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Bald Head Island, N.C. Beach Monitoring Program

Monitoring Report No. 14 (April 2015 to April 2016)

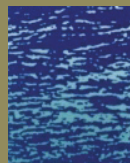
Prepared for:
Village of Bald Head Island

Prepared by:
Olsen Associates, Inc.
2618 Herschel Street
Jacksonville, FL 32204
(904) 387-6114
(Fax) 384-7368
olsen-associates.com
C-1468



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BALD HEAD ISLAND, N.C.
Beach Monitoring Program
Report No. 14
(April 2015 – April 2016)

EXECUTIVE SUMMARY

This engineering report presents the physical changes along the South Beach, West Beach and East Beach shorelines of Bald Head Island (BHI) based principally upon historical and recent monitoring surveys performed on behalf of the Village of Bald Head Island (Village). It likewise addresses actions taken by the Village or others which have or could affect shoreline conditions. More, specifically, this report addresses:

- (1) A summary of Bald Head Island's physical setting including a discussion of the Federal Navigation Channel and the Wilmington Harbor Sand Management Plan.
- (2) A summary of historical erosion control activities on Bald Head Island constructed by the Village.
- (3) A discussion of the most recent 2015 1.33 Mcy federal beach disposal project carried out at South Beach by the Wilmington District, COE.
- (4) Recent volume and shoreline position changes measured between monitoring surveys of April 2015, November 2015 and April 2016 along West Beach, "the Point" and the South Beach shoreline, as well as *long-term changes* since November 2000. Updates of East Beach and the Cape Fear Spit conditions are likewise provided, as well as near term changes for the Row Boat Row shoreline which was added to the monitoring program in 2015.
- (5) Measured changes in the Bald Head Creek borrow site last utilized for the 2012 Post-Irene small scale mitigation project. An additional condition survey in 2016 was performed for purposes of assessing the Creek site's potential reuse as a sand source in the near future.
- (6) A discussion of the Village's terminal groin project construction in 2015 following a spring 2015 federal beach disposal event. Additional survey data required to monitor the performance of that project are likewise included. Any project related changes between the November 2015 and the May 2016 monitoring surveys are presented.
- (7) A discussion of the extension of the two (2) rock jetties which protect the entrance channel to Bald Head Marina and the continuing need to bypass sand from West Beach to the Row Boat Row shorefront.
- (8) An overview of newly proposed shore stabilization efforts by the Village which presently include the development of a Frying Pan Shoals borrow site, the construction of four (4) detached rock breakwaters seaward of the Row Boat Row shoreline and the probable need for sand placement along portions of West Beach.

The most recent Wilmington Harbor Inner Ocean Bar maintenance dredging of Bald Head Shoal Channel Reaches 1 and 2, as well as the Smith Island Channel segment occurred between January and April 2015. The work was performed by a cutter-suction dredge. The CORPS contractor was Great Lakes Dredge and Dock Company. Approximately 1.33 Mcy of sand excavated during that operation was placed along S. Beach at Bald Head Island. For this project, the Village of Bald Head Island was required to contribute approximately \$945,000 in order to have sand placed so as to enhance fillet formation updrift of the 1,300 ft terminal groin constructed after the disposal project.

Between November 2000 and April 2015, Bald Head Island has received over 7.0 Mcy, of sand from the initial widening/deepening and four (4) subsequent maintenance dredging operations associated with the Wilmington Harbor Navigation Project ocean entrance channel. That work was performed in accordance with the original Wilmington Harbor Sand Management Plan. In addition, the Village was required to place approximately 1.85 Mcy of sand in the form of an “engineered beach” intended to offset the adverse consequences of a channel maintenance event contracted to occur at the Oak Island alternate disposal location. Prior to that, the Village constructed a 47,000 cy fill along West Beach. In 2012, the Village constructed a Post-Irene emergency fill comprised of 138,000 cy of sand dredged from Bald Head Creek. Accordingly, in the net, Bald Head Island has experienced a total estimated sand placement volume of over 9 Mcy since November 2000.

Prior to the most recent 2015 federal disposal project, the *gross* volumetric sediment *loss* over the November 2000 to April 2015 monitoring timeframe was conservatively computed at -5,733,100 cy, or approximately 371,700 cy per year – on “average”. The assignment of an average annual long-term rate of sand loss at Bald Head Island however, is *not* necessarily a meaningful indicator of navigation project impact. Such an “average rate” has been often temporally biased by periods of beach fill equilibration, sand tube groinfield effectiveness, major storm events, the occurrence of episodic destabilizing dredging events in close proximity to the island, as well as other physiographic phenomena temporally affecting annualized quantities of alongshore sediment transport – from Bald Head Island.

Even though the latest (post-disposal) April 2016 monitoring survey documents some +3.306 Mcy of additional sand within the island’s littoral system since November 2000 (*after* fill placement of over 9 Mcy), surveys performed prior to each federal disposal event have documented areas of S. Beach with large *net loss* (nearest the inlet) and large *net gain* (eastward thereof). Hence, this report’s continuing conclusion that certain basic tenets of the F.O.N.S.I. and *Environmental Assessment* (USACE, 2000) regarding assurances of no net impact to Bald Head Island – that ultimately led to the favorable C.Z.M. consistency finding by the State of N.C. – have not been fully met. It is currently the position of the Village of

Bald Head Island that these findings continue to be relevant to the Wilmington District's ongoing re-evaluation and proposed update of the Wilmington Harbor Sand Management Plan (WHSMP). Affecting this conclusion is the fact that the Village has not only placed in excess of 2 Mcy at their expense since 2000, but also has been required to build a \$4.5M terminal groin (in 2015) immediately abutting the navigation project so as to reduce annual sediment losses to the channel – as well as maintain a beneficial shoreline configuration seaward of the line of development.

In this regard, comprehensive beach monitoring over the past fifteen years by the Village of Bald Head Island has resulted in the conclusion that sand placement alone has *not* served to offset navigational channel impacts to the west end of South Beach thereby resulting in chronic rates of erosion and consistent northerly recession and migration of the Point. The net result of these phenomena has historically been periods of accelerated erosion and ensuing threat to public infrastructure, homes, protective dunes and wildlife habitat.

As a result, in 2015 the Village constructed a single terminal groin designed to complement the future placement of beach fill at South Beach. Theoretically, the project involves 2 Phases. The Phase-1 1,300 ft. long terminal groin was designed as a “leaky” structure (*i.e.* semi-permeable) so as to provide for some level of sand transport to West Beach and portions of the Point (located northward of the proposed groin). Similarly, the structure serves as a “template” for channel disposal material recently placed (spring 2015) eastward thereof on South Beach. It can reasonably be shown that the construction of such a structure should likewise have some level of benefit to the abutting navigation channel. Construction of the structure was initiated in May/June 2015 and determined to be complete by December 2015. By Permit, the Village has the option to extend the groin in the future by varying amounts up to an ultimate length of 1,900 ft. – if determined to be necessary.

Although not directly impacted by long-term navigation channel improvements and maintenance of the Cape Fear River entrance, the Village Council elected to initiate monitoring of the East Beach shorefront at Bald Head Island in 2008. It is observed at this location that East Beach principally undergoes strong seasonal variations of beach width and profile volume to a large degree dependent upon storm frequency and intensity, as well as the ever-changing configuration of the Cape Fear Spit. The current April 2016 survey data show a net shoreline accretion of approximately +20,400 cy (above elevation -16 ft NGVD) throughout the 3,000 ft East Beach shoreline lying northward of Cape Fear. Conversely, the spit configuration has adversely impacted the S. Beach shorefront at the Shoals Club. Documentation of this effect is addressed in this report.

The third and final year of permit required monitoring of the Bald Head Creek borrow site was performed in October 2015. During the Year 2 to 3 monitoring period (16 months) the permitted borrow site area gained approximately 33,500 cy. A condition survey was performed in April 2016 – due to the probable reuse of the site as a sand source for West Beach and Row-Boat-Row fill placement projects in the near future. To date, approximately 70,000 cy (i.e. 51%) of the estimated dredge volume of 137,990 cy has “recovered”. Permit required monitoring of the Jay Bird Shoal borrow site is not scheduled to occur again until May 2017 (i.e. year 7).

In early 2015, the Village initiated a project to extend the two (2) jetties stabilizing the entrance channel to the Bald Head Island marina. The purpose of the project was to reduce high frequency channel maintenance and sand bypass dredging necessary to keep the channel clear for safe and reliable barge and ferry vessel operations. At about the same time, the Village assumed responsibility for all future channel maintenance and sand bypass requirements from BHI, Ltd. The success of the jetty extension project has however resulted in the cessation of almost monthly sand disposal events performed along the Row-Boat-Row shorefront by BHI, Ltd. The net result has been erosion and recession of the beach at that location. Accordingly, in April 2016, the Village submitted a permit application to construct four (4) small low-profile detached breakwaters seaward of the affected shorefront. Subsequently sand will be placed at that location from bypass and/or the Bald Head Creek borrow site. After the construction of additional stabilizing structures, future sand maintenance requirements should be minimal and easily addressed by limited sand bypass operations performed once or twice a year.

In April 2016, a *Sand Source Investigation of Frying Pan Shoals* (Olsen 2016) was completed and submitted to the Village. The nexus for the study was the findings of the E.I.S. performed for the terminal groin project which acknowledged the need for additional sand sources required for both beach renourishment and compliance with permit conditions necessitating that the updrift fillet of the structure be maintained into the future. In May 2016, a Phase II Cultural Resource Investigation was authorized within the limits of a preliminarily identified borrow area.

A running chronology of detailed *annual* monitoring results for the Bald Head Island Shorelines (since 2000) are available from *Bald Head Island, N.C. Beach Monitoring Program Report No. 1* (Olsen 2003), through *Report No. 13* (Olsen 2015).

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1.0 INTRODUCTION

1.1 Overview

This engineering report presents the physical changes along the South Beach, West Beach and East Beach shorelines of Bald Head Island (BHI) based principally upon historical and recent monitoring surveys performed on behalf of the Village of Bald Head Island (Village). More, specifically, this report addresses:

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- (8) An overview of newly proposed shore stabilization efforts by the Village which presently include the development of a Frying Pan Shoals borrow site, the construction of four (4) detached rock breakwaters seaward of the Row Boat Row shoreline and the probable need for sand placement along portions of West Beach.

1.2 Physical Setting

Bald Head Island is located in Brunswick County, North Carolina at approximately 33°51' N, 78°00' W (**Figure 1.1**). It is roughly 25 miles south of the City of Wilmington and 32 miles east of the South Carolina/North Carolina state line. It is the southernmost of the coastal barrier islands which form the Smith Island complex at the mouth of the Cape Fear River. The southeastern tip of the island is Cape Fear (also referred to as Cape Fear Point) from which Frying Pan Shoals extend seaward over 20 miles to the southeast.

The island's east and south shorelines, "East Beach" and "South Beach", front the Atlantic shoreline. The west shoreline, or "West Beach", fronts the Cape Fear River. The north side of the island is bounded by the Bald Head Creek estuary, Middle Island and Bluff Island. The Cape Fear River entrance, over one mile in width, separates Bald Head Island from Oak Island (or Caswell Beach).

The astronomical tides in the vicinity of Bald Head Island are semi-diurnal and have average mean and spring ranges of approximately 4.3 ft and 5.0 ft, respectively. Tidal datums for Bald Head Island are listed in **Table 1.1** and the predicted astronomical tides during the April 2015 to April 2016 monitoring period are plotted as **Figure 1.2**.

Table 1.1: Tidal datums for Bald Head Island, North Carolina¹.

Datum	Elevation (ft-NGVD 29 ²)
Mean Higher High Water (MHHW)	+2.82
Mean High Water (MHW)	+2.51
NAVD 1988	+1.10
Mean Tide Level (MTL)	+0.35
NGVD 1929	0.00
Mean Low Water (MLW)	-1.81
Mean Lower Low Water (MLLW)	-1.98

¹ Approximations based upon extrapolation from Southport, N.C.

² NGVD 1929: National Geodetic Vertical Datum of 1929 (1929 Mean Seas Level). Horizontal coordinates are referenced to the North Carolina State Plane Coordinate System, North American Datum of 1927.

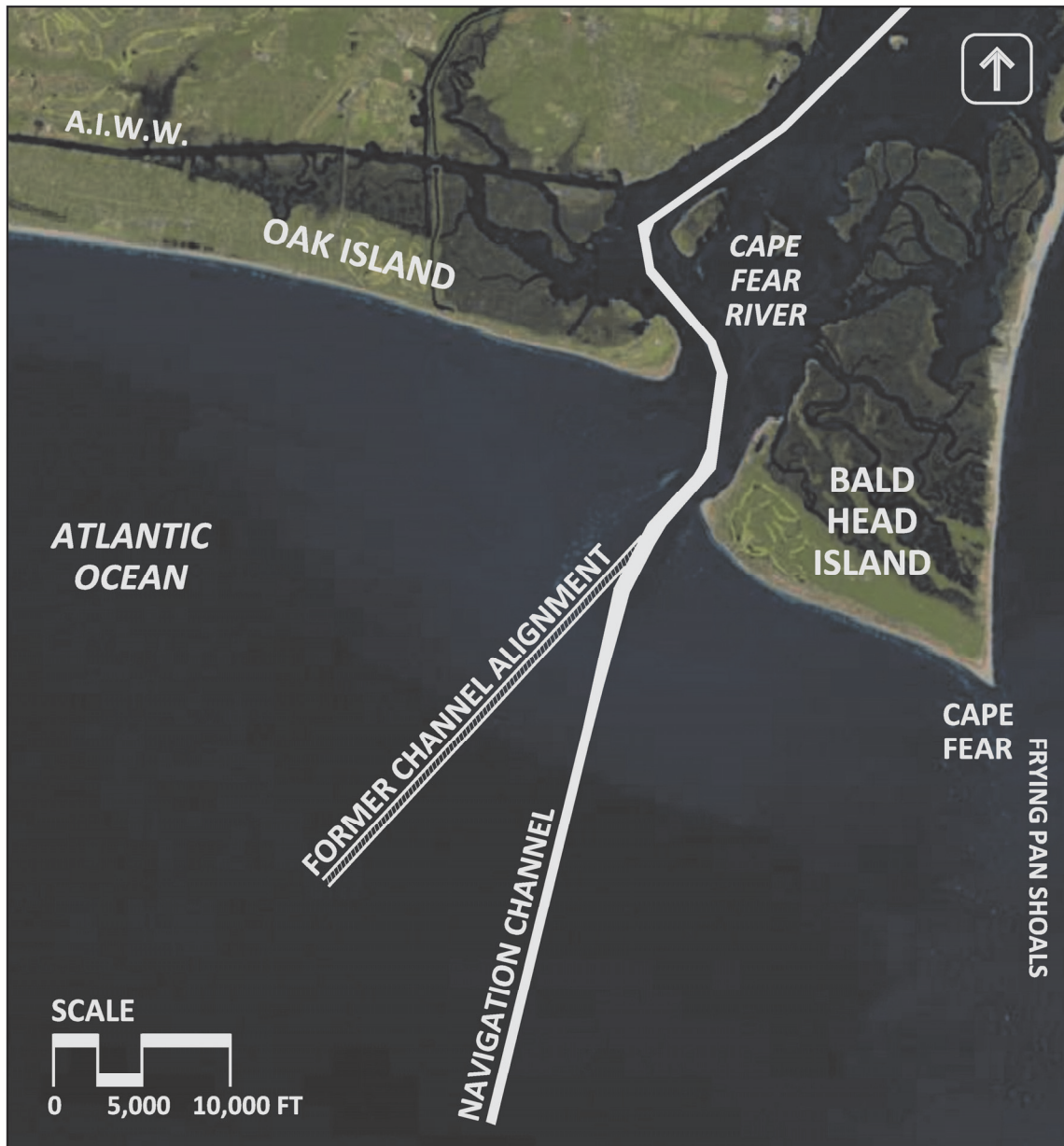


Figure 1.1: Location of Bald Head Island, N.C. and Federal Navigation Channel.

April 2015 through April 2016 Predicted Astronomical Tides Bald Head Island, North Carolina

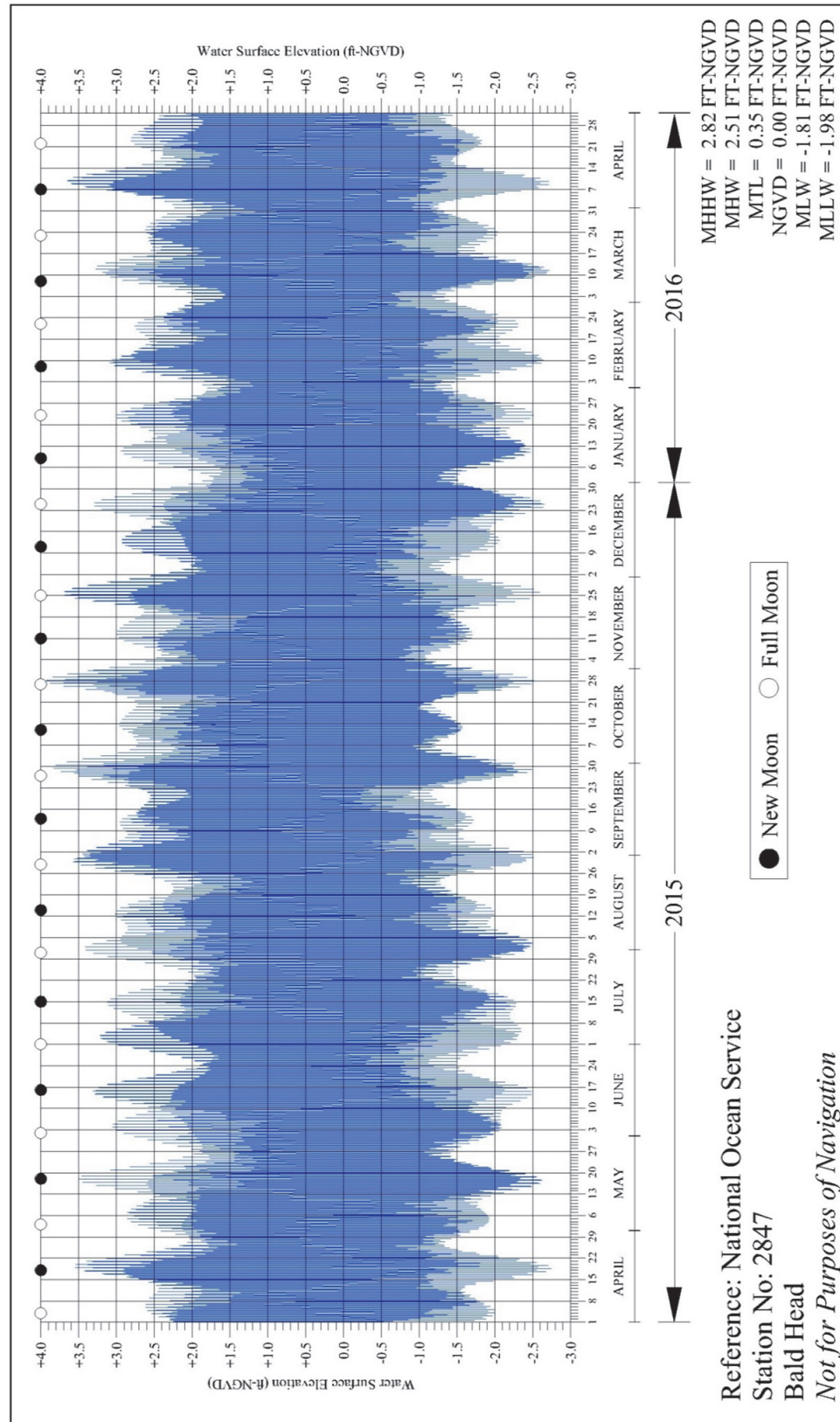


Figure 1.2: April 2015 through April 2016 predicted astronomical tides, Bald Head Island, North Carolina.

1.3 Monitoring Period Wave Climate (April 2015 to April 2016)

Figure 1.3 displays a time series of significant wave heights measured at NOAA Buoy 41108 from April 2015 through April 2016. NOAA Buoy 41108 is located roughly 9 miles south of Bald Head Island in approximately 42 feet of water. The buoy was deployed in March 1988 and has been collecting data nearly continuously for 28+ years except for an approximate 5 year period between April 1992 and May 1997. The data collected by the buoy includes significant wave height (average of the highest one-third of all waves in a 20-minute sampling period), wave period, wave direction, wind speed and other standard meteorological data.

The average significant wave height at NOAA Buoy 41108 during the Year 14 monitoring period (April 1, 2015 to April 26, 2016³) was 3.28 feet with a maximum wave height of 12.5 ft measured during Winter Storm Jonas (January 2016). The Year 14 average value is slightly higher than the full record average significant wave height of 3.18 feet (March 1988 through April 2016⁴) and 13 percent higher than the Year 13 average wave height (2.89 feet). Additionally, during the monitoring year roughly 6.7 percent of the recorded wave heights were above 6 feet, compared to 5.9 percent for the full record average. That is, there were roughly 12 percent more wave events recorded above 6 feet during the Year 14 monitoring period than would be expected during a typical similar period of time. Interestingly, during the Year 14 monitoring period, the occurrence of waves above 8 feet was slightly less than the full record average (1.1 percent for Year 14 compared to 1.3 percent for the long-term average). The explanation for the overall more energetic than average wave climate with fewer extreme waves (>8 feet) may be the relatively mild hurricane season coupled with the occurrence of multiple nor'easters during the monitoring period.

³ The April 2015 beach profile survey was initiated on April 1, 2015 and the April 2016 beach profile survey completed on April, 26 2016.

⁴ Wave data not recorded at NOAA Buoy 41108 between April 1992 and May 1997.

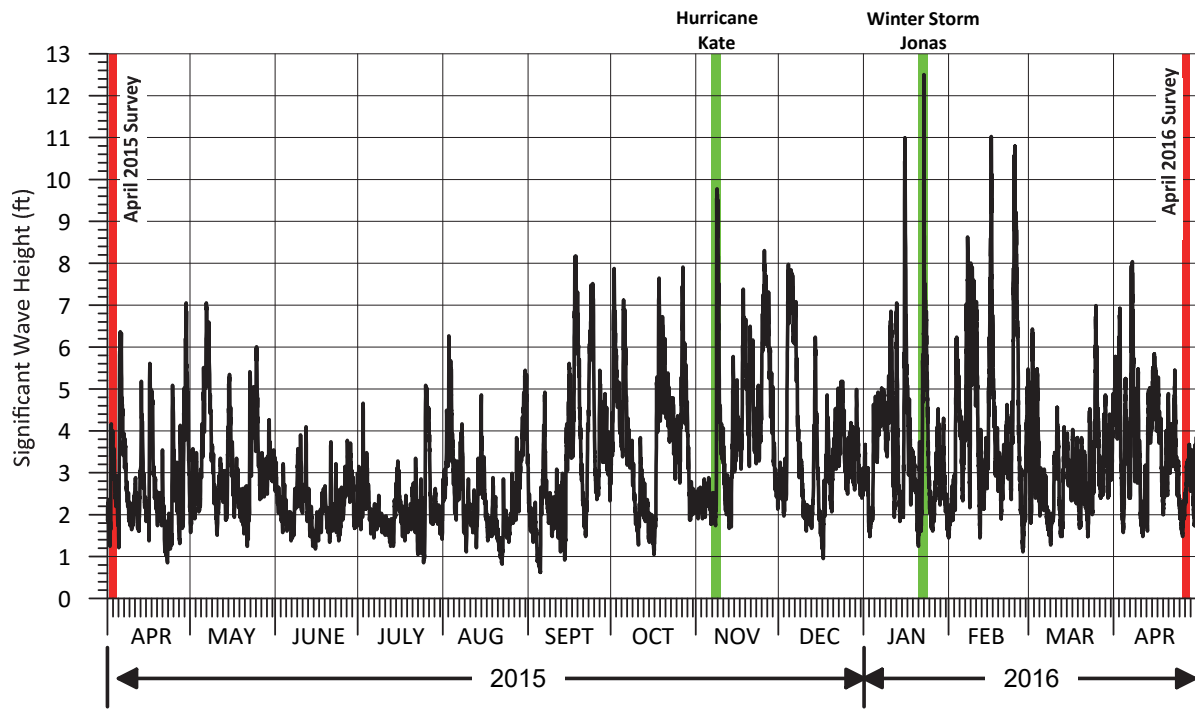


Figure 1.3: Significant wave heights recorded by NOAA Buoy 41108 (Wilmington Harbor, NC).

1.4 Federal Navigation Channel

The Wilmington Harbor Federal Navigation Project extends up the Cape Fear River from a point seven statute miles seaward of the Bald Head Island Marina, upstream 30.4 miles to a location just north of the City of Wilmington, N.C. The Wilmington District, U.S. Army Corps of Engineers (USACE) is responsible for maintaining the project at its congressionally authorized depths and widths.

The Wilmington Harbor entrance channel, which extends seaward of Bald Head Island, is not stabilized by jetties and until channel modifications in 2000, had been maintained at a single location by dredging since the late 1800's. The modern history of the Ocean Bar Channel authorized dimensions is as summarized in **Table 1.2**.

Table 1.2: Cape Fear River Entrance Channel Improvements (Pre-2000).

Year Constructed	Bottom Elevation FEET-MLW	Bottom Elevation FEET-NGVD	Channel Width (FEET)
1892	-20.0	-21.8	250
1911	-26.0	-27.8	400
1925-1926	-30.0	-31.8	400
1949	-32.0	-33.8	400
1956	-35.0	-36.8	400
1968	-40.0	-41.8	500

Immediately prior to the 2000 project modifications, maintenance of the entrance channel typically required the removal of 850,000-1,000,000 cubic yards (cy) of material *each year*. Of that total volume removed annually, the project Environmental Assessment (USACE 2000) stated that approximately 300,000 to 400,000 cy was littoral material principally derived from the adjacent beaches of Oak Island and Bald Head Island and inlet shoals. The EA likewise predicted however that future average annual maintenance of littoral material entrained by the deepened navigation channel project would rise by an estimated 36 to 81%. Except for two (2) small Section 933 projects constructed by the Wilmington District in the 90's, most excavated beach quality maintenance material had been historically removed from the littoral system and deposited at an offshore deepwater disposal site thereby continuously significantly adversely affecting the sediment budget of the Cape Fear River Entrance. Several resultant major consequences of these actions over time was the complete loss of a naturally occurring sediment bypass bar extending between the two abutting coastal barrier islands, (see **Figure 1.4**), the formation of seaward-extending linear bar features paralleling the maintained channel and the long-term vertical deflation of Bald Head Shoal located offshore of Bald Head Island.

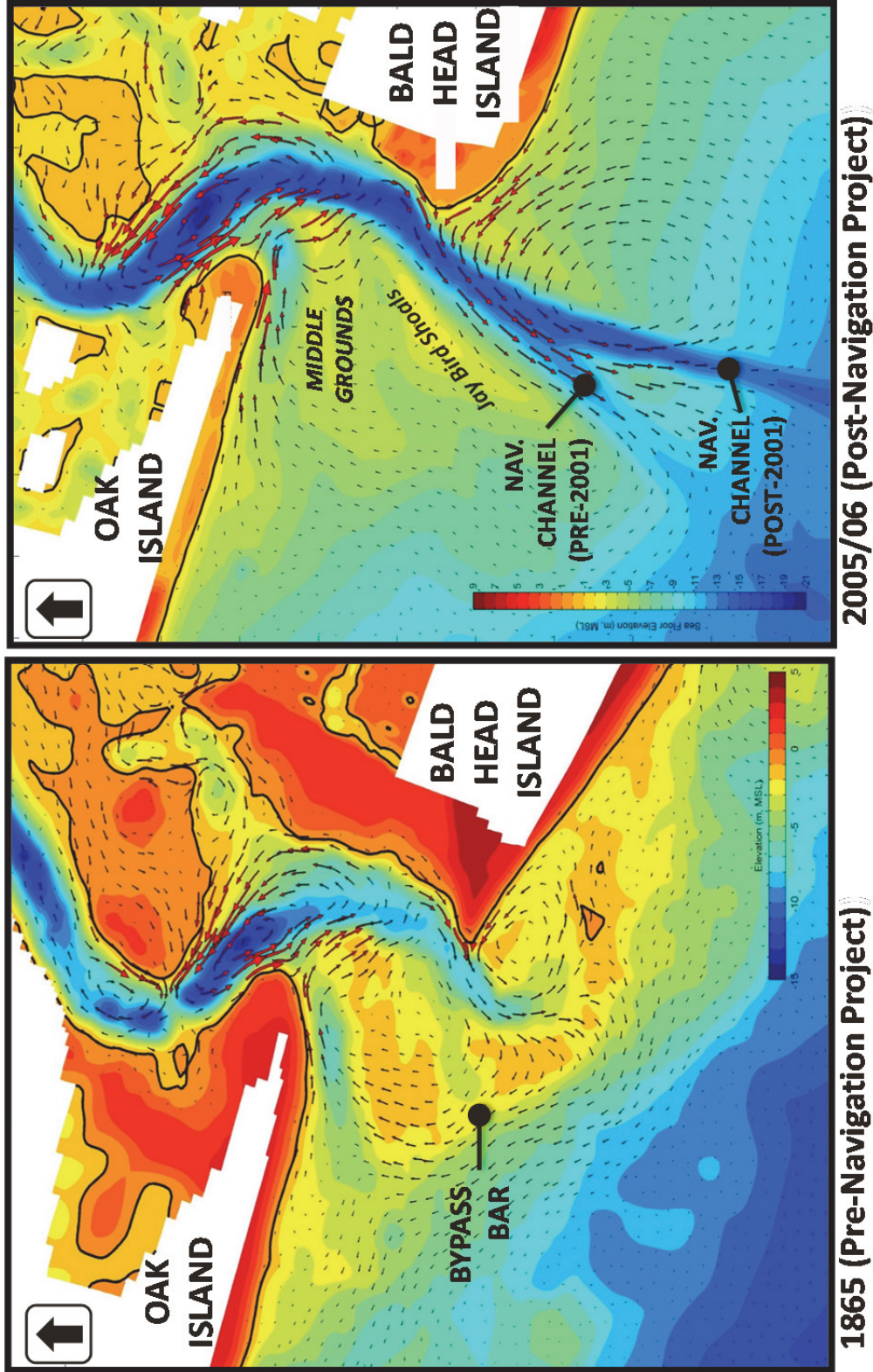


Figure 1.4: Navigation Project induced morphological changes at the Cape Fear River Entrance.

Beginning in 2000, the authorized Federal navigation channel was deepened by up to four feet (not including allowable overdepth) and widened at several locations. Most significantly, the seven mile long segment of the ocean entrance channel was reoriented from its historical location to a new location directly seaward of Bald Head Island (see **Figure 1.1**). The initial construction was completed under two contracts. The first contract, *Ocean Bar I*, covered the outer bar channel (Bald Head Shoal – Outer Reach). Construction of *Ocean Bar I* began in December 2000 and was completed in April 2001 with all the material being deposited in the designated ocean disposal site. The second contract, *Ocean Bar II*, covered Bald Head Shoal – Inner Reach as well as the lower river channel ranges of Smith Island, Bald Head-Caswell, Southport, Battery Island, Lower Swash and Snows Marsh. Construction of *Ocean Bar II* began in February 2001 and was completed in December 2002. Placement of beach compatible material along the Bald Head Island shoreline from that work was completed in July 2001. The Oak Island beaches disposal project was completed in April 2002. The dredging and offshore disposal of non-suitable beach material continued until December 2002.

The first post-deepening maintenance cycle was started approximately two years following initial construction. Two maintenance dredging operations were completed during that cycle, termed *Clean Sweep I* and *Clean Sweep II*. *Clean Sweep I*, was completed in January 2004 and involved the removal of material unsuitable for beach placement from along the outer channel reaches. *Clean Sweep II* was completed in January 2005 and involved the removal of beach compatible material along the inner channel reaches in the vicinity of Bald Head Island and subsequent placement along the Island's South Beach shoreline. The second biannual maintenance cycle began in 2007 and included the placement of approximately 0.98 Mcy of beach compatible material along the Bald Head Island shoreline. The third biannual maintenance cycle occurred between February and April 2009 with approximately 1.064 Mcy of beach compatible material placed on Oak Island/Caswell Beach. No major maintenance dredging of the entrance channel's three (3) inner segments has occurred since spring 2009. As a result, an emergency dredging in Bald Head Reach 2 was required in April 2012. The excavated volume of 77,000 cy was taken to the ODMDS by hopper dredge. After a 4-year hiatus, the fourth major maintenance dredging of the channel was performed in the spring of 2013. The estimated volume removed and placed as beach disposal on Bald Head Island was between 1.6 and 1.8 Mcy. The fifth scheduled major disposal was performed in the winter of 2015 (see **Section 1.5**).

1.5 Wilmington Harbor Sand Management Plan

The Wilmington Harbor Sand Management Plan (USACOE 2000) was formulated as a specific action element of the deepening project for Wilmington Harbor. For the most part, the Plan was in direct response to the stated concerns of the Village of Bald Head Island regarding the historical harbor maintenance impacts and potential new impacts of the deepening project to both the regional sediment budget and Bald Head Island. The Plan's stated purpose was to reverse the practice of placing beach quality sand in the off-shore disposal area by calling for placement of this sand onto adjacent beaches. Over a theoretical six-year biennial maintenance cycle, the initial Wilmington Harbor Sand Management Plan (WHSMP) stipulated that approximately 1.0 Mcy of sand was to be placed on the beaches of Bald Head Island in years two and four (*after* initial construction) and on Oak Island/Caswell Beach during year six. The six-year disposal cycle was proposed for the life of the project but, accordingly to its terms, could be altered based upon documentation of impacts to adjacent beaches, changes in conditions and other relevant factors. The first six-year (3 maintenance event) cycle was completed in April 2009. In early 2011, the Wilmington District issued a draft report-of-findings both summarizing approximately 10-years of monitoring and readdressing the tenets of the original (2000) Sand Management Plan based upon their interpretation of monitoring results, related analyses and other salient factors or considerations. Subsequently the District solicited public comments from the two (2) principal stakeholders – the Village of Bald Head Island and Caswell Beach.

In February and April 2011, the Village of Bald Head Island submitted formal comments to the Wilmington District, USACOE, regarding the findings and methodologies represented by *draft* federal Monitoring Report 8 (USACOE, 2011a) and the *draft* Wilmington Harbor Sand Management Plan Re-evaluation Report (USACOE, 2011b). These submittals are discussed in detail in Olsen (2011).

It has been OAI's continuing opinion that the division of sand between the two (2) abutting shorefronts of Oak Island and Bald Head Island should be based upon the cumulative quantities of sediment lost from each shoreline over the prior dredging cycle(s) as documented by survey, as well as impacts which exceed the November 2000 (pre-project) benchmark survey. Similarly, it has been strongly recommended by OAI there should be no future federal disposal event where some volume of sand is *not* placed on Bald Head Island as "mitigation".

1.6 Historical Erosion Control Activities (1991 to 2016)

1.6.1 Channel Maintenance Beach Disposal

Beach disposal activities constructed at Bald Head Island since 1991 are summarized in **Table 1.3**. The three small scale disposal projects constructed between 1991 and 1997 were cost-shared or paid for by the Village of Bald Head Island. The 2001 disposal event was constructed as an element of the Wilmington Harbor Deepening Project. The disposal sand was placed as a designed berm along approximately 15,500 feet of shoreline. The limits of work and design templates were provided to the Wilmington District by Olsen Associates, Inc. on behalf of the Village. All work was performed in general conformance with the requirements of the Wilmington Harbor Sand Management Plan. The 2005 beach disposal project was the initial event (intended for Year 2, but actually occurring in Year 3) of the scheduled disposal cycle and was constructed between November 2004 and January 2005. The 2006, non-Federal West Beach limited sand placement project was constructed by the Village in January 2006.

The 2007 disposal project was the second declared “maintenance” event (intended for Year 4, but actually occurring in Year 5) and was constructed between February and April 2007. Approximately 0.98 Mcy of beach quality material was placed along the South Beach shoreline between Sta. 46+00 and 174+00.

Between February and April 2009, approximately 1.064 Mcy of beach quality sand was excavated from three navigation channel segments (Smith Island Channel thru Bald Head Shoal Reach 1 and 2). All 2009 channel maintenance material was placed on Oak Island/Caswell Beach and none was placed on Bald Head Island. In 2013, all material was placed on Bald Head Island. This included fill placement on West Beach which was the first occasion of channel material disposal at that location since the construction of the 2000 Wilmington Harbor Deepening Project.

In the winter of 2015, the Wilmington District awarded a maintenance contract (W912PM-15-C-002) for the Wilmington Harbor Inner Ocean Bar to the dredging firm Great Lakes Dredge & Dock, Inc. The disposal of the material which derived from the Smith Island Channel, as well as the Baldhead Shoal Channel (Reaches 1 & 2), was performed in accordance with the Wilmington Harbor Sand Management Plan (WHSMP). Accordingly, all material was placed on the South Beach portion of Bald Head Island between STA 41+50 and 154+00. The estimated placed volume was $1.33 \pm$ Mcy. In order to allow for sand placement extending to STA 41+50 for purposes of benefiting a proposed terminal groin, the Village was required to pay approximately \$945,000 to the USACOE.

Table 1.3: Beach disposal/placement activities at Bald Head Island since 1991.

Year	Volume	Sponsor	Location
1991	0.35 ± Mcy	VBHI	(Sta. 24+00 to 138+00)
1996	0.65 ± Mcy	VBHI	(Sta. 24+00 to 142+00)
1997	0.45 ± Mcy	VBHI	(Sta. 24+00 to 128+00)
2001	1.849 ± Mcy	USACE	South Beach (Sta. 41+60 to 205+50)
2005	1.217 ± Mcy	USACE	South Beach (Sta. 46+00 to 126+00)
2006	47,800 cy	VBHI	West Beach (Sta. 16+00 to 34+00)
2007	0.9785 ± Mcy	USACE	South Beach (Sta. 46+00 to 174+00)
2009/10	1.850 ± Mcy	VBHI	West Beach (Sta. 8+00 to 32+00) South Beach (Sta. 40+00 to 190+00)
2012	137,990 cy	FEMA/VBHI	West Beach & Western South Beach
2013	1.566 ± Mcy	USACE	South Beach (Sta. 44+00 to 150+00)
	92,500 cy		West Beach (Sta. 8+00 to 27+00)
2015	1.33 ± Mcy	USACE	South Beach (Sta. 41+50 to 154+00)

1.6.2 Beach Restoration

Locally Sponsored Renourishment Prior Monitoring Reports prepared on behalf of the Village had predicted a looming net sediment deficit along portions of South Beach concurrent with the third biennial channel maintenance event where beach disposal would *not* be scheduled to occur at Bald Head Island. As a result, the Village had strategically prepared to perform a locally sponsored renourishment project with groin field rehabilitation – as warranted. The first such locally sponsored renourishment occurred in 2009/10. These interim measures were deemed necessary until the Wilmington Harbor Sand Management Plan had run its full 3-maintenance operation cycle and the Wilmington District USACOE had completed its associated monitoring sufficient to re-evaluate the Plan and make recommendations for the future.

The maximum volume of sand placement permitted for the 2009/10 renourishment project was 2 Mcy or less. Approximately 5% of the total dredge contract pay volume was to be placed on West Beach. The remainder was to be directed toward South Beach with the highest fill density scheduled for placement on the westernmost end closest the navigation project. The final “pay” volume (in-place) by Contract was 1,594,553 cy. The actual volume of sand excavated and pumped to the two Bald Head Island shoreline segments was estimated at approximately 1.85 Mcy \pm .

By design, the borrow area for the Village 2009/10 project was located on the seaward end of a highly dynamic linear shoal feature bordering the western perimeter of the original navigation project entrance channel. As such it is part of the overall Jay Bird Shoal complex westward of Bald Head Island, which forms much of the present day Cape Fear River ebb tidal platform. The latter large scale morphological unit has been significantly altered in spatial extent, volume, ambient depths, etc. from its natural configuration due to the construction and long-term maintenance of the Cape Fear River Entrance Navigation Channel beginning in the late 1800s (see **Figure 1.3**).

As previously noted, in 2009/10 the Village determined that the groin field sand tubes again warranted some level of scheduled maintenance or replacement concurrent with the renourishment program. Several of the westernmost tubes in the vicinity of “The Point” became undermined or flanked by erosion at that location and failed. Similarly, it was determined that the seawardmost ends of many tubes were becoming degraded due principally to abrasion. Accordingly, a decision was made to replace all tubes for purposes of ensuring a relatively uniform project life. Removal and installation operations began in January 2010 and were determined to be substantially complete on 22 April 2010. The groin

tubes were fabricated by Bradley Industrial Textiles and the materials specified by the Engineer were intended to allow for a more robust design and ideally greater longevity – assuming the tubes were not flanked and compromised due to shoreline recession.

Without direct beach disposal on Bald Head Island concurrent with Federal channel maintenance operations occurring in February through April of 2009, the Island lost 900,000 cy, mol. of sand between May and 1 November 2009 – *i.e.* immediately *following* the federal dredging project and *prior to* the initiation of beach renourishment. The gross fill placement quantity associated with the subsequent Village project approached some 1.85 Mcy. Considering the level of major erosion which immediately preceded the work (in addition to continuing losses during the period of construction) the potential *net* benefits associated with the Village restoration project were therefore proportionally reduced. For example, unlike prior federal beach disposal operations, the as-built fill template constructed by the Village was insufficient to completely bury all tubes thereby establishing an initial water line seaward of the groin field. Similarly, the constructed fill limits likewise could *not* reconstruct the historical shoreline alignment which had pre-existed along the west end of south beach at/or about the time of initiation of the 2000 Harbor Deepening project.

Post-Irene Mitigation Project (FEMA) During the period 25 August to 1 September 2011, Hurricane Irene impacted portions of the coastline of North Carolina. During the incident period, storm surge and high waves associated with the declared event, resulted in erosion of varying severity along the engineered shorefront of Bald Head Island. In a predictable fashion, the erosion was most severe for the shoreline nearest the mouth of the Cape Fear River.

As a result of an on-site inspection by FEMA representatives, three (3) Project Worksheets (PW's) were issued allowing for the following actions by the Village:

- Mechanical pushing of sand from the lower beach to the duneline along a section of East Beach facing Onslow Bay.
- The reconstruction of the westernmost 5 sand tube groins, partially damaged or displaced during the event, and
- The placement of 10,000 cy of sand along West Beach and 95,000 cy along the westernmost segment of South Beach.

The Village's strategic permitting of the Bald Head Creek "emergency" dredging project allowed the FEMA project to be expeditiously bid and constructed within the non-turtle nesting window addressed by State and Federal permits. The 140,000 cy project was

initiated by Cottrell Contracting Corporation on 19 January and completed on 25 February 2012. Of the total permitted 137,990 cy placed, 105,000 cy were reimbursable by FEMA under P.W. BHGJS03. It was decided at the time that groin tube replacement would need to occur during the 2013 federal disposal project which restored the affected shoreline to a much wider beach condition conducive to sand tube removal and replacement – primarily “in the dry,” or at least above the MLWL.

1.6.2 Erosion Control Structures (Pre-2015 Projects)

A temporary sand-filled tube groin field was installed by the Village along western South Beach in March 1996, immediately following completion of a small-scale sand placement project. Sixteen (16) soft groins (geotube-type structures) were constructed of geotextile material and sand fill.

In 2003/2004 a pre-existing sand bag revetment located in the back beach berm and dune was greatly expanded by the Village along western South Beach as an emergency erosion control “back-up” measure in order to protect residences as well as a road and adjacent sub-grade public utilities. The original revetment was constructed in 1994 along 645 ft of shoreline. At the time, that structure was restricted to a base width of 20 ft and a height of 6 ft. The sand bags were originally installed above the mean high water line, however severe erosion in subsequent years lowered the beach profile so that wave run-up reached the base of the bags on a normal high tide and partially covered them during a lunar or storm tide. The sand bag revetment was placed at the most landward location possible so as to be subject to burial within a dune or beach berm during future beach nourishment operations. The 2003/2004 improvements included the lengthening of the structure by approximately 200 ft. Additionally, the base width was increased to 40 ft and the crest elevation to +12 ft-NGVD.

A sand-filled tube groin field (sixteen tubes) replacement project was constructed between January and March 2005, immediately following a 1.217 Mcy federal disposal project. Minor changes in groin location were made in an effort to improve performance. Similarly, experimental “tapered” tubes were deployed in an attempt to better accommodate beach profile recession over time. As with all such “soft” structures, maintenance requirements are high and overall project life limited. This action was required by the Wilmington District, USACOE with the goal of reducing the rate of shoaling within the authorized navigation channel in the vicinity of the Point. The \$743,000 construction cost for groin field reconstruction was paid by the Village.

The westernmost sand tube groins are subject to quickened downdrift destabilization due to navigation project related sand losses at “the Point”, as well as sand starvation when the updrift portion of the groin field becomes activated to the point that net alongshore transport (toward the west) is diminished. Prior to beach fill construction by the Village in 2009/2010, several of the westernmost groins had been severely flanked and eventually destroyed by a rapidly receding dune line and downdrift shoreline. The Village obtained a renewal of the groin field permit(s) so as to be able to reconstruct all *or* portions of the structures subsequent to the locally funded and constructed winter 2009/10 beach renourishment project. Some adjustment of groin length, and the westward relocation of groin no. 16 were made in an attempt to refine the project design. Work began on January 27, 2010, mol. and was completed on 17 April 2010. The construction cost alone incurred by the Village for this work was \$1.14M, mol.

Although the Village had not planned for any new level of construction during the May 2010 – May 2011 monitoring year, certain emergency actions were initiated immediately after May 2011 – during the formulation of Report No. 9 (Olsen, 2011).

For example, between the time of acquisition of aerial photography in April 2011 and mid-May, the beach located westward of sand tube groin no. 16 suffered extensive erosion. More specifically, the downdrift shoreline abutting the upland end of the last groin receded by over 70-ft in a very short time frame. As a result, the flanked groin was extended by approximately 70 ft. so that it “retied” to the heavily scarped dune line. This *emergency* type measure was successfully completed on July 7th. A corresponding updrift erosional area at the base of the groin was backfilled to reduce continuing immediate near-term flanking phenomena from the eastward direction. Despite these efforts, downdrift erosion continued and within weeks of the work, the 70 ft extension was again in jeopardy of flanking as the protective duneline continued to rapidly recede.

Within months of the groin no. 16 extension landward, a 300 ft. long sand bag revetment was constructed on the downdrift (western side) of the last sand tube groin in order to protect several endangered residential structures.

In the spring of 2013, the westernmost five (5) sand tube groins were replaced in their entirety. This work was co-funded by FEMA as part of a post-Irene damage mitigation effort. The project P.W. was BHGJS04 in accordance with FEMA declaration 4019 DR NC. The work was initiated during the federal beach disposal event.

In the spring of 2015, construction was initiated on a single 1,300 ft. long rock terminal groin designed to complement future placement of beach fill at South Beach. At that time, the westernmost three (3) geotube groins were removed in their entirety. A detailed description of the project is provided in **Section 1.6** of this report. Additionally, a discussion the 2015 extension of the two (2) rock jetties which protect the entrance channel to Bald Head Marina is provided in **Section 1.7** of this report.

1.7 2015 VBHI Terminal Groin Project

1.7.1 Background & Purpose

Comprehensive beach monitoring over the past decade by the Village of Bald Head Island resulted in the conclusion that sand placement alone would *not* offset the net negative impacts to the west end of South Beach and the resulting chronic rates of sediment loss and consistent northerly recession of the Point. The net result of these phenomena had been shoreline realignment and associated threat to public infrastructure, homes, roads, beaches, protective dunes and wildlife habitat, as well as the requirement for supplementary sand placement by the Village.

As a result, the Village permitted a single 1,900 ft. long terminal groin designed to complement future placement of beach fill at South Beach. The structure was to serve as a “template” for fill material placed eastward thereof on South Beach. The terminal groin was designed as a “leaky” structure (*i.e.* semi-permeable) so as to provide for some level of sand transport to West Beach and portions of the Point (located northward of the proposed groin). It is the Village’s position that the construction of the structure may have direct benefits to the abutting navigation channel. The structure was to be constructed in 2 phases. Phase I, constructed in 2015 is approximately 1,300 ft in length. Phase II will only be initiated after some period of monitoring of the groin’s post-construction performance.

The Final EIS was published in the Federal Register on 1 August 2014. The various project permits (CAMA, USACOE and NCDENR -401 WQ) were issued in the fall of 2014.

In late 2014, three bids were received for the construction of Phase I (1,300 ft rock terminal groin). The effective low bidder was Orion Marine Construction, Inc. and the contract awarded on December 16, 2014. A notice-to-proceed for the work was issued on January 6, 2015. Actual work at the project site began on June 1, 2015. Demobilization from the project site by the contractor occurred on December 6, 2015.

1.7.2 Construction Equipment & Technique

Orion Marine Construction, Inc. was selected to construct the 1,300 ft rock terminal groin. Photographs taken during construction are provided as **Figures 1.5** through **1.8**. An area immediately adjacent to the structure was utilized as an access and staging area. **Figure 1.9** illustrates the access/staging area, as depicted in the project plans. Access to the beach and groins site was by water only. All material and equipment was off-loaded to the staging area via barge. At the request of Orion, the Village modified project permits to allow for the construction of a temporary offloading structure along the Cape Fear River.

Construction was initiated at the landward end of the project. Prior to construction it was anticipated that construction of the landward end of the structure would progress more quickly than the seaward end due to less influence from tidal fluctuations and wave impacts. The project design specified that a marine mattress base be placed under the entire rock footprint of the structure (**Figure 1.10**). The purpose of the mattresses was to reduce the effects of long-term settling which would ultimately adversely affect both project performance and design intent. The marine mattress underlayment will likewise significantly reduce the need for long-term maintenance of the structure. Details of the individual mattress design are provided in **Figure 1.11**.

Logistically, the project required the placement of over 14,000 tons of three (3) classes of large armor stone. Stone varied in size from 1.5 ton (3 ft dia.) to 9 ton (6.5 ft dia.). All stone was quarried in the vicinity of Raleigh, N.C., then transported by truck to Oak Island and transferred to barges and finally brought to Bald Head Island.

Most of the groin stem was constructed “in the dry” and subsequently buried below the federal disposal sand berm. Construction of the structure head required rock placement from a temporary work trestle. At the completion of work, only the structure head was exposed.



Figure 1.5: Material and equipment offload area, Bald Head Island terminal groin project (July 7, 2015).



Figure 1.6: Rock and mattress placement verification (July 21, 2015).



Figure 1.7: Rock and mattress placement along seaward end of terminal groin utilizing a temporary trestle structure (October 22, 2015).

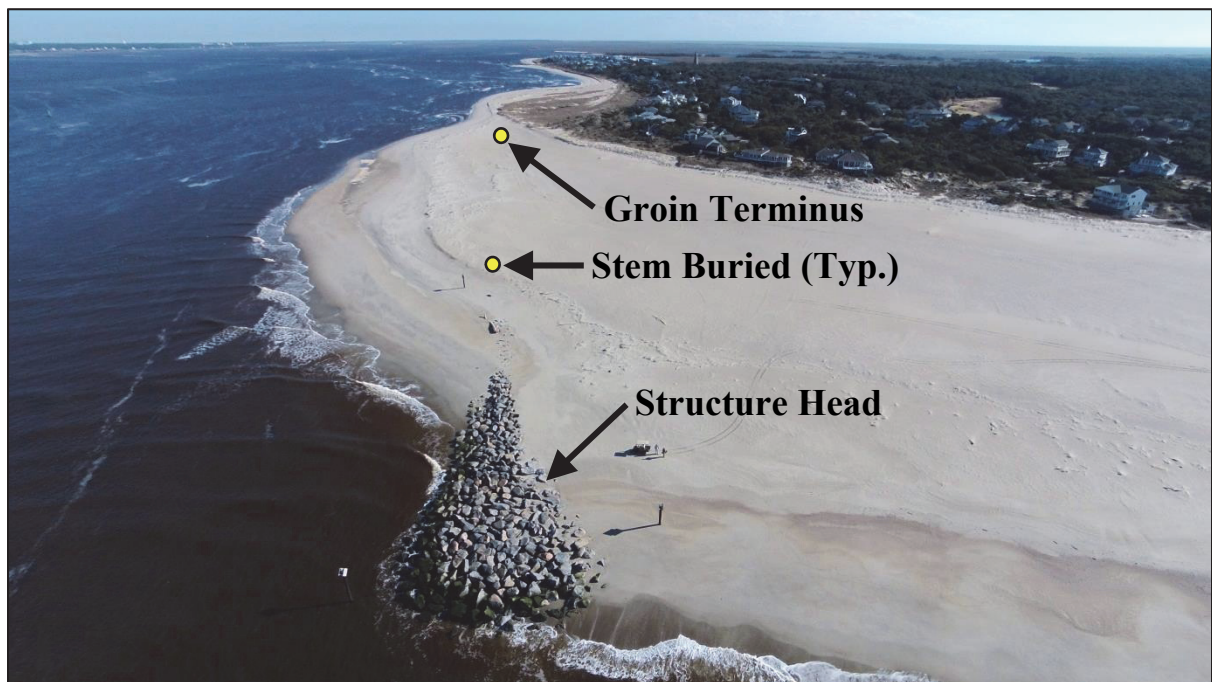


Figure 1.8: Completed Bald Head Island terminal groin (March 3, 2016).

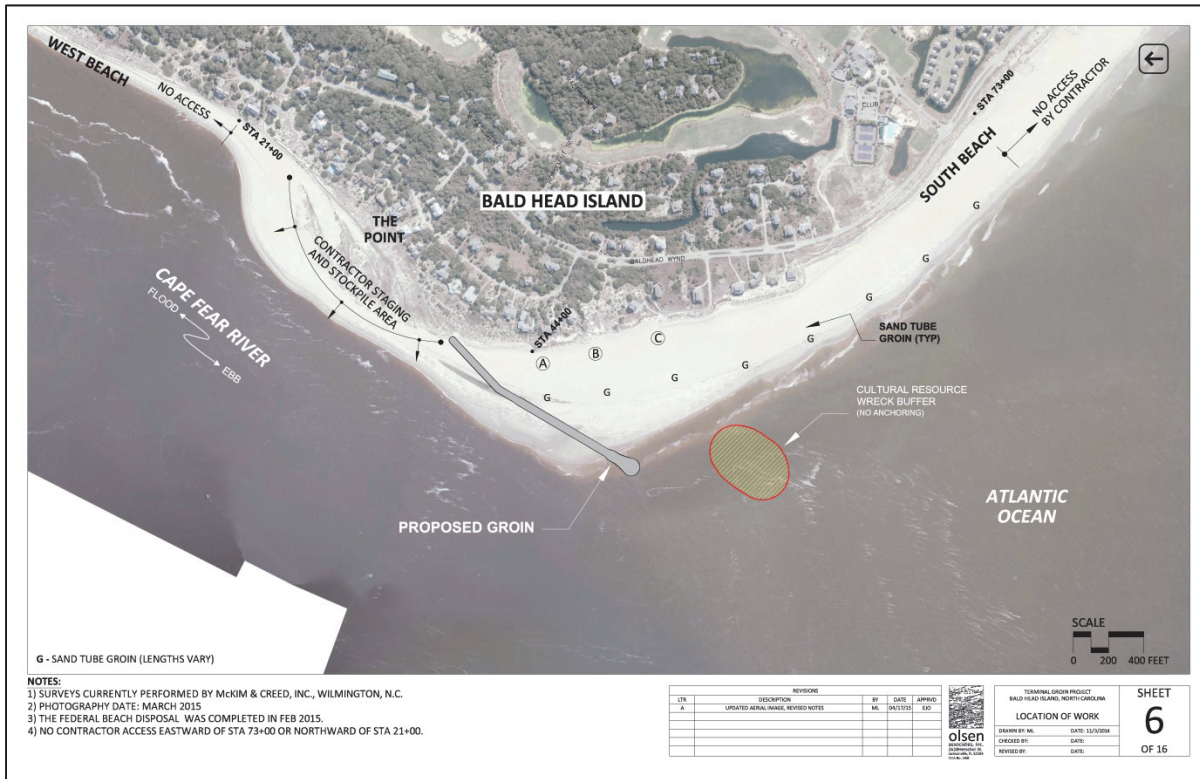


Figure 1.9: Access/staging/storage area utilized by Orion for construction of the terminal groin.

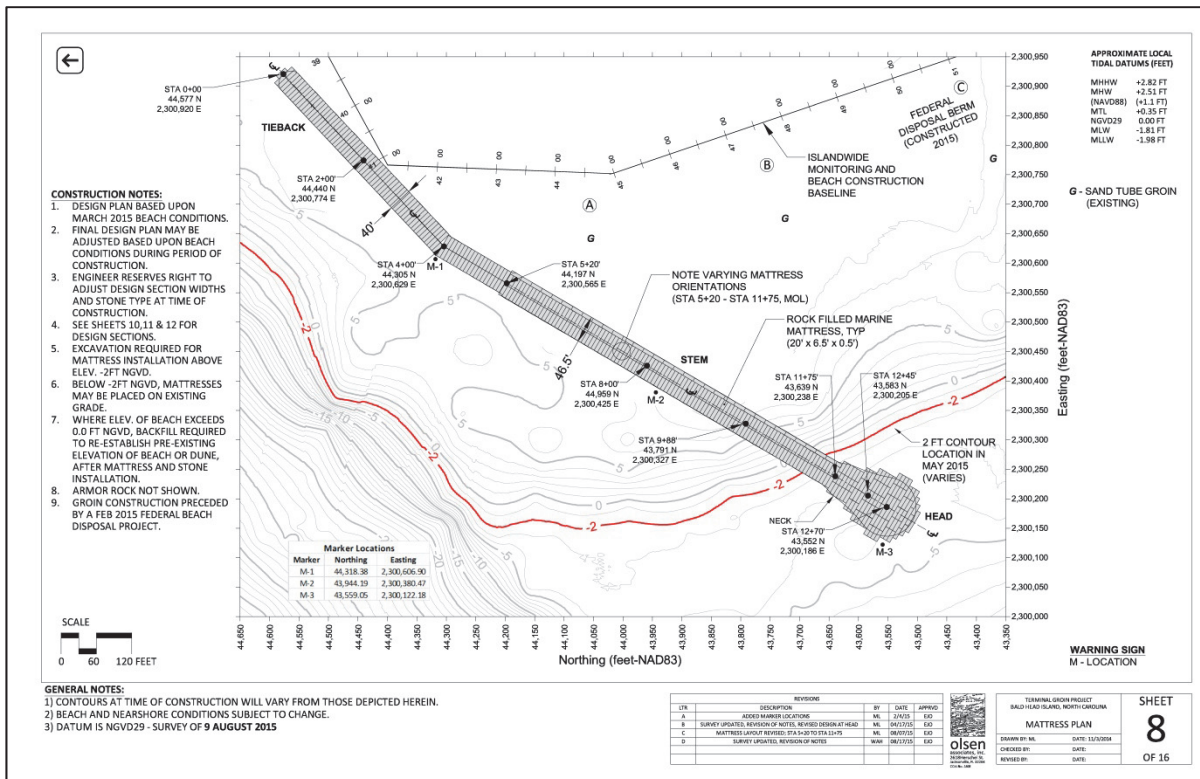


Figure 1.10: Marine mattress layout.

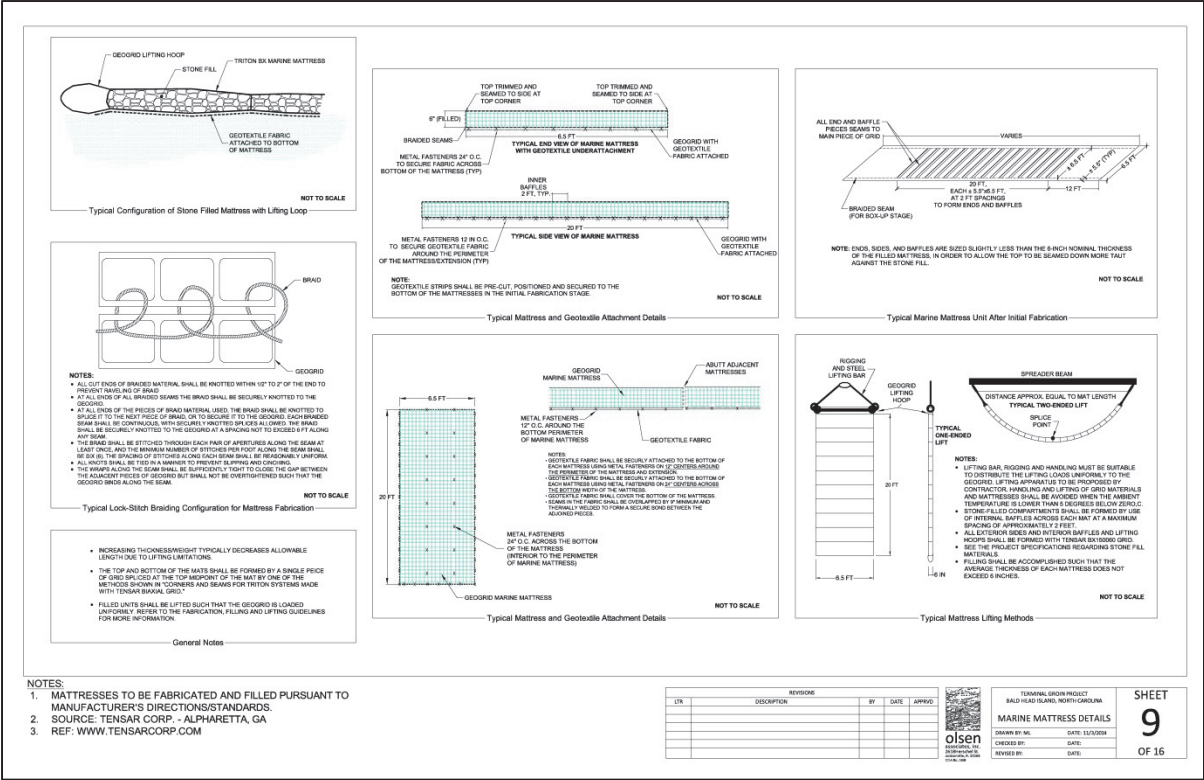


Figure 1.11: Marine mattress details.

1.8 2015 VBHI Marina Jetties Extension Project

1.8.1 Background & Purpose

The two marina entrance channel jetties located to the south of the Row-Boat-Row shorefront were originally constructed by Bald Head Island, Ltd., at lengths which over time failed to effectively control shoaling due to northerly directed littoral transport along West Beach. As a result, high frequency maintenance dredging of the navigation channel had been required in order to provide reasonably reliable ferry and barge access between the mainland and the island. Records indicated that dredging operations occurred almost monthly over a 6-year period. Both channel maintenance and advance dredging of the West Beach shoreline were performed. In 2015, the Village of Bald Head Island assumed responsibility for marina entrance channel shorefront maintenance operations. Accordingly, the Village commissioned the permitting and design of jetty extensions intended to reduce chronic shoaling.

1.8.2 Construction Equipment & Technique

The Village sponsored jetty extension project was completed in early 2015. It was constructed by Orion Marine Construction, Inc. under a separate contract from that awarded for the terminal groin construction. Photographs taken during construction are provided as **Figures 1.12** through **1.15**.

Each rock jetty extension was placed on Tensar marine mattresses for purposes of minimizing future maintenance requirements due to scour and settlement (see Figure 1.12 and 1.13). All work was performed by barge. Since project completion, no maintenance dredging has been required. A limited (3,000 cy) sand bypass operation however is expected to be initiated in July 2016 in an effort to address downdrift impacts occurring north of the entrance along the Row-Boat-Row shorefront caused by a cessation of high-frequency sand disposal (monthly) at that location.



Figure 1.12: Laying of the first mattress for the south jetty extension at the Bald Head Island marina (March 25, 2015).



Figure 1.13: Location verification of placed mattress, Bald Head Island marina (April 6, 2015).



Figure 1.14: New rock placement at the North Jetty, Bald Head Island marina (May 29, 2015).



Figure 1.15: Completed jetty extensions at the Bald Head Island marina (July 12, 2015).

2.0 PHYSICAL MONITORING PROGRAM

2.1 Monitoring Baseline & Beach Profiles

MONITORING BASELINE The monitoring baseline extends 31,400 ft from the northern end of Row Boat Row (Sta. -014+72), southward along West Beach, around “the Point”, then eastward along South Beach to Cape Fear and finally northward along East Beach. The individual profile stationing and coordinates are listed in **Table 2.1** and graphically depicted in **Figure 2.1**.

BEACH PROFILES In order to document and assess any potential adverse effects of the Wilmington Harbor Navigation Channel Navigation project to Bald Head Island, the Village Council initiated a comprehensive beach monitoring program which commenced in 1999. As part of the program onshore and offshore profiles are measured annually at seventy-six (76) stations spaced approximately 400 ft apart along the roughly 31,400 ft of Bald Head Island’s shorefront. **Table 2.2** summarizes the monitoring surveys conducted to date as part of the monitoring program. The primary focus of this monitoring report (No. 14) is beach profile and shoreline changes occurring over the latest set of surveys (April 2015 to November 2015 to April 2016).

Typically, survey transects extend across the upland berm or from the dune line seaward a distance of up to 3,000 ft. Depending upon the location of the survey profile, this distance corresponds to offshore waters depths of at least -40 ft relative to NGVD within the Cape Fear River Channel and -16 ft-NGVD along the Atlantic Ocean shorefront. In Chapter 3, these surveys are intra-compared in order to determine trends in the condition of the beaches of Bald Head Island. Plots of selected historical comparative beach profile data (through April 2016) are provided in **Appendix A**.

Prior to October 2003, fifty-five (55) stations were surveyed as part of the monitoring program. Five (5) additional intermediate stations were added at the Point, commencing with the October 2003 survey. These profile stations were added to more accurately capture the extreme changes that occur at the Point. Seven (7) profiles were added along East Beach (EB-01 to EB-07) beginning with the November 2008 survey. Finally, beginning with the November 2015 survey five (5) profiles were added along Row Boat Row and four (4) were added at the Point, as part of the terminal groin monitoring requirement.

Table 2.1: Bald Head Island baseline stationing and beach monitoring profile locations.

Station	Station Location		Grid Azimuth (Deg.)	Station	Station Location		Grid Azimuth (Deg.)
	Easting (FT-NAD83)	Northing (FT-NAD83)			Easting (FT-NAD83)	Northing (FT-NAD83)	
Row Boat Row				088+23	2,303,372.1	40,705.0	214
-014+72	2,304,277.9	49,117.4	302	092+15	2,303,714.1	40,513.9	209
-012+00	2,304,068.6	48,776.5	302	097+10	2,304,146.1	40,272.5	206
-008+00	2,303,937.2	48,538.1	302	102+08	2,304,592.1	40,057.6	204
-004+00	2,303,728.0	48,197.2	302	106+00	2,304,960.4	39,915.3	201
-003+00	2,303,518.7	47,856.3	302	110+00	2,305,333.5	39,771.1	201
West Beach				114+00	2,305,708.5	39,626.3	202
000+00	2,303,309.3	47,515.5	302	118+00	2,306,080.6	39,482.5	202
004+00	2,303,100.4	47,174.4	301	122+00	2,306,451.7	39,339.2	201
008+00	2,302,891.5	46,833.3	301	126+00	2,306,824.0	39,195.3	200
012+00	2,302,682.5	46,492.2	301	130+00	2,307,196.5	39,051.4	200
016+00	2,302,473.6	46,151.1	301	134+00	2,307,569.6	38,907.3	200
020+00	2,302,264.7	45,810.0	301	138+00	2,307,943.9	38,767.8	200
024+00	2,302,055.2	45,468.8	302	142+00	2,308,320.5	38,633.0	200
028+00	2,301,845.1	45,126.6	303	146+00	2,308,697.1	38,498.2	200
"the Point"				150+00	2,309,073.8	38,363.4	200
028+00	2,301,845.1	45,126.6	303	154+00	2,309,452.4	38,228.0	201
032+00	2,301,566.1	44,843.7	301	158+00	2,309,818.8	38,074.6	202
034+00	2,301,394.4	44,742.0	301	162+00	2,310,179.1	37,895.6	203
036+00	2,301,220.2	44,647.1	299	166+00	2,310,539.0	37,716.9	204
038+00	2,301,043.1	44,550.6	296	170+00	2,310,903.5	37,552.0	204
039+60	2,300,902.6	44,473.9	291	174+00	2,311,267.9	37,387.2	204
041+50	2,300,765.0	44,365.0	287	178+00	2,311,632.4	37,222.3	204
043+47	2,300,757.5	44,167.6	284	182+00	2,311,996.9	37,057.4	204
044+25	2,300,754.6	44,090.2	276	186+00	2,312,361.3	36,892.6	204
045+07	2,300,751.4	44,007.0	268	190+00	2,312,725.8	36,727.8	204
046+00	2,300,784.9	43,920.7	260	194+00	2,313,090.2	36,562.9	204
046+89	2,300,813.7	43,836.0	251	198+00	2,313,454.7	36,398.1	204
049+00	2,300,881.5	43,636.5	247	202+00	2,313,819.2	36,233.2	204
050+50	2,300,913.5	43,541.9	247	206+00	2,314,183.6	36,068.4	204
051+00	2,300,945.8	43,447.1	247	210+00	2,314,548.1	35,903.5	204
052+64	2,300,998.3	43,292.1	243	214+00	2,314,912.5	35,738.7	204
054+00	2,301,042.2	43,163.0	243	218+00	2,315,277.0	35,573.8	204
South Beach				East Beach			
056+56	2,301,148.7	42,933.8	233	224+80	2,315,748.8	36,063.3	90
060+51	2,301,399.6	42,628.3	230	234+80	2,315,748.8	37,063.3	90
065+50	2,301,716.0	42,243.2	229	244+80	2,315,748.8	38,063.3	90
069+46	2,301,967.6	41,937.0	227	254+80	2,315,748.8	39,063.3	90
073+39	2,302,246.1	41,660.5	223	264+80	2,315,748.8	40,063.3	90
076+37	2,302,609.2	41,320.5	222	274+80	2,315,748.8	41,063.3	90
084+16	2,303,032.1	40,924.5	219	284+80	2,315,748.8	42,063.3	90



Figure 2.1:
Island-wide beach monitoring baseline.
olsen associates, inc.

Table 2.2: Bald Head Island monitoring surveys collected as of April 2016.

Survey Date	Surveyor	Comments
1999 Nov.	Brunswick Surveying., Inc.	16 months pre-construction (2001 disposal)
2000 Nov.	Brunswick Surveying., Inc.	4 months pre-construction (2001 disposal)
2001 Aug.	Brunswick Surveying., Inc.	1 month post-construction (2001 disposal)
2002 July	Brunswick Surveying., Inc.	12 months post-construction (2001 disposal)
2002 Dec.	Brunswick Surveying., Inc.	17 months post-construction (2001 disposal)
2003 May	Brunswick Surveying., Inc.	22 months post-construction (2001 disposal)
2003 Oct.	McKim & Creed	27 months post-construction (2001 disposal) Five additional stations added at "the Point"
2004 Apr.	McKim & Creed	33 months post-construction (2001 disposal)
2004 Oct.	McKim & Creed	39 months post-construction (2001 disposal)
2005 Apr.	McKim & Creed	3 months post-construction (2004/05 disposal) 1 month post-construction (2005 groin field)
2005 Nov.	McKim & Creed	10 months post-construction (2004/05 disposal) 8 months post-construction (2005 groin field)
2006 Apr	McKim & Creed	15 months post-construction (2004/05 disposal)
2006 Nov.	McKim & Creed	22 months post-construction (2004/05 disposal)
2007 June	McKim & Creed	2 months post-construction (2007 disposal)
2007 Nov.	McKim & Creed	7 months post-construction (2007 disposal)
2008 May	McKim & Creed	13 months post-construction (2007 disposal)
2008 Nov.	McKim & Creed	19 months post-construction (2007 disposal) Seven additional stations added along East Beach
2009 May	McKim & Creed	25 months post-construction (2007 disposal)
2009 Sept.	Gahagan & Bryant	Survey required by dredge Contractor. East Beach not included this period.
2010 May	McKim & Creed	2 months post-renourishment (09/10)
2010 Sept.	McKim & Creed	6 months post-renourishment (09/10)
2011 May	McKim & Creed	14 months post-renourishment (09/10)
2011 Sept.	McKim & Creed	18 months post-renourishment (09/10)
2012 May	McKim & Creed	26 months post-renourishment (09/10)
2012 Nov.	McKim & Creed	32 months post-renourishment (09/10)
2013 May	McKim & Creed	38 months post-renourishment (09/10)
2013 Nov.	McKim & Creed	44 months post-renourishment (09/10)
2014 May	McKim & Creed	50 months post-renourishment (09/10)
2014 Nov.	McKim & Creed	56 months post-renourishment (09/10)
2015 April	McKim & Creed	1 month post-construction (2015 Disposal)
2015 Nov.	McKim & Creed	8 months post-construction (2015 Disposal) Five stations added along Row Boat Row Four stations added along the Point
2016 April	McKim & Creed	13 months post-construction (2015 Disposal)

MHWL SUVEYS As part of the permit required monitoring for the terminal groin project completed in late 2015, post-construction MHWL surveys were initiated in November 2015. Each survey was specified to begin at the Marina entrance (Sta. 0+00) and extend to St. 75+00, about 3,000 ft eastward of the terminal groin head. On an annual basis, surveys are to be intercompared to assess both updrift fillet conditions and the location of the downdrift shoreline fronting the Cape Fear River.

2.2 Bald Head Creek Borrow Site Surveys

The Bald Head Creek borrow site utilized for the 2012 Post-Irene small scale mitigation project continues to be resurveyed annually. **Table 2.4** summarizes the borrow site surveys conducted to date.

Table 2.3: Bald Head Creek borrow site surveys collected as of April 2016.

Borrow Site Survey Date	Comment
March 2011	Pre-Construction Survey
March 2012	After Dredge (AD) Survey
January 2013	10 Months Post-Dredge (Year 1)
December 2013	21 Months Post-Dredge (Year 2)
April 2015	37 Months Post-Dredge (Year 3)
October 2015*	43 Months Post-Dredge (Year 3.5)
April 2016*	49 Months Post-Dredge (Year 4)

*Not required. Performed as condition surveys for future borrow site assessment.

2.3 Jay Bird Shoal Borrow Site Surveys

Permits for the beach renourishment project constructed by the Village in 2009/2010 necessitates the resurveying of the Jay Bird Shoal borrow site as part of the annual island-wide monitoring program. **Table 2.4** summarizes the borrow site surveys conducted to date. Specifically, borrow site surveys are required both pre- and post-excavation, as well as at 12-, 24- and 36-months and biennially thereafter. The next scheduled borrow site survey will be performed in or about May 2017. The area surveyed is 400-acres \pm which includes a buffer

area outside the “permitted” limits of work. The actual work area in 2009/10 utilized only about 2/3 of the permitted area (and associated total dredge volume). As a result, somewhere between 1 and 2 Mcy of beach compatible material continue to exist within the undisturbed portion of the previously permitted borrow area.

Table 2.4: Jay Bird Shoal borrow site surveys collected as of May 2015.

Borrow Site Survey Date	Comment
October 2009	Before Dredge (BD) Survey
March 2010	After Dredge (AD) Survey
May 2011	14 Months Post-Dredge
May 2012	26 Months Post-Dredge
May 2013	38 Months Post-Dredge
April 2015	61 Months Post-Dredge

2.4 Orthorectified Aerial Photography

In addition to the beach profile surveys, digital color aerial photography of the island’s shoreline has been acquired at a minimum, annually by Independent Mapping Consultants, Inc.⁵ **Table 2.5** summarizes the aerial photography collected to date as part of the monitoring program. Reproductions of the four most recent aerial photography sets (April 2016, November 2015, August 2015 and April 2014) are presented in **Appendices B, C, D** and **E**, respectively. The August 2015 aerial was associated with terminal groin construction and not the annual monitoring program.

⁵ Independent Mapping Consultants, Inc.; 3909 Wrightsville Ave. Suite 200; Wilmington, NC 28403.

Table 2.5: Bald Head Island monitoring aerial photography collected as of April 2016.

Photo Date			Comment
Year	Month	Day	
2001	September	NA	2-months post-construction (2001 disposal)
2002	November	14	16-months post-construction (2001 disposal)
2003	April	NA	21-months post-construction (2001 disposal)
2004	January	NA	30-months post-construction (2001 disposal)
2004	May	NA	34-months post-construction (2001 disposal)
2004	October	NA	39-months post-construction (2001 disposal)
2005	May	NA	4-months post-construction (2004/05 disposal)
2005	November	NA	10-months post-construction (2004/05 disposal)
2006	April	NA	15-months post-construction (2004/05 disposal)
2006	October	NA	21-months post-construction (2004/05 disposal)
2007	May	20	1-month post-construction (2007 disposal)
2008	May	13	13-months post-construction (2007 disposal)
2009	January	14	21-months post-construction (2007 disposal)
2009	May	31	25-months post-construction (2007 disposal)
2009	August	26	3-months pre-renourishment (2009/10)
2010	April	NA	1-month post-renourishment (09/10)
2011	April	NA	13-months post-nourishment (09/10)
2012	May	NA	26-months post-nourishment (09/10)
2012	December	14	33-months post-nourishment (09/10)
2013	May	14	38-months post-nourishment (09/10)
2013	November	14	44-months post-nourishment (09/10)
2014	May	23	50-months post-nourishment (09/10)
2014	November	03	56-months post-nourishment (09/10)
2015	March	29	Post-construction (2015 Disposal)
2015	August	9	5 months post-construction (2015 Disposal)
2015	November	29	8 months post-construction (2015 Disposal)
2016	April	3	13 months post-construction (2015 Disposal)

3.0 MONITORING (SURVEY) RESULTS

3.1 Methodology

For purposes of analysis and discussion, the Bald Head Island monitoring baseline is qualitatively broken into seven (7) shoreline segments, or zones of interest, with significantly varying physiographic characteristics as follows:

- Station -018+72 to -003+00 “Row Boat Row”
- Station -001+60 to 028+00 “West Beach”
- Station 028+00 to 046+00 “The Point” – North of Terminal Groin
- Station 046+00 to 056+56 “The Point” – South of Terminal Groin
- Station 056+56 to 214+00 “South Beach”⁶
- Station 214+00 to 224+80 “Cape Fear Point”⁷
- Station 224+80 to 284+80 “East Beach”

These zones differ slightly from the shoreline segments used in the prior monitoring reports (OAI 2015). More specifically, “the Point” is now divided into two areas rather than one, based upon the location of the recently completed terminal groin. The update is intended to more accurately capture the influence of that structure on the physical processes along the Bald Head Island shoreline. Additionally, the “Row Boat Row” reach was added to the monitoring analysis with the initial two monitoring surveys along this reach completed in November 2015 and April 2016.

Alongshore volume changes were calculated using an average end-area method, where the cross-sectional areas are determined by comparing beach profiles at each beach monitoring station above several different vertical datums. This approach allows evaluation of beach changes at different elevations along the project in addition to the total profile.

Average shoreline position changes were calculated were spatially weighted based upon the distance due to the non-uniform alongshore spacing of survey monuments.

⁶ East of Sta. 214+00, the remaining 400 ft of surveyed Atlantic oceanfront shoreline becomes part of Cape Fear Point and is not included in the South Beach analysis due to its highly dynamic nature.

⁷ The general condition of the Cape Fear spit is qualitatively monitored primarily through controlled aerial photography. This depositional feature is routinely subject to episodic periods of accretion and erosion resulting from eventual detachment via tidal channel breakthrough during storms. It is likewise influenced by beach fill activities and sediment added to the littoral system of South Beach as well as storm waves originating from the east or southeast.

3.2 Year 14: Monitoring Program (April 2015 - November 2015 - April 2016)

The April 2015 to April 2016 monitoring period represents the fourteenth (14) year of measured shoreline change following completion of the initial 2001 federal +1.849 Mcy beach disposal event at Bald Head Island. For compliance purposes, the April 2016 survey represents the first year following completion of the 1.33 Mcy 2015 Federal beach disposal, the second year following a 2013 disposal event of 1.66 Mcy as well as the sixth year following the 1.84 Mcy beach renourishment constructed by the Village of Bald Head Island in the winter of 2009/2010. This period also represents the eleventh year of measured shoreline change following the 2005/06 beach disposal, the tenth year following the placement of +47,800 cy of beach fill along the West Beach shoreline (by the Village) and the ninth year following the 2007 Federal 978,000 cy beach disposal placed along the South Beach shoreline (Sta. 46+00 to 174+00).

During the first half of the current monitoring period (April to November 2015) a single 1,300 ft. long terminal groin was constructed in the vicinity of STA 46+00. Construction began in June 2015 and was completed by December 2015. Also during this monitoring period the two (2) rock jetties which protect the entrance channel to Bald Head Marina in the vicinity of Sta. 0+00 were both lengthened and reconfigured.

Volume changes between condition surveys were computed using the average end-area method above the mean high water line (MHWL; +2.51 ft-NGVD) and the assumed typical depth of closure (-16.0 ft-NGVD). **Tables 3.1** through **3.3** list the computed changes along the Bald Head Island shoreline for the April 2015 – November 2015 – April 2016 survey intervals. **Figures 3.1, 3.2** and **3.3** depict the cumulative and local volume changes for the same intervals. Changes in shoreline position at each station were computed at the MHWL and the seaward edge of berm (+6 ft-NGVD contour). The results are summarized in **Tables 3.4** and **3.5** and graphically depicted in **Figures 3.4** and **3.5** (relative to their November 2000 pre-disposal locations).

Table 3.1: Bald Head Island shoreline volume change (April 2015 to November 2015).

				Volume Change						Volume Change				
	Start Station	End Station	Reach (FT)	Above +2.51 (FT)	Above -16 (FT)		Start Station	End Station	Reach (FT)	Above +2.51 (FT)	Above -16 (FT)			
West Beach	Jetty	000+00	160	+1,200	+4,600	South Beach	056+56	060+51	423	-6,900	-7,200			
	000+00	004+00	400	+2,000	+6,200		060+51	065+50	510	-14,600	-24,200			
	004+00	008+00	400	+500	+200		065+50	069+46	423	-13,600	-24,300			
	008+00	012+00	400	-400	-1,600		069+46	073+39	442	-12,800	-18,500			
	012+00	016+00	400	-1,000	-2,900		073+39	076+37	516	-12,800	-16,100			
	016+00	020+00	400	-1,400	-3,500		076+37	084+16	611	-11,300	-14,500			
	020+00	024+00	400	+1,700	+7,200		084+16	088+23	471	-8,000	-17,100			
	024+00	028+00	400	+3,100	+5,200		088+23	092+15	455	-6,300	-17,800			
	Subtotal		2,960	+5,700	+15,400		092+15	097+10	536	-6,500	-15,000			
Point (North of Groin)	028+00	032+00	395	+2,700	-6,200		097+10	102+08	525	-7,100	-15,600			
	032+00	034+00	200	+1,700	-2,200		102+08	106+00	436	-4,800	-12,100			
	034+00	036+00	210	+1,100	-2,100		106+00	110+00	400	-4,500	-10,200			
	036+00	038+00	230	+1,600	-300		110+00	114+00	388	-5,800	-9,800			
	038+00	039+60	230	+4,100	+8,100		114+00	118+00	407	-7,800	-8,800			
	039+60	041+50	220	+6,600	+19,200		118+00	122+00	413	-8,400	-9,700			
	041+50	043+47	220	+7,900	+25,200		122+00	126+00	405	-7,500	-8,100			
	043+47	044+25	190	+6,700	+20,200		126+00	130+00	405	-6,400	-8,100			
	044+25	045+07	190	+5,900	+16,400		130+00	134+00	398	-6,000	-7,300			
	045+07	046+00	200	+6,500	+15,400		134+00	138+00	401	-5,500	-6,800			
	Subtotal		2,285	+44,800	+93,700		138+00	142+00	400	-4,600	-12,600			
Point (South of Groin)	046+00	046+89	200	+7,900	+14,000		142+00	146+00	400	-5,100	-17,400			
	046+89	049+00	250	+9,400	+13,100		146+00	150+00	399	-4,600	-16,000			
	049+00	050+50	100	+2,800	+3,100		150+00	154+00	385	0	-7,900			
	050+50	051+00	100	+2,000	+2,500		154+00	158+00	383	+4,600	+5,400			
	051+00	052+64	240	+3,700	+8,400		158+00	162+00	386	+5,400	+12,900			
	052+64	054+00	135	+1,000	+3,800		162+00	166+00	393	+4,000	+10,600			
	054+00	056+56	380	-1,500	+1,600		166+00	170+00	394	+2,900	+6,100			
	Subtotal		1,405	+25,300	+46,500		170+00	174+00	400	+2,200	+5,600			
Note: Elevations are referenced to NGVD 1929.							174+00	178+00	400	+1,400	+6,100			
							178+00	182+00	400	+1,400	+5,800			
							182+00	186+00	400	+2,000	+2,400			
							186+00	190+00	400	+2,700	-4,700			
							190+00	194+00	400	+3,000	+900			
							194+00	198+00	400	+3,700	+10,600			
							198+00	202+00	400	+2,900	+7,000			
							202+00	206+00	400	+800	-100			
							206+00	210+00	400	-900	-7,000			
							210+00	214+00	400	-4,500	-6,800			
							Subtotal		16,105	-139,300	-249,300			
							Bald Head Total		22,755	-63,500	-93,700			

Table 3.2: Bald Head Island shoreline volume change (November 2015 to April 2016).

	Start Station	End Station	Reach (FT)	Volume Change			Start Station	End Station	Reach (FT)	Volume Change		
				Above +2.51 (FT)	Above -16 (FT)					Above +2.51 (FT)	Above -16 (FT)	
West Beach	Jetty	000+00	160	+100	+1,600		056+56	060+51	423	-1,500	-9,700	South Beach
	000+00	004+00	400	+100	+2,800		060+51	065+50	510	700	-3,800	
	004+00	008+00	400	-500	+100		065+50	069+46	423	1,700	-1,300	
	008+00	012+00	400	-1,500	-2,600		069+46	073+39	442	900	-6,400	
	012+00	016+00	400	-1,300	-2,500		073+39	076+37	516	-1,500	-15,700	
	016+00	020+00	400	+100	+600		076+37	084+16	611	-4,700	-26,600	
	020+00	024+00	400	-800	-1,300		084+16	088+23	471	-2,500	-12,700	
	024+00	028+00	400	-2,500	-6,900		088+23	092+15	455	-3,500	-11,700	
	Subtotal		2,960	-6,300	-8,200		092+15	097+10	536	-4,700	-18,500	
Point (North of Groin)	028+00	032+00	395	-4,000	-12,900		097+10	102+08	525	-4,700	-15,900	
	032+00	034+00	200	-2,400	-8,200		102+08	106+00	436	-4,200	-12,200	
	034+00	036+00	210	-1,100	-3,500		106+00	110+00	400	-3,600	-11,300	
	036+00	038+00	230	+1,000	+7,200		110+00	114+00	388	-3,000	-12,100	
	038+00	039+60	230	+600	+8,100		114+00	118+00	407	-2,800	-12,600	
	039+60	041+50	220	-1,400	-2,000		118+00	122+00	413	-3,400	-14,700	
	041+50	043+47	220	-2,400	-6,400		122+00	126+00	405	-3,100	-13,600	
	043+47	044+25	190	-2,500	-2,900		126+00	130+00	405	-3,400	-11,500	
	044+25	045+07	190	-2,600	+2,200		130+00	134+00	398	-3,800	-11,700	
	045+07	046+00	200	-2,600	+3,300		134+00	138+00	401	-3,400	-8,000	
	Subtotal		2,285	-17,400	-15,100		138+00	142+00	400	-3,200	-6,800	
Point (South of Groin)	046+00	046+89	200	-1,100	-3,000		142+00	146+00	400	-3,400	-10,300	
	046+89	049+00	250	+2,200	+4,500		146+00	150+00	399	-2,800	-10,400	
	049+00	050+50	100	+1,300	+4,900		150+00	154+00	385	-1,800	-7,000	
	050+50	051+00	100	+900	+300		154+00	158+00	383	-1,100	-5,500	
	051+00	052+64	240	+1,000	+8,000		158+00	162+00	386	-500	-4,200	
	052+64	054+00	135	-100	+8,600		162+00	166+00	393	200	-1,100	
	054+00	056+56	380	-1,000	+3,400		166+00	170+00	394	200	900	
	Subtotal		1,405	+3,200	+26,700		170+00	174+00	400	-300	+1,000	
Note: Elevations are referenced to NGVD 1929.						174+00	178+00	400	-600	+200		
						178+00	182+00	400	-800	-1,200		
						182+00	186+00	400	-1,100	-500		
						186+00	190+00	400	-1,500	+4,500		
						190+00	194+00	400	-1,300	-2,200		
						194+00	198+00	400	-1,000	-8,500		
						198+00	202+00	400	-800	-1,500		
						202+00	206+00	400	-1,300	-10,000		
						206+00	210+00	400	-1,200	-15,100		
						210+00	214+00	400	-2,300	-15,500		
						Subtotal		16,105	-75,100	-323,200		
						Bald Head Total		22,755	-95,600	-319,800		

Table 3.3: Bald Head Island shoreline volume change (April 2015 to April 2016).

				Volume Change						Volume Change			
	Start Station	End Station	Reach (FT)	Above +2.51 (FT)	Above -16 (FT)		Start Station	End Station	Reach (FT)	Above +2.51 (FT)	Above -16 (FT)		
West Beach	Jetty	000+00	160	+1,300	+6,200		056+56	060+51	423	-8,400	-16,900	South Beach	
	000+00	004+00	400	+2,100	+9,000		060+51	065+50	510	-13,900	-28,000		
	004+00	008+00	400	0	+300		065+50	069+46	423	-11,900	-25,600		
	008+00	012+00	400	-1,900	-4,200		069+46	073+39	442	-11,900	-24,900		
	012+00	016+00	400	-2,300	-5,400		073+39	076+37	516	-14,300	-31,800		
	016+00	020+00	400	-1,300	-2,900		076+37	084+16	611	-16,000	-41,100		
	020+00	024+00	400	+900	+5,900		084+16	088+23	471	-10,500	-29,800		
	024+00	028+00	400	+600	-1,700		088+23	092+15	455	-9,800	-29,500		
	Subtotal		2,960	-600	+7,200		092+15	097+10	536	-11,200	-33,500		
Point (North of Groin)	028+00	032+00	395	-1,300	-19,100		097+10	102+08	525	-11,800	-31,500		
	032+00	034+00	200	-700	-10,400		102+08	106+00	436	-9,000	-24,300		
	034+00	036+00	210	0	-5,600		106+00	110+00	400	-8,100	-21,500		
	036+00	038+00	230	+2,600	+6,900		110+00	114+00	388	-8,800	-20,900		
	038+00	039+60	230	+4,700	+16,200		114+00	118+00	407	-10,600	-21,400		
	039+60	041+50	220	+5,200	+17,200		118+00	122+00	413	-11,800	-24,400		
	041+50	043+47	220	+5,500	+18,800		122+00	126+00	405	-10,600	-21,700		
	043+47	044+25	190	+4,200	+17,300		126+00	130+00	405	-9,800	-19,600		
	044+25	045+07	190	+3,300	+18,600		130+00	134+00	398	-9,800	-19,000		
	045+07	046+00	200	+3,900	+18,700		134+00	138+00	401	-8,900	-14,800		
	Subtotal		2,285	+27,400	+78,600		138+00	142+00	400	-7,800	-19,400		
Point (South of Groin)	046+00	046+89	200	+6,800	+11,000		142+00	146+00	400	-8,500	-27,700		
	046+89	049+00	250	+11,600	+17,600		146+00	150+00	399	-7,400	-26,400		
	049+00	050+50	100	+4,100	+8,000		150+00	154+00	385	-1,800	-14,900		
	050+50	051+00	100	+2,900	+2,800		154+00	158+00	383	+3,500	-100		
	051+00	052+64	240	+4,700	+16,400		158+00	162+00	386	+4,900	+8,700		
	052+64	054+00	135	+900	+12,400		162+00	166+00	393	+4,200	+9,500		
	054+00	056+56	380	-2,500	+5,000		166+00	170+00	394	+3,100	+7,000		
	Subtotal		1,405	+28,500	+73,200		170+00	174+00	400	+1,900	+6,600		
Note: Elevations are referenced to NGVD 1929.						174+00	178+00	400	+800	+6,300			
						178+00	182+00	400	+600	+4,600			
						182+00	186+00	400	+900	+1,900			
						186+00	190+00	400	+1,200	-200			
						190+00	194+00	400	+1,700	-1,300			
						194+00	198+00	400	+2,700	+2,100			
						198+00	202+00	400	+2,100	+5,500			
						202+00	206+00	400	-500	-10,100			
						206+00	210+00	400	-2,100	-22,100			
						210+00	214+00	400	-6,800	-22,300			
						Subtotal		16,105	-214,400	-572,500			
						Bald Head Total		22,755	-159,100	-413,500			

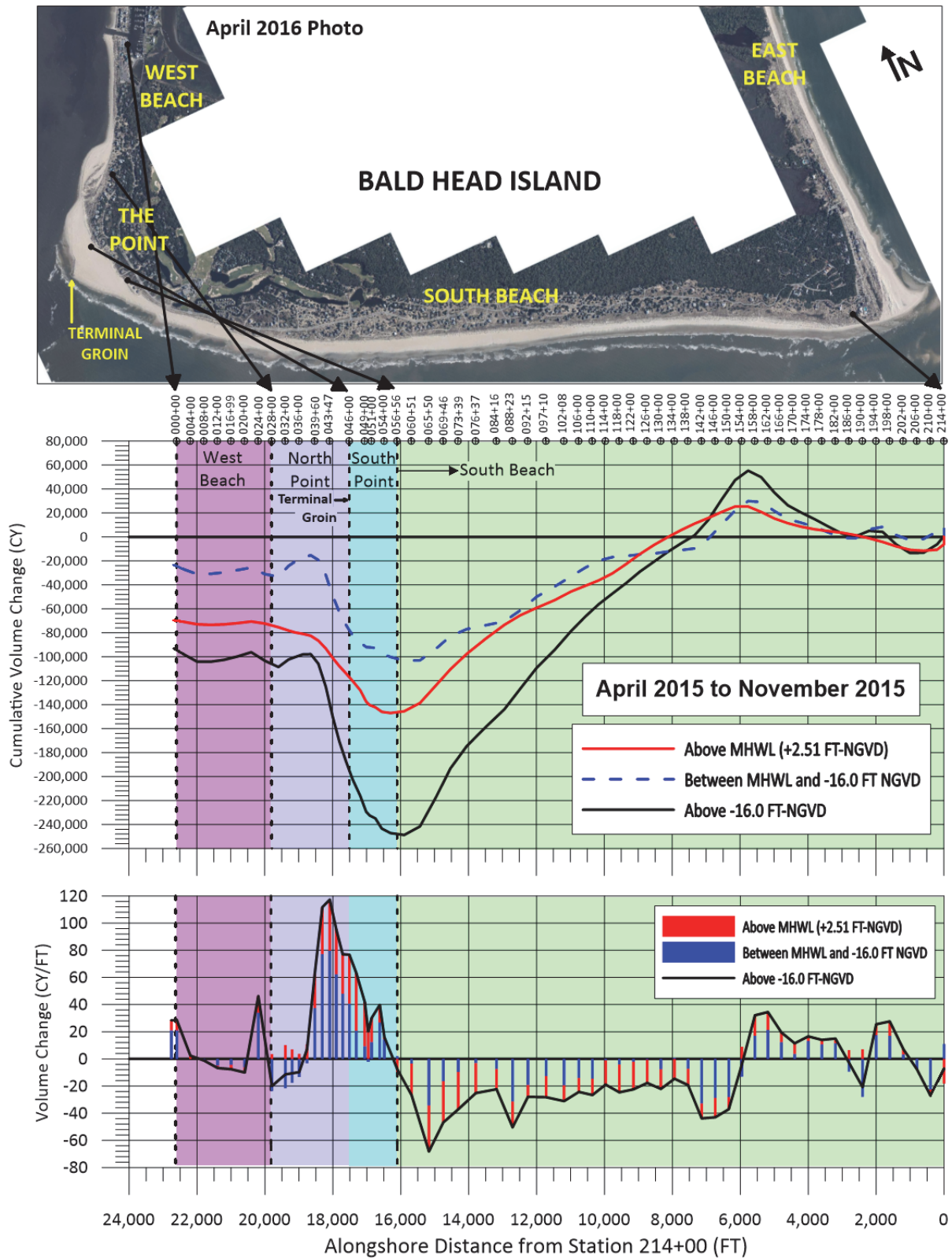


Figure 3.1: Volume change along the Bald Head Island shoreline between April 2015 and November 2015.

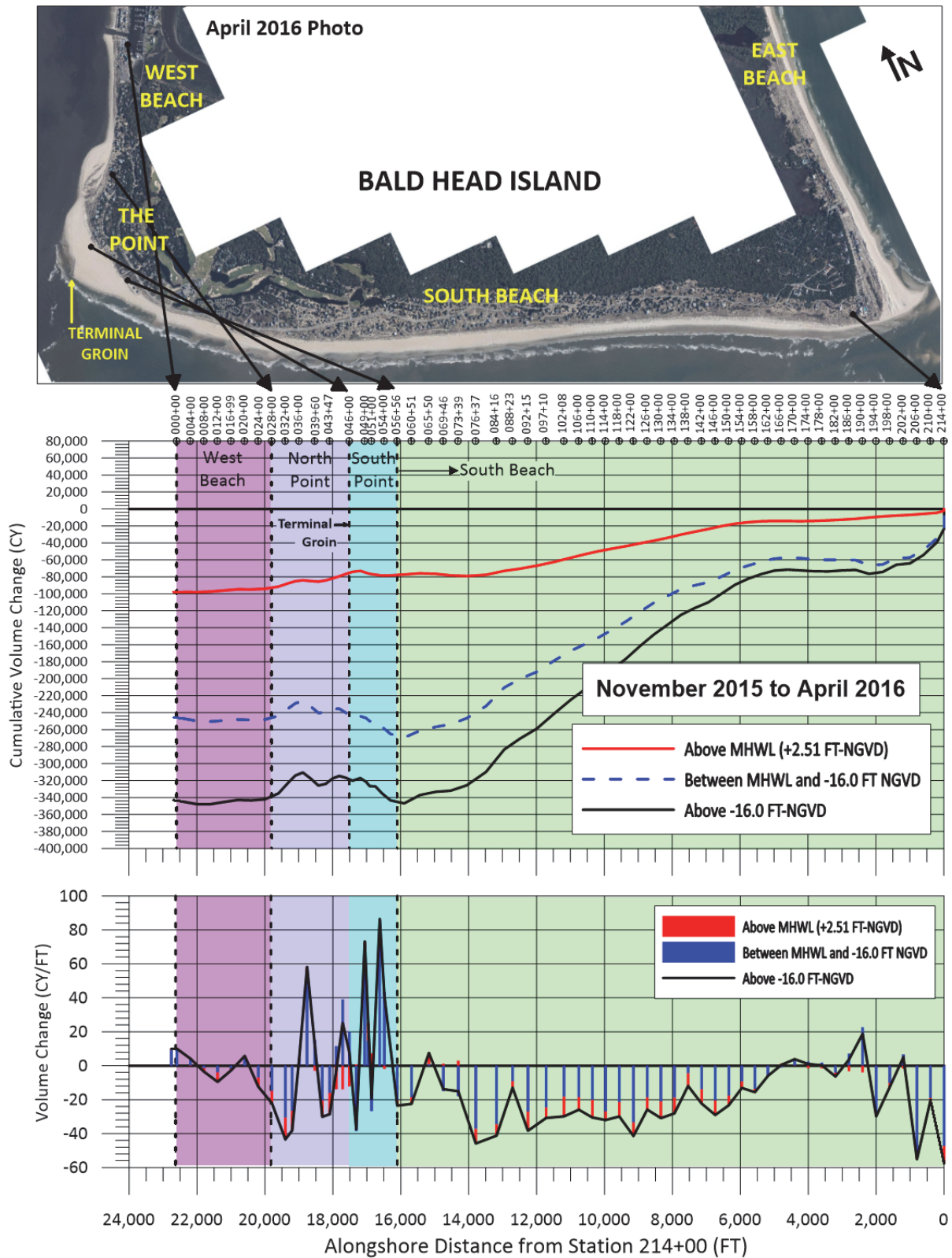


Figure 3.2: Volume change along the Bald Head Island shoreline between November 2015 and April 2016.

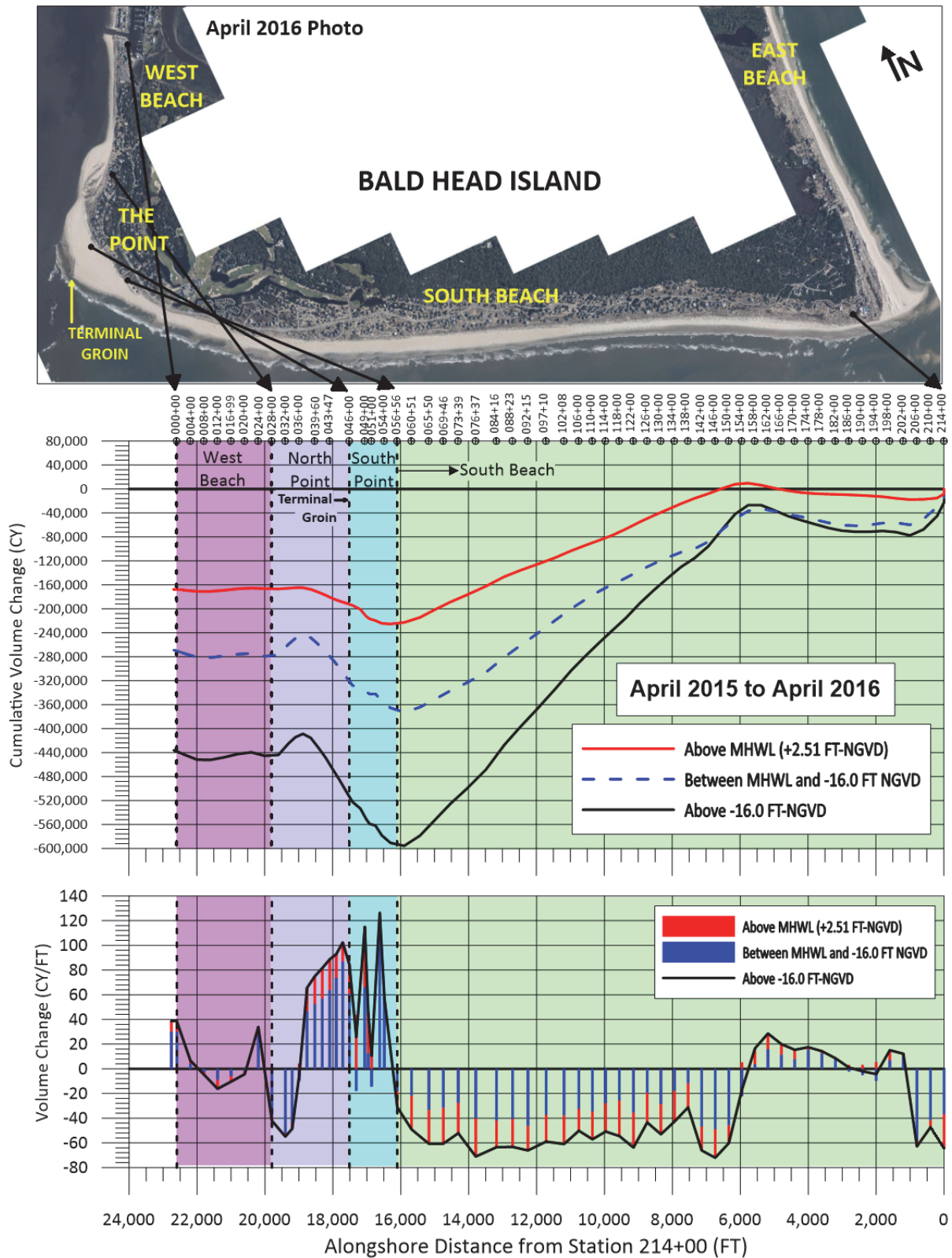


Figure 3.3: Volume change along the Bald Head Island shoreline between April 2015 and April 2016.

Table 3.4: Location of the **BERM** (+6.0 ft-NGVD) relative to the November 2000 (pre-2001 fill) location for selected monitoring surveys.

	Station	Location Relative to Nov. 2000				Station	Location Relative to Nov. 2000		
		April 2015	Nov. 2015	April 2016			April 2015	Nov. 2015	April 2016
West Beach	000+00	+2.6	+68.9	+109.0	South Beach	060+51	+196.1	+82.9	+85.8
	004+00	-22.0	-1.1	+33.7		065+50	+263.7	+90.7	+173.0
	008+00	-6.2	-1.7	+21.6		069+46	+273.1	+145.7	+180.2
	012+00	+47.4	+46.2	+63.7		073+39	+324.9	+193.7	+234.3
	016+00	+37.8	+25.6	+55.4		076+37	+319.7	+221.4	+191.4
	020+00	+45.2	+24.9	+73.6		084+16	+344.6	+255.3	+275.7
	024+00	+156.8	+352.0	+404.4		088+23	+365.3	+285.8	+317.9
	028+00	+184.9	+418.1	+408.4		092+15	+315.1	+251.4	+263.2
Point (North of Groin)	032+00	+301.0	+315.2	+264.4		097+10	+271.9	+191.8	+203.8
	034+00	No November 2000 profile				102+08	+262.4	+214.6	+185.7
	036+00	+68.4	+105.0	+164.5		106+00	+277.0	+214.6	+249.5
	038+00	No November 2000 profile				110+00	+310.7	+242.0	+253.7
	039+60	-78.7	+83.9	+167.8		114+00	+339.1	+271.5	+268.0
	041+50	No November 2000 profile				118+00	+376.8	+283.3	+302.1
	043+47	-181.4	+141.4	+84.6		122+00	+418.6	+300.4	+326.4
	044+25	No November 2000 profile				126+00	+434.6	+338.4	+362.2
	045+07	-166.8	+105.3	+56.9		130+00	+428.3	+352.2	+358.9
Point (South of Groin)	046+00	No November 2000 profile				134+00	+424.8	+374.3	+363.5
	046+89	-45.1	+210.4	+339.5		138+00	+415.4	+355.5	+376.5
	049+00	No November 2000 profile				142+00	+398.9	+337.8	+354.3
	050+50	No November 2000 profile				146+00	+380.9	+310.2	+318.8
	051+00	No November 2000 profile				150+00	+315.7	+264.6	+291.7
	052+64	+242.4	+266.6	+331.4		154+00	+137.4	+225.0	+272.4
	054+00	No November 2000 profile				158+00	+114.4	+187.6	+245.6
	056+56	+211.1	+160.7	+177.4		162+00	+115.0	+165.3	+235.8
Positive values indicate shoreline advance relative to the pre-construction location. Negative values indicate shoreline erosion and are highlighted in red.						166+00	+131.2	+156.1	+248.3
						170+00	+118.0	+141.5	+232.7
						174+00	+107.3	+118.3	+207.7
						178+00	+125.7	+134.5	+205.9
						182+00	+125.8	+133.6	+176.4
						186+00	+102.0	+118.9	+167.4
						190+00	+113.0	+142.5	+197.1
						194+00	+137.0	+166.5	+228.9
						198+00	+116.0	+159.6	+217.6
						202+00	+127.7	+151.4	+198.7
						206+00	+88.4	+92.2	+98.7
						210+00	+35.5	+25.2	+67.1
						214+00	-74.9	-117.3	-97.3

Table 3.5: Location of the **MHWL** (+2.51 ft-NGVD) relative to the November 2000 (pre-2001 fill) location for selected monitoring surveys.

	Station	Location Relative to Nov. 2000				Station	Location Relative to Nov. 2000		
		April 2015	Nov. 2015	April 2016			April 2015	Nov. 2015	April 2016
West Beach	000+00	+7.1	+53.1	+65.6	South Beach	060+51	+191.9	+67.7	+45.0
	004+00	-22.3	-13.9	-4.6		065+50	+241.9	+75.4	+129.5
	008+00	-4.1	-9.6	-11.9		069+46	+264.3	+134.8	+139.7
	012+00	+2.4	-7.1	-11.0		073+39	+319.5	+200.6	+203.1
	016+00	+19.8	-0.1	+8.1		076+37	+311.9	+226.9	+162.7
	020+00	+36.8	+17.6	+34.9		084+16	+341.2	+305.6	+246.0
	024+00	+316.2	+375.9	+362.2		088+23	+378.4	+287.1	+290.5
	028+00	+352.4	+317.2	+290.1		092+15	+338.3	+313.7	+227.7
Point (North of Groin)	032+00	+257.8	+230.0	+155.5		097+10	+282.3	+209.2	+172.2
	034+00	No November 2000 profile				102+08	+270.8	+236.0	+156.5
	036+00	+61.1	+42.1	+76.1		106+00	+293.8	+263.2	+219.4
	038+00	No November 2000 profile				110+00	+320.3	+283.7	+213.4
	039+60	-36.7	+79.9	+81.2		114+00	+347.9	+274.3	+235.6
	041+50	No November 2000 profile				118+00	+378.6	+318.7	+270.3
	043+47	-133.2	+73.4	-39.2		122+00	+406.1	+353.6	+285.8
	044+25	No November 2000 profile				126+00	+421.2	+370.0	+324.2
	045+07	-17.3	+110.2	+8.9		130+00	+412.7	+378.3	+321.0
	046+00	No November 2000 profile				134+00	+413.8	+379.4	+330.3
Point (South of Groin)	046+89	+188.6	+260.0	+294.9		138+00	+404.1	+370.4	+332.7
	049+00	No November 2000 profile				142+00	+408.1	+351.8	+315.6
	050+50	No November 2000 profile				146+00	+380.0	+319.5	+276.7
	051+00	No November 2000 profile				150+00	+334.4	+281.4	+250.8
	052+64	+217.2	+246.0	+285.5		154+00	+266.6	+249.5	+230.7
	054+00	No November 2000 profile				158+00	+163.9	+227.0	+210.1
	056+56	+202.9	+150.3	+131.7		162+00	+139.9	+201.9	+197.8
						166+00	+147.7	+189.7	+196.6
Positive values indicate shoreline advance relative to the pre-construction location. Negative values indicate shoreline erosion and are highlighted in red.						170+00	+135.5	+167.4	+180.1
						174+00	+137.8	+158.2	+169.7
						178+00	+162.4	+190.8	+179.3
						182+00	+161.1	+181.2	+138.1
						186+00	+124.8	+171.9	+126.5
						190+00	+119.7	+157.3	+147.6
						194+00	+147.3	+182.2	+175.1
						198+00	+130.2	+181.4	+182.7
						202+00	+135.3	+147.5	+146.6
						206+00	+99.1	+90.6	+48.4
						210+00	+42.2	+5.0	+12.6
						214+00	-85.2	-135.7	-137.5

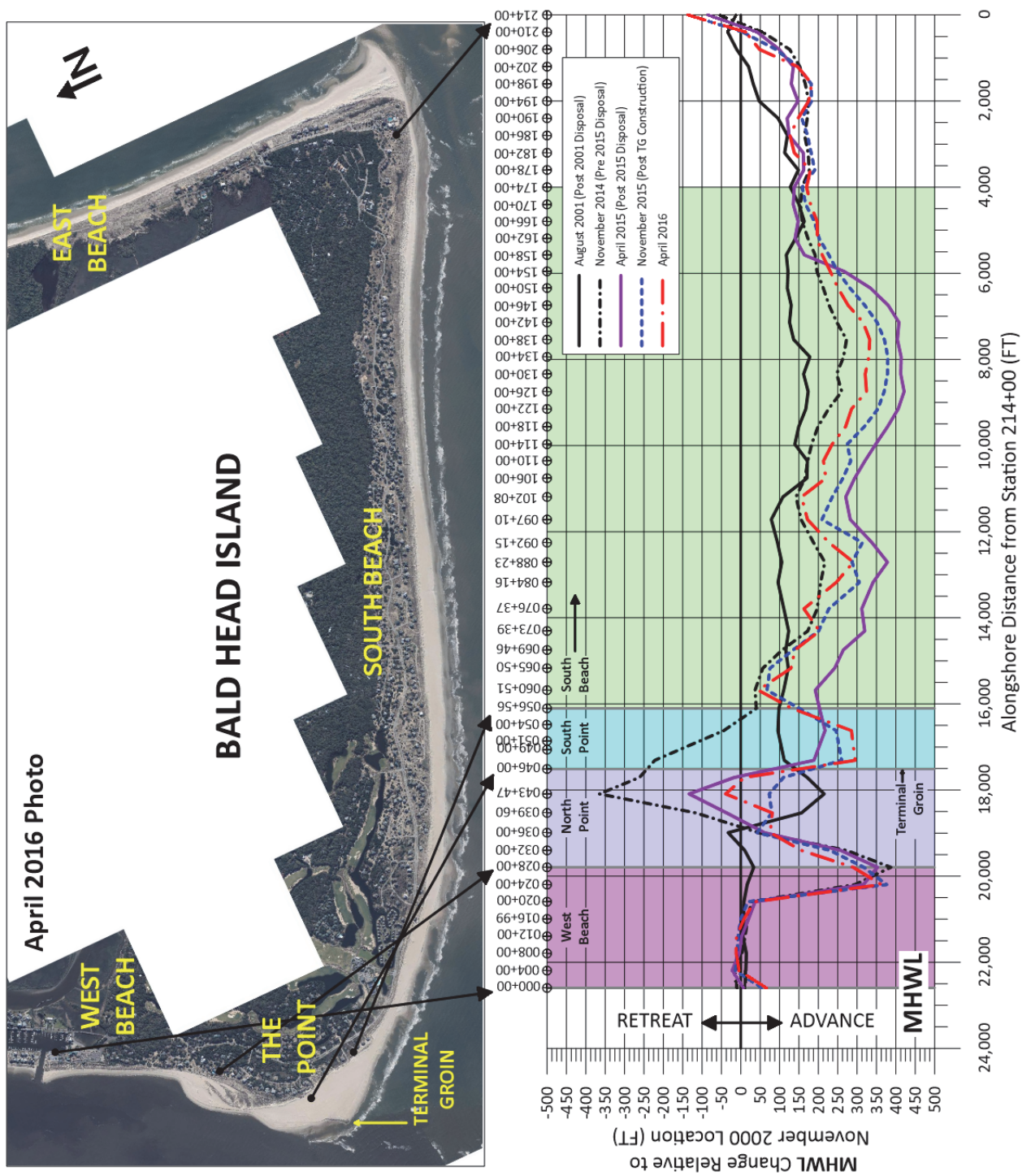


Figure 3.4: Location of the MHWL (+2.51 ft-NGVD) relative to the Nov. 2000 (pre-2001 fill) location.

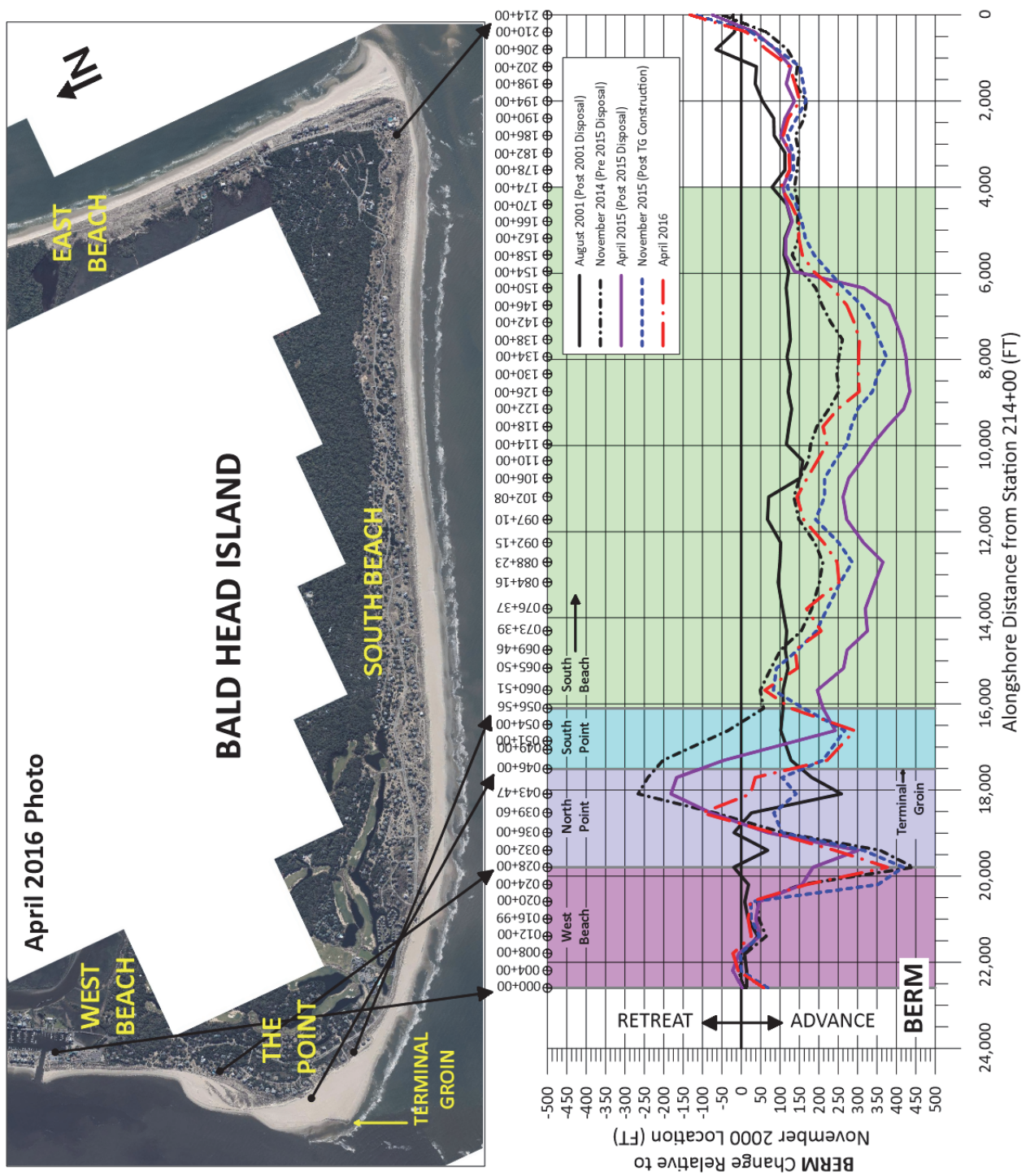


Figure 3.5: Location of the BERM (+6.00 ft-NGVD) relative to the Nov. 2000 (pre-2001 fill) location.

3.3 West Beach, “The Point” and South Beach: Discussion

3.3.1 Survey Period: April 2015 to November 2015

This 7 month survey period represents changes immediately following completion of the 1.3 Mcy 2015 federal disposal project along South and West Beaches. Also during this period, a 1,300 ft terminal groin was constructed at “the Point” (~June to November 2015) and the Bald Head Island marina jetties located at the northern limit of West Beach were extended. This period also represents the 61 to 68 months post-construction monitoring period for the 2009/10 Village sponsored beach renourishment.

As depicted by **Table 3.1**, the island-wide *net* shoreline volume change trend for this period was mildly erosional with -93,700 cy (-4.1 cy/ft) of loss, mol. over the 7 month span. Consistent with the overall loss, the MHWL retreated by an average of just over 3 ft along the approximate 22,755 ft of shoreline (West Beach, “the Point”, and South Beach). However, despite experiencing a relatively mild overall erosion and recession, subreaches of the monitored shoreline experienced significant changes over this monitoring period.

West Beach was net accretional during this period with a gain of +15,400 cy (5.2 cy/ft) during this period above the -16 ft-NGVD contour. The continued northwesterly migration of the Point contributed to the net +12,400 cy gain of sand along the southern 800 feet West Beach shoreline. However, along the middle 1,200 ft of the West Beach reach (Sta 8+00 to 20+00) the shoreline was erosional, losing -2,800 cy and -8,000 cy above the MHWL and -16 ft-NGVD contours, respectively. The erosion along this reach was also evident in the measured shoreline locations as the MHWL and berm receded by averages of -11 ft and -16 ft, respectively.. Along the entire West Beach shoreline, the berm advanced by an average of +56 ft while the MHWL experienced no average change. The greatest advancement occurred immediately south of the newly extended groins (Sta. 0+00) where the berm and MHWL advanced by +66 ft and +46 ft respectively.

The entire 3,690 ft of “the Point” shoreline (Sta. 28+00 to 56+56) was net accretional during this monitoring period, gaining +140,200 cy above -16 ft-NGVD (+38.0 cy/ft). For purposes of evaluating the impacts of the newly constructed terminal groin completed in November 2015, “the Point” shoreline is subdivided into two reaches with Sta. 46+00, the approximate location of the terminal groin, as the dividing station. North of the terminal groin (Sta. 28+00 to 46+00), the shoreline was net accretional, gaining +44,800 cy (+19.6 cy/ft) above the MHWL and +93,700 cy (41.0 cy/ft) above -16 ft-NGVD. Along this reach, the MHWL advanced by an average of +114 ft. South of the terminal groin (Sta. 46+00 to

56+56), the shoreline gained +23,300 (+16.6 cy/ft) above the MHWL and +46,500 cy (+33.1 cy/ft) above the -16 ft-NGVD contour. Similarly, the MHWL advanced by an average of +44 ft along this reach.

South Beach was net erosional during the period, losing roughly -139,300 cy (-8.6 cy/ft) above the MHWL and -249,300 cy (-15.5 cy/ft) above -16 ft-NGVD. Approximately 71% of the monitoring stations (27 of 38) were net erosional include all of the profiled west of Sta 154+00. During this period, The MHWL and berm receded by averages of -40 ft and -30 ft, respectively. Consistent with the volume losses, every monitoring station west of Sta 154+00 experienced berm and MHWL recession. The average berm recession along this subreach was 84 ft and the average MHWL recession was 66 ft.

3.3.2 Survey Period: November 2015 to April 2016

This five (5) month survey period represents changes immediately following completion of terminal groin and Bald Head Island marina jetties extensions. The island-wide *net* volume change was a loss of approximately -319,800 cy (-14.1 cy/ft). Likewise, the MHWL and berm on average retreated by averages of -15 ft and -32 ft, respectively.

West Beach was net erosional during this period with losses of -6,300 cy (-2.1 cy/ft) and -8,200 cy (-2.8 cy/ft) above the MHWL and -16 ft-NGVD contours, respectively. Similarly, the berm receded by an average of 15 ft while the MHWL remained unchanged on average.

Along “the Point” shoreline north of the terminal groin, the beach lost -15,100 cy (-6.6 cy/ft) above the -16 ft-NGVD contour. However, most of this net loss occurred above the MHWL. Above the MHWL, the net loss was -17,400 cy while between the MHWL and the -16 ft-NGVD contour, the shoreline *gained* +2,300 cy. The losses along the upper “dry beach” are apparent in the measured shoreline changes. During this period, the berm retreated by an average of -94 ft and the MHWL by -43.6 ft.

Along “the Point” shoreline south of the terminal groin, the beach gained +3,200 cy (+2.3 cy/ft) above the MHWL and +26,700 cy (19.0 cy/ft) above the -16 ft-NGVD contour. However, most of this net loss occurred above the MHWL. During this period, the berm advanced by an average of +37 ft and the MHWL by +48 ft.

South Beach was net erosional during the period, losing roughly -75,100 cy (-4.7 cy/ft) above the MHWL and -323,200 cy (-20.1 cy/ft) above -16 ft-NGVD. Similar to the previous monitoring period, all of the monitoring stations west of Sta. 162+00 were net erosional. In total, approximately xx% of the monitoring stations (27 of 38) were net erosional include all of the profiled west of Sta 154+00. During this period, The MHWL and berm receded by averages of -40 ft and -30 ft, respectively. Consistent with the volume losses, every monitoring station west of Sta 154+00 experienced berm and MHWL recession. The average berm recession along this subreach was 84 ft and the average MHWL recession was 66 ft.

3.3.3 Year 14 Monitoring Results: April 2015 to April 2016

As previously discussed, observed volumetric changes are highly influenced by the direct placement of approximately 1.3 Mcy of sand associated with the 2015 federal beach disposal project immediately prior to the monitoring year and the construction of the terminal groin and Bald Head Island marina jetty extensions during the monitoring year. During Year 14 in its entirety, the island experienced a net loss of -413,500 cy (-18.2 cy/ft) above the -16 ft contour. Above the MHWL, the island lost -159,100 cy (-7.0 cy/ft). However, all of these net losses occurred along South Beach, as both West Beach and “the Point” experienced net accretion.

Along West Beach, the shoreline gained approximately +7,300 cy above -16 ft-NGVD and lost -600 cy (-0.2 cy/ft) above the MHWL. During this period, the berm advanced by an average of +15 ft and the MHWL receded by -9 ft.

The entire Point shoreline (north and south of the terminal groin), experienced a net gain of roughly +151,800 cy (41.1 cy/ft) above -16 ft-NGVD during the latest monitoring year. Likewise, the shoreline advanced by averages of +113 ft (berm) and +84 ft (MHWL). A portion of this reach as well as the adjacent south beach received direct sand placement as part of the 2015 disposal project completed immediately prior to the monitoring year.

Nearly the entire Point shoreline was net accretional during the monitoring year. Of the 14 monitoring stations located along these reaches, only 3 exhibited net volume loss. These stations (Sta. 28+00, 32+00 and 34+00) are located at the northern limit of the Point shoreline, immediately adjacent to West Beach and represent approximate 21 percent (800 ft) of the combined Point shoreline (north and south of the terminal groin).

The South Beach shorefront which received the majority of the 2015 disposal sand lost approximately -214,400 cy (13.3 cy/ft) above the MHWL and -572,500 cy (35.5 cy/ft) above -16 ft-NGVD. Much of the measured change can be assumed to be associated with post-fill equilibration of the beach profile. Similarly, the South Beach shoreline receded by averages of -68 ft (berm) and -57 ft (MHWL). All of the monitoring stations west of Sta. 154+00 experienced net erosion over the most recent monitoring year. Along this reach (Stat. 56+56 to 154+00), the beach lost -568,600 cy (-56.6 cy/ft) with berm and MHWL line average recession of -113 ft and -101 ft, respectively.

3.3.4 Long-Term Beach Changes: November 2000 to April 2016

For purposes of tracking gross sand placement performance, **Figure 3.6** plots a time history of cumulative volume change relative to November 2000 conditions. **Figure 3.7** presents net volumetric change (alongshore above -16 ft NGVD) for the maximum period of comparison to date (*i.e.* November 2000 and April 2016). In both figures the effects of direct sand placement are included. As with other similar analyses over the last decade, East Beach, Cape Fear and Row Boat Row are excluded from this analysis.

The classic “saw-tooth” effects of episodic sand placement, as reflected in **Figure 3.6**, are indicative of the periodic infusion of sand along South Beach at Bald Head Island associated with the placement of sand during initial construction of the channel deepening project, three (3) subsequent beach disposal operations pursuant to the WHSMP, the proactive beach renourishment project constructed by the Village in 2009/10 and to a smaller degree the emergency fill of 2012. The Village 1.85 Mcy fill was constructed with the knowledge gained through monitoring that certain irreparable large scale impacts to Bald Head Island would predictably occur as a direct result of the proposed diversion of channel maintenance material in 2009 to Oak Island. *Note – a similar diversion is expected to occur in 2017 or 18, i.e. the next disposal event.*

Accordingly, in the next reformulation of the Wilmington Harbor Sand Management Plan by the Wilmington District, USACOE, it is strongly recommended that they evaluate not only the time history, or “performance” of sand placement on Oak Island and Bald Head Island but also any areas of spatial deficits – particularly relative to the November 2000 benchmark survey as illustrated in **Figure 3.7**.

Table 3.6 presents a chronology of sediment volumes (measured in-place) for the three (3) segments of shoreline noted between the benchmark survey of November 2000 and present (*i.e.* April 2016). Currently, within the **approximate** 22,755 ft of shoreline considered, there is a net gain of +3,305,700 cy. However, after removing the effects of the sand artificially placed along the Bald Head Island shoreline since the 2000 deepening project, the net change in Island-wide volume (exclusive of East Beach and the Cape Fear Point) is a measured sediment *loss* of -5,733,100 cy. It is important to note that the chronology of sand volumes presented by this Table reflects the *actual volumes* of sand *measured in-place* by survey and therefore is not related to projections based upon *estimated* volumes dredged in the channel or borrow site, *estimated* sand volumes placed, contractual “net pay” volumes, etc.

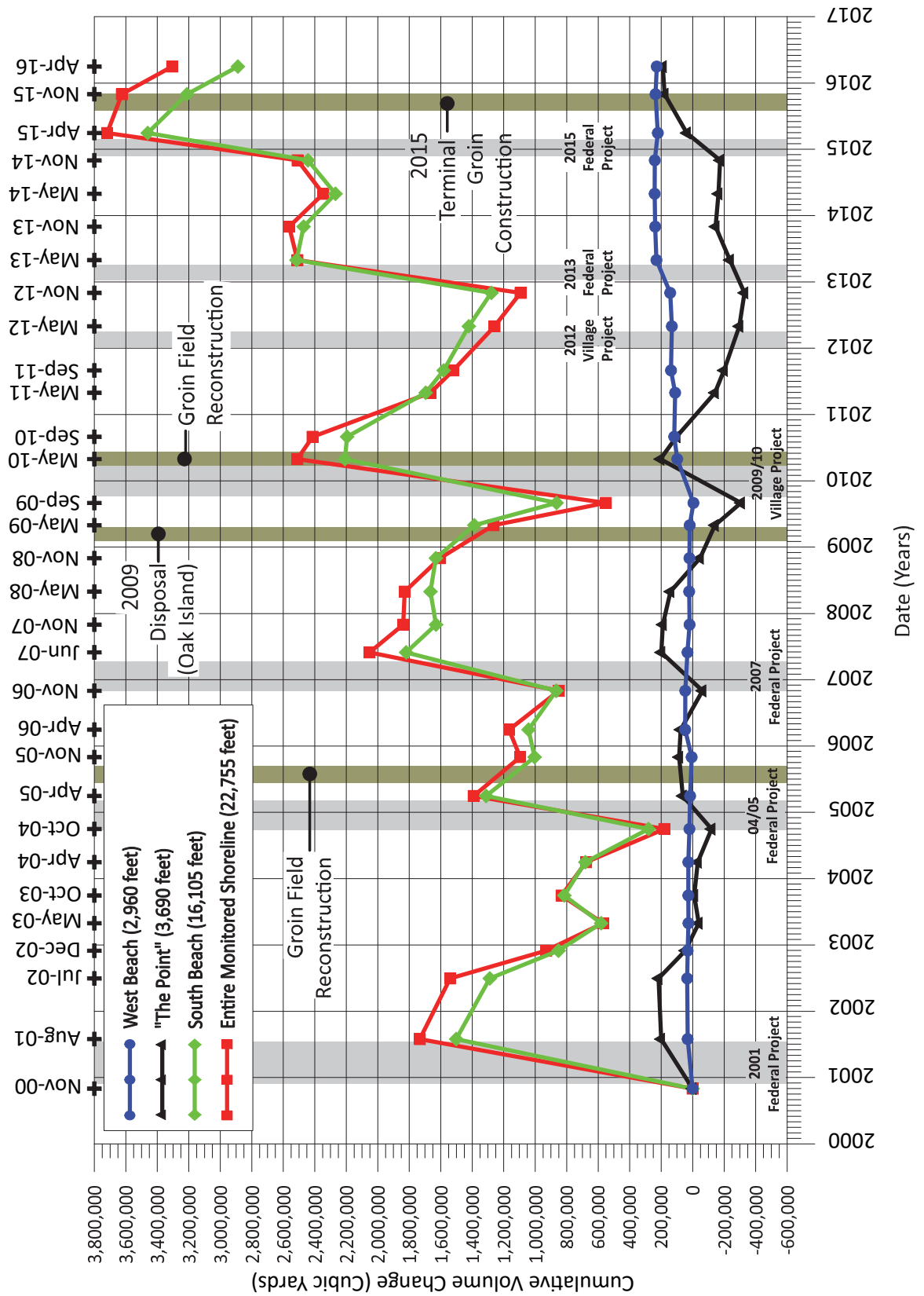


Figure 3.6: Cumulative volume change (above -16 ft-NGVD) relative to November 2000 conditions.

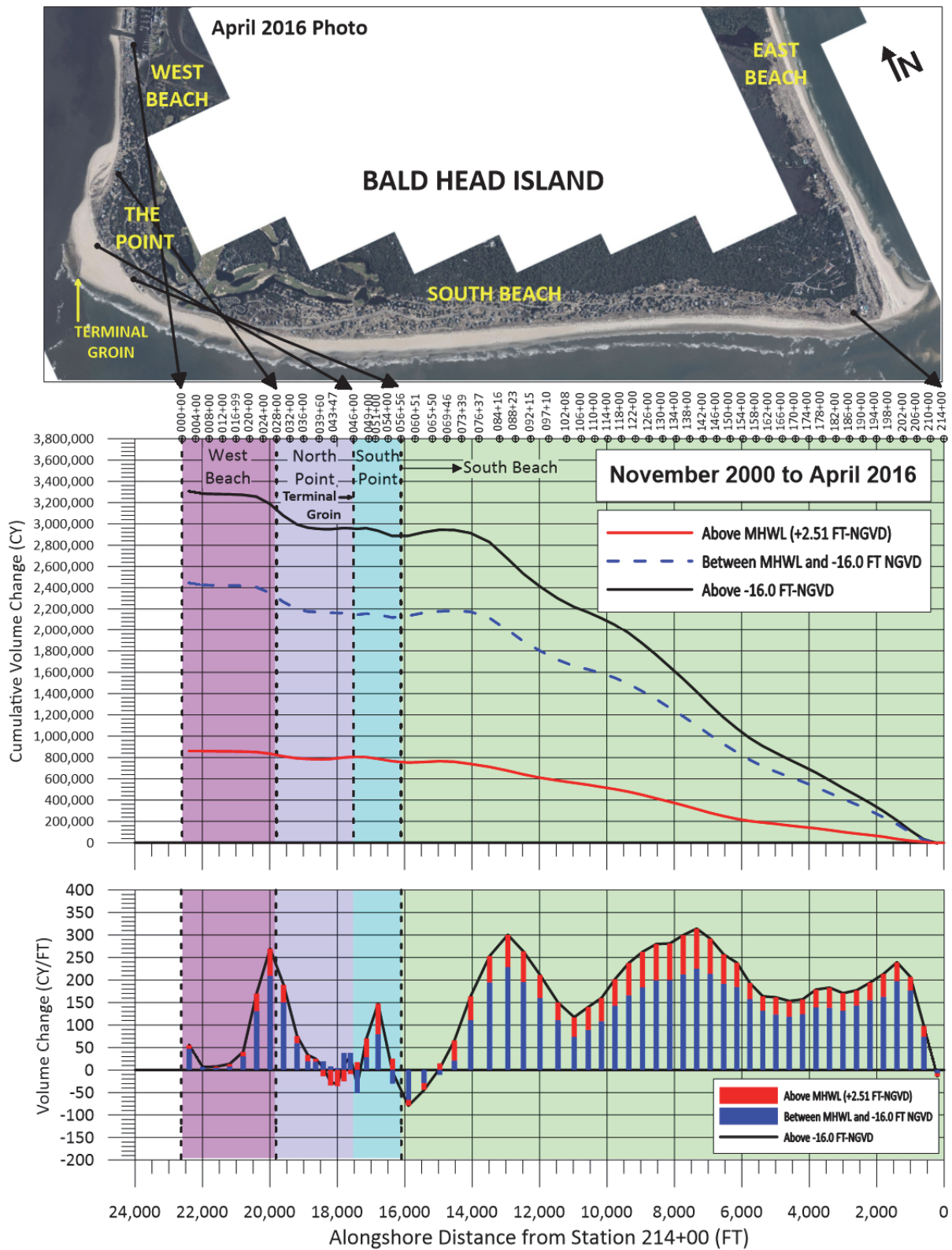


Figure 3.7: Volume change along the Bald Head Island shoreline between November 2000 and April 2016.

Table 3.6: Bald Head Island historic net volume change above -16 ft-NGVD (presumed closure depth).

Period	Start Date	End Date	Span (Months)	Volume Change Above -16 ft-NGVD (CY)			
				West Beach	The Point	South Beach	Total
Construction ⁸	Nov. 2000	Aug. 2001	9	+31,900	+199,500	+1,501,800	+1,733,200
Year 1	Aug. 2001	Jul. 2002	11	+2,900	+17,400	-213,300	-193,000
Year 2	Jul. 2002	May 2003	10	-8,000	-255,500	-707,400	-970,900
Year 3	May 2003	Apr. 2004	11	+1,000	+6,500	+99,900	+107,400
Year 4 (2004/05 Project) ⁹	Apr. 2004	Apr. 2005	12	-11,800	+94,700	+631,200	+714,100
Year 5 (2006 WB Project) ¹⁰	Apr. 2005	Apr. 2006	12	+32,000	+13,300	-270,200	-224,900
Year 6 (2007 Project) ¹¹	Apr. 2006	Jun. 2007	14	-15,400	+123,500	+778,100	+886,200
Year 7	Jun. 2007	May 2008	11	-10,300	-58,200	-154,600	-223,100
Year 8	May 2008	May 2009	12	-3,400	-282,800	-278,200	-564,400
Year 9 (2009/10 Project) ¹²	May 2009	May 2010	12	+79,300	+346,000	+821,300	+1,246,600
Year 10	May 2010	May 2011	12	+13,200	-346,100	-512,700	-845,600
Year 11 (2012 Beach Fill) ¹³	May 2011	May 2012	12	+20,800	-154,600	-273,300	-407,100
Year 12 (2013 Disposal)	May 2012	May 2013	12	+97,600	+59,800	+1,093,900	+1,251,300
Year 13	May 2013	May 2014	12	+11,600	+72,100	-247,500	-163,800
Year 14 (2015 Disposal)	May 2014	April 2015	11	-20,400	+201,800	+1,191,800	+1,373,200
Year 15	April 2015	April 2016	12	+7,200	+151,800	-572,500	-413,500
Pre-2000 Construction to Year 14	Nov. 2000	April 2016	162	+228,200	+189,200	+2,888,300	+3,305,700
Pre-2000 Construction to Year 14 (Fill Removed)	Nov. 2000	April 2016	162	NA	NA	NA	-5,733,100

⁸ 2001 Initial Disposal (1,849,500± CY)

⁹ 2005 Beach Disposal (1,217,000± CY)

¹⁰ 2006 West Beach Fill (47,800± CY)

¹¹ 2007 Beach Disposal (978,500± CY)

¹² 2009/10 Beach Fill (1,850,000± CY)

¹³ 2012 Beach Fill (138,000 ± CY)

¹⁴ 2013 Beach Disposal Fill (1,658,000 ± CY)

¹⁵ 2015 Beach Disposal Fill (1,320,000 ± CY)

The estimated *average* annual loss of sand from the monitored section of Bald Head Island shorefront (excluding East Beach) since November 2000, is approximately 371,700 cy per year. The assignment of an “average” annual long-term rate of sand loss at Bald Head Island however, is *not* necessarily a meaningful indicator of navigation project impact. Such an “average rate” is temporally biased by periods of beach fill equilibration, groin field effectiveness, the occurrence of episodic destabilizing dredging events in close proximity to the island, as well as other physiographic phenomena temporally affecting annualized quantities of alongshore sediment transport – from Bald Head Island – to the navigation channel, -- including meteorological effects.

3.3.5 MHWL Shoreline Position

As part of the permit required monitoring for the terminal groin project completed in late 2015, the MHWL was surveyed in December 2015 (post-construction) and April 2016 (5 months post-construction). The two surveys completed to date are plotted in **Figure 3.8**. In future monitoring reports, surveys are to be intercompared to assess both updrift fillet conditions and the location of the downdrift shoreline fronting the Cape Fear River.

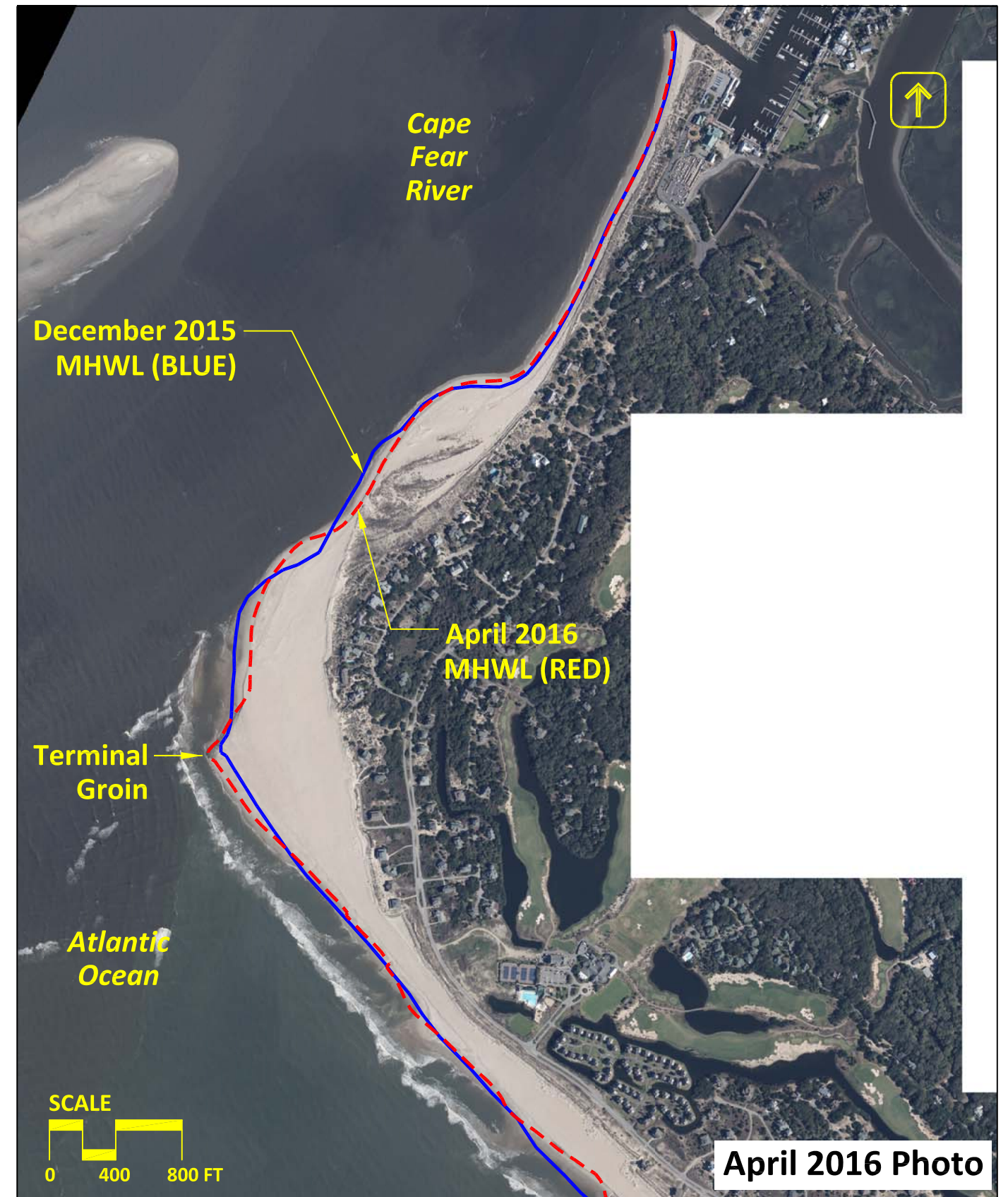
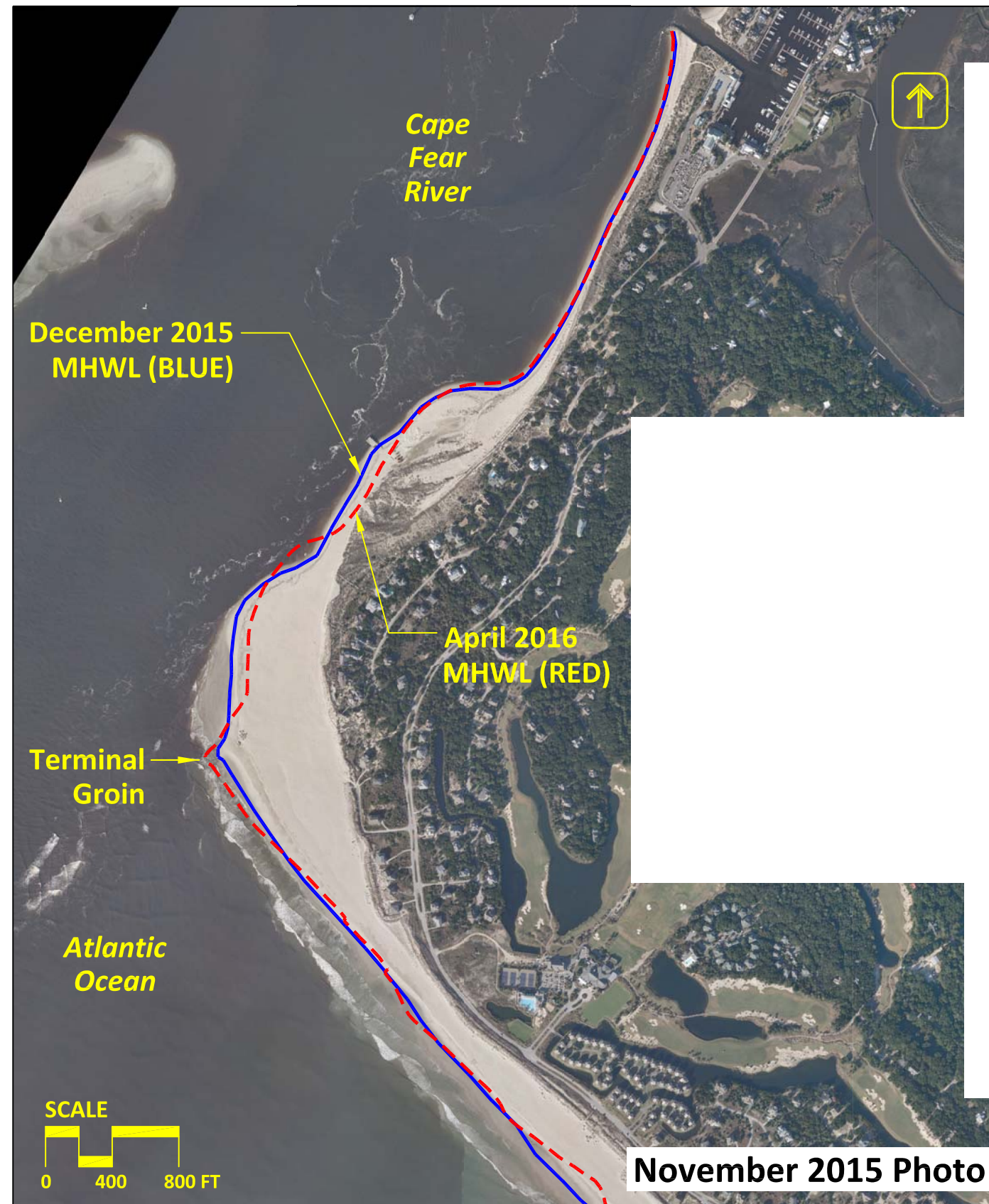


Figure 3.8:
MHWL positions in the vicinity of the
terminal groin Bald Head Island, NC
olsen associates, inc.

3.3.6 Chronology of the Point

Since the construction of the last Wilmington Harbor Channel Deepening Project – in about 2001, the spatial configuration of the spit feature (known as the “Point”) located at the juncture of South Beach and the entrance channel, has been a focal point of both the Village’s and the Corps’ monitoring programs. Accordingly, the chronology of the Point’s condition and evolution over time is indicative of the dynamic interaction between the ever increasing rate of sand transport westward along South Beach and the man-altered inlet hydrodynamics, as well as episodic dredging operations which result in sand removal from the island’s littoral system. In its simplest sense, the Point is to a large degree, a visual indicator of the processes involved and a potential “bellwether” as to direct and indirect impacts associated with the Navigation Project – irrespective of proactive or remedial actions specified within the Wilmington Harbor Sand Management Plan. The latter take the form of alongshore sand placement events intended to mitigate adverse impacts associated with both project construction and biennial channel maintenance required to ensure navigability.

Appendix F includes a high resolution visual chronology of the Point from 1998 to April 2016. Demarcated on each photo panel are the approximate September 2001 (blue line) and April 2016 (red line) apparent vegetation lines. Also placed on each photo are two reference marks (green dots). The variation in spit configuration from the before project photos (1998 and 1999) throughout the last approximate twelve years for pre- and post-fill timeframes can be easily visualized. Similarly, the advance and recession of the Point, as well as its gradual net northerly migration are self-evident. An additional perspective can be gained by an assessment of the locations of the pre-project and present day “vegetation lines” over the 1998 through 2016 timeframe.

As has been concluded throughout the fourteen years of comprehensive beach monitoring funded by the Village of Bald Head Island – improved conditions along the westernmost segment of South Beach and the Point are documented to last only about 2 years after each federal disposal event. Tantamount to that conclusion is the resultant fact that Bald Head Island must receive channel maintenance sand on a biennial basis – *if* the tenets of the State of N.C. Coastal Zone Consistency Finding required to permit the last federal navigation project improvement project are to be upheld. The latter was predicated upon the federal *Environmental Assessment* (USACOE 2000) for the proposed deepening project which stated that initial construction and subsequent channel maintenance beach disposal activities “will serve to maintain the shoreline in its present location”. Not only has this

commitment not been met pursuant to the tenets of the Sand Management Plan, it has *not* been met even with the additional placement of over 2 Mcy of sand and the complete reconstruction of a sand tube groinfield (twice), by the Village of Bald Head Island.

Both long term monitoring, as well as numerical modeling of the Cape Fear River Entrance by Olsen Associates, Inc. (Olsen 2013a), and the abutting Bald Head Island shoreline, indicated that additional structural measures appeared to be warranted. As the westernmost segment of South Beach shoreline has “rolled back,” the annualized rate of littoral transport at that location has correspondingly increased. Hence, in 2012 the Village initiated the permitting for a 1,300 ft terminal structure intended to both reorient the effective updrift shoreline alignment (so as to reduce annual sediment losses) and to allow for the reconstruction of a protective beach where one now cannot be reliably established through sand placement alone. That project was constructed during the summer of 2015. Beginning with this report, future monitoring reports will address the “new dynamic” expected to result from the implementation of the terminal groin structure. Predictions of shoreline change to both the updrift and downdrift shorelines abutting the structure – via DELFT 3D modeling – are discussed in a detailed report formulated for purposes of both design and permitting (Olsen 2013a). Additional monitoring data required by Permit will assist in the quantification of the terminal groin effects on littoral processes and resultant shoreline configuration. These include additional transects in the vicinity of the structure as well as an approximate MHWL delineation performed by survey every 6-months.

3.4 East Beach Shoreline Conditions

In November 2008, East Beach was added to the island-wide beach monitoring program¹⁶. Profiles along the East Beach shoreline are collected at seven (7) monitoring stations starting just north of Cape Fear and extending approximately 6,000 feet northward along the Onslow Bay facing shoreline (see **Figure 3.1**). Plots of these profiles are provided at the end of **Appendix A (Figures A-70 to A-76)**.

Tables 3.7 and 3.8 summarize the shoreline and volume changes measured during the April 2015 to November 2015 to April 2016 monitoring periods. Overall, the East Beach shoreline was strongly accretional, gaining approximately +20,400 cy (above the -16 ft-NGVD contour). The beach was likewise accretional above the MHWL, gaining approximately 20,800 cy over the entire monitoring year. Similarly, the BERM advanced by an average distance of +7.5 ft over this period while the MHWL remained relatively stable (<1 ft of average change).

Table 3.9 summarizes shoreline and volume changes measured over the entire period of survey record (November 2008 – April 2016). Over the 90-month period, the East Beach shoreline gained approximately +192,800 cy above the -16 ft-NGVD contour and +51,300 cy above the MHWL. Likewise, the MHWL and Berm advanced by averages of +62.5 and +27.7 ft, respectively over this period. However, most of these shoreline gains occurred immediately adjacent to Cape Fear (Sta. 224+80 to 254+80). In contrast, the 3,000 feet of monitored East Beach shoreline north of Sta. 254+80, lost approximately -30,400 cy and -87,400 cy above the MHWL and -16 ft-NGVD contour, respectively during this period.

As demonstrated by the survey data, it can be reasonably assumed that the condition of East Beach at any one time is, has been and will continue to be highly influenced by the configuration of the depositional spit and shoals associated with the “Cape Fear Point”. **Figure 3.8** photographically depicts the size, shape and effective footprint of Cape Fear for the six most recent available aerial photographs (August 2015, November 2015 & April 2016). Of further interest are the variations in spit size and orientation over the last several years (2008-2016) which are depicted by **Figure 3.9**. In its simplest sense, the Cape Fear spit is a highly dynamic feature which is influenced by sand supply originating from both the west (along South Beach) and the north (along East Beach). The Point is also susceptible to storm waves originating from *both* the west (Atlantic Ocean) and the east (Onslow Bay) and resultant tidal channels which episodically break through and subsequently influence localized patterns of sand deposition (or erosion).

¹⁶ Profiles were not acquired at East Beach in the fall of 2009

Table 3.7: East Beach shoreline and volume changes between April 2015 and November 2015.

Station	Reach (FT)	Volume Change (CY)			Shoreline Change (FT)	
		Above MHWL (+2.51 FT)	Above -16 FT		Berm (+6 FT)	MHWL (+2.51 FT)
224+80					+31.0	-47.5
	1,000	+5,400	-20,300			
234+80					+34.9	-10.3
	1,000	+5,000	-4,900			
244+80					+17.3	-6.1
	1,000	+2,700	+10,600			
254+80					+12.9	-11.0
	1,000	+2,800	+3,600			
264+80					+33.7	-21.4
	1,000	+300	-10,800			
274+80					+0.4	-41.3
	1,000	-2,200	-16,300			
284+80					+7.7	-30.1
Total	6,000	+14,000	-38,100		+19.7	-24.0

Table 3.8: East Beach shoreline and volume changes between November 2015 and April 2016.

Station	Reach (FT)	Volume Change			Shoreline Change (FT)	
		Above MHWL (+2.51 FT)	Above -16 FT		Berm (+6 FT)	MHWL (+2.51 FT)
224+80					-33.0	+25.5
	1,000	+1,400	+28,000			
234+80					-15.3	+31.2
	1,000	+200	+12,300			
244+80					-15.3	+20.7
	1,000	+1,500	+3,600			
254+80					-0.8	+27.4
	1,000	+300	+200			
264+80					-21.8	+3.1
	1,000	+700	+3,300			
274+80					+4.1	+35.8
	1,000	+2,700	+11,100			
284+80					-3.3	+23.4
Total	6,000	+6,800	+58,500		-12.2	+23.4

Table 3.9: Volume changes along East Beach (Sta. 224+80 to 284+80).

Survey Period	Volume Change Above Datum (CY)		
	Above MHWL (+2.51 ft-NGVD)	Below MHWL to -16 ft-NGVD	Total Change Above -16 ft-NGVD
November 2008 to May 2009	+700	-65,600	-64,900
May 2009 to May 2010	-23,300	-8,600	-31,900
May 2010 to May 2011	+10,600	+18,000	+31,300
May 2011 to May 2012	+5,700	+87,700	+93,400
May 2012 to May 2013	+20,000	-41,600	-21,600
May 2013 to May 2014	+17,700	+105,200	+122,900
May 2014 to April 2015	-900	+44,100	+43,200
April 2015 to November 2015	+14,000	-52,100	-38,100
November 2015 to April 2016	+6,800	+51,700	+58,500
November 2008 to April 2016	+51,300	+138,800	+192,800

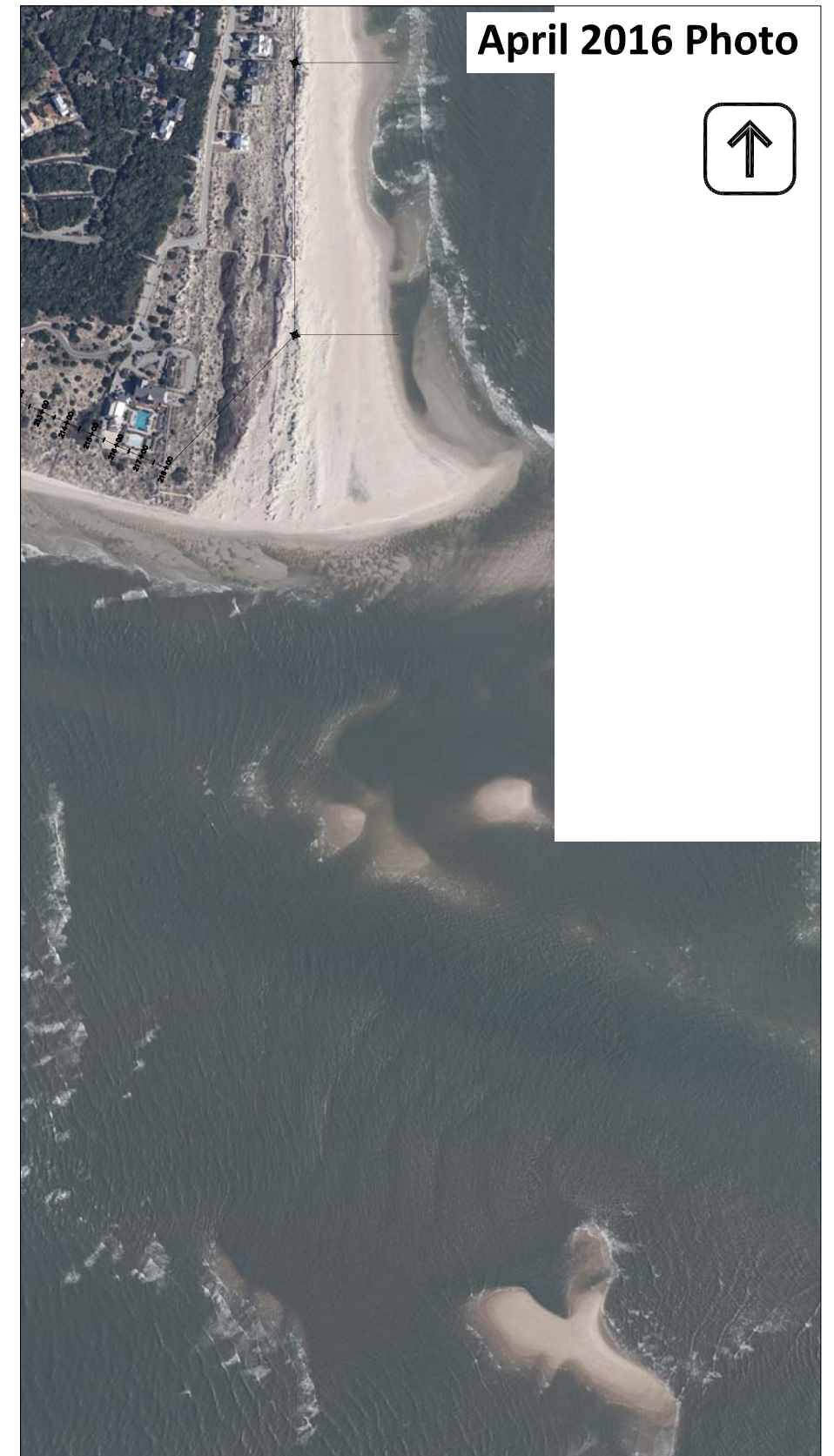


Figure 3.9:
Cape Fear aerial photography
Bald Head Island, NC
olsen associates, inc.

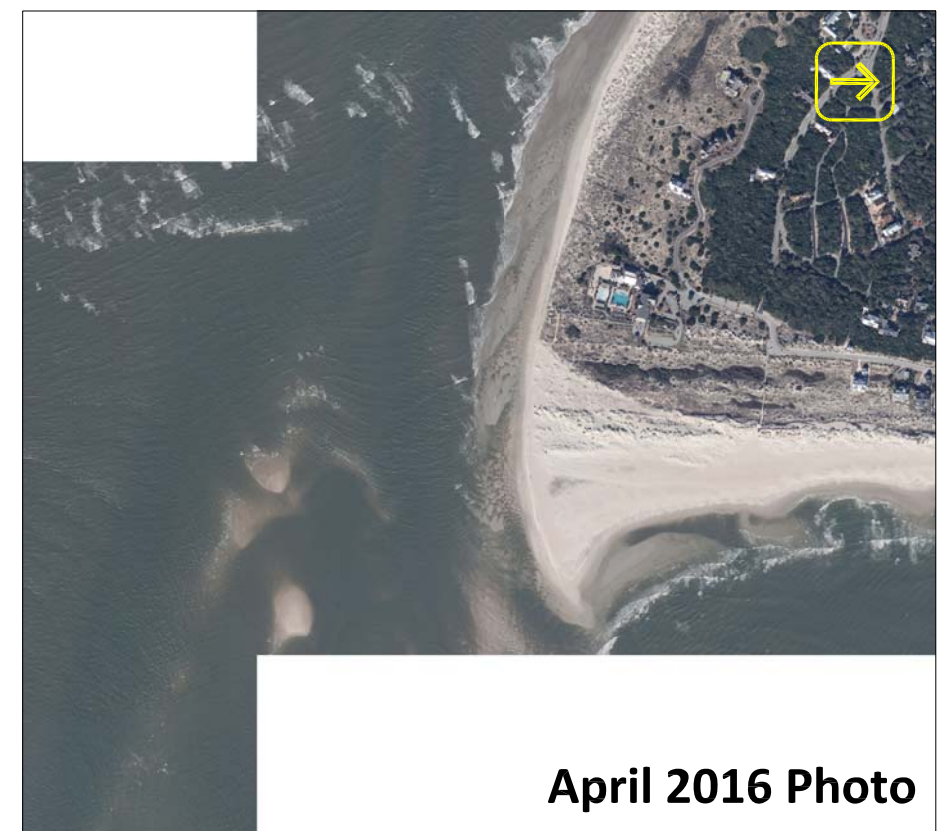


Figure 3.10:
Cape Fear aerial photography
Bald Head Island, NC
olsen associates, inc.

Although the location of the Cape Fear spit has been beneficial to East Beach properties, it has caused significant shoreline and dune recession seaward of the South Beach Shoals Club facility. That section of shorefront is monitored via beach profiles B-54 and B-55 (Sta. 214+00 and 218+00). The Shoals Club lies approximately mid-way between these two survey stations. April 2016 shoreline conditions are visually shown by Figure B-9 (Appendix B – April 2016 Aerial Photography – page B-10). Since November 2000, the MHWL at profile B-54 has receded by -150 ft, or about -10 ft/yr. At B-55, over the same period of time, the MHWL has receded -280 ft, or about -18 ft/yr. More recently however, between November 2014 and April 2016, the MHWL at B-55 had receded by about -90 ft which equates to a rate of -60 ft/yr.

3.5 Row Boat Row Shoreline Conditions

In November 2015, the “Row Boat Row” shoreline was added to the island-wide beach monitoring program. Survey data are collected at five (5) monitoring stations starting just north of the marina entrance and extending approximately 1,500 feet northward along the Cape Fear River facing shoreline (see **Figure 3.1**). Plots of these profiles are provided at the beginning of **Appendix A (Figures A-1 to A-5)**.

Tables 3.10 summarizes the shoreline and volume changes measured during the short-term November 2015 to April 2016 monitoring period (6 months). Overall, the Row Boat Row shoreline was erosional, losing approximately -6,500 cy (above the -16 ft-NGVD contour). The upper beach was likewise erosional, losing approximately -3,200 cy over this period above the MHWL. Similarly, the BERM and MHWLs receded by spatially weighted averages of -13.0 ft and -6.8 ft, respectively.

Table 3.10: Row Boat Row shoreline and volume changes between Nov. 2015 and April 2016.

Station	Reach (FT)	Volume Change (CY)			Shoreline Change (FT)	
		Above MHWL (+2.51 FT)	Above -16 FT		Berm (+6 FT)	MHWL (+2.51 FT)
-018+72					+6.8	+18.9
	400	400	400			
-014+72					-10.1	-1.8
	272	-300	-800			
-012+00					-16.0	-5.2
	400	-1,200	-2,500			
-008+00					-19.4	-15.6
	400	-1,400	-2,900			
-004+00					-17.3	-19.7
	100	-300	-700			
Marina					NA	NA
Total	1,572	-3,200	-6,500		-13.0	-6.8

4.0 BORROW SITE MONITORING (SURVEY) RESULTS

4.1 Borrow Site Evaluation – Bald Head Creek

The Bald Head Creek borrow site utilized for the 2012 Post-Irene small scale mitigation project continues to be resurveyed annually. Approximately 137,990 cy of sand was dredged from the borrow site between January and February 2012. Depictions of the two most recent condition surveys (October 2015 and April 2016) are included as **Figures 4.1** and **4.2**.

Figure 4.3 presents the relative seabed elevation change between the Year 3 to Year 4 surveys (April 2015 to April 2016) and **Figure 4.4** presents the seabed elevation change since project completion (March 2010 to April 2015). **Table 4.1** summarizes the volume changes within the permitted borrow site limits between the monitoring surveys conducted to date. During the Year 3 to 4 monitoring period (April 2015 to April 2016), the borrow site gained approximately +4,700 CY *within the entire permitted area* (both excavated and unexcavated). In the four years since project completion (March 2012 to April 2016), the permitted borrow site gained roughly +70,000 CY or approximately 51 percent of the estimated dredge volume (-137,990 CY).

Table 4.1: Bald Head Creek borrow site volume changes (within permitted limits).

Survey Period	Duration	Volume Change (CY)		
		Gross Gain	Gross Loss	Net Change
March 2012 to January 2013 (AD to Year 1)	10 months	+22,400	-10,600	+11,800
January 2013 to December 2013 (Year 1 to Year 2)	11 months	+21,800	-1,800	+20,000
December 2013 to April 2015 (Year 2 to Year 3)	16 months	+34,700	-1,200	+33,500
April 2015 to October 2015 (Year 3 to Year 3.5)	6 months	+9,900	-6,200	+3,700
October 2015 to April 2016 (Year 3.5 to Year 4)	6 months	+5,700	-4,700	+1,000
Since Construction (March 2012 to April 2016)	49 months	+94,500	-24,500	+70,000

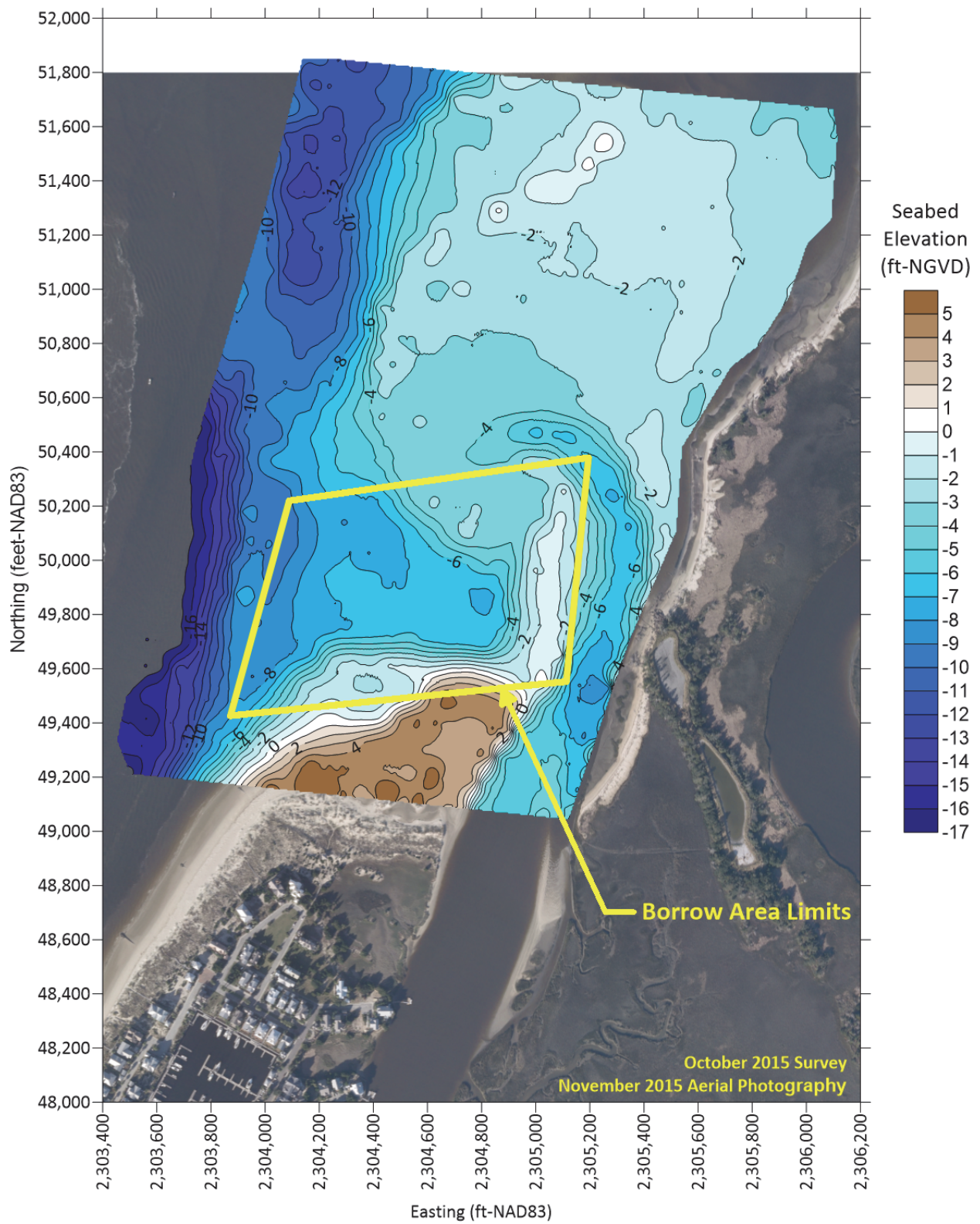


Figure 4.1: 43 months post-dredge (October 2015) Bald Head Creek borrow site condition.

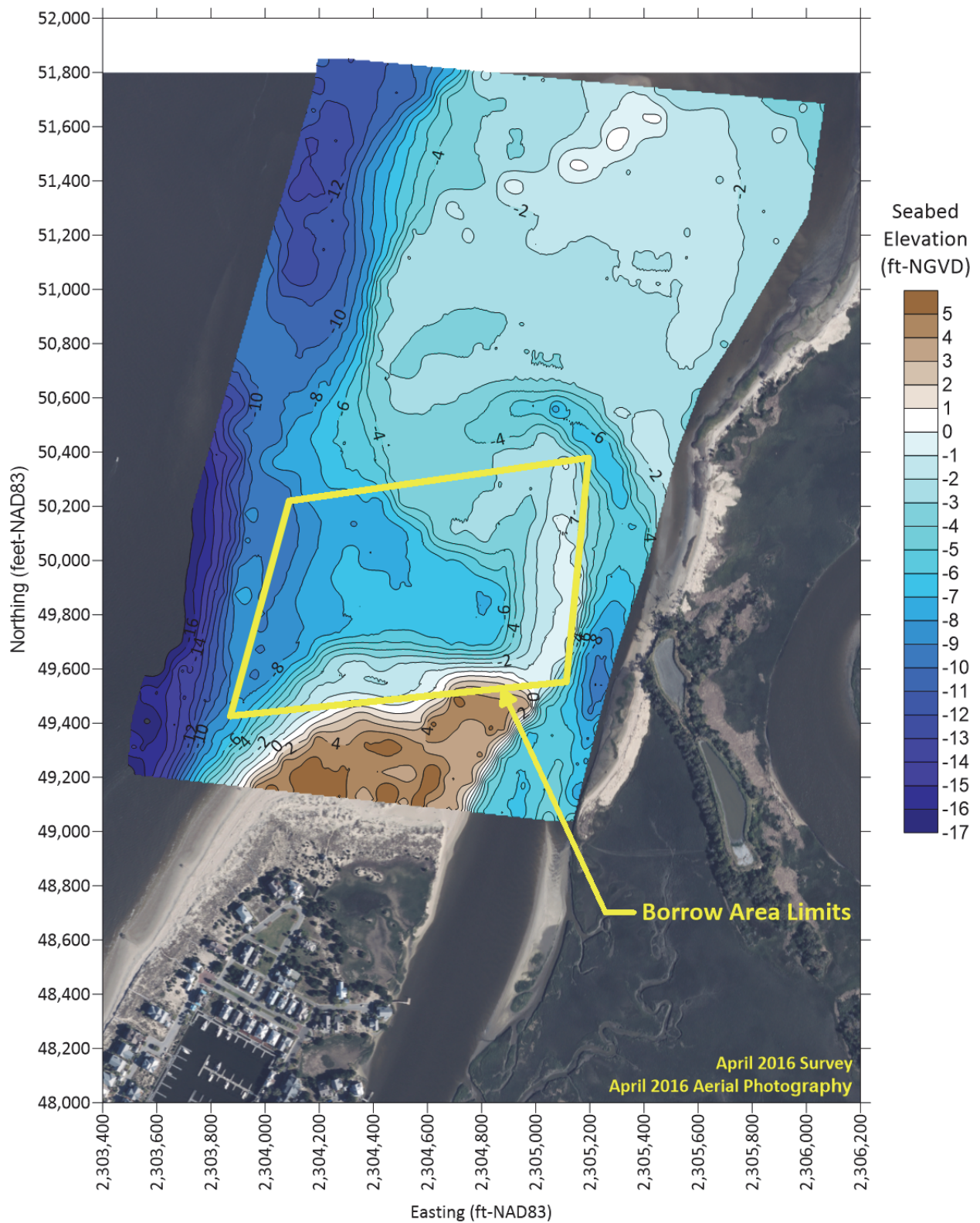


Figure 4.2: 49 months post-dredge (April 2016) Bald Head Creek borrow site condition.

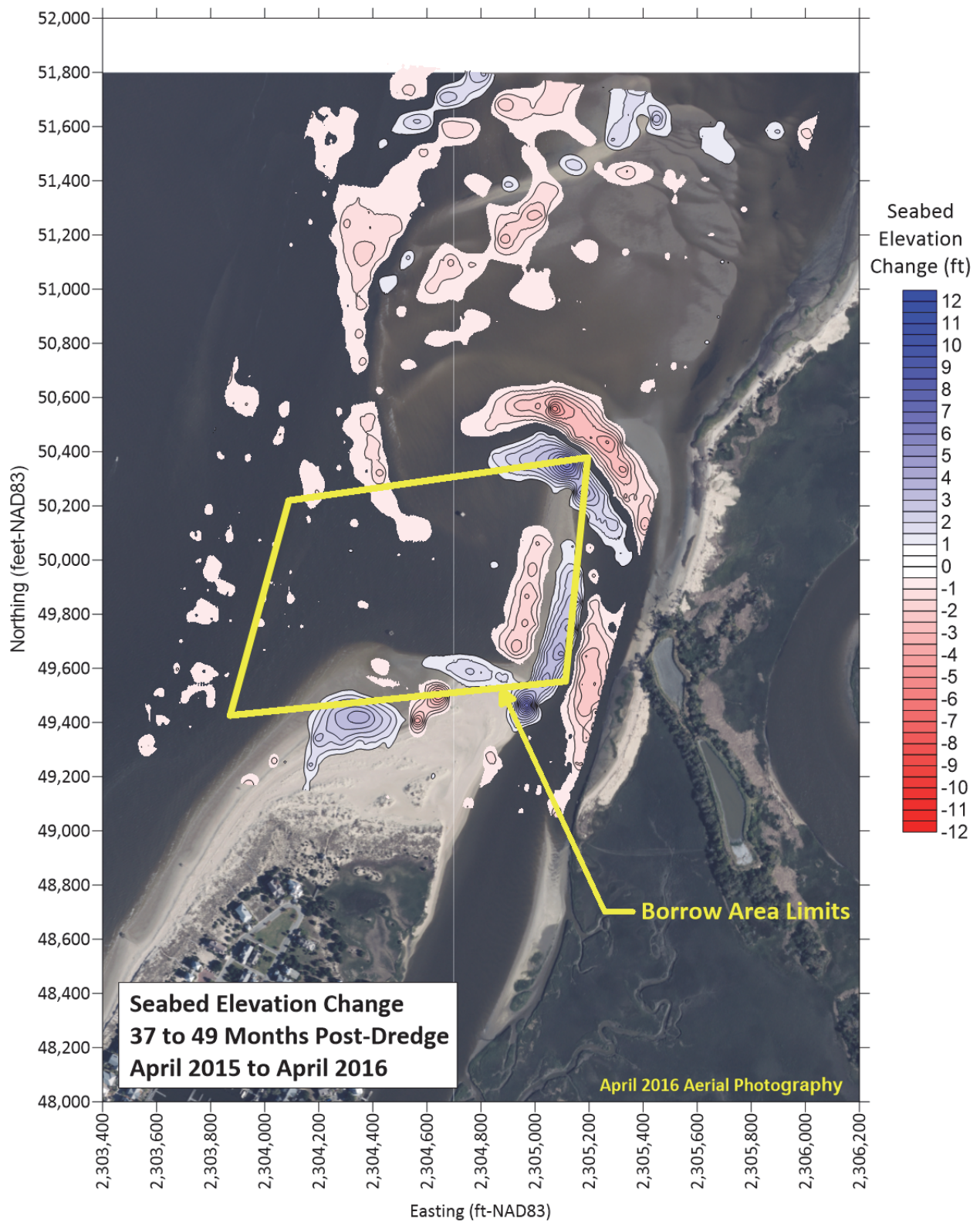


Figure 4.3: Bald Head Creek borrow site seabed elevation changes Year 3 to 4.
(April 2015 to April 2016)

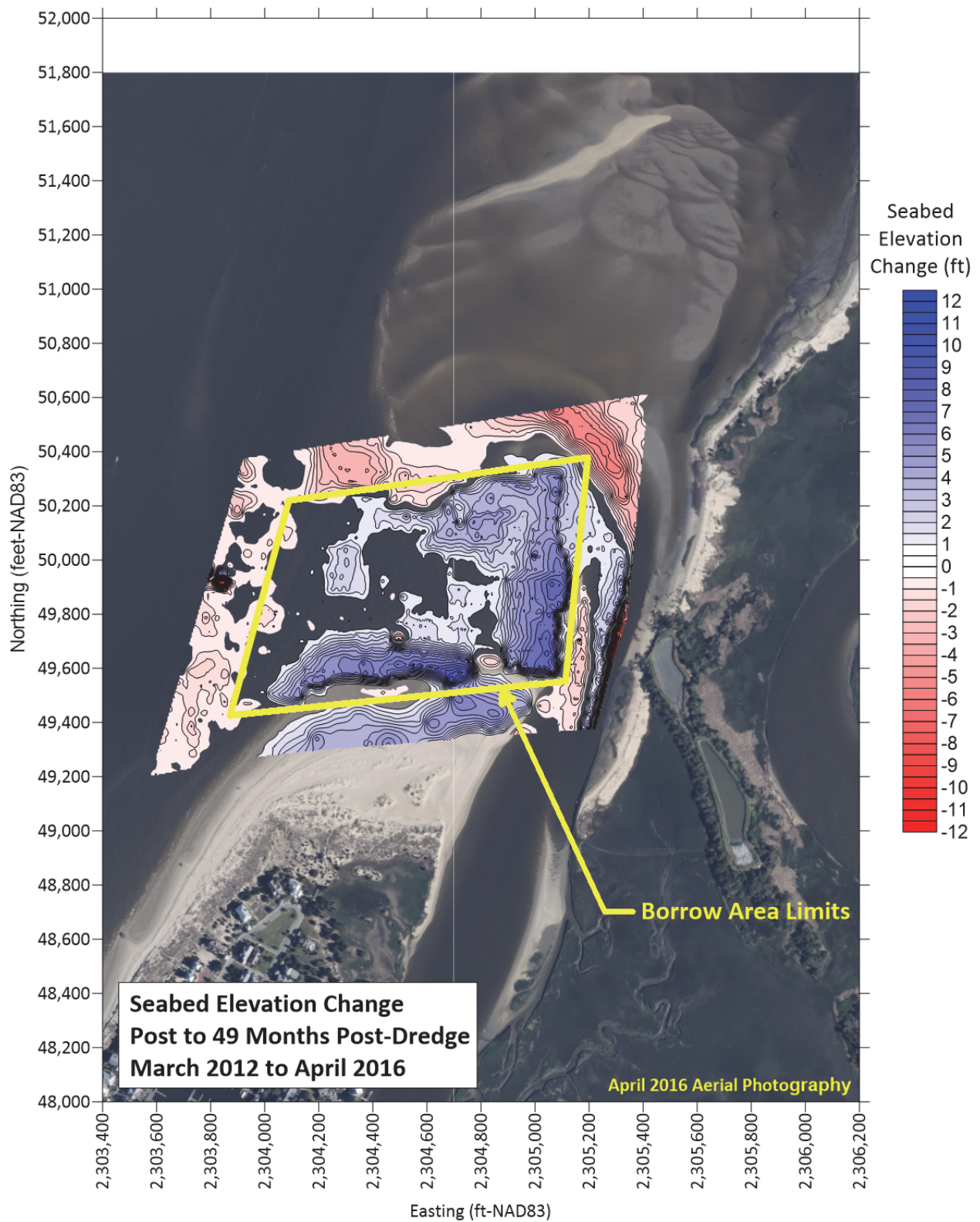


Figure 4.4: Bald Head Creek borrow site seabed elevation changes AD to Year 4.
(March 2012 to April 2016)

4.2 Borrow Site Evaluation – Jay Bird Shoals

Pursuant to permit requirements, the Jay Bird Shoal borrow site is next scheduled to be surveyed in May 2017 and no survey was conducted during the current monitoring year (April 2015 to April 2016). **Figure 4.5** depicts the most recent 5-year post 2009/10 project (61 months) borrow site condition as surveyed in April 2015. **Table 4.2** summarizes the volume changes within the permitted borrow site limits between the monitoring surveys conducted to date.

Table 4.2: Jay Bird Shoals borrow site volume changes.

Survey Period	Duration	Volume Change (CY)		
		Gross Gain	Gross Loss	Net Change
October 2009 to March 2010 (Construction)	5 months	+52,700	-1,888,400	-1,835,700
March 2010 to May 2011 (Year 1 Post-Construction)	14 months	+307,200	-104,800	+202,400
May 2011 to May 2012 (Year 2 Post-Construction)	12 months	+112,700	-107,200	+5,500
May 2012 to May 2013 (Year 3 Post-Construction)	12 months	+179,400	-77,700	+101,700
May 2013 to April 2015 (Year 4 & 5 Post-Construction)	23 months	+342,400	-321,800	+20,600
Since Construction (March 2010 to April 2015)	38 months	+941,700	-32,100	+330,200

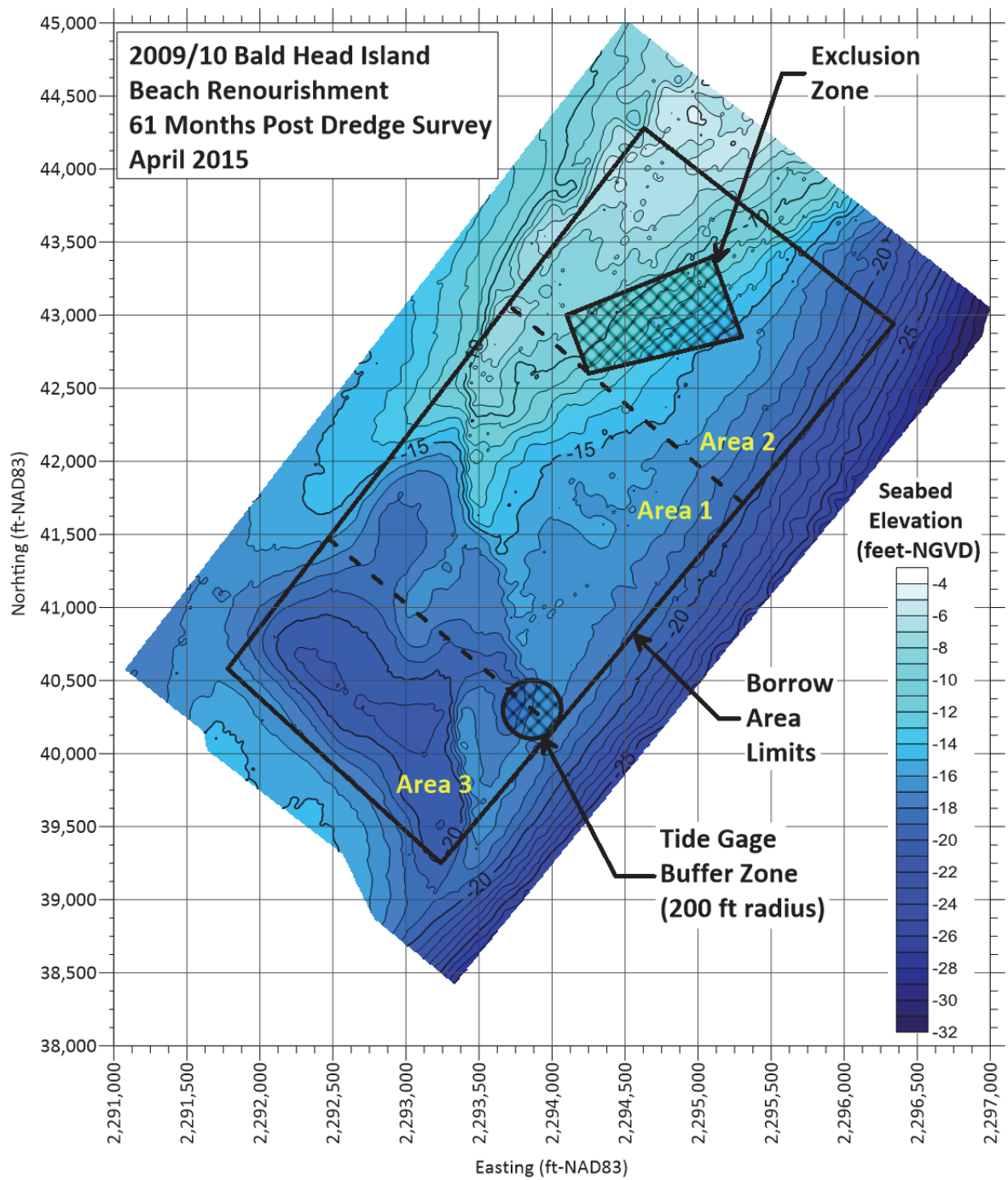


Figure 4.5: 61-month post-dredge (April 2015) Jay Bird Shoal borrow site condition.

5.0 FUTURE PLANNED OR PROPOSED ACTIVITIES

5.1 Row-Boat-Row Shoreline Detached Breakwater Project

The two marina entrance channel jetties located to the south of the Row-Boat-Row shorefront were originally constructed by Bald Head Island, Ltd, at lengths which over time failed to effectively control shoaling due to northerly directed littoral transport along West Beach. As a result, high frequency maintenance dredging of the marina navigation channel had been required in order to provide reasonably reliable ferry and barge access between the mainland and the island. To complement this activity, “advance dredging” of the West Beach shorefront immediately southward of the south jetty was likewise performed on a high frequency basis in an attempt to create a “sink” intended to intercept sand before it shoaled the channel. Recent records indicate that the construction of such a sand sink (and actual channel maintenance dredging) were performed on essentially a monthly basis during a six year period. The average monthly volume dredged was almost 1,500 cy per event. All sand dredged was placed on (i.e. or bypassed to) the Row-Boat-Row shorefront. This resulted in a relatively stable beach and dune system at that location through 2014.

In 2015, the Village of Bald Head Island formally assumed various marina entrance channel and shorefront maintenance responsibilities from the development company. In consideration of the undesirable frequency and cost of channel dredging operations, the Village both permitted (CAMA 208-86) and constructed rock jetty extensions at the ends of the two pre-existing marina entrance channel structures (see **Figure 1.14**). The purpose of the extended jetties was to reduce chronic channel shoaling, as well as potential temporary closures associated with extreme storm events.

The Village sponsored jetty extension project was completed in early 2015. Subsequently, the entrance channel has to this date *not* required maintenance dredging. As a result, the Row-Boat-Row shorefront – no longer the recipient of high frequency (but indirectly beneficial) sand disposal from either the channel and/or West Beach – has suffered erosion to the point that the previously accreting/stable dune line and beach have become highly recessional. Although the Village had been planning to “bypass” a limited quantity of sand from West Beach once or twice a year, it is clear that the existing low profile Row-Boat-Row groinfield is not capable of providing an acceptable level of shoreline stabilization at that location – given a greatly reduced frequency of sand disposal operations. In order to seek a reasonable balance between sand bypass activities and the protection of upland

development, as well as to reduce the continuing chronic loss of beach and dune resources, additional stabilization measures or remedial actions are required seaward of the Row-Boat-Row shorefront.

Hence, several breakwaters capable of reducing (or intercepting) direct wave impacts are proposed. More specifically, the proposed plan is to construct four (4) detached low-profile rock breakwaters – each approximately 90 ft. in length along its crest (114 ft. overall including end slopes). Each detached breakwater would be constructed between two existing structures and sited *below the MHWL* in approximately 2 to 5 ft of water (MLW datum) (see **Figure 5.1**).

The strategic placement of breakwaters would initially combine the attributes of each of the two types of stabilization structure so as to reduce the rate of sediment transport from the eroding shoreline. The subject expanded shore stabilization project (detached breakwaters *and* existing groinfield) will initially need to have a sand fill and be allowed to come to a designed equilibrium condition. The proposed source of the fill is an existing Bald Head Creek borrow area. Eventually, it is predicted that after detached breakwater construction and sand placement, the existing groins will again become essentially quasi-buried and therefore only partially active. This will maximize benefits to the beach/dune system and at the same time greatly reduce the frequency of dredging operations associated with discrete Sand Bypass events intended solely to benefit the Row-Boat-Row shoreline.

The design sand volume necessary to fill the subject Row-Boat-Row shoreline *after breakwater installation* is unknown at present. It will depend upon beach conditions at the time, but could approach 15-25,000 cy. In the interim, the Plan is to episodically place limited quantities of Bypass sand along the Row-Boat-Row shoreline in an attempt to “hold the-line” until permits are acquired for the detached breakwater project. Permit applications for the subject breakwater project were submitted in March 2016.

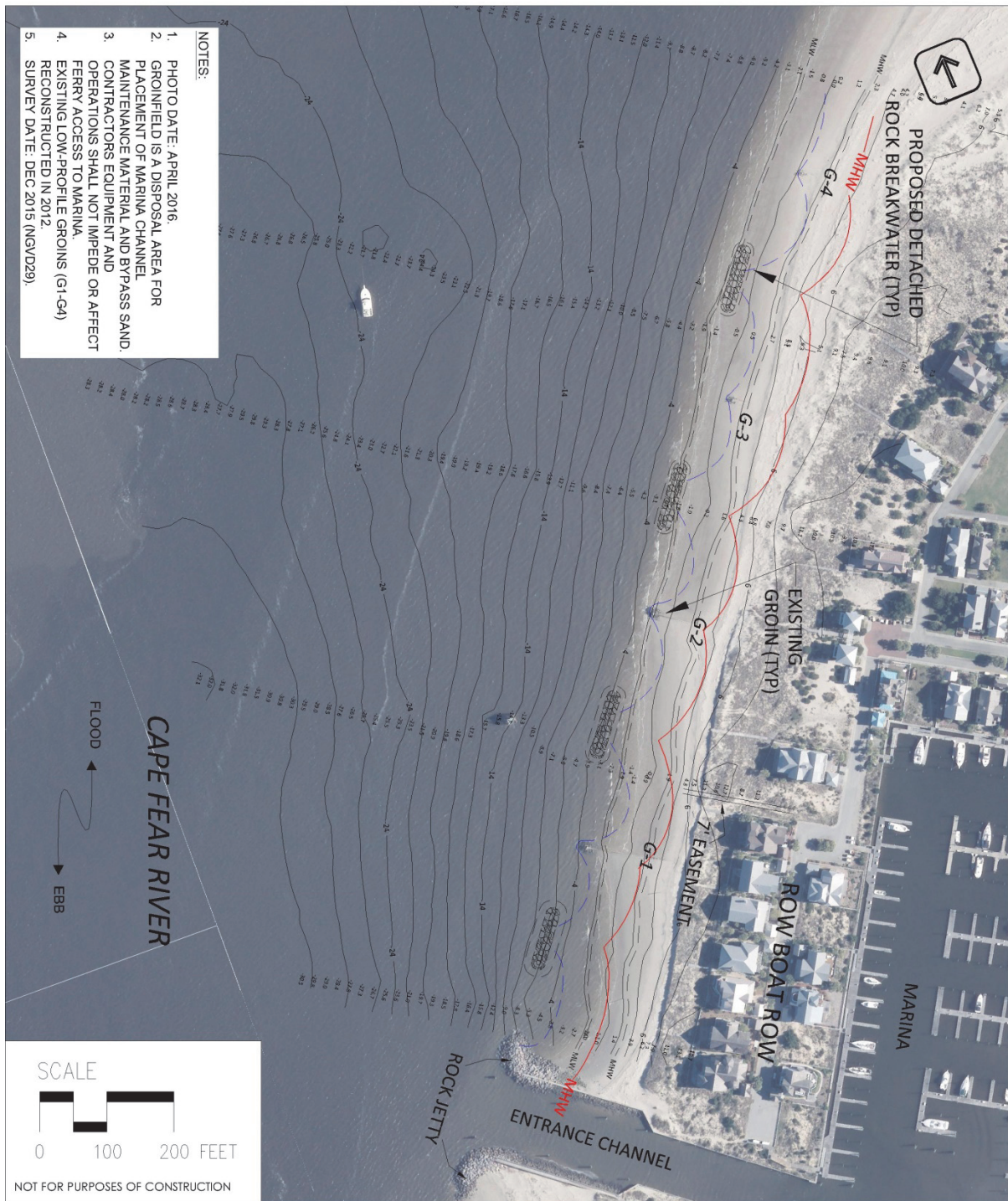


Figure 5.1: Proposed plan for Row-Boat-Row shoreline detached breakwater project.

5.2 Frying Pan Shoals Borrow Site Development

In April 2016, a sand search investigation of Frying Pan Shoals was performed in response to the identified future sand requirements of Bald Head Island (Olsen, 2016). As such, it was intended to be suitable for purposes of permitting a project specific borrow site. Sand placement requirements necessary to maintain the Village's "engineered" beaches now include the Statutory precepts and associated permit conditions directly associated with the construction of the 2015 terminal groin sited in close proximity to the federal navigation channel. More specifically, the subject permits include potential actions by the Village associated with updrift sand fillet maintenance as well as potential downdrift shoreline mitigation – if proven necessary by comprehensive post-construction monitoring. The goal of the 2016 sand search investigation was to develop an initial Frying Pan Shoals borrow site nominally yielding a minimum of 2-3 Mcy, of beach quality sand. As of this date, the only remaining work to be performed prior to the submittal of the requisite State and Federal permit applications is a Phase II Marine Archaeological Survey to identify potential cultural resources (i.e. shipwrecks) of significance to be avoided. It is currently assumed that borrow site permitting will be initiated by the Village of Bald Head Island before the end of 2016.

6.0 SUMMARY AND CONCLUSIONS

The most recent Wilmington Harbor Inner Ocean Bar maintenance dredging of Bald Head Shoal Channel Reaches 1 and 2, as well as the Smith Island Channel segment occurred between January and April 2015. Approximately 1.33 Mcy of sand excavated during that operation were placed at Bald Head Island along South Beach. For this project, the Village of Bald Head Island was required to contribute \$945,000 in order to have disposal sand placed more westerly so as to benefit a terminal groin project scheduled to begin immediately following the completion of the federal contract.

Between November 2000 and April 2015, Bald Head Island had received about 7.0 Mcy, mol of sand from the initial widening/deepening and four (4) subsequent maintenance dredging operations for the Wilmington Harbor Navigation Project entrance channel. That work was performed in accordance with the original Wilmington Harbor Sand Management Plan. In addition, the Village was required to place at their expense approximately 1.85 Mcy of sand in the form of an “engineered beach” intended to offset the adverse consequences of a channel maintenance event contracted to occur with an Oak Island alternate disposal location. Prior to that, the Village constructed a 47,000 cy fill along West Beach. In 2012, the Village had constructed a Post-Irene emergency fill comprised of 138,000 cy of sand dredged from Bald Head Creek. Accordingly, in the net Bald Head Island has experienced a total estimated sand placement volume of approximately 9.04 Mcy since November 2000.

Conversely, the *gross* volumetric sediment *loss* over the November 2000 to April 2016 monitoring timeframe is conservatively computed at -5,733,000 cy, or approximately 371,700 cy per year – on “average”. The assignment of an *average annual* long-term rate of sand loss at Bald Head Island however, has *not* necessarily been a meaningful indicator of navigation project impact. Such an “average rate” is often temporally biased by periods of beach fill equilibration, groinfield effectiveness, major storm events, the occurrence of episodic destabilizing dredging events in close proximity to the island, as well as other physiographic phenomena temporally affecting annualized quantities of alongshore sediment transport – from Bald Head Island.

Even though the latest April 2016 monitoring survey documents some 3.306 Mcy of additional sand within the island’s littoral system since November 2000 (*after* fill placement of over 9 Mcy), historical surveys have routinely documented an area of S. Beach with large *net losses* (nearest the inlet) and large *net gain* (eastward thereof). Hence, it would be neither

accurate nor technically acceptable to conclude that Bald Head Island as a whole has experienced a net “improvement” since November 2000 when discrete sections of shorefront have been shown to lie hundreds of ft landward of their location prior to the pre-harbor deepening project benchmark condition survey of November 2000. Hence, this report’s continuing conclusion that certain basic tenets of the F.O.N.S.I. and *Environmental Assessment* (USACE, 2000) regarding assurances of no net impact to Bald Head Island – that ultimately led to the favorable C.Z.M. consistency finding by the State of N.C. – have not been met. It is currently the position of the Village of Bald Head Island that these findings are extremely significant and immediately relevant to the Wilmington District’s ongoing re-evaluation and proposed update of the Wilmington Harbor Sand Management Plan (WHSMP).

Comprehensive beach monitoring over the past 16 years by the Village of Bald Head Island has resulted in the conclusion that sand placement alone has *not* served to successfully offset navigational channel impacts to the west end of South Beach resulting in chronic rates of erosion and consistent northerly recession and migration of the Point. The net result of these phenomena has been accelerating erosion and ensuing threat to public infrastructure, homes, protective dunes and wildlife habitat.

As a result, the Village was ultimately forced to “change the existing dynamic” by constructing a single terminal groin designed to complement the placement of beach fill at a documented South Beach erosional “hot spot”. The project is being performed in 2 Phases. The structure is intended to serve as a “template” for fill material placed eastward thereof on South Beach. The Phase 1 1,300 ft. long terminal groin (completed in Nov. 2015), was designed as a “leaky” structure (*i.e.* semi-permeable) so as to provide for some level of sand transport to West Beach and portions of the Point (located northward of the groin stem). It can reasonably be shown that the construction of such a structure should ultimately have some level of direct benefit to the abutting navigation channel. Additional monitoring data required by Permit will assist in the quantification of the terminal groin’s effects on littoral processes and resultant shoreline configurations – both updrift and downdrift. Such an evaluation will take a number of years and will necessitate multiple sand fill applications until some level of dynamic equilibrium of the post-structure shoreline can be defined.

Although not directly impacted by long-term navigation channel improvements and maintenance of the Cape Fear River entrance, the Village Council elected to initiate monitoring of the East Beach shorefront at Bald Head Island in November 2008. The limited nature of survey results at that location continues to preclude any meaningful long-term conclusions. However, it is observed at this juncture that East Beach principally undergoes

strong seasonal variations of beach width and profile volume to a large degree dependent upon storm frequency and intensity as well as the ever-changing configuration of the Cape Fear spit. The current April 2016 survey data show a net shoreline accretion of approximately 20,400 cy (above elevation -16 ft NGVD) throughout the 3,000 ft East Beach shoreline lying northward of Cape Fear over the last 12 months.

Unfortunately, recent configurations of the Cape Fear spit deemed beneficial to East Beach have resulted in a high rate of erosion and duneline recession along the easternmost section of South Beach – directly seaward of the Shoals Club facility. For example, between 2000 and 2016, the average MHWL erosion rate at that location has been about -14 ft/yr. Conversely, for the most recent 18 month period, November 14 – April 16, the MHWL receded approximately 90 ft.

In 2015, the Village was required by Permit to perform the 5th year of monitoring for the Jay Bird Shoals borrow site utilized to construct the 1.85 Mcy beach fill in 09/10. The computed change within the monitored survey area (excavated and unexcavated) was a *net* gain of approximately 330,200 cy over the 62 month monitoring period following project construction. The next scheduled survey will occur in 2017 and additional sand gain is expected. The Bald Head Creek borrow area was resurveyed in 2016 for purposes of assessing its future use as a sand source for Row-Boat-Row and/or West Beach. The survey indicated that since its last use in 2012, over 70,000 cy of accretion has occurred – approaching 51% of the estimated dredge volume (-137,990 cy). Although not required by Permit, additional condition surveys of the Bald Head Creek ebb tidal platform may be performed in the near future for purposes of borrow site design.

It has been recommended that the Village of Bald Head Island construct a detached breakwater project along Row-Boat-Row for purposes of addressing ongoing erosion and duneline recession at that location. The subject project is currently in the Permit stage. Subsequent to construction, the shoreline would need a small-scale sand fill utilizing the Bald Head Creek borrow area. Any such fill project may likewise include portions of West Beach which require renourishment at that point in time.

It has been similarly recommended that the Village authorize the submittal of permits and associated studies and environmental analyses necessary to develop a borrow site located within Frying Pan Shoals. The purpose of such a borrow site would be to ensure compliance with Permit conditions necessitating the maintenance of the updrift fillet associated with the

2015 terminal groin project. The borrow site would also be available for sand placement along South Beach (if required) resulting from a scheduled hiatus in the disposal of channel maintenance sand by the Wilmington District, USACOE. Pursuant to the existing tenets of the Wilmington Harbor Sand Management Plan, all beach quality channel maintenance material excavated in 2017 (or 2018) will be placed at Oak Island. Any future “engineered beach” renourishment project by the Village along the South Beach shorefront may likewise need to consider ongoing erosional processes near the Cape Fear spit seaward of the Shoals Club facility.

A running chronology of detailed *annual* monitoring results for the Bald Head Island Shorelines (since 2000) are available from *Bald Head Island, N.C. Beach Monitoring Program Report No. 1* (Olsen 2003), through *Report No. 13* (Olsen 2015).

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