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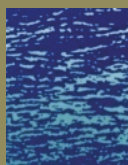


# Bald Head Island, N.C. Beach Monitoring Program

## Monitoring Report No. 18 (May 2019 to May 2020)

**Prepared for:**  
Village of Bald Head Island

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Photo Date: 20 Dec 2019



**BALD HEAD ISLAND, N.C.**  
**Beach Monitoring Program**  
**Report No. 18**  
**(May 2019 – May 2020)**

**EXECUTIVE SUMMARY**

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The most recent Wilmington Harbor Inner Ocean Bar maintenance dredging of Bald Head The most recent Wilmington Harbor Inner Ocean Bar maintenance dredging of Bald Head Shoal Channel Reach 2, and the Smith Island Channel segment was initiated in the summer months of May/June 2018. Approximately 1.15 Mcy of sand excavated during that operation were placed at Oak Island pursuant to the terms of the Wilmington Harbor Sand Management Plan (WHSMP). Subsequent to federal beach disposal on Oak Island, Bald Head Island will be the recipient of the next two *future* beach disposal operations in accordance with the continued implementation of a present day WHSMP. Prior to that time (with the next Bald Head Island disposal not scheduled until the spring of 2021) the need to offset annual erosional losses at South Beach on Bald Head Island, as well as to maintain the updrift fillet of the terminal groin constructed in 2015, necessitated that the Village design and permit a 1 Mcy *interim* beach fill project. The latter was constructed between 13 January 2019 and 22 March 2019. The project borrow site was Jay Bird Shoals. The final fill volume was 1.1 Mcy due to the addition of a Post-Florence FEMA Claim for documented storm related losses from the *engineered beach* in September 2018 (Olsen 2018).

As part of the assessment for the 2019 beach renourishment project to be constructed at South Beach by the Village, it was determined that numerous sand tube groins had reached the end of their effective life and that replacement was warranted. Permits allowed for both an extension of time beyond April 1<sup>st</sup> for *both removal and replacement* of all remaining thirteen (13) sand tube groins (and underlayments). The work was initiated on/about 13 February and Substantially Completed by 22 March 2019. A *Post-Construction Report*, formulated to document the 2018-2019 project, details all elements of work performed by both contractors (Olsen 2019).

By about 2013, the results of a comprehensive annual beach monitoring program initiated in 2000 by the Village of Bald Head Island yielded the conclusion that sand placement alone could *not* successfully offset navigation channel impacts to the west end of South Beach which have been typically manifest in chronic rates of erosion and a consistent northerly recession of the shorefront. Accordingly, 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 the persistent South Beach erosional “hot spot”. The project was permitted to be constructed in two phases – with Phase 2 being optional. Simplistically, the structure was designed 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 however as a “leaky” structure (*i.e.* semi-permeable) so as to provide for some level of continued sand transport to West Beach and portions of the Point (located both westward and northward of the groin stem). Through May 2020, terminal groin project performance – based upon monitoring – has been both as intended – and as predicted.

Between November 2000 and April 2020, 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. Including 2019, the Village has placed another 3.2Mcy along the West Beach and South Beach shorelines. Accordingly, in the net Bald Head Island has experienced a total estimated sand placement volume of approximately 10.2 Mcy since 2000 at those two locations – with South Beach receiving some 90% or more of the total.

Conversely, the *gross* volumetric sediment *loss* over the November 2000 to May 2020 (post-fill) monitoring timeframe is conservatively computed at -7.703 Mcy, or approximately -394,800 cy per year – on “average”. This “loss” addresses the continuous section of Bald Head Island shorefront extending from the marina entrance to the Cape Fear spit. 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 Hurricanes Florence and Dorian), the occurrence of episodic destabilization 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. In addition, the island’s littoral system continues to adjust to the quasi-stabilizing effect of the terminal groin in existence only since 2015. Along South Beach per se, there has been historically a “nodal point” some 7,000 ft. eastward of the terminal groin (approx. STA 116+00). At or close to the nodal point, the directionality of *net littoral transport* on an annual basis changes from West (toward the groin) to East (toward Cape Fear). *Note* – depending on wave climatology, the condition and exposure of the sand tube groinfield, as well as other factors, the effective location of the nodal point can vary slightly along South Beach from year to year. Currently, within the 22,755 shoreline influenced by sand placed since 2000, some 2.992 Mcy remain in the littoral system (measured above elevation -16 ft. NGVD 29). This includes the 1.1 Mcy beach fill recently constructed in early 2019.

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. Since that time, it is observed that East Beach can undergo 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. For example, the most recent May 2020 survey data show a net shoreline loss of approximately -88,600 cy (above elevation -16 ft NGVD). throughout the 6,000 ft East Beach shoreline lying northward of Cape Fear over the last 12 months. In the prior year, it had accreted by almost 150,000 cy – due to sand accumulation associated with the spit. Between November 2008 and May 2020, the total change has been +350,500 cy. Again, most of this volume has been associated with accretion of the Cape Fear spit facing Onslow Bay.

Typically, episodic 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 2020, the average MHWL erosion rate at this general location has been over -20 ft/yr – due to sand losses either directly or indirectly associated with Hurricane Dorian in 2019.

In 2020, the Village was required by Permit to again perform monitoring of the Jay Bird Shoals borrow site utilized to construct the non-federal 1.85 Mcy beach fill sponsored by the Village in 2009/10. The same borrow site was also used for the 1.10 Mcy beach constructed in 2018/19. During the Year 10 monitoring period (March 2019 to May 2020), the first year following the 2018/19 project excavation, the entire permitted borrow site gained +133,600 cy (inclusive of the exclusion and buffer zones). As of May 2020, there is approximately +1,150,500 cy of material available within the permitted borrow site limits above the permitted cut elevation (-22 ft-NGVD).

After an extension of the two marina entrance channel jetties in 2015, temporarily reduced shoaling within the navigation channel resulted in a corresponding reduced volume of disposal sand being place along the Row Boat Row shoreline. Although the Village had planned to continue to proactively bypass sand from the south jetty fillet (at the distal end of West Beach) to the Row Boat Row shorefront, it became clear that the existing four (4) low level timber groins would not be capable of providing an acceptable level of shoreline stabilization at that location.

Hence, near the end of the 2017 monitoring period, the Village initiated construction of two (2) shore parallel detached rock breakwaters located north of the marina entrance seaward of the Row Boat Row shoreline. The placement of breakwaters between existing groins northward of the marina entrance was intended to 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 by ferry/barge generated waves. The subject expanded shore stabilization project (detached breakwaters *and* existing groinfield) was designed to have a sand fill prior to construction. The source of the fill was the exiting Bald Head Creek



borrow area. A previously permitted Bald Head Creek borrow area was dredged in early 2017 by Marcol Dredging. Some 26,000 cy were placed at Row Boat Row prior to breakwater implementation. Since that time several channel maintenance/sand bypass operations have occurred – most with increasing volume. This is primarily due to an increased rate of sediment transport along West Beach caused by a continuing reconfiguration of the Point. As a result, the Village has been forced to seek means of bypassing sand northward of the influence of the breakwaters. This has required a modification of the permits associated with maintenance dredging of the channel.

In the spring of 2019, the Village resubmitted permit applications accompanied by indepth geotechnical studies and environmental analyses necessary to develop a long term (and large scale) borrow site located within Frying Pan Shoals. The purpose of such a borrow site is to both ensure compliance with Permit conditions necessitating the maintenance of the updrift fillet associated with the 2015 terminal groin project and to provide a long-term source of beach quality material sufficient to meet future South Beach renourishment requirements. When pursuant to the existing tenets of the Wilmington Harbor Sand Management Plan, all beach quality channel maintenance material excavated is to be placed at Oak Island.

An important secondary precept of the spring of 2019 beach fill project constructed by the Village was to allow for the replacement of a sand tube groinfield which had become damaged over time. During the spring 2021 federal disposal project, the groin field in its entirety will again be covered by beach fill.

The original Permits for construction of the terminal groin at Bald Head Island stipulated that if the permittee elected to dredge more than 250,000 cy from the Jay Bird Shoals borrow site after 2015, limited monitoring of the eastern end of Oak Island must be performed. Accordingly, in November 2018, the Village initiated the requisite monitoring at Oak Island (Caswell Beach). The first report of findings for Oak Island followed a November 2019 monitoring survey. A second year of monitoring is on underway. It has been tacitly agreed that depending upon the results of the Year 2 report, the Village's responsibility for continued monitoring may end.

In 2019, the Port of Wilmington, NC both sponsored and formulated a Section 203 Report which proposes a plan to deepen and widen (in places), the Federal navigation project, which extends from the Atlantic Ocean up the Cape Fear River to the Port of Wilmington. The Village of Bald Head Island has formally submitted comments to the record which address deficiencies in the project analyses and which requests clarification to impacts addressed or unaddressed by the consultant prepared report.

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## **1.0 INTRODUCTION**

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### **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 both historical and updated monitoring surveys performed annually 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) Recent volume and shoreline position changes measured between monitoring surveys of May 2019, November 2019 and May 2020 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 receives episodic sand placement associated with routine marina entrance channel sand bypass operations.
- (3) A discussion of the 1.1 Mcy 2018/19 Beach Restoration Project constructed along a portion of S. Beach and the dredging of the Jay Bird Shoals borrow site.
- (4) A discussion of the next (as proposed) South Beach disposal project to be constructed pursuant to the Wilmington Harbor Sand Management Plan.
- (5) A discussion of a recent Section 203 Harbor Deepening Project Investigation initiated by the Wilmington Harbor Port Authority and its potential implications to Bald Head Island.

## 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 May 2019 to May 2020 monitoring period are plotted as **Figure 1.2**.

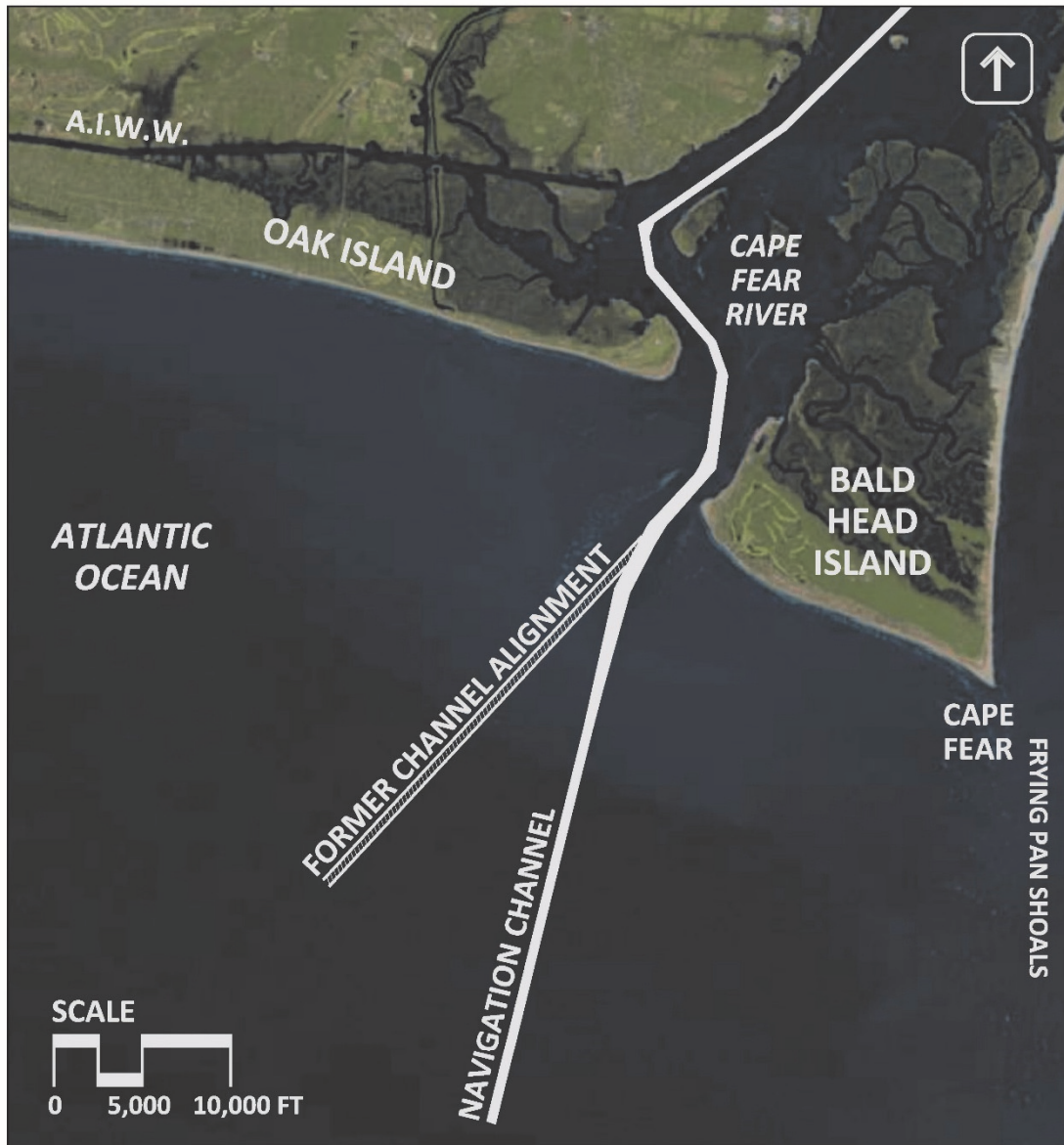
**Table 1.1:** Tidal datums for Bald Head Island, North Carolina<sup>1</sup>.

<b>Datum</b>	<b>Elevation (ft-NGVD29<sup>2</sup>)</b>
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

<sup>1</sup> Approximations based upon extrapolation from Southport, N.C.

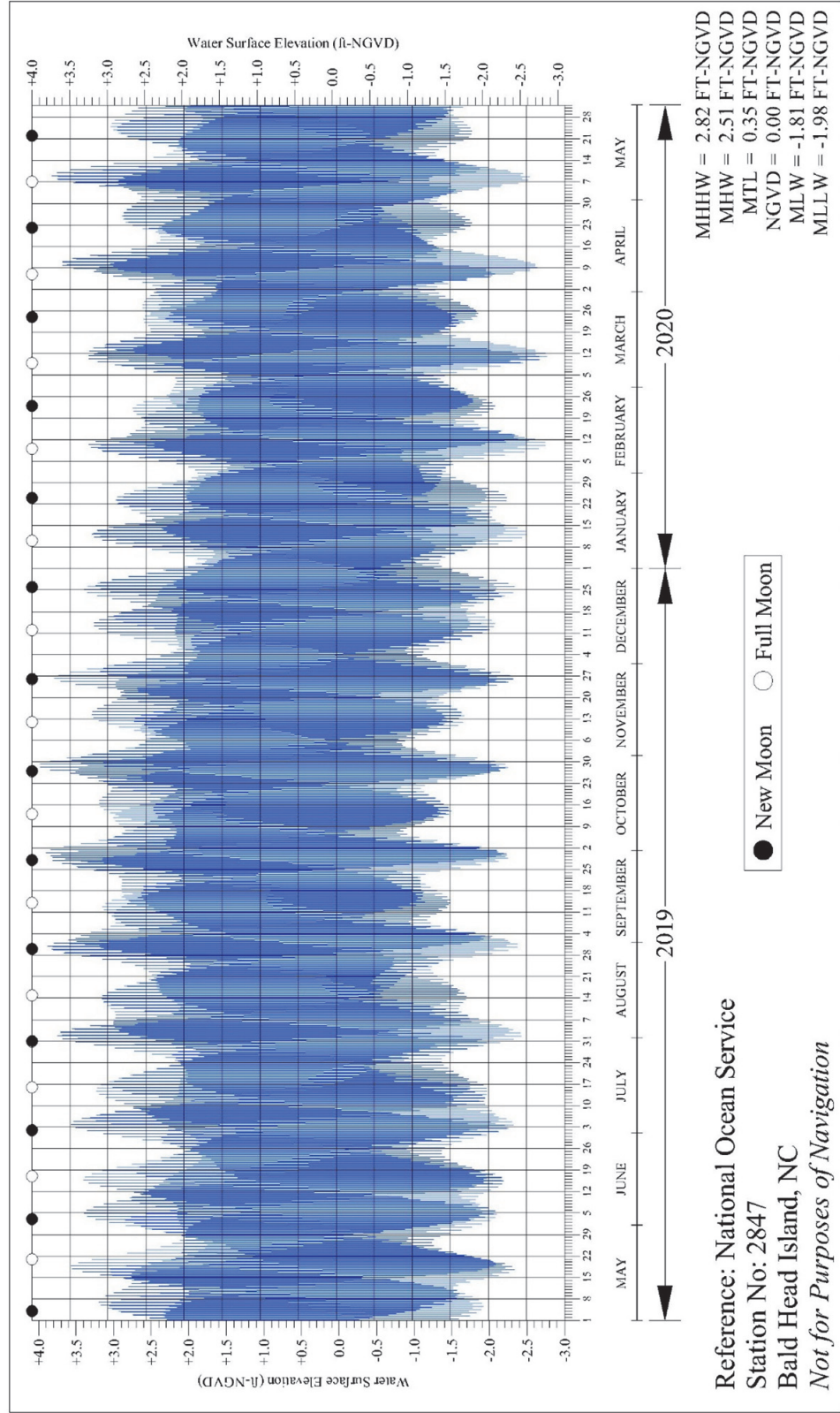
<sup>2</sup> NGVD 1929: National Geodetic Vertical Datum of 1929 (1929 Mean Seas Level). Horizontal coordinates are referenced to the North Carolina State Plane Coordinate System, North American Datum of 1983.





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

# May 2019 through May 2020 Predicted Astronomical Tides Bald Head Island, North Carolina

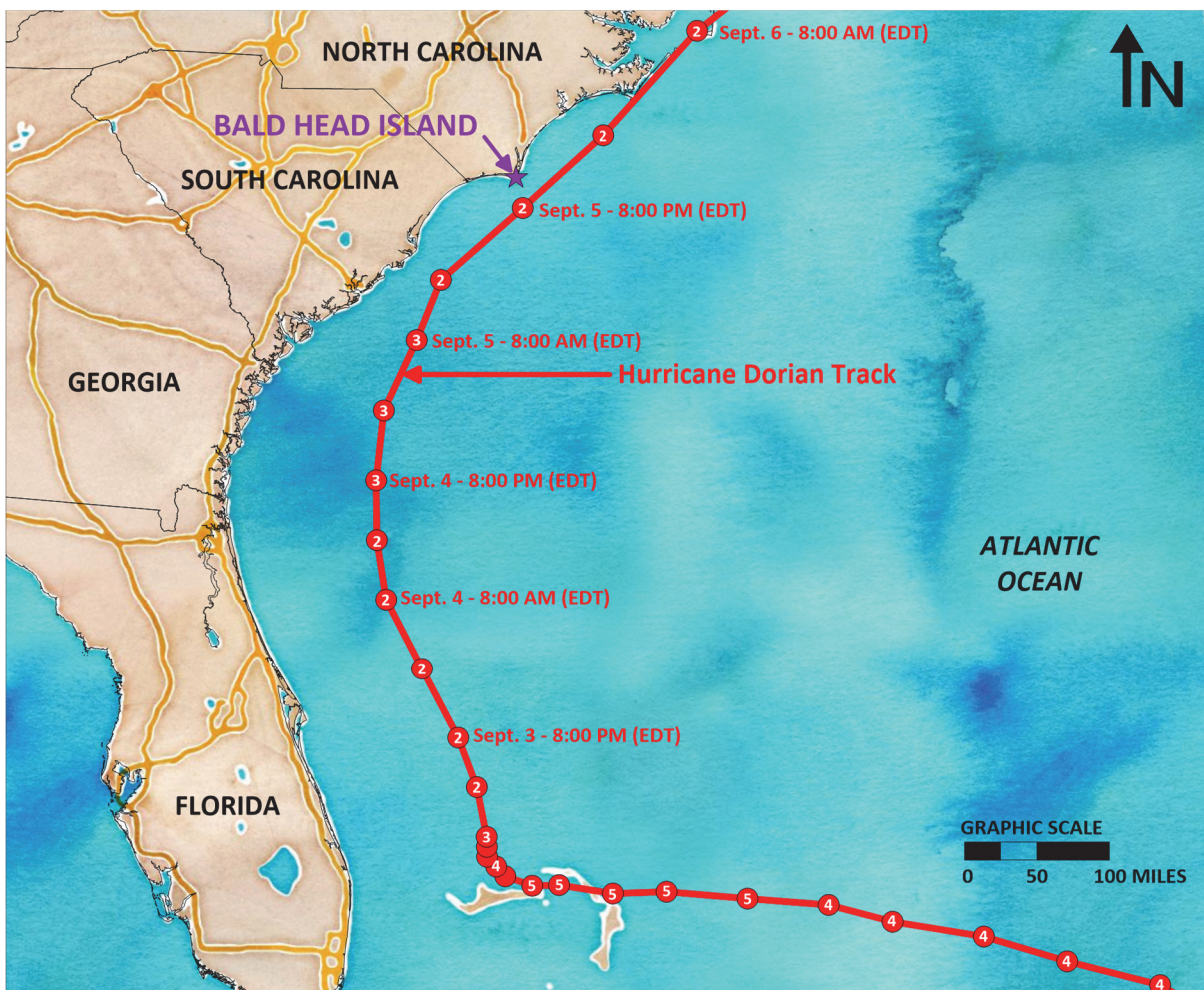


**Figure 1.2:** May 2019 through May 2020 predicted astronomical tides, Bald Head Island, North Carolina.



### 1.3 Monitoring Period Storm Effects (May 2019 to May 2020)

During the current 12-month monitoring period, Bald Head Island experienced the effects of Hurricane Dorian (September 2019). **Figure 1.3** plots the track of Hurricane Dorian as the storm approached the east coast of the United States. Dorian impacted Bald Head Island primarily on September 5, 2019. At the closest, the center of then Category 2 Hurricane Dorian passed about 26 miles south east of Bald Head Island, bringing sustained winds of 41 mph and gusts of 56 mph to the monitored shoreline. On October 4<sup>th</sup>, 2019 Hurricane Dorian was declared a major disaster in 26 North Carolina counties, including Brunswick County, by the Federal Emergency Management Agency (FEMA DR-4465)<sup>3</sup>.



**Figure 1.3:** Hurricane Dorian (2019) track as the storm approached the coast of the United States. Track retrieved from the National Hurricane Center (NHC 2020).

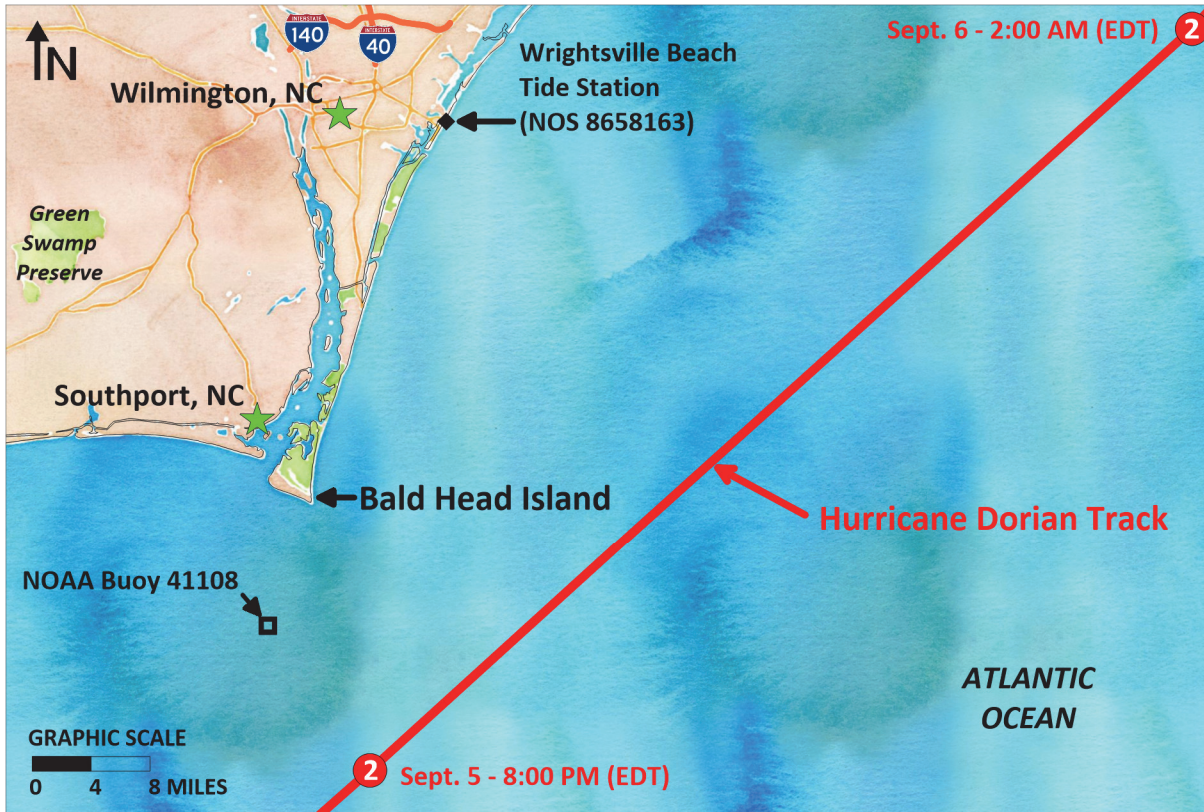
<sup>3</sup> Initially, fourteen (14) North Carolina counties, including Brunswick, were included in FEMA's Hurricane Dorian Disaster Declaration on October 4, 2019. The number of counties was expanded to twenty-six (26) on October 18, 2019.

Hurricane Dorian formed as a large tropical wave off the west coast of Africa on August 19, 2019 (NOAA 2020). The storm moved west and northwest across the Atlantic Ocean, reaching hurricane strength on August 28, as it approached the US Virgin Islands. After passing the Virgin Islands, the storm intensified rapidly, reaching Category 5 strength on September 1 as it neared the Bahamas. Later that day, Dorian made landfall as a Category 5 hurricane at Elbow Cay and a few hours later at Grand Bahama Island, becoming the most intense tropical cyclone on record to strike the Bahamas. After passing over the Bahamas, Dorian weakened to a Category 2 hurricane and began moving northwestward, paralleling the Florida coast. By September 4, the storm had turned to the northeast, briefly reaching Category 3 strength before making landfall at Cape Hatteras on September 6 as a Category 2 hurricane with 98 mph sustained winds. After landfall, the storm continued to the northeast, moving out into the Atlantic Ocean and transitioning to an extratropical cyclone. On September 8 the storm brought hurricane force winds to Nova Scotia and Newfoundland then continued to move northeast over the Atlantic Ocean before dissipating on September 10.

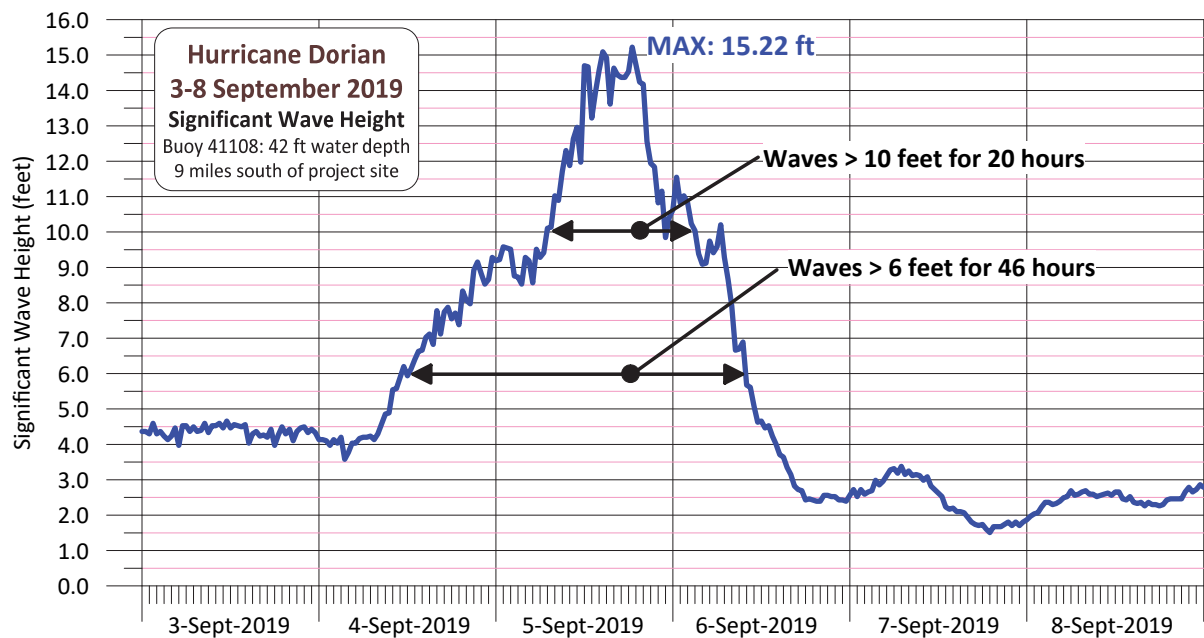
**Figure 1.4** plots the track of Hurricane Dorian in the vicinity of Bald Head Island. The figure also displays the location of NOAA Buoy 41108, located roughly 9 miles south of Bald Head Island in approximately 42 feet of water. The center of Hurricane Dorian passed within about 21 miles of the buoy. The buoy was deployed in March 1988 and has been collecting data nearly continuously for 32+ 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 tide station (NOS 8658163), owned and maintained by NOAA's National Ocean Service (NOS) Water Level Observation Network. The tide 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 Dorian. The center of Hurricane Dorian passed within about 39 miles of the station.

**Figure 1.5** depicts the time series measured at the buoy during the passage of Hurricane Florence. 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.



**Figure 1.4:** Track of Hurricane Dorian in the vicinity of Bald Head Island showing the location of NOAA Buoy 41108 and the Wrightsville Beach tide station (NOS 8658163). Track retrieved from the National Hurricane Center (NHC 2020).



**Figure 1.5:** Time series of significant wave heights measured at NOAA Buoy 41108 as Hurricane Florence 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 Dorian, significant wave heights peaked at 15.22 feet on the evening of September 5<sup>th</sup>, as the storm's center was approximately 21 miles southeast of the wave buoy. The dominant wave period peaked at about 12 seconds during this time. It is noted that these measurements reflect the significant wave height, or the average of the highest 1/3<sup>rd</sup> 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 20 hours and waves greater than 6 feet for 46 hours. For comparison, during Hurricane Florence (September 2018), wave heights greater than 10 feet lasting for about 36 hours and waves greater than 6 feet for 100 hours.

**Figure 1.6** displays a time series of significant wave heights measured at NOAA Buoy 41108 from May 2019 through May 2020. The average significant wave height<sup>4</sup> at NOAA Buoy 41108 during the Year 19 monitoring period (May 22, 2019 to May 7, 2020<sup>5</sup>) was 3.40 feet with a maximum wave height of 15.22 ft measured during Hurricane Dorian. The Year 19 average value is approximately 5 percent higher than the full record average significant wave height of 3.22 feet (March 1988 through May 2020).

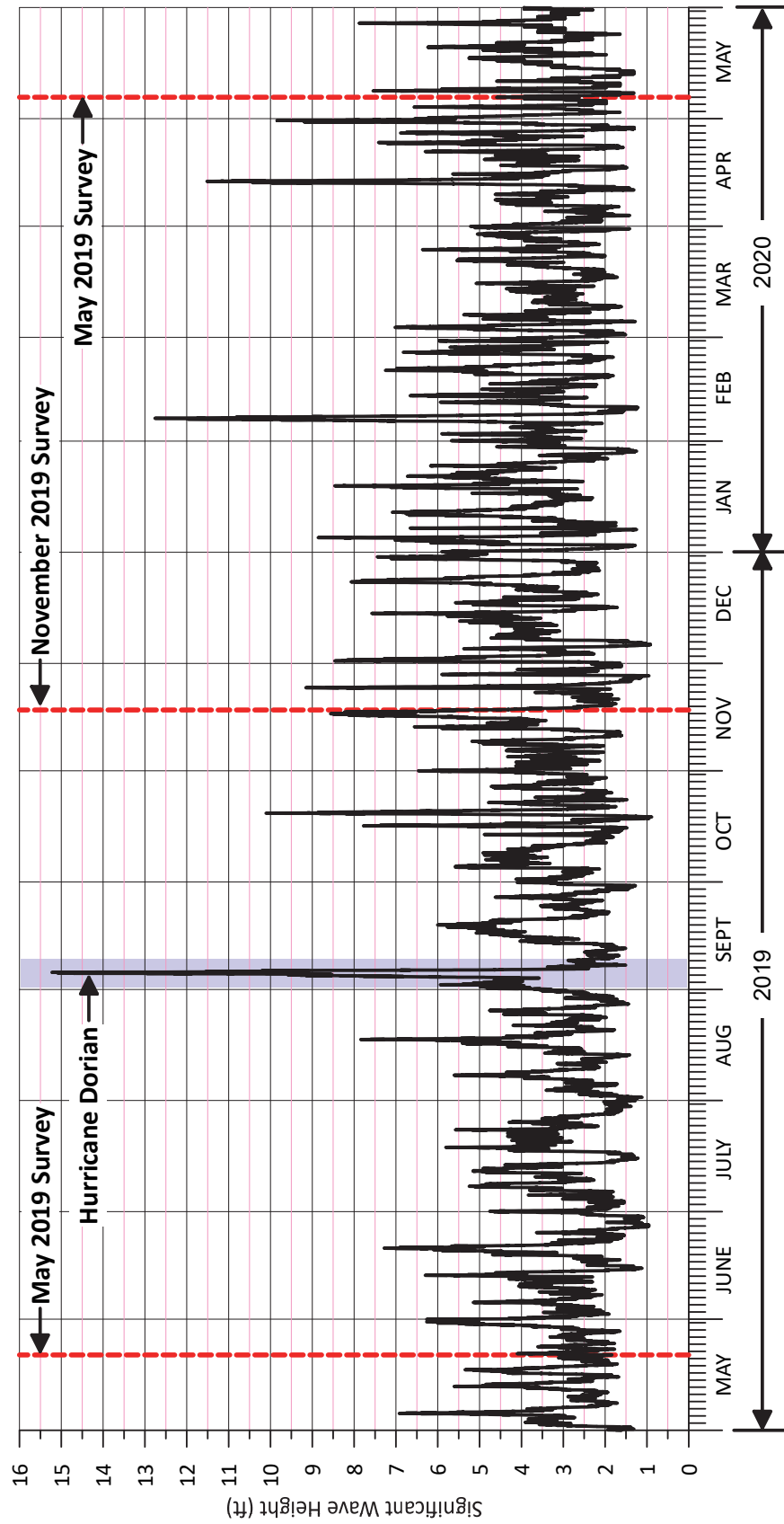
During the Year 19 monitoring period, roughly 5.8 percent of the recorded wave heights were above 6 feet, the same as the full record average. However, the occurrence of waves above 10 feet was higher than the full record average (0.5 percent for Year 19 compared to 0.2 percent for the long-term average), largely due to the effects of Hurricane Dorian experienced during Year 19.

**Figure 1.7** displays the time series of water levels measured at the Wrightsville Beach, NC tide gage as Hurricane Dorian passed. The maximum water level recorded during Hurricane Dorian was approximately +4.51 ft-NGVD. This occurred at the predicted high tide (+3.11 ft-NGVD). The corresponding storm surge (i.e. level above predicted tides) at this time was +0.75 ft. The maximum storm surge of +2.36 ft occurred approximately 2 hours after low tide. At this time, the predicted water level was -0.37 ft-NGVD yielding a measured water level of +1.99 ft-NGVD.

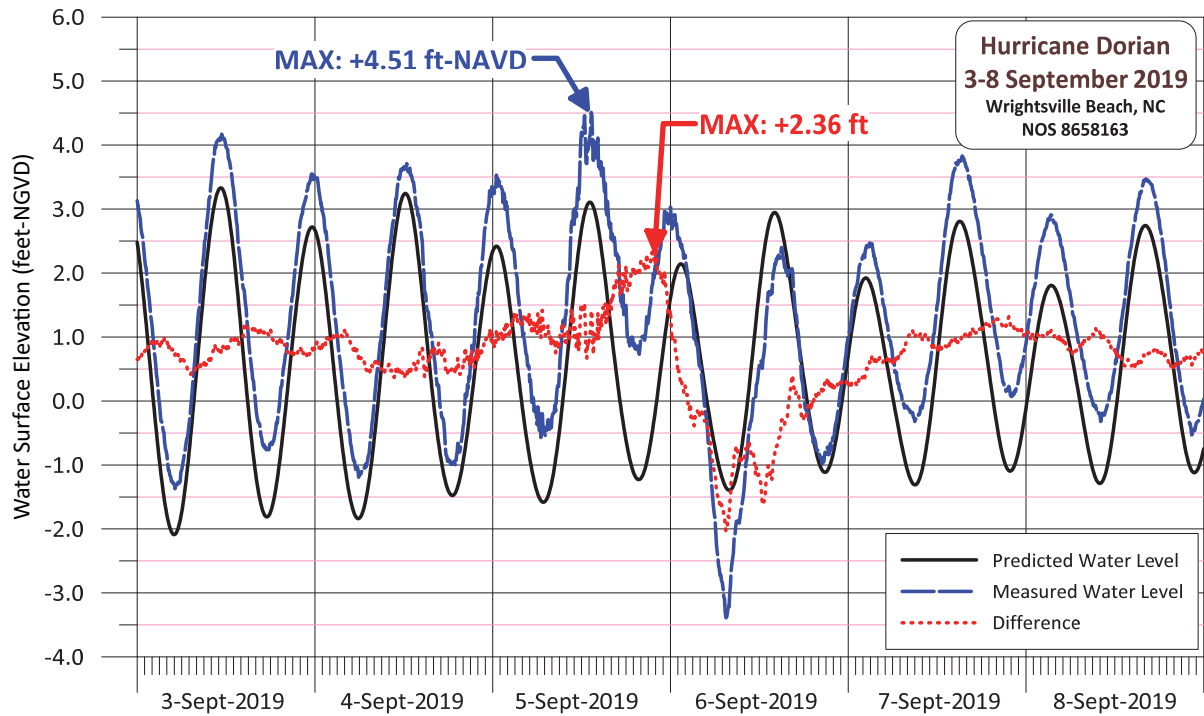
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<sup>4</sup> These measurements reflect the significant wave height, or the average of the highest 1/3<sup>rd</sup> of waves passing the buoy during a 20 minute sampling period.

<sup>5</sup> The May 2019 beach profile survey was completed May 22, 2019 and the May 2020 beach profile survey completed on May 7, 2020.



**Figure 1.6:** Significant wave heights recorded by NOAA Buoy 41108 during the 2019-20 monitoring period (Wilmington Harbor, NC).



**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 Hurricane Dorian moved by Bald Head Island, NC.

#### **1.4 Wilmington Harbor Federal Navigation Channel and Sand Management Plan**

A detailed discussion of the history of the navigation channel and the Wilmington Harbor Sand Management Plan is provided in Monitoring Report No. 15 (Olsen 2017).

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 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. Alternatively, it should be based upon the ratio of documented littoral transport rates for each island toward the Cape Fear River.

## 1.5 Historical Erosion Control Activities (1991 to 2020)

### 1.5.1 Channel Maintenance Beach Disposal and Beach Restorations – Chronology

Beach fill placement activities constructed at Bald Head Island since 1991 are summarized in **Table 1.2**. Not including 2018/19, a detailed discussion of the history of channel maintenance beach disposal and beach restoration activities is provided in Monitoring Report No. 15 (Olsen 2017).

**Table 1.2:** Beach disposal or sand 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)
2016/17	50,000 cy	VBHI	West Beach and Row Boat Row
2018/19	1.1 Mcy	VBHI	South Beach (Sta. 49+00 to Sta. 146+00)

\* Disposal pursuant to the WHSMP

### 1.5.2 Erosion Control Structures (1996 to 2020) - Chronology

Erosion control structures constructed at Bald Head Island since 1996 are summarized in **Table 1.3**. A detailed discussion of the (pre-2019) history of erosion control structures is provided in Monitoring Report No. 15 (Olsen 2017).



**Table 1.3:** History of erosion control structures at Bald Head Island since 1994.

<b>Year</b>	<b>Location</b>	<b>Description</b>
1994	Western South Beach	Sand bag revetment located along 645 feet of the back-beach berm
1996 (March)	Western South Beach	Sixteen (16) soft groins (geotube-type structures) were constructed of geotextile material and sand fill
2003/2004	Western South Beach	Rehabilitation of 1994 constructed sand bag revetment. Revetment lengthened by approximately 200 feet and base width increased to 40 ft and crest elevation raised to +12 ft-NGVD).
2005 (January to March)	Western South Beach	Replacement of 1996 constructed sand tube groin field. 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.
2009	Western South Beach	Complete rehabilitation of the sand tube groin field. Some adjustment of groin lengths, and the westward relocation of groin no. 16 were made in an attempt to refine the project design.
2011	Western South Beach	300 ft sand bag revetment was constructed on the downdrift (western side) of the last sand tube groin in order to protect several endangered residential structures.
2013	Western South Beach	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.
2015	Western South Beach	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 Monitoring Report No. 15 (Olsen 2017).
2015	Bald Head Marina	The two marina entrance channel structures seaward of Row-Boat-Row originally constructed by Bald Head Island, Ltd., were modified through the addition of rock extensions.
2017	Row Boat Row	Two (2) detached breakwaters were constructed just north of the Marina Entrance. Construction details are provided in Monitoring Report No. 16 (Olsen, 2018).
2019	Western South Beach	All remaining 13 sand tube groins were removed and replaced coincident with the 2019 beach fill.

## **2.0 PHYSICAL MONITORING PROGRAM**

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### **2.1 Monitoring Baseline & Beach Profiles**

**MONITORING BASELINE** The present day Bald Head Island 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-nine (79) stations spaced approximately 400 ft apart along the roughly 31,400 ft of Bald Head Island’s shorefront. **Table 2.2** summarizes the monitoring surveys conducted to date as part of the monitoring program. The primary focus of this monitoring report (No. 18) is beach profile and shoreline changes occurring over the latest set of surveys (May 2019 to May 2020).

Typically, survey transects extend across the upland berm or from the dune line seaward a distance of up to 3,000 ft. Depending upon the location of the survey profile, this distance corresponds to offshore waters depths of at least -40 ft relative to NGVD within the Cape Fear River Channel and -16 ft-NGVD along the Atlantic Ocean shorefront. In Chapter 5.0, 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 2020) 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. 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. Finally, in November 2016, three (3) additional profiles were added along West Beach.

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

Station (Monument)	Station Location		Grid Azi. (Deg.)	Station	Station Location		Grid Azi. (Deg.)
	Easting (FT-NAD83)	Northing (FT-NAD83)			Easting (FT-NAD83)	Northing (FT-NAD83)	
<b>Row Boat Row</b>				084+16 (B-22)	2,303,032.1	40,924.5	219
-014+72 (RB-01)	2,304,277.9	49,117.4	302	088+23 (B-23)	2,303,372.1	40,705.0	214
-012+00 (RB-02)	2,304,068.6	48,776.5	302	092+15 (B-24)	2,303,714.1	40,513.9	209
-008+00 (RB-03)	2,303,937.2	48,538.1	302	097+10 (B-25)	2,304,146.1	40,272.5	206
-004+00 (RB-04)	2,303,728.0	48,197.2	302	102+08 (B-26)	2,304,592.1	40,057.6	204
-003+00 (RB-05)	2,303,518.7	47,856.3	302	106+00 (B-27)	2,304,960.4	39,915.3	201
<b>West Beach</b>				110+00 (B-28)	2,305,333.5	39,771.1	201
000+00 (B-01)	2,303,309.3	47,515.5	302	114+00 (B-29)	2,305,708.5	39,626.3	202
004+00 (B-02)	2,303,100.4	47,174.4	301	118+00 (B-30)	2,306,080.6	39,482.5	202
008+00 (B-03)	2,302,891.5	46,833.3	301	122+00 (B-31)	2,306,451.7	39,339.2	201
010+00 (I-03)	2,302,788.1	46,662.0	301	126+00 (B-32)	2,306,824.0	39,195.3	200
012+00 (B-04)	2,302,682.5	46,492.2	301	130+00 (B-33)	2,307,196.5	39,051.4	200
014+00 (I-04)	2,302,578.8	46,321.1	301	134+00 (B-34)	2,307,569.6	38,907.3	200
016+00 (B-05)	2,302,473.6	46,151.1	301	138+00 (B-35)	2,307,943.9	38,767.8	200
018+00 (I-05)	2,302,369.5	45,980.3	301	142+00 (B-36)	2,308,320.5	38,633.0	200
020+00 (B-06)	2,302,264.7	45,810.0	301	146+00 (B-37)	2,308,697.1	38,498.2	200
024+00 (B-07)	2,302,055.2	45,468.8	302	150+00 (B-38)	2,309,073.8	38,363.4	200
<b>"the Point"</b>				154+00 (B-39)	2,309,452.4	38,228.0	201
028+00 (B-08)	2,301,845.1	45,126.6	303	158+00 (B-40)	2,309,818.8	38,074.6	202
032+00 (B-09)	2,301,566.1	44,843.7	301	162+00 (B-41)	2,310,179.1	37,895.6	203
034+00 (I-09)	2,301,394.4	44,742.0	301	166+00 (B-42)	2,310,539.0	37,716.9	204
036+00 (B-10)	2,301,220.2	44,647.1	299	170+00 (B-43)	2,310,903.5	37,552.0	204
038+00 (I-10)	2,301,043.1	44,550.6	296	174+00 (B-44)	2,311,267.9	37,387.2	204
039+60 (B-11)	2,300,902.6	44,473.9	291	178+00 (B-45)	2,311,632.4	37,222.3	204
041+50 (I-11)	2,300,765.0	44,365.0	287	182+00 (B-46)	2,311,996.9	37,057.4	204
043+47 (B-12)	2,300,757.5	44,167.6	284	186+00 (B-47)	2,312,361.3	36,892.6	204
044+25 (I-12)	2,300,754.6	44,090.2	276	190+00 (B-48)	2,312,725.8	36,727.8	204
045+07 (B-13)	2,300,751.4	44,007.0	268	194+00 (B-49)	2,313,090.2	36,562.9	204
046+00 (I-13)	2,300,784.9	43,920.7	260	198+00 (B-50)	2,313,454.7	36,398.1	204
046+89 (B-14)	2,300,813.7	43,836.0	251	202+00 (B-51)	2,313,819.2	36,233.2	204
049+00 (H-13)	2,300,881.5	43,636.5	247	206+00 (B-52)	2,314,183.6	36,068.4	204
050+50 (I-14)	2,300,913.5	43,541.9	247	210+00 (B-53)	2,314,548.1	35,903.5	204
051+00 (J-14)	2,300,945.8	43,447.1	247	214+00 (B-54)	2,314,912.5	35,738.7	204
052+64 (B-15)	2,300,998.3	43,292.1	243	218+00 (B-55)	2,315,277.0	35,573.8	204
054+00 (I-15)	2,301,042.2	43,163.0	243	<b>East Beach</b>			
<b>South Beach</b>				224+80 (EB-01)	2,315,748.8	36,063.3	90
056+56 (B-16)	2,301,148.7	42,933.8	233	234+80 (EB-02)	2,315,748.8	37,063.3	90
060+51 (B-17)	2,301,399.6	42,628.3	230	244+80 (EB-03)	2,315,748.8	38,063.3	90
065+50 (B-18)	2,301,716.0	42,243.2	229	254+80 (EB-04)	2,315,748.8	39,063.3	90
069+46 (B-19)	2,301,967.6	41,937.0	227	264+80 (EB-05)	2,315,748.8	40,063.3	90
073+39 (B-20)	2,302,246.1	41,660.5	223	274+80 (EB-06)	2,315,748.8	41,063.3	90
076+37 (B-21)	2,302,609.2	41,320.5	222	284+80 (EB-07)	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 2020.

<b>Survey Date</b>	<b>Surveyor</b>	<b>Comments</b>
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)
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)
2005 Nov.	McKim & Creed	10 months post-construction (2004/05 disposal)
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)
2009 May	McKim & Creed	25 months post-construction (2007 disposal)
2009 Sept.	Gahagan & Bryant	Survey required by dredge Contractor.
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)
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)
2018 Nov.	McKim & Creed	32 months post-construction (2015 Disposal)
2018 May	McKim & Creed	38 months post-construction (2015 Disposal)
2019 Sept.	McKim & Creed	Post-Hurricane Florence
2019 May	McKim & Creed	2 months post-renourishment (18/19)
2019 Nov	McKim & Creed	8 months post-renourishment (18/19)
2020 May	McKim & Creed	14 months post-renourishment (18/19)



**MHWL SURVEYS** 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 were monitored at 6 months and thereafter annually for the following 3 years. **Table 2.3** summarizes selected surveys collected to date. No survey was required or conducted during the current monitoring year. The purpose of the monitoring is 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 has been the rate of recovery and the composition of the material that infills the area(s) excavated by hydraulic dredge below that addressed by permit. In addition to annual surveys, limited grab samples and sediment analysis are performed by the firm LMG. The Marcol March 2017 AD Survey is considered as the “baseline condition”. As of May 2019, physical monitoring was deemed complete.

**Table 2.3:** Selected Bald Head Creek borrow site surveys collected as of May 2020.

<b>Borrow Site Survey Date</b>	<b>Comment</b>
March 2012	After Dredge (AD) Survey (11/12 Project)
January 2013	10 Months Post-Dredge (11/12 Project)
December 2013	21 Months Post-Dredge (11/12 Project)
April 2015	37 Months Post-Dredge (11/12 Project)
April 2016	49 Months Post-Dredge (11/12 Project)
November 2016	Before Dredge (BD) Survey (16/17 Project)
March 2017	After Dredge (AD) Survey (16/17 Project)
November 2017	7 Months Post-Dredge (11/12 Project)
May 2018	14 Months Post-Dredge (11/12 Project)
May 2019 <sup>(1)</sup>	26 onths Post-Dredge (11/12 Project)

(1) Last monitoring survey required.

### 2.3 Jay Bird Shoal Borrow Site Surveys

Permits for the most recent beach renourishment project constructed by the Village in 2019 necessitate the resurveying of the Jay Bird Shoal borrow site as part of the annual island-wide monitoring program. **Table 2.4** summarizes the borrow site surveys conducted to date. Specifically, borrow site surveys are required both pre- and post-excavation, as well as at 12-, 24- and 36-months and biennially thereafter. The area typically surveyed is 400-acres  $\pm$  which includes a buffer area outside the “permitted” limits of work.

**Table 2.4:** Jay Bird Shoal borrow site surveys collected as of May 2020.

Borrow Site Survey Date	Comment
October 2009	Before Dredge (BD) Survey (09/10 Project)
March 2010	After Dredge (AD) Survey (09/10 Project)
May 2011	14 Months Post-Dredge (09/10 Project)
May 2012	26 Months Post-Dredge (09/10 Project)
May 2013	38 Months Post-Dredge (09/10 Project)
April 2015	61 Months Post-Dredge (09/10 Project)
May 2017	86 Months Post-Dredge (09/10 Project)
November 2017	92 Months Post-Dredge (09/10 Project)
May 2018	98 Months Post-Dredge (09/10 Project)
September 2018	98 Months Post-Dredge (09/10 Project)
December 2018	Before Dredge (BD) Survey (19 Project)
March 2019	After Dredge (AD) Survey (19 Project)
May 2020	14 Months Post Project (19 Project)

### 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 Greenman-Pedersen, Inc.<sup>6</sup> **Table 2.5** summarizes the aerial photography collected to date as part of the monitoring program. Reproductions of the three most recent aerial photography sets (May 2020, November 2019 and April 2019) are presented in **Appendices B, C and D**, respectively.

<sup>6</sup> Greenman-Pederson, Inc.; 3909 Wrightsville Ave. Suite 200; Wilmington, NC 28403.

**Table 2.5:** Bald Head Island monitoring aerial photography collected as of May 2020.

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 (09/10)
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
2017	November	27	24 months post-construction (T.G.)
2018	April	19	29 months post-construction (T.G.)
2018	October	14	Post-Hurricane Florence
2019	April	10	1 month post-renourishment (18/19)
2019	Nov	13	8 months post-renourishment (18/19)
2020	May	15	13 months post-renourishment (18/19)

### 3.0 MONITORING (SURVEY) RESULTS

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#### 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”<sup>7</sup>
- Station 214+00 to 224+80 “Cape Fear Point”<sup>8</sup>
- Station 224+80 to 284+80 “East Beach”

These zones differ slightly from the shoreline segments used monitoring reports prior to 2015 (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 spatially weighted based upon the distance between stations due to the non-uniform alongshore spacing of survey monuments.

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<sup>7</sup> 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.

<sup>8</sup> 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 19: Monitoring Program (May 2019 – November 2019 – May 2020)

The May 2019 to May 2020 monitoring period represents the nineteenth year of measured shoreline change following completion of the initial 2001 Federal +1.849 Mcy beach disposal at Bald Head Island. For compliance purposes, the May 2020 survey represents the first year following completion of the +1.1 Mcy beach fill constructed by the Village of Bald Head Island in the winter of 2018/2019 at South Beach. The period also represents the fifth year following completion of the 1.33 Mcy 2015 Federal beach disposal.

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 May 2019 – November 2019 – May 2020 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).

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

#### 3.3.1 Survey Period: May 2019 to November 2019 (Hurricane Dorian)

This survey period represents the first monitoring period following completion of the +1.1 Mcy 2018/19 beach fill. The May 2019 and November 2019 surveys were performed approximately 2 and 8 months, respectively, following project completion in March 2019. This six (6) month survey period also depicts the direct impacts of Hurricane Dorian (early September 2019).

As depicted in **Figure 3.1**, the island-wide *net* shoreline volume change trend for this period was erosional with -361,600 cy (-15.9 cy/ft) of loss, mol. over the 6 month span above -16 ft-NGVD. Similarly, above the MHWL, the shoreline lost -10,400 cy. Consistent with the volume losses above the MHWL, the berm receded by a spatially weighted average<sup>9</sup> of roughly -9 feet while the MHWL retreated by -11 feet. However, subreaches of the monitored shoreline experienced varied changes over this monitoring period.

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<sup>9</sup> 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 3.1:** Bald Head Island shoreline volume change (May 2019 to November 2019).

	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	-700	-3,000		056+56	060+51	423	-2,000	-20,300	
	000+00	004+00	400	-800	-4,100		060+51	065+50	510	-2,600	-26,300	
	004+00	008+00	400	+100	-300		065+50	069+46	423	-300	-16,000	
	008+00	010+00	200	+100	-300		069+46	073+39	442	-500	-15,900	
	010+00	012+00	200	-100	-900		073+39	076+37	516	-3,000	-20,200	
	012+00	014+00	200	-100	-1,200		076+37	084+16	611	-6,700	-25,400	
	014+00	016+00	200	-200	-1,500		084+16	088+23	471	-6,200	-19,200	
	016+00	018+00	200	-400	-1,400		088+23	092+15	455	-6,100	-20,200	
	018+00	020+00	200	-200	-600		092+15	097+10	536	-6,500	-23,100	
	020+00	024+00	400	+300	+4,200		097+10	102+08	525	-4,800	-16,600	
	024+00	028+00	400	+1,500	+5,100		102+08	106+00	436	-3,200	-11,000	
	Subtotal		2,960	-500	-4,000		106+00	110+00	400	-2,100	-8,700	
Point (North of Groin)	028+00	032+00	395	+1,200	+200		110+00	114+00	388	-1,700	-8,600	
	032+00	034+00	200	-200	-1,000		114+00	118+00	407	-2,000	-9,100	
	034+00	036+00	210	-700	-900		118+00	122+00	413	-1,900	-9,800	
	036+00	038+00	230	+300	+1,800		122+00	126+00	405	-2,800	-12,200	
	038+00	039+60	230	+2,200	+7,000		126+00	130+00	405	-3,300	-12,200	
	039+60	041+50	220	+4,000	+12,400		130+00	134+00	398	-3,500	-12,400	
	041+50	043+47	220	+5,500	+16,700		134+00	138+00	401	-4,100	-13,700	
	043+47	044+25	190	+4,700	+13,900		138+00	142+00	400	-2,200	-11,200	
	044+25	045+07	190	+4,100	+9,700		142+00	146+00	400	+900	-7,700	
	045+07	046+00	200	+3,900	+5,200		146+00	150+00	399	+1,800	-8,700	
	Subtotal		2,285	+25,000	+65,000		150+00	154+00	385	+2,900	-4,300	
Point (South of Groin)	046+00	046+89	200	+2,800	+1,000		154+00	158+00	383	+4,600	-2,000	
	046+89	049+00	250	+3,000	-200		158+00	162+00	386	+4,100	-5,200	
	049+00	050+50	100	+1,300	-300		162+00	166+00	393	+2,300	-6,100	
	050+50	051+00	100	+1,000	-1,400		166+00	170+00	394	+2,100	+1,100	
	051+00	052+64	240	+1,900	-4,600		170+00	174+00	400	+3,500	+9,900	
	052+64	054+00	135	+700	-2,700		174+00	178+00	400	+3,100	+7,900	
	054+00	056+56	380	+300	-11,100		178+00	182+00	400	+2,900	+2,500	
	Subtotal		1,405	+11,000	-19,300		182+00	186+00	400	+2,700	+3,100	
<b>Note:</b> Elevations are referenced to NGVD 1929.							186+00	190+00	400	+2,600	+100	
							190+00	194+00	400	+2,000	-7,800	
							194+00	198+00	400	-1,200	-9,400	
							198+00	202+00	400	-4,900	-17,400	
							202+00	206+00	400	-6,100	-21,800	
							206+00	210+00	400	-3,300	-16,500	
							210+00	214+00	400	-400	-8,900	
							Subtotal		16,105	-45,900	-403,300	
							Bald Head Total		22,755	-10,400	-361,600	

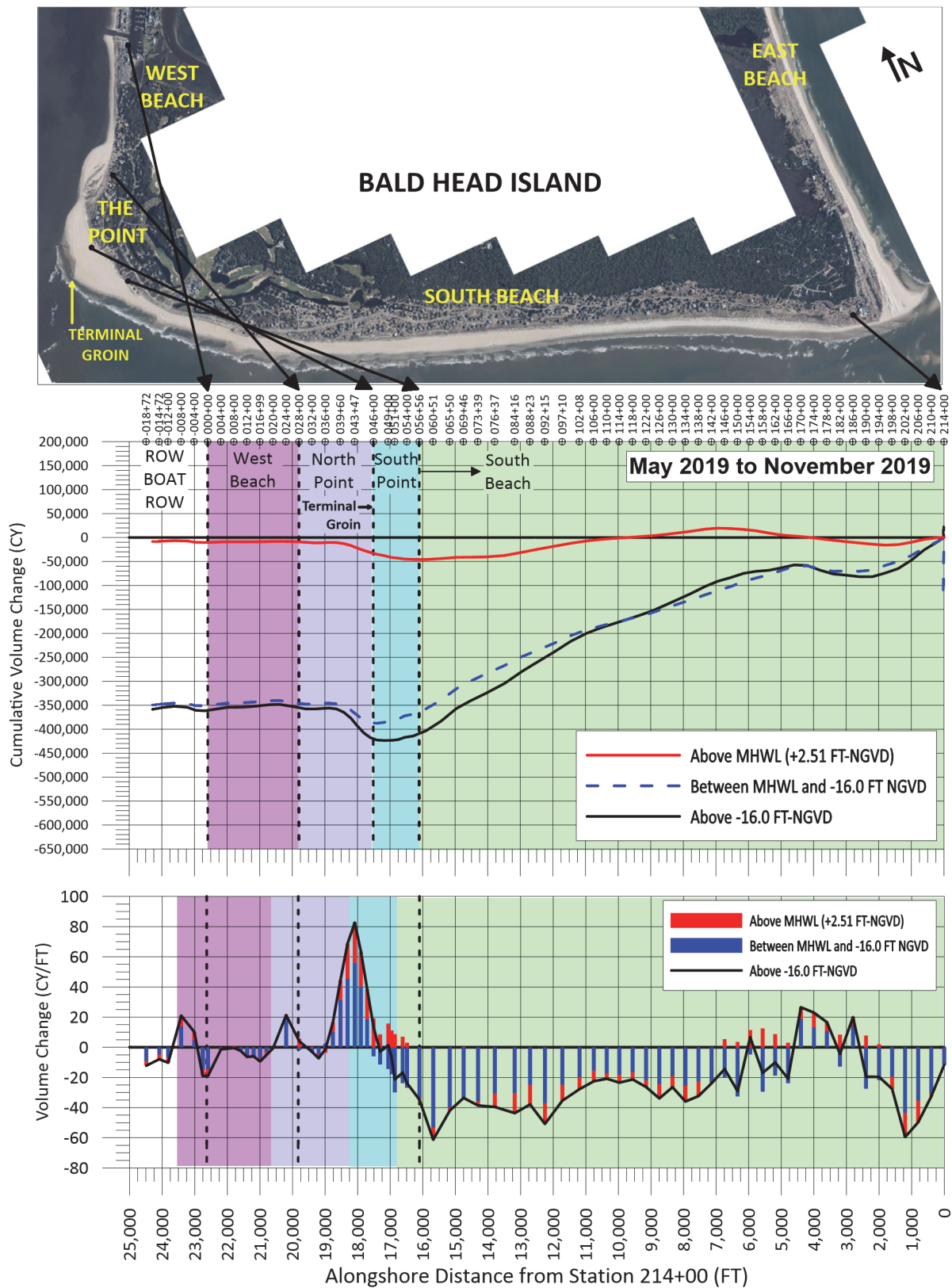
**Table 3.2:** Bald Head Island shoreline volume change (November 2019 to May 2020).

				Volume Change						Volume Change		
	Start Station	End Station	Reach (FT)	Above +2.51 (FT)	Above -16 (FT)		Start Station	End Station	Reach (FT)	Above +2.51 (FT)	Above -16 (FT)	
West Beach	Jetty	000+00	160	+300	+1,600		056+56	060+51	423	-5,200	-3,900	South Beach
	000+00	004+00	400	0	0		060+51	065+50	510	-6,000	-5,400	
	004+00	008+00	400	-300	-1,000		065+50	069+46	423	-5,100	-7,700	
	008+00	010+00	200	-100	-200		069+46	073+39	442	-5,700	-11,900	
	010+00	012+00	200	0	+300		073+39	076+37	516	-7,700	-16,200	
	012+00	014+00	200	+300	+1,100		076+37	084+16	611	-10,900	-19,000	
	014+00	016+00	200	+500	+1,800		084+16	088+23	471	-9,400	-13,900	
	016+00	018+00	200	+900	+4,100		088+23	092+15	455	-7,800	-13,400	
	018+00	020+00	200	+1,200	+5,400		092+15	097+10	536	-7,500	-17,600	
	020+00	024+00	400	+800	+2,100		097+10	102+08	525	-7,300	-14,600	
	024+00	028+00	400	-2,200	-10,000		102+08	106+00	436	-5,500	-7,600	
	Subtotal			2,960	+1,400		+5,200	106+00	110+00	400	-4,500	
Point (North of Groin)	028+00	032+00	395	-4,000	-13,900		110+00	114+00	388	-4,300	-7,000	
	032+00	034+00	200	-1,400	-3,900		114+00	118+00	407	-4,300	-6,800	
	034+00	036+00	210	+1,000	+8,100		118+00	122+00	413	-3,600	-4,900	
	036+00	038+00	230	+3,600	+20,500		122+00	126+00	405	-3,600	-6,000	
	038+00	039+60	230	+2,600	+15,300		126+00	130+00	405	-3,100	-8,000	
	039+60	041+50	220	-900	+1,700		130+00	134+00	398	-2,400	-7,700	
	041+50	043+47	220	-2,100	-2,100		134+00	138+00	401	-3,400	-5,700	
	043+47	044+25	190	-1,400	+900		138+00	142+00	400	-3,000	-1,700	
	044+25	045+07	190	-1,800	-500		142+00	146+00	400	-1,700	+700	
	045+07	046+00	200	-1,800	+600		146+00	150+00	399	-1,400	+400	
	Subtotal			2,285	-6,200		+26,700	150+00	154+00	385	-1,600	
Point (South of Groin)	046+00	046+89	200	-1,400	+800		154+00	158+00	383	-1,700	+4,800	
	046+89	049+00	250	-2,500	-3,000		158+00	162+00	386	-1,100	+10,800	
	049+00	050+50	100	-1,300	-1,800		162+00	166+00	393	-1,200	+5,700	
	050+50	051+00	100	-1,700	-2,800		166+00	170+00	394	-2,200	-2,400	
	051+00	052+64	240	-5,300	-9,400		170+00	174+00	400	-2,100	-1,300	
	052+64	054+00	135	-3,100	-5,400	174+00	178+00	400	-1,700	-1,600		
	054+00	056+56	380	-6,400	-8,600	178+00	182+00	400	-1,700	-2,100		
	Subtotal			1,405	-21,700	-30,200	182+00	186+00	400	-2,800	-3,700	
Note: Elevations are referenced to NGVD 1929.					186+00	190+00	400	-3,700	+500			
					190+00	194+00	400	-6,000	-1,100			
					194+00	198+00	400	-9,000	-9,200			
					198+00	202+00	400	-5,400	-2,800			
					202+00	206+00	400	-600	+8,400			
					206+00	210+00	400	0	+13,200			
					210+00	214+00	400	0	+13,400			
					Subtotal		16,105	-154,200	-152,600			
					Bald Head Total		22,755	-180,700	-150,900			

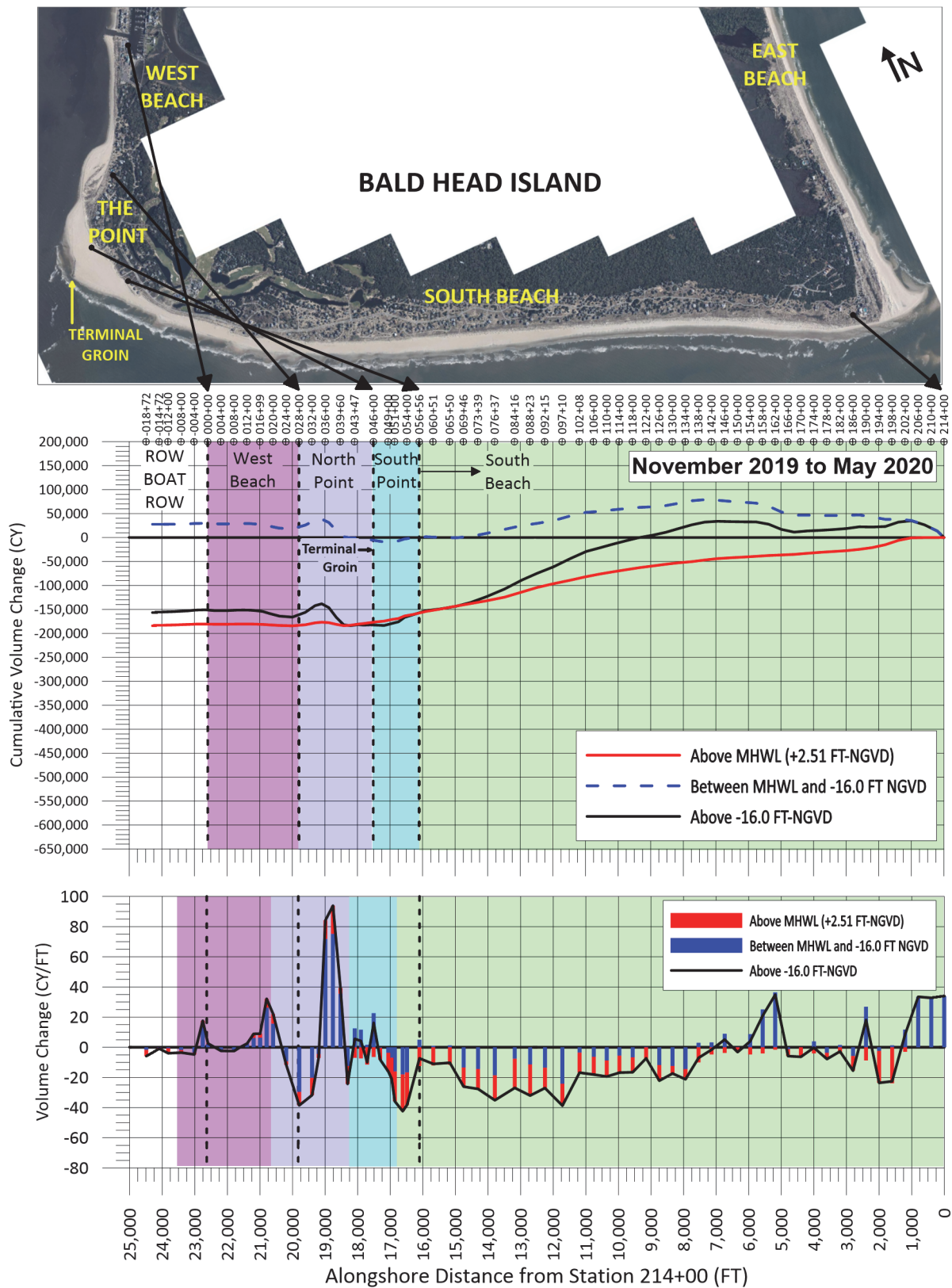
**Table 3.3:** Bald Head Island shoreline volume change (May 2019 to May 2020).

				Volume Change						Volume Change		
	Start Station	End Station	Reach (FT)	Above +2.51 (FT)	Above -16 (FT)		Start Station	End Station	Reach (FT)	Above +2.51 (FT)	Above -16 (FT)	
West Beach	Jetty	000+00	160	-400	-1,400		056+56	060+51	423	-7,200	-24,200	South Beach
	000+00	004+00	400	-800	-4,100		060+51	065+50	510	-8,600	-31,700	
	004+00	008+00	400	-200	-1,300		065+50	069+46	423	-5,400	-23,700	
	008+00	010+00	200	0	-500		069+46	073+39	442	-6,200	-27,800	
	010+00	012+00	200	-100	-600		073+39	076+37	516	-10,700	-36,400	
	012+00	014+00	200	+200	-100		076+37	084+16	611	-17,600	-44,400	
	014+00	016+00	200	+300	+300		084+16	088+23	471	-15,600	-33,100	
	016+00	018+00	200	+500	+2,700		088+23	092+15	455	-13,900	-33,600	
	018+00	020+00	200	+1,000	+4,800		092+15	097+10	536	-14,000	-40,700	
	020+00	024+00	400	+1,100	+6,300		097+10	102+08	525	-12,100	-31,200	
	024+00	028+00	400	-700	-4,900		102+08	106+00	436	-8,700	-18,600	
	Subtotal			2,960	+900		+1,200	106+00	110+00	400	-6,600	
Point (North of Groin)	028+00	032+00	395	-2,800	-13,700		110+00	114+00	388	-6,000	-15,600	
	032+00	034+00	200	-1,600	-4,900		114+00	118+00	407	-6,300	-15,900	
	034+00	036+00	210	+300	+7,200		118+00	122+00	413	-5,500	-14,700	
	036+00	038+00	230	+3,900	+22,300		122+00	126+00	405	-6,400	-18,200	
	038+00	039+60	230	+4,800	+22,300		126+00	130+00	405	-6,400	-20,200	
	039+60	041+50	220	+3,100	+14,100		130+00	134+00	398	-5,900	-20,100	
	041+50	043+47	220	+3,400	+14,600		134+00	138+00	401	-7,500	-19,400	
	043+47	044+25	190	+3,300	+14,800		138+00	142+00	400	-5,200	-12,900	
	044+25	045+07	190	+2,300	+9,200		142+00	146+00	400	-800	-7,000	
	045+07	046+00	200	+2,100	+5,800		146+00	150+00	399	+400	-8,300	
Subtotal			2,285	+18,800	+91,700		150+00	154+00	385	+1,300	-4,100	
Point (South of Groin)	046+00	046+89	200	+1,400	+1,800		154+00	158+00	383	+2,900	+2,800	
	046+89	049+00	250	+500	-3,200		158+00	162+00	386	+3,000	+5,600	
	049+00	050+50	100	0	-2,100		162+00	166+00	393	+1,100	-400	
	050+50	051+00	100	-700	-4,200		166+00	170+00	394	-100	-1,300	
	051+00	052+64	240	-3,400	-14,000		170+00	174+00	400	+1,400	+8,600	
	052+64	054+00	135	-2,400	-8,100		174+00	178+00	400	+1,400	+6,300	
	054+00	056+56	380	-6,100	-19,700		178+00	182+00	400	+1,200	+400	
	Subtotal			1,405	-10,700		-49,500	182+00	186+00	400	-100	
Note: Elevations are referenced to NGVD 1929.							186+00	190+00	400	-1,100	+600	
							190+00	194+00	400	-4,000	-8,900	
							194+00	198+00	400	-10,200	-18,600	
							198+00	202+00	400	-10,300	-20,200	
							202+00	206+00	400	-6,700	-13,400	
							206+00	210+00	400	-3,300	-3,300	
							210+00	214+00	400	-400	+4,500	
							Subtotal		16,105	-200,100	-555,900	
							Bald Head Total		22,755	-191,100	-512,500	

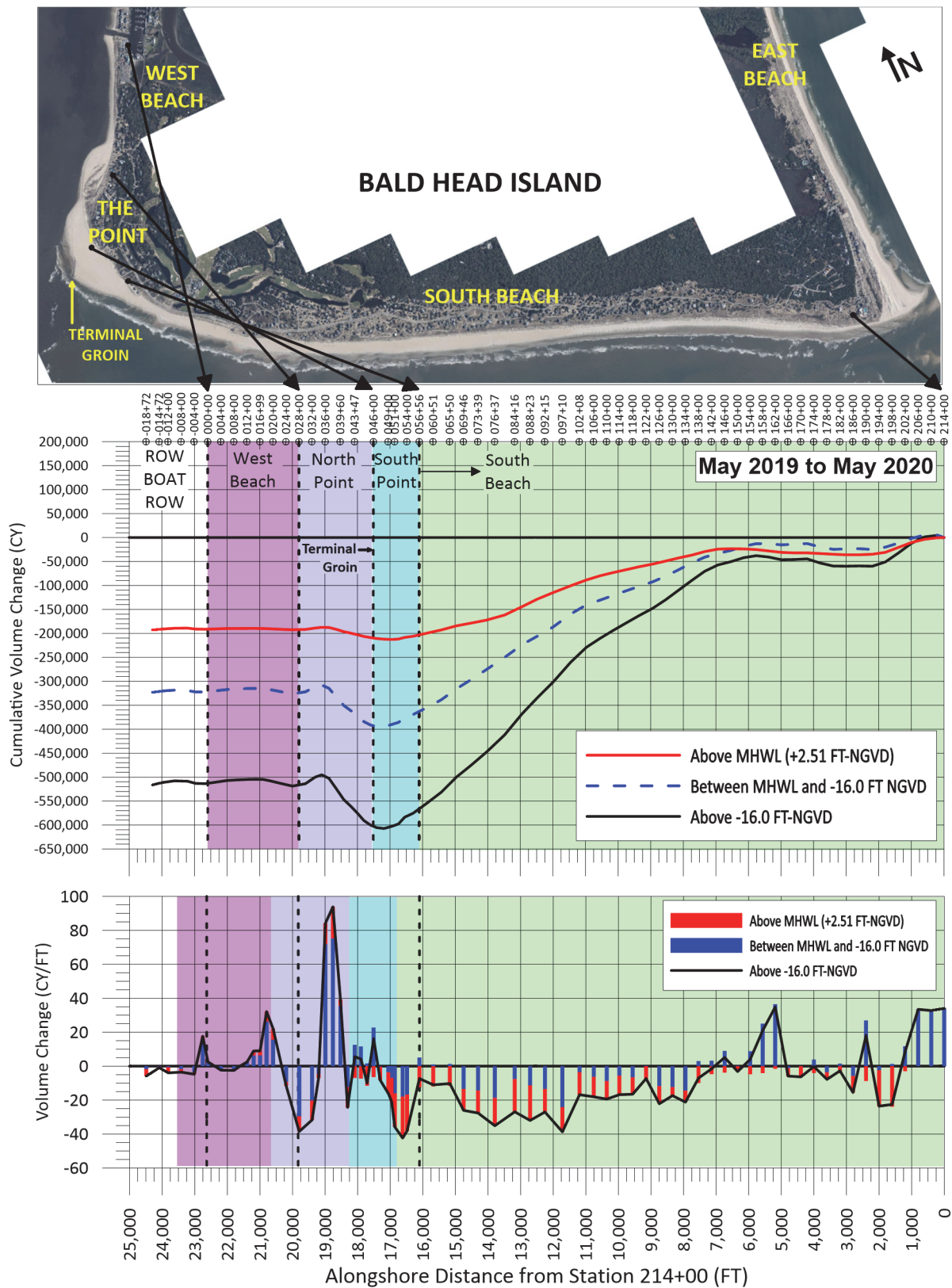




**Figure 3.1:** Volume change along the Bald Head Island shoreline between May 2019 and November 2019.



**Figure 3.2:** Volume change along the Bald Head Island shoreline between November 2019 and May 2020.



**Figure 3.3:** Volume change along the Bald Head Island shoreline between May 2019 and May 2020 (Year 19).

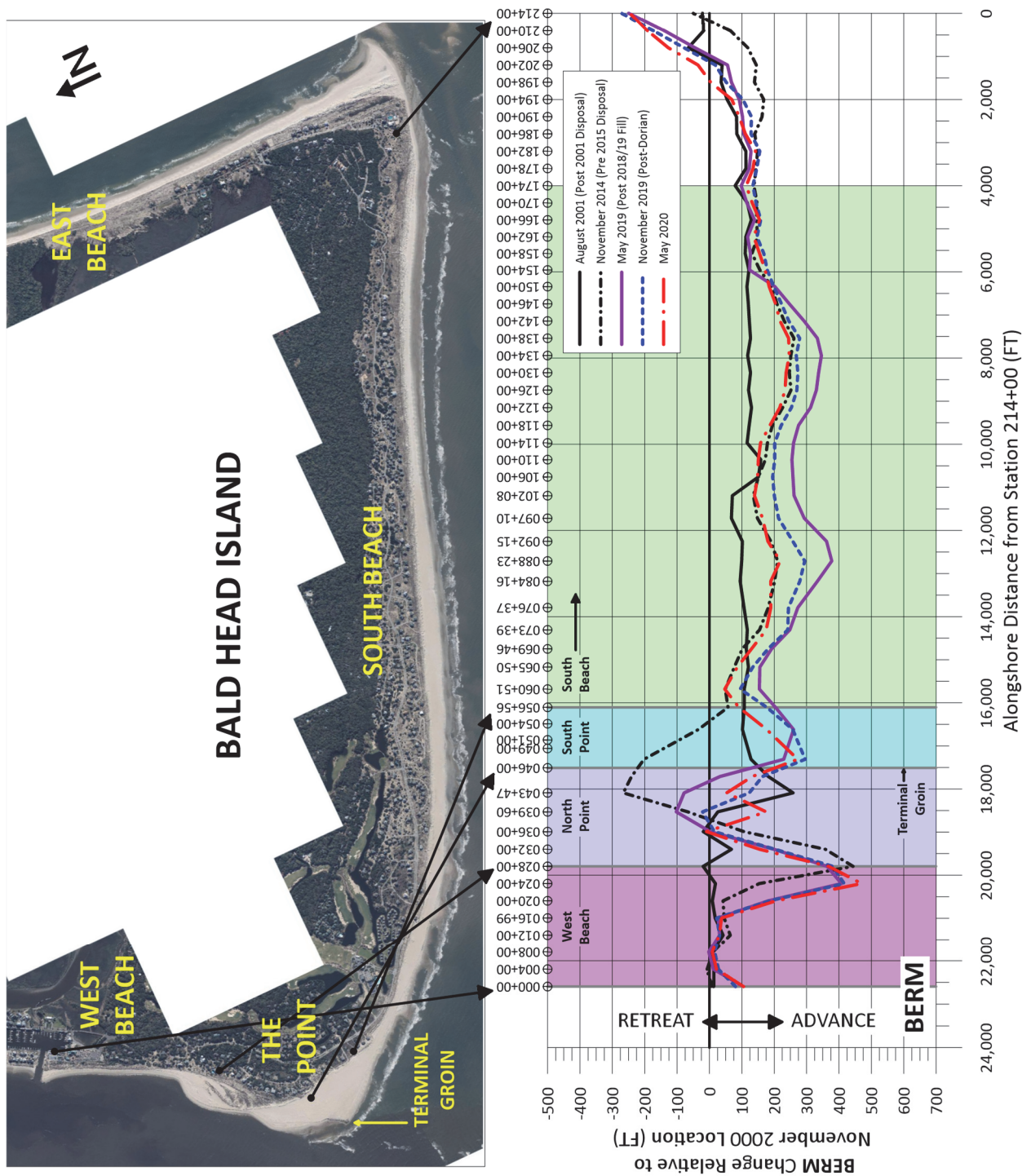
**Table 3.4:** Location of the **BERM** (+6.0 ft-NGVD) relative to the November 2000 (pre-2001 fill) location for selected monitoring surveys.

	Station	Location Relative to Nov. 2000				Station	Location Relative to Nov. 2000		
		May 2019	Nov. 2019	May 2020			May 2019	Nov. 2019	May 2020
West Beach	000+00	+106.0	+80.8	+105.6	South Beach	060+51	+154.2	+95.0	+47.2
	004+00	+12.0	+27.7	+21.9		065+50	+155.6	+133.8	+86.0
	008+00	-2.0	+16.1	+8.7		069+46	+191.9	+180.9	+129.8
	010+00	No November 2000 profile				073+39	+248.4	+241.9	+175.2
	012+00	+31.4	+31.7	+30.6		076+37	+273.0	+244.1	+189.5
	014+00	No November 2000 profile				084+16	+333.4	+279.1	+189.4
	016+00	+26.7	+22.3	+37.2		088+23	+377.9	+294.2	+218.3
	018+00	No November 2000 profile				092+15	+361.8	+257.7	+180.6
	020+00	+181.9	+184.7	+205.5		097+10	+292.9	+213.5	+163.9
	024+00	+407.9	+415.9	+469.9		102+08	+261.4	+200.4	+139.2
	028+00	+363.5	+381.0	+368.4		106+00	+257.9	+195.3	+148.8
Point (North of Groin)	032+00	+199.2	+202.9	+155.4		110+00	+254.8	+201.8	+151.0
	034+00	No November 2000 profile				114+00	+259.9	+201.7	+157.9
	036+00	+2.3	+15.1	-9.5		118+00	+275.1	+221.7	+186.9
	038+00	No November 2000 profile				122+00	+312.4	+253.2	+217.4
	039+60	-102.4	-21.0	+175.0		126+00	+330.3	+270.1	+233.5
	041+50	No November 2000 profile				130+00	+337.2	+273.1	+236.8
	043+47	-78.3	+123.0	+53.2		134+00	+345.8	+268.2	+246.5
	044+25	No November 2000 profile				138+00	+333.3	+278.6	+244.5
	045+07	+32.8	+164.0	+132.4		142+00	+292.3	+245.1	+218.0
	046+00	No November 2000 profile				146+00	+246.5	+222.3	+204.2
Point (South of Groin)	046+89	+229.6	+295.6	+272.7		150+00	+202.2	+198.6	+184.4
	049+00	No November 2000 profile				154+00	+123.8	+178.6	+172.0
	050+50	No November 2000 profile				158+00	+126.7	+167.9	+154.7
	051+00	No November 2000 profile				162+00	+117.9	+146.9	+137.1
	052+64	+259.8	+257.4	+176.8		166+00	+139.3	+158.4	+154.7
	054+00	No November 2000 profile				170+00	+115.6	+144.1	+132.2
	056+56	+204.0	+177.2	+90.8		174+00	+98.0	+134.3	+113.7
Positive values indicate shoreline advance relative to the pre-construction location. Negative values indicate shoreline erosion and are highlighted in red.						178+00	+123.0	+146.2	+134.7
						182+00	+128.4	+155.3	+142.4
						186+00	+105.9	+128.5	+110.9
						190+00	+102.0	+129.5	+92.0
						194+00	+92.0	+103.5	+69.0
						198+00	+68.1	+51.7	+3.6
						202+00	+55.7	+18.2	-35.3
						206+00	-44.5	-78.4	-127.1
						210+00	-139.7	-173.4	-191.6
						214+00	-249.0	-271.1	-245.4

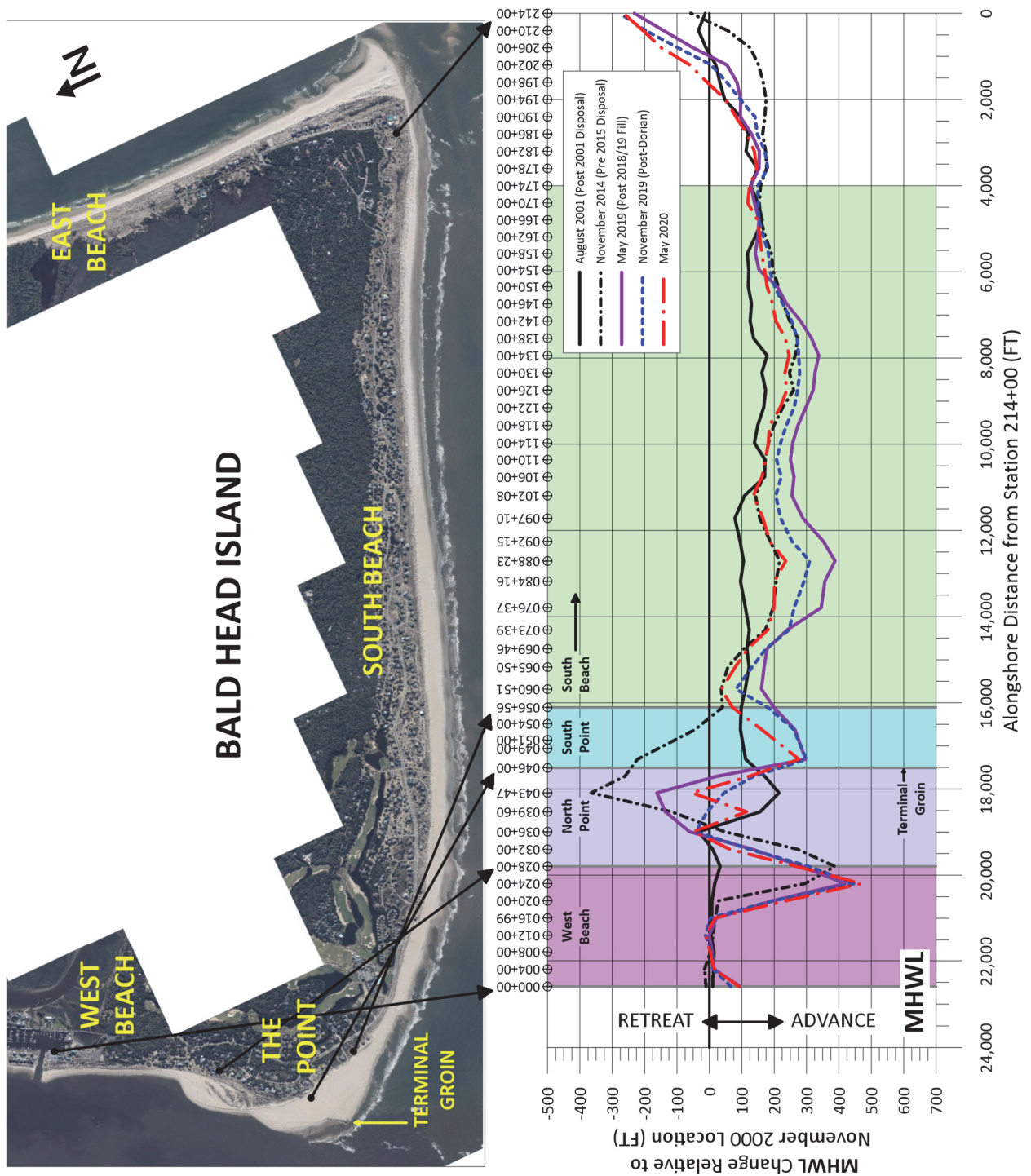
**Table 3.5:** Location of the **MHWL** (+2.51 ft-NGVD) relative to the November 2000 (pre-2001 fill) location for selected monitoring surveys.

	Station	Location Relative to Nov. 2000				Station	Location Relative to Nov. 2000		
		May 2019	Nov. 2019	May 2020			May 2019	Nov. 2019	May 2020
West Beach	000+00	+95.0	+66.1	+92.5	South Beach	060+51	+160.7	+82.2	+36.5
	004+00	+14.8	+11.6	+14.3		065+50	+169.0	+131.9	+79.9
	008+00	+8.6	+7.8	+2.4		069+46	+177.8	+174.2	+118.2
	010+00	No November 2000 profile				073+39	+240.3	+245.9	+180.8
	012+00	-0.4	-12.0	-12.0		076+37	+345.6	+261.9	+199.6
	014+00	No November 2000 profile				084+16	+356.5	+292.4	+200.9
	016+00	+21.0	+2.5	+17.4		088+23	+388.0	+309.4	+235.9
	018+00	No November 2000 profile				092+15	+351.9	+255.2	+186.2
	020+00	+195.2	+196.5	+235.4		097+10	+288.8	+220.0	+165.5
	024+00	+419.2	+447.0	+469.2		102+08	+254.9	+205.2	+135.5
	028+00	+284.0	+306.2	+268.5		106+00	+261.3	+221.8	+162.4
Point (North of Groin)	032+00	+133.4	+123.9	+63.6		110+00	+250.1	+207.6	+173.2
	034+00	No November 2000 profile				114+00	+257.3	+219.9	+182.1
	036+00	-61.7	-41.5	-49.1		118+00	+273.5	+237.7	+185.8
	038+00	No November 2000 profile				122+00	+297.4	+261.8	+218.5
	039+60	-136.0	-7.3	+115.0		126+00	+320.6	+272.4	+239.0
	041+50	No November 2000 profile				130+00	+326.2	+278.9	+233.3
	043+47	-162.1	+45.6	-54.2		134+00	+337.8	+275.5	+246.0
	044+25	No November 2000 profile				138+00	+315.3	+271.0	+234.9
	045+07	+20.8	+135.8	+122.2		142+00	+281.3	+254.2	+205.0
	046+00	No November 2000 profile				146+00	+238.2	+226.6	+195.2
Point (South of Groin)	046+89	+296.8	+299.1	+276.6		150+00	+209.6	+201.5	+178.1
	049+00	No November 2000 profile				154+00	+153.5	+186.0	+170.6
	050+50	No November 2000 profile				158+00	+141.8	+182.6	+161.7
	051+00	No November 2000 profile				162+00	+149.8	+167.5	+156.0
	052+64	+264.1	+260.6	+161.4		166+00	+153.0	+152.7	+148.5
	054+00	No November 2000 profile				170+00	+139.4	+150.6	+118.2
	056+56	+199.4	+180.2	+71.5		174+00	+128.1	+149.6	+124.4
Positive values indicate shoreline advance relative to the pre-construction location. Negative values indicate shoreline erosion and are highlighted in red.						178+00	+153.1	+179.9	+146.0
						182+00	+154.2	+171.7	+138.8
						186+00	+130.3	+147.7	+116.3
						190+00	+95.4	+140.9	+81.6
						194+00	+97.1	+95.2	+49.8
						198+00	+85.0	+53.9	-7.3
						202+00	+54.5	+5.5	-60.0
						206+00	-50.3	-96.8	-148.6
						210+00	-141.5	-197.0	-204.8
						214+00	-231.7	-276.7	-265.5





**Figure 3.4:** Location of the BERM (+6.00 ft-NGVD) relative to the November 2000 (pre-2001 fill) location.



**Figure 3.5:** Location of the MHWL (+2.51 ft-NGVD) relative to the November 2000 (pre-2001 fill) location.

In the net, West Beach was relatively stable during this period losing -500 cy above the MHWL and -3,500 cy between the MHWL and the -16 ft-NGVD contour. Overall West Beach gained roughly -4,000 cy above the -16 ft contour. All of the losses occurred along the northernmost 2,160 ft (Jetty to Sta 020+000). Most of the gains occurred along the southernmost 1,000 ft of West Beach, adjacent to the Point. Along the southernmost 800 ft of West Beach, adjacent to the point, the beach gained +9,300 cy. During this period, the berm advanced by an average of +4 ft while the MHWL receded by -3 ft.

The entire 3,690 ft of “the Point” shoreline (Sta. 28+00 to 56+56) was net accretional during this monitoring period, gaining +45,700 cy above -16 ft-NGVD. 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 gained +25,000 cy above the MHWL and +65,000 cy above -16 ft-NGVD. Along this reach, the berm advanced by roughly +85 ft on average and the MHWL by +2 ft. South of the terminal groin (Sta. 46+00 to 56+56), the shoreline gained +11,000 cy above the MHWL and lost -19,300 cy above the -16 ft-NGVD contour. The berm and MHWL advanced by averages of +30 ft and +12 ft, respectively.

South Beach was net erosional during the period, losing roughly -45,900 cy above the MHWL and -403,300 cy above -16 ft-NGVD. All but five (33 of 38) of the monitoring stations were net erosional above -16 ft-NGVD. During this period, the berm receded by an average of -27 ft while the MHWL receded by -28 ft.

### **3.3.2 Survey Period: November 2019 to May 2020 (Post-Hurricane Dorian)**

As depicted in **Figure 3.2**, the island-wide *net* volume change was a loss of approximately -150,900 cy (-6.6 cy/ft) above -16 ft-NGVD. Consistent with the overall volume losses, the berm and MHWL receded by spatially weighted averages of roughly -30 ft and -36 ft, respectively, along the approximate 22,755 ft of shoreline (West Beach, “the Point”, and South Beach).

In the net, West Beach was relatively stable during this period with a gain of +1,400 cy above the MHWL and +3,800 cy between the MHWL and the -16 ft-NGVD contour. Overall West Beach gained roughly +5,200 cy above the -16 ft contour. During this period, the berm and MHWL advanced by weighted averages of +12 and +11 ft, respectively.

Along “the Point” shoreline north of the terminal groin, the beach lost -6,200 cy above the MHWL and gained +26,700 cy above the -16 ft-NGVD contour. During this period, the berm retreated by an average of -3 ft and the MHWL remained unchanged. Along “the Point” shoreline south of the terminal groin, the beach lost -30,200 cy above -16 ft-NGVD. During this period, the berm receded by an average of -67 ft and the MHWL by -80 ft.



South Beach was net erosional during the period, losing roughly -154,600 cy above the -16 ft-NGVD. However, most of this loss occurred above the MHWL. Above the MHWL, the shoreline lost -154,200 cy while below the MHWL to -16 ft-NGVD, the shoreline gained +1,600 cy. During this period the berm and MHWL receded by spatially weighted averages of roughly -39 ft and -45 ft, respectively.

### **3.3.3 Year 19 Monitoring Results: May 2019 to May 2020 (Excluding East Beach & Row Boat Row)**

During Year 19 in its entirety, the island experienced a net loss of -512,500 cy -22.5 cy/ft) above the -16 ft contour. Approximately 70 percent of this loss occurred during the first six months of the monitoring period (May 2019 to November 2019), during which Hurricane Dorian impacted the Bald Head Island shoreline.

Along West Beach, the shoreline gained approximately +900 cy above the MHWL and +1,200 cy above -16 ft-NGVD. During Year 19, the berm advanced by an average of +16 ft and the MHWL by +8 ft.

The entire Point shoreline (north and south of the terminal groin), experienced a net gain of roughly +8,100 cy above the MHWL and +42,200 cy above -16 ft-NGVD. During this period, the berm advanced by an average of 36 ft and the MHWL receded by -25 ft.

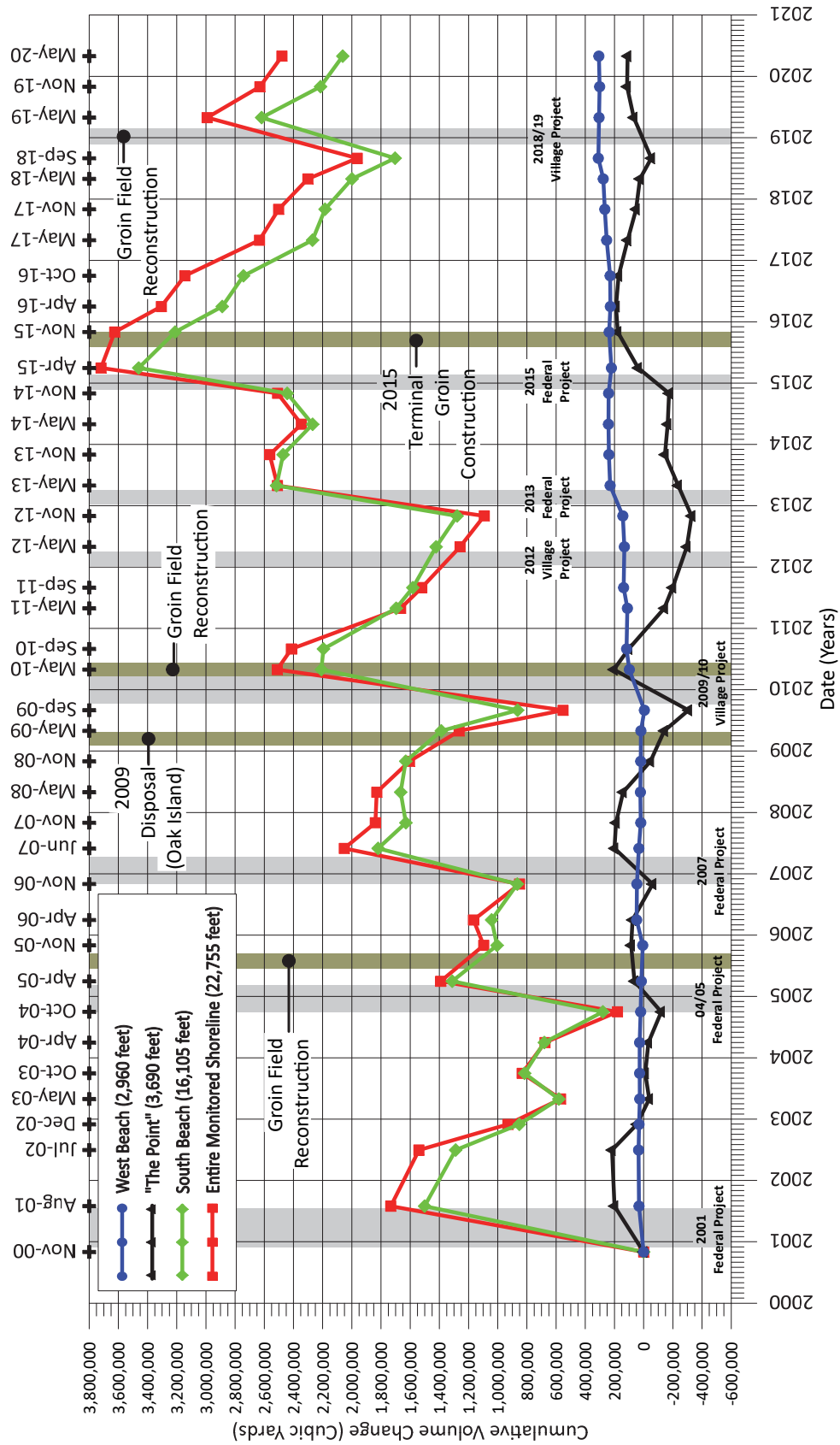
The South Beach shorefront lost -200,100 cy above the MHWL and -555,900 cy above -16 ft-NGVD. During this period, the berm and MHWL receded by averages of -66 ft and -73 ft, respectively.

### 3.3.4 Long-Term Beach Changes: November 2000 to May 2020

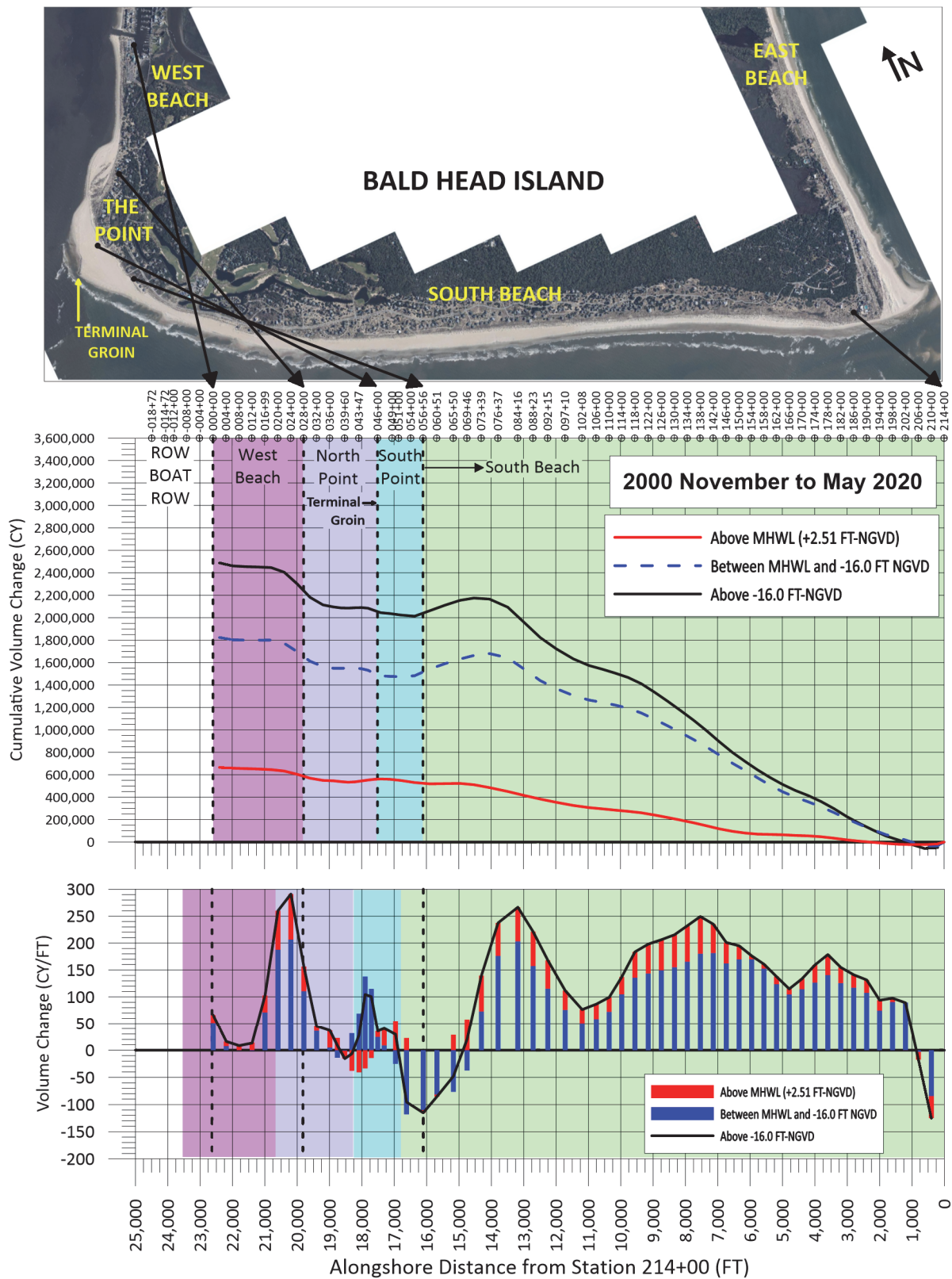
For purposes of tracking gross sand placement performance, **Figure 3.6** plots a time history of cumulative volume change relative to November 2000 conditions. **Figure 3.7** presents net volumetric change (alongshore above -16 ft NGVD) for the maximum period of comparison to date (*i.e.* November 2000 and May 2020). In both figures the effects of direct sand placement over time are included. As with other similar analyses over the last decade, East Beach, Cape Fear and Row Boat Row are excluded from this analysis.

The classic “saw-tooth” effects of episodic sand placement, as reflected in **Figure 3.6**, are indicative of the periodic infusion of sand along South Beach at Bald Head Island associated with the placement of sand during initial construction of the channel deepening project, three (3) subsequent beach disposal operations pursuant to the WHSMP, the proactive beach renourishment project constructed by the Village in 2009/10 and to a smaller degree the emergency fill of 2012. The Village 1.85 Mcy fill was constructed with the knowledge gained through monitoring that certain irreparable large-scale impacts to Bald Head Island would predictably occur as a direct result of the proposed diversion of channel maintenance material in 2009 to Oak Island. *Note – a similar diversion of Federal sand occurred in the summer of 2018.* As a result of the 2018 federal sand disposal at Oak Island, the Village constructed a 1.1 Mcy interim beach fill at South Beach in the fall/winter of 2018/19. The next federal beach disposal project is scheduled to occur in the early months of 2021 along South Beach on Bald Head Island.

**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 2020). Currently, within the **approximate** 22,755 ft of shoreline considered, there is a net gain of +2,479,500 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 -7,703,300 cy. It is important to note that the chronology of sand volumes presented by this Table reflects the *actual volumes* of sand *measured in-place* by survey and therefore is not related to projections based upon *estimated* volumes dredged in the channel or borrow site, *estimated* sand volumes placed, contractual “net pay” volumes, etc.



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



**Figure 3.7:** Volume change along the Bald Head Island shoreline between November 2000 and May 2020.

**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 <sup>1</sup>	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) <sup>2</sup>	Apr. 2004	Apr. 2005	12	-11,800	+94,700	+631,200	+714,100
Year 5 (2006 WB Project) <sup>3</sup>	Apr. 2005	Apr. 2006	12	+32,000	+13,300	-270,200	-224,900
Year 6 (2007 Project) <sup>4</sup>	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) <sup>5</sup>	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) <sup>6</sup>	May 2011	May 2012	12	+20,800	-154,600	-273,300	-407,100
Year 12 (2013 Disposal) Project) <sup>7</sup>	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) <sup>8</sup>	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	April 2016	May 2017	13	+25,500	-79,000	-619,000	-672,500
Year 17	May 2017	May 2018	12	+23,200	-84,600	-270,500	-331,900
Year 18 (2018/19 Beach Fill) <sup>10</sup>	May 2018	May 2019	12	+29,000	+42,200	+619,500	+690,700
Year 19	May 2019	May 2020	12	+1,200	+42,200	-555,900	-512,500
Pre-2000 Construction to Year 19	Nov. 2000	May 2020	234	+307,100	+110,000	+2,062,400	+2,479,500
Pre-2000 Construction to Year 19 (10,182,800 CY of Fill Removed)	Nov. 2000	May 2020	234	NA	NA	NA	-7,703,300

<sup>1</sup> 2001 Initial Disposal (1,849,500± CY); <sup>2</sup> 2005 Beach Disposal (1,217,000± CY); <sup>3</sup> 2006 West Beach Fill (47,800± CY)<sup>4</sup> 2007 Beach Disposal (978,500± CY); <sup>5</sup> 2009/10 Beach Fill (1,850,000± CY); <sup>6</sup> 2012 Beach Fill (138,000 ± CY)<sup>7</sup> 2013 Beach Disposal Fill (1,658,000 ± CY); <sup>8</sup> 2015 Beach Disposal Fill (1,320,000 ± CY);<sup>9</sup> 2016/17 Beach Disposal (24,000± CY); <sup>10</sup> 2018/19 Beach Fill (1,100,000± CY)

The estimated *average* annual loss of sand from the monitored section of Bald Head Island shorefront (excluding East Beach and Row Boat Row) since November 2000, is approximately 394,800 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 – such as Hurricanes Florence and Dorian.

### **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), June 2017 (19 months post-construction), May 2018 (30 months post-construction), September 2018 (post-Florence), May 2019 (post-fill), November 2019 (post-Dorian) and May 2020. The selected surveys are plotted in **Figure 3.8**. The purpose of the surveys is to be able to intercompare and assess both updrift fillet conditions and the location of the downdrift shoreline fronting the Cape Fear River. Through May 202-, terminal groin project performance – based upon monitoring – has been both as intended and as predicted.





**Figure 3.8:**  
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 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 has historically been 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 in 2000 and episodic channel maintenance required to ensure navigability.

**Appendix E** includes a high resolution visual chronology of the Point from 1998 to May 2020. Demarcated on each photo panel are the approximate September 2001 (blue line) and May 2020 (red line) apparent vegetation lines. Also placed on each photo are two reference marks (green dots). The variation in spit configuration from the before navigation improvement project photos (1998 and 1999) throughout the last approximate eighteen 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 2020 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 – prior to terminal groin construction in 2015.

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 had “rolled back,” the annualized rate of littoral transport at that location had 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 could not be reliably established through sand placement alone. That project was constructed during the summer of 2015. Subsequently, monitoring reports now document a “new dynamic” predicted to result from the implementation of the terminal groin structure. Analytical predictions of shoreline change to both the updrift and downdrift shorelines abutting



the structure – via DELFT 3D modeling – were discussed in a detailed report formulated for purposes of both design and permitting of the terminal groin (Olsen 2013a). Additional monitoring data required by Permit are intended to 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 May 2019 to May 2020 monitoring period, the inlet facing shoreline adjacent to the terminal groin continues to realign (as predicted) and adjust to a new equilibrium condition. An intertidal spit formation continues to form 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 3.8**. The configuration of the sand fillet updrift of the terminal groin continues to be influenced by the sand tube groin field as fill berms recede and the formerly buried groins become “activated”.

### 3.4 East Beach Shoreline Conditions

In November 2008, East Beach was added to the island-wide beach monitoring program<sup>10</sup>. 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 2.1**). 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 May 2019 to November 2019 to May 2020 monitoring periods. **Figure 3.9** depicts the April 2019, November 2019 and May 2020 aerial photographs along southern East Beach.

During the May 2019 to November 2019 period, the East Beach shoreline gained approximately +13,200 cy (+2.2 cy/ft) above the MHWL and lost -10,700 cy (-1.8 cy/ft) below the MHWL for a net total change above -16 ft-NGVD of +2,500 cy (+0.4 cy/ft). During this same period the backshore berm (at elevation +6 ft-NGVD) advanced by a spatially weighted average<sup>11</sup> of +33.0 ft while the MHWL receded by an average of -15.4 ft. However, the average advance at the berm is *heavily influenced* by the advancement at the southernmost stations, STA 224+80 and STA 234+80, located immediately north of Cape Fear. At these stations, the berm advanced by +148.3 ft (STA 224+80) and +103.3 ft (STA 234+80), respectively.

During the November 2019 to May 2020 winter period, the East Beach shoreline lost approximately -25,700 cy (-4.3 cy/ft) above the MHWL and -65,400 cy (-10.9 cy/ft) below the MHWL for a net total change above -16 ft-NGVD of -91,100 cy (-15.2 cy/ft). During this same period the berm retreated by a spatially weighted average of -38.3 ft while the MHWL receded by an average of -61.8 ft. However, the average retreat at both the berm and MHWL is *heavily influenced* by the large retreat at the two southernmost station, STA 224+80 and STA 234.80, located immediately north of Cape Fear. After removing these stations from the weighted average, the +6 ft berm advanced by an average of +13.3 ft and the MHWL receded by -11.3 ft.

**Table 3.10** summarizes the volume changes measured over the entire period of survey record (November 2008 – May 2020). Over the 139 month period, the East Beach shoreline gained approximately +84,300 cy above the MHWL and +350,500 cy above the -16 ft-NGVD contour. Likewise, the backshore berm and MHWL advanced by weighted averages of +29.3 ft and +30.9 ft, respectively over this period.

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<sup>10</sup> Profiles were not acquired at East Beach in the fall of 2009

<sup>11</sup> 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 3.7:** East Beach shoreline and volume changes between May 2019 and November 2019.

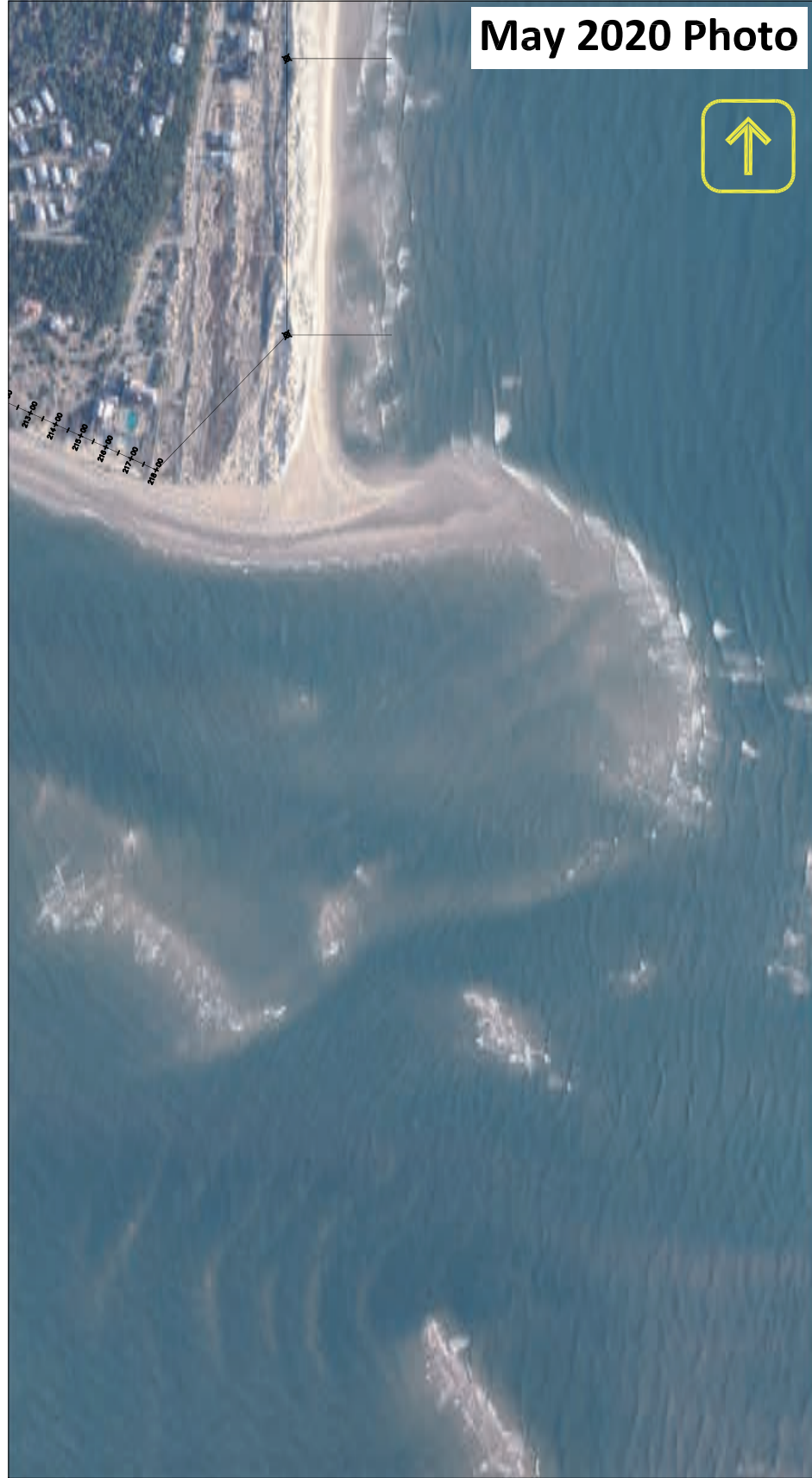
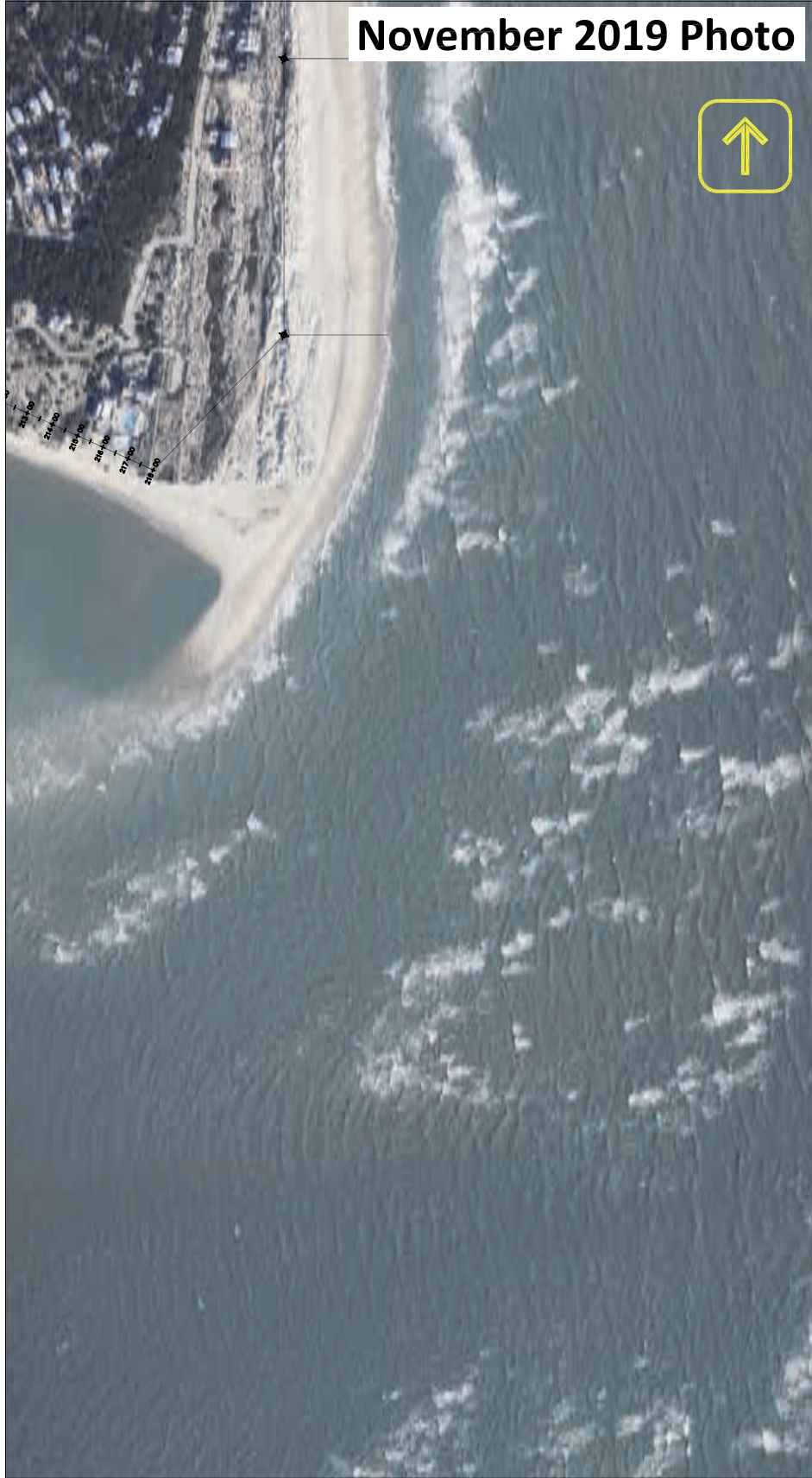
Station	Reach (FT)	Volume Change (CY)			Shoreline Change (FT)	
		Above MHWL (+2.51 FT)	Above -16 FT		Berm (+6 FT)	MHWL (+2.51 FT)
224+80					+148.3	-148.7
	1,000	-3,500	-30,900			
234+80					+103.3	-14.0
	1,000	+6,300	+4,900			
244+80					+25.2	+18.3
	1,000	+3,000	-2,300			
254+80					-34.6	-8.2
	1,000	+3,000	+3,900			
264+80					+18.0	+48.7
	1,000	+4,000	+18,100			
274+80					-12.7	+8.6
	1,000	+400	+8,800			
284+80					-16.5	-12.2
<b>Total</b>	<b>6,000</b>	<b>+13,200</b>	<b>+2,500</b>		<b>+33.0 (AVG)</b>	<b>-15.4 (AVG)</b>

**Table 3.8:** East Beach shoreline and volume changes between November 2019 and May 2020.

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					-224.0	-251.2
	1,000	-24,900	-112,700			
234+80					-110.3	-125.3
	1,000	-4,100	-11,200			
244+80					+14.4	-14.6
	1,000	+1,600	+27,300			
254+80					+23.0	-7.0
	1,000	+1,500	+20,100			
264+80					+18.3	-18.6
	1,000	-500	-6,300			
274+80					-2.4	-12.8
	1,000	+700	-8,300			
284+80					+13.0	-3.3
<b>Total</b>	<b>6,000</b>	<b>-25,700</b>	<b>-91,100</b>		<b>-38.3 (AVG)</b>	<b>-61.8 (AVG)</b>

**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 April 2016	+20,800	-400	+20,400
April 2016 to May 2017	+4,500	+38,200	+42,700
May 2017 to May 2018	+31,400	+25,000	+56,400
May 2018 to May 2019	+9,600	+140,300	+149,900
May 2019 to May 2020	-12,500	-76,100	-88,600
<b>November 2008 to May 2020</b>	<b>+84,300</b>	<b>+266,200</b>	<b>+350,500</b>



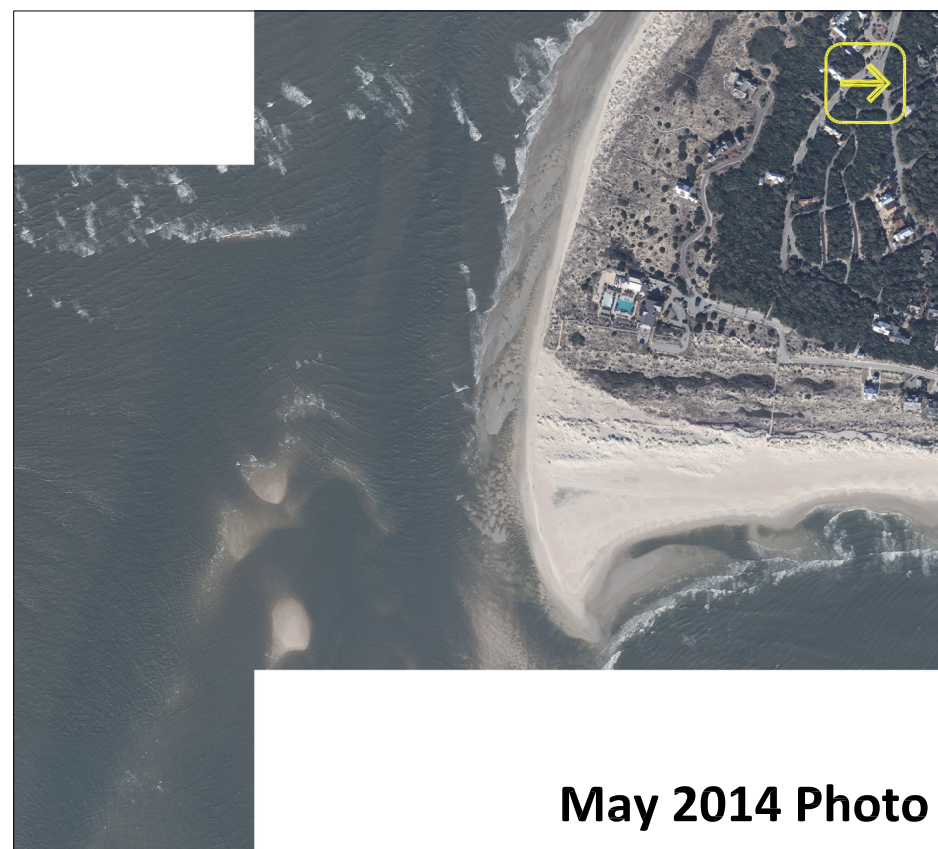
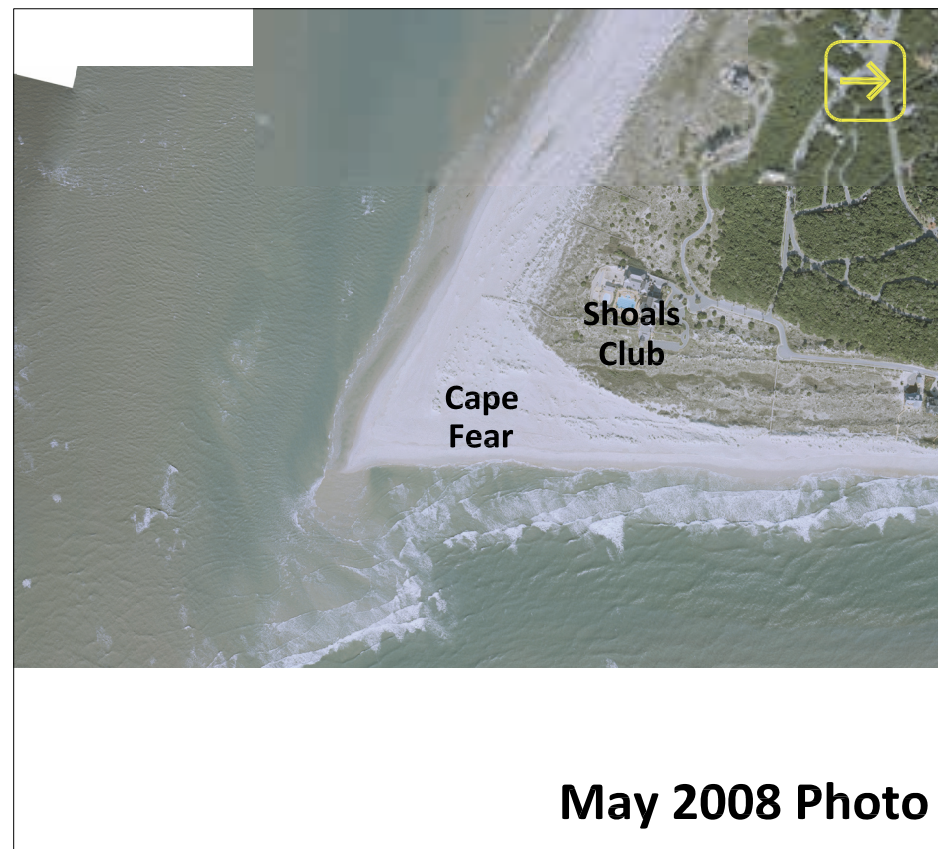
**Figure 3.9:**  
Cape Fear aerial photography  
Bald Head Island, NC



As demonstrated by the survey and photographic data (**Figure 3.9**), 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 12 years (2008-2020) which are depicted by **Figure 3.10**. 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 highly 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).

Although the near-term locations of the Cape Fear spit have 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 2020 shoreline conditions are visually shown by **Figure B-9** (Appendix B – May 2020 Aerial Photography – page B-10). Since November 2000, the MHWL at profile B-54 has receded by -265 ft, or about -14 ft/yr. More recently however, between November 2014 and May 2020, the MHWL at B-54 had receded by about -208 ft which equates to a rate of -38 ft/yr. At B-55, over the same period of time, the MHWL has receded -130 ft, or about -24 ft/yr.





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



### 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 2.1**). 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 May 2019 to November 2019 to May 2020 monitoring period (12 months).

In early 2017, after completion of a 26,000 cy beach fill placed by Marcol Dredging along the Row Boat Row shoreline, two detached rock breakwaters were constructed by Intra Coastal Marine Construction. Final acceptance of the project occurred in July 2017. Subsequently, the shorefront within the influence of the two shore parallel structures has equilibrated into a series of discrete crenulate features between tombolos which extend from the center of each breakwater in a landward direction (**Figure 3.11**).

During the monitoring year (May 2019 to May 2020), the shoreline showed net losses of roughly -1,700 cy (-1.1 cy/ft) above the MHWL and -2,900 cy (-1.8 cy/ft) above -16 ft-NGVD. During this period the berm advanced by an average of +9.1 ft while the MHWL receded by an average of 8.0 ft.



**Figure 3.11:** Northward looking view of the Row-Boat-Row shoreline detached breakwaters. (May 2020 Photo)

**Table 3.10:** Row Boat Row shoreline and volume changes between May 2019 and November 2019.

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				+35.3	-19.4
	400	-1,300	-4,000		
-014+72				-3.4	-11.1
	272	-900	-2,500		
-012+00				-10.2	-18.8
	400	+700	+2,200		
-008+00				+63.2	+68.6
	400	+2,500	+6,200		
-004+00				+34.4	+33.3
	100	+600	+1,000		
Marina					
<b>Total</b>	<b>1,572</b>	<b>+1,600</b>	<b>+2,900</b>	<b>+23.8 (AVG)</b>	<b>+10.5 (AVG)</b>

**Table 3.11:** Row Boat Row shoreline and volume changes between November 2019 and May 2020.

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	-1,000	-1,400	-27.5	-40.7
-014+72					
	272	-600	-700	-8.6	-6.7
-012+00					
	400	-1,000	-1,500	-12.1	-11.7
-008+00					
	400	-600	-1,700	-15.3	-15.9
-004+00					
	100	-100	-500	-9.9	-17.6
Marina					
<b>Total</b>	<b>1,572</b>	<b>-3,300</b>	<b>-5,800</b>	<b>-14.7 (AVG)</b>	<b>-18.5 (AVG)</b>

**Note** – Volumes of sand associates with multiple sand bypass operations since 2017 have not been accounted for in these tables.

## 4.0 JAY BIRD SHOALS BORROW SITE MONITORING (SURVEY) RESULTS

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Pursuant to permit requirements for the 2009/10 project, the Jay Bird Shoal borrow site has been surveyed for purposes of monitoring its recovery. Approximately 1.8 Mcy of material was excavated during the 2009/10 project and 1.1 Mcy during the 2018/19 project.

**Figure 4.1** depicts the most recent borrow site (May 2020) seabed elevations. This plot represents the approximate 1 year post-2018/19 project and 10 year post-2009/10 project conditions. In the plot, the full permitted borrow area limits are shown. The permitted limits are further subdivided into three subareas. For the 2009/10 project, only portions of Area 1 and Area 3 were excavated. For the 2018/19 project, only portions of Area 2 and Area 3 were excavated. Also plotted in the figure are the locations of two dredging exclusion zones<sup>12</sup> (both located in Area 3) and a 200 ft tide gage buffer zone (Area 1 & 2). No excavation was conducted within either the exclusion or buffer zones during the 2009/10 and 2018/19 projects.

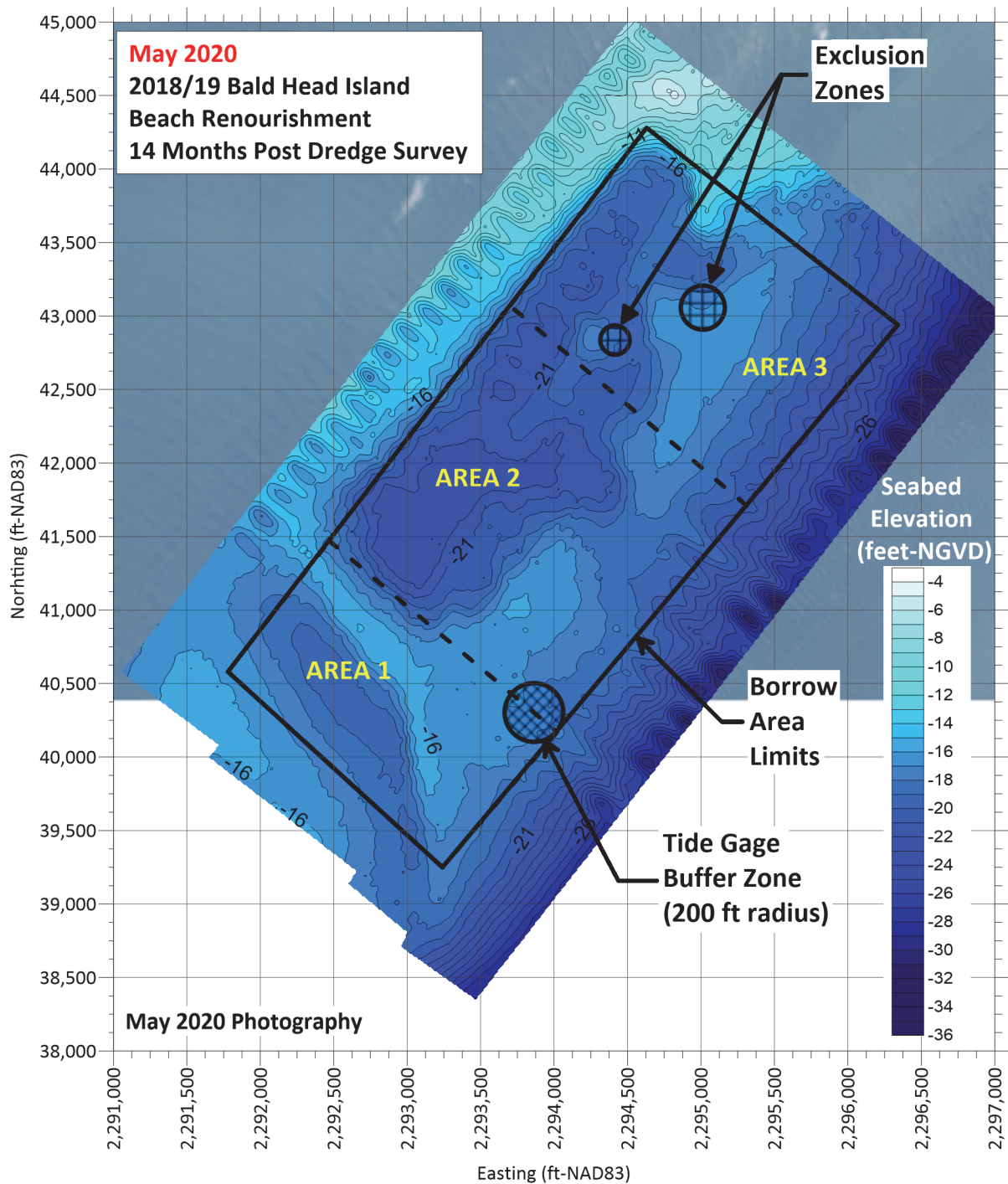
**Figure 4.2** depicts the seabed elevations since completion of the 18/19 project construction (March 2019 to May 2020, AD/One-Year Post-Construction). **Figure 4.3** depicts the seabed elevation changes during the 10 years (122 months) since 09/10 project construction to the most recent survey (March 2010 to May 2020).

**Table 4.1** summarizes the volume changes within the permitted borrow site limits between the monitoring surveys conducted to date. During the Year 10 monitoring period (March 2019 to May 2020), the first year following the 2018/19 project excavation, the entire permitted borrow site gained +133,600 cy (inclusive of the exclusion and buffer zones). Within just the excavated areas (Areas 2 & 3), the borrow site gained +150,300 cy. Within just theses areas, the average seabed elevation increased from -19.7 ft-NGVD to -19.2 ft-NGVD over this period.

**Table 4.2** summarizes the volume of material theoretically remaining above the permitted cut elevation (-22 ft-NGVD) by survey date and subarea. These volumes are exclusive of the exclusion and buffer zones shown in **Figure 4.1**. As of May 2020, there is approximately +1,150,500 cy of material available within the permitted borrow site limits.

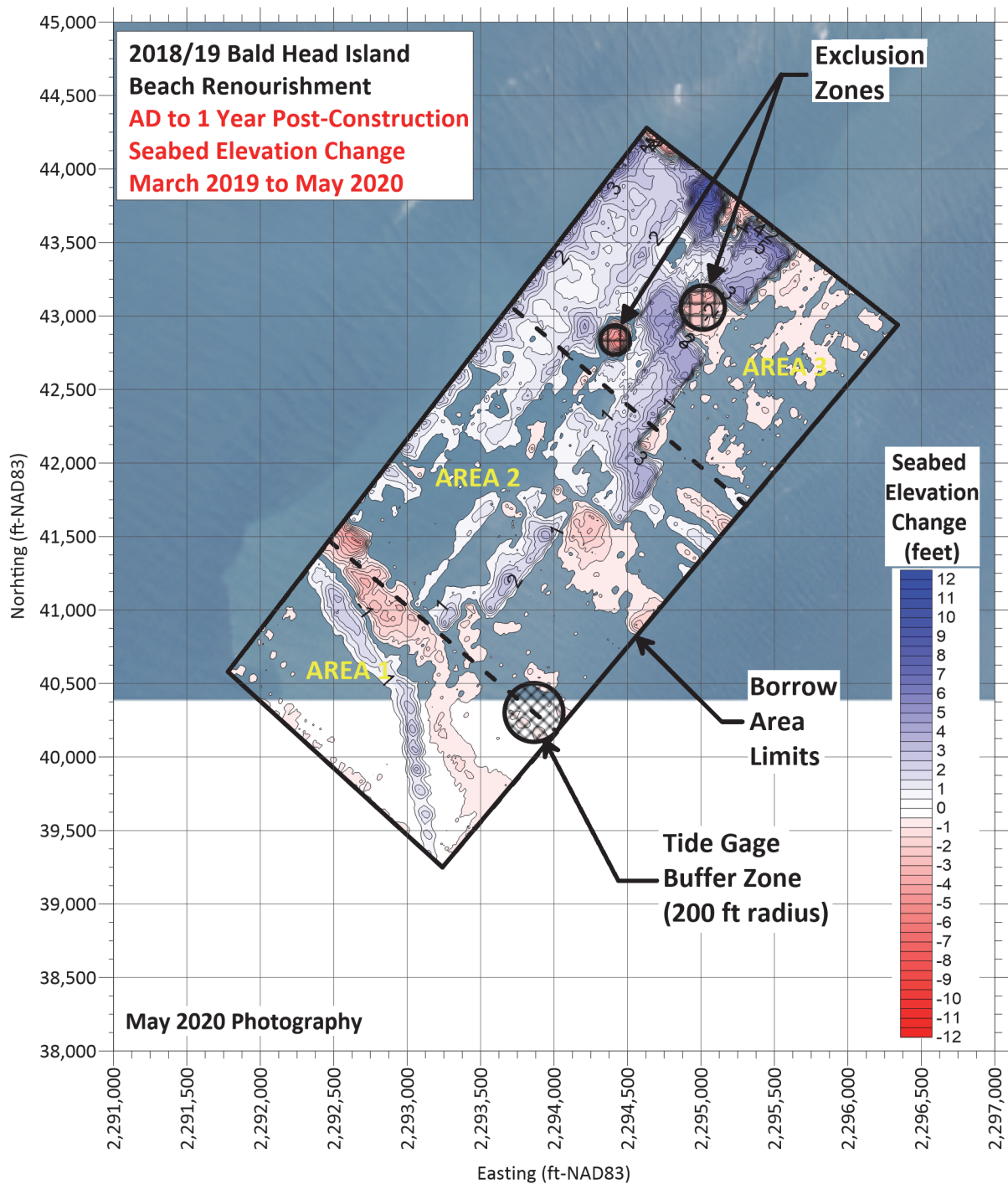
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<sup>12</sup> By permit, no work was allowed within 150 feet and 100 feet of two potential shipwreck sites located within the Jay Bird Shoals borrow site..

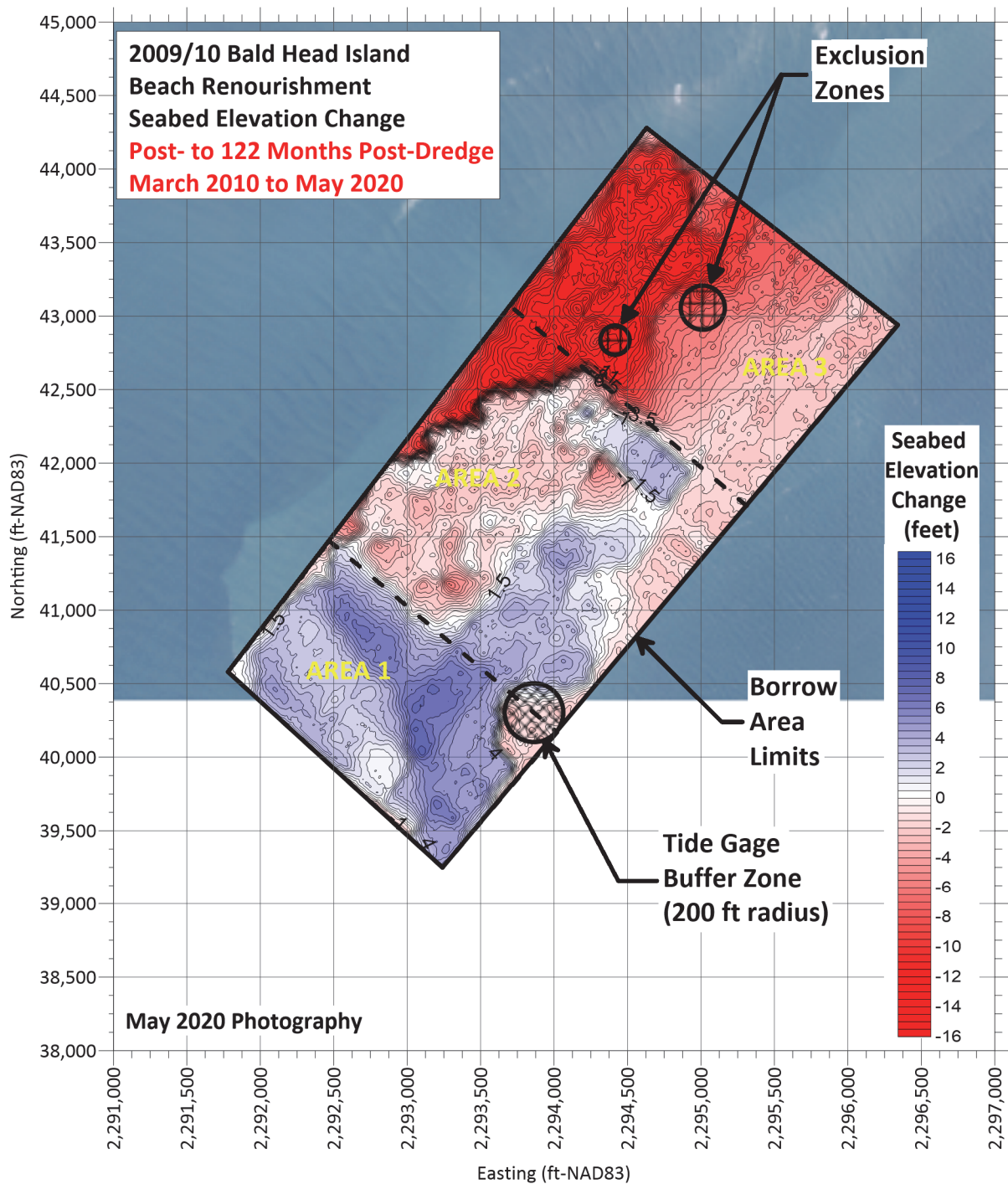


**Figure 4.1:** Jay Bird Shoals borrow site conditions in May 2020 (14 months post-dredge 2018/19 project).





**Figure 4.2:** Jay Bird Shoals seabed elevation changes during the first 14 months post-dredge 2018/19 project (March 2019 to May 2020).



**Figure 4.3:** Jay Bird Shoals seabed elevation changes since the initial 2009/10 project completion (March 2010 to May 2020).

**Table 4.1:** Jay Bird Shoals borrow site volume changes (*PERMITTED LIMITS*).

Survey Period	Duration	Volume Change (CY)		
		Gross Gain	Gross Loss	Net Change
October 2009 to March 2010 (Construction)	5 months	+52,700	-1,888,400	-1,835,700
March 2010 to May 2011 (Year 1 Post-Construction)	14 months	+307,200	-104,800	+202,400
May 2011 to May 2012 (Year 2 Post-Construction)	12 months	+112,700	-107,200	+5,500
May 2012 to May 2013 (Year 3 Post-Construction)	12 months	+178,700	-77,600	+101,100
May 2013 to April 2015 (Years 4 & 5 Post-Construction)	23 months	+286,000	-217,100	+68,900
April 2015 to May 2017 (Years 6 & 7 Post-Construction)	25 months	+144,900	-328,500	-183,600
May 2017 to May 2018 (Year 8 Post-Construction)	12 months	+136,800	-71,400	+64,400
May 2018 to September 2018	4 months	+24,400	-246,300	-221,900
September 2018 to December 2018	3 months	+188,700	-5,400	+183,300
December 2018 to March 2019 (BD/AD 18/19 Project)	3 months	+63,700	-1,229,300	-1,165,600
March 2019 to May 2020	14 months	+239,200	-105,600	+133,600
<b>Since 2009/10 Construction (March 2010 to May 2020)</b>	122 months	+1,682,300	-2,493,200	-810,900
<b>Since 2018/19 Construction (March 2019 to May 2020)</b>	14 months	+239,200	-105,600	+133,600



**Table 4.2:** Jay Bird Shoals borrow site theoretical volume available above -22 ft-NGVD.

Survey	Volume above -24 ft-NGVD (CY)			
	Area 1	Area 2	Area 3	Total
October 2009 (Pre-2009/10 Excavation)	812,200	1,593,100	1,330,000	<b>3,735,300</b>
March 2010 (Post-2009/10 Excavation)	89,100	540,900	1,291,600	<b>1,921,600</b>
May 2011 (1 Year Post-2009/10)	157,900	685,600	1,275,500	<b>2,119,000</b>
May 2012 (2 Years Post-2009/10)	154,900	734,400	1,237,900	<b>2,127,200</b>
May 2013 (3 Years Post-2009/10)	186,300	844,000	1,200,200	<b>2,230,500</b>
April 2015 (5 Years Post-2009/10)	232,300	992,800	1,081,500	<b>2,306,600</b>
May 2017 (7 Years Post-2009/10)	289,300	942,100	898,800	<b>2,130,200</b>
November 2017 (7.5 Years Post-2009/10)	297,400	969,600	923,000	<b>2,190,000</b>
May 2018 (8 Years Post-2009/10)	315,200	966,400	912,800	<b>2,194,400</b>
September 2018 (8.5 Years Post-2009/10)	318,600	862,600	800,000	<b>1,981,200</b>
December 2018 (Pre-2018/19 Excavation)	355,000	945,200	858,900	<b>2,159,100</b>
March 2019 (Post-2018/19 Excavation)	398,700	332,900	286,200	<b>1,017,800</b>
May 2020 (1 Year Post-2018/19)	383,000	356,600	410,900	<b>1,150,500</b>

**Notes:**

- (1) The red shaded areas for the pre-/post 2009/10 and 2018/19 surveys are the areas excavated during those projects.
- (2) Material in thin layers is not accessible to an ocean certified dredge.

## **5.0 ONGOING PLANNED OR PROPOSED ACTIVITIES**

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### **5.1 Development of a Frying Pan Shoals Borrow Site**

In early 2017, the Village submitted permit applications with associated in-depth geotechnical studies and environmental analyses necessary to develop a long-term (and large scale) borrow site located within Frying Pan Shoals. The purpose of such a borrow site was to ensure compliance with Permit conditions necessitating the maintenance of the updrift fillet associated with the 2015 terminal groin project and to allow for large-scale beach renourishment of South Beach. Historically, sand placement from an alternate site has been required due to the scheduled hiatus in the disposal of channel maintenance sand on Bald Head Island by the Wilmington District, USACOE. To that end, pursuant to the exiting tenets of the Wilmington Sand Management Plan, all beach quality channel maintenance material excavated in the summer of 2018 was placed at Oak Island.

In June 2017, the National Marine Fisheries Service (NMFS) issued concerns related to permits associated with the near-term use of the Frying Pan Shoals (FPS) borrow site *without first exploring and exhausting other viable sand source alternatives*. Realistically, the only alternate borrow area available for near-term sand placement at Bald Head Island (BHI) was sand remaining in the previously permitted Jay Bird Shoals (JBS) borrow site. Accordingly, in consideration of the NMFS request, the Village agreed to withdraw their application and prioritize the use of the previously authorized borrow site permitted at JBS (including both a partially “recovered” area dredged in 2009/10 and the remaining undredged portion of the borrow site). With the virtual depletion the Jay Bird Shoals borrow site, resulting from the 2018/19 renourishment project, the Village has reinitiated the permitting of a long-term borrow site located within Frying Pan Shoals in 2019. At the request of the Wilmington District, USACOE, Regulatory Branch, the permit request has been submitted as a modification of the 2015 Terminal Groin permit. As of July 2020, the permit application is in the RAI stage.

### **5.2 Wilmington Harbor Navigation Project**

In early 2021, the Wilmington District, USACOE is scheduled to perform a routine maintenance operation for the Smith Island Range as well as Bald Head Reaches 1 and 2. All beach compatible material excavated is to be placed on South Beach, Bald Head Island. The tentative volume to be dredged is about 1 Mcy, mol., depending upon the rate of shoaling experienced over the 6 months. At the time of disposal, the sand tube groin field will again be buried below the beach disposal project berm.

### **5.3 Wilmington Harbor Deepening Project**

In 2019, the Port of Wilmington, NC both sponsored and formulated a Section 203 Report which proposes a plan to deepen and widen (in places), the Federal navigation project, which extends from the Atlantic Ocean up the Cape Fear River to the Port of Wilmington. The Village of Bald Head Island has formally submitted comments to the record which address deficiencies in the project analyses and which requests clarification to impacts addressed or unaddressed by the consultant prepared report.

## 6.0 SUMMARY AND CONCLUSIONS

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The most recent Wilmington Harbor Inner Ocean Bar maintenance dredging of Bald Head The most recent Wilmington Harbor Inner Ocean Bar maintenance dredging of Bald Head Shoal Channel Reach 2, and the Smith Island Channel segment was initiated in the summer months of May/June 2018. Approximately 1.15 Mcy of sand excavated during that operation were placed at Oak Island pursuant to the terms of the Wilmington Harbor Sand Management Plan (WHSMP). Subsequent to federal beach disposal on Oak Island, Bald Head Island will be the recipient of the next two *future* beach disposal operations in accordance with the continued implementation of a present day WHSMP. Prior to that time (with the next Bald Head Island disposal not scheduled until the spring of 2021) the need to offset annual erosional losses at South Beach on Bald Head Island, as well as to maintain the updrift fillet of the terminal groin constructed in 2015, necessitated that the Village design and permit a 1 Mcy *interim* beach fill project. The latter was constructed between 13 January 2019 and 22 March 2019. The project borrow site was Jay Bird Shoals. The final fill volume was 1.1 Mcy due to the addition of a Post-Florence FEMA Claim for documented storm related losses from the *engineered beach* in September 2018 (Olsen 2018).

As part of the assessment for the 2019 beach renourishment project to be constructed at South Beach by the Village, it was determined that numerous sand tube groins had reached the end of their effective life and that replacement was warranted. Permits allowed for both an extension of time beyond April 1<sup>st</sup> for *both removal and replacement* of all remaining thirteen (13) sand tube groins (and underlayments). The work was initiated on/about 13 February and Substantially Completed by 22 March 2019. A *Post-Construction Report*, formulated to document the 2018-2019 project, details all elements of work performed by both contractors (Olsen 2019).

By about 2013, the results of a comprehensive annual beach monitoring program initiated in 2000 by the Village of Bald Head Island yielded the conclusion that sand placement alone could *not* successfully offset navigation channel impacts to the west end of South Beach which have been typically manifest in chronic rates of erosion and a consistent northerly recession of the shorefront. Accordingly, 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 the persistent South Beach erosional “hot spot”. The project was permitted to be constructed in two phases – with Phase 2 being optional. Simplistically, the structure was designed 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 however as a “leaky” structure (*i.e.* semi-permeable) so as to provide for some level of continued sand transport to West Beach and portions of the Point (located both westward

and northward of the groin stem). Through May 2020, terminal groin project performance – based upon monitoring – has been both as intended – and as predicted.

Between November 2000 and April 2020, 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. Including 2019, the Village has placed another 3.2Mcy along the West Beach and South Beach shorelines. Accordingly, in the net Bald Head Island has experienced a total estimated sand placement volume of approximately 10.2 Mcy since 2000 at those two locations – with South Beach receiving some 90% or more of the total.

Conversely, the *gross* volumetric sediment *loss* over the November 2000 to May 2020 (post-fill) monitoring timeframe is conservatively computed at -7.703 Mcy, or approximately -394,800 cy per year – on “average”. This “loss” addresses the continuous section of Bald Head Island shorefront extending from the marina entrance to the Cape Fear spit. 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 Hurricanes Florence and Dorian), the occurrence of episodic destabilization 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. In addition, the island’s littoral system continues to adjust to the quasi-stabilizing effect of the terminal groin in existence only since 2015. Along South Beach per se, there has been historically a “nodal point” some 7,000 ft. eastward of the terminal groin (approx. STA 116+00). At or close to the nodal point, the directionality of *net littoral transport* on an annual basis changes from West (toward the groin) to East (toward Cape Fear). *Note* – depending on wave climatology, the condition and exposure of the sand tube groinfield, as well as other factors, the effective location of the nodal point can vary slightly along South Beach from year to year. Currently, within the 22,755 shoreline influenced by sand placed since 2000, some 2.992 Mcy remain in the littoral system (measured above elevation -16 ft. NGVD 29). This includes the 1.1 Mcy beach fill recently constructed in early 2019.

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. Since that time, it is observed that East Beach can undergo 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. For example, the most recent May 2020 survey data show a net shoreline loss of approximately -88,600 cy (above elevation -16 ft NGVD).

throughout the 6,000 ft East Beach shoreline lying northward of Cape Fear over the last 12 months. In the prior year, it had accreted by almost 150,000 cy – due to sand accumulation associated with the spit. Between November 2008 and May 2020, the total change has been +350,500 cy. Again, most of this volume has been associated with accretion of the Cape Fear spit facing Onslow Bay.

Typically, episodic 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 2020, the average MHWL erosion rate at this general location has been over -20 ft/yr – due to sand losses either directly or indirectly associated with Hurricane Dorian in 2019.

In 2020, the Village was required by Permit to again perform monitoring of the Jay Bird Shoals borrow site utilized to construct the non-federal 1.85 Mcy beach fill sponsored by the Village in 2009/10. The same borrow site was also used for the 1.10 Mcy beach constructed in 2018/19. During the Year 10 monitoring period (March 2019 to May 2020), the first year following the 2018/19 project excavation, the entire permitted borrow site gained +133,600 cy (inclusive of the exclusion and buffer zones). As of May 2020, there is approximately +1,150,500 cy of material available within the permitted borrow site limits above the permitted cut elevation (-22 ft-NGVD).

After an extension of the two marina entrance channel jetties in 2015, temporarily reduced shoaling within the navigation channel resulted in a corresponding reduced volume of disposal sand being placed along the Row Boat Row shoreline. Although the Village had planned to continue to proactively bypass sand from the south jetty fillet (at the distal end of West Beach) to the Row Boat Row shorefront, it became clear that the existing four (4) low level timber groins would not be capable of providing an acceptable level of shoreline stabilization at that location.

Hence, near the end of the 2017 monitoring period, the Village initiated construction of two (2) shore parallel detached rock breakwaters located north of the marina entrance seaward of the Row Boat Row shoreline. The placement of breakwaters between existing groins northward of the marina entrance was intended to 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 by ferry/barge generated waves. The subject expanded shore stabilization project (detached breakwaters *and* existing groinfield) was designed to have a sand fill prior to construction. The source of the fill was the exiting Bald Head Creek borrow area. A previously permitted Bald Head Creek borrow area was dredged in early 2017 by Marcol Dredging. Some 26,000 cy were placed at Row Boat Row prior to breakwater



implementation. Since that time several channel maintenance/sand bypass operations have occurred – most with increasing volume. This is primarily due to an increased rate of sediment transport along West Beach caused by a continuing reconfiguration of the Point. As a result, the Village has been forced to seek means of bypassing sand northward of the influence of the breakwaters. This has required a modification of the permits associated with maintenance dredging of the channel.

In the spring of 2019, the Village resubmitted permit applications accompanied by indepth geotechnical studies and environmental analyses necessary to develop a long term (and large scale) borrow site located within Frying Pan Shoals. The purpose of such a borrow site is to both ensure compliance with Permit conditions necessitating the maintenance of the updrift fillet associated with the 2015 terminal groin project and to provide a long-term source of beach quality material sufficient to meet future South Beach renourishment requirements. When pursuant to the existing tenets of the Wilmington Harbor Sand Management Plan, all beach quality channel maintenance material excavated is to be placed at Oak Island.

An important secondary precept of the spring of 2019 beach fill project constructed by the Village was to allow for the replacement of a sand tube groinfield which had become damaged over time. During the spring 2021 federal disposal project, the groin field in its entirety will again be covered by beach fill.

The original Permits for construction of the terminal groin at Bald Head Island stipulated that if the permittee elected to dredge more than 250,000 cy from the Jay Bird Shoals borrow site after 2015, limited monitoring of the eastern end of Oak Island must be performed. Accordingly, in November 2018, the Village initiated the requisite monitoring at Oak Island (Caswell Beach). The first report of findings for Oak Island followed a November 2019 monitoring survey. A second year of monitoring is on underway. It has been tacitly agreed that depending upon the results of the Year 2 report, the Village's responsibility for continued monitoring may end.

In 2019, the Port of Wilmington, NC both sponsored and formulated a Section 203 Report which proposes a plan to deepen and widen (in places), the Federal navigation project, which extends from the Atlantic Ocean up the Cape Fear River to the Port of Wilmington. The Village of Bald Head Island has formally submitted comments to the record which address deficiencies in the project analyses and which requests clarification to impacts addressed or unaddressed by the consultant prepared report.

## 7.0 REFERENCES

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NOAA (2020). “*National Hurricane Center Tropical Cyclone Report; Hurricane Dorian*”, National Oceanic and Atmospheric Administration. 74 pp (April 2020)

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. (2007a) “*Bald Head Island, N.C. Beach Restoration Project – Sand Search Investigation*”. Olsen Associates, Inc., 2618 Herschel St., Jacksonville, FL 32204. 40 pp plus app. (June 2007).

Olsen Associates, Inc. (2007b). “*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. 14 (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).

Olsen Associates, Inc. (2017). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 15 (April 2016 – May 2017)*”, 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. (2018a). “*Bald Head Island, N.C. Beach Monitoring Program Report No. 16 (May 2017 – May 2018)*”, Report prepared for Village of Bald Head Island. Olsen Associates, Inc. 2618 Herschel St., Jacksonville, FL 32204. 69 pp plus app. (July 2018).

Olsen Associates, Inc. (2018b). “Documentation for the Village of Bald Head Island, N.C., Engineered Beach Project”, Olsen Associates, Inc., 2618 Herschel St., Jacksonville, FL 32204. 18 pp plus app. (September 2018).

Olsen Associates, Inc. (2019). “Village of Bald Head Island; 2018-2019 Beach Renourishment Project: Post-Construction Report”, Olsen Associates, Inc., 2618 Herschel St., Jacksonville, FL 32204. 36 pp plus app. (April 2019).

Olsen Associates, Inc. (2019,b). “Bald Head Island, N.C.; Beach Monitoring Program Report No. 17 (May 2018 to May 2019)”, Report Prepared for Village of Bald Head Island. Olsen Associates, Inc., 2618 Herschel St., Jacksonville, FL 32204. 81 pp plus app. (July 2019).

Olsen Associates, Inc. (2019,c). “Terminal Groin Project – Inlet Management Plan – Oak Island Monitoring (November 2018 to November 2019)”, Report Prepared for Village of Bald Head Island. Olsen Associates, Inc., 2618 Herschel St., Jacksonville, FL 32204. 18 pp plus app. (December 2019).

Tidewater Atlantic Research, Inc. (2017). “A Remote Sensory Survey and Anomaly Assessment Investigation on Jay Bird Shoal off Smith Island Channel, Cape Fear River, Brunswick County, North Carolina”. Tidewater Atlantic Research, Inc., P.O. Box 2494, Washington, NC 27889. 22 pp plus app (30 November 2017).

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).