yards in 1996, and 450,000 cubic yards in 1997 were placed with slight variations of the start and stop locations between stations 36+00 and 134+00. These projects were cost-shared or paid for by the Village of Bald Head Island. In 2001, 1,849,000 cubic yards were placed between stations 41+60 and 205+50 in conjunction with the entrance channel realignment and deepening. This was followed by the 2005 and 2007 placement of 1,217,500 cubic yards and 978,500 cubic yards of sand, respectively, as part of the navigation channel maintenance.

In 1994 a 645-foot-long sand bag revetment was placed along the badly eroding portion of western South Beach. In 2003-2004 the sand bag revetment was expanded by increasing the overall length by 200 feet, increasing the base width from 20 to 40 feet and increasing the crest elevation by 6 feet to +12 feet NGVD. A view of the expanded sand bags are shown in Figure 2.3, as it appeared in April 2003.

Figure 2.3 Sand Bag Revetment along South Bald Head Wynd, April 2003.

In 1996, the Village constructed sixteen geo-textile groins from station 49+00 to Station 114+00. The groins were 9 feet in diameter and 325 feet long. The spacing between the groins was about 450 feet. The groin field slowed the erosion for several years before they began to fail and ceased to function in 2000. Due to apparent effectiveness of the geo-textile groins, the Village of Bald Head Island decided to rebuild the groin field following the beach fill placement in 2005. As such a sixteen structure sand tube groin field was reconstructed along South Beach between stations 47+00 and 105+00. The replacement geo-tubes were constructed between January and March 2005. Some modifications were made to the original 1996 plan. These modifications included: (1) the spacing was reduced from 450 feet to 385 feet thereby reducing the overall extent for the groin field, (2) the tube lengths were 300 feet for 14 of the structures and 250 feet for the remaining two, (3) the individual tubes were tapered with a landward maximum diameter of 10 feet to 6 feet at the seaward end, and (4) the entire groin field was shifted westward to be more aligned with the problem area. Figure 2.4 shows an aerial view of the completed groins taken in July 2006, about 16 months following placement.

Figure 2.4 Reconstructed Groin field along Bald Head Island, July 2006 (Courtesy of Village of Bald Head Island)

A further recent beach disposal operation was undertaken by the Village of Bald Head in January 2006. This involved dredging of Bald Head Creek, located just north of the marina, and placing approximately 47,800 of beach quality sediments along an eroding portion of West Beach. Placement occurred along a 1600-foot-reach (between Profile 16 and 34) immediately north of the point.

Most recently, Bald Head Island is undertaking a large beach re-nourishment project to cover portions of South and West Beach. The work commenced in November 2009 (Figure 2.5) with completion in March 2010. This operation was undertaken to cover the "open" maintenance cycle, when according to the sand management plan, material is designated to go to Oak Island. Approximately 1.6 million cubic yards of sand were dredged from an offshore borrow site comprising the seawardmost portions of Jay Bird Shoals. The contract also involves the replacement of the geotextile groins in conjunction with the fill placement.

Figure 2.5 Start of 2009-10 local Beach Fill Project along Bald Head Island, November 2009 (Courtesy of Village of Bald Head Island)

Part 3 DATA ANALYSIS AND RESULTS THRU THE CURRENT MONITORING CYCLE

General. Data collection for the monitoring program was initiated in August 2000 just prior to construction of the entrance channel improvements. This part of the report describes the data collected to date and results through May 2009, the end of the seventh monitoring cycle. The data analyses generally describe changes that have occurred since those last reported in July 2008 and also relative to the base (pre-project) conditions established with the initial monitoring surveys. The following discussion covers the four main data collection efforts, namely: shoreline and volumetric changes as measured from the beach profile surveys, ebb and nearshore shoal response, wave data, and current measurements in the entrance channel.

Beach Profile Analysis-Shoreline and Profile Change

The beach profile surveys were analyzed using BMAP (Beach Morphology Analysis Program) (Sommerfield, 1994) to determine both shoreline and unit volume changes over time for each profile of interest. The beach profile locations were given previously in Figure 1.3 for Bald Head Island and Figure 1.4 for Oak Island. It is noted that the beach profile numbers are reflective of their location on the baseline. For example, the origin of beach profile 43 is located near station 43+00 on the Bald Head Island baseline. The shoreline is represented by the mean high water line which is 2.71 feet above NGVD29 for the monitoring area.

Bald Head Island. Shoreline changes measured along Bald Head Island over the current monitoring cycle are given in Figures 3.1 and 3.2. The present monitoring period includes two surveys undertaken in January 2009 and May 2009. Figure 3.1 shows the shoreline changes relative to the July 2008 position, i.e. the last referenced location in Report 6. Figure 3.2 gives the shoreline changes with respect to the start of the monitoring program in September 2000.

As indicted in Figure 3.1, most of the profile locations along Bald Head Island have been erosional over the last year. Significant erosion occurred along the spit and western portions of South Beach, between Profiles 40 through 74, and along the eastern portions of South Beach between Profiles 110 through 170. The peak erosion value was measured at Profile 43 being 304 feet of change in January 2009 and 254 feet in May 2009. The peak losses along the eastern portions of South Beach were on the order of 60 to 70 feet. In general, the erosional areas are located approximately where fill material was placed in April 2007 which created an offset in the shoreline position from which the current monitoring period surveys are compared. The erosion measurements computed for these areas are strongly influenced by natural processes shaping the beach fill to an equilibrium profile shape. In contrast, some profiles within the monitoring area have accreted since the last monitoring cycle ended. These include Profiles 28 thru 36 (located within the spit west of South Beach), and the area between Profiles 178 and 194 (located near the east end of South

Beach). Both of these areas were outside the limits of the fill placed in April 2007, which indicates that the fill has diffused longitudinally contributing to the accretion.

The greatest variability was found within the spit area which has been defined in previous reports as a zone between Profiles 32 to 45. This very dynamic area had shoreline changes which ranged from gains of about 70 feet to losses of more than 300 feet. Although a large range of shoreline change is typical for the spit area, the peak losses recorded over the present period are some of the highest measured throughout the monitoring program. These peak recessions were located in vicinity of the western terminus of the existing groin field. Further inspection has revealed that this shoreline response may have been the result of the interaction of the retreating shoreline with the groins and subsequent progressive failure of the groins themselves. This groin interaction along with some other possible factors influencing this shoreline response are discussed in Part 4 of this report.

The remaining area along West Beach (Profiles 0 thru 28) has shown a general loss over the period, with the shoreline retreating on average 3 feet. Overall, the alongshore average shoreline changes measured over the entire monitoring area were losses of 41 feet between July 2008 and May 2009.

Shoreline change patterns as measured over the last 8.7-year period, i.e., since the monitoring was initiated, are shown in Figure 3.2. Included in the figure are the three most recent surveys of July 2008, January 2009 and May 2009. This figure reveals that for the majority of the profiles, the shoreline changes are positive when measuring relative to the September 2000 base survey. For example, all lines along South Beach, extending eastward from Profile 73 are largely accretional, with the May 2009 shoreline being an average of 113 feet seaward of its September 2000 position. Large gains are also present within the spit area where the shoreline has advanced on the order of 250 feet over the monitoring period. In contrast, an area of progressive erosion is seen along the western portion of South Beach between Profiles 43 through 73. Average shoreline loss within this region is approximately 170 feet with a peak loss of 331 feet occurring at Profile 43 (as of May 2009). Peak recessions (as well as some peak advances within the northern portions of the spit) were even greater with the January 2009 survey as shown in Figure 3.2. As noted above, these peak recessions (and spit gains) are the highest recorded to date and may be related to the interaction of the failing groin field.

For West Beach (Profiles 0 through 28), located immediately along the river channel, the shoreline has shown an average loss of about 25 feet when compared to the base condition. When considering all locations along Bald Head Island (Profiles 0 through 218), the shoreline is presently on the average 49 feet more seaward that it was in 2000.

Typical profile plots shown in Figures 3.3 and 3.4 are taken along Bald Head's South Beach. Figure 3.3 shows Profile 61 within an area which has been prone to erosion; whereas, Figure 3.4 gives Profile 150 in the more stable area to the east. Both of these profiles received beach fill associated with the initial channel dredging during the February-July 2001 time frame and with the third, most recent (April 2007), beach disposal. However, the second fill in January 2005 did not extend to Profile 150. Figure 3.3 shows the widened beach berm from the initial fill marked by maximum seaward extent of the July 2001 survey. In July 2001 the shoreline was about 80 feet seaward of the September 2000 position. From this point, the profile is shown to march progressively landward, reaching its maximum landward retreat January 2004. At this time the shoreline retreated about 250 feet from its initial position. The nearly uniform retreat is displayed graphically in Figure 3.5. This figure shows the cumulative change in shoreline position over the 8.7-year monitoring period as measured from the September 2000 position. (For comparison purposes both Profile 61 and 150 are given on the chart). After reaching the maximum recession, Profile 61 remained about the same in June 2004, possibly being restrained by sand bags placed at this location. The second fill was then added, advancing the berm and shoreline to about 25 feet beyond its September 2000 location in February 2005, where it remained stable for about 6-months. Beginning in August 2005, the fill began once again to erode, in a manner similar to the first cycle immediately following the initial fill. By January 2007, the shoreline was about 60 feet landward of its September 2000 position. With the most recent fill, a gain occurred moving the shoreline back to near its original position being about 13 feet shy its location in 2000. The profile has continued to erode since placement of the third fill and is currently 144 feet landward of the September 2000 base year position. Examination of the shoreline loss rates following fill placement show a similar response, with a rapid retreat of shoreline at Profile 61 occurring after each fill. However, the rate of loss is significantly less for the second and third fills (64 feet/year and 61 feet/year for the second and third fills, respectively, versus 120 ft/year with the initial fill), as indicated on the figure. One possible explanation of this difference could be the positive influence of the groin field in reducing the loss rate of the fill at this profile location.

For Profile 150 (Figure 3.4) a much more stable behavior is evident. In this instance much of the initial fill has remained intact and the shoreline retreat has occurred at a slower rate. The response is clearly apparent in Figure 3.5 as well, especially when compared to Profile 61. Profile 150 actually widened some beyond the July 2001 fill extent, and remained stable for about the next 2 years, at which time it experienced a much slower but progressive loss of material. After the second fill, the shoreline gained slightly even though this profile line was outside of the limits of the fill, indicating some dispersal of sediment by natural means. Following the third disposal, the shoreline advanced significantly to 257 feet seaward of its September 2000 position. The material has eroded much more rapidly following the third fill placement with an annual loss rate of 79 feet/year, similar to the loss rate at Profile 61. The shoreline position of Profile 150 at the end of the current monitoring period, May 2009, remained positive being approximately 114 feet seaward of the September 2000 shoreline position.

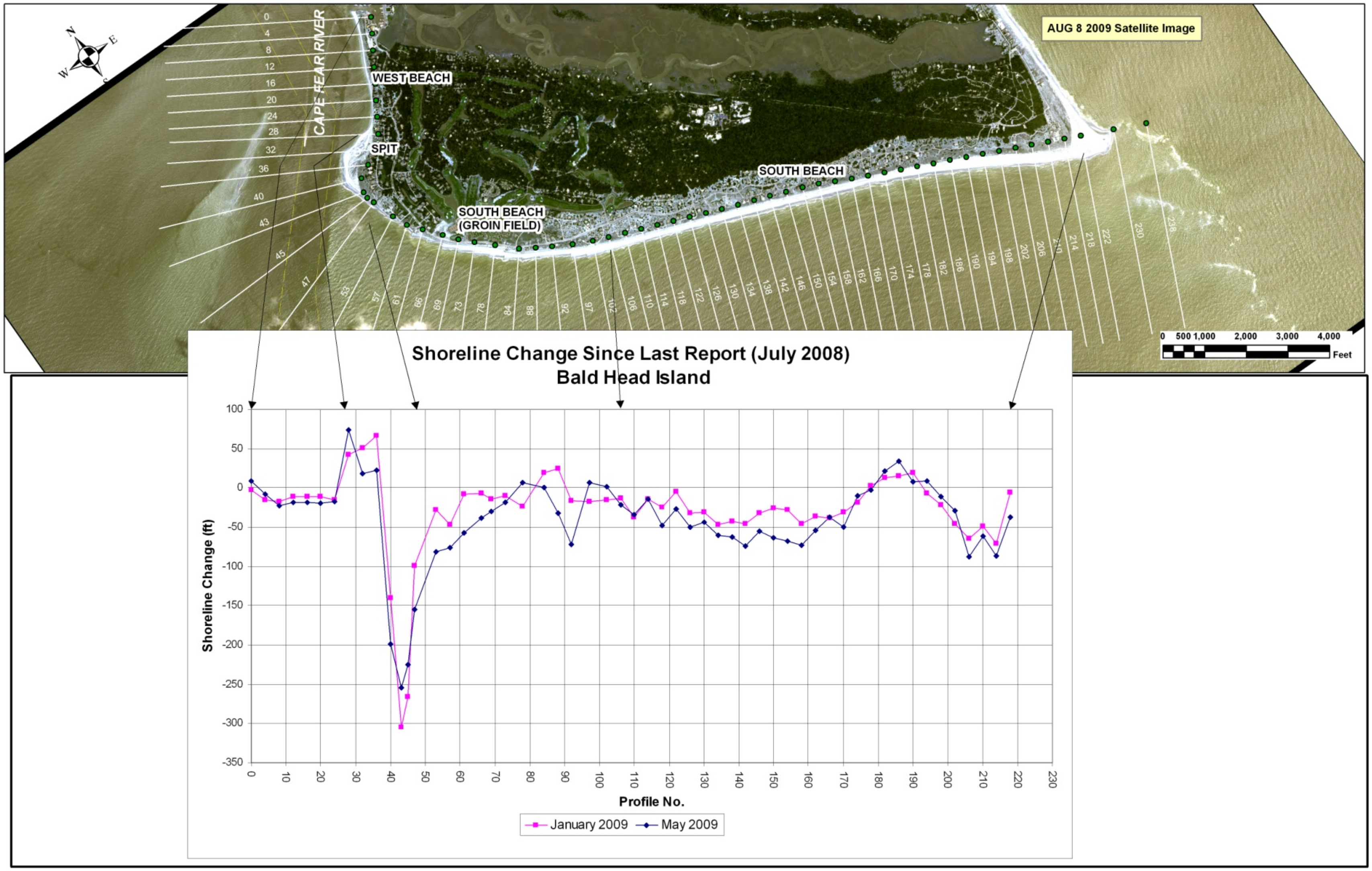


Figure 3.1 Shoreline Change Since Last Report (July 2008) Bald Head Island

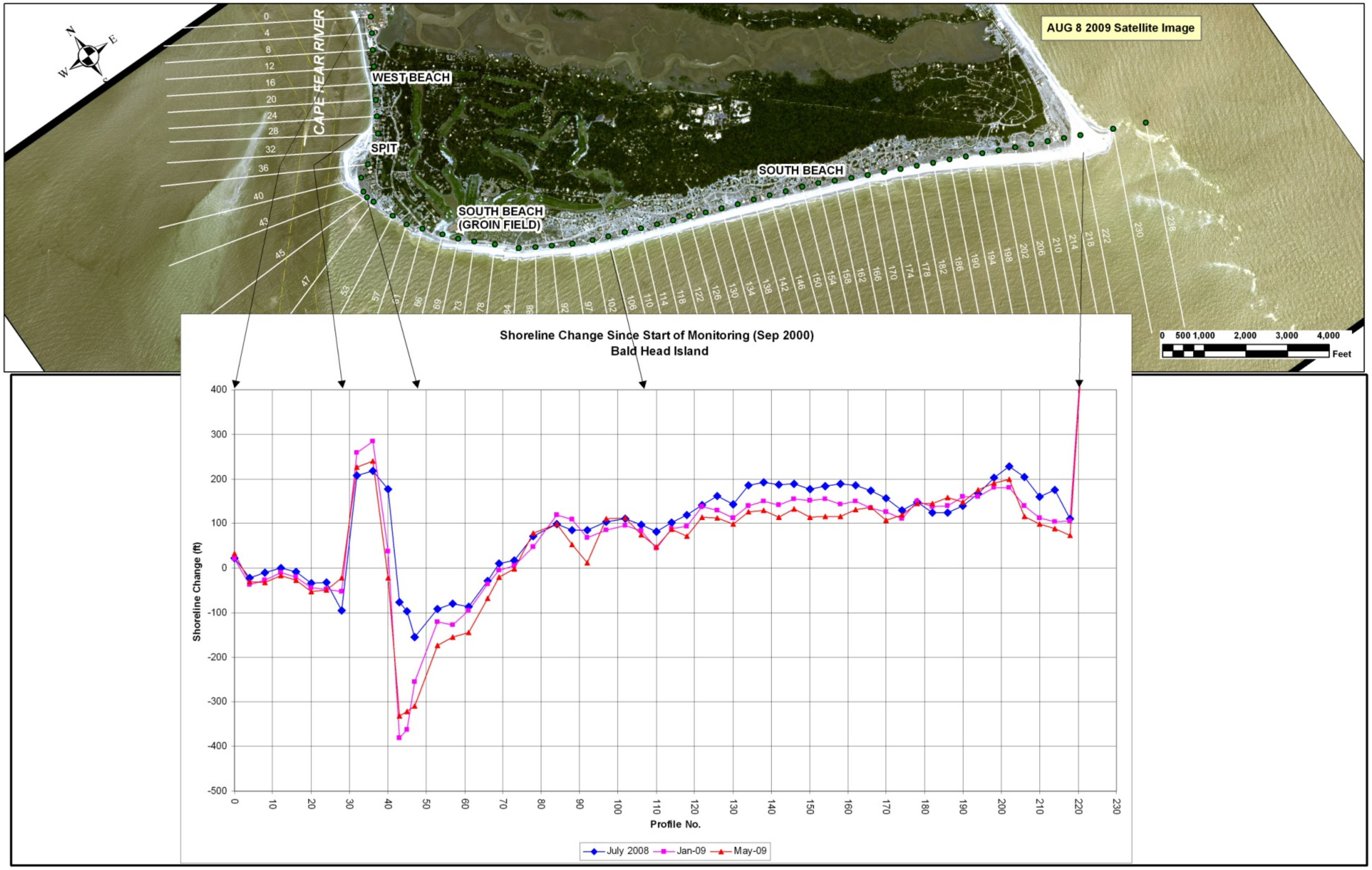


Figure 3.2 Shoreline Change Since Start of Monitoring (Sep 2000) Bald Head Island

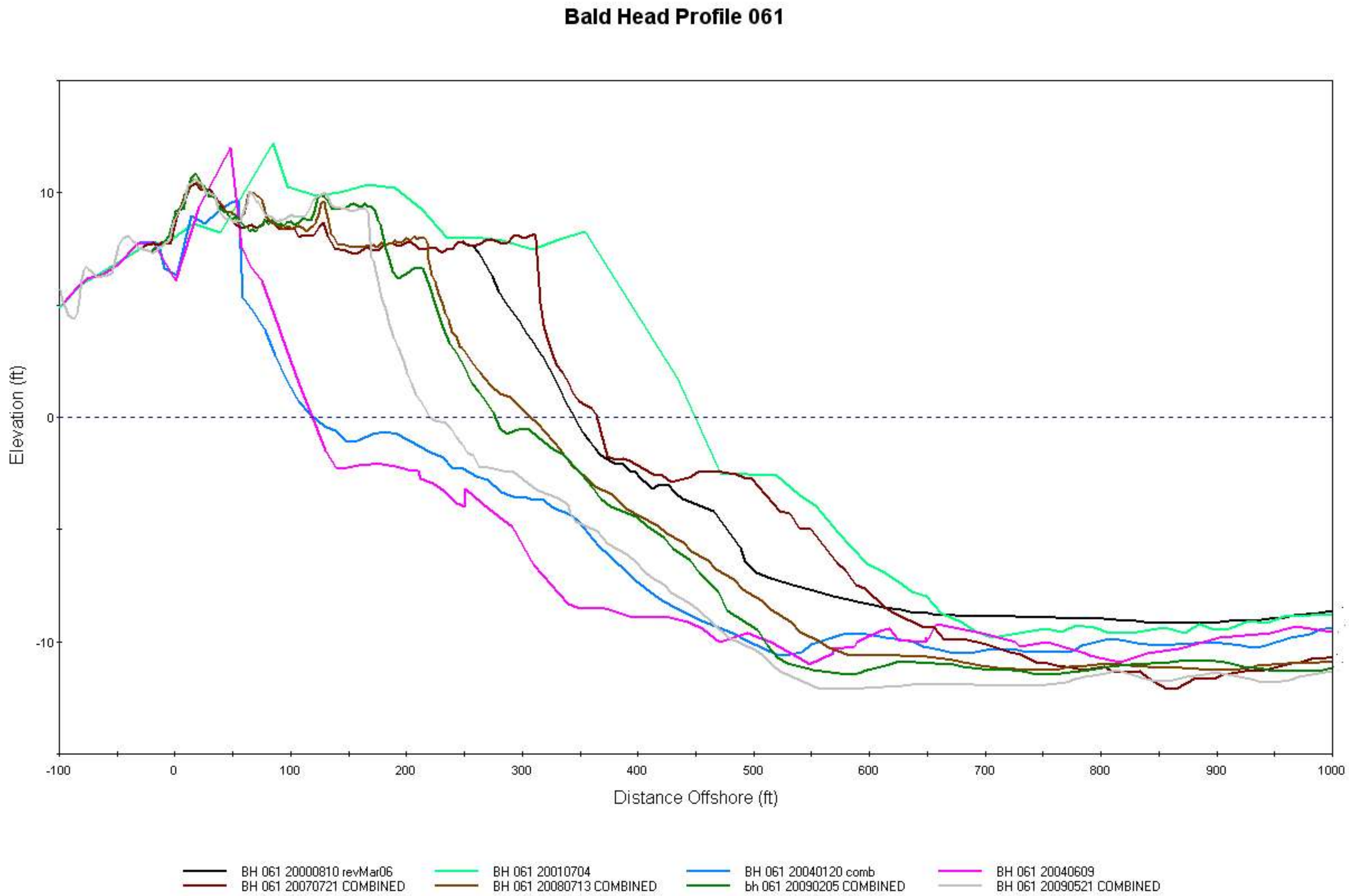


Figure 3.3 Bald Head Island Profile 061

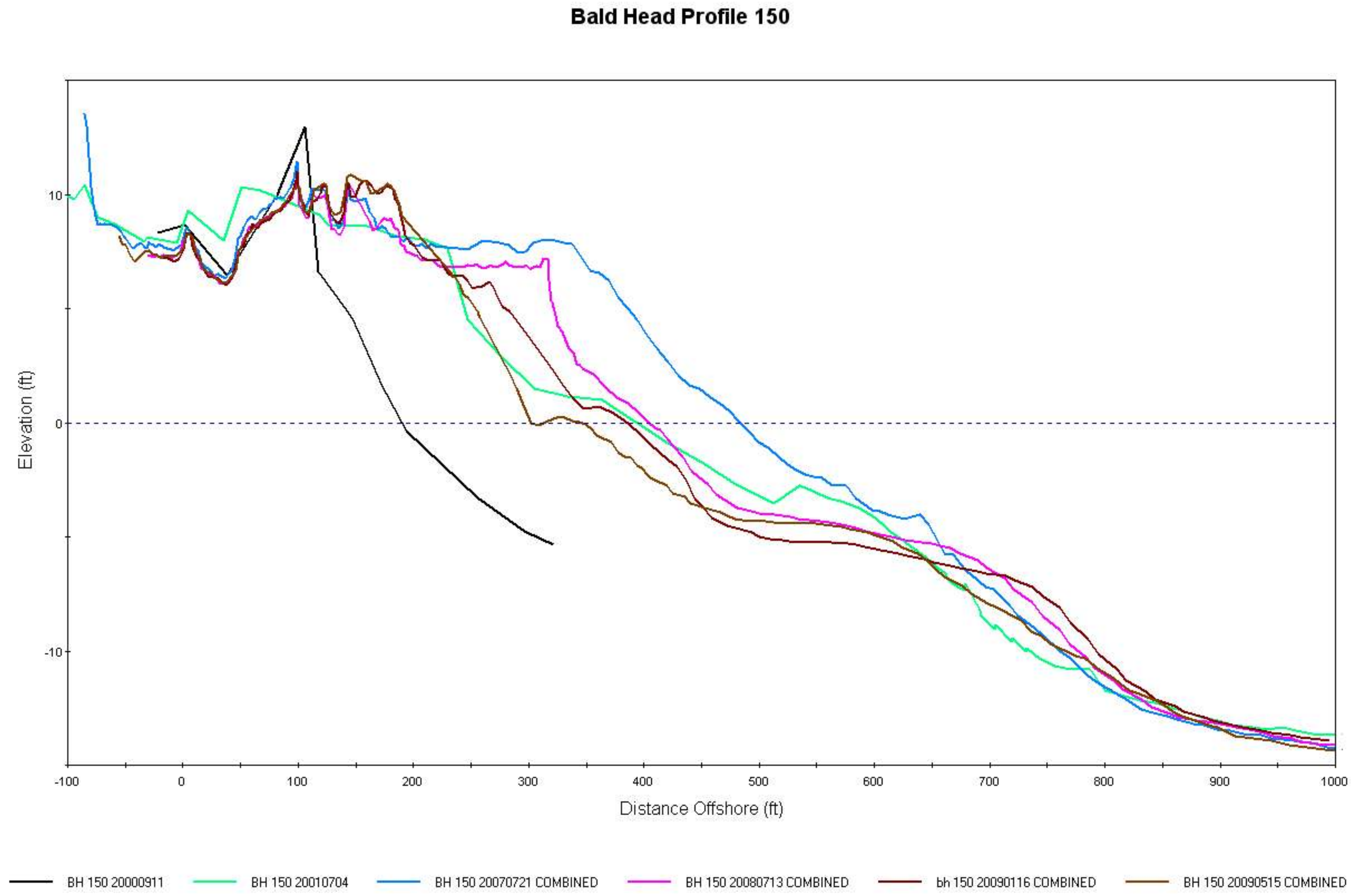


Figure 3.4 Bald Head Island 150

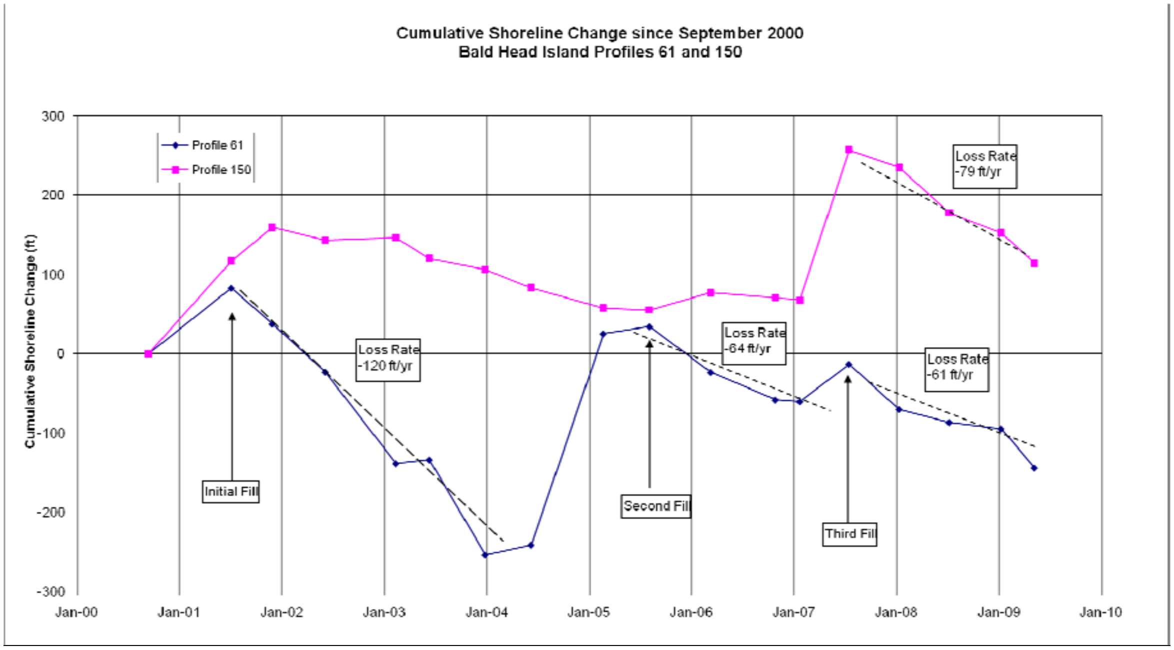


Figure 3.5 Cumulative Shoreline Changes Since September 2000

Bald Head Island Profiles 61 and 150

Oak Island. Shoreline changes measured along Oak Island over the current monitoring cycle are given in Figure 3.6 and Figure 3.7. The present monitoring period includes the January 2009 and May 2009 surveys. Figure 3.6 shows the shoreline changes relative the July 2008 position, i.e. the last referenced location in Report 6. Figure 3.7 gives the shoreline changes with respect to the initial monitoring survey in August 2000.

The two surveys of the present period bracket the most recent beach disposal operation which was completed in April 2009. The disposal occurred in two zones namely between Profiles 60 and 95 and Profiles 120 to 260. The result of this operation is clearly evident in Figure 3.6, with the May 2009 survey showing the significant advance in the position of the shoreline. Prior to the fill placement, the shoreline was generally receding particularly within the western half of the monitoring area. Typically, the shoreline eroded between 20 to 30 feet along this reach between July 2008 and January 2009. The western portion of the island was more variable with some profiles gaining and some eroding. With the beach disposal, the shoreline typically advanced between 80 and 180 feet by May 2009. Even the gap not receiving the direct fill placement (between Profiles 95 and 120) showed an advance in shoreline position of about 30 feet. At the end of the period, all profiles except those at each end of the monitoring area showed overall gains. When considering all profiles within the Oak

Island monitoring area (Profiles 5 thru 310), the average shoreline change was a gain of 66 feet for the present period of July 2008 to May 2009.

When comparing the shoreline changes back to August 2000 (i.e. the pre-project survey), Figure 3.7 shows a definite pattern of accretion at almost all locations. In this regard, the relatively stable condition of Oak Island/Caswell Beach indicated by the July 2008 and January 2009 surveys became even more so with the most recent beach disposal. As shown by the May 2009 shoreline change plot, the beach has widened between 150 feet, to more than 250 feet over most locations. In fact, except for one profile location (Profile 45) and a few other locations along the eastern tip of the island (which are marginally stable), all other profile lines have shown gains of 50 feet or more. This overall beach stability has resulted not only from the recent beach disposal, but also from the positive effect of the initial fill placement in 2001, as well as, the nearby Sea Turtle Habitat Project. This latter project (also completed in 2001) was placed just to the west of the monitoring limits, but sediment has dispersed eastward into the study area. In considering all the profile data, the alongshore average shoreline position was 69 feet more seaward in January 2009 before the fill and 140 feet more seaward in May 2009 after the fill.

Typical profiles along Oak Island are given in Figures 3.8 and 3.9. Figure 3.8 shows Profile 80 within the eastern portion of the fill area and Figure 3.9 shows Profile 220 within the western portion of the fill area. The plot of Profile 80 shows the seaward advance of the initial fill followed by a period of adjustment between the September 2001 and January 2004 surveys. Following this initial adjustment period, over which about half of the berm width was eroded, the profile remained stable. The beach was widened again with the 2009 fill to near the approximate 2001 location. A similar response is shown in Figure 3.9 for Profile 220; however, the berm remained generally wider through January 2009 leading up to the most recent fill. Plots of the cumulative shoreline changes for each of these profiles are given on Figure 3.10. For Profile 80, the shoreline has remained generally stable over the last six years following the adjustment to the initial fill. Over this time period (between June 2002 and January 2009), the mean high water shoreline at Profile 80 has varied between about 70 and 95 seaward of its August 2000 position. Following the 2009 beach disposal, the shoreline was advanced to 168 feet beyond what it was in 2000. For Profile 220, the shoreline has also remained relatively stable following the initial fill adjustment; however an erosional trend is noticeable over the last six years. With the latest fill placement, the shoreline was pushed seaward to a point which was 185 feet beyond its initial location in 2000.

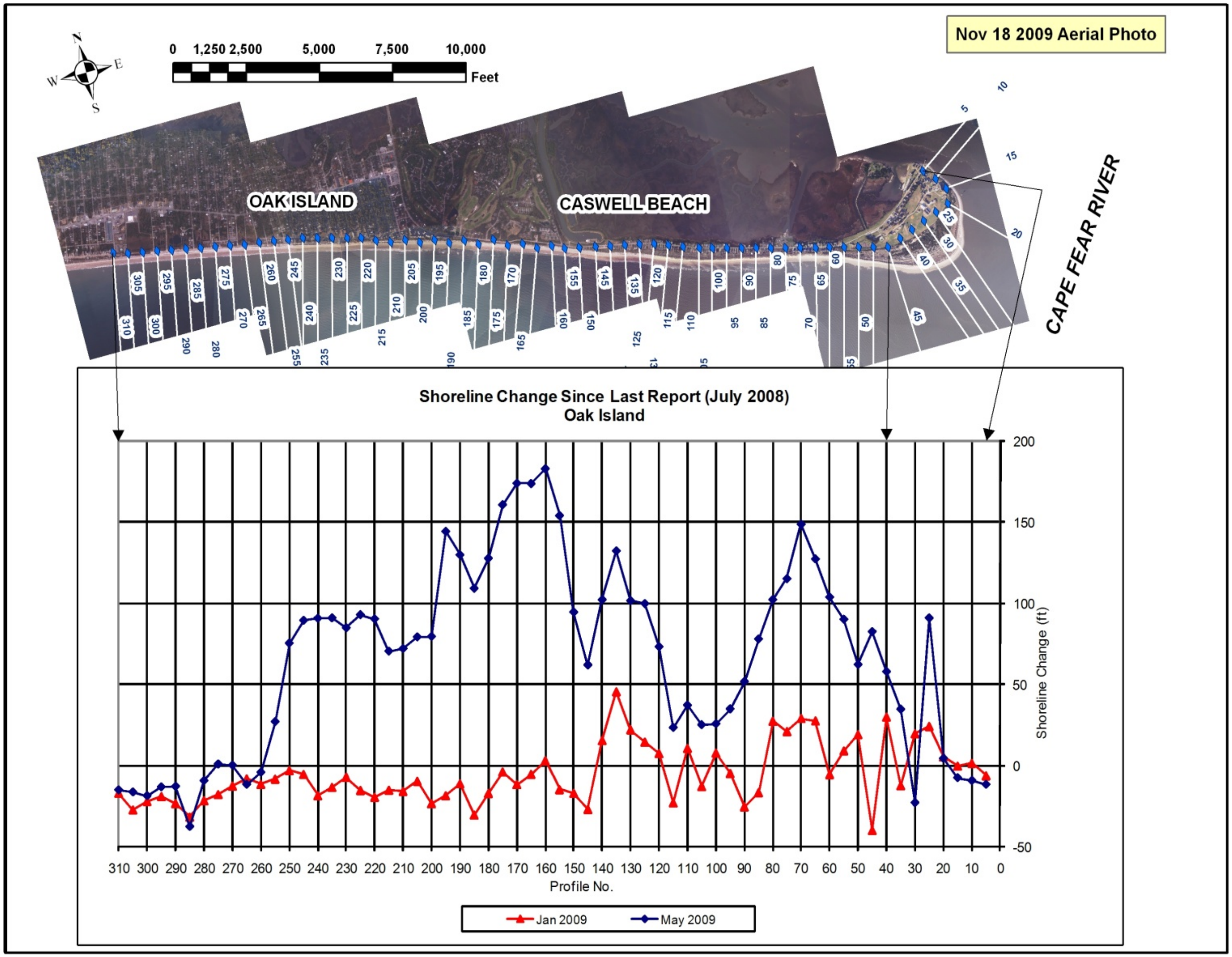


Figure 3.6 Shoreline Change Since Last Report (July 2008) Oak Island

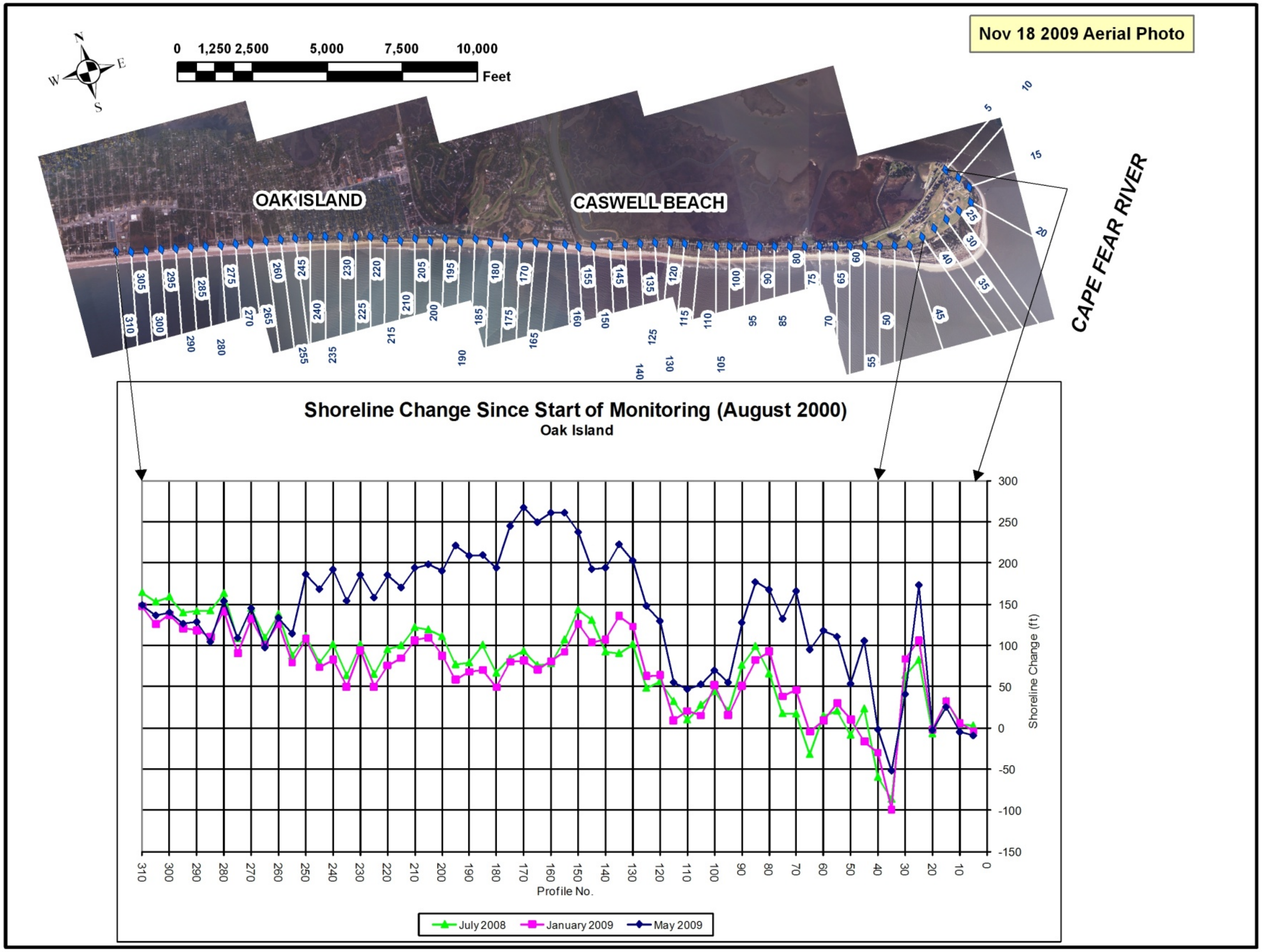


Figure 3.7 Shoreline Change Since Start of Monitoring (August 2000) - Oak Island

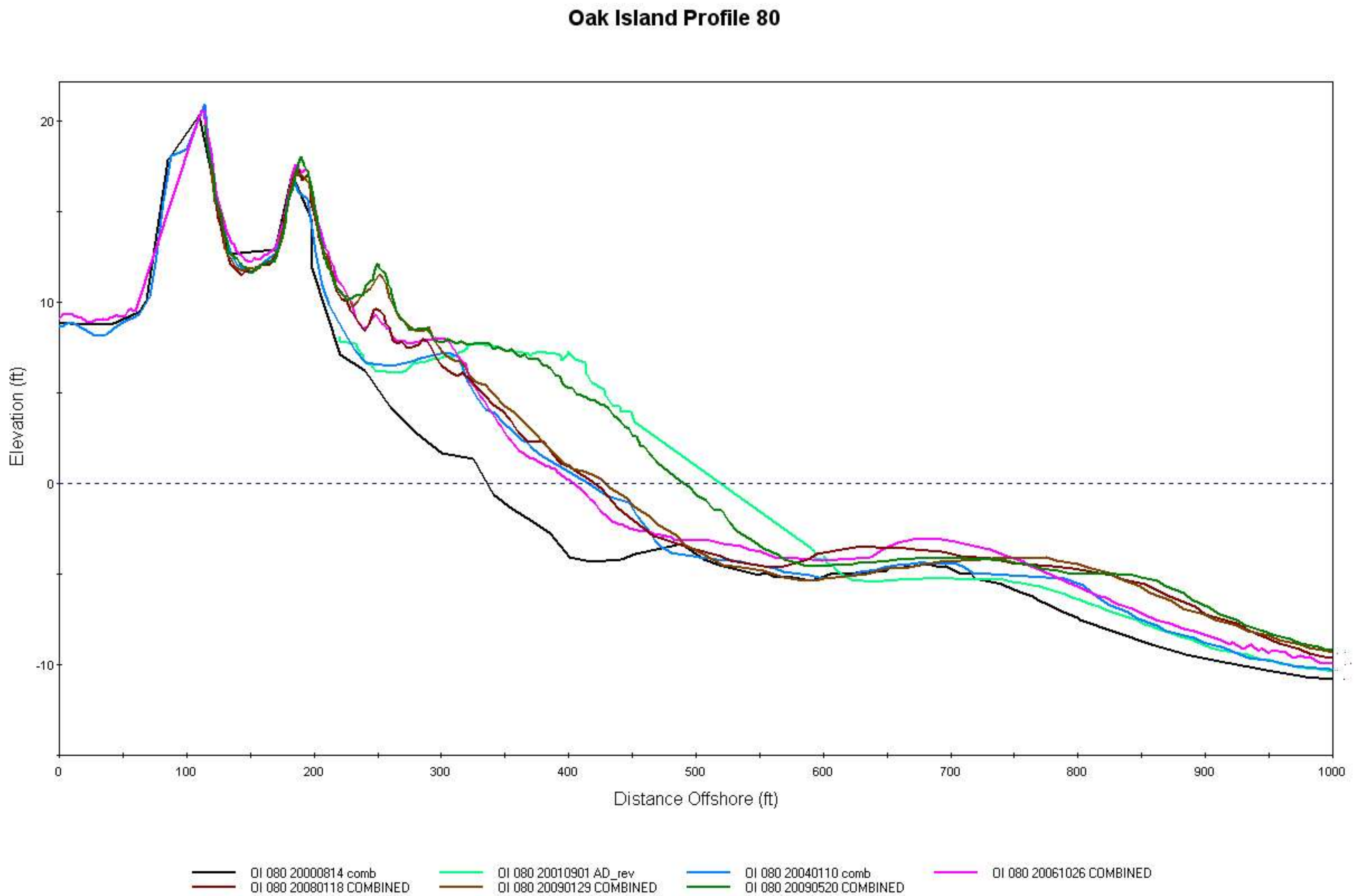


Figure 3.8 Oak Island Profile 80

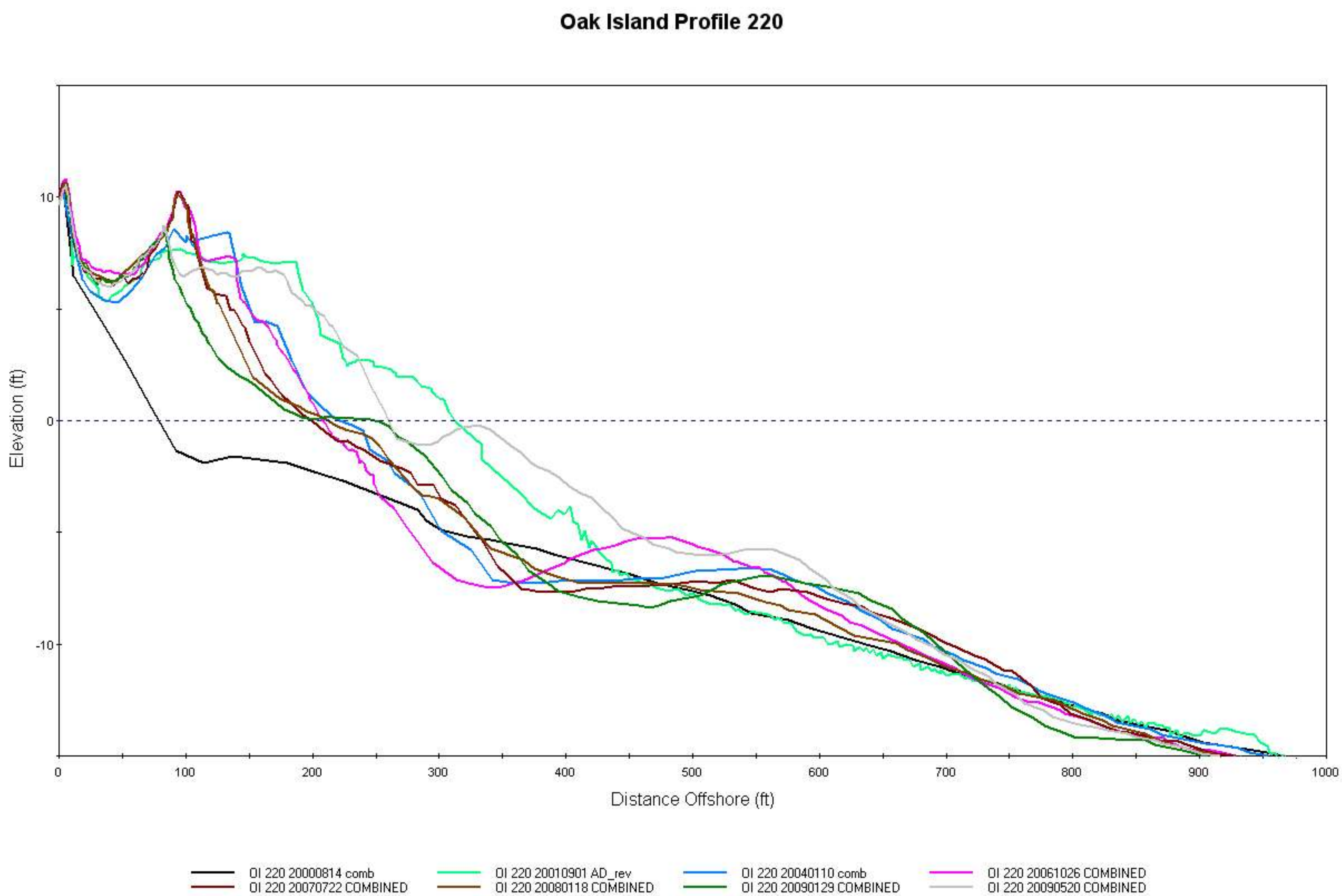


Figure 3.9 Oak Island Profile 220

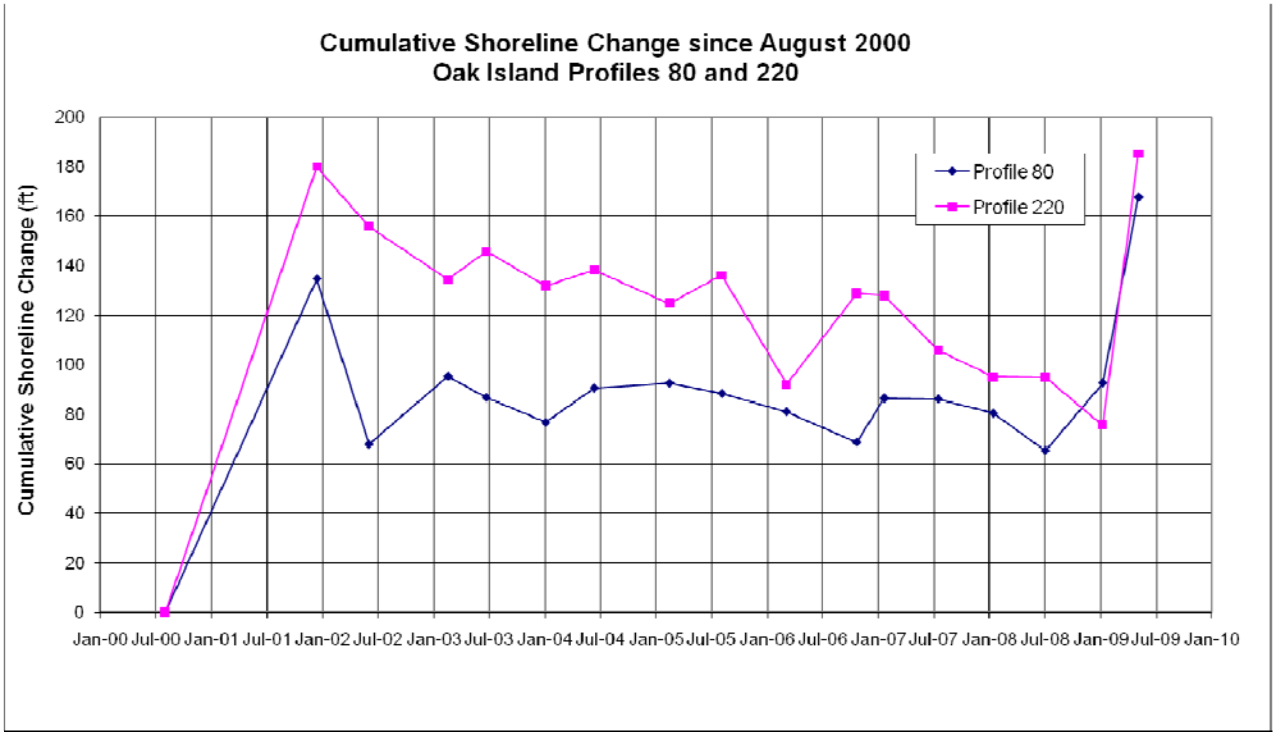


Figure 3.10 Cumulative Shoreline Change Since August 2000

Oak Island Profiles 80 and 220

Beach Profile Analysis-Volumetric Change

General. The analysis of each beach profile also included volumetric changes over time. As with the shoreline change data, the volumetric changes are made relative to the last report and also since the start of the project. Volumes are computed from both the onshore beach profile surveys (i.e. to wading depth) and from total surveys covering both the onshore and offshore areas. The onshore volumes are calculated from a common stable landward point to an elevation down to –2 ft NGVD. The offshore volumes are computed to an observed closure depth for each profile line. The volumes are calculated using the BMAP program where unit volume changes are computed for each profile. The average area end method is then used between profile locations in computing the volume over the length of the respective islands.

The current monitoring cycle includes two complete beach surveys, both of which covered the onshore and offshore portions of the profile. As noted previously, the surveys were accomplished in January 2009 and May 2009 with coverage along both Bald Head and Oak Islands.

Bald Head Island. The onshore volumetric changes measured along Bald Head Island over the current monitoring cycle are given in Figures 3.11 and Figures 3.12. Figure 3.11 shows the volumetric changes relative to the July 2008 onshore survey, i.e. the last referenced onshore survey in Report 6. Figure 3.12 gives the volumetric changes with respect to the start of the monitoring program in September 2000.

The pattern of onshore volumetric changes shown in Figure 3.11 for Bald Head Island (since the last report) generally follow those of the reported changes in the mean high water shoreline. As such, most of the profile locations show losses over the period. These volume losses were primarily contained within the areas where fill material was placed in April 2007. These areas (Profiles 45-78 and 97-170) combined for a loss of about 193,000 cubic yards. The greatest portion of this onshore volumetric loss was contained within the westernmost portions of South Beach with a peak loss occurring in the vicinity of Profile 47. Conversely, the areas on South Beach west of the fill area were more stable, with some profiles accreting. In addition to the loss of material within the fill area, West Beach (Profiles 0-28), eroded slightly as well losing about 1,100 cubic yards of sand. This area was split between areas of erosion and accretion with profiles 0-20 eroding somewhat uniformly with a total loss of approximately 10,300 cubic yards. The remaining West Beach profiles (24 and 28) accreted nearly 9,200 cubic yards since the last report period. These two profiles are closest to the Bald Head spit and have benefited from the accumulation of material lost from South Beach. In considering the total onshore volume changes for all profiles over the current monitoring cycle, approximately 260,000 cubic yards of material were lost between July 2008 and May 2009.

The results of the onshore beach profile analysis surveys since the start of the monitoring in August/September 2000 are given in Figure 3.12. This graph shows that while the majority of the island has experienced net gains over the last 8.7 years, some areas are eroding. The two areas that experienced onshore losses since the beginning of the project are along the majority of West Beach (Profiles 0-24) which lost approximately 30,000 cubic yards, and along an area that covers part of the spit and the east end of South Beach (Profiles 40-69). This area lost nearly 215,500 cubic yards of sand since the start of the monitoring program.

To illustrate the overall trends in volume change, Figure 3.13 shows a plot of cumulative volume changes over time with respect to the August/September 2000 survey. The graph includes not only the onshore volumes (i.e. above –2 ft NGVD) but also the offshore volumes (below –2 ft NGVD) and total onshore/offshore volumes (discussed in the following paragraphs). In each case, the volumes for each survey are total summations over the entire island. With respect to the onshore volumes, the graph indicates the steady volumetric loss following the November 2001 post fill placement survey. By the June 2004 survey, the total onshore volume becomes slightly negative indicating an overall loss of about 48,300 cubic yards (above –2-feet NGVD) compared to the 2000 survey. With the second fill (January 2005), this trend is reversed showing total onshore volumes of around 500,000 cubic yards with the August 2005 surveys. After this fill an overall moderate loss was recorded up to the February 2007 date followed by the substantial increase with the most recent beach disposal effort. The volume measured in the onshore portion of the profile totaled nearly 964,000 cubic yards of sand using the July 2007 survey, which was the first monitoring survey following the third fill. The two surveys taken during the most recent monitoring period (January and May 2009) continue the trend established in the previous monitoring report of more rapid erosion of onshore beach material following the third fill. The current trend in onshore losses is similar to what was observed following the initial placement on the island. At the end of the period, a net gain of 409,000 cubic yards has been measured overall when considering all onshore volume changes since 2000.

Total volumetric changes computed over the entire active profile are given in Figures 3.14 and 3.15 for Bald Head Island. Figure 3.14 shows volume changes relative to the latest survey contained in Report 6 (July 2008); whereas, Figure 3.15 gives changes relative to the August 2000 survey at the beginning of the monitoring. For each profile comparison, volumes were computed from a common stable landward point to an observed closure depth offshore.

Figure 3.14 shows, that as indicated previously with the onshore volumes, the total volume changes are dominated by losses in the areas where fill material was placed in April 2007. Erosion was not limited exclusively to the fill areas during the current monitoring period. As shown in Figure 3.14 all profiles eroded and have lost material since Monitoring Report 6. This is a change from the previous report where areas along the spit and east South Beach gained material. In summing the changes over the entire monitoring area, the losses total to approximately 937,000 cubic yards of material since July 2008. The most significant erosion occurred along the western end of South Beach from profile 32 through 61 where nearly 455,000 cubic yards of material were lost, which is roughly 49% of total losses. The zones along South Beach which received dredged material (Profiles 45 to 78 and 97 to 170) during the April 2007 placement were found to have lost nearly 642,000 cubic yards of sand since the last report. These areas were determined to have lost 410,500 cubic yards between the April 2007 fill and July 2008 (the end of Monitoring Report # 6). Summing these two losses yields a total loss within the fill area of 1,052,500 cubic yards which is greater than the 978,500 cubic yards of material placed in April 2007.

When comparing the changes in total profile volume back to the initiation of the project given in Figure 3.15, the majority of Bald Head Island has gained material over the last 8.7 years. The most substantial increases are found along the eastern half of South Beach and in the vicinity of the spit, which is consistent with Monitoring Report 6, although at a lower rate. Elsewhere, there are three areas which have recorded net overall losses for the period. One is located at the extreme eastern end of South Beach, where some losses have occurred near the cape. Another is northern West Beach which recorded minor losses. The third, which is of greater concern, is along the westernmost portion South Beach extending into the spit area between Profiles 45 to 106. This reach, which has grown from 2,500 feet in the last monitoring report to nearly 6,100 feet, has been the site of chronic erosion in the past. Volumetrically this erosive region has lost about 758,000 cubic yards to date and has worsened since Report 6 which reported a loss within the then 2,500 foot erosive region of 357,000 cubic yards. These losses and expansion of the profiles experiencing loss are most likely related to the failure of the groin field in this area and the resulting rapid loss of material. Groin field performance is discussed in detail in the Groin Field Performance section of this report. As a result of this overall response in the profiles, the net volume change over the entire monitoring area is a modest gain of nearly 118,000 cubic yards as of May 2009 with respect to the beginning of the monitoring in 2000.

Listed in Table 3.1 are the computed volume changes for Bald Head Island for each survey separated into the specific reaches. These reaches were determined in prior reports based on similar physiographic characteristics, namely West Beach (Profiles 0-24), the spit area (Profiles 32-45), South Beach-West Portion (Profiles 53-106), South Beach-East Portion (Profiles 114-194) and the Cape area (Profiles 198-218). The South Beach West portion consists of the profiles which contain the reconstructed groin field. Of the five reaches, two are showing net losses and the remaining three have accreted to date. The two areas showing an overall net loss since August 2000 are the South Beach-West Portion and the area near the Cape. Both of these areas have shown a large degree of variability over the last 8.7 years. The western portion of South Beach has gone through cycles of accretion and erosion controlled by the 2001, 2005 and 2007 beach disposals, which covered this area. The large variability for the Cape area reflects the highly dynamic nature of this physiographic feature. Coupled with the gains measured within the three other reaches of West Beach, the spit, and the eastern portion of South Beach, the beaches of Bald Head have 118,000 cubic yards more at this time than in 2000 at the start of the project. This is also indicated in previously mentioned Figure 3.13 that shows the cumulative volume changes over time for the island.

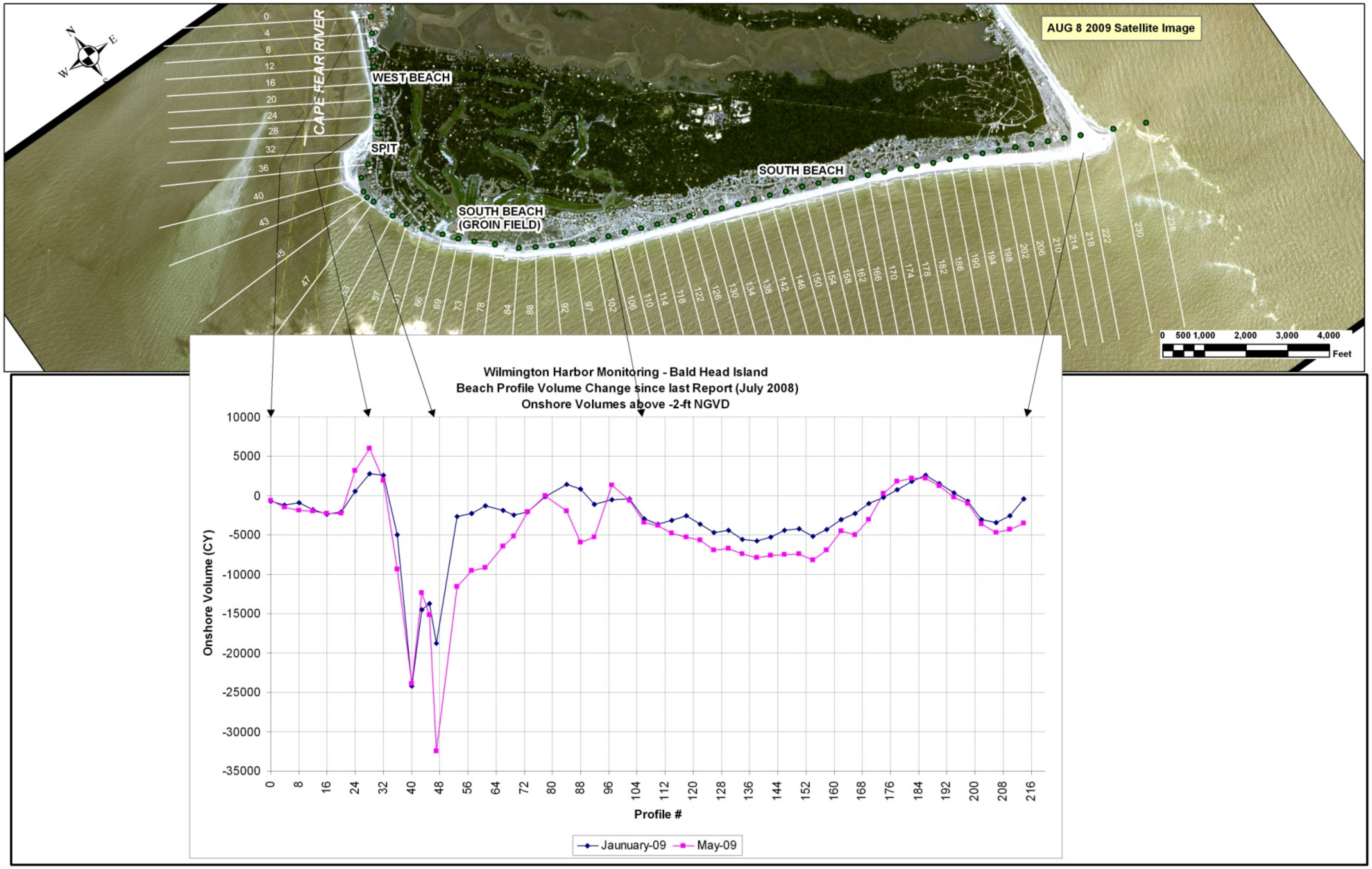


Figure 3.11 Wilmington Harbor Monitoring – Bald Head Island Beach Profile Volume Change Since last Report (July 2008) Onshore Volumes above –2 ft NGVD

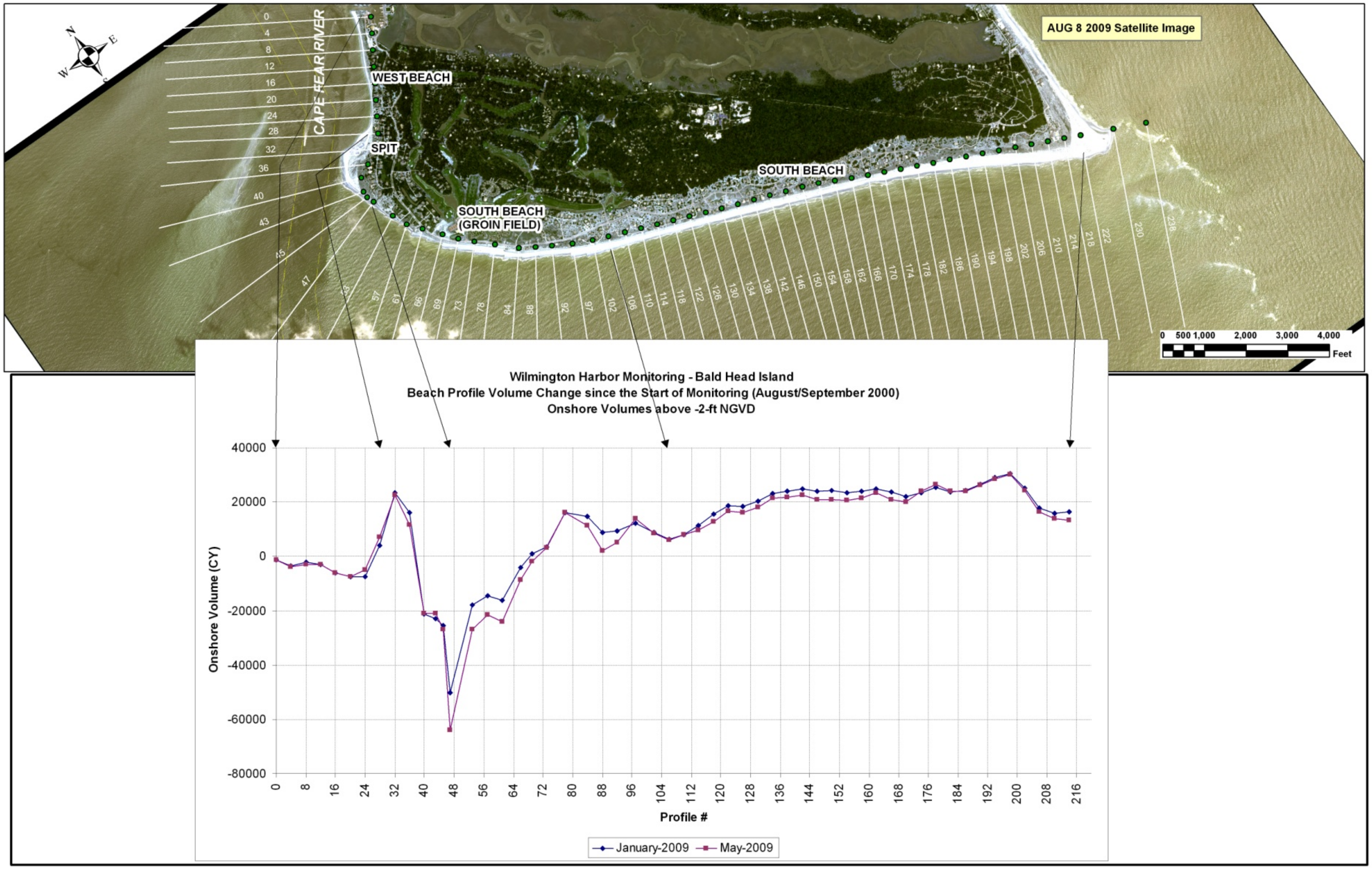


Figure 3.12 Wilmington Harbor Monitoring – Bald Head Island Beach Profile Volume Change since Start of Monitoring (August/September 2000) Onshore Volumes above –2 ft NGVD

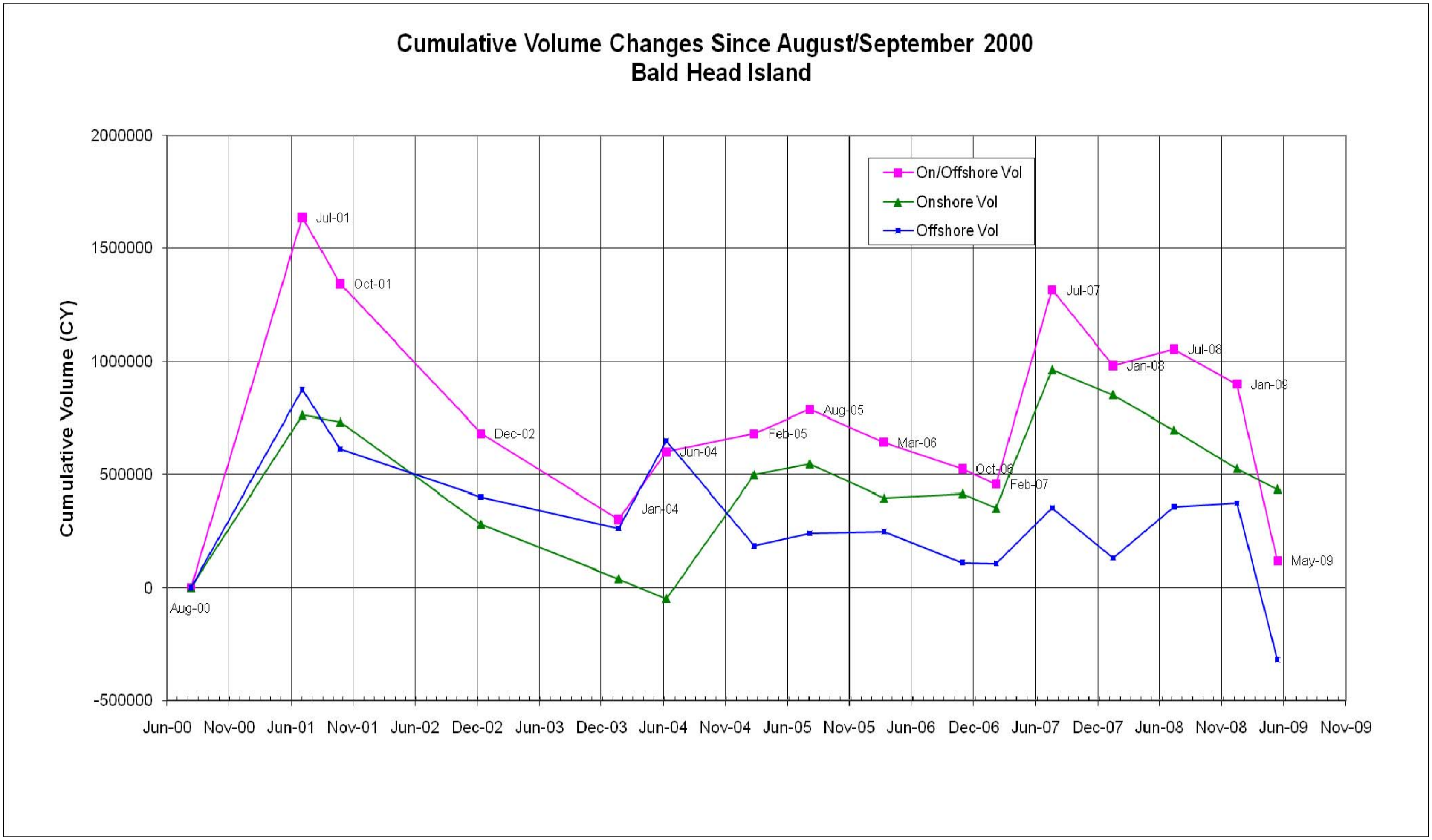


Figure 3.13 Cumulative Volume Changes Since August/September 2000 for Bald Head Island

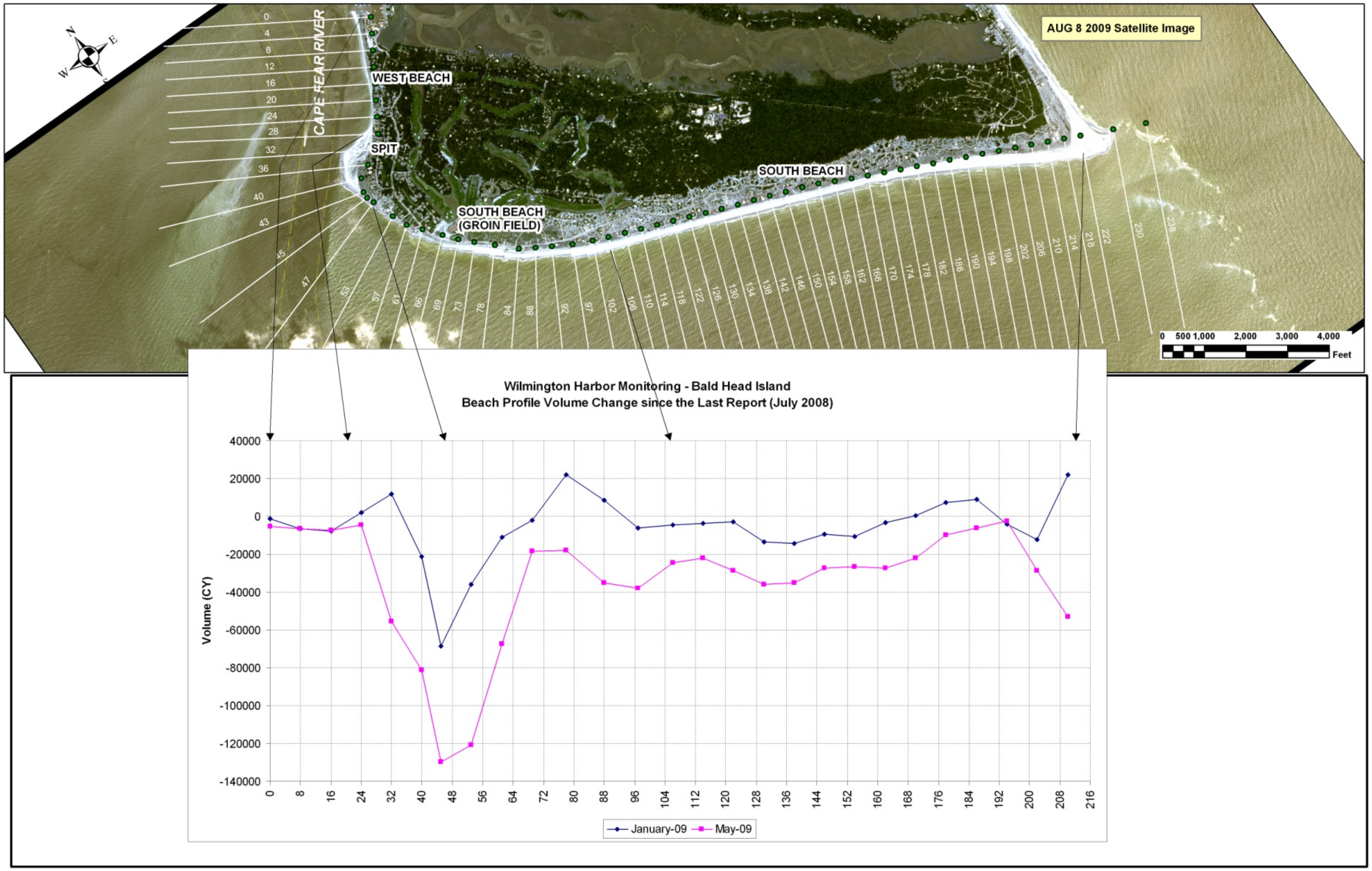


Figure 3.14 Wilmington Harbor Monitoring – Bald Head Island Beach Profile Volume Changes Since Last Report (July 2008)

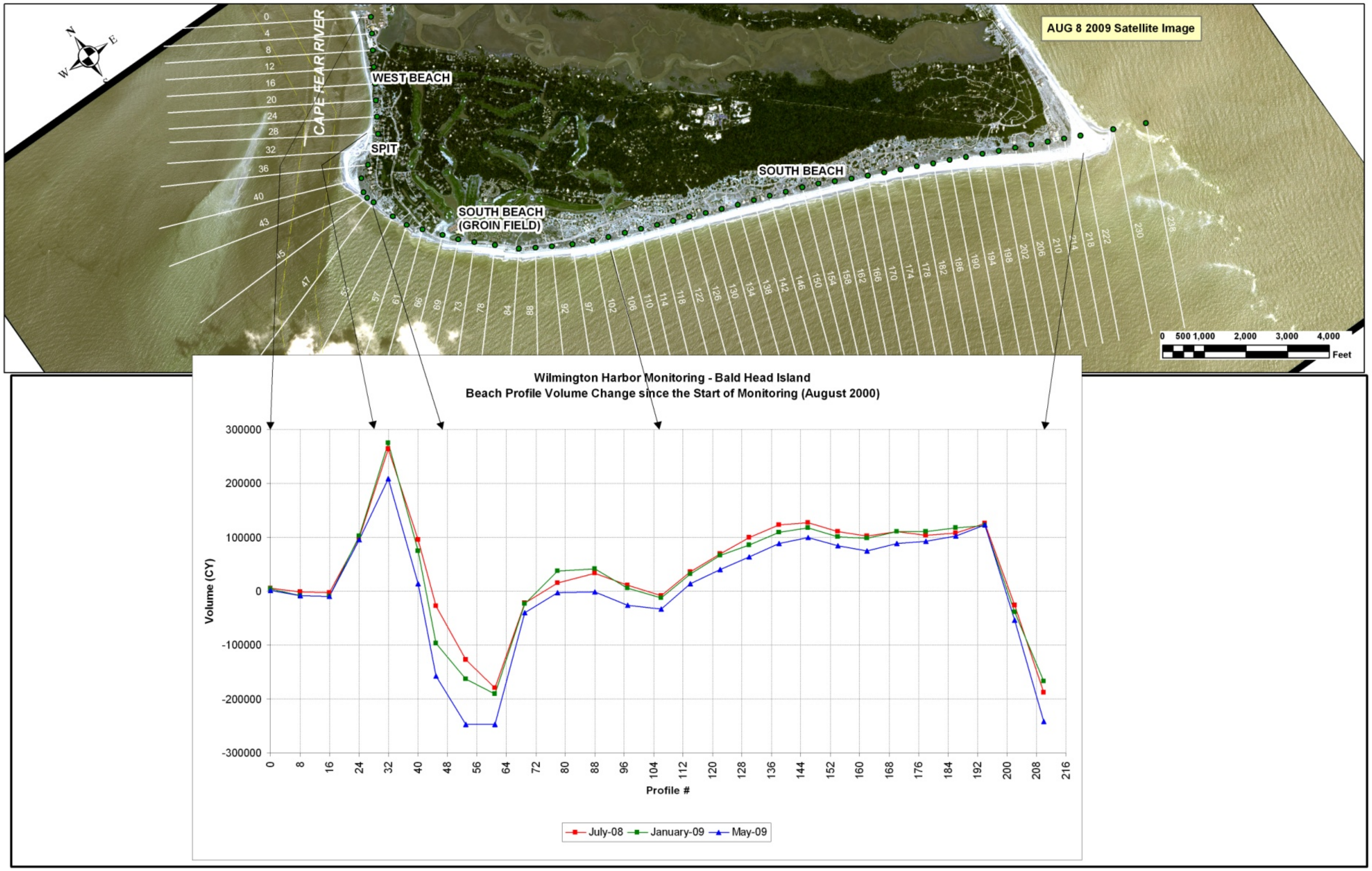


Figure 3.15 Wilmington Harbor Monitoring – Bald Head Island Beach Profile Volume Changes Since the Start of Monitoring (August 2000)

TABLE 3.1 Total Volume Changes Along Bald Head Island Since August 2000 (cubic yards)

Location	July-01	October-01	December-02	January-04	June-04	February-05	August-05	March-06	October-06	February-07	July-07	January-08	July-08	January-09	May-09
West Beach (Profiles 0 - 24)	0	3,048	29,564	11,618	1,854	14,646	34,221	113,468	166,722	111,871	106,678	97,715	101,369	87,863	77,730
Spit (Profiles 32 - 45)	145,509	54,159	-31,546	250,297	303,507	88,229	152,494	270,403	236,708	216,348	224,456	271,896	331,928	253,983	65,297
South Beach-West Portion (Profiles 53 - 106)	319,882	251,137	-91,457	-462,106	-406,485	192,205	187,910	-206,714	-274,592	-246,745	-133,383	-297,262	-277,827	-306,639	-600,063
South Beach-East Portion (Profiles 114 - 194)	1,166,870	1,065,270	887,997	671,808	787,235	624,679	632,903	504,521	457,576	446,455	1,214,278	1,077,662	1,113,637	1,068,978	870,990
Near Cape (Profiles 198 - 218)	-538,703	-29,536	-113,416	-169,758	-85,524	-238,965	-220,972	-46,246	-62,096	-71,646	-95,284	-168,045	-214,328	-204,716	-296,089
Total	1,093,558	1,344,078	681,143	301,859	600,586	680,794	786,557	635,431	524,318	456,283	1,316,745	981,966	1,054,778	899,470	117,865

Oak Island. The onshore volumetric changes measured along Oak Island over the current monitoring cycle are given in Figures 3.16 and Figures 3.17. Figure 3.16 shows the volumetric changes relative to the July 2008 survey, i.e. the last referenced onshore survey in Report 6. Figure 3.17 gives the volumetric changes with respect to the start of the monitoring program in August 2000.

The patterns of onshore volume changes shown in figure 3.16 for Oak Island (since the last report) are dominated by the disposal activity that occurred on the island between February and April 2009. The January 2009 survey within this Figure shows changes were variable throughout the monitoring area and remained relatively small, following the trend established in Monitoring Report 6. Between January and May 2009 a total of 1,064,400 cubic yards of material was placed along Oak Island as part of the third maintenance cycle of the Wilmington Harbor Sand Management Plan. The impact of the placement of fill along Oak Island is clearly visible in the plot of the May 2009 onshore volume calculation within Figure 3.16, which mimics the shoreline changes documented earlier in this report. The material placed between profiles 60 and 95 resulted in an increase in the onshore portion of the profile within this region of approximately 103,700 cubic yards, when comparing the most recent May 2009 survey with the January 2008 survey (the final survey included in Monitoring Report 6). During this same disposal nearly 941,000 cubic yards of material were placed between profiles 120 and 260, resulting in a net gain of 517,000 cubic yards of sand within the onshore portion of the profile within this region between January 2008 and May 2009.

The results from the onshore beach profile surveys obtained since the start of the monitoring in August 2000 are given in Figure 3.17. This graph includes the last three surveys, namely July 2008, January 2009 and May 2009. The figure shows that all areas have gained sediment within the onshore except for two profiles (5 and 35) at the east end of the island. Profiles 5 and 35 were noted in the previous monitoring reports as having lost material and although they have gained material since the previous report, they remain slightly negative relative to the August 2000 survey. Profile 40 which was observed to have lost material over the life of the monitoring along Oak Island has benefited from the adjacent fill placed in 2009 and is now showing net gains relative to August 2000. Overall, these data reflect the positive impact of the beach fills placed in 2001 and 2009, as well as the general stability of the fill over the past 8.7 years.

To further illustrate the stable nature of the Oak Island beaches over the last 8.7 years of monitoring, Figure 3.18 shows a plot of cumulative volume changes over time with respect to the August 2000 survey. Both the onshore and combined onshore/offshore changes (discussed in the following paragraphs) are plotted on the graph. In each case, the volumes for each survey are total summations covering all profiles included in the monitoring plan (approximately 5.9 miles). With respect to the onshore volumes, the graph indicates the large increase resulting from the beach fill placement as marked by the December 2001 survey, with a total onshore volume of 926,000 cubic yards. Over the next two years, a mild loss is seen to occur through February 2003, followed by a period of recovery and stability. Between June 2003 and July 2008 the onshore beach volume has fluctuated between 840,000 and 1,040,000 cubic yards, approximately. The January 2009 survey indicated an increase in onshore volume compared to the July 2008 survey, however, the downward trend previously observed in the volumetric calculations beginning in July 2007 continues when seasonal differences between surveys are taken into account. The remaining total onshore volume just prior to the 2009 placement was roughly 880,700 cubic yards, which represents a loss of approximately 4.9% from the 926,100 cubic yards that was placed in December 2001. With the recent placement of 1,064,400 cubic yards of material along Oak Island as previously described, the onshore volume over the entire monitoring area increased approximately 642,800 cubic yards by May 2009. The most recent beach placement brings the total increase of material relative to the August 2000 survey in the onshore portion of the profile to 1,523,500 cubic yards.

Total volumetric changes computed over the entire active profile are given in Figures 3.19 and 3.20 for Oak Island. Figure 3.19 shows volume changes relative to the latest survey contained in Report 6 (July 2008); whereas, Figure 3.20 gives changes relative to the August 2000 survey at the beginning of the monitoring. For each profile comparison, volumes were computed from a common stable landward point to an observed closure depth.

As displayed in Figure 3.19, the overall response of the total profile volume changes along Oak Island is again dominated by the recent February-April 2009 beach placement. The January 2009 survey showed that the profile response was mixed throughout the monitoring area with some profiles accreting and some eroding, resulting in a net gain within the area of approximately 86,500 cubic yards. The May 2009 survey shows that relative to the July 2008 survey, the vast majority of profiles accreted due to the beach fill placement. Profiles 10 through 45 on the eastern end and Profile 300 on the western experienced minor erosion relative to the last monitoring report, however these profiles were outside the fill limits and it would be expected that material from the fill should diffuse to these areas over time and reduce future erosion. The overall change at the conclusion of the current monitoring period was positive, with a total gain of 1,130,100 cubic yards since July 2008.

As with the onshore volumes discussed previously, the total (onshore+offshore) profile volume changes have been generally positive and have shown relatively little change over time since the beginning of the monitoring program. Figure 3.20 shows the volume changes for last three onshore/offshore surveys relative to the August 2000 pre-project survey. In this regard, all reported volume changes are positive with the exception of 4 profiles along the eastern end of the island which show small losses. The pattern of volumetric change prior to the beach fill was relatively similar from July 2008 to January 2009 with some areas eroding along the western third of the island and some profiles accreting along the middle section of the island. Significant changes are observed throughout the majority of the island with the February-April 2009 beach placement causing most profiles to accrete. Measured volumes for the entire monitoring area with the May 2009 survey totaled nearly 2,411,800 cubic yards greater than what was measured in August 2000. This exceeds the total volume placed along the island in both the 2001 and 2009 beach placement operations which totaled 2,246,200 cubic yards. The source of the material being transported into the monitoring area causing the additional accretion is unknown; however, it may be related to diffusion of the Sea Turtle Habitat beach fill that was constructed in 2001.

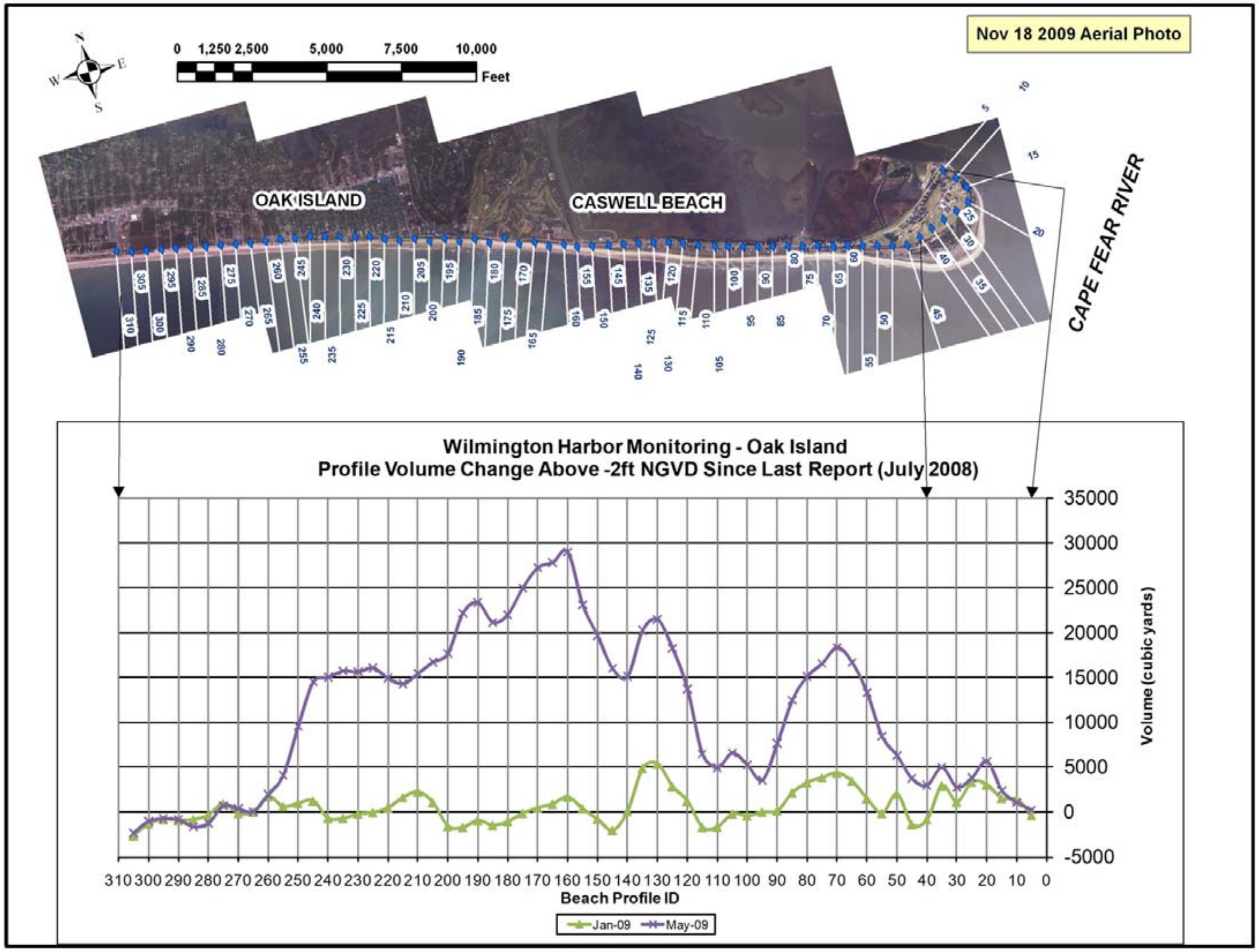


Figure 3.16 Wilmington Harbor Monitoring – Oak Island Beach Profile Volume Change Since Last Report (July 2008) Onshore Volumes above – 2 ft NGVD

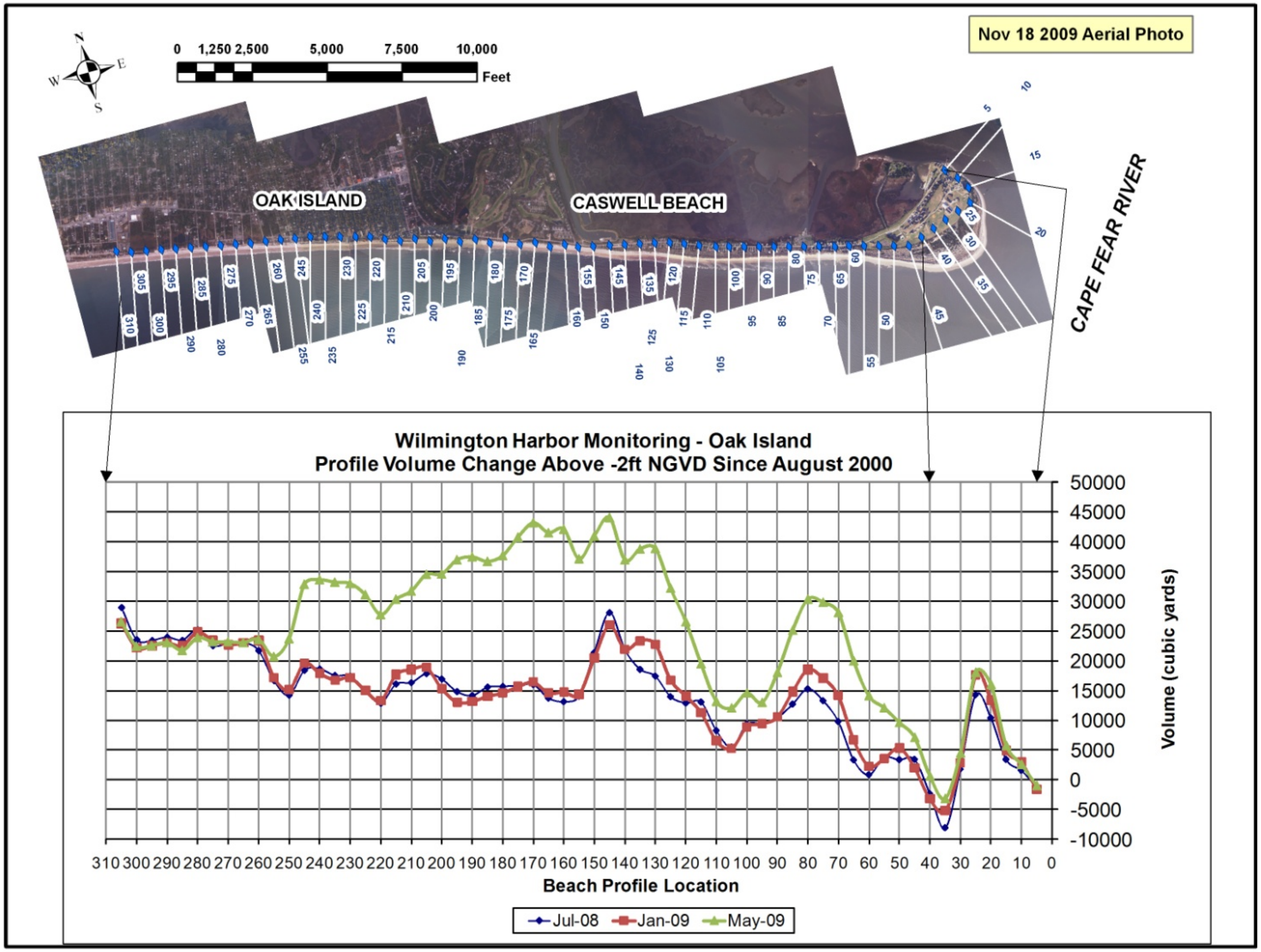


Figure 3.17 Wilmington Harbor Monitoring – Oak Island Beach Profile Volume Change since Start of Monitoring (August 2000) Onshore Volumes above –2 ft NGVD

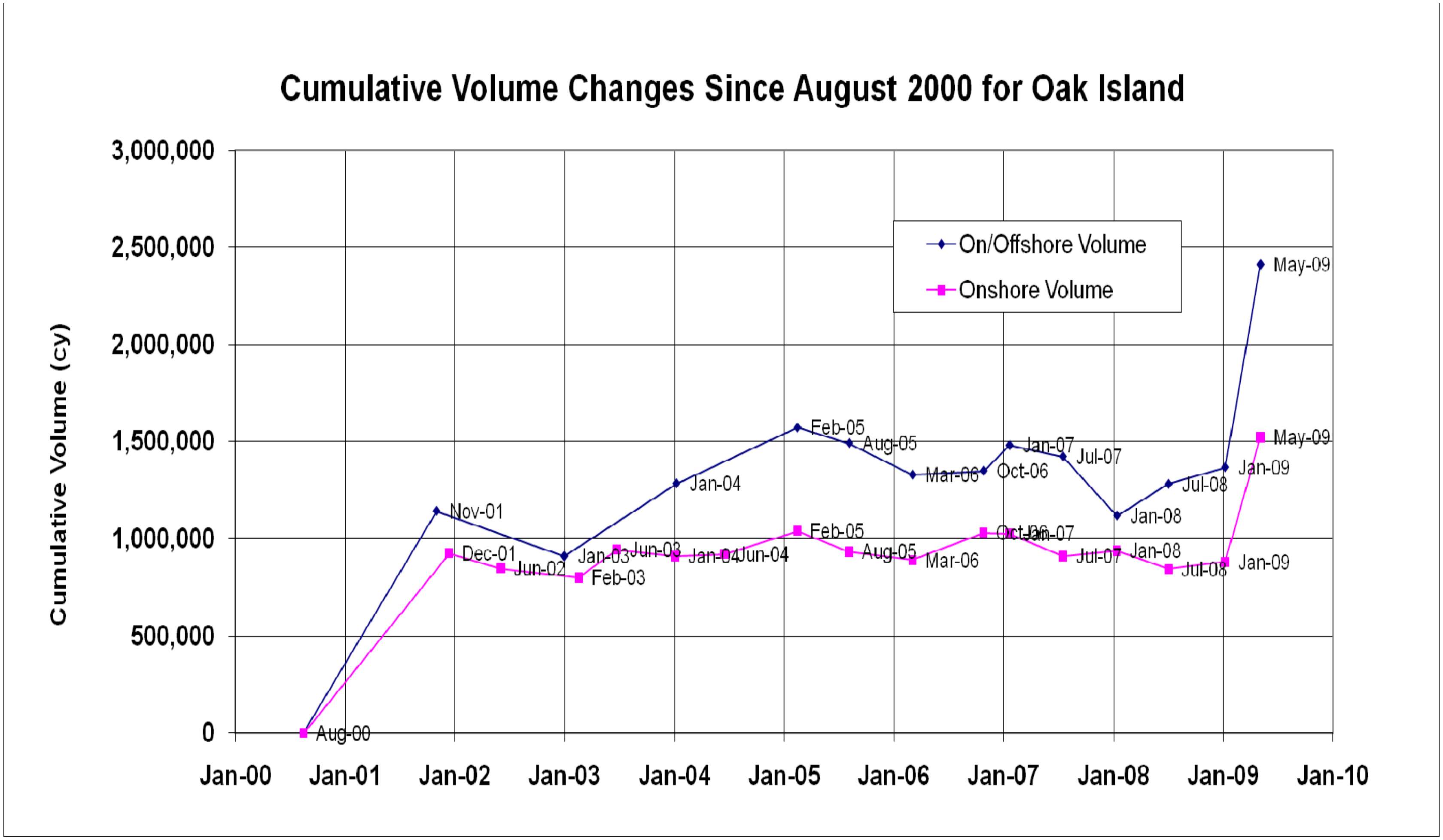


Figure 3.18 Cumulative Volume Changes Since August 2000 for Oak Island

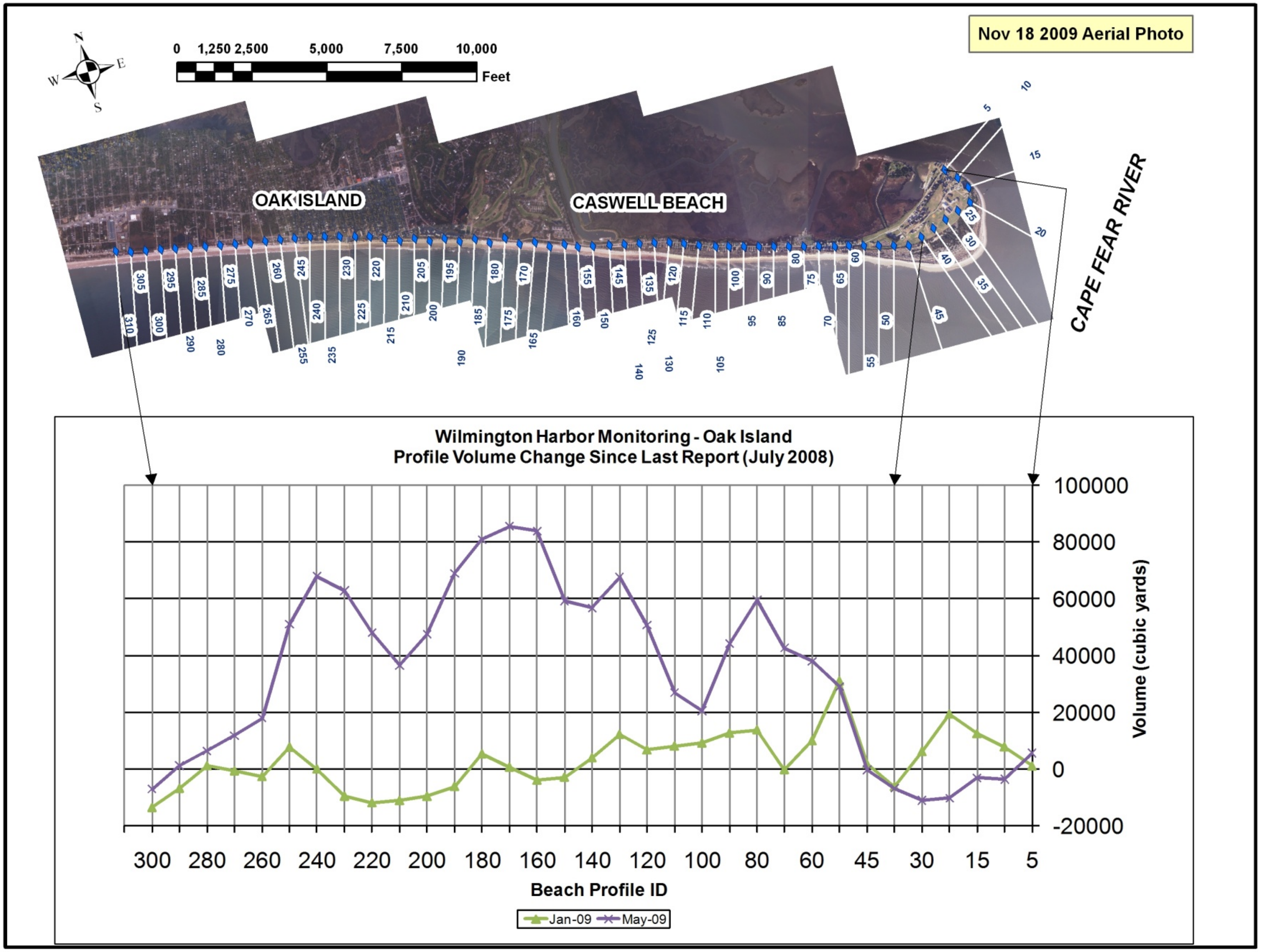


Figure 3.19 Wilmington Harbor Monitoring - Oak Island Beach Profile Volume Change Since Last Report (July 2008)

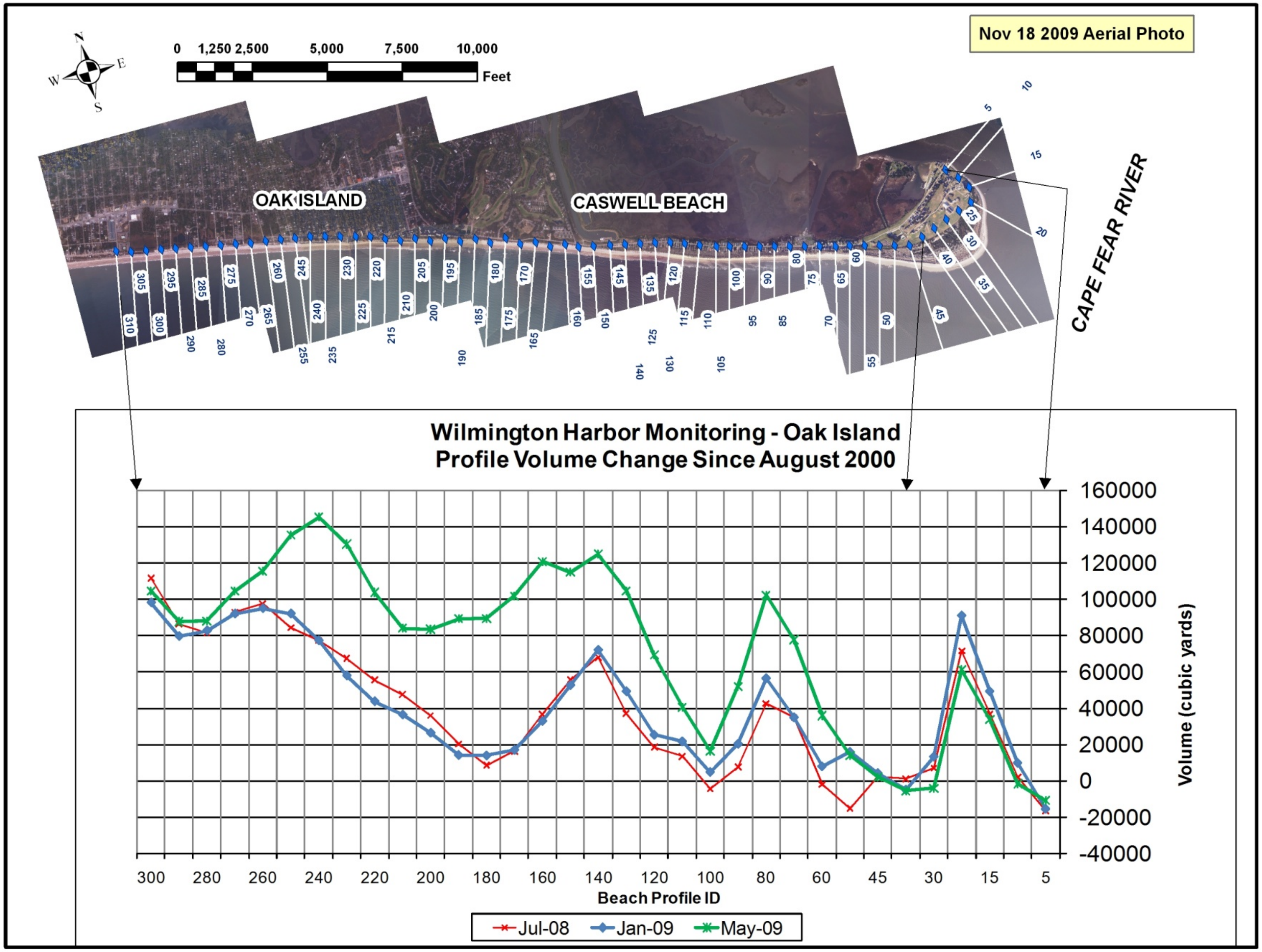


Figure 3.20 Wilmington Harbor Monitoring - Oak Island Beach Profile Volume Change Since the Start of Monitoring (August 2000)

Ebb and Nearshore Shoal Analysis

Bathymetric Data Collection. Detailed bathymetry of the Cape Fear River ebb tidal delta and channels were collected on nine occasions specifically; August-September 2000, December 2001-January 2002, January 2003 and 2004, March 2005, April 2006, and in January 2007, 2008, and 2009. These data are collected using an interferometric swath sonar system integrated with a motion sensor that removes vessel motion in real-time. Dual-channel RTK GPS provides horizontal and vertical control to correct for water level fluctuations forced by astronomical tides and wind-driven tides using the vertical RTK-GPS measurements. For details of this system and methodology on data collection and reduction refer to the following referenced letter reports; McNinch 2002, McNinch 2003, McNinch 2004, Part 2 of USACE 2005a, McNinch 2006, McNinch 2007, USACE 2008, and USACE 2009.

Bathymetric data from the USACE LARC cross-shore surveys along the offshore profile lines were combined with those of the interferometric system to produce a comprehensive survey of the monitoring area. A plot of the combined coverage for the January 2009 survey is shown in Figure 3.21 showing the LARC and interferometric system track lines. The results of the surveys are discussed below which are summarized from the previously referenced letter reports.

Results. The ebb tidal delta surrounding the mouth of the Cape Fear River is shown in Figure 3.22 from the most recent survey of January 2009. From the latest bathymetric survey the gross patterns of the seafloor morphology are clearly evident in the figure and have changed very little since the last report with the exception of some significant channel shoaling. This survey shows the newly realigned channel as well as the remnants of the pre-project channel alignment. Also apparent are three linear shoals that compose much of the ebb tidal delta. Two shoals are present on the west side of the shipping channel which comprise Jay Bird Shoals. The third or Bald Head Shoal protrudes off the southwestern corner of Bald Head Island east of the main channel. The main channel is seen to hug very near Bald Head Island as it exits into the ocean. A well-developed flood margin channel can also be seen flanking Oak Island. However, a similar companion flood channel is not apparent through Bald Head Shoal on the opposite side of the entrance channel.

A side-by-side comparison of the inlet area is shown in Figure 3.23 for each of the nine bathymetric surveys taken in 2000, 2001 and 2003 through 2009. These comparisons show a persistence of the three linear shoals and their relative positions. In addition, they show how the deltas have expanded and contracted over the monitoring period. Also shown is the deepening of the flood margin channel on the Oak Island side which has stabilized over the last several surveys. Maximum depths within the flood margin channel are approximately 39 feet, and only slight changes in the area of the flood margin channel are visible. The most obvious change is the deepening of the main shipping channel which is attributed to the dredging of the new channel in 2001.

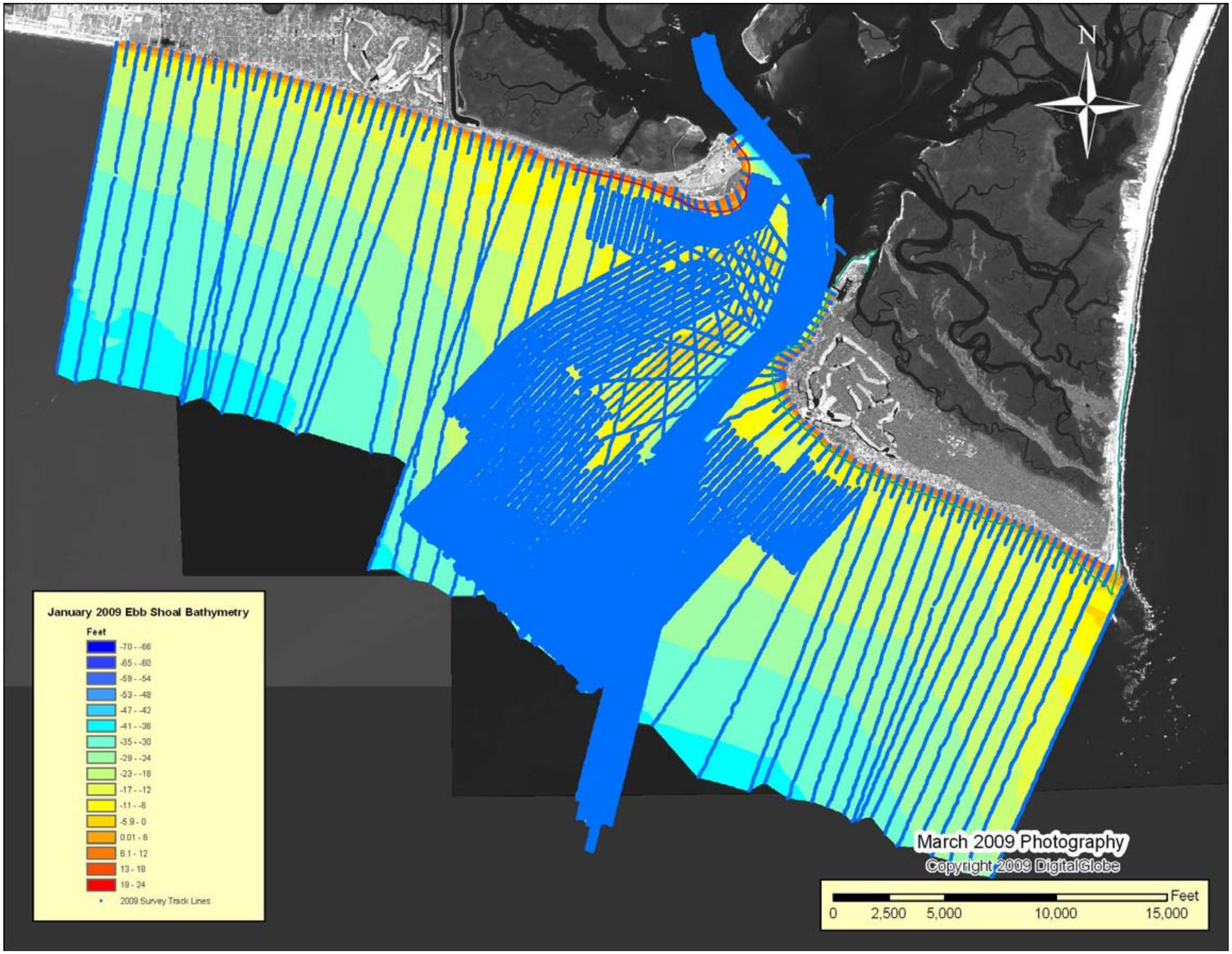


Figure 3.21 Survey Track Lines Collected by the LARC5 and the Interferometric System during the 2009 Survey

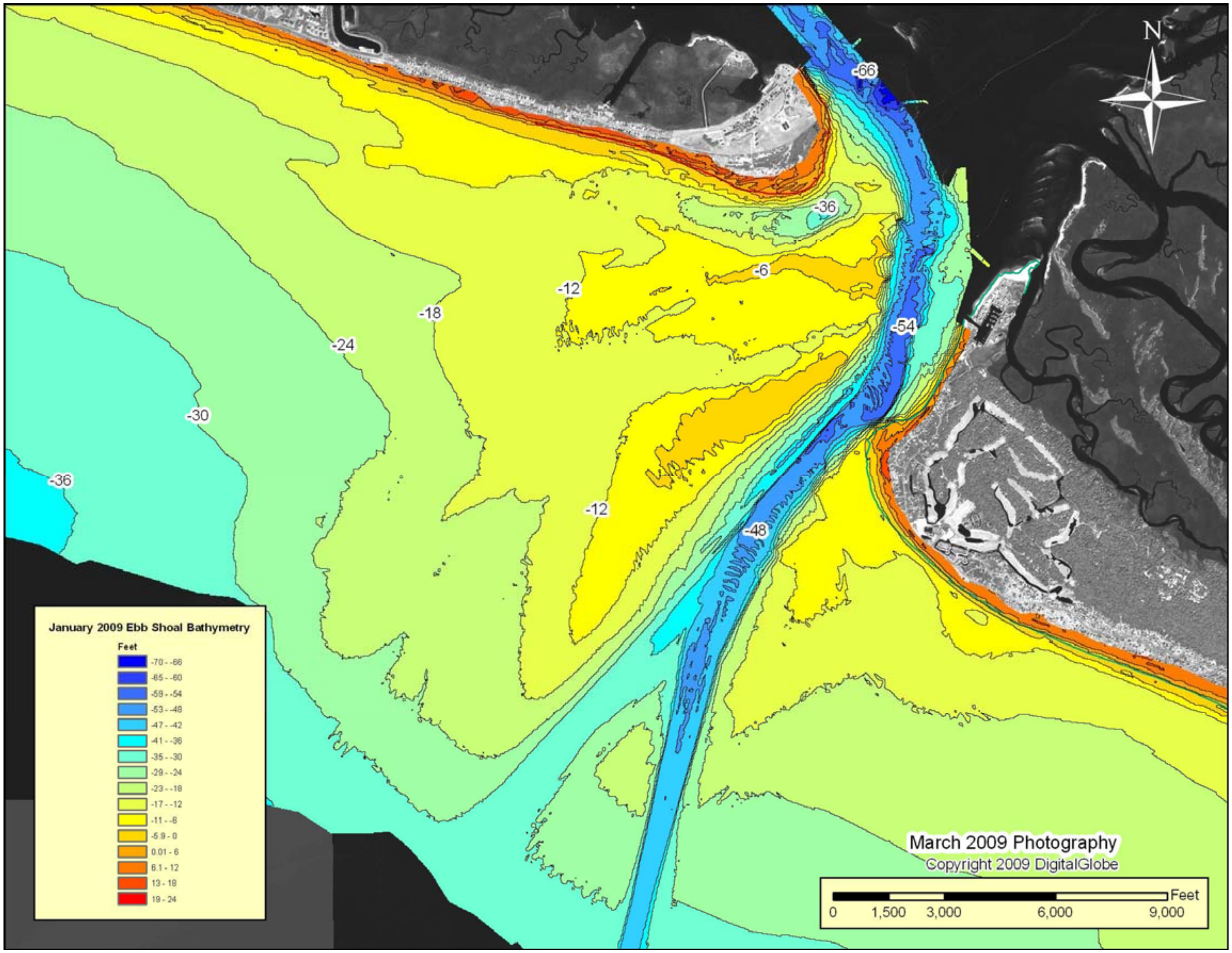


Figure 3.22 January 2009 Ebb Tide Delta Survey

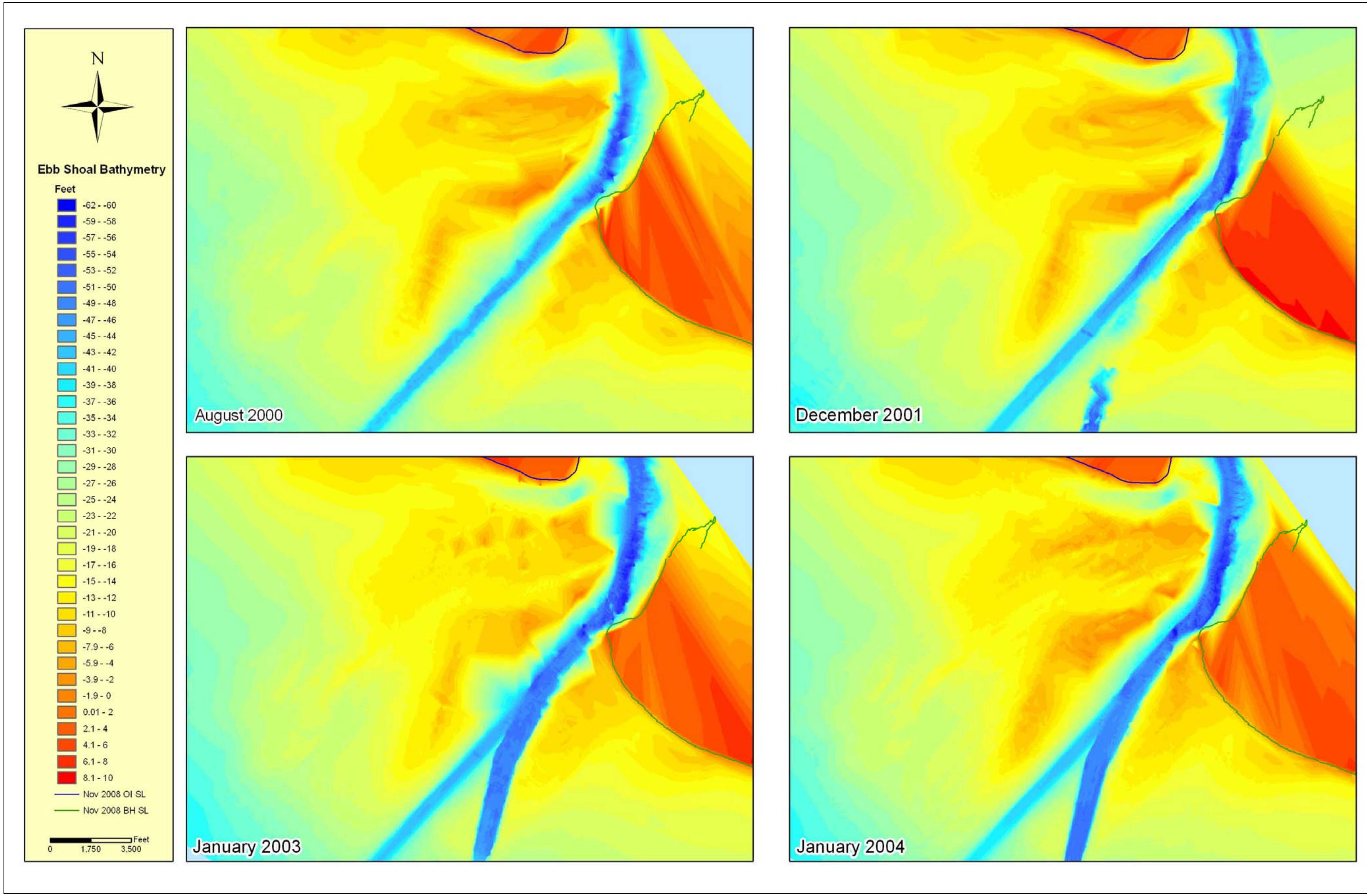


Figure 3.23 Inlet Bathymetry Surveys

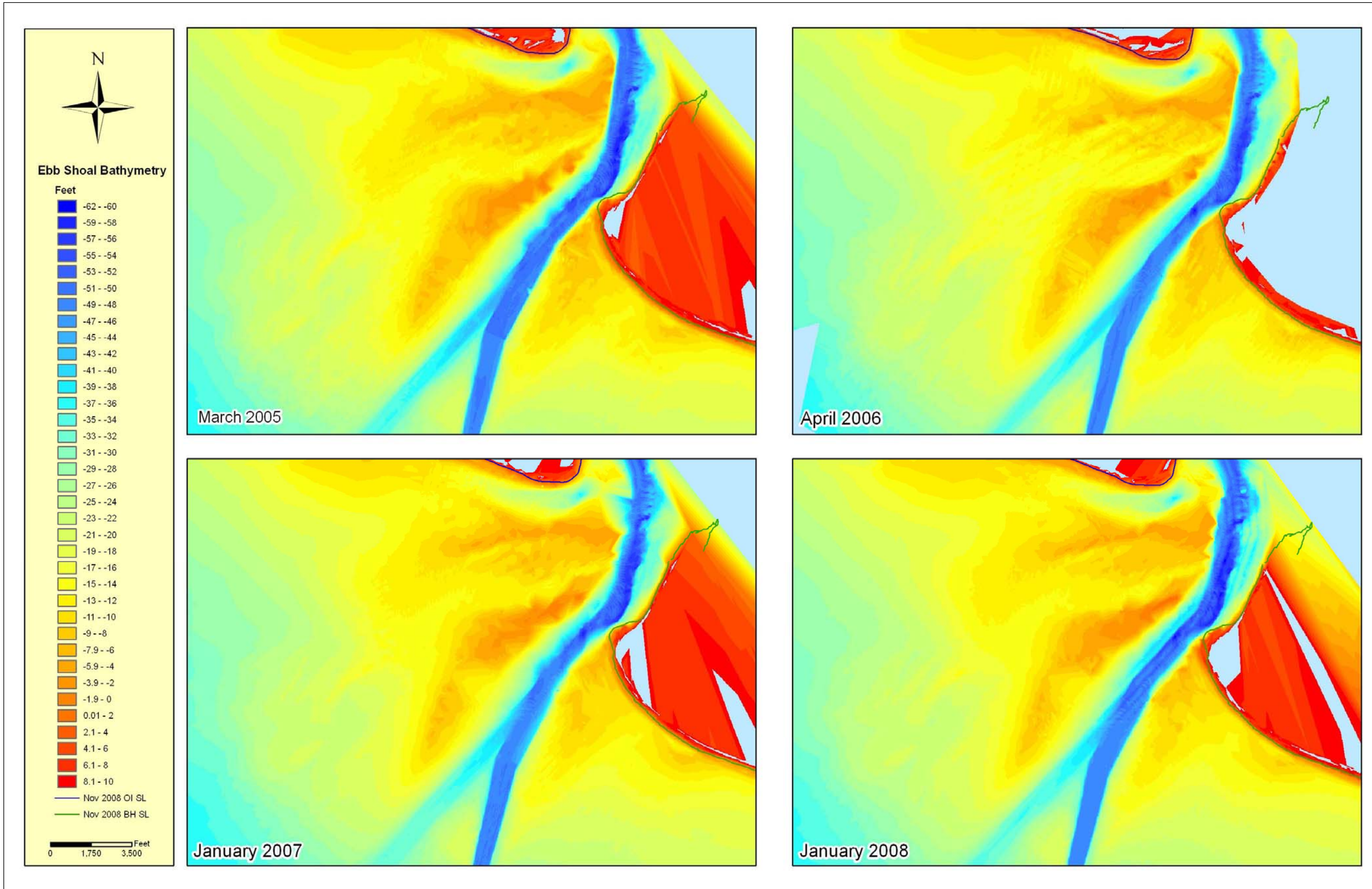


Figure 3.23 Inlet Bathymetry Surveys (Continued)

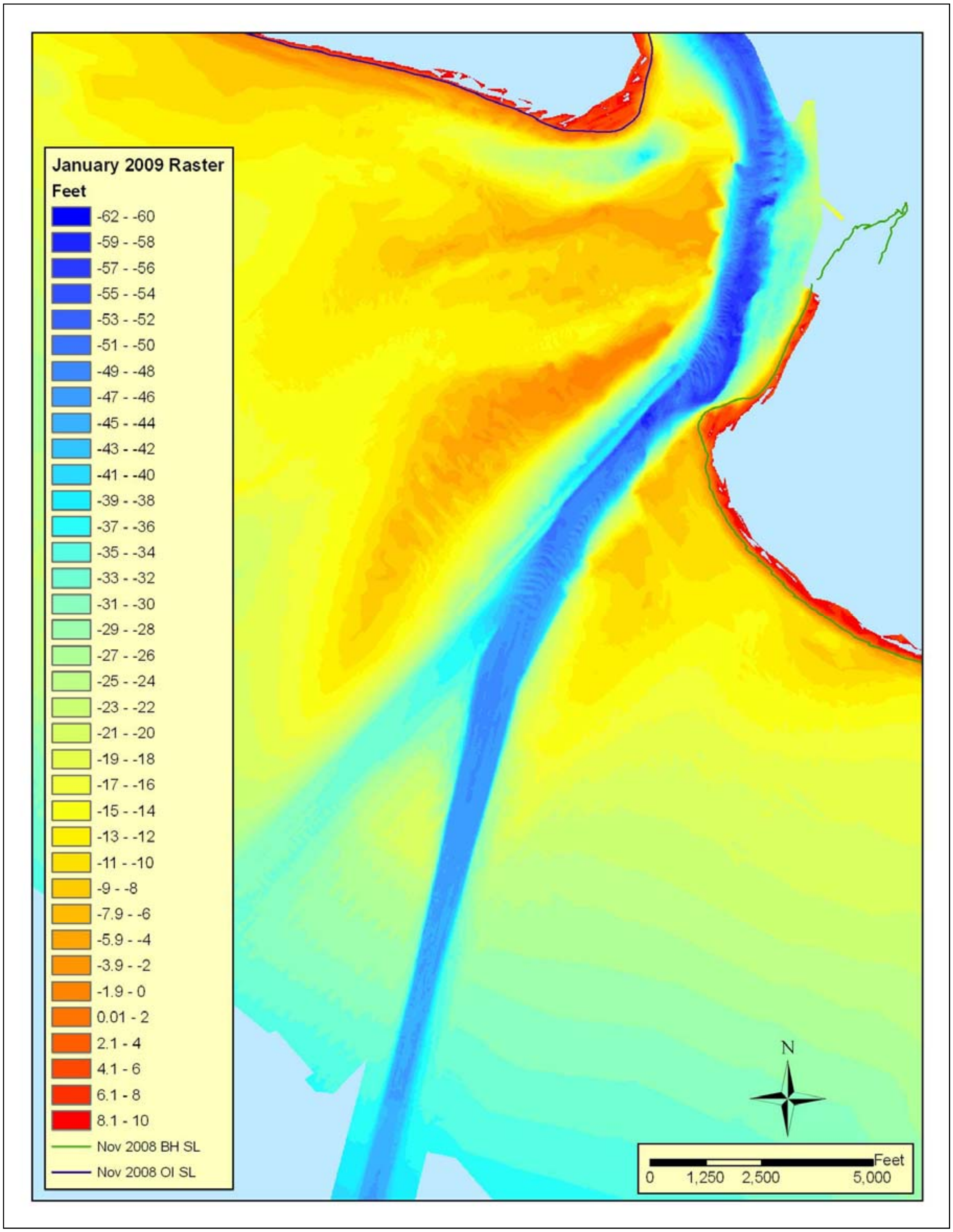


Figure 3.23 Inlet Bathymetry Surveys (Continued)

Further comparisons between surveys are made by generating maps showing changes in the bathymetry over time. Difference plots were made comparing the most recent survey of January 2009 with the prior survey of January 2008 as well as with the initial pre-project survey of August 2000. Figure 3.24 shows the bathymetric changes for the most recent period between January 2008 and January 2009. Detailed insets of these changes are also shown for two areas namely the vicinity of the inlet and along the realigned channel. These detailed insets are given in Figure 3.25(a) which shows the inlet region and Figure 3.25(b) which shows the new channel area. As noted on the legend, areas of erosion are indicated in shades of blue and infilling areas are in shades of green to red.

As shown in Figures 3.24 and 3.25 the majority of the system had little change relative to the last survey in January 2008 with the exception of the channel and areas adjacent to the channel. Significant erosion is noted on the point of the Bald Head Island spit with elevation changes of up to -12 feet. Just west of the point within the channel boundaries, significant accretion of up to 19 feet occurred. General shoaling is noted within the channel boundaries with the majority occurring in the offshore portion of the navigation channel and old entrance channel. Shoaling patterns in the offshore portion of the navigation channel appeared to be more uniform across the channel width, while channel shoaling within the inlet occurred mostly on the east and west toe of the channel alignment.

In addition to the most recent changes in the ebb tidal bathymetry, Figure 3.26 shows the changes which have occurred since the initiation of the monitoring program. This figure compares the August 2000 pre-project survey with the most recent, January 2009, survey. Detailed insets for the inlet region and the new channel area are given in Figures 3.27(a) and 3.27(b).

There are five areas of change noticed when looking Figure 3.26, as follows: (1) The major excavation of the realigned new channel is very prominent in the figure. This cut was through the relatively shallow portion of the ebb tidal delta to project depths of 42 feet. (2) The channel deepening is evident as well from the outer bar channel through the inlet between the two islands. (3) The west end of South Beach has eroded when compared to the pre-existing conditions in the vicinity of the newly rebuilt groin field. This is a reversal of patterns from the previous report which showed the cumulative change within this area to be positive. The southern end of west beach has continued to show overall accretion as previously reported. (4) Significant accretion along the west side of Bald Head Shoal is evident. (5) The final area of change occurred in the flood margin channel just off the tip of Oak Island. While parts of the channel have scoured out as much as 8 to 10 feet, the northern most part of the flood channel has accreted.

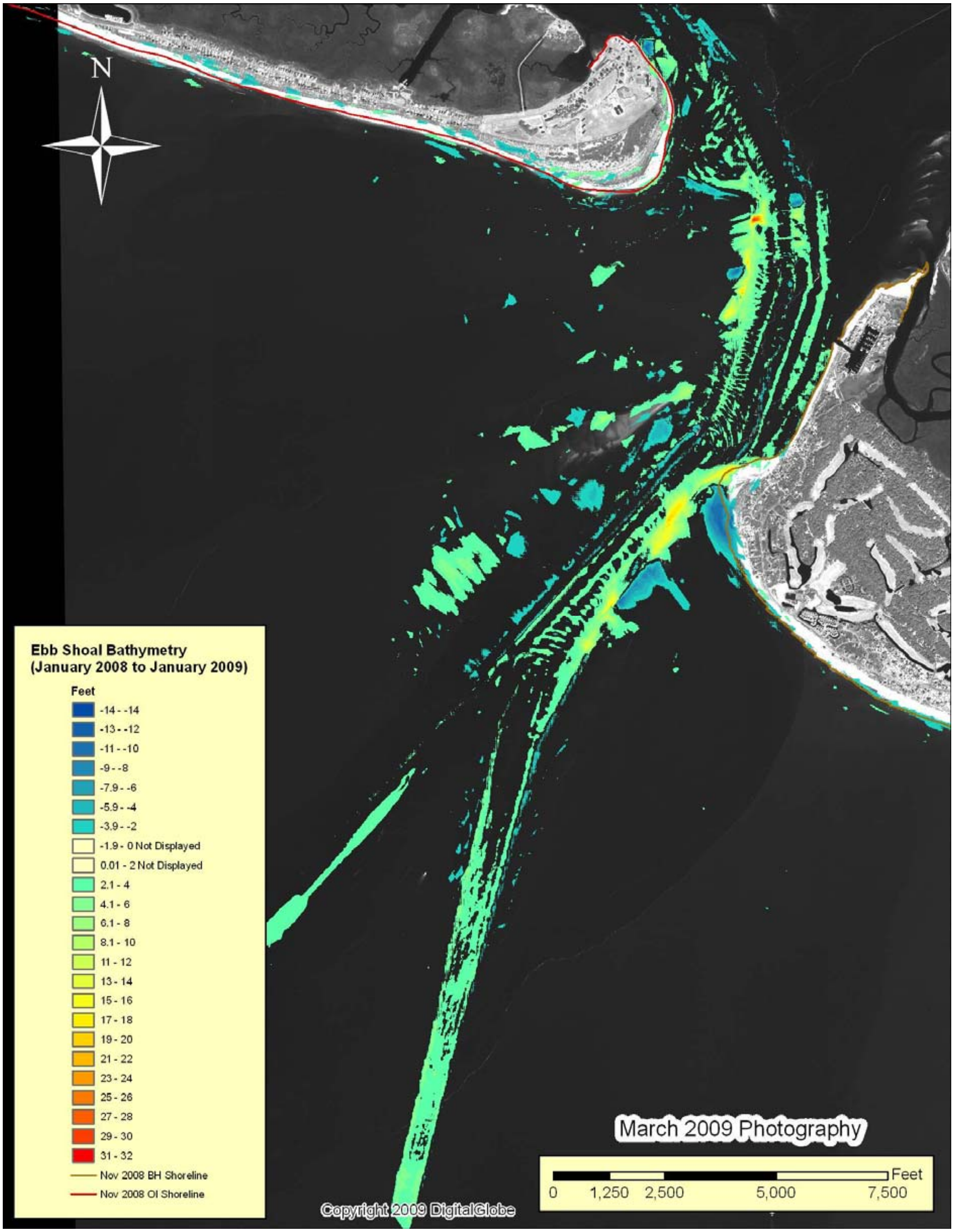


Figure 3.24 Bathymetric Changes of the Ebb Tidal Delta (January 2008 to January 2009)

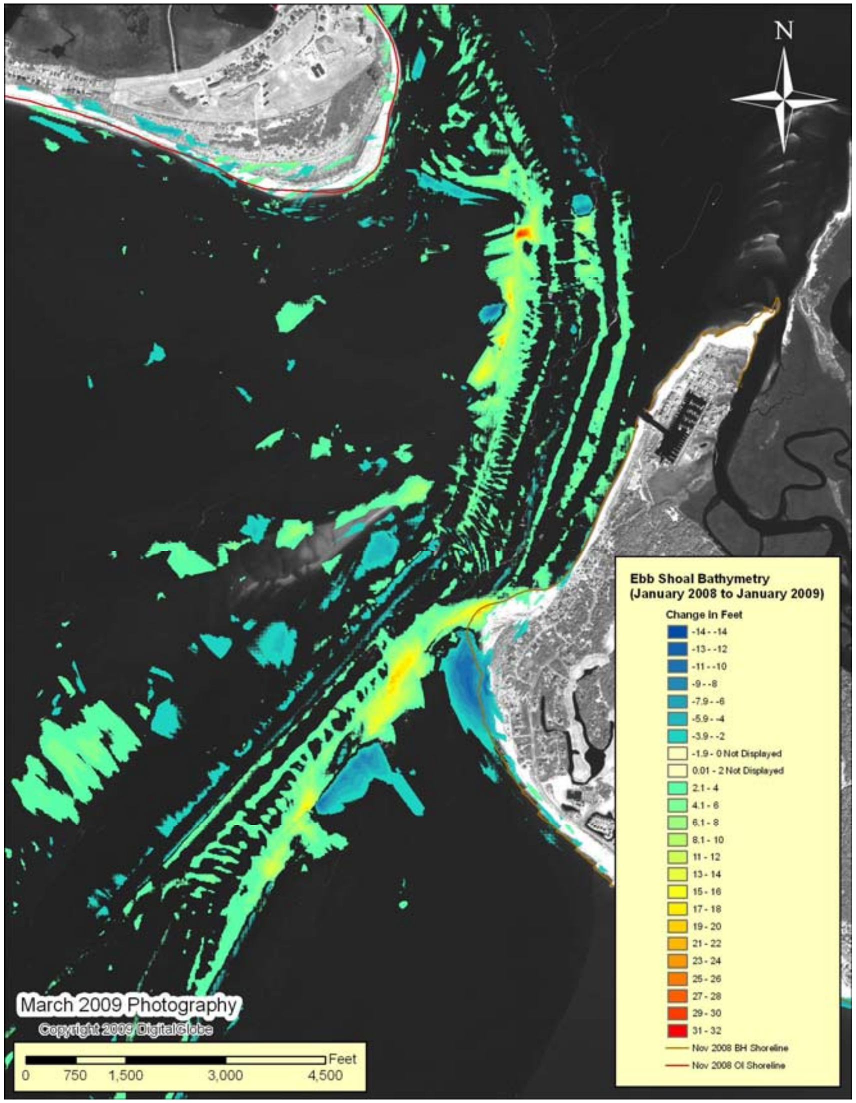


Fig 3.25 (a) Bathymetric Changes of Inlet (January 2008 to January 2009)

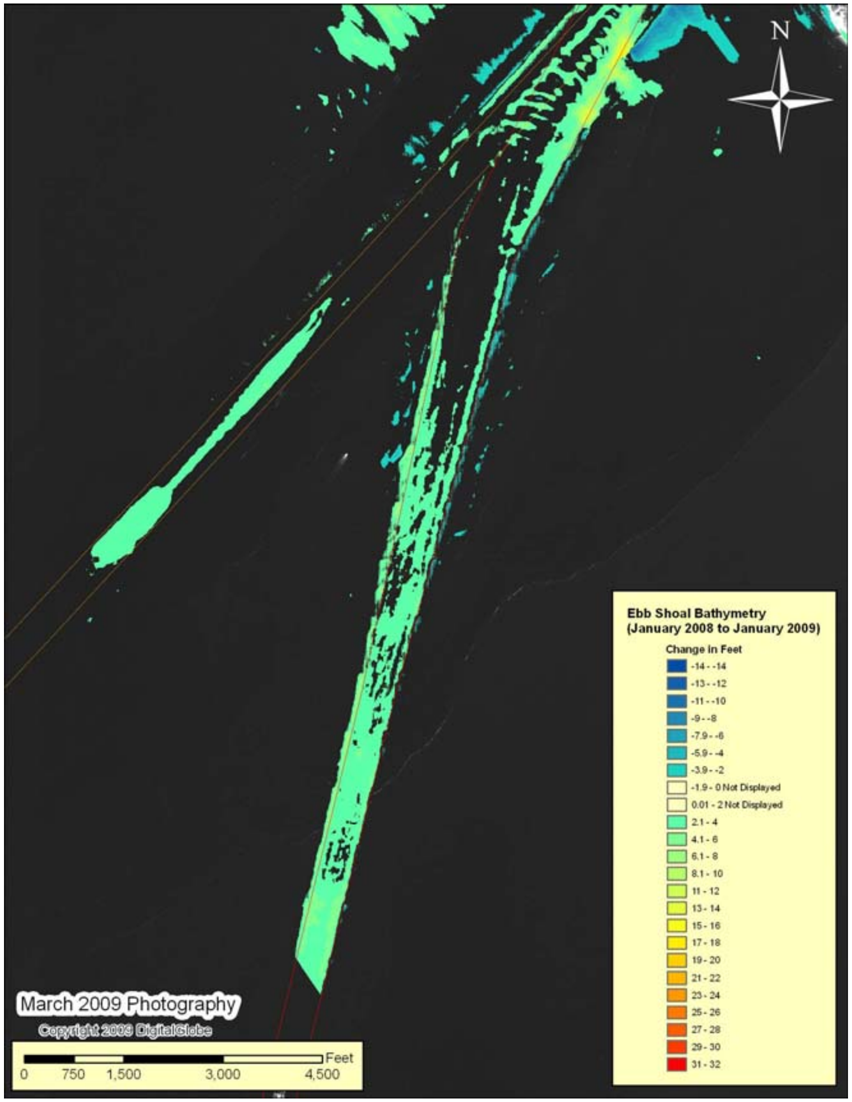


Fig 3.25 (b) Bathymetric Changes of New Channel (January 2008 to January 2009)

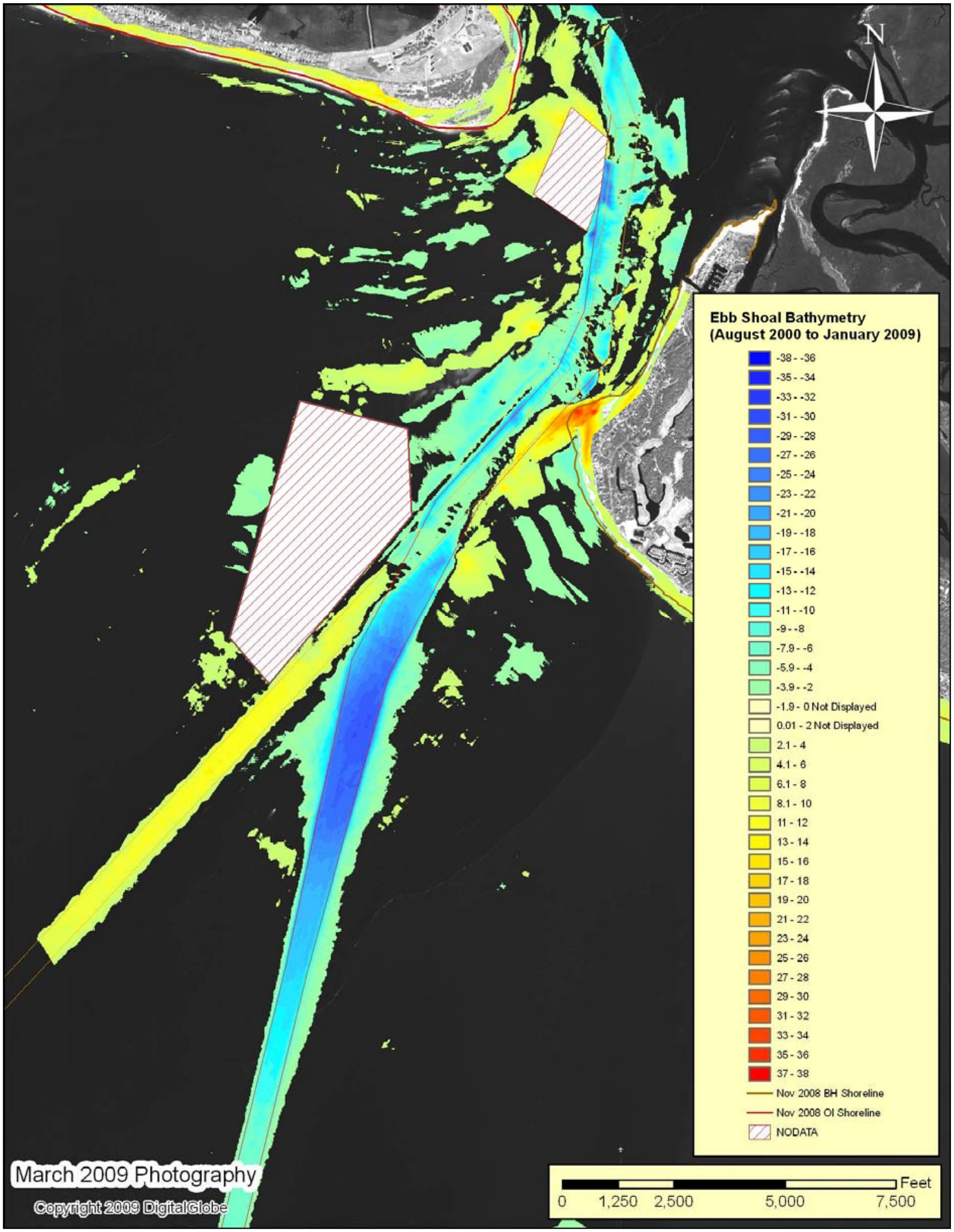


Figure 3.26 Bathymetric Changes of the Ebb Tidal Delta (August 2000 to January 2009)

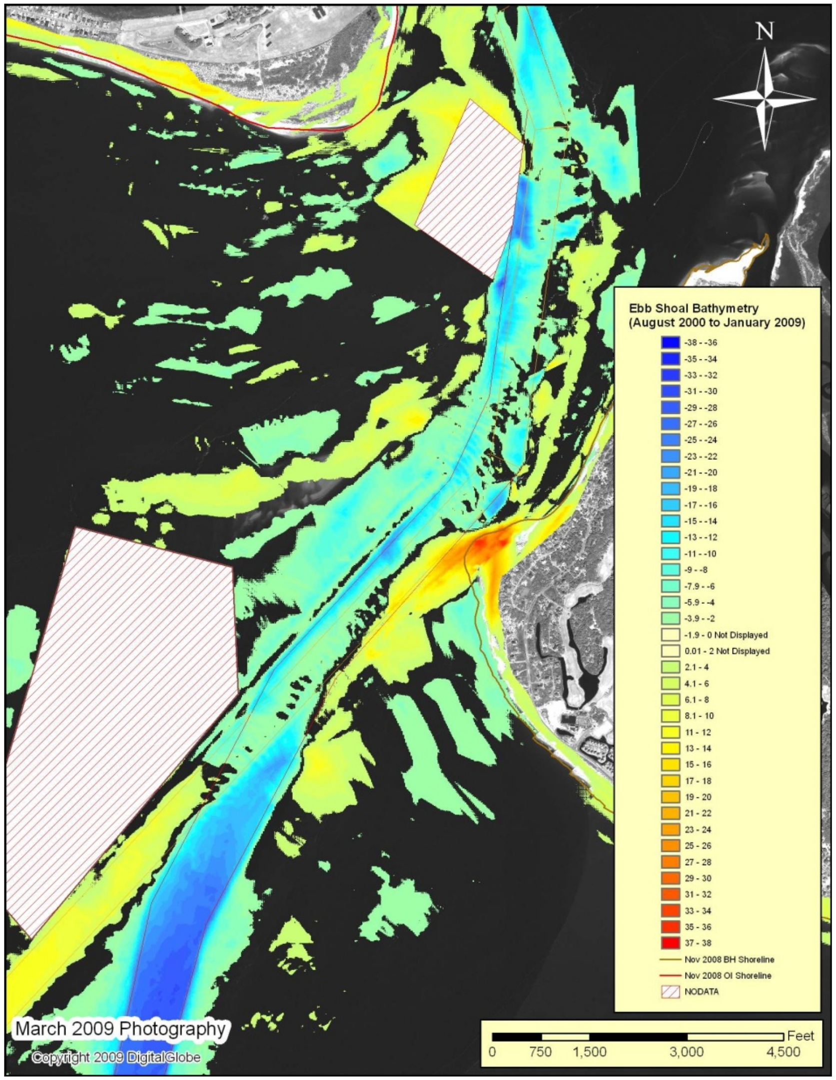


Figure 3.27 (a) Bathymetric Changes of Inlet (August 2000 to January 2009)

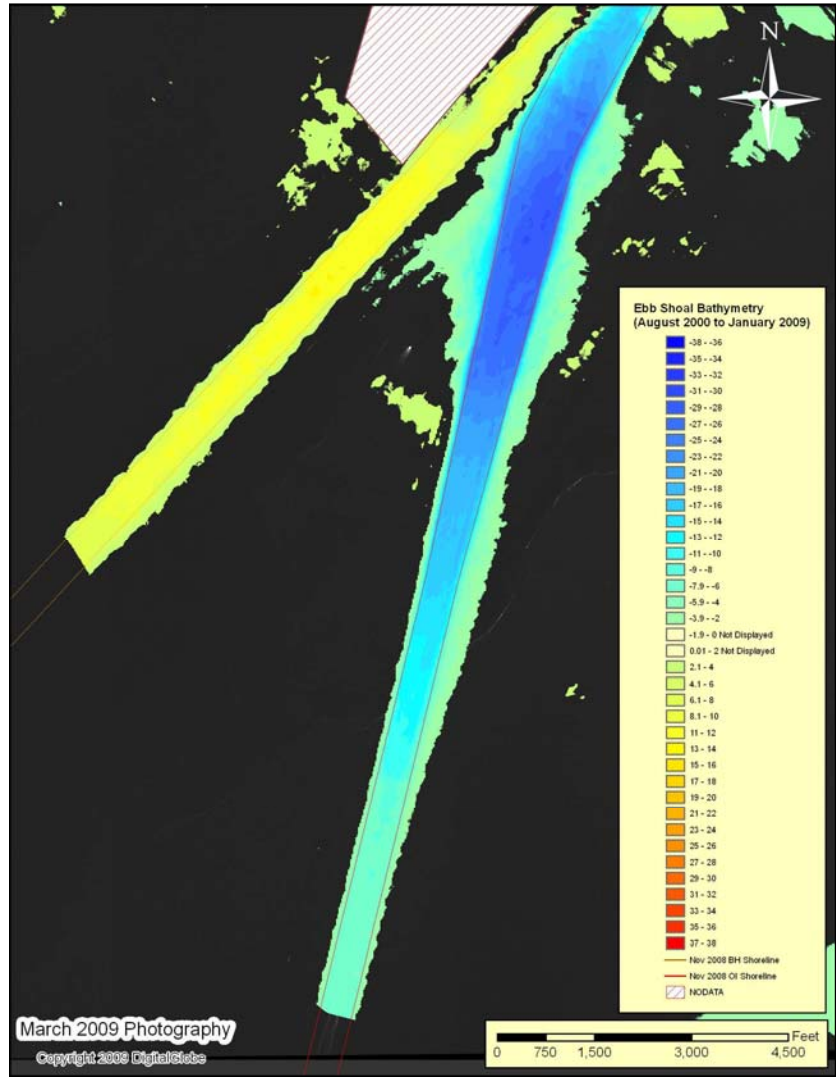


Figure 3.27 (b) Bathymetric Changes of New Channel (August 2000 to January 2009)

Current Measurements

Methodology. Mean currents were measured across the mouth of the Cape Fear River tidal inlet and the seaward portion of the ebb tidal delta around the new and original shipping channel using a ship-mounted Acoustic Doppler Current Profiler (ADCP). The location of the inlet and offshore transects are shown in Figure 3.28. Typically two +13-hour transects were performed during each survey episode. To date nine current surveys have been accomplished on both the inlet and new channel loops as listed in Table 3.2. The current measurements are scheduled to take place on or near spring tide for consistency and all but one of the surveys were accomplished in this manner. The initial October 11-12, 2000 transects were taken prior to the new entrance channel deepening and realignment, with the most recent being collected on April 25, 2009 (inlet region) and April 24, 2009 (new channel region). The specific ADCP transects for the 2009 data collection are given in Figures 3.29 and 3.30. For details of this system and methodology on data collection and reduction refer to the following referenced letter reports: McNinch 2000, 2002a, 2003a, 2004a, USACE 2005a, Waller and Pratt 2006, McNinch 2007a, and McNinch 2008a. Details of the most recent current measurements are given in McNinch 2009a.

Tidal Inlet Region Results. The results of each transect were processed and analyzed in a time series for each hourly loop. Figures 3.31 and 3.32 show the details of the flow patterns during times of peak flood and peak ebb, respectively, for the April 2009 measurements. The current vectors shown on the figures represent the near surface flow (upper half of the water column) shown in red and the near bottom flow (lower half of the water column) shown in blue. These flow patterns are influenced by the local bathymetry and are generally similar with those measured on previous occasions in overlapping areas. The current track lines for the inlet region were extended further seaward to capture current velocities and directions around the Bald Head spit. No comparison is available within this extended track line region. During flood flow, the currents are concentrated within the main channel between Bald Head Island and Jay Bird Shoals. Flow is also concentrated through the flood margin channel near Oak Island. A similar flow pattern is seen just off the Bald Head spit entering the main channel; however, there is not an associated flood margin channel visible within the bathymetric survey offshore of the Bald Head Island spit. One interesting feature is also evident with the flood flow pattern which reveal eddies off the main flow. These are evident in the lee of the point at the juncture between South Beach and West Beach and also near Oak Island. For comparison purposes, the similar peak flood flow patterns from the prior measurements collected in October 2000, April 2002, March 2003, Jan 2004, March 2005, March 2006, February 2007, and March 2008 are given in Appendix D.

The peak ebb flow patterns (Figure 3.32) have two velocity peaks along the inlet transect, one near the marginal channel along Oak Island and the other within the main channel. These flows are funneled into the main channel during ebb impinging on the bank along Bald Head's West Beach. The similar peak ebb flow patterns from the prior measurements collected in October 2000, April 2002, March 2003, Jan 2004, March 2005, March 2006, February 2007 and March 2008 are given in Appendix D. One significant change from the previous current surveys is the divergence of flow patterns at the seaward end of the survey transect. Previous surveys indicated that flow was constrained within the main channel. The new survey transect shows that while significant velocities are still recorded within the main channel further offshore, they also begin to flow over the eastern ebb tide delta. In addition, an eddy is noticed along the eastern side of the main channel just landward of the seaward extent of the current profile track.

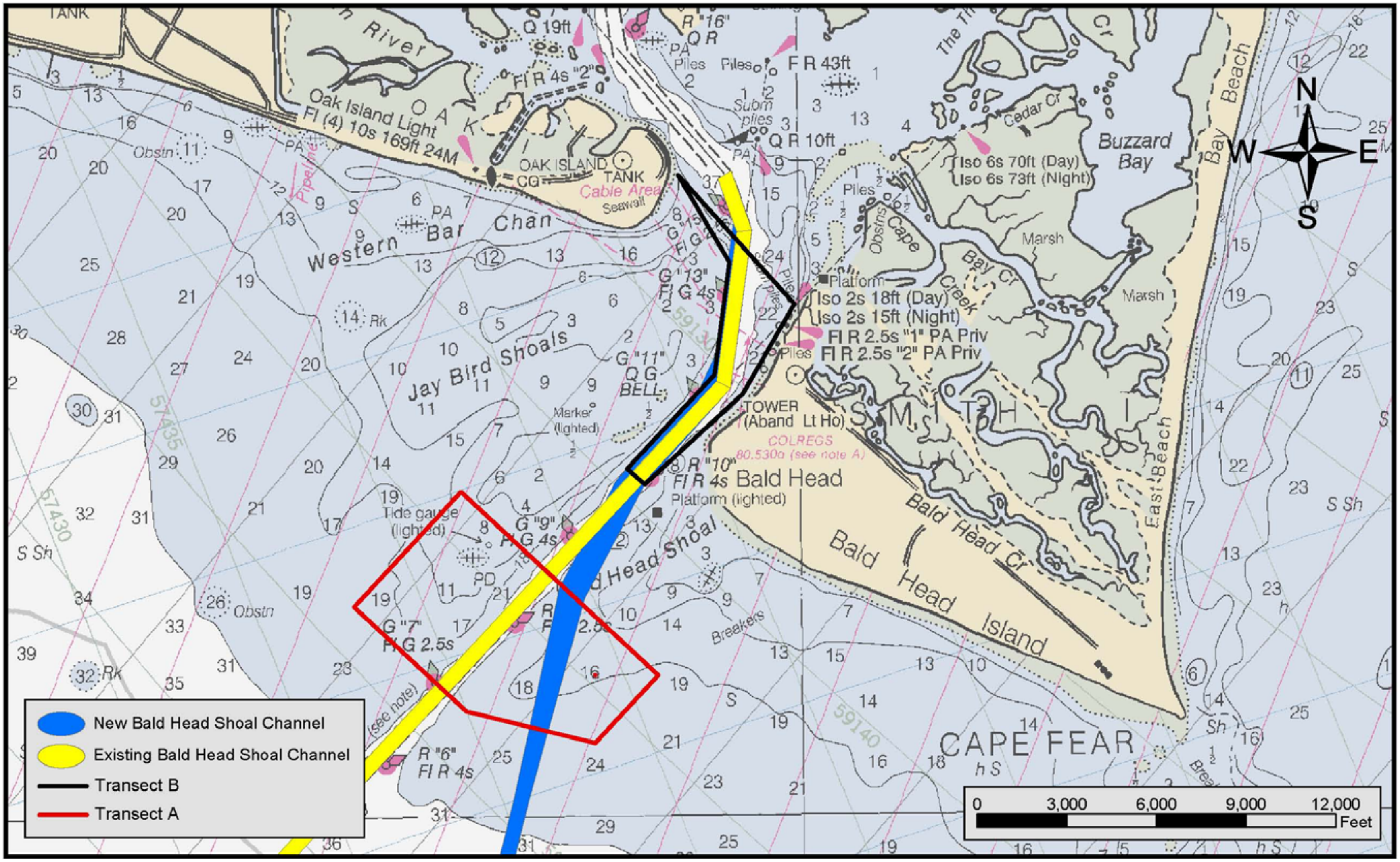


Figure 3.28 Ship-Board current profile track lines

Table 3.2 Listing of ADCP Current Surveys for the Wilmington Harbor Monitoring Program

	Inlet Region	**New Channel Region**
Survey Year	2000	2000
Survey Date	12-Oct	13-Oct
Survey Time	09:00-23:00	10:00-23:00
Tidal Phase	Spring	Spring
Survey Year	2002	2002
Survey Date	13-Apr	12-Apr
Survey Time	06:00-19:00	06:00-19:00
Tidal Phase	Spring	Spring
Survey Year	2003	2003
Survey Date	4-Mar	18-Mar
Survey Time	06:00-19:00	06:00-19:00
Tidal Phase	Spring	Spring
Survey Year	2004	2004
Survey Date	13-Jan	11-Jan –12-Jan
Survey Time	09:00-23:00	15:00-05:00
Tidal Phase	Neap	Neap
Survey Year	2005	2005
Survey Date	10-Mar	9-Mar
Survey Time	07:00-20:00	09:00-21:00
Tidal Phase	Spring	Spring
Survey Year	2006	2006
Survey Date	27-Mar & 29-Mar	28-Mar
Survey Time	11:00-19:00 & 10:00-1300	09:30-17:30
Tidal Phase	Spring	Spring
Survey Year	2007	2007
Survey Date	19-Feb	20-Mar
Survey Time	06:30-20:30	05:45-17:00
Tidal Phase	Spring	Spring
Survey Year	2008	2008
Survey Date	10-Mar	11-Mar
Survey Time	15:00-04:00 (11-Mar)	09:30-22:00
Tidal Phase	Spring	Spring
Survey Year	2009	2009
Survey Date	25-April	24-April
Survey Time	11:30-24:00	12:00-24:50
Tidal Phase	Spring	Spring

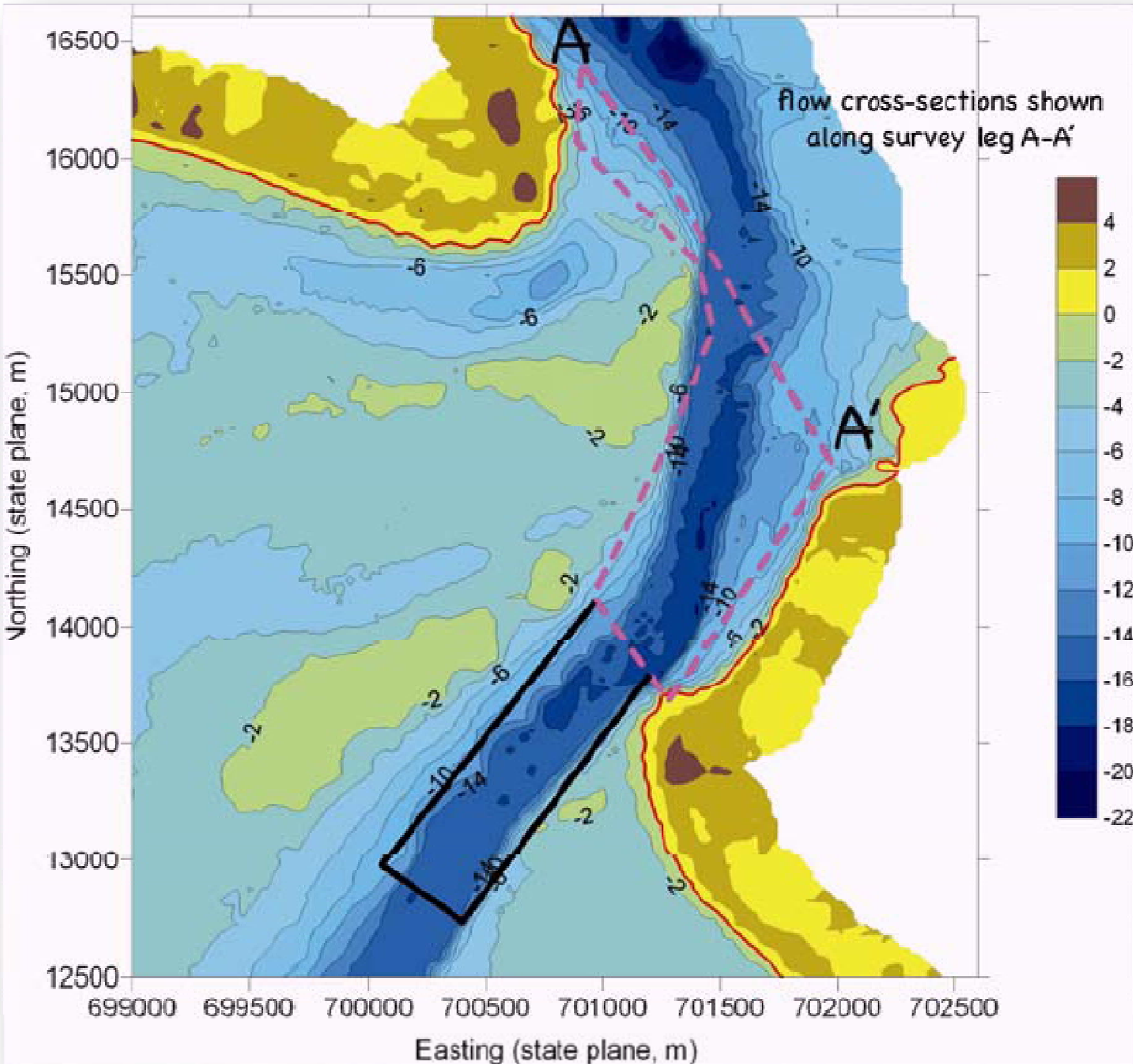


Figure 3.29 Plan View Showing the ADCP Transect Collected 25 April 2009 in the Tidal Inlet Region

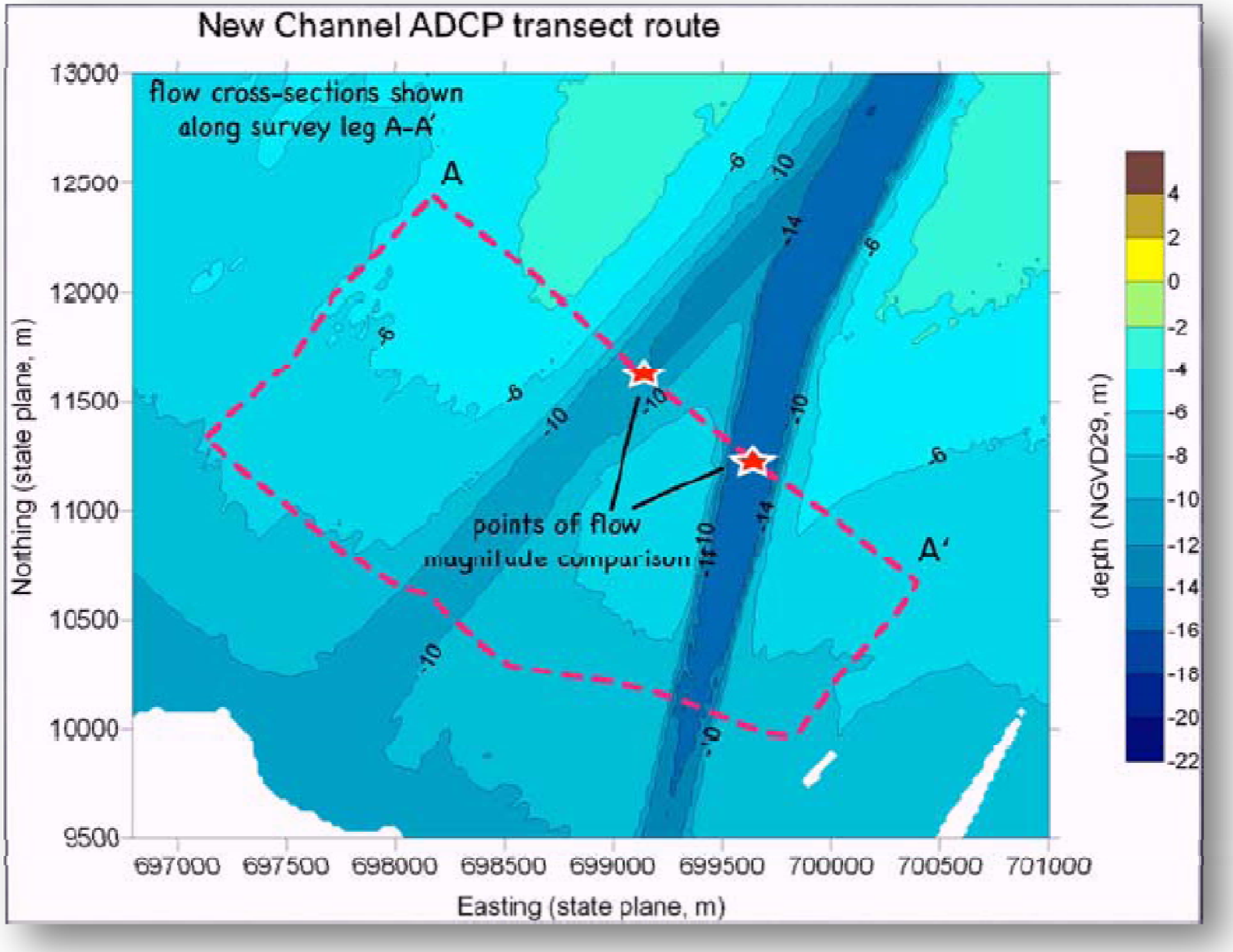


Figure 3.30 Plan View Showing the ADCP transect Collected 24 April 2009 in the New Channel Region

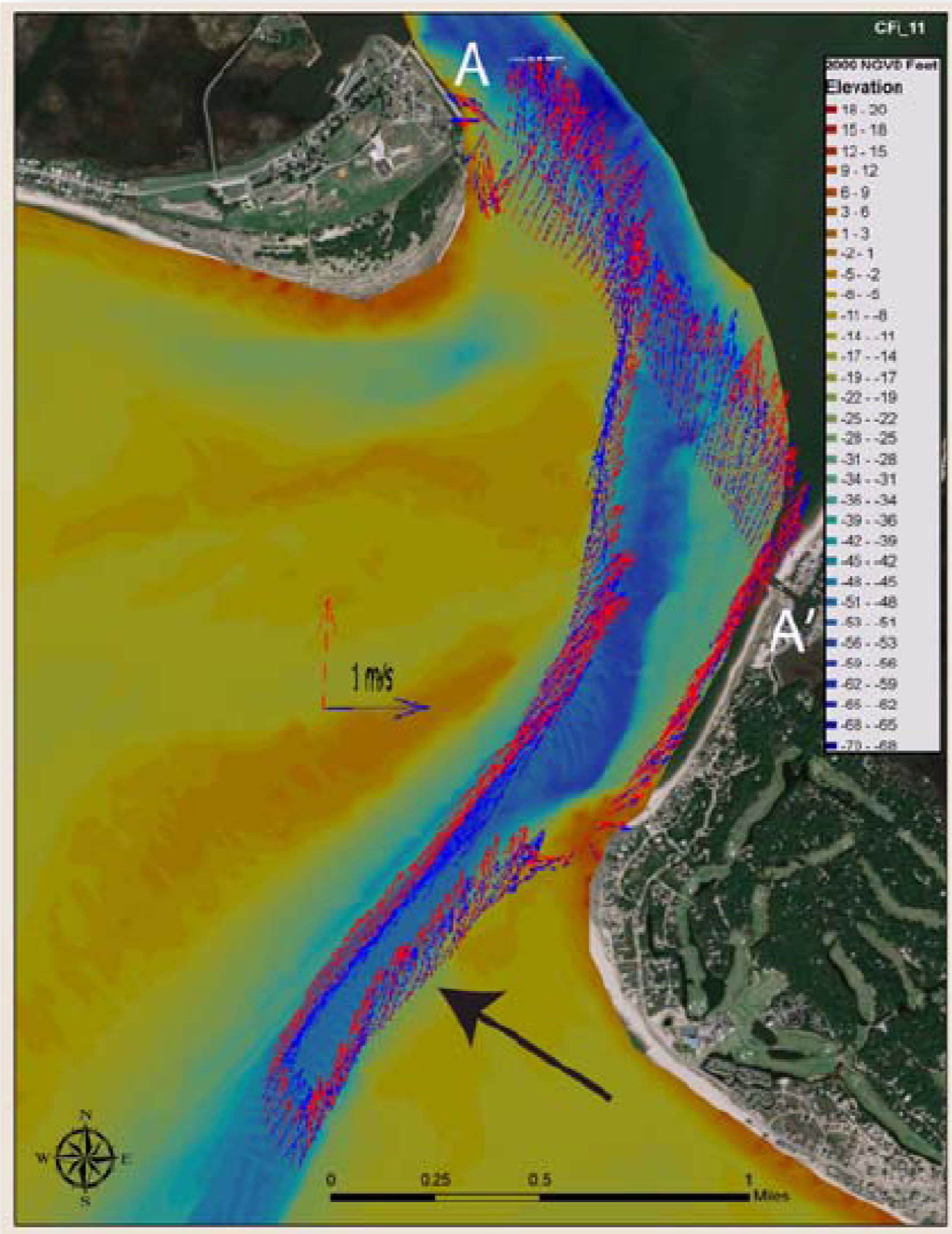


Figure 3.31 April 2009 ADCP Survey at the Inlet Transect during Peak Flood Flow

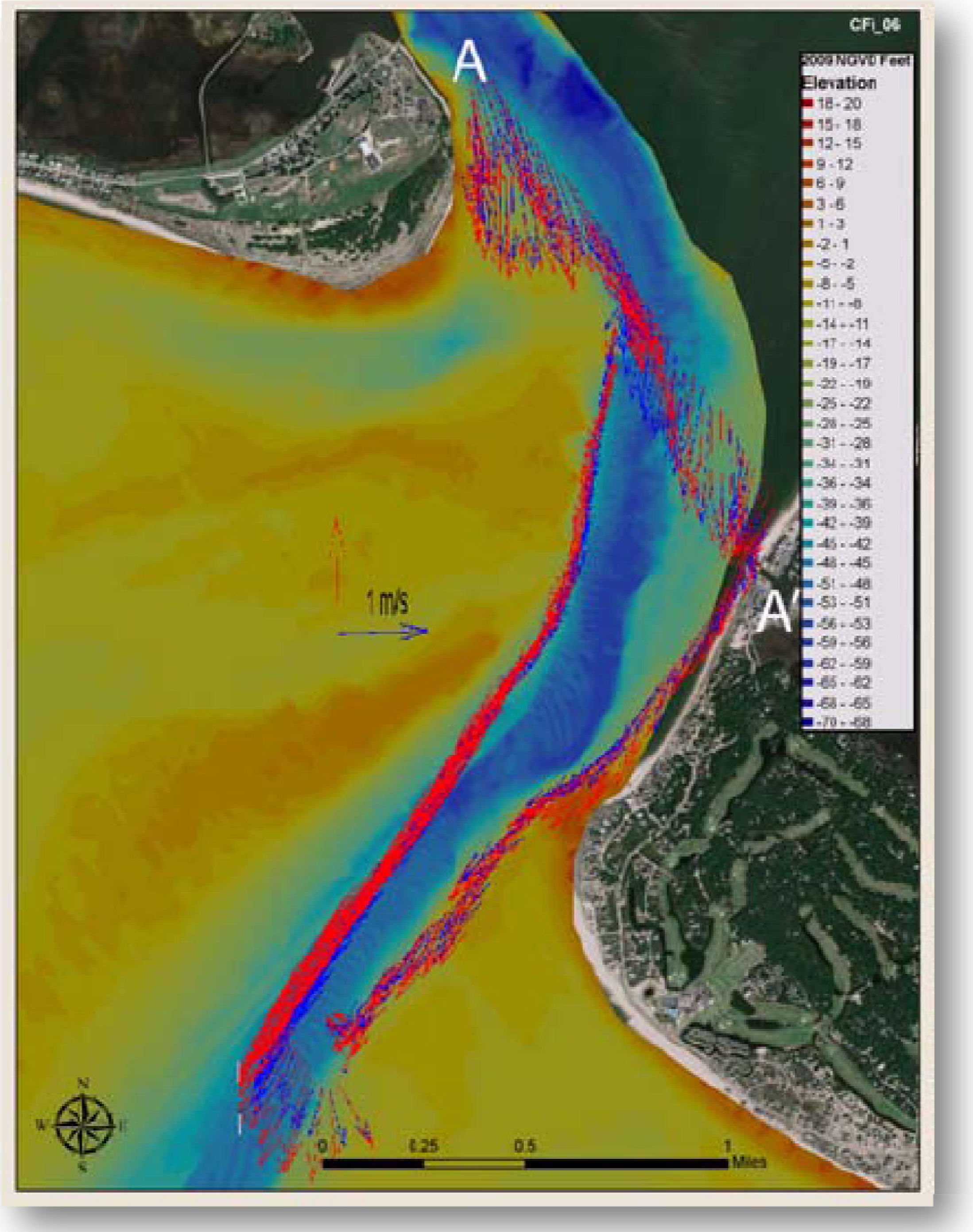


Figure 3.32 April 2009 ADCP Survey at the Inlet Transect During Peak Ebb Flow

The maximum near-surface and near-bottom current velocities measured throughout each of the surveys are listed in Table 3.3 for the inlet region. The April 2009 records are generally comparable to prior years. The overall magnitudes of the currents ranged from a peak surface ebb value of 5.28 ft/s to near-bottom flood values of just under 4 ft/s. Another trend is evident from the table when comparing the October 2000 pre-project measurements with the eight post-construction measurements. In this regard, all of the maximum velocities are greater than the initial pre-project magnitudes. The only exceptions to this remains the January 2004 near bottom flood and near-surface ebb measurements. One reason for this exception may be that in this instance the survey was not taken near spring tide as all the others were. Since only one pre-project survey was taken as part of the monitoring effort, it is difficult to draw a firm conclusion regarding the increase in peak flows through the inlet. However, this issue warrants further investigation during the proposed future modeling efforts to determine the significance of this trend in the post-project measurements. In comparing the average of the post-project values with the October 2000 values, all are greater. Specifically for the near-bottom case, the average values are –4.6 ft/s (ebb) and 4.1 ft/s (flood) versus -3.5 ft/s and 3.3 ft/s, respectively. For the near-surface case, the average values are likewise –5.2 ft/s (ebb) and 4.3 ft/s (flood), versus -4.4 ft/s (ebb) and 3.6 ft/s (flood) for the October 2000 measurements.

Table 3.3 Maximum Magnitude of Mean Flows at Inlet Transect

		October 2000	April 2002	March 2003	January 2004	March 2005	March 2006	February 2007	March 2008	April 2009
Near-bottom*	***ebb***	3.48 ft/s (1.06 m/s)	3.83 ft/s (1.17 m/s)	3.87 ft/s (1.18 m/s)	5.14 ft/s (1.57 m/s)	4.43 ft/s (1.35 m/s)	3.61 ft/s (1.10 m/s)	5.74 ft/s (1.75 m/s)	5.31 ft/s (1.62 m/s)	4.86 ft/s (1.48 m/s)
	flood	3.28 ft/s (1.00 m/s)	3.67 ft/s (1.12 m/s)	4.82 ft/s (1.47 m/s)	3.23 ft/s (0.98 m/s)	3.87 ft/s (1.18 m/s)	3.81 ft/s (1.16 m/s)	4.46 ft/s (1.36 m/s)	4.66 ft/s (1.42 m/s)	3.94 ft/s (1.2 m/s)
Near-surface*	***ebb***	4.43 ft/s (1.35 m/s)	6.46 ft/s (1.97 m/s)	5.41 ft/s (1.65 m/s)	3.88 ft/s (1.18 m/s)	5.58 ft/s (1.70 m/s)	4.53 ft/s (1.38 m/s)	5.41 ft/s (1.65 m/s)	5.31 ft/s (1.62 m/s)	5.28 ft/s (1.61 m/s)
	flood	3.61 ft/s (1.10 m/s)	4.13 ft/s (1.26 m/s)	4.17 ft/s (1.27 m/s)	3.75 ft/s (1.14 m/s)	4.40 ft/s (1.34 m/s)	4.50 ft/s (1.37 m/s)	4.59 ft/s (1.40 m/s)	4.66 ft/s (1.42 m/s)	4.56 ft/s (1.39 m/s)
	*Near-bottom defined by lower half of water column; near-surface defined by upper half of water column									

Tidal Prism. Tidal prism represents the total volume of water passing though the inlet over the tidal period. Tidal prisms were computed using the inlet throat transect (see Figure 3.29 for example transect) for each of the past current measurements—pre-construction (October 2000) and post-construction (April 2002, March 2003, January 2004, March 2005, February 2007, March 2008 and April 2009) ADCP surveys. Unfortunately, calculation of the tidal prism was not possible for the March 2006 ADCP survey due to the shortened data collection resulting from the hazardous weather and sea state conditions. The results are displayed graphically for each of the survey dates in Figure 3.33. These computations represent snapshots of the tidal period for each respective date and include the results of other non-tidal forcing agents as well as natural variations in tide conditions. Other forces which influence flow are wind-forcing, river discharge as well as differences in astronomical tides at different times of the year and across a tidal epoch (i.e. spring tides are not necessarily equal through time). To make more meaningful comparisons of the eight surveys, the tidal prism computations were normalized across the inlet cross-section area as defined by the January 2003 bathymetry and associated transect. Table 3.4 summarizes the tidal prism computations and the results are shown graphically in Figure 3.33.

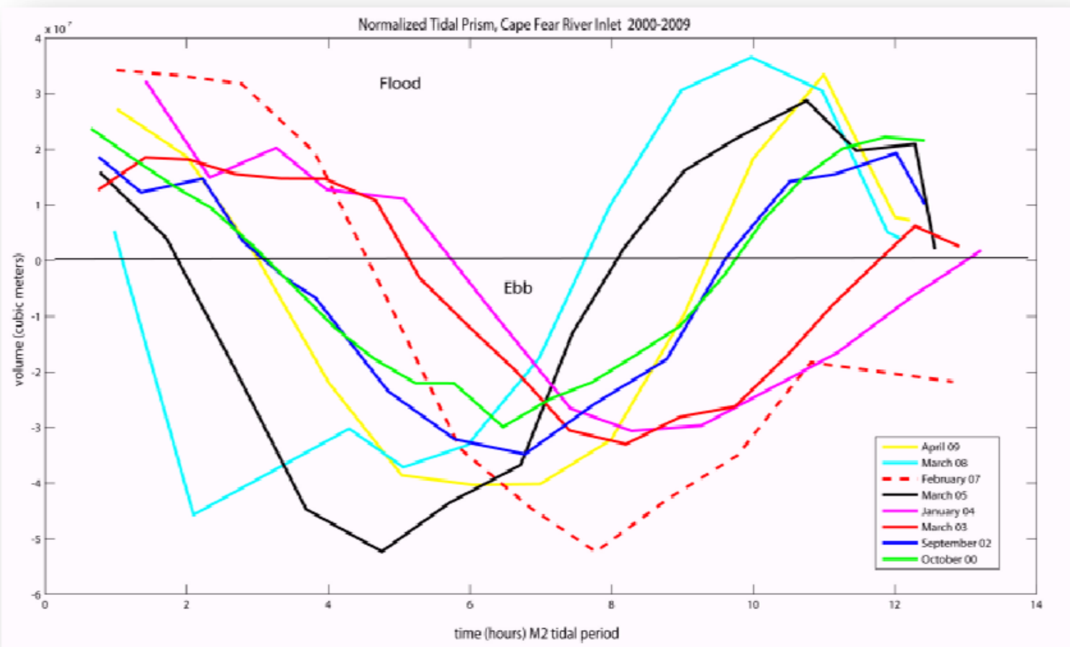


Figure 3.33 Volume of Water Passing through the inlet over the tidal period for all ADCP surveys (2000-2009)

Table 3.4 Normalized Tidal Prism Values for each of the ADCP Surveys (2000-2009)

Survey Date	**Ebb**	**Flood**	**Total**
Oct 2000	$6.7x10^{9}$ ft^{3}	$4.7x10^{9}$ ft^{3}	$1.1x10^{10}$ ft^{3}
	$1.9x10^{8}$ m^{3}	*$1.3x10^{8}$ m^{3}*	*$3.2x10^{8}$ m^{3}*
Apr 2002	$5.3x10^{9}$ ft^{3}	$3.9x10^{9}$ ft^{3}	$9.2x10^{9}$ ft^{3}
	$1.5x10^{8}$ m^{3}	*$1.1x10^{8}$ m^{3}*	*$2.6x10^{8}m^{3}$*
Mar 2003	$6.0x10^{9}$ ft^{3}	$4.0x10^{9}$ ft^{3}	$1.0x10^{10}$ ft^{3}
	$1.7x10^{8}$ m^{3}	*$1.2x10^{8}$ m^{3}*	*$2.8x10^{8}$ m^{3}*
Jan 2004	$5.0x10^{9}$ ft^{3}	$3.0x10^{9}$ ft^{3}	$8.0x10^{10}$ ft^{3}
	$1.5x10^{8}$ m^{3}	*$0.9x10^{8}$ m^{3}*	*$2.4x10^{8}$ m^{3}*
Mar 2005	$8.3x10^{9}$ ft^{3}	$3.9x10^{9}$ ft^{3}	$1.2x10^{10}$ ft^{3}
	$2.3x10^{8}$ m^{3}	*$1.1x10^{8}$ m^{3}*	*$3.4x10^{8}$ m^{3}*
Feb 2007	$7.4x10^{9}$ ft^{3}	$5.3x10^{9}$ ft^{3}	$1.3x10^{10}$ ft^{3}
	$2.1x10^{8}$ m^{3}	*$1.5x10^{8}$ m^{3}*	*$3.6x10^{8}$ m^{3}*
Mar 2008	$5.3x10^{9}$ ft^{3}	$5.2x10^{9}$ ft^{3}	$1.1x10^{10}$ ft^{3}
	$1.5x10^{8}$ m^{3}	*$1.5x10^{8}$ m^{3}*	*$3.0x10^{8}$ m^{3}*
April 2009	*$6.5x10^{9}ft^{3}$*	*$3.7x10^{9}ft^{3}$*	*$1.0x10^{10}ft^{3}$*
	$1.8x10^{8}m^{3}$	*$1.1x10^{8}m^{3}$*	*$2.9x10^{8}m^{3}$*

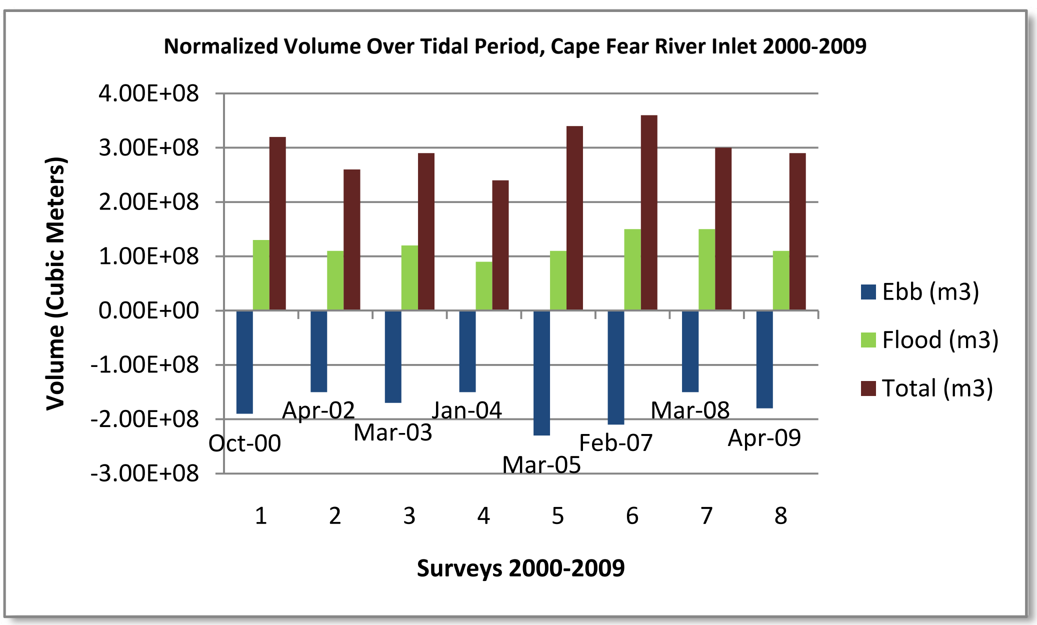


Figure 3.34 Normalized tidal prism for eight surveys—(1) October 2000, (2) April 2002, (3) March 2003, (4) January 2004 (5) March 2005 (6) February 2007 (7) March 2008 and (8) April 2009. Blue—ebb, Green—flood, Red—total

The normalizing process applies the average velocity from the ADCP survey across the inlet cross-section area multiplied by the tidal period. The October 2000 inlet transect survey only covered the inlet throat because at that time it was believed that insignificant flow existed over the shoals adjacent to Oak Island. Subsequent hydrographic surveys and current measurements indicated otherwise, so beginning with the April 2002 survey the inlet transects were enlarged. Thus the average velocity for the October 2000 survey, since it only incorporated a portion of the inlet cross-section, possibly differed from what would have been measured if the whole cross-section had been surveyed. In addition, differences from survey periods relative to spring tides, winds, river discharge, and astronomical period should be considered when explaining the differences observed in Figure 3.33.

The tidal prism results show that the Cape Fear is an ebb-dominated inlet with the average ebb flow volume being 47% greater than the flood volume. The April 2009 current survey resulted in a total tidal prism that was very near the computed total volume for the pre-construction October 2000 survey (being only about 9% less). In addition, the present prism calculations more closely resemble those of the October 2000 survey indicating significant ebb dominance. Ebb volume for the current survey was approximately 64% larger than the flood volume. This exceeds the differential between the ebb and flood volumes for the October 2000 survey in which the ebb volume exceed the flood volume by 46%.

<u>Offshore-New Channel Region Results.</u> As with the inlet transect, the offshore transect in the vicinity of the new channel was also processed and analyzed for each hourly loop. Figures 3.35 and 3.36 show the detailed flow patterns recorded during the April 2009 measurements. Figure 3.35 shows the time of near peak flood flow and Figure 3.36 gives the peak ebb condition. The current vectors shown on the figures represent the near surface flow (upper half of the water column) shown in red and the near bottom flow (lower half of the water column) shown in blue. These flow patterns are generally similar with those measured on previous occasions and reach peak velocities on the order of 1 m/s (3.3 fps). During peak flood flow, the currents are somewhat uniform spatially around the transect, but are slightly more concentrated along the old and new channel beds and in the region between the two channels. For comparison purposes, the similar peak flood flow patterns from the prior measurements collected in Oct 2000, April 2002, March 2003, Jan 2004, March 2005, March 2006 and March 2007 are given in Appendix D.

The peak ebb in the offshore transect is found to start in the new channel and shift to the old ebb channel location. At peak flow the strongest ebb is located generally over the “v” intersection between the old and new channel regions. This velocity concentration spreads out laterally as the ebb flow proceeds seaward between the two channels. Outside of this region the ebb flows are greatly reduced particularly around Jay Bird Shoals. The comparative peak ebb flow patterns from the prior measurements are given in Appendix D.

The maximum near-surface and near-bottom current velocities measured throughout each of the surveys are listed in Table 3.5 for the outer transect. Overall, as with the inlet transect, the peak ebb velocities exceed the peak flood velocities. The velocities range from a high measured at near-surface ebb of 3.4 ft/s with a low peak found at near-bottom flood of just over 1.6 ft/s.

As indicated in the table, the most recent measurements of April 2009 are found to be lower than the flow rates for the previous two years. As discussed in Monitoring Report 6, ebb flow rates for March 2007 and 2008 were above normal when compared to the first 5 years of post construction current surveys. The April 2009 near bottom ebb current measured 2.91 ft/s, which is very close to the 2.98 ft/s average of the near bottom measurements from April 2002 through March 2006. Similarly, the near surface ebb current measured in April 2009 was 3.44 ft/s just slightly lower than the 3.65 ft/s average from April 2002 through March 2006.

When comparing the October 2000 pre-project measurements with the post-construction measurements, all of the maximum velocities are found to be greater than the measured pre-project magnitudes. As noted previously since only one pre-project survey was taken as part of the monitoring effort it is difficult to draw a firm conclusion regarding the increase in peak flows in the area of the new channel. However, this issue warrants further investigation during the proposed future modeling efforts to determine the significance of this trend in the post-project measurements. Nevertheless, it is of interest to compare the average of all the post-project values with the October 2000 values. Specifically for the near-bottom case, the average values are –3.2 ft/s (ebb) and 1.9 ft/s (flood) versus -2.0 ft/s and 1.3 ft/s, respectively. For the near-surface case, the average values are likewise –3.9 ft/s (ebb) and 1.9 ft/s (flood), versus –3.1 ft/s (ebb) and 1.4 ft/s (flood) for the October 2000 readings.

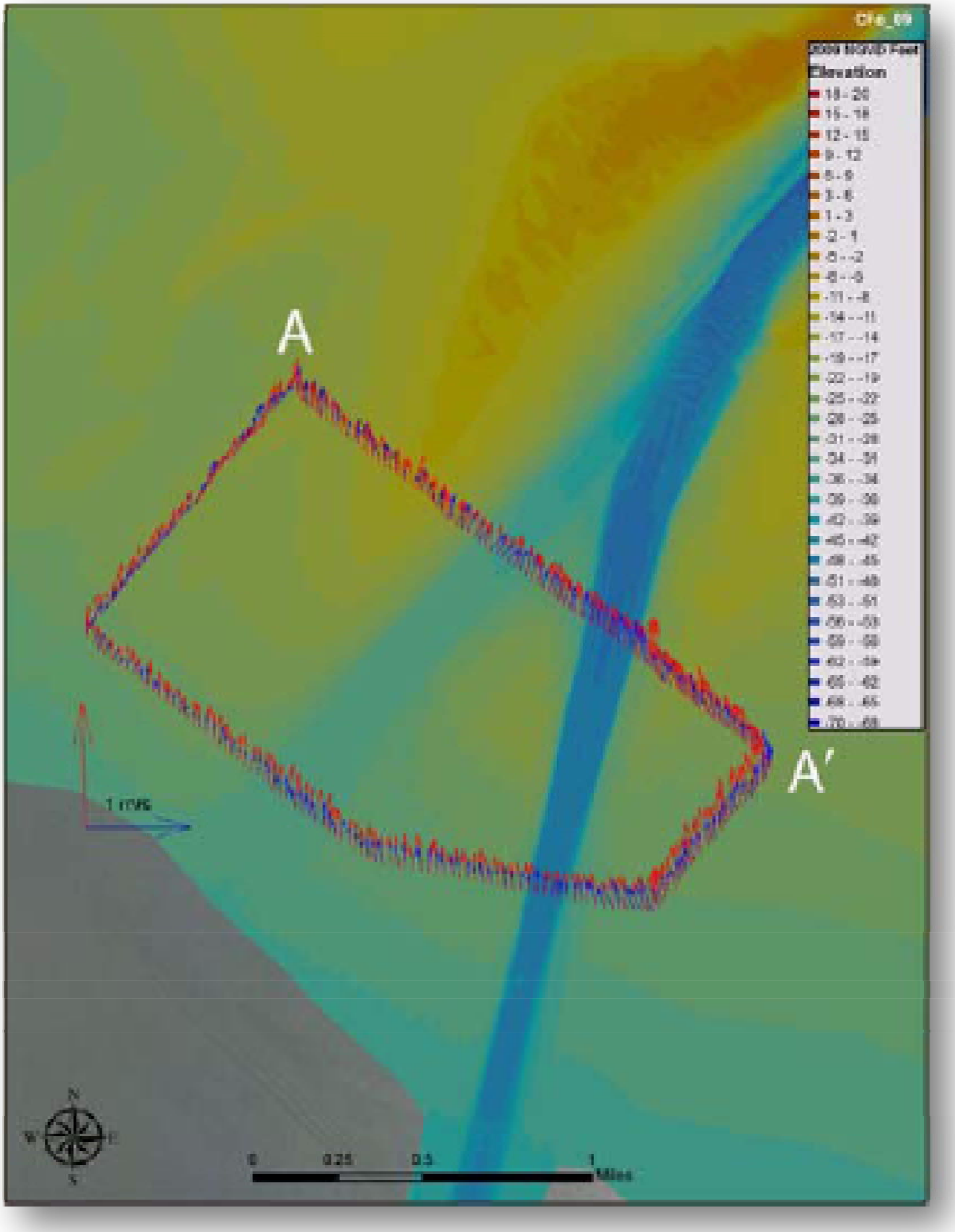


Figure 3.35 April 2009 ADCP survey at the Offshore-New Channel Transect near peak flood flow

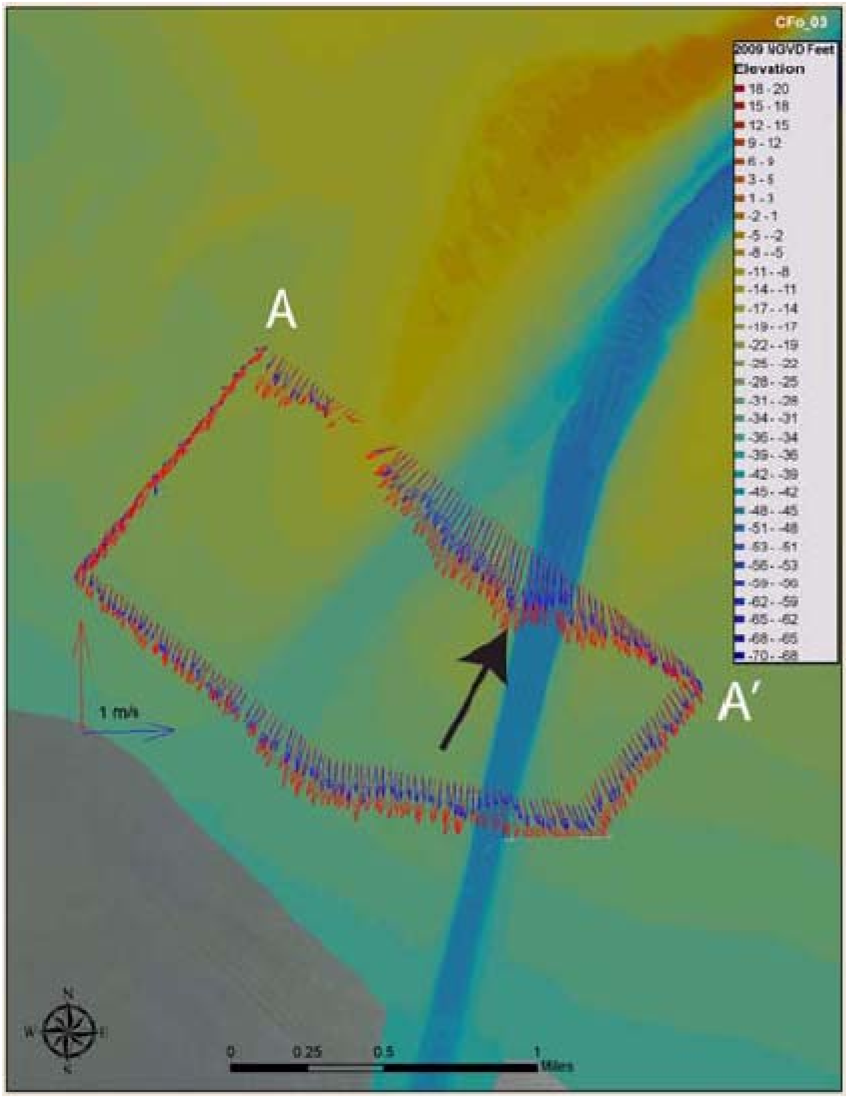


Figure 3.36 April 2009 ADCP survey at the Offshore-New Channel Transect near peak ebb flow

Table 3.5 Maximum Magnitude of Mean Flows at New Channel Transect

		October 2000	April 2002	March 2003	January 2004	March 2005	March 2006	March 2007	March 2008	April 2009
Near-bottom*	***ebb***	2.03 ft/s (0.62 m/s)	3.08 ft/s (0.94 m/s)	3.15 ft/s (0.96 m/s)	3.00 ft/s (0.91 m/s)	2.79 ft/s (0.85 m/s)	2.89 ft/s (0.88 m/s)	3.64 ft/s (1.11 m/s)	3.71 ft/s (1.1 m/s)	2.91 ft/s (0.89 m/s)
	flood	1.31 ft/s (0.40 m/s)	1.94 ft/s (0.59 m/s)	2.69 ft/s (0.82 m/s)	1.32 ft/s (0.40 m/s)	2.20 ft/s (0.67 m/s)	NA	2.17 ft/s (0.66 m/s)	1.34 ft/s (0.41 m/s)	1.61 ft/s (0.49 m/s)
Near-surface*	***ebb***	3.08 ft/s (0.94 m/s)	3.38 ft/s (1.03 m/s)	3.87 ft/s (1.18 m/s)	3.64 ft/s (1.11 m/s)	3.71 ft/s (1.13 m/s)	3.64 ft/s (1.11 m/s)	4.36 ft/s (1.33 m/s)	4.36 ft/s (1.33 m/s)	3.44 ft/s (1.05 m/s)
	flood	1.41 ft/s (0.43 m/s)	2.49 ft/s (0.76 m/s)	1.87 ft/s (0.57 m/s)	1.58 ft/s (0.48 m/s)	2.20 ft/s (0.67 m/s)	NA	2.07 ft/s (0.63 m/s)	1.48 ft/s (0.45 m/s)	1.61 ft/s (0.49 m/s)

Wave Data Analysis

Detailed investigations of wave conditions associated with Wilmington Harbor monitoring are being conducted through the use of field data collection using three wave gauges. One gauge is located offshore and the other two are located nearshore so that the local wave climate can be assessed with respect to offshore conditions. In this section the wave data collected to date are presented through relative comparisons over time and with each other. Significant wave events are also identified for the entire monitoring period to date, which covers from September 2000 to June 2009.

Wave Gauge Analysis. Directional wave, water level, and current data are collected at one offshore location (referred to as the 11-Mile gauge) and two nearshore locations (Oak Island and Bald Head Island), as shown in Figure 3.55. Water depths are about 42 ft at 11-Mile, 23 ft at Oak Island, and 19 ft at Bald Head Island gauges. The 11-Mile gauge was placed just south of a proposed dredged material disposal area, seaward of the navigation channel and ebb shoal influence. The nearshore gauges provide data in the vicinity of the navigation channel, nearshore shoals and adjacent beaches. All three gauges are Acoustic Doppler Current Profiler (ADCP) instruments accompanied by a pressure transducer. Directional wave spectra are calculated from time series of velocity at various depths obtained by the ADCP. Corresponding significant wave height Hm0, peak period Tp, and peak direction Dp parameters are determined from the directional spectrum. Peak frequency represents the highest energy density in the frequency spectrum integrated over all directions. Peak direction is determined as the vector mean at the peak frequency. Water level is determined from the pressure transducer record. Time series of current velocity at the surface, mid-depth, and bottom are also provided from the ADCP gauges. The 11-Mile and Bald Head Island gauges currently collect 20-min time series at 3-hr intervals. The Oak Island gauge collects 20-min time series at 1-hr intervals.

All gauges were initially deployed in September 2000. The 11-Mile gauge has operated consistently from initial deployment on 22 Sep 2000, except for a two month data gap between Dec-04 and Feb 05, a three month gap between Feb-06 and May-06, and also between 21 January 2009 and 1 February 2009. The Bald Head Island gauge was operational during the same time period, but experienced some data losses for periods of 13 Aug to 27 Sep 2001, 6 Jan to 17 Jan 2001, 1 Sep to 25 Sep 2005, 7 Jan to 26 Apr 2006, 29 March 2007 to 21 September 2007, and 21 Jan 2009 to 1 Feb 2009, plus some other minor periods of up to several days. The Oak Island gauge has had the most down time of the three gauges. This gauge was damaged by a trawler on 23 Oct 2000 and not successfully reactivated until June 2001. Additional significant periods of data gaps occurred between 1 July and 27 Sep 2001, 6 Mar and 24 Apr 2002, 4 July and 1 August 2002, 8 Apr and 24 Apr 2003, 28 May and 11 June 2003 and 29 Mar and 12 May 2004. Further, the gauge was apparently hit by lightning on 8 Apr 2005 and was not operational again until it was serviced in Sept 2005. A weak battery lead to sporadic data collection between 24 Dec 2005 and 10 Feb 2006. Additional data losses are noted between 10 Feb and 27 April

2006, 28 Sep 2006 and 29 March 2007, 5 April and 29 July 2008. During the current monitoring period the gauge was out of service nearly a month between 9 Jan and 26 Jan 2009.

Wave Climate. The wave data were analyzed using the Coastal Engineering Design and Analysis System (**CEDAS**), Nearshore Evolution Modeling System (NEMOS) software (NEMOS 2000). The data were updated from the last reporting through the June 2009 deployment for the Oak Island and Eleven Mile gauges. The data for the Bald Head gauge were found to have erroneous wave heights when processed due to a pressure offset in the gauge related to an apparent lightening strike in January 2009. The data collected from the Bald Head gauge will be reprocessed and will be incorporated into the next monitoring report. Tables 3.6 through 3.8 summarize the mean monthly conditions for all gauges for the available data. These tables include the mean monthly wave height, period and direction (Hsmean, Tpmean & Dpmean). The average annual wave height (Hsmean) observed for the 11-mile gauge since its initial deployment did not change from the previous two monitoring reports, remaining at 3.3 feet. The average annual wave height for the Bald Head gauge is 1.9 feet as reported in monitoring report 6. Over this same time period the average annual wave height for the Oak Island gauge slightly increased from 1.6 feet to 1.7 feet. The comparison of average annual wave heights between the offshore 11 mile gauge and the nearshore Bald Head and Oak Island gauges demonstrate the significant wave transformation induced as waves travel over the shoals. In addition to determining average wave conditions, the monthly time series for all gauges were analyzed to determine the maximum wave height (Hsmax). The associated peak period (Tpmax) and wave direction (Dpmax) with each event were also computed. The 11-Mile gauge had monthly maximum wave heights ranging from 5.6 to 9.7 feet within the current monitoring period, with waves typically arriving from the southeast to southwest directions. The Oak Island gauge had an average monthly maximum wave height of 6.0 feet over the current monitoring period. The gauge clearly shows the filtering effect of the nearshore shoals, with the predominant number of events having wave directions confined to the south-southwest directions, which has been consistent throughout the entire monitoring period.

The seasonality of the wave climate is illustrated in Figure 3.38. This graph shows the mean monthly wave heights for the all the data collected to date (2000-2009) for each of the three gauges. For the 11-mile gauge the largest waves are found to occur during the late Fall through the winter months and during September reflecting the effect of the northeasters and tropical storms, respectively. For the nearshore gauges, which are sheltered from the east to northeast, the opposite pattern is evident. Both the Bald Head and Oak Island locations generally have the largest mean monthly wave heights during the summer months when the local winds turn predominately onshore. Of further interest, the wave heights measured at Oak Island are slightly lower than Bald Head for all months of the year. The seasonal shift is also seen in Figure 3.39 which is a plot of mean monthly wave direction for each gauge. The directions are given in a meteorological reference with degrees measured from north from indicating the direction from which the waves are traveling. For the nearshore gauges, the mean wave directions are from the south-southwest throughout the majority of the year shifting to the south-

southeast during September and October. While the 11 mile gauge wave orientations fluctuate between winter and summer time frames, the mean monthly wave directions consistently originate from the south-southeast.

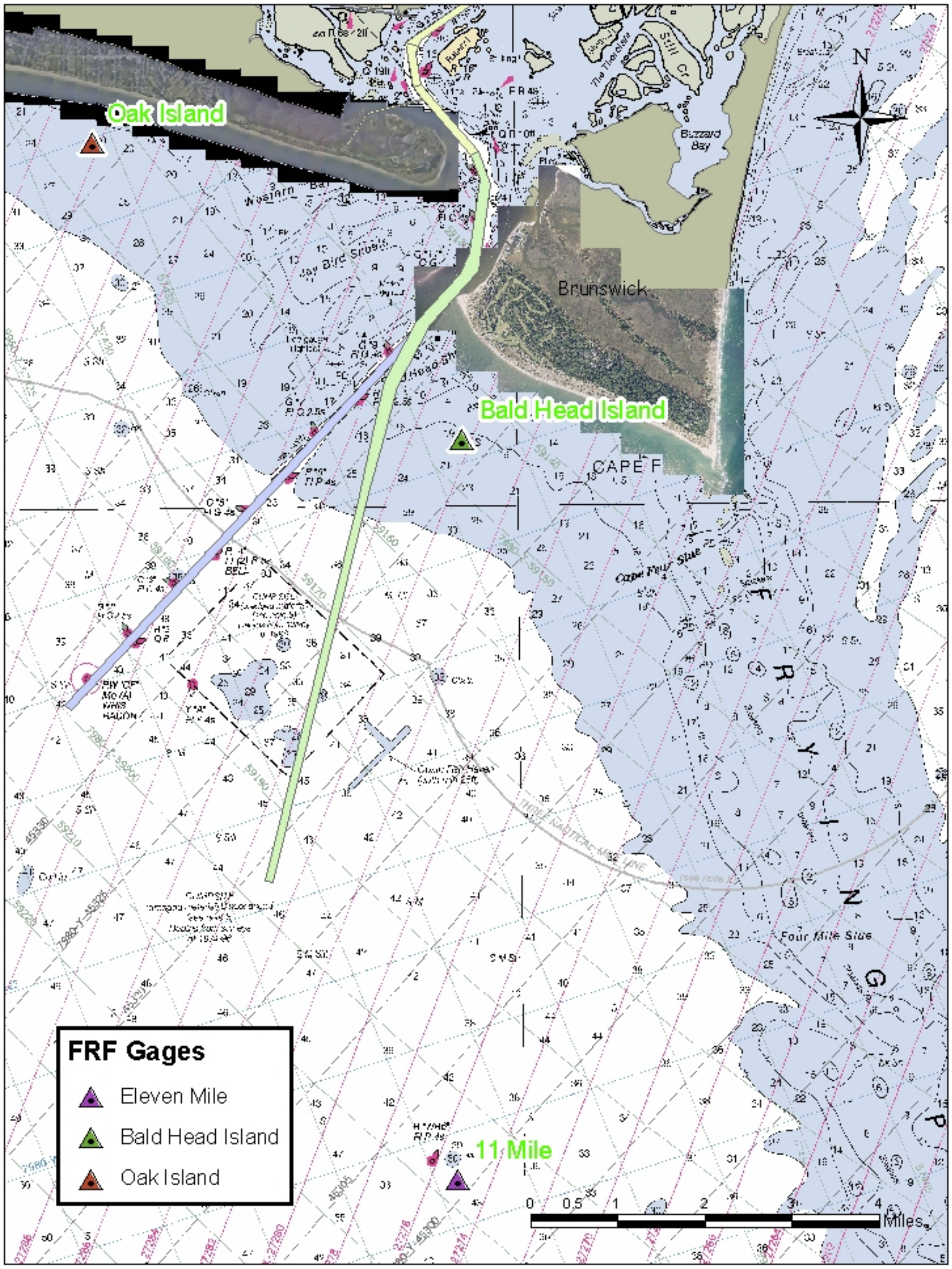


Figure 3.37 FRF Wave and Current Gauges.

Table 3.6 Eleven Mile Gauge Monthly Summaries

GAGE	STAT	YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVERAGE
Eleven Mile	HsMax	2000	--	--	--	--	--	--	--	--	6.6	5.3	9.0	11.3	**8.1**
Eleven Mile	HsMax	2001	7.1	7.3	10.8	5.1	5.7	8.1	8.6	5.5	7.3	5.9	6.6	8.3	**7.2**
Eleven Mile	HsMax	2002	11.2	8.5	11.5	8.4	7.2	5.9	6.4	4.6	5.6	6.8	9.7	8.8	**7.9**
Eleven Mile	HsMax	2003	7.4	9.7	8.5	7.3	9.3	6.3	6.0	5.9	9.1	6.3	9.7	9.1	**7.9**
Eleven Mile	HsMax	2004	7.3	6.9	6.5	8.5	6.1	5.2	5.2	11.1	9.9	6.8	8.6	--	**7.5**
Eleven Mile	HsMax	2005	--	9.9	11.7	9.5	8.1	5.6	6.0	5.0	11.5	8.0	10.1	11.7	**8.8**
Eleven Mile	HsMax	2006	10.5	--	--	--	8.1	10.9	5.5	10.1	9.5	6.4	13.3	14.1	**9.8**
Eleven Mile	HsMax	2007	12.8	16.4	15.5	11.7	8.1	9.7	5.5	5.4	5.6	6.0	8.7	9.2	**9.6**
Eleven Mile	HsMax	2008	8.8	9.5	10.2	5.3	8.8	6.8	6.4	6.7	15.8	9.5	9.0	10.4	**8.9**
Eleven Mile	HsMax	2009	9.7	8.7	8.2	9.0	6.1	5.6	--	--	--	--	--	--	**7.9**
	AVERAGE		**9.4**	**9.6**	**10.4**	**8.1**	**7.5**	**7.1**	**6.2**	**6.8**	**9.0**	**6.8**	**9.4**	**10.4**	

GAGE	STAT	YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVERAGE
Eleven Mile	DpMax	2000	--	--	--	--	--	--	--	--	213.0	89.0	166.0	253.0	**180.3**
Eleven Mile	DpMax	2001	221.0	159.0	146.0	205.0	33.0	190.0	165.0	227.0	21.0	203.0	154.0	186.0	**159.2**
Eleven Mile	DpMax	2002	182.0	188.0	164.0	212.0	203.0	154.0	217.0	72.0	182.0	153.0	187.0	190.0	**175.3**
Eleven Mile	DpMax	2003	208.0	187.0	160.0	172.0	236.0	191.0	209.0	177.0	319.0	157.0	180.0	187.0	**198.6**
Eleven Mile	DpMax	2004	236.0	144.0	168.0	174.0	231.0	199.0	214.0	198.0	197.0	205.0	184.0	--	**195.5**
Eleven Mile	DpMax	2005	--	161.0	185.0	225.0	17.0	64.0	265.0	194.0	286.0	137.0	191.0	146.0	**170.1**
Eleven Mile	DpMax	2006	172.0	--	--	--	231.0	183.0	231.0	177.0	191.0	146.0	139.0	221.0	**187.9**
Eleven Mile	DpMax	2007	198.0	206.0	194.0	205.0	157.0	160.0	192.0	205.0	213.0	157.0	201.0	193.0	**190.1**
Eleven Mile	DpMax	2008	177.0	173.0	204.0	207.0	219.0	207.0	146.0	117.0	182.0	120.0	217.0	157.0	**177.2**
Eleven Mile	DpMax	2009	197.0	216.0	205.0	185.0	92.0	176.0	--	--	--	--	--	--	**178.5**
	AVERAGE		**198.9**	**179.3**	**178.3**	**198.1**	**157.7**	**169.3**	**204.9**	**170.9**	**200.4**	**151.9**	**179.9**	**191.6**	

GAGE	STAT	YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVERAGE
Eleven Mile	HsMean	2000	--	--	--	--	--	--	--	--	3.6	2.5	2.5	3.1	**2.9**
Eleven Mile	HsMean	2001	2.7	2.7	3.6	2.6	2.7	2.7	3.3	3.0	3.0	2.9	3.2	3.2	**3.0**
Eleven Mile	HsMean	2002	3.3	3.2	3.3	3.5	3.4	3.3	3.4	2.8	3.2	2.8	3.0	3.3	**3.2**
Eleven Mile	HsMean	2003	3.3	2.9	3.1	3.1	3.0	3.2	2.8	2.4	3.6	2.8	3.2	3.1	**3.0**
Eleven Mile	HsMean	2004	2.8	3.2	2.9	2.7	3.1	3.0	2.8	3.3	4.4	2.9	2.8	--	**3.1**
Eleven Mile	HsMean	2005	--	3.9	4.0	3.7	2.8	2.8	2.6	2.5	3.5	3.0	3.2	3.2	**3.2**
Eleven Mile	HsMean	2006	3.2	--	--	--	3.2	3.3	3.3	2.9	3.2	2.9	6.5	6.0	**3.8**
Eleven Mile	HsMean	2007	6.1	7.8	6.4	2.8	2.7	2.6	2.5	2.4	2.9	3.5	3.3	3.2	**3.9**
Eleven Mile	HsMean	2008	3.1	3.8	3.4	3.0	2.8	2.6	2.8	3.1	4.4	3.6	3.6	3.8	**3.3**
Eleven Mile	HsMean	2009	3.4	2.8	3.3	3.6	3.5	2.5	--	--	--	--	--	--	**3.2**
	AVERAGE		**3.5**	**3.8**	**3.7**	**3.1**	**3.0**	**2.9**	**2.9**	**2.8**	**3.5**	**3.0**	**3.5**	**3.6**	

(Continued)

Table 3.6 Eleven Mile Gauge Monthly Summaries (Continued)

GAGE	STAT	YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVERAGE
Eleven Mile	TpMax	2000	--	--	--	--	--	--	--	--	12.8	**	14.2	**	**13.5**
Eleven Mile	TpMax	2001	**	10.6	16.0	25.6	14.2	**	10.6	11.6	**	18.2	14.2	**	**15.1**
Eleven Mile	TpMax	2002	16.0	16.0	**	10.6	**	11.6	9.8	18.2	12.8	21.3	18.2	18.2	**15.3**
Eleven Mile	TpMax	2003	12.8	14.2	16.0	14.2	14.2	9.1	9.1	16.0	16.0	14.2	14.2	16.0	**13.8**
Eleven Mile	TpMax	2004	11.6	14.2	14.2	12.8	11.6	25.6	9.8	25.6	16.0	25.6	25.6	--	**17.5**
Eleven Mile	TpMax	2005	--	10.6	16.0	16.0	14.2	12.8	10.6	25.6	12.8	14.2	16.0	12.8	**14.7**
Eleven Mile	TpMax	2006	14.2	--	--	--	14.2	12.8	9.8	12.8	25.6	12.8	10.6	10.6	**13.7**
Eleven Mile	TpMax	2007	9.8	10.6	11.6	12.8	25.6	25.6	14.2	16.0	12.8	16.0	14.2	14.2	**15.3**
Eleven Mile	TpMax	2008	14.2	14.2	25.6	12.8	14.2	16.0	16.0	11.6	16.0	25.6	25.6	12.8	**17.1**
Eleven Mile	TpMax	2009	25.6	14.2	14.2	12.8	9.1	25.6	--	--	--	--	--	--	**16.9**
	AVERAGE		**14.9**	**13.1**	**16.2**	**14.7**	**14.7**	**17.4**	**11.2**	**17.2**	**15.6**	**18.5**	**17.0**	**14.1**	

GAGE	STAT	YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVERAGE
Eleven Mile	TpMean	2000	--	--	--	--	--	--	--	--	7.2	7.5	6.8	7.0	**7.1**
Eleven Mile	TpMean	2001	6.8	6.7	7.5	6.1	6.9	5.5	5.8	5.9	6.7	6.1	7.4	7.2	**6.5**
Eleven Mile	TpMean	2002	6.3	6.9	7.2	5.9	6.3	6.2	5.6	6.4	7.1	7.2	7.7	6.8	**6.6**
Eleven Mile	TpMean	2003	6.7	7.5	7.0	7.4	6.1	7.1	5.9	6.6	8.9	7.5	7.2	7.7	**7.1**
Eleven Mile	TpMean	2004	6.5	7.1	7.3	6.8	6.8	5.6	6.2	6.8	8.4	8.3	7.2	--	**7.0**
Eleven Mile	TpMean	2005	--	6.3	7.0	6.9	6.5	5.9	5.9	7.7	7.7	7.1	7.1	6.8	**6.8**
Eleven Mile	TpMean	2006	6.9	--	--	--	6.1	6.5	6.3	5.9	8.5	6.5	4.2	5.8	**6.3**
Eleven Mile	TpMean	2007	4.8	4.6	5.3	6.4	7.5	7.1	6.6	7.4	6.2	7.1	6.7	7.5	**6.4**
Eleven Mile	TpMean	2008	7.1	7.1	7.1	7.0	6.3	6.3	7.1	7.1	8.0	6.7	7.0	7.1	**7.0**
Eleven Mile	TpMean	2009	6.7	6.8	7.4	6.9	6.4	6.4	--	--	--	--	--	--	**6.8**
	AVERAGE		**6.5**	**6.6**	**7.0**	**6.7**	**6.5**	**6.3**	**6.2**	**6.7**	**7.6**	**7.1**	**6.8**	**7.0**	

GAGE	STAT	YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVERAGE
Eleven Mile	Dpmean	2000	--	--	--	--	--	--	--	--	143.3	137.8	169.7	147.7	**149.6**
Eleven Mile	Dpmean	2001	173.0	149.7	160.9	171.4	168.9	172.5	155.9	166.8	126.8	150.3	142.7	154.0	**157.7**
Eleven Mile	Dpmean	2002	167.2	160.2	145.4	145.8	158.4	147.1	182.0	117.7	127.5	120.5	157.2	157.3	**148.9**
Eleven Mile	Dpmean	2003	183.8	156.0	148.2	165.2	160.5	168.4	178.3	164.5	143.5	140.1	160.6	166.6	**161.3**
Eleven Mile	Dpmean	2004	168.0	142.5	157.7	171.1	175.2	177.2	173.9	152.7	151.6	143.4	140.0	--	**159.4**
Eleven Mile	Dpmean	2005	--	123.6	171.2	170.5	158.2	147.5	173.3	147.3	141.7	141.4	148.2	158.7	**152.9**
Eleven Mile	Dpmean	2006	179.6	--	--	--	178.4	170.5	181.2	160.3	149.0	145.8	145.1	148.7	**162.1**
Eleven Mile	Dpmean	2007	165.0	152.8	148.1	171.2	145.7	162.3	157.0	157.8	135.4	158.8	158.2	154.8	**155.6**
Eleven Mile	Dpmean	2008	163.0	167.4	164.5	146.7	165.0	178.9	170.2	167.1	138.6	145.9	176.1	167.6	**162.6**
Eleven Mile	Dpmean	2009	175.3	175.3	145.9	173.7	158.3	166.4	--	--	--	--	--	--	**165.8**
	AVERAGE		**171.9**	**153.4**	**155.2**	**164.5**	**163.2**	**165.6**	**171.5**	**154.3**	**139.7**	**142.7**	**155.3**	**156.9**	

NOTE: Wave Height (HsMax, HsMean) Units are feet, Wave Period (TpMax, TpMean) Units are seconds, Wave Direction (DpMax, DpMean) are meteorological (deg North, from).
-- denotes no data or missing data. ** denotes suspect wave period measurements.

Table 3.7 Bald Head Gauge Monthly Summaries

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
Bald Head	HsMax	2000	--	--	--	--	--	--	--	--	6.3	2.5	6.6	7.8	**5.8**
Bald Head	HsMax	2001	6.9	5.4	8.9	4.4	4.3	7.0	6.1	4.8	1.3	4.3	4.3	6.4	**5.3**
Bald Head	HsMax	2002	9.0	6.3	8.1	6.3	6.0	5.0	4.6	4.1	4.3	5.2	7.4	6.5	**6.1**
Bald Head	HsMax	2003	6.3	7.6	5.8	5.9	7.4	5.0	5.4	4.6	6.5	4.9	7.2	8.0	**6.2**
Bald Head	HsMax	2004	6.5	5.0	5.4	6.7	4.6	4.5	4.4	6.5	7.7	5.7	6.8	5.9	**5.8**
Bald Head	HsMax	2005	6.9	4.9	8.5	7.5	5.9	3.4	5.9	4.5	--	5.2	8.5	7.8	**6.3**
Bald Head	HsMax	2006	--	--	--	--	7.9	7.9	4.3	6.8	6.6	8.1	8.2	6.4	**7.0**
Bald Head	HsMax	2007	6.1	6.6	8.2	--	--	--	--	--	2.8	4.2	5.5	7.7	**5.9**
Bald Head	HsMax	2008	--	--	6.0	3.7	4.7	4.9	5.6	4.5	9.8	5.7	6.8	7.8	**6.0**
Bald Head	HsMax	2009	7.1	--	--	--	--	--	--	--	--	--	--	--	**7.1**
	AVERAGE		**7.0**	**6.0**	**7.3**	**5.8**	**5.8**	**5.4**	**5.2**	**5.1**	**5.7**	**5.1**	**6.8**	**7.1**	

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
Bald Head	DpMax	2000	--	--	--	--	--	--	--	--	192.0	203.0	173.0	198.0	**191.5**
Bald Head	DpMax	2001	206.0	195.0	192.0	222.0	159.0	201.0	195.0	195.0	149.0	201.0	209.0	205.0	**194.1**
Bald Head	DpMax	2002	202.0	179.0	183.0	183.0	189.0	211.0	208.0	204.0	212.0	188.0	194.0	202.0	**196.3**
Bald Head	DpMax	2003	203.0	203.0	169.0	201.0	217.0	200.0	189.0	165.0	250.0	186.0	194.0	200.0	**198.1**
Bald Head	DpMax	2004	195.0	175.0	195.0	203.0	205.0	205.0	202.0	189.0	176.0	197.0	198.0	189.0	**194.1**
Bald Head	DpMax	2005	193.0	203.0	212.0	192.0	235.0	190.0	235.0	214.0	--	149.0	200.0	172.0	**199.5**
Bald Head	DpMax	2006	--	--	--	--	209.0	209.0	191.0	192.0	224.0	177.0	199.0	198.0	**199.9**
Bald Head	DpMax	2007	190.0	202.0	194.0	--	--	--	--	--	180.0	200.0	180.0	168.0	**187.7**
Bald Head	DpMax	2008	--	--	195.0	199	198.0	216.0	207.0	201.0	186.0	197.0	188.0	196.0	**198.3**
Bald Head	DpMax	2009	202.0	--	--	--	--	--	--	--	--	--	--	--	**202.0**
	AVERAGE		**198.7**	**192.8**	**191.4**	**200.0**	**201.7**	**204.6**	**203.9**	**194.3**	**196.1**	**188.7**	**192.8**	**192.0**	

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
Bald Head	HsMean	2000	--	--	--	--	--	--	--	--	2.1	1.2	1.8	1.9	**1.8**
Bald Head	HsMean	2001	1.9	1.8	2.4	2.0	2.1	2.0	2.2	2.0	1.0	1.5	1.7	2.0	**1.9**
Bald Head	HsMean	2002	1.9	1.8	1.8	2.1	2.0	2.1	2.4	1.7	1.7	1.4	1.8	2.0	**1.9**
Bald Head	HsMean	2003	2.2	1.7	1.7	2.0	1.9	2.2	2.2	1.8	1.7	1.4	1.7	2.0	**1.9**
Bald Head	HsMean	2004	1.8	1.7	1.8	1.9	2.3	2.0	1.9	1.9	2.5	1.8	1.5	1.9	**1.9**
Bald Head	HsMean	2005	1.8	1.6	2.5	2.4	1.7	1.6	1.8	1.4	--	1.7	2.0	2.2	**1.9**
Bald Head	HsMean	2006	--	--	--	--	1.9	2.0	2.0	1.7	1.7	1.6	1.8	1.8	**1.8**
Bald Head	HsMean	2007	2.2	2.0	1.9	--	--	--	--	--	1.2	1.8	1.7	2.6	**1.9**
Bald Head	HsMean	2008	--	--	1.8	1.2	1.5	1.6	1.6	1.8	2.1	1.6	2.0	2.2	**1.7**
Bald Head	HsMean	2009	2.1	--	--	--	--	--	--	--	--	--	--	--	**2.1**
	AVERAGE		**2.0**	**1.8**	**2.0**	**1.9**	**1.9**	**1.9**	**2.0**	**1.8**	**1.8**	**1.6**	**1.8**	**2.1**	

(Continued)

Table 3.7 Bald Head Gauge Monthly Summaries (Continued)

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
Bald Head	TpMax	2000	--	--	--	--	--	--	--	--	16.0	**	**	14.2	**14.2**
Bald Head	TpMax	2001	**	25.6	18.2	16.0	16.0	25.6	**	10.6	**	**	**		**18.7**
Bald Head	TpMax	2002	**	**	25.6	**	**	**	**	21.3	14.2	18.2	18.2	16.0	**18.9**
Bald Head	TpMax	2003	16.0	16.0	16.0	14.5	16.0	16.0	9.1	16.0	16.0	14.2	12.8	16.0	**14.9**
Bald Head	TpMax	2004	11.6	14.2	14.2	12.8	10.6	10.6	9.8	14.2	18.2	--	--	--	**12.9**
Bald Head	TpMax	2005	12.8	16.0	16.0	16.0	16.0	16.0	14.2	14.2	--	16	12.8	12.8	**14.8**
Bald Head	TpMax	2006	--	--	--	--	16.0	10.6	9.8	14.2	14.2	21.2	14.2	10.6	**13.9**
Bald Head	TpMax	2007	14.2	25.6	10.6	--	--	--	--	--	14.2	18.2	14.2	11.6	**15.5**
Bald Head	TpMax	2008	--	--	16.0	12.8	16.0	16.0	25.6	12.8	16.0	14.2	12.8	25.6	**16.8**
Bald Head	TpMax	2009	21.3	--	--	--	--	--	--	--	--	--	--	--	**21.3**
	AVERAGE		**15.2**	**19.5**	**16.7**	**14.4**	**15.1**	**15.8**	**13.7**	**14.8**	**15.5**	**17.0**	**14.2**	**15.3**	

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
Bald Head	TpMean	2000	--	--	--	--	--	--	--	--	7.6	9.0	7.5	7.4	**7.9**
Bald Head	TpMean	2001	7.2	6.8	7.5	6.1	6.7	6.0	6.2	6.0	11.4	7.5	7.9	7.5	**7.2**
Bald Head	TpMean	2002	7.6	7.5	7.6	6.3	6.3	6.1	5.6	6.2	7.4	8.2	7.7	7.2	**7.0**
Bald Head	TpMean	2003	7.1	7.9	7.3	7.5	6.4	6.8	5.3	5.9	9.1	8.1	7.5	7.9	**7.2**
Bald Head	TpMean	2004	6.9	7.8	7.7	6.4	6.2	5.3	5.7	6.6	9.3	8.5	7.8	7.7	**7.2**
Bald Head	TpMean	2005	7.7	8.5	6.9	7.1	6.7	6.2	5.1	6.3	--	7.7	7.4	7.1	**7.0**
Bald Head	TpMean	2006	--	--	--	--	6.6	6.3	6.0	6.3	8.4	7.2	7.6	7.8	**7.0**
Bald Head	TpMean	2007	7.0	7.0	7.3	--	--	--	--	--	7.8	7.4	7.5	7.5	**7.4**
Bald Head	TpMean	2008	--	--	7.8	7.4	6.5	5.7	6.7	6.8	8.5	7.2	7.0	7.6	**7.1**
Bald Head	TpMean	2009	7.0	--	--	--	--	--	--	--	--	--	--	--	**7.0**
	AVERAGE		**7.2**	**7.6**	**7.4**	**6.8**	**6.5**	**6.1**	**5.8**	**6.3**	**8.7**	**7.9**	**7.5**	**7.5**	

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
Bald Head	Dpmean	2000	--	--	--	--	--	--	--	--	171	165.5	184.9	185	**176.6**
Bald Head	Dpmean	2001	191.4	185	189.4	185.8	186.1	186.1	188.3	199.1	152	179.5	177.6	187.1	**184.0**
Bald Head	Dpmean	2002	189.5	187.3	181.4	183.9	185.9	180.6	193.6	180.4	177.7	172.2	184.0	184.2	**183.4**
Bald Head	Dpmean	2003	198.3	183.7	179.3	186.3	186.5	189.1	193.4	189.1	174.9	175.5	184.2	187.0	**185.6**
Bald Head	Dpmean	2004	187.7	177.3	182.5	188.6	194.6	193.1	193.3	182.7	185.6	179.6	179.2	188.4	**186.1**
Bald Head	Dpmean	2005	185.1	182.0	190.0	191.6	187.6	179.9	196.0	183.5	--	--	--	186.1	**186.9**
Bald Head	Dpmean	2006	--	--	--	--	186.6	188.5	194.6	185	177.7	183.6	178.7	184.0	**184.8**
Bald Head	Dpmean	2007	191.3	188.5	184.3	--	--	--	--	--	165.6	178.4	185.4	189.5	**182.0**
Bald Head	Dpmean	2008	--	--	187.5	181	187.2	197.3	188.8	191.1	181.0	182.9	194.7	189.5	**188.9**
Bald Head	Dpmean	2009	196.0	--	--	--	--	--	--	--	--	--	--	--	**196.0**
	AVERAGE		**191.3**	**184.0**	**184.9**	**187.2**	**187.8**	**187.8**	**192.6**	**187.3**	**173.2**	**177.2**	**183.6**	**186.8**	

NOTE: Wave Height (HsMax, HsMean) Units are feet, Wave Period (TpMax, TpMean) Units are seconds, Wave Direction (DpMax, DpMean) are meteorological (deg North, from).
-- denotes no data or missing data. ** denotes suspect wave period measurements.

Table 3.8 Oak Island Gauge Monthly Summaries

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
Oak Island	HsMax	2000	--	--	--	--	--	--	--	--	5.3	2.9	--	--	**4.1**
Oak Island	HsMax	2001	--	--	--	--	--	6.0	3.7	--	1.0	4.2	3.9	5.8	**4.1**
Oak Island	HsMax	2002	8.3	5.3	6.6	4.4	4.1	4.7	2.7	3.9	4.2	4.7	6.6	6.0	**5.1**
Oak Island	HsMax	2003	5.4	6.6	5.3	4.2	3.8	4.5	5.3	4.5	6.0	4.2	6.4	6.1	**5.2**
Oak Island	HsMax	2004	6.1	4.9	5.3	5.5	4.5	4.6	4.6	9.9	6.5	5.3	5.6	5.0	**5.7**
Oak Island	HsMax	2005	6.2	4.1	7.3	--	--	--	--	--	3.2	4.2	5.8	5.1	**5.1**
Oak Island	HsMax	2006	6.2	--	--	--	4.8	6.2	3.4	5.9	5.0	--	--	--	**5.3**
Oak Island	HsMax	2007	--	--	--	6.8	2.7	5.1	5.2	4.8	5.2	3.1	4.1	3.4	**4.5**
Oak Island	HsMax	2008	4.3	5.2	5.8	2.3	--	--	--	4.9	9.6	5.6	6.1	7.9	**5.7**
Oak Island	HsMax	2009	6.9	7.0	6.2	6.7	4.6	4.4	--	--	--	--	--	--	**6.0**
	AVERAGE		**6.2**	**5.5**	**6.1**	**5.0**	**4.1**	**5.1**	**4.2**	**5.7**	**5.1**	**4.3**	**5.5**	**5.6**	

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
Oak Island	DpMax	2000	--	--	--	--	--	--	--	--	206.0	239.0	--	--	**222.5**
Oak Island	DpMax	2001	--	--	--	--	--	192.0	236.0	--	172.0	190.0	181.0	197.0	**194.7**
Oak Island	DpMax	2002	185.0	191.0	182.0	201.0	202.0	193.0	234.0	202.0	177.0	185.0	183.0	193.0	**194.0**
Oak Island	DpMax	2003	214.0	191.0	185.0	185.0	209.0	203.0	209.0	196.0	238.0	210.0	201.0	203.0	**203.7**
Oak Island	DpMax	2004	210.0	224.0	184.0	197.0	175.0	180.0	200.0	172.0	186.0	219.0	189.0	198.0	**194.5**
Oak Island	DpMax	2005	179.0	192.0	190.0	--	--	--	--	--	184.0	171.0	209.0	184.0	**187.0**
Oak Island	DpMax	2006	195.0	--	--	--	206.0	195.0	175.0	183.0	247.0	--	--	--	**200.2**
Oak Island	DpMax	2007	--	--	--	200.0	183.0	188.0	202.0	226.0	208.0	178.0	197.0	194.0	**197.3**
Oak Island	DpMax	2008	210.0	193.0	199.0	186.0	--	--	--	218.0	176.0	181.0	218.0	177.0	**195.3**
Oak Island	DpMax	2009	190.0	220.0	198.0	203.0	186.0	203.0	--	--	--	--	--	--	**200.0**
	AVERAGE		**197.6**	**201.8**	**189.7**	**195.3**	**193.5**	**193.4**	**209.3**	**199.5**	**199.3**	**196.6**	**196.9**	**192.3**	

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
Oak Island	HsMean	2000	--	--	--	--	--	--	--	--	2.3	1.2	--	--	**1.8**
Oak Island	HsMean	2001	--	--	--	--	--	1.6	2.5	--	0.8	1.4	1.5	1.8	**1.6**
Oak Island	HsMean	2002	1.8	1.5	2.0	2.0	1.6	2.0	1.6	1.6	1.5	1.3	1.6	1.8	**1.7**
Oak Island	HsMean	2003	1.8	1.6	1.4	1.6	1.6	1.8	2.3	1.8	1.5	1.3	1.5	1.5	**1.6**
Oak Island	HsMean	2004	1.6	1.4	1.6	1.7	2.2	2.0	1.8	1.8	2.4	1.4	1.3	1.6	**1.7**
Oak Island	HsMean	2005	1.6	1.4	2.0	--	--	--	--	--	1.4	1.2	1.5	1.4	**1.5**
Oak Island	HsMean	2006	2.2	--	--	--	1.6	1.7	1.6	1.4	1.2	--	--	--	**1.6**
Oak Island	HsMean	2007	--	--	--	1.4	1.2	1.8	1.7	1.7	1.5	1.2	1.1	1.6	**1.5**
Oak Island	HsMean	2008	1.1	1.6	1.5	1.5	--	--	--	1.7	1.8	1.4	1.7	2.0	**1.6**
Oak Island	HsMean	2009	1.8	1.7	1.8	2.3	1.9	1.6	--	--	--	--	--	--	**1.9**
	AVERAGE		**1.7**	**1.5**	**1.7**	**1.8**	**1.7**	**1.8**	**1.9**	**1.7**	**1.6**	**1.3**	**1.5**	**1.7**	

(Continued)

Table 3.8 Oak Island Gauge Monthly Summaries (Continued)

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
Oak Island	TpMax	2000	--	--	--	--	--	--	--	--	16.0	**	--	--	**16.0**
Oak Island	TpMax	2001	--	--	--	--	--	**	5.1	--	**	**	**	**	**5.1**
Oak Island	TpMax	2002	**	**	**	**	**	**	9.1	21.3	21.3	21.3	21.3	16.0	**18.4**
Oak Island	TpMax	2003	16.0	16.0	16.0	16.0	16.0	9.8	9.1	16.0	16.0	14.2	14.2	16.0	**14.6**
Oak Island	TpMax	2004	11.6	14.2	16.0	12.8	25.6	9.1	9.1	25.6	16.0	16.0	25.6	25.6	**17.3**
Oak Island	TpMax	2005	25.6	11.6	16.0	--	--	--	--	--	25.6	16.0	25.6	21.3	**20.2**
Oak Island	TpMax	2006	11.6	--	--	--	25.6	25.6	9.8	21.3	25.6	--	--	--	**19.9**
Oak Island	TpMax	2007	--	--	--	25.6	16.0	25.6	14.2	25.6	25.6	25.6	18.2	10.6	**20.8**
Oak Island	TpMax	2008	25.6	25.6	21.3	9.1	--	--	--	12.8	25.6	25.6	25.6	25.6	**21.9**
Oak Island	TpMax	2009	25.6	18.2	14.2	14.2	10.6	25.6	--	--	--	--	--	--	**18.1**
	AVERAGE		**19.3**	**17.1**	**16.7**	**15.5**	**18.8**	**19.1**	**9.4**	**20.4**	**21.5**	**19.8**	**21.8**	**19.2**	

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
Oak Island	TpMean	2000	--	--	--	--	--	--	--	--	6.1	9.9	--	--	**8.0**
Oak Island	TpMean	2001	--	--	--	--	--	6.4	4.3	--	13.2	8.2	8.6	7.9	**8.1**
Oak Island	TpMean	2002	7.3	8.1	9.2	8.4	11.4	10.1	5.6	5.9	7.6	8.0	8.1	7.2	**8.1**
Oak Island	TpMean	2003	7.2	7.3	7.2	7.3	6.6	5.5	5.1	5.6	8.7	7.6	7.3	7.8	**6.9**
Oak Island	TpMean	2004	6.7	7.8	7.5	6.2	6.0	5.1	5.4	6.5	9.2	8.6	7.4	7.6	**7.0**
Oak Island	TpMean	2005	7.5	7.9	6.8	--	--	--	--	--	7.7	7.7	7.4	7.4	**7.5**
Oak Island	TpMean	2006	6.4	--	--	--	6.0	6.4	5.8	6.1	8.4	--	--	--	**6.5**
Oak Island	TpMean	2007	--	--	--	6.7	7.2	6.1	6.1	6.5	7.0	7.5	7.0	6.5	**6.7**
Oak Island	TpMean	2008	7.5	7.0	6.7	7.2	--	--	--	6.5	8.3	6.7	6.9	7.0	**7.1**
Oak Island	TpMean	2009	7.4	6.7	7.9	6.5	6.2	5.5	--	--	--	--	--	--	**6.7**
	AVERAGE		**7.1**	**7.5**	**7.6**	**7.1**	**7.2**	**6.4**	**5.4**	**6.2**	**8.5**	**8.0**	**7.5**	**7.3**	

GAGE	STAT	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
Oak Island	DpMean	2000	--	--	--	--	--	--	--	--	202.2	181.1	--	--	**191.7**
Oak Island	DpMean	2001	--	--	--	--	--	188.2	217.5	--	163.9	183.9	178.8	183.8	**186.0**
Oak Island	DpMean	2002	189.5	187.4	183	187.8	188.2	186.2	201.2	157.6	150.5	144.9	176	192.6	**178.7**
Oak Island	DpMean	2003	198.6	191.7	187.6	190.3	193.2	197.4	197.9	194.6	182.2	179.5	186.4	188.1	**190.6**
Oak Island	DpMean	2004	193.8	184.1	190.6	196.6	199.4	196.9	195.3	189.7	185.9	182.5	184.4	189.9	**190.8**
Oak Island	DpMean	2005	189.2	179.8	195.2	--	--	--	--	--	187.2	182.2	185.8	186.2	**186.5**
Oak Island	DpMean	2006	203.8	--	--	--	194.6	192.9	197.2	192	185.5	--	--	--	**194.3**
Oak Island	DpMean	2007	--	--	--	194.1	187.5	193.8	190.5	196.2	184.3	181.5	190.4	193.4	**190.2**
Oak Island	DpMean	2008	190.2	192.1	193.5	183.1	--	--	--	192.6	188.1	189.0	195.3	195.1	**191.0**
Oak Island	DpMean		194.6	195.5	187.4	194.8	188.1	194.0	--	--	--	--	--	--	**192.4**
	AVERAGE		**194.2**	**188.4**	**189.6**	**191.1**	**191.8**	**192.8**	**199.9**	**187.1**	**181.1**	**178.1**	**185.3**	**189.9**	

NOTE: Wave Height (HsMax, HsMean) Units are feet, Wave Period (TpMax, TpMean) Units are seconds, Wave Direction (DpMax, DpMean) are meteorological (deg North, from).
-- denotes no data or missing data. ** denotes suspect wave period measurements.

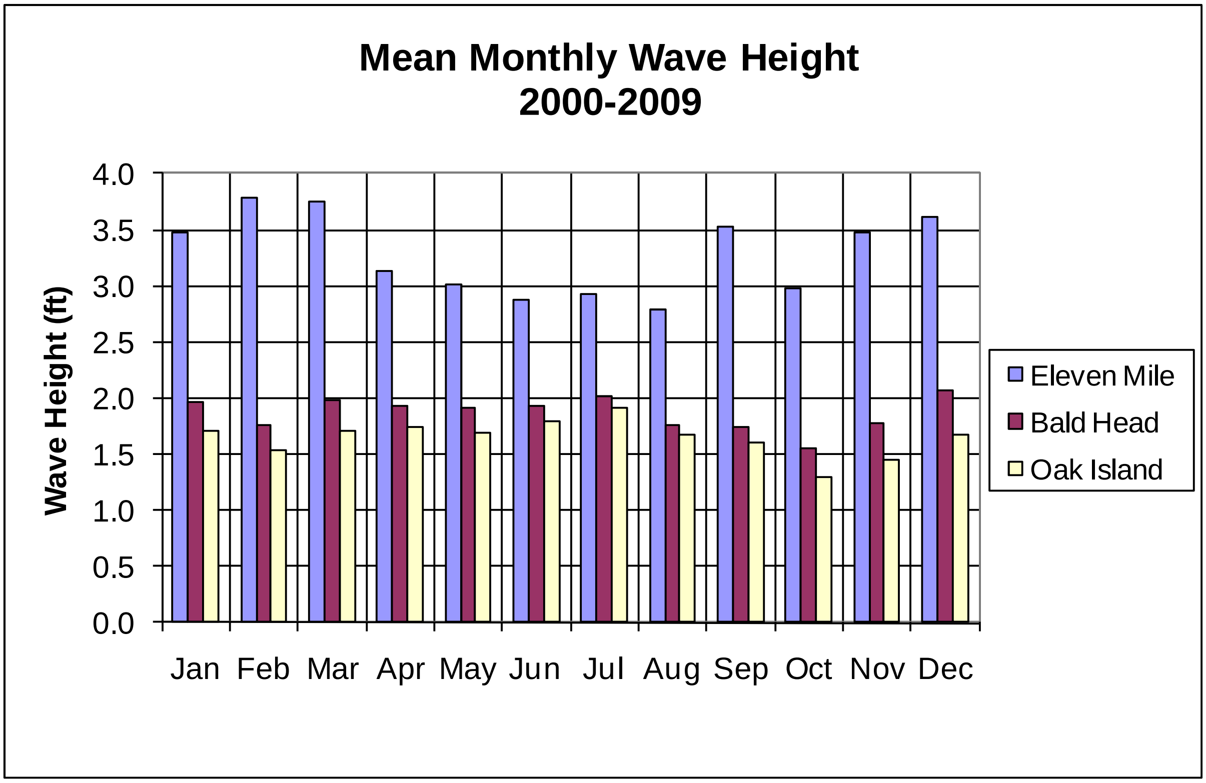


Figure 3.38 Mean Monthly Wave Height from Sep 2000- June 2009 for the Eleven Mile and Oak Island Gauges and Sep 2000- Jan 2009 for the Bald Head Gauge

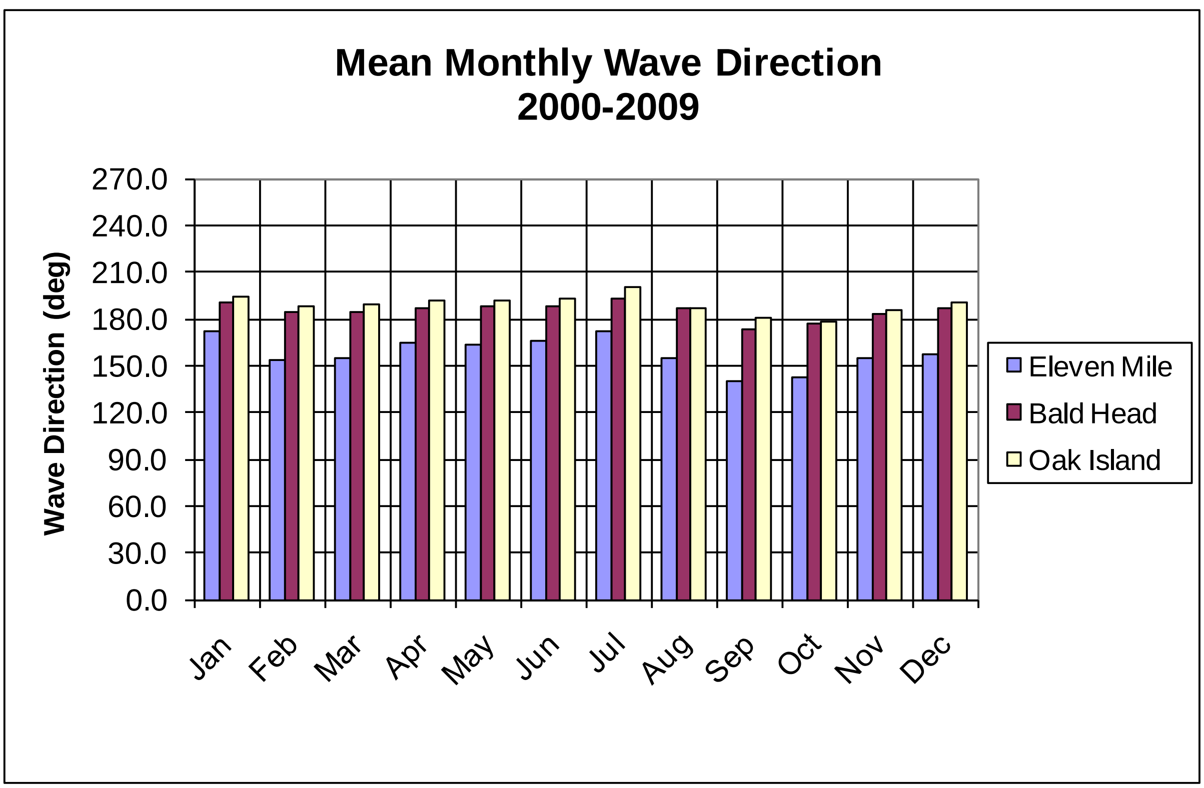


Figure 3.39 Mean Monthly Wave Direction from Sep 2000- June 2009 for the Eleven Mile and Oak Island Gauges and Sep 2000- Jan 2009 for the Bald Head Gauge

Further insights on the wave climate variability and the impacts of Frying Pan Shoals are shown on Figures 3.40 and 3.41. Figure 3.40 shows wave histograms that were created using all available data from each gauge which varied from September 2000 to June 2009 for the Oak Island and Eleven Mile gauge and from September 2000 to January 2009 for the Bald Head gauge. Figure 3.41 shows wave roses that were generated for available data revealing the characteristic differences in wave climate for the three locations. Dominant wave directions at 11-Mile Gauge are from southeast and south southeast. At Bald Head Island gauge, dominant directions are shifted to south-southeast through the south-southwest. Oak Island directions are further confined to primarily south and south-southwest. These direction shifts between offshore and nearshore locations are consistent with expected effects of wave refraction.

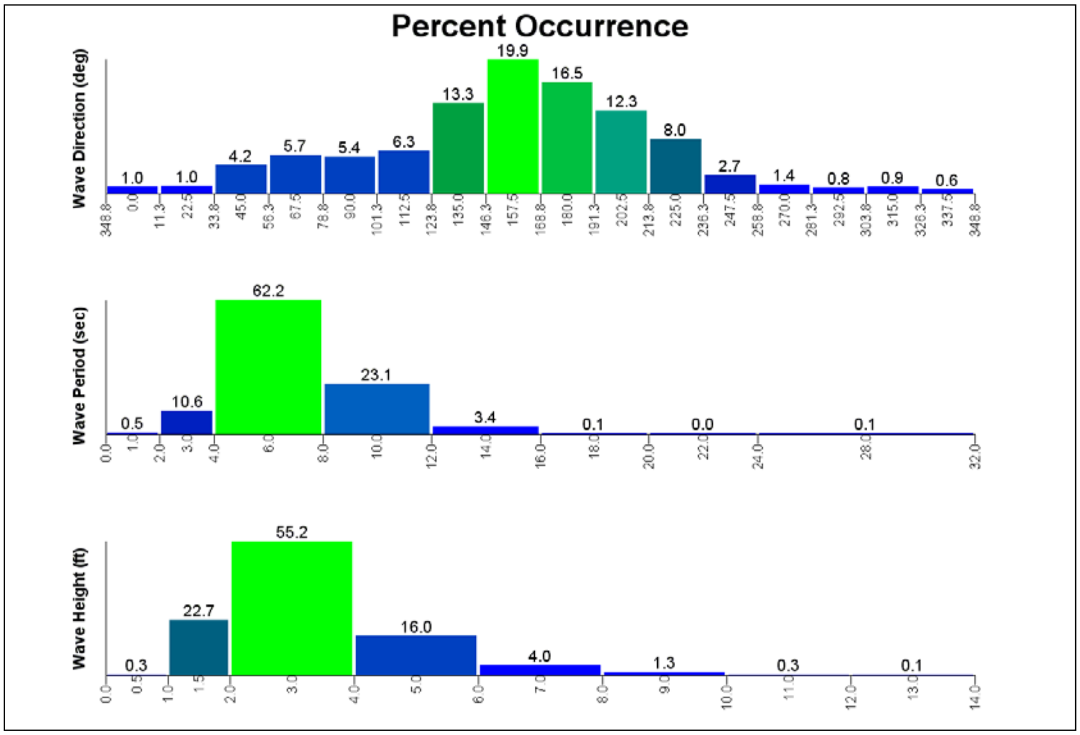
The 11-Mile Gauge wave rose shows a small, but significant component of the wave climate coming from easterly directions. These waves have passed across Frying Pan Shoals to reach the gauge. Frying Pan Shoals filters, but does not eliminate, wave energy reaching the 11-Mile Gauge site from these directions. Waves from easterly directions are virtually absent at the Bald Head Island and Oak Island gauges. This site is sheltered to the east by the Bald Head Island land mass and to the east-southeast by an extremely shallow part of Frying Pan Shoals extending from Cape Fear.

Time series for each gauge were separated into yearly components and analyzed to assess the statistical variation in wave climate. Annual wave height roses for all three gauges for the years 2000 through 2009 were generated and are given in Appendix A. The year to year comparison of the roses shows very similar patterns in the distribution of wave height and direction.

Figures 3.42 and 3.43 give the yearly mean wave height and direction for each of the three gauges. In terms of mean wave height, only minor variation is evident over the initial six years (2000-2005) of the monitoring program, while the next two years (2006-2007) show a significant increase at the offshore gauge. For the current monitoring period, wave heights have decreased slightly from the previous year but remain relatively similar to the majority of annual wave heights measured since the year 2000. For the 11-mile gauge, the yearly mean wave height for the first six years of the monitoring program averaged 3.1 feet while the average for the next two years (2006 and 2007) increased to 3.9 feet, nearly a 27% increase. For the current monitoring period (January 2009 to June 2009) the average wave height is 3.2 feet, nearly the same as the initial six year period. The nearshore gauges have been relatively consistent over the entire monitoring period. The wave transformation occurring between the offshore and nearshore gauges show that the gauges have remained relatively consistent over the duration of the monitoring program. The Bald Head gauge average wave height remains at 1.9 feet while the average wave height at the Oak Island gauge increased slightly by 0.1 feet to an average of 1.7 feet. With regard to the yearly variation in terms of mean wave direction, Figure 3.42 shows that while there is some fluctuation from year to year the general wave direction is relatively consistent for each gauge with no pattern of directional change observed. The Eleven Mile gauge has the highest yearly fluctuation with a standard deviation of 5.7 degrees while the deviation at both the Bald Head and Oak Island gauges is smaller at only 4.4 degrees.

Significant Events. Several large storm events have occurred since the inception of the monitoring program that may have significantly altered adjacent beach shorelines and beach profiles. An analysis was conducted to identify storm event parameters that exceeded a 6-ft significant wave height threshold with a minimum duration of 12-hrs. Events were selected through screening of the 11-Mile Gauge time series and were considered to be continuous events until significant wave height fell below 6 feet for more than one three hour recording. Parameters for the Bald Head and Oak Island gauges that correlate to the 11-Mile gauge peaks are reported as well. Five additional events were added since report six, with Table 3.9 summarizing the 106 events that exceeded the set criteria over the entire monitoring period. The majority of the events, 64%, occurred in the winter (December through March) which was exactly the same percentage as reported in Report 6. For the current monitoring period, waves typically originated from the south-southwest through south south-east, with offshore wave heights of 6.7 to 8.7-ft and wave periods of 6.7 to 9.8 seconds. These parameters were slightly lower at the top end in magnitude and direction as those reported for the previous monitoring period. This most recent collection of significant events has a more south-southwest approach direction than the remainder of the database; however, it is only representative of six months of data which may skew the average for this period. Corresponding conditions at the nearshore gauges indicate significant reduction in wave height, with Oak Island being reduced by 48 percent. The largest significant wave recorded to date at the 11-mile gauge remained 16.4 feet recorded on February 2007. At this peak time the wave height recorded at the Bald Head gauge was 5.6 feet. Unfortunately, the Oak Island gauge was out of service at this time and no corresponding wave height is available. The largest wave measured at the Bald Head site was 9.8 feet which occurred during the month of September 2008. This wave height peak was associated with Tropical Storm Hanna which made landfall on September 6, 2008 near Myrtle Beach, SC. On 14-August 2004, during Hurricane Charlie, a wave height of 9.9 feet was measured at Oak Island, the largest recorded so far at this gauge.

Eleven-Mile Gauge (Sep 2000 – June 2009)



Bald Head Gauge (Sep 2000 – Jan 2009)

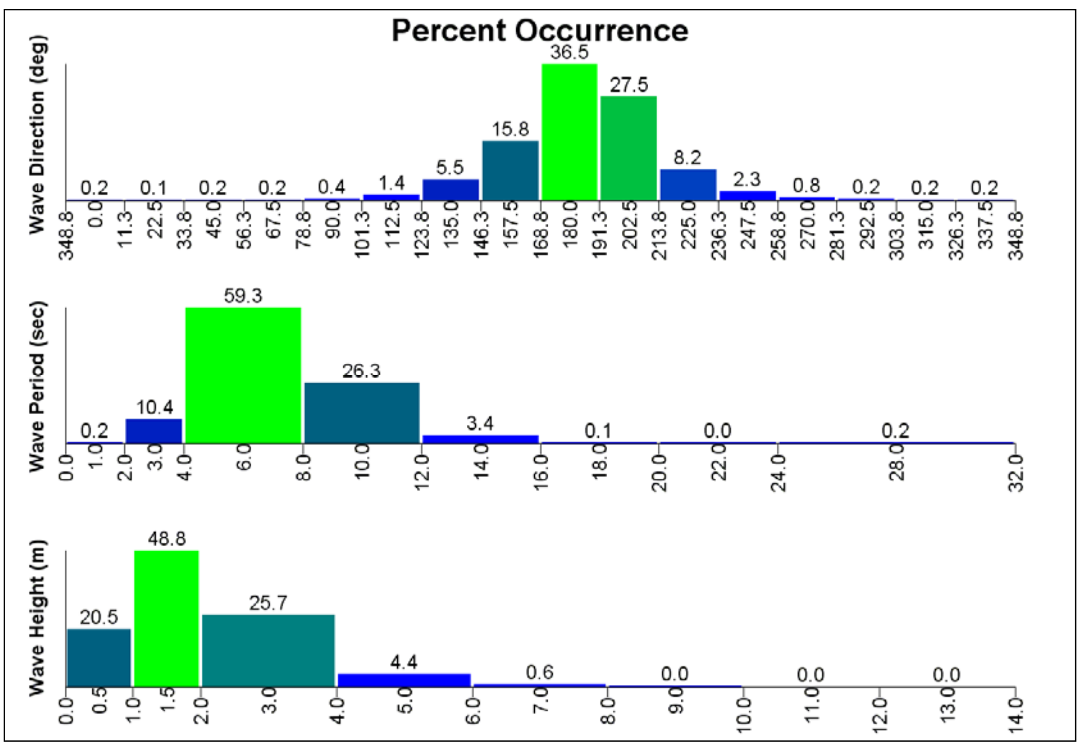


Figure 3.40 Wave Histograms for FRF Gauges throughout deployment.

Oak Island Gauge (Sep 2000 – June 2009)

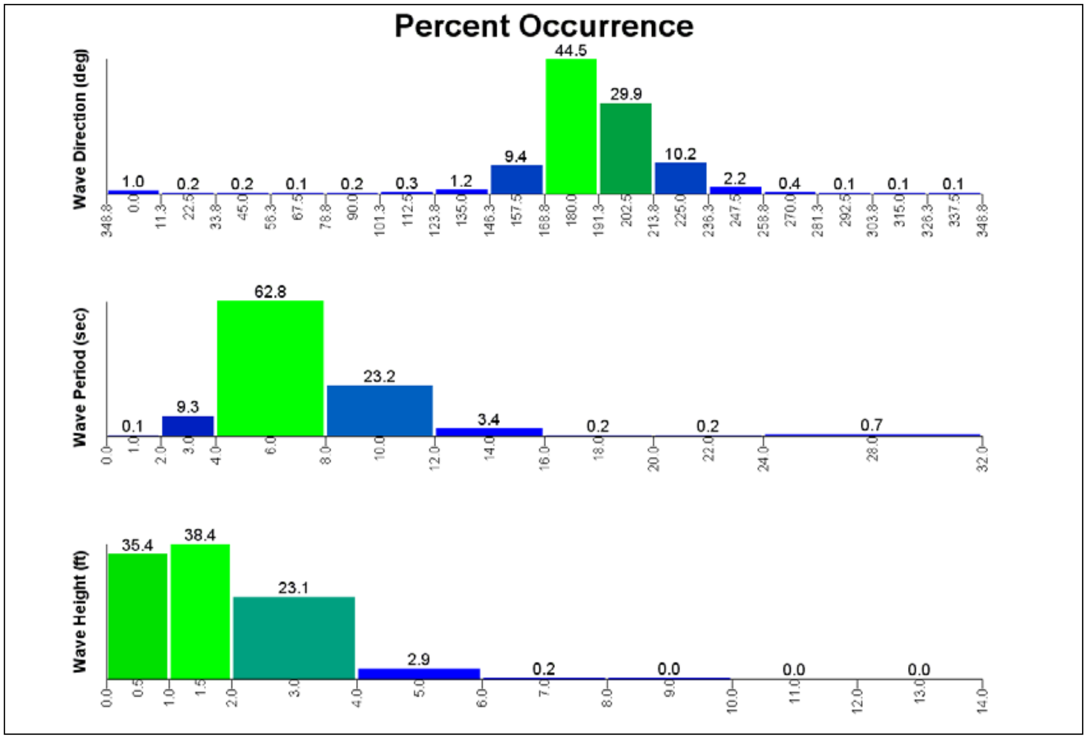
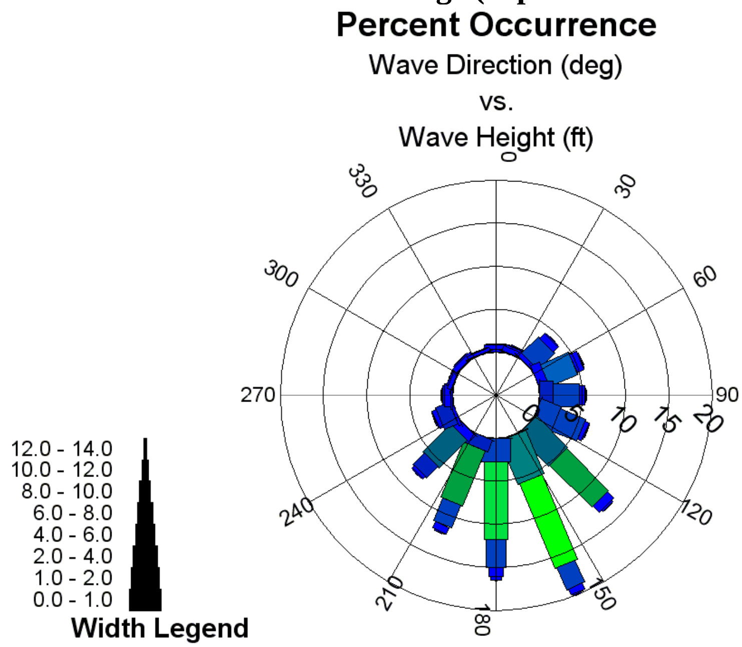


Figure 3.40 Wave Histograms for FRF Gauges throughout deployment. (Continued)

Eleven-Mile Gauge (Sep 2000 – June 2009)



Bald Head Gauge (Sep 2000 – Jan 2009)

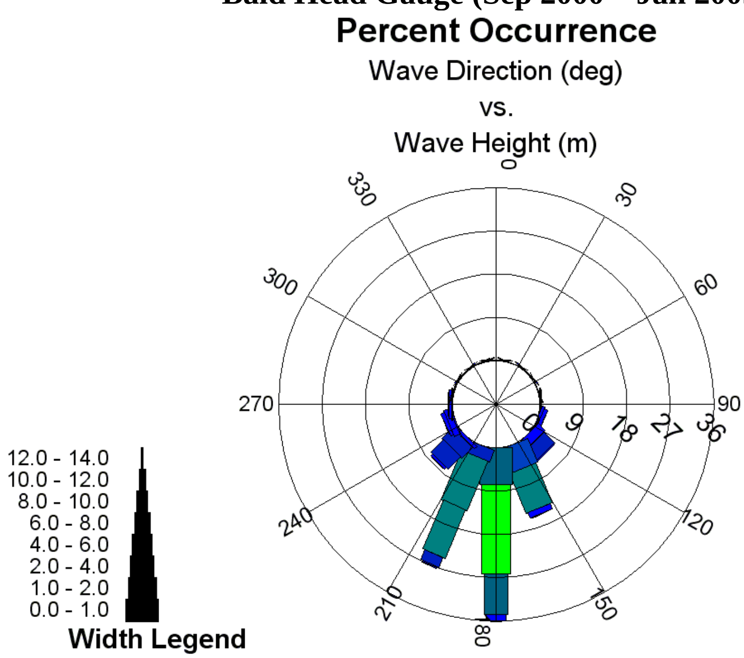


Figure 3.41 Wave Height Roses for FRF Gauges throughout deployment.

Oak Island Gauge (Sep 2000 – June 2009)

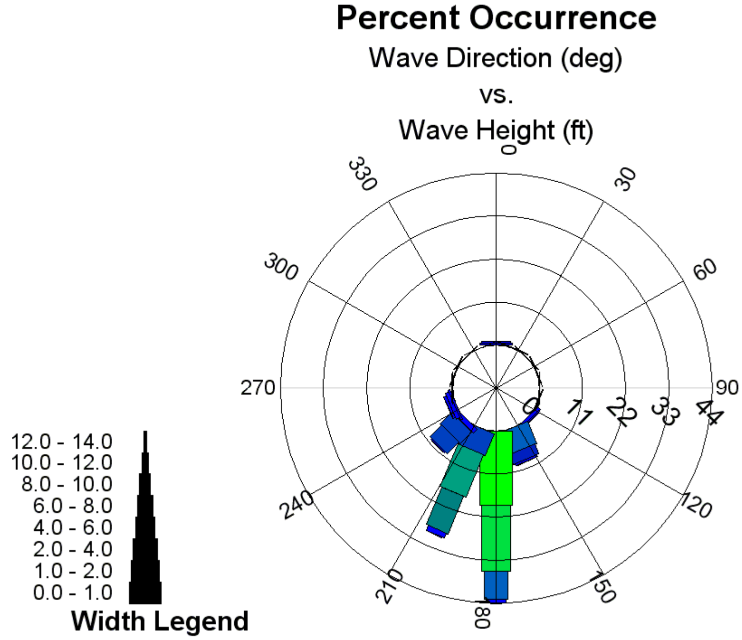


Figure 3.41 Wave Height Roses for FRF Gauges throughout deployment. (Continued)

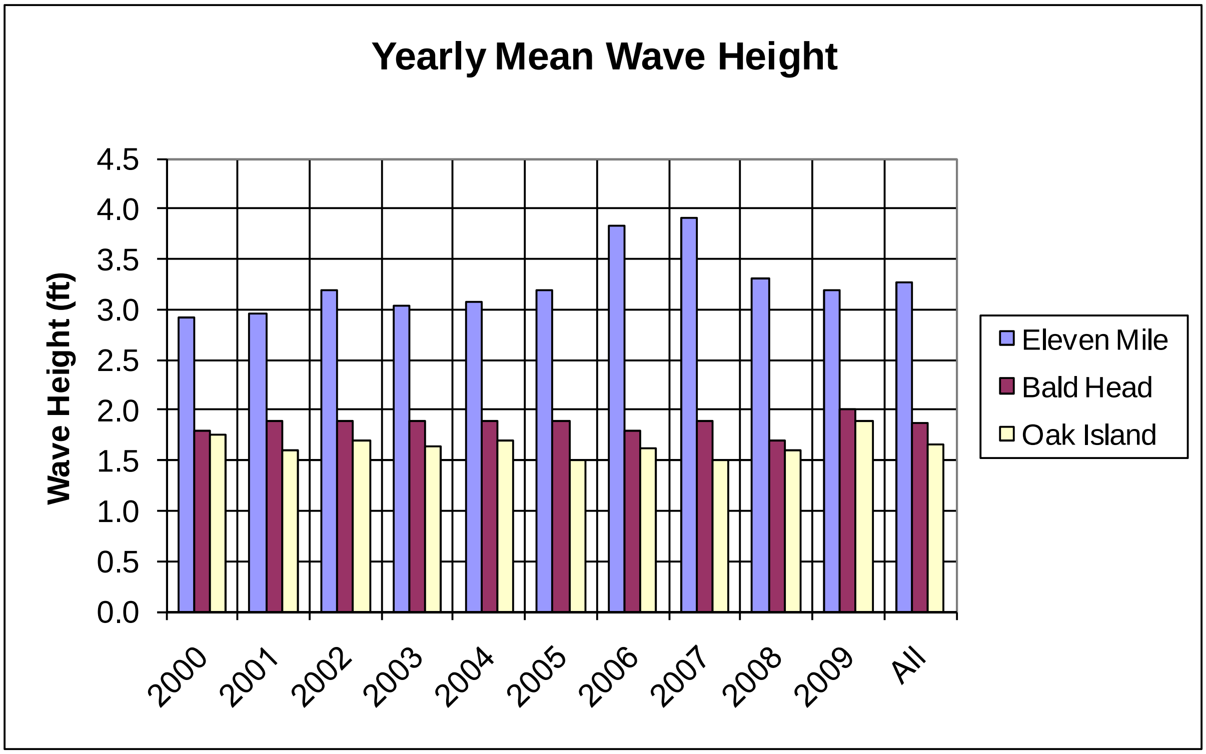


Figure 3.42 Yearly Mean Wave Heights for Years 2000 through 2009

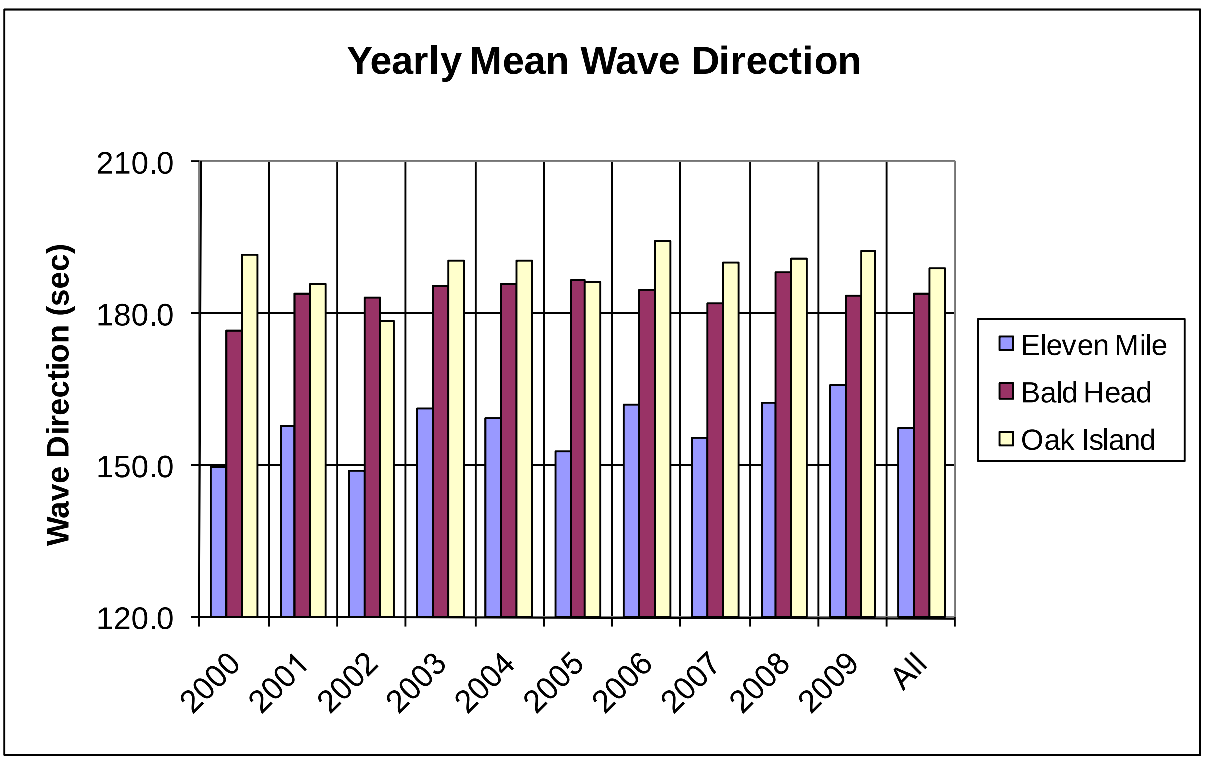


Figure 3.43 Yearly Mean Wave Directions for Years 2000 through 2009

Table 3.9 Significant Events at 11-Mile Gauge Exceeding Significant Wave Height of 6-ft.

						ELEVEN MILE GAGE					BALD HEAD GAGE			OAK ISLAND		
EVENT	START DATE	TIME	STOP DATE	TIME	Duration (hrs)	Hs (ft)	Tp (sec)	Dp (deg)	DATE PEAK	TIME	Hs (ft)	Tp (sec)	Dp (deg)	Hs (ft)	Tp (sec)	Dp (deg)
1	16-Dec-00	3:00	16-Dec-00	18:00	15.00	11.3	9.8	199.5	16-Dec-00	15:00	1.3	6.4	173.0	--	--	--
2	20-Jan-01	6:00	21-Jan-01	0:00	18.00	6.6	8.5	196.3	21-Jan-01	0:00	4.5	6.7	194.0	--	--	--
3	20-Mar-01	12:00	22-Mar-01	0:00	36.00	10.8	11.6	169.0	20-Mar-01	18:00	7.1	10.6	188.0	--	--	--
4	29-Mar-01	9:00	30-Mar-01	3:00	18.00	7.9	9.1	169.3	29-Mar-01	12:00	--	--	--	--	--	--
5	23-Jul-01	21:00	24-Jul-01	12:00	15.00	8.6	8.5	182.8	24-Jul-01	6:00	6.1	9.8	191.4	--	--	--
6	15-Sep-01	3:00	16-Sep-01	6:00	27.00	7.3	11.6	90.3	15-Sep-01	18:00	--	--	--	--	--	--
7	26-Dec-01	23:30	29-Dec-01	2:45	51.25	6.5	7.5	216.5	27-Dec-01	14:45	4.8	6.4	234.0	4.7	6.0	197.0
8	6-Jan-02	11:30	7-Jan-02	8:45	21.25	11.2	10.6	189.6	6-Jan-02	14:45	8.0	9.8	194.0	7.1	9.1	194.0
9	7-Feb-02	4:00	7-Feb-02	22:00	18.00	8.5	9.1	181.3	7-Feb-02	7:00	6.3	8.5	179.0	4.2	8.0	195.0
10	2-Mar-02	13:00	3-Mar-02	22:00	33.00	11.5	10.6	167.8	2-Mar-02	19:00	7.3	9.8	195.0	6.4	9.8	181.0
11	6-Nov-02	4:00	6-Nov-02	19:00	15.00	9.7	10.6	195.8	6-Nov-02	10:00	7.1	9.8	196.0	6.3	9.8	185.0
12	29-Nov-02	22:00	30-Nov-02	22:00	24.00	8.6	8.0	203.4	30-Nov-02	4:00	6.3	7.5	212.0	5.6	6.7	207.0
13	13-Dec-02	13:00	14-Dec-02	16:00	27.00	7.6	9.8	169.2	14-Dec-02	4:00	5.0	9.8	196.0	4.8	9.1	189.0
14	20-Dec-02	1:00	21-Dec-02	1:00	24.00	8.4	9.1	182.6	20-Dec-02	7:00	6.1	8.5	195.0	5.0	9.1	191.0
15	25-Dec-02	10:00	26-Dec-02	1:00	15.00	8.8	9.8	198.0	25-Dec-02	13:00	6.4	9.8	190.0	5.7	9.1	193.0
16	1-Jan-03	1:00	1-Jan-03	16:00	15.00	7.2	9.8	175.8	1-Jan-03	4:00	4.9	9.1	190.0	4.0	8.5	187.0
17	8-Jan-03	4:00	10-Jan-03	4:00	48.00	7.3	8.5	209.8	9-Jan-03	7:00	5.2	7.5	191.0	4.7	6.0	203.0
18	19-Jan-03	7:00	20-Jan-03	19:00	36.00	7.4	8.0	211.9	20-Jan-03	10:00	5.8	6.7	211.0	5.3	6.7	205.0
19	22-Feb-03	19:00	23-Feb-03	16:00	21.00	9.7	9.8	182.4	23-Feb-03	7:00	6.0	9.1	195.0	5.6	8.5	187.0
20	20-Mar-03	7:00	21-Mar-03	7:00	24.00	8.5	9.1	163.1	20-Mar-03	16:00	5.1	8.5	196.0	3.2	8.5	170.0
21	17-Sep-03	1:00	18-Sep-03	19:00	42.00	9.1	6.7	319.0	18-Sep-03	13:00	6.5	6.7	250.0	4.5	5.5	279.0
22	19-Nov-03	1:00	20-Nov-03	1:00	24.00	9.5	7.5	193.0	19-Nov-03	10:00	6.2	8.5	190.0	5.5	7.5	195.0
23	28-Nov-03	19:00	29-Nov-03	7:00	12.00	9.7	6.0	180.0	28-Nov-03	22:00	6.8	8.0	190.0	6.0	6.7	194.0
24	10-Dec-03	10:00	11-Dec-03	10:00	24.00	9.7	9.1	187.0	10-Dec-03	22:00	7.4	9.8	183.0	4.8	9.8	198.0
25	17-Dec-03	7:00	19-Dec-03	10:00	51.00	6.7	7.5	214.0	19-Dec-03	10:00	3.9	6.0	227.0	--	--	--
26	26-Feb-04	10:00	27-Feb-04	1:00	15.00	6.9	6.9	144.0	26-Feb-04	16:00	2.4	2.9	167.0	1.8	9.8	188.0
27	12-Apr-04	16:00	14-Apr-04	10:00	41.00	8.5	8.5	174.0	13-Apr-04	16:00	5.9	8.5	195.0	5.4	8.5	185.0
28	13-Aug-04	4:00	14-Aug-04	16:00	36.00	11.1	11.6	198	14-Aug-06	1:00	2.5	7.1	198	2.6	6.7	228
29	29-Aug-04	1:00	30-Aug-04	4:00	25.00	8.6	7.1	169	29-Aug-04	19:00	6.3	6.7	222	6.1	6.7	210
30	8-Sep-04	1:00	9-Sep-04	4:00	25.00	7.3	6.7	189	9-Sep-04	4:00	5.2	7.5	202	4.8	7.1	191
31	17-Sep-04	13:00	18-Sep-04	7:00	18.00	9.9	7.1	197	17-Sep-04	19:00	7	7.5	194	6.5	6.7	201

32	25-Sep-04	7:00	28-Sep-04	19:00	84.00	9.2	7.5	189	28-Sep-04	16:00	7.7	7.5	176	5.9	7.5	187
33	15-Oct-04	13:00	16-Oct-04	22:00	33.00	6.8	7.5	205	15-Oct-04	19:00	5.7	8	197	4.8	7.5	203
34	24-Nov-04	22:00	25-Nov-04	19:00	21.00	8.6	9.1	184	25-Nov-04	13:00	6	9.8	193	4.7	5.3	227
35	27-Feb-05	19:00	1-Mar-05	22:00	46.00	9.9	10.6	161	28-Feb-05	4:00	3.9	10.6	195	3	11.6	175
36	8-Mar-05	4:00	8-Mar-05	19:00	15.00	11.7	8.5	185	8-Mar-05	7:00	8.5	9.1	212	7.1	8.5	196
37	11-Mar-05	16:00	14-Mar-05	1:00	57.00	9.4	7.5	217	12-Mar-05	16:00	6.2	7.5	207	5.1	7.5	207
38	22-Mar-05	22:00	23-Mar-05	19:00	21.00	7.5	8	150	23-Mar-05	13:00	5.7	8	187	4	7.5	191
39	27-Mar-05	16:00	29-Mar-05	4:00	36.00	8.8	7.1	193	28-Mar-05	22:00	6.9	8	200	5.3	8	195
40	2-Apr-05	4:00	3-Apr-05	10:00	30.00	9.5	7.1	225	2-Apr-05	19:00	7.5	8	192	5.1	8.5	204
41	8-Apr-05	1:00	8-Apr-05	13:00	12.00	6.5	7.5	189	8-Apr-05	1:00	3.7	7.5	191	2.4	8.5	195
42	5-May-05	16:00	6-May-05	7:00	15.00	8.1	4.9	17	6-May-05	1:00	2.6	9.1	187	--	--	--
43	11-Sep-05	10:00	14-Sep-05	19:00	81.00	11.5	7.5	286	14-Sep-05	13:00	--	--	--	3.9	5.5	248
44	6-Oct-05	4:00	8-Oct-05	10:00	54.00	7.8	8.5	162	8-Oct-05	1:00	5.1	8.5	198	3.4	8.5	185
45	21-Nov-05	7:00	22-Nov-05	10:00	27.00	10.1	8	191	22-Nov-05	4:00	7.3	7.1	213	5.6	7.5	206
46	23-Nov-05	22:00	24-Nov-05	19:00	21.00	10	6.7	250	24-Nov-05	1:00	8.5	7.1	200	5.8	7.1	209
47	29-Nov-05	4:00	29-Nov-05	19:00	15.00	6.9	7.1	159	29-Nov-05	19:00	5	8	168	3.2	8	163
48	15-Dec-05	13:00	16-Dec-05	4:00	15.00	7.4	7.5	118	15-Dec-05	19:00	5.1	7.1	192	3.4	7.1	190
49	25-Dec-05	16:00	26-Dec-05	10:00	18.00	7.2	8	186	25-Dec-05	19:00	5.8	9.1	187	--	--	--
50	14-Jan-06	4:00	14-Jan-06	22:00	15.00	6.9	6.7	183	14-Jan-06	4:00	--	--	--	3.3	6	197
51	17-Jan-06	19:00	18-Jan-06	16:00	12.00	10.5	8.5	172	18-Jan-06	4:00	--	--	--	--	--	--
52	31-Aug-06	16:00	1-Sep-06	4:00	12.00	10.1	10.6	177	31-Aug-06	19:00	6.2	8	192	4.1	10.6	197
53*	6-Nov-06	13:00	9-Nov-06	4:00	63.00	10.6	8	175	7-Nov-06	13:00	4.5	8	182	--	--	--
54	20-Nov-06	13:00	24-Nov-06	7:00	90.00	13.3	4.5	139	21-Nov-06	10:00	2.1	10.6	188	--	--	--
55	24-Nov-06	22:00	27-Nov-06	10:00	60.00	9.5	4.9	82	25-Nov-06	7:00	1.4	5.8	150	--	--	--
56*	28-Nov-06	16:00	2-Dec-06	4:00	108.00	12.8	8.5	225	1-Dec-06	19:00	6	8.5	198	--	--	--
57	2-Dec-06	22:00	4-Dec-06	22:00	48.00	9.7	3.2	65	3-Dec-06	16:00	1.9	7.1	134	--	--	--
58	6-Dec-06	19:00	7-Dec-06	7:00	12.00	7.3	4	143	6-Dec-06	22:00	2.2	4.7	149	--	--	--
59	12-Dec-06	16:00	14-Dec-06	10:00	42.00	8.1	5.3	42	13-Dec-06	13:00	2.3	9.1	190	--	--	--
60	20-Dec-06	4:00	21-Dec-06	1:00	21.00	9.2	3.4	146	20-Dec-06	4:00	1.5	6.4	170	--	--	--
61*	22-Dec-06	4:00	24-Dec-06	4:00	48.00	13.3	7.5	215	23-Dec-06	4:00	5.3	8	190	--	--	--
62	25-Dec-06	1:00	27-Dec-06	10:00	57.00	14.1	7.5	221	25-Dec-06	13:00	5.8	7.1	191	--	--	--
63*	31-Dec-06	10:00	2-Jan-07	4:00	42.00	9.1	5.8	146	31-Dec-06	19:00	2.6	6	194	--	--	--

Table 3.9 Significant Events at 11-Mile Gauge Exceeding Significant Wave Height of 6-ft (Continued).

64	4-Jan-07	13:00	5-Jan-07	4:00	15.00	8.4	4.2	46	4-Jan-07	13:00	1.9	4.9	178	--	--	--
65*	5-Jan-07	13:00	7-Jan-07	7:00	42.00	9.2	7.5	161	6-Jan-07	1:00	3.5	6.7	190	--	--	--
66	8-Jan-07	1:00	8-Jan-07	13:00	12.00	11.5	7.1	214	8-Jan-07	10:00	5.7	7.1	194	--	--	--
67*	9-Jan-07	16:00	10-Jan-07	16:00	24.00	11.2	5.5	198	9-Jan-07	22:00	3.9	6.4	218	--	--	--
68	16-Jan-07	1:00	16-Jan-07	16:00	15.00	8.6	3.5	18	16-Jan-07	10:00	2.5	4.9	178	--	--	--
69*	17-Jan-07	7:00	19-Jan-07	13:00	54.00	10.3	2.9	261	17-Jan-07	16:00	1.5	8	137	--	--	--
70	20-Jan-07	7:00	20-Jan-07	19:00	12.00	8.1	3	282	20-Jan-07	13:00	0.9	9.8	169	--	--	--
71*	21-Jan-07	13:00	23-Jan-07	10:00	45.00	12.8	6.7	198	22-Jan-07	1:00	5.2	6.7	194	--	--	--
72	27-Jan-07	10:00	28-Jan-07	4:00	18.00	11.5	5.3	157	27-Jan-07	22:00	4	5.3	202	--	--	--
73*	1-Feb-07	16:00	8-Feb-07	13:00	167.00	15.1	6	181	7-Feb-07	13:00	4.2	6.4	203	--	--	--
74*	12-Feb-07	19:00	15-Feb-07	16:00	69.00	7.8	4.9	234	13-Feb-07	7:00	1.7	5.1	178	--	--	--
75	20-Feb-07	22:00	22-Feb-07	22:00	48.00	14.4	2.9	294	20-Feb-07	22:00	4.2	5.5	194	--	--	--
76*	26-Feb-07	1:00	27-Feb-07	13:00	36.00	16.4	8.5	206	26-Feb-07	1:00	5.6	8.5	202	--	--	--
77*	28-Feb-07	16:00	11-Mar-07	4:00	252.00	15.5	7.1	194	1-Mar-07	19:00	4.8	6.4	174	--	--	--
78	11-Mar-07	22:00	12-Mar-07	13:00	15.00	7.9	2.9	31	12-Mar-07	10:00	1.3	7.5	146	--	--	--
79*	15-Mar-07	13:00	18-Mar-07	16:00	75.00	10.9	8.5	222	16-Mar-07	19:00	4.2	8.5	195	--	--	--
80	21-Mar-07	16:00	23-Mar-07	16:00	48.00	9.6	6	50	22-Mar-07	7:00	2.3	6	178	--	--	--
81	24-Mar-07	22:00	26-Mar-07	22:00	48.00	8.7	3.8	142	25-Mar-07	22:00	1.7	6.4	162	--	--	--
82	15-Apr-07	1:00	16-Apr-07	16:00	39.00	11.7	9.1	205	15-Apr-07	22:00	--	--	--	5.3	9.8	212
83	7-May-07	13:00	8-May-07	10:00	21.00	8.1	16	157	7-May-07	22:00	--	--	--	2.2	14.2	172
84	2-Jun-07	16:00	3-Jun-07	22:00	24.00	9.7	9.1	160	3-Jun-07	4:00	--	--	--	3.5	9.1	182
85	2-Nov-07	4:00	3-Nov-07	1:00	21.00	7.5	4.7	74	2-Nov-07	10:00	2.2	9.1	172.0	1.1	9.1	174
86	16-Dec-07	4:00	17-Dec-07	1:00	21.00	9.2	8.5	193	16-Dec-07	4:00	6.3	9.1	200.0	--	--	--
87	21-Dec-07	16:00	22-Dec-07	10:00	18.00	6.9	9.1	97	22-Dec-07	4:00	3.1	9.8	152.0	--	--	--
88	1-Feb-08	10:00	1-Feb-08	22:00	12.00	8.6	8	185	1-Feb-08	13:00	--	--	--	3.8	7.5	194
89	12-Feb-08	19:00	14-Feb-08	4:00	33.00	9.5	9.8	173	13-Feb-08	7:00	--	--	--	3.6	9.1	194
90	18-Feb-08	4:00	18-Feb-08	22:00	18.00	7.8	7.5	125	18-Feb-08	7:00	--	--	--	3.8	7.5	190
91	4-Mar-08	13:00	5-Mar-08	10:00	21.00	8.7	8.5	180	5-Mar-08	1:00	--	--	--	4.3	7.5	194
92	7-Mar-08	19:00	9-Mar-08	1:00	30.00	10.2	8	204	8-Mar-08	16:00	6.0	8.5	195.0	5.4	9.1	202
93	19-Mar-08	19:00	20-Mar-08	10:00	15.00	7.6	7.5	193	19-Mar-08	22:00	4.6	8.5	187.0	3.7	8.0	197
94	5-Sep-08	10:00	6-Sep-08	22:00	36.00	15.8	12.8	182	6-Sep-08	1:00	9.8	14.2	186.0	9.1	12.8	181
95	24-Sep-08	13:00	26-Sep-08	7:00	42.00	10.7	10.6	160	25-Sep-08	19:00	3.1	5.5	185.0	3.9	8.5	181

Table 3.9 Significant Events at 11-Mile Gauge Exceeding Significant Wave Height of 6-ft (Continued).

96	24-Oct-08	16:00	2-Oct-08	19:00	27.00	9.5	9.1	120	25-Oct-08	4:00	5.8	9.1	197.0	5.6	8.5	181
97	3-Nov-08	16:00	4-Nov-08	10:00	18.00	6.9	9.8	162	3-Nov-08	22:00	3.0	9.1	149.0	2.2	9.1	162
98	15-Nov-08	7:00	15-Nov-08	22:00	15.00	6.7	7.5	176	15-Nov-08	19:00	5.1	7.5	179.0	5.2	7.1	202
99	1-Dec-08	1:00	1-Dec-08	19:00	18.00	9.3	9.8	189	1-Dec-08	1:00	6.5	9.8	198.0	5.2	8.0	197
100	11-Dec-08	13:00	12-Dec-08	13:00	24.00	10.4	8.5	157	12-Dec-08	4:00	7.4	9.1	189.0	7.3	9.1	184
101	7-Jan-09	10:00	8-Jan-09	19:00	33.00	9.7	8.5	197	7-Jan-09	19:00	6.5	8.5	189.0	6.4	6.7	225.0
102	18-Feb-09	19:00	19-Feb-09	13:00	18.00	8.7	7.5	216	19-Feb-09	1:00:03	--	--	--	5.5	5.5	220.0
103	26-Mar-09	10:00	26-Mar-09	22:00	12.00	7.6	6.7	176	26-Mar-09	13:00:03	--	--	--	4.0	6.7	199.0
104	29-Mar-09	4:00	30-Mar-09	1:00	21.00	8.2	6.7	205	29-Mar-09	13:00:03	--	--	--	4.5	4.1	179.0
105	3-Apr-09	7:00	3-Apr-09	19:00	12.00	6.7	9.8	184	3-Apr-09	16:00:03	--	--	--	4.7	9.8	195.0
106	6-Apr-09	10:00	7-Apr-09	4:00	18.00	7.8	5.8	232	7-Apr-09	1:00:03	--	--	--	4.9	6.4	207.0
* Denotes significant events where data gaps exist within the event. Significant wave height is assumed to maintain a minimum of 6' within these gaps.																

Table 3.9 Significant Events at 11-Mile Gauge Exceeding Significant Wave Height of 6-ft (Continued).

Part 4 PROJECT EFFECTS/PERFORMANCE TO DATE

Beach Response – Shoreline Change Rates

General Shoreline Change Information. One measure of the potential project impact is to compare the rate of shoreline change that existed before the channel improvements were initiated with those that have been measured after. For this study the shoreline change rates selected for the pre-construction period where those of the updated NCDCM rates presented earlier in Part 2 of this report (See Figure 2.1 for Oak Island and Figure 2.2 for Bald Head Island). These change rates are based on shoreline data spanning a 62-year period from 1938 to 2000 (the survey just prior to dredging of the new channel), and therefore represent long-term trends in shoreline change.

Shoreline change rates were computed for seven post-construction periods beginning with the August/September 2000 survey through; (1) the survey of June 2003 (as presented in Report 1), (2) the survey of June 2004 (as presented in Report 2), (3) the survey of August 2005 (as presented in Report 3), (4) the survey of October 2006 (as presented in Report 4), (5) the survey of July 2007 (as presented in Report 5), (6) the survey of July 2008 (as presented in Report 6) and (7) through the most recent survey of May 2009. The post-construction rates were developed in the same manner as the pre-construction rates and represent a least squares trend of the data. See Appendices B (Oak Island) and C (Bald Head Island) for shoreline change plots for each monitoring profile for a graphical representation of these calculations. As shown in these appendices, the slope of the trend line for each profile indicates the computed shoreline change rate. A longshore average was then calculated by computing a running average, to be consistent with the NCDCM methodology. Specifically, 5 profiles (2 either side) for Oak Island and 7 profiles (3 either side) for Bald Head Island were averaged together resulting in the longshore average shoreline change rate for that profile of interest. The computed rates for each of the periods are summarized in Table 4.1 for Oak Island and Table 4.2 for Bald Head Island. These rates are plotted in Figure 4.1 and Figure 4.2 for Oak Island/Caswell Beach and Bald Head Island, respectively. These post-construction rates were generated to establish a trend in shoreline response including and encompassing the beach fill activities.

In general, it is apparent that the post-construction shoreline change rates are more variable (alongshore and magnitude), when compared to the pre-construction rates. This is due in part to the relatively short time frame of the post rate data (2000 through 2009), when compared to the pre-construction rate data (1938 through 2000), and is also a result of shoreline equilibration that is expected following each beach disposal activity.

Oak Island. As indicated on Table 4.1 and Figure 4.1, the pre-construction data for Oak Island covers from Profile 35 through 310. The area east of profile 35 near Fort Caswell along the Cape Fear River entrance was not included in the NCDCM data base so direct comparisons between pre- and post-construction shoreline change rates cannot be made in that area.

For the entire Oak Island monitoring area, the pre-construction shoreline change rates along the beach vary from positive (accretion) of more than 29 feet per year to negative (erosion) of 5.8 feet per year. The overall trend shows accretionary shoreline change rates within the eastern one-third of the study area with the remaining two-thirds showing a general pattern of long-term erosion. By comparison, shoreline change rates for all the post construction periods are largely accretionary over the study area except for those in the immediate vicinity of Ft. Caswell (east of Profile 50). In this area, the rates are generally stable to slightly accretional, but the rates are still less than the historically large accretion of this area.

When compared to pre-construction shoreline change rates, the post construction rates reflect the influence of the beach fills placed along Oak Island. Beach disposal occurred in 2001 during the initial channel deepening and with the 2009 maintenance cycle. In 2001, the fill was placed west of Profile 60 to Profile 294, except for a gap between Profile 80 through Profile 121 that did not require fill. Further, material associated with the Sea Turtle Habitat Project extending into the far west end of the monitoring area, specifically Profiles 300 through 310. For 2009, the sediment was deposited between Profiles 60 and 95 and 120 thru 260. Positive shoreline change rates were recorded over this entire fill area with a localized minimum occurring near the middle of the non-fill area. With this measured response, all profiles (except for three nearest to the river entrance, Profiles 35, 40, and 45) have significantly more positive post-construction shoreline change when compared to the computed pre-construction rates. As expected the rates have moderated with time, with each subsequent survey period being generally less than the prior period, as the placed fills are redistributed and the rates begin to trend more toward the long-term pattern.

In most cases within the fill area the positive changes in the shoreline rate are an order of magnitude greater than the pre-construction change rates. For example, within the easternmost disposal area between Profiles 60 and 80, the post-construction change rates through the current period are about +10 feet per year. This compares to an average of approximately +1 feet per year for the pre-construction period. Within the remaining disposal area from station 121+00 through the western end, the current rates generally range from about +10 to +30 feet per year, while the pre-construction shoreline change rates for this area are erosional ranging from –0.3 to –5.8 feet per year.

In the area of Profiles 5 through 45, encompassing the eastern tip of Oak Island, the measured post-construction rates calculated through June 2003 previously indicated an area of erosion except for the last three profiles along the inlet shoulder, which were stable. Historically, this area, which is in the vicinity of Ft. Caswell, has been accretionary; but has also experienced a rather high degree of shoreline variability being located immediately adjacent to the entrance channel. Beginning with the August 2005 and continuing through the current monitoring period, the rates of the eroding profiles have become positive. This could be an indication that this area is returning to a more accretionary pattern consistent with the long-term shoreline behavior.

Overall, the shoreline change rate averaged over the entire 5.2 mile section of Oak Island/Caswell Beach (from Profiles 35-310) is +16.5 feet per year for the 8.7-year post-construction period. By comparison the pre-construction rate over the entire reach was an average of –1.1 feet per year.

Table 4.1 Oak Island Shoreline Change Rates

Profile ID	Post-Construction Rate (ft/yr) Aug-00 thru							Longshore Average Rate (ft/yr) Aug-00 thru							Longshore Average Pre-Construction Rate 1938-2000 (ft/yr)
	Jun-03	Jun-04	Aug-05	Oct-06	Jul-07	Jul-08	May-09	Jun-03	Jun-04	Aug-05	Oct-06	Jul-07	Jul-08	May-09	
5	-5.4	-3.2	-2.0	-1.4	-1.3	-1.0	-0.9	1.0	1.3	1.9	2.0	1.6	1.7	1.5	
10	1.3	0.8	0.9	0.8	0.4	0.5	0.3	-1.5	-1.2	-0.8	-0.4	-0.3	0.1	0.2	
15	7.0	6.4	7.0	6.8	5.8	5.6	5.0	-7.1	3.2	5.6	4.8	4.5	3.3	4.0	
20	-8.7	-8.7	-9.1	-7.7	-6.1	-4.6	-3.4	-2.8	9.4	10.4	9.0	8.2	6.4	6.7	
25	-29.7	20.9	31.1	25.8	23.9	15.9	18.8	-9.7	4.4	6.2	5.8	5.9	4.4	4.7	
30	16.1	27.7	22.1	19.5	16.8	14.8	12.7	-15.5	-0.9	1.7	2.8	3.4	2.2	2.8	
35	-33.4	-24.3	-20.2	-15.3	-10.8	-9.7	-9.5	-15.9	1.5	5.4	6.4	6.5	4.7	5.0	29.9
40	-21.9	-20.1	-15.3	-8.3	-6.9	-5.5	-4.5	-6.1	0.3	2.0	3.3	3.6	2.9	2.4	17.2
45	-10.6	3.5	9.2	10.1	9.5	7.9	7.2	-3.2	-0.5	1.5	2.2	2.6	1.8	1.7	7.9
50	19.2	14.8	14.2	10.6	9.4	6.8	6.0	11.7	10.3	10.3	8.8	7.7	6.0	5.6	2.5
55	30.8	23.5	19.6	14.2	12.0	9.6	9.2	20.8	17.4	15.8	12.1	10.1	7.7	7.3	0.8
60	41.3	29.6	24.0	17.5	14.3	11.3	10.2	30.7	21.9	18.2	13.4	10.9	8.3	8.0	0.3
65	23.3	15.6	11.9	8.1	5.3	3.1	3.8	32.9	23.0	18.6	13.6	11.0	8.4	8.5	0.2
70	38.8	25.9	21.5	16.4	13.5	10.5	11.0	35.9	24.9	20.1	15.1	12.4	9.7	9.8	0.4
75	30.4	20.6	15.7	11.8	10.1	7.7	8.3	35.0	24.2	19.7	15.1	12.7	10.3	10.7	0.9
80	45.8	33.0	27.2	21.5	18.6	15.8	15.7	35.5	24.7	20.3	16.0	13.9	11.8	12.0	1.6
85	36.4	26.0	22.2	17.8	16.0	14.5	14.7	27.3	19.6	16.0	12.8	11.4	9.9	10.2	1.9
90	25.9	18.0	14.8	12.4	11.1	10.3	10.4	22.9	17.0	14.5	11.9	10.7	9.6	9.9	2.2
95	-1.9	0.2	0.1	0.5	1.0	1.3	2.1	13.4	10.7	9.5	8.1	7.3	6.9	7.3	2.5
100	8.2	7.9	8.0	7.3	6.6	6.2	6.4	8.0	7.0	6.5	5.7	5.1	4.8	5.1	2.6
105	-1.6	1.3	2.7	2.6	1.9	2.2	2.7	4.4	5.2	5.2	4.6	3.9	3.7	3.9	2.5
110	9.6	7.4	7.2	5.9	5.0	4.0	4.0	12.0	10.9	10.1	8.4	7.2	6.3	6.2	2.1
115	7.6	9.2	8.1	6.5	5.1	4.6	4.4	17.8	15.4	13.2	10.4	8.8	7.6	7.4	1.5
120	36.2	28.9	24.3	19.7	17.3	14.6	13.7	32.9	25.7	20.8	16.1	13.7	11.6	11.2	0.7
125	37.1	30.2	23.6	17.1	14.9	12.5	12.5	44.9	34.7	27.1	21.1	18.1	15.4	14.9	-0.3
130	73.8	52.7	40.6	31.2	26.3	22.4	21.5	55.4	42.4	33.2	25.9	22.4	18.9	18.2	-0.9
135	69.7	52.3	39.0	30.8	27.1	22.7	22.2	62.1	47.6	36.8	28.7	24.8	21.0	20.0	-1.4
140	60.2	47.8	38.5	30.6	26.7	22.2	21.0	68.7	51.7	40.6	32.3	28.0	23.9	22.6	-2.1
145	69.7	54.8	42.2	33.6	28.9	24.9	22.7	64.5	49.4	39.1	31.4	27.4	23.5	22.4	-2.3
150	70.2	50.8	42.9	35.3	30.8	27.0	25.4	62.9	47.3	38.0	30.5	26.6	22.8	21.9	-2.5
155	52.9	41.4	33.1	26.6	23.5	20.6	20.7	61.9	45.8	36.4	29.1	25.3	21.8	21.2	-2.8
160	61.4	41.5	33.5	26.6	23.1	19.5	19.7	61.6	44.5	35.6	28.4	24.6	21.1	20.9	-3.3
165	55.0	40.4	30.3	23.6	20.4	17.1	17.6	60.1	43.9	34.1	26.6	23.1	19.6	19.7	-3.9
170	68.7	48.5	38.2	29.8	25.4	21.3	21.1	60.7	43.4	33.4	25.8	22.1	18.6	18.6	-4.3
175	62.2	47.9	35.3	26.5	22.9	19.3	19.2	60.3	43.5	32.9	25.2	21.5	18.2	18.1	-4.7
180	56.0	38.6	29.9	22.5	18.9	15.8	15.4	61.4	44.2	33.4	25.5	21.8	18.4	18.1	-5.0
185	59.6	42.4	30.6	23.4	20.1	17.3	17.0	59.6	43.2	32.0	24.4	20.9	17.6	17.3	-5.3
190	60.6	43.5	33.0	25.6	21.7	18.3	17.8	59.8	42.7	31.9	24.6	21.0	17.7	17.2	-5.4
195	59.4	43.8	31.1	24.0	20.7	17.2	17.0	61.1	44.5	33.2	25.9	22.2	18.9	18.3	-5.5
200	63.5	45.4	35.1	27.6	23.6	20.2	19.1	63.5	46.3	35.3	27.8	23.8	20.2	19.3	-5.6
205	62.3	47.6	36.1	28.8	25.1	21.6	20.6	63.9	46.8	35.8	28.3	24.2	20.6	19.5	-5.7
210	71.9	51.2	41.2	33.0	27.9	23.9	22.2	66.3	48.2	37.8	30.0	25.6	21.8	20.3	-5.8
215	62.3	46.1	35.4	27.9	23.8	20.2	18.7	64.0	47.1	36.9	29.3	24.9	21.0	19.5	-5.7
220	71.6	50.9	41.2	32.5	27.5	22.9	20.8	64.2	46.7	37.2	29.5	25.1	21.1	19.5	-5.5
225	52.3	39.9	30.8	24.0	20.1	16.5	15.3	57.5	42.3	33.7	26.7	22.6	19.0	17.7	-5.2
230	63.1	45.2	37.3	30.1	26.0	22.1	20.5	56.1	41.3	33.8	26.9	22.8	19.2	17.8	-4.8
235	38.1	29.3	24.0	19.1	15.9	13.4	13.0	50.3	37.9	31.3	25.1	21.3	18.0	16.9	-4.4
240	55.5	41.2	35.6	28.8	24.5	21.0	19.6	52.1	39.3	33.3	27.0	23.2	19.8	18.5	-4.1
245	42.6	33.6	28.6	23.2	20.2	17.1	16.2	48.1	37.3	31.9	25.9	22.3	19.0	17.7	-3.9
250	61.4	47.4	41.1	34.0	29.5	25.4	23.1	53.7	41.5	35.8	29.3	25.4	21.9	19.9	-3.7
255	42.8	35.2	30.1	24.5	21.4	18.3	16.3	53.9	41.7	36.0	29.5	25.7	22.1	19.8	-3.6
260	66.0	50.1	43.7	36.2	31.6	27.5	24.1	60.5	46.3	40.2	33.1	28.7	24.8	21.9	-3.5
265	56.5	42.1	36.4	29.8	25.7	22.3	19.2	58.9	45.2	38.9	31.9	27.6	23.9	20.9	-3.3
270	75.7	56.9	49.6	40.9	35.4	30.7	26.7	66.1	50.1	43.4	35.6	30.7	26.7	23.2	-3.2
275	53.5	41.8	35.0	28.2	24.1	20.9	18.2	67.4	51.2	43.8	35.7	30.8	26.6	23.0	-3.0
280	78.9	59.6	52.2	42.9	36.8	32.0	27.9	72.0	54.5	46.6	37.9	32.6	28.1	24.3	-2.8
285	72.3	55.4	45.8	36.9	31.7	27.3	23.1	73.5	55.8	46.9	37.8	32.4	27.9	24.0	-2.7
290	79.7	58.8	50.5	40.6	34.8	29.8	25.5	82.7	61.8	52.0	41.8	35.7	30.6	26.2	-2.6
295	83.0	63.3	50.9	40.3	34.5	29.3	25.0	86.9	64.5	53.1	42.2	35.9	30.6	26.1	-2.5
300	99.5	72.1	60.7	48.2	40.9	34.7	29.6	95.8	69.7	57.4	45.5	38.5	32.7	27.9	-2.3
305	99.9	73.1	57.4	44.8	37.5	31.8	27.1	99.8	72.4	59.1	46.7	39.5	33.4	28.4	-2.2
310	116.9	81.2	67.2	53.3	45.0	37.8	32.1	105.5	75.5	61.8	48.8	41.1	34.8	29.6	-2.1

Table 4.2 Bald Head Island Shoreline Change Rates

Profile ID	Post-Construction Rate (ft/yr)							Longshore Average Rate (ft/yr)							Average Pre-Construction Rate 1938-2000
	Aug-00 thru							Aug-00 thru							
	Jun-03	Jun-04	Aug-05	Oct-06	Jul-07	Jul-08	May-09	Jun-03	Jun-04	Aug-05	Oct-06	Jul-07	Jul-08	May-09	
0	-3.1	1.0	2.3	3.0	3.2	2.6	2.8	-3.0	-2.1	-1.6	-1.0	-0.8	-0.9	-1.0	
4	-6.2	-5.6	-5.0	-4.1	-3.7	-3.6	-3.7	-1.6	-1.1	-1.0	-0.4	-0.4	-0.5	-0.8	
8	0.3	-1.7	-2.3	-1.9	-1.8	-1.7	-2.2	0.0	0.4	-0.1	0.4	0.3	0.0	-0.5	
12	2.6	1.9	0.7	1.2	0.9	0.7	0.0	1.7	1.2	-0.3	0.1	-0.3	-0.8	-1.5	
16	6.3	6.2	3.9	3.7	2.9	1.7	0.5	5.9	4.3	1.2	1.6	0.9	0.0	-1.1	
20	5.7	5.0	1.0	1.4	0.5	-0.9	-2.3	4.6	1.3	-3.1	-2.0	-2.1	-2.6	-3.0	
24	14.7	10.0	2.7	3.5	2.1	0.4	-1.3	1.3	-3.9	-6.7	-1.2	0.6	0.9	1.2	
28	-6.5	-16.7	-23.8	-19.8	-16.9	-15.1	-12.0	-3.3	-1.7	-1.9	4.5	5.8	6.2	6.9	
32	-13.7	-23.9	-17.0	5.0	14.5	18.4	21.2	15.1	10.5	7.0	9.9	10.0	10.9	10.7	
36	-16.6	16.9	27.8	32.4	28.9	28.1	28.8	18.1	6.6	1.2	2.4	3.4	6.6	5.5	
40	97.6	66.1	45.1	28.4	21.4	22.9	16.8	22.2	6.1	1.3	0.0	1.0	5.4	2.6	
43	29.9	-9.6	-26.1	-34.2	-31.0	-21.2	-27.2	21.6	4.0	-0.6	-6.9	-6.5	-2.0	-6.2	
45	13.6	-18.8	-23.1	-31.6	-28.9	-21.2	-26.6	19.8	-7.5	-10.6	-16.7	-14.2	-9.5	-14.3	
47	-16.3	-34.3	-26.5	-29.3	-23.0	-18.6	-22.8	-5.1	-30.0	-24.1	-25.4	-20.4	-16.0	-20.0	
53	-25.5	-40.9	-22.2	-16.8	-9.5	-9.5	-11.7	-18.1	-39.3	-24.9	-22.8	-17.3	-14.6	-17.4	-2.4
57	-27.0	-46.1	-22.5	-15.2	-9.5	-9.6	-11.6	-24.4	-40.5	-20.9	-16.5	-11.5	-10.5	-12.5	-5.5
61	-35.2	-56.4	-30.2	-21.1	-15.8	-14.1	-14.1	-23.6	-37.4	-15.6	-10.0	-6.1	-6.1	-7.5	-5.6
66	-18.1	-24.9	-3.2	-0.2	0.3	-0.7	-2.2	-19.7	-32.5	-10.3	-5.5	-3.2	-3.3	-4.5	-5.9
69	-12.0	-19.0	0.1	3.5	4.0	3.5	2.1	-14.8	-24.7	-3.8	-0.4	0.7	0.7	-0.3	-6.4
73	-6.1	-16.1	4.3	5.7	5.0	4.6	3.3	-6.5	-14.5	5.6	7.1	6.8	6.5	5.3	-5.5
78	-2.4	-7.3	10.0	10.4	10.0	10.1	9.4	-2.0	-10.6	9.1	9.8	9.1	9.0	8.0	-4.6
84	6.2	-5.3	17.0	16.3	14.8	14.7	14.2	2.7	-7.3	12.3	11.9	10.8	10.8	9.7	-3.7
88	4.3	-5.4	14.3	13.0	11.6	11.8	11.2	5.6	-4.6	14.3	13.5	12.8	12.9	11.8	-3.1
92	11.3	-2.3	15.8	13.9	12.8	12.6	10.3	8.8	-3.1	15.4	14.2	13.8	13.8	12.8	-2.6
97	8.8	-2.8	14.2	13.7	14.9	15.1	14.1	13.7	0.4	16.1	14.3	14.1	13.9	12.6	-2.0
102	13.5	0.2	15.5	14.0	14.9	15.0	14.2	19.0	3.8	17.3	14.8	14.5	14.2	12.6	-1.6
106	30.8	12.5	20.8	17.1	16.1	15.2	13.5	26.0	8.9	19.5	16.2	15.7	15.2	13.7	-1.5
110	30.5	11.6	20.0	15.4	13.9	13.1	10.9	34.2	14.8	22.5	17.8	16.8	16.1	14.2	-1.6
114	46.2	23.2	27.0	20.9	18.9	17.7	15.7	43.0	21.4	26.1	20.1	18.7	17.7	15.5	-1.6
118	50.1	26.5	28.9	21.4	20.3	19.4	16.6	47.9	25.3	28.1	21.5	20.1	19.4	17.0	-1.8
122	57.6	33.0	33.7	25.9	24.2	23.2	20.8	50.2	27.2	28.1	21.5	20.6	20.2	18.0	-1.9
126	54.9	32.3	31.1	23.8	23.5	23.4	20.8	51.5	28.9	27.3	20.8	20.6	20.9	18.8	-2.0
130	42.4	21.2	19.7	15.4	16.1	17.5	16.1	53.4	31.1	26.8	20.9	20.9	21.8	19.7	-2.1
134	52.4	31.6	22.9	17.6	19.1	21.2	19.6	53.2	31.5	24.7	19.3	20.1	21.6	19.6	-2.0
138	59.9	37.3	26.8	21.5	21.7	23.4	21.5	54.4	33.0	24.1	19.0	19.8	21.6	19.8	-2.0
142	56.3	35.1	22.9	18.2	20.3	22.4	20.3	59.0	37.4	25.7	20.1	21.0	22.9	20.9	-2.3
146	60.9	39.8	28.2	22.0	21.6	23.5	21.7	61.8	39.9	27.4	21.5	22.2	23.8	21.6	-2.6
150	65.8	43.3	27.6	21.0	22.5	23.9	21.5	65.0	42.9	29.2	22.3	23.1	24.4	21.9	-2.9
154	66.0	44.1	31.5	24.7	25.0	25.7	23.0	69.5	46.2	32.5	24.4	24.9	25.6	22.9	-3.9
158	75.9	52.3	35.9	25.5	26.1	26.4	23.2	72.6	48.7	34.2	25.3	26.1	26.3	23.3	-4.7
162	78.9	51.8	39.4	28.7	29.1	28.4	25.1	72.8	49.3	35.8	26.1	26.4	26.1	23.1	-5.2
166	76.3	52.3	36.9	26.7	28.0	26.9	23.8	71.6	49.5	36.0	25.7	25.2	24.7	21.9	-5.4
170	67.1	45.9	35.5	25.0	24.1	23.2	20.5	71.6	49.3	36.8	26.8	25.0	24.0	21.6	-5.6
174	59.7	45.0	32.2	22.7	19.0	18.4	17.0	67.5	47.1	34.8	25.5	22.9	21.9	20.1	-5.9
178	76.1	51.4	40.1	30.7	25.0	23.3	21.6	62.0	43.2	32.4	24.3	20.8	19.9	18.8	-6.2
182	58.2	40.9	29.2	22.2	18.5	17.8	17.5	57.1	39.9	29.7	22.9	19.4	18.8	18.2	-6.5
186	48.7	33.0	25.1	20.7	17.4	17.0	17.1	51.6	35.5	27.1	21.8	19.0	18.8	18.5	-7.0
190	42.9	29.3	22.0	18.1	16.9	17.4	17.6	42.0	30.0	22.9	19.1	17.8	18.4	18.5	-7.8
194	31.8	22.9	18.9	17.1	17.1	18.3	18.7	34.5	26.3	20.8	18.3	18.4	19.7	19.7	-8.6
198	28.3	23.7	19.1	17.4	19.2	21.6	21.7	25.4	21.9	17.6	16.9	19.1	21.0	20.5	-10.0
202	20.8	22.7	18.7	18.2	21.2	24.0	23.5	15.1	16.7	14.3	16.3	20.5	22.4	21.2	-11.9
206	3.2	10.7	9.0	13.5	21.2	23.5	21.1	6.8	12.4	12.1	17.7	23.9	24.9	22.5	-13.7
210	-8.8	3.4	5.8	15.3	24.0	24.4	21.0	0.2	8.9	11.2	23.2	29.7	28.5	24.5	-15.0
214	-9.6	1.2	7.6	24.2	34.1	31.0	25.3	-3.6	4.3	9.3	24.4	31.9	29.6	24.7	-17.8
218	-4.8	6.2	14.7	44.5	48.3	39.4	31.3	0.1	3.4	9.4	28.0	35.5	31.6	25.9	-20.8
222															

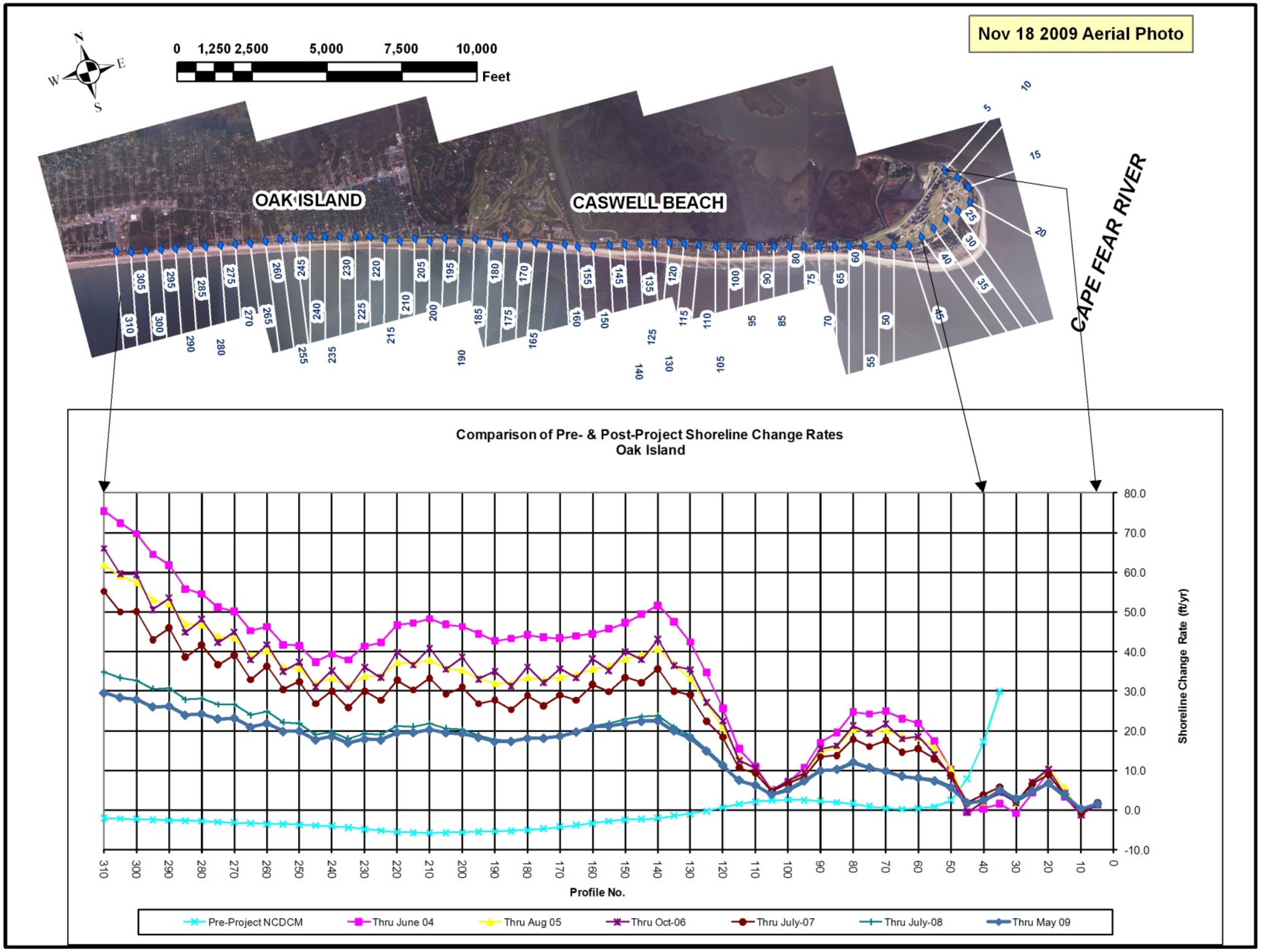


Figure 4.1 Wilmington Harbor Monitoring - Oak Island Comparison of Pre- and Post-Construction Shoreline Change Rates

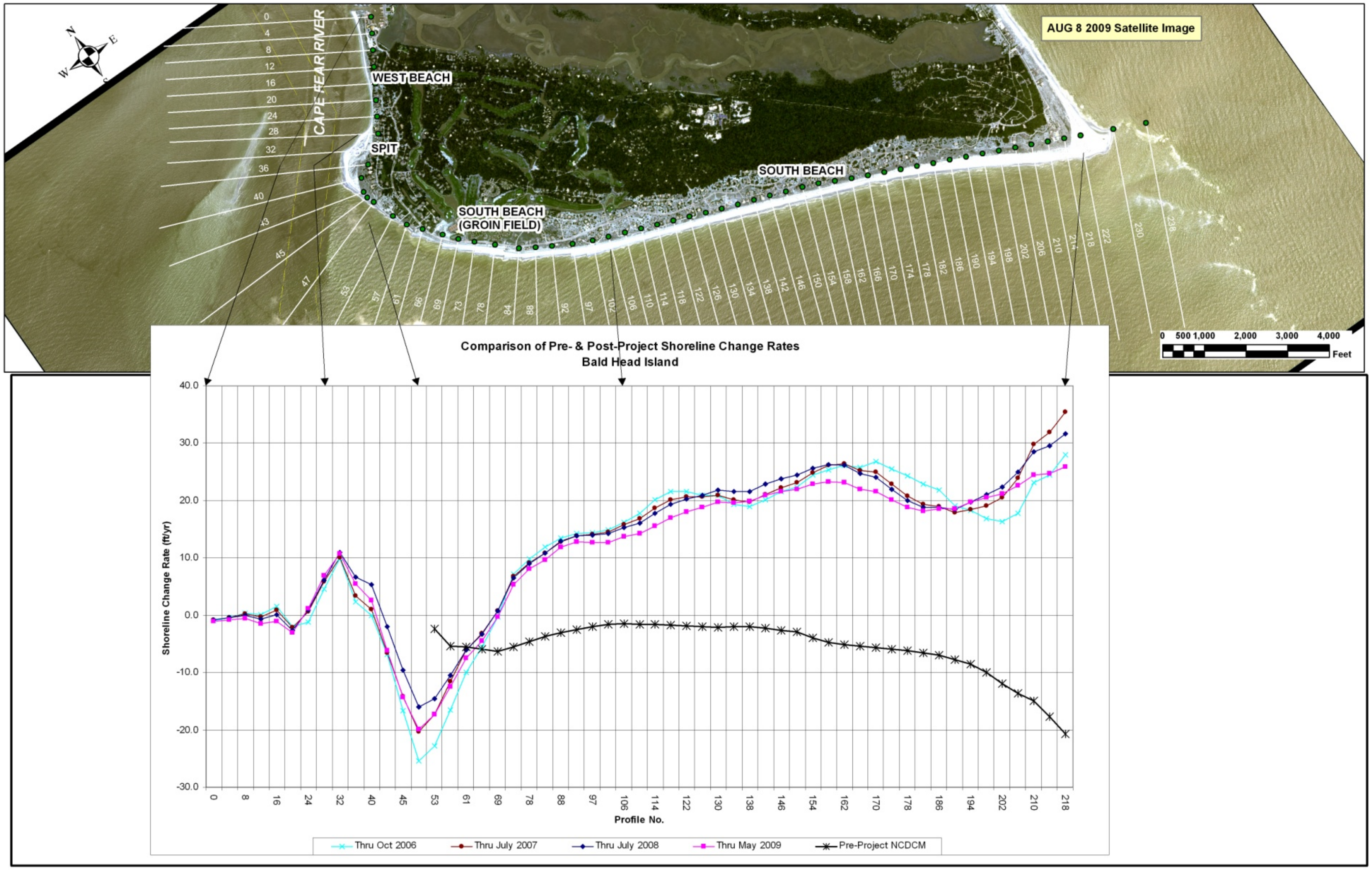


Figure 4.2 Wilmington Harbor Monitoring - Bald Head Island Comparison of Pre- and Post-Construction Shoreline Change Rates

Bald Head Island: Table 4.2 and Figure 4.2 give the comparison of pre- and post-construction shoreline change rates along Bald Head Island. The updated NCDCM pre-construction data are available for Profiles 53 through 218, generally encompassing shoreline along South Beach. Pre-construction shoreline change rates along the beach are all negative and indicate a pattern of higher erosion towards each end of the island with lower erosion rates near the middle. Erosion rates along the western third of South Beach covering about one mile range from –2 feet per year to a maximum of –6.6 feet per year. The rates then range from –2 to –3 feet per year average along the central portions of South Beach. Eastward beyond this relatively more stable central reach, the rates gradually increase towards Cape Fear reaching a maximum erosion rate of about -20 feet per year.

As indicated on Figure 4.2, the computed post-construction shoreline change rates are found to be generally positive over the monitoring area for all of the time frames. This in part reflects the positive influence of the beach fills placed throughout this area. In spite of the positive effects of the fill, the western end of South Beach continues to experience relatively high rates of erosion. Prior reports have shown that this area of relatively high erosion expands and contracts with each beach disposal cycle. For example, with the rates measured thru Oct 2006, the zone showing greater erosion rates was relatively large as shown in Figure 4.2. With the subsequent beach disposal in 2007, the zone diminished thru the July 2007 and July 2008 time periods. Presently the zone is once again expanding with the computed rates thru May 2009. Specifically for July 2007, the average rate over the zone of erosion was –11.3 feet per year with a maximum of –20.4 feet per year. By July 2008, the average had reduced to -8.9 feet per year with a maximum of -16.0 feet per year. The current rates as of May 2009 are an average of -10.3 feet per year and peak of -20.0 feet per year. This current erosion rate zone extends from Profile 43 thru 69 representing an alongshore distance of about 2,600 feet.

Eastward of this erosion zone, the post-construction rates turn positive reflecting the positive impact of the fills placed along this reach. The computed peak shoreline change rates for this area remain highly positive, but as noted with past reporting are found to be diminishing, as the effect of the fills on the rate of change moderates with time. As shown in Figure 4.2, the current accretion rates thru May 2009 are slightly less than those of the prior three periods but still remain relatively high. The present rate of change over the eastern accretionary area is an average of 18.3 feet per year. This is in sharp contrast to the erosion indicated along this entire area by the pre-construction rates.

In summary, the comparison of the pre- and post-construction shoreline change rates show that most of Bald Head Island is eroding less over the initial 8.7-year monitoring period. However, notwithstanding this overall positive response, the post-construction erosion rates continue to be greater along the western corner of South Beach. A direct comparison of the pre- and post-construction shoreline change rates show that only three profile lines are eroding at a higher rate during the post-construction period. These lines at located at the western end of South Beach (Profiles 53, 57 and 61). Adjacent Profile 66 is presently eroding but at a lower rate as compared to the pre-construction condition. All other lines are accreting in direct contrast to the long-term erosion experienced along the remaining areas of South Beach. Most of this response is attributable to the beach fill placement along Bald Head.

Bald Head Shoal Channel Shoaling and Spit Growth

Channel Shoaling (Settlement Surveys). On 24 March 2005, the Village of Bald Head Island and the Wilmington District entered into an agreement to conduct bi-monthly navigation channel surveys for the three channel reaches adjacent to Bald Head Island: Smith Island Channel, Baldhead Shoal Channel 1 and Baldhead Shoal Channel 2 (Figure 4.3). These surveys are intended to document channel shoaling and spit migration after channel dredging events which occurred initially in January 2005. There have been two subsequent dredging events since 2005 with the first occurring in 2007 between the months of March and April and the most recent occurring between February and April of 2009. Ultimately, these surveys will serve as a catalyst for discussion of possible measures to be taken if navigation becomes restricted during the scheduled two-year period between dredging events. The threshold criterion outlined in the settlement agreement at which discussions would initiate is a navigable width less than 500 feet at a depth of –42 feet MLW.

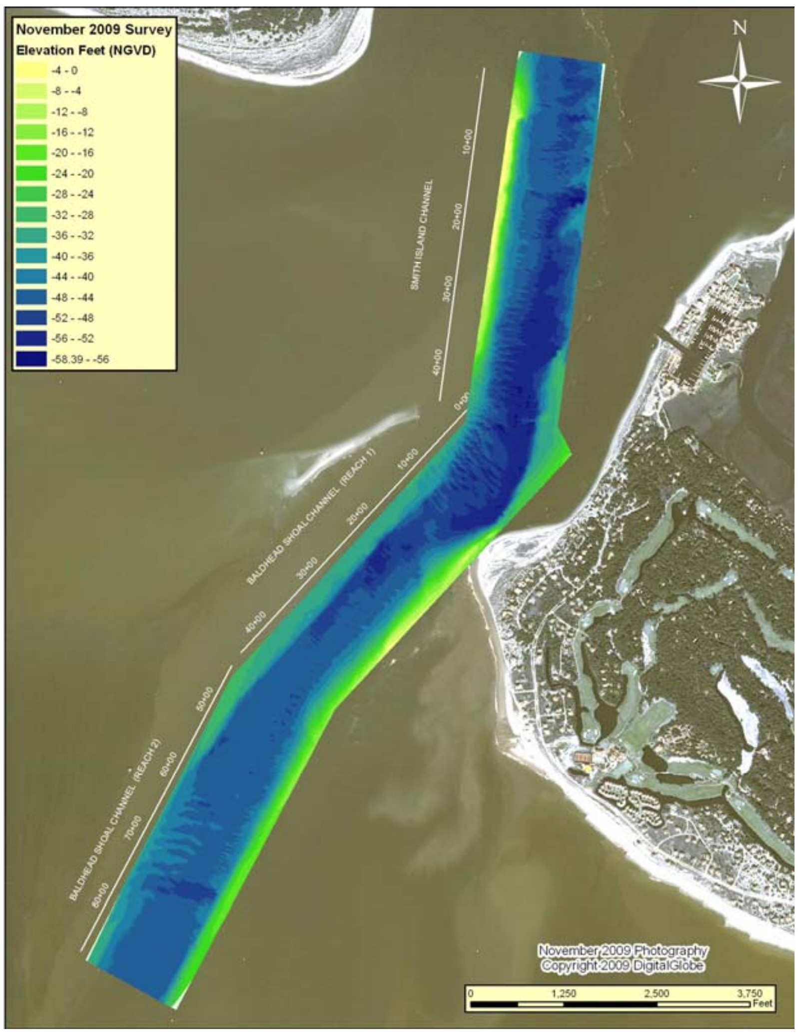


Figure 4.3 Locations for Baldhead Shoal (Reach 1 & 2) and Smith Island Channels

The first settlement agreement survey was conducted in March 2005. It and all subsequent surveys prior to the second dredging event were compared to the post-dredging survey conducted in January 2005 to track changes. The second dredging event occurred between March and April 2007 and the post dredging settlement survey was completed in June 2007. This survey served as the base to which subsequent surveys were compared within the second analysis period. The most recent dredging event occurred between February and April of 2009. Following this third dredging event a settlement survey was obtained in June 2009 which will serve as the base condition survey for the third dredging period. Bi-monthly surveys have been made on the dates shown in Table 4.3. The navigable widths discussed in this section of the report focus on Bald Head Channel 1 due to its proximity to Bald Head Island and the tendency of widths in this section of the channel to fall below the 500 foot threshold limit. However, all three channels are analyzed and future reports may include more analysis of the other two channels if necessary.

Table 4.3. BHI Settlement Survey Dates

	SI Channel	BH Channel 1	BH Channel 2
January 2005[1]	3-Dec-04 to 25-Jan-05		
March 2005	23-Mar-05	18-Mar-05	18-Mar-05
May 2005	17-May-05	12-May-05	13,17-May-05
July 2005	20-Jul-05	22-28-July-05	25-28-July-05
September 2005	22-Sep-05	21-23-Sep-05	22-23-Sep-05
October 2005[2]	18-Oct-05	18-19-Oct-05	19-Oct-05
November 2005	29-Nov-05	30-Nov-05	30-Nov-05
January 2006	28-Jan-06	27-Jan-06	27-Jan-06
March 2006	17,21-Mar-2006	16-Mar-06	17-Mar-06
May 2006[3]	23-May-06	19-May-06	18-May-06
July 2006[3]	25-Jul-06	21-Jul-06	20-Jul-06
September 2006[3]	26,27-Sep-06	28-Sep-06	26-Sep-06
November 2006[3]	17-Nov-06	28-Nov-06	20-Nov-06
January 2007[4]	25-Jan-07	29-Jan-07	21-Jan-07
March 2007[4]	19-Mar-07	8-Mar-07	9-Mar-07
June 2007[4]	26-Jun-07	27-Jun-07	26-Jun-07
September 2007[4]	27-Sep-07	26-Sep-07	26-Sep-07
November 2007[4]	28-Nov-07	30-Nov-07	11-Dec-07
February 2008[5]	20-Feb-08	14-Feb-08	12-Feb-08
April 2008[5]	17-Apr-08	16-Apr-08	15-Apr-08
June 2008[5]	26-Jun-08	27-Jun-08	1-Jul-08
September 2008[5]	10-Sep-08	9-Sep-08	9-Sep-08
November 2008[6]	19-Nov-08	20-Nov-08	20-Nov-08
February 2008[6]	8-Feb-09	27-Jan-09	28-Jan-09
June 2009[6]	5-Jun-09	11-Jun-09	4-Jun-09
August 2009[6]	26-Aug-09	25-Aug-09	25-Aug-09
November 2009[6]	5-Nov-09	4-Nov-09	3-Nov-09

[1]Post dredging surveys are a mosiac of surveys between these dates

[2]October 2005 was an extra survey conducted post-Hurricane Ophelia to determine if any accelerated shoaling had occurred

[3]Surveys included in Monitoring Report 4

[4]Surveys included in Monitoring Report 5

[5]Surveys included in Monitoring Report 6

[6]Surveys included in Monitoring Report 7

The settlement agreement specifies that a survey report documenting the channel conditions be produced within 20 days of completion of surveying and provided to the Village of Bald Head and the State of North Carolina. These reports are posted on the Wilmington Harbor Project web site at http://www.saw.usace.army.mil/wilmington-harbor/main.htm under the "Sand Management Survey Reports" section.

Figures 4.4 and 4.5 show the condition of the three channel reaches in September 2008 and November 2009, respectively. The September 2008 survey is the last survey included in Monitoring Report 6. The November 2009 survey is the last settlement survey to be included in the analysis for the current monitoring report. The channel widths by reach for Baldhead Shoal Channel 1 in September 2008 and November 2009 are shown in Figure 4.6. A difference plot of the total amount of change (September 2008 – November 2009) in all three channels is shown in Figure 4.7. Significant increases in channel width are observed during the current period due to the channel dredging that occurred between February and April 2009. This is particularly evident between stations 20+00 and 28+00 which was noted as an area of concern in the previous monitoring report as being marginally wider than the minimum navigable width threshold of 500 feet. The change in navigable width measured at -42 feet mllw, ranged from an increase of 186 feet at station 23+00, which has historically been a location of increased shoaling, to a maximum reduction of 78 feet at station 17+00. The minimum navigable width did fall below the threshold limit of 500 feet at station 23+00 during the November 2008 survey to a width of 478 feet. However, due to the temporal proximity of this survey to the upcoming dredging event in February 2009, no intermediate action was taken to increase navigable width.

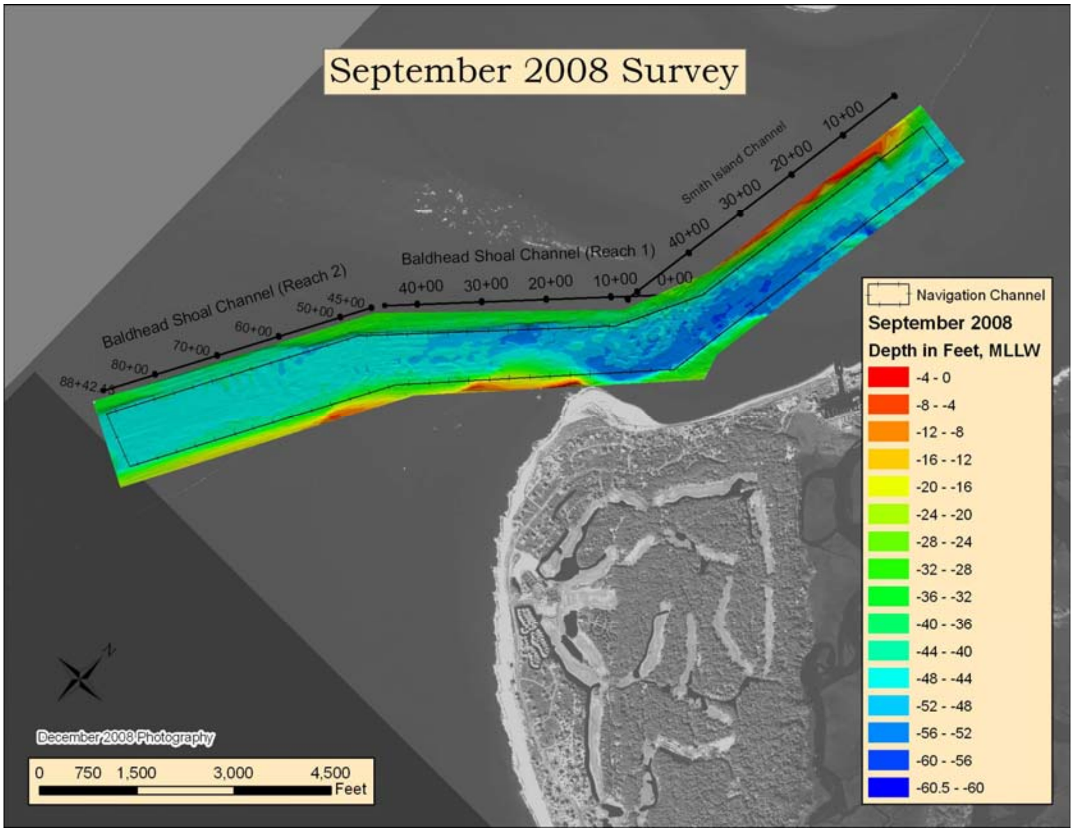


Figure 4.4. September 2008 Channel Conditions

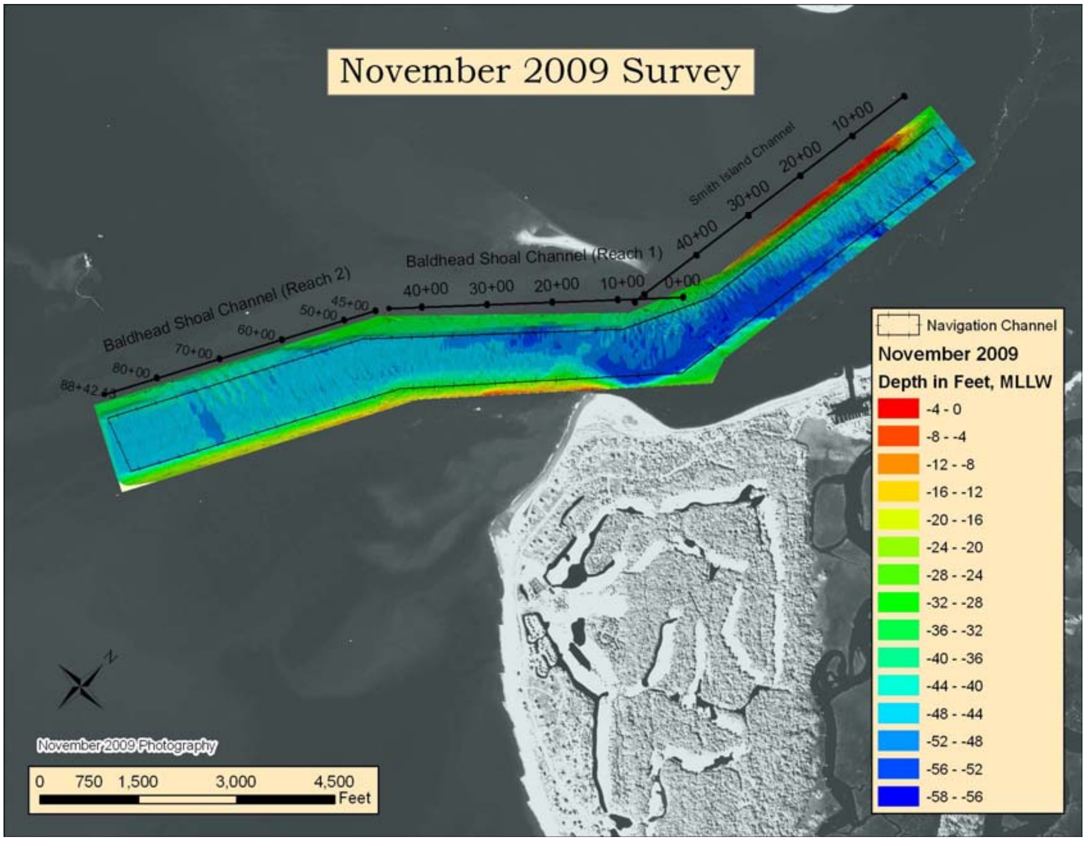


Figure 4.5. November 2009 Channel Conditions

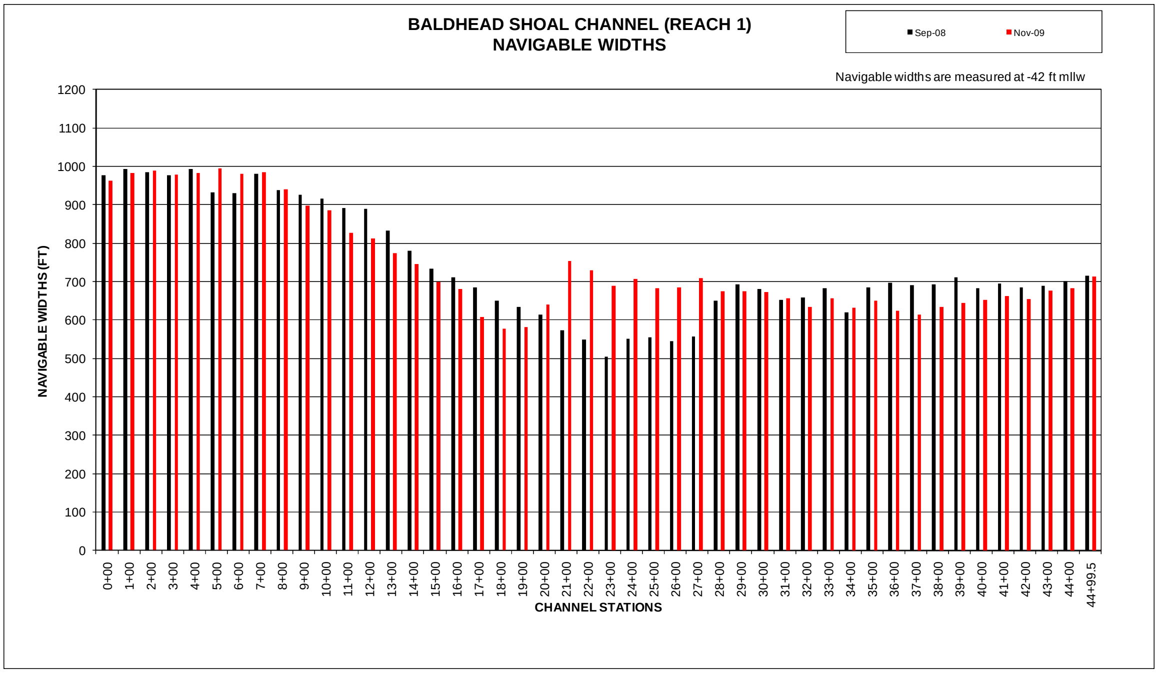


Figure 4.6. Baldhead Shoal Channel 1 Navigable Widths

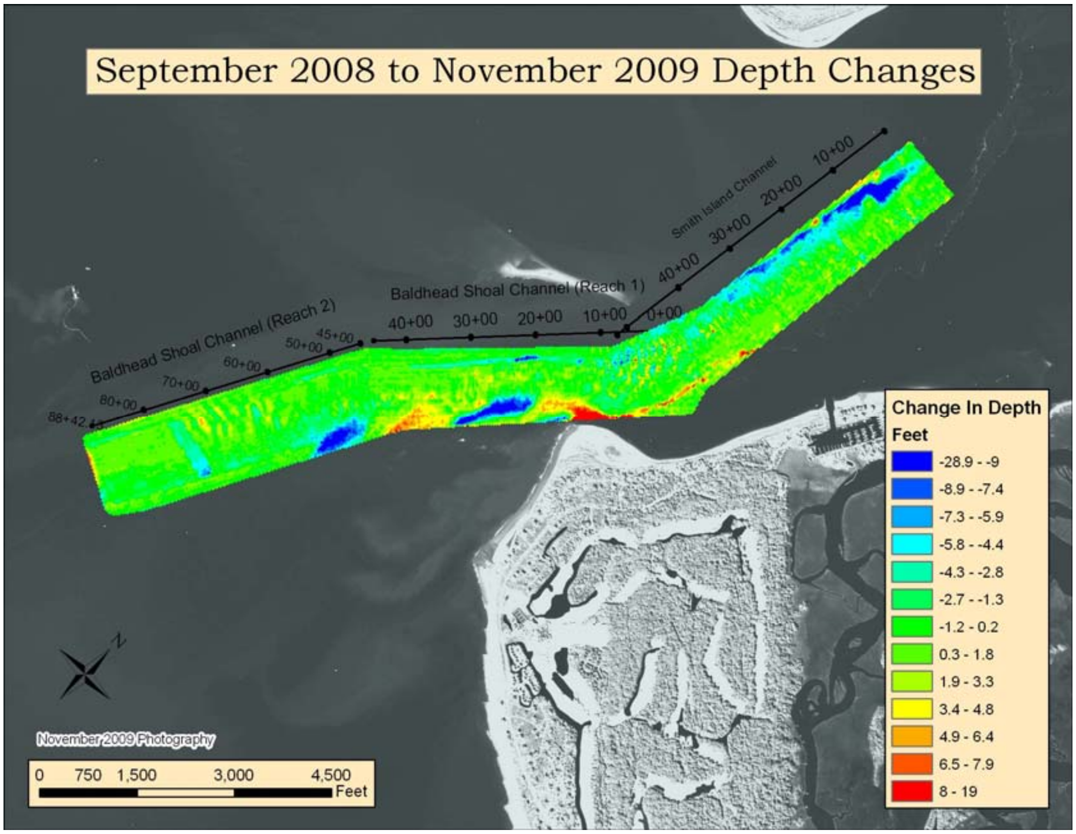


Figure 4.7 Depth changes from September 2008 to November 2009

The survey capturing base conditions following the third dredging event was obtained in June 2009 and is shown in Figure 4.8. This survey serves as the base to which all subsequent surveys are compared when capturing changes that may occur during the third dredging cycle. The minimum navigable width measured in the June 2009 survey was 605 feet at Station 35+00. Cumulative changes from the most recent survey included in Monitoring Report 7, November 2009, to the June 2009 base condition survey are shown in Figure 4.9. Areas of significant change within this Figure are similar to those observed in Figure 4.7. Areas may indicate shoaling during one time period while in other time periods they are erosive, however, this is due to dredging events in these areas not necessarily changes in shoaling patterns. Typically the areas of extreme change are the western side of the Smith Island channel, the eastern side of Bald Head Shoal Reach 1, and landward end of Bald Head Shoal Reach 2 along the eastern edge. The bottom depth changes show slight shoaling throughout all three reaches. The relatively small changes seen throughout the channel are most likely due to the small five month duration separating the two surveys used for comparison.

Figure 4.10 (Stations 0+00 to 23+00) and 4.11 (Stations 24+00 to 45+00) show navigable widths for various time periods along Reach 1 over the entire third dredge monitoring cycle. This graph illustrates the impact of the dredging event on the navigable width of the channel. Significant increases in channel width are observed between stations 19+00 and 28+00 as well as stations 42+00 through 44+99. Since the base survey the majority of the stations within this reach have remained relatively stable. The areas of exception to this stability were between stations19+00 and 20+00 and stations 42+00 through 44+99. These areas rapidly lost navigable width following the dredge activity; however all remain much greater than the deemed minimum navigable threshold width.

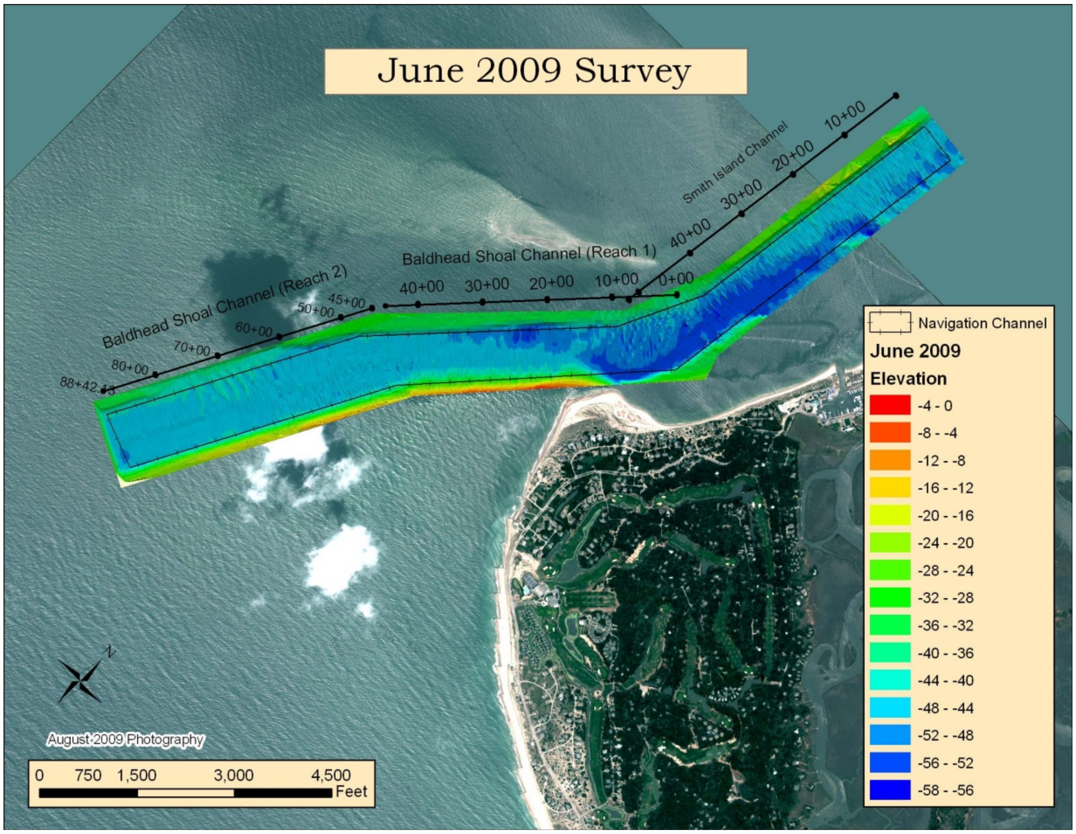


Figure 4.8 June 2009 Survey

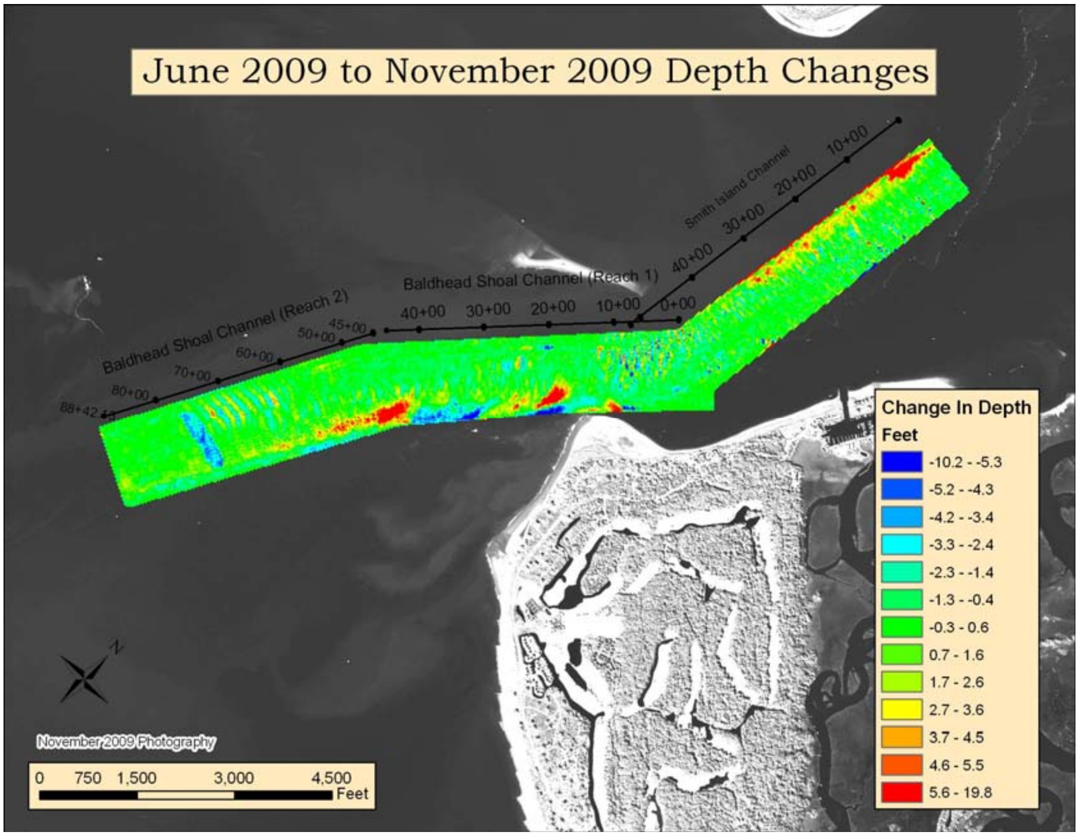


Figure 4.9 Depth changes from June 2009 to November 2009

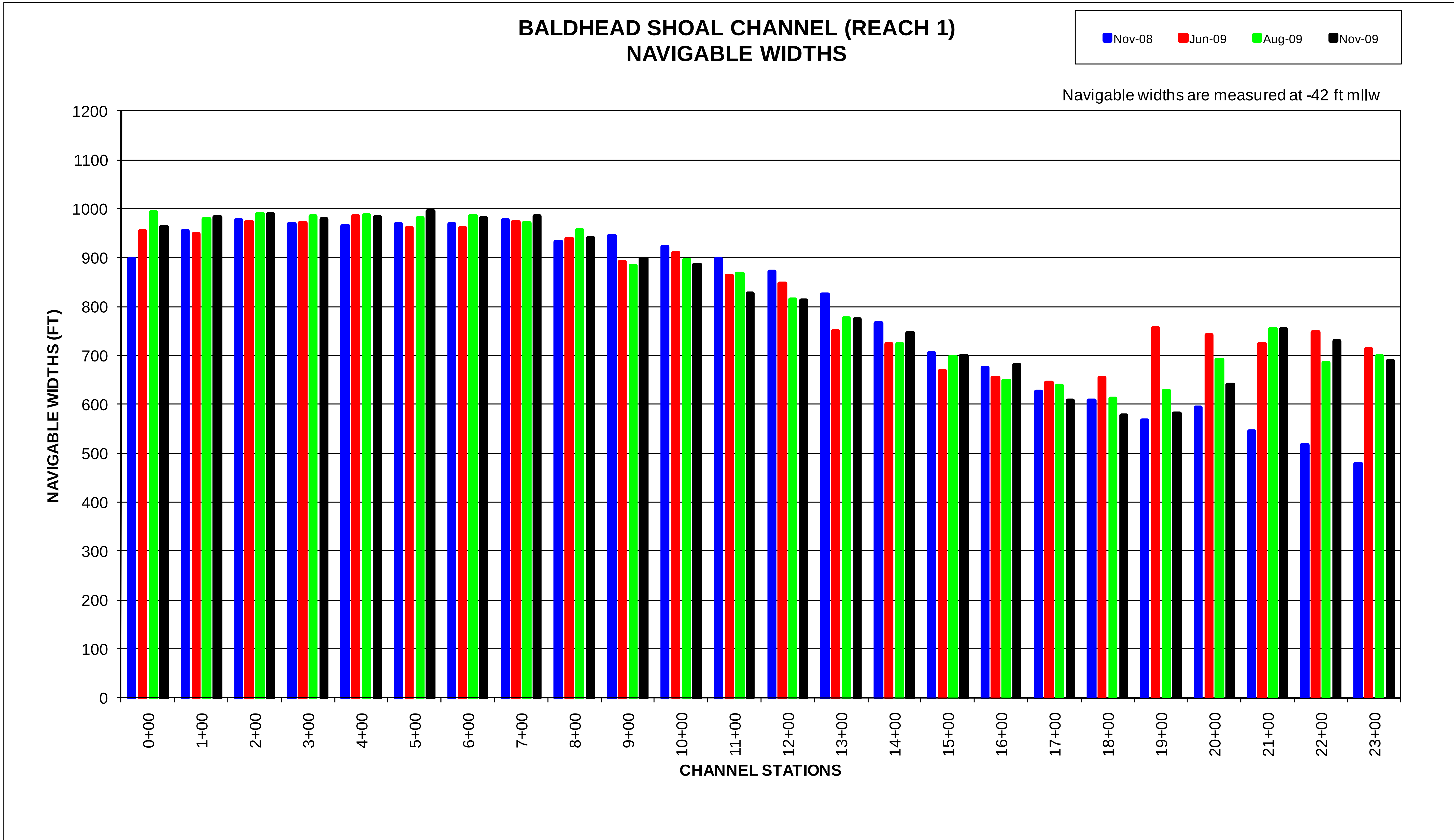


Figure 4.10. Baldhead Shoal Channel 1 width by station: Station 0+00 to 23+00

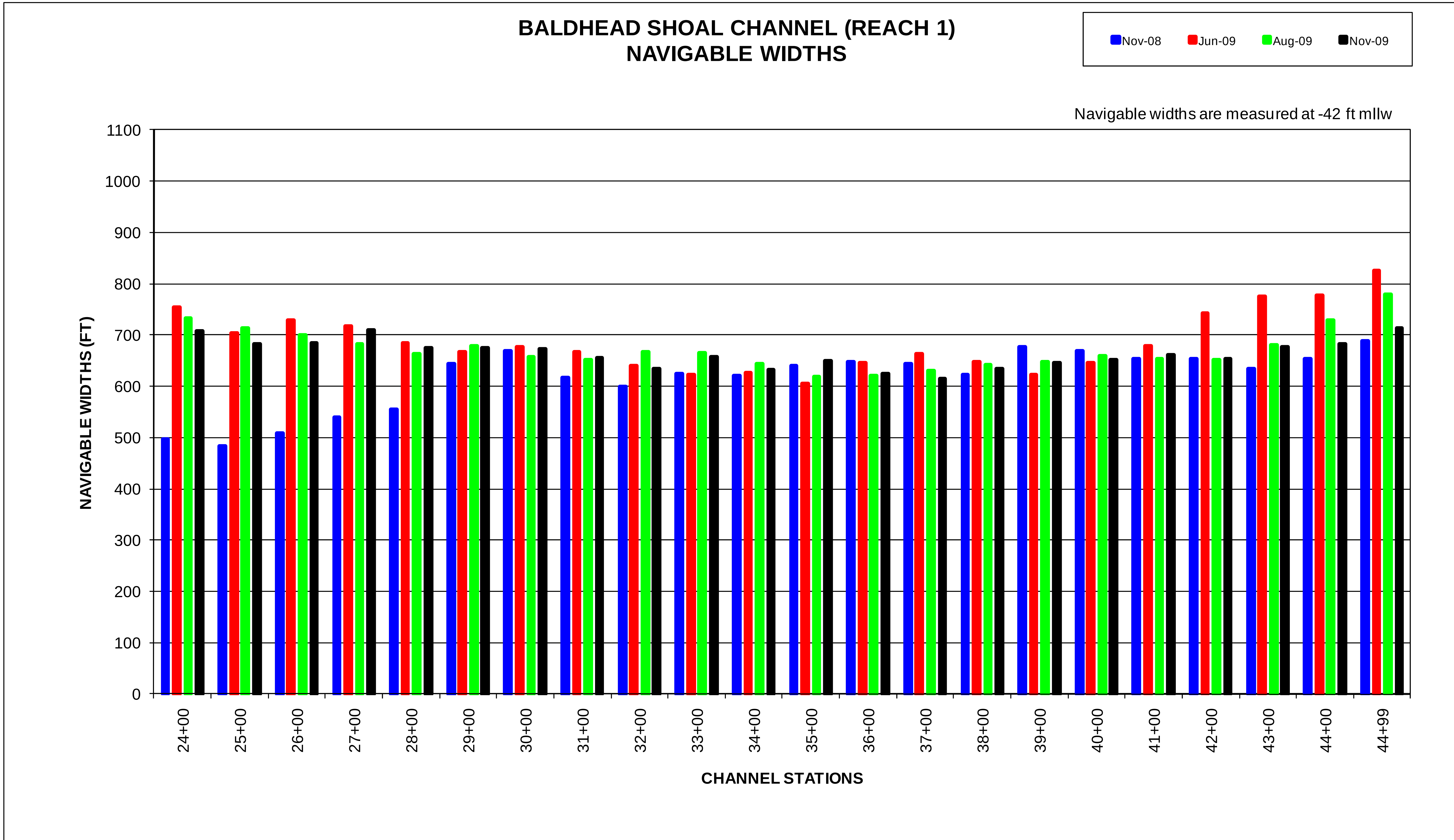


Figure 4.11. Baldhead Shoal Channel 1 width by station: Station 24+00 to 45+00

Spit Growth. To measure and compare the shoaling rates of the navigation channel adjacent to the Bald Head Island spit following dredging and beach nourishment activities, a portion of the adjacent navigation channel was separated into three separate analysis areas. The analysis and comparison of the shoaling rates within the areas seen in Figure 4.12 aid in determining the evolution of adjacent beach fills and provide information useful in determining future placement design locations. In addition, they offer another way to measure the efficacy of the groin field constructed along the western portion of South Beach by the Village of Bald Head Island.

The change in spit volumes above -44 ft MLLW for Baldhead Shoal Reach 1 are shown in Figure 4.13 with the four dredging/placement events noted. Figure 4.14 shows a comparison of the four post-placement shoaling trends from Figure 4.13. Slopes following the first three dredging events were progressively shallower while the slope following the most recent dredging event more closely matches the original dredging response, although this most recent trend line is limited to only three data points. These slope differences indicate a different rate of spit volume growth, with a slower growth rate after the 2004/2005 and after the 2007 placement identified by the flatter slopes. Specifically, the initial rate was about 16,500 cubic yards per month. An analysis of all settlement surveys for the second dredging event, January 2005 through March 2007, showed that the spit growth had slowed to about 9,900 cubic yards per month, i.e., a 40 % reduction in the shoaling rate. Calculation of the shoaling rate from the data collected during the third monitoring period showed that the growth rate had continued to decrease from the previous two dredging cycles to a rate of 8,950 cubic yards per month. This is a 46% reduction in the shoaling rate versus the initial dredging operation and a 10% reduction when compared to the second dredge cycle. The most recent data collected within Reach 1 indicates the shoaling rate has increased to 13,500 cubic yards per month, which is approximately a 51% increase over the previous monitoring cycle. When compared to the shoaling rate following the initial dredging cycle, the current shoaling rate is lower by approximately 18%.

Among the possible explanations for the slower spit growth rate following the initial three dredging events are: (1) sand tube groin field constructed immediately after the 2004/2005 placement was effective in retaining the fill following the 2004/2005 and 2007 beach placements, (2) smaller volume of material placed in the 2004/2005 placement dispersed from the island at a slower rate, (3) smaller volume of material placed at a lower density over longer reaches during the 2007 dredge disposal, (4) different location of placement with the second fill being farther away from the channel, and/or (5) possible dissimilar wave and current conditions for each period of record.

The increased shoaling rate within Reach 1 of the navigation channel observed during the current monitoring period is most likely related to the failure of the groin field which was reconstructed following the 2004/2005 beach nourishment. Figure 4.15 displays the section of Bald Head Island where the reconstructed groin field is located, as well as a collection of digitized shorelines which show the impact of the groin field along the shoreline in this area. The shoreline comparison shows the most sever changes occurred along the western end of South Beach where the groin field was progressively failing over the monitoring period. As the western most groin would fail or have landward breaching, the corresponding shoreline loss within the vicinity of the groin would dramatically increase. This would put additional pressure on the next groin which would eventually cause its failure. Failure of the groin by landward breeching produced some of the most dramatic shoreline losses observed over the entire monitoring period. When the most current November 2009 shoreline position is compared to the June 2008 shoreline position included in Monitoring Report 6, the magnitude of the erosion along the west end of South Beach is clear. The shoreline has dramatically eroded between profiles 40 and 61 and is currently at its most landward position within the majority of this area since the start of the monitoring program. Erosion in this area is measured to be as much as 460' in the vicinity of profile 47 relative to the June 2008 shoreline position. A small section of the beach between stations 40+00 and 43+00, at which accretion was observed during the previous monitoring cycle has reversed trends and has eroded as much as 450' when compared with the June 2008 shoreline. The remainder of the shoreline east of profile 61 has seen less dramatic, but consistent erosion when compared to the June 2008 shoreline with only the area between profile 178 and 190 (not shown) remaining relatively stable. More detailed discussion of the failure of the Bald Head Island groin field is contained in the Groin Field Performance section of this report.

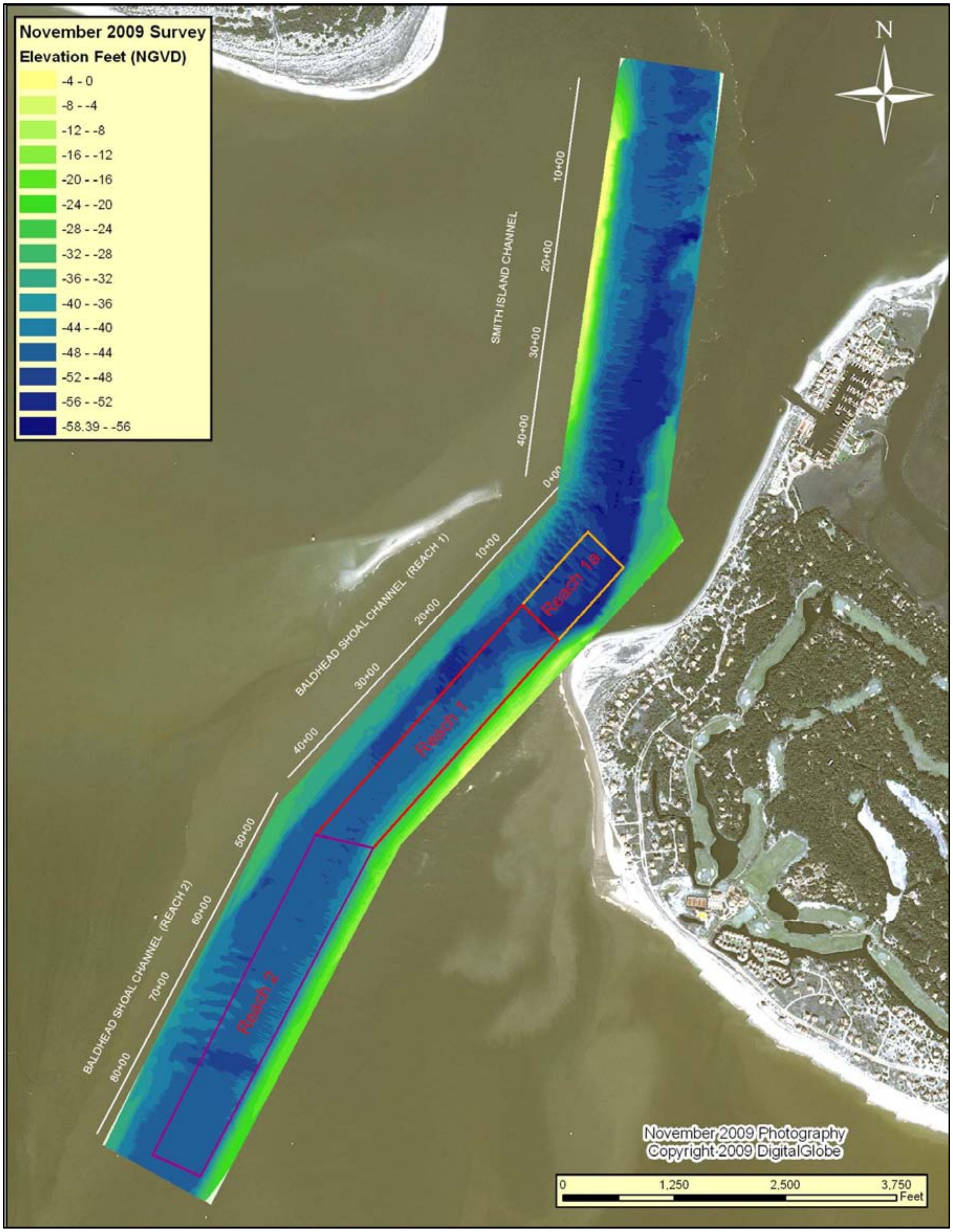


Figure 4.12 Spit Volume Bounding Polygons

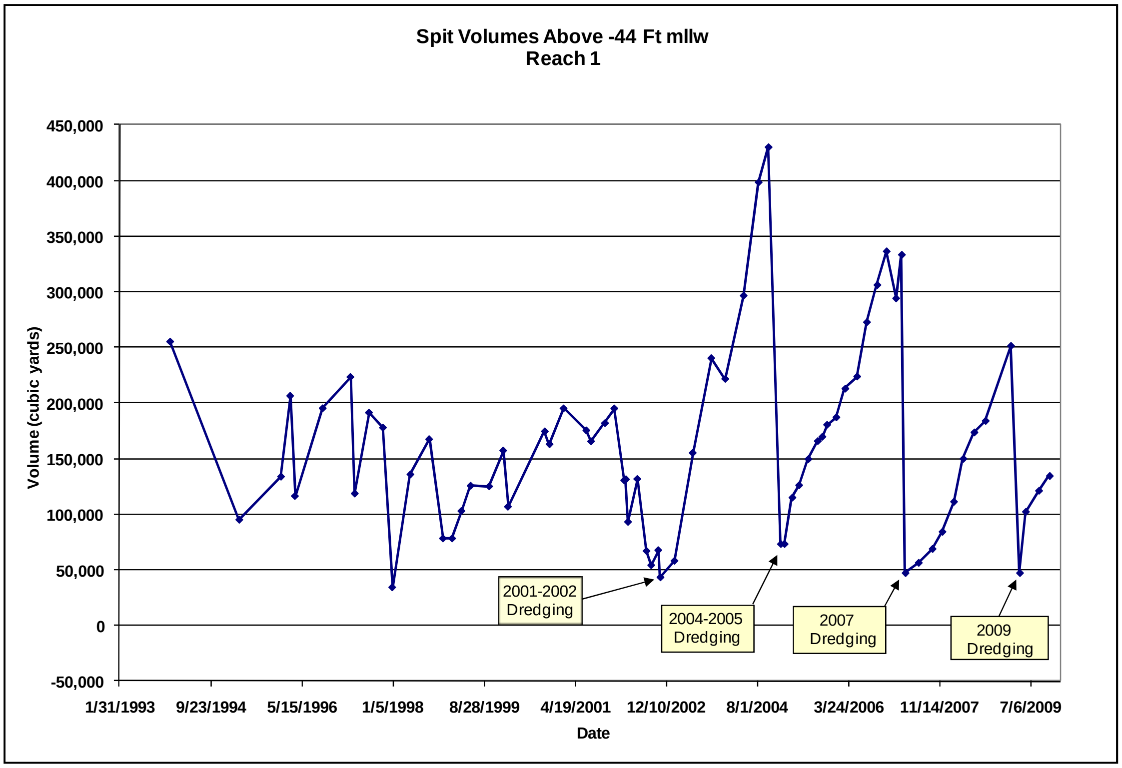


Figure 4.13 Baldhead Shoal Channel 1 Spit Volumes

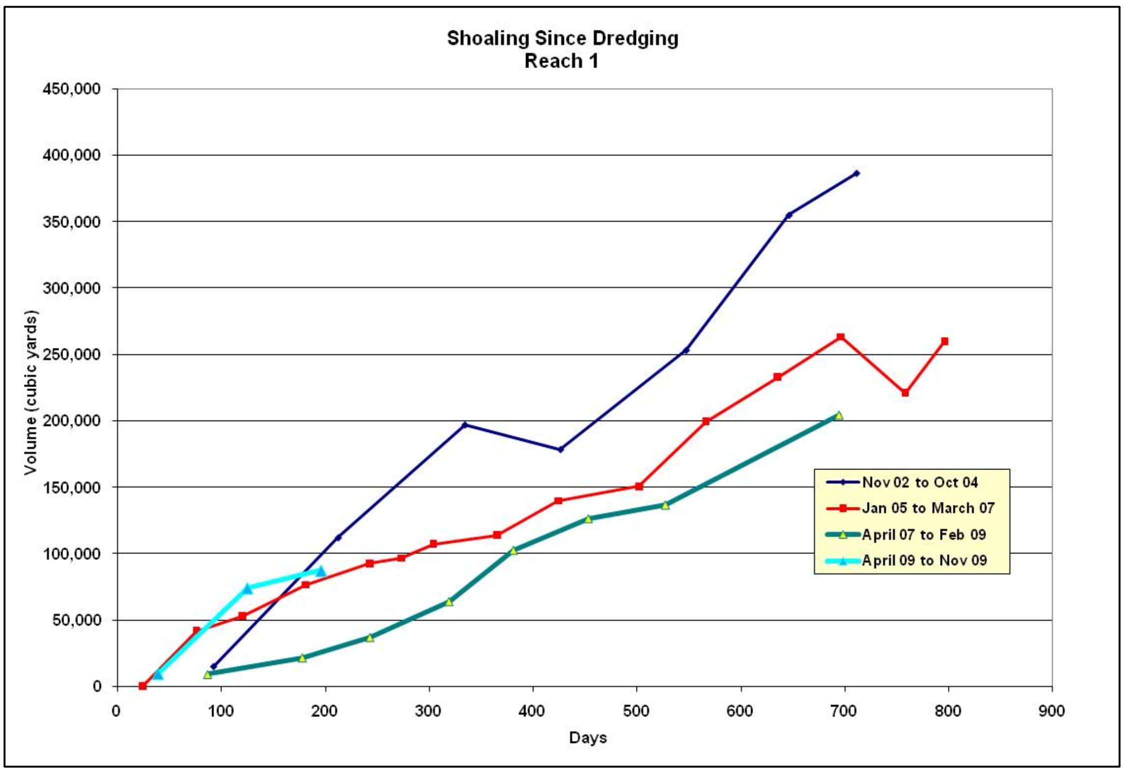


Figure 4.14 Comparison of post-placement spit growth from Figure 4.14 (Above)

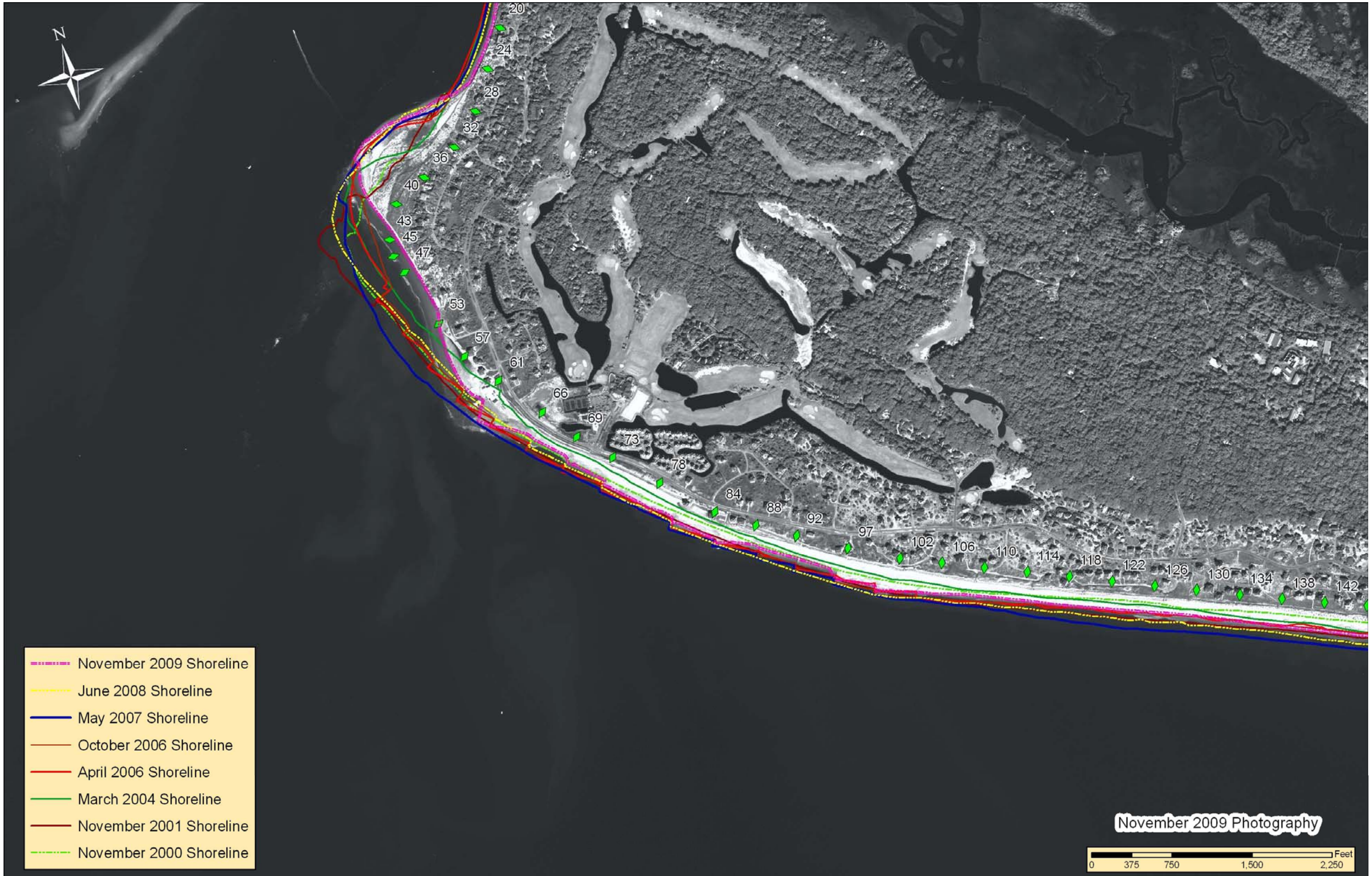


Figure 4.15 Shoreline Comparison: Pre and Post groin field reconstruction and beach disposal

Bald Head Groin Field Performance

General. In 1996, the Village of Bald Head Island constructed sixteen geo-textile groins. The groin field slowed the erosion for several years before they began to fail and ceased to function in 2000. Due to apparent effectiveness of the geo-textile groins, the Village decided to rebuild the groin field following the beach fill placement in 2005. As such, a sixteen structure sand tube groin field was reconstructed along South Beach between stations 47+00 and 105+00. The replacement geo-tubes were constructed between January and March 2005 using the in situ sand to fill the 300-foot long tubes.

The section of beach contained within the limits of the reconstructed groins has now received beach fill on three occasions to date. These occasions include the 2001 fill before the reconstruction, the 2005 fill with the reconstruction and the most recent 2007 fill. In this regard, it is possible to assess the performance of the groins by comparing the beach response with and without groins in place.

Shoreline Response. Changes in the position of the mean high water shoreline were calculated for selected monitoring surveys following each of the first three fills. In each case, the shorelines measured from the profiles contained within the influence of the groin field were compared to the first post-fill survey (for 2001, 2005, and 2007). The results are given in Figure 4.18, showing the shoreline changes for six surveys following the first fill, four surveys following the second fill, and four surveys following the third and most recent fill. The surveys following the first fill are displayed as solid brown lines, the post-second fill surveys are displayed as dashed blue lines, and the surveys following the third fill are displayed as solid green lines. The total time spans reported in the figure are different for each of the fills, spanning 35 months for the first fill cycle, 23 months for the second fill, and 22 months for the third fill. In this regard, shoreline changes over similar time frames can be compared by using the June 2003, February 2007, and May 2009 survey dates all of which are approximately 22 to 24 months after their respective fills. This comparison, shown as a heavy weighted line in each case, shows the shoreline retreats on average are decreasing with each successive fill event. Specifically, the average retreat within the area of the groin field approximately 23 months after each fill event was 164 feet for the first fill with no groin field in place, 94 feet after the second fill with the newly constructed groin field in place, and 80 feet following the third event with the groin field in place. The results further indicate that the shoreline losses vary throughout the groin field during the post-third fill analysis period and are not uniformly eroding which was the trend following the first and second fill. This is due in part to the adjustment of the shoreline that followed the failure of sections of the groin field which is discussed further within this section. The magnitude of the shoreline losses also varies throughout the groin field which is a reversal of trends previously reported in Monitoring Report 6. The western end of the groin field has experienced the largest shoreline changes during the post-third fill period since the initial fill in 2001. During this same time the shoreline along the eastern half of the groin field is in its most stable period.

As an additional comparison in shoreline response, the rate of shoreline change was computed for each of the periods following the three beach fill placements. This comparison is shown in Figure 4.18. The results show that when compared to the shoreline change rates computed following the first fill, all of the profiles following the third fill have a lower change rate with the exception of the two most western profiles within the groin field area. In addition, the change rates following the third fill are all lower than those calculated following the second fill with the exception of the four most western profiles. This is consistent with the results reported in Monitoring Report 6.

Aerial photography was obtained for six time periods since the placement of the third fill on Bald Head Island which include: May 2008, November 2008, January 2009, March 2009, August 2009, and November 2009. Figures 4.19 and 4.20 display the available aerial photography with digitized shorelines overlaid to show changes relative to the May 2008 shoreline condition. The May 2008 shoreline was chosen as a representative shoreline condition following the fill which concluded in April 2008 where the majority of the groin field appeared to be intact and functioning properly. The May 2008 shoreline is included in each photograph within the figures to serve as a reference shoreline when viewing subsequent photography.

Analysis of the existing groin field through comparison of available aerial photography shows that the changes in the shoreline position and rate of shoreline change have been significantly impacted by the failure or degradation of the groin field structures. The first image in Figure 4.19 is the May 2008 photography showing a post-fill condition along the beach where the shoreline appears relatively stable with the majority of the groin field cells on each end of the groin field near capacity. The second image in Figure 4.19 shows the significant changes that occurred within the six months between May and November 2008. During this period of time the central portion of the groin field functioned as designed and captured sediment moving west and extended the shoreline seaward in these areas. The dramatic decrease in shoreline width in the area surrounding profile 43, which was as much as 240 feet, may have been influenced by this groin field capturing of some of the longshore sediment flow toward the inlet. The erosion within this area is predominately due to the coastal processes that occur at the downdrift end of the groin field. Wave refraction around the end groin in the field results in changed wave impact angles and localized currents that play a significant role in downdrift erosion. As this downdrift erosion progresses into January 2009 (image three of Figure 4.19) the shoreline is eroded beyond the end point of the western most groin. As a result, this section of the groin field is exposed to severe wave and tide action which begins to rapidly deteriorate the structure. Failure of this structure and subsequent loss of beach shift the erosional pressure to the next groin (# 2) and puts it under increased stress from increased wave and current forces.

Also visible in the January 2009 image is the reaction of the shoreline to the apparent deterioration of groin 13 near the eastern end of the field. While the reason for the failure of this groin is unknown, it appears from the January 2009 survey data and photography that the seaward end of the groin was undermined which damaged its seaward end and resulted in rapid deflation of the groin. The reaction of the groin cells to the east and west of groin 13 is evident in the figure with the shoreline retreating significantly just downdrift of groin 14, forming one cell between groin 12 and 14.

The progressive cycle of groin failure and negative shoreline response continues into March 2009, (Image 1 in Figure 4.19). By this point groins 1, 2, and 3 are not functioning and groin 4 is being flanked on the western side by wave and tide action. Figures 4.20 and 4.21 are ground images taken along the western end of the groin field which show the western most groins in a failed condition. Notice that in addition to the deflation of these groins shown in the photographs, the shoreline has eroded beyond the landward limit of the groin. This not only renders them ineffective, but also can accelerate the erosion process as water is forced between the remaining landward end of the groin and the eroding beach scarp. The process is most acute during periods of high water when tidal and wave induced currents are constrained within this flanked area.

The remaining two photographs in Figure 4.19 show the continued degradation of the shoreline though November 2009. The shoreline along the western end of the groin field has eroded in some locations to its most landward location since the start of the monitoring program. These shoreline positions are discussed in greater detail within the shoreline analysis section of this report. Visible within the November 2009 image in Figure 4.19 is the initial stages of a beach re-nourishment operation between profile 61 and 66 along the western end of South Beach. The project is planned to place between 1.5 and 2.0 million cubic yards of material along South Beach along with the construction of a new groin field within the same general area of the field constructed in 2005. The construction of a new groin field within this area will conclude the analysis of the performance of the groin field constructed in 2005. A new cycle of performance monitoring will be included in Monitoring Report 8 to document the performance of the newly constructed groin field following the 2009/2010 beach fill.

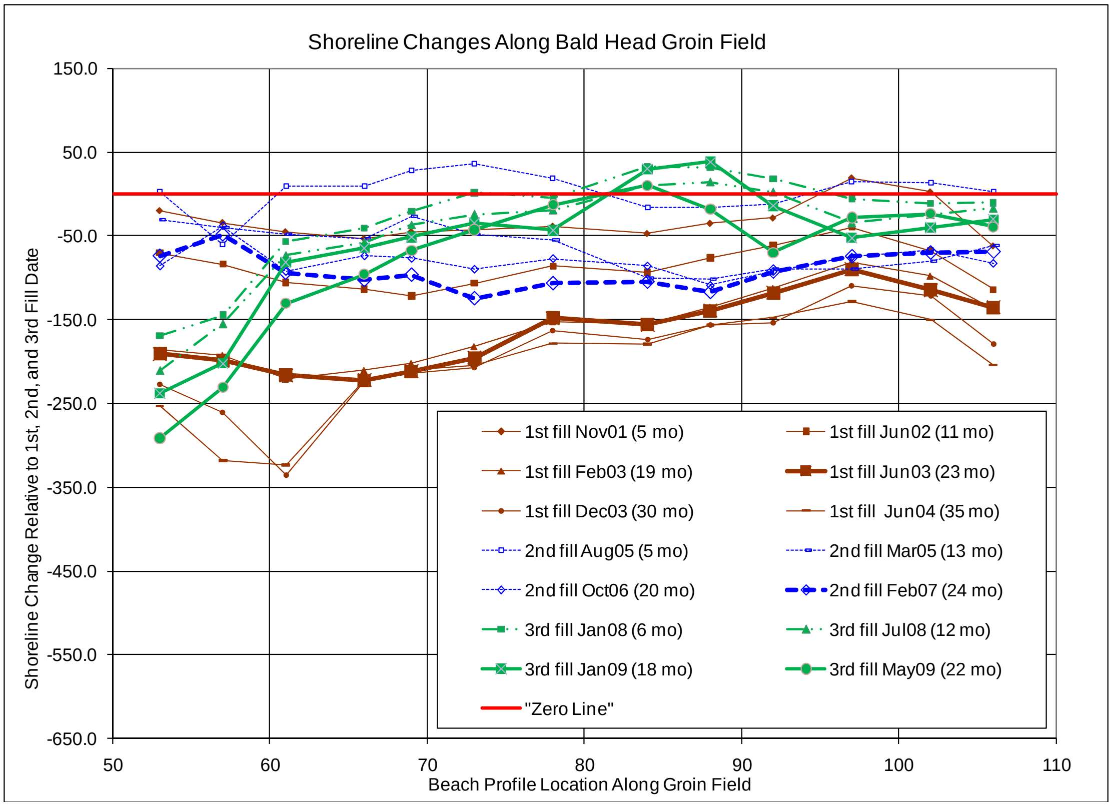


Figure 4.16 Shoreline Changes Along Bald Head Groin Field

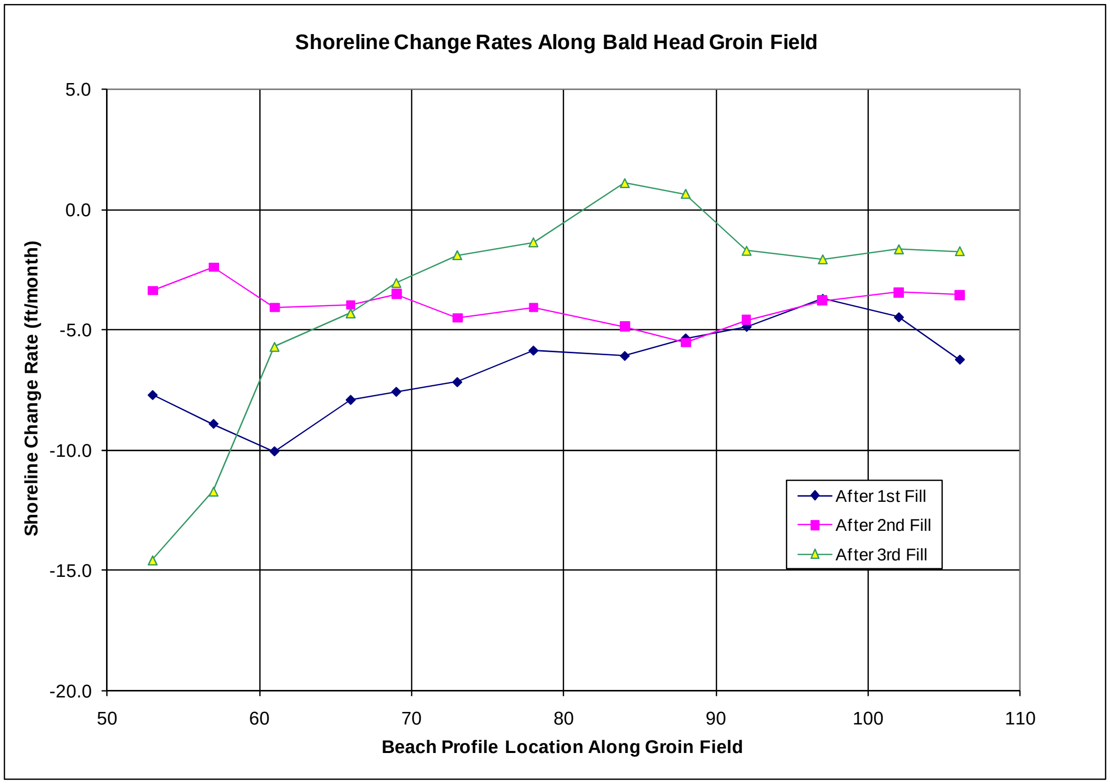


Figure 4.17 Shoreline Change Rates Along Bald Head Groin Field

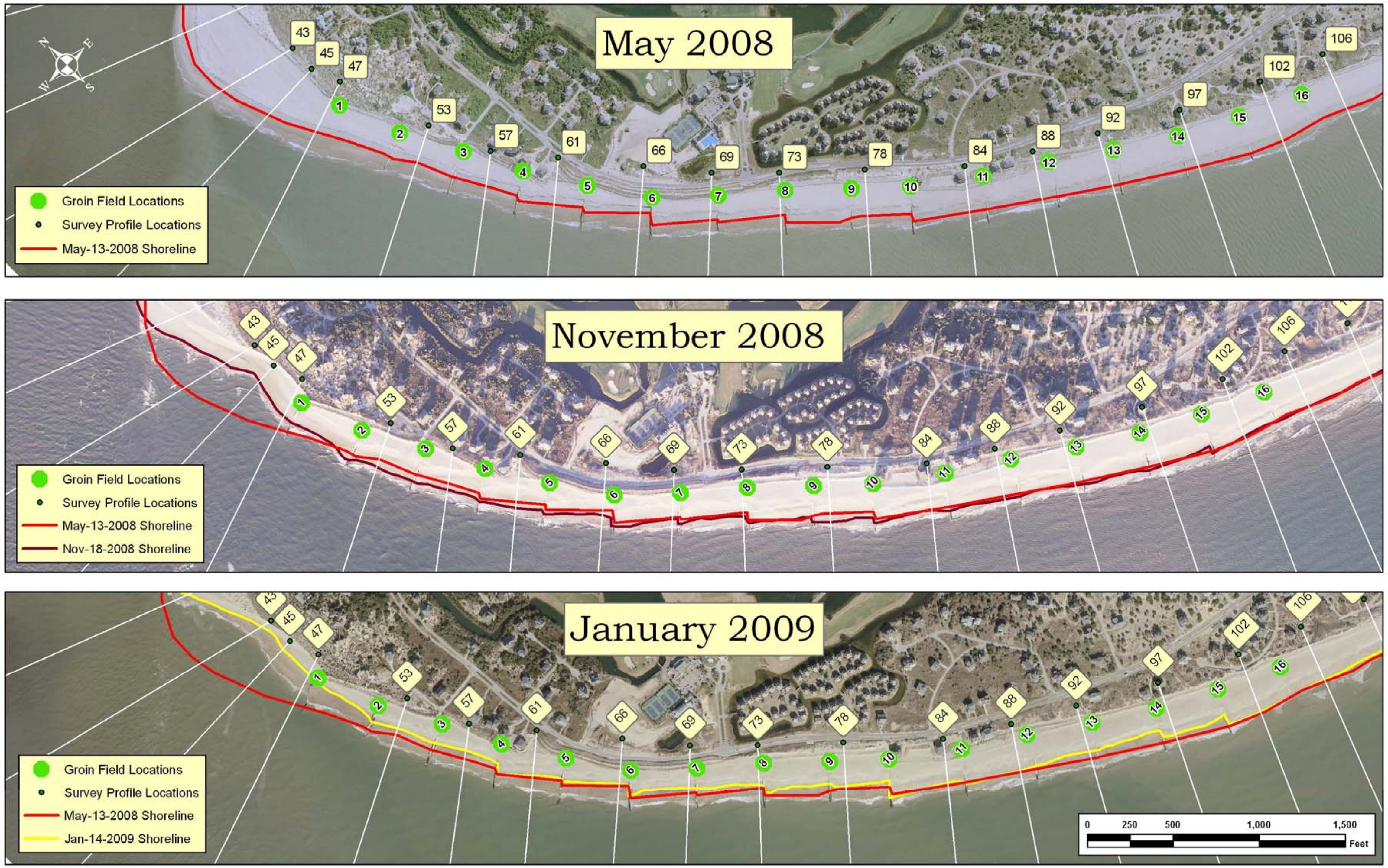


Figure 4.18 Evolution of Groin Field Shoreline (May 2008, November 2008, and January 2009)

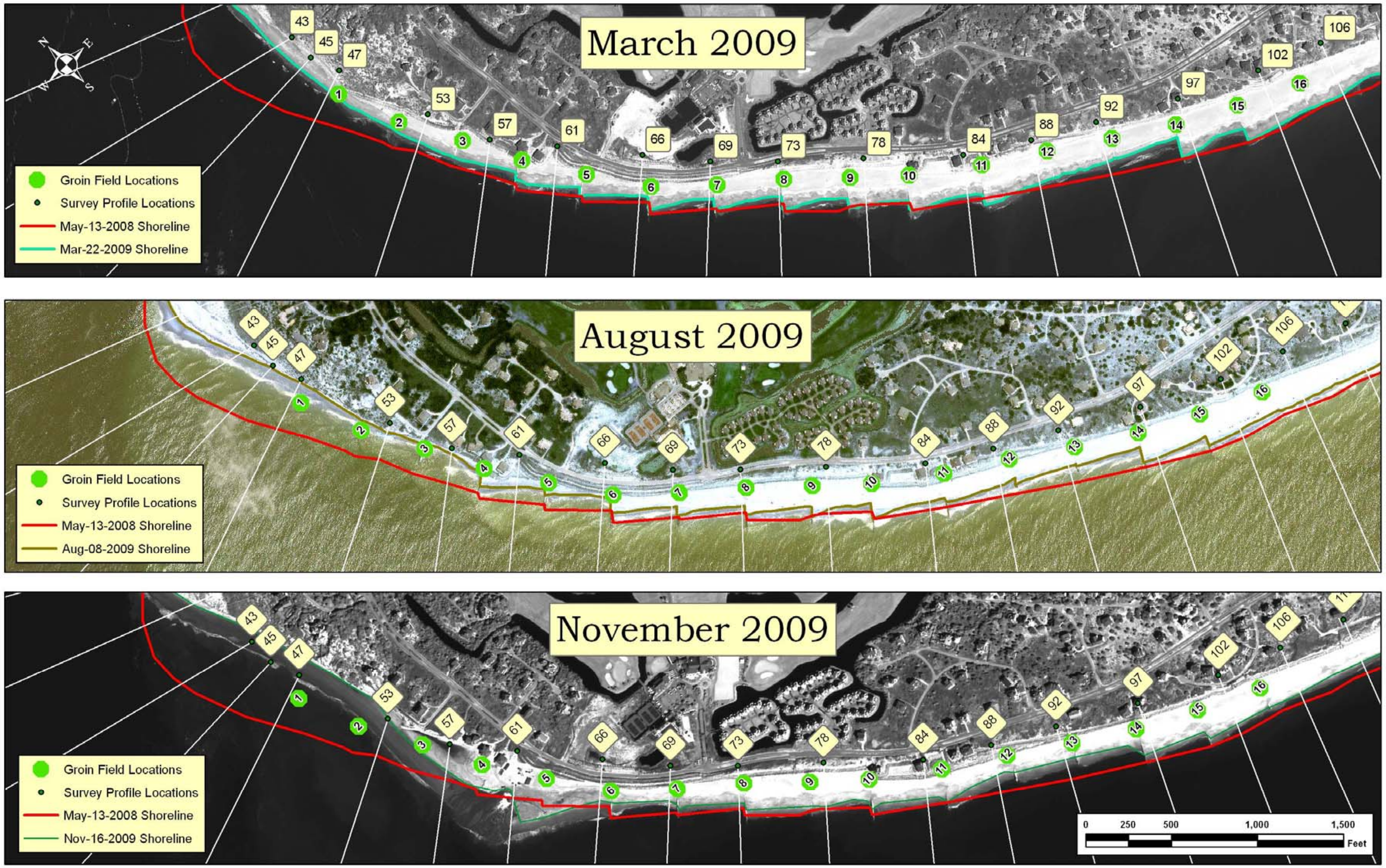


Figure 4.19 Evolution of Groin Field Shoreline (March 2009, August 2009, and November 2009)

Figure 4.20 May 2009 Ground Photography of Western Groin

Figure 4.21 September 2009 Ground Photography of Western Groin

Profile Volume Response. Volumetric changes were also computed and compared for each of the three post-fill periods within the zone covered by the reconstructed groins. Similar to the prior section of the report documenting the shoreline changes, the volumetric changes were computed for selected post fill surveys documenting changes for each profile within the groin field area following each fill placement. These volume changes are shown in Figure 4.22 and reflect the total volumes computed over the entire active profile out to the depth of closure. The values associated with the first fill are given in solid brown lines on the graph, the second fill volume change data are shown with dashed blue lines, and the third fill volume change data are shown as solid green lines. Unlike the first two post-fill periods which show a general progressive loss of the fills over time, the post-third fill is more erratic. The western end of the groin field zone is losing material at a faster rate than the first two time periods. Over this same time period the eastern two thirds of the zone are relatively stable, with overall losses less than the previous two time periods. As stated earlier in this section, the extreme loss of material in the western third of the groin field zone is most likely related to the damaged groins in the area no longer functioning as designed.

In comparing the post-fill response over similar spans of time, two surveys associated with the initial fill, namely December 2002 (17 months) and the January 2004 (30 months) are used to bracket the comparable date of the second and third fill. These dates bracket the comparable 23 month time span of the January 2007 survey of the second fill and the 22 month time span of the May 2009 survey for the third fill. These plots are shown with a heavy weighted line for each case, where with all other factors being the same, the January 2007 (23 month) blue-dash line and May 2009 solid green line should fall about midway between the two bold solid-brown lines from the initial fill period. This comparison reveals that for the overall volume change, the losses are found to be about the same along the eastern half of the groin field between the first and second fill, however, the losses following the third fill are slightly less in this area for the similar time period. Losses along the western half of the groin field are similar between the first and third fill which is due to the failure of the groin field in this area during the third fill period. The average loss across the entire groin field for these similar time periods is estimated to be 600,000 cubic yards associated with the first fill versus 440,000 cubic yards, for the second fill, and 470,000 cubic yards following the third fill.

The volumetric rates of change along the Bald Head groin field are shown plotted in Figure 4.23 for each of the fills. Following the trend noted in the above paragraph, the volumetric rate losses are found to be greater in the western portion of the groin field with the highest rates following the third fill. The rates following the third fill for the eastern two-thirds of the groin field are less than the erosion rates following both the initial and second fill. None of the profiles within the groin field indicate accretion during any of the time periods analyzed, unlike what was observed at profiles 88 and 97 and reported in the previous monitoring report.

Due to the overall extent of the structures, which can only directly influence the upper portions of the profile, (typically above the -2 foot elevation or greater), the volumetric changes are further divided into onshore and offshore changes, i.e. above and below -2 ft NGVD. The onshore changes are given in Figure 4.24 for selected post fill surveys for all three fills. Figure 4.25 likewise shows the rates of onshore volume change computed over each of the fill periods.

From Figure 4.24 it is evident that onshore volume losses were significantly greater following the first fill without the benefit of the groins, versus the second and third fill periods. Along the western portions of the groin field is where the greatest difference is found, with losses being on the order of three times as large. The third fill period continues to show even lower losses of material throughout the zone than the second fill. Losses within the third time period were fairly uniform as reported in the previous monitoring report, with the most significant losses occurring along the western end of the groin field. When comparing the onshore changes within the groin field along a similar time frame (22 to 23 months), the third fill period lost the least amount of fill material with a total of 86,600 cubic yards. This compares to a 187,000 cubic yard loss measured over the second fill through the January 2007 (22 month) survey and a loss of 405,000 cubic yards measured over the initial fill through the average of the December 2002 (17 month) and January 2004 (30 month) survey.

When the volumetric change rates are compared (as shown in Figure 4.25), no significant similarities are found between the first two fills and the most recent event. The change rates are erosive in the western and eastern ends of the groin field and are accreting between profiles 78 and 97. This is a reversal of what is observed following the second fill even though the groin field is in place during both time periods. This reversal is most likely due to placement location and quantity differences between the second and third fills.

The offshore volumetric changes (below -2 ft NGVD) computed along the groin field are shown in Figure 4.26. As in the previous figures, the bold solid brown lines of the first fill (without groins) can be compared to the second fill (with groins) in the associated bold dashed blue line and the third fill (with groins) in the associated bold solid green line. It is evident from Figure 4.26 that the response in the offshore is similar except for the middle portions of the area around Profile 88 and the western end of the field. Where the post-first fill response in the middle portion of the island was erosive, the post-second and third fill responses are more erosive particularly in the vicinity of Profile 88. The higher erosion observed during the post-second and third fills is most likely due to the groin field functioning and retaining material in the nearshore. This retention of material in the nearshore prevented the replenishment of material in the offshore that would normally occur during profile equilibration of a beach fill. During the post-third fill period the groin field is observed to be damaged and possibly is not retaining material in the nearshore as efficiently as during the post-second fill time period. The material is allowed to migrate from the nearshore into the offshore, lessening the observed erosion within the offshore area. In terms of overall volume change in the offshore (compared using the same time periods as the onshore), the total losses of the first fill amounted to 191,400 cubic yards. This compares with a loss of 251,900 cubic yards with the second fill and 380,000 cubic yards following the third fill at approximately 23 months following each fill. This quantity for the third fill is heavily skewed by the extensive erosion on the western end where approximately 264,000 of the 380,000 cubic yards of material were lost.

The computed volumetric change rates for the offshore portions of the profiles are shown in Figure 4.27. This plot shows that along the western end of the groin field the erosion rates are higher following each fill period, particularly following the third fill. The eastern two thirds of the groin field shows a similar pattern of volumetric change rates following the first and third fills, while the change rates following the second fill are generally more erosive.

In summary, the reconstructed groins have had an overall positive effect in retaining the beach to date. This is evident by comparing the beach fill response for two periods, one with and one without the groins. This is particularly evident within the upper portions of the beach profile which are reflected in the positive response measured with respect to shoreline change and changes in the onshore volumes. Changes of this nature would be expected given the cross-shore extent of the groins having a length of about 300 feet, and with the shoreward end of the groins terminating at elevations of about -2 feet or above. Damage to the groin field has been observed and evidence of this is shown in the increased erosion in the nearshore portion of the profile along the western end of the field. Other groins within the field are misaligned and many have failed. However, the positive effects on the shoreline from a properly functioning groin field are clearly visible from the monitoring data presented within this report. The re-construction of the groin field during the locally funded beach nourishment project between November 2009 and January 2010 will be monitored to see if a similar positive response is observed as with the 2005 re-construction.

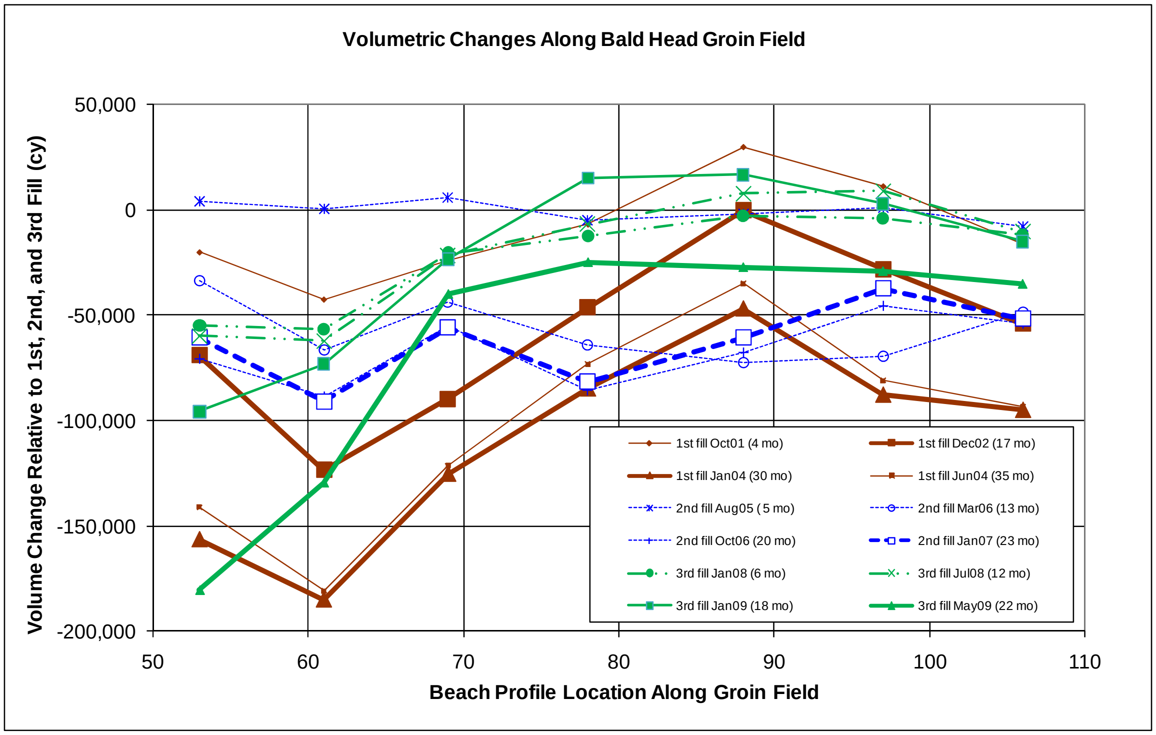


Figure 4.22 Volumetric Changes Along Bald Head Groin Field

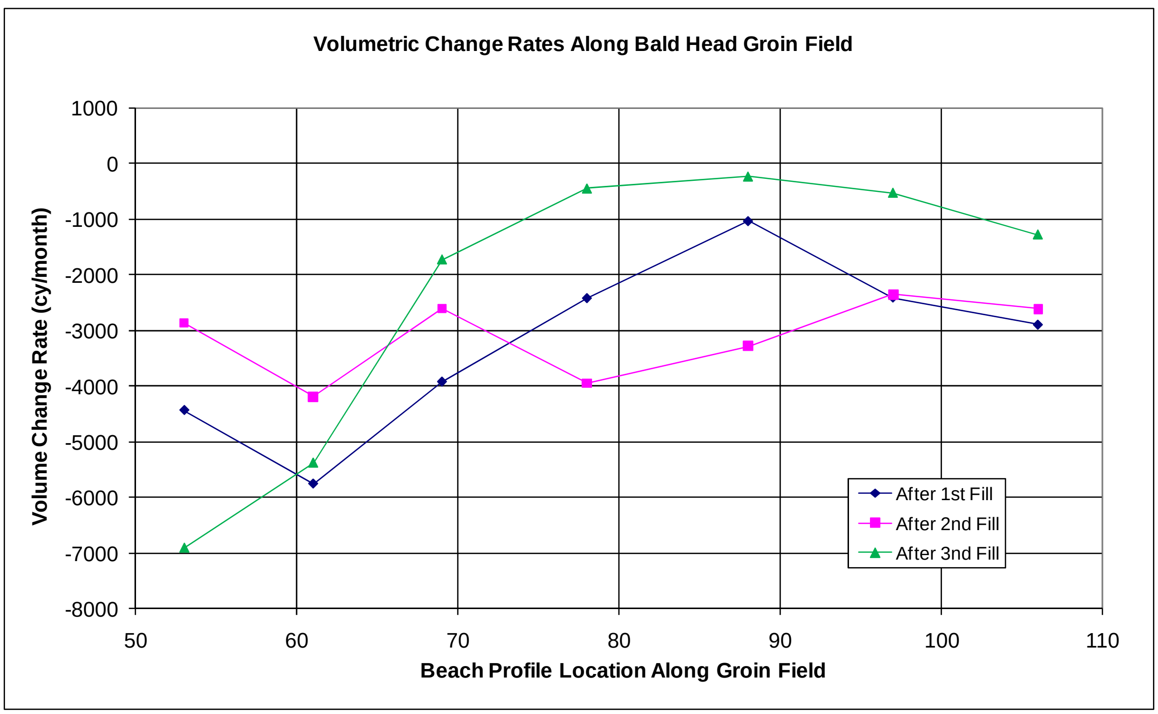


Figure 4.23 Volumetric Change Rates Along Bald Head Groin Field

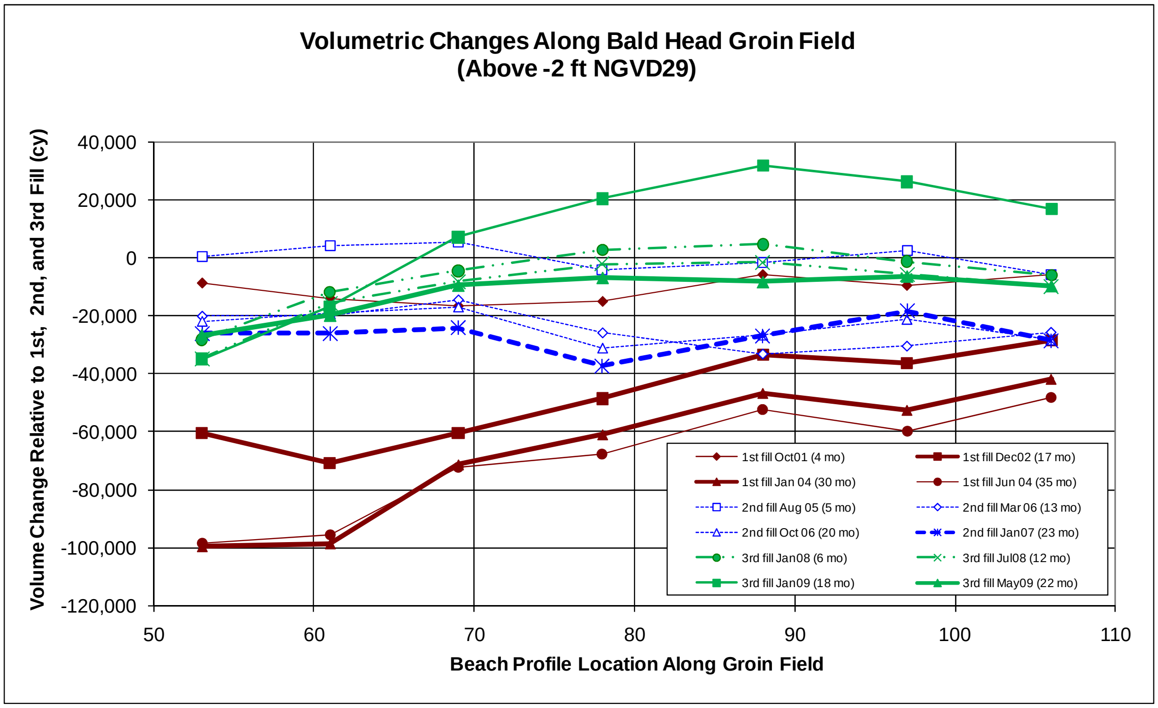


Figure 4.24 Onshore Volumetric Changes Along Bald Head Groin Field (Above -2 ft NGVD29)

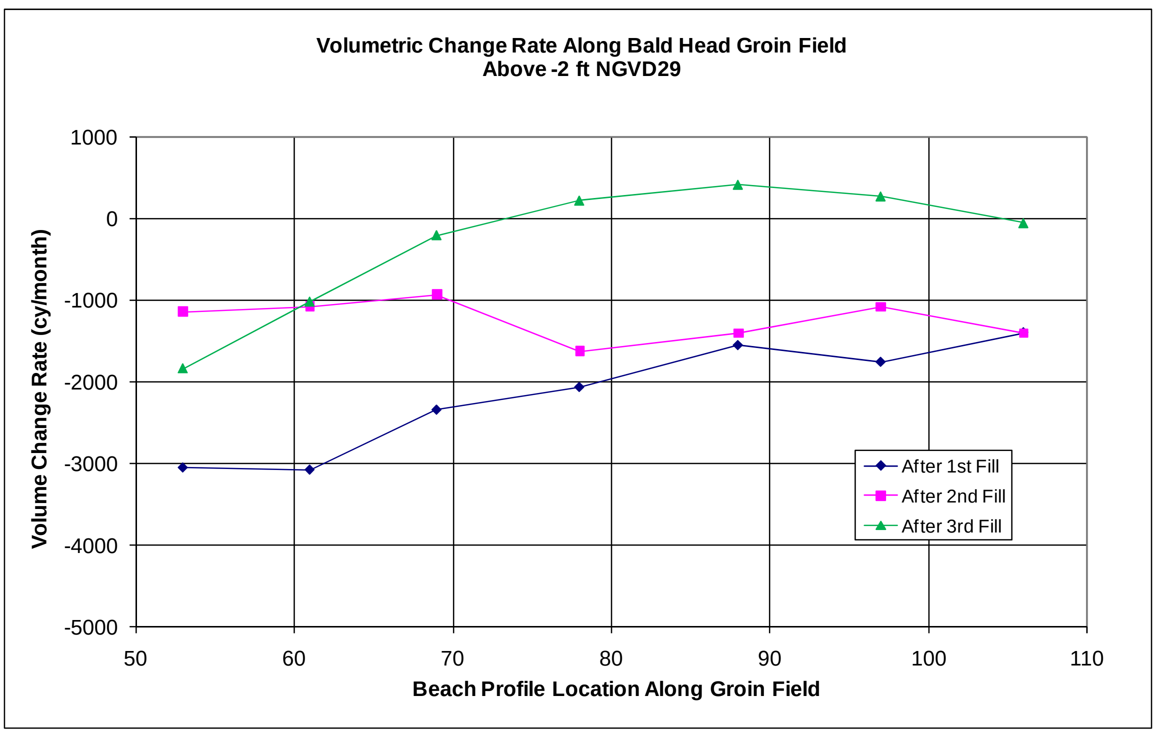


Figure 4.25 Onshore Volumetric Change Rates Along Bald Head Groin Field (Above -2 ft NGVD29)

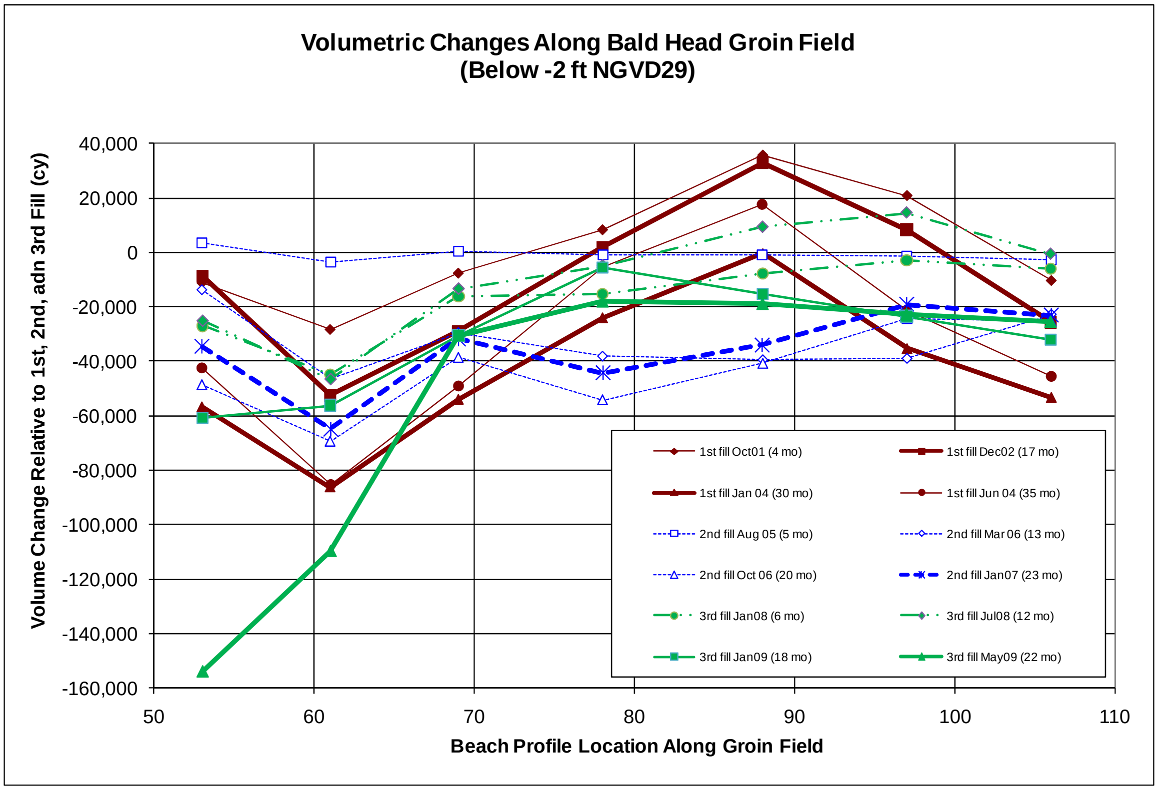


Figure 4.26 Offshore Volumetric Changes Along Bald Head Groin Field (Below -2 ft NGVD29)

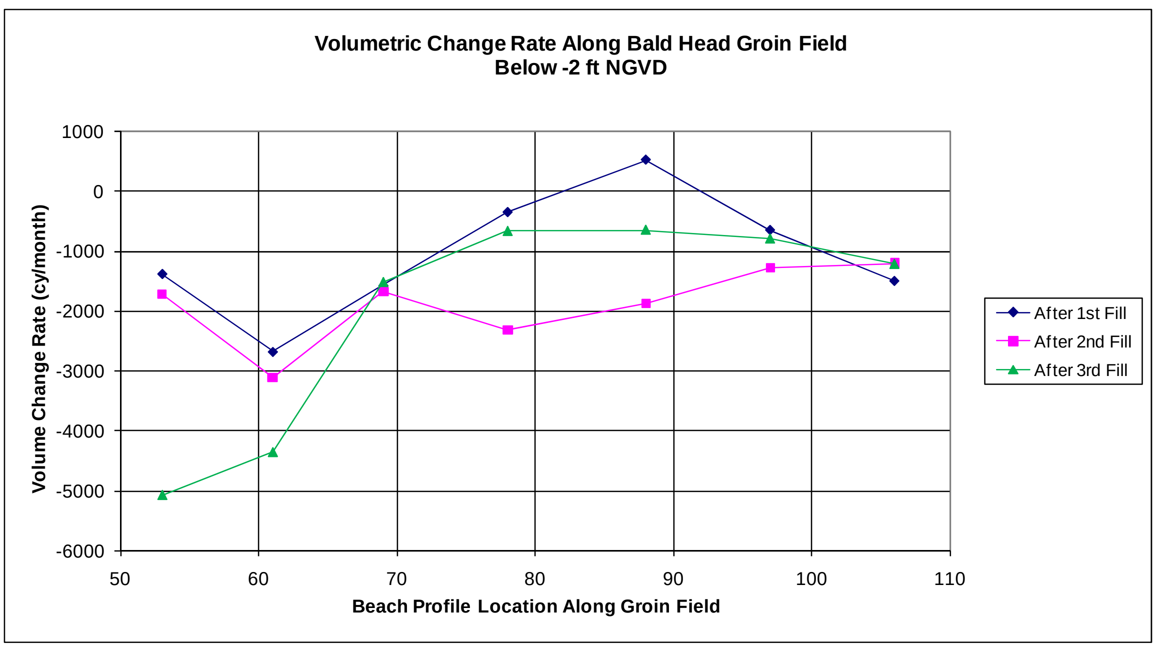


Figure 4.27 Offshore Volumetric Change Rates Along Bald Head Groin Field (Below -2 ft NGVD29)

Part 5 SUMMARY

This report is the seventh of a series updating the data collection and results of the physical monitoring program for the Wilmington Harbor Project. The program consists of periodic beach profile and bathymetric surveys, wave and current measurements designed to document changes associated with the project. The monitoring focuses on the entrance channel improvements and impacts to the adjacent beaches of Oak Island/Caswell Beach to the west and Bald Head Island to the east. It also serves as a tool for overall sand management considerations for the Cape Fear entrance and adjacent beaches. The report covers through the ninth year of data collection and focuses on the most recent period of October 2008 through September 2009. It also serves to update the overall monitoring program which was initiated in August 2000 just prior to the dredging and realignment of the entrance channel.

Over the 2001/2002 time period, the entrance channel was deepened and realigned with all beach compatible sediment being placed on the Brunswick County beaches including the beaches of Oak Island/Caswell and Bald Head Islands, both of which fall within the monitoring limits. Within the monitoring area, approximately 1,181,800 cubic yards of sand were placed on Oak Island/Caswell and 1,849,000 cubic yards were placed along Bald Head Island. In early 2005, the first maintenance dredging of the new channel was completed. In accordance with the sand management plan for the project, the first two maintenance cycles would involve disposal of all beach compatible material along Bald Head Island (with the third cycle to Oak Island). As such, approximately 1,217,500 cubic yards of beach fill were placed along the western half of Bald Head's South Beach. Following the fill placement, the Village of Bald Head proceeded with the reconstruction of a groin field along South Beach. The work consisted of replacement of 16 sand filled tubes, 250-300 feet in length, covering about 6,500 feet along the western end of the island. This was followed two years later by the second maintenance cycle, with an additional 978,500 cubic yards placed along Bald Head Island, over the period of February-April 2007. The most recent maintenance dredging undertaken involved placement of beach compatible sediments along Oak Island/Caswell Beach where approximately 1,064,400 cubic yards were placed between February and April 2009 as part of the third maintenance cycle. With this recent maintenance dredging/disposal along eastern Oak Island/Caswell Beach, the first full cycle has been accomplished in accordance with the sand management plan. The response of the beaches to this most recent disposal will continue to be monitored over the next two years to assess the overall effectiveness of the sand management cycle.

Results to Date.

Beach profile surveys were compared for the beaches on either side of the entrance channel. In each case comparisons were made from the current surveys to the last survey as reported in Report 6 (July 2008) and with respect to the initial pre-project condition established with the survey of August/September 2000. Comparisons were analyzed to determine the overall condition of the beach with respect to both changes in shoreline and profile volumes. Shoreline and volumetric changes were computed over the current period (from July 2008 to May 2009) and for the entire period (from August/September 2000 to May 2009).

For Oak Island/Caswell Beach, the shoreline change measured over the last year has been greatly influenced by the disposal activity between February and April 2009 which resulted in an overall accreting beach. The disposal occurred in two zones along Oak Island between Profiles 60 and 95 (123,400 cubic yards) and Profiles 120 and 260 (941,000 cubic yards). Prior to the placement, the shoreline was generally receding particularly within the western half of the monitoring area. The placement of material within these zones advanced the shoreline between 80 and 180 feet. When considering the shoreline changes along Oak Island with respect to the pre-construction position in August 2000, the beach width has increased an average of 140 feet. In fact, with the exception of one profile location (Profile 45) and a few other locations along the eastern tip of the island all other lines have shown an increase in beach width of 50 feet or more. The shoreline position along the island just prior to the 2009 beach disposal was largely accretionary when compared to the pre-construction position as well. The average shoreline increase of 69 feet prior to the 2009 disposal is a reflective of the relative stability of this section of the beach as a whole.

In terms of volume change, Oak Island/Caswell Beach has shown mostly accretion over the current monitoring period due in most part to the disposal activity discussed above. The only exceptions were a zone extending between Profiles 10 & 45 on the eastern tip of the island and Profile 300 on the far western end of the island, which lost minor amounts of material. When considering all profile lines, a net gain of 1,130,098 cubic yards was computed since the last report, between July 2008 and May 2009. This gain reverses the general overall trend of losses that had been observed over the last several years. The overall volume response has been positive when considering the measurements over the entire 8.7-year monitoring period. As such, all reported volume changes are positive with the exception of four isolated profiles on the eastern tip of the island which show small losses. All other areas are very healthy with respect to volumetric gains relating back to August 2000 base condition. Specifically, by the end of the period, an excess of 2,411,837 cubic yards of material remains on Oak Island above the August 2000 pre-project condition. This quantity actually reflects a modest net gain above the sum of the fill volumes placed in 2001 and 2009 of about 204,693 cubic yards. This surplus above the placed quantity is believed to be the result of the eastward spreading of a separate beach fill (Sea Turtle Habitat Project in 2001) placed just beyond the boundary of the project area. The alongshore distribution of material basically follows the shoreline response where net gains are seen along most of the island.

Since the last reporting, most of the profile locations along Bald Head Island have been erosional. The profile locations found to be accretionary occurred along a short section of West Beach and a portion of the spit (Profiles 28 to 36) and along the eastern end of South Beach (Profiles 182 to 194), as well as a few intermittent profiles spread throughout the monitoring area. The largest retreats were measured along a 1,100 ft section of South Beach in the vicinity of the spit (Profiles 40 to 47). Specifically, the peak recession measured at the end of the period was 254 feet (Profile 43) and the average loss in this area was 208 feet. These losses represent some of the largest losses along the island since the initiation of the monitoring program. The area covering Profiles 32 through 45 which defines the spit had an average loss of 128 feet over the current period, while the area along West Beach (Profiles 0 thru 28) lost an average of 3 feet. When considering the overall area bounded by the limits of the 2007 fill (between Profiles 45 to 170), the shoreline was found to have eroded an average of 52 feet. The average loss for the entire monitoring area since Monitoring Report 6 is 40 feet.

Shoreline change patterns as measured over the last 8.7-year period, i.e., since the monitoring was initiated, are generally positive when measuring relative to the September 2000 base survey. For example, all lines along South Beach, extending eastward from Profile 78 are largely accretional, with the May 2009 shorelines being an average of 127 feet seaward of their September 2000 positions. In contrast, the western portion of South Beach is once again developing a highly erosional pattern as documented in prior reports. As of May 2009, the shoreline was found to be landward of the base position between Profiles 40 and 73, an area nearly 1,100 feet larger than the erosive area reported in Monitoring Report 6. The average shoreline loss over this 3,380 foot reach was 155 feet, with a peak recession of 331 feet occurring at Profile 43. Extending westward from this erosional reach is a 400 foot zone dominated by large accretions within the limits of the Bald Head spit. Here the shoreline is on the order of 230 feet wider than in 2000. For West Beach (Profiles 0 thru 28), located immediately along the river channel, the shoreline has shown an average loss of about 25 feet when compared to the base condition. When considering all locations along Bald Head Island (Profiles 0 to Profile 218), the shoreline is presently on the average 48 feet more seaward than it was in 2000.

In terms of volumetric change from the last survey (July 2008) of Report 6 to the present, Bald Head Island is dominated by losses throughout the monitoring area. Every profile within the monitoring area showed volumetric losses when compared to the July 2008 condition. In summing the changes over the entire monitoring area, the losses total to approximately 937,000 cubic yards of material. Of this, 49% was lost between Profiles 32 and 61 on the west end of South Beach. The zones along South Beach which received dredged material (Profiles 44 to 91 and 110 to 170) during the April 2007 placement were found to have lost nearly 614,000 cubic yards of sand. Cumulatively, since the fill was placed in 2007, this area has lost 1,052,500 cubic yards of sand which exceeds the 978,500 cubic yards placed.

When analyzing the total volumetric profile changes since the beginning of the monitoring in August 2000, Bald Head Island is split between areas of gains and losses over the last 8.7 years. The most substantial increases are found along the western half of South Beach and in the vicinity of the spit. Elsewhere, there are two areas which have recorded net overall losses for the entire period. One is located at the extreme eastern end of South Beach, where some losses have occurred near the cape. The other, which is of greater concern, is along the westernmost portion South Beach extending into the spit area between Profiles 45 to 106. This reach, which has expanded from 2,500 feet to nearly 6,100 feet since Monitoring Report 6, has been the site of chronic erosion in the past. Volumetrically this represents net loss of about 758,000 cubic yards. Aside from these areas of erosion, only Profiles 8 and 16 along West Beach shows a minor net loss of material compared with the base year condition. As a result of this overall response in the profiles, the net volume change is a modest gain of 118,000 cubic yards as of May 2009 with respect to the beginning of the monitoring in 2000.

Rates of shoreline change were likewise computed over the monitoring period. These rates were compared with long-term shoreline change rates computed from the North Carolina Division of Coastal Management (NCDCM) shoreline data based on a 62-year period of record (1938-2000). Although the monitoring period spans a relatively shorter time period of about 8.7 years to date, it is of interest to compare these trends with established long-term shoreline response for the area.

Shoreline change rates computed over the initial 8.7-year period show that for Oak Island/Caswell Beach substantial accretion is present over most of the island largely reflecting the influence of the 2001 and 2009 beach fills. Although these positive rates have been found to moderate since the fill placement, they remain in sharp contrast to the long-term trend. Overall, the shoreline change rate averaged over the entire monitoring area was about +16.3 feet per year for the 8.7-year period. By comparison the long-term NCDCM rate over the entire reach was –1.1 feet per year.

For Bald Head Island, the comparison of the long-term rates with the rates computed since 2000 show that most of the island is eroding less over the initial 8.7-year monitoring period. However, notwithstanding this overall positive response, the post-construction erosion rates continue to be greater along the western corner of South Beach. A direct comparison of the pre- and post-construction shoreline change rates show that only three profile lines are eroding at a higher rate during the post-construction period. These lines are located at the western end of South Beach (Profiles 53, 57 and 61). Adjacent Profiles 66 and 69 are presently eroding but at a lower rate as compared to the pre-construction condition. All other lines are accreting in direct contrast to the long-term erosion experienced along the remaining areas of South Beach. Most of this response is attributable to the beach fill placements and possibly to the positive effect of the rehabilitated groin field.

In March 2005, the Village of Bald Head and the Wilmington District entered into an agreement to conduct bi-monthly navigation channel surveys within the channel locations along the island. These surveys are intended to document the channel shoaling and to record the navigable channel width throughout the area. The threshold deemed to be a minimum acceptable channel width is 500 feet at the -42 feet mean low water (MLW) elevation. As of 2009, 27 condition surveys have been accomplished, five of which occurred over the present reporting period (February 2009, April 2009, June 2009, August 2009 and November 2009). The three most recent surveys are post-dredging settlement surveys, which follow the Feb-April 2009 channel dredging operation. The 2009 dredging event increased the navigable width measured at -42' MLW so that every profile within the navigation channel exceeds the minimum required navigable width of 500 feet. Widths within the channel as of November 2009 ranged from a minimum of 577 feet at station 18+00 to a maximum of 996 feet at station 5+00. The width at station 23+00, which has historically been a location of increased shoaling, had a navigable width of 690 feet as of November 2009.

The navigation channel surveys have also been used to analyze the rate of shoaling along Reach 1 in the immediate vicinity of the Bald Head spit. Following the initial placement of fill 2001-02 (1.8 million cubic yards), the area of the spit was found to have enlarged volumetrically to at least twice as large as previously observed. The same area of growth was monitored following the two subsequent dredging events (i.e. 2004-05 (1.2 million cubic yards and 2007 (1.0 million cubic yards). The comparison showed that the rate of growth was slower following both the second event and third events. Specifically, the initial rate was about 16,500 cubic yards per month. An analysis of all settlement surveys for the second dredging event, January 2005 through March 2007, showed that the spit growth had slowed to about 9,900 cubic yards per month, i.e., a 40 % reduction in the shoaling rate. Analysis for the third monitoring period, April 2007 through February 2009, shows that the growth rate has continued to decrease from the previous two dredging cycles and is now at a rate of 8,950 cubic yards per month. This is a 46% reduction in the shoaling rate versus the initial dredging operation and a 10% reduction when compared to the second dredge cycle. Calculation of the shoaling rate following the most recent dredging event in February-April 2009 revealed that the growth rate has increased to 13,500 cubic yards per month. This represents a 51% increase over the computed rate from the previous dredge cycle. However, this rate remains lower than the initial rate by nearly 18%. The recent increase in shoaling rates within the channel is most likely associated with the failure of the Bald Head Island groin field and the subsequent loss of material that had been retained within the field.

In prior reports the effectiveness of the reconstructed groins was analyzed by comparing the response of the 2001 beach fill (without the groins) to the 2006 beach fill (with the groins). The analysis revealed that the new groin field had an apparent positive effect in retaining the beach, particularly within the upper portions of the beach profile. This is reflected in the positive response with respect to shoreline change and changes in the onshore volumes. Changes of this nature would be expected given the cross-shore extent of the groins having a length of about 300 feet, and with the shoreward end of the groins terminating at elevations of about -2 feet or above. For the present report, this analysis was updated to include a similar comparison with the third beach fill for which about 22 months of monitoring data are now available. Comparisons were made over similar 22 to 24 month periods following each respective fill event. The results indicate that the groins have continued to have a positive effect on retaining the fill. Specifically, the average retreat within the area of the groin field approximately 22 to 24 months after each fill event was 164 feet for the first fill with no groin field in place, 94 feet after the second fill with the newly constructed groin field in place and 80 feet following the third event with the groin field in place. In contrast to this general response, the shoreline loss during the third fill continues to be much greater in the western end of the groin field, when compared to the prior two cycles. Shoreline retreats of over 250 feet are measured for the third 22 to 24 month period versus about 200 feet and 100 feet for the first and second fills. This accelerated erosion appears to be due to the western end of the groin field being damaged and as a result, not functioning properly.

Aerial photography of Bald Head Island obtained during the current monitoring period covers a longer timeline than the profile surveys from which volumetric changes within the groin field are measured. Photography for the island was obtained for May 2008, November 2008, and January, March, August, and November of 2009. Digitized shorelines from this photography were used to separately quantify shoreline impacts related to the failure of the groin field. The photography revealed that the majority of the groin field had progressively failed from the west toward the east. This failure and the resulting loss of the sand contained within the groin field coupled with the down drift erosion associated with the groin field adjusting to its new western limits have produced shoreline erosion to its most landward point since the initiation of the monitoring program. The photography also shows, in the November 2009 image, the initial stages of a reconstruction of the groin field within the same general area as the 2005 construction. This new groin field is being constructed as part of the locally funded beach nourishment project undertaken by the Village of Bald Head Island in 2009/2010.

Detailed bathymetric surveys were made of the ebb and nearshore shoals in the vicinity of the entrance channel to assess any changes associated with the entrance channel deepening and realignment. Aside from the direct changes resulting from dredging the new channel, the major overall changes in morphology of the ebb and nearshore shoals since the start of the monitoring have included changes along Jay Bird Shoals, Bald Head Shoals, and within the vicinity of the old channel bed. The changes within Jay Bird Shoals have been somewhat complex with some portions shoaling and some portions scouring. Generally, the outer portions have shown a generalized lowering but a moderate amount of shoaling has occurred within the northernmost area of Jay Bird Shoals just off the tip of Oak Island. Adjacent to this shoal is a scour feature associated with a flood channel just offshore of Oak Island although the most recent surveys have shown this feature to have become more stable, and little change is noted in this area when the January 2009 survey is compared with the January 2008 survey. On the other side of the channel, Bald Head Shoal has shown significant gains extending off of the southwestern corner of Bald Head Island. Additionally, the old channel bed has also accreted since the beginning of the monitoring period, as this area is used as a disposal site for other dredging operations in the river. In general, the offshore area, with the exception of the old and new channels, have remained relatively stable since the last monitoring report with only minor shoaling noted west of the channel.

To date currents have been measured on nine occasions, with the initial occurring before the channel improvements and the remaining eight after the deepening. Currents are measured over a complete tidal cycle along transects across the mouth of the entrance channel and along the seaward portion of the ebb tide delta near the intersection of the old and new channel alignments. Comparison of current measurements taken before and after the channel dredging show very similar flow regimes and are consistent with the minimal change seen in the overall bathymetry of the ebb tide delta. Of interest, however, is that with each of the post-dredging measurements, the maximum velocities are found to be greater than those of initial current survey. This was evident with both the inlet and offshore transects.

Sand Management Considerations.

Operation of the project involves the implementation of a Sand Management Plan. Under this plan, disposal of beach compatible sediment is to occur on the beaches adjacent to the Cape Fear River entrance every 2 years. The distribution is such that disposal is to occur in a 2 to 1 ratio with two-thirds of the material going to Bald Head Island and the remaining one-third to Oak Island/Caswell Beach. This sediment ratio is accomplished by having the first two maintenance cycles (i.e. years 2 and 4) place sediment on Bald Head with the last cycle going to Oak Island/Caswell. Thus a complete operation and maintenance cycle will take 6-years to accomplish.

The first maintenance dredging was accomplished between November 2004 and January 2005. In accordance with the sand management plan, the beach compatible material dredged during the first cycle was placed along Bald Head Island. The Corps of Engineers and the Village of Bald Head worked jointly to develop this disposal plan. Approximately 1,217,500 cubic yards of beach quality sediment were placed along the most critically eroding portions of South Beach. This work was coupled with the replacement of geo-textile groins by the Village of Bald Head under a private permit action, with the intent of reducing the erosion of the in-place fill. The groin reconstruction took place over the period of March-May 2005. The second maintenance cycle occurred February-April 2007 and involved disposal of material along Bald Head Island as scheduled. This operation amounted to an additional 978,500 cubic yards placed along South Beach. The most recent maintenance dredging involved placement of beach compatible sediments along Oak Island/Caswell Beach. During this work, the third maintenance cycle, approximately 1,064,400 cubic yards were placed between February and April 2009. With the completion of this maintenance dredging, the first overall 2 to 1 sand management cycle has been accomplished (i.e. through the 6-year cycle).

In accordance with the sand management plan, an assessment is to be made following the completion of the first full cycle regarding the effectiveness of the current sand distribution scheme and determine if changes are warranted. To properly evaluate the present sand sharing ratio, an additional two years of monitoring data will be evaluated following the Oak Island/Caswell disposal, thereby assessing a full disposal cycle. The results of the reevaluation will be contained in the next monitoring report. Aside from the analysis of the physical data collected to date, the reassessment will also include the results of a numerical modeling effort which is presently underway. The modeling study uses the Corps' Coastal Modeling System (CMS) to estimate circulation, wave transformation, sediment transport and morphology changes within the Cape Fear region. This involves a wave transformation model, (CMS-WAVE) and a current/sediment transport model (CMS-FLOW). In the mean time, plans are being made for the next disposal operation on Bald Head Island in 2011 as originally scheduled; assuming funds are available for this purpose.

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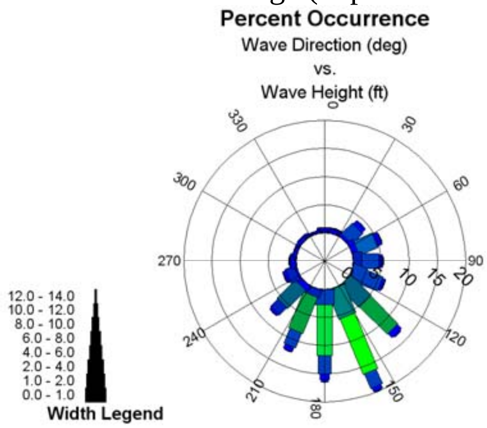
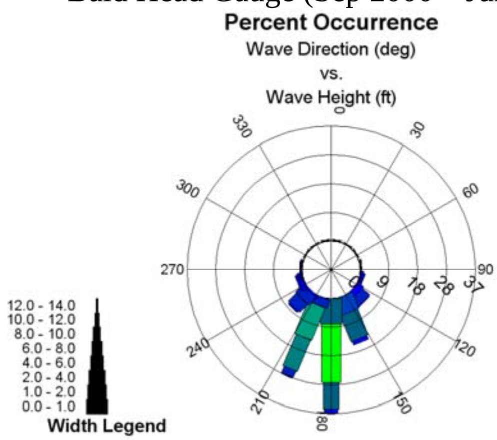
Appendix A

WAVE GAUGE DATA
Wave Roses (2000 thru 2009)

Eleven-Mile Gauge (Sep 2000 – Jun 2009)



Bald Head Gauge (Sep 2000 – Jun 2009)



Oak Island Gauge (Sep 2000 –Jun 2009)

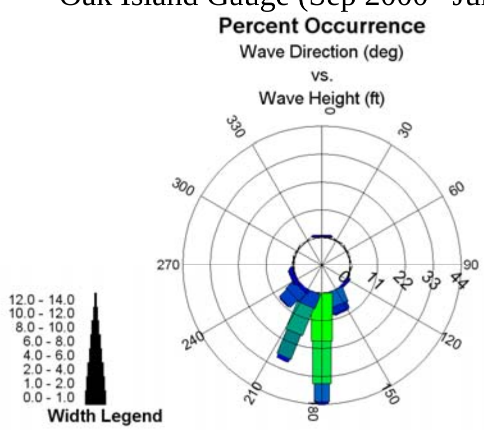
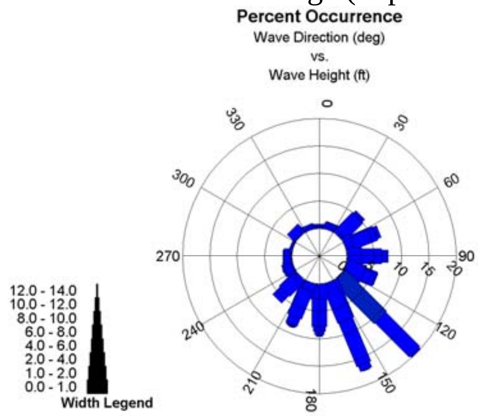
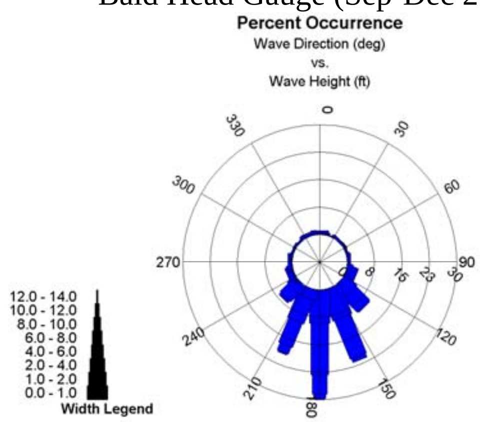


Figure A-1 Wave Height Roses for FRF Gauges throughout deployment.

Eleven-Mile Gauge (Sep-Dec 2000)



Bald Head Gauge (Sep-Dec 2000)



Oak Island Gauge (Sep-Oct 2000)

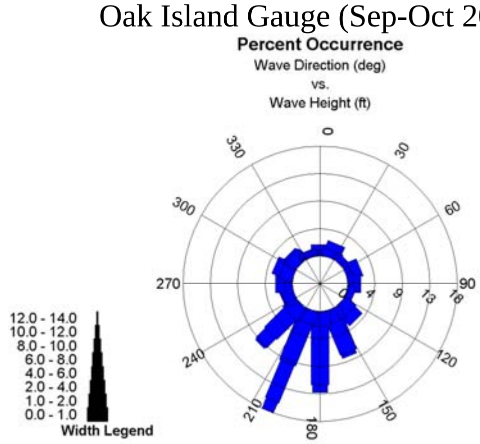
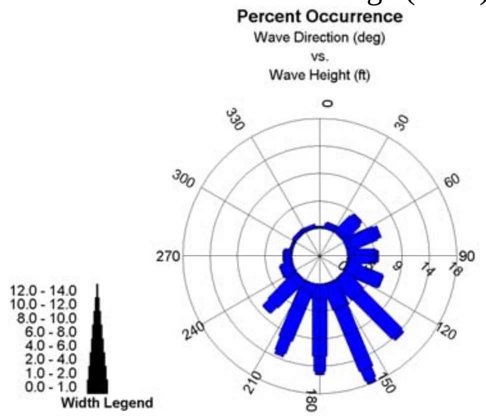
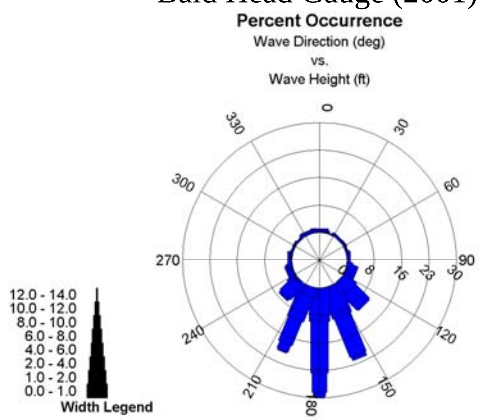


Figure A-2 Wave Height Roses for FRF Gauges (2000).

Eleven-Mile Gauge (2001)



Bald Head Gauge (2001)



Oak Island Gauge (2001)

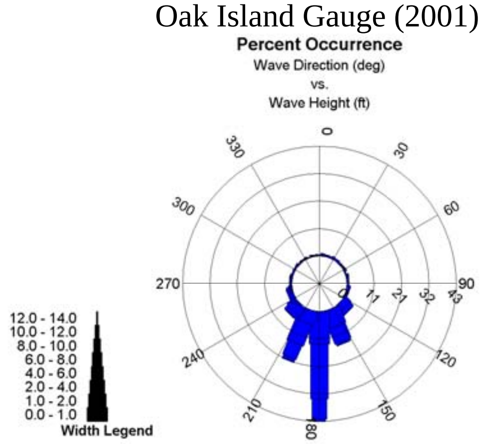
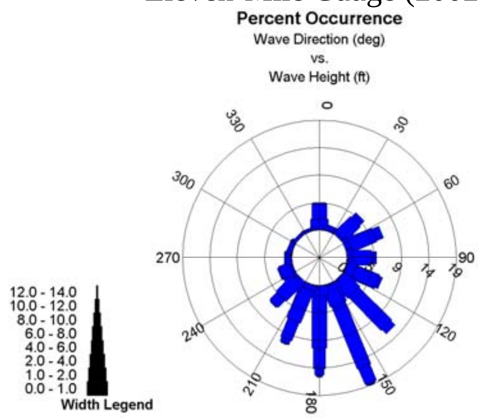
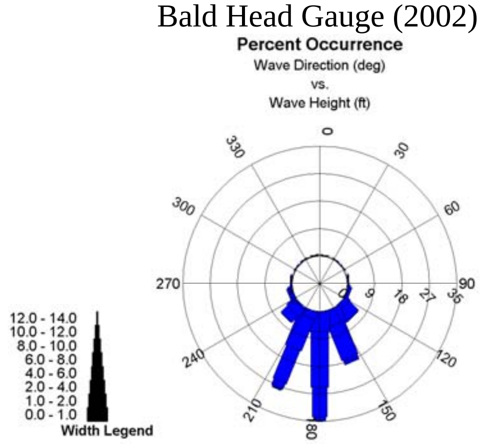


Figure A-3 Wave Height Roses for FRF Gauges (2001).

Eleven-Mile Gauge (2002)



Bald Head Gauge (2002)



Oak Island Gauge (2002)

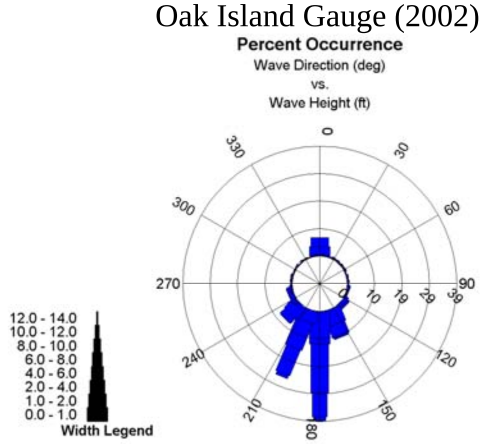
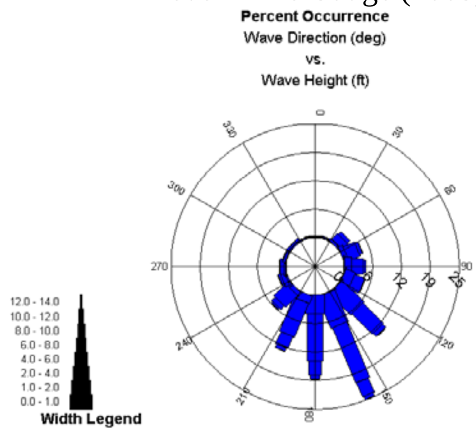
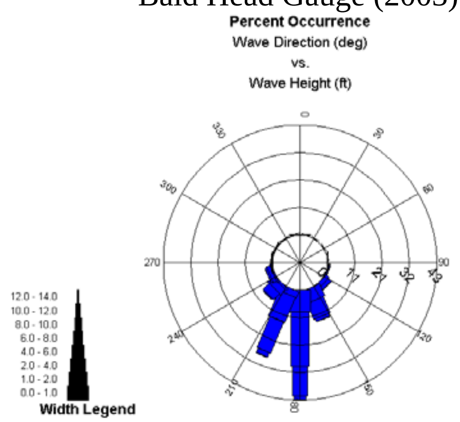


Figure A-4 Wave Height Roses for FRF Gauges (2002).

Eleven-Mile Gauge (2003)



Bald Head Gauge (2003)



Oak Island Gauge (2003)

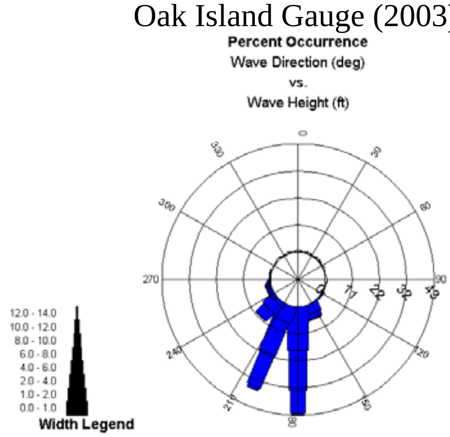
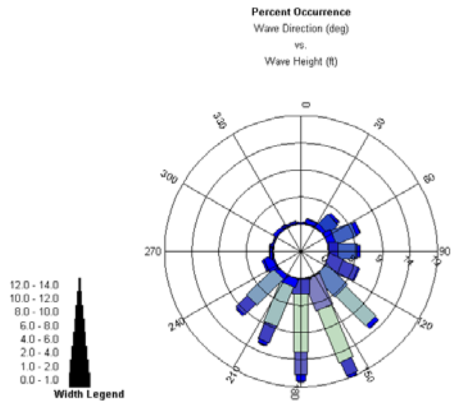
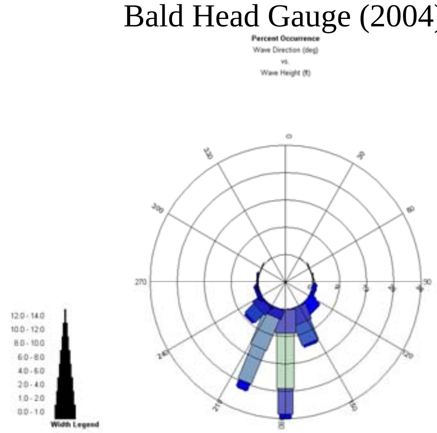


Figure A-5 Wave Height Roses for FRF Gauges (2003).

Eleven-Mile Gauge (2004)



Bald Head Gauge (2004)



Oak Island Gauge (2004)

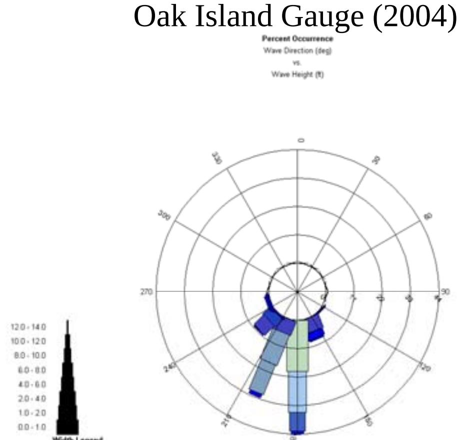
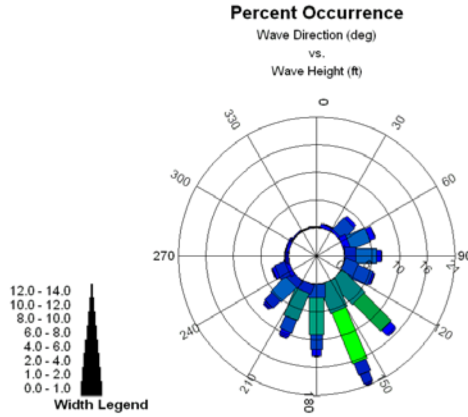
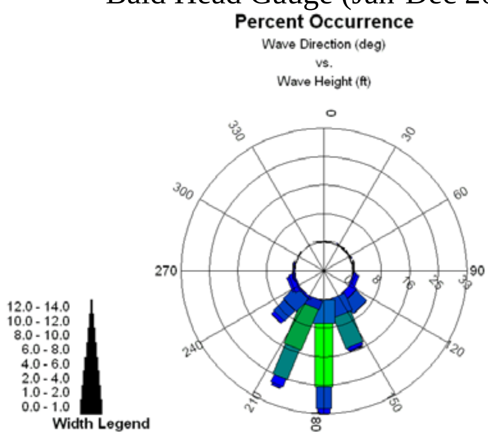


Figure A-6   Wave Height Roses for FRF Gauges (2004).

Eleven-Mile Gauge (Jan-Dec 2005)



Bald Head Gauge (Jan-Dec 2005)



Oak Island Gauge (Jan-Dec 2005)

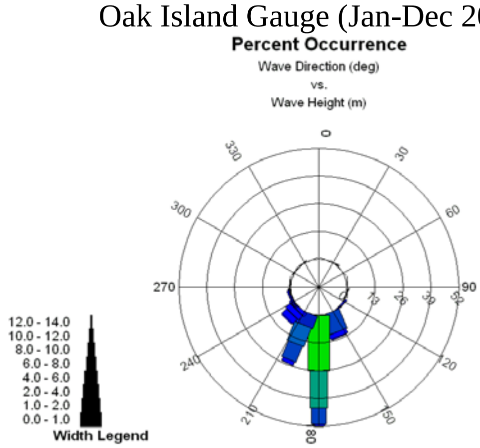
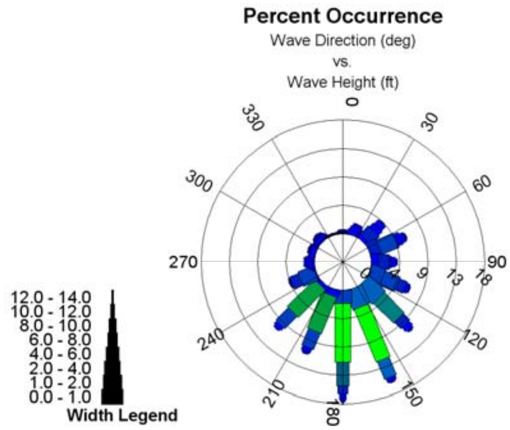
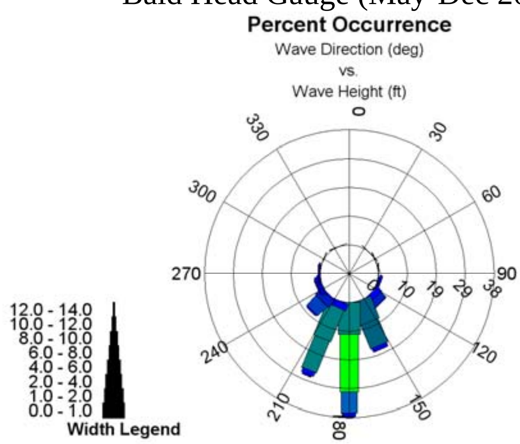


Figure A-7 Wave Height Roses for FRF Gauges (2005).

Eleven-Mile Gauge (Jan-Dec 2006)



Bald Head Gauge (May-Dec 2006)



Oak Island Gauge (Jun-Sep 2006)

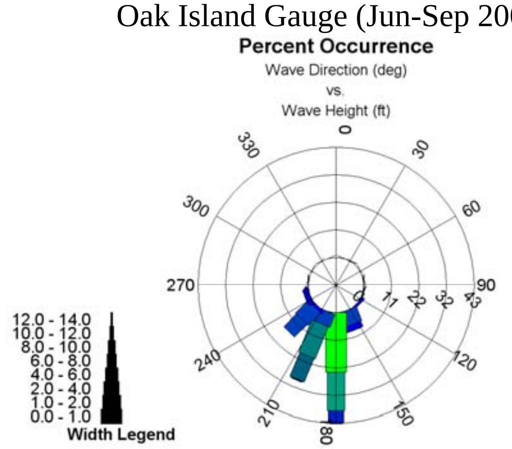
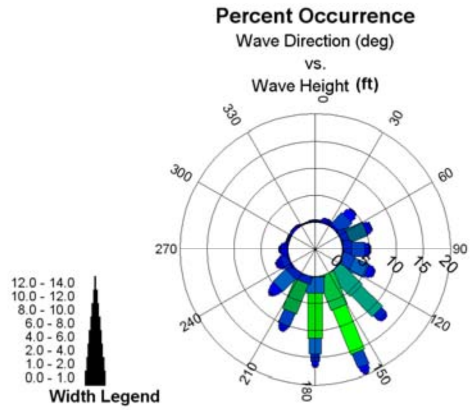
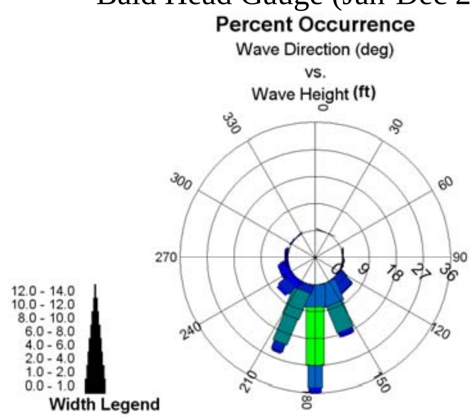


Figure A-8 Wave Height Roses for FRF Gauges (2006).

Eleven-Mile Gauge (Jan-Dec 2007)



Bald Head Gauge (Jan-Dec 2007)



Oak Island Gauge (Apr-Dec 2007)

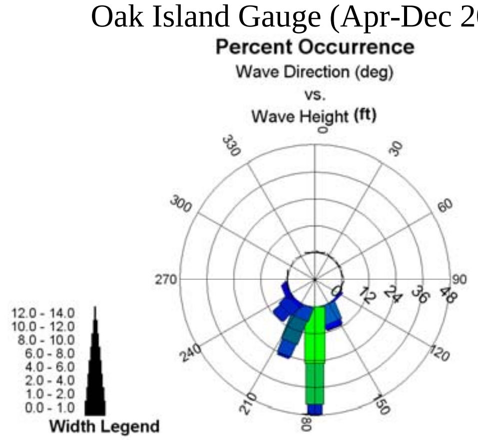
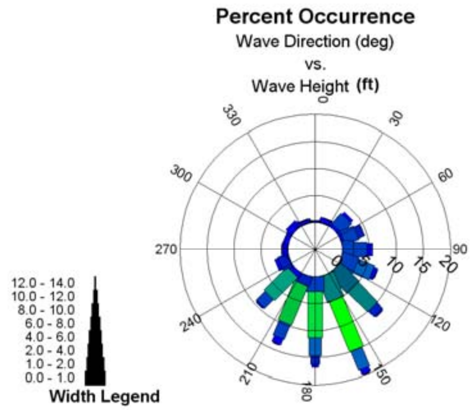
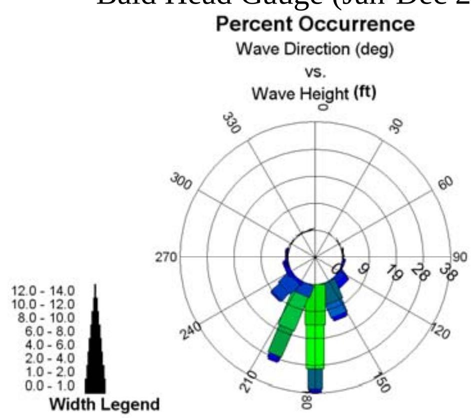


Figure A-9 Wave Height Roses for FRF Gauges (2007).

Eleven-Mile Gauge (Jan-Dec 2008)



Bald Head Gauge (Jan-Dec 2008)



Oak Island Gauge (Jan-Dec 2008)

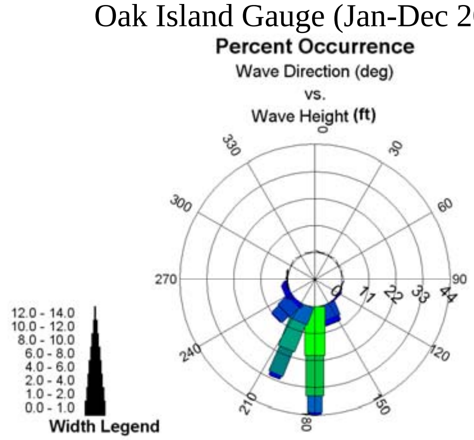
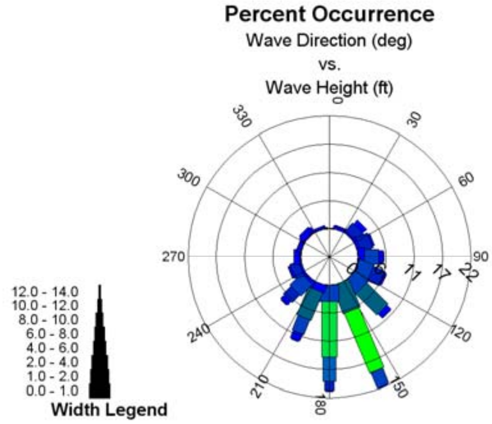
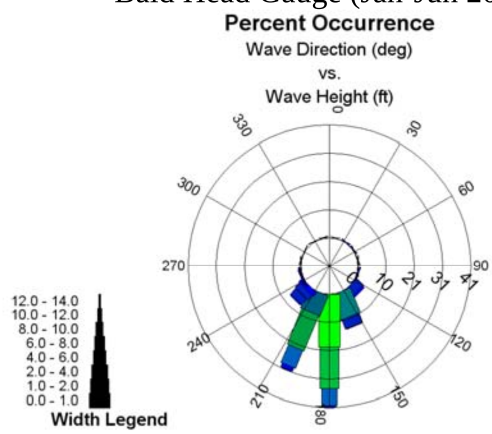


Figure A-10 Wave Height Roses for FRF Gauges (2008).

Eleven-Mile Gauge (Jan-Jun 2009)



Bald Head Gauge (Jan-Jun 2009)



Oak Island Gauge (Jan-Jun 2009)

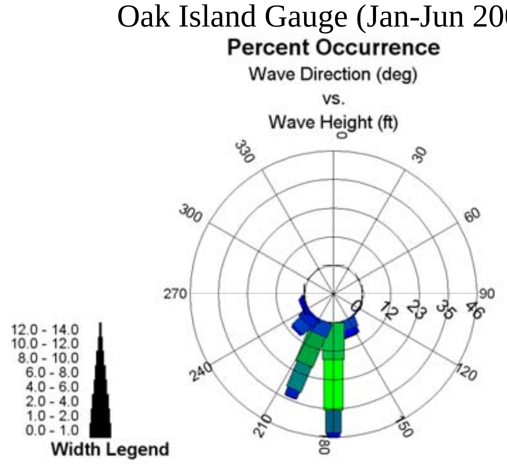
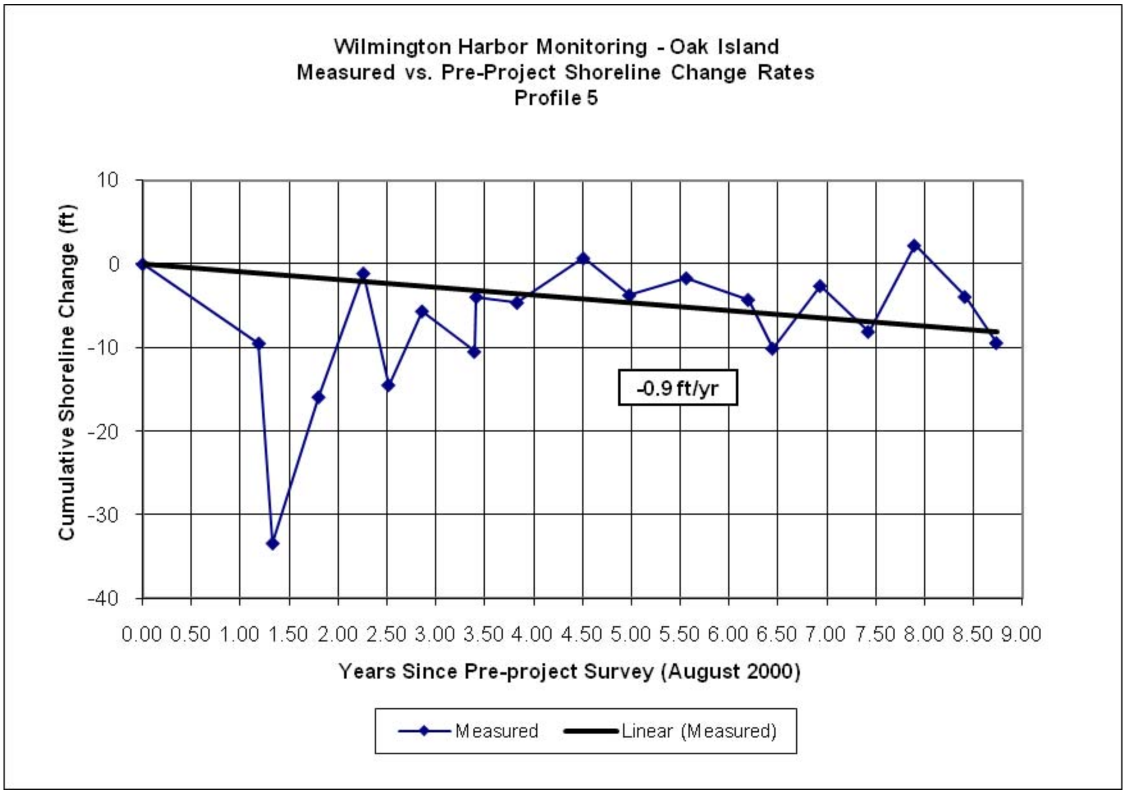
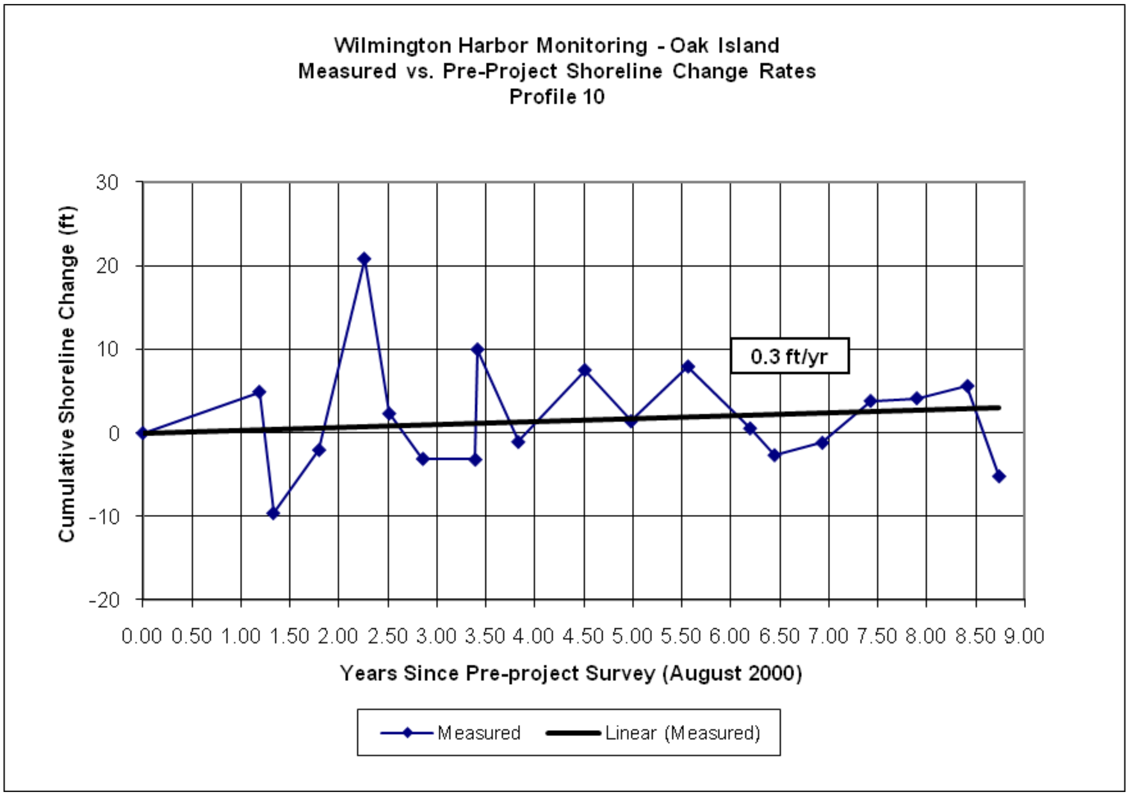


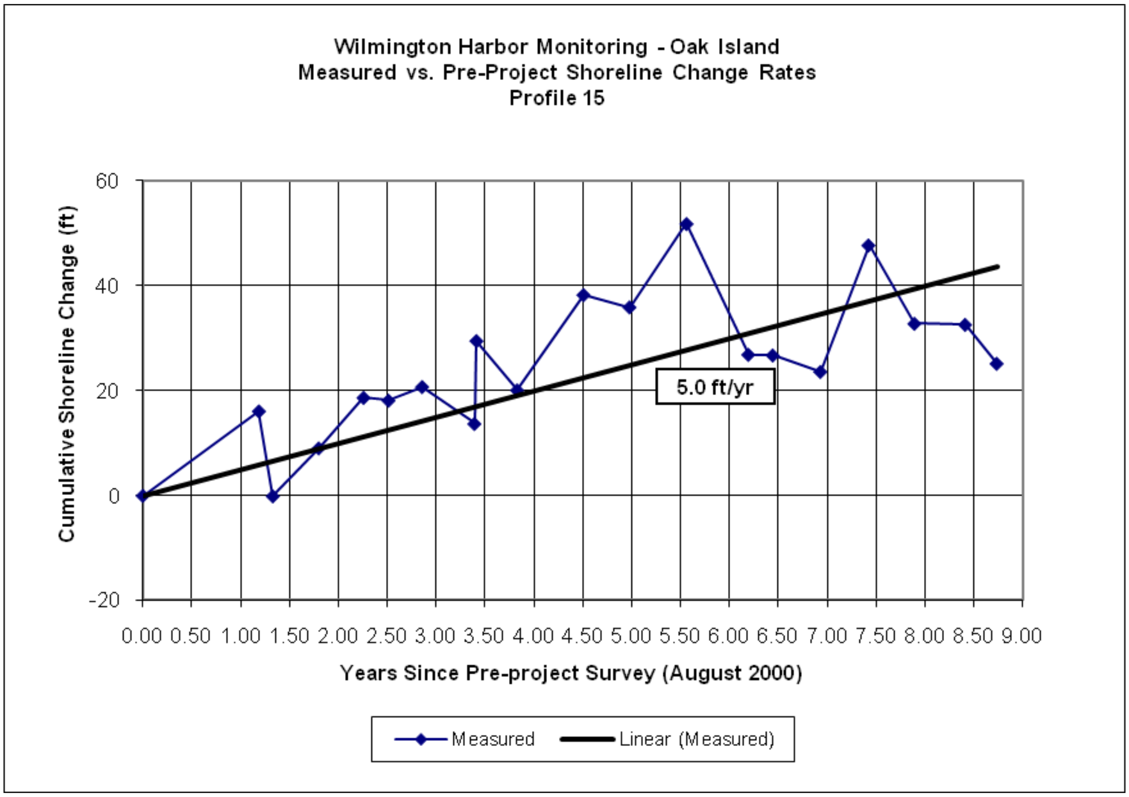
Figure A-10 Wave Height Roses for FRF Gauges (2009).

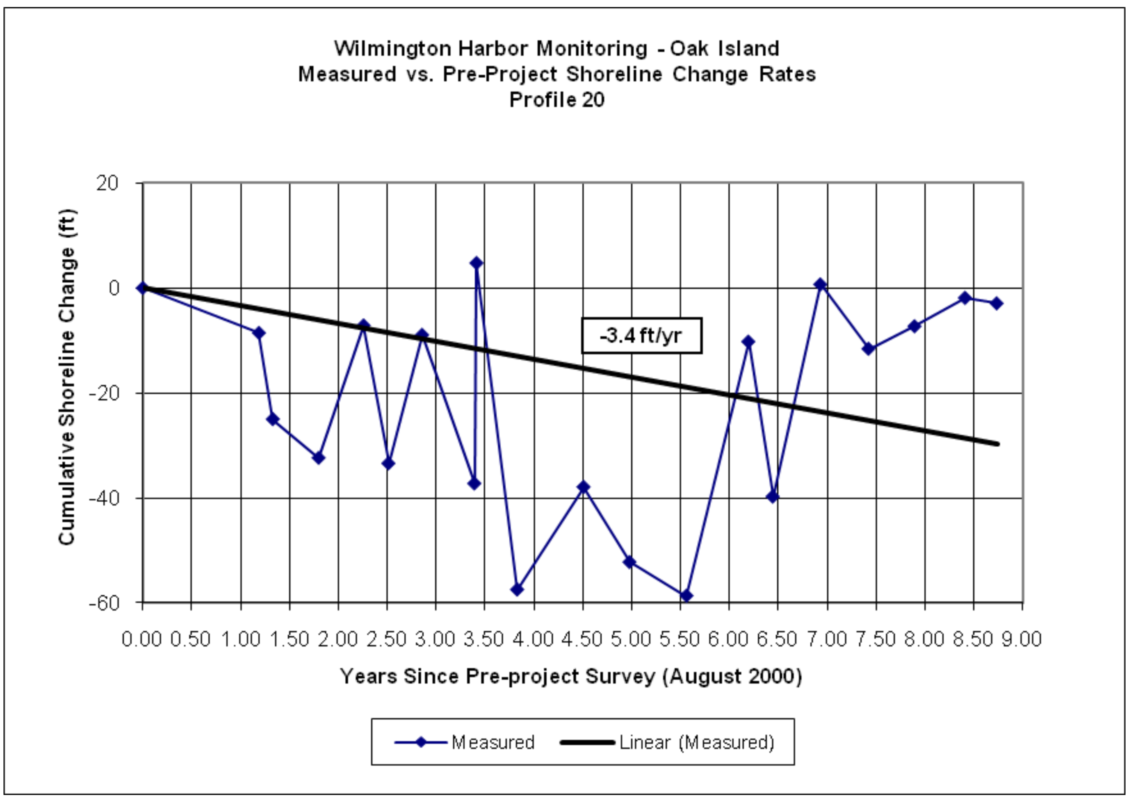
Appendix B

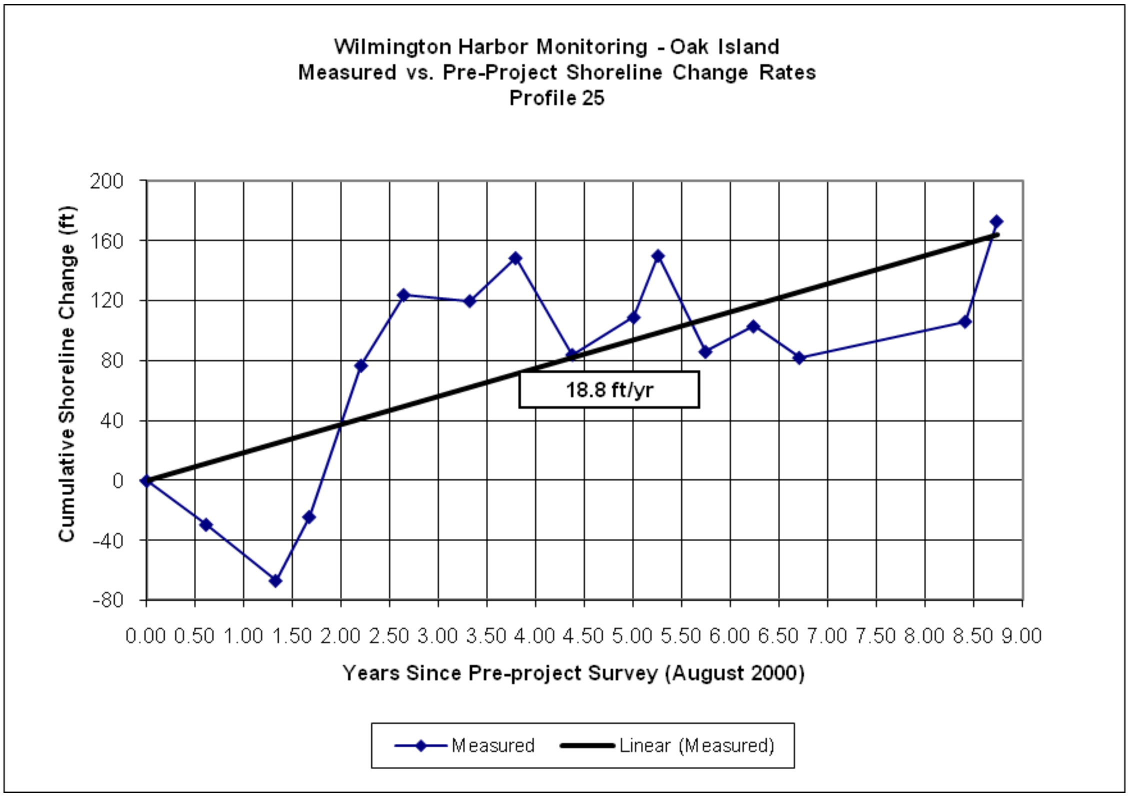
SHORELINE CHANGE RATES
(Oak Island)

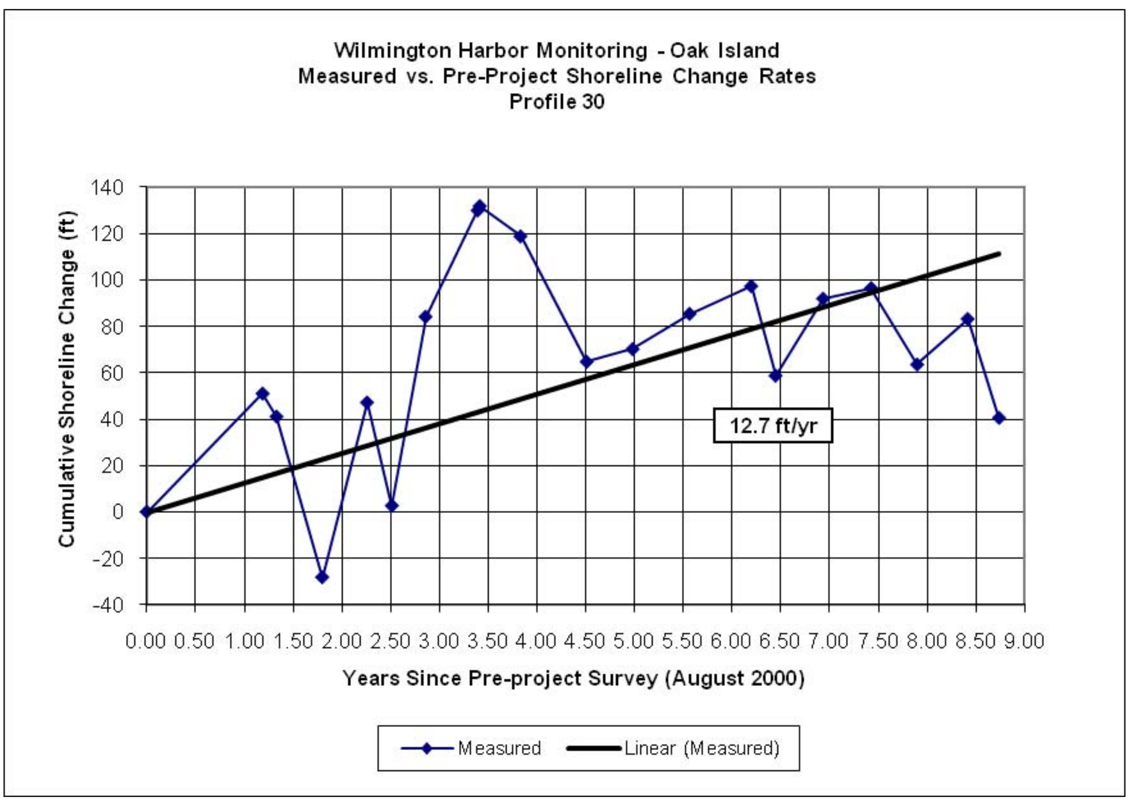

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 5
Cumulative Shoreline Change (ft)
10
0
-10
-20
-30
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
-0.9 ft/yr
Measured
Linear (Measured)

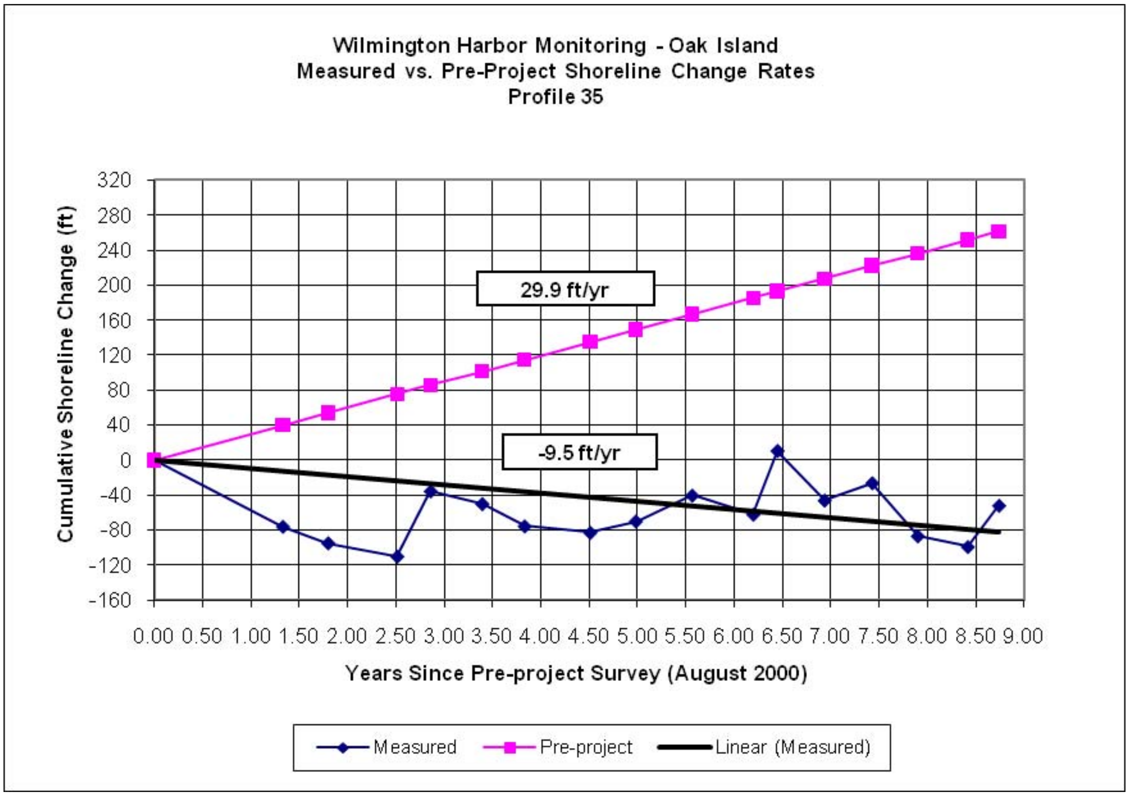

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 10
Cumulative Shoreline Change (ft)
30
20
10
0
-10
-20
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
0.3 ft/yr
Measured
Linear (Measured)

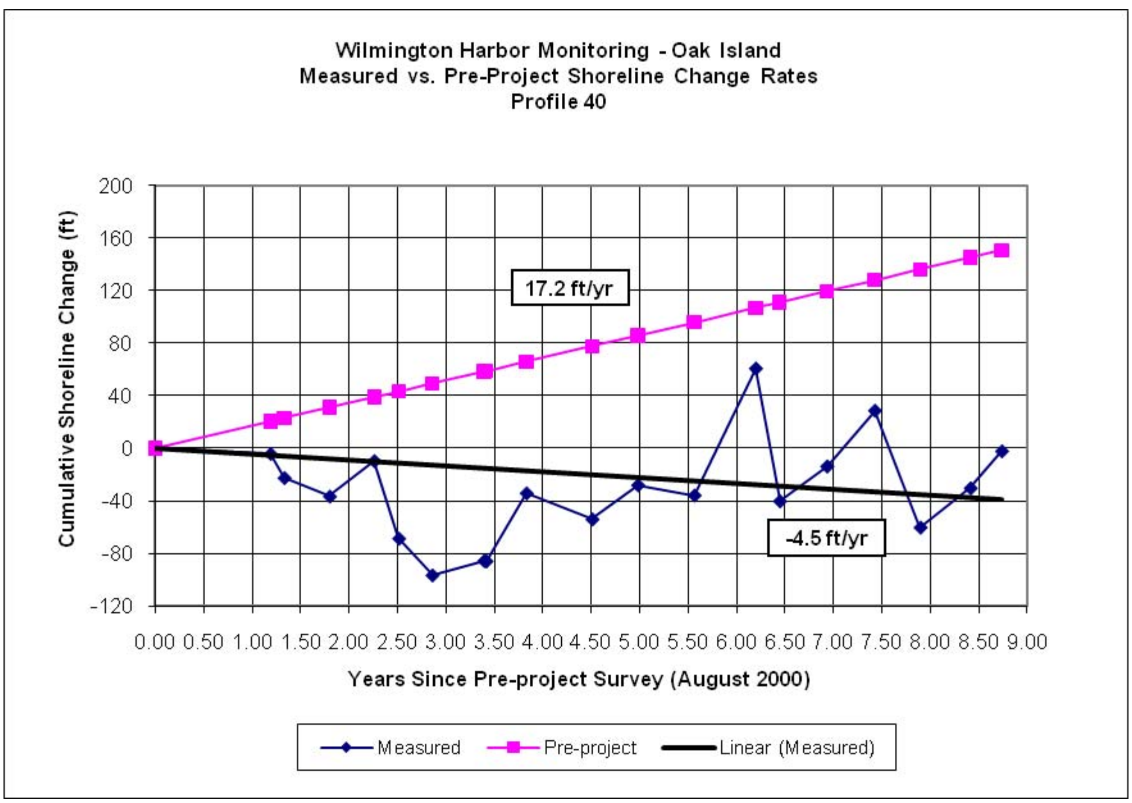

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 15
Cumulative Shoreline Change (ft)
60
40
20
0
-20
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
5.0 ft/yr
Measured
Linear (Measured)

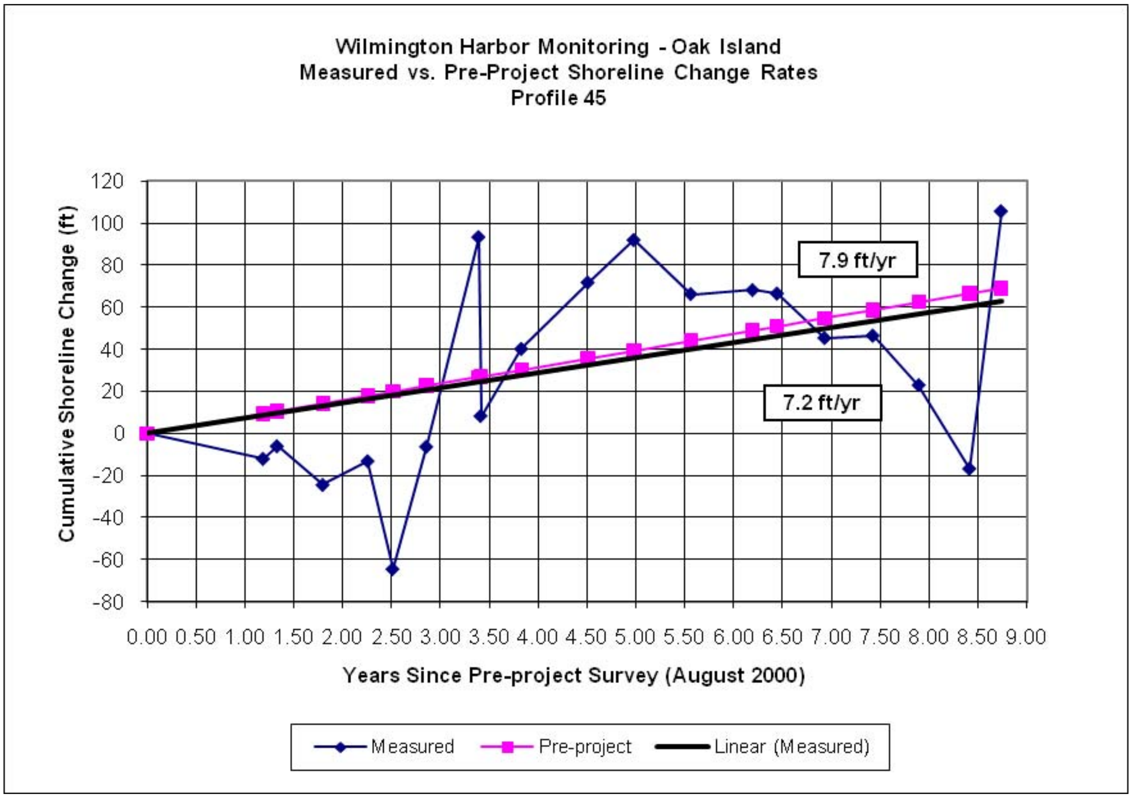

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 20
Cumulative Shoreline Change (ft)
20
0
-20
-40
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
-3.4 ft/yr
Measured
Linear (Measured)

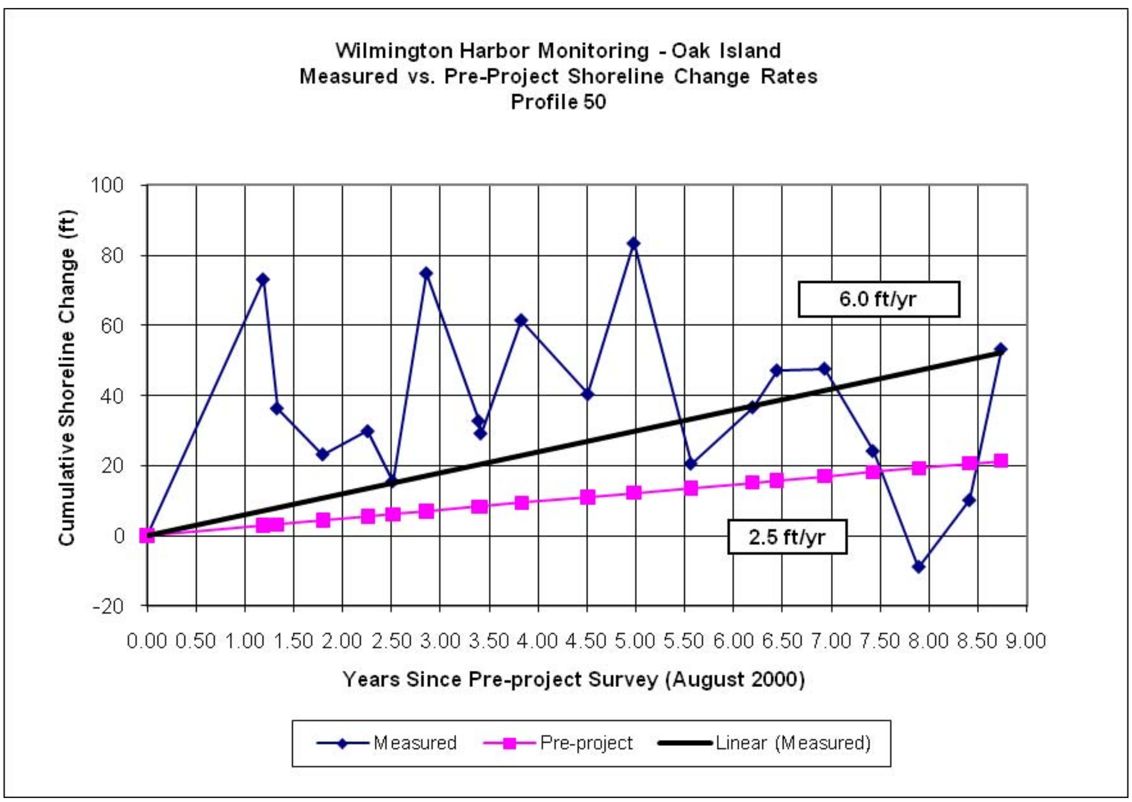

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 25
Cumulative Shoreline Change (ft)
200
160
120
80
40
0
-40
-80
18.8 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Linear (Measured)

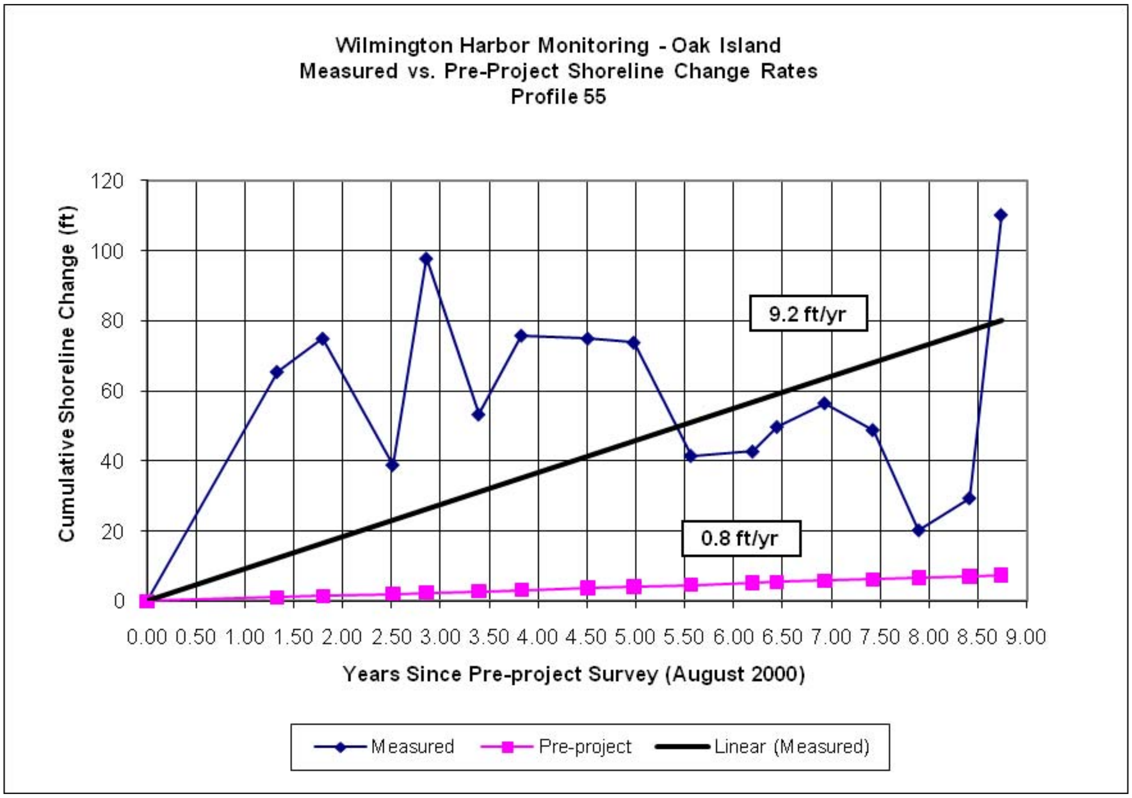

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 30
Cumulative Shoreline Change (ft)
140
120
100
80
60
40
20
0
-20
-40
12.7 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 35
29.9 ft/yr
-9.5 ft/yr
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

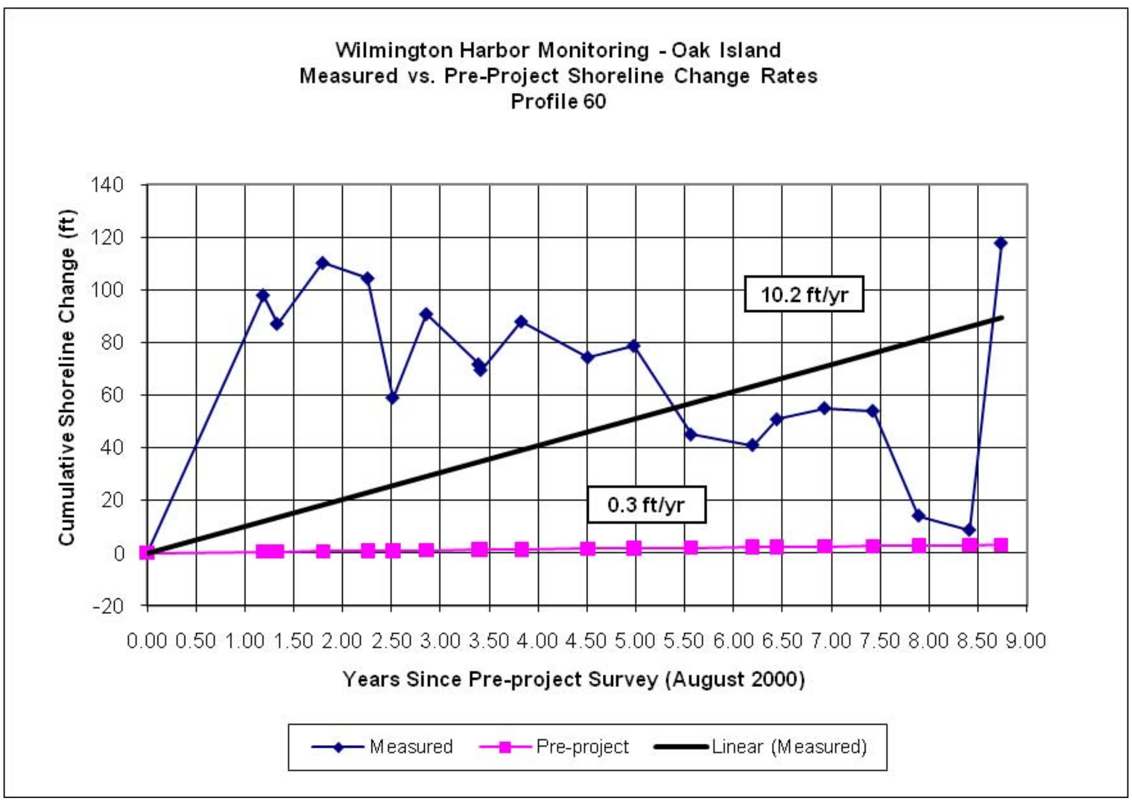

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 40
17.2 ft/yr
-4.5 ft/yr
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 45
Cumulative Shoreline Change (ft)
120
100
80
60
40
20
0
-20
-40
-60
-80
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
7.9 ft/yr
7.2 ft/yr
Measured
Pre-project
Linear (Measured)

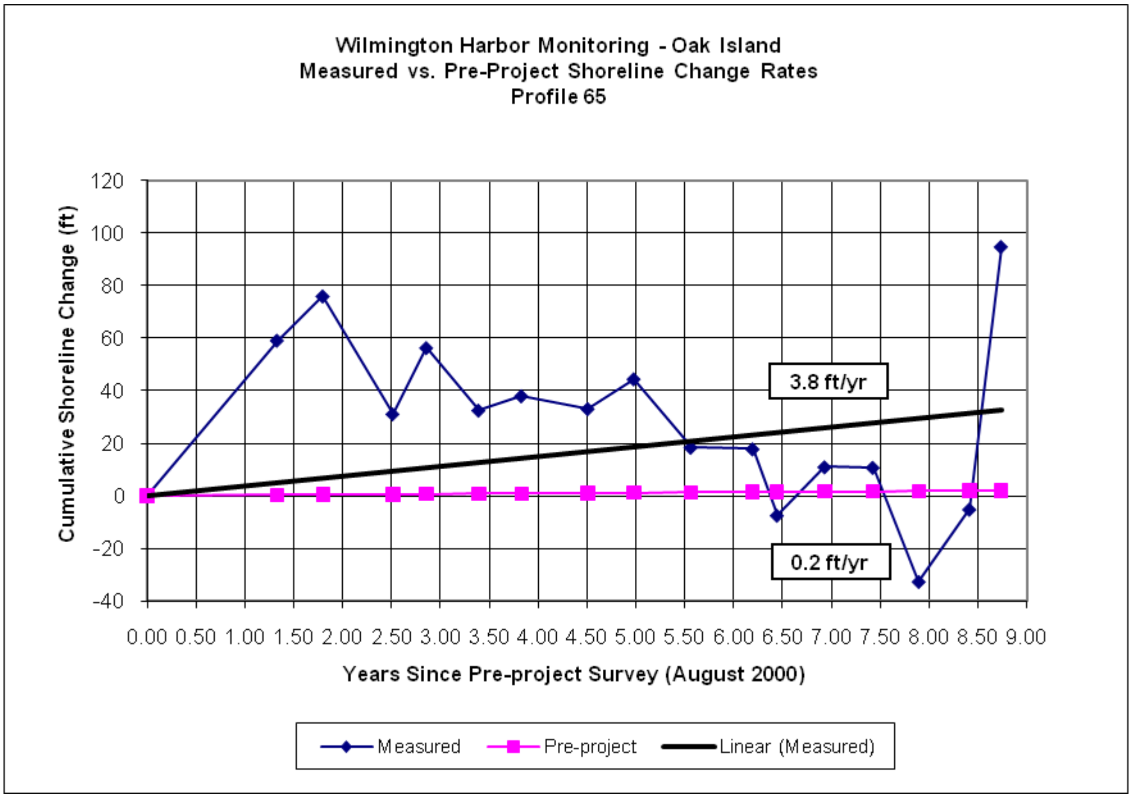

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 50
Cumulative Shoreline Change (ft)
100
80
60
40
20
0
-20
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
6.0 ft/yr
2.5 ft/yr
Measured
Pre-project
Linear (Measured)

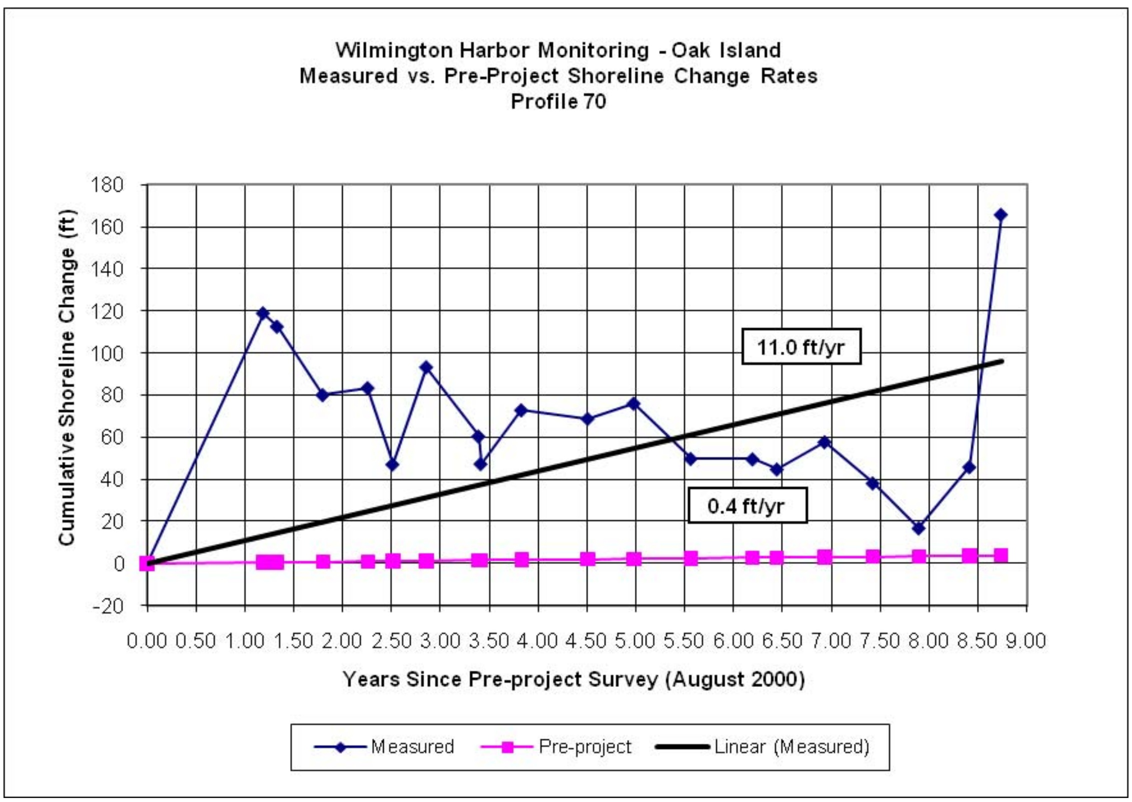


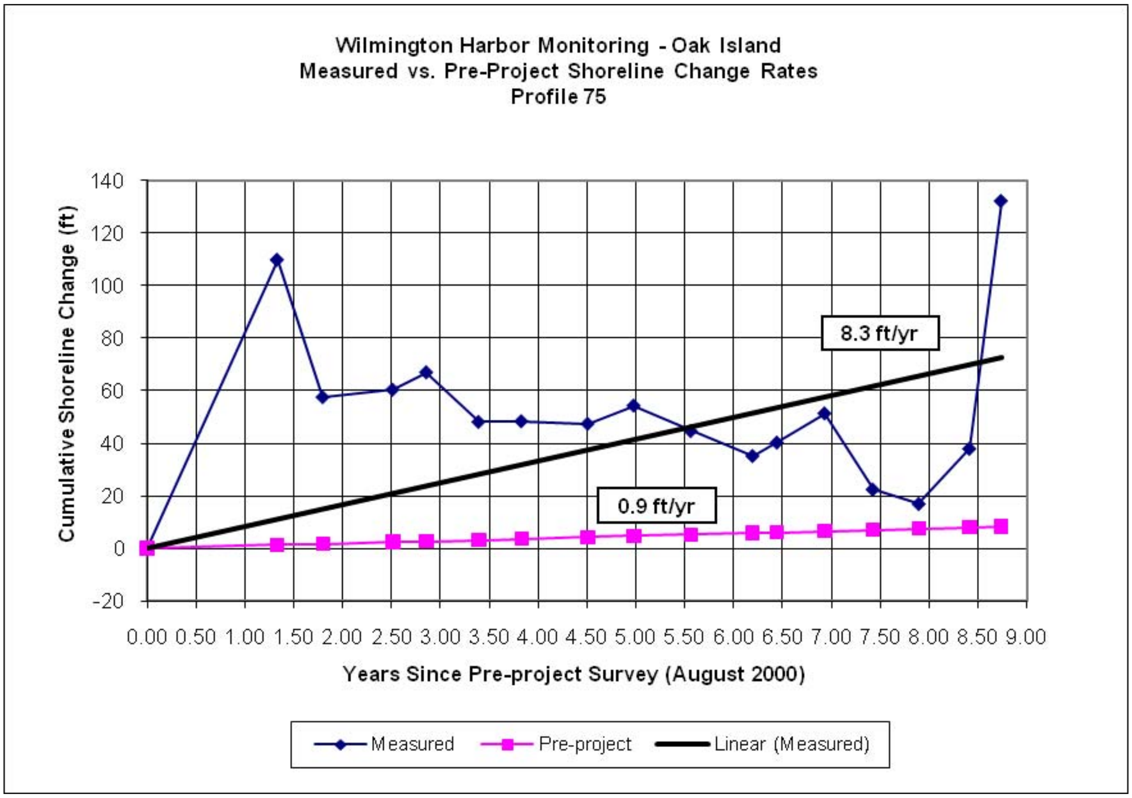
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 55
Cumulative Shoreline Change (ft)
120
100
80
60
40
20
0
9.2 ft/yr
0.8 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

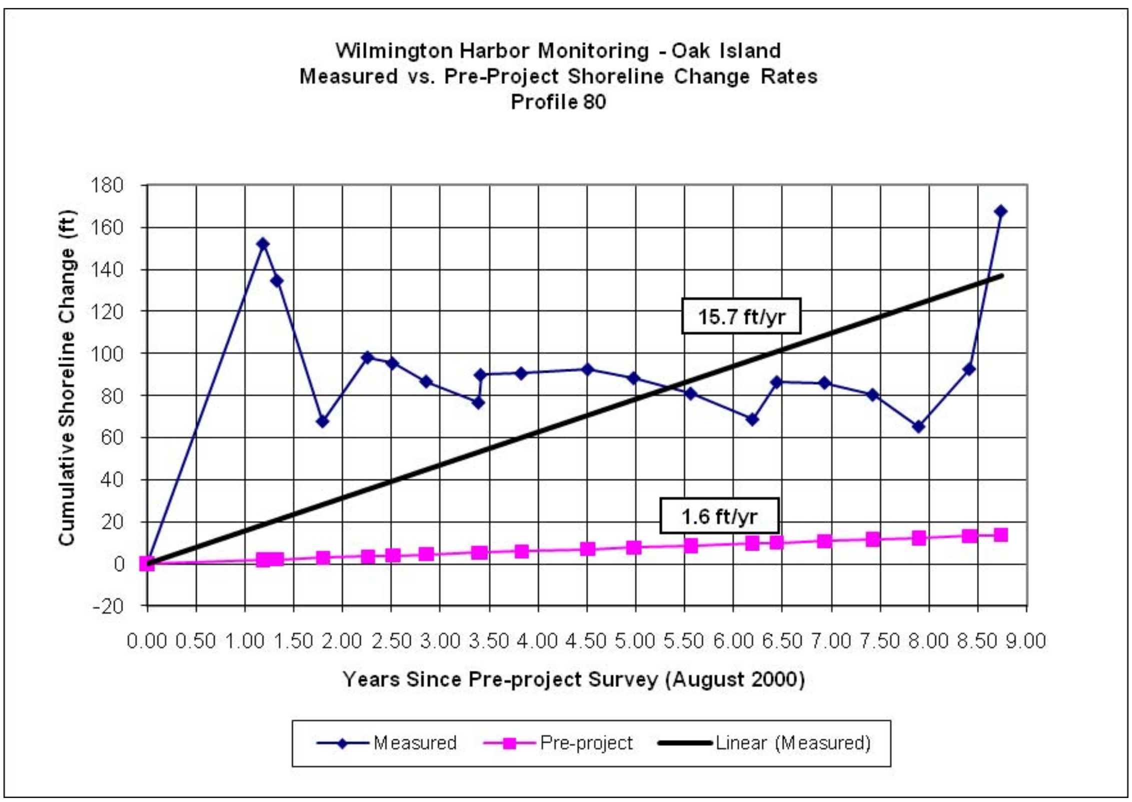


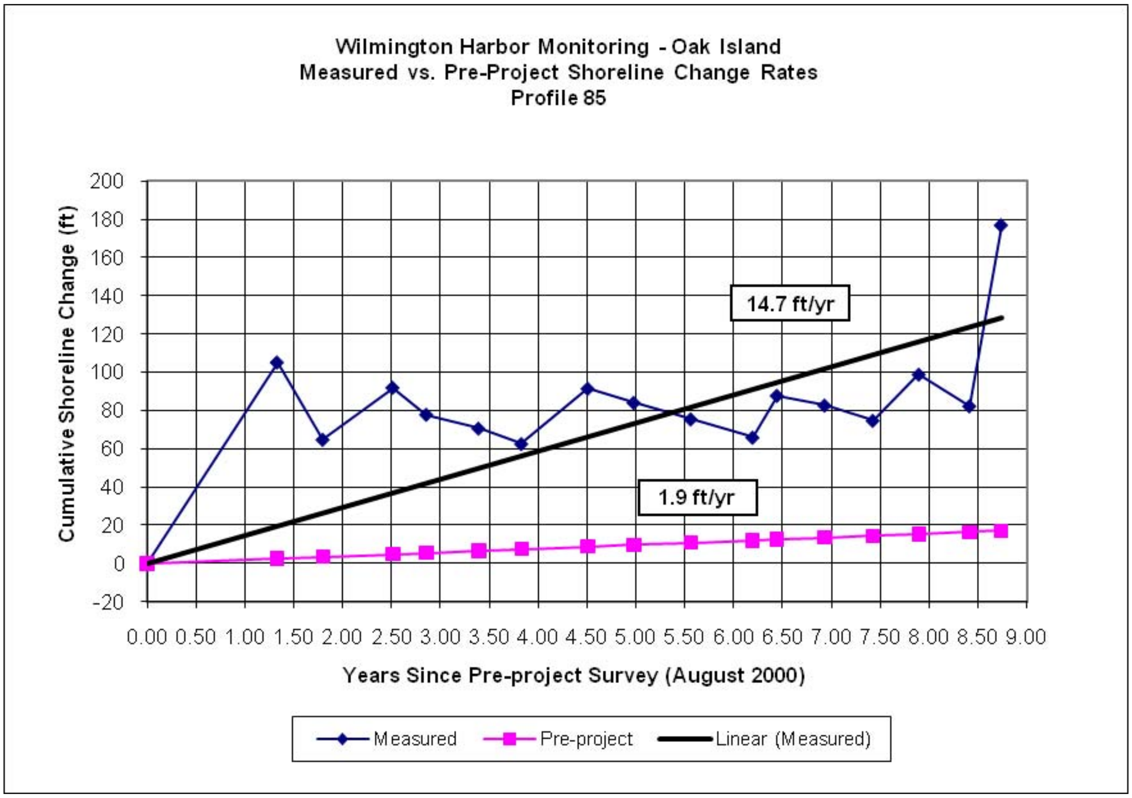
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 60
Cumulative Shoreline Change (ft)
140
120
100
80
60
40
20
0
-20
10.2 ft/yr
0.3 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 65
Cumulative Shoreline Change (ft)
120
100
80
60
40
20
0
-20
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
3.8 ft/yr
0.2 ft/yr
Measured
Pre-project
Linear (Measured)

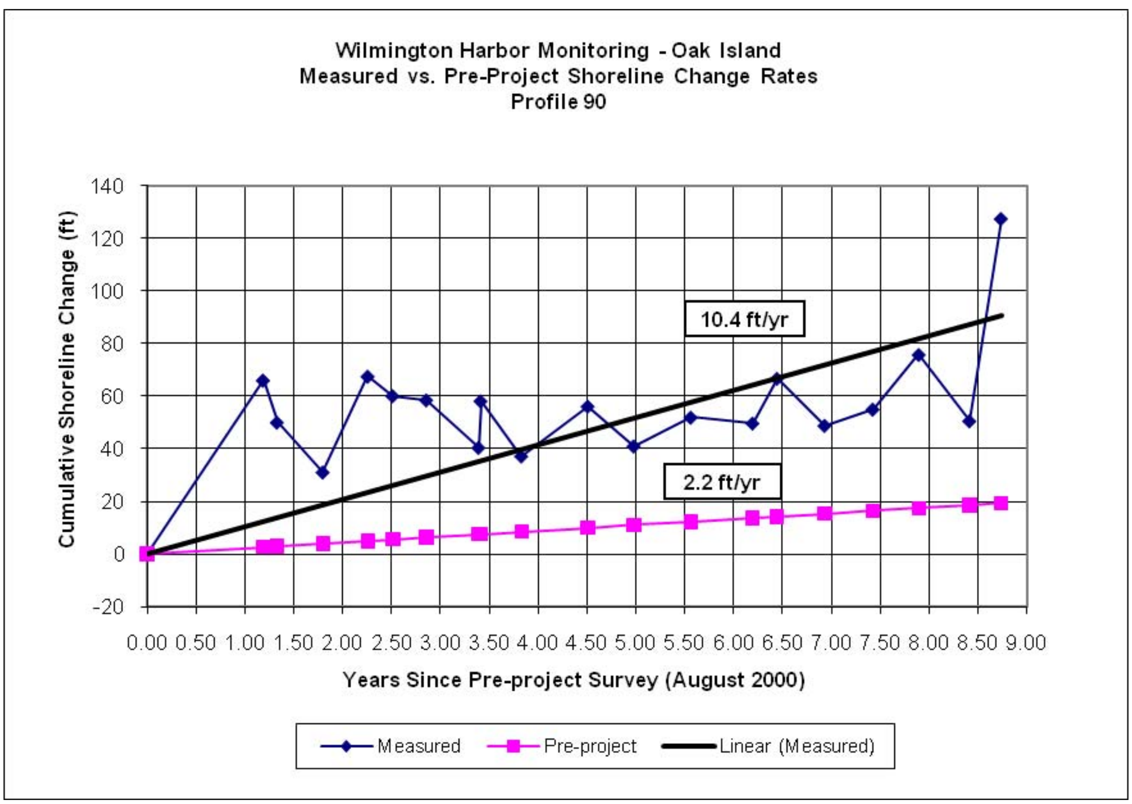

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 70
Cumulative Shoreline Change (ft)
180
160
140
120
100
80
60
40
20
0
-20
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
11.0 ft/yr
0.4 ft/yr
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 75
Cumulative Shoreline Change (ft)
140
120
100
80
60
40
20
0
-20
8.3 ft/yr
0.9 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

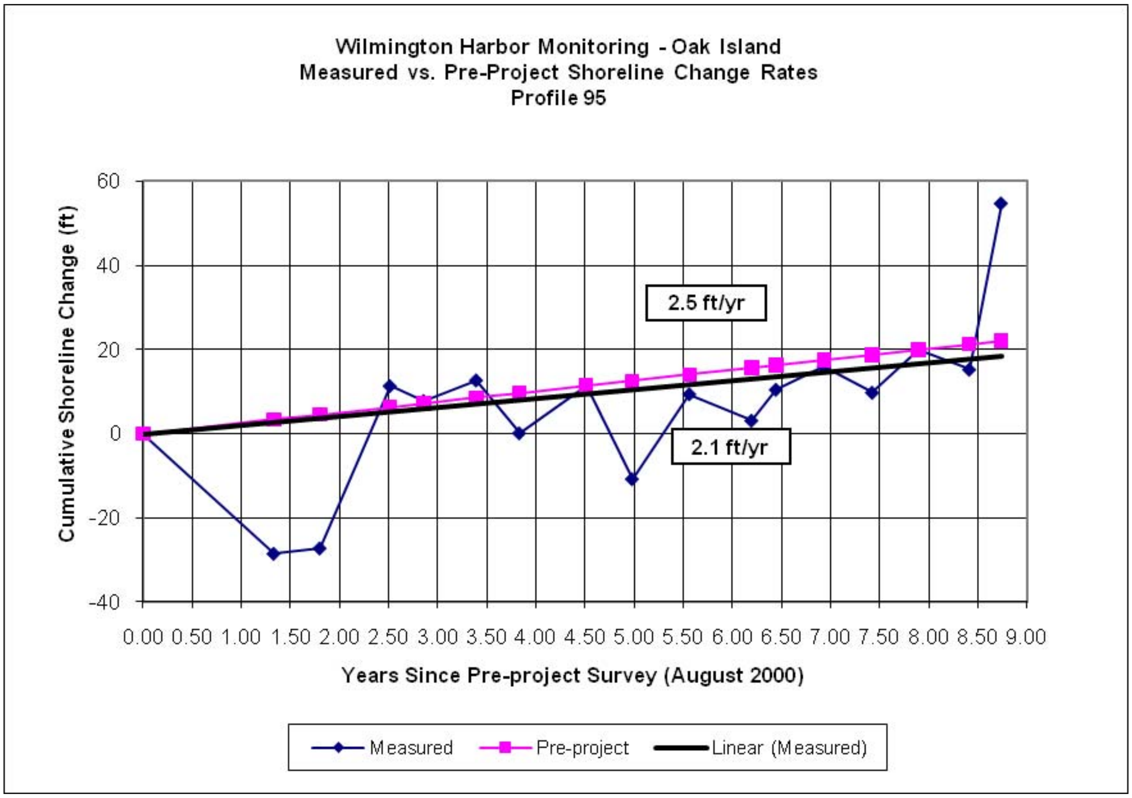

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 80
Cumulative Shoreline Change (ft)
180
160
140
120
100
80
60
40
20
0
-20
15.7 ft/yr
1.6 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

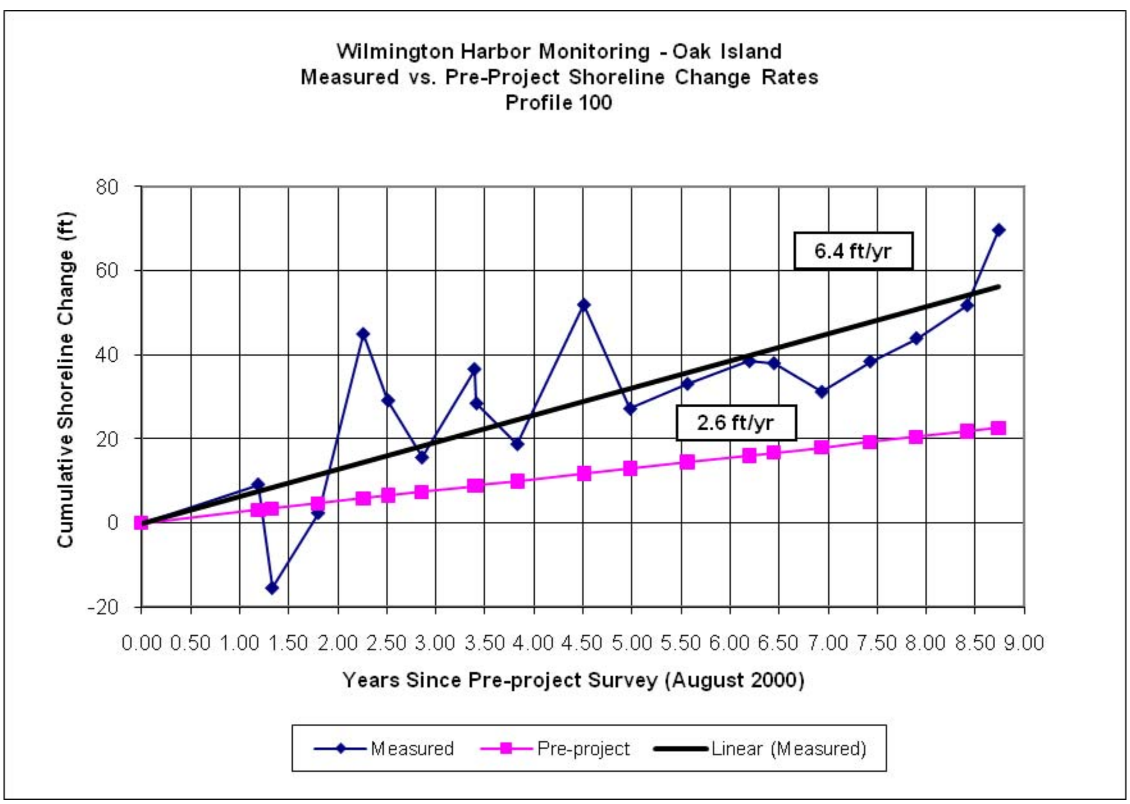


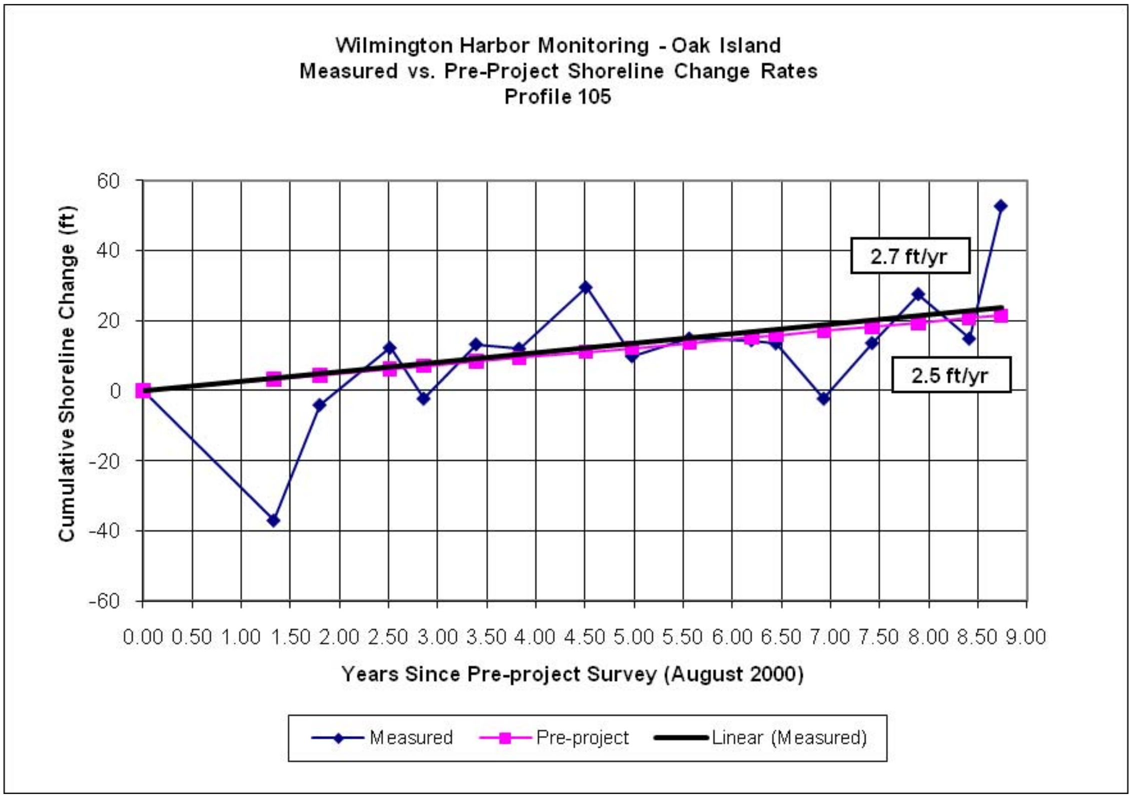
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 85
Cumulative Shoreline Change (ft)
14.7 ft/yr
1.9 ft/yr
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

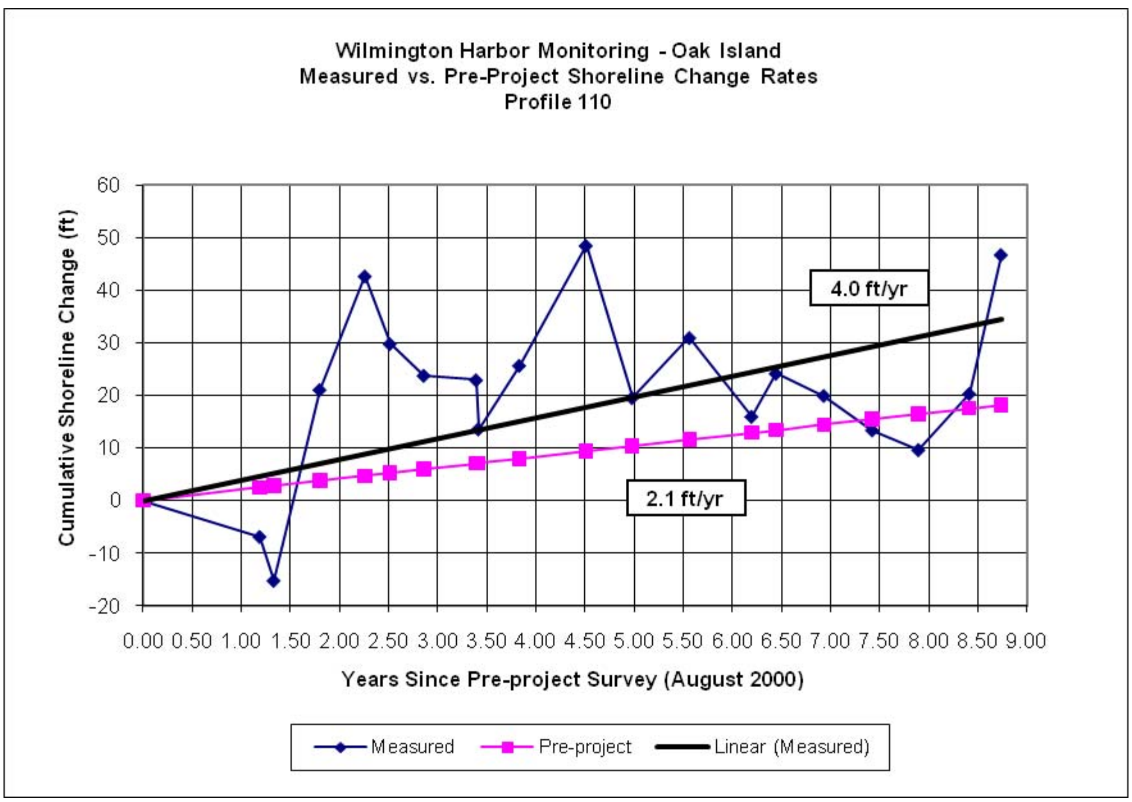


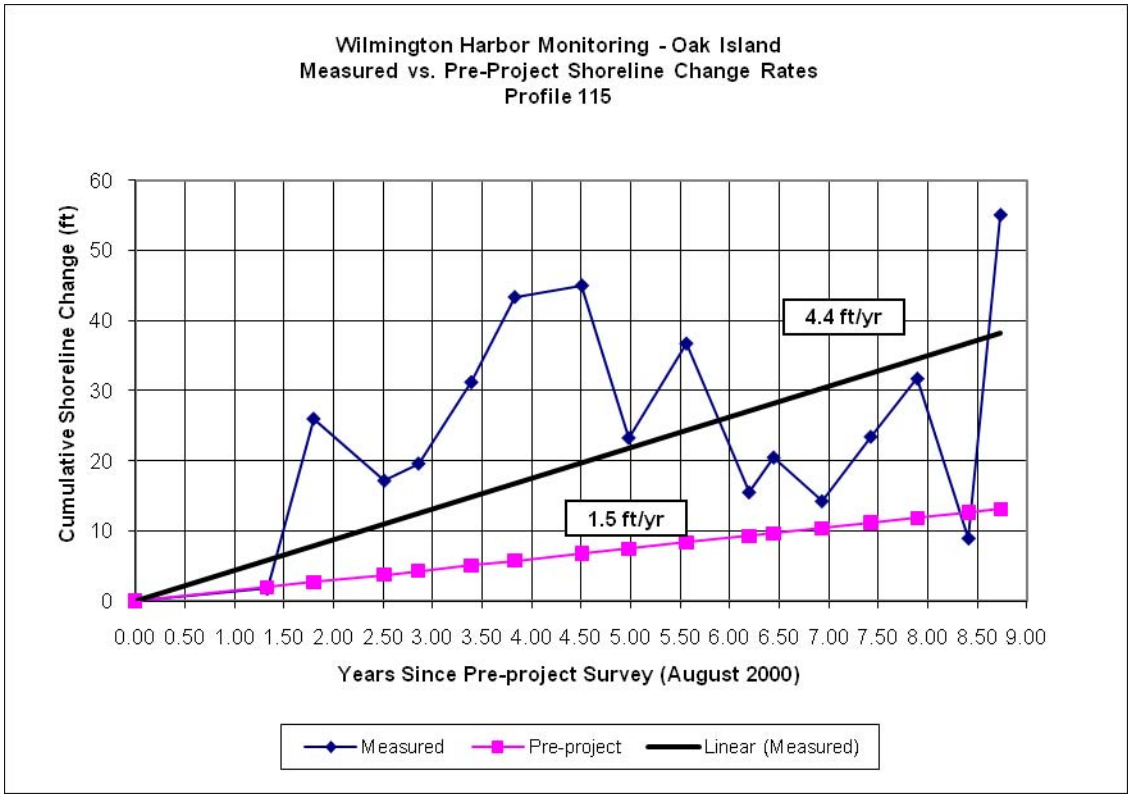
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 90
Cumulative Shoreline Change (ft)
10.4 ft/yr
2.2 ft/yr
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

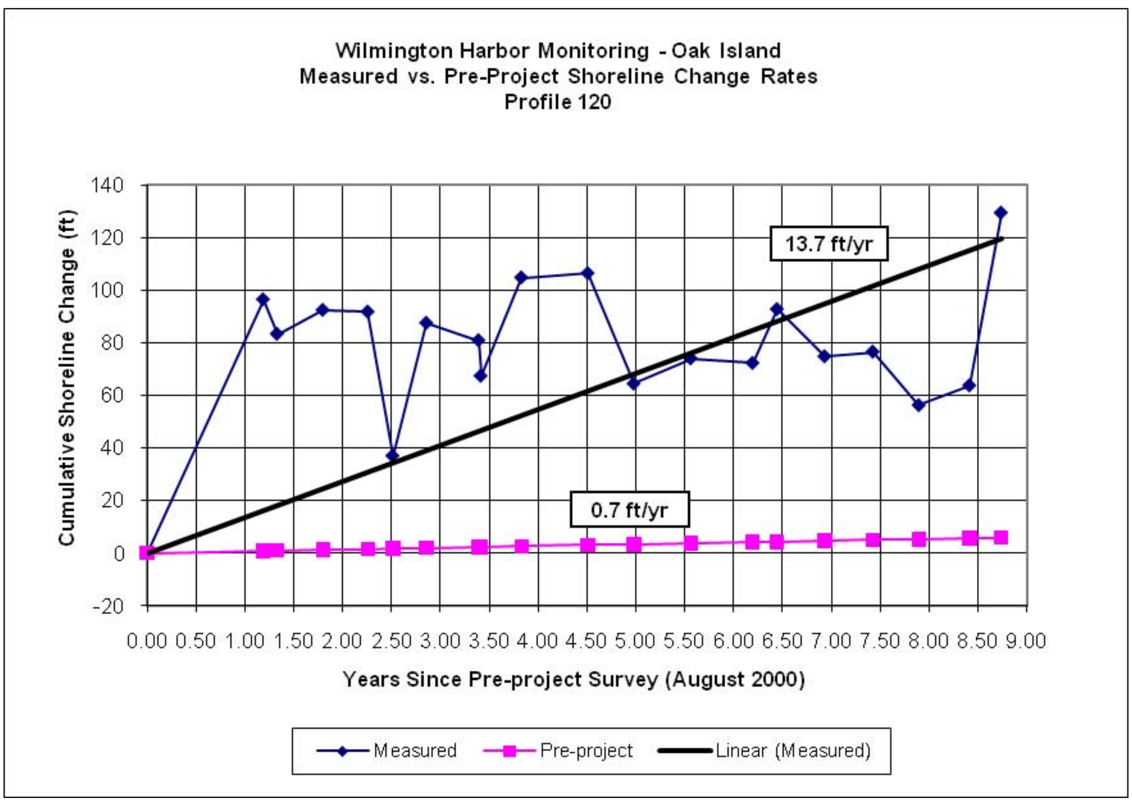

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 95
2.5 ft/yr
2.1 ft/yr
Cumulative Shoreline Change (ft)
60
40
20
0
-20
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

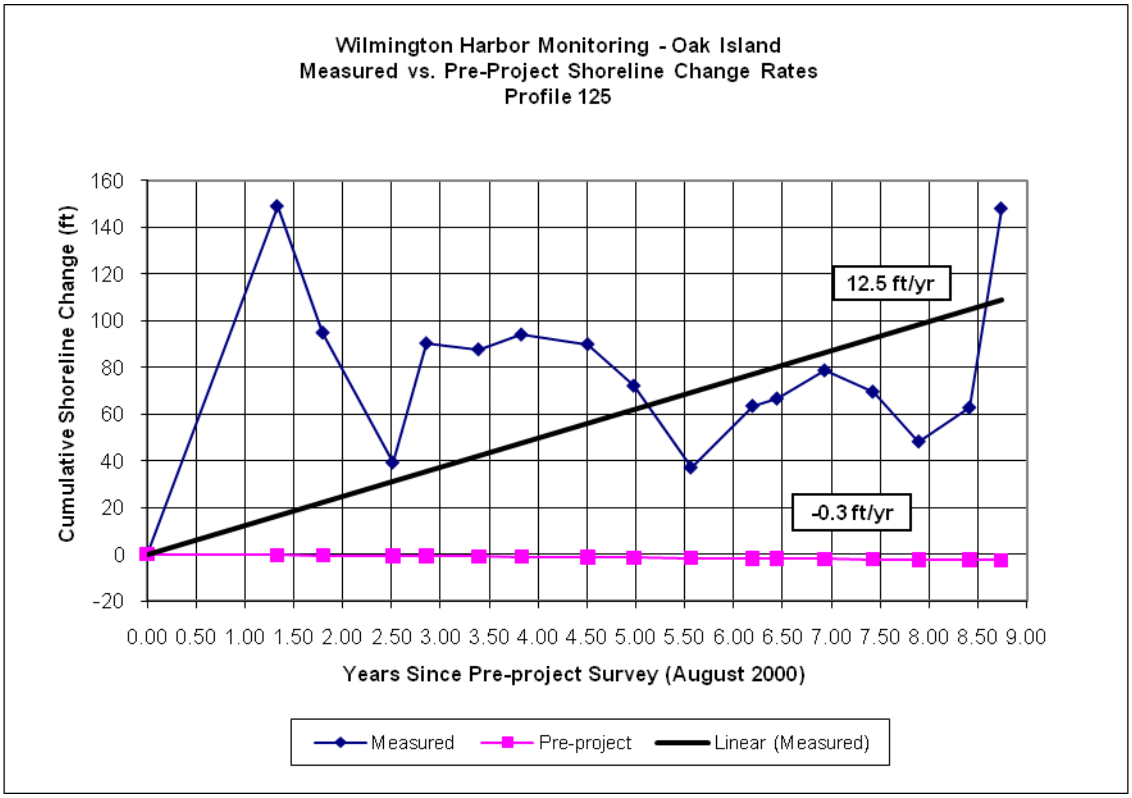

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 100
6.4 ft/yr
2.6 ft/yr
Cumulative Shoreline Change (ft)
80
60
40
20
0
-20
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 105
Cumulative Shoreline Change (ft)
60
40
20
0
-20
-40
-60
2.7 ft/yr
2.5 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

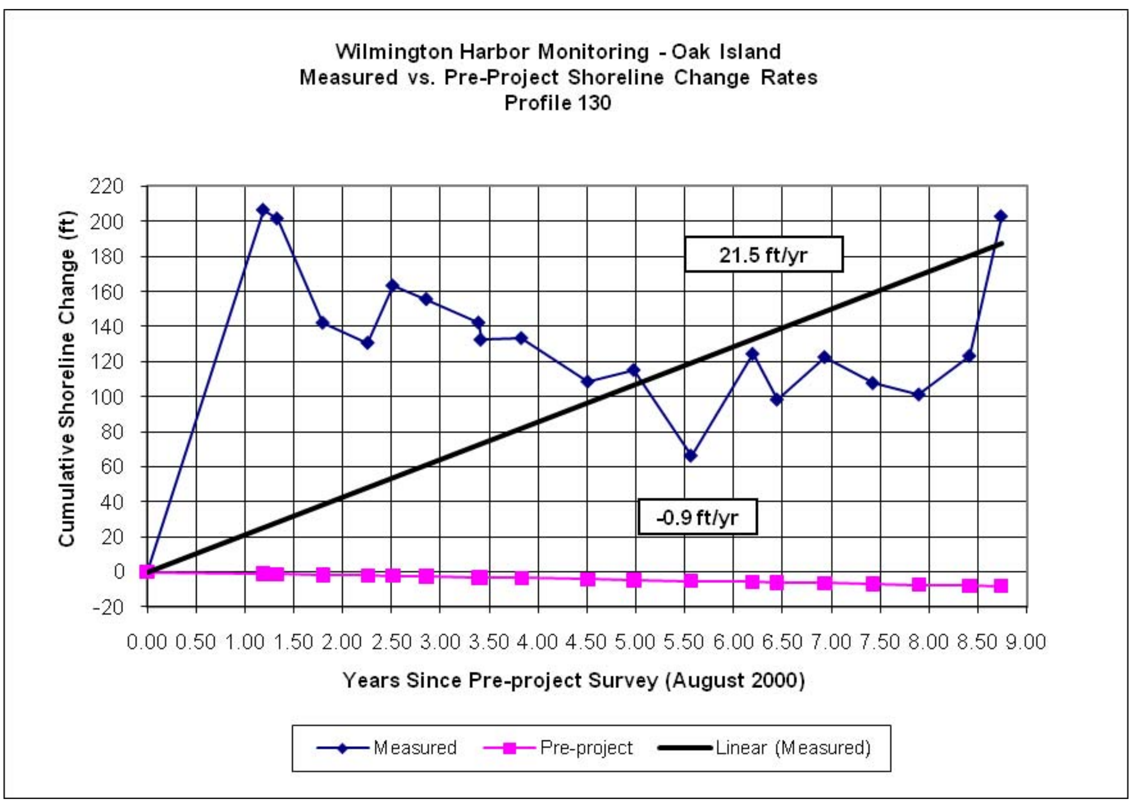

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 110
Cumulative Shoreline Change (ft)
60
50
40
30
20
10
0
-10
-20
4.0 ft/yr
2.1 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 115
Cumulative Shoreline Change (ft)
60
50
40
30
20
10
0
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
4.4 ft/yr
1.5 ft/yr
Measured
Pre-project
Linear (Measured)

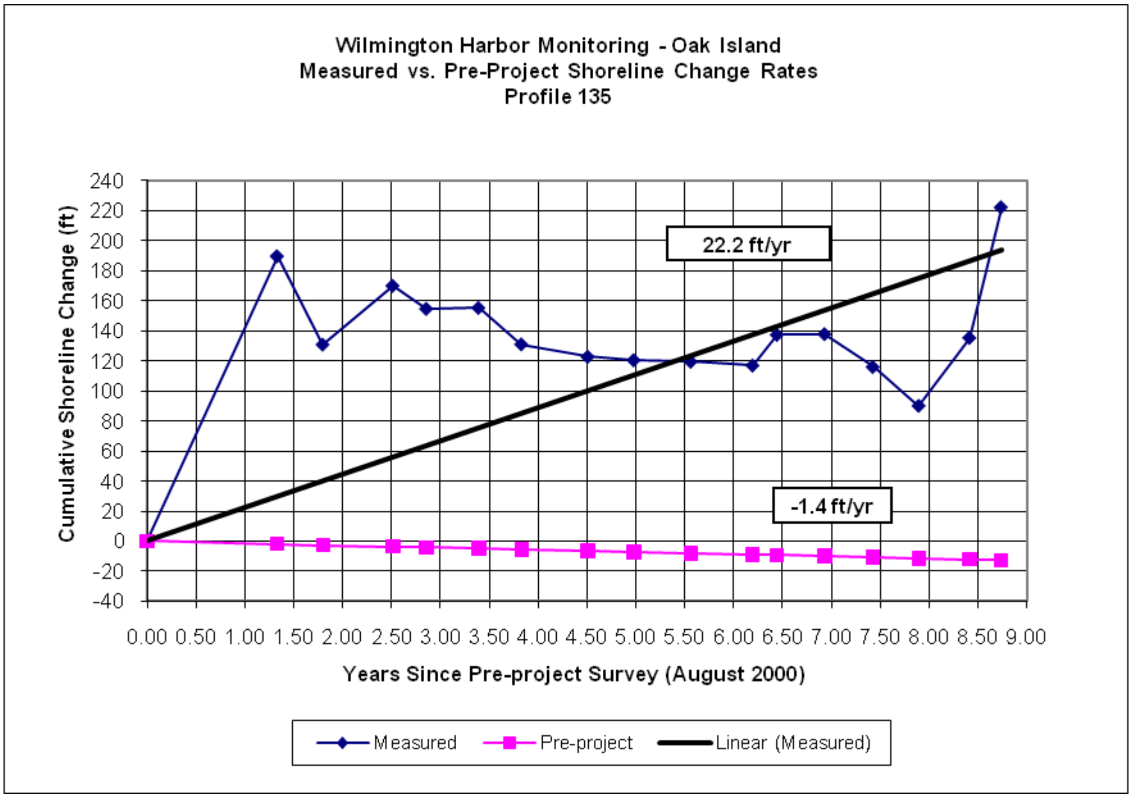

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 120
Cumulative Shoreline Change (ft)
140
120
100
80
60
40
20
0
-20
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
13.7 ft/yr
0.7 ft/yr
Measured
Pre-project
Linear (Measured)



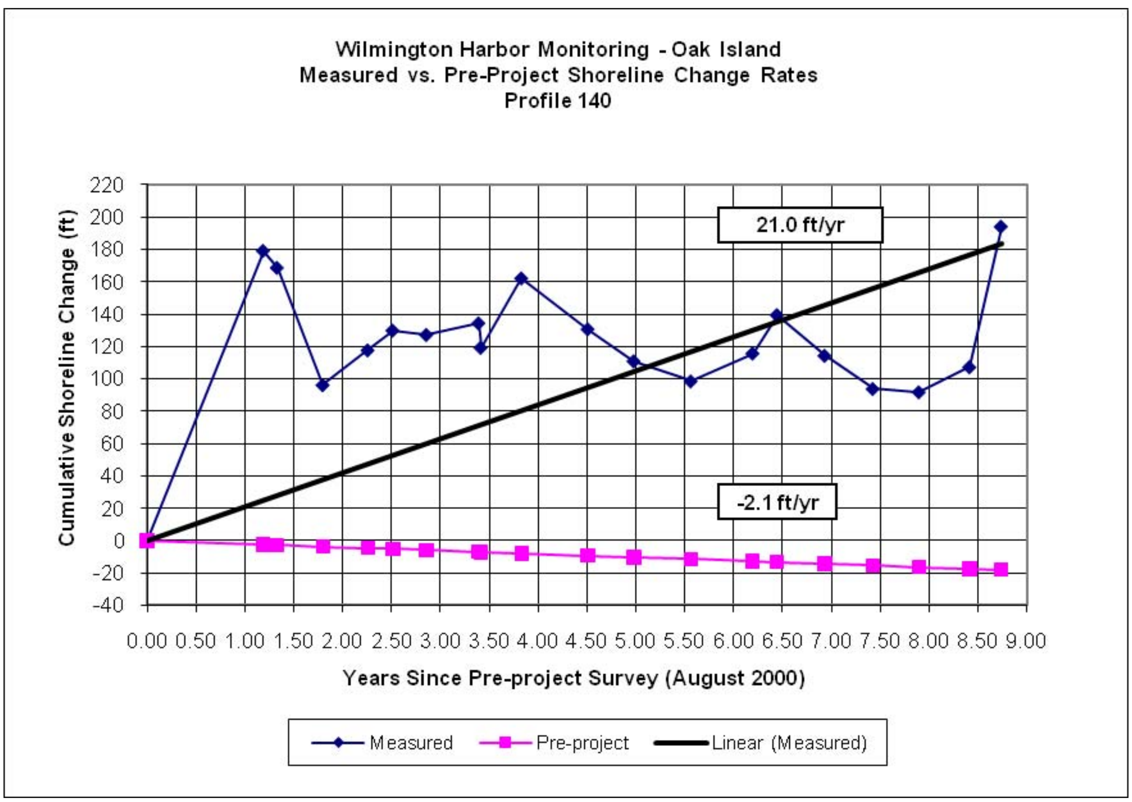
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 125
Cumulative Shoreline Change (ft)
160
140
120
100
80
60
40
20
0
-20
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
12.5 ft/yr
-0.3 ft/yr
Measured
Pre-project
Linear (Measured)



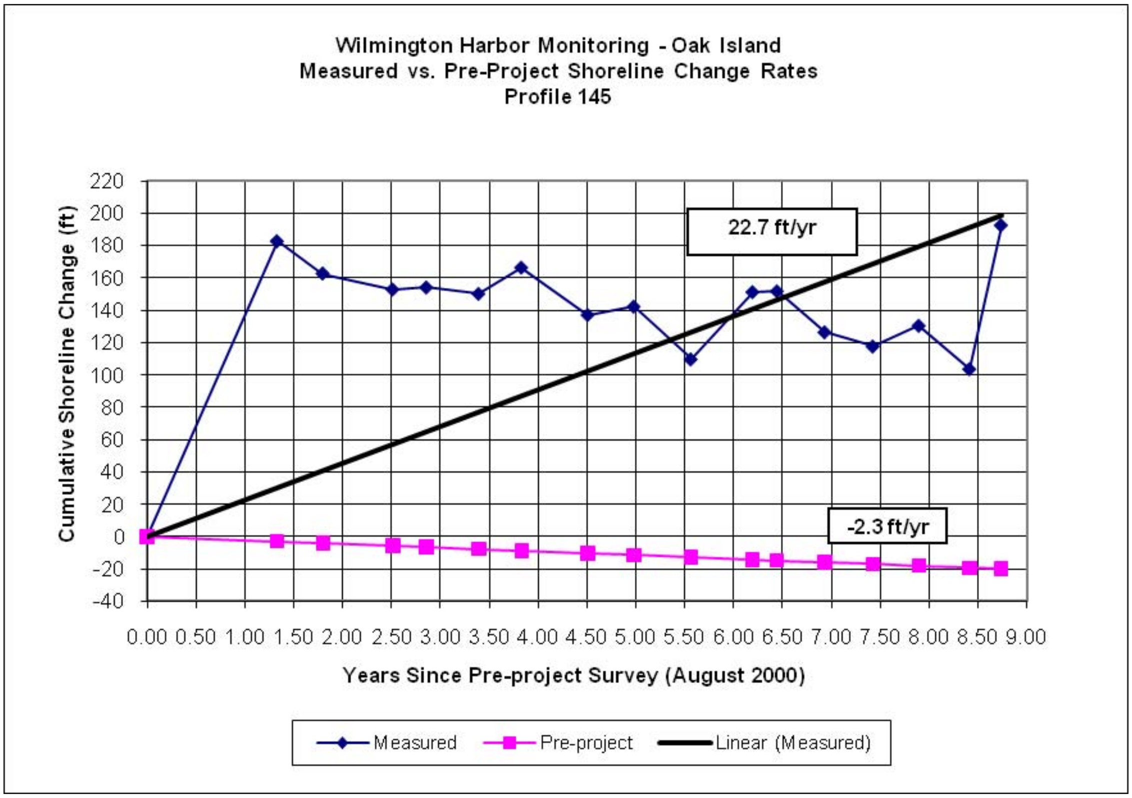
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 130
Cumulative Shoreline Change (ft)
220
200
180
160
140
120
100
80
60
40
20
0
-20
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
21.5 ft/yr
-0.9 ft/yr
Measured
Pre-project
Linear (Measured)



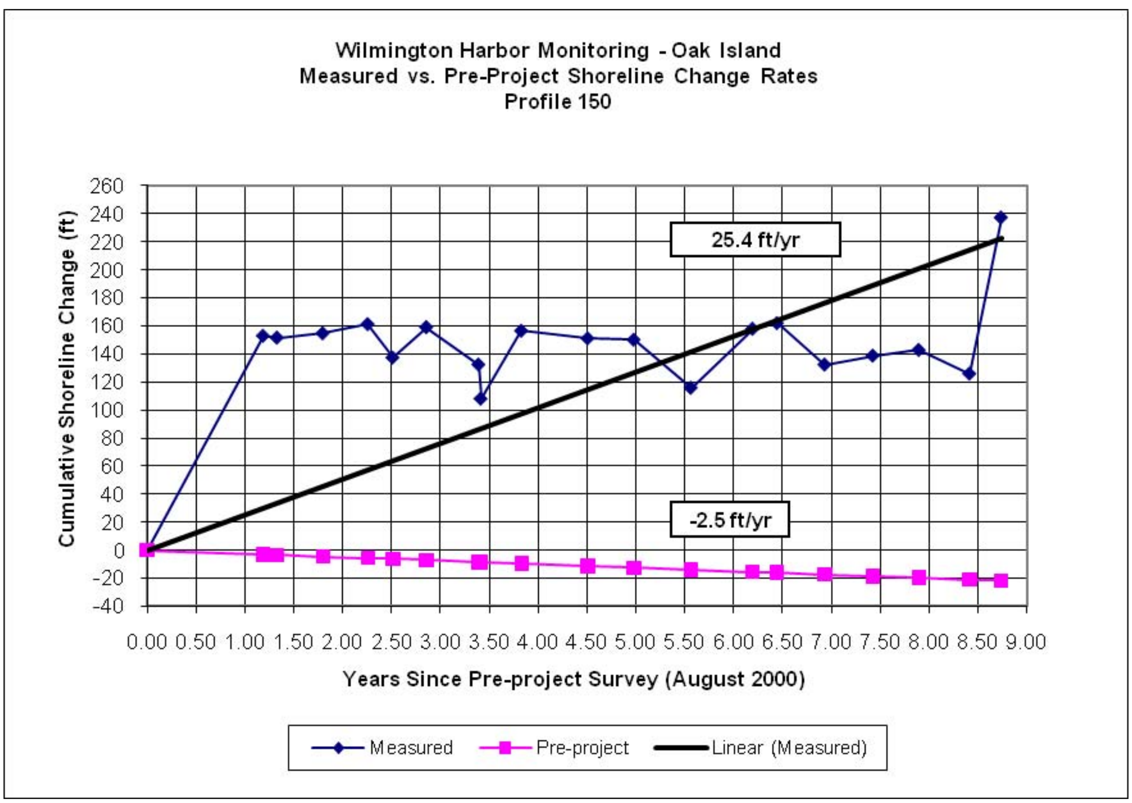
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 135
Cumulative Shoreline Change (ft)
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
22.2 ft/yr
-1.4 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)



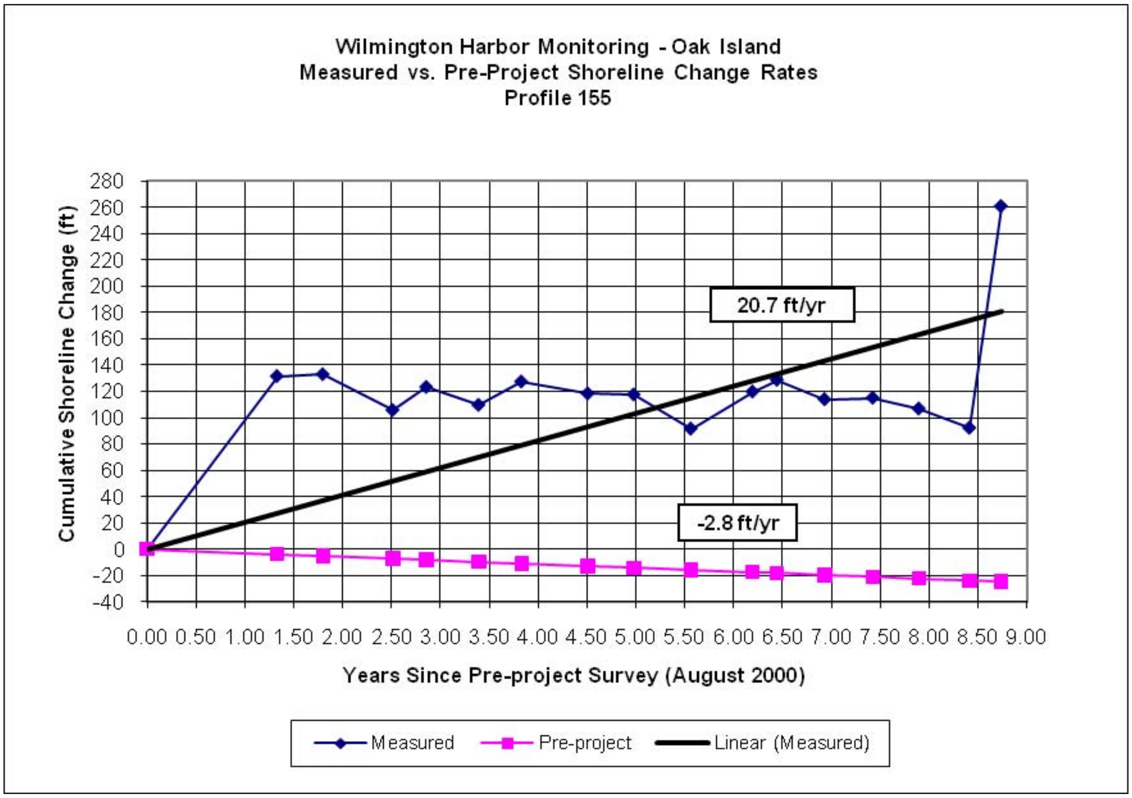
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 140
Cumulative Shoreline Change (ft)
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
21.0 ft/yr
-2.1 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

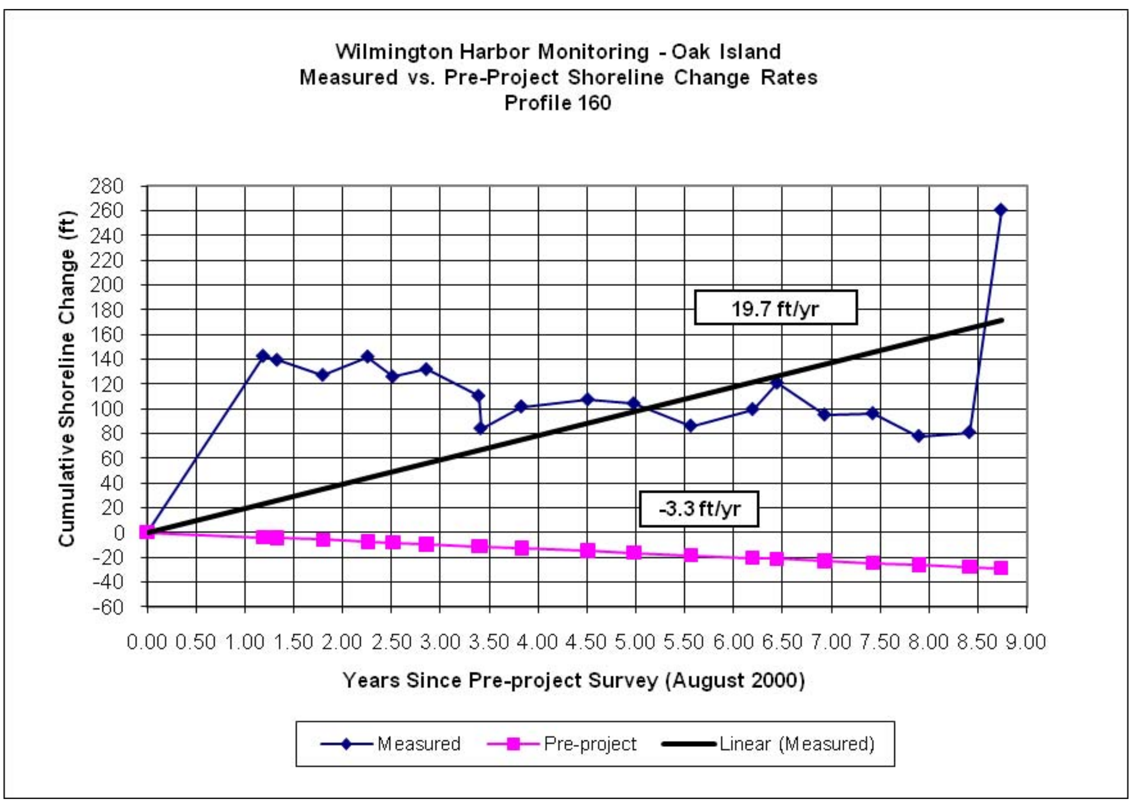


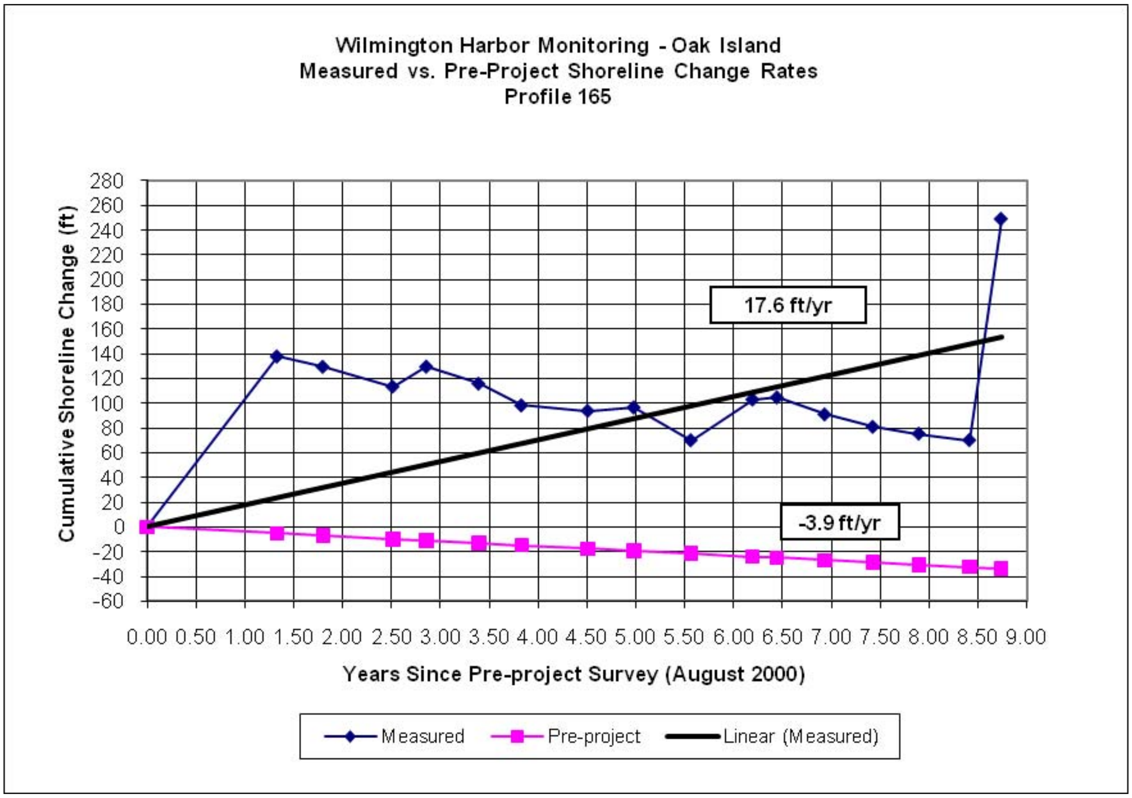
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 145
Cumulative Shoreline Change (ft)
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
22.7 ft/yr
-2.3 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

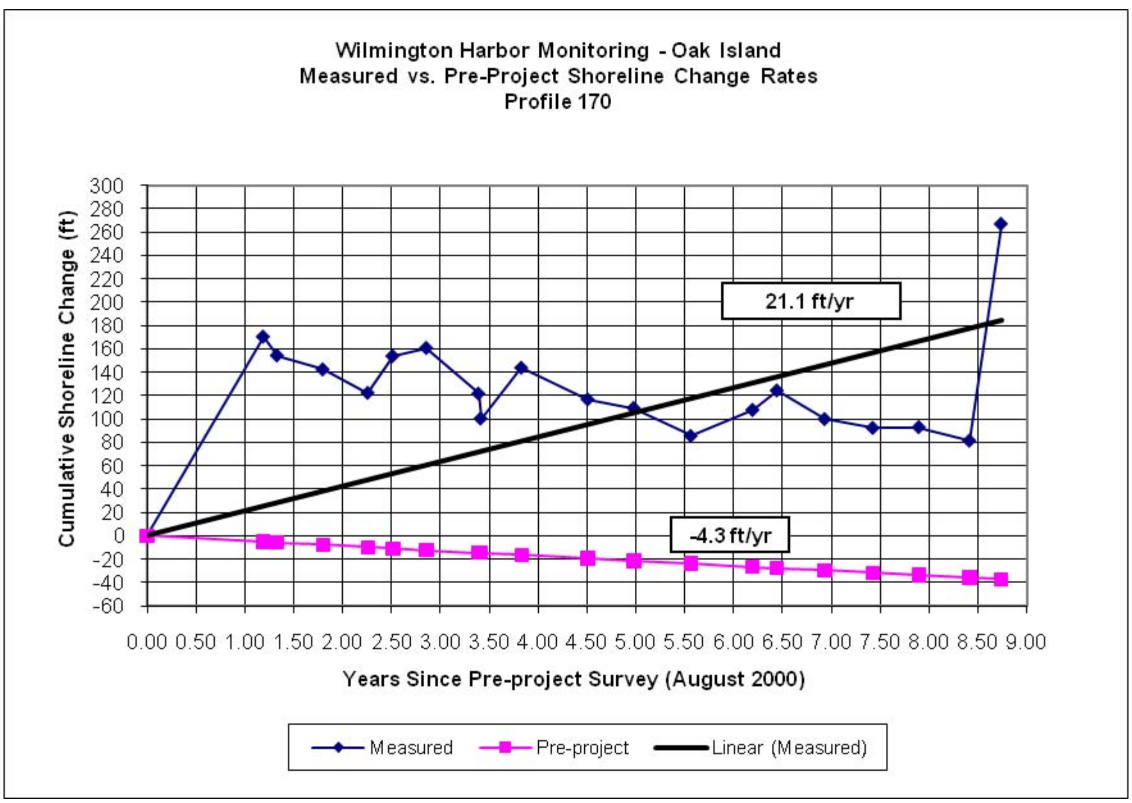


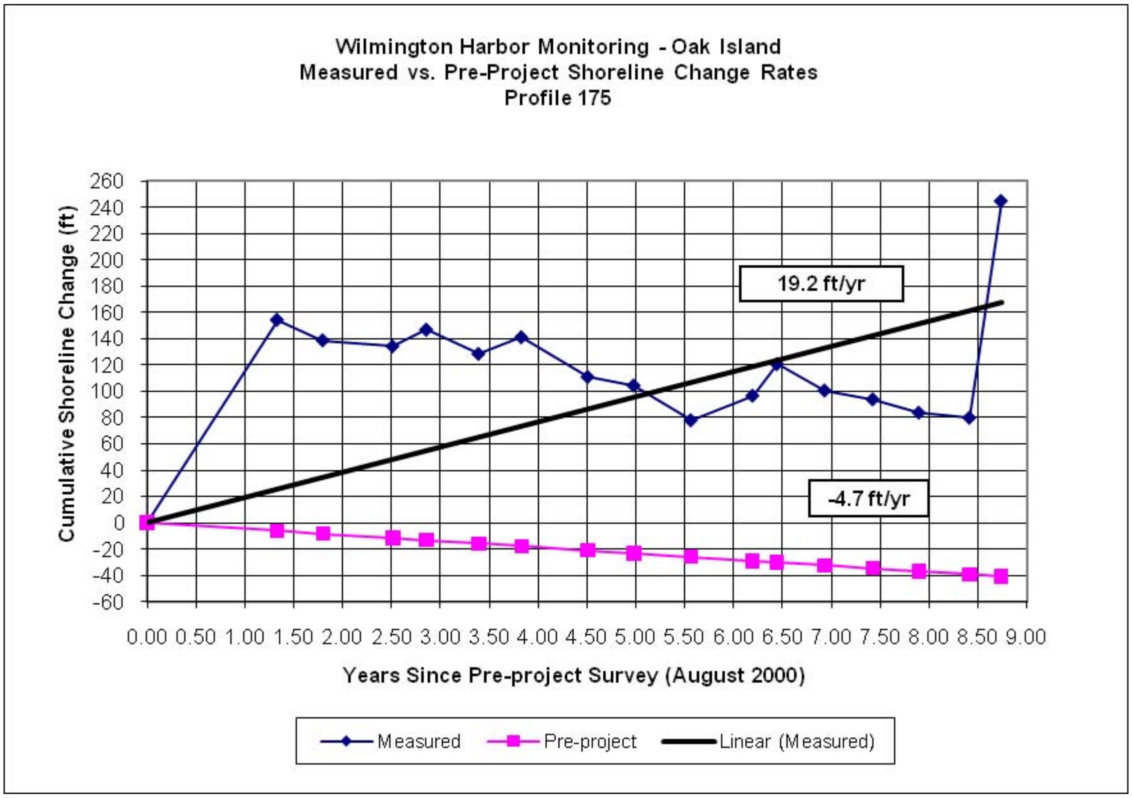
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 150
Cumulative Shoreline Change (ft)
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
25.4 ft/yr
-2.5 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 155
Cumulative Shoreline Change (ft)
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
20.7 ft/yr
-2.8 ft/yr
Measured
Pre-project
Linear (Measured)

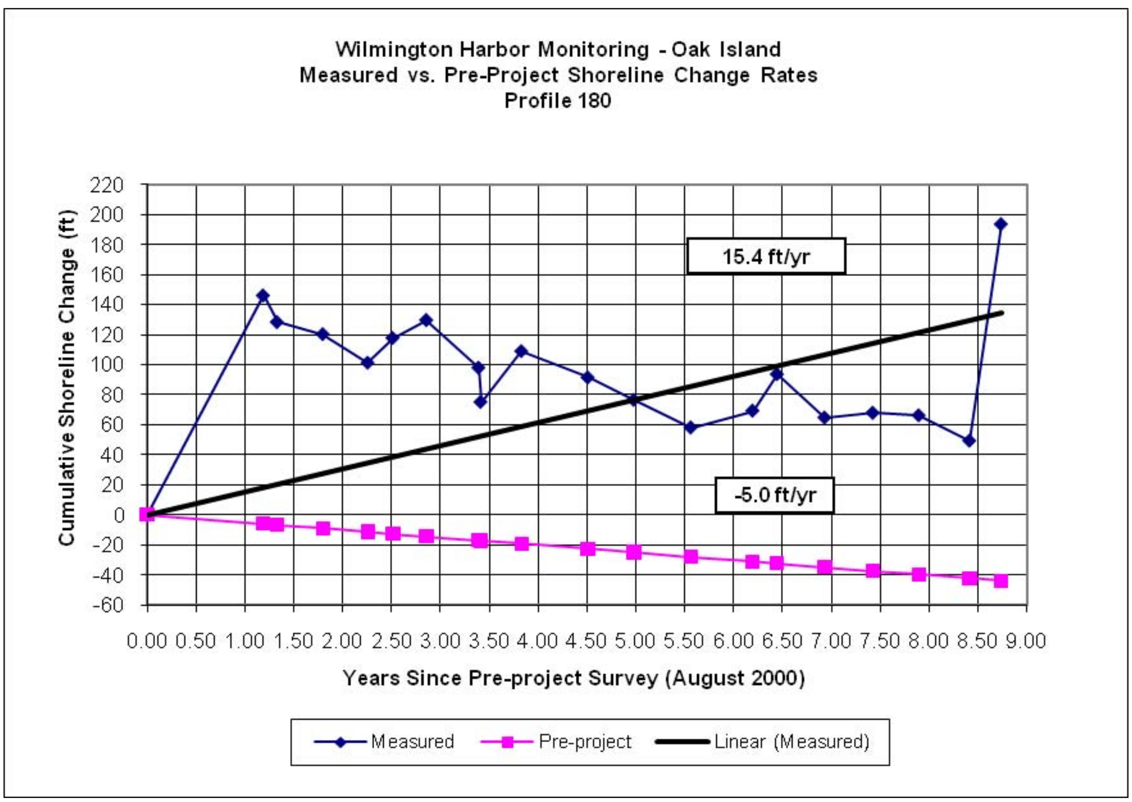

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 160
Cumulative Shoreline Change (ft)
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
19.7 ft/yr
-3.3 ft/yr
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 165
Cumulative Shoreline Change (ft)
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
17.6 ft/yr
-3.9 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

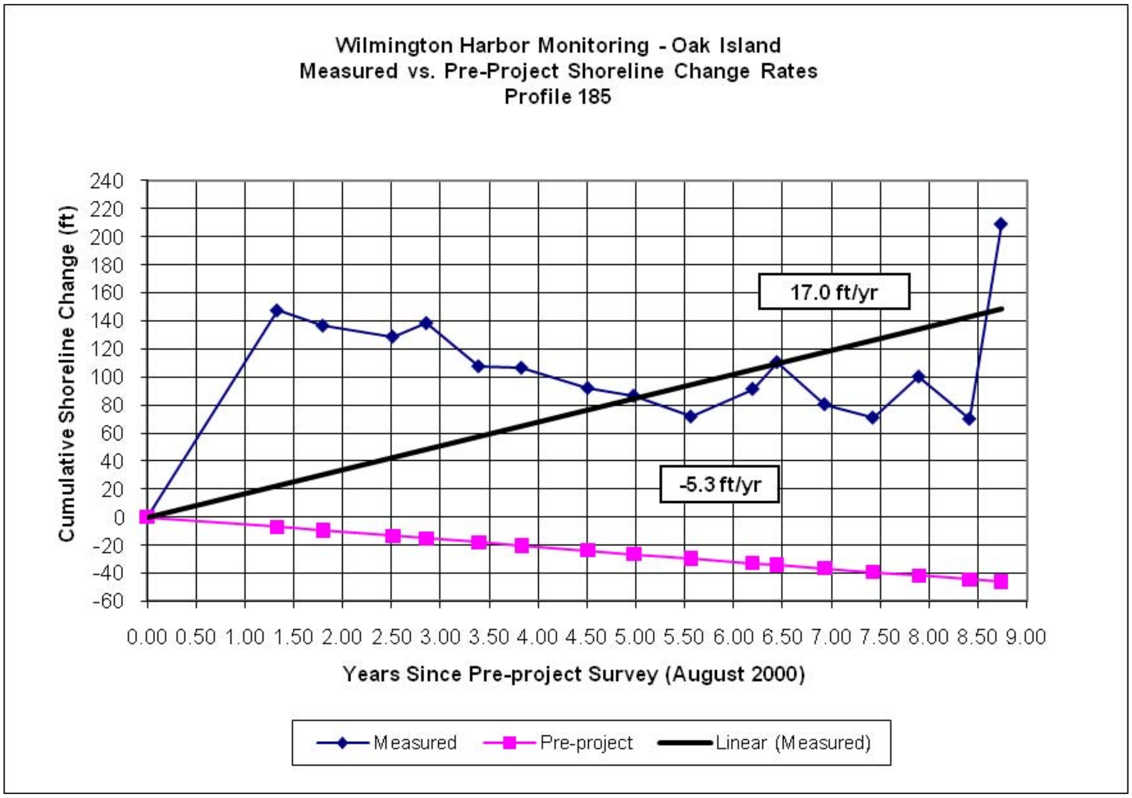

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 170
Cumulative Shoreline Change (ft)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
21.1 ft/yr
-4.3 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

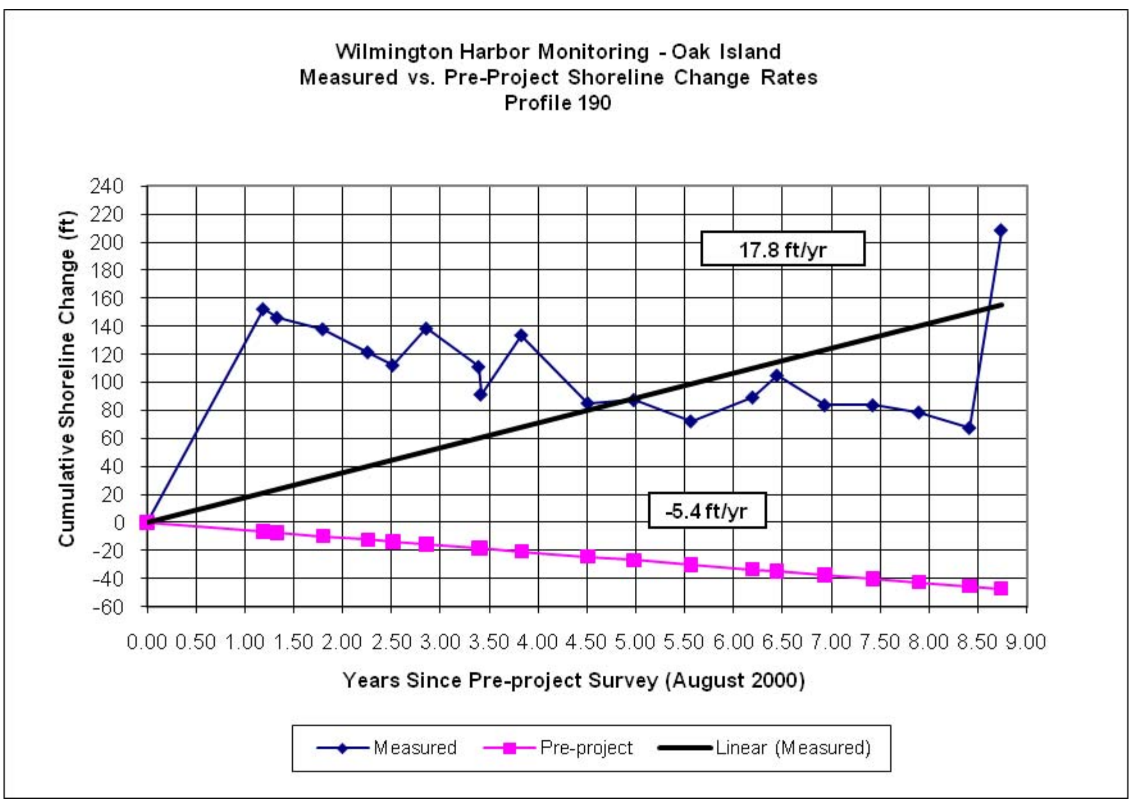


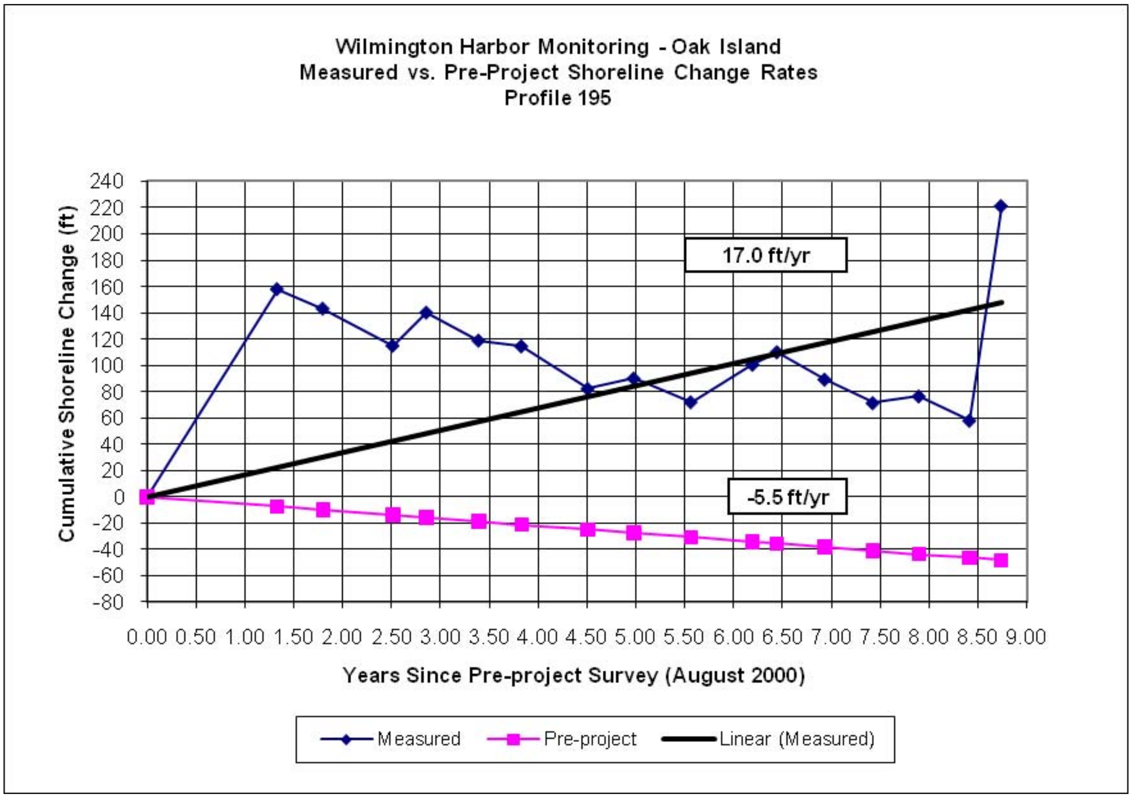
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 175
Cumulative Shoreline Change (ft)
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
19.2 ft/yr
-4.7 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)



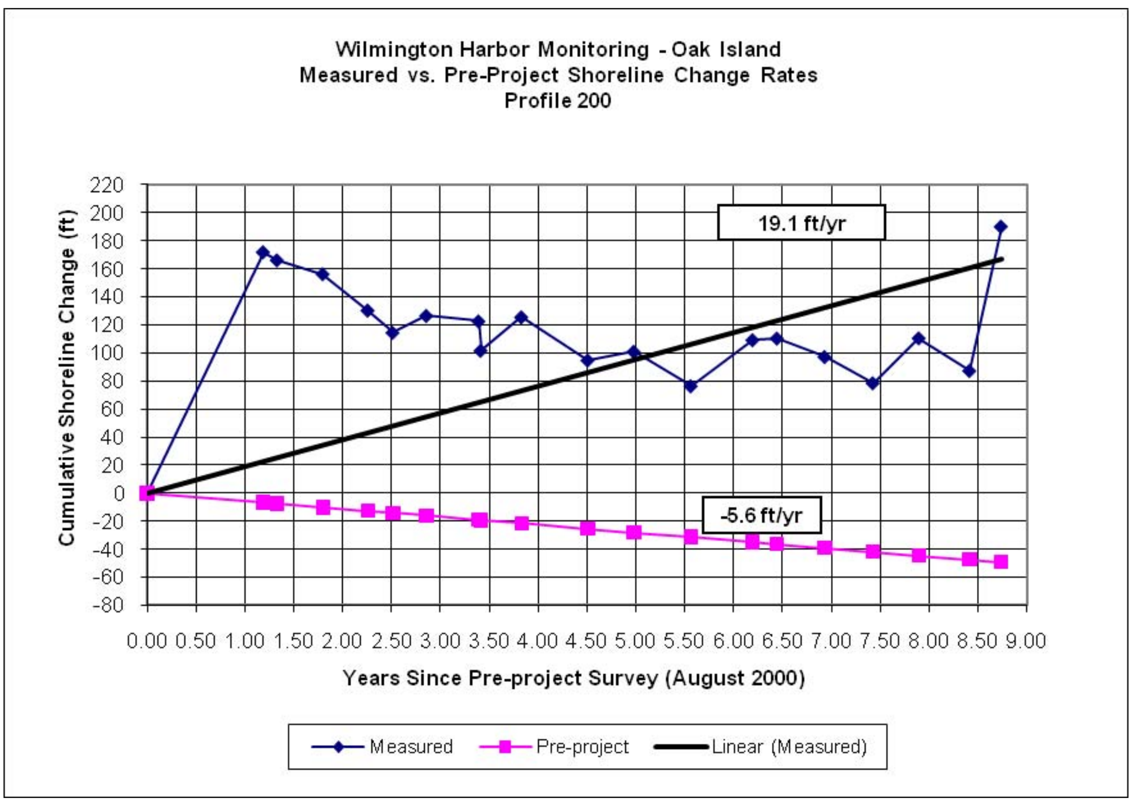
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 180
Cumulative Shoreline Change (ft)
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
15.4 ft/yr
-5.0 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 185
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (August 2000)
17.0 ft/yr
-5.3 ft/yr
Measured
Pre-project
Linear (Measured)

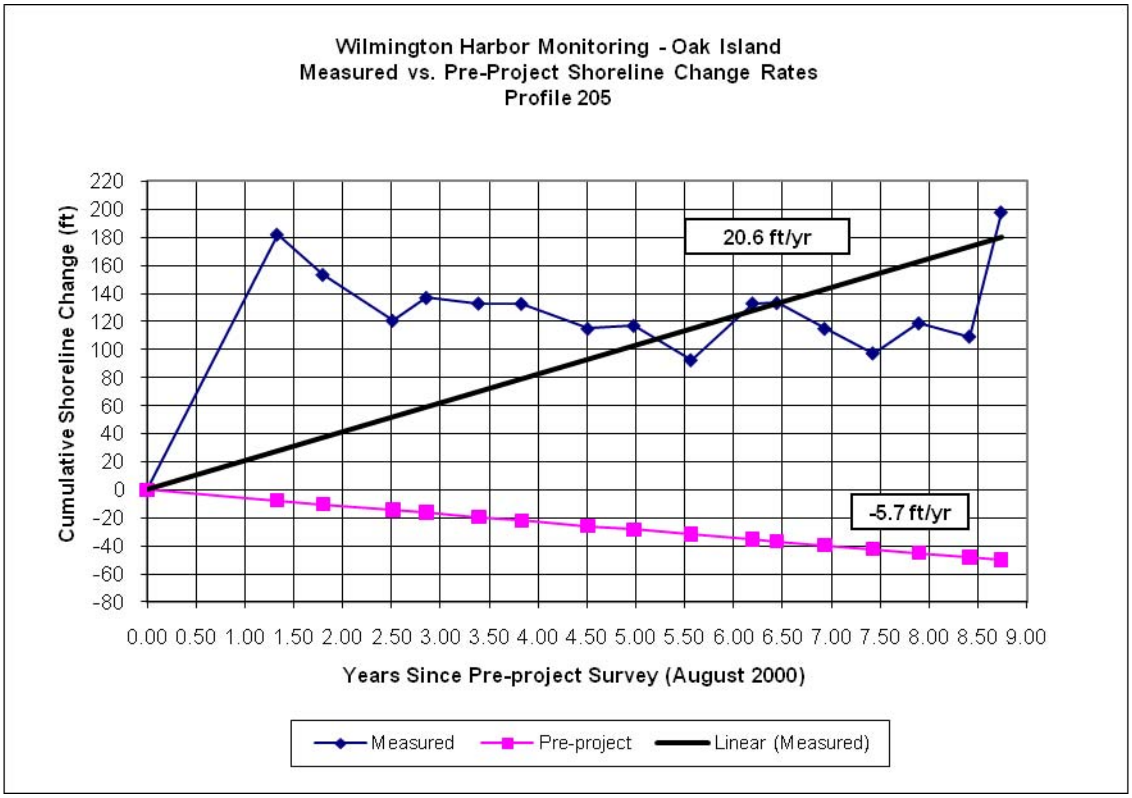

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 190
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (August 2000)
17.8 ft/yr
-5.4 ft/yr
Measured
Pre-project
Linear (Measured)

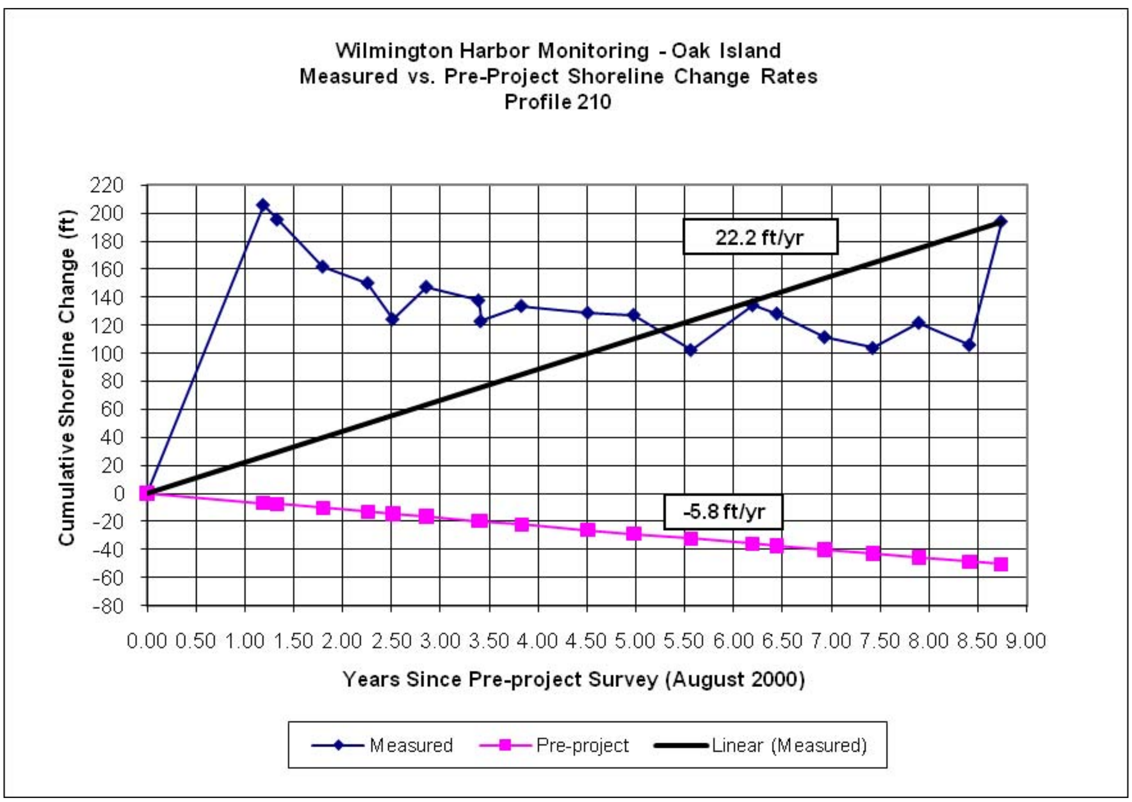


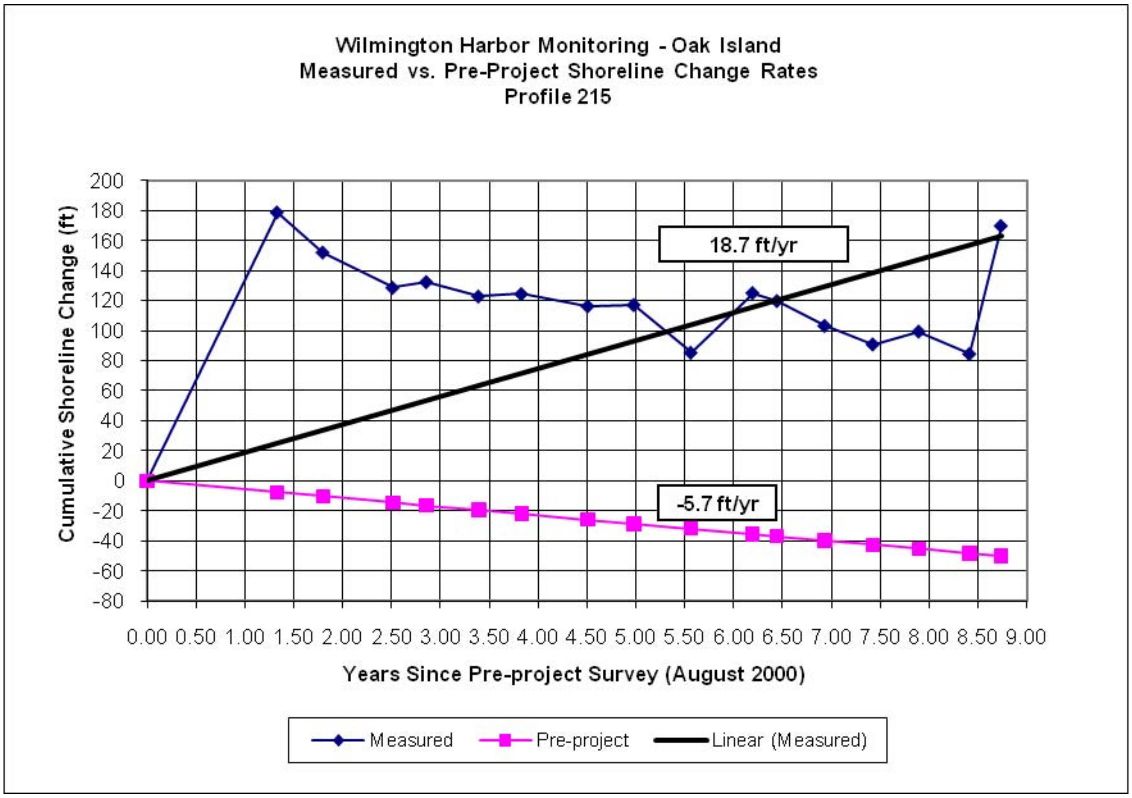
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 195
17.0 ft/yr
-5.5 ft/yr
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)



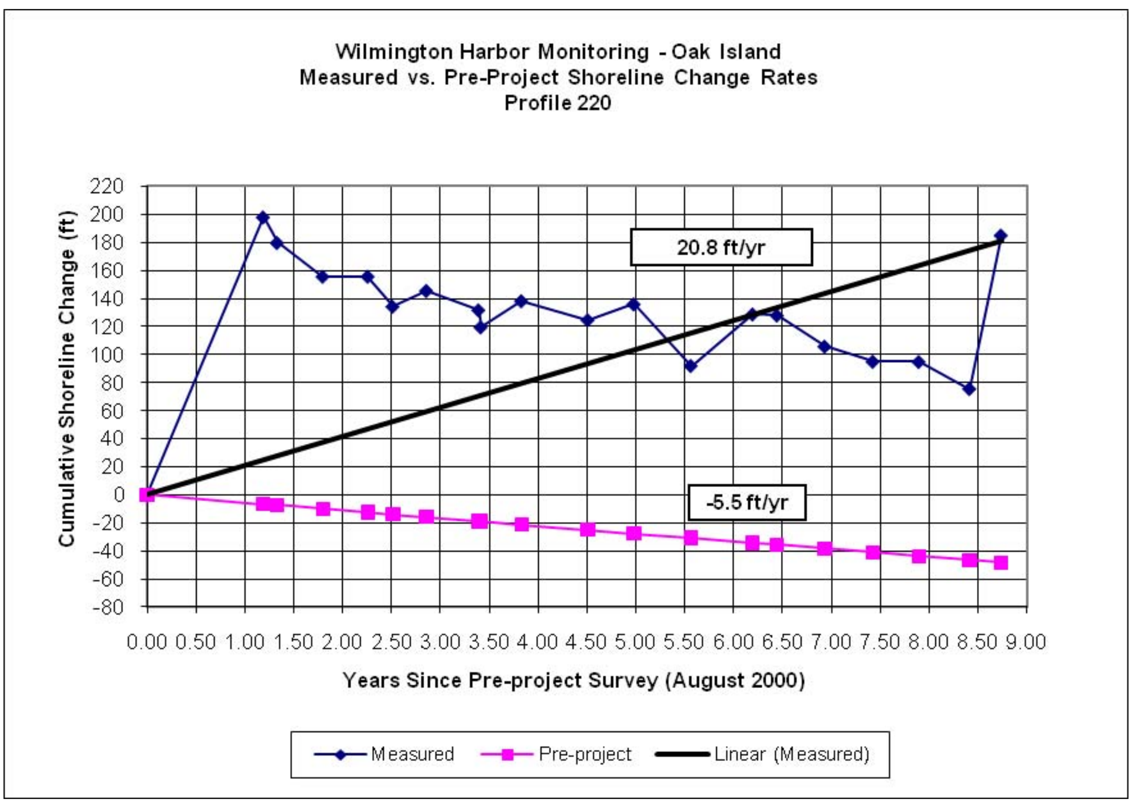
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 200
19.1 ft/yr
-5.6 ft/yr
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 205
20.6 ft/yr
-5.7 ft/yr
Cumulative Shoreline Change (ft)
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

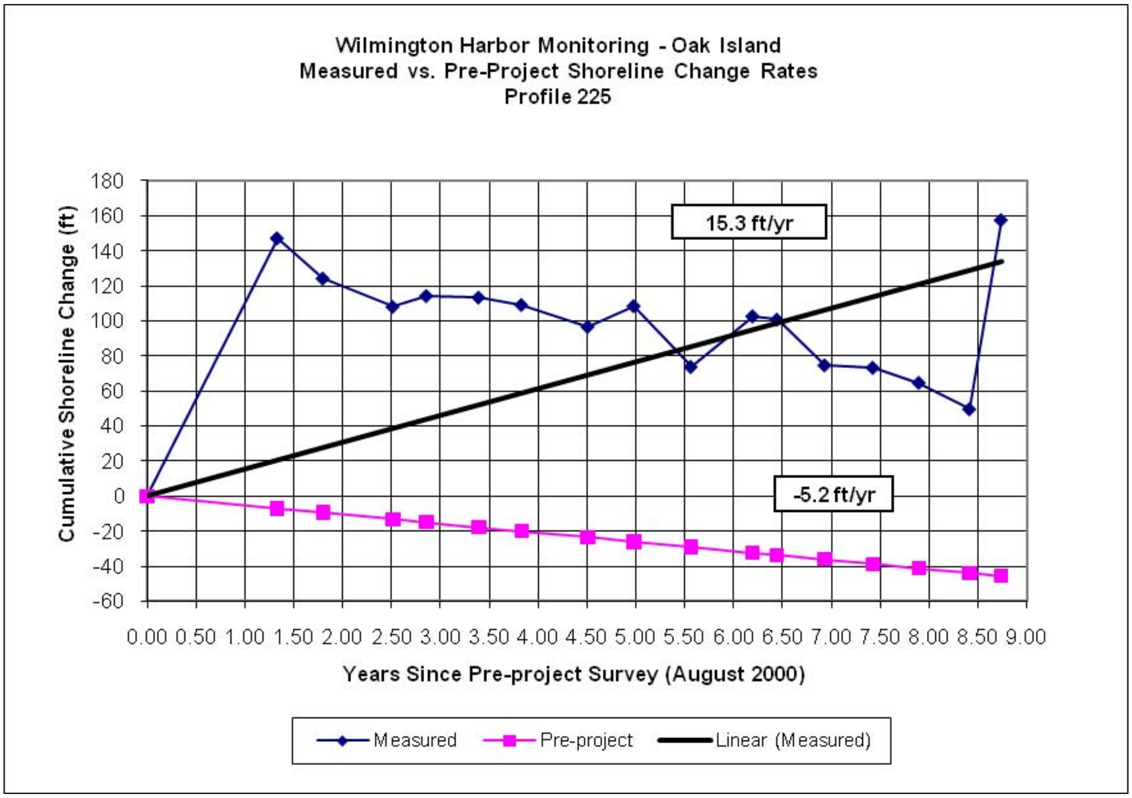

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 210
22.2 ft/yr
-5.8 ft/yr
Cumulative Shoreline Change (ft)
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

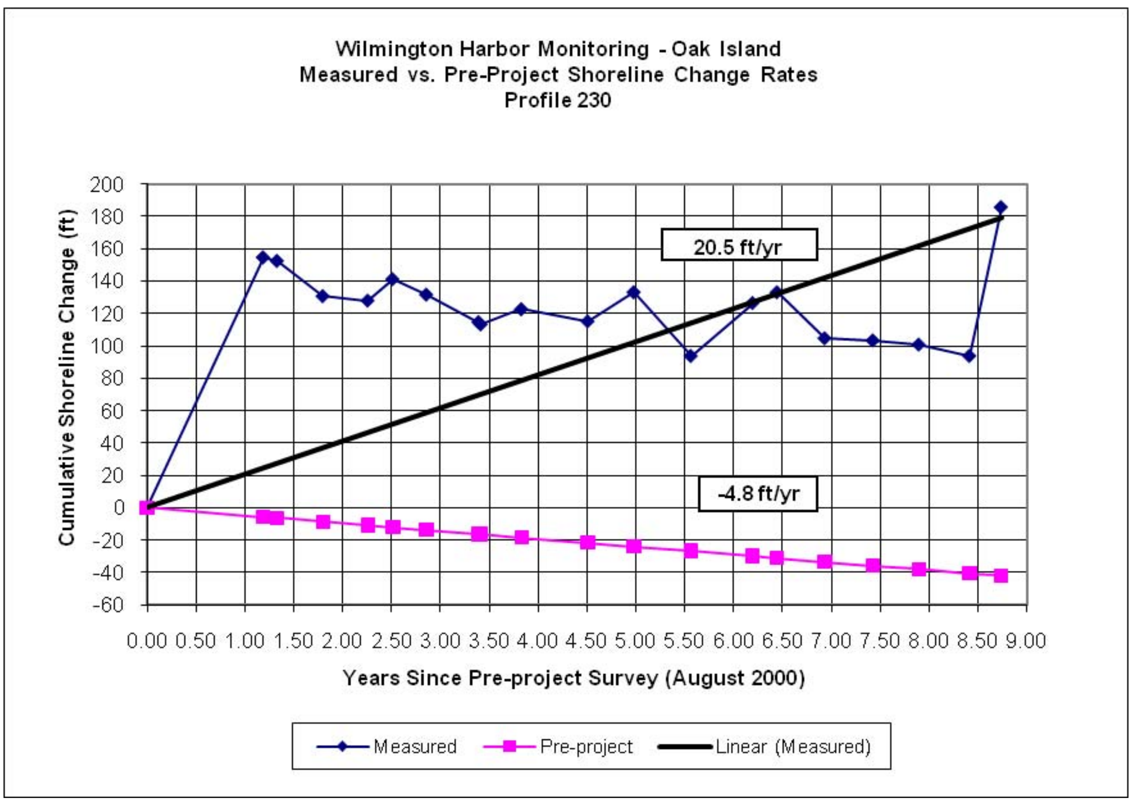


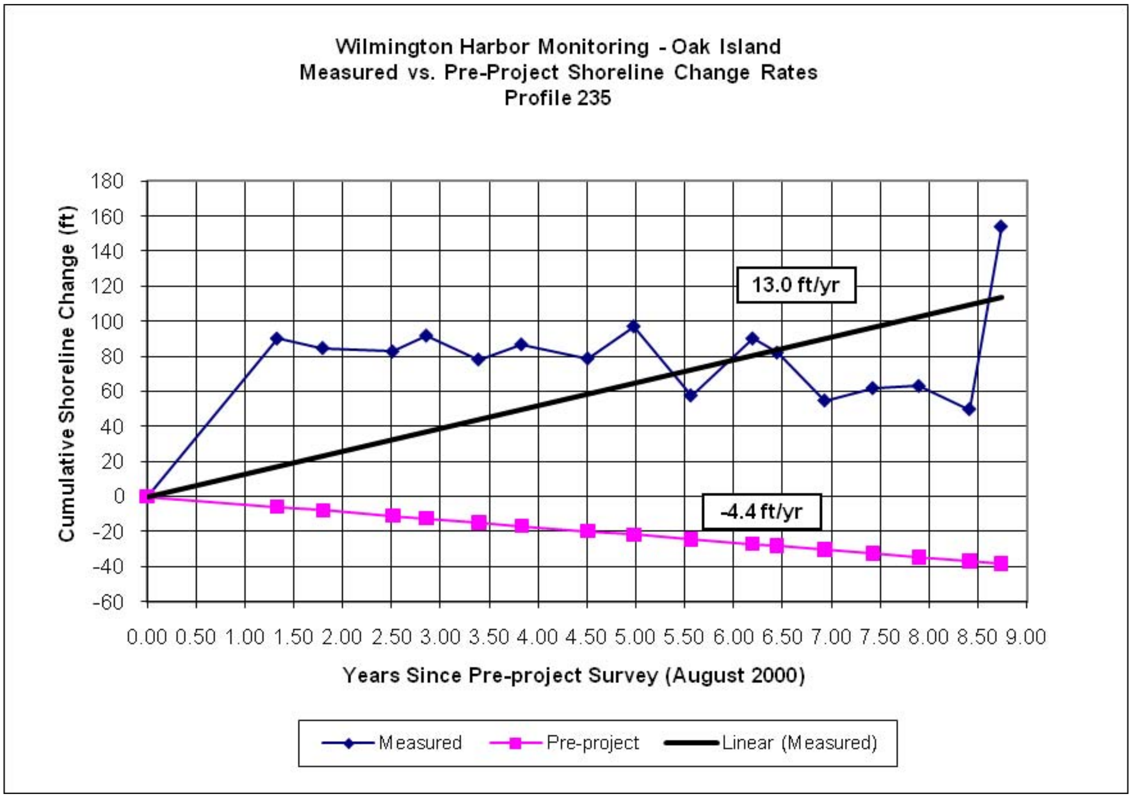
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 215
18.7 ft/yr
-5.7 ft/yr
Cumulative Shoreline Change (ft)
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

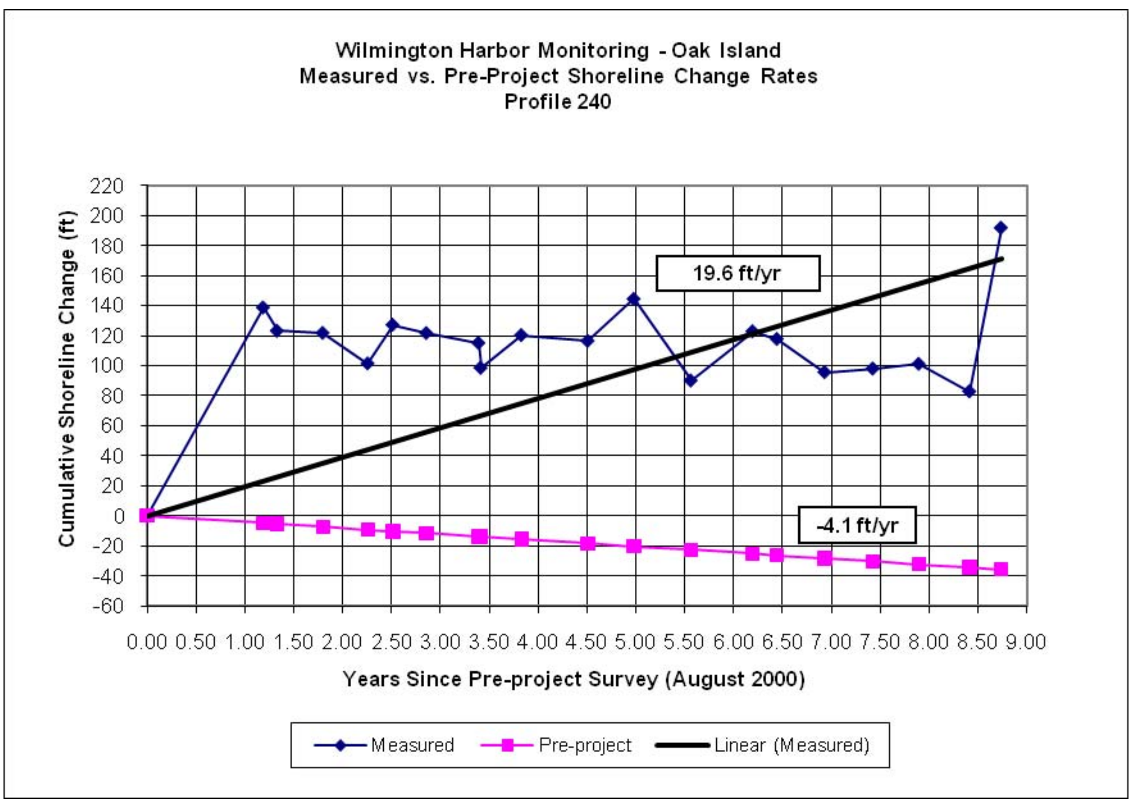


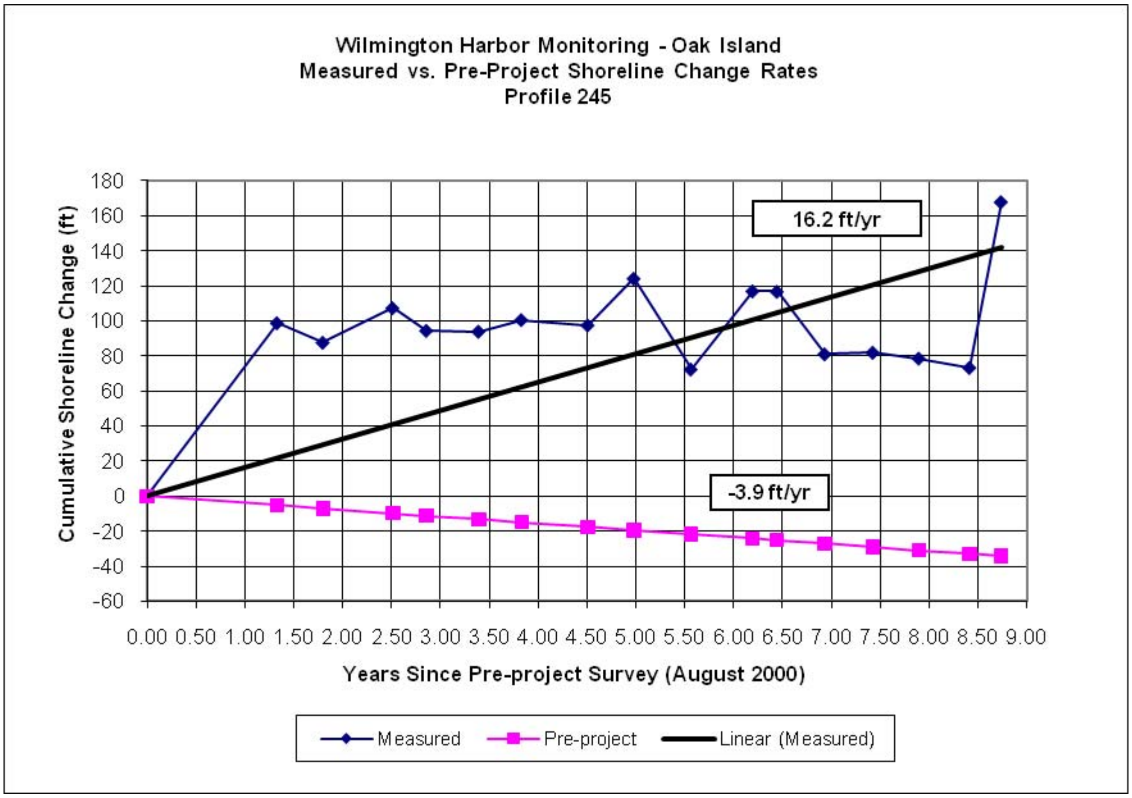
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 220
20.8 ft/yr
-5.5 ft/yr
Cumulative Shoreline Change (ft)
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 225
15.3 ft/yr
-5.2 ft/yr
Cumulative Shoreline Change (ft)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

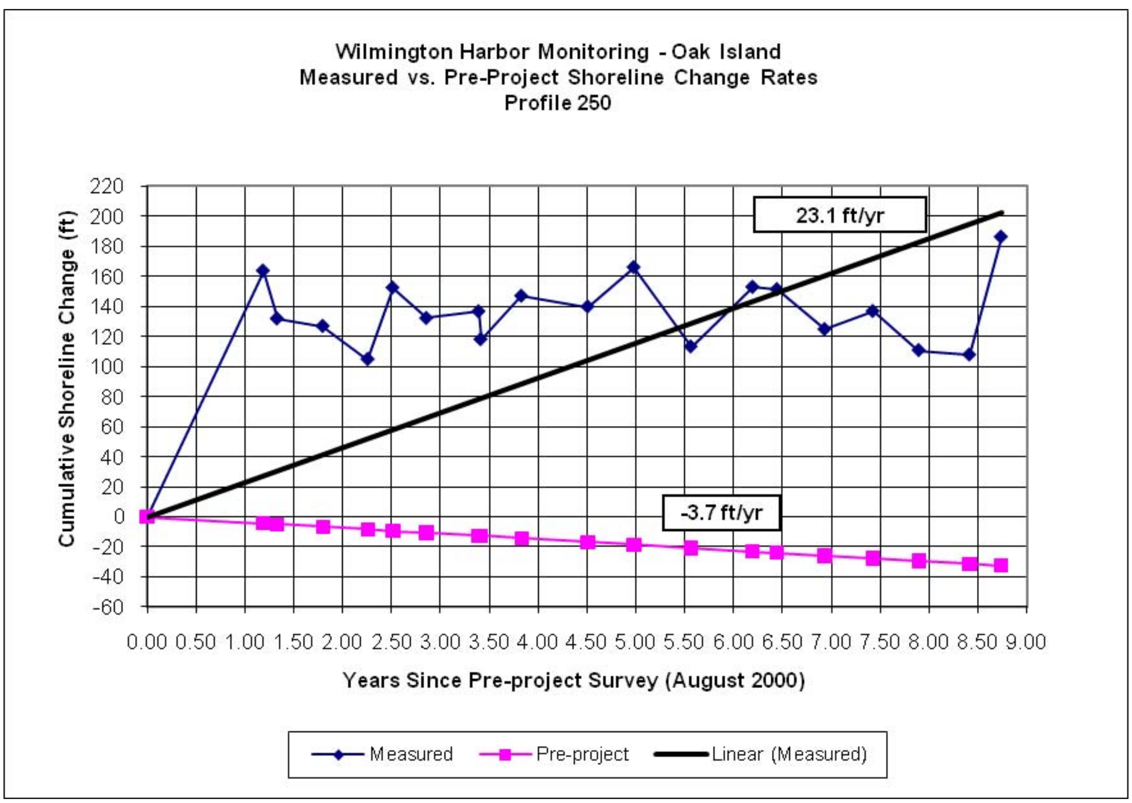

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 230
20.5 ft/yr
-4.8 ft/yr
Cumulative Shoreline Change (ft)
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 235
Cumulative Shoreline Change (ft)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
13.0 ft/yr
-4.4 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

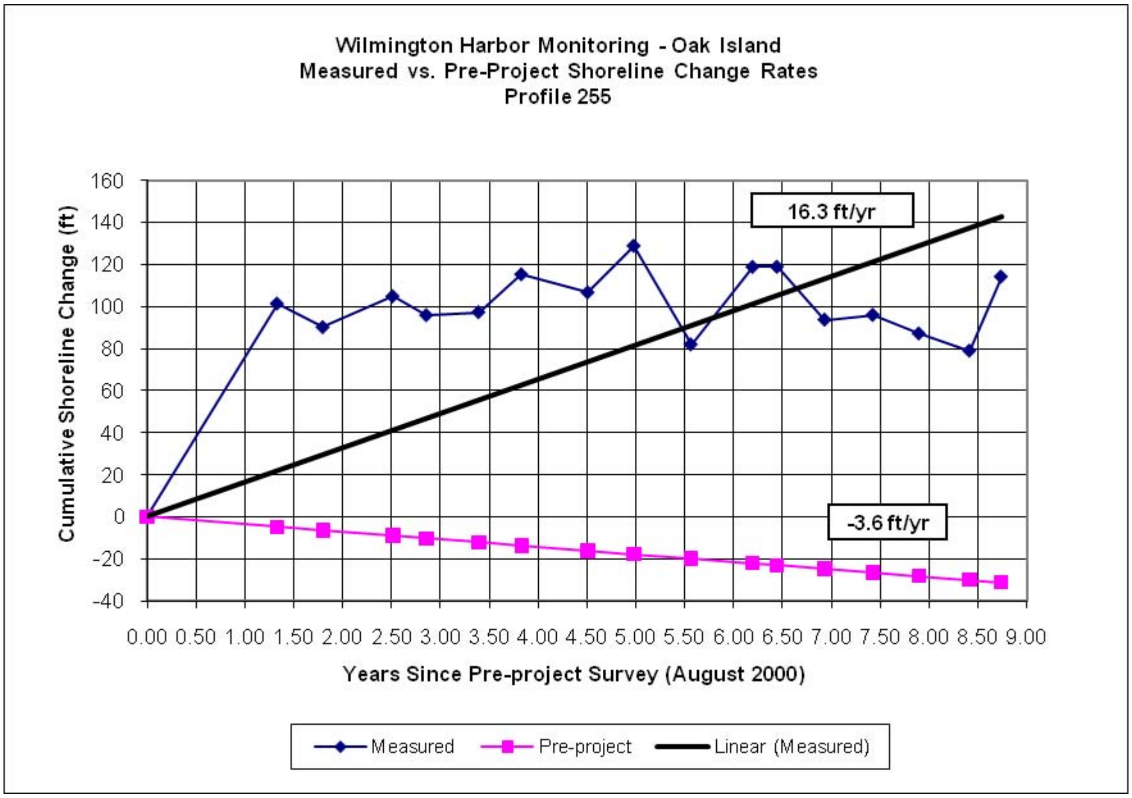

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 240
Cumulative Shoreline Change (ft)
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
19.6 ft/yr
-4.1 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

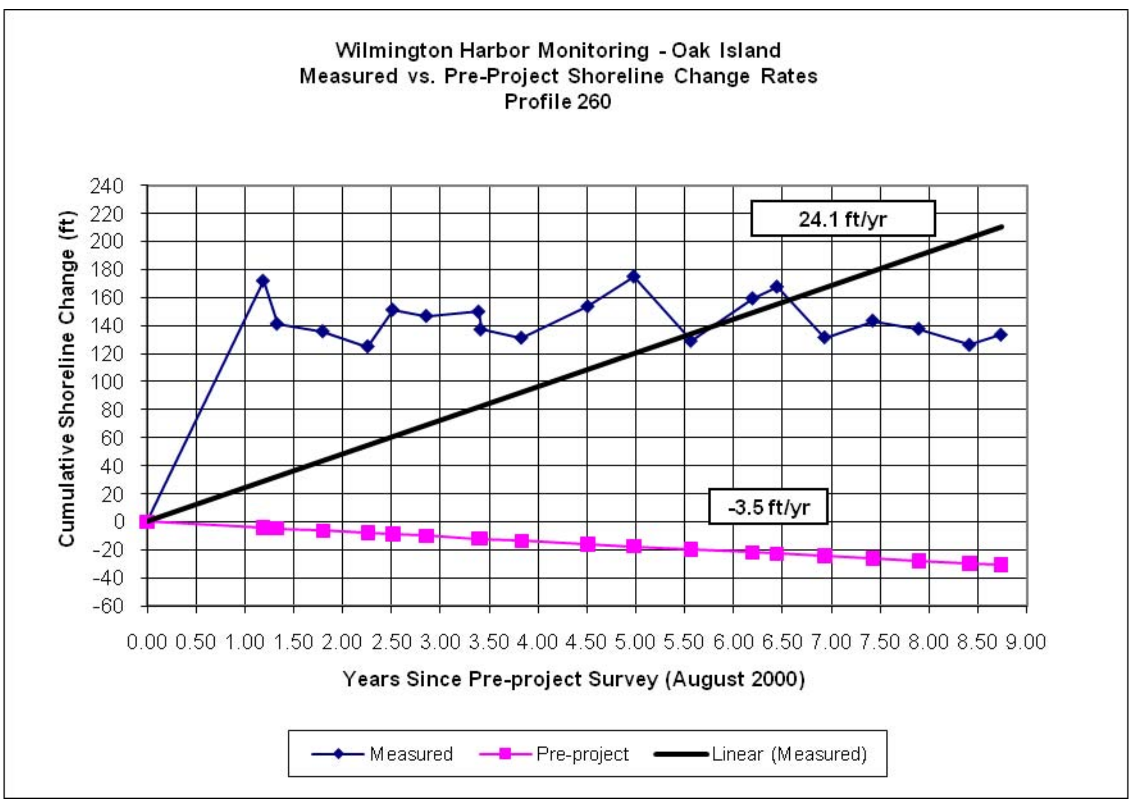


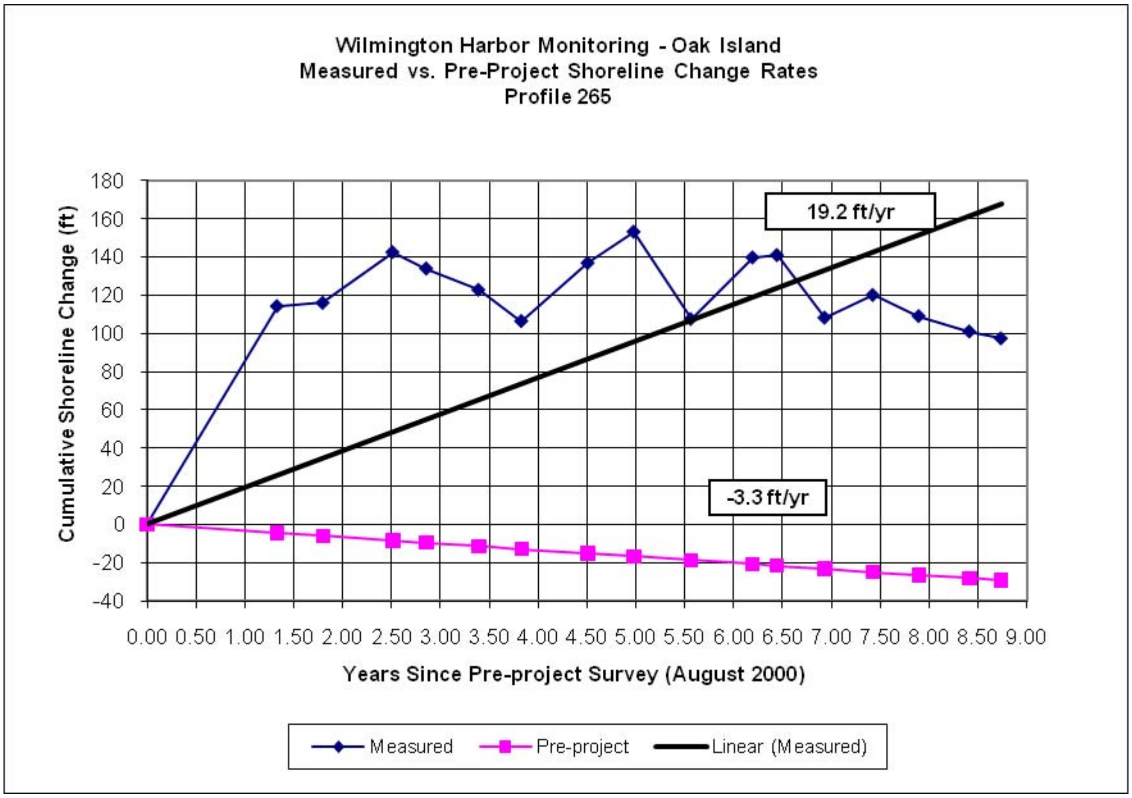
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 245
16.2 ft/yr
-3.9 ft/yr
Cumulative Shoreline Change (ft)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

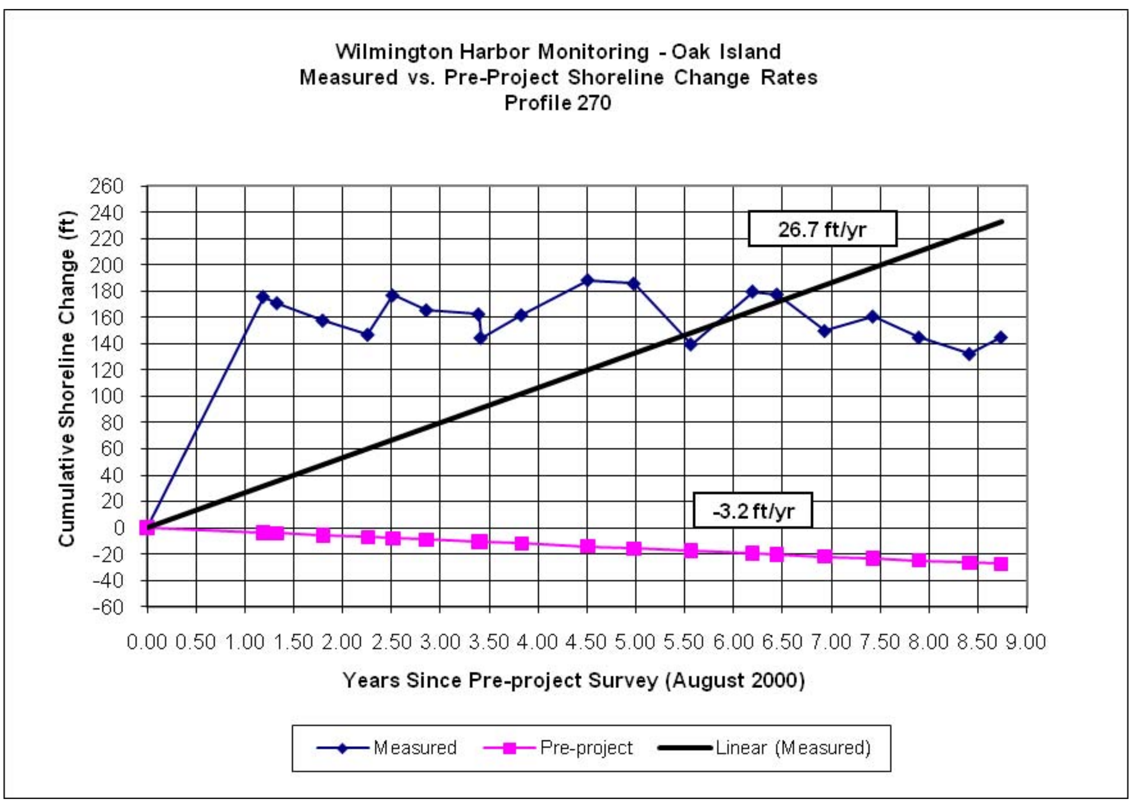


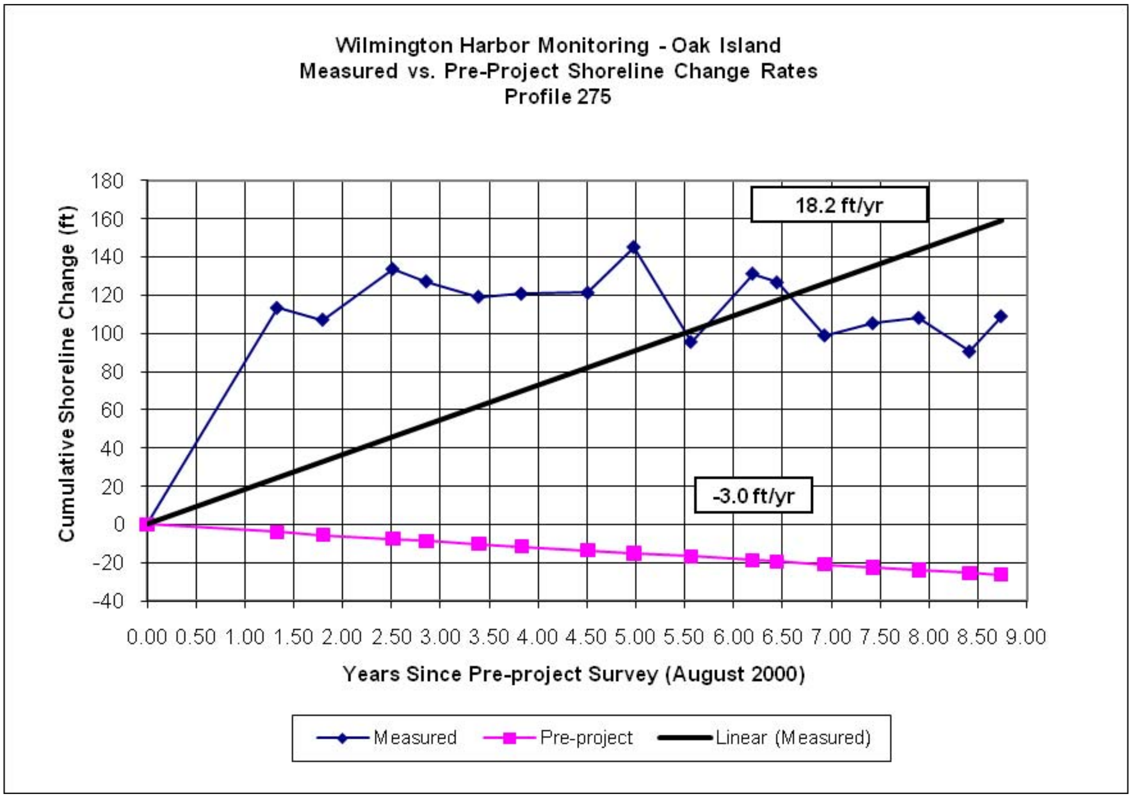
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 250
23.1 ft/yr
-3.7 ft/yr
Cumulative Shoreline Change (ft)
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 255
16.3 ft/yr
-3.6 ft/yr
Cumulative Shoreline Change (ft)
160
140
120
100
80
60
40
20
0
-20
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

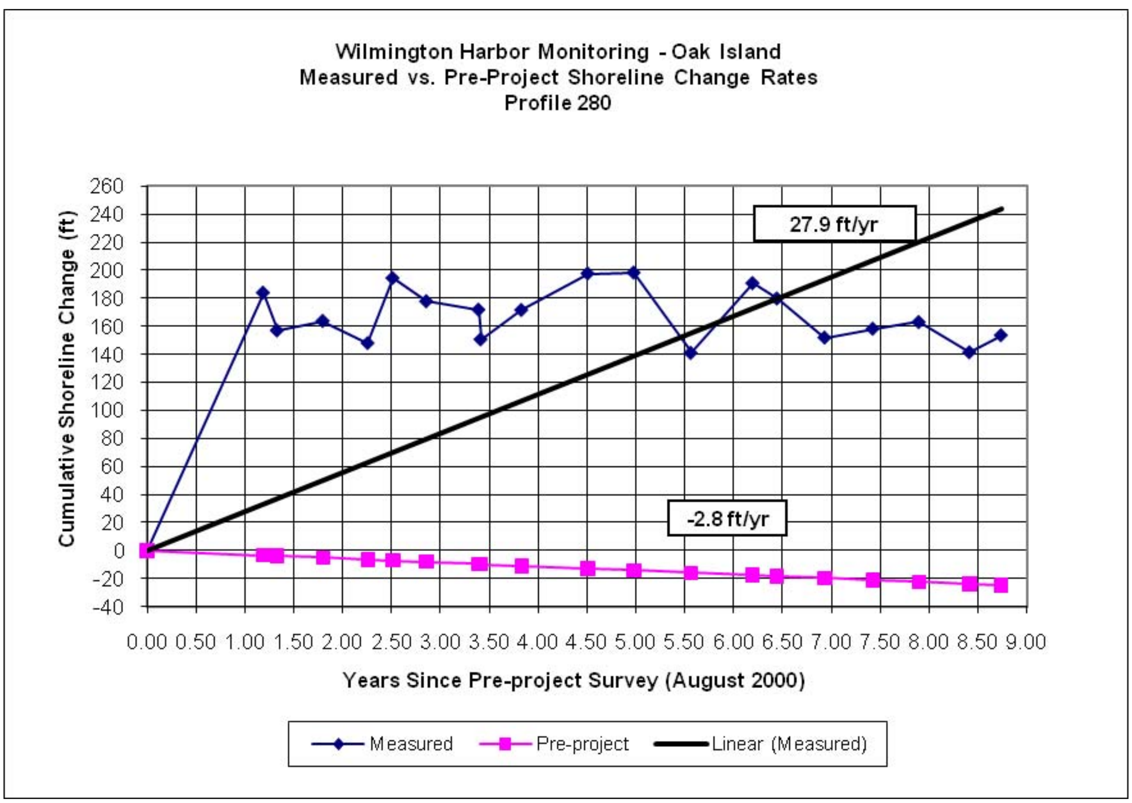

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 260
24.1 ft/yr
-3.5 ft/yr
Cumulative Shoreline Change (ft)
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 265
19.2 ft/yr
-3.3 ft/yr
Cumulative Shoreline Change (ft)
180
160
140
120
100
80
60
40
20
0
-20
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

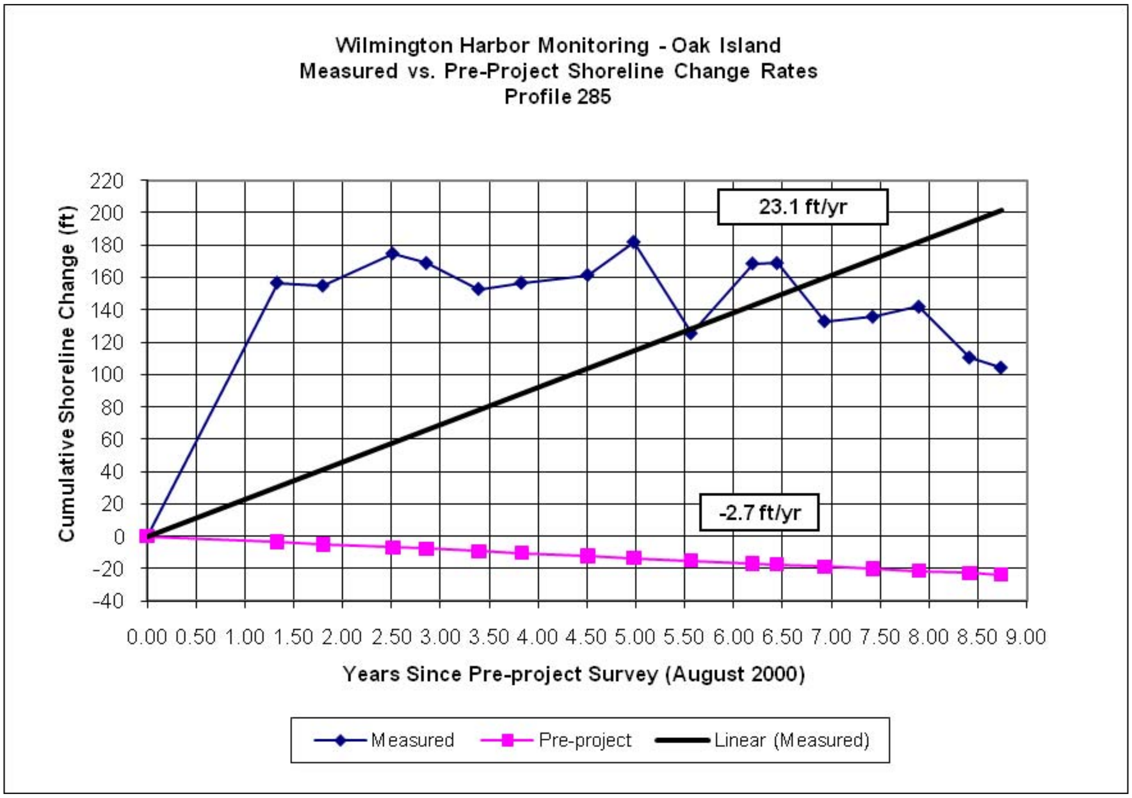

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 270
26.7 ft/yr
-3.2 ft/yr
Cumulative Shoreline Change (ft)
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

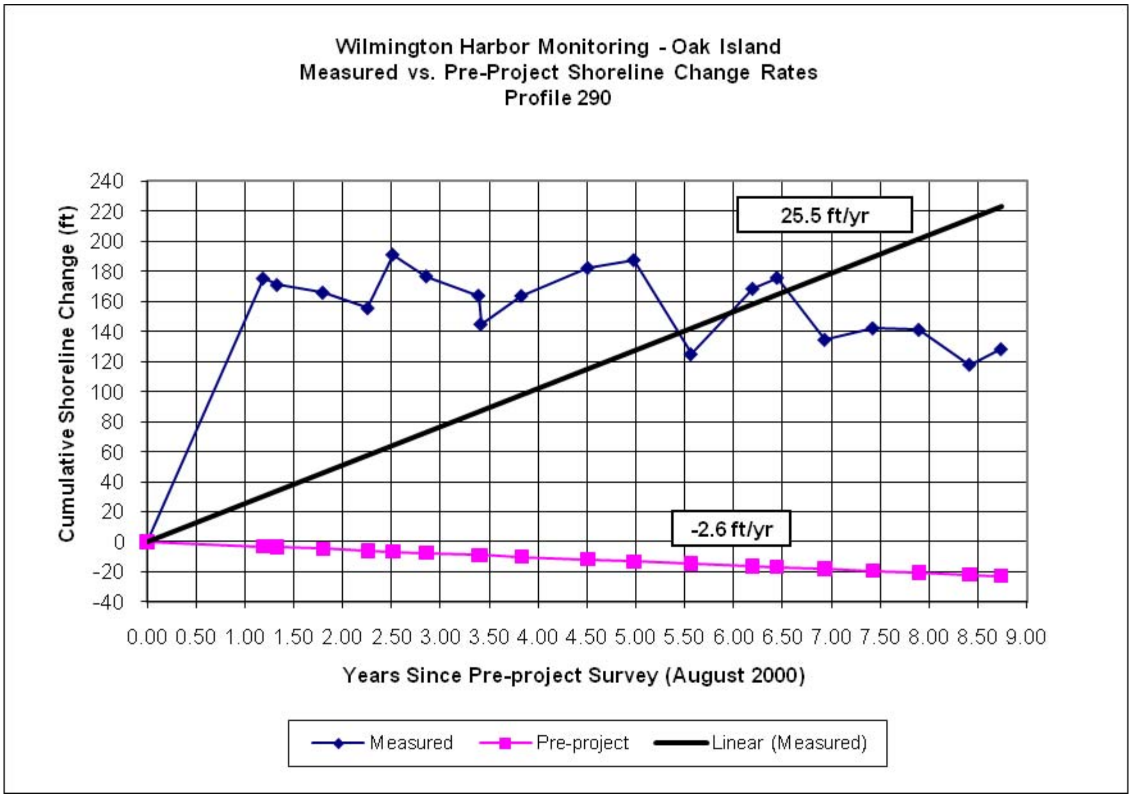


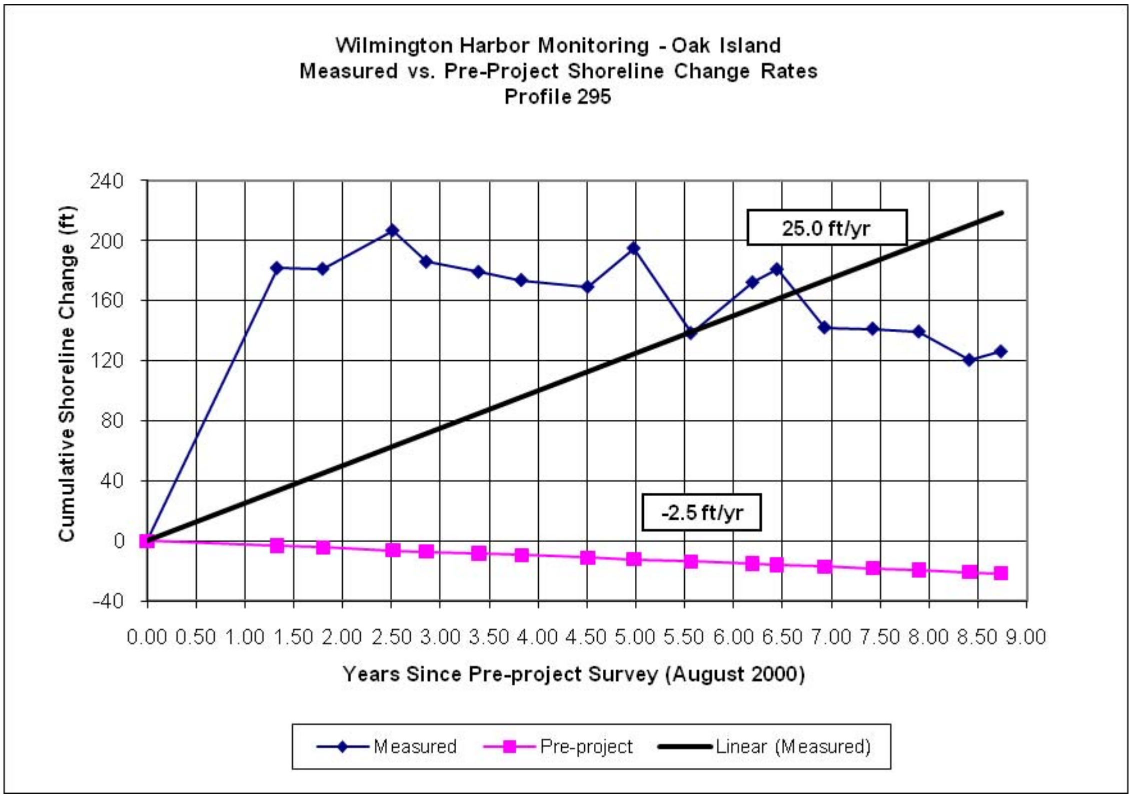
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 275
18.2 ft/yr
-3.0 ft/yr
Cumulative Shoreline Change (ft)
180
160
140
120
100
80
60
40
20
0
-20
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

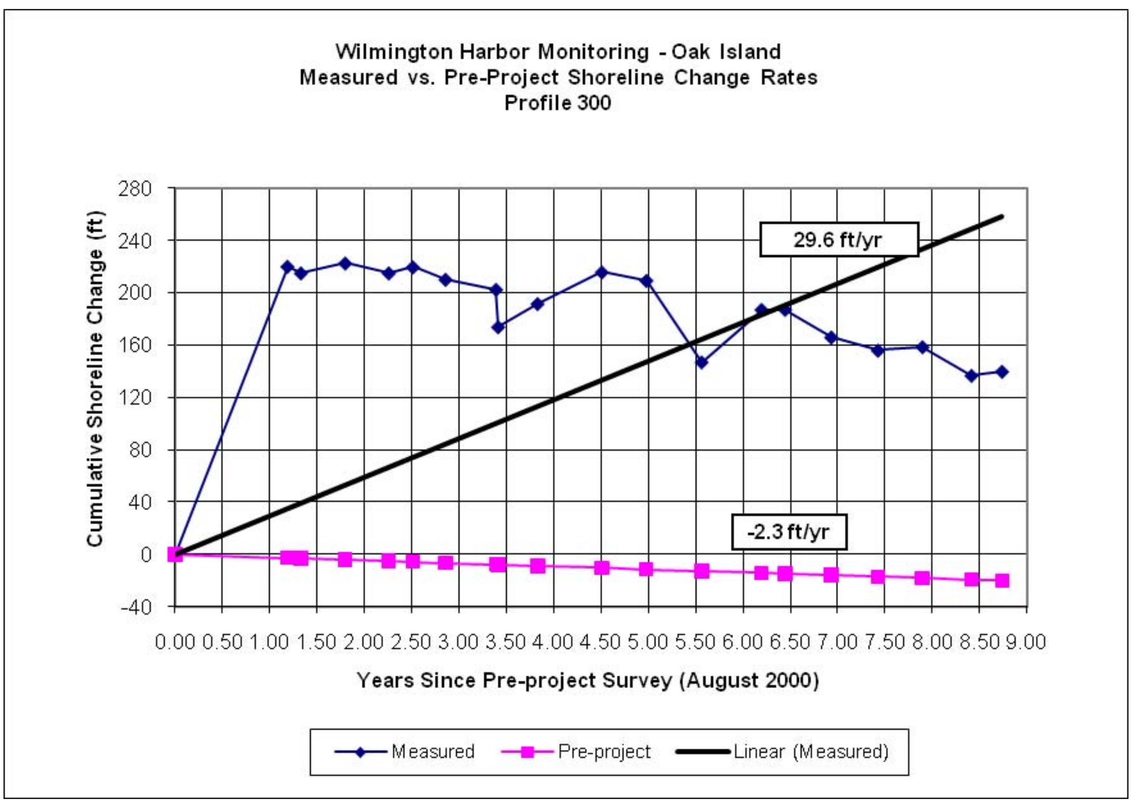


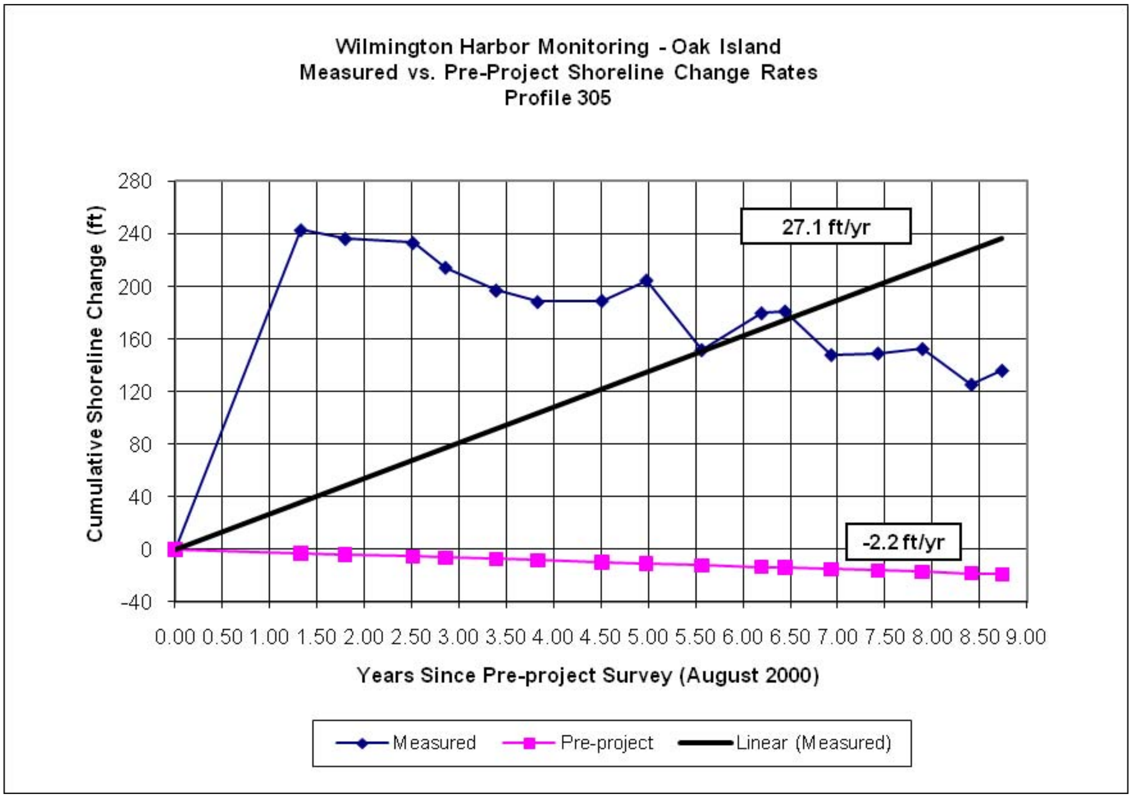
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 280
27.9 ft/yr
-2.8 ft/yr
Cumulative Shoreline Change (ft)
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 285
23.1 ft/yr
-2.7 ft/yr
Cumulative Shoreline Change (ft)
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

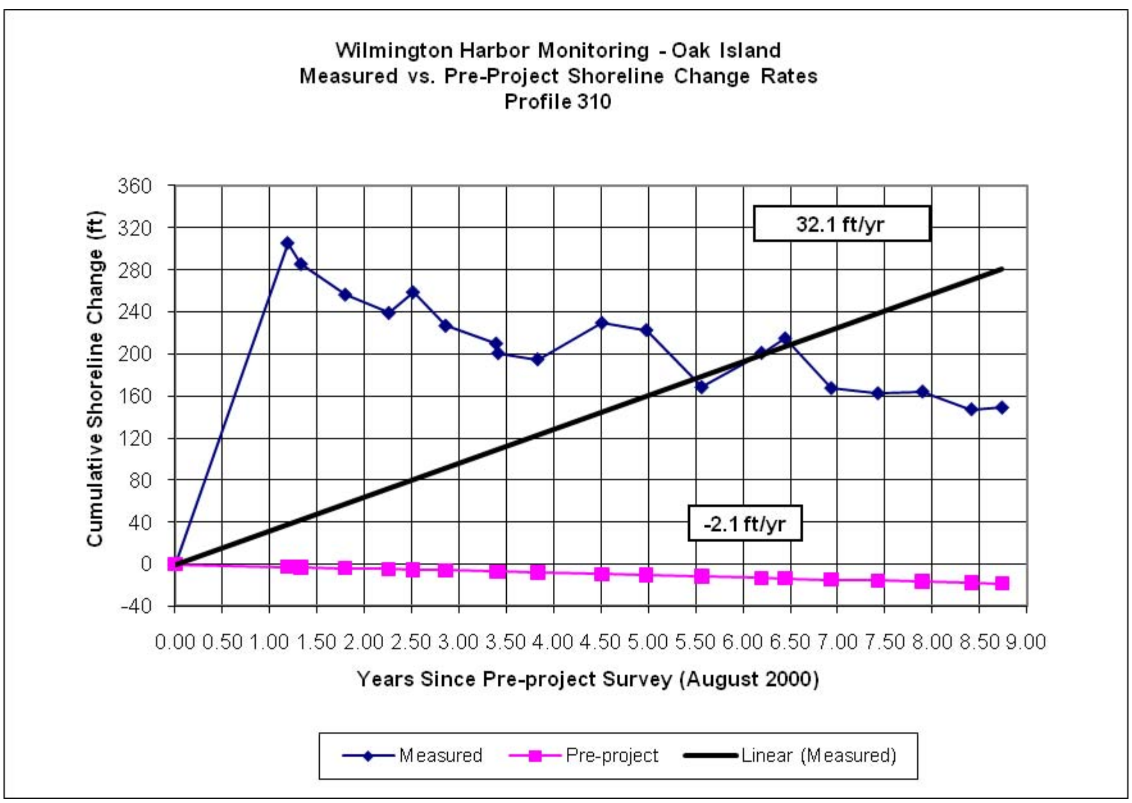

Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 290
25.5 ft/yr
-2.6 ft/yr
Cumulative Shoreline Change (ft)
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 295
25.0 ft/yr
-2.5 ft/yr
Cumulative Shoreline Change (ft)
240
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)


Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 300
29.6 ft/yr
-2.3 ft/yr
Cumulative Shoreline Change (ft)
280
240
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)



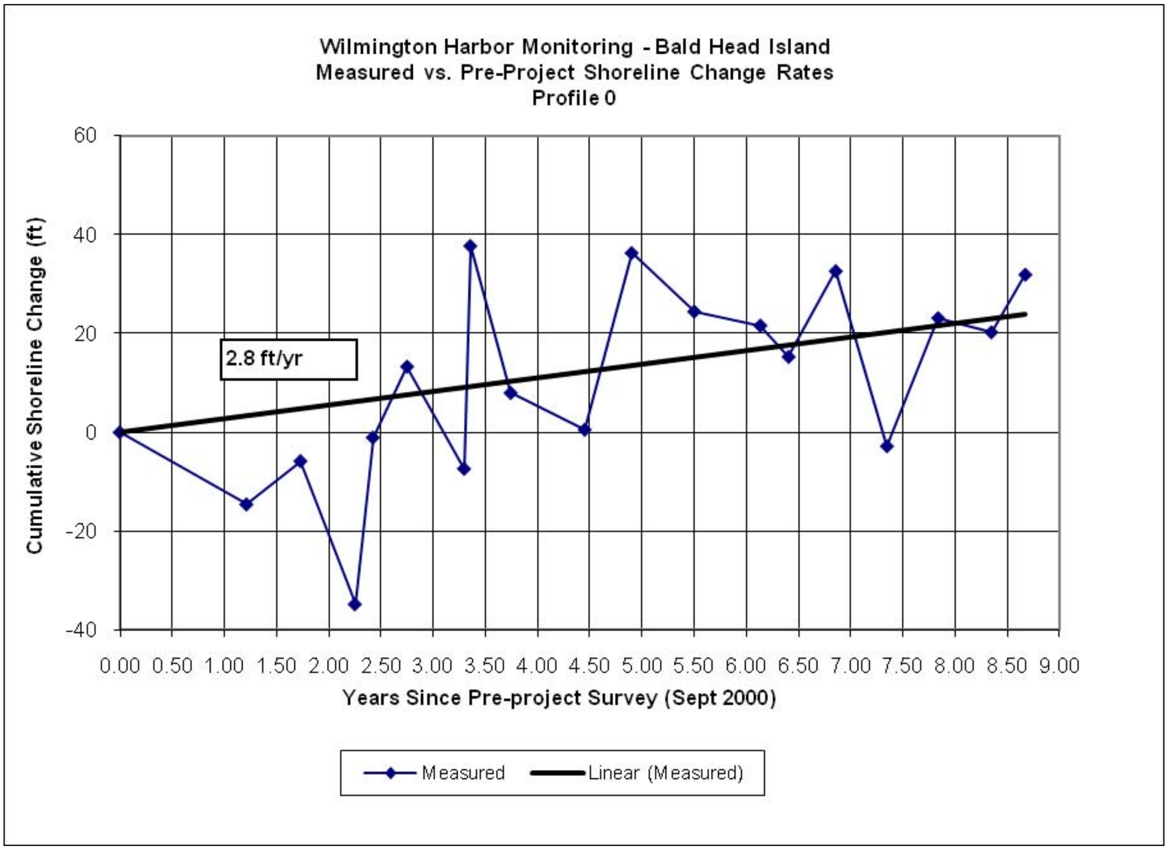
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 305
27.1 ft/yr
-2.2 ft/yr
Cumulative Shoreline Change (ft)
280
240
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

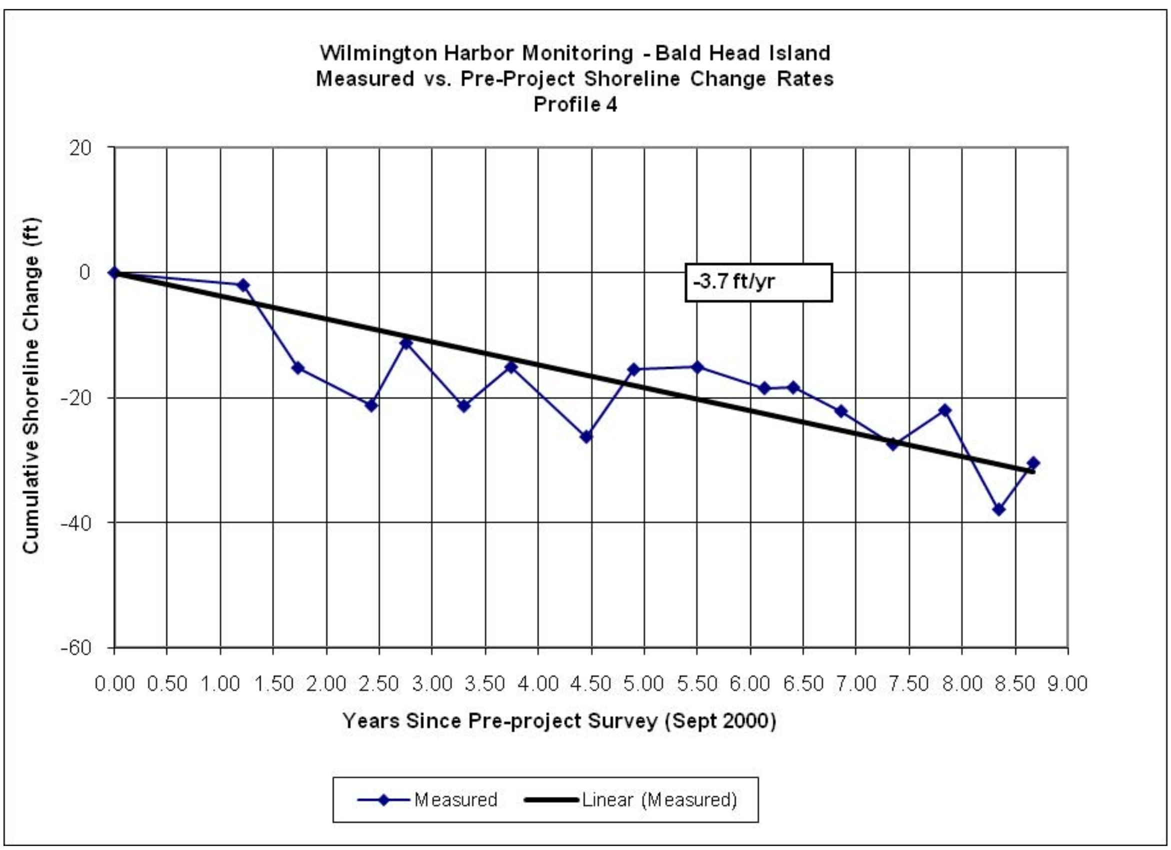


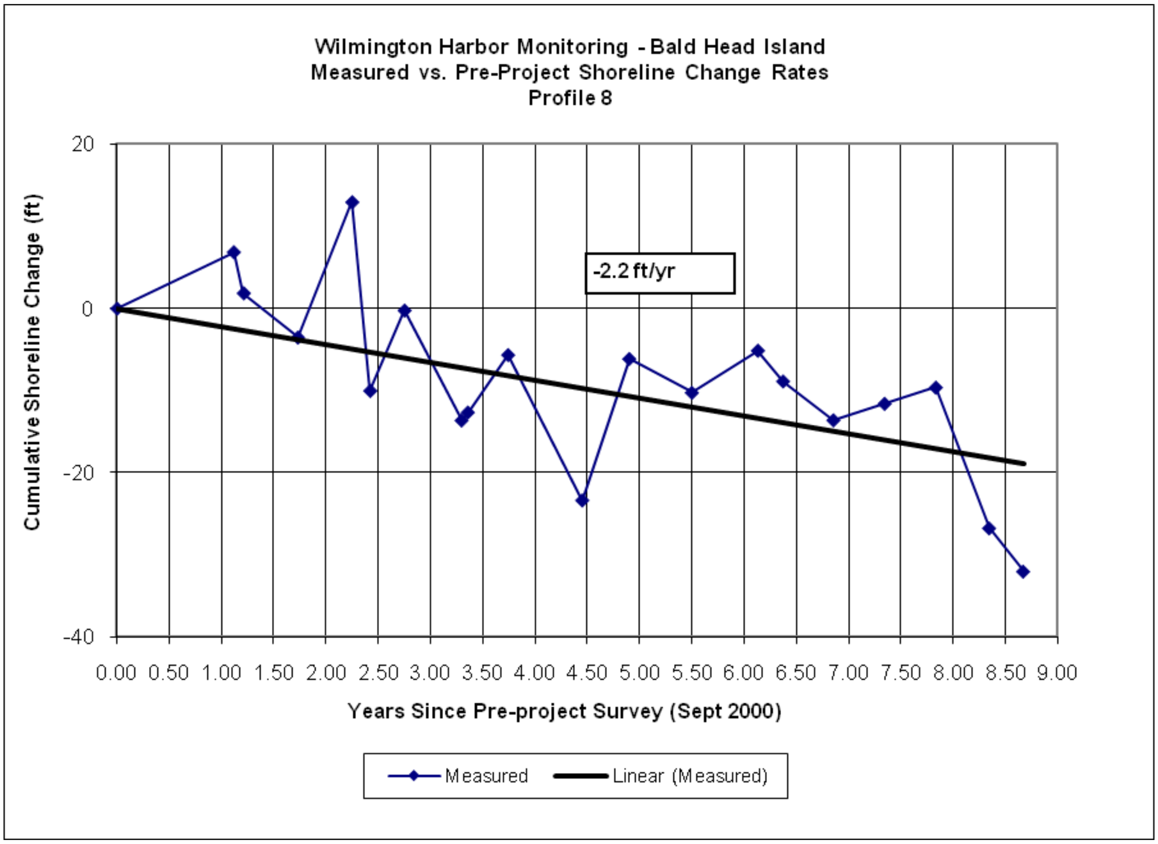
Wilmington Harbor Monitoring - Oak Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 310
32.1 ft/yr
-2.1 ft/yr
Cumulative Shoreline Change (ft)
360
320
280
240
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (August 2000)
Measured
Pre-project
Linear (Measured)

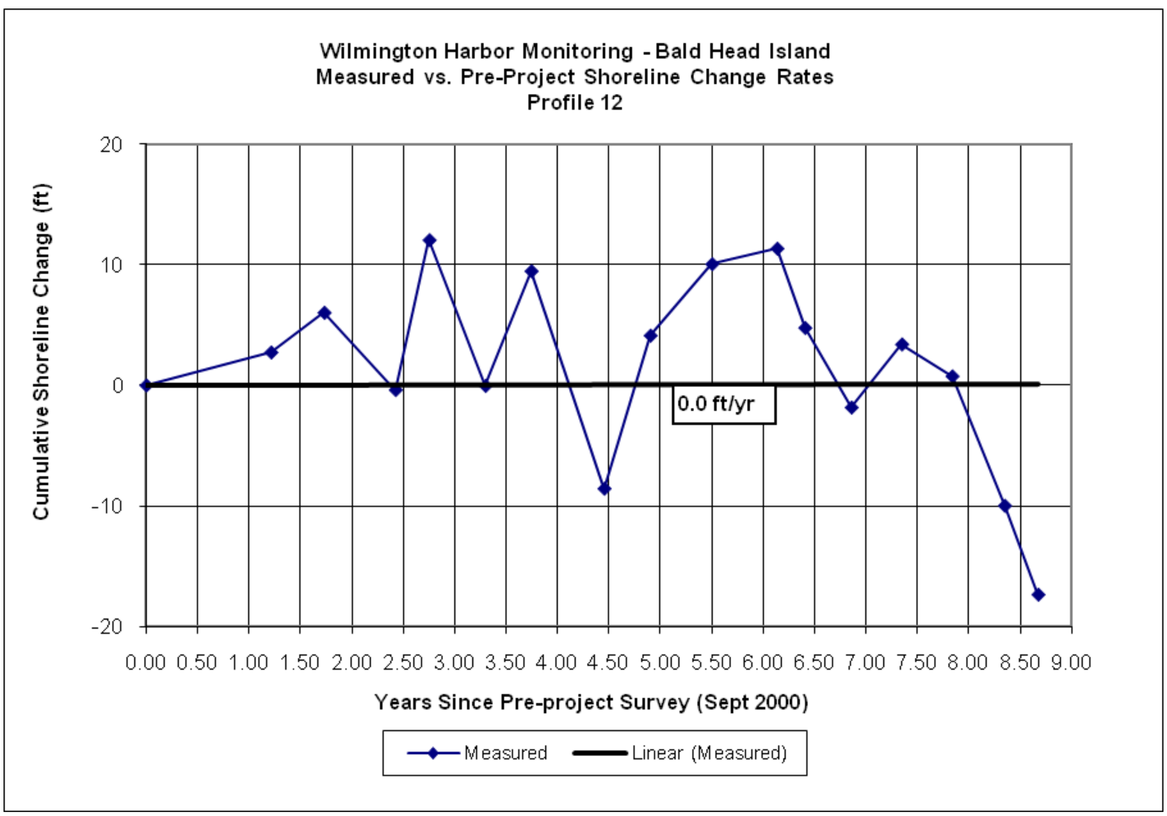
<u>Appendix C</u>

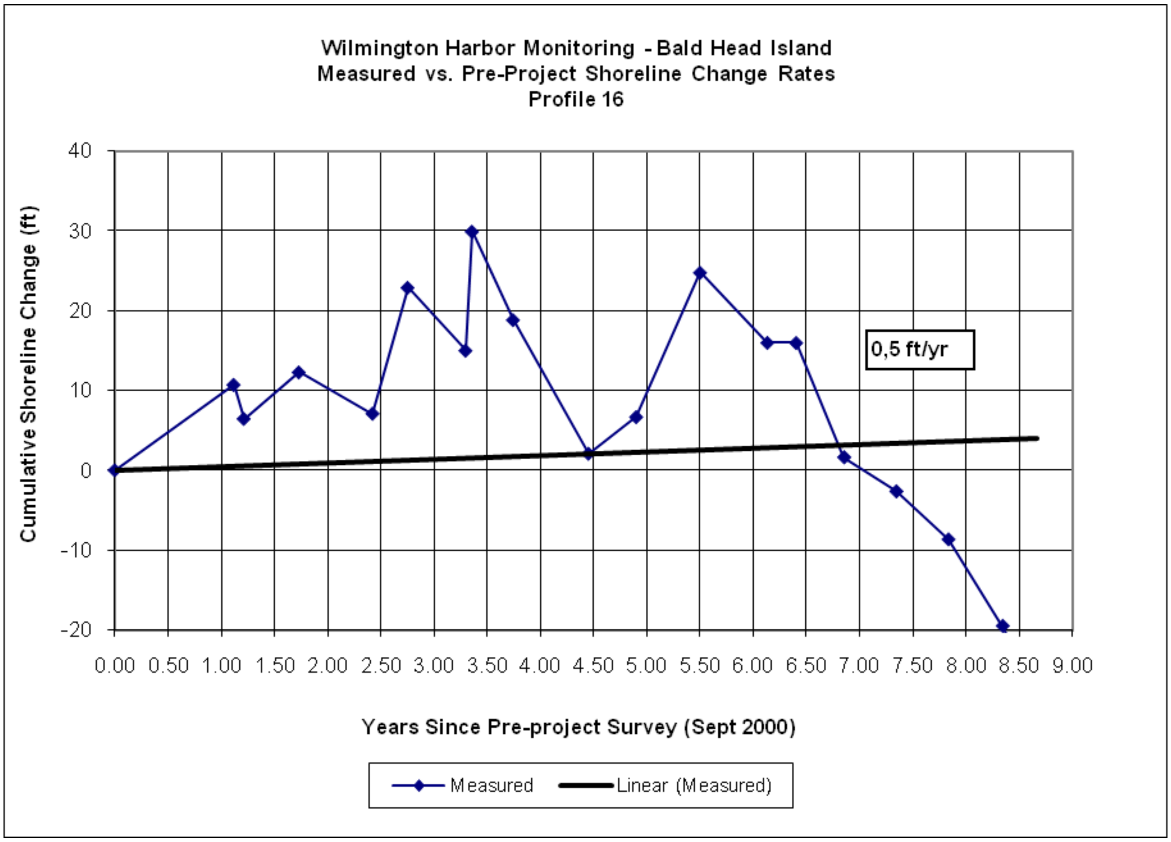
SHORELINE CHANGE RATES
(Bald Head Island)

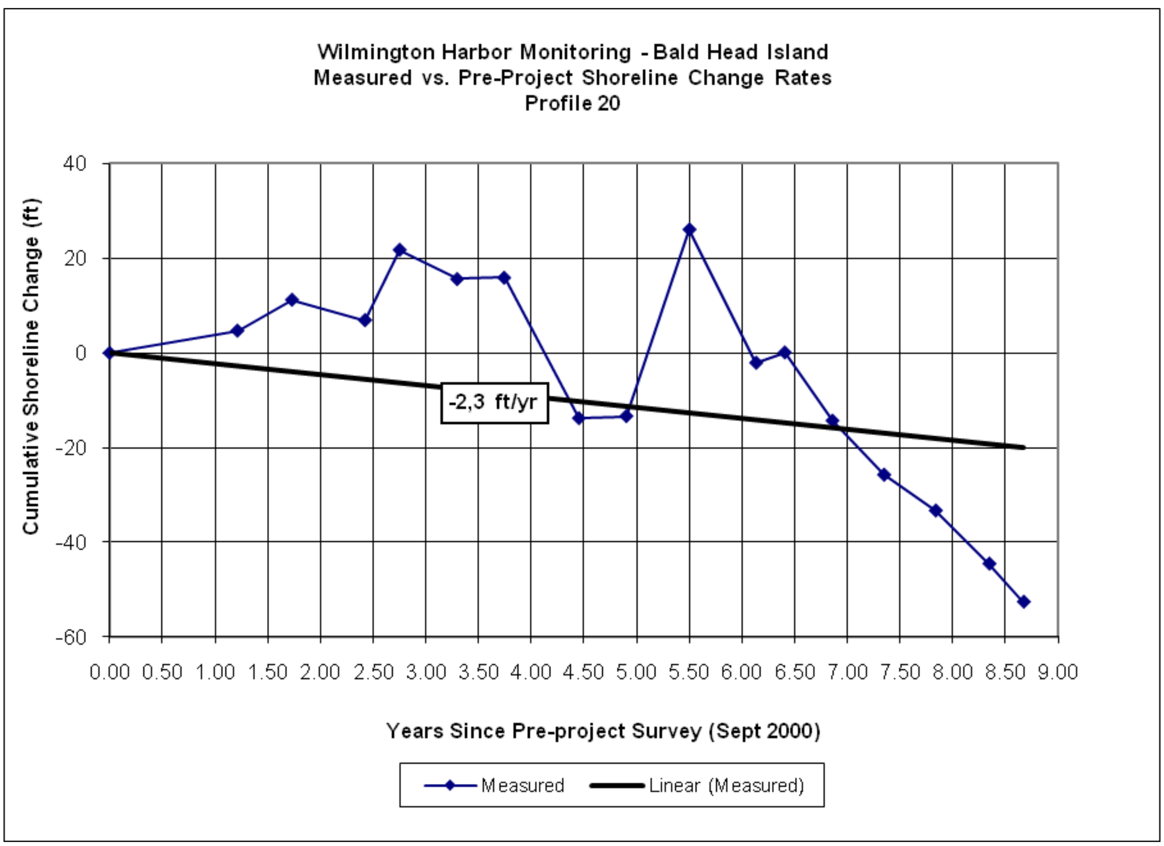

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 0
Cumulative Shoreline Change (ft)
60
40
20
0
-20
-40
2.8 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

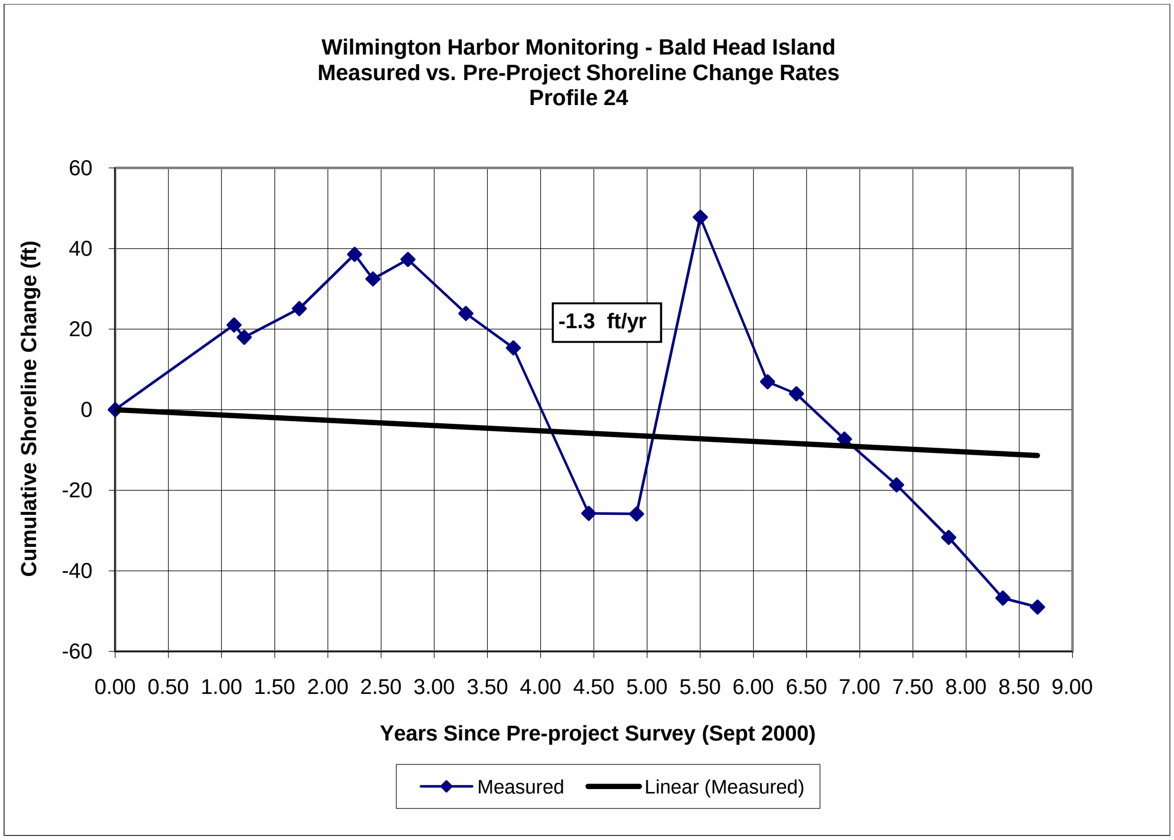

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 4
Cumulative Shoreline Change (ft)
20
0
-20
-40
-60
-3.7 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

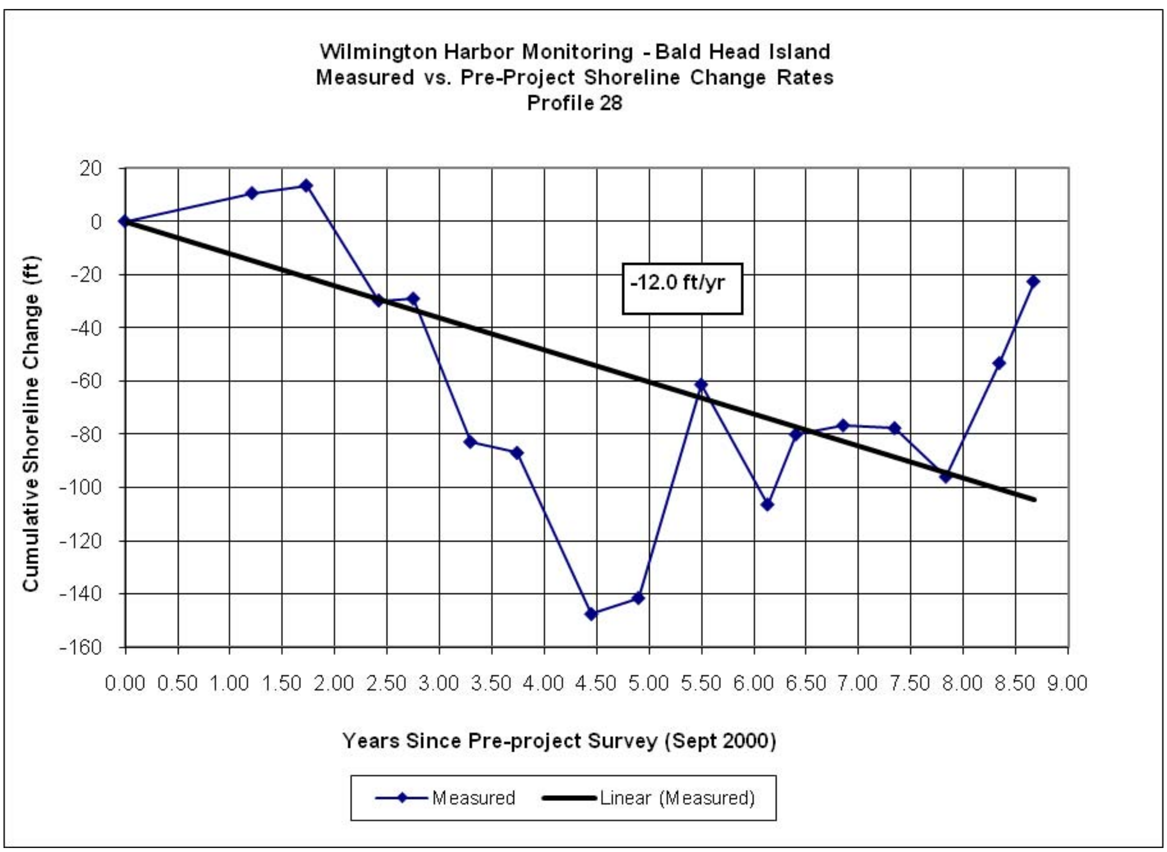

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 8
-2.2 ft/yr
20
0
-20
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

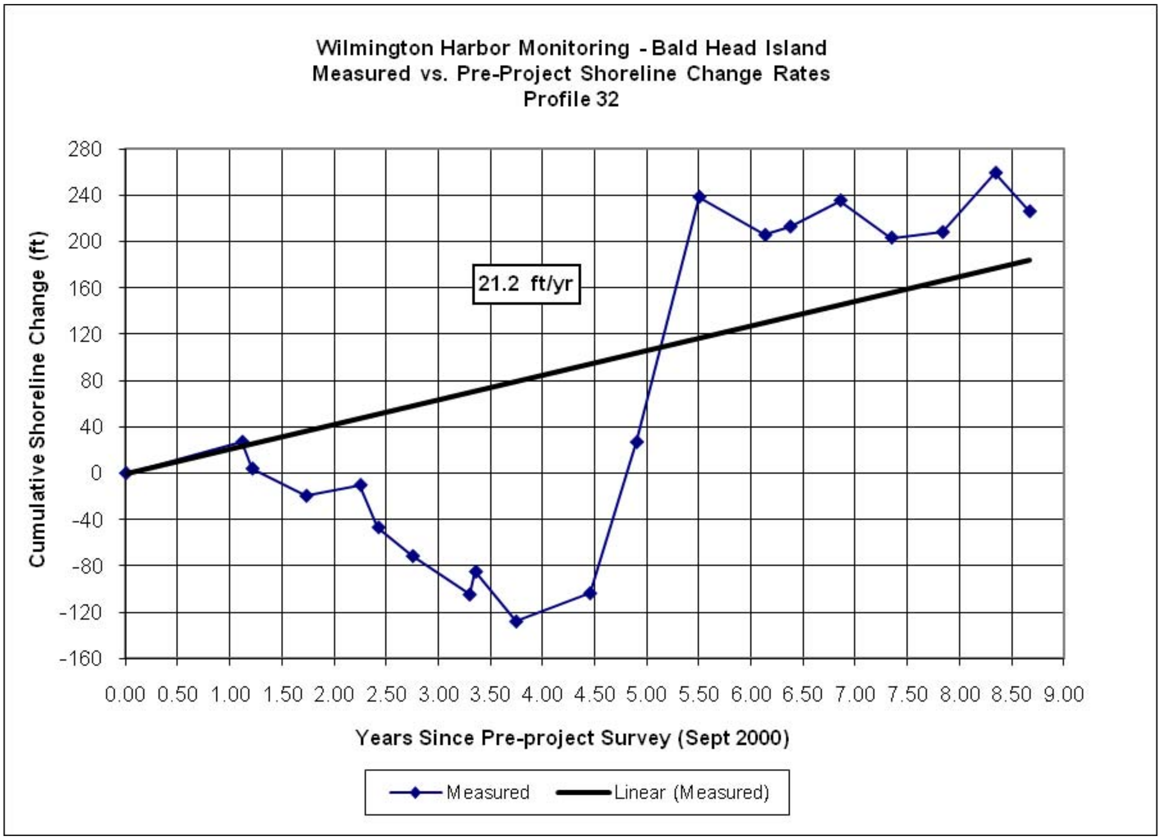

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 12
0.0 ft/yr
20
10
0
-10
-20
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

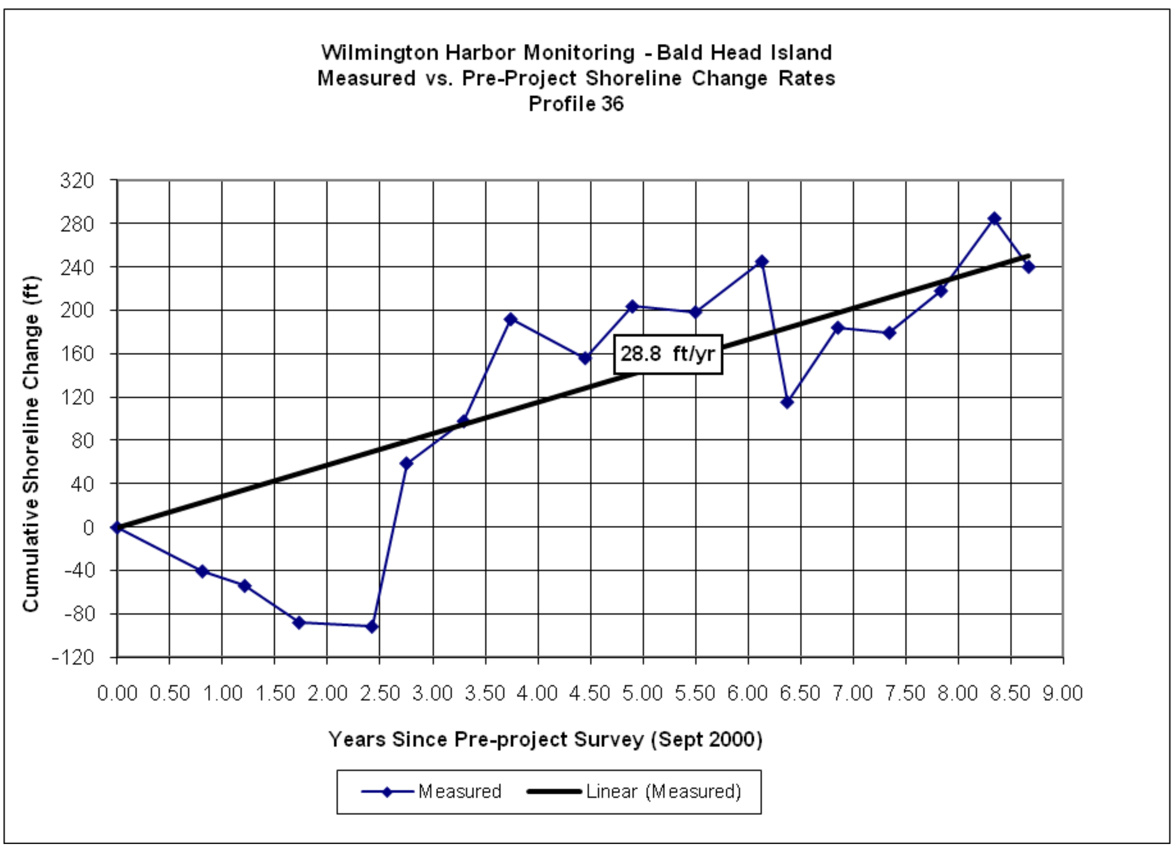

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 16
Cumulative Shoreline Change (ft)
40
30
20
10
0
-10
-20
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
0,5 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

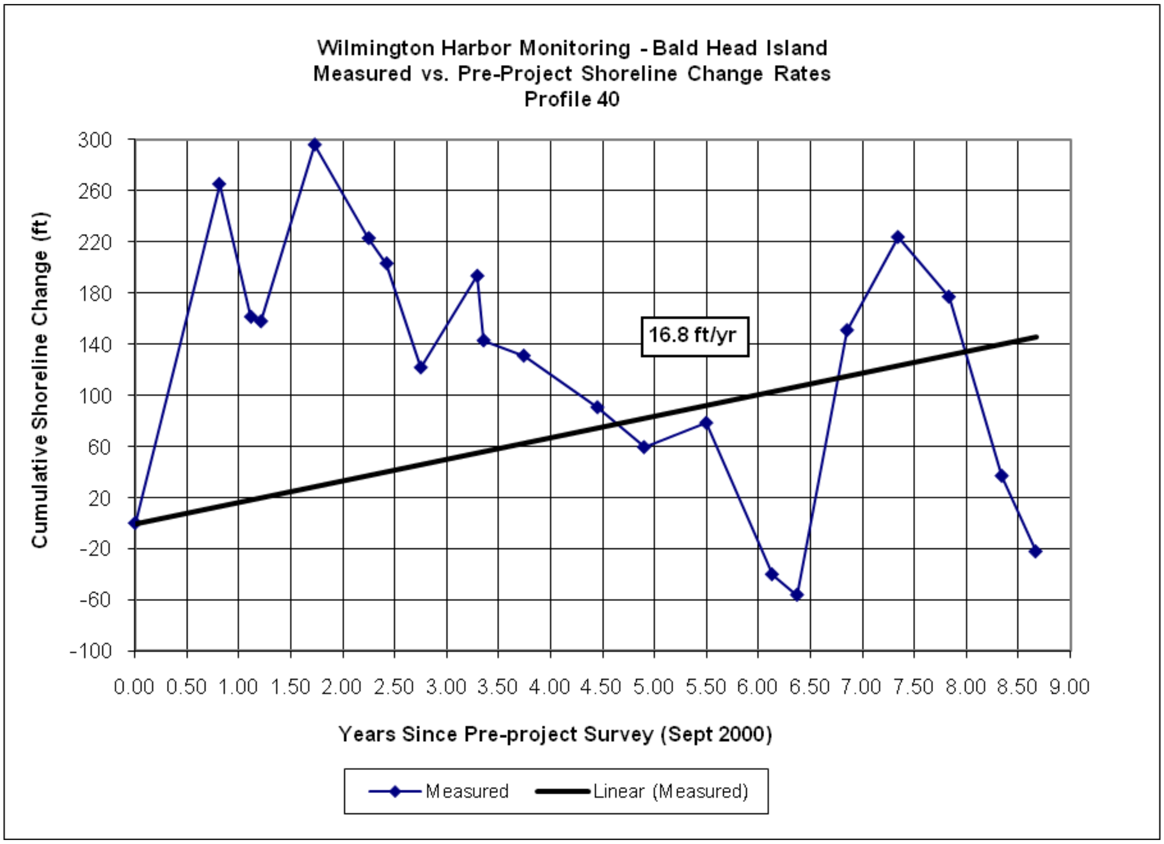

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 20
Cumulative Shoreline Change (ft)
40
20
0
-20
-40
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
-2,3 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

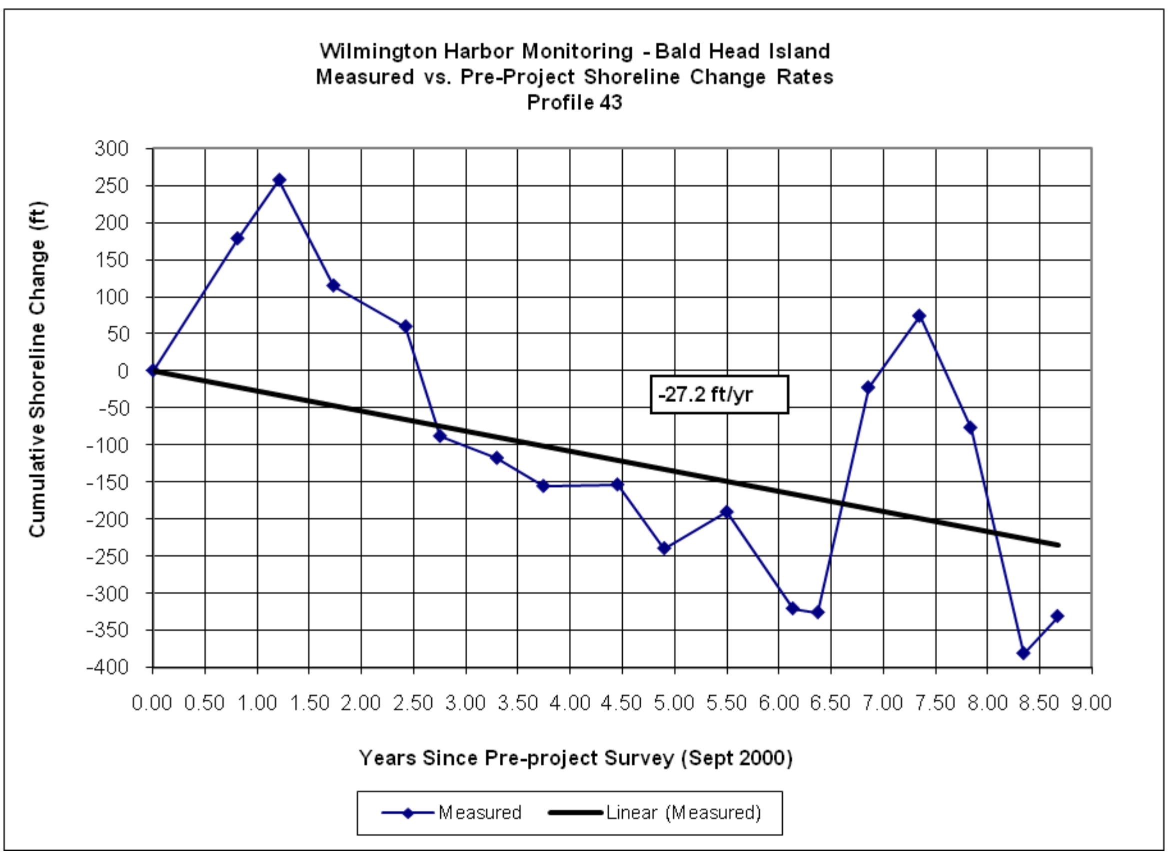

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 24
-1.3 ft/yr
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

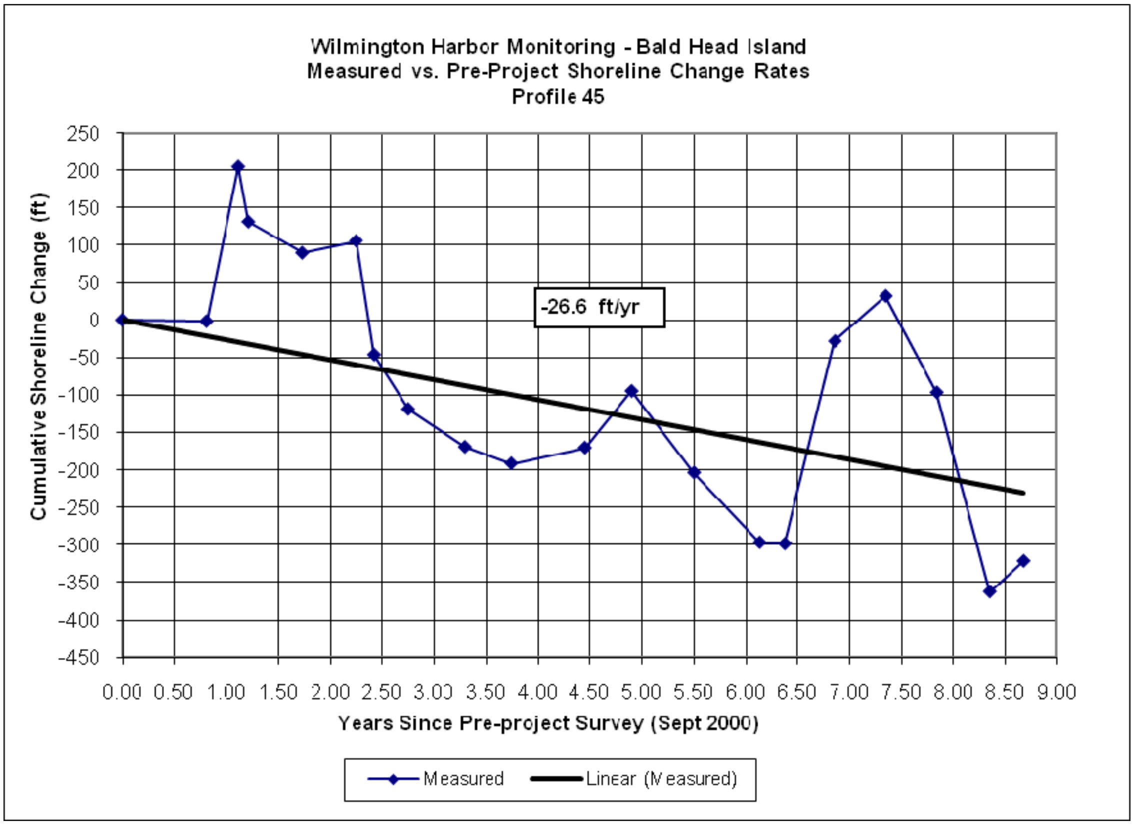

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 28
-12.0 ft/yr
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

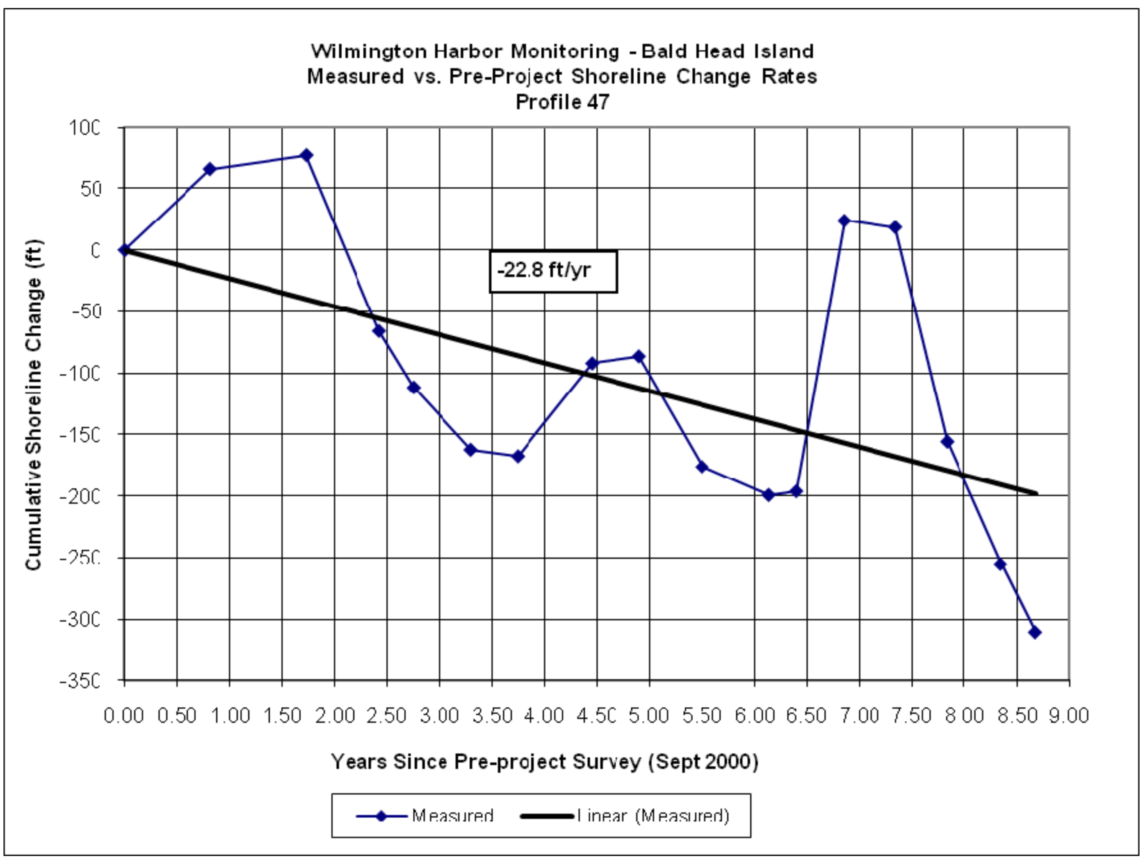

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 32
21.2 ft/yr
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

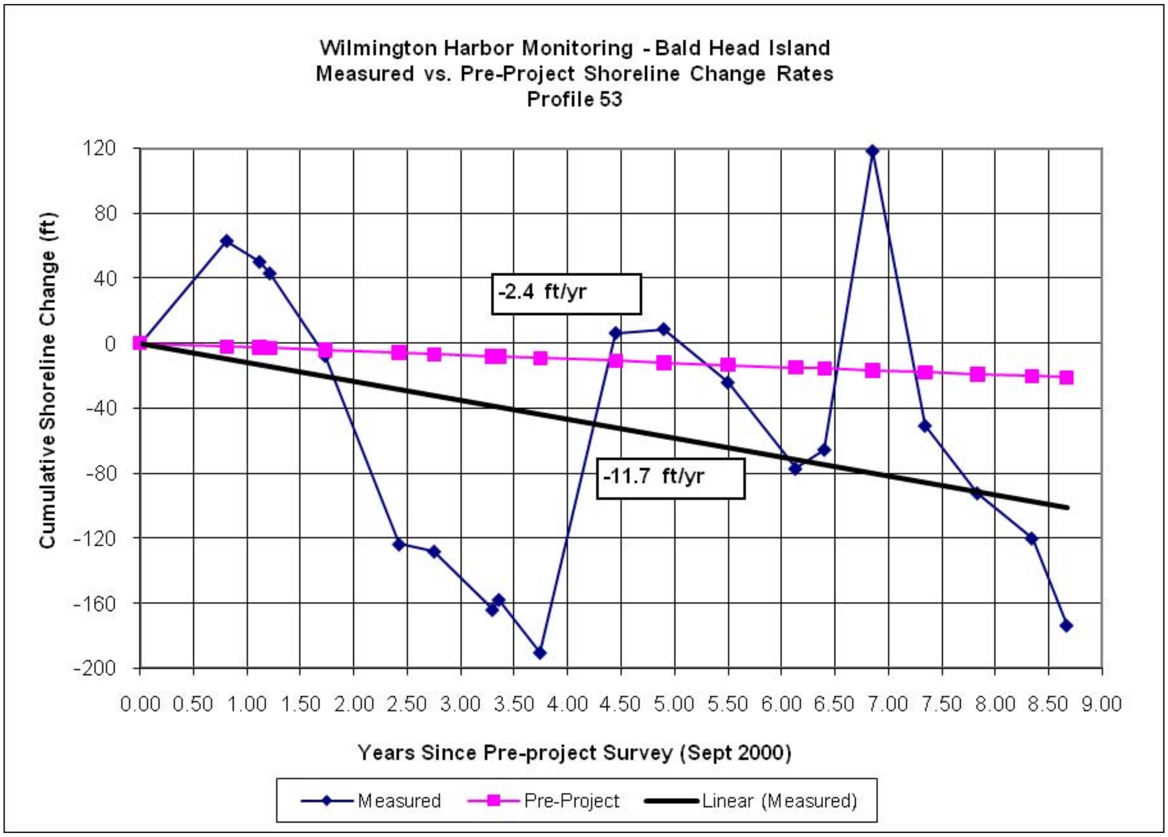

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 36
28.8 ft/yr
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

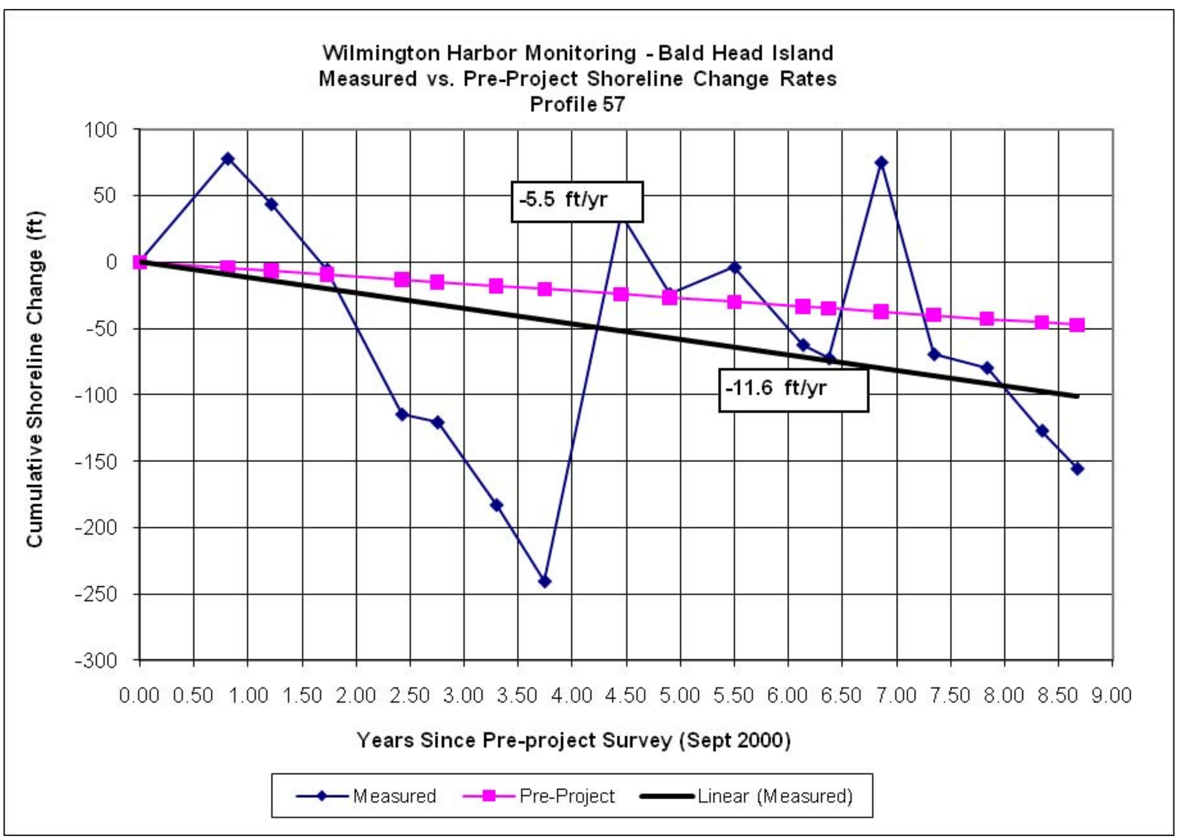

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 40
16.8 ft/yr
Cumulative Shoreline Change (ft)
300
260
220
180
140
100
60
20
-20
-60
-100
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

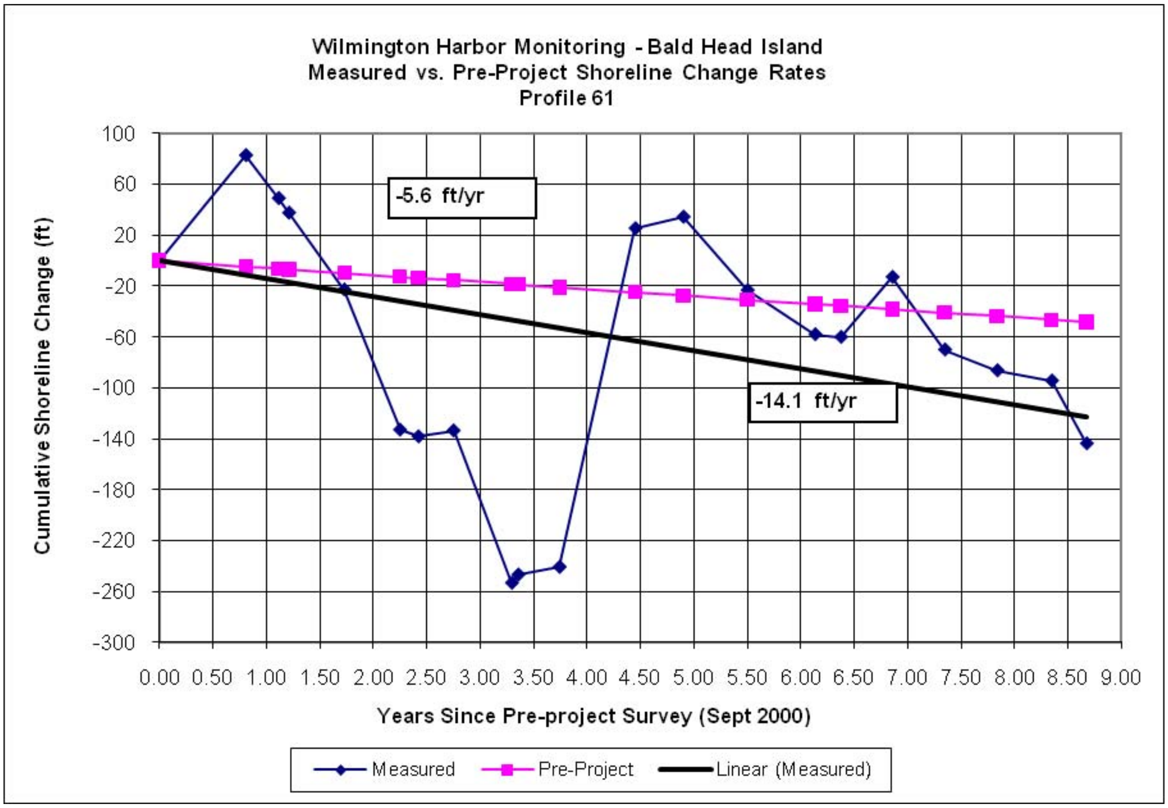

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 43
-27.2 ft/yr
Cumulative Shoreline Change (ft)
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 45
-26.6 ft/yr
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)

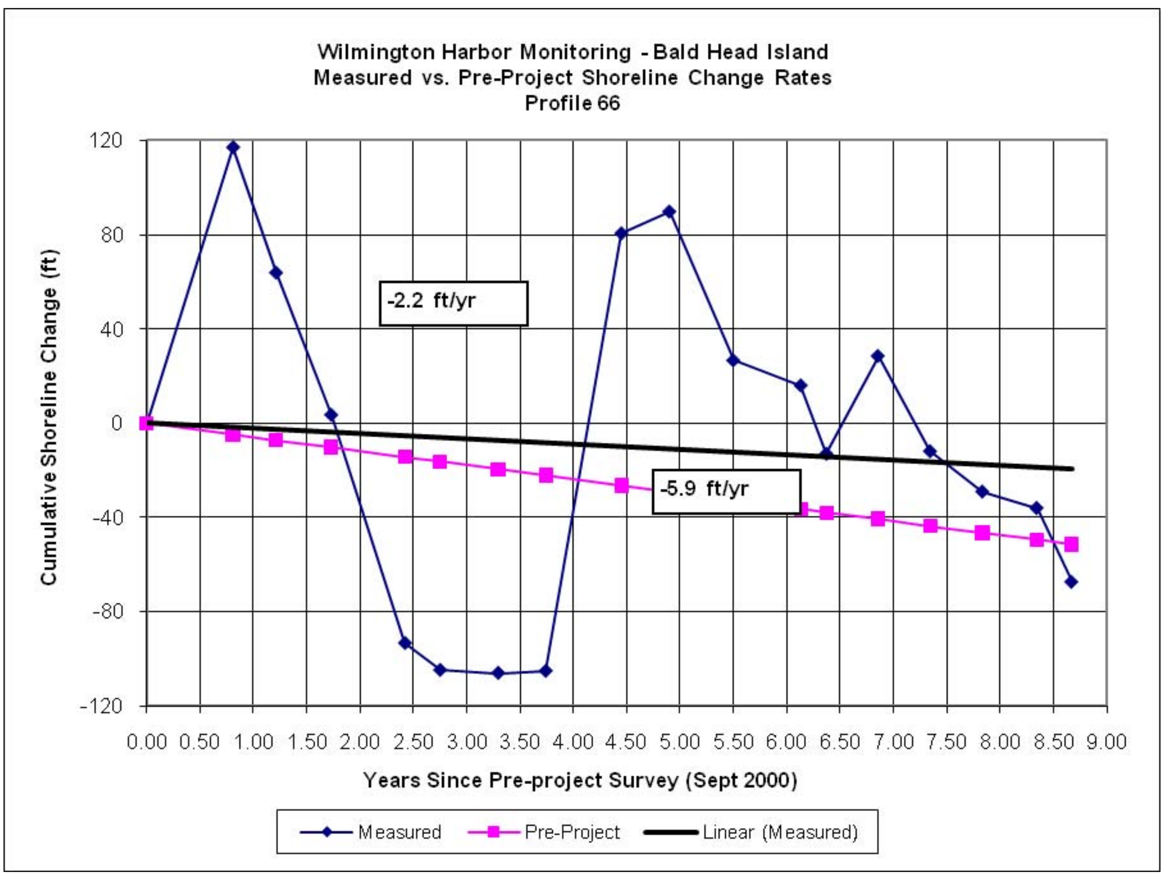

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 47
-22.8 ft/yr
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
Measured
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 53
Cumulative Shoreline Change (ft)
120
80
40
0
-40
-80
-120
-160
-200
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
-2.4 ft/yr
-11.7 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

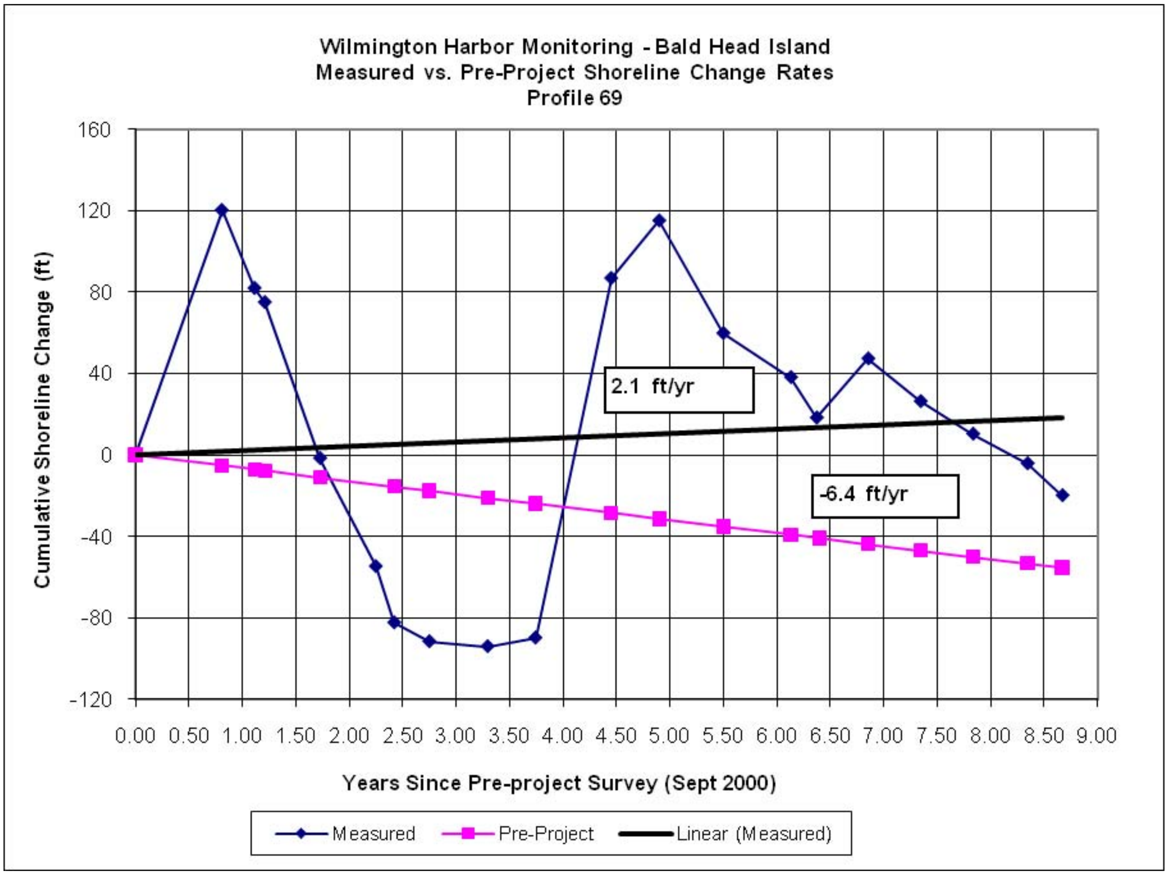

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 57
Cumulative Shoreline Change (ft)
100
50
0
-50
-100
-150
-200
-250
-300
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
-5.5 ft/yr
-11.6 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

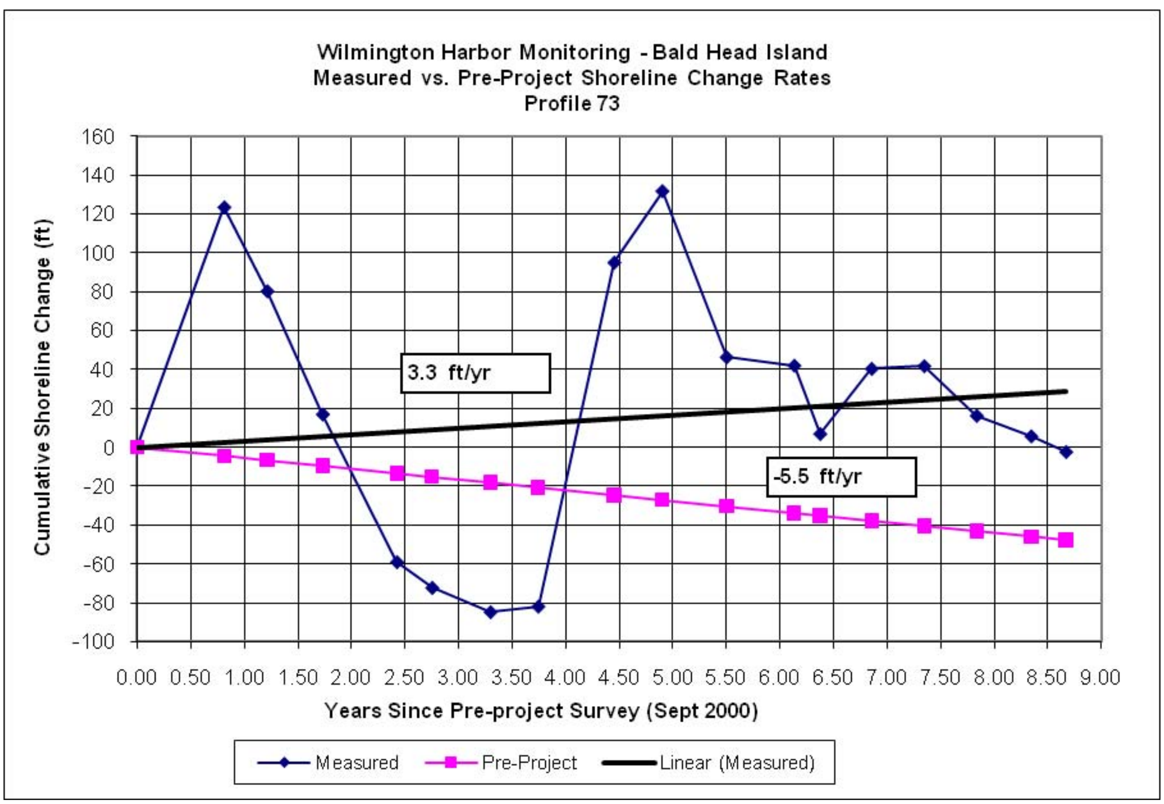


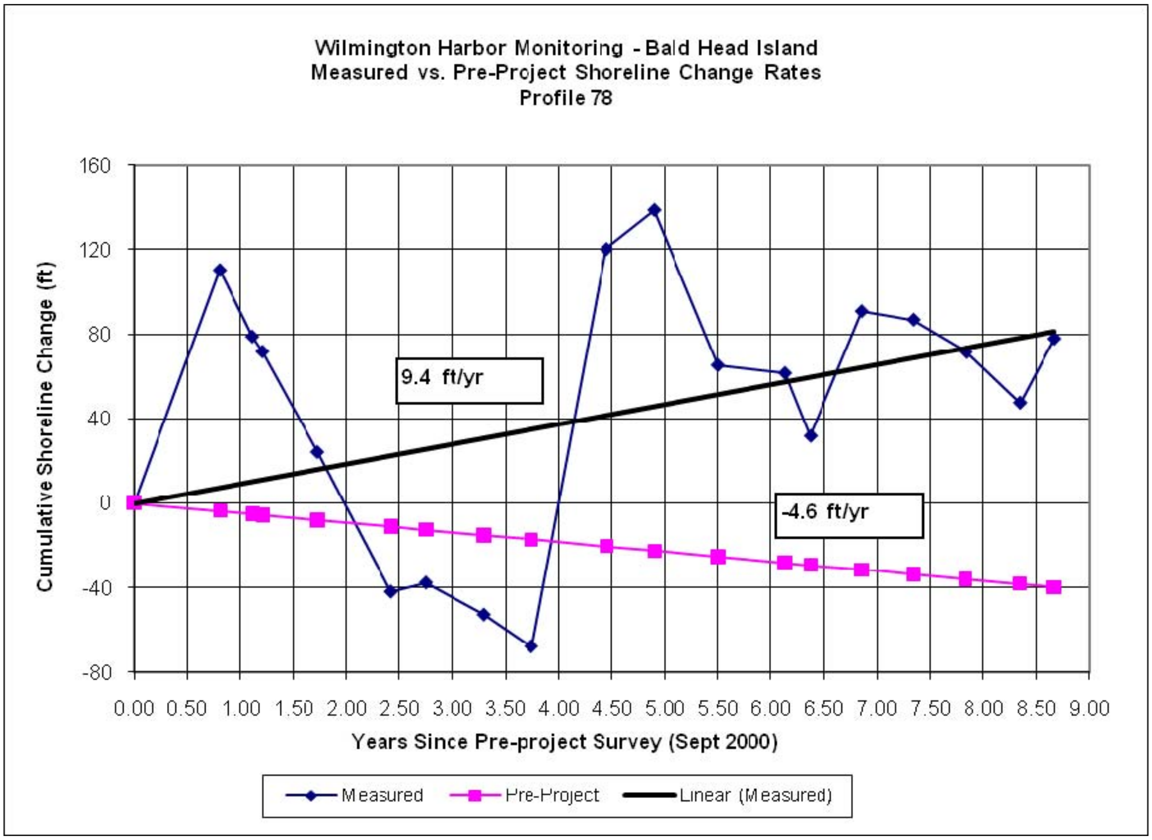
Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 61
-5.6 ft/yr
-14.1 ft/yr
Cumulative Shoreline Change (ft)
100
60
20
-20
-60
-100
-140
-180
-220
-260
-300
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

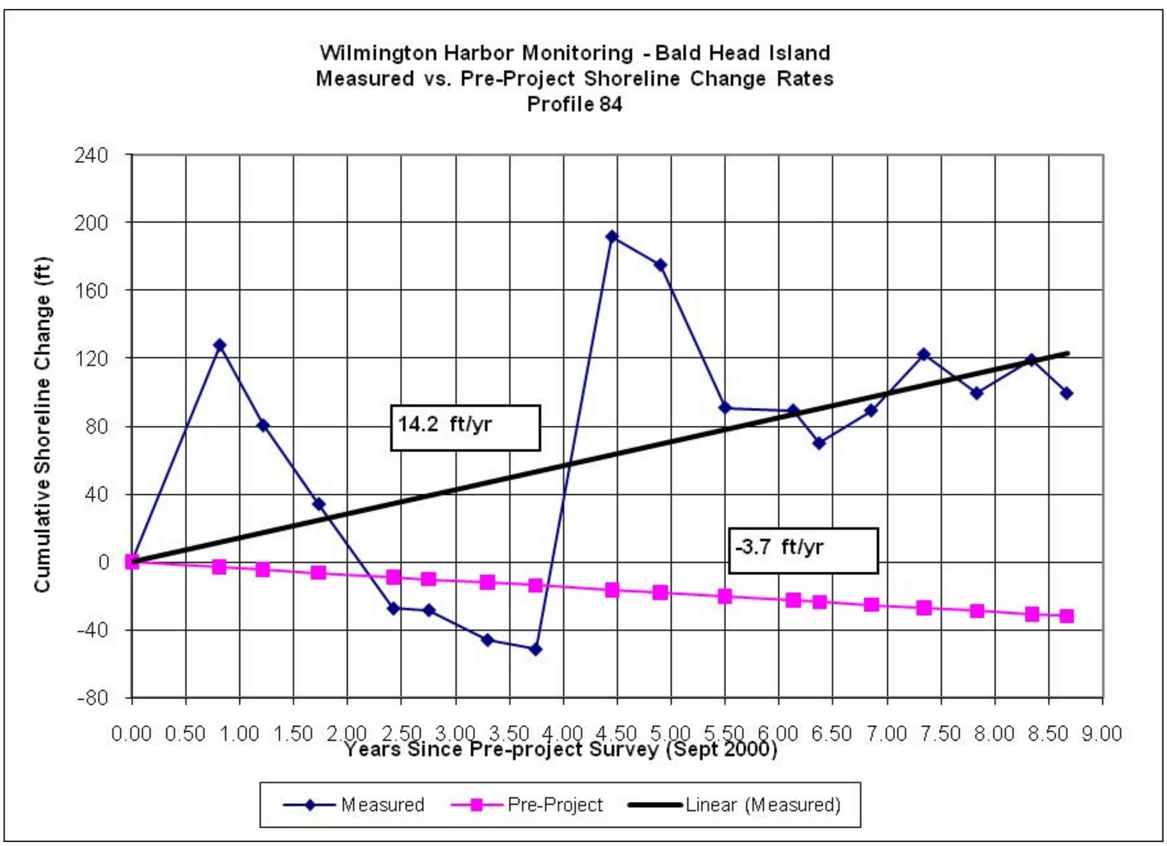


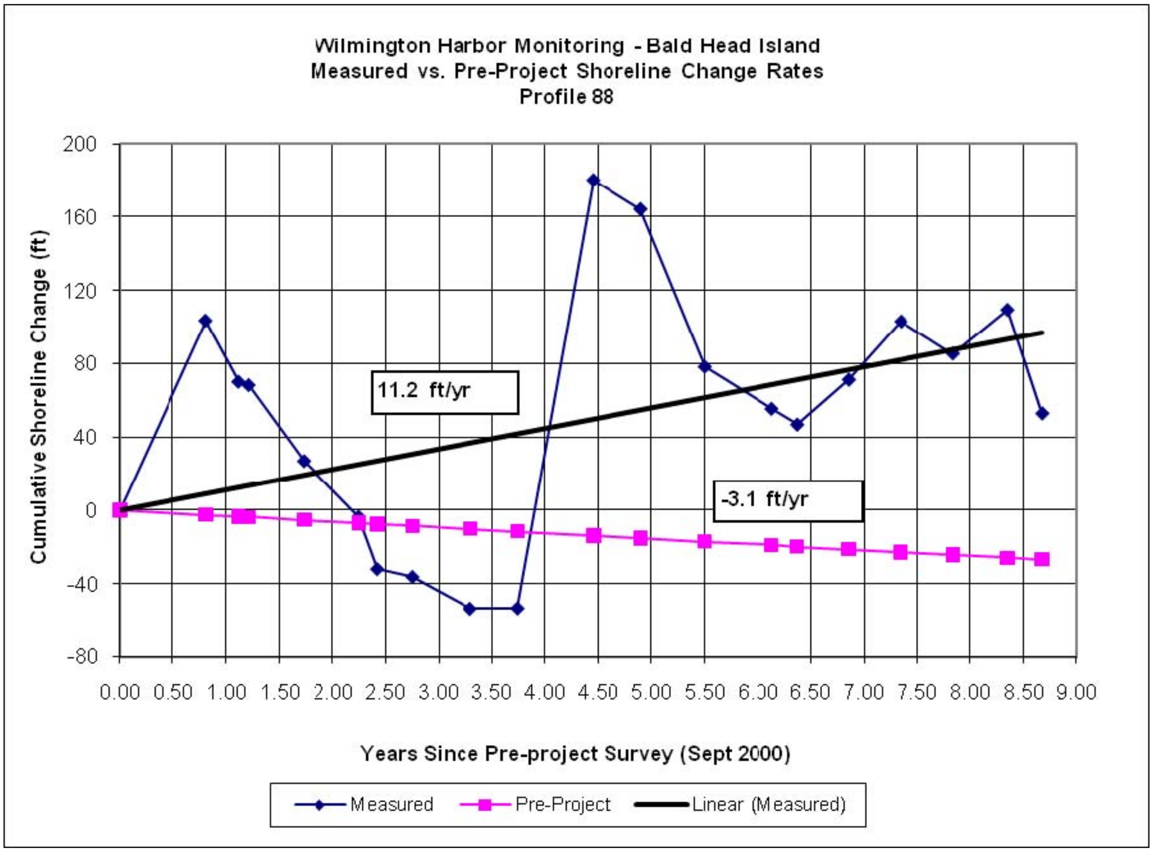
Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 66
-2.2 ft/yr
-5.9 ft/yr
Cumulative Shoreline Change (ft)
120
80
40
0
-40
-80
-120
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

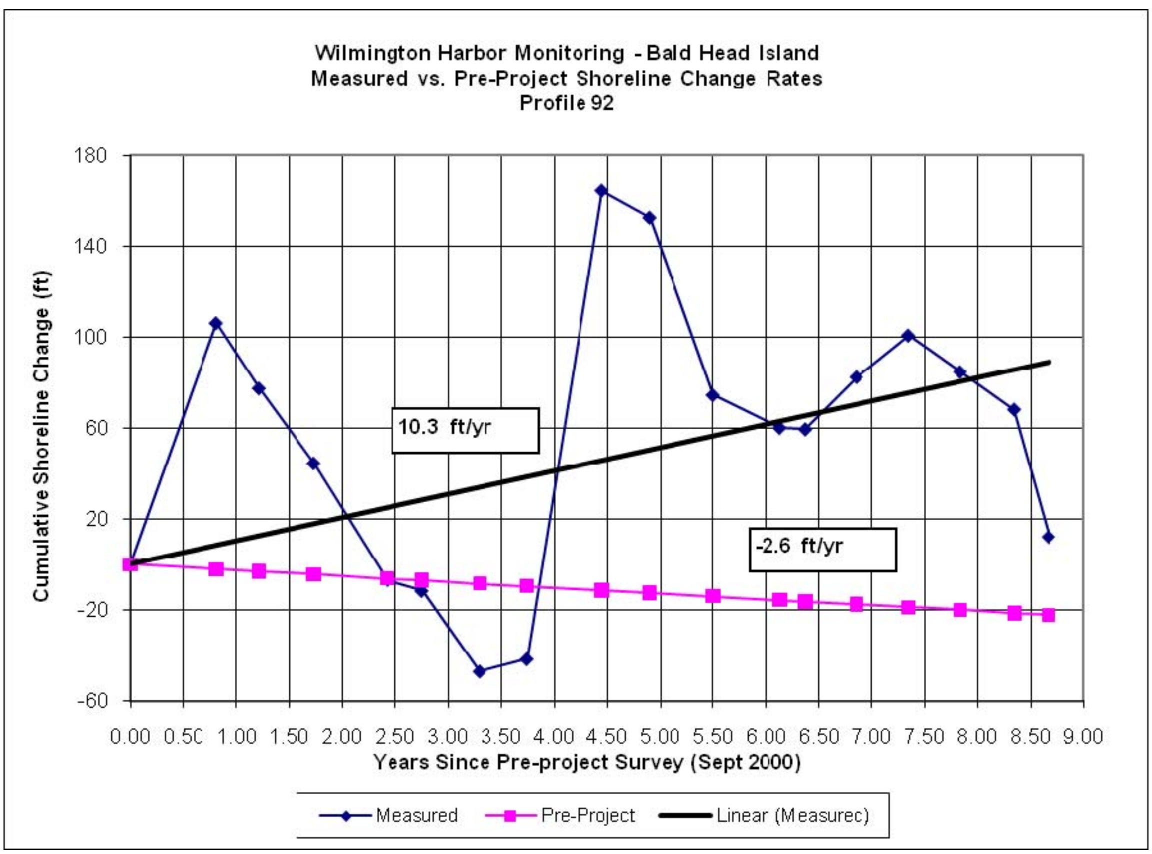

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 69
160
120
80
40
0
-40
-80
-120
Cumulative Shoreline Change (ft)
2.1 ft/yr
-6.4 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

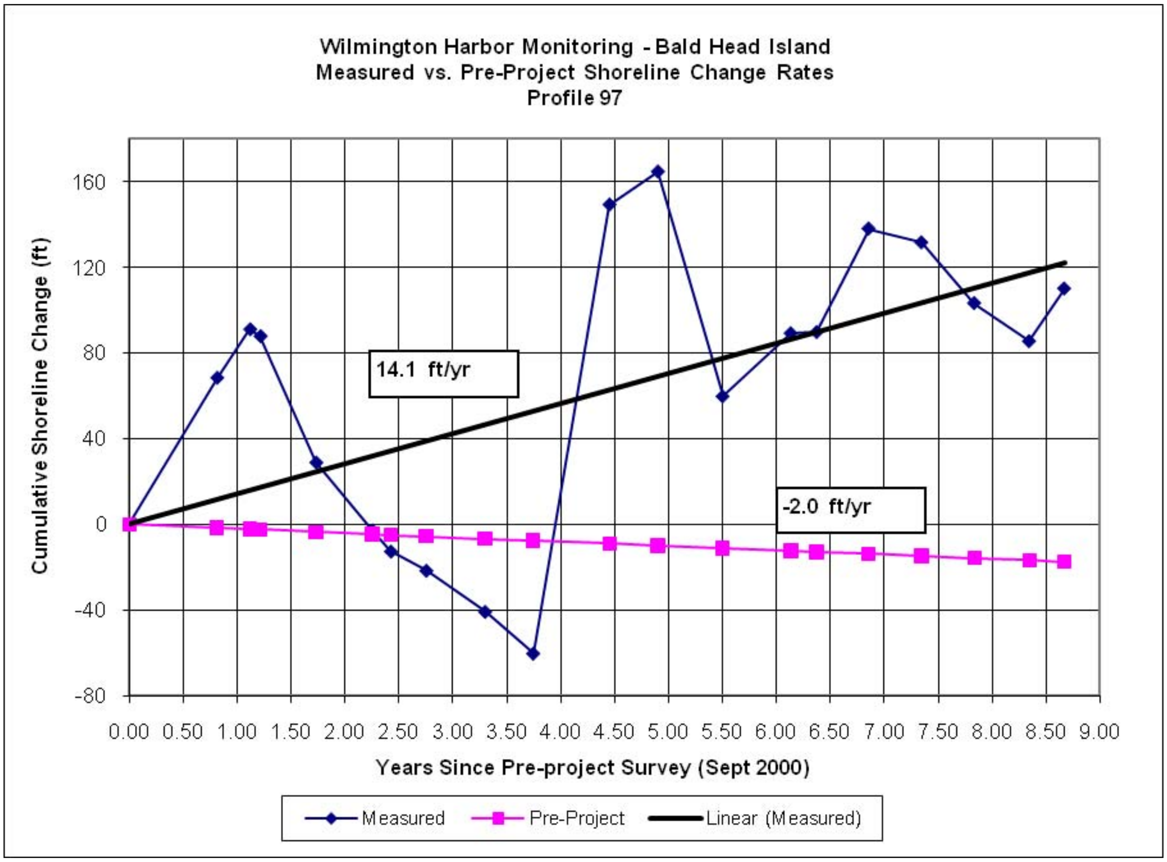

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 73
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
Cumulative Shoreline Change (ft)
3.3 ft/yr
-5.5 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

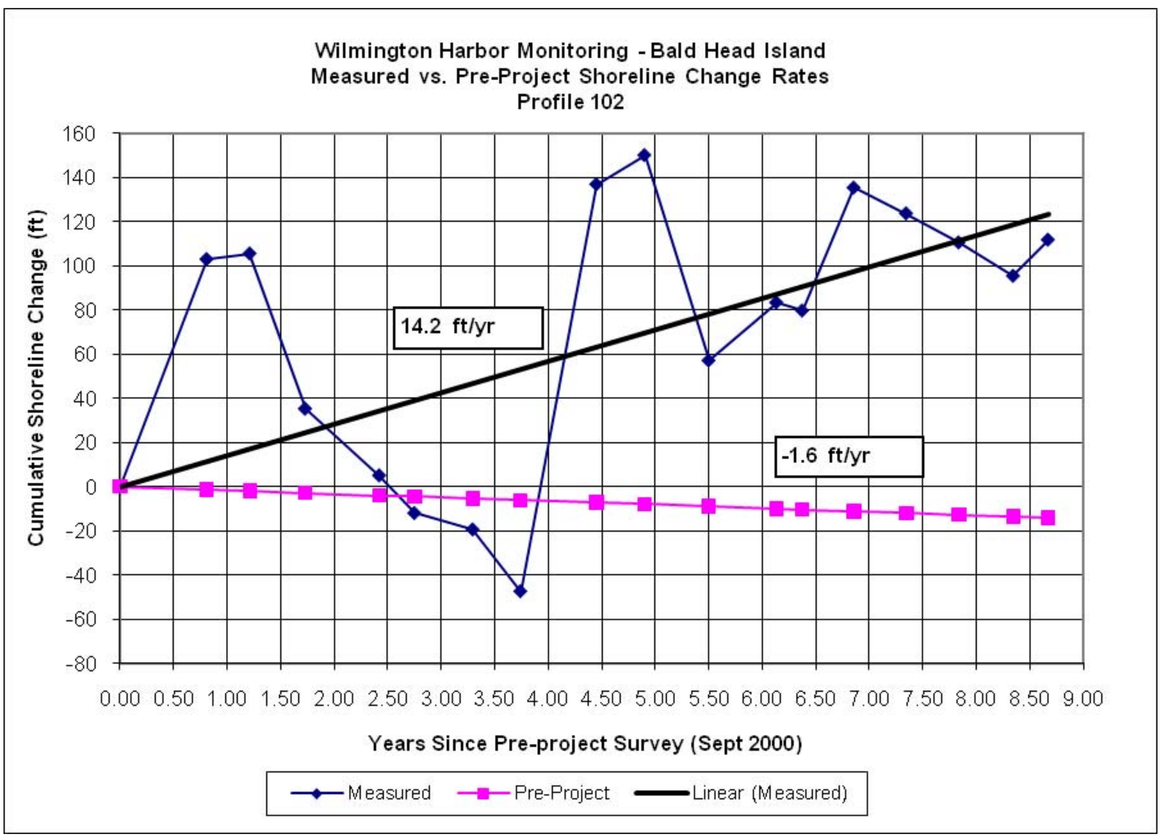

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 78
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
9.4 ft/yr
-4.6 ft/yr
Measured
Pre-Project
Linear (Measured)

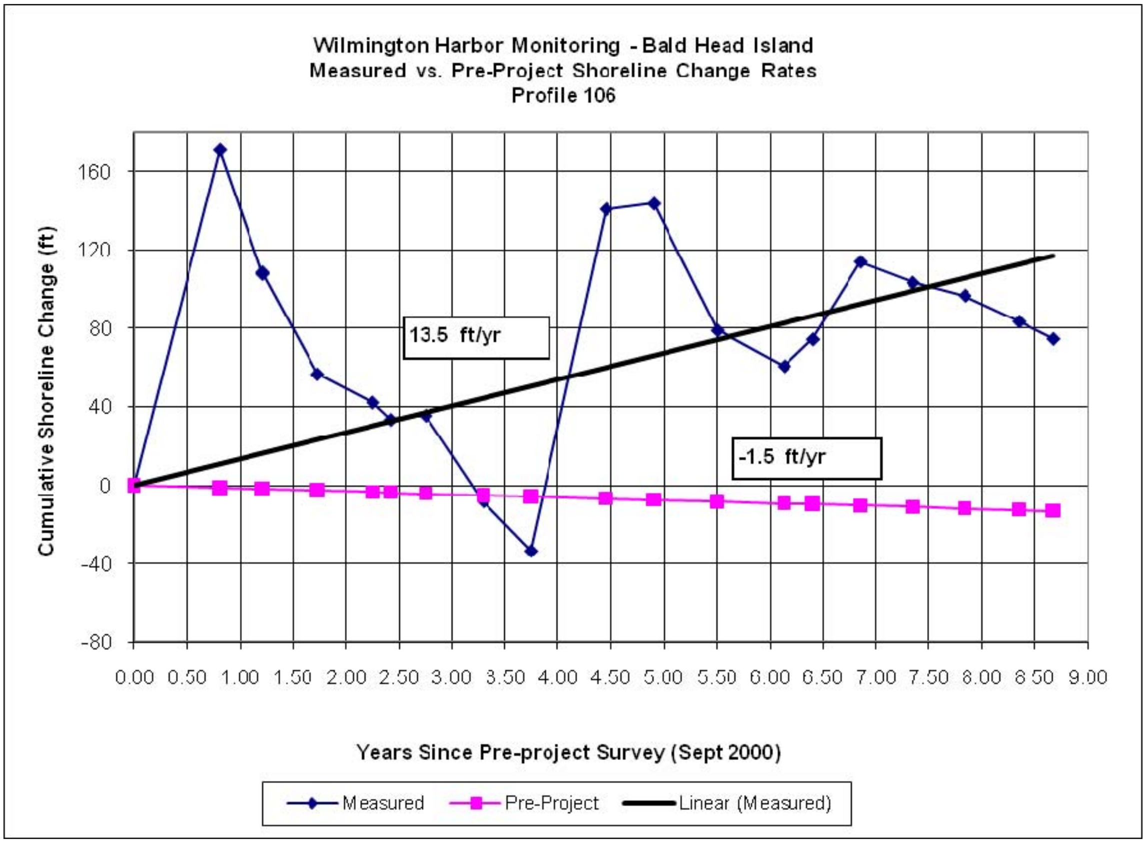

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 84
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
14.2 ft/yr
-3.7 ft/yr
Measured
Pre-Project
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 88
Cumulative Shoreline Change (ft)
200
160
120
80
40
0
-40
-80
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
11.2 ft/yr
-3.1 ft/yr
Measured
Pre-Project
Linear (Measured)

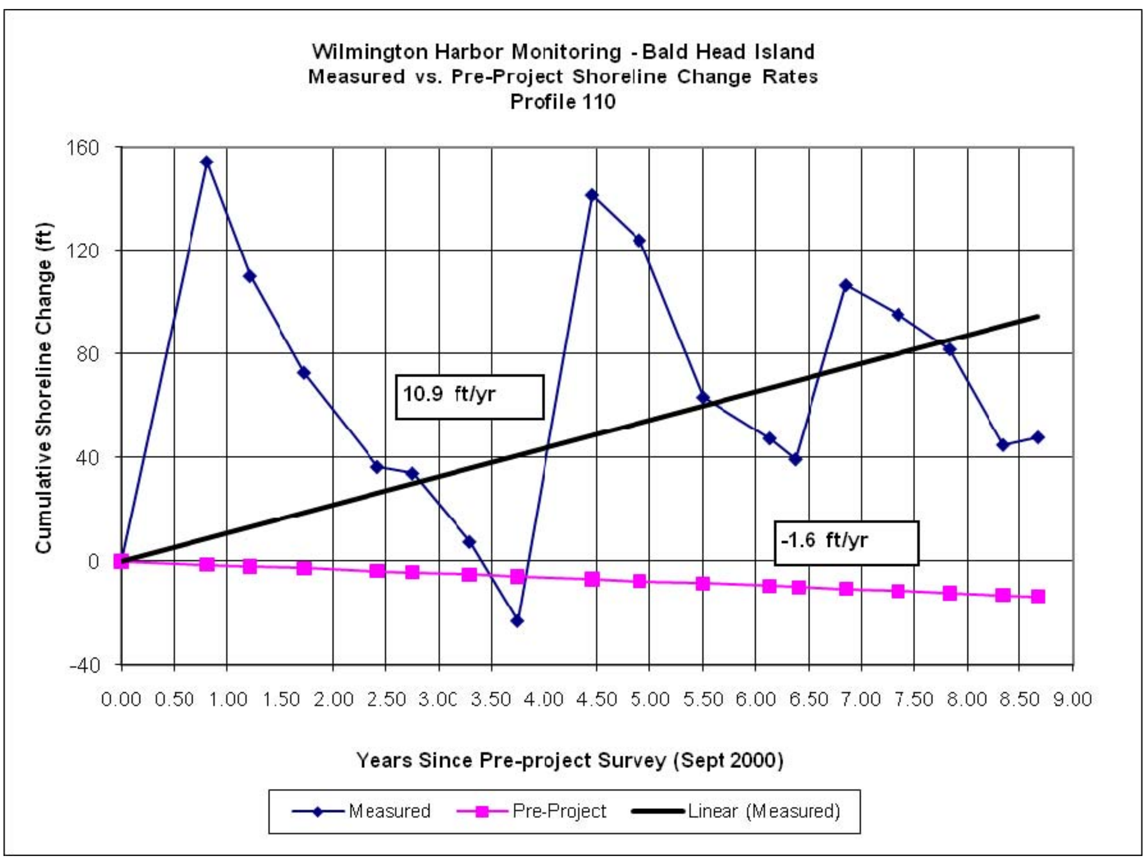

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 92
Cumulative Shoreline Change (ft)
180
140
100
60
20
-20
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
10.3 ft/yr
-2.6 ft/yr
Measured
Pre-Project
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 97
Cumulative Shoreline Change (ft)
160
120
80
40
0
-40
-80
14.1 ft/yr
-2.0 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

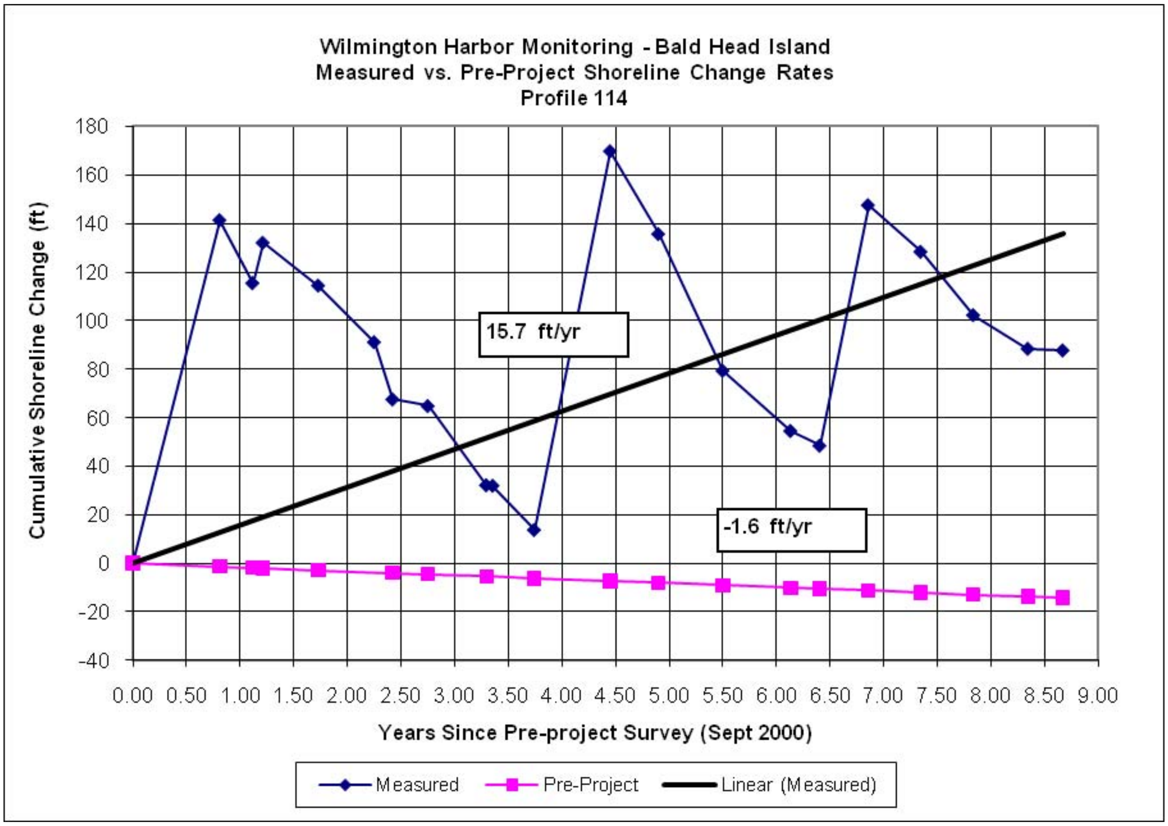

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 102
Cumulative Shoreline Change (ft)
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
14.2 ft/yr
-1.6 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)



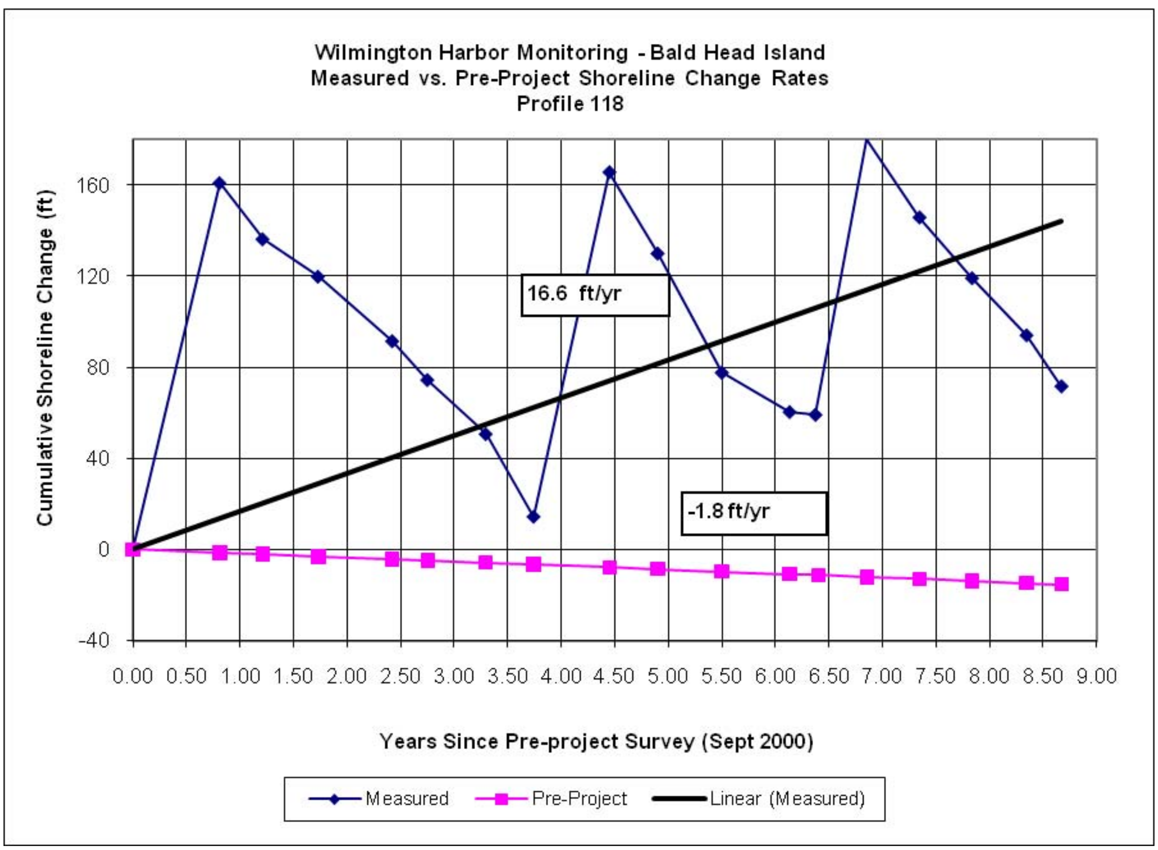
Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 106
Cumulative Shoreline Change (ft)
160
120
80
40
0
-40
-80
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
13.5 ft/yr
-1.5 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)



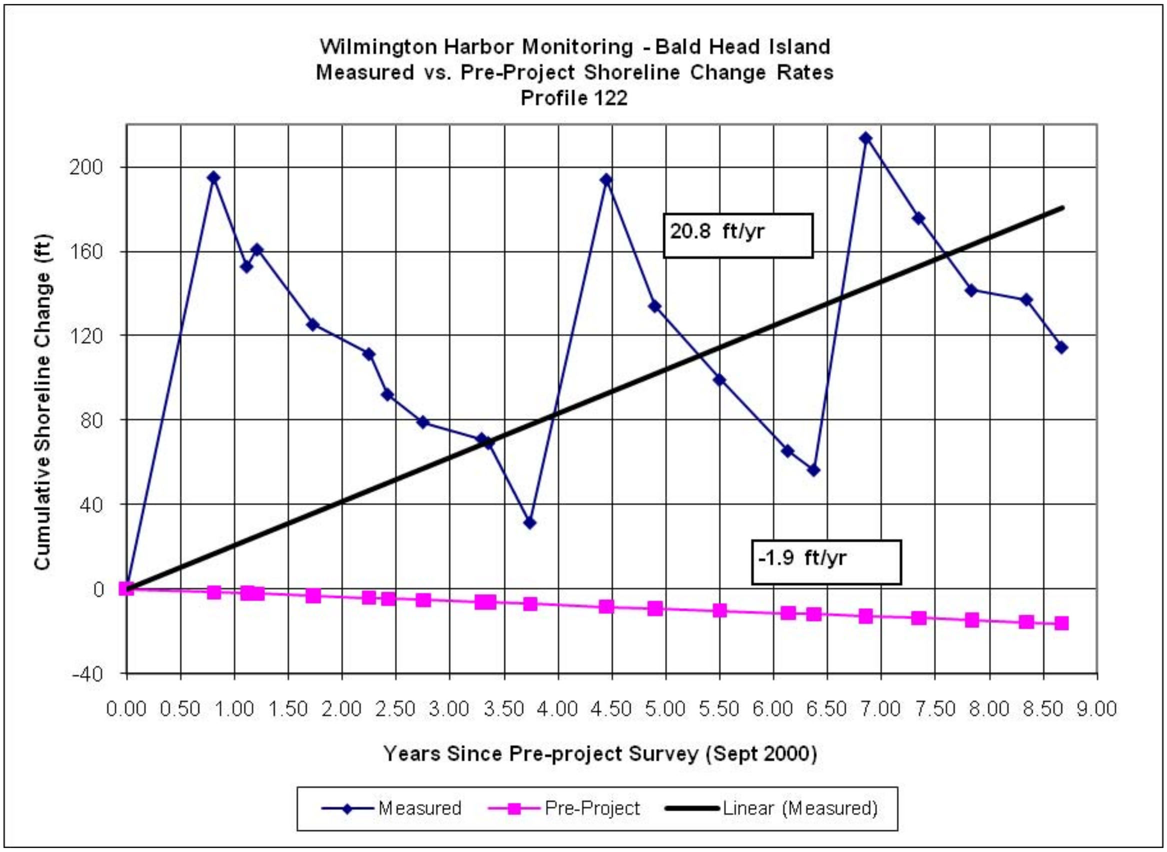
Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 110
Cumulative Shoreline Change (ft)
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
10.9 ft/yr
-1.6 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

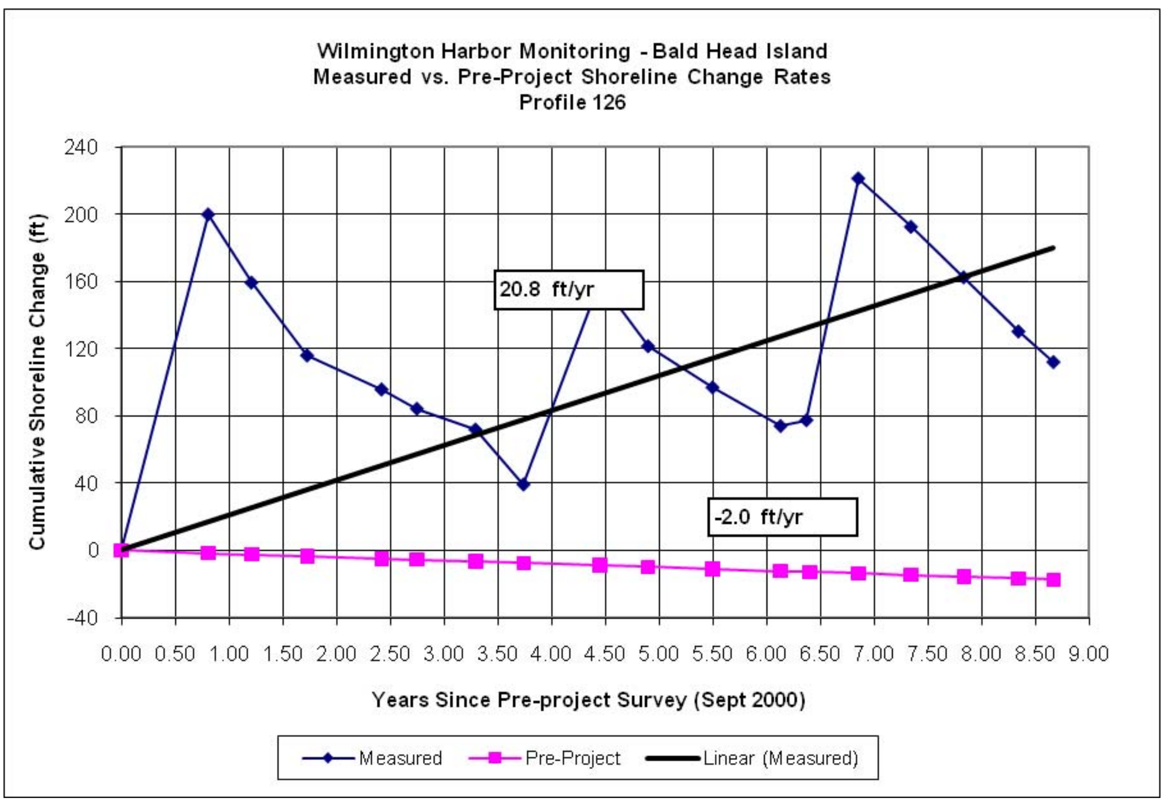


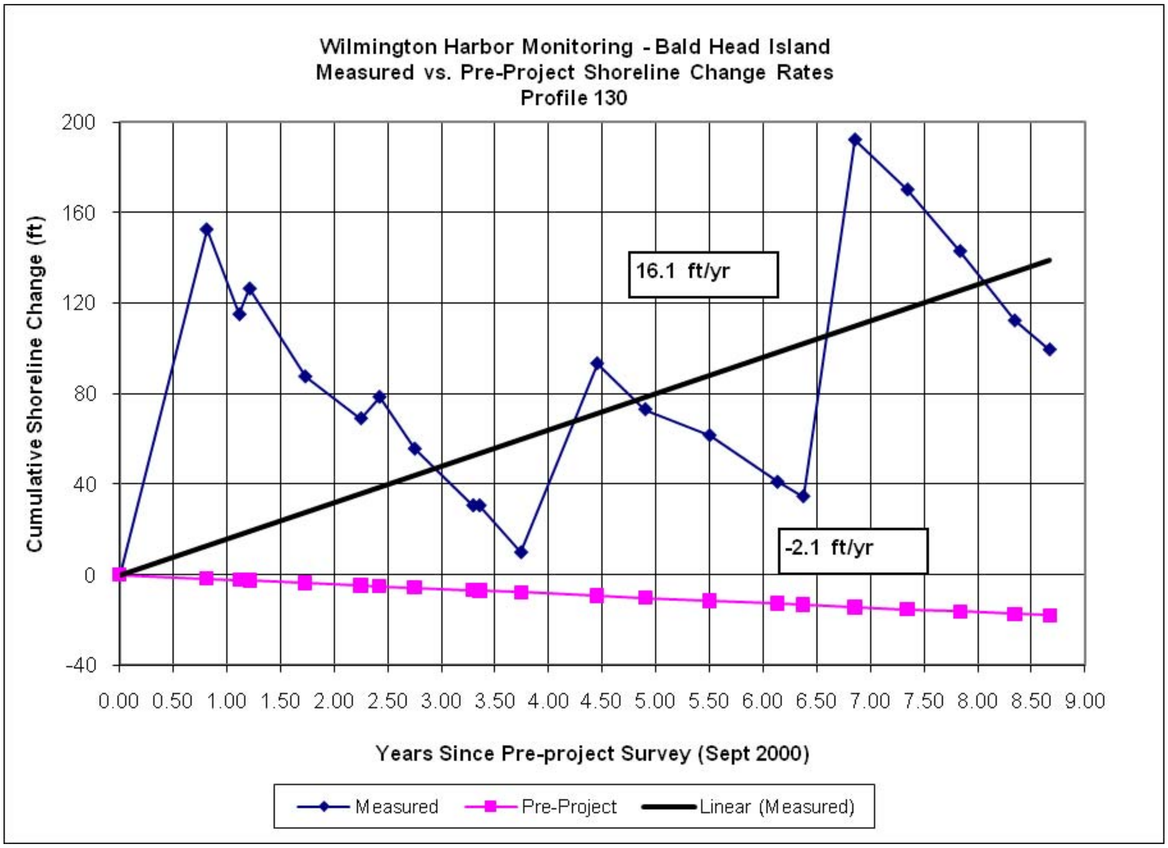
Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 114
Cumulative Shoreline Change (ft)
180
160
140
120
100
80
60
40
20
0
-20
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
15.7 ft/yr
-1.6 ft/yr
Measured
Pre-Project
Linear (Measured)

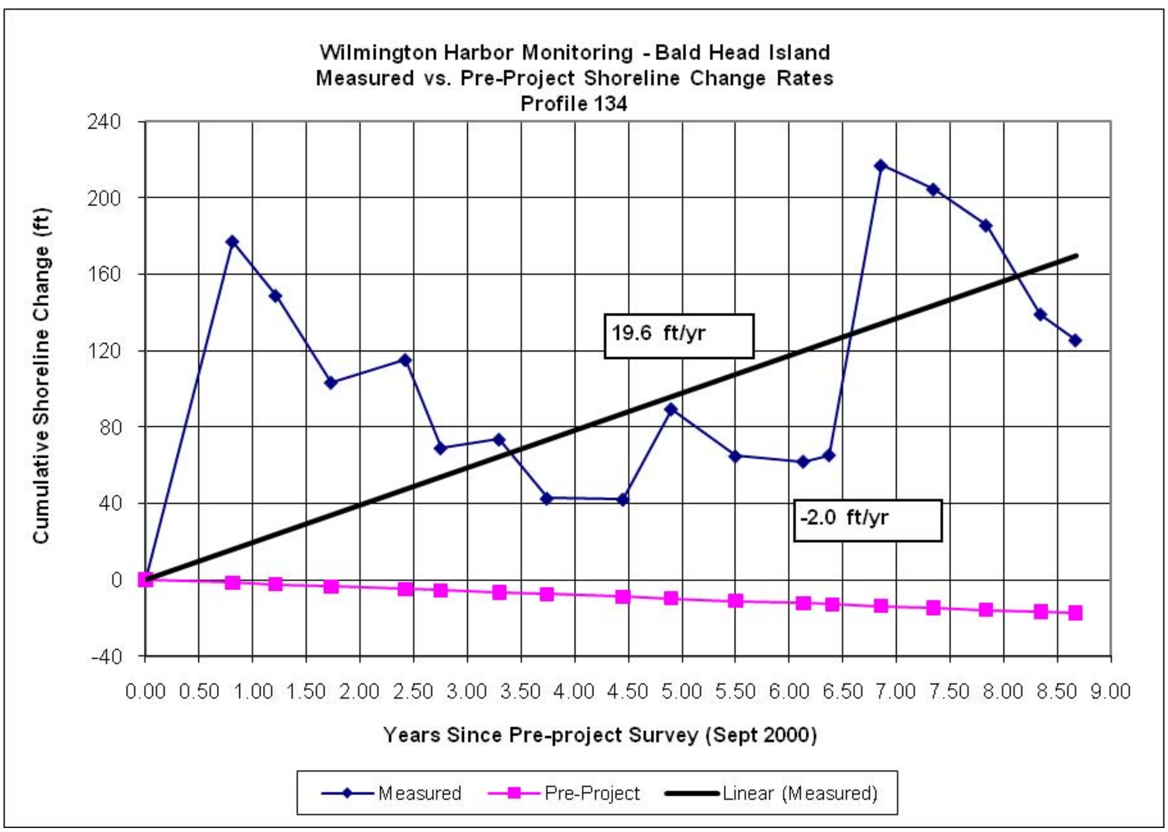


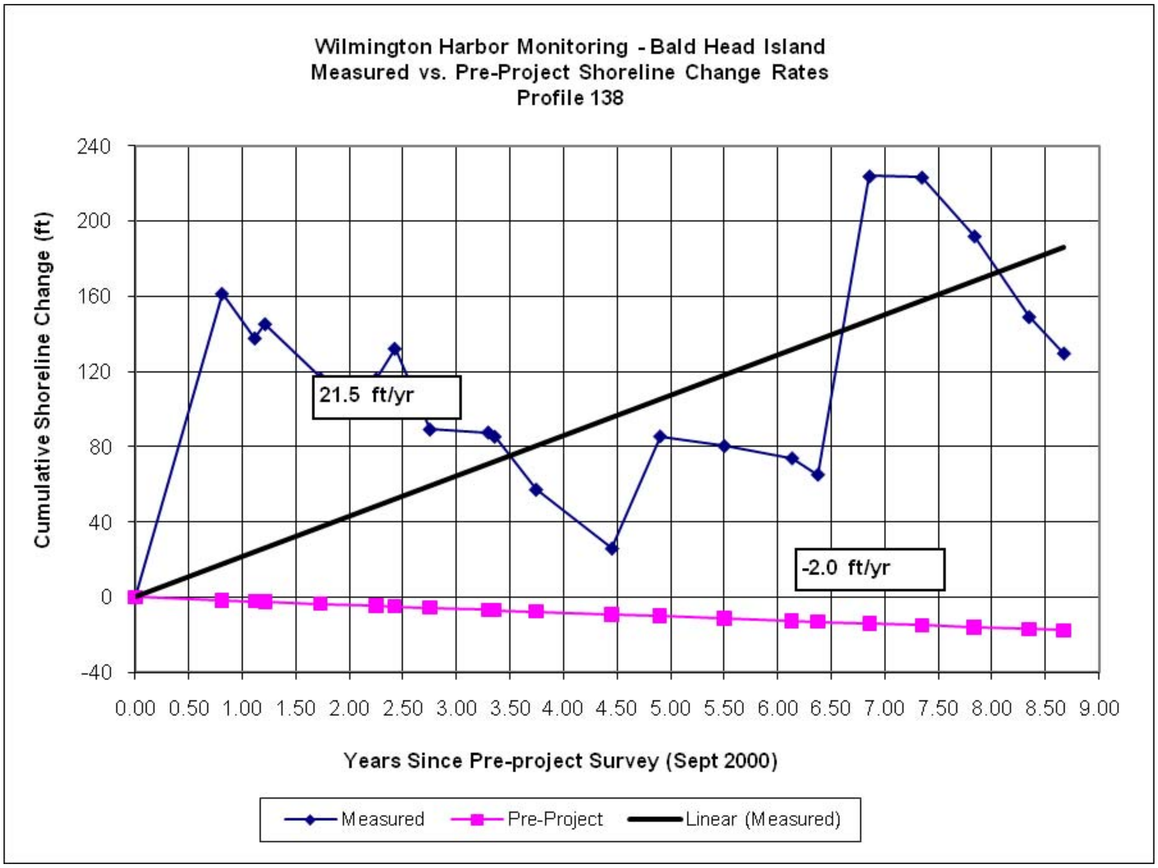
Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 118
Cumulative Shoreline Change (ft)
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
16.6 ft/yr
-1.8 ft/yr
Measured
Pre-Project
Linear (Measured)

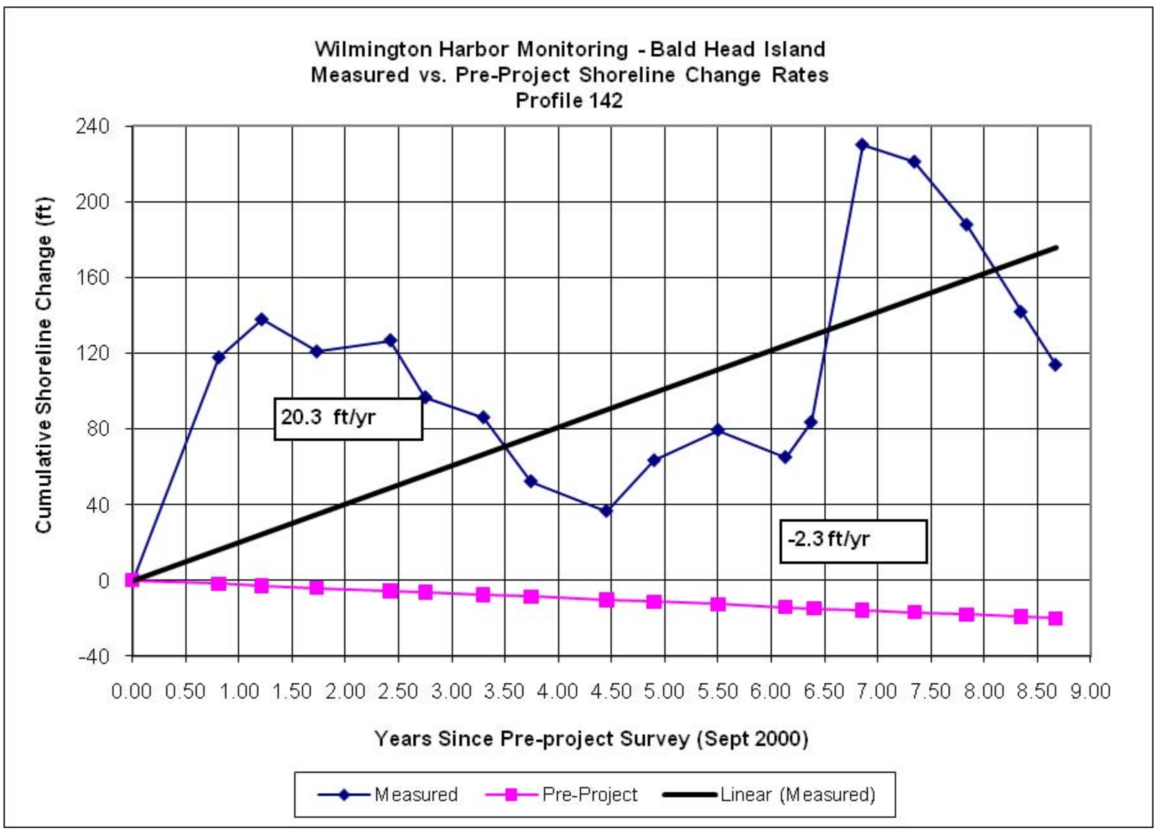

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 122
20.8 ft/yr
-1.9 ft/yr
Cumulative Shoreline Change (ft)
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

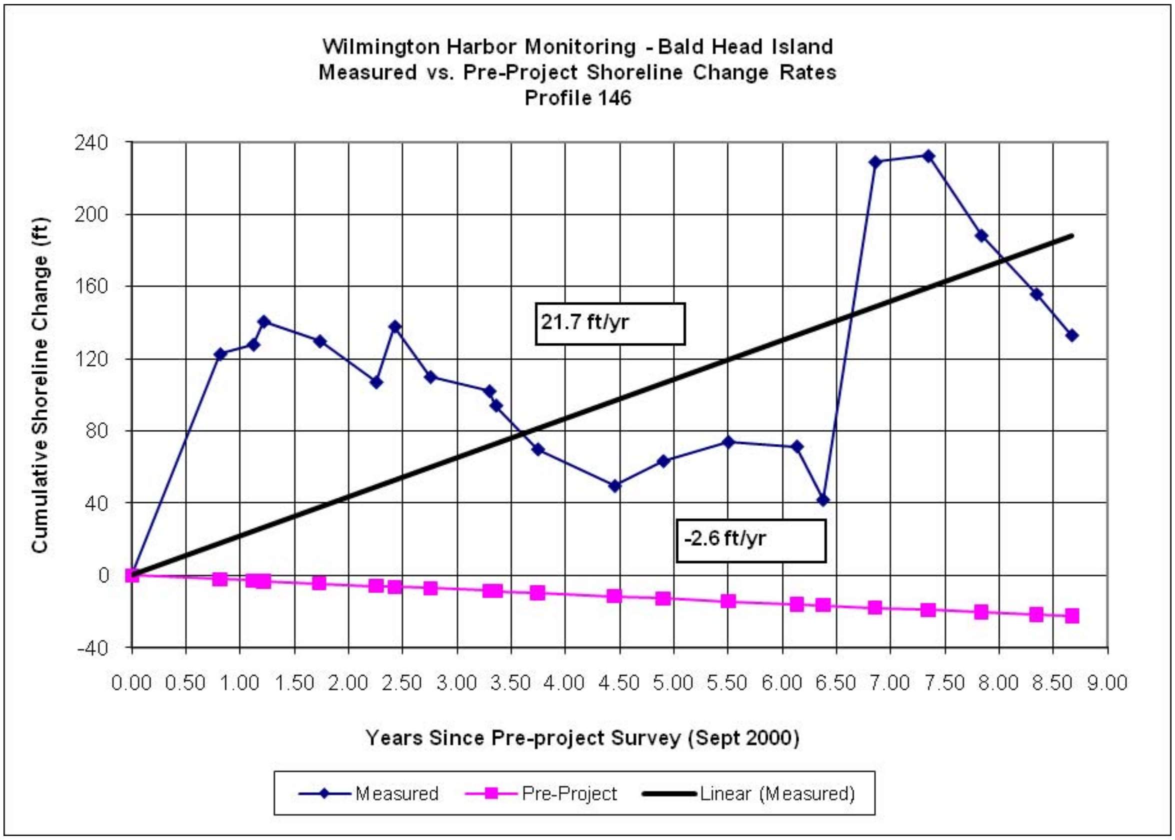

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 126
20.8 ft/yr
-2.0 ft/yr
Cumulative Shoreline Change (ft)
240
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

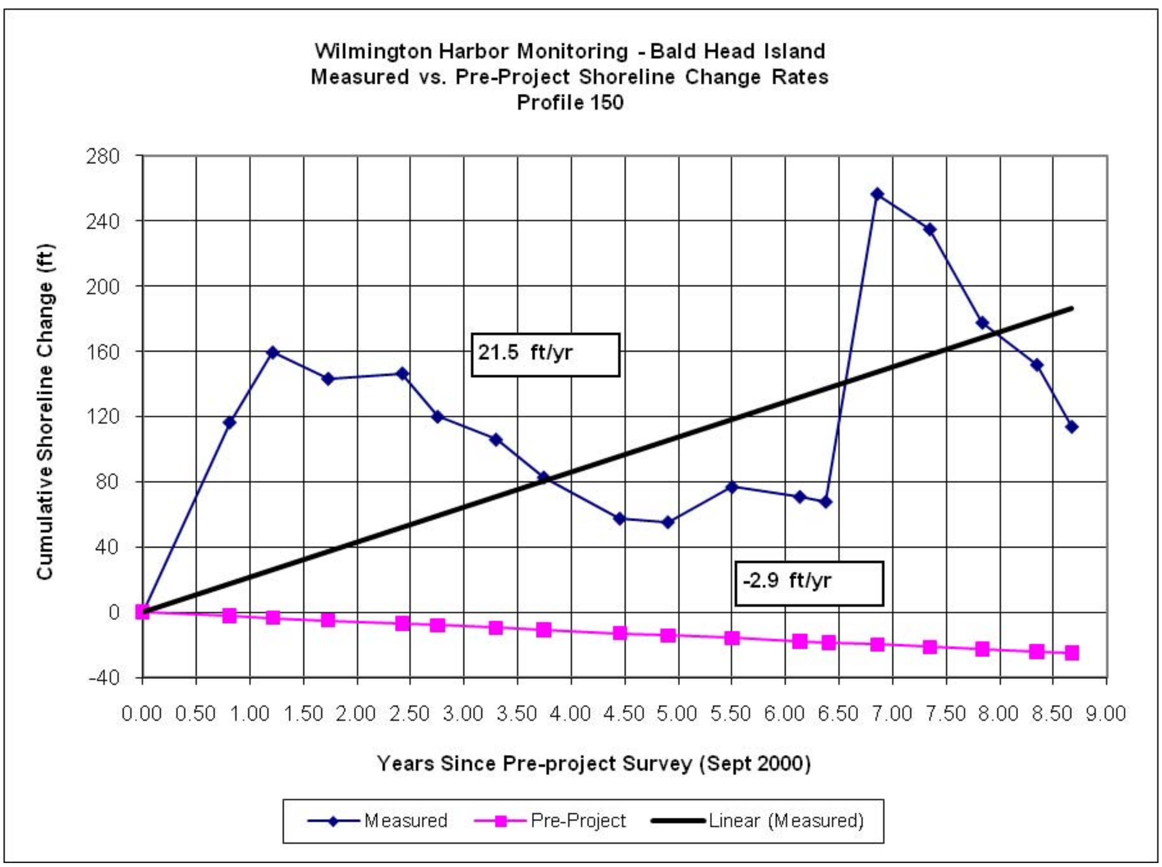

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 130
Cumulative Shoreline Change (ft)
200
160
120
80
40
0
-40
16.1 ft/yr
-2.1 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

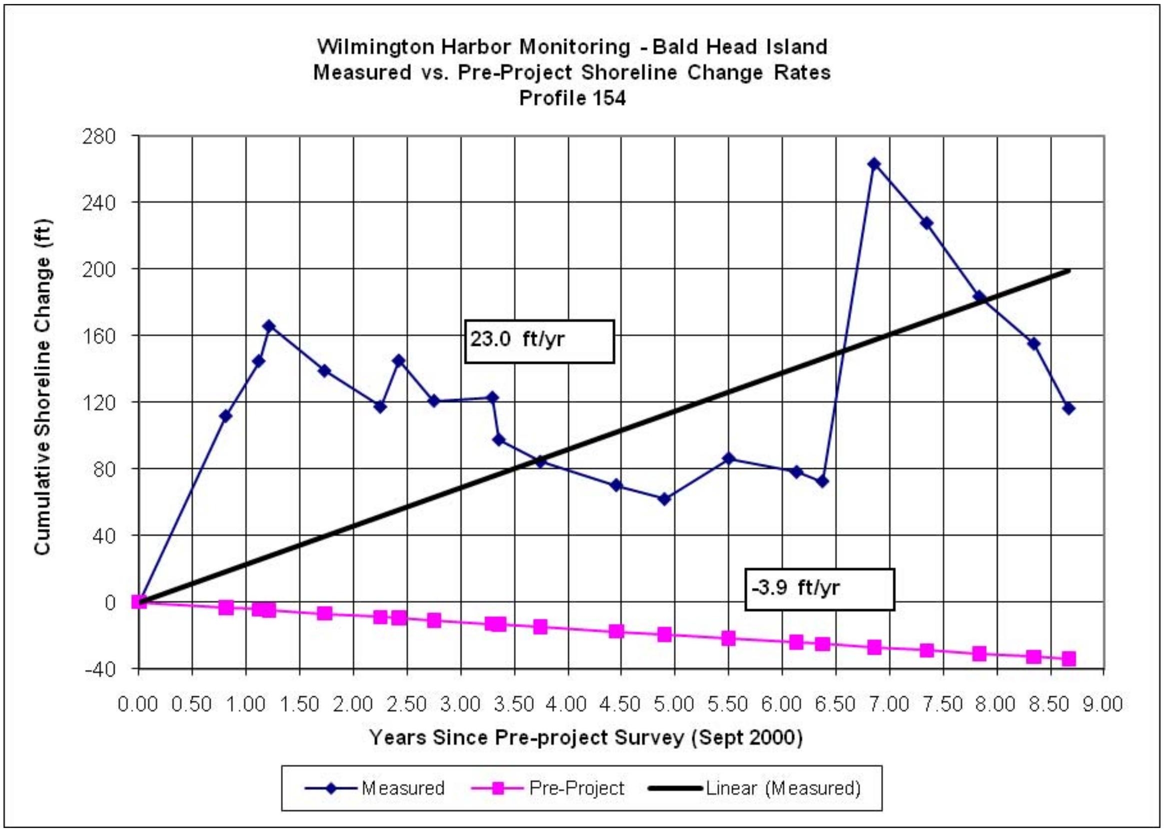

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 134
Cumulative Shoreline Change (ft)
240
200
160
120
80
40
0
-40
19.6 ft/yr
-2.0 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

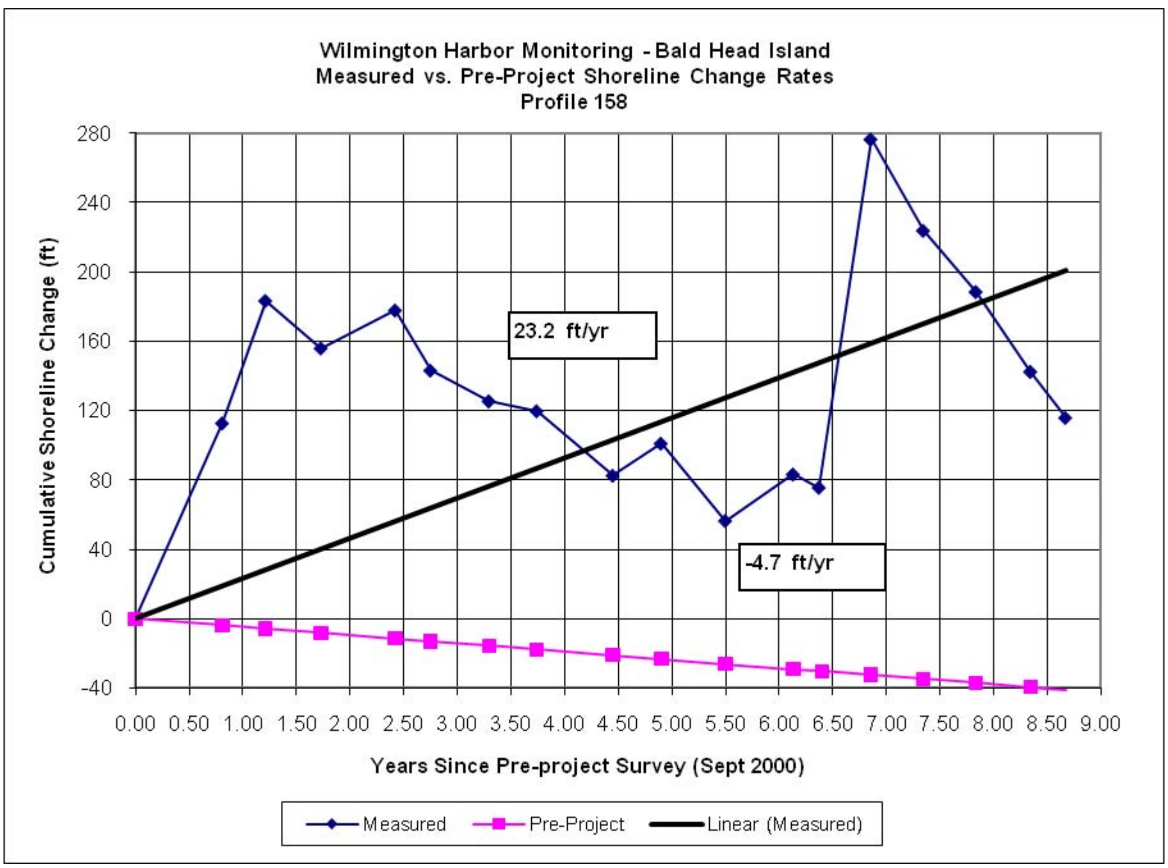

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 138
Cumulative Shoreline Change (ft)
240
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
21.5 ft/yr
-2.0 ft/yr
Measured
Pre-Project
Linear (Measured)

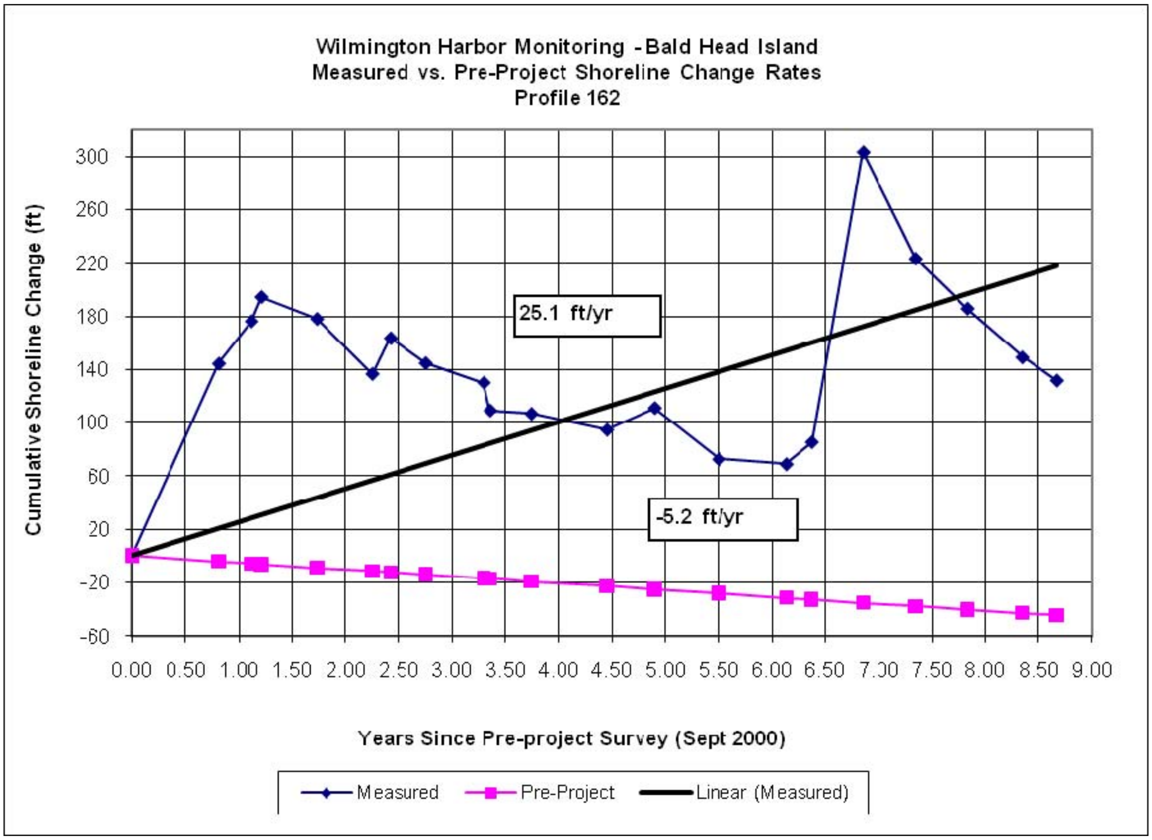

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 142
Cumulative Shoreline Change (ft)
240
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
20.3 ft/yr
-2.3 ft/yr
Measured
Pre-Project
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 146
Cumulative Shoreline Change (ft)
240
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
21.7 ft/yr
-2.6 ft/yr
Measured
Pre-Project
Linear (Measured)

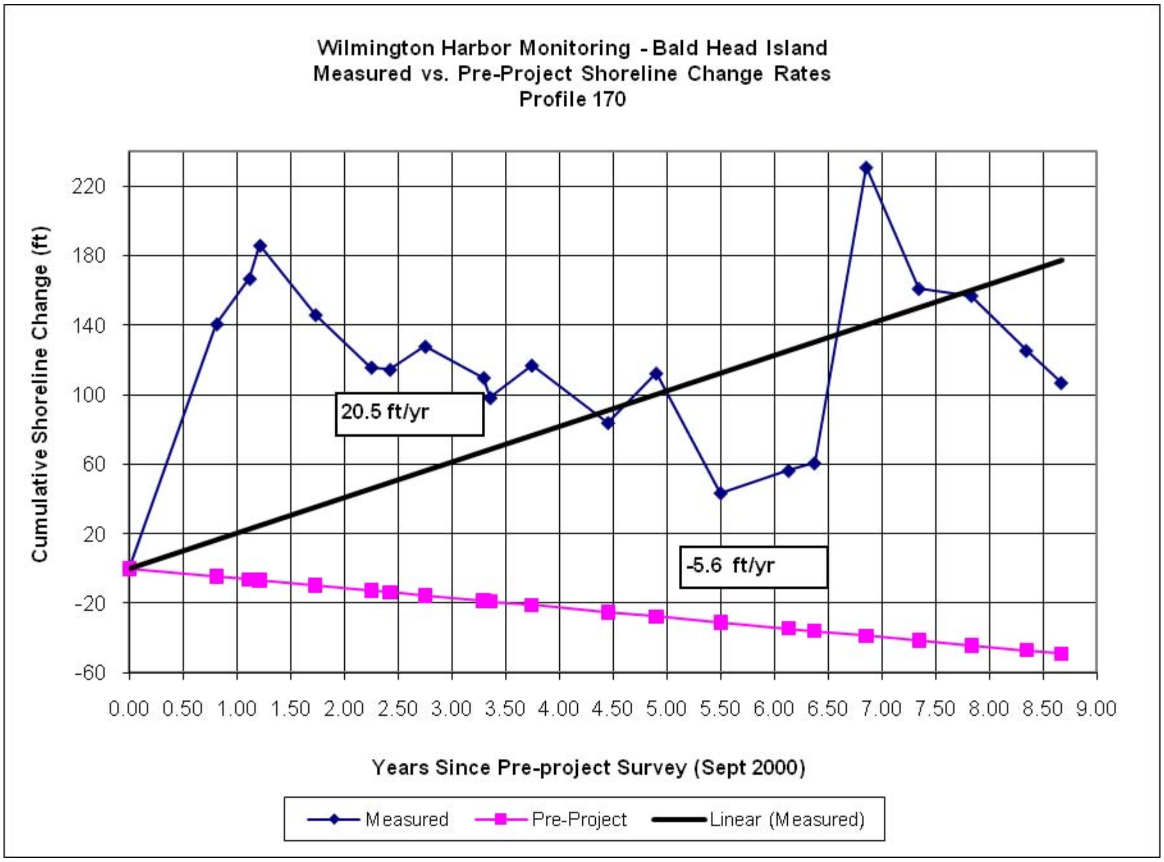

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 150
Cumulative Shoreline Change (ft)
280
240
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
21.5 ft/yr
-2.9 ft/yr
Measured
Pre-Project
Linear (Measured)

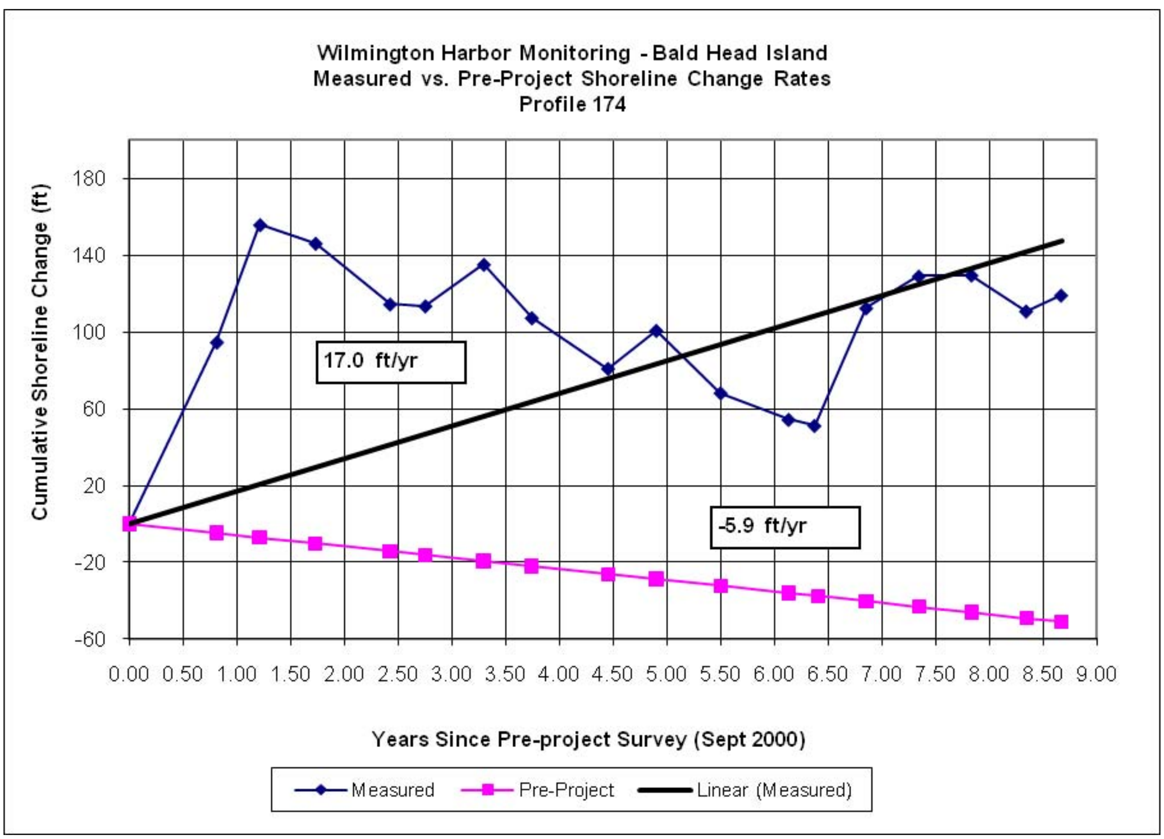

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 154
Cumulative Shoreline Change (ft)
280
240
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
23.0 ft/yr
-3.9 ft/yr
Measured
Pre-Project
Linear (Measured)

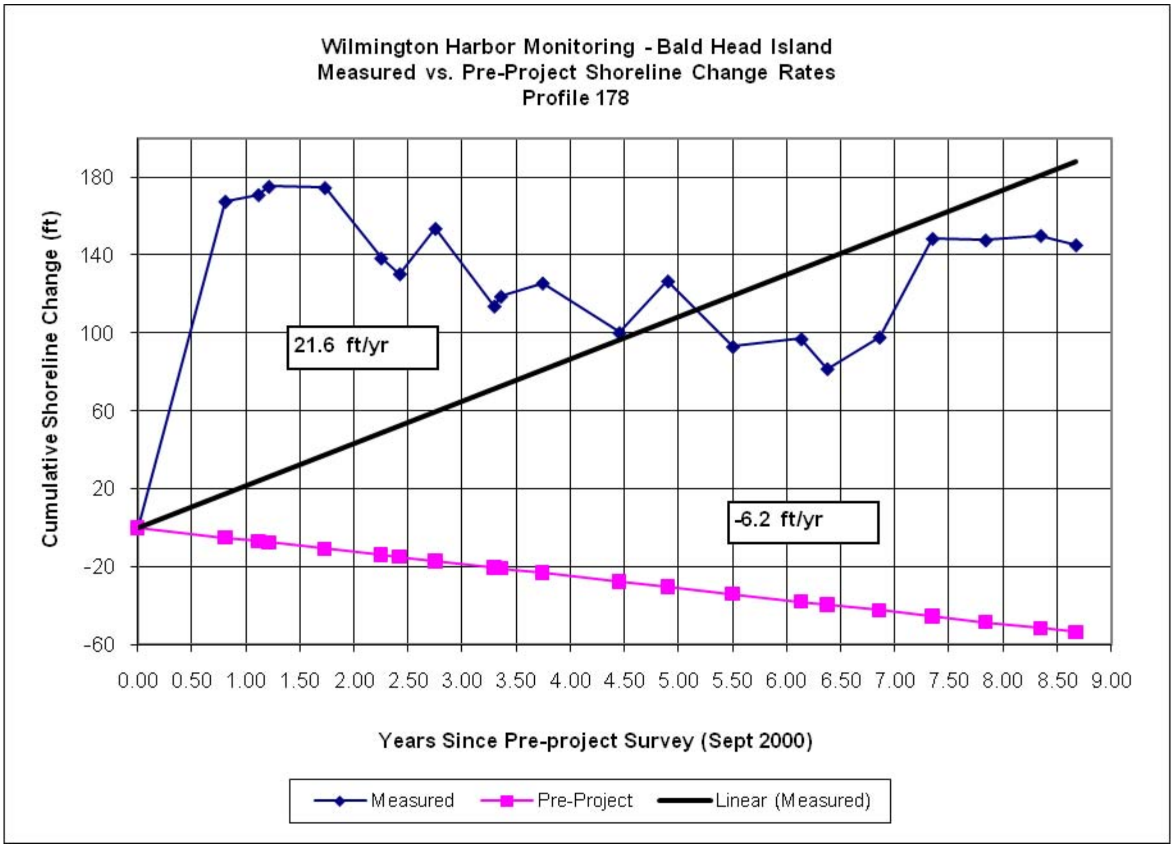

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 158
Cumulative Shoreline Change (ft)
280
240
200
160
120
80
40
0
-40
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
23.2 ft/yr
-4.7 ft/yr
Measured
Pre-Project
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 162
Cumulative Shoreline Change (ft)
300
260
220
180
140
100
60
20
-20
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
25.1 ft/yr
-5.2 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

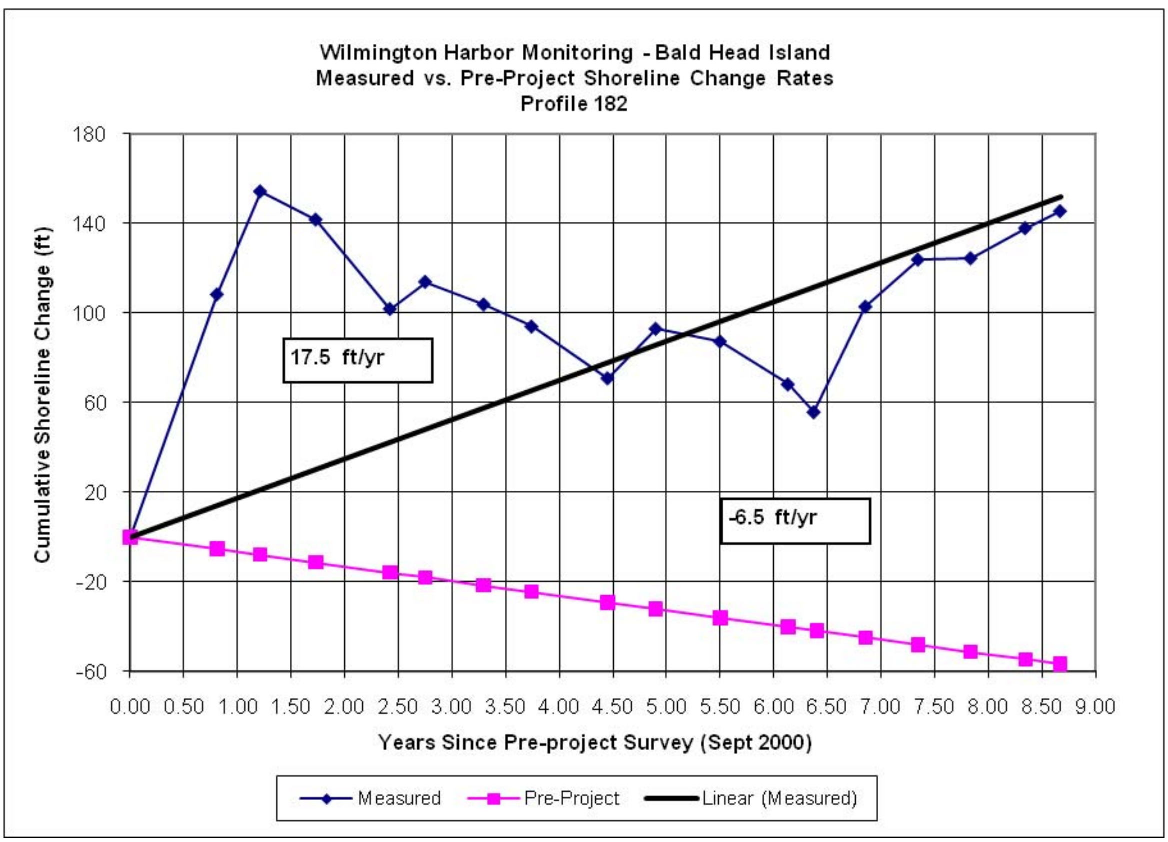

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 166
Cumulative Shoreline Change (ft)
300
260
220
180
140
100
60
20
-20
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
23.8 ft/yr
-5.4 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 170
Cumulative Shoreline Change (ft)
220
180
140
100
60
20
-20
-60
20.5 ft/yr
-5.6 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

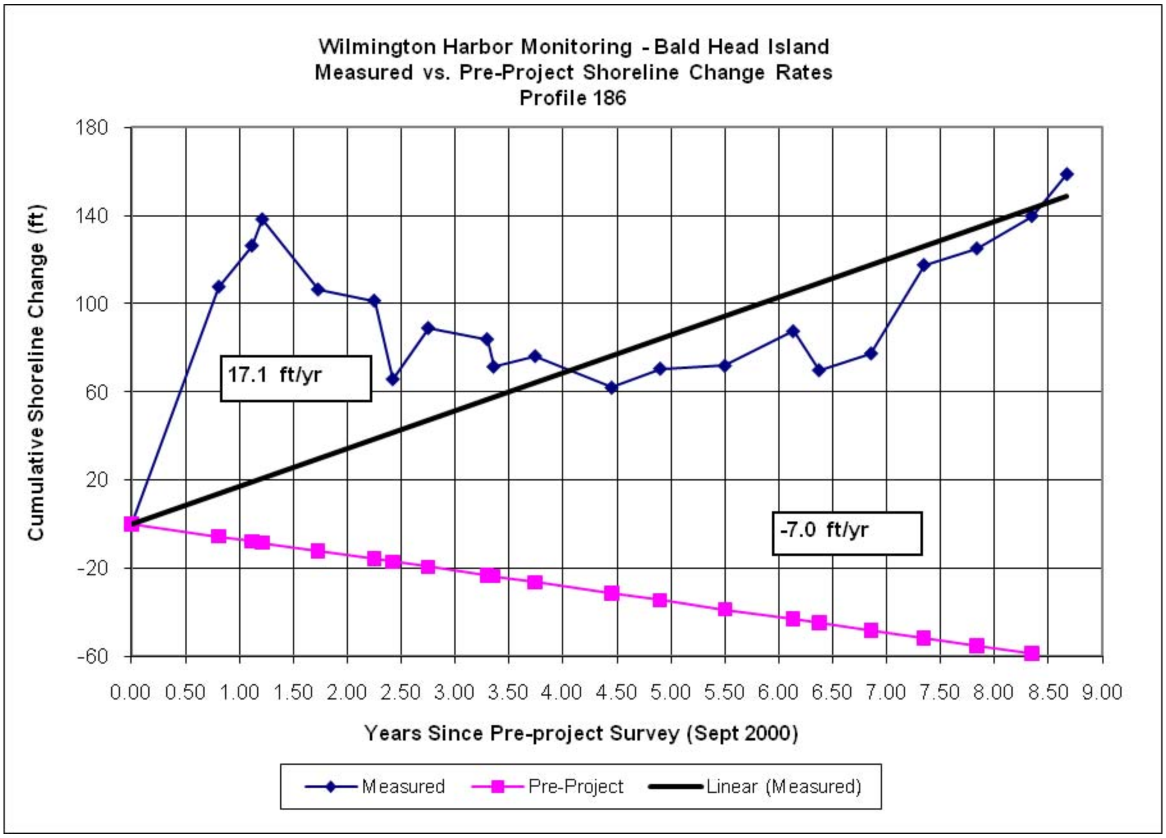

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 174
Cumulative Shoreline Change (ft)
180
140
100
60
20
-20
-60
17.0 ft/yr
-5.9 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

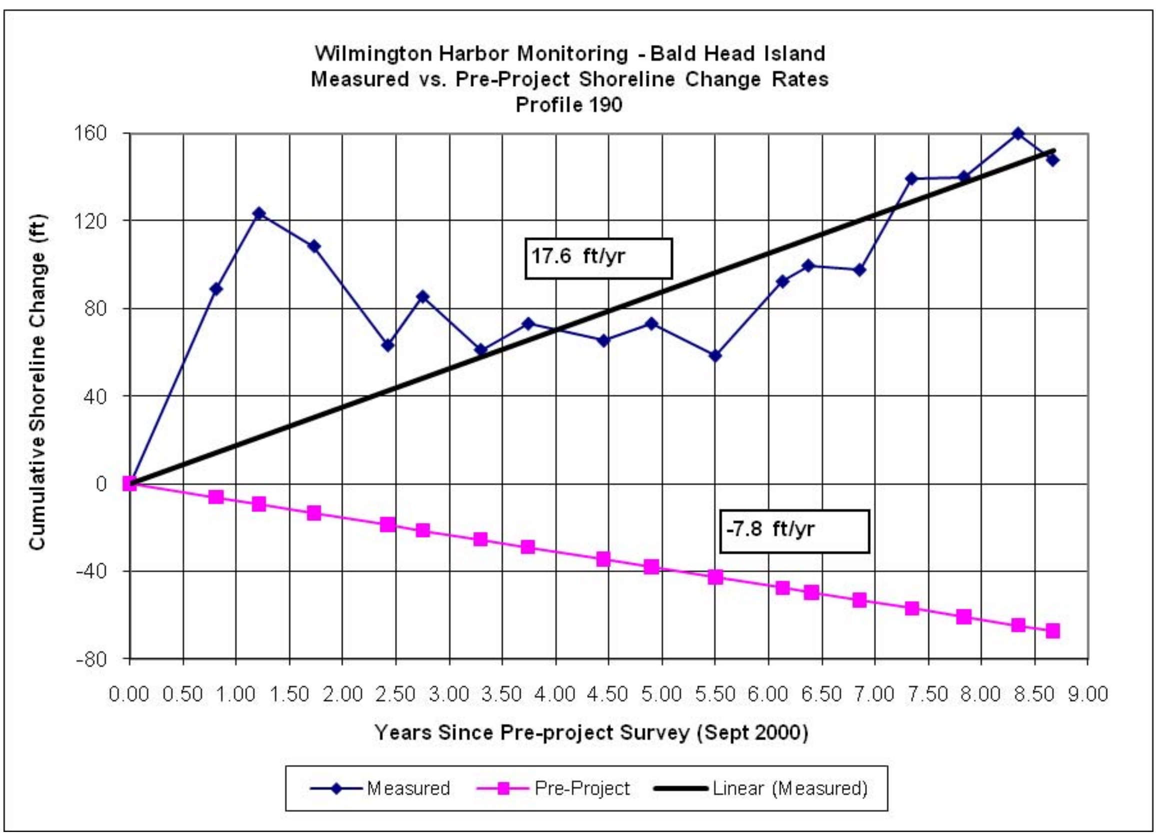


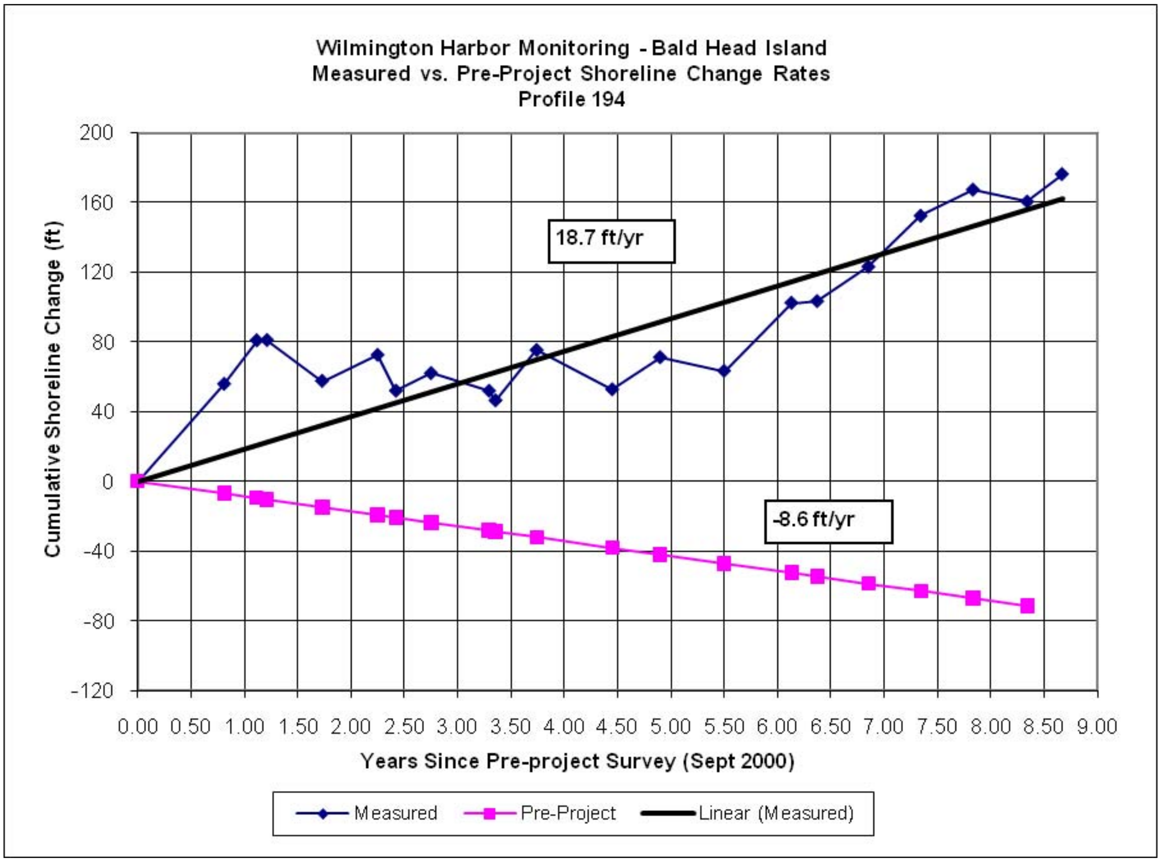
Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 178
Cumulative Shoreline Change (ft)
180
140
100
60
20
-20
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
21.6 ft/yr
-6.2 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

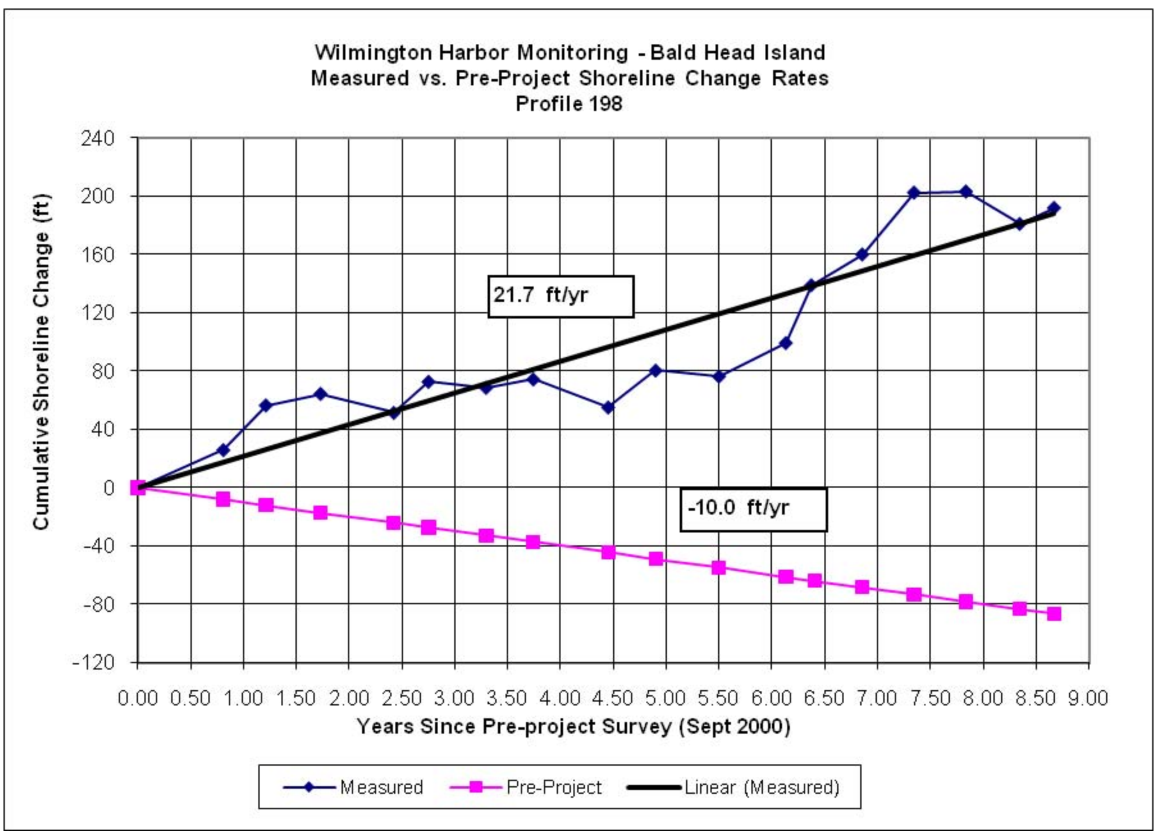


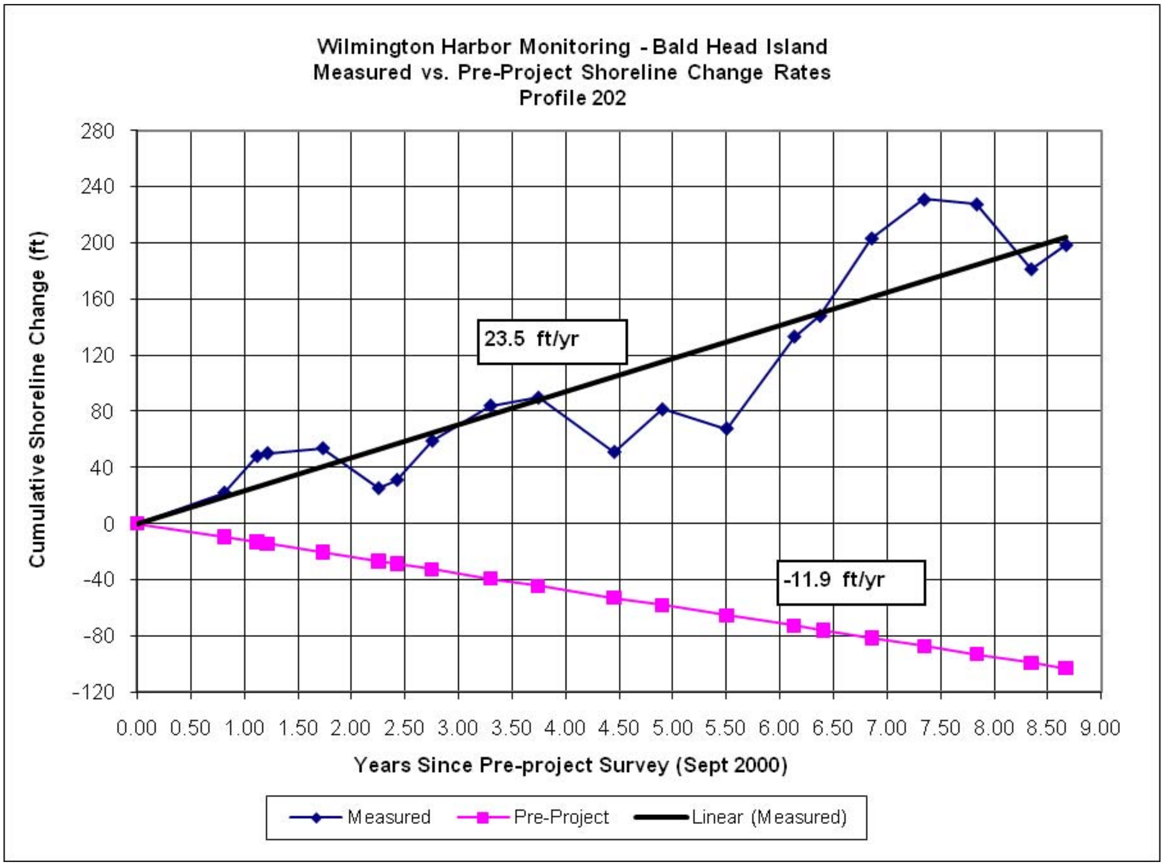
Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 182
Cumulative Shoreline Change (ft)
180
140
100
60
20
-20
-60
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
17.5 ft/yr
-6.5 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

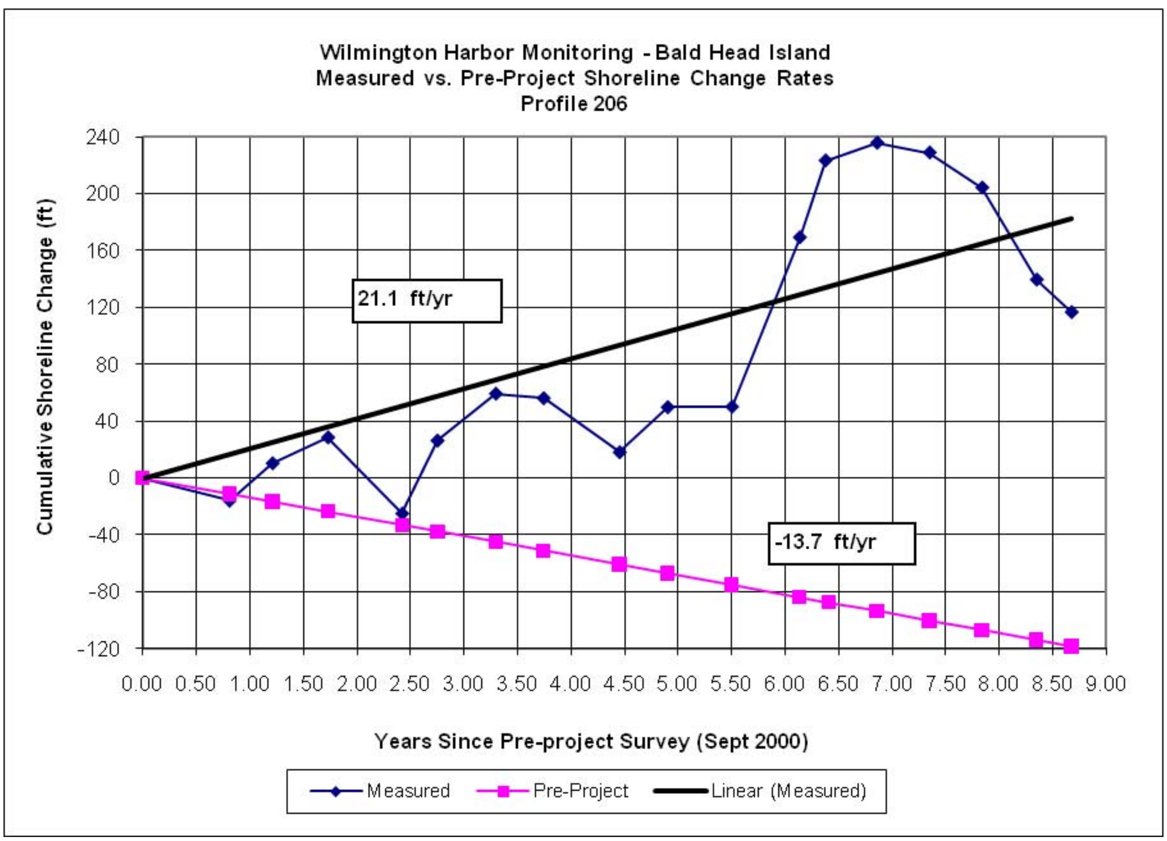

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 186
Cumulative Shoreline Change (ft)
180
140
100
60
20
-20
-60
17.1 ft/yr
-7.0 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

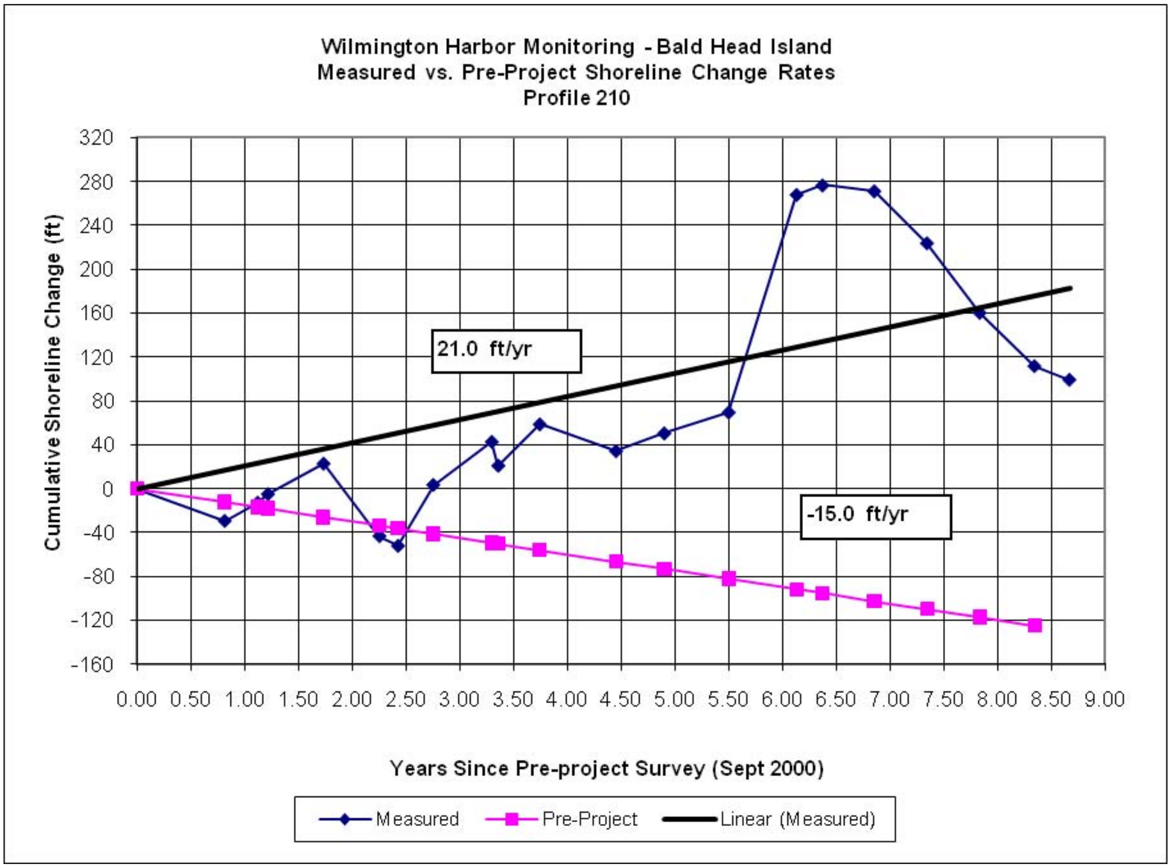

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 190
Cumulative Shoreline Change (ft)
160
120
80
40
0
-40
-80
17.6 ft/yr
-7.8 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)

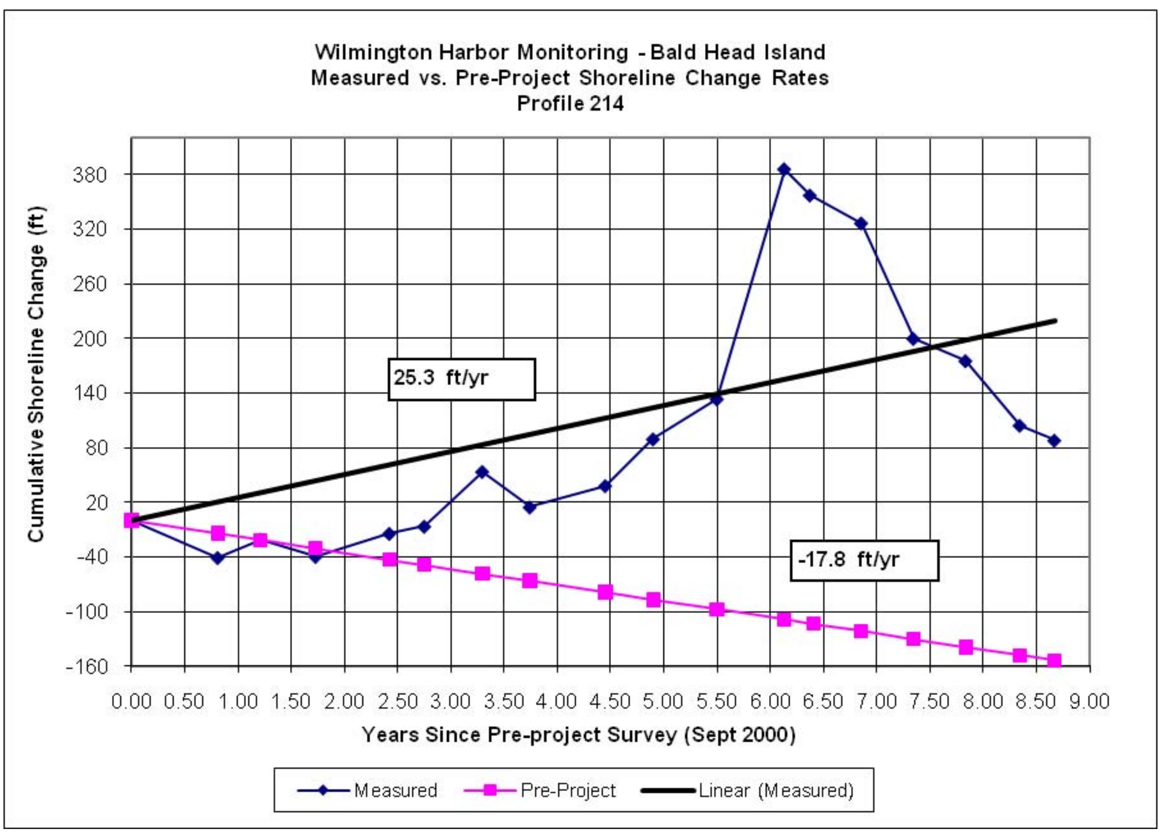

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 194
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
18.7 ft/yr
-8.6 ft/yr
Measured
Pre-Project
Linear (Measured)

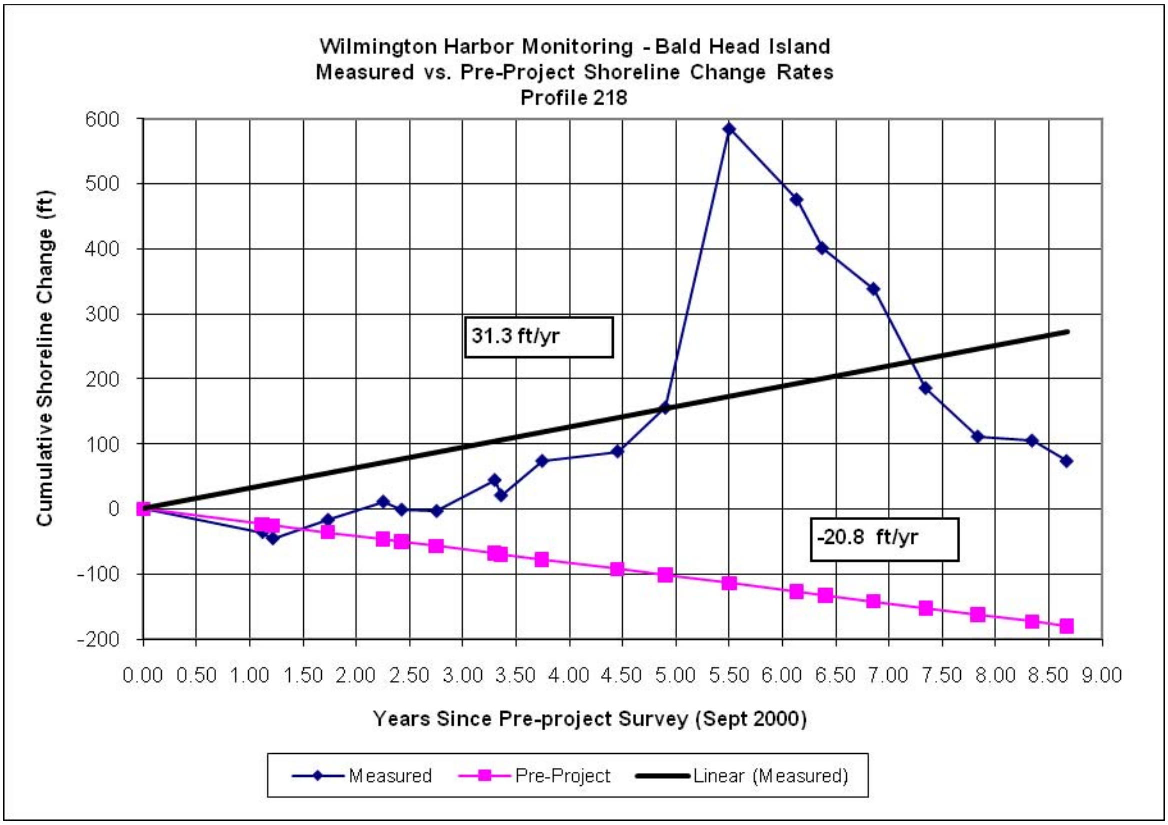

Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 198
Cumulative Shoreline Change (ft)
Years Since Pre-project Survey (Sept 2000)
21.7 ft/yr
-10.0 ft/yr
Measured
Pre-Project
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 202
Cumulative Shoreline Change (ft)
280
240
200
160
120
80
40
0
-40
-80
-120
23.5 ft/yr
-11.9 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 206
Cumulative Shoreline Change (ft)
240
200
160
120
80
40
0
-40
-80
-120
21.1 ft/yr
-13.7 ft/yr
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 210
Cumulative Shoreline Change (ft)
320
280
240
200
160
120
80
40
0
-40
-80
-120
-160
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
21.0 ft/yr
-15.0 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 214
Cumulative Shoreline Change (ft)
380
320
260
200
140
80
20
-40
-100
-160
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
25.3 ft/yr
-17.8 ft/yr
Years Since Pre-project Survey (Sept 2000)
Measured
Pre-Project
Linear (Measured)


Wilmington Harbor Monitoring - Bald Head Island
Measured vs. Pre-Project Shoreline Change Rates
Profile 218
Cumulative Shoreline Change (ft)
600
500
400
300
200
100
0
-100
-200
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00 8.50 9.00
Years Since Pre-project Survey (Sept 2000)
31.3 ft/yr
-20.8 ft/yr
Measured
Pre-Project
Linear (Measured)

Appendix D

CURRENT MEASUREMENTS
(Tidal inlet and New Channel Regions)

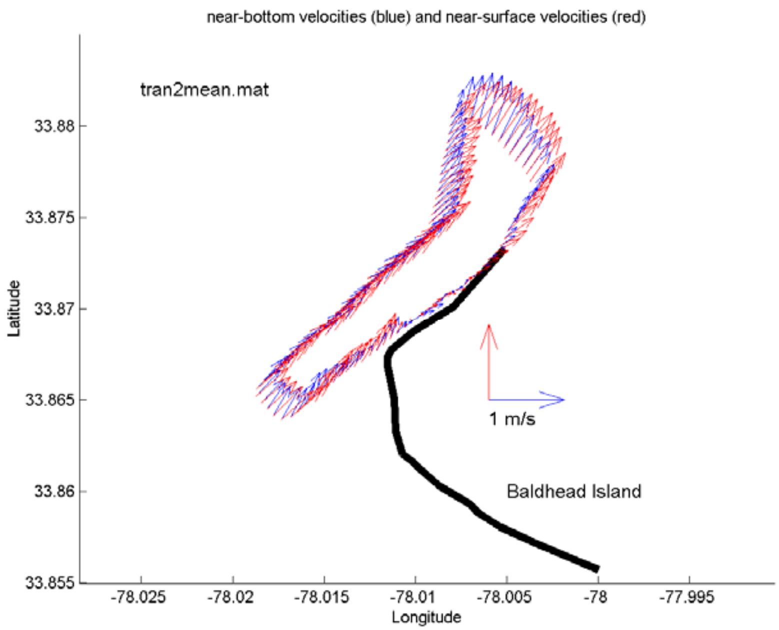


Figure D-1 October 2000 ADCP survey at inlet transect during peak flood flow. Note that survey transect does not cover same area as the April 2002, March 2003 and January 2004 surveys.

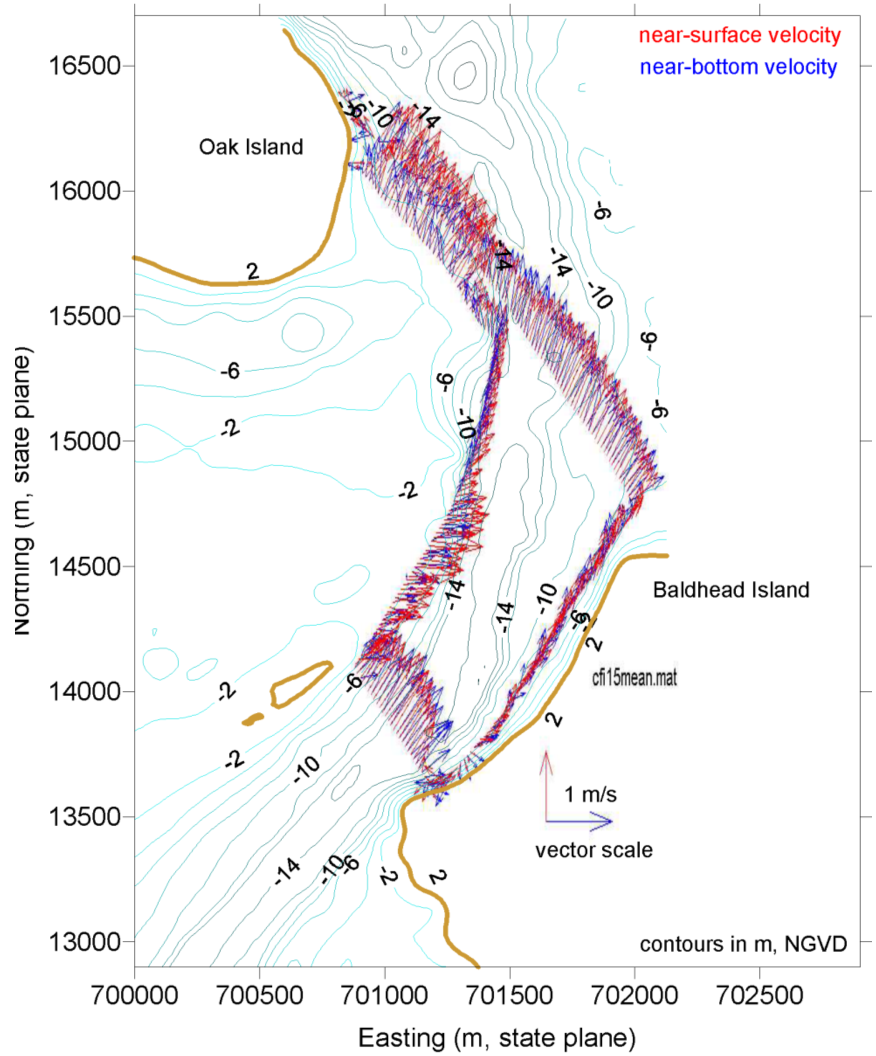


Figure D-2 April 2002 ADCP survey at inlet transect during peak flood flow.

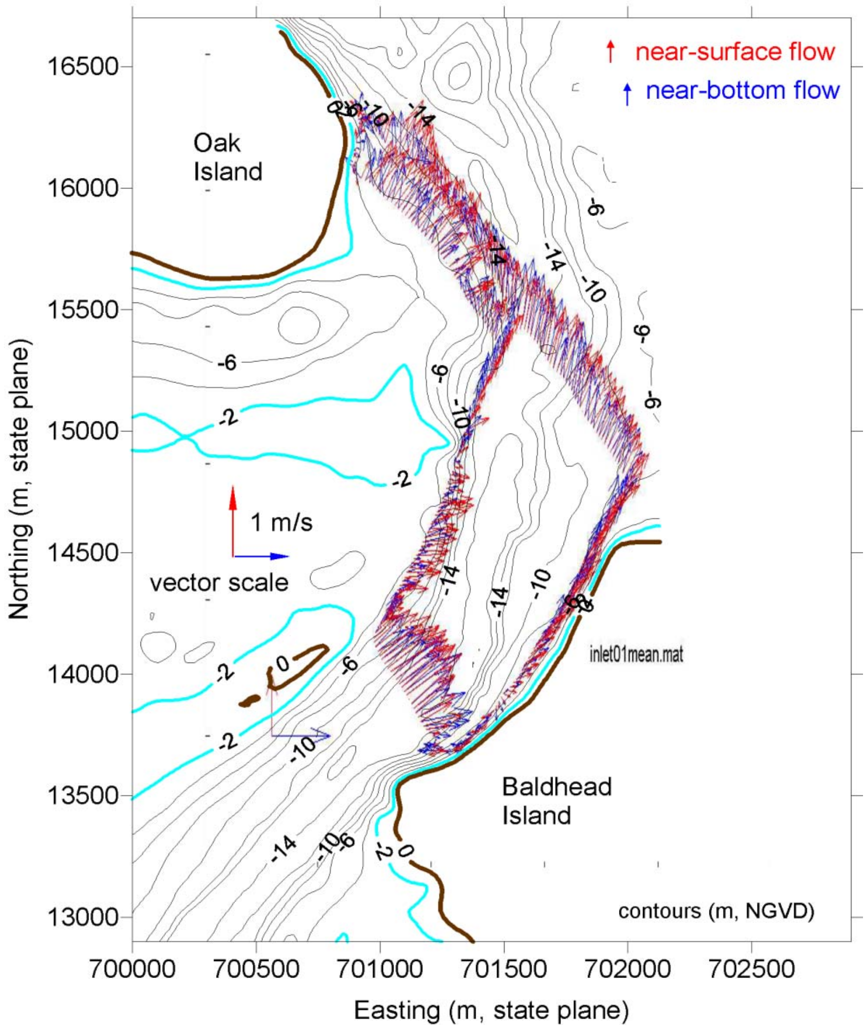


Figure D-3 March 2003 ADCP survey at inlet transect during flood flow.

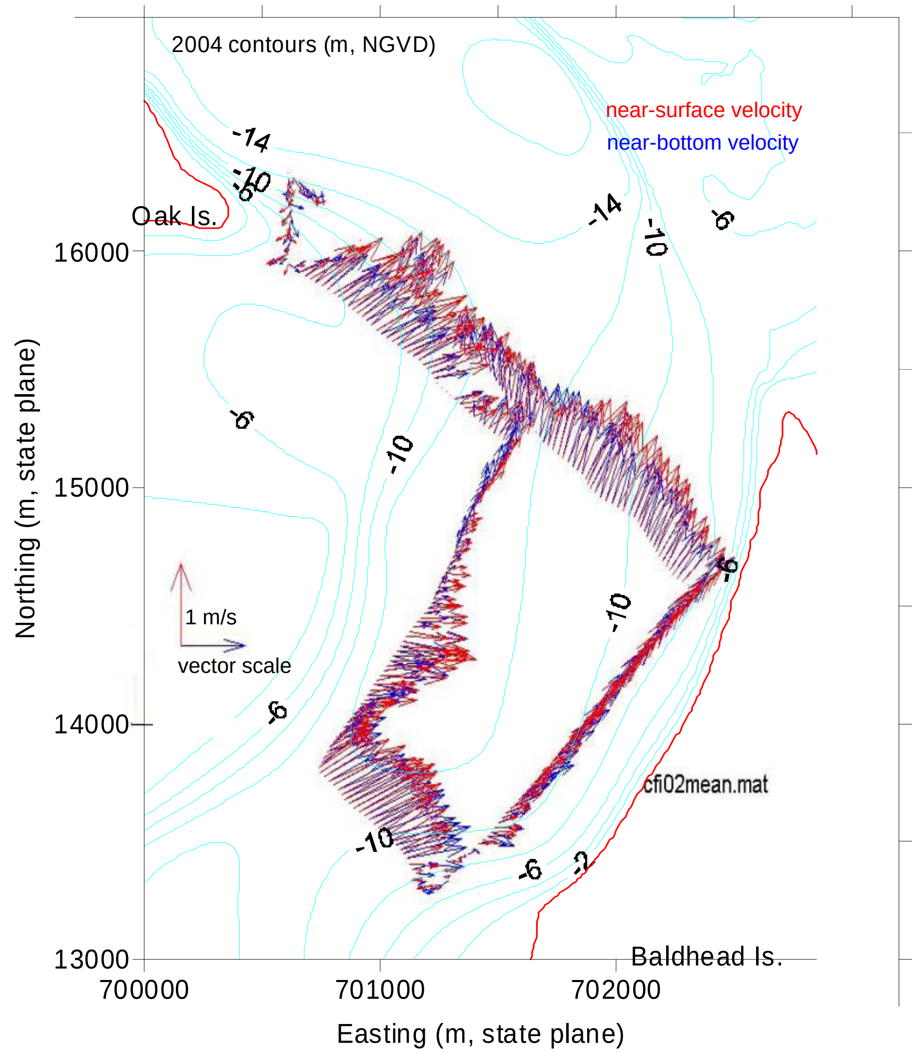


Figure D-4 January 2004 ADCP survey at inlet transect during flood flow.

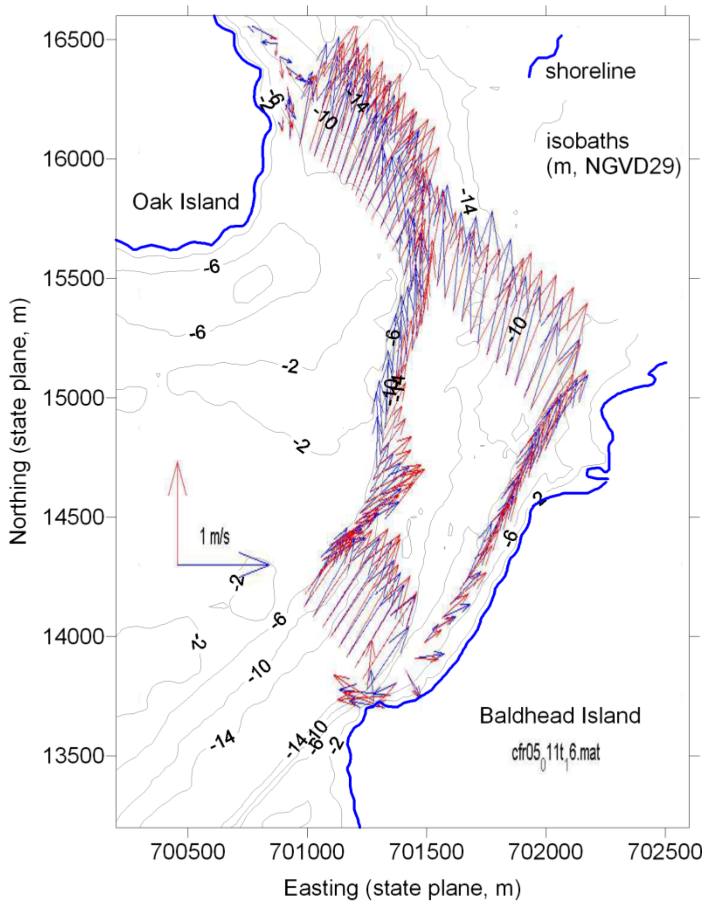


Figure D-5 March 2005 ADCP survey at inlet transect during flood flow.

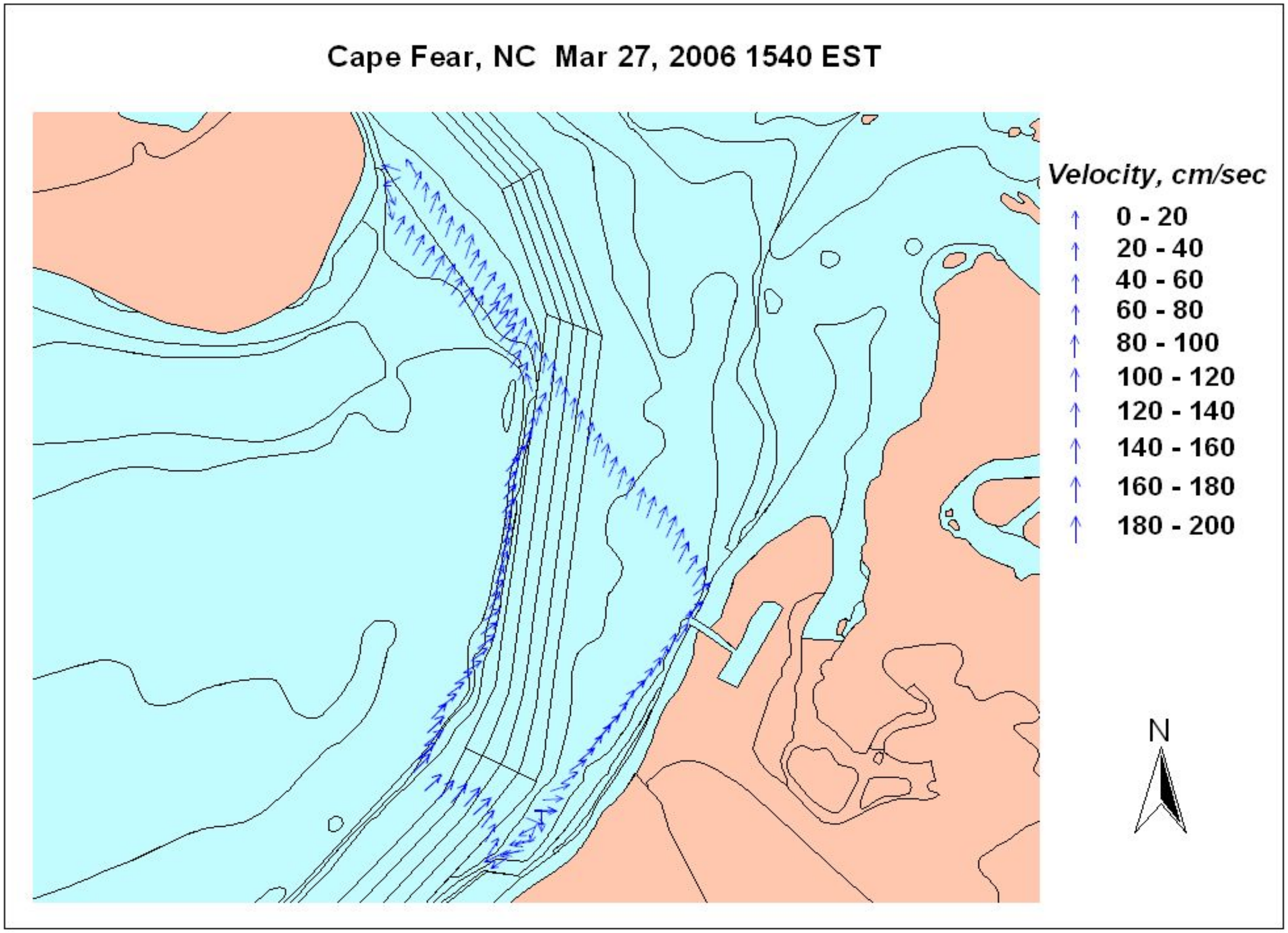


Figure D-6 March 2006 ADCP survey at the inlet transect during peak flood flow

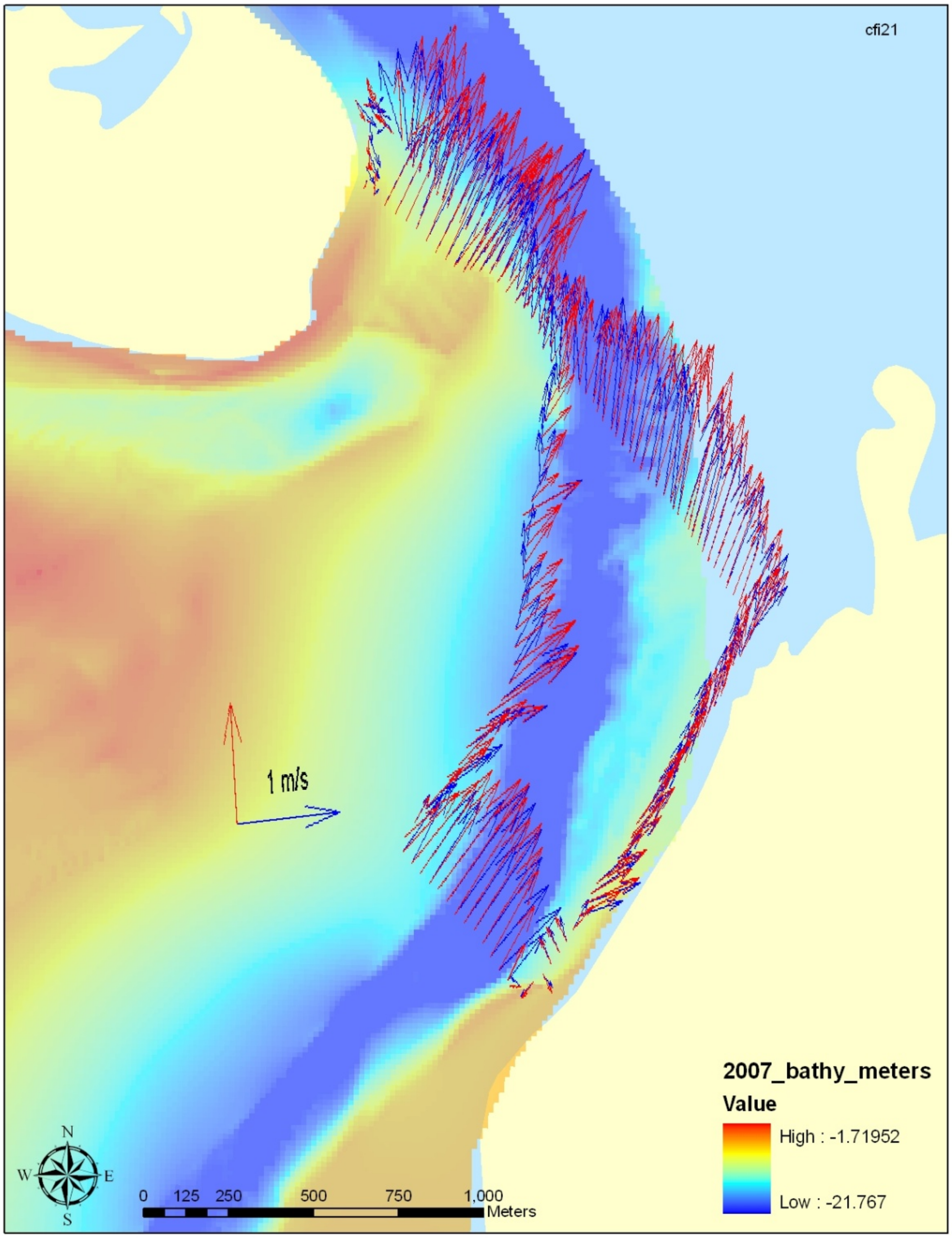


Figure D-7 February 2007 ADCP Survey at the Inlet Transect during Peak Flood Flow

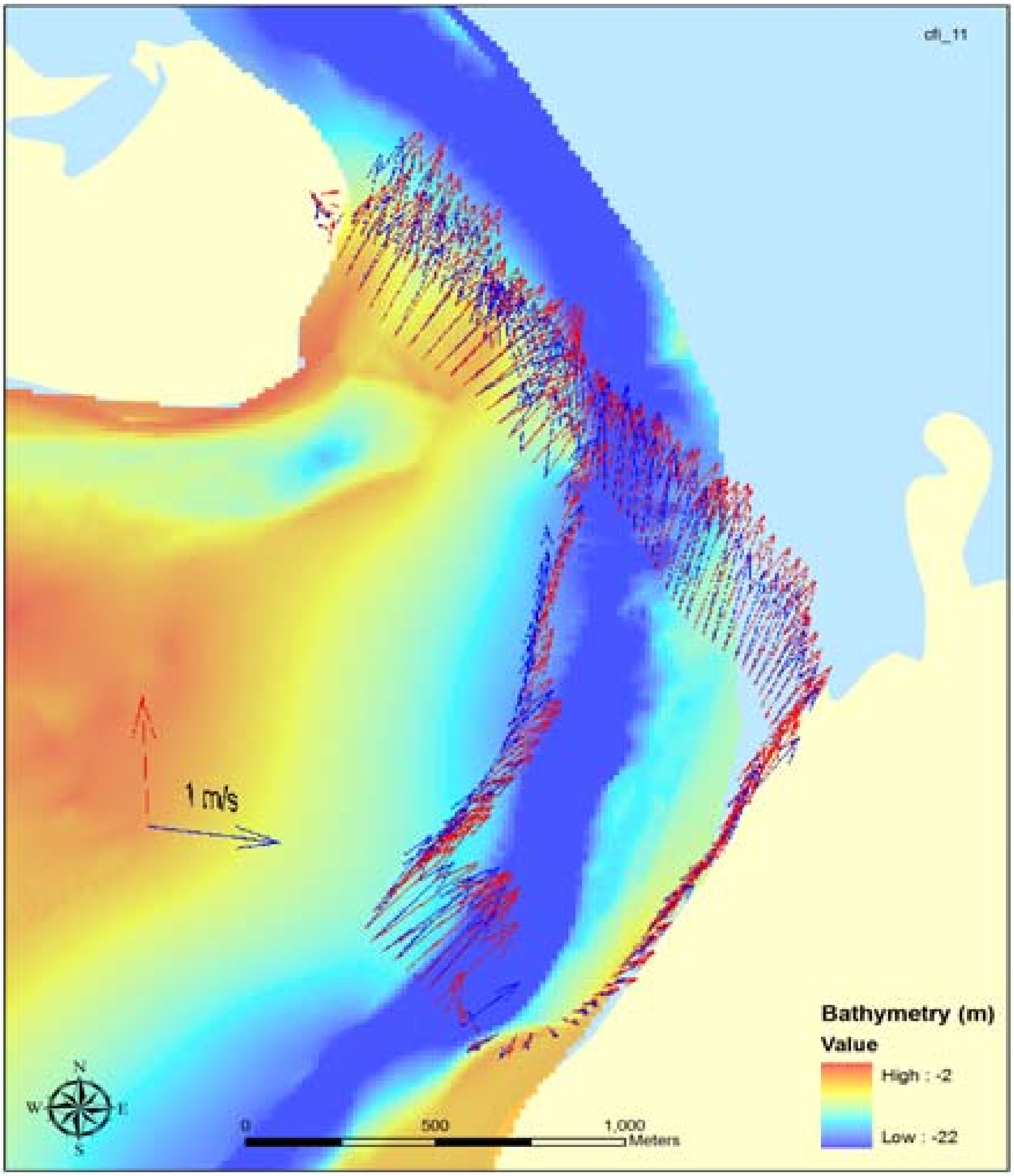


Figure D-8 March 2008 ADCP Survey at the Inlet Transect during Peak Flood Flow

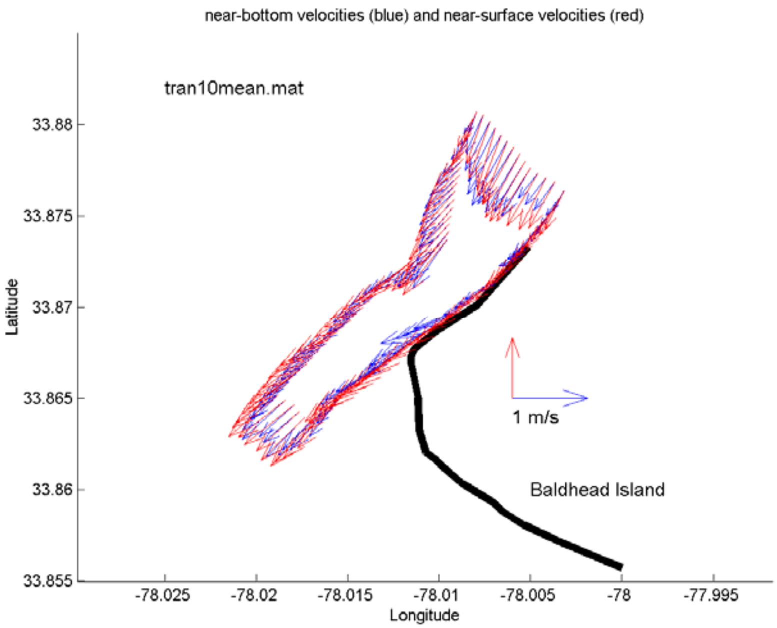


Figure D-9 October 2000 ADCP survey at inlet transect during peak ebb flow. Note that survey transect does not cover same area as the April 2002 survey.

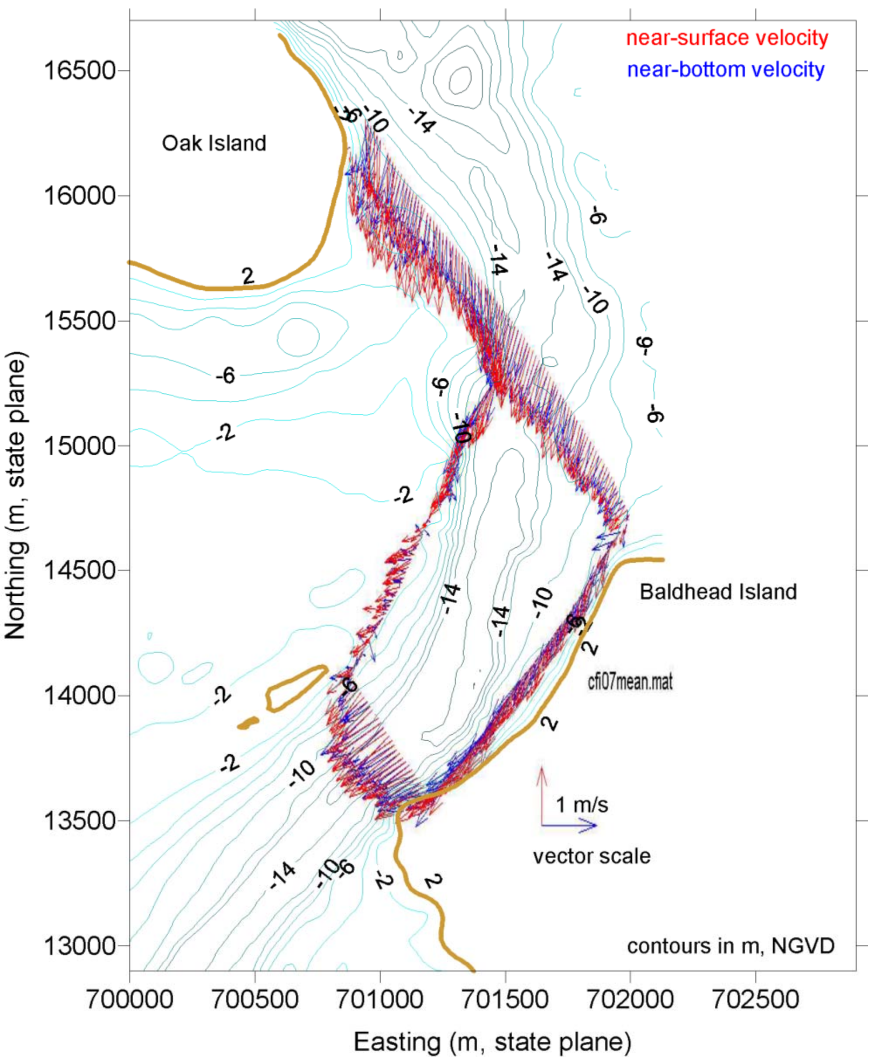


Figure D-10 April 2002 ADCP survey at inlet transect during peak ebb flow. Note that survey transect does not cover same area as the October 2000 survey.

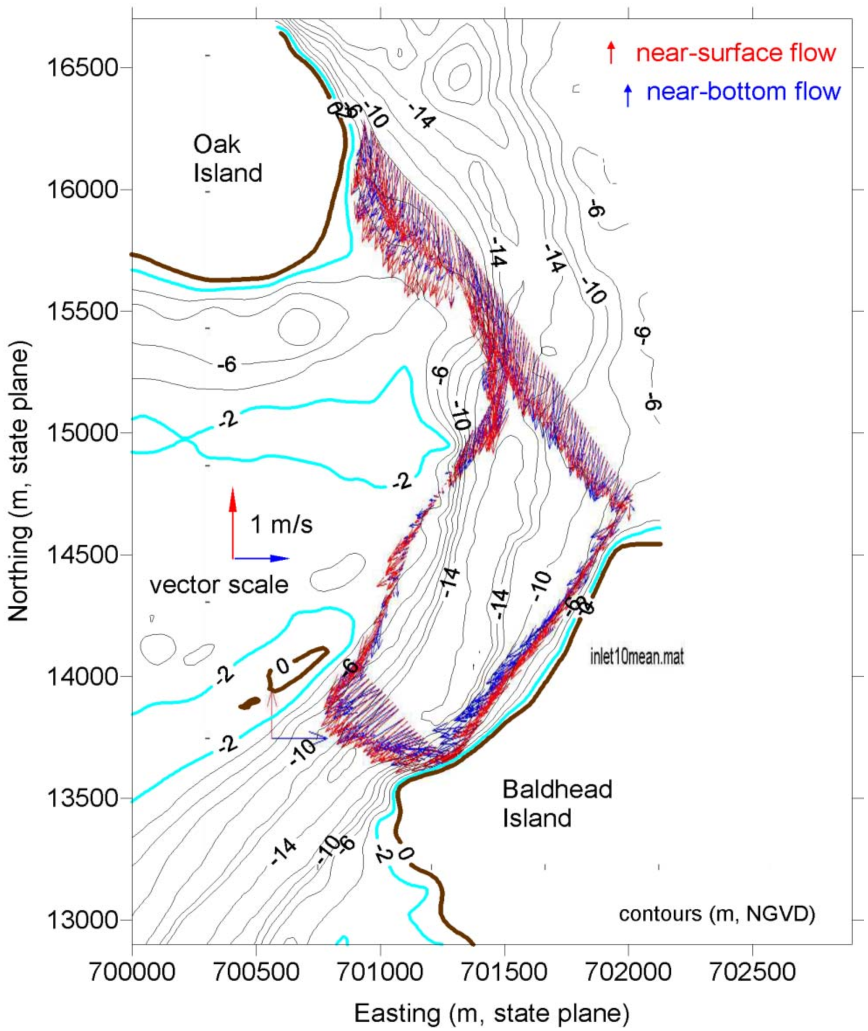


Figure D-11 March 2003 ADCP survey at inlet transect during ebb flow.

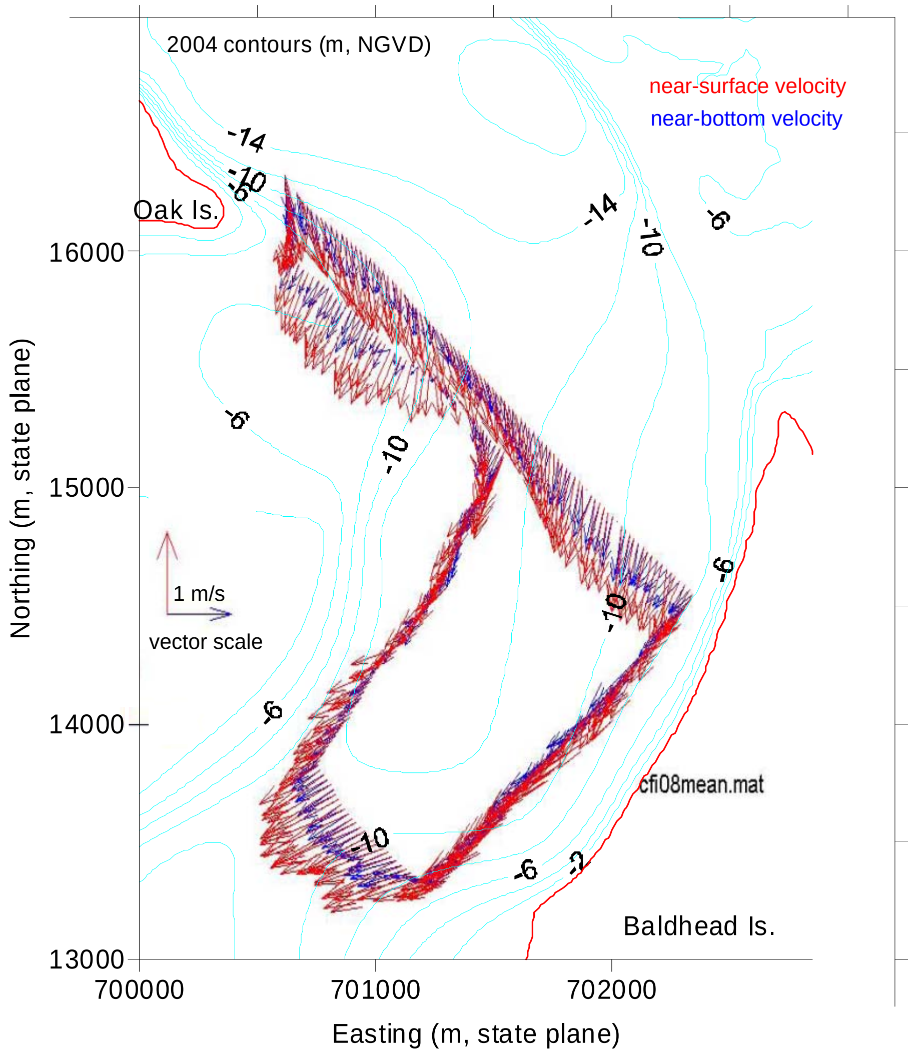


Figure D-12 January 2004 ADCP survey at inlet transect during ebb flow.

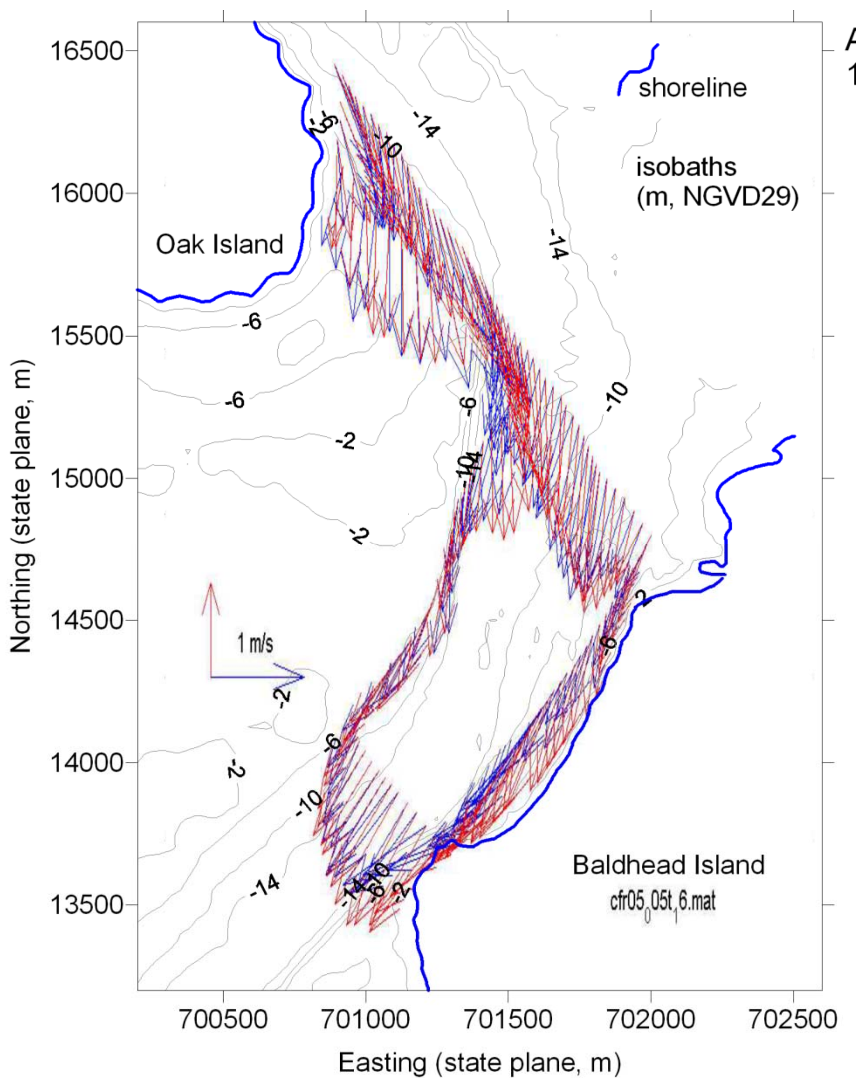


Figure D-13 March 2005 ADCP survey at inlet transect during ebb flow.

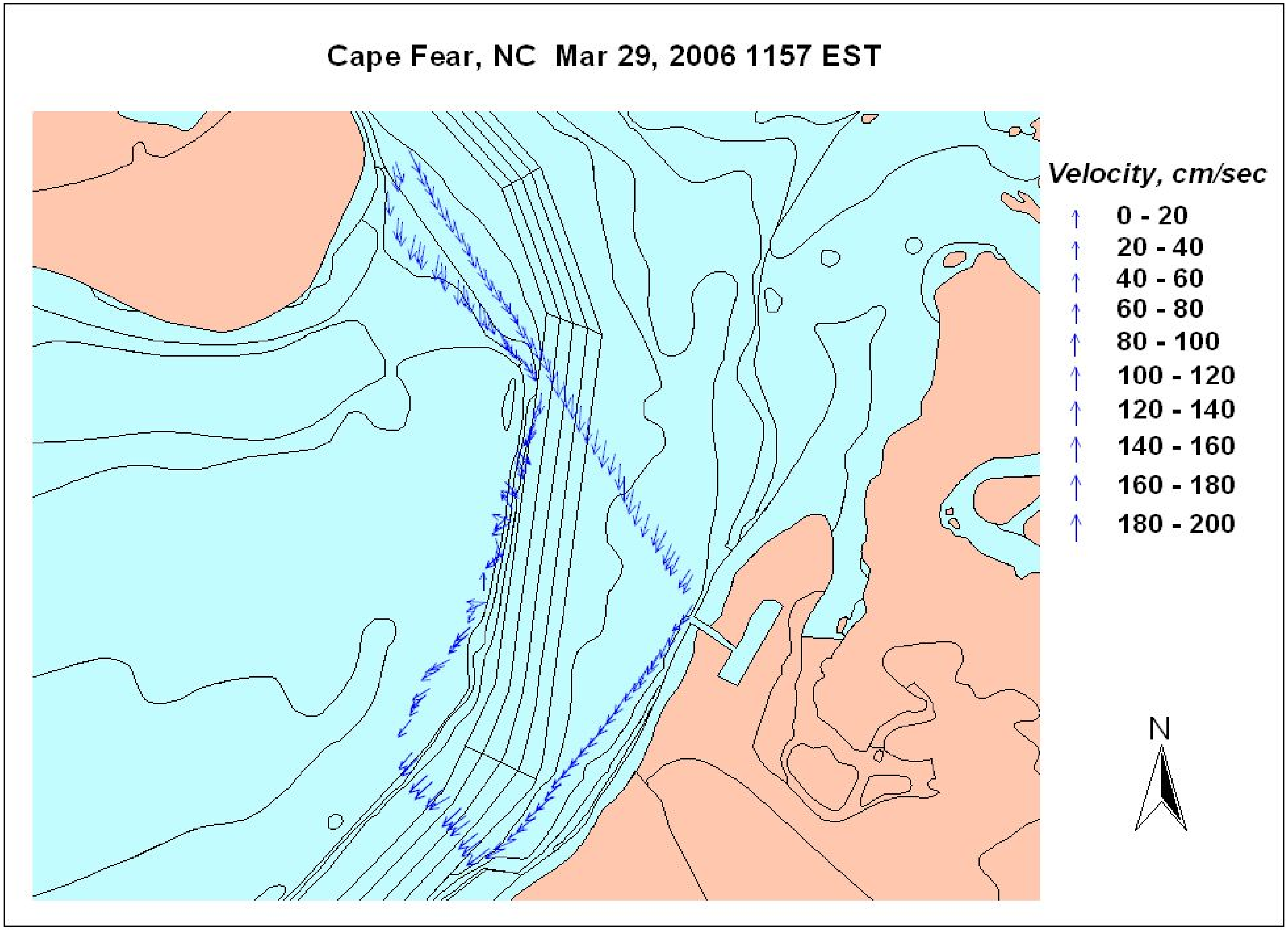


Figure D-14 March 2006 ADCP survey at the inlet transect during peak ebb flow

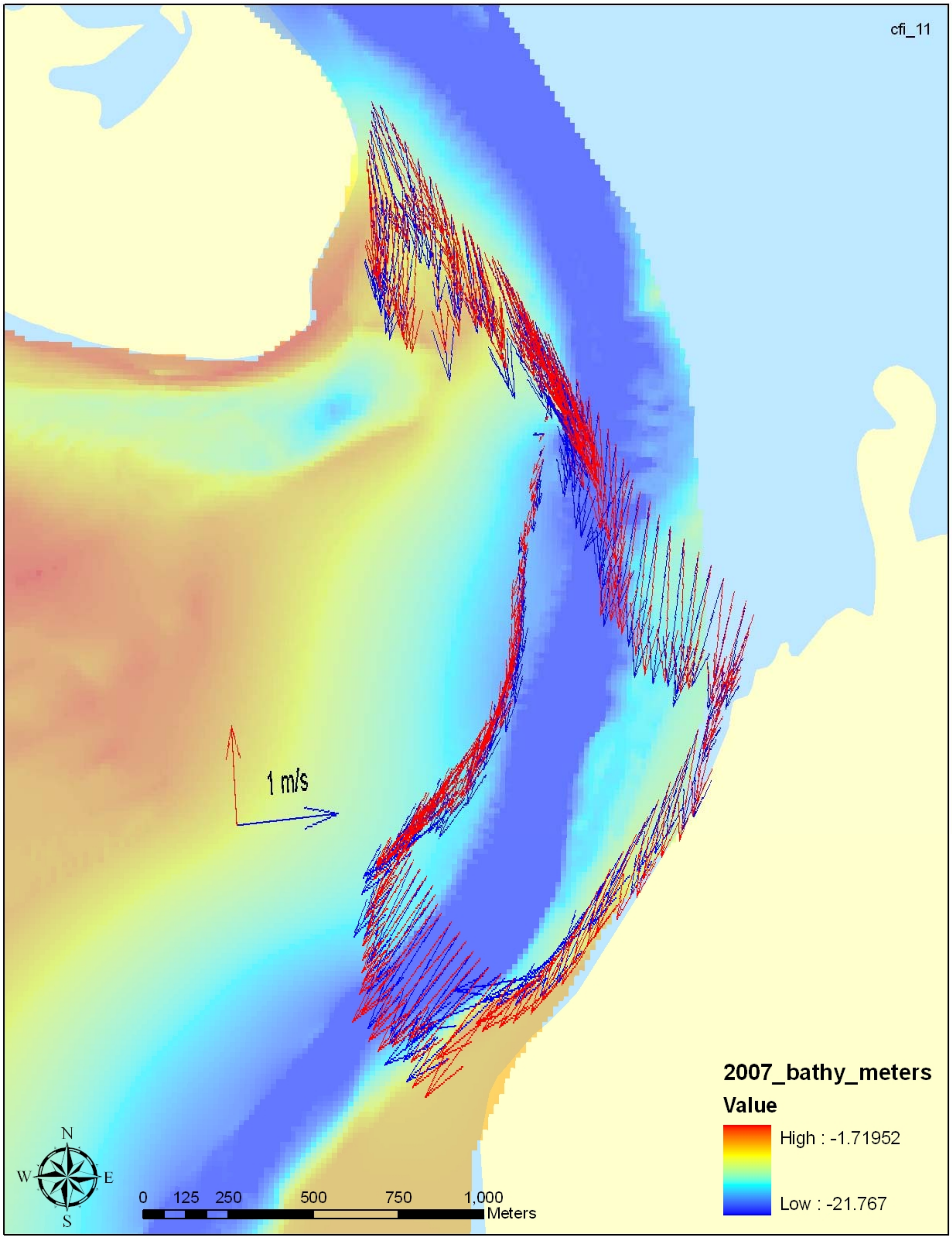


Figure D-15 February 2007 ADCP Survey at the Inlet Transect During Peak Ebb Flow

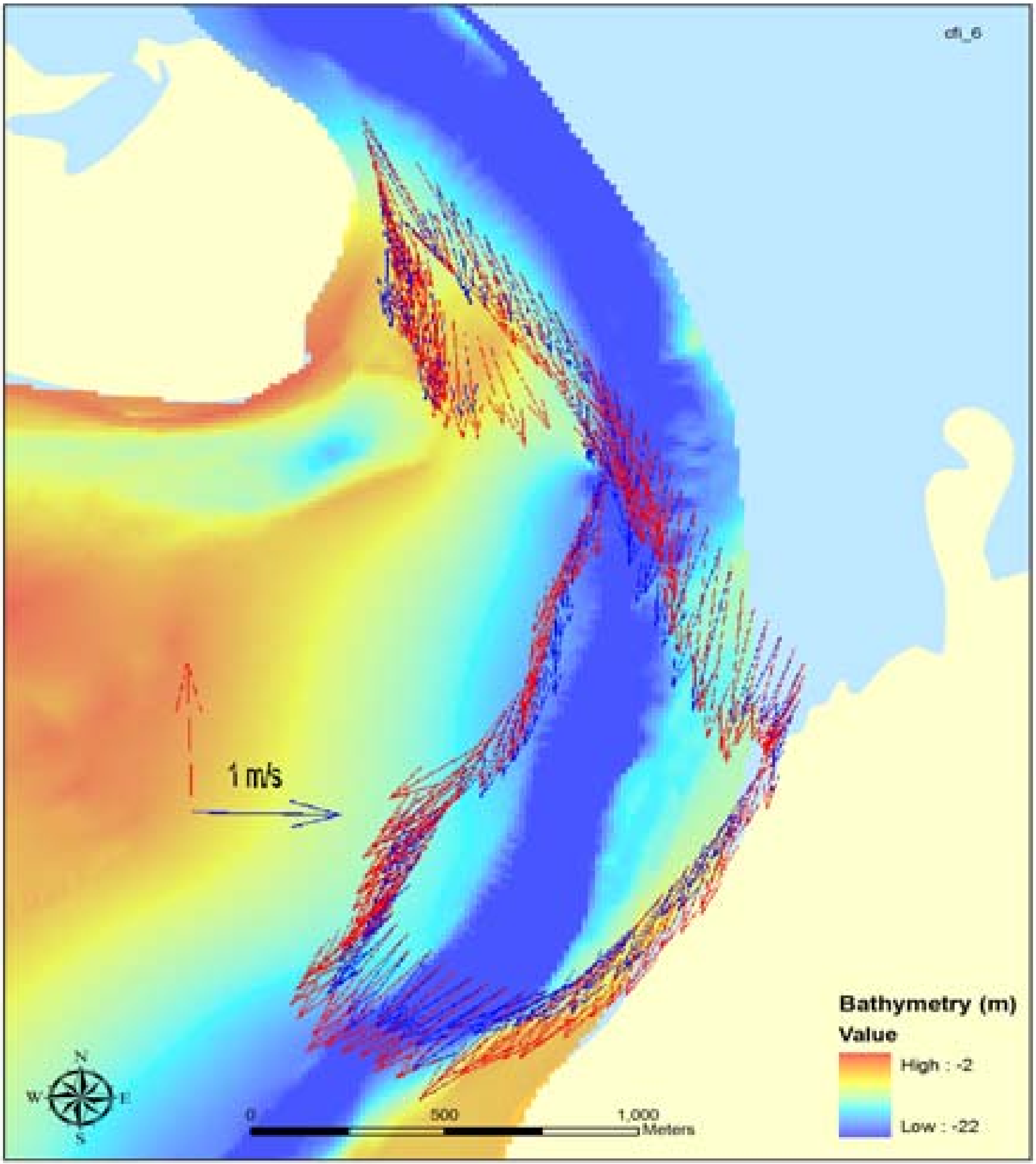


Figure D-16 March 2008 ADCP Survey at the Inlet Transect During Peak Ebb Flow

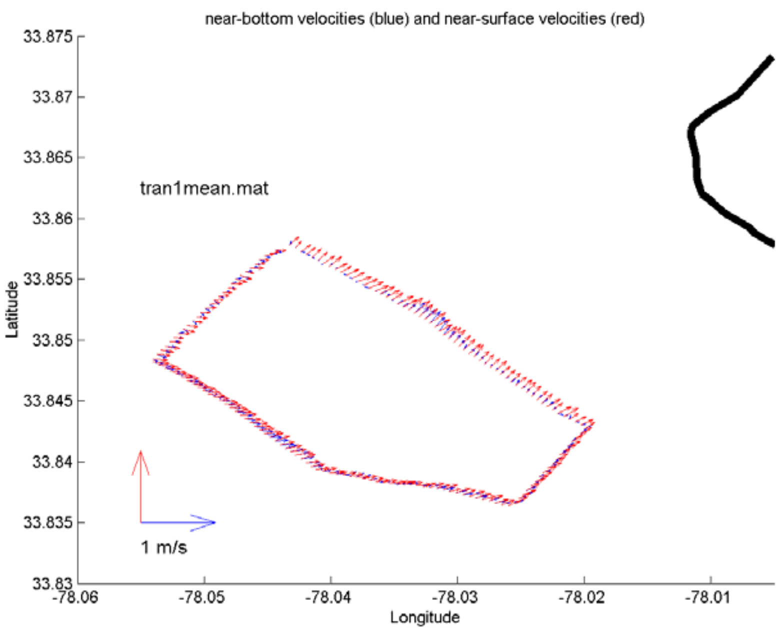


Figure D-17 October 2000 ADCP survey at offshore transect during peak flood flow.

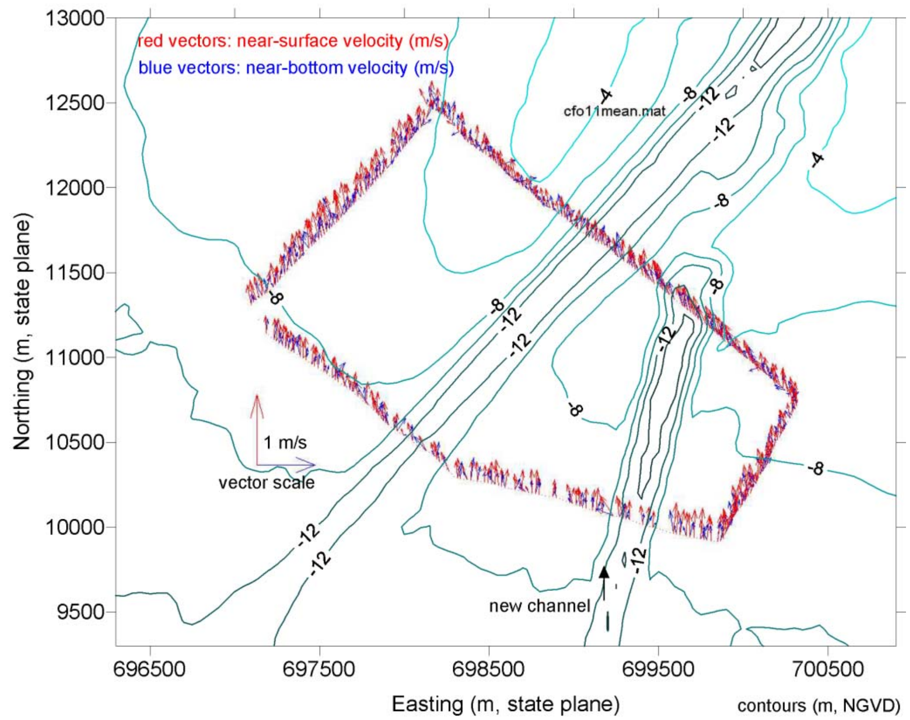


Figure D-18 April 2002 ADCP survey at offshore transect during peak flood flow.

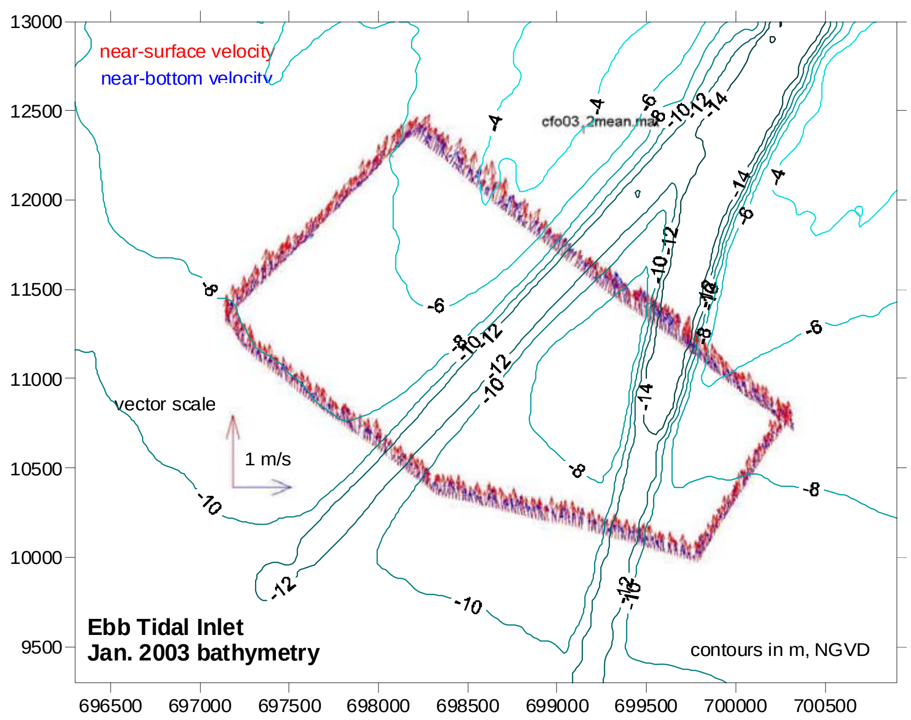


Figure D-19 March 2003 ADCP survey at offshore transect during flood flow.

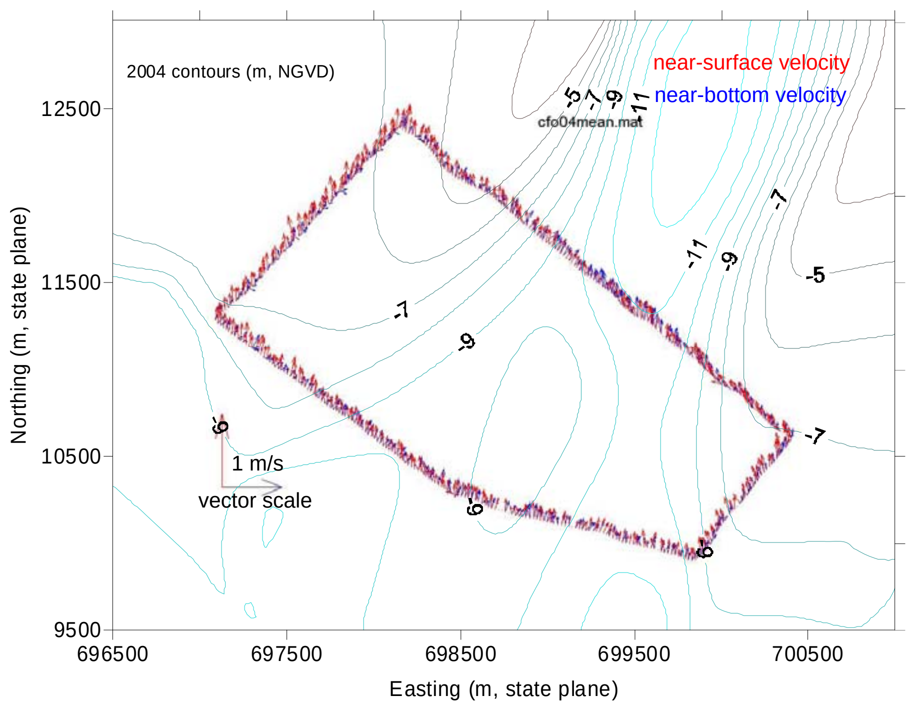


Figure D-20 January 2004 ADCP survey at offshore transect during flood flow.

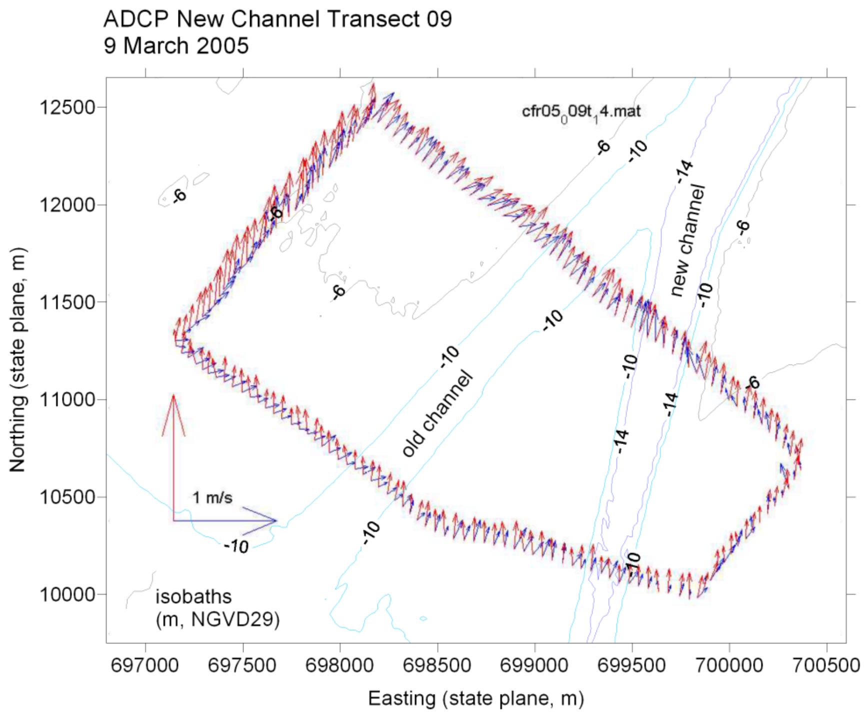


Figure D-21 March 2005 ADCP survey at offshore transect during flood flow.

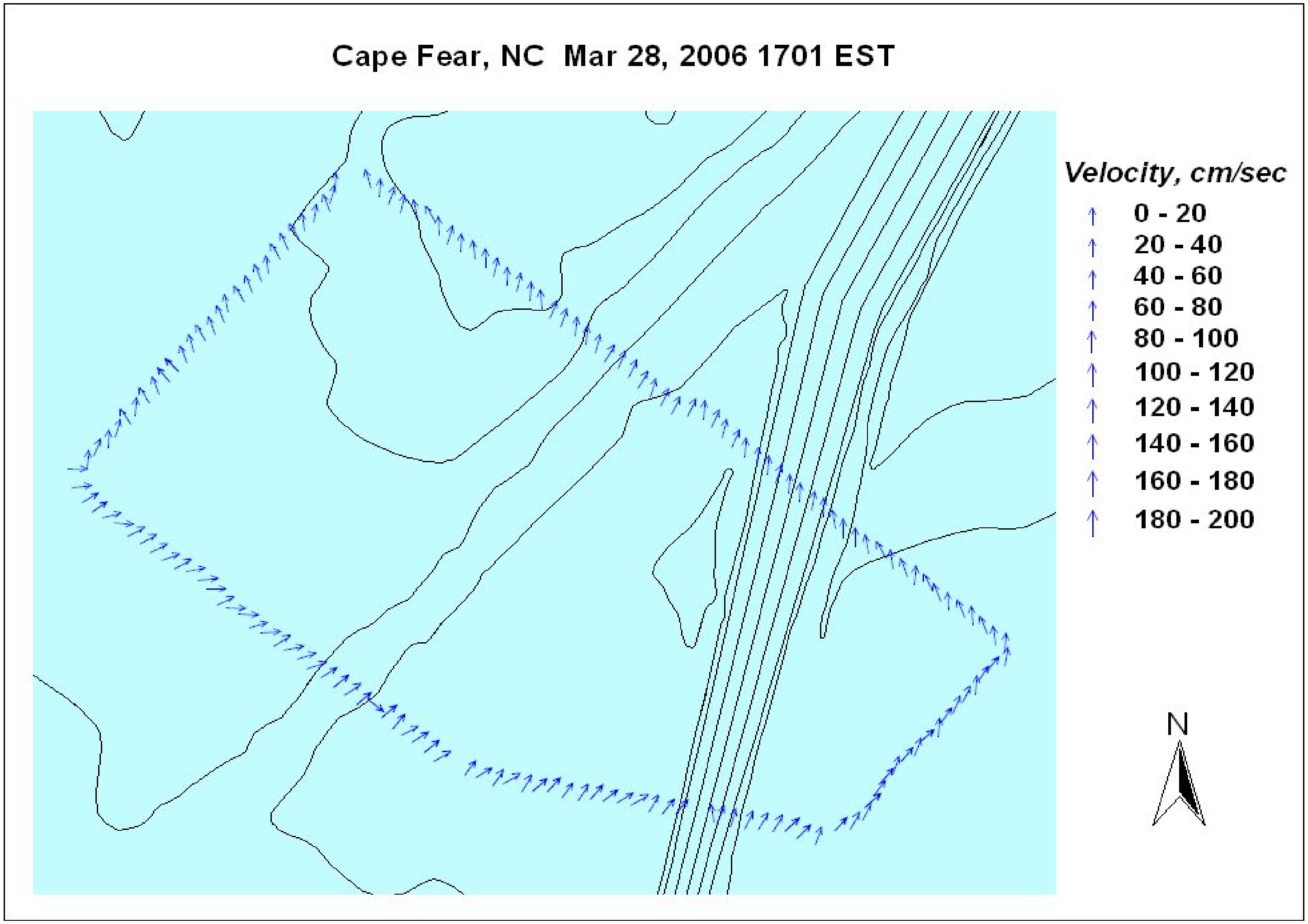


Figure D-22 March 2006 ADCP survey at the offshore-new channel transect approaching peak flood flow

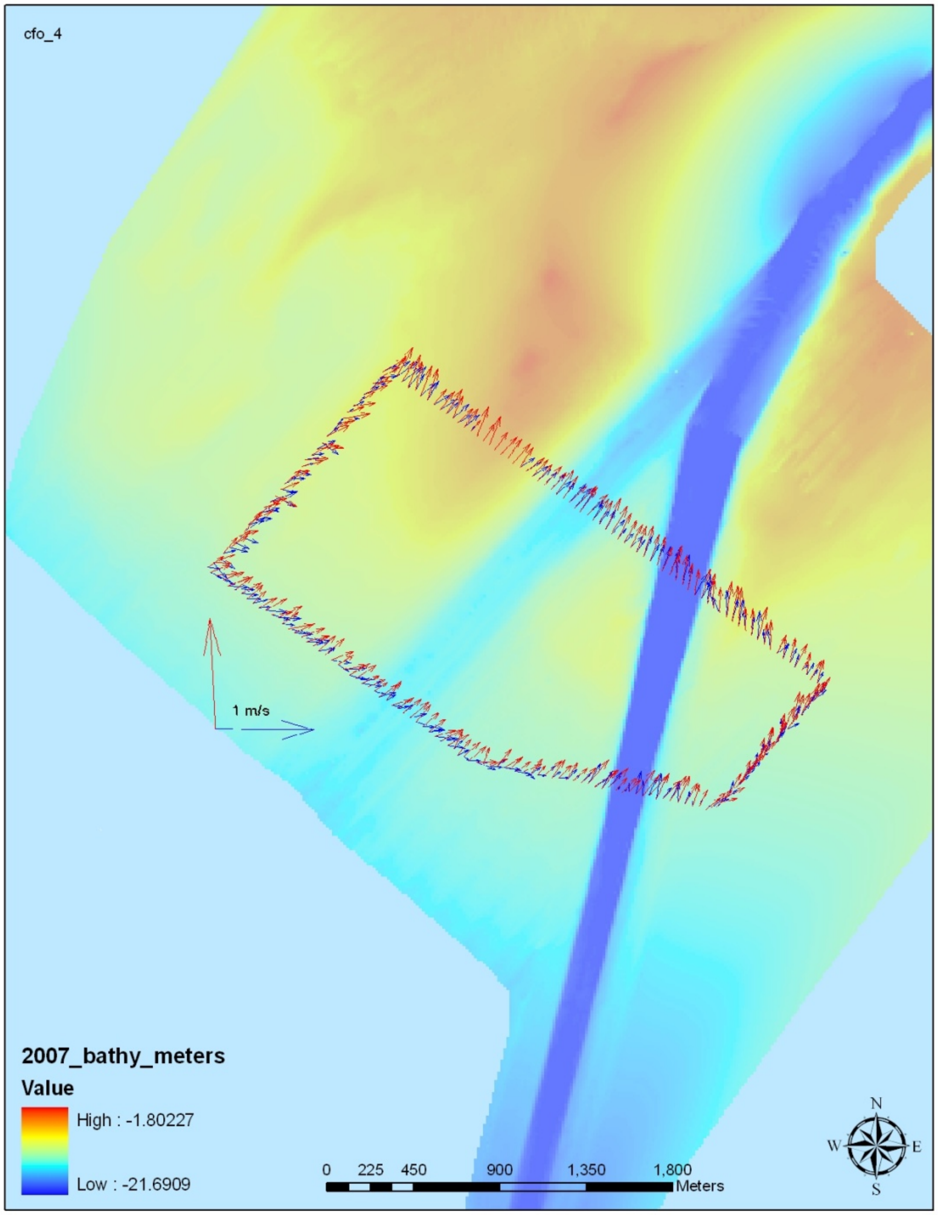


Figure D-23 March 2007 ADCP survey at the Offshore-New Channel Transect near peak flood flow

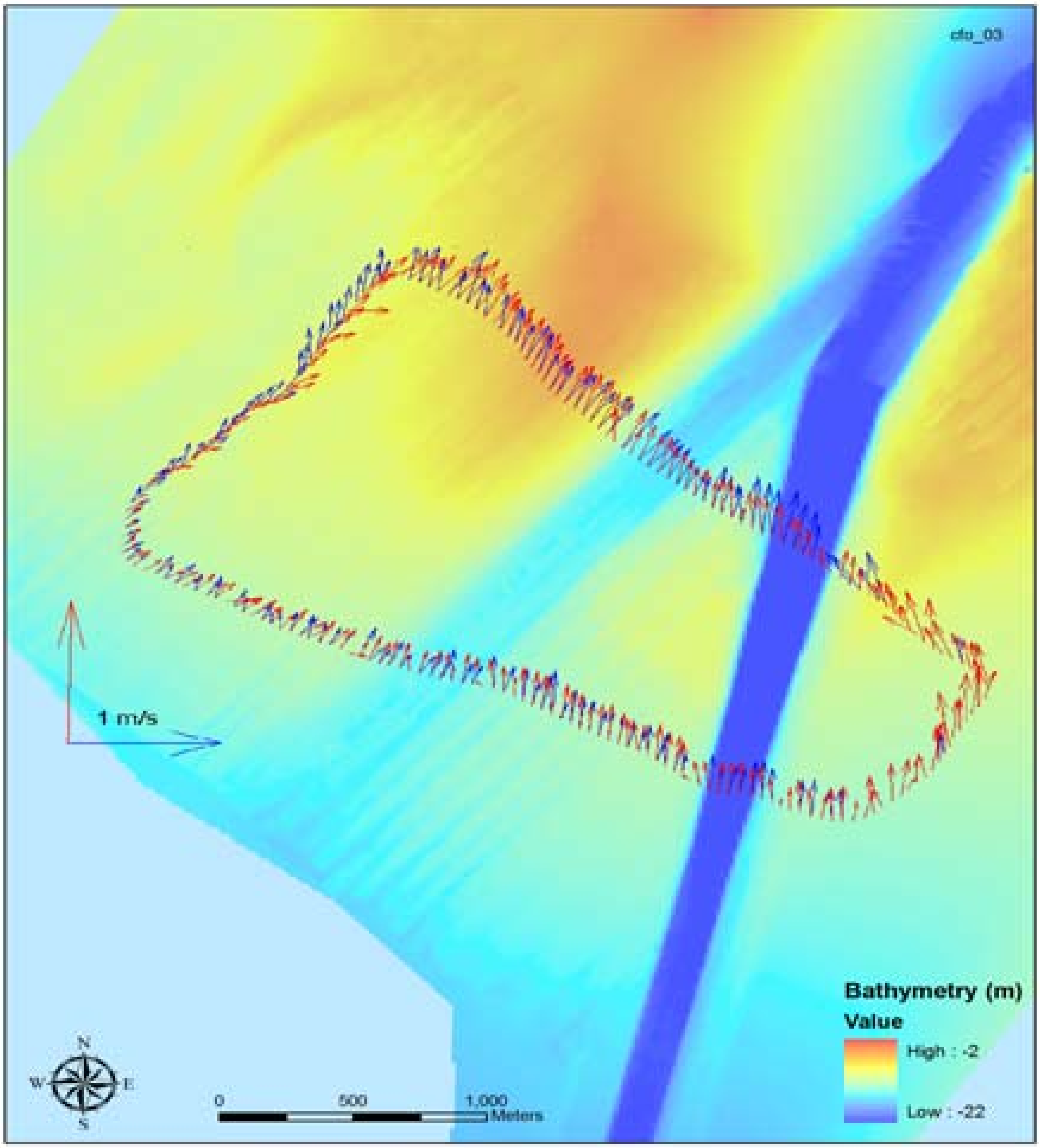


Figure D-24 March 2008 ADCP survey at the Offshore-New Channel Transect near peak flood flow

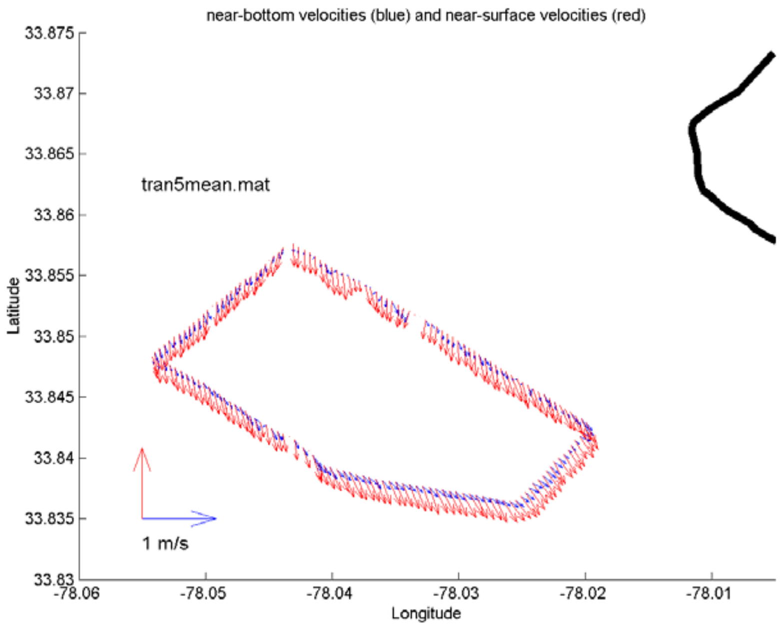


Figure D-25 October 2000 ADCP survey at offshore transect during peak ebb flow.

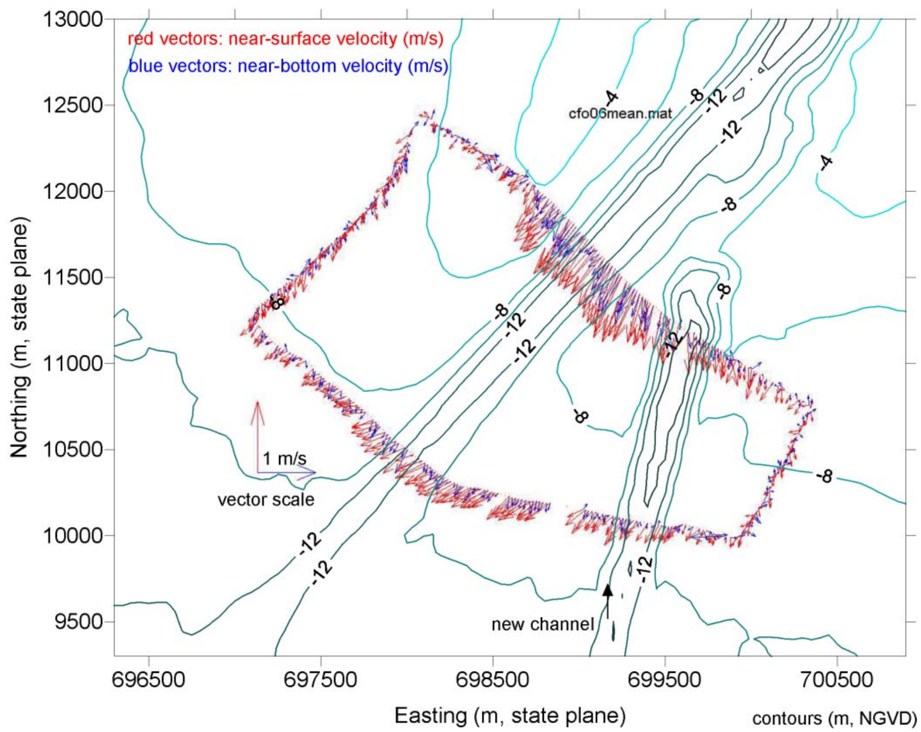


Figure D-26 April 2002 ADCP survey at offshore transect during peak ebb flow.

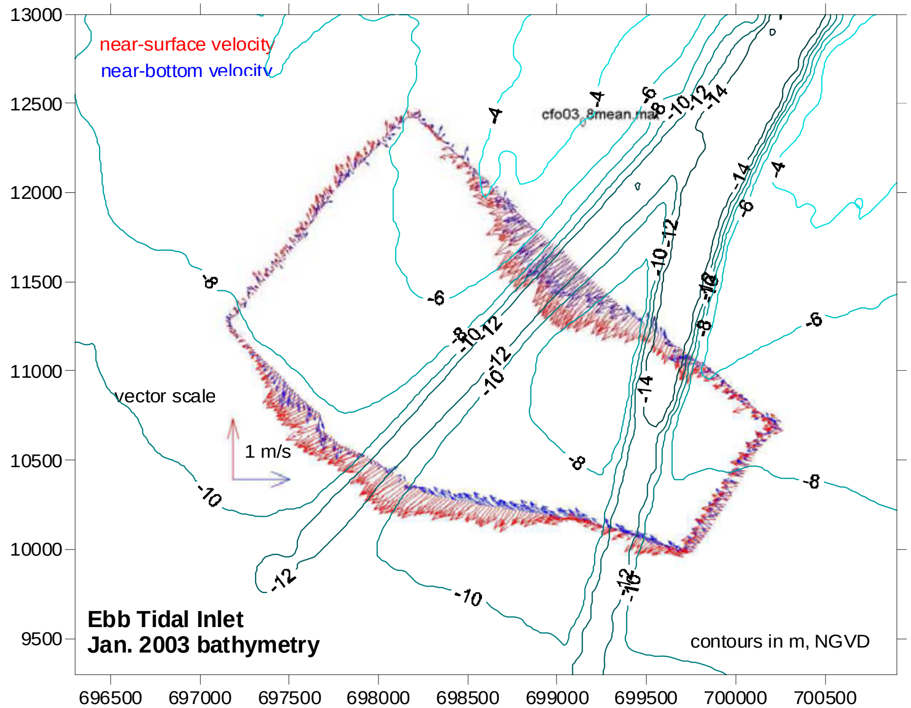


Figure D-27 March 2003 ADCP survey at offshore transect during ebb flow.

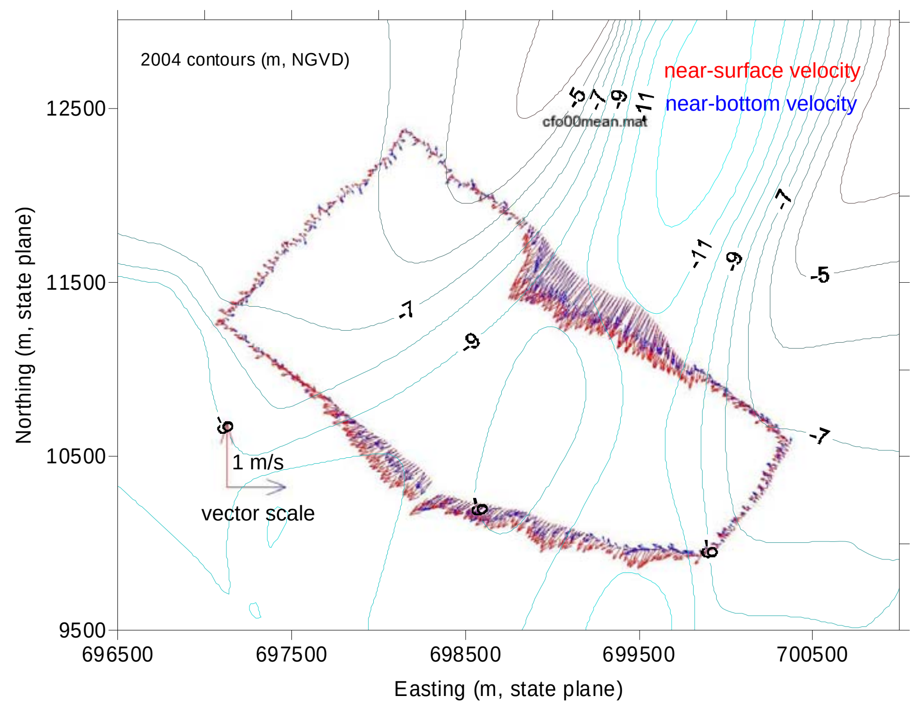


Figure D-28 January 2004 ADCP survey at offshore transect during ebb flow.

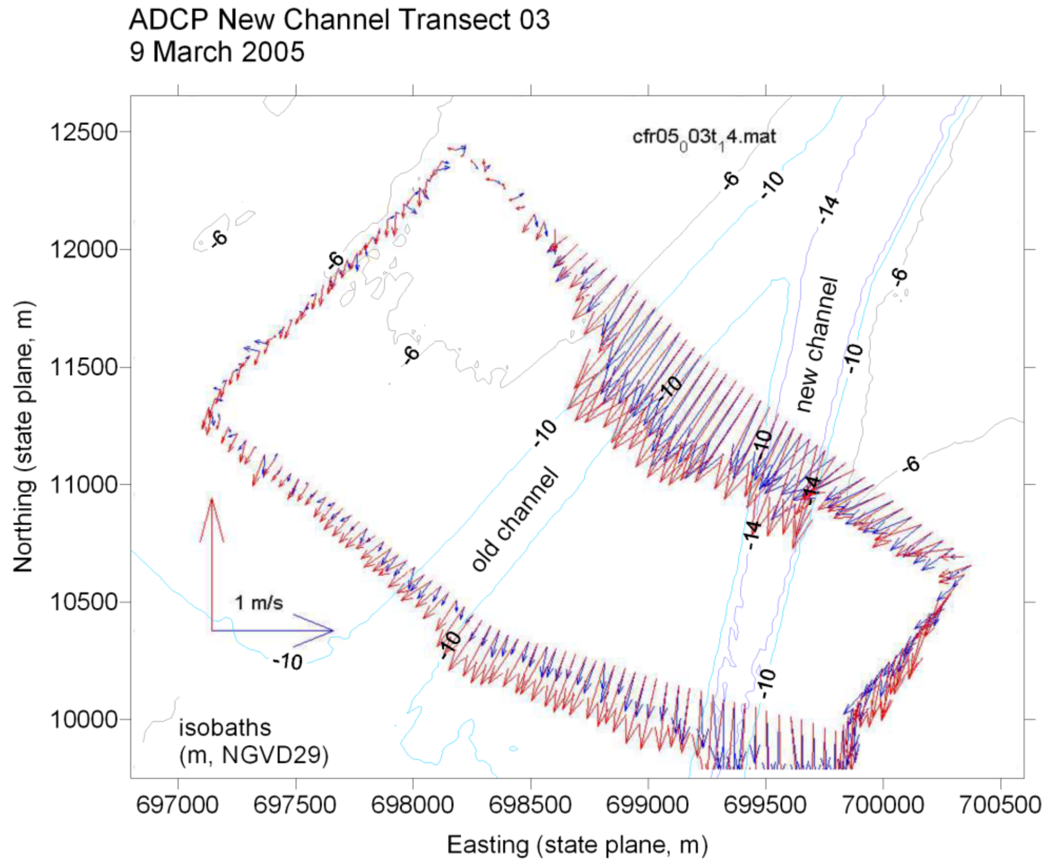


Figure D-29 March 2005 ADCP survey at offshore transect during ebb flow.

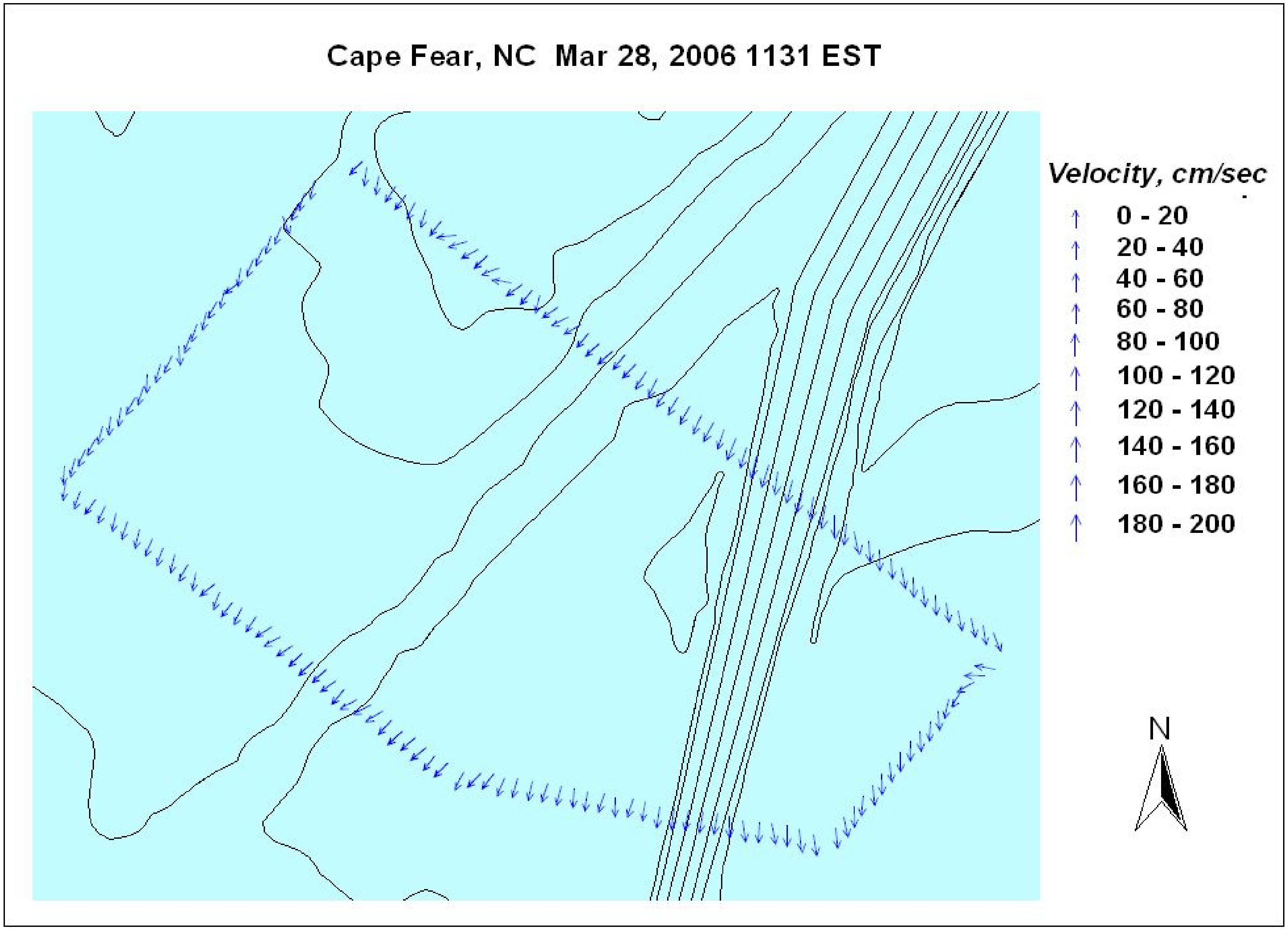


Figure D-30 March 2006 ADCP survey at the offshore-new channel transect during peak ebb flow

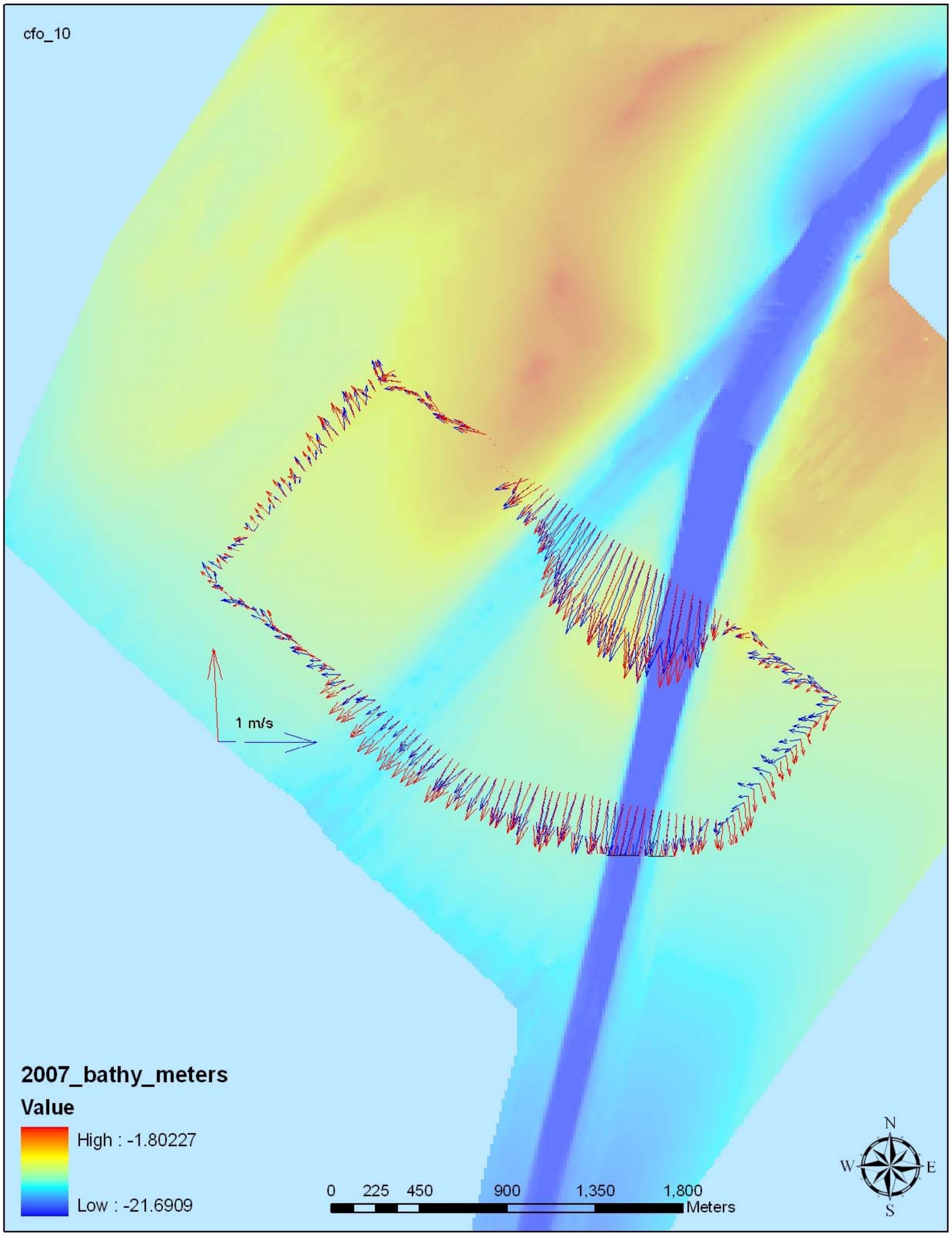


Figure D-31 March 2007 ADCP survey at the Offshore-New Channel Transect near peak ebb flow

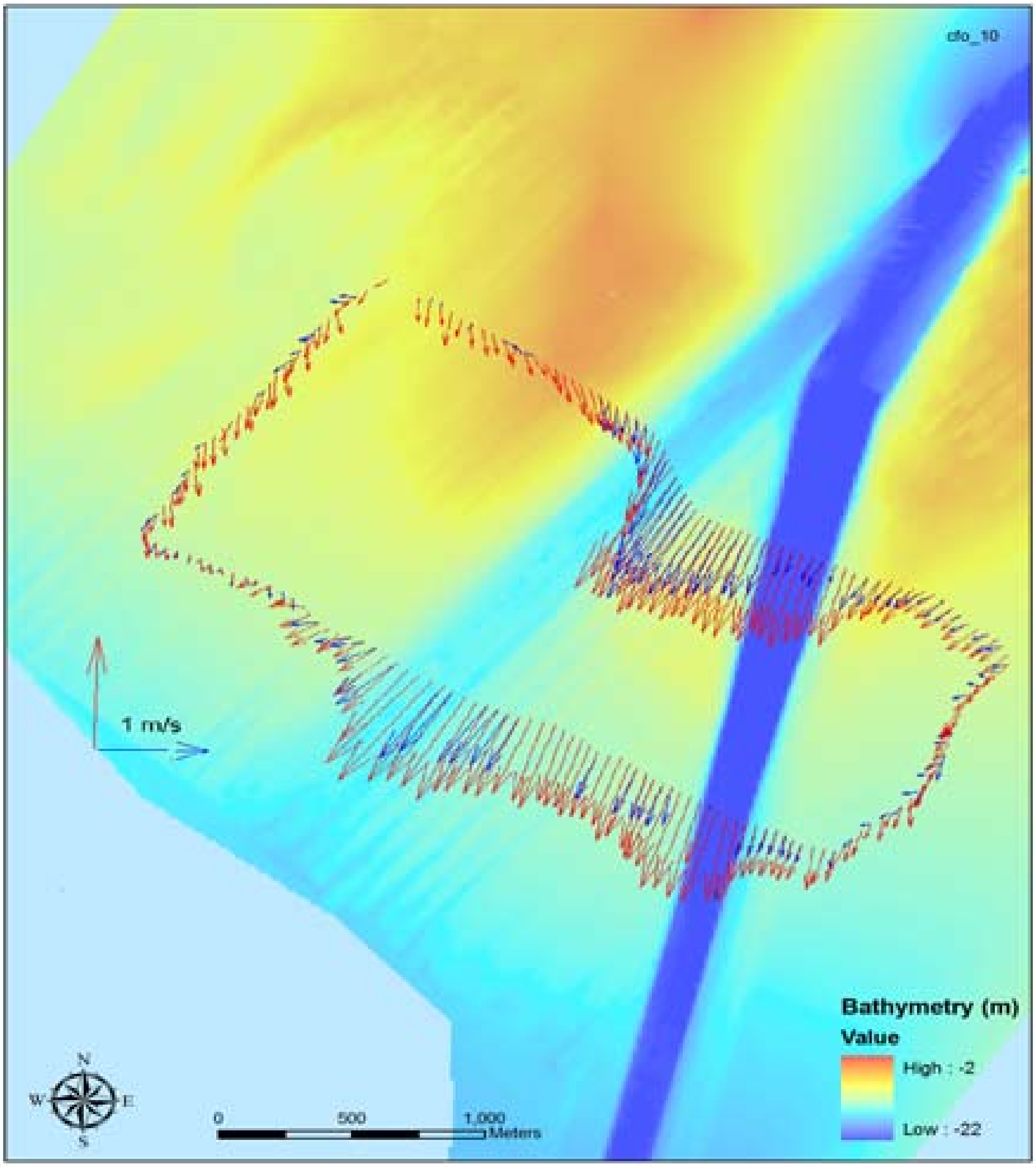


Figure D-32 March 2008 ADCP survey at the Offshore-New Channel Transect near peak ebb flow