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Bald Head Island, N.C. Beach Monitoring Program

Monitoring Report No. 15 (April 2016 to May 2017)

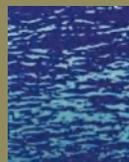
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July 2017



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BALD HEAD ISLAND, N.C.
Beach Monitoring Program
Report No. 15
(April 2016 – May 2017)

EXECUTIVE SUMMARY

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 9.1 Mcy since November 2000.

Conversely, the *gross* volumetric sediment *loss* over the November 2000 to May 2017 monitoring timeframe is conservatively computed at -6,449,600 cy, or approximately -390,900 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 (such as Hurricane Matthew), 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 May 2017 monitoring survey documents some 2.633 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 shoreline nearest the navigation channel 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.

Comprehensive beach monitoring over the past 17 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 was being performed in 2 Phases. The structure was 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 shoreline 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 May 2017 survey data show a net shoreline accretion of approximately 42,700 cy (above elevation -16 ft NGVD) throughout the 6,000 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 2017, the average MHWL erosion rate at this general location has been about -13 ft/yr.

In 2017, the Village was required by Permit to perform the 7th year of monitoring for the Jay Bird Shoals borrow site utilized to construct the non-federal 1.85 Mcy beach fill constructed in 09/10. The computed change within the monitored survey area (excavated and unexcavated) was a *net* gain of approximately 611,600 cy over the 86 month monitoring period following project construction. The next scheduled survey will occur in 2019 and additional sand gain is expected.

The Bald Head Creek borrow area was dredged in 2017 for purposes of fill placement at Row Boat Row and West Beach. Prior to the excavation of some 55,000 cy, the borrow site had accreted by approximately 78,000 cy.

During the current monitoring period, the Village initiated construction of two (2) detached rock breakwaters located north of the marina entrance. The original project proposed four (4) structures. To receive permission to construct during the “moratorium”, the Village was required to reduce the project scope. It is anticipated that final acceptance of the project will occur in early August 2017.

In early 2017, the Village submitted 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. It is currently anticipated that the borrow site will be needed for limited sand placement along South Beach in 2018/19 between the terminal groin and Sta. 134+00. This conclusion results from the scheduled hiatus in the disposal of channel maintenance sand on Bald Head Island 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 2018 will be placed at Oak Island. Any future comprehensive “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.

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BALD HEAD ISLAND, N.C.
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1.0 INTRODUCTION

1.1 Overview

This engineering report presents measured physical changes along the South Beach, West Beach, East Beach and Row Boat Row 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 status of the Wilmington Harbor Sand Management Plan.
- (2) An overview 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) An evaluation of the impacts of Hurricane Matthew to the Bald Head Island shoreline.
- (5) Recent volume and shoreline position changes measured between monitoring surveys of April 2016, October 2016 and May 2017 along the West Beach, "the Point" and South Beach shorelines, 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 and which was recently nourished in 2016.
- (6) Measured changes in the Bald Head Creek borrow site dredged in 2016 as the sand source for the West Beach and Row Boat Row beach fills.
- (7) A discussion of the Village's terminal groin project constructed in 2015 following a spring 2015 federal beach disposal event. Project related changes between the November 2015 and the May 2017 monitoring surveys are presented.
- (8) A discussion of the continuing need to bypass sand from West Beach to the Row Boat Row shorefront.

- (9) An overview of recent shore stabilization efforts by the Village which presently include the development of a Frying Pan Shoals borrow site, the pending construction of two (2) detached rock breakwaters seaward of the Row Boat Row shoreline and the most recent sand placement along a portion of West Beach and Row Boat Row.
- (10) Monitoring results for the Jay Bird Shoals borrow site surveyed in May 2017.

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 2016 to May 2017 monitoring period are plotted as **Figure 1.2**.

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

Datum	Elevation (ft-NGVD29 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 1928.

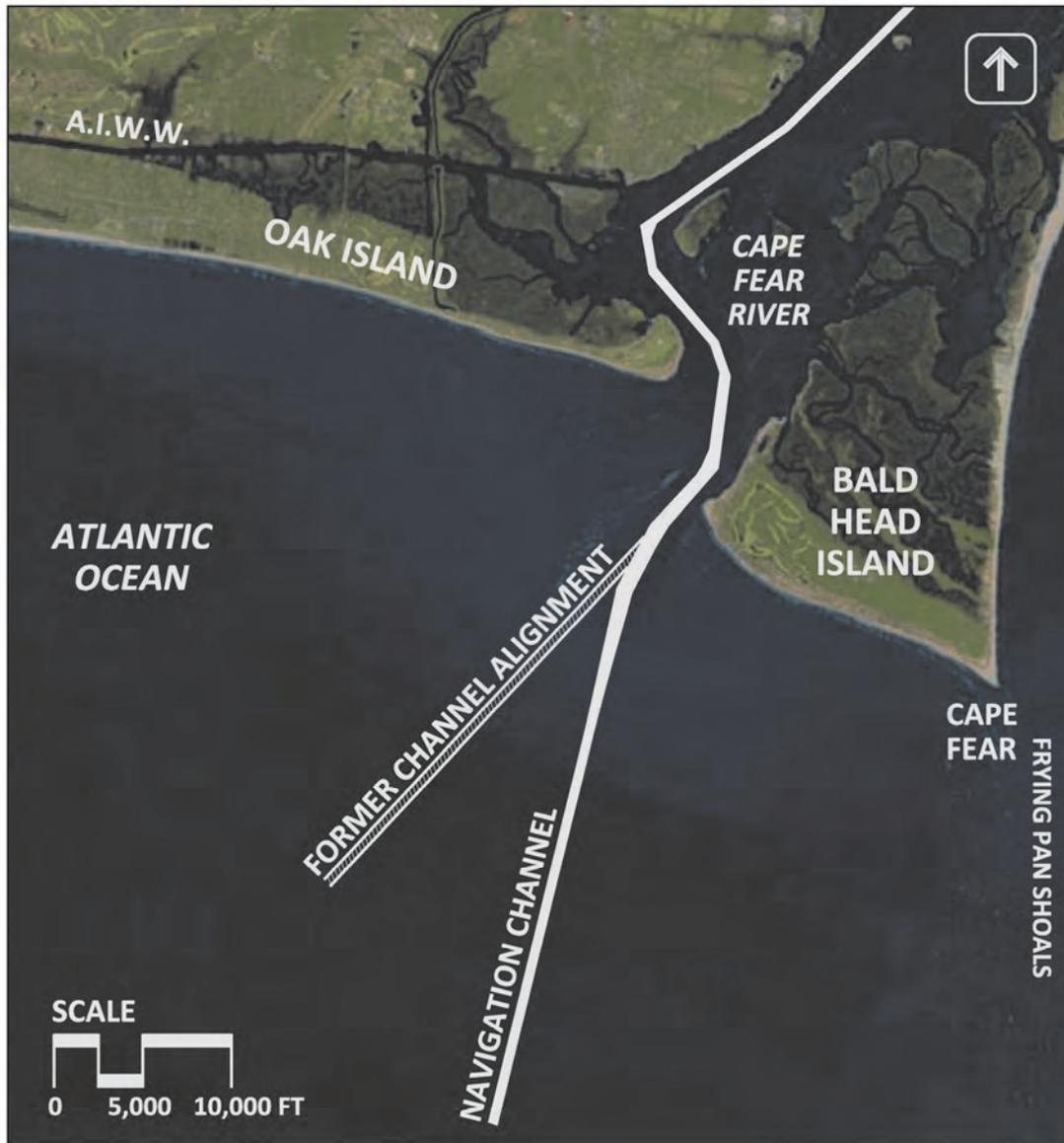


Figure 1.1: Location of Bald Head Island, N.C. and Federal Navigation Channel.

April 2016 through May 2017 Predicted Astronomical Tides Bald Head Island, North Carolina

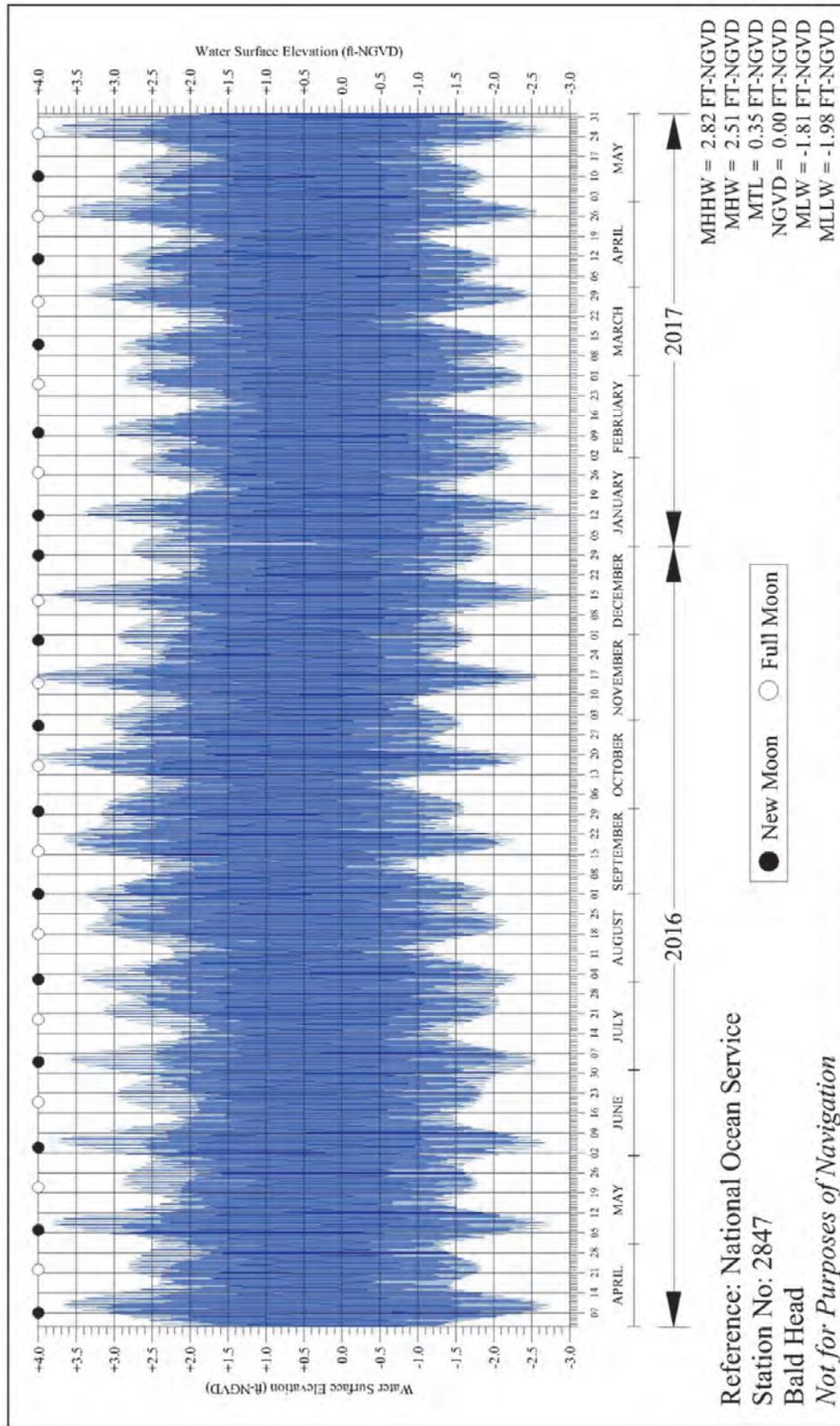


Figure 1.2: April 2016 through May 2017 predicted astronomical tides, Bald Head Island, North Carolina.

1.3 Monitoring Period Wave Climate (April 2016 to May 2017)

During the 13 month monitoring period, Bald Head Island experienced the effects of Hurricanes Hermine (September 2016) and Matthew (October 2016). **Figure 1.3** plots the tracks of both storms.

Hurricane Hermine formed as a tropical depression in the Florida Straits on August 28, 2016. The storm moved north and northeast and steadily intensified to a Category 1 hurricane prior to making landfall in the Florida panhandle on September 2. After landfall, Hermine maintained tropical storm strength as it moved over Florida, Georgia, South Carolina and North Carolina, before becoming extratropical near the Outer Banks on September 3. At the closest, the center of then Tropical Storm Hermine passed within about 30 miles of Bald Head Island, bringing sustained winds of 44 mph and gusts of 48 mph to the monitored shoreline (NOAA 2017a).

Hurricane Matthew developed from a tropical wave that formed on September 22, 2016 off the coast of Africa and strengthened into a tropical storm on September 28 about 35 miles southeast of Saint Lucia in the eastern Caribbean Sea. Matthew intensified rapidly, becoming a hurricane the next day (September 29) north of the Leeward Antilles and a Category 5 hurricane the following day (September 30) just north of Guajira Peninsula, Colombia, making it the southernmost Category 5 hurricane ever recorded in the Atlantic Ocean. Hurricane Matthew then turned north and weakened to Category 4 strength, eventually making landfall in far western Haiti on October 4. The storm remained at Category 4 strength until its second landfall over eastern Cuba, where it weakened to Category 3. The storm strengthened back to a Category 4 as it moved away from Cuba, turning to the northwest toward the Bahamas. On October 6, Hurricane Matthew made its third landfall over Grand Bahama Island, approximately 15 miles west-northwest of Freeport. The storm continued to track northwest toward the US mainland, tracking generally parallel to and about 25 to 50 miles offshore of the Florida and Georgia coasts while gradually weakening. As Hurricane Matthew moved past Florida, it continued to weaken prior to making its final landfall on October 8 as a Category 1 storm in South Carolina over the Cape Romain National Wildlife Refuge. On October 8, the center of Hurricane Matthew passed approximately 7 miles offshore of Bald Head Island as a Category 1 hurricane, bringing sustained winds in excess of 55 mph and gusts of 80 mph to the monitored area (NOAA 2017b).

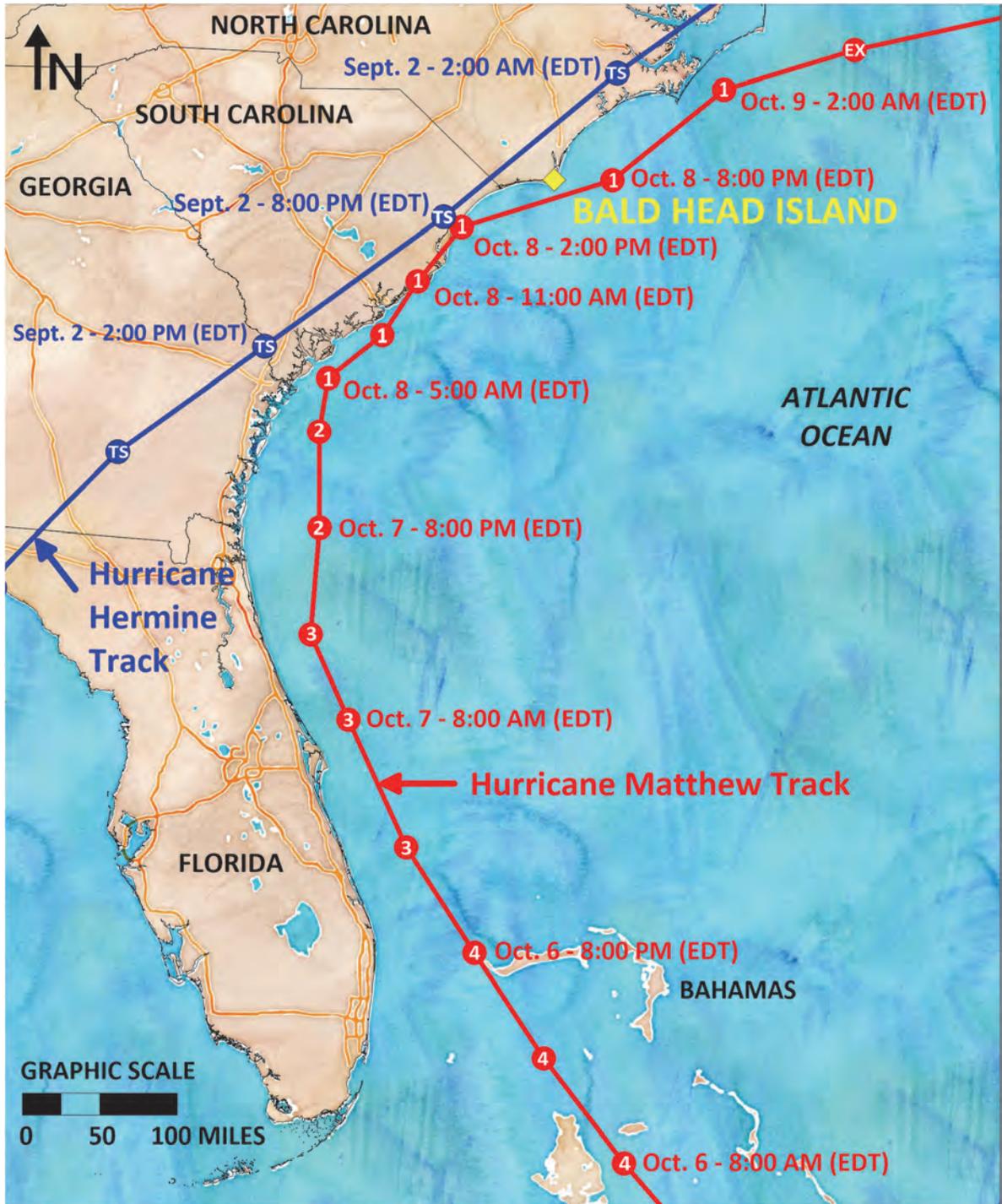


Figure 1.3: Storm tracks of Hurricane Hermine and Matthew in the vicinity of the southeast US. (Track available from the National Hurricane Center)

Figure 1.4 plots the track of both storms in the vicinity of Bald Head Island. The figure also displays the location of NOAA Buoy 41108, 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 29+ 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.

Additionally, Figure 1.4 shows the location of the Wrightsville Beach, NC tidal station (NOS 8658163), owned and maintained by NOAA's National Ocean Service (NOS) Water Level Observation Network. The tidal station is located at the offshore end of the Johnny Mercers Fishing Pier, approximately 28 miles northeast of the monitored area. In addition to water levels, the station typically collects readings of wind speed, gust speed, atmospheric pressure, and other meteorological data. However, the station did not collect meteorological data during Hurricanes Hermine or Matthew. While located along the open ocean, the center of Hurricane Matthew passed approximately 30 miles offshore of the station, compared to 7 miles offshore of Bald Head Island. As such, water levels reported here are likely to be somewhat lower than those experienced along the open coastline of Bald Head Island.

Figure 1.5 displays a time series of significant wave heights measured at NOAA Buoy 41108 from April 2016 through May 2017. **Figure 1.6** depicts the time series measured at the buoy during the passage of Hurricane Hermine (upper panel) and Matthew (lower panel). While the buoy is located offshore in unprotected waters, the wave conditions measured can generally be related to nearshore conditions along the monitored area. Additionally, some fraction of the waves measured at the buoy are directed offshore. All wave statistics mentioned in this section will be from measurements at Buoy 41108.

During Hurricane Hermine, significant wave heights peaked at 14.8 feet on the evening of September 2nd, as the storm's center was approximately 40 miles northwest of the wave buoy. It is noted that these measurements reflect the significant wave height, or the average of the highest 1/3rd of waves passing the buoy during a 20 minute sampling period. There are waves that passed during the storm that were larger in height – some waves may have been as much as twice as high. Large waves persisted along the coast for a significant duration of time with significant wave heights greater than 10 feet lasting for more than 7 hours and waves greater than 6 feet for 16 hours. The dominant wave period peaked at about 12 seconds during this time.

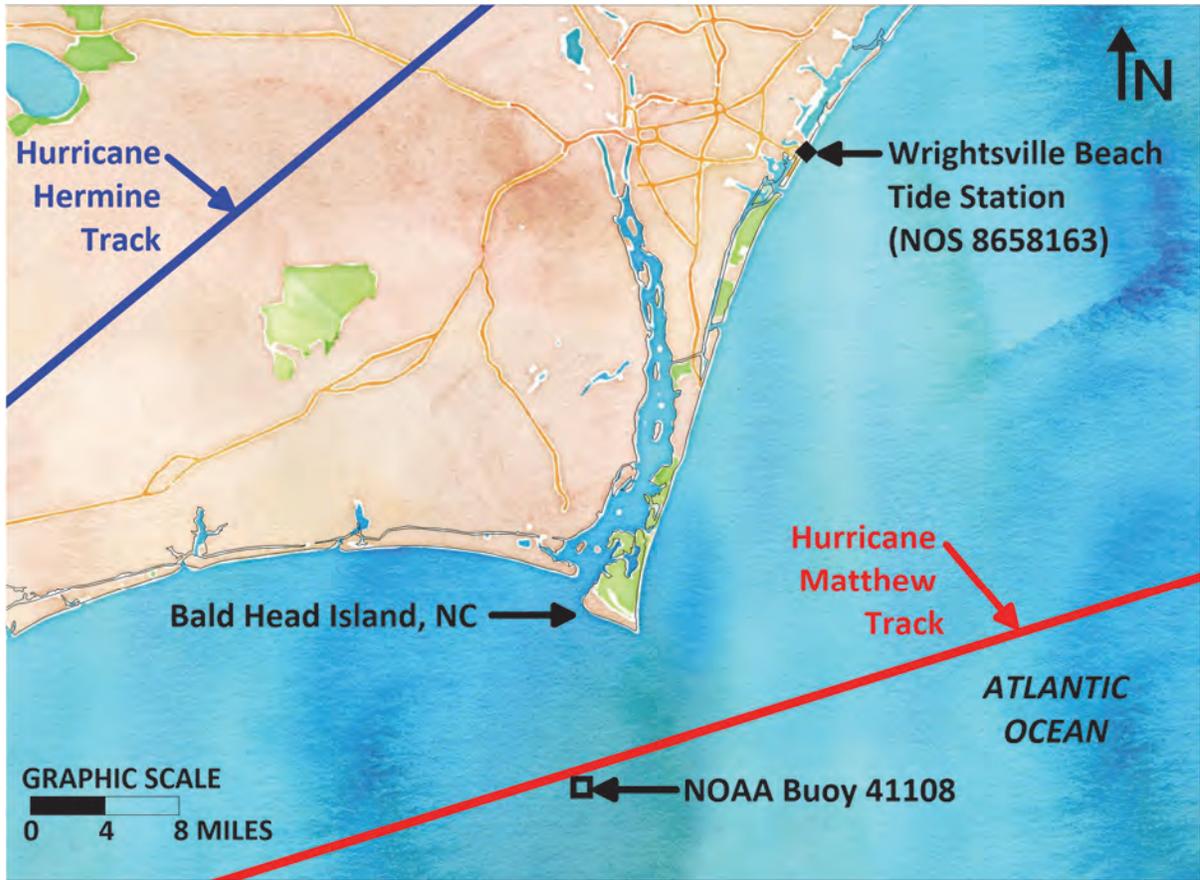


Figure 1.4: Storm tracks of Hurricane Hermine and Matthew in the vicinity of Bald Head Island showing the location of NOAA Buoy 41108 and the Wrightsville Beach, NC tide station (NOS 8658163). Track available from the National Hurricane Center.

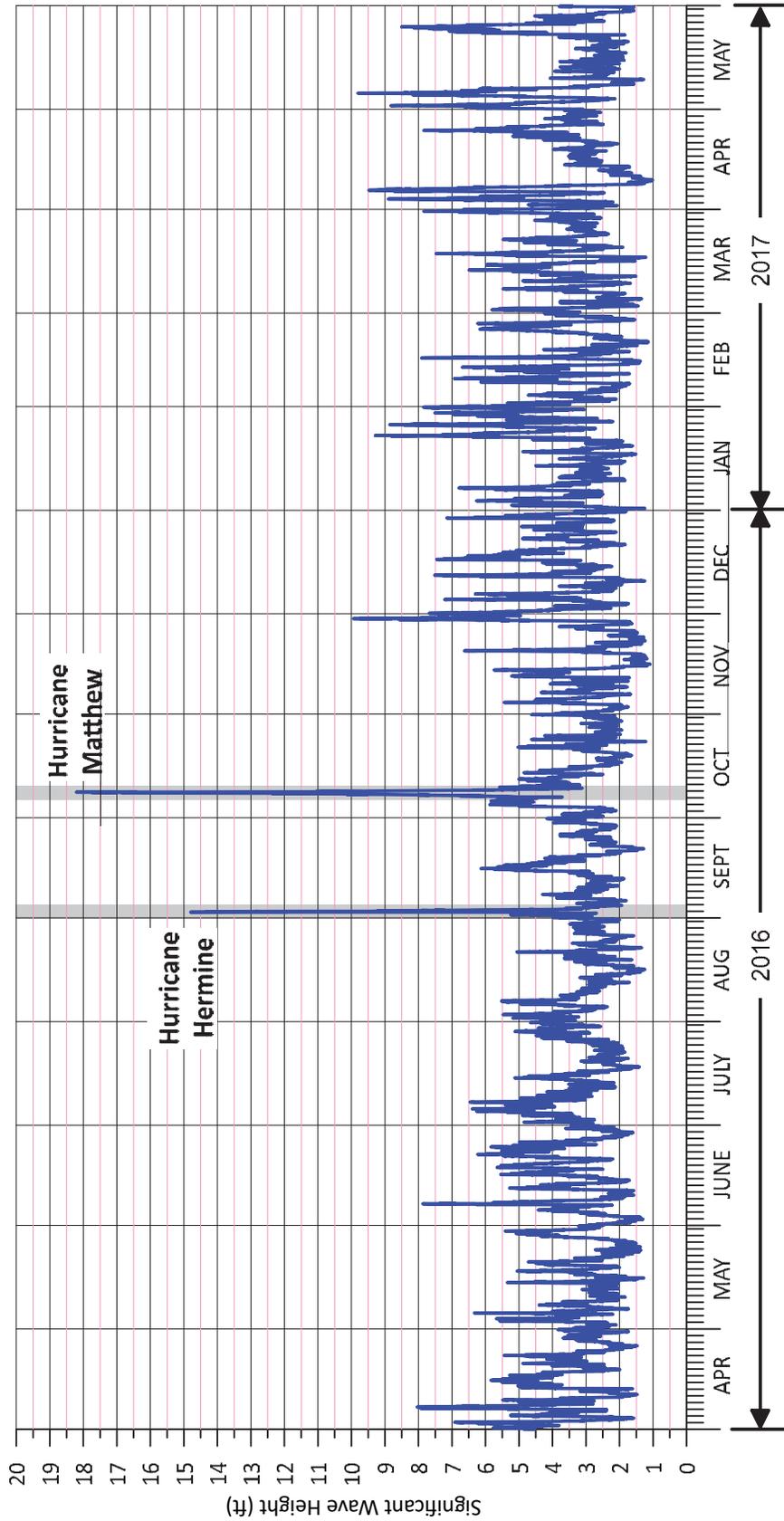


Figure 1.5: Significant wave heights recorded by NOAA Buoy 41108 during the 2016-17 monitoring period (Wilmington Harbor, NC).

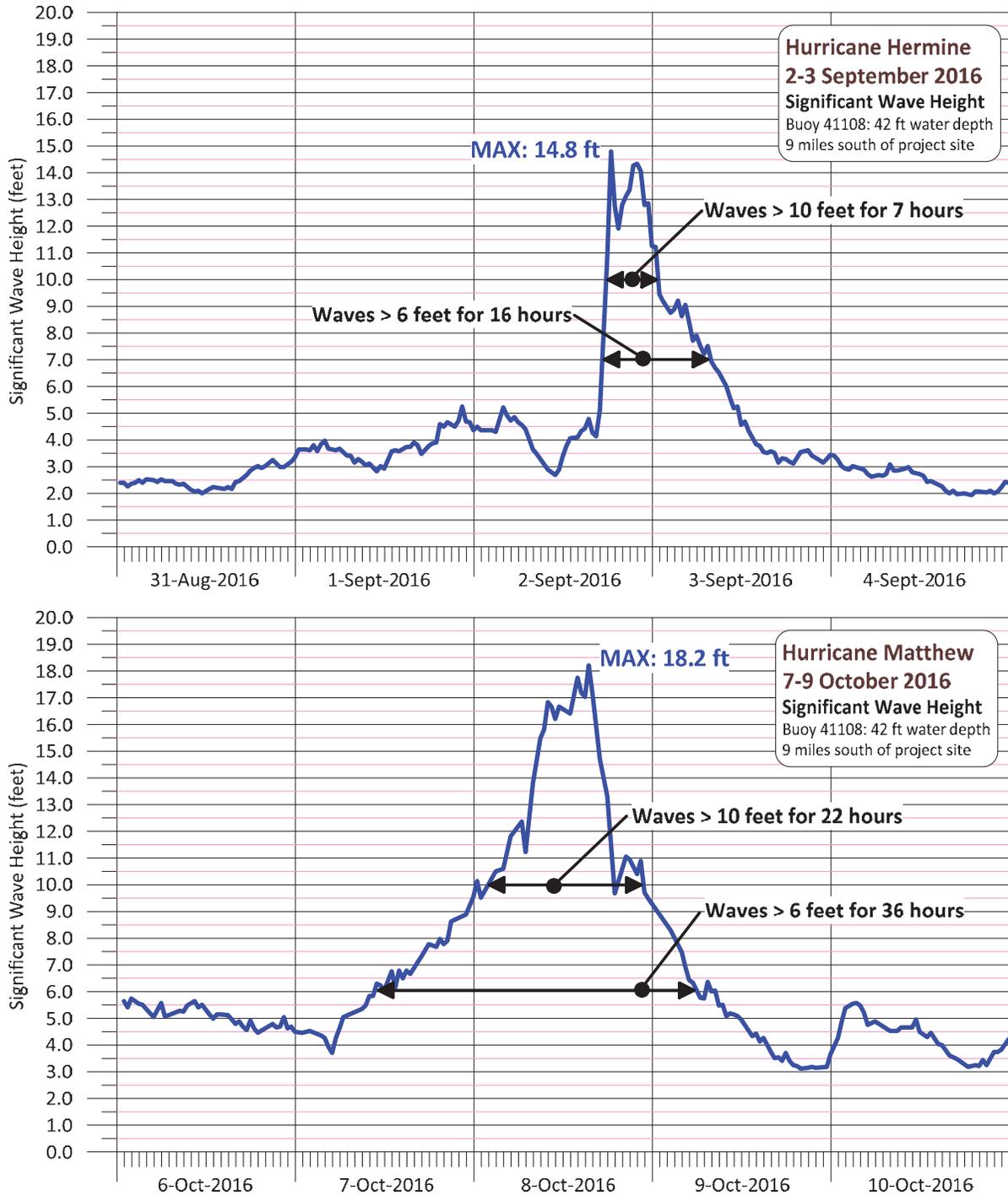


Figure 1.6: Time series of significant wave heights measured at NOAA Buoy 41108 as Hurricanes Hermine and Matthew moved by Bald Head Island, NC. The buoy is located approximately 9 miles south of Bald Head Island in 42 feet of water.

During Hurricane Matthew, significant wave heights peaked at 18.2 feet on the afternoon of October 8th, as the storm's center neared the wave buoy. Large waves persisted along the coast for a significant duration of time with significant wave heights greater than 10 feet lasting for more than 22 hours and waves greater than 6 feet for 36 hours. The dominant wave period peaked at about 13 seconds during this time.

Overall, the average significant wave height at NOAA Buoy 41108 during the Year 15 monitoring period (April 26, 2016 to May 12, 2017³) was 3.33 feet with a maximum wave height of 18.2 ft measured during Hurricane Matthew (October 2016). The Year 15 average value is slightly higher than the full record average significant wave height of 3.19 feet (March 1988 through April 2016⁴) and the Year 14 average wave height (3.28 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 15 monitoring period than would be expected during a typical similar period of time. The occurrence of waves above 10 feet was also higher than the full record average (0.33 percent for Year 15 compared to 0.2 percent for the long-term average). The explanation for the overall more energetic than average wave climate with more extreme waves (>10 feet) may be the relatively active hurricane season.

Figure 1.7 displays the time series of water levels measured at the Wrightsville Beach, NC tide gage as Hermine (upper panel) and Matthew (lower panel) passed. Water levels peaked at +4.9 ft-NGVD at the gage during Hermine and +4.9 ft-NGVD during Matthew. However, the center of Hurricane Matthew passed approximately 30 miles offshore of the station, compared to 7 miles offshore of Bald Head Island. As such, water levels reported here are likely to be somewhat lower than those experienced along the open coastline of Bald Head Island.

³ The April 2016 beach profile survey was initiated on April 26, 2016 and the May 2017 beach profile survey completed on May 12, 2017.

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

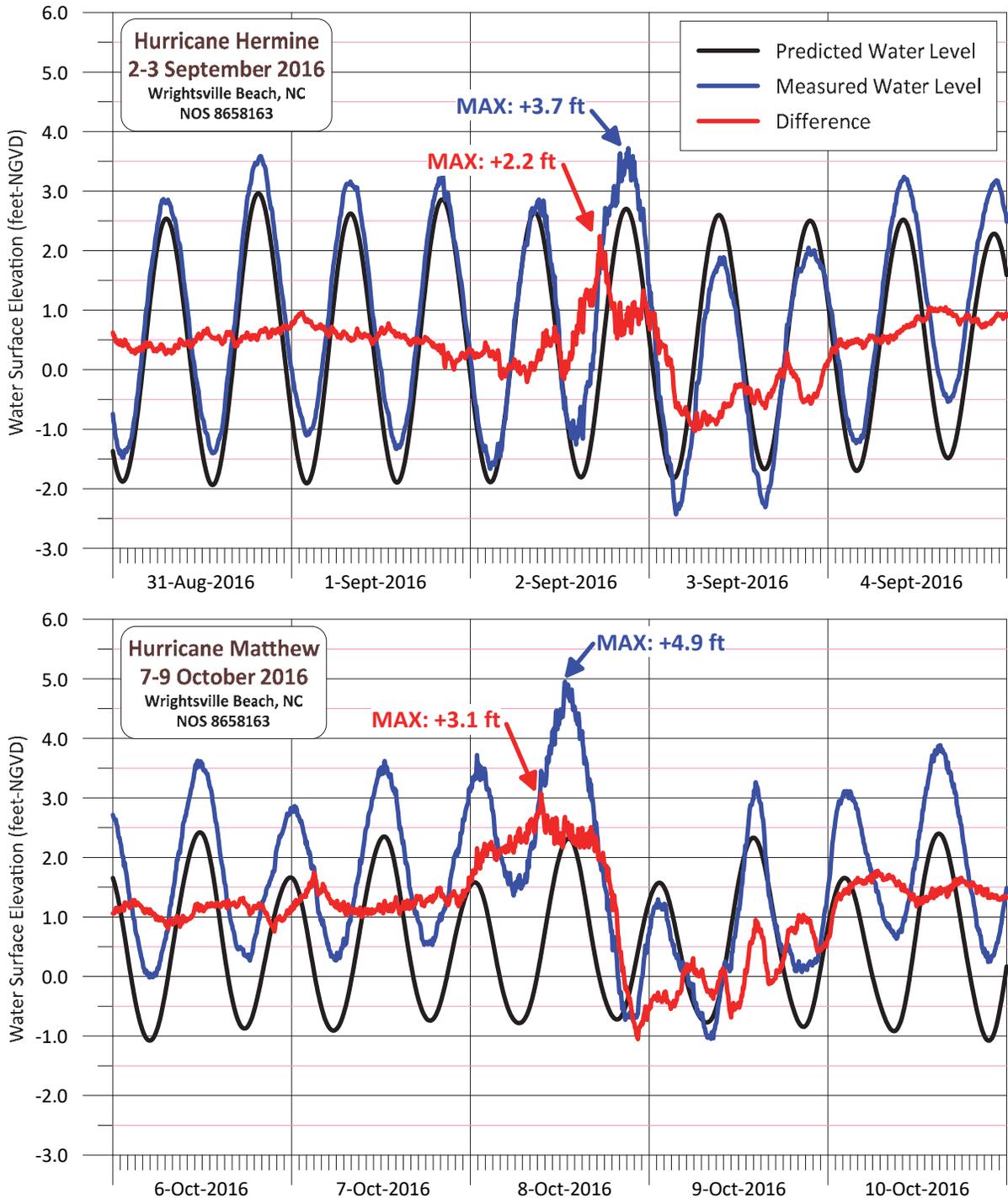


Figure 1.7: Time series of water levels measured at the Wrightsville Beach NOAA tide gage (NOS 8658163) located along the open Atlantic Coast, as Hurricanes Hermine and Matthew passed. The center of Hurricane Matthew passed approximately 30 miles offshore of the station, compared to 7 miles offshore of Bald Head Island. As such, water levels reported here are likely to be somewhat lower than those experienced along the open coastline of Bald Head Island.

1.4 Federal Navigation Channel

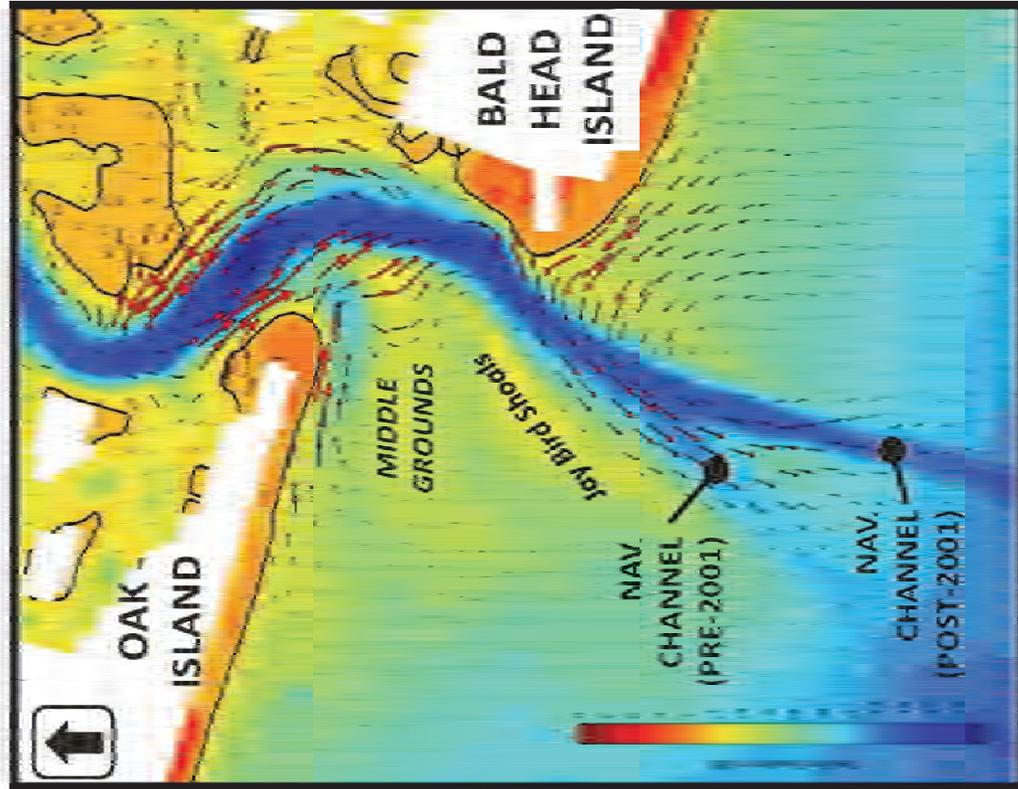
The Wilmington Harbor Federal Navigation Project extends up the Cape Fear River from a point seven statute miles seaward of the Bald Head Island Marina, upstream 30.4 miles to a location just north of the City of Wilmington, N.C. The Wilmington District, U.S. Army Corps of Engineers (USACE) is responsible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

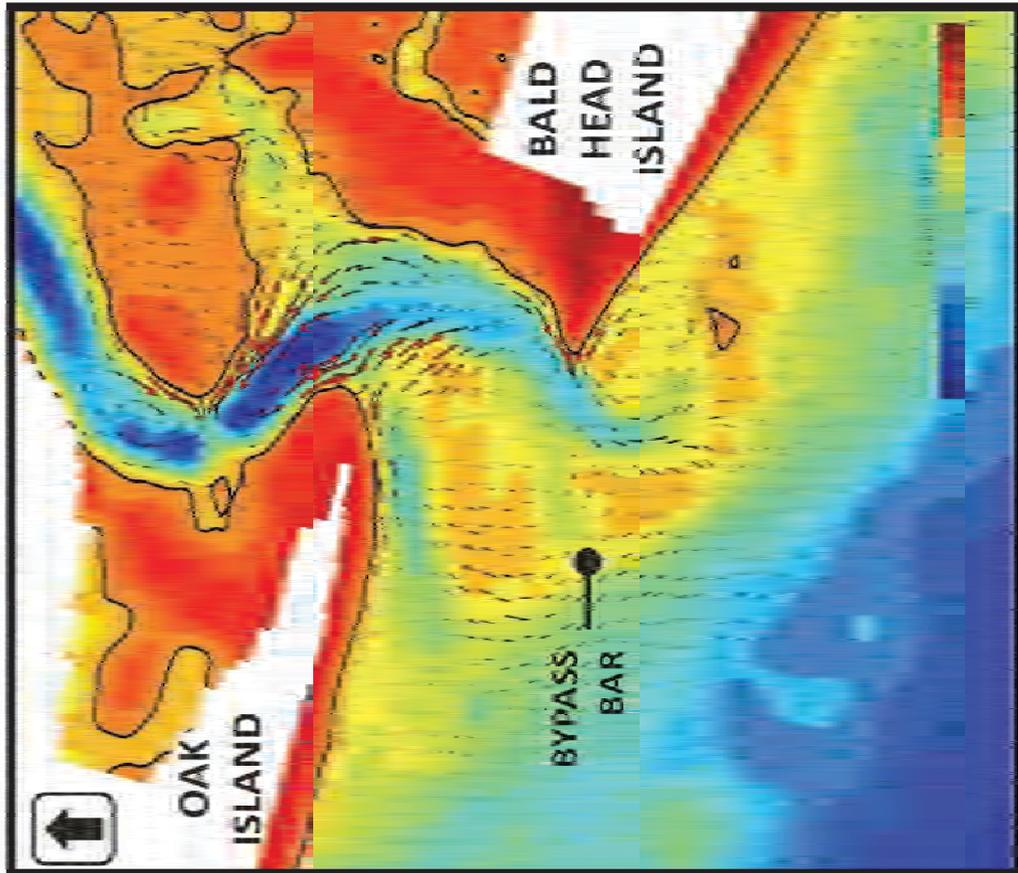
Table 1.2: Cape Fear River Entrance Channel Improvements (Pre-2000).

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 1.8**), 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.



2005/06 (Post-Navigation Project)



1865 (Pre-Navigation Project)

Figure 1.8: 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 spring of 2015 (see **Section 1.5**). The next scheduled event will occur in spring 2018 with all material going to Oak Island/Caswell Beach.

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.

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 identifiable impacts which exceed the November 2000 (pre-project) benchmark survey.

1.6 Historical Erosion Control Activities (1991 to 2017)

1.6.1 Channel Maintenance Beach Disposal

Beach fill placement 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 spring 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)
2016	50,000 cy	VBHI	West Beach and Row Boat Row

* Disposal pursuant to the WHSMP

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 whereby beach disposal would *not* be scheduled to occur at Bald Head Island but rather at Oak 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. Those interim measures were deemed necessary until the Wilmington Harbor Sand Management Plan had run its full 3-maintenance operation cycle and was subject to reinitiation.

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 ±. Presently, slightly less than 1 Mcy of sand remains in the “*undredged*” portion of the developed Jay Bird Shoal borrow site.

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 upgraded materials specified 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 or storm impact.

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 the Village beach renourishment. The gross fill placement quantity associated with the subsequent Village fill 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.

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.

2016/17 Shore Stabilization Project A small-scale sand placement project totaling approximately 50,000 cy was constructed by Marcol Dredging beginning in late December 2016 and finishing in the first week of March 2017. The specified borrow site was the southernmost permitted section of the Bald Head Creek ebb tidal platform – previously utilized for two prior small-scale beach fill projects. Approximately 26,000 cy were placed along 1,500 ft of Row Boat Row shorefront beginning at the north jetty. Subsequently 24,000 cy were placed at West Beach between Sta. 8+00 and 22+00.

1.6.3 Erosion Control Structures (Pre-2015 Project)

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. 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.

The westernmost sand tube groins have historically been 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. The Village obtained a

renewal of the groinfield 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 lengths, and the westward relocation of groin no. 16 were made in an attempt to refine the project design.

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 at westernmost groin no. 16 immediately after May 2011 – during the formulation of Report No. 9 (Olsen, 2011). 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 1.7** of this report. Additionally, a discussion of the 2015 extension of the two (2) rock jetties which protect the entrance channel to Bald Head Marina is provided in **Section 1.8** 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 and the determination that some level of additive structure is warranted.

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 was 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. An area immediately adjacent to the structure was utilized as an access and staging area. Access to the beach and groin 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 in June 2015 at the landward end of the project. The project design specified that a marine mattress base be placed under the entire rock footprint of the structure. The purpose of the mattresses was to reduce the effects of long-term settlement 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.

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 in November 2015, only the structure head was exposed. Several views of the structure as it existed in March 2017 are included as **Figures 1.9** and **1.10**. Monitoring Report No. 14 (Olsen Associates, Inc. (2016) depicts various design details and stages of construction.

1.8 2015 VBHI Marina Jetty 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 as a result. 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.

Each rock jetty extension was placed on Tensar marine mattresses for purposes of minimizing future maintenance requirements due to scour and settlement. All work was performed by barge. Since project completion, no maintenance dredging has been required. The 2016 Shore Stabilization Project constructed by Marcol Dredging (see **Section 1.6.1**) was predicated primarily upon the need to place sand along the Row Boat Row shorefront due to post-jetty extension erosion and shoreline recession at that location. The purpose of that fill project was to reconstruct the shoreline prior to the placement in 2017 of two (2) small detached breakwaters intended to reduce the daily effects of barge and ferry wake. Photographs depicting shoreline conditions on both the north and south side of the jetties are included as **Figures 1.11** and **1.12**.



Figure 1.9: Bald Head Island terminal groin (Photo Date: March 21, 2017)



Figure 1.10: Bald Head Island terminal groin (Photo Date: March 21, 2017)



Figure 1.11: View looking *northward* from the marina jetties along the recently filled Row Boat Row shoreline. (Photo Date: March 21, 2017)



Figure 1.12: View looking *southward* from the marina jetties along the West Beach shoreline. (Photo Date: March 21, 2017)

2.0 PHYSICAL MONITORING PROGRAM

2.1 Monitoring Baseline & Beach Profiles

MONITORING BASELINE The monitoring baseline extends roughly 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 (Sta, 284+00). 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 shoreline. **Table 2.2** summarizes the monitoring surveys conducted to date as part of the monitoring program. The primary focus of this monitoring report (No. 15) is beach profile and shoreline changes occurring over the latest set of surveys (April 2016 to October 2016 to May 2017).

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 shoreline. 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 May 2017) 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.

Table 2.2: Bald Head Island monitoring surveys collected as of May 2017.

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)
2016 Oct.	McKim & Creed	19 months post-construction (2015 Disposal)
2017 May	McKim & Creed	26 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 and adjacent areas utilized for the 2017 Shore Stabilization Project constructed by Marcol Dredging will be monitored at 6 months and thereafter for the next 3 years. The purpose of the monitoring will be to document hydrographic changes throughout the borrow site and in particular areas which were “over-dredged” by the Contractor. Of specific interest to State and Federal regulatory agencies will be the rate of recovery and the composition of the material which infills the composition of the material which infills the area(s) excavated by hydraulic dredge. In addition to annual surveys, limited grab samples and sediment analysis will be performed by a Village Consultant. The Marcol March 2017 AD Survey will be considered as the baseline condition.

2.3 Jay Bird Shoal Borrow Site Surveys

Permits for the beach renourishment project constructed by the Village in 2009/2010 necessitate the resurveying of the Jay Bird Shoal borrow site as part of the annual island-wide monitoring program. **Table 2.3** 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 last scheduled borrow site survey was performed in May 2017. The area surveyed is 400-acres ± 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 and developed borrow area. Part of that area is restricted from excavation due to potential cultural resources.

Table 2.3: Jay Bird Shoal borrow site surveys collected as of May 2017.

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
May 2017	86 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 2.4** summarizes the aerial photography collected to date as part of the monitoring program. Reproductions of the three most recent aerial photography sets (May 2017, November 2016 and April 2016) are presented in **Appendices B, C and D**, respectively.

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 2017.

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	Post-terminal groin construction
2016	April	3	4- months post-construction (T.G.)
2016	October	13	Post-Hurricane Matthew
2017	April	14	5-Months Post-Hurricane Matthew

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 monitoring surveys along this reach completed in November 2015.

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 15: Monitoring Program (April 2016 - October 2016 – May 2017)

The April 2016 to May 2017 monitoring period includes the direct effects of the passage of Hurricanes Hermine (September 2016) and Matthew (October 2016). The October 2016 survey was performed between October 10-16, 2016 and represents the immediate post-Matthew beach conditions. The May 2017 (completed between May 9-12, 2017) survey represents the approximate 7-month post-Matthew conditions. A description of each storm and the resulting wave and water level effects to the Bald Head Island shoreline are described in **Section 1.3** of the report.

This period also includes the effects of a small scale beach restoration project totaling approximately 50,000 cy constructed between December 2016 and March 2017. Approximately 26,000 cy were placed along 1,500 ft of Row Boat Row shorefront beginning at the north jetty and 24,000 cy were placed along 1,400 ft of West Beach.

For compliance purposes the April 2016 to May 2017 survey period represents the fifteenth (15) year of measured shoreline change following completion of the initial 2001 federal +1.849 Mcy beach disposal event at Bald Head Island. The period also represents the second year following completion of the 1.33 Mcy 2015 Federal beach disposal, the third year following a 2013 disposal event of 1.66 Mcy as well as the seventh 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 twelfth year of measured shoreline change following the 2005/06 beach disposal, the eleventh year following the placement of +47,800 cy of beach fill along the West Beach shoreline (by the Village) and the tenth 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 previous Year 14 monitoring year (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 2016 – October 2016 – May 2017 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 2016 to October 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	+600	+2,200	056+56	060+51	423	-1,100	-4,700	South Beach
	000+00	004+00	400	+1,000	+3,700	060+51	065+50	510	-5,200	-13,400	
	004+00	008+00	400	+300	+1,200	065+50	069+46	423	-5,600	-12,600	
	008+00	012+00	400	0	+100	069+46	073+39	442	-5,500	-12,000	
	012+00	016+00	400	-1,100	-2,400	073+39	076+37	516	-5,000	-10,500	
	016+00	020+00	400	-1,400	-2,700	076+37	084+16	611	-5,100	-2,700	
	020+00	024+00	400	+600	+1,100	084+16	088+23	471	-5,900	-9,600	
	024+00	028+00	400	+2,400	-1,400	088+23	092+15	455	-5,500	-13,700	
Subtotal			2,960	+2,400	+1,800	092+15	097+10	536	-5,200	-11,100	
Point (North of Groin)	028+00	032+00	395	+900	-5,400	097+10	102+08	525	-5,200	-7,500	
	032+00	034+00	200	+600	+1,700	102+08	106+00	436	-5,300	-5,900	
	034+00	036+00	210	+1,500	+5,600	106+00	110+00	400	-5,000	-6,500	
	036+00	038+00	230	+200	-600	110+00	114+00	388	-5,300	-6,200	
	038+00	039+60	230	-2,100	-6,900	114+00	118+00	407	-5,100	-5,100	
	039+60	041+50	220	-2,100	-4,000	118+00	122+00	413	-3,900	-4,100	
	041+50	043+47	220	-1,500	-1,500	122+00	126+00	405	-4,500	-6,900	
	043+47	044+25	190	-1,000	-900	126+00	130+00	405	-4,900	-6,700	
	044+25	045+07	190	+400	+900	130+00	134+00	398	-4,200	-2,600	
	045+07	046+00	200	+2,900	+4,200	134+00	138+00	401	-4,700	-5,300	
Subtotal			2,285	-200	-6,900	138+00	142+00	400	-4,000	-7,300	
Point (South of Groin)	046+00	046+89	200	+2,800	+3,400	142+00	146+00	400	-2,400	-3,700	
	046+89	049+00	250	+100	-400	146+00	150+00	399	-3,000	-3,400	
	049+00	050+50	100	-500	-500	150+00	154+00	385	-2,400	-2,400	
	050+50	051+00	100	-700	-400	154+00	158+00	383	-700	+2,600	
	051+00	052+64	240	-1,900	-4,500	158+00	162+00	386	-600	+2,600	
	052+64	054+00	135	-800	-3,300	162+00	166+00	393	-400	+1,700	
	054+00	056+56	380	-700	-4,500	166+00	170+00	394	+600	+3,800	
Subtotal			1,405	-1,700	-10,200	170+00	174+00	400	+1,600	+5,200	
Note: Elevations are referenced to NGVD 1929.											
						174+00	178+00	400	+2,200	+5,700	
						178+00	182+00	400	+2,600	+5,800	
						182+00	186+00	400	+3,400	+5,800	
						186+00	190+00	400	+3,300	+3,600	
						190+00	194+00	400	+2,200	+3,300	
						194+00	198+00	400	+1,300	+600	
						198+00	202+00	400	+500	-5,500	
						202+00	206+00	400	-100	-2,900	
						206+00	210+00	400	-2,100	-7,700	
						210+00	214+00	400	-1,800	-6,500	
						Subtotal		16,105	-92,000	-145,800	
						Bald Head Total		22,755	-91,500	-161,100	

Table 3.2: Bald Head Island shoreline volume change (October 2016 to May 2017).

	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	200	600	056+56	060+51	423	1,400	-14,600
	000+00	004+00	400	700	1,400	060+51	065+50	510	1,300	-16,900
	004+00	008+00	400	1,400	2,200	065+50	069+46	423	400	-14,500
	008+00	012+00	400	2,500	4,400	069+46	073+39	442	1,400	-9,400
	012+00	016+00	400	4,000	7,300	073+39	076+37	516	700	-9,800
	016+00	020+00	400	4,500	9,200	076+37	084+16	611	-1,700	-17,600
	020+00	024+00	400	3,200	5,900	084+16	088+23	471	-2,600	-16,400
	024+00	028+00	400	-400	-7,300	088+23	092+15	455	-1,700	-14,900
	Subtotal		2,960	+16,100	+23,700	092+15	097+10	536	-1,400	-20,900
Point (North of Groin)	028+00	032+00	395	700	600	097+10	102+08	525	-2,700	-29,200
	032+00	034+00	200	1,300	6,000	102+08	106+00	436	-1,700	-22,700
	034+00	036+00	210	200	200	106+00	110+00	400	-1,500	-15,900
	036+00	038+00	230	-400	-4,700	110+00	114+00	388	-1,100	-15,700
	038+00	039+60	230	-200	-6,500	114+00	118+00	407	-1,000	-15,400
	039+60	041+50	220	-400	-7,300	118+00	122+00	413	-1,000	-11,300
	041+50	043+47	220	-1,300	-5,500	122+00	126+00	405	-1,200	-9,100
	043+47	044+25	190	-1,700	-1,000	126+00	130+00	405	-2,000	-11,900
	044+25	045+07	190	-2,400	2,000	130+00	134+00	398	-2,000	-13,800
	045+07	046+00	200	-3,600	1,200	134+00	138+00	401	-1,900	-11,900
	Subtotal		2,285	-7,800	-15,000	138+00	142+00	400	-2,500	-10,200
Point (South of Groin)	046+00	046+89	200	-2,600	-1,000	142+00	146+00	400	-3,100	-13,000
	046+89	049+00	250	1,800	-3,800	146+00	150+00	399	-2,600	-10,500
	049+00	050+50	100	1,700	-3,200	150+00	154+00	385	-1,600	-3,900
	050+50	051+00	100	1,600	-4,000	154+00	158+00	383	-1,500	-6,800
	051+00	052+64	240	2,900	-10,100	158+00	162+00	386	-1,900	-8,300
	052+64	054+00	135	900	-6,400	162+00	166+00	393	-2,200	-8,100
	054+00	056+56	380	1,700	-18,400	166+00	170+00	394	-2,400	-11,000
	Subtotal		1,405	+8,000	-46,900	170+00	174+00	400	-2,600	-9,700
Note: Elevations are referenced to NGVD 1929.										
						174+00	178+00	400	-2,700	-7,500
						178+00	182+00	400	-2,800	-5,100
						182+00	186+00	400	-2,800	-3,300
						186+00	190+00	400	-2,900	-2,600
						190+00	194+00	400	-3,500	-5,100
						194+00	198+00	400	-3,600	-7,500
						198+00	202+00	400	-3,000	-7,800
						202+00	206+00	400	-3,500	-16,600
						206+00	210+00	400	-3,600	-19,300
						210+00	214+00	400	-2,800	-25,000
						Subtotal		16,105	-69,900	-473,200
						Bald Head Total		22,755	-53,600	-511,400

Table 3.3: Bald Head Island shoreline volume change (April 2016 to May 2017).

	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	800	2,800	056+56	060+51	423	300	-19,300	South Beach
	000+00	004+00	400	1,700	5,100	060+51	065+50	510	-3,900	-30,300	
	004+00	008+00	400	1,700	3,400	065+50	069+46	423	-5,200	-27,100	
	008+00	012+00	400	2,500	4,500	069+46	073+39	442	-4,100	-21,400	
	012+00	016+00	400	2,900	4,900	073+39	076+37	516	-4,300	-20,300	
	016+00	020+00	400	3,100	6,500	076+37	084+16	611	-6,800	-20,300	
	020+00	024+00	400	3,800	7,000	084+16	088+23	471	-8,500	-26,000	
	024+00	028+00	400	2,000	-8,700	088+23	092+15	455	-7,200	-28,600	
	Subtotal	2,960	+18,500	+25,500	092+15	097+10	536	-6,600	-32,000		
Point (North of Groin)	028+00	032+00	395	1,600	-4,800	097+10	102+08	525	-7,900	-36,700	
	032+00	034+00	200	1,900	+7,700	102+08	106+00	436	-7,000	-28,600	
	034+00	036+00	210	1,700	+5,800	106+00	110+00	400	-6,500	-22,400	
	036+00	038+00	230	-200	-5,300	110+00	114+00	388	-6,400	-21,900	
	038+00	039+60	230	-2,300	-13,400	114+00	118+00	407	-6,100	-20,500	
	039+60	041+50	220	-2,500	-11,300	118+00	122+00	413	-4,900	-15,400	
	041+50	043+47	220	-2,800	-7,000	122+00	126+00	405	-5,700	-16,000	
	043+47	044+25	190	-2,700	-1,900	126+00	130+00	405	-6,900	-18,600	
	044+25	045+07	190	-2,000	2,900	130+00	134+00	398	-6,200	-16,400	
	045+07	046+00	200	-700	5,400	134+00	138+00	401	-6,600	-17,200	
	Subtotal	2,285	-8,000	-21,900	138+00	142+00	400	-6,500	-17,500		
Point (South of Groin)	046+00	046+89	200	200	2,400	142+00	146+00	400	-5,500	-16,700	
	046+89	049+00	250	1,900	-4,200	146+00	150+00	399	-5,600	-13,900	
	049+00	050+50	100	1,200	-3,700	150+00	154+00	385	-4,000	-6,300	
	050+50	051+00	100	900	-4,400	154+00	158+00	383	-2,200	-4,200	
	051+00	052+64	240	1,000	-14,600	158+00	162+00	386	-2,500	-5,700	
	052+64	054+00	135	100	-9,700	162+00	166+00	393	-2,600	-6,400	
	054+00	056+56	380	1,000	-22,900	166+00	170+00	394	-1,800	-7,200	
	Subtotal	1,405	+6,300	-57,100	170+00	174+00	400	-1,000	-4,500		
Note: Elevations are referenced to NGVD 1929.											
						174+00	178+00	400	-500	-1,800	
						178+00	182+00	400	-200	700	
						182+00	186+00	400	600	2,500	
						186+00	190+00	400	400	1,000	
						190+00	194+00	400	-1,300	-1,800	
						194+00	198+00	400	-2,300	-6,900	
						198+00	202+00	400	-2,500	-13,300	
						202+00	206+00	400	-3,600	-19,500	
						206+00	210+00	400	-5,700	-27,000	
						210+00	214+00	400	-4,600	-31,500	
						Subtotal	16,105	-161,900	-619,000		
						Bald Head Total	22,755	-145,100	-672,500		

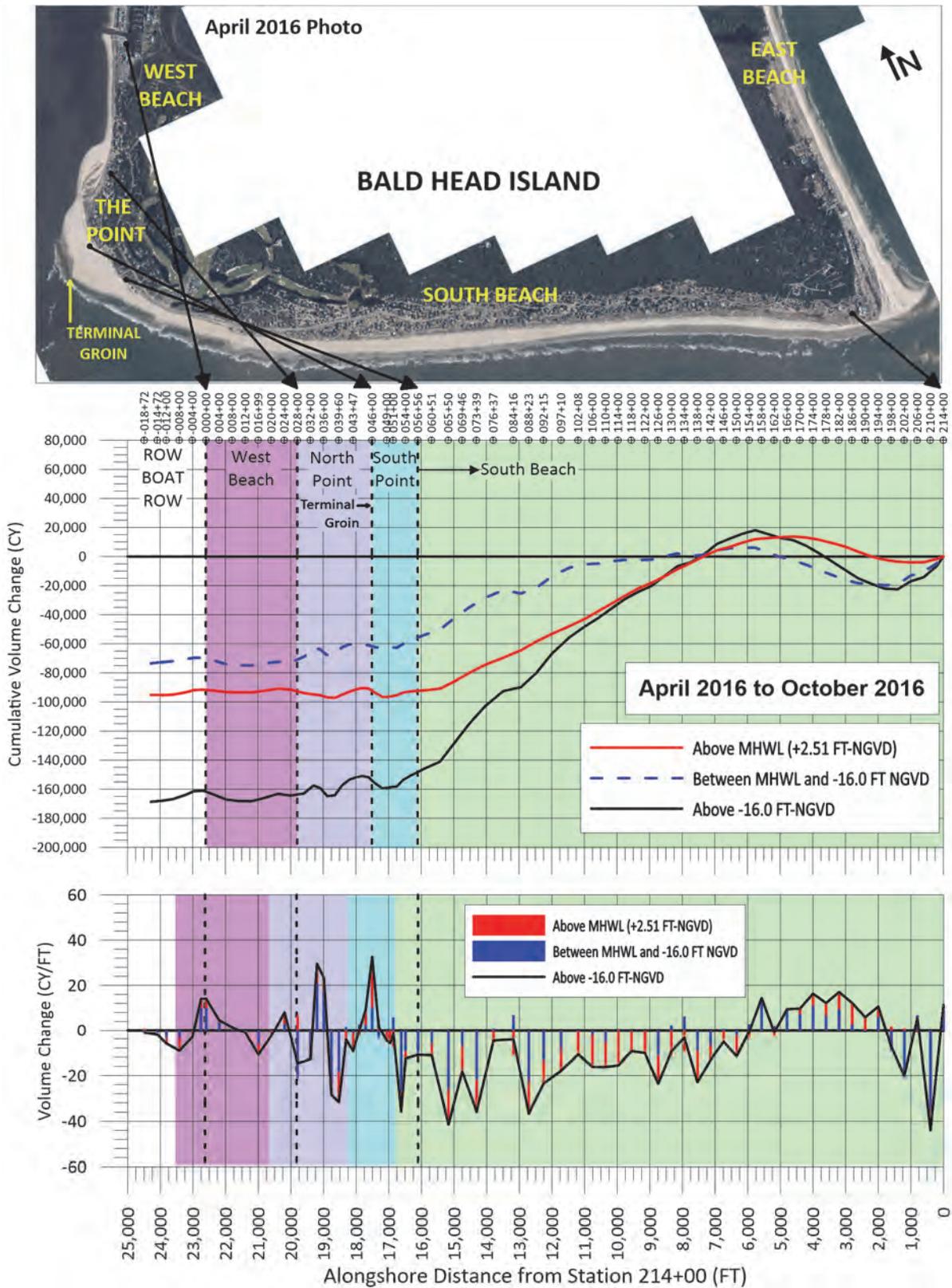


Figure 3.1: Volume change along the Bald Head Island shoreline between April 2016 and October 2016 (Post-Matthew).

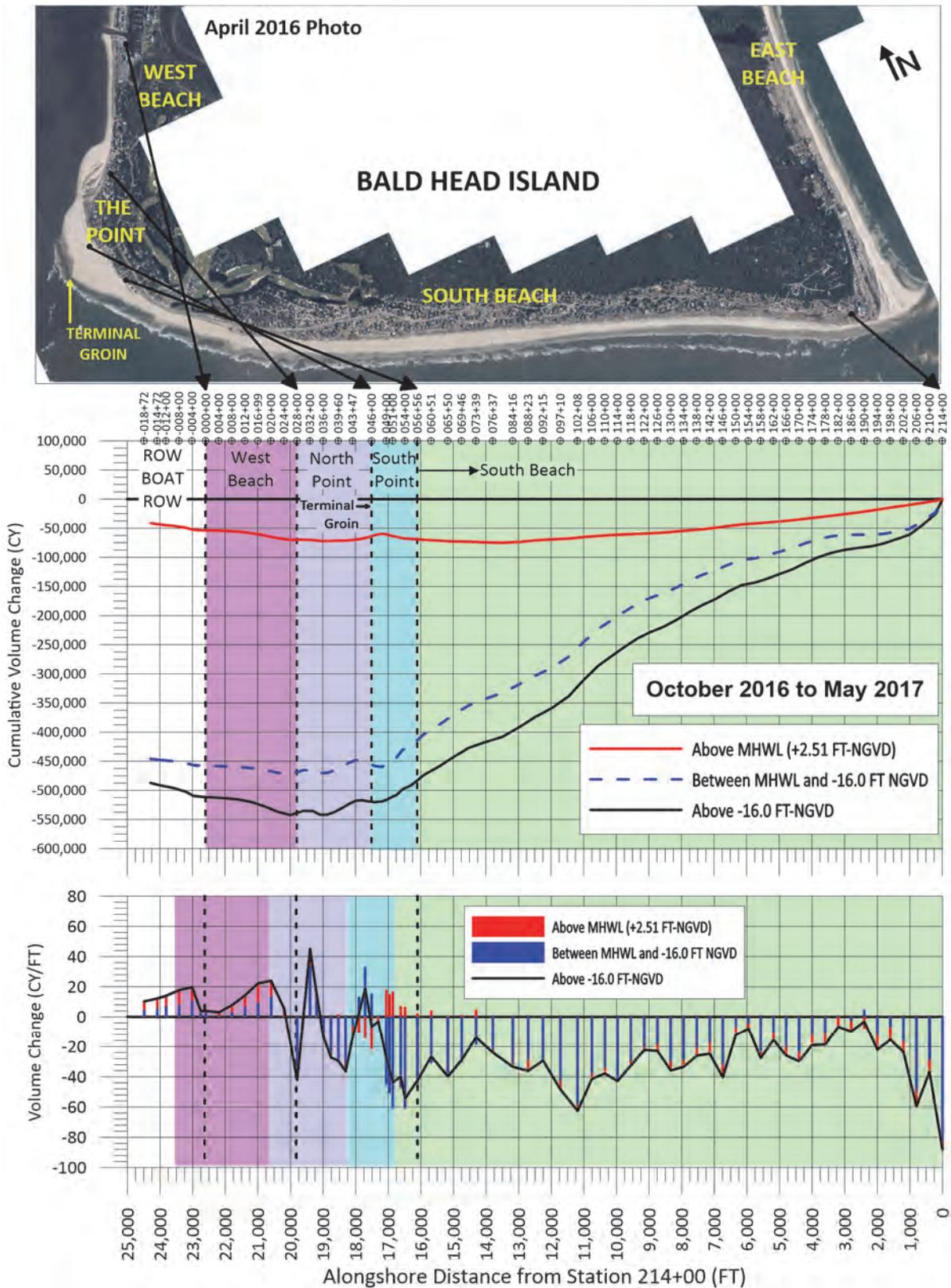


Figure 3.2: Volume change along the Bald Head Island shoreline between October 2016 & May 2017.

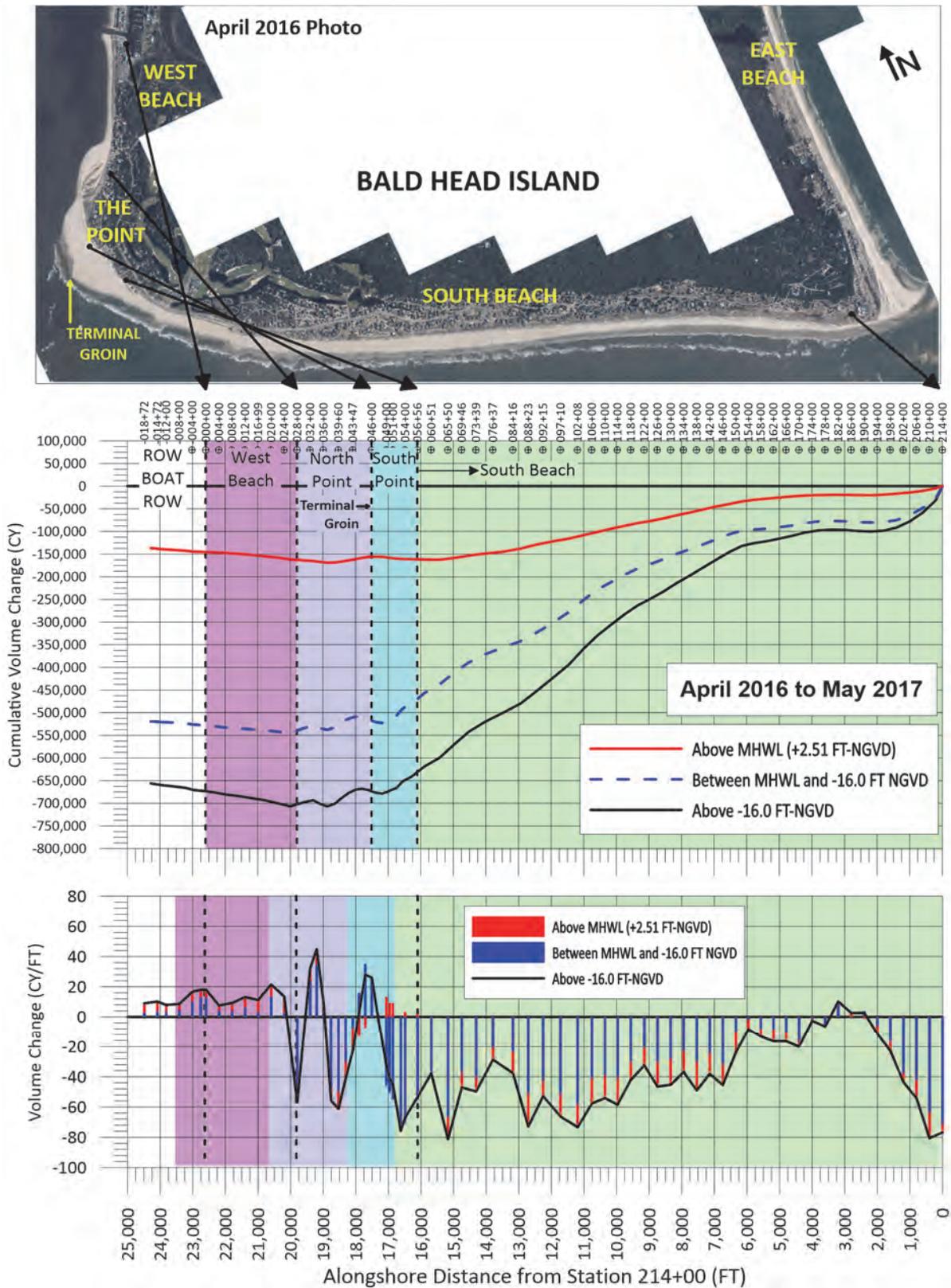


Figure 3.3: Volume change along the Bald Head Island shoreline between April 2016 and May 2017.

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 2016	Oct. 2016	May 2017			April 2016	Oct. 2016	May 2017
West Beach	000+00	+57.7	+69.5	+96.2	South Beach	060+51	+60.6	+42.6	+42.7
	004+00	-8.0	-2.4	+8.5		065+50	+144.3	+67.6	+50.5
	008+00	-21.2	-6.1	+9.8		069+46	+139.1	+105.3	+91.2
	012+00	+25.5	+30.5	+60.1		073+39	+206.0	+152.7	+159.8
	016+00	+17.5	+6.2	+58.7		076+37	+168.4	+136.1	+132.9
	020+00	+23.9	+24.3	+57.5		084+16	+251.9	+198.4	+165.1
	024+00	+167.8	+339.1	+372.2		088+23	+247.5	+210.3	+154.5
	028+00	+376.8	+281.3	+258.1		092+15	+212.2	+142.9	+166.6
Point (North of Groin)	032+00	+241.3	+208.1	+325.7		097+10	+160.8	+100.7	+93.8
	034+00	No November 2000 profile				102+08	+143.7	+78.3	+74.4
	036+00	+80.5	+110.9	+132.0		106+00	+169.8	+93.0	+80.6
	038+00	No November 2000 profile				110+00	+195.9	+124.8	+111.7
	039+60	-101.2	-107.7	+7.6		114+00	+221.2	+139.1	+132.7
	041+50	No November 2000 profile				118+00	+210.6	+159.7	+163.9
	043+47	+24.0	-137.6	-81.9		122+00	+249.0	+192.1	+201.9
	044+25	No November 2000 profile				126+00	+304.5	+230.3	+220.2
	045+07	+36.1	+2.8	-46.0		130+00	+301.6	+229.5	+214.4
	046+00	No November 2000 profile				134+00	+302.6	+240.3	+227.4
Point (South of Groin)	046+89	+221.4	+314.6	+252.2		138+00	+304.6	+238.8	+225.9
	049+00	No November 2000 profile				142+00	+291.0	+275.4	+222.6
	050+50	No November 2000 profile				146+00	+271.9	+268.1	+202.4
	051+00	No November 2000 profile				150+00	+235.0	+236.6	+175.3
	052+64	+292.3	+226.1	+264.9		154+00	+186.5	+208.6	+160.2
	054+00	No November 2000 profile				158+00	+157.3	+198.7	+139.7
	056+56	+128.2	+130.8	+121.8		162+00	+148.2	+184.7	+133.5
						166+00	+148.6	+199.1	+142.2
				170+00		+128.7	+182.7	+130.5	
				174+00		+102.1	+169.3	+106.2	
				178+00	+124.7	+138.8	+121.3		
				182+00	+122.6	+179.8	+125.4		
				186+00	+108.4	+179.2	+117.7		
				190+00	+121.2	+129.9	+116.3		
				194+00	+151.1	+199.9	+119.9		
				198+00	+138.2	+176.5	+105.9		
				202+00	+125.1	+121.7	+104.2		
				206+00	+65.1	+68.1	+23.4		
				210+00	+12.9	-8.9	-35.7		
				214+00	-132.0	-132.3	-152.9		

Positive values indicate shoreline advance relative to the pre-construction location. Negative values indicate shoreline erosion and are highlighted in red.

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 2016	Oct. 2016	May 2017			April 2016	Oct. 2016	May 2017
West Beach	000+00	+65.6	+76.3	+89.4	South Beach	060+51	+45.0	+31.1	+105.6
	004+00	-4.6	-10.1	+7.4		065+50	+129.5	+45.5	+32.9
	008+00	-11.9	-15.8	+8.3		069+46	+139.7	+94.2	+34.4
	012+00	-11.0	-25.1	+15.3		073+39	+203.1	+145.8	+85.0
	016+00	+8.1	-22.1	+35.6		076+37	+162.7	+171.9	+170.2
	020+00	+34.9	+16.2	+88.9		084+16	+246.0	+194.7	+154.2
	024+00	+362.2	+349.3	+367.2		088+23	+290.5	+213.0	+165.3
028+00	+290.1	+216.8	+148.8	092+15		+227.7	+193.5	+170.0	
Point (North of Groin)	032+00	+155.5	+139.2	+253.4		097+10	+172.2	+172.7	+108.9
	034+00	No November 2000 profile				102+08	+156.5	+159.9	+89.2
	036+00	+76.1	+72.3	+68.9		106+00	+219.4	+181.3	+124.3
	038+00	No November 2000 profile				110+00	+213.4	+183.8	+147.5
	039+60	+81.2	-25.4	-59.3		114+00	+235.6	+182.0	+188.0
	041+50	No November 2000 profile				118+00	+270.3	+227.5	+183.3
	043+47	-39.2	-71.7	-179.7		122+00	+285.8	+252.0	+213.2
	044+25	No November 2000 profile				126+00	+324.2	+281.6	+236.1
	045+07	+8.9	+145.4	-50.5		130+00	+321.0	+287.2	+230.8
046+00	No November 2000 profile			134+00		+330.3	+287.7	+242.2	
Point (South of Groin)	046+89	+294.9	+291.0	+289.5		138+00	+332.7	+284.2	+233.0
	049+00	No November 2000 profile				142+00	+315.6	+285.6	+224.7
	050+50	No November 2000 profile				146+00	+276.7	+258.9	+207.5
	051+00	No November 2000 profile			150+00	+250.8	+231.5	+195.3	
	052+64	+285.5	+229.2	+254.7	154+00	+230.7	+207.8	+172.6	
	054+00	No November 2000 profile			158+00	+210.1	+207.3	+170.0	
	056+56	+131.7	+120.1	+105.6	162+00	+197.8	+176.1	+145.3	
					166+00	+196.6	+176.3	+146.1	
				170+00	+180.1	+154.9	+121.4		
				174+00	+169.7	+163.4	+113.3		
				178+00	+179.3	+193.6	+137.2		
				182+00	+138.1	+184.7	+137.3		
				186+00	+126.5	+168.1	+130.9		
				190+00	+147.6	+172.6	+124.6		
				194+00	+175.1	+175.9	+120.3		
				198+00	+182.7	+170.9	+122.0		
				202+00	+146.6	+147.2	+98.2		
				206+00	+48.4	+63.8	+5.0		
				210+00	+12.6	+1.2	-64.3		
				214+00	-137.5	-112.2	-165.4		

Positive values indicate shoreline advance relative to the pre-construction location. Negative values indicate shoreline erosion and are highlighted in red.

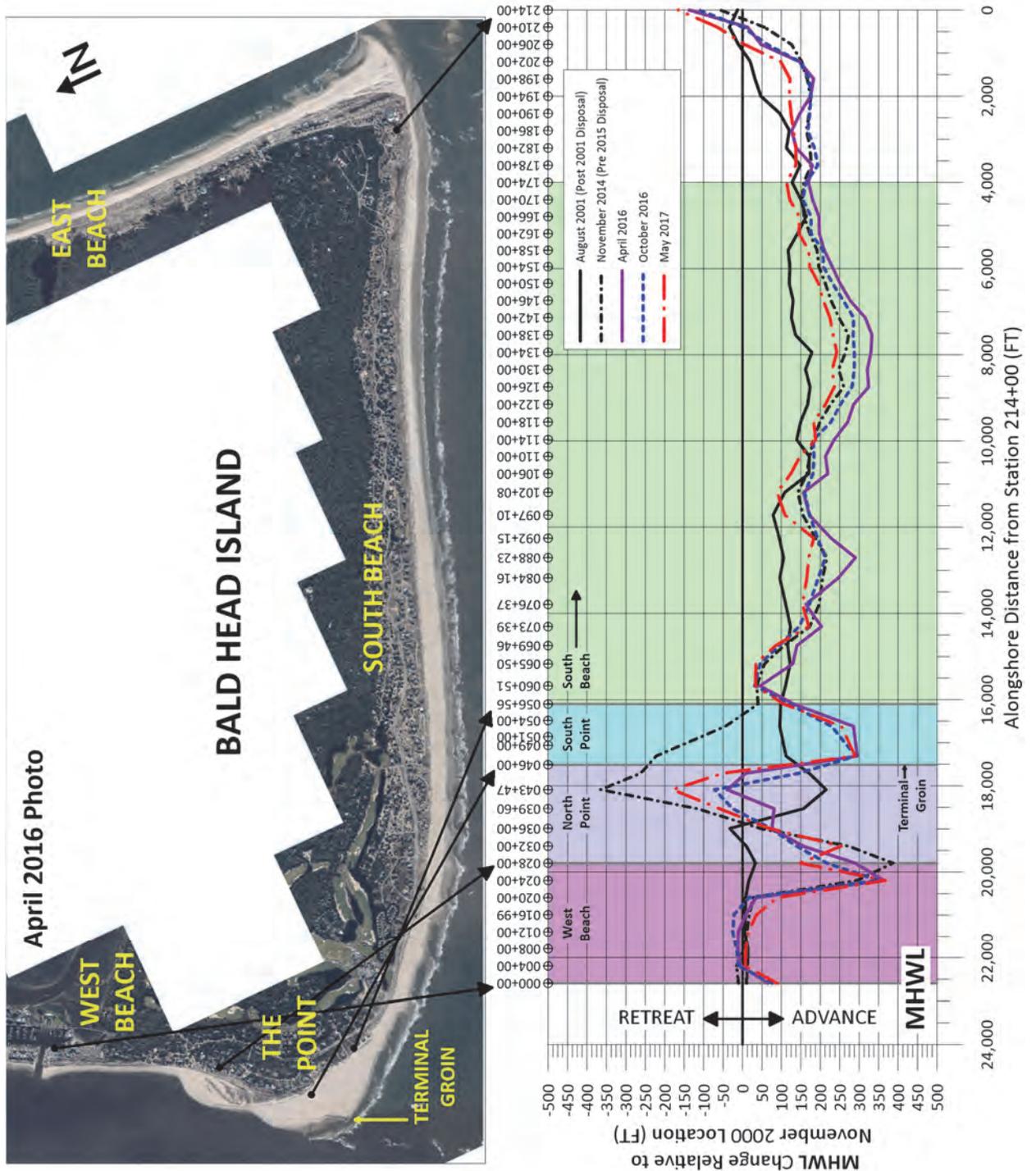


Figure 3.4: Location of the MHWL (+2.51 ft-NGVD) relative to the Nov. 2000 (pre-2001 fill) location.

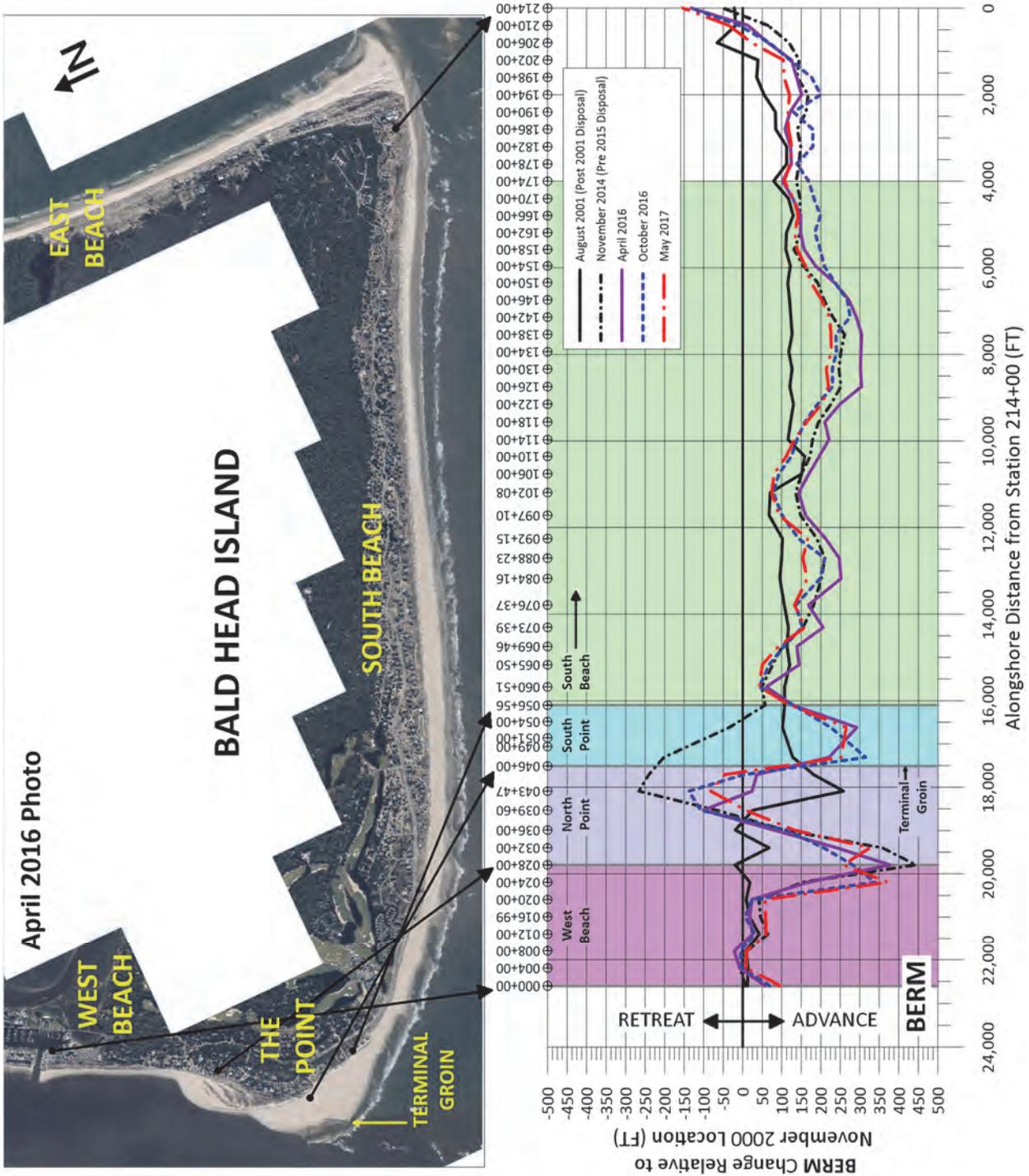


Figure 3.5: Location of the BERM (+6.00 ft-NGVD) relative to the Nov. 2000 (pre-2001 fill) location.

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

3.3.1 Survey Period: April 2016 to October 2016

This six (6) month survey period represents the 73 to 79 months post-construction monitoring period for the 2009/10 Village sponsored renourishment. This period also includes the impact from Hurricane Matthew in early October 2016. The October 2016 survey was completed on October 13, less than one week after the passage of the storm. The October 2016 also represents the approximate one-year post-construction beach conditions following completion of the terminal groin construction and marina jetties extensions and 18 months following the +1.3 Mcy 2015 federal disposal.

As depicted in **Figure 3.1**, the island-wide *net* shoreline volume change trend for this period was erosional with -161,100 cy (-7.1 cy/ft) of loss, mol. over the 6 month span. Consistent with the overall loss, the berm and MHWL retreated by spatially weighted averages⁸ of roughly -15 ft and -21 ft, respectively, along the approximate 22,755 ft of shoreline (West Beach, “the Point”, and South Beach). However, despite experiencing overall erosion and recession, subreaches of the monitored shoreline experienced varied changes over this monitoring period.

In the net, West Beach was relatively stable during this period with a gain of +2,400 cy (0.8 cy/ft) above the MHWL and a loss of 600 cy between the MHWL and the -16 ft-NGVD contour. Overall West Beach gained roughly +1,800 cy above the -16 ft contour. Most of the gains occurred along the northernmost 960 ft of West Beach, adjacent to the recently extended marina jetties. Along this reach (Sta 000+00 to 008+00), the beach gained 7,100 cy (7.4 cy/ft) above -16 ft. Along the remaining 2,000 ft of West Beach, the shoreline lost a net -5,300 cy (-2.7 cy/ft). During this period, the berm and MHWL retreated by weighted averages of -3 and -15 ft, respectively.

The entire 3,690 ft of “the Point” shoreline (Sta. 28+00 to 56+56) was net erosional during this monitoring period, losing -17,100 cy above -16 ft-NGVD (-4.6 cy/ft). For purposes of evaluating the impacts of the 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 mildly erosional, losing -200 cy (-0.1 cy/ft) above the MHWL and -6,900 cy (-3.0 cy/ft) above -16 ft-NGVD. Along this reach, the berm receded by roughly -23 ft on

⁸ Due to the irregular spacing of the profile stations, the average shoreline changes are weighted based upon the distance between stations and calculated using an average end method.

average and the MHWL by -17 ft. South of the terminal groin (Sta. 46+00 to 56+56), the shoreline lost -1,700 (-1.2 cy/ft) above the MHWL and -10,200 cy (-7.3 cy/ft) above the -16 ft-NGVD contour. Similarly, the berm and MHWL retreated by averages of -10 ft and -22 ft, respectively.

South Beach was net erosional during the period, losing roughly -92,000 cy (-5.7 cy/ft) above the MHWL and -145,800 cy (-9.1 cy/ft) above -16 ft-NGVD. Approximately 74% of the monitoring stations (28 of 38) were net erosional include all of the profiled west of Sta 158+00. During this period, the berm and MHWL receded by weighted averages -17 and -20 ft, respectively. Consistent with the volume losses, every monitoring station west of Sta 142+00 experienced berm recession. Similarly, 25 of the 28 profiles west of Sta 174+00 experienced MHWL recession.

3.3.2 Survey Period: October 2016 to May 2017

This seven (7) month survey period represents the 79 to 86 months post-construction monitoring period for the 2009/10 Village sponsored renourishment. This period also includes the effects of a small scale beach restoration project that placed approximately 26,000 cy along Row Boat Row and 24,000 cy along a portion of West Beach.

The island-wide *net* volume change was a loss of approximately -511,400 cy (-22.5 cy/ft). Likewise, the MHWL and berm on average retreated by weighted averages of -10 ft and -36 ft, respectively.

West Beach was net accretional during this period with a gain of +23,700 cy (+8.0 cy/ft). This net gain is largely due to the placement of +24,000 cy during the 2016/17 beach restoration. During this period, the berm advanced by +48 ft and the MHWL by 28 ft, on weighted average.

Along “the Point” shoreline north of the terminal groin, the beach lost -15,000 cy (-6.6 cy/ft) above the -16 ft-NGVD contour. Over half of this net loss occurred above the MHWL (-7,800 cy). The losses along the upper “dry beach” are apparent in the measured MHWL change. During this period, the MHWL retreated by an average of -44 ft.

Along “the Point” shoreline south of the terminal groin, the beach lost -46,900 cy (33.3 cy/ft). However, all of this net loss occurred below the MHWL. Above the MHWL, the beach gained 8,000 cy. This gain along the upper portions of the profile is reflected in the measured changes of the berm and MHWL. During this period, the berm advanced by an average of +12 ft and the MHWL by +11 ft, on weighted average.

South Beach was net erosional during the period, losing roughly -69,900 cy (-4.3 cy/ft) above the MHWL and -473,200 cy (-29.4 cy/ft) above -16 ft-NGVD. All 38 monitoring stations along South Beach were net erosions. **Figure 3.6** depicts the measured volume changes in half foot vertical increments measured along the South Beach shoreline during this period. The figure indicates that losses were observed across all elevations of the beach profile below +9 ft-NGVD with the largest losses occurring between -4 and -7 ft-NGVD.

During this period, The berm and MHWL receded by averages of -27 ft and -38 ft, respectively. Consistent with the volume losses, all but 2 of the 38 monitoring stations experienced MHWL recession. Similarly, all but 3 of the 38 monitoring stations experienced berm recession.

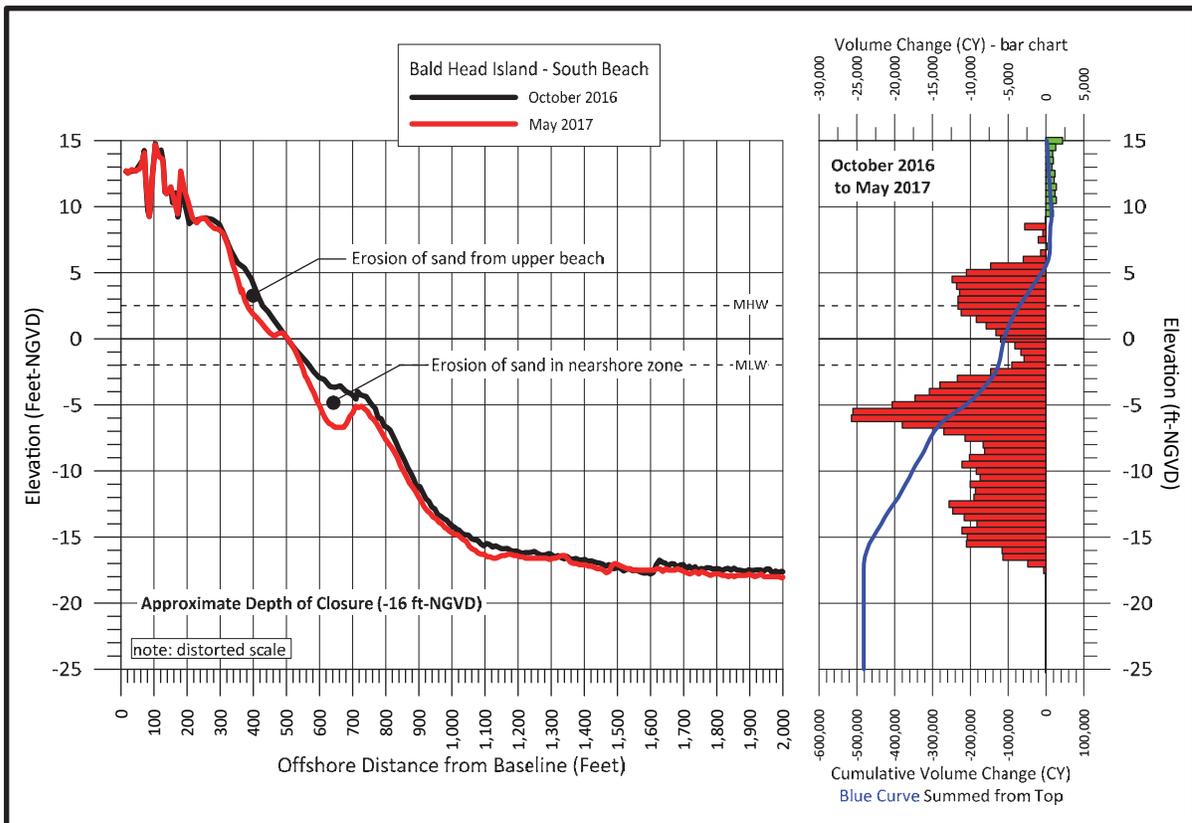


Figure 3.6: Vertical distribution of volume changes for the South Beach shoreline of Bald Head Island (Sta. 56+56 to Sta. 214+00) from October 2016 to May 2017. The graph on the right depicts the volume changes measured at 0.5 ft vertical intervals (bar chart), as well as a summation of the total volume change measured from the dunes seaward to survey closure (blue curve). The example beach profiles depicted in the left panel are from Sta. 134+00..

3.3.3 Year 15 Monitoring Results: April 2016 to May 2017 (Excluding East Beach & Row Boat Row)

As previously discussed, this Year 15 monitoring report includes the effects of Hurricane Matthew and the placement of approximately 24,000 cy along West Beach as part of the 2016/17 beach restoration project. During Year 15 in its entirety, the island experienced a net loss of -672,500 cy (-29.6 cy/ft) above the -16 ft contour. Above the MHWL, the island lost -145,100 cy (-6.4 cy/ft). However, all of these net losses occurred along South Beach and “the Point”, as West Beach experienced net accretion due to the restoration project.

Along West Beach, the shoreline gained approximately +18,500 cy (+6.3 cy/ft) above the MHWL and +25,500 cy (+8.6 cy/ft) above -16 ft. During this period, the berm advanced by an average of +46 ft and the MHWL advanced by +13 ft.

The entire Point shoreline (north and south of the terminal groin), experienced a net loss of roughly -79,000 cy (-21.5 cy/ft) above -16 ft-NGVD during the latest monitoring year. However, most of this loss occurred below the MHWL. Above the MHWL, this reach lost -1,700 cy (-0.5 cy/ft). During this period, the berm advanced by an average of +3 ft and the MHWL receded by -42 ft.

The South Beach shorefront, which received the majority of the 2015 disposal sand lost approximately -161,900 cy (-10.0 cy/ft) above the MHWL and -619,000 cy (-38.4 cy/ft) above -16 ft-NGVD. All but 3 of the 38 monitoring stations along South Beach experienced net erosion above -16 ft during Year 15.

During this period, the berm and MHWL receded by averages of -47 ft and -59 ft, respectively. Consistent with the volume losses, all but 3 of the 38 monitoring stations experienced MHWL recession. Similarly, all but 1 of the 38 South Beach monitoring stations experienced berm recession.

3.3.4 Long-Term Beach Changes: November 2000 to May 2017

For purposes of tracking gross sand placement performance, **Figure 3.7** plots a time history of cumulative volume change relative to November 2000 conditions. **Figure 3.8** presents net volumetric change (alongshore above -16 ft NGVD) for the maximum period of comparison to date (*i.e.* November 2000 and May 2017). 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 3.7**, 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, any future reformulation of the Wilmington Harbor Sand Management Plan by the Wilmington District, USACOE, it continues to be 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 3.8**.

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.* May 2017). Currently, within the **approximate** 22,755 ft of shoreline considered, there is a net gain of +2,633,200 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 -6,449,600 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.

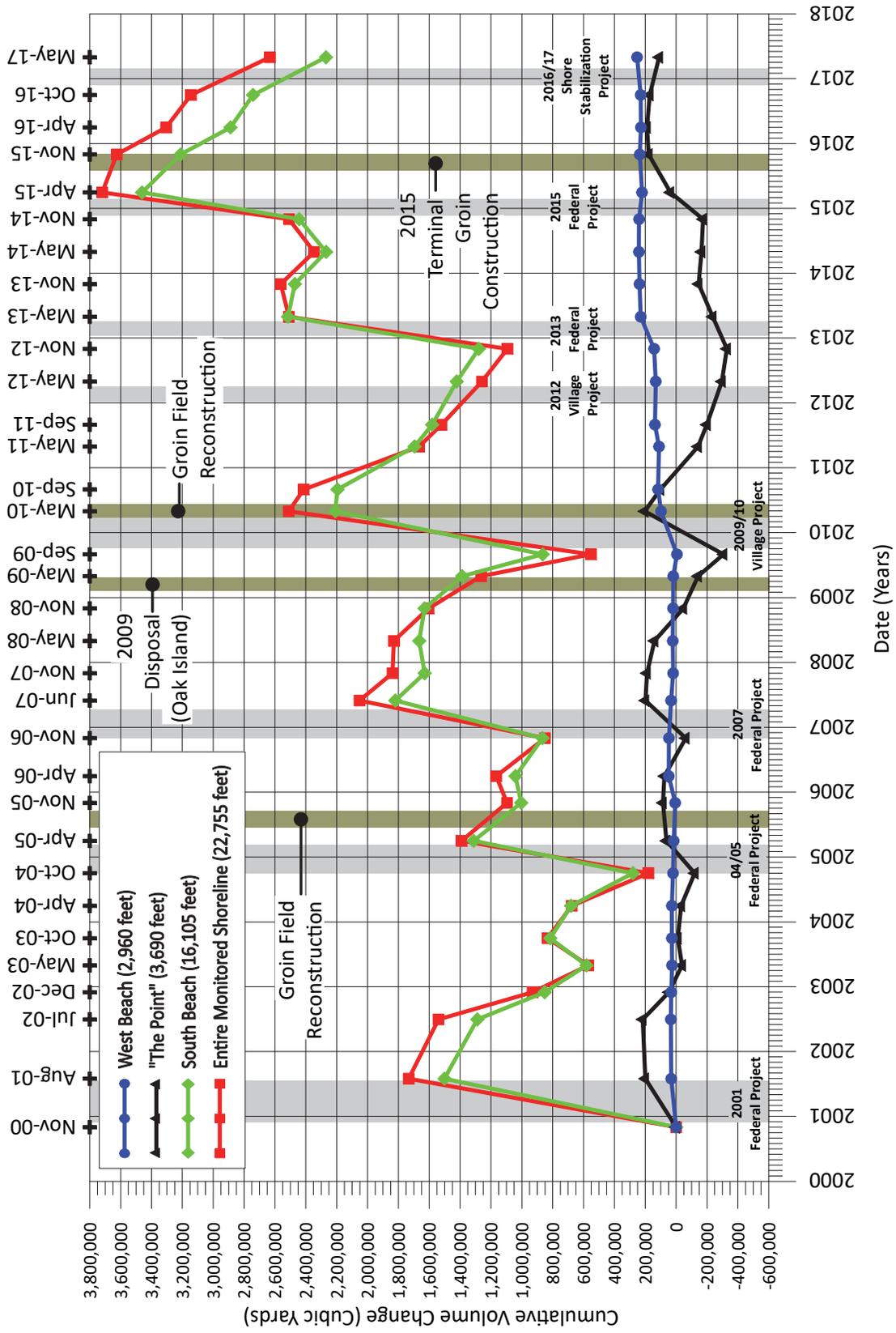


Figure 3.7: Cumulative volume change (above -16 ft-NGVD) relative to November 2000 conditions.

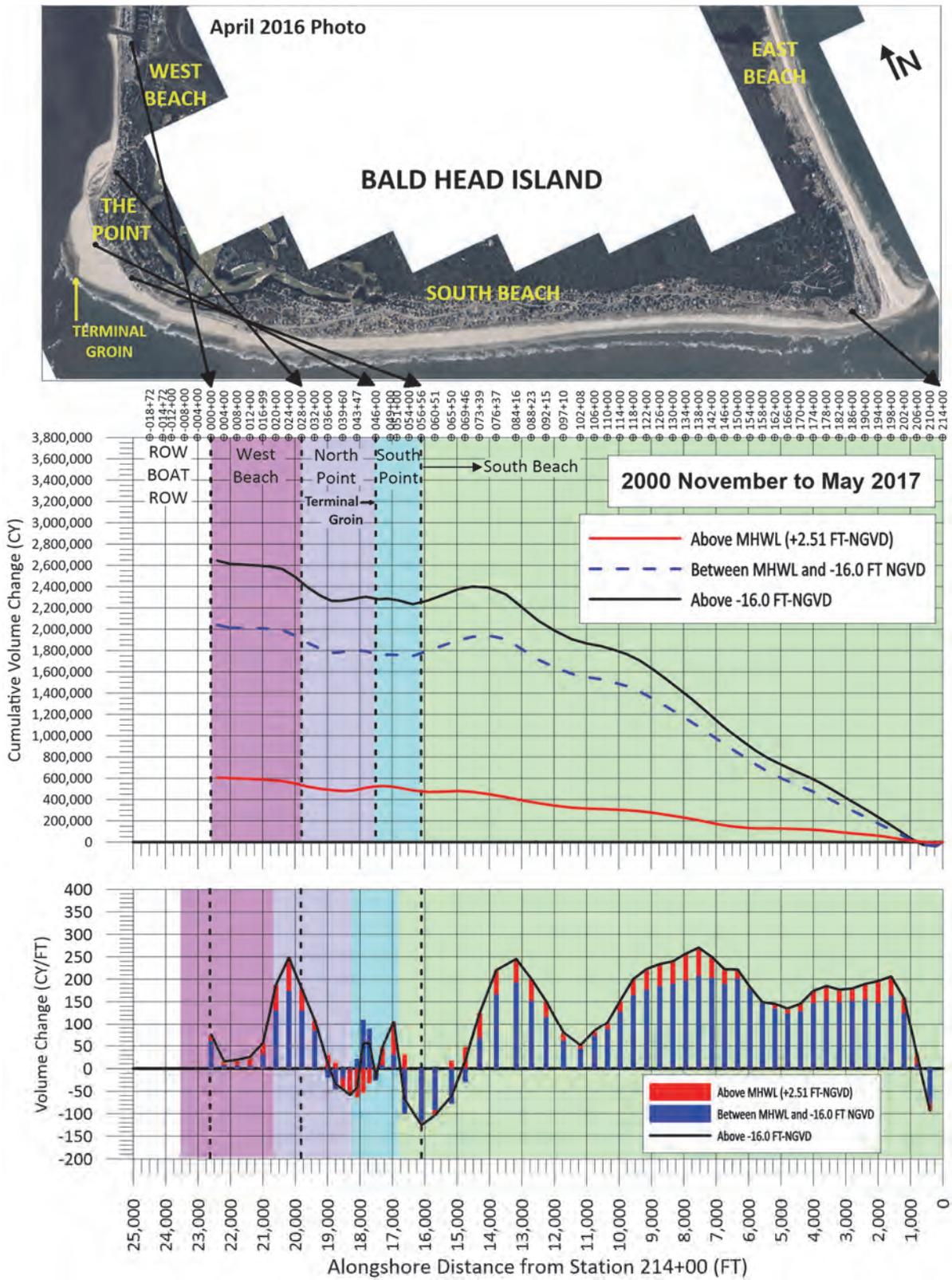


Figure 3.8: Volume change along the Bald Head Island shoreline between November 2000 and May 2017.

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 ⁹	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) ¹⁰	Apr. 2004	Apr. 2005	12	-11,800	+94,700	+631,200	+714,100
Year 5 (2006 WB Project) ¹¹	Apr. 2005	Apr. 2006	12	+32,000	+13,300	-270,200	-224,900
Year 6 (2007 Project) ¹²	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) ¹³	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) ¹⁴	May 2011	May 2012	12	+20,800	-154,600	-273,300	-407,100
Year 12 (2013 Disposal) Project ¹⁵	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) Project ¹⁶	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
Year 16 ¹⁷	April 2016	May 2017	13	+25,500	-79,000	-619,000	-672,500
Pre-2000 Construction to Year 16	Nov. 2000	May 2017	198	+253,700	+110,200	+2,269,300	+2,633,200
Pre-2000 Construction to Year 16 (Fill Removed)	Nov. 2000	May 2017	198	NA	NA	NA	-6,449,600

⁹ 2001 Initial Disposal (1,849,500± CY)

¹⁰ 2005 Beach Disposal (1,217,000± CY)

¹¹ 2006 West Beach Fill (47,800± CY)

¹² 2007 Beach Disposal (978,500± CY)

¹³ 2009/10 Beach Fill (1,850,000± CY)

¹⁴ 2012 Beach Fill (138,000 ± CY)

¹⁵ 2013 Beach Disposal Fill (1,658,000 ± CY)

¹⁶ 2015 Beach Disposal Fill (1,320,000 ± CY)

¹⁷ 2016/17 Beach Disposal (24,000± 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 390,900 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), April 2016 (5 months post-construction) and June 2017 (19 months post-construction). The three surveys completed to date are plotted in **Figure 3.9**. 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.

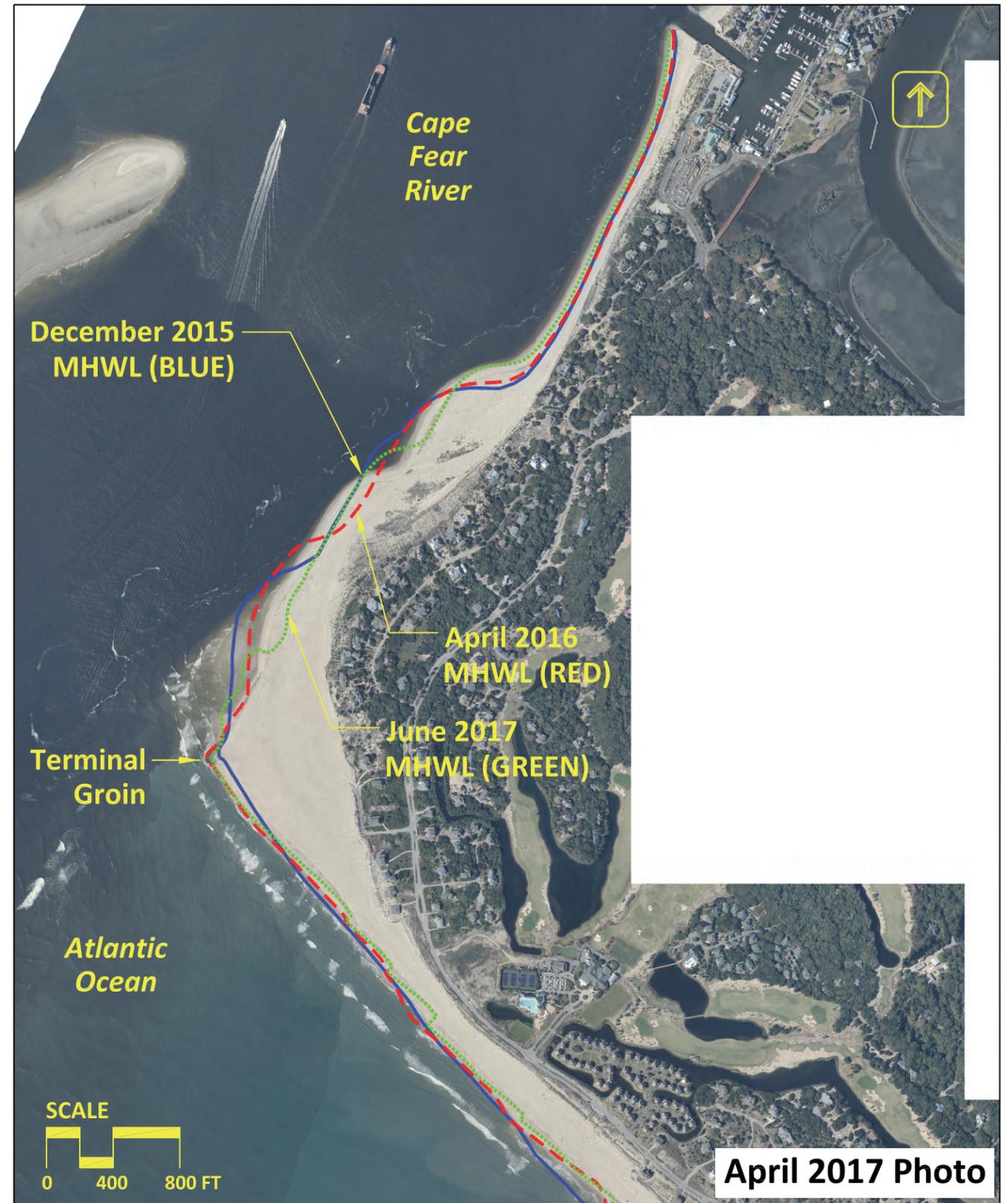
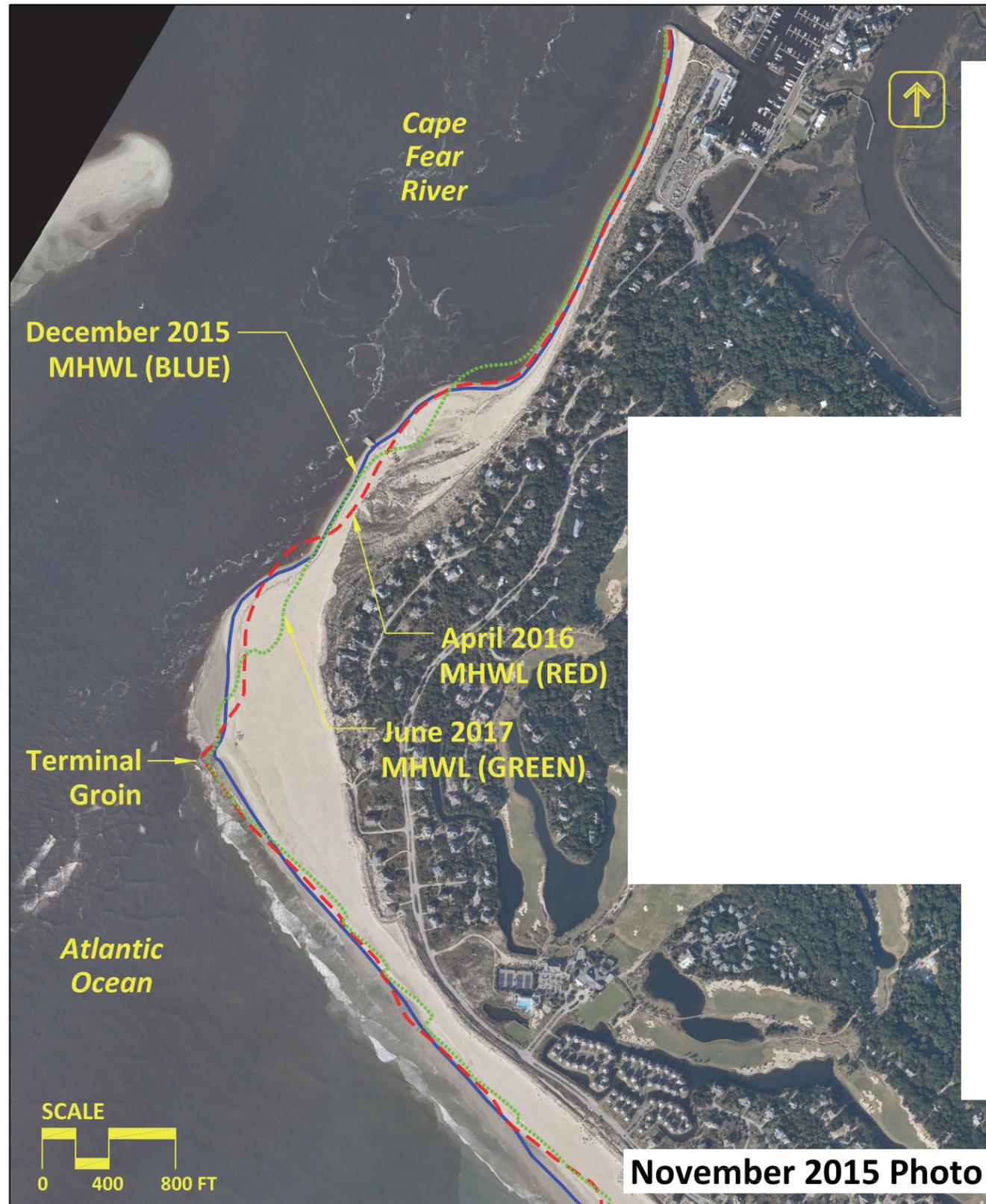


Figure 3.9:
MHWL positions in the vicinity of the terminal groin Bald Head Island, NC

3.3.6 Chronology of the Point

Since the construction of the 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 the Village’s and monitoring program. 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 E includes a high resolution visual chronology of the Point from 1998 to April 2017. Demarcated on each photo panel are the approximate September 2001 (blue line) and April 2017 (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 consistent *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 2017 timeframe. As had been concluded throughout the numerous 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 were documented to last only about 2 years after each federal disposal event.

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 were 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. Subsequently, future monitoring reports will address the “new dynamic” expected to result from the implementation of the terminal groin structure. Predictions of future 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 reconfiguration. These include additional transects in the vicinity of the structure as well as an approximate MHWL delineation performed by survey every 6-months.

For the April 2016 to May 2017 monitoring period, the inlet facing shoreline adjacent to the terminal groin continues to recede back (as predicted) and adjust to a new equilibrium condition. An intertidal spit formation remains on the inlet side of the structure as a result of sediment transported from South Beach through or across the structure. Updrift thereof, portions of the historical Point continue to migrate northward as they did prior to terminal groin construction. This is best represented by the surveyed MHWL locations depicted in **Figure 3.9**. It has been noted previously that the majority of the terminal groin was constructed “in the dry” – with only the distal head of the structure evident at completion in late 2015. Since that time, portions of the berm west of the structure are receding as a new equilibrium condition evolves.

Eastward of the structure, the updrift sand fillet retained by the groin is relatively stable – or mildly recessive. As predicted, the need for episodic sediment placement extending eastward of the groin some 9,300 ft to approximately Sta. 134+00 was addressed by the project permits. The sources of such future fill activities were identified as Jay Bird Shoals, the federal channel, Bald Head Creek and/or Frying Pan Shoals.

3.4 East Beach Shoreline Conditions

In November 2008, East Beach was added to the island-wide beach monitoring program¹⁸. 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 2016 to October 2016 to May 2017 monitoring periods.

The April 2016 to October 2016 period includes the impacts of Hurricane Matthew. During this period the East Beach shoreline was accretional, gaining +47,300 cy (+7.9 cy/ft) above -16 ft-NGVD. However, above the MHWL, East Beach was erosional, losing approximately -8,100 cy (-1.4 cy/ft). During this same period the berm and MHW shorelines advanced by spatially weighted averages¹⁹ of +8.4 ft and +4.0 ft. However, these average advances are *heavily influenced* by the large advancement at the southernmost station, STA 224+80, located immediately north of Cape Fear. At this station, the berm advanced by over 68 ft and the MHWL by over 141 ft. This advancement is evident in **Figure 3.10** which depicts the April 2016, November 2016 and April 2017 aerial photographs along East Beach.

During the October 2016 to May 2017 period, the East Beach shoreline gained approximately +12,600 cy above the MHWL but lost -17,200 cy below MHWL for a net total change above -16 ft-NGVD of -4,600 cy. During this same period the berm advanced by a spatially weighted average of +9.6 ft while the berm receded by an average of -1.3.

Table 3.9 summarizes shoreline and volume changes measured over the entire period of survey record (November 2008 – May 2017). Over the 103-month period, the East Beach shoreline gained approximately +232,800 cy above the -16 ft-NGVD contour and +55,100 cy above the MHWL. Likewise, the berm and MHWL advanced by weighted averages of +37.1 ft and +56.8 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 -33,500 cy and -81,000 cy above the MHWL and -16 ft-NGVD contour, respectively during this period.

¹⁸ Profiles were not acquired at East Beach in the fall of 2009

¹⁹ Due to the irregular spacing of the profile stations, the average shoreline changes are weighted based upon the distance between stations and calculated using an average end method.

As demonstrated by the survey and photographic data (**Figure 3.10**), 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”. Of further interest are the variations in spit size and orientation over the last several years (2008-2017) which are depicted by **Figure 3.11**. 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).

Table 3.7: East Beach shoreline and volume changes between April 2016 and October 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)
224+80				+68.3	+141.4
	1,000	+5,000	+28,900		
234+80				-7.6	-3.4
	1,000	-2,100	+3,000		
244+80				+15.5	-10.1
	1,000	-2,700	+9,300		
254+80				-0.5	-14.2
	1,000	-2,500	+10,000		
264+80				+11.6	-5.9
	1,000	-2,400	-300		
274+80				-0.6	-12.3
	1,000	-3,400	-3,600		
284+80				-4.5	-1.2
Total	6,000	-8,100	+47,300	+11.7	+13.5

Table 3.8: East Beach shoreline and volume changes between October 2016 and May 2017.

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				+45.0	+5.4
	1,000	+4,300	+30,200		
234+80				+34.6	-10.6
	1,000	+2,800	-17,600		
244+80				-2.5	-19.2
	1,000	+300	-17,500		
254+80				-7.3	-8.9
	1,000	-1,100	-12,600		
264+80				-12.2	-7.5
	1,000	+2,400	+6,400		
274+80				+22.4	+40.4
	1,000	+3,900	+6,500		
284+80				0.0	-9.3
Total	6,000	+12,600	-4,600	+11.4	-1.4

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	+28,600
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
April 2016 to October 2016	-8,100	+55,400	+47,300
October 2016 to May 2017	+12,600	-17,200	-4,600
November 2008 to May 2017	+55,100	+177,000	+232,800

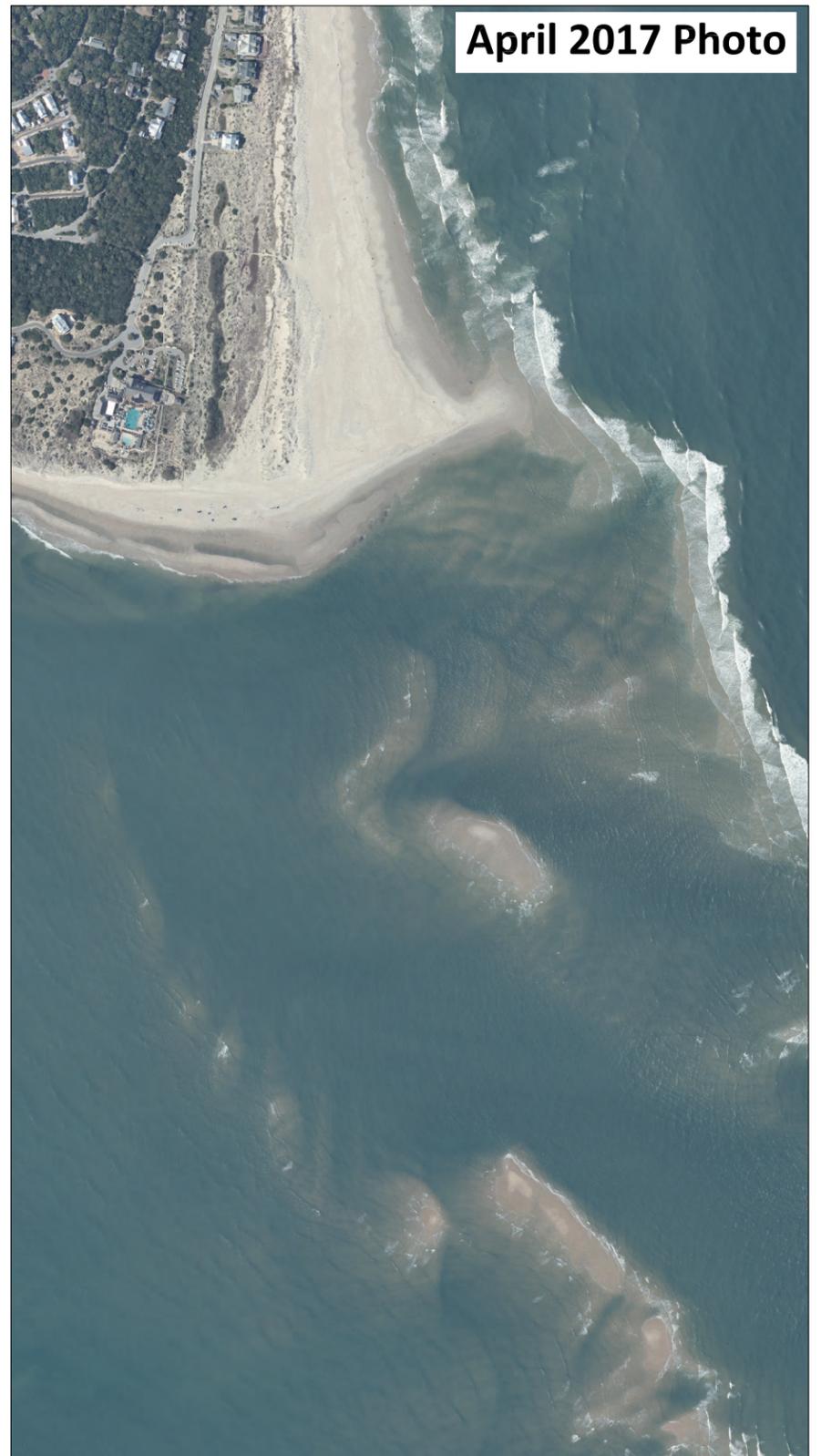


Figure 3.10:
Cape Fear aerial photography
Bald Head Island, NC

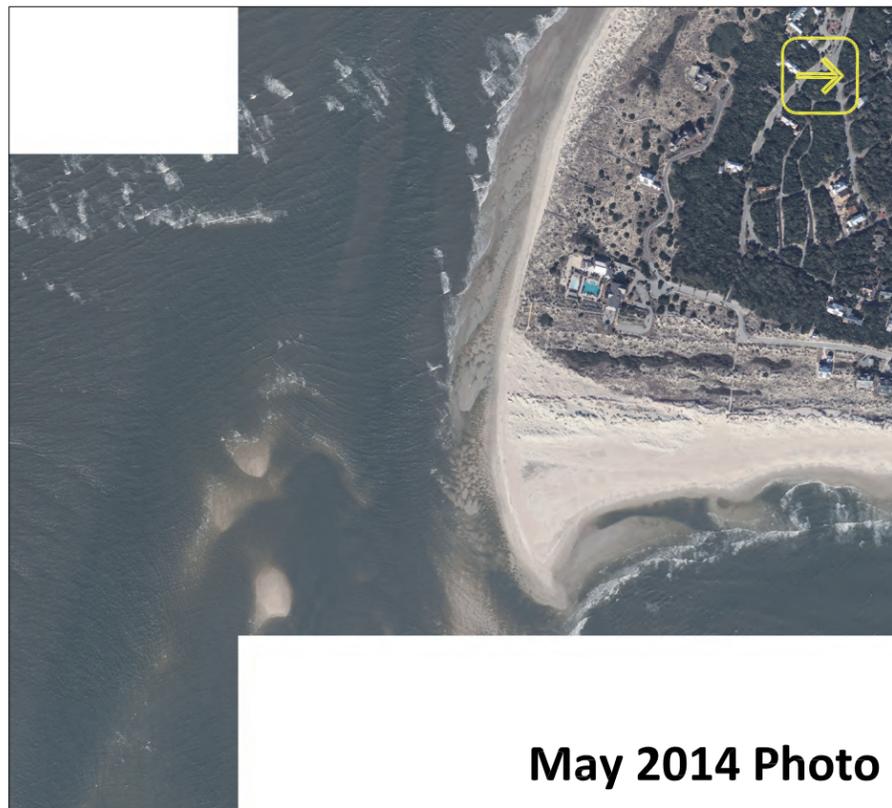


Figure 3.11:
Cape Fear aerial photography
Bald Head Island, NC

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. May 2017 shoreline conditions are visually shown by **Figure B-9** (Appendix B – May 2017 Aerial Photography – page B-10). Since November 2000, the MHWL at profile B-54 has receded by -165 ft, or about -10 ft/yr. At B-55, over the same period of time, the MHWL has receded -270 ft, or about -16 ft/yr. More recently however, between November 2014 and May 2017, the MHWL at B-55 had receded by about -80 ft which equates to a rate of -23 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** and **3.11** summarize the shoreline and volume changes measured during the April 2016 to October 2016 to May 2017 monitoring period (13 months).

The April 2016 to October 2016 period includes the impacts of Hurricane Matthew. During this period the Row Boat Row shoreline was erosional, losing approximately -3,700 cy (-2.4 cy/ft) above the MHWL and -7,600 cy (-4.8 cy/ft) above -16 ft-NGVD. Likewise, the berm and MHW shorelines receded by spatially weighted averages²⁰ of -21.2 and -18.2 ft.

The October 2016 to May 2017 period includes the direct placement of approximately +26,000 cy along the Row Boat shoreline excavated from the Bald Head Creek borrow site. During this period, the shoreline showed a gain of roughly +12,100 cy (+7.7 cy/ft) above the MHWL and +24,000 cy (+15.3 cy/ft) above -16 ft-NGVD. Similarly, the berm and MHW shorelines advanced by weighted averages of +44.6 and +51.0 ft, respectively.

²⁰ Due to the irregular spacing of the profile stations, the average shoreline changes are weighted based upon the distance between stations and calculated using an average end method.

Table 3.10: Row Boat Row shoreline and volume changes between April 2016 and October 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				-91.6	-23.2
	400	+100	-700		
-014+72				-10.8	-19.7
	272	-300	-1,100		
-012+00				-13.1	-21.7
	400	-1,600	-3,000		
-008+00				-13.8	-18.7
	400	-1,600	-2,500		
-004+00				-4.8	-8.8
	100	-300	-300		
Marina					
Total	1,572	-3,700	-7,600	-21.2 (avg)	-18.2 (avg)

Table 3.11: Row Boat Row shoreline and volume changes between October 2016 and May 2017.

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					
	400	+2,400	+4,500	+3.1	+39.0
-014+72					
	272	+1,800	+3,600	+50.5	+49.1
-012+00					
	400	+3,300	+6,400	+49.4	+52.8
-008+00					
	400	+3,700	+7,500	+55.5	+59.3
-004+00					
	100	+900	+2,000	+45.8	+48.2
Marina					
Total	1,572	+12,100	+24,000	+44.6 (avg)	+51.0 (avg)

4.0 BORROW SITE MONITORING (SURVEY) RESULTS

4.1 Borrow Site Evaluation – Bald Head Creek

A small-scale beach restoration project utilizing sand from the Bald Head Creek borrow site was constructed between December 2016 and March 2017 along the West Beach and Row Boat Row shorefronts (see **Section 1.6.2**). Approximately 50,000 cy were dredged from the northeastern corner of the permitted borrow site. This same borrow site was utilized for the 2012 Post-Irene small scale mitigation project and continues to be resurveyed annually. Approximately 138,000 cy of sand were dredged from the borrow site between January and February 2012.

Depictions of the November 2016 (pre-project) and March 2017 (post-project) seabed conditions within the borrow site are provided as **Figures 4.1** and **4.2**, respectively. **Figure 4.3** presents the relative seabed elevation change between the pre- and post-project surveys (November 2016 to March 2017) and **Figure 4.4** presents the seabed elevation change since project completion (March 2010 to March 2017). **Table 4.1** summarizes the volume changes within the permitted borrow site limits between the monitoring surveys conducted to date.

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
April 2016 to November 2016 (Year 4 to Year 4.5)	7 months	+9,700	-2,000	+7,700
November 2016 to March 2017 (Year 4.5 to Year 5)	4 months	+1,800	-55,000	-53,200
Since Construction (March 2012 to March 2017)	60 months	+106,000	-81,500	+24,500

During the pre to post-2016 construction monitoring period (November 2016 to March 2017), the borrow site “lost” approximately -53,200 CY *within the entire permitted area* (both excavated and unexcavated). Within the excavation limits, approximately -48,700 were removed during project construction. In the five years since project completion (March 2012 to March 2017), the permitted borrow site gained roughly +24,500 CY. Most deposition areas this time frame derived from sediment transported from the Row Boat Row shoreline.

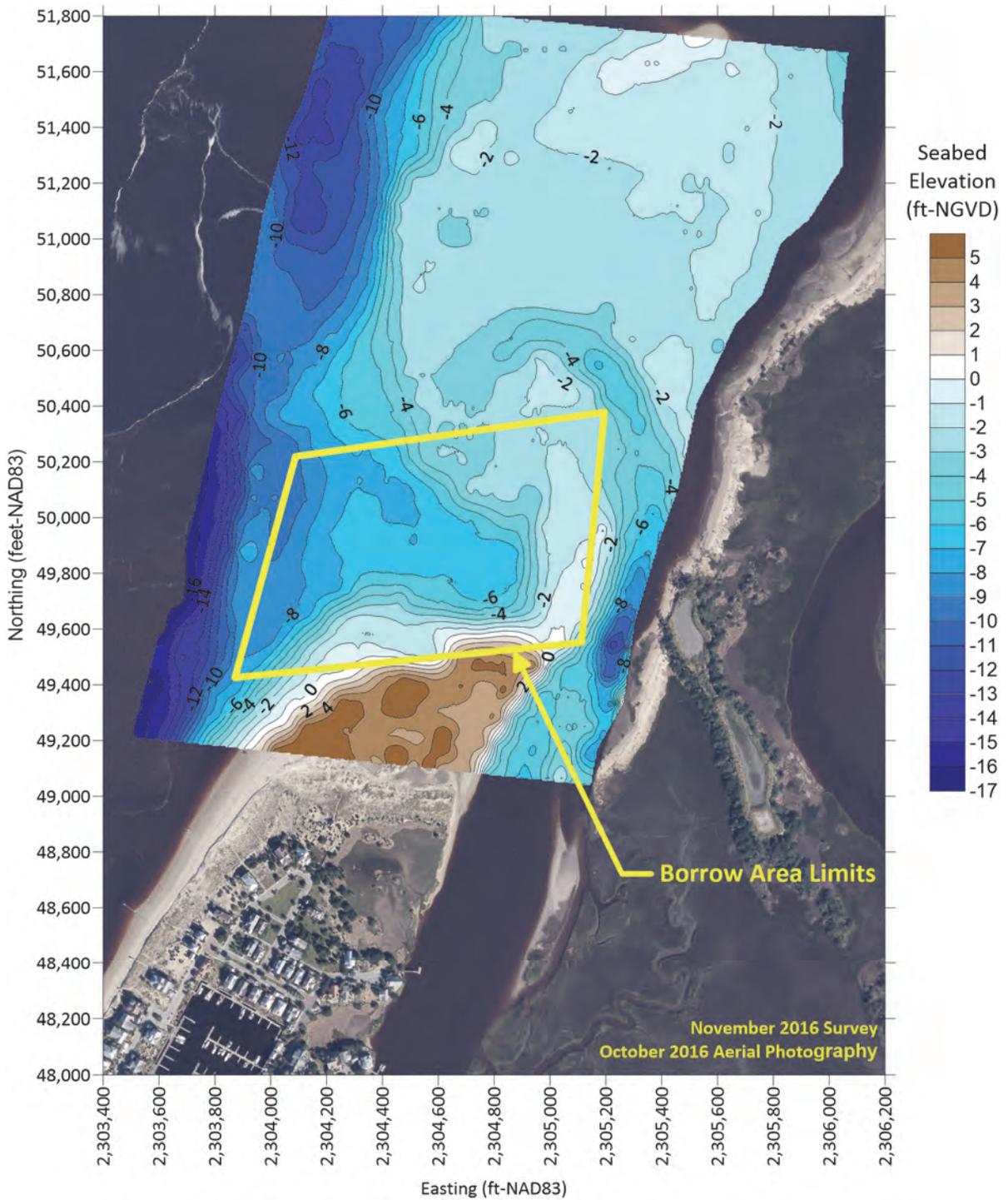


Figure 4.1: Pre-2016/17 project (56 months post-2012 project) Bald Head Creek borrow site conditions (November 2016 survey).

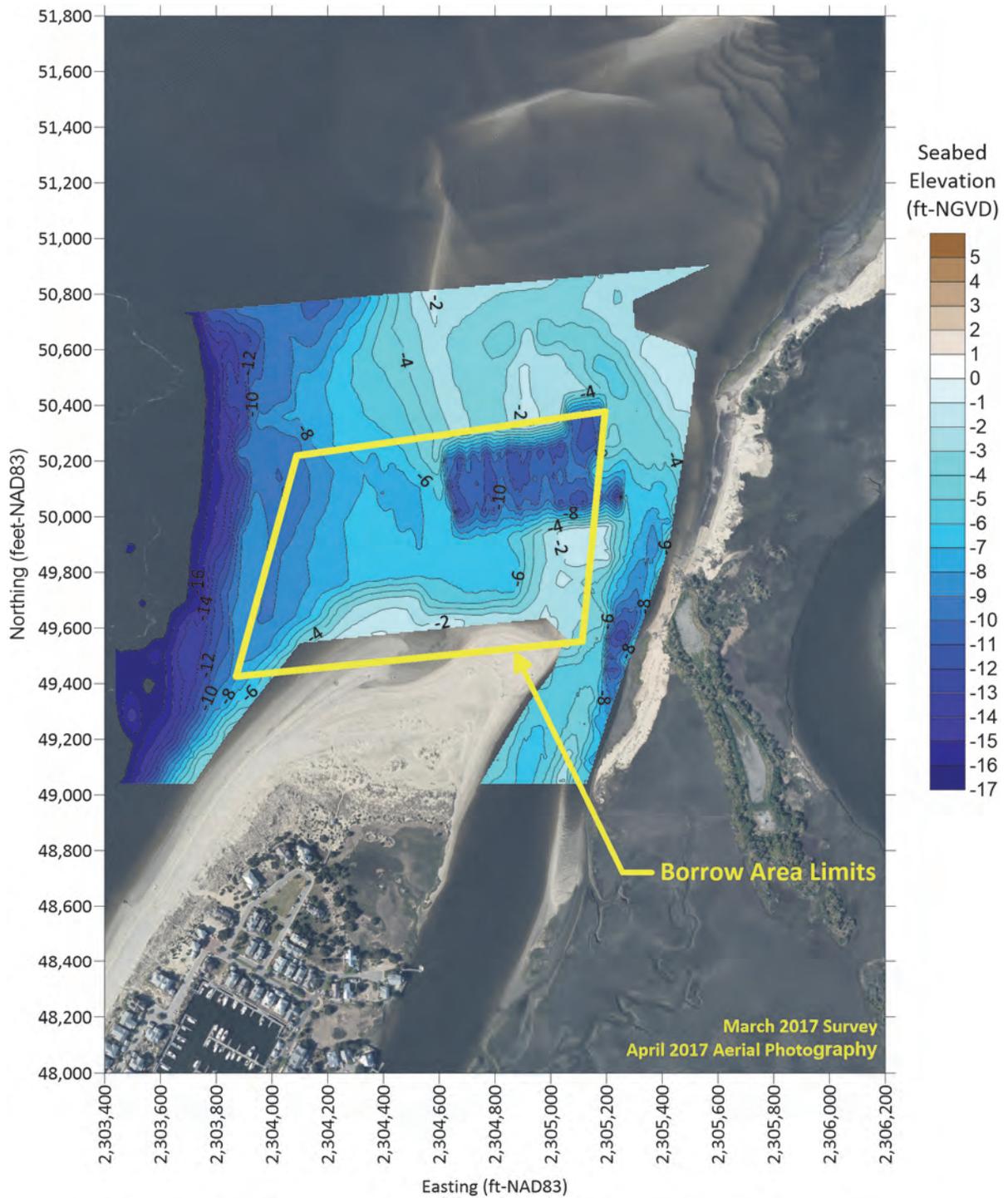


Figure 4.2: Post-2016/17 project (60 months post-2012 project) Bald Head Creek borrow site conditions (March 2017 survey).

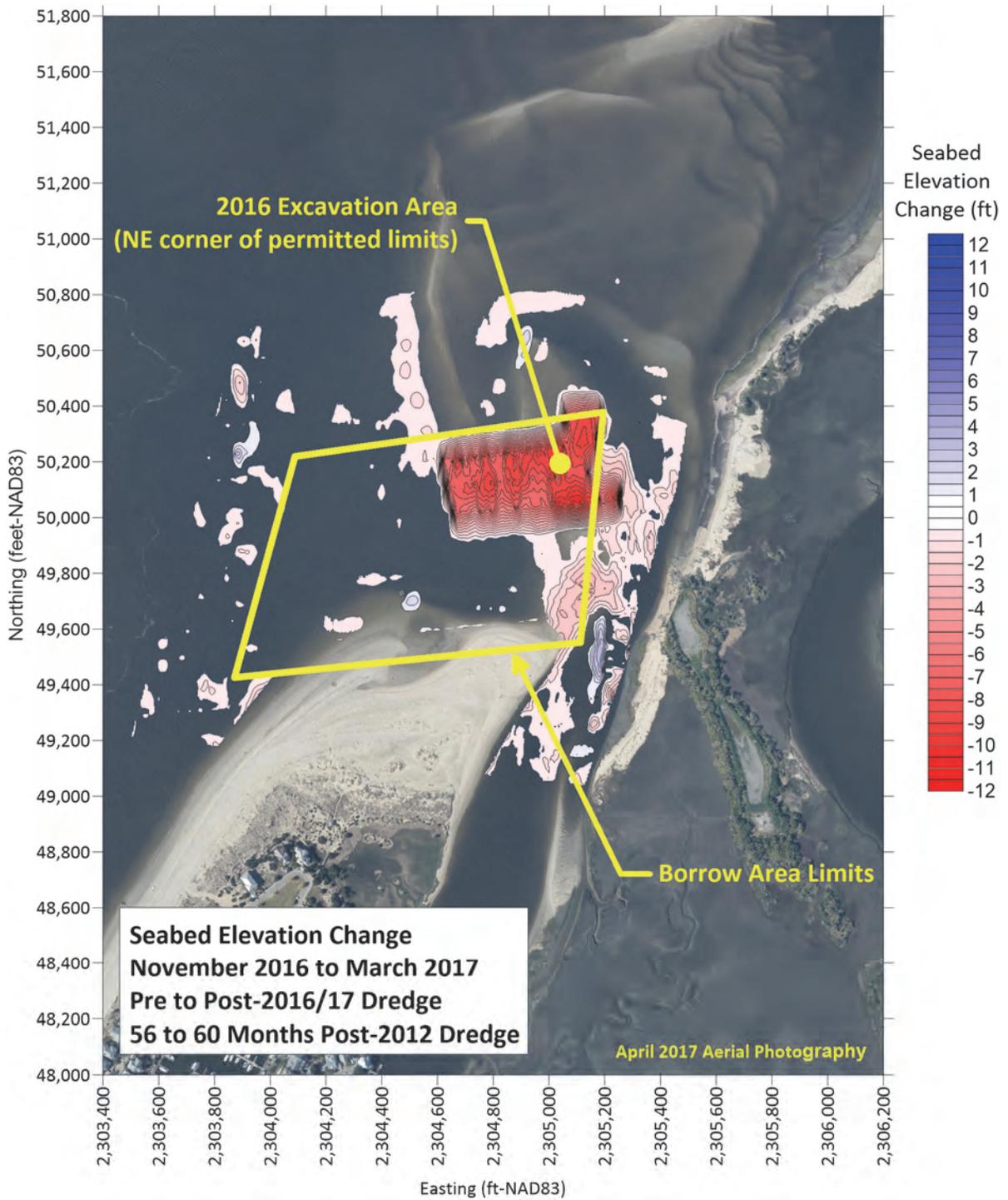


Figure 4.3: Bald Head Creek borrow site seabed elevation changes pre- to post-2016/17 project (November 2016 to March 2017).

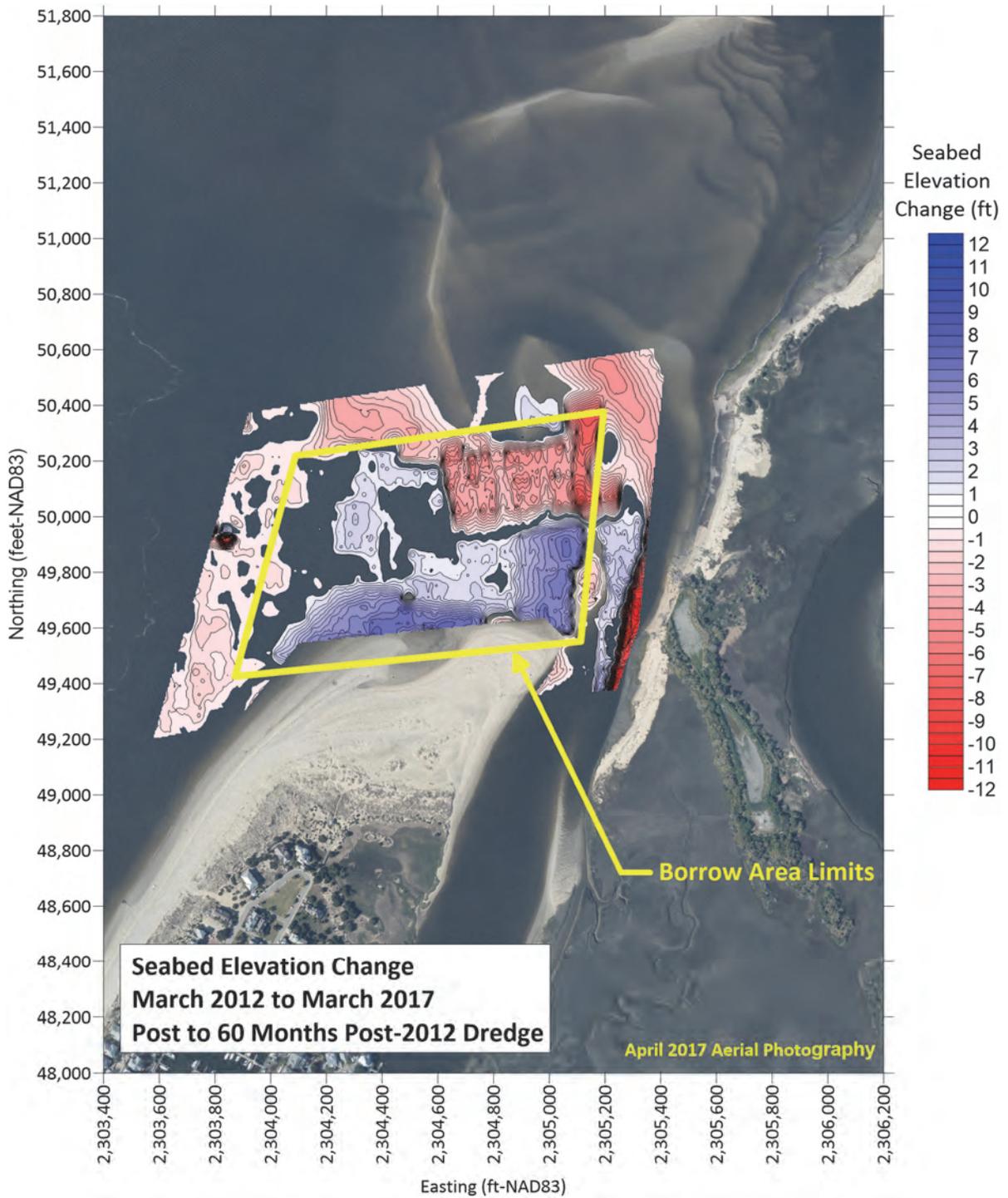


Figure 4.4: Bald Head Creek borrow site seabed elevation changes post-2012 project (March 2012) to March 2017 to post-2016/17 project.

4.2 Borrow Site Evaluation – Jay Bird Shoals

Pursuant to permit requirements, the Jay Bird Shoal borrow site was surveyed in May 2017. **Table 4.2** summarizes the volume changes within the *excavated* borrow site limits²¹ between the monitoring surveys conducted to date. **Figure 4.5** depicts the most recent 7-year post 2009/10 project (86 months) borrow site condition as surveyed in May 2017. **Figure 4.6** depicts the changes between the April 2015 and May 2017 surveys (Years 6 & 7). **Figure 4.7** depicts the changes during the 86 months since project construction (March 2010 to May 2017).

During the Year 6 and 7 monitoring period (April 2015 to May 2017), the borrow site gained approximately +20,600 CY within the entire *excavated* area. In the seven years since project completion (March 2010 to April 2015), the *excavated* area gained roughly +611,600 CY or approximately 33 percent of the estimated dredge volume (-1,835,700 CY). Overall, within the *permitted* limits (both excavated and unexcavated), the borrow site gained +194,300 CY during this same period. Pursuant to permit requirements, the Jay Bird Shoal borrow site is next scheduled to be surveyed in May 2019.

Table 4.2: Jay Bird Shoals borrow site volume changes (*EXCAVATED limits*).

Survey Period	Duration	Volume Change (CY)		
		Gross Gain	Gross Loss	Net Change
October 2009 to March 2010 (Construction)	5 months	+6,000	-1,791,400	-1,785,400
March 2010 to May 2011 (Year 1 Post-Construction)	14 months	+259,400	-36,800	+222,600
May 2011 to May 2012 (Year 2 Post-Construction)	12 months	+84,700	-39,000	+45,700
May 2012 to May 2013 (Year 3 Post-Construction)	12 months	+155,300	-13,300	+142,000
May 2013 to April 2015 (Years 4 & 5 Post-Construction)	23 months	+249,700	-54,700	+195,000
April 2015 to May 2017 (Years 6 & 7 Post-Construction)	25 months	+141,800	-135,500	+6,300
Since Construction (March 2010 to May 2017)	86 months	+890,900	-279,300	+611,600

²¹ Excavation occurred with Areas 1 & 3 (minus the exclusion zones) depicted in **Figure 4.5**.

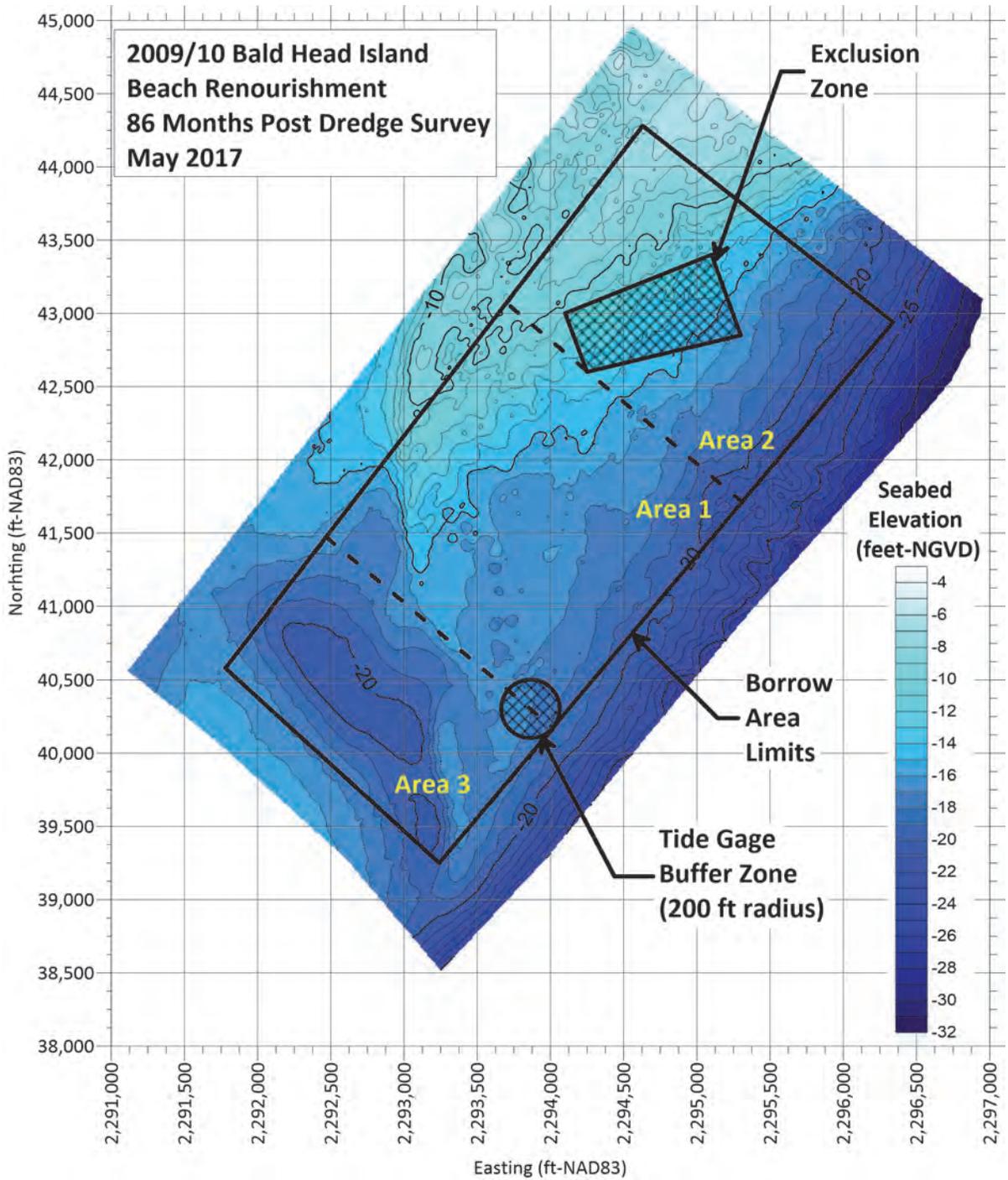


Figure 4.5: 86-months post-dredge (May 2017) Jay Bird Shoal borrow site conditions.

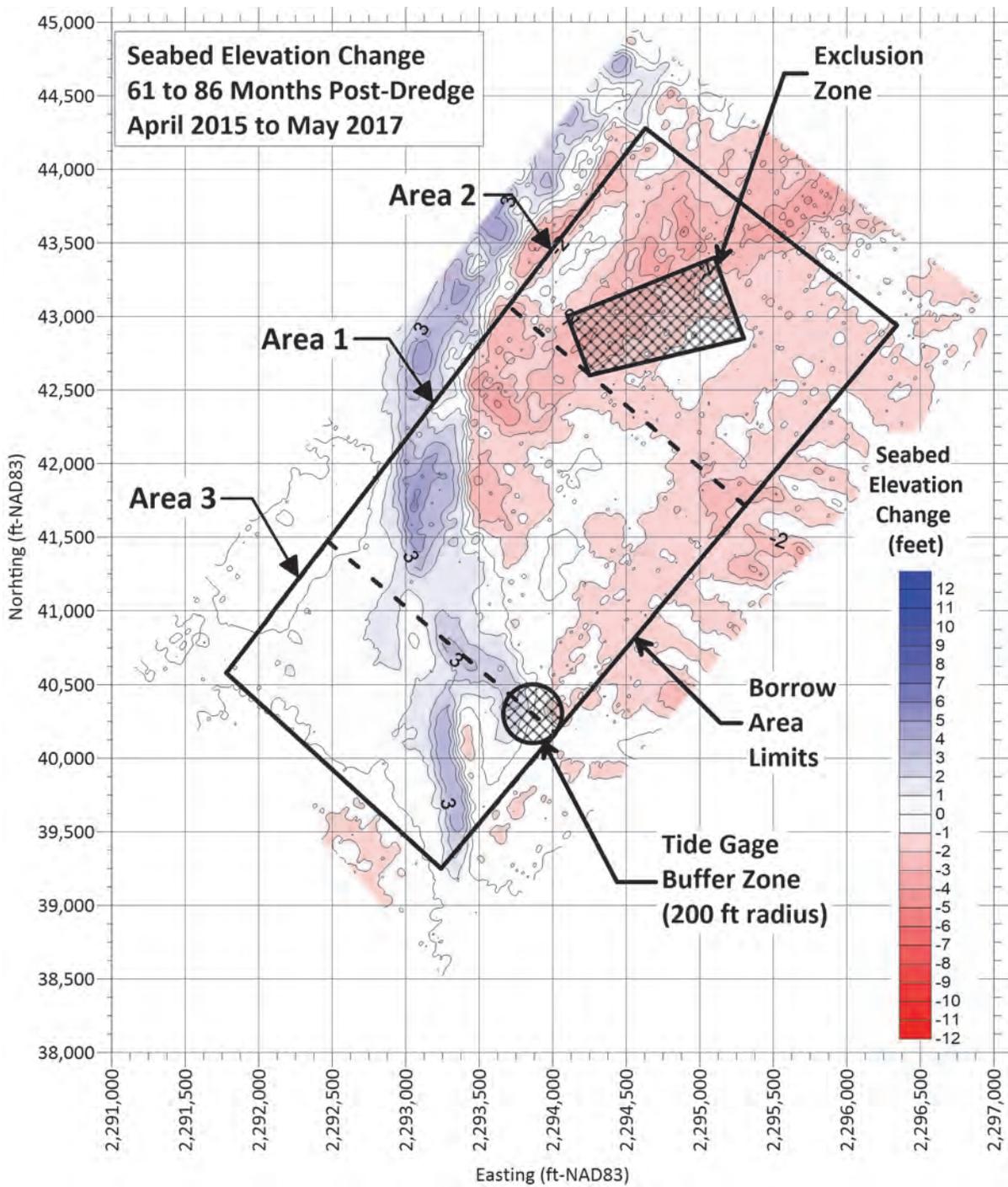


Figure 4.6: Jay Bird Shoals seabed elevation changes 61 to 86 months post-dredge (April 2015 to May 2017).

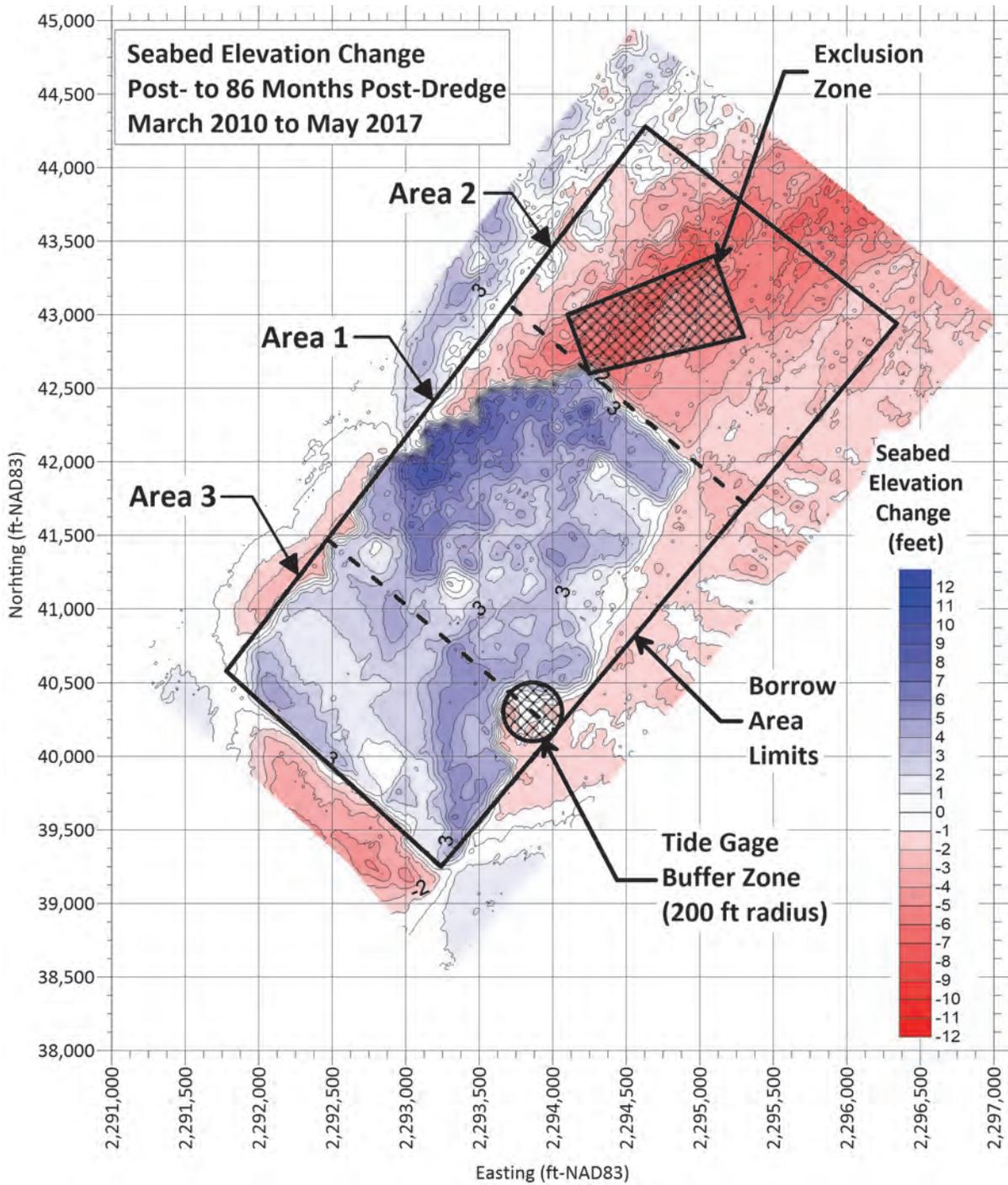


Figure 4.7: Jay Bird Shoals seabed elevation changes since project completion (March 2010 to May 2017).

5.0 ONGOING 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 1.11**). 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, were determined to be required seaward of the Row-Boat-Row shorefront.

Hence, several breakwaters capable of reducing (or intercepting) vessel generated wave impacts at that location were proposed. More specifically, the original proposed plan was 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 caused principally to ferry/barge generated waves. The subject expanded shore stabilization project (detached breakwaters *and* existing groinfield) would initially need to have a sand fill and be allowed to come to a designed equilibrium condition. The proposed source of the fill was the existing Bald Head Creek borrow area. It was predicted that after detached breakwater construction and sand placement, the existing groins would again become essentially quasi-buried and therefore only partially active. That would 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.

A delay in the issuance of the breakwater permits necessitated that the beach fill be constructed first. As discussed in **Section 3.5**, roughly 26,000 cy of clean sand fill was placed in early 2017 by Marcol Dredging. Similarly, in order to construct the breakwater project in the fair weather months of 2017 – coincident with a State moratorium of such work – the Village agreed to reduce the project scope to include only the two southernmost breakwaters (see **Figure 5.2** for the modified plan). In early 2017, the project was awarded to the firm Intracoastal Marine. Final acceptance of the work is expected in early August 2017. Future monitoring reports will document the residual crenulate beach formations expected to evolve in the lee of the breakwaters and between groin G-1 and G-2.



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



Figure 5.2: Modified 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. The submittal of the requisite State and Federal permit applications followed a Phase II Marine Archaeological Survey intended to identify potential cultural resources (i.e. shipwrecks) of significance that must be avoided. Since permit submittal in January 2017, the Village consultants have responded to numerous RAI’s required by the Corps and DCM. At present, the USF&WS has requested that the Village exhaust all alternative sand sources, prior to the utilization of a borrow site within Frying Pan Shoals. The Village is assessing the feasibility of that request – which in all probability would necessitate the reutilization of the 2009 Jay Bird Shoals borrow site. It is anticipated that 1 Mcy of fill would need to be placed eastward of the terminal groin extending to Sta. 134+00 in the winter of 2018/19.

5.3 Sand Tube Groinfield

Since its last partial replacement in 2013 (westernmost 5 groins), Village staff has had to respond to the ad hoc repair of the ends of several tubes which have recently been damaged due to natural (abrasion) or manmade (propeller strikes) causes. As such, it is highly possible that numerous tubes will require replacement during the next major sand placement operation since the tubes must be replaced “in the dry”.

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 9.1 Mcy since November 2000.

Conversely, the *gross* volumetric sediment *loss* over the November 2000 to May 2017 monitoring timeframe is conservatively computed at -6,449,600 cy, or approximately -390,900 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 (such as Hurricane Matthew), 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 May 2017 monitoring survey documents some 2.633 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

nearest the navigation channel 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.

Comprehensive beach monitoring over the past 17 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 was being performed in 2 Phases. The structure was 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 May 2017 survey data show a net shoreline accretion of approximately 42,700 cy (above elevation -16 ft NGVD) throughout the 6,000 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 2017, the average MHWL erosion rate at this general location has been about -13 ft/yr.

In 2017, the Village was required by Permit to perform the 7th year of monitoring for the Jay Bird Shoals borrow site utilized to construct the non-federal 1.85 Mcy beach fill constructed in 09/10. The computed change within the monitored survey area (excavated and unexcavated) was a *net* gain of approximately 611,600 cy over the 86 month monitoring period following project construction. The next scheduled survey will occur in 2019 and additional sand gain is expected.

The Bald Head Creek borrow area was dredged in 2017 for purposes of fill placement at Row Boat Row and West Beach. Prior to the excavation of some 55,000 cy, the borrow site had accreted by approximately 78,000 cy.

During the current monitoring period, the Village initiated construction of two (2) detached rock breakwaters located north of the marina entrance. The original project proposed four (4) structures. To receive permission to construct during the “moratorium”, the Village was required to reduce the project scope. It is anticipated that final acceptance of the project will occur in early August 2017.

In early 2017, the Village submitted 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. It is currently anticipated that the borrow site will be needed for limited sand placement along South Beach in 2018/19 between the terminal groin and Sta. 134+00. This conclusion results from the scheduled hiatus in the disposal of channel maintenance sand on Bald Head Island 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 2018 will be placed at Oak Island. Any future comprehensive “engineered beach” renourishment project by the Village along the South Beach shoreline 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. 14* (Olsen 2016).

7.0 REFERENCES

NOAA (2017a). “*National Hurricane Center Tropical Cyclone Report; Hurricane Hermine*”, National Oceanic and Atmospheric Administration. 63 pp (January 2017)

NOAA (2017b). “*National Hurricane Center Tropical Cyclone Report; Hurricane Hermine*”, National Oceanic and Atmospheric Administration. 96 pp (April 2017)

Olsen Associates, Inc. (2003). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 1 (Nov. 1999 – May 2003)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 66 pp plus app. (June 2003).

Olsen Associates, Inc. (2004). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 2 (May 2003 – April 2004)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 51 pp plus app. (August 2004).

Olsen Associates, Inc. (2005). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 3 (May 2004 – April 2005)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 38 pp plus app. (December 2005).

Olsen Associates, Inc. (2006). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 4 (April 2005 – May 2006)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 40 pp plus app. (July 2006).

Olsen Associates, Inc. (2007). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 5 (June 2006 – May 2007)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 37 pp plus app. (December 2007).

Olsen Associates, Inc. (2008). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 6 (June 2007 – May 2008)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 40 pp plus app. (August 2008).

Olsen Associates, Inc. (2009). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 7 (June 2008 – May 2009)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 49 pp plus app. (August 2009).

Olsen Associates, Inc. (2010). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 8 (June 2009 – May 2010)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 64 pp plus app. (August 2010).

Olsen Associates, Inc. (2011). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 9 (May 2010 – May 2011)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 69 pp plus app. (August 2011).

Olsen Associates, Inc. (2012). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 10 (May 2011 – May 2012)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 70 pp plus app. (July 2012).

Olsen Associates, Inc. (2013a). “*Shoreline Stabilization Analysis*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 338 pp. (July 2013).

Olsen Associates, Inc. (2013b). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 11 (May 2012 – May 2013)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 63 pp plus app. (August 2013).

Olsen Associates, Inc. (2014). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 12 (May 2013 – May 2014)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 63 pp plus app. (August 2014).

Olsen Associates, Inc. (2015). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 13 (May 2014 – May 2015)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 65 pp plus app. (June 2015).

Olsen Associates, Inc. (2016). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 13 (April 2015 – April 2016)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 80 pp plus app. (June 2016).

Olsen Associates, Inc. (2016). “*Frying Pan Shoals, Sand Search Investigation*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 38 pp plus app. (April 2016).

USACOE (2000). “*Environmental Assessment – Wilmington Harbor, N.C.*”, U.S. Army Corps of Engineers, Wilmington District. (February 2000).

USACOE, (2011a). Draft – “*Physical Monitoring, Wilmington Harbor Navigation Project, Report 8: October 2009 – September 2010*”, U.S. Army Corps of Engineers, Wilmington District, January, 2011.

USACOE (2011b). “*Draft – Reevaluation Report, Sand Management Plan, Wilmington Harbor Navigation Project*”, U.S. Army Corps of Engineers, Wilmington District. (January 2011).