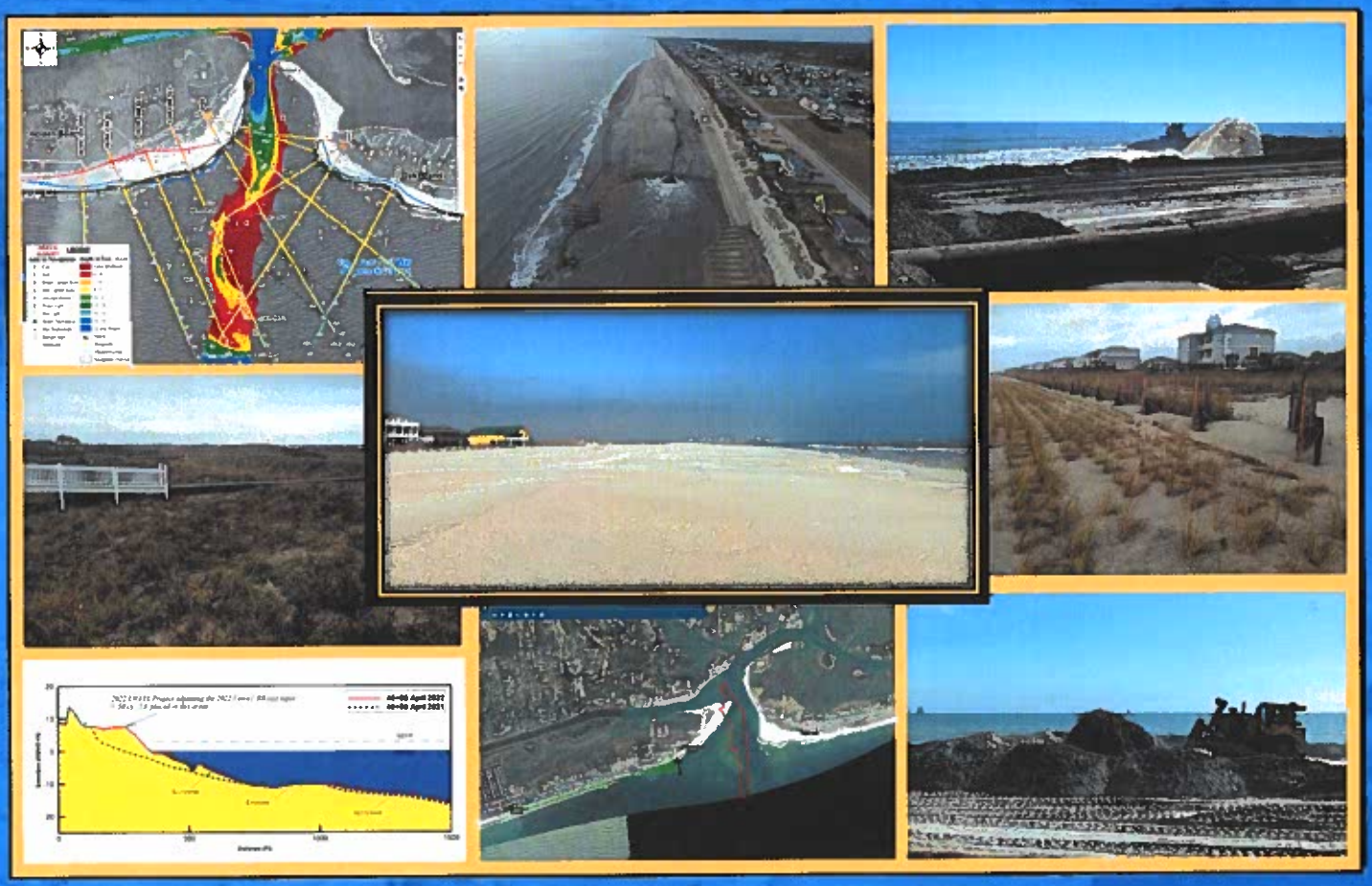
Holden Beach

Annual Beach Monitoring Report

Prepared For:
Town of Holden Beach, North Carolina



January 2023

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TABLE OF CONTENTS

1.0 INTRODUCTION

Holden Beach is a 9-mile-long barrier island located in Brunswick County, North Carolina (see Figure 1-1), where long-term and episodic storm erosion continually threatens the coastal habitats, recreational beach, tourism, and upland developments. Consequently, the Town of Holden Beach, referred to herein as the "Town," has undertaken a comprehensive beach management and maintenance program to protect and enhance its beach system. All nourishment and dune enhancement activities resulting from this program have proven valuable in providing a healthy beach system as well as a storm buffer to reduce losses to homeowners and to Town, State, and Federal infrastructure.

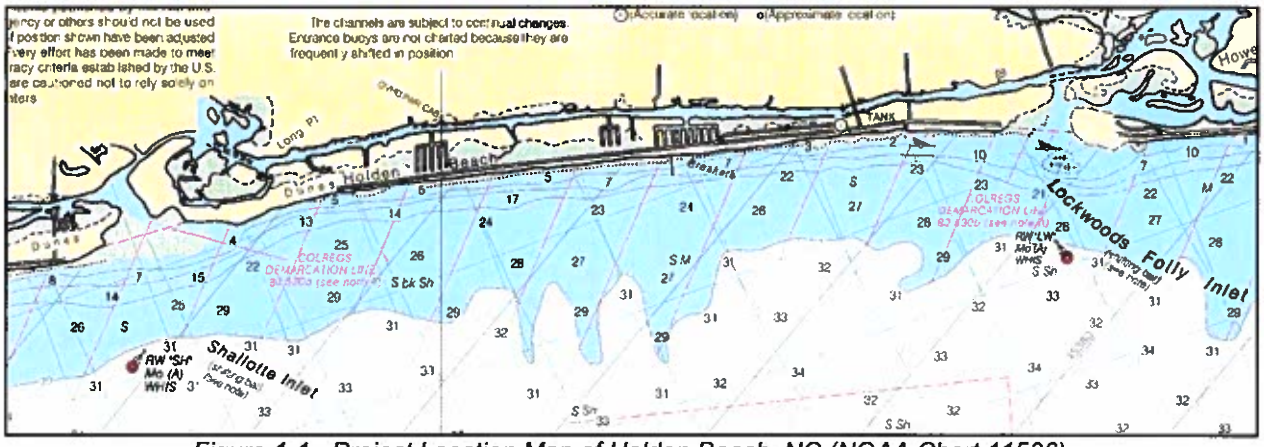

Figure 1-1. Project Location Map of Holden Beach, NC (NOAA Chart 11536)

The Town has been documenting nourishment and dune project performance and environmental effects through annual field surveys, analyses, and monitoring reports according to regulatory agency permit conditions, as well as to remain eligible for Federal Emergency Management Agency (FEMA) mitigation funding related to "engineered" beaches. Another objective is to identify erosional areas of shoreline that warrant future nourishment consideration.

This report summarizes the 2021 to 2022 beach management activities and compares the most recent annual survey (April 2022) with beach profile surveys collected from 2000 through 2021. Beach profile data is used to assess the status of the beach through an evaluation of volume and contour change and to establish rates of change with respect to nourishment projects and historical background erosion rates.

2.0 RECENT AND FUTURE PROJECTS

This section provides a brief project site history, beginning with the 2001/2002 U.S. Army Corps of Engineers (USACE) Wilmington Harbor Deepening nourishment project. Prior to this event, Town and USACE beach management efforts were sporadic and on smaller scales, with the first documented nourishment occurring in 1971. Beach scraping and dune repairs have been documented as far back as 1954, mitigating Hurricane Hazel impacts. Significant erosion and the loss of more than 30 houses on the eastern end of Holden Beach in the 1990s were major factors in establishing current beach management activities. Table 2-1 and Figure 2-1 summarize nourishment activities and locations since 2001.

Following the spring 2002 completion of the USACE Wilmington Harbor Deepening nourishment project, the Town conducted six beach nourishment projects using upland borrow sources. The most recent upland truck haul project occurred in spring 2009, when the Town placed 190,000 cubic yards (cy) of upland fill along approximately 10,000 linear feet (lf) of shoreline. In addition to upland fill beach nourishments, the Town has also taken a more active role in working with the USACE to maximize fill placement from dredging the Lockwood Folly (LWF) Inlet Atlantic Intracoastal Waterway (AIWW) crossing (LWFIX) and the "bend-widener" (which is discussed in Section 2.4.4).

In terms of "major" nourishment activity, the major nourishment activity of 2017 was the Town's Central Reach Project (CRP), which placed approximately 1.31 million cubic yards (mcy) along approximately 4.1 miles of shoreline from January to mid-March 2017. In addition to the 2017 CRP project, the Town also participated in the LWFIX Project that placed approximately 120,000 cy of material dredged from the LWFIX and the bend widener along about 2,400 lf of shoreline in 2017.

The most recent major nourishment activity was the Central Reach Reimbursement (CRR) Project completed this past winter/spring (2022). The CRR represents the largest beach fill project on Holden Beach to date, where the Town placed approximately 1.54 million cubic yards (MCY) of sand along the Central Reach from Station 40+00 to Station 260+00. Similar to the 2017 Central Reach Project, the 2022 CRR project took place in conjunction with a USACE LWIFX project which placed approximately 115,000 cy along ~2,000 lf of shoreline on the eastern end of the island.

The fill placements from these two 2022 nourishment projects are reflected in the 2022 survey (discussed in Section 3). Further details of these projects are provided in subsequent sections.

Table 2.1. Summary of Holden Beach Nourishment Projects since 2001

Date	Completed By	Beach Stations Nourished	Approx. Volume of Material Placed (cubic yards)	Nourishment Material Source
12/8/01 – 2/20/02	USACE	87+00 – 192+00	525,000	Wilmington Harbor Deepening Project
3/7/02 – 4/30/02	Town of Holden Beach Phase I	66+00 - 90+00, 175+00 – 217+00	141,700	Oyster Harbor upland site
3/02-4/02	USACE	20+00 – 30+00[1)]	32,000	Lockwood Folly Inlet crossing of AIWW
Winter 2002-2003	Town of Holden Beach	90+00 – 175+00	30,000	Boyd Street Disposal Area
9/16/04 – 11/2/04	USACE	15+00 – 40+00	113,230	Lockwood Folly Inlet crossing of AIWW
12/03 – 4/04	Town of Holden Beach	46+00 – 68+00 and 215+00 – 238+00	123,000	Smith borrow site
5/5/06 – 5/24/06	USACE	15+00 – 40+00	62,853	Lockwood Folly Inlet crossing of AIWW
Early 2006	Town of Holden Beach	Eastern Reach	42,000	Smith borrow site
Early 2006	Town of Holden Beach	Western Reach	3,200	Smith borrow site
1/24/08 – 3/28/08	Town of Holden Beach	60+00 – 95+00 and 245+00 – 270+00	201,000	Smith borrow site
2008/2009	USACE	20+00 – 40+00	100,000	Lockwood Folly Inlet crossing of AIWW
03/24/09 – 4/30/09	Town of Holden Beach	55+00 – 110+00 and 210+00 – 255+00	190,000	Smith borrow site
Spring 2010	USACE	20+00 – 55+00	140,000	Lockwood Folly Inlet crossing of AIWW
February 2011	USACE	20+00 – 40+00	32,000	Lockwood Folly Inlet crossing of AIWW
January 2012	USACE	20+00 – 30+00	25,000	Lockwood Folly Inlet crossing of AIWW
2/10/14 - 2/27/14	USACE	18+00 – 50+00	93,000	Lockwood Folly Inlet crossing of AIWW
2/27/14 - 3/15/14	Town of Holden Beach	50+00 –73+00	95,000	Lockwood Folly Inlet crossing of AIWW
9/4/15 - 9/15/15	Town of Holden Beach	Nearshore (60+00 - 90+00)	24,000	Lockwood Folly Outer Navigation Channel
1/3/17 – 3/17/17	Town of Holden Beach	45+00 – 257+00	1,310,000	Offshore borrow area
March 2017	Town / USACE	20+00 – 45+00	120,000	Lockwood Folly Inlet crossing of AIWW
Spring 2020	USACE	15+00 - 45+00	80,000	Lockwood Folly Inlet crossing of AIWW
1/7/22 – 4/14/22	Town of Holden Beach	40+00 – 260+00	1,540,000	Offshore borrow areas
March 2022	USACE	20+00 – 40+00	115,000	Lockwood Folly Inlet crossing of AIWW
		Approximate Total Volume since 2001	**5,137,983**	

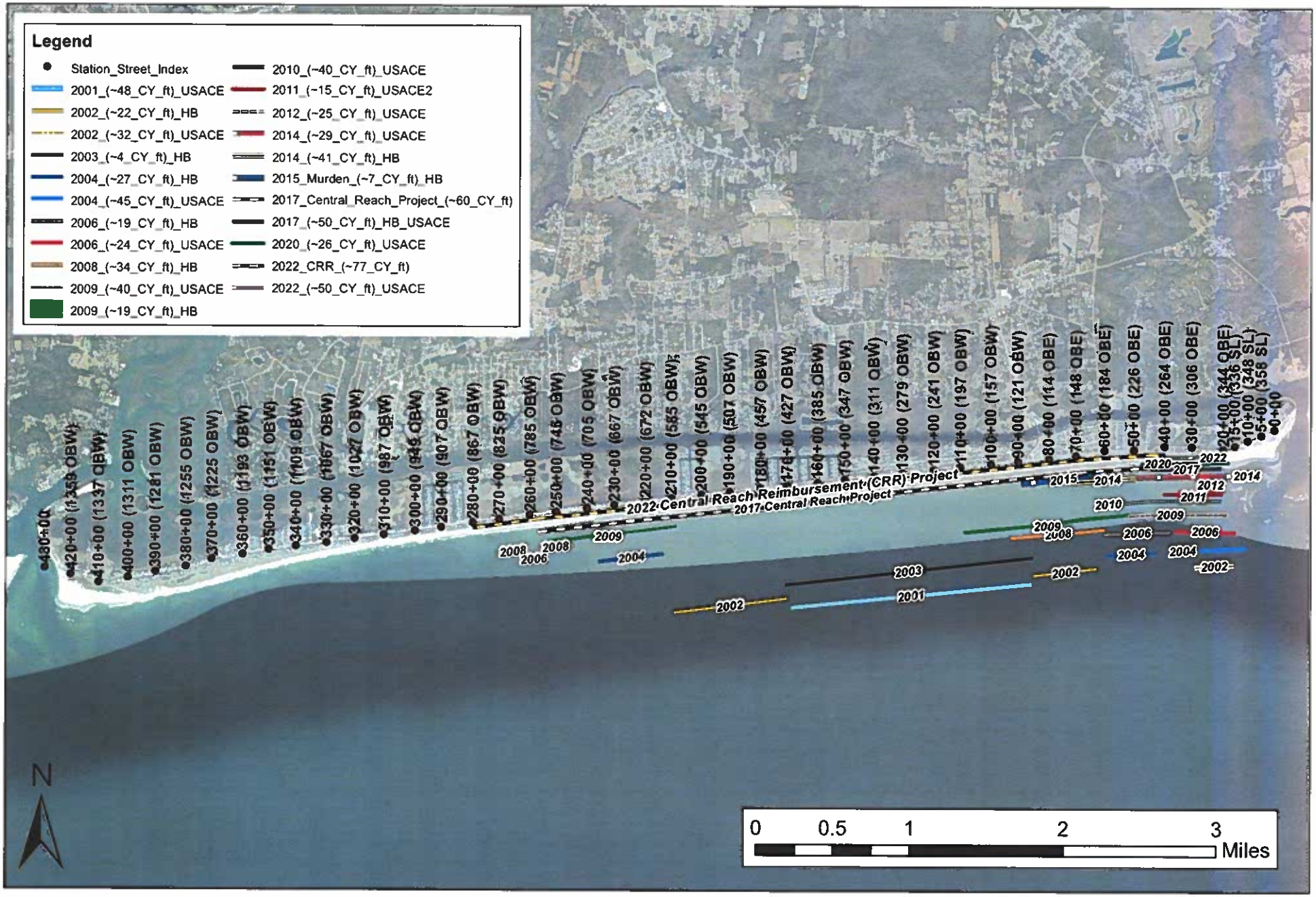

Figure 2-1
Holden Beach nourishments since 2001 and beach stationing for surveying.
Survey stations begin at LWF Inlet (0+00) and are generally at 1,000 foot intervals, ending at Shallotte Inlet (430+00).

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2.1 TOWN UPLAND FILL PROJECTS

The Town has a history of successful upland fill projects, with the most recent occurring in 2009, primarily as Hurricane Hanna mitigation. Approximately 115,000 cy was placed between Stations 55+00 and 110+00 [21 cubic yard per linear foot (cy/lf) average] along the Eastern Reach and 75,000 cy between Stations 210+00 and 255+00 (16.5 cy/lf average) along the Western Reach. Figure 2-2 illustrates the placed-fill footprint and the permitted footprint. Sand was obtained from the Smith upland borrow site.

Note that upland sand has been used in emergency dune rebuilding following Hurricane Hanna in 2008 and Hurricane Irene in 2011.

Figure 2-2. 2009 Constructed Project Reaches and 2009 Permitted Sand Placement (the permitted placement has been modified over the years)

While the last upland-sourced beach nourishment occurred over a decade ago, the use of upland borrow areas remains a feasible alternative for Holden Beach. Fill projects utilizing upland borrow areas can be extremely valuable for unplanned/emergency mitigation efforts, such as the responses to Hurricanes Hanna and Irene.

Additionally, truck haul projects do not involve the expensive mobilization/demobilization costs associated with offshore dredges and can occur much more quickly.

Potential negative aspects of upland borrow areas include variations in sand color, practical volume limitations, and placement methods (i.e., trucking). Additionally, the North Carolina

Department of Transportation (NCDOT) requires permitting and has the ability to shut down operations or require roadway mitigation.

The Town owns the Turkey Trap Road upland borrow site whereas other potential borrow area sites have been used in the past and may be available in the future. The Turkey Trap Road and other upland borrow sites (such as the Smith site shown in Figure 2-3) have been successfully permitted, which significantly enhances post-storm mitigation response time.

Figure 2-3. Smith Upland Borrow Area during 2009 Holden Beach Nourishment Project

2.2 TOWN 2017 CENTRAL REACH PROJECT (CRP)

The Town Central Reach Project (CRP) nourishment occurred in winter/spring 2017 and represents the second largest beach fill project to date on the island, now that the 2022 Central Reach Reimbursement (CRR) project has been completed. CRP construction began on January 3, 2017 and was completed on March 17, 2017 (74 days) by Weeks Marine using two hopper dredges, the R.N. Weeks and the B.E. Lindholm. The nourishment utilized an offshore borrow area and placed approximately 1.31 mcy along 4.1 miles (22,000 ft) of shoreline [Ocean Boulevard East (OBE) 240 to Ocean Boulevard West (OBW) 781].

Figure 2-4 presents the beach fill project footprint. On average, constructed berm widths were about 150 ft wide and fill placements were about 60 cy/lf (with a range typically varying between 50 and 70 cy/lf).

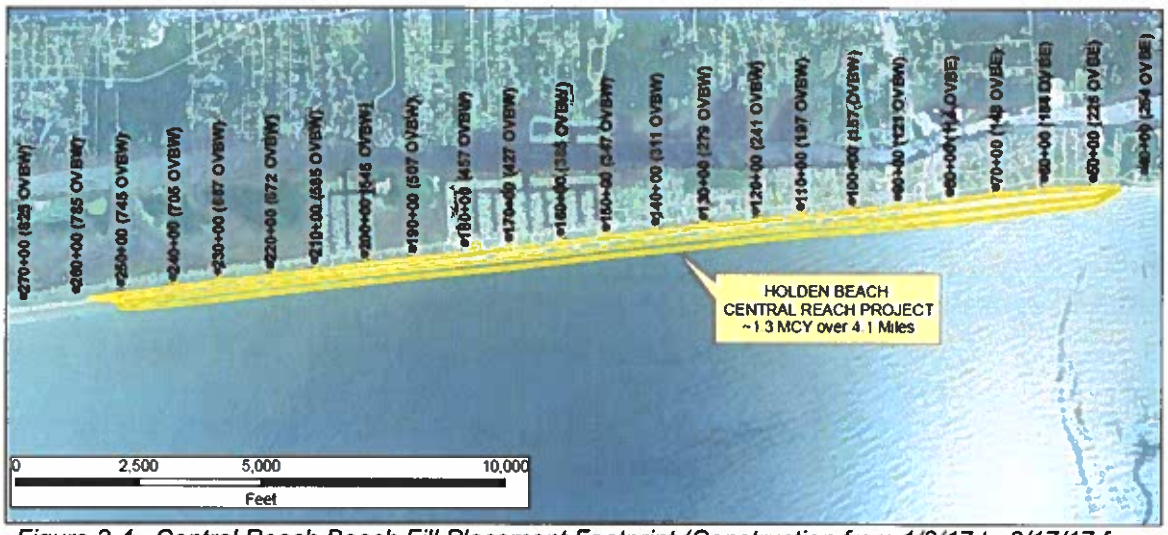


Figure 2-4. Central Reach Beach Fill Placement Footprint (Construction from 1/3/17 to 3/17/17 from Approximately Station 45+00 to Station 257+00)

The CRP utilized an offshore borrow area approximately 5 miles southeast of the Holden Beach project shoreline. Dredging was generally only 2 to 4 ft deep in most areas.

The offshore borrow area for the CRP was delineated based on the need for enough sand for at least 2 large nourishments. The borrow area was allocated into different zones for the dredgers to work, in order to conserve some zones for future projects. However, the dredger encountered some isolated pockets of incompatible material - generally rock or hard clay that damaged one of the dredge's drag arm cables (hoppers have debris screens on board that prevent most rocks from reaching the beach). Weeks coordinated closely with ATM and Town staff to ensure beach-compatible material was placed while leaving some areas for future projects.

Following the project, it was estimated that approximately 500,000 cy of material was still available for future nourishments. The 2002 USACE project placed about 525,000 cy of material, therefore, while there was enough sand in the borrow area for a large project, there was not enough for another CRP.

Additionally, due to the CRP borrow area location offshore (~2 to 3 miles offshore from western Oak Island) and depths (about 35 to 40 feet), it is not anticipated that any substantial amount of sand will "fill in" the used portions of the borrow area in the near

future. Therefore, the portions of the CRP borrow area that have been dredged more than 2 ft deep likely cannot be reused in the future.

As a result of Hurricanes Florence (2018), Michael (2018), Dorian (2019), and Isaias (2020), a Central Reach Reimbursement (CRR) project design was initiated where the Town could place up to 1.7 mcy in FEMA "engineered beach" mitigation. ATM completed additional offshore borrow area reconnaissance and identified/permitted ~1.9 mcy of beach compatible sand (in addition to the CRP borrow area). The CRR nourishment project utilizing offshore borrow areas occurred this past winter/spring 2022 and placed ~1.54 mcy. More discussion on borrow area reconnaissance and the 2022 CRR project construction is provided in Section 2.3.

2.2.1 STATIC VEGETATION LINE

Due to the CRP's size, the Division of Coastal Management (DCM) required a Static Vegetation Line (SVL). The SVL is basically the seaward limit of stable dune vegetation prior to a large beach nourishment, and the SVL is the baseline for the Coastal Area Management Act (CAMA) setback distances. The SVL is only along the CRP shoreline (not the east end or western areas of the beach), and the SVL was delineated prior to Hurricane Matthew dune erosion. The SVL was recently expanded a few thousand feet westward prior to the 2022 CRR project to match the permitted CRR footprint.

The SVL line may not be an issue for Holden Beach because of the Town's proactive and beneficial dune enhancements over the years. However, if the SVL becomes an issue in the future, two options are available to the Town to exempt itself from the SVL. The first is to develop an SVL exception document that provides data for 30 years' worth of future beach nourishments. This exception must be re-visited every 5 years as well. The second and more recent alternative is for the Town to propose and create a Development Line. The Development Line alternative is a simpler and faster process.

Town and ATM staff have already coordinated with DCM staff regarding the Development Line process and several other towns have used this process since it became effective in 2016.

2.2.2 CRP PERFORMANCE

The 2017 CRP nourishment took place just months after Hurricane Matthew in 2016 and vastly revitalized the beach and dune system. The revitalized beach has and continues to provide added cumulative protection from storms. Recent surveys show that the project has held up well considering impacts from Hurricanes Florence (2018), Michael (2018), Dorian (2019), and Isaias (2020).

Figure 2-5 shows an example profile from the most recent annual surveys (2021 and 2022) just west of the pier (at Station 180+00) illustrating how the beach has changed since the CRP nourishment. The 2022 survey of course reflects the recent CRR fill placement, nonetheless, the favorable performance of the 2017 CRP is observed in the 2021 (pre-CRR) conditions, providing cumulative benefits. Figure 2-6 presents a photograph of recent beach conditions in this approximate location, just prior to the CRR project. Despite anticipated CRP project equilibration, combined with the coastal impacts of several hurricanes, still over 100 feet of dry recreational beach berm remained over 4.5 years later, providing a good base of pre-project beach for the 2022 CRR project to expand on.

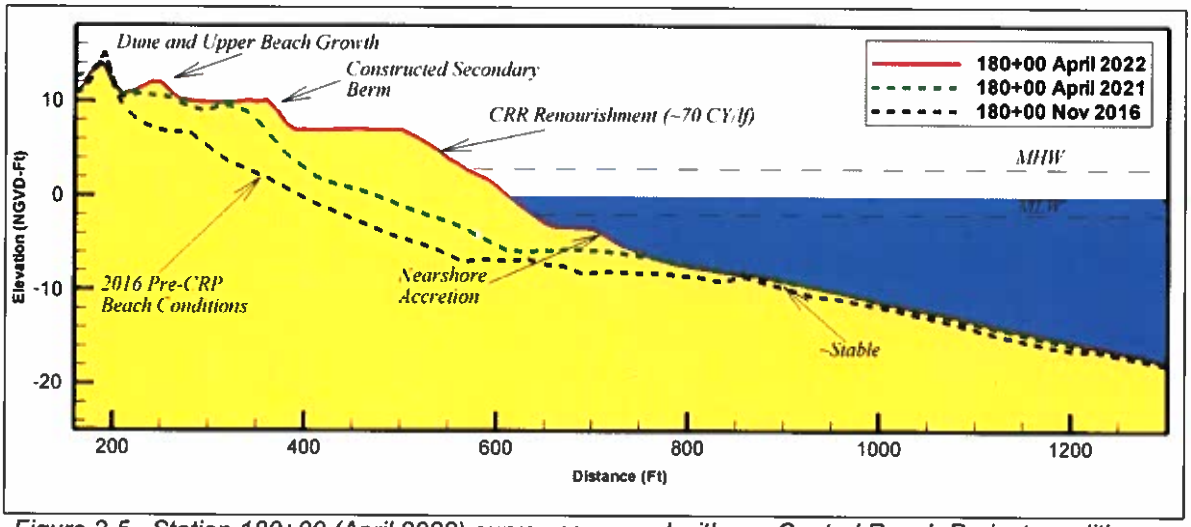


Figure 2-5. Station 180+00 (April 2022) survey compared with pre-Central Reach Project conditions and 2021 conditions (~4.5 year post-CRP).

Figure 2-6. October 2021 Photograph Taken Near Pier (~Station 170+00) Looking West. Photo shows ~4.5-year post-CRP conditions taken ~3 months prior to 2022 CRR project.

2.3 2022 CENTRAL REACH REIMBURSEMENT (CRR) PROJECT

The CRR nourishment occurred this past winter/spring (2022) and now represents the largest beach fill project to date on the island. The CRR project was a direct result of the Town's significant investments in its beach management program. The CRR was a FEMA mitigation project that placed about 1.54 million cubic yard (mcy) of material along the Central Reach shoreline. The CRR project is 100% reimbursable where FEMA will reimburse 75 percent and the State will reimburse 25 percent. Note that submitted reimbursable costs are thoroughly reviewed/evaluated and that this process can take years.

Project construction began on January 7, 2022 and was completed on April 12, 2022 (96 days) by Weeks Marine. The nourishment utilized two offshore borrow areas and placed approximately 1.54 mcy along ~4.2 miles (~22,000 ft) of shoreline, between 240 Ocean Boulevard East (OBE) to 785 Ocean Boulevard West (OBW).

Similar to the 2017 CRP borrow area dredging, shallow dredge cuts using a hopper dredge were used due to the presence of compatible materials in the upper layer, generally underlain by marginal material. In fact the same dredging contractor, Weeks Marine, and the same hopper dredges that were used for the 2017 project (the R.N Weeks and B.E. Lindholm), were used for the 2022 project. The project placed sand dredged offshore from two different borrow areas and placed beach compatible sand from Station 40+00 to just west of Station 260+00 (refer to Figure 2-7 and Figure 2-10 in the following section).

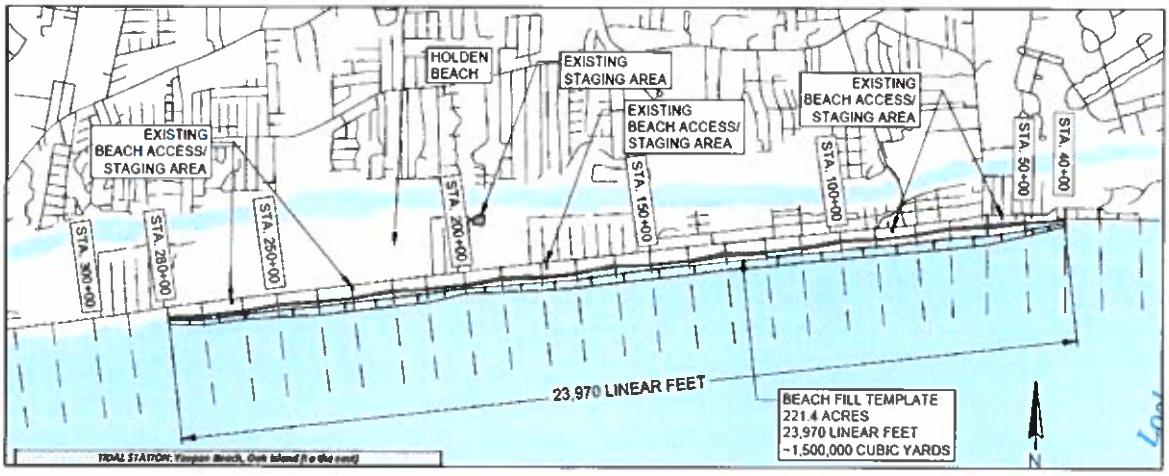


Figure 2-7. CRR Permitted Beach Fill Template. Actual Placement Extended from Station 40+00 to just east of 270+00 (~23,000 Linear Feet from ~240 Ocean Boulevard East to ~815 Ocean Boulevard West)

Taken as a whole, the average fill placement density was ~77 cubic yards per foot along the entire length of the project, including tapers. Figure 2-8 presents a typical fill cross-section following construction. The project included a varying secondary berm feature to blend in with existing dunes, although this secondary berm feature was blended into the primary dune during Hurricane Ian on September 30, 2022.

With the help of the two hopper dredges, the Weeks Marine crew worked quickly, pumping sand on the beach and progressing at an average rate of about 300 feet of shoreline per

day. Aerial and ground photographs taken during construction can be seen in Figures 2-9 (A-D).

During the end of the project when offshore waters began to warm, turtle trawling in the borrow areas occurred in front of the dredges to mitigate inadvertent "turtle takes" while dredging the borrow area, but unfortunately two small (less than 1-foot carapace length) juvenile Kemp's ridley turtle takes occurred towards the end of the project in late March and early April. Although numerous measures were taken to avoid any detrimental impact to wildlife, incidents like these are sometimes unavoidable, especially when considering the record setting turtle nesting numbers over the last several years. Due to numerous juvenile Kemp's ridley turtle interactions within the entire southeast dredge fleet (on USACE and private projects) and due to USACE regional South Atlantic Regional Biological Opinion (SARBO) Kemp's ridley turtle take limitations, the USACE requested project construction to stop on April 12.

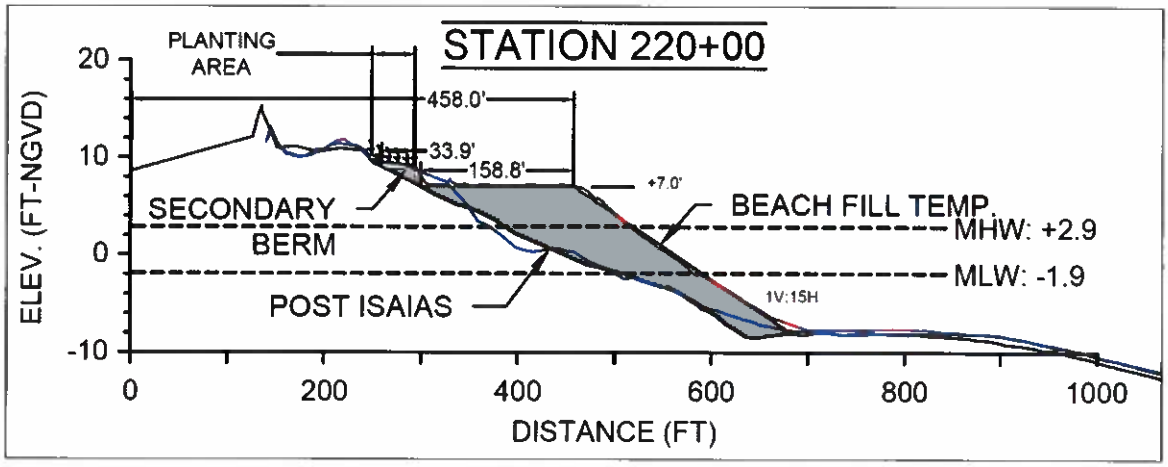


Figure 2-8. Typical CRR "As-Built" Cross-Section Following Completion Shown Relative to August 2020 Post-Hurricane Isaias Beach Profile.

Figure 2-9 (A). Aerial Photograph During CRR Construction, Photo Taken Near East Taper, ~Station 40+00, Looking West (ATM Drone Photo 01/20/22).

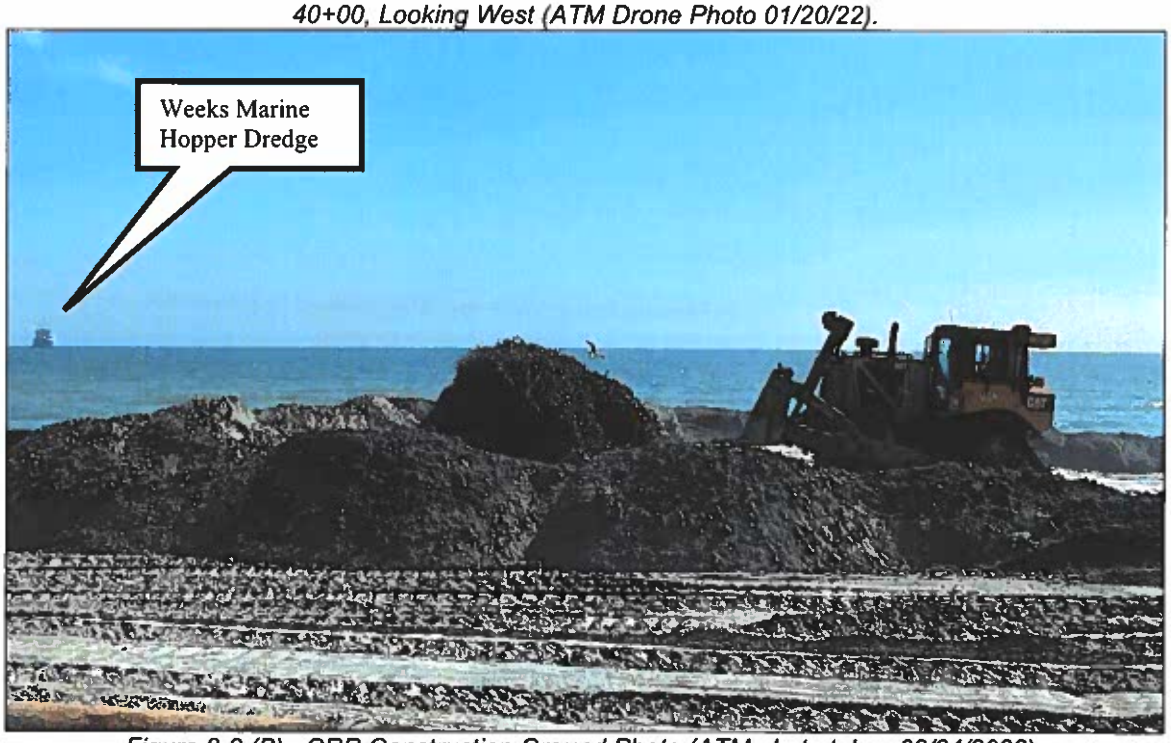


Figure 2-9 (B). CRR Construction Ground Photo (ATM photo taken 02/24/2022).

Figure 2-9 (C). CRR Construction Ground Photo (ATM photo taken 03/03/2022).

Figure 2-9 (D). Aerial Photograph Take From ~Station 180+00 Following CRR Construction During Active Planting Efforts Near Pier (ATM photo taken 04/28/2022).

2.3.1 BORROW AREAS

The two CRR project borrow areas are highlighted in red on Figure 2-10. Borrow Area 1 (BA1) for the CRR project represents the lightly dredged and undredged eastern portions of the previously permitted borrow area for the 2017 CRP, approximately 5 miles steam

distance from the Holden Beach project site. Borrow Area 2 (BA2) was recently delineated in 2020 and is located between ~2 and 3 miles offshore of Holden Beach.

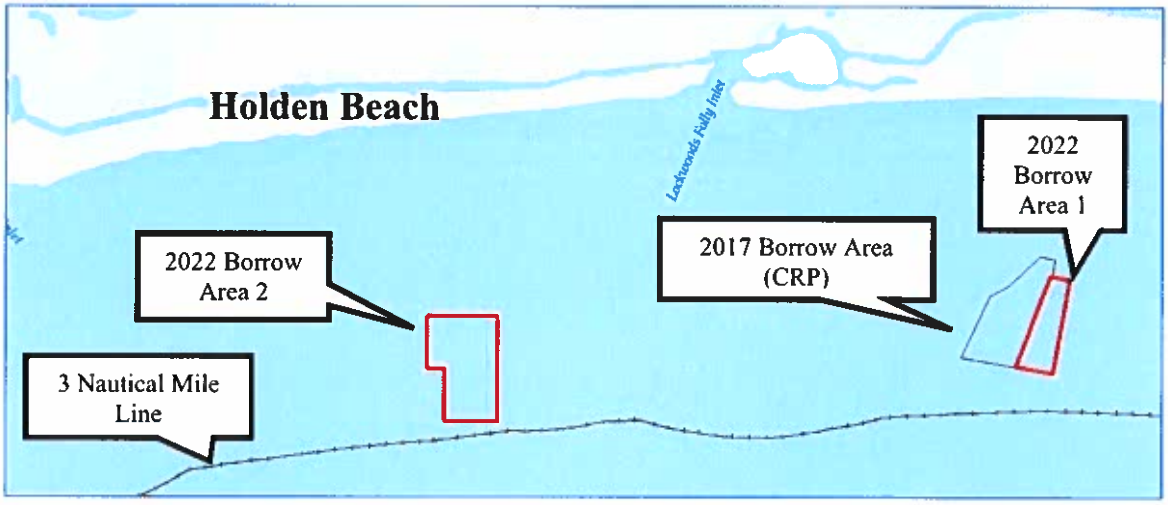


Figure 2-10. CRR Offshore Borrow Areas Outlined in Red.

Estimated potential volume yields of beach compatible sand for maximum cut depth for BA1 and BA2 were ~600,000 cubic yards (cy) and ~1.9 million cy, respectively, assuming 100% volume recovery. Of course, 100% volume recovery is not possible due to losses inherent with the hydraulic dredge process and therefore typical buffers/tolerances of ~15-25% were established to account for losses of excavated to in-place quantities.

Weeks Marine coordinated closely with ATM and Town staff to ensure beach compatible material. Two small pockets of less suitable material (larger sediment/rocks) were discovered in each borrow area. Hoppers have debris screens on board which prevent rocks from reaching the beach, however, some rocks did occur on the beach and beach raking was subsequently performed to remove the incompatible, large rock sediment material. Note that the beach raking effort collected mostly shells and subsequently, shell collectors focused on the beach raking material. Shell and shark-teeth collectors were frequent and consistent during and immediately after the project.

2.3.2 MONITORING

Sediment monitoring of the placed sand occurred daily throughout the project and immediately following completion. The nourishment sand was found to be a very good match to the existing beach with slightly coarser sand than the native sand (but well within

tolerance standards), which is fortunate as slightly coarser sand erodes less quickly than finer material. Figure 2-11 (A-C) show photographs of the good color and consistency of the nourishment sand placed as well as the significantly widened beach conditions immediately following construction.

Turbidity monitoring was also conducted several times daily throughout the project. Measurements were taken updrift and downdrift of the beach pipe discharge location, as well as a significant distance updrift to determine background turbidity due to environmental conditions (winds, waves, currents, etc.) and that is not project related. The effort revealed that background/natural turbidity rates for Holden Beach typically range between 30 and 50 NTUs (Nephelometric Turbidity Units). There were no turbidity concerns/issues during the project construction (which is not unexpected considering the good compatibility of the sand).

The Central Reach Reimbursement (CRR) was very successful and in total the project cost approximately $21.8 million, equating to less than $15 per cubic yard. This is a very favorable rate, especially when compared to similar nearby beach nourishment projects.

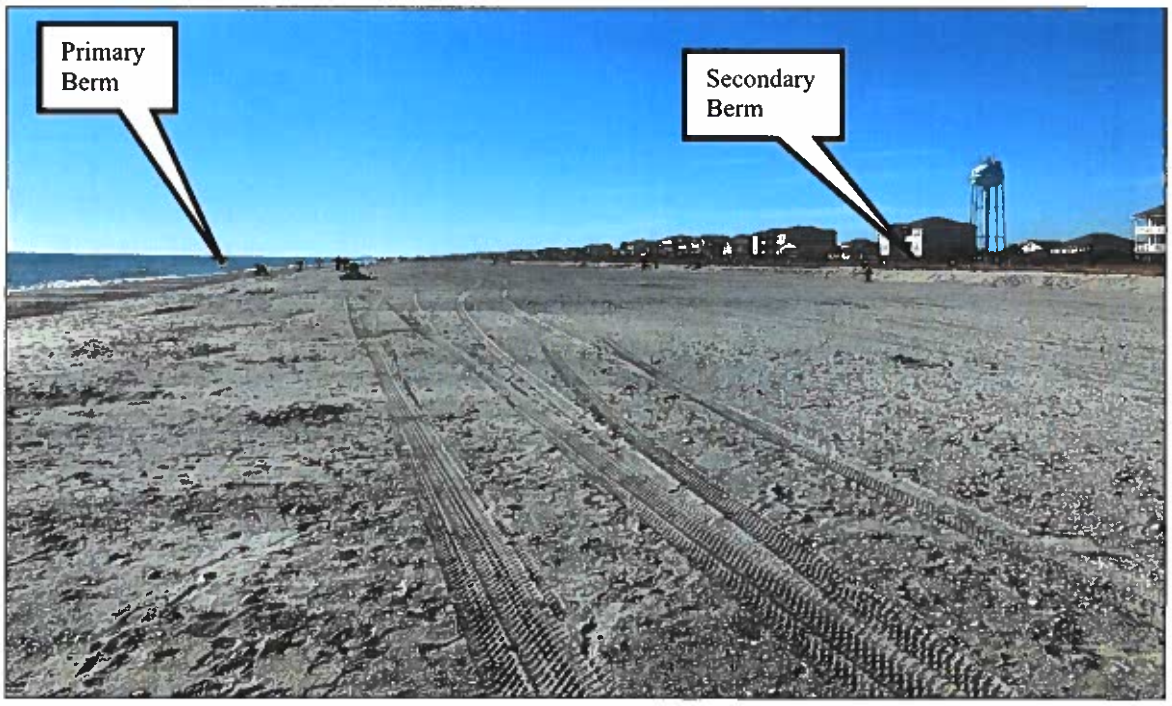


Figure 2-11 (A). CRR Post-Construction Near Station 80+00 (ATM photo taken 02/10/2022).

Figure 2-11 (B). CRR Post-Construction Aerial Photograph Taken Near Pier looking west (ATM photo taken 04/28/2022).

Figure 2-11 (C). CRR Post-Construction Aerial Photograph Taken Near Pier looking east (ATM photo taken 04/28/2022).

This project is designed to last 10 to 12 years (based on historical erosion rates and recent beach nourishment performance) and this report and future annual monitoring surveys will track the spreading and progress of the placed sand. Of course annual hurricane activity has a major influence on nourishment performance and it is anticipated that FEMA mitigation will likely be required in the next 5-10 years.

The results of the latest survey and fill volume measurements are discussed in detail in Section 3.

2.4 USACE AND TOWN LWFIX PROJECTS

The LWFIX borrow area has acted as a beneficial use of dredged material (i.e., a borrow area for beach nourishment) since the 1970s. The primary reason for the USACE LWFIX dredging project is navigation; however, the dredged material is beach compatible and Station 20+00 on the east end (beginning of the beach fill placement) is less than 4,000 feet away.

The USACE typically performs this project every 1 to 2 years, depending on shoaling and funding. The primary goal of this project is navigation, while a secondary and important benefit is placement of this compatible material on the beach.

The LWFIX project typically includes the AIWW itself as well as a "bend widener." The bend widener typically varies from 50 ft wide (Figure 2-12 [A]) to 400 ft wide (Figure 2-12 [B]). The 400-ft bend widener is the largest widener allowed by USACE permit conditions. The 400-ft bend widener was rarely dredged by the USACE due to limited Federal funding prior to 2010, however, the USACE did include it for the 140,000-cy project in 2010 due to economic stimulus funding (i.e., American Reinvestment and Recovery Act).

Immediately following the successful 2010 USACE LWFIX project, the USACE continued to minimize projects due to limited federal funding despite sufficient sand volume within the bend widener dredge footprint. For example, the February 2011 and January 2012 USACE LWFIX projects provided only 32,000 cy and 25,000 cy of material placed, respectively.

The increased benefits of the bend-widener for the 2010 project in comparison to the 2011 and 2012 reduced volume projects prompted the Town and ATM to actively pursue use of

the bend-widener for future projects. In correlation with this effort, the State established a shallow draft dredging fund in 2013, which was a game changer for LWFIX and outer ebb shoal channel dredging.

The Town performed an independent project that "piggybacked" the 2014 USACE LWFIX project and expanded the borrow area to include the 400-ft bend widener so more material could be placed on the beach. Since the 400-ft bend widener is within the authorized Federal navigation project footprint, the Town's separate permitting process was simplified.

The Town's piggybacking of the USACE project maximized sand placement while minimizing costs by use of the dredge already onsite for the Federal project. The Town project placed approximately 95,000 cy of beach-compatible material along approximately 2,300 ft of Holden Beach shoreline, between baseline Stations 50+00 and 73+00 (41 cy/lf average). Figure 2-13 provides an aerial photograph taken during the 2014 LWFIX project.

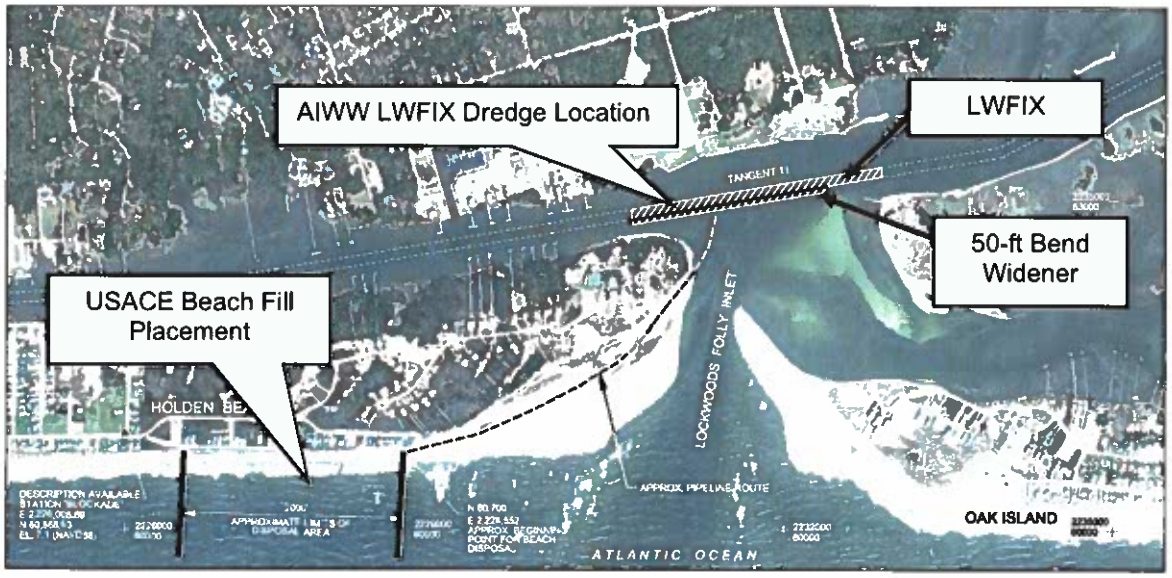


Figure 2-12 (A). USACE LWFIX Dredging and Beach Placement Schematic (source USACE request for proposal). Placement typically occurs between Holden Beach Stations 20+00 and 40+00.

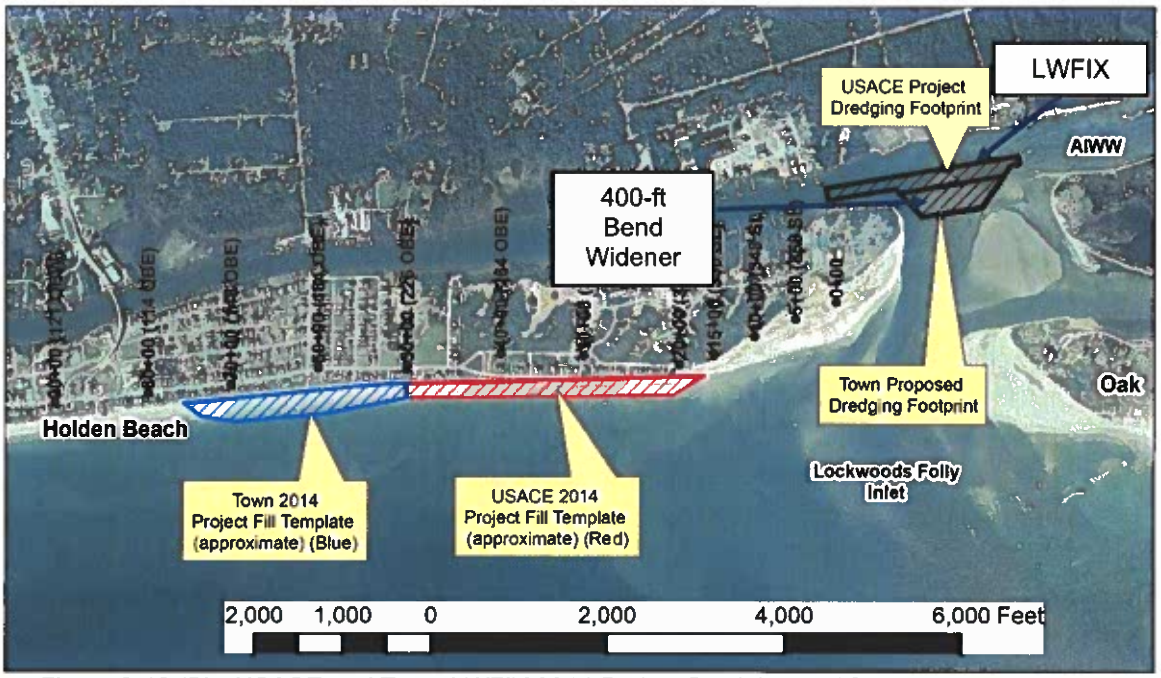


Figure 2-12 (B). USACE and Town LWFIX 2014 Project Dredging and Beach Placement which included the 400-ft bend widener.

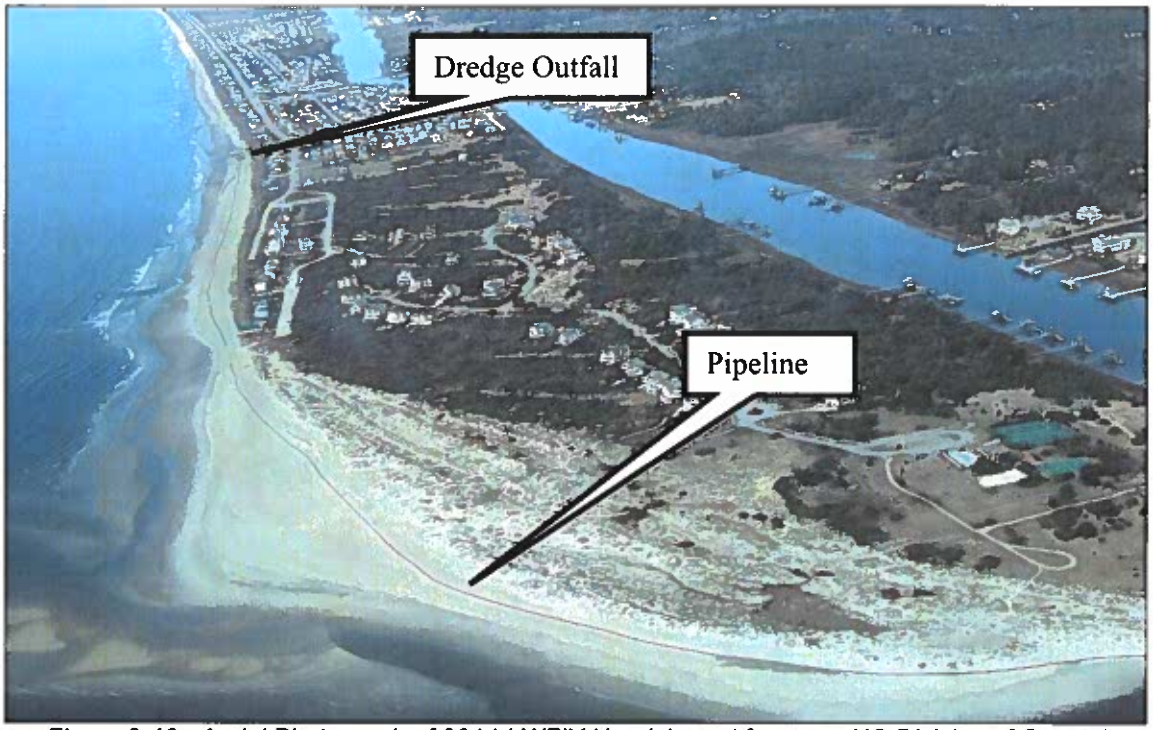


Figure 2-13. Aerial Photograph of 2014 LWFIX Nourishment [source: NC Division of Coastal Management (DCM)].

The Town's 2014 LWFIX project was very successful. Approximately 95,000 cy of material was placed for about $8/cy, which is a very favorable rate (this in addition to the USACE component of the project that placed ~93,000 cy). Nourishment dredging costs are typically much higher than this (depending on the borrow area and pumping distance) and can range from $10/cy to $25/cy. The North Carolina Department of Environmental Quality (NCDEQ) paid for half the project cost, and Brunswick County also contributed to the funding of the project. Additionally, Town resources (staff, equipment, oversight) expended for this project were significantly less than those expended for upland fill projects.

2.4.1 2017 USACE AND TOWN LWFIX PROJECT

Due to the successes of the 2010 and 2014 LWFIX projects using the 400-ft widener, the Town has been more involved in the LWFIX projects. Following a slightly different course of action than the 2014 LWFIX project, the Town and ATM staff coordinated with the USACE Navigation Branch personnel in charge of this dredging project to include the 400-ft widener under the USACE permit authorizations (not the Town's permits). The project was completed in mid-March 2017 and is also referred to as the Eastern Reach Project.

Figure 2-14 presents a plan view schematic of the 2017 LWIFX dredging and Town nourishment project. Including the 400-ft widener resulted in a total of approximately 130,000 cy that was dredged and approximately 120,000 cy placed along the Eastern Reach Project area (a small percentage of material is always lost during the dredging and construction process). To ensure maximum benefits to the central and eastern reaches of Holden Beach, the dredged material was placed immediately adjacent to the Town's CRP's eastern taper, where CRP construction began in January 2017.

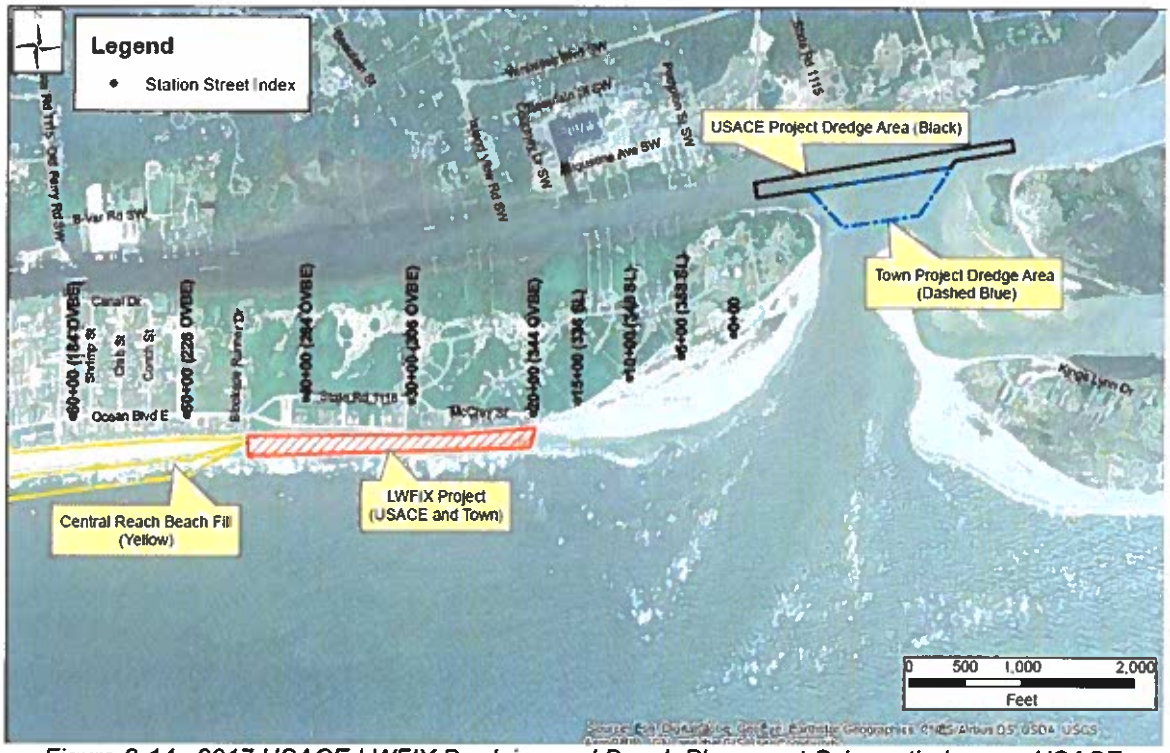


Figure 2-14. 2017 USACE LWFIX Dredging and Beach Placement Schematic (source USACE request for proposal). Placement of Approximately 120,000 cy occurred in March 2017 between Holden Beach Stations 20+00 and 45+00 to meet in with the Central Reach Project.

The Eastern Reach Project was very successful, and photographs taken during construction are presented in Figures 2-15 and 2-16. The Town involvement allowed for the placement of an additional 60,000 cy at a very inexpensive rate. The cost for the project was $465,000, and the Town's portion was only about $76,000 (with the State providing 66.7 percent).

Figure 2-15. Holden Beach POA Photograph Taken near 323 McCray Street (approximately Station 26+00) during 2017 Eastern Reach Project construction.

Figure 2-16. Holden Beach POA Aerial Photograph taken during 2017 Eastern Reach Project Construction (pumping just west of Station 30+00).

The timing of this nourishment coincided very well with the CRP and helped fill out much of the remaining shoreline of Holden Beach east of the larger CRP. Moreover, the Town's involvement helped maximize the restoration effort needed following the recent hurricanes and has helped mitigate more recent storm activity.

The eastern end of shoreline has historically shown the highest erosion rates on the island, and LWFIX dredging projects and piggybacking opportunities on the east end are a crucial part of the Town's proactive management strategies to mitigate this.

Figure 2-17 presents a 2-year post-project photograph monitoring the progression of the 2017 Eastern Reach Project. In general and based on site observations, the east end is continuing to benefit from this and the more recent 2022 LWFIX project (discussed in a following section). The east end does need nourishing every 2 years to avoid extreme erosional conditions that have occurred in past decades. More details on beach survey monitoring are provided in Section 3.

Figure 2-17. Two-Year Post Construction Photo of the 2017 Eastern Reach Project (ATM photo taken April 2018, at Station 20+00). The most eastern oceanfront house, Amazing Grace, is shown. Dune growth has occurred however this is still a vulnerable area.

2.4.2 2019 USACE LWFIX PROJECT

The USACE's 2019 LWFIX project occurred in spring 2019 and, unfortunately, the USACE chose to place this material onto Oak Island. Figure 2-18 presents an overview of the project. The project placed about 120,000 cy of material from the LWFIX with only a small 25-ft bend widener. The bend-widener was not a realistic option for this project as the winter/spring dredging window did not allow for additional dredging.

The LWFIX project is combined by the USACE with several other NC shallow draft inlet dredging projects to obtain more competitive pricing. The base-bid projects get priority and delays due to weather (e.g., Hurricanes Florence and Michael) and dredger scheduling/mechanical issues can also limit additional work like bend-widener dredging.

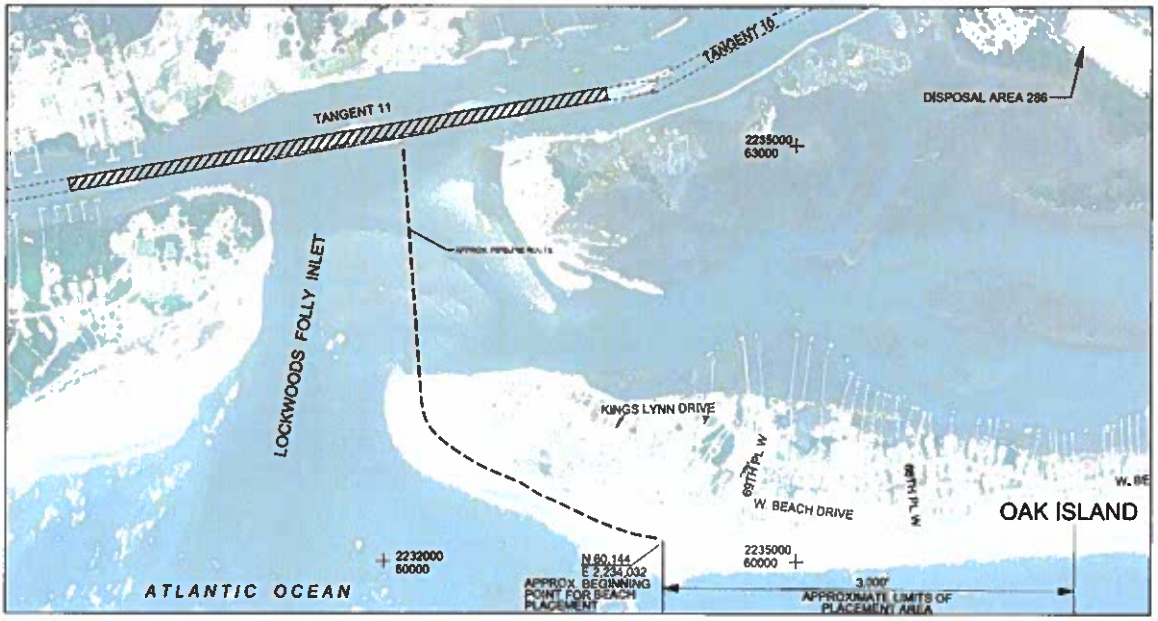


Figure 2-18. Planned 2019 LWFIX Placement on Oak Island. Actual Final Placement Area Approximately 2,500 ft. Refer to Section 3.5 for more information on 2019 LWFIX and Oak Island west end volume changes.

Town and ATM staff have met with USACE and Oak Island staff on several occasions over the past five years regarding placement options. For the 2019 project, the USACE maintained that an easement issue from another USACE project had led them to re-evaluate *all* easements for *all* Wilmington District projects.

According to the USACE, Oak Island fill placement only required easements from the Town of Oak Island (i.e., not from individual homeowners). For the east end of Holden Beach, the USACE identified more than 50 homeowner easements needed, with many of these on active beach (not buildable lots, see Figure 2-19). Updated easements were obtained in 2019 and placement on the east end can now again occur.

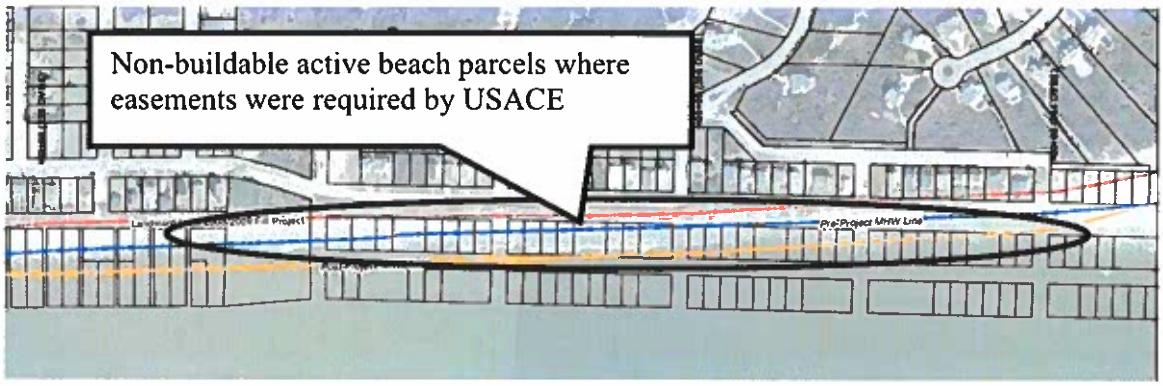


Figure 2-19. In 2018, the USACE Required Easements for numerous lots before East End LWFIX Placement Can Resume Easements were obtained in 2019.

2.4.3 2020 LWFIX PROJECT

The 2020 LWFIX dredging project was completed in early spring of 2020 with placement on the east end of Holden Beach (see Figure 2-20). Goodloe Marine was awarded the USACE contract. Approximately 60,000 cy of dredge material was estimated in the inlet crossing for the base-bid, and ~110,000 cy of material to be dredged was estimated within the 400 ft bend widener.

The bid included the 400 ft bend widener as an optional bid item, however, as mentioned previously the base-bid items get priority and dredger scheduling/mechanical issues or other delays can limit additional work like bend-widener dredging. Some dredging of the bend widener did occur as part of the 2020 LWFIX Project, but not near the full amount of the alternative bid.

Dredge material was placed along ~3,000 linear feet of shoreline on Holden Beach's east end with placements ranging between ~20 to 40 cy/ft. It was estimated the project added approximately 80,000 cy of in-place material to the beach from east of Station 20+00 to past Station 40+00 (based on the April 2020 annual beach survey).

Figure 2-21 presents photographs taken during and after construction of the 2020 LWIFX project placement on the east end. Figure 2-21 (D) and (E) present photographs of the 2020 LWFIX project area conditions (~1.5-year post project).

The east end beach conditions are currently generally healthy due to the recent 2022 LWFIX (discussed in an upcoming section) and a relatively wide, dry recreational beach is present along this vulnerable and historically highly erosional shoreline reach.

Figure 2-20. 2020 LWFIX Placement on Holden Beach. 400-ft Bend Widener Included as Bid Option Item (Alt) But Was Only Lightly Dredged During Actual Project.

Figure 2-21 (A). Photograph in East End Taken During 2020 LWFIX Construction. (Holden Beach Town Newsletter)

Figure 2-21 (B). Photograph in East End near Amazing Grace / Station 20+00 Showing Post-2020 LWIFX beach conditions (May 1, 2020).

Figure 2-21 (C). July 2020 photograph near Amazing Grace.

Figure 2-21 (D). October 2021 photograph near Station 30+00 looking East.

Figure 2-21 (E). October 2021 photograph near Station 30+00 looking West. Relatively narrow beach conditions observed in 2021, just prior to 2022 LWFIX project.

2.4.4 2021 LWFIX PROJECT

Similar to the 2019 LWIFX project, dredging placement for the 2021 LWFIX project was on Oak Island's west end. The project estimated 165,000 cy be dredged from the LWFIX and a

200-ft bend widener (note that volume placed on the beach will be ~20-30% less than volume dredged) (see Figure 2-22).

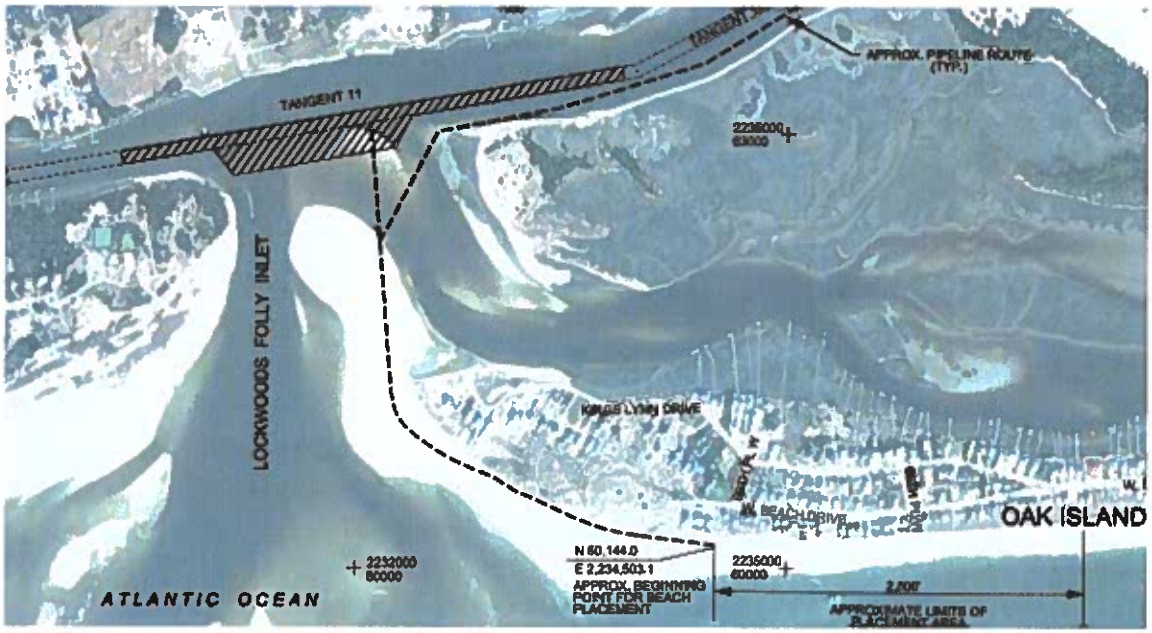


Figure 2-22. LWFIX 2020/2021 bid plans (November 3, 2020 plans).

2.4.5 2022 LWFIX PROJECT

Similar to the 2017 USACE and Town LWFIX Project and the 2017 CRP, the 2022 USACE LWFIX project occurred in conjunction with the Town's 2022 Central Reach Reimbursement Project this past winter/spring. The 2022 LWFIX project was completed in the early spring of 2022 with placement along ~2,000 linear feet of shoreline on the east end of Holden Beach between (see Figure 2-23). The Town and ATM staff coordinated with USACE-Navigation personnel in order to maximize volume placed on Holden Beach. It was estimated the project added approximately 115,000 cy of in-place material to the beach from east of Station 20+00 to past Station 40+00 (based on the April 2022 annual beach survey).

To avoid overlapping with the CRR, the dredged material was placed from ~Station 20+00 to Station 40+00 with fill placements of ~50 cubic yards per linear foot, which closely matched with the CRR nourishment fill volumes at the east taper where the two projects adjoin, near Station 40+00.

Post-construction photos are shown on Figures 2-24 (A-C), showing the wide dry beach as a result of the recent project. The 2022 USACE LWFIX was very successful and the timing of this nourishment coincided well with the Central Reach Project and to help "fill out" much of the remaining shoreline of Holden Beach east of the larger CRR.

Figure 2-23. LWFIX 2021/2022 bid plans and actual placement tying in with the CRR project highlighted. (July 2021 plans).

Moreover, the Town's involvement helped maximize the restoration effort needed following the recent hurricanes, and will help mitigate against future issues as the eastern end of shoreline has historically shown the highest erosion rates on the island. More detail on east end volume changes and recent accretional/erosional trends are provided in Section 3.

Figure 2-24 (A). April 2022 upland photograph taken near Station 40+00 showing healthy dune vegetation and wide beach following 2022 LWFIX construction.

Figure 2-24 (B). April 2022 photograph near Station 40+00 looking east. Note newly constructed secondary berm along east taper of CRR which ties in with the 2022 LWFIX project at this location.

Figure 2-24 (C). April 2022 photograph taken between Station 20+00 and Station 30+00 looking west showing newly constructed 2022 LWFIX beach fill.

2.5 SHALLOW DRAFT INLET PROGRAM

The NC shallow draft inlet dredging program includes two primary elements: 1) inlet and AIWW reaches landward of the Coast Guard COLREGs (collision regulation) line and 2) outer inlet dredging where small dredges must also be "ocean-certified" by the Coast Guard for potentially rough/dangerous inlet conditions (seaward of the COLREGs line). The USACE side-caster the *Merritt* and the two USACE shallow draft hopper dredges, the *Murden* and the *Currituck* (Figure 2-25), are the only vessels that can realistically work the shallow draft inlets seaward of the COLREGs line. Private dredgers have been consulted for these projects, but their equipment generally consists of large cutterhead ocean dredges (high mobilization fees), ocean-going hopper dredges (draft too deep), or barges with clamshell excavator dredges (no pipeline disposal and low productivity).

Figure 2-25. USACE Shallow Draft Split-Hull Hopper Dredge the Currituck Rarely Dredges the LWF Inlet

About 10 years ago, the historical lack of USACE funding for North Carolina shallow draft inlet maintenance led the State, in conjunction with local county and municipal governments, to accomplish the following:

1. Obtain a memorandum of agreement (MOA) with the USACE to fund shallow draft inlet dredging,
2. Obtain permits to maintain the navigability of the State's shallow draft inlets independently of the USACE, and

3. Establish the Shallow Draft Navigation Channel and Lake Dredging Fund; (which has recently been renamed the Shallow Draft Navigation Channel and Aquatic Weed Fund - effective July 1, 2016). Funds can be used for the MOA or independently of Federally sponsored projects.

More information on all these initiatives is provided in the following sections.

One significant item to result from the shallow draft inlet funding program was the construction of another shallow draft hopper dredge. Dare County and the State built a shallow draft hopper dredge, the Miss Katie, that primarily serves the Outer Banks (focusing on Oregon and Hatteras Inlets). At a minimum, this dredge will ease demand for other USACE shallow draft dredging projects (i.e., LWF Inlet). In shallow draft quarterly meetings by the USACE and the state, this new dredge has remained in the Outer Banks area and will likely not be available for future LWF Inlet work. Shallotte Inlet is not considered a shallow draft inlet due to the large inlet borrow area dredging for the Ocean Isle USACE nourishment program.

2.5.1 STATE AND USACE SHALLOW DRAFT MOA

In November 2013, North Carolina signed an MOA that allows the State and local stakeholders to contribute funds to the USACE for shallow draft inlet maintenance dredging. The North Carolina General Assembly established the Shallow Draft Navigation Channel and Aquatic Weed Fund to provide State funding, which will be endowed by both an increase in boat registration fees and an excise on motor fuel, to the North Carolina Wildlife Resources Commission's boating account. While the limit to the USACE under the MOA is $12 million per year, additional funding is available for shallow draft dredging projects independent of the MOA.

The USACE and NCDEQ have quarterly meetings regarding the implementation of the long-term MOA. Town staff have attended these meetings previously and Town and/or ATM staff will keep abreast of these meetings on a regular basis.

The USACE typically dredges the LWFIX and AIWW every 1 to 2 years, whereas the USACE typically sidecast dredges the outer LWF Inlet once per quarter, if adequate funding is available. Each sidecast dredge maintenance event costed between $225,000 and

$250,000 back in 2013, including the associated pre-dredging and post-dredging surveys (USACE navigation communication, 2013) and costs have increased since. In recent years, the USACE has reduced the dredging frequency to once every 6 months or even longer. Additional effort can be required if the intervals between dredging events are longer.

2.5.2 STATE SHALLOW DRAFT INLET PERMITTING

The State took the lead in the shallow draft inlet permitting following the 2013 Shallow Draft Inlet (SDI) report. This effort was predicated on two major factors: 1) there was only one sidecast dredge that remained in the Federal government fleet, the refurbished *Merritt*, and 2) Federal funding had been limited/absent and this trend was likely to continue.

Following the reconnaissance study, the State gathered the necessary materials (geotechnical data, biological reports, survey data, etc.) to apply for permits for locally held authorizations. These authorizations allow the Town an additional option for maintaining (at current USACE templates) the LWFIX crossing, the inlet throat, and the outer channel beyond the COLREGs line (refer to Section 2.5.4 for more on this topic).

The permits for this effort were issued in May 2016 and have been extended since. The permits are now good until December 31, 2026. The authorizations include all currently approved dredge material management locations, including shoreline beneficial placement, nearshore placement and/or upland confined disposal placement. Note that there are some additional monitoring requirements when compared to the USACE authorizations (which were originally developed decades ago).

2.5.3 STATE DREDGING FUND

Independent of the MOA, dredging funds can be obtained directly from the State via the Water Resources Development Grant process. The Town has used this mechanism for the 2014 LWFIX project. In 2014, the State cost-sharing was 50 percent while it is now 66.7 percent for non-tier-one counties. The dredging fund has expanded in scope since its inception and funding has also increased. More than 12 Federally authorized inlets and associated channels are included, and some non-Federal channels are also included (mostly related to State ferry routes). Of course, there is also a lake/freshwater component of the fund (as identified in the fund's name). The fund has shown robust growth and availability since its inception.

2.5.4 LOCKWOOD FOLLY INLET PROJECTS

As previously discussed, LWFIX projects are eligible for State dredging funding while other elements of LWF Inlet maintenance are also eligible. LWF Inlet is a Federally authorized shallow draft inlet. Due to different and separate historical USACE funding sources, two basic routine maintenance activities historically occur at LWF Inlet:

1. Outer bar sidecast dredging, and
2. LWFIX cutter-head dredging and beach fill placement.

Figure 2-26 (A) provides a representation of these two regions. The LWFIX projects are described in detail in Section 2.4. This section focuses on the outer shoal, seaward of the COLREGs line.

The SDI permit authorizations allow the Town (with State, County and potentially Oak Island funding assistance) to dredge/maintain LWF Inlet both landward and seaward of the COLREGs line. The COLREGs line is the Coast Guard collision regulation demarcation that only allows "ocean-certified" dredges seaward of this delineation.

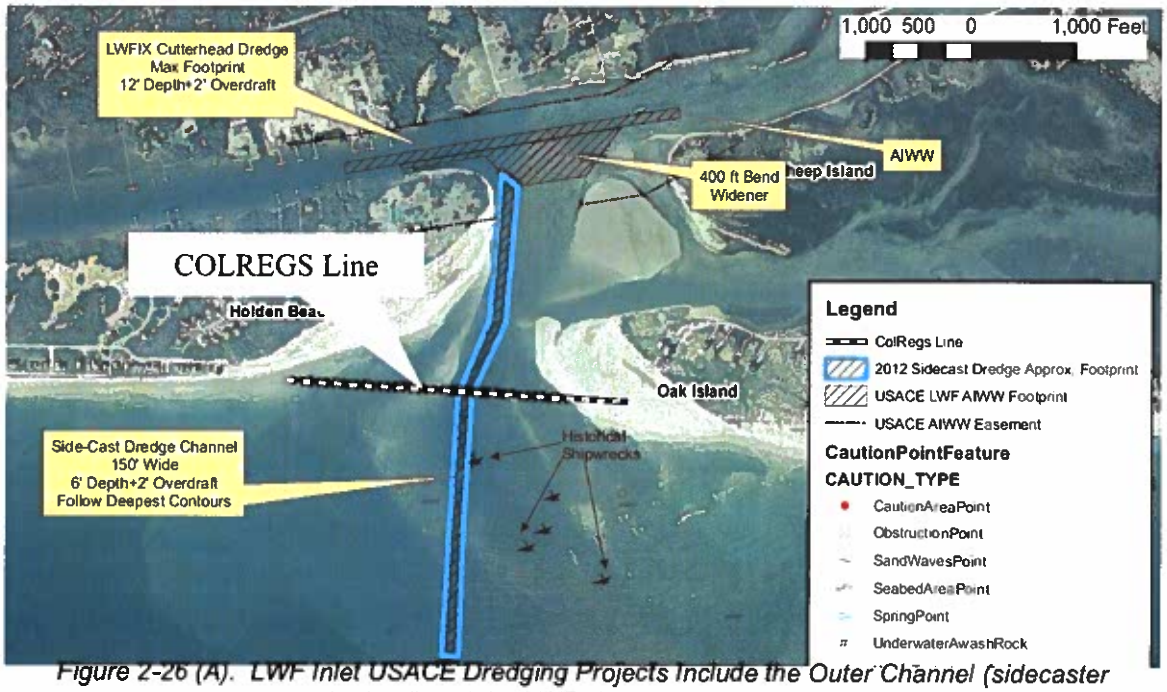


Figure 2-26 (A). LWF Inlet USACE Dredging Projects Include the Outer Channel (sidecaster dredged) and the LWFIX (cutterhead dredged)

Ocean-certified dredges are typically larger dredges that are much more expensive to mobilize/demobilize (typically between $3 to $4 million per event). The LWFIX dredge projects are predominantly awarded to smaller dredge companies with dredges that are not ocean certified (e.g., Southwinds, Cottrell, Goodloe) since this area is landward of the COLREGs line.

Figure 2-26 (B) on the next page presents an example USACE LWF Inlet survey identifying several major features involved in sediment transport, including the flood shoal, ebb shoal, and inlet throat. The inlet throat is consistently deep [18-20 feet above mean lower low water (MLLW)] on USACE surveys. The ebb and flood shoals are consistently shallow and typically require dredging for safe navigation. The ebb shoal typically consists of several shallow sandbars that slowly migrate across the inlet from the Oak Island side to the Holden Beach side.

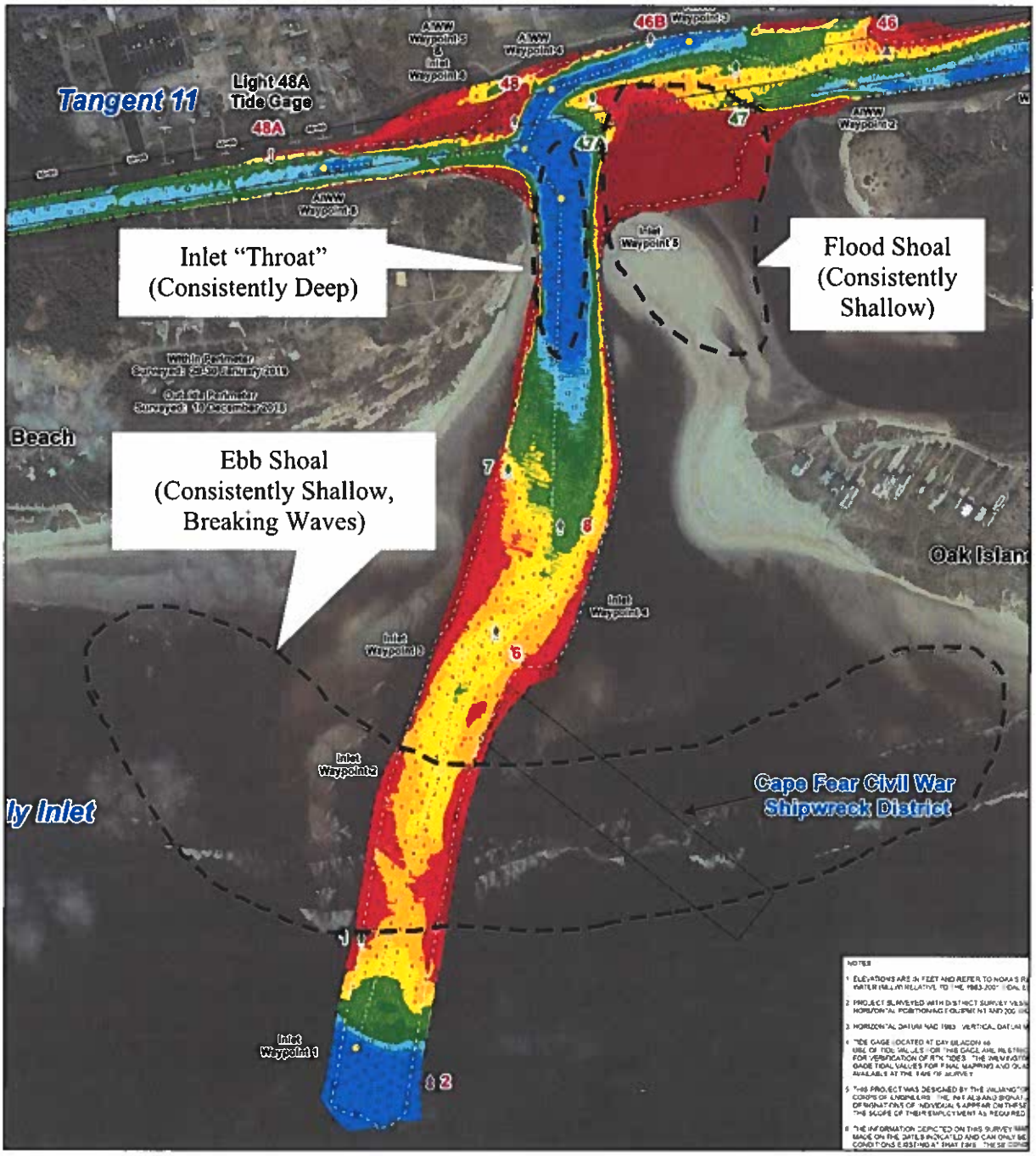


Figure 2-26 (B). Inlet Throat, Flood Shoal and Ebb Shoal at LWF Inlet
(Image Source: USACE Wilmington Navigation Branch)

2.6 LWF OUTER EBB SHOAL DREDGING

Outer ebb shoal (see Figure 2-2 [B]) dredging is typically performed by the *Merritt*, which is the USACE's only remaining sidecaster; however, the *Murden* and *Currituck* are also used. The *Murden* was used exclusively when the *Merritt* was in extended drydock in 2017/2018. All three shallow-draft dredges (*Merritt*, *Murden*, and *Currituck*) typically spend 1 to 2 months in drydock per year, with some extended drydock maintenance occurring every 5 to 20 years.

The *Merritt* dredged about 17,000 cy in February, followed by *Murden* dredging in March (about 24,000 cy). The *Merritt* also worked LWF Inlet in June (about 30,000 cy) and August/September (about 17,000 cy).

While the *Merritt* merely sidecasts material about 100 feet to the side, the *Murden* places material nearshore in approximately 8 to 15 feet of water between 500 and 1,000 feet from shore. The nearshore placement generally occurs between Ferry Road (approximately Station 60+00) and the Holden Beach bridge (approximately Station 90+00). The USACE generally refers to this area as the authorized placement location as determined by its analysis/review decades ago.

Figure 2-27 presents a figure of the 2017 LWF outer bar dredging and nearshore placement in comparison to the 2015 nearshore placement. Placement locations for each load (about 300 cy) are shown for the 2015 and 2017 efforts. The 2019 *Murden* dredging also placed material in the same location, however, it did not provide drop-point locations for each load.

Due to the project's purpose (i.e., shallow draft inlet dredging and nearshore disposal), the State funded 66.7 percent of the project costs and Brunswick County contributed funding also. The nearshore placement results in mounds generally 2 to 3 feet high. Subsequent surveys found the mounds to have dispersed; however, their onshore movement could not be detected as these are relatively small amounts of material that quickly assimilate into the littoral system. Nonetheless, ATM believes this nearshore placement is the best disposal option for the *Murden* or *Currituck* and is favored over sidecaster dredging.

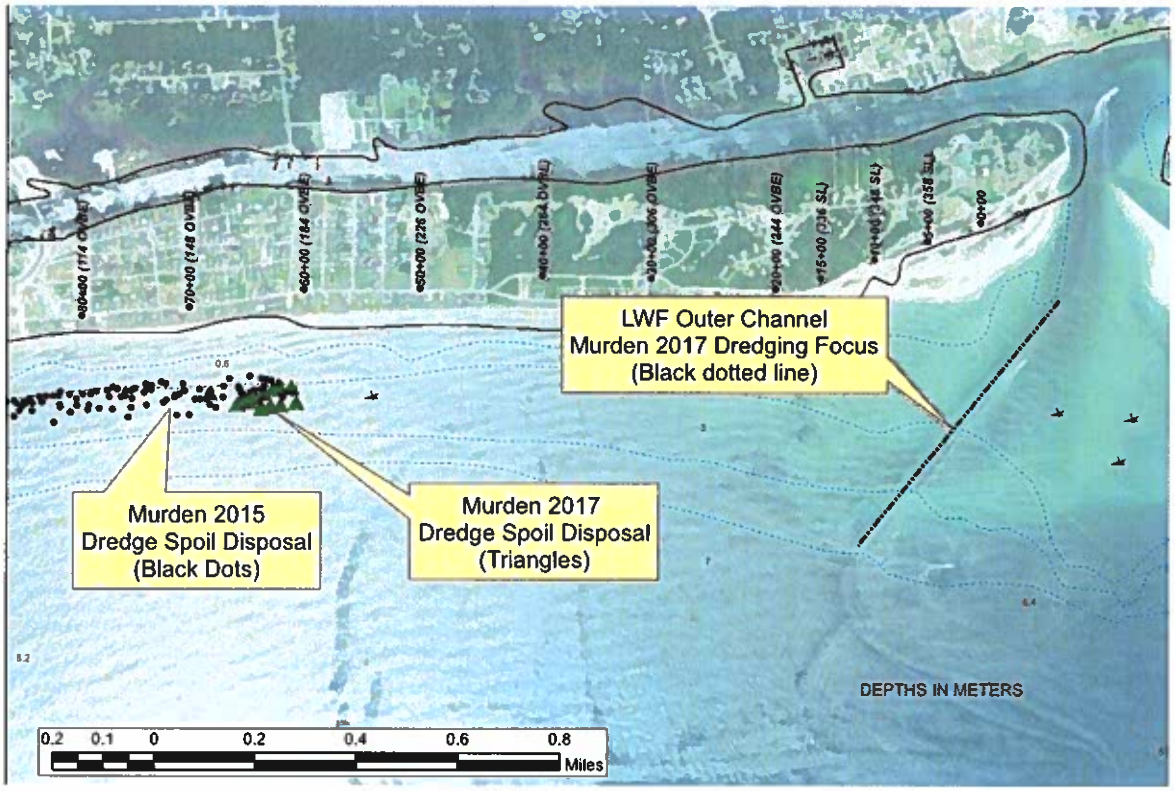


Figure 2-27. LWF Outer Channel USACE Dredging Projects by the Murden in 2015 and 2017. The 2019 Murden project also placed material in this general area however did not provide drop-point locations for each load.

2.6.1 COUNTY LWF OUTER SHOAL DREDGING PROJECT

In 2019, Brunswick County rescinded its proposal to dredge a deeper and wider outer LWF ebb channel and to place this material either on Holden Beach or Oak Island. The outer ebb channel is currently authorized to 150 feet wide and 8 feet deep. The County was proposing to deepen the channel to 12 to 14 feet deep and widen it by 50 to 150 feet. The County estimated that at least 250,000 cy would be available for beach nourishment.

ATM was never enthusiastic about this project. In general, utilizing large ebb shoal borrow areas is typically discouraged because it can interrupt the natural sediment bypassing process by creating a "sediment trap." Shallotte Inlet ebb shoal dredging has been cited as acting as an "effective sediment trap" (USACE OCTI report, 2008). Modeling and analysis also indicated that a deeper/wider channel could detrimentally affect estuarine shorelines and habitat (and significantly more long-term monitoring/analysis would be required). The project qualified for State shallow-draft inlet funding due to its dredging-for-navigation component. Without this State funding, this project would likely not be cost-effective.

2.7 DUNE ENHANCEMENT

In addition to placement of sand, the Town has been proactively enhancing dune habitat on an annual basis. The dune-building program includes the following:

- Vegetation planting (sea oats, American beach grass, bitter panicum, etc.)
- Fertilization
- Sand fence maintenance and expansion
- Dune walkover maintenance

The continued diligence and effort of Holden Beach has resulted in a stable and healthy dune system along a majority of the island, although hurricanes still damage the dune system. Dune vegetation planting and sand fencing was a planned component of the 2017 CRP and has stabilized and largely restored the dune system along Holden Beach since Hurricane Matthew. Older dune fencing has gradually been buried as a result of dune growth (see Figure 2-28). Post-project monitoring photographs of the starter dunes and plantings are provided in Figures 2-28 (A) - (D). The observed dune growth over recent years suffered some substantial damage as a result of Hurricane Isaias in August of 2020 and Hurricane Ian in September 2022. Similar to the 2017 CRP, vegetation planting occurred following the 2022 CRR fill placement. An approximate 50 ft wide planting area was conducted for the length of the project template and planting occurred primarily along the newly constructed secondary berm extending seaward from the existing sand fencing (see Figure 2-29).

Some areas of shoreline on the west end experienced dune erosion and vegetation loss in recent years and could benefit from proactive dune enhancement efforts. A large dune system is present along the west end, so planting of more mature vegetation could help to promote growth of a thick maritime forest and increase accretion steadily over the years to come. Recent studies have shown maritime forest vegetation (wax myrtles, holly, shrubs, etc.) build up the ground, creating "green barriers" as formidable defense against future erosion from rising seas and storm surge. In addition to plantings, the Town of Holden Beach recently received a state grant for $106,000 for dune fencing.

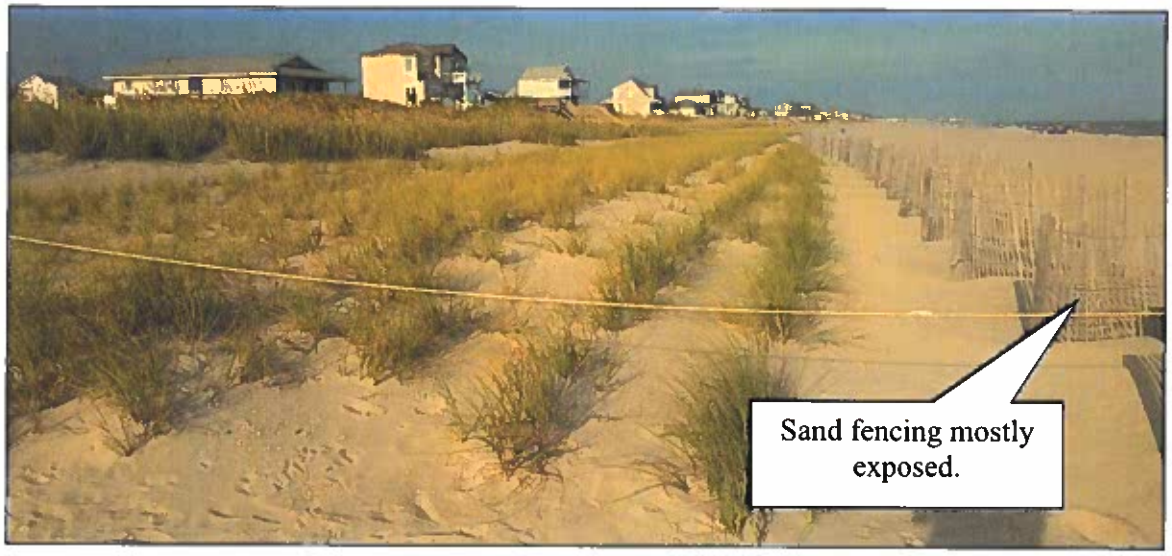


Figure 2-28 (A). Sand Fencing along the Seaward Edge of the Starter Dune for the Central Reach Project at Station ~60+00 Showing Planted Dune Vegetation. (ATM photo, taken August 2018).

Figure 2-28 (B). Sand Fencing for the Central Reach Project at Station 60+00 showing dune vegetation and sand growth about 2-years post project. (ATM photo, taken September 2019).

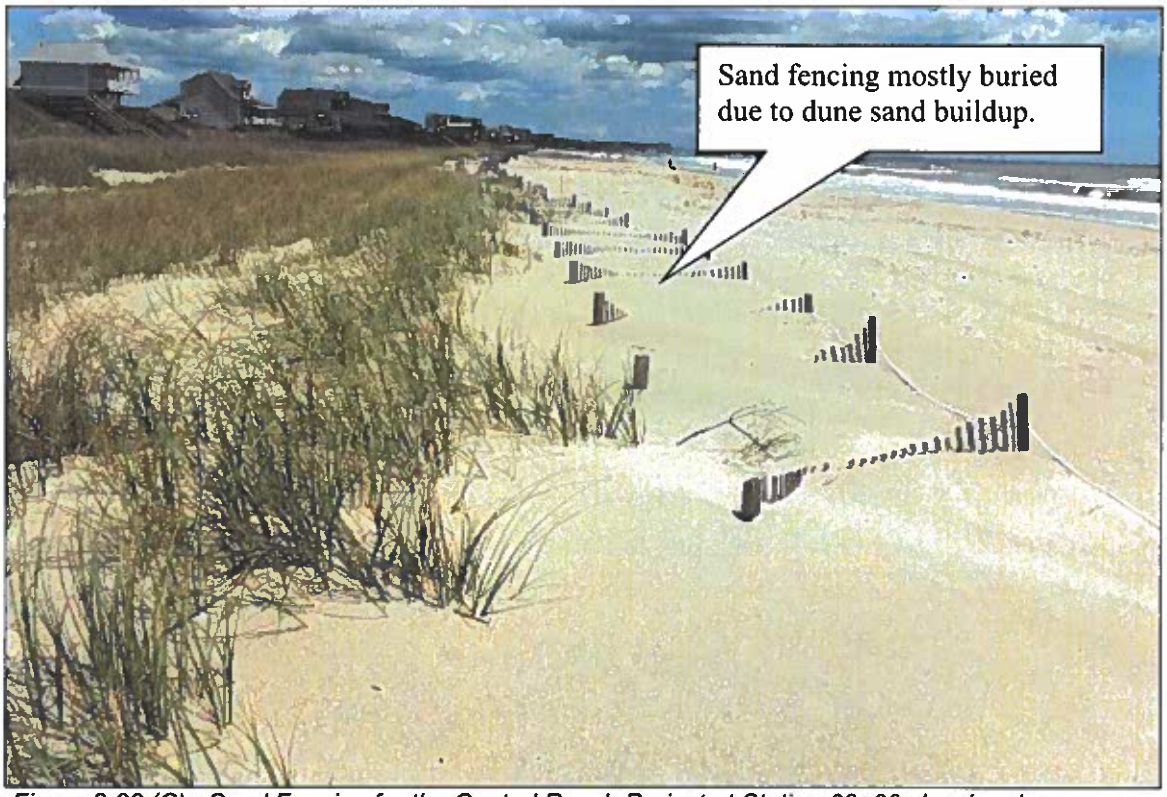


Figure 2-28 (C). Sand Fencing for the Central Reach Project at Station 60+00 showing dune vegetation and continued sand growth about 3.5-years post project. (ATM photo, taken May 2020).

Figure 2-28 (D). November 2021 Station 60+00 after Hurricane Isaias which created some dune losses

Figure 2-29. November 2022 near Station 80+00 showing new plantings following CRR along newly constructed secondary berm (and after Hurricane Ian).

2.8 STORM ACTIVITY

Figure 2-30 presents a summary of 2021 Atlantic Hurricane tracks. The 2021 hurricane season began early, with the first named storm forming in May. The 2021 hurricane season was active and had 21 named storms, with 4 storms reaching major hurricane status (i.e., a Category 3 hurricane or greater and noted as "MH" in Figure 2-30).

Fortunately, 2021 was relatively mild for Holden Beach and other regional beaches and no major hurricanes significantly affected Holden Beach during the 2021 hurricane season. Despite the lack of a hurricane passings nearby, the combination of storm surge and large swells can still create erosional conditions that directly impact the Holden Beach dune system. In addition to tropical systems, periods of sustained southeast winds and winter Nor-easters can create highly erosive conditions also.

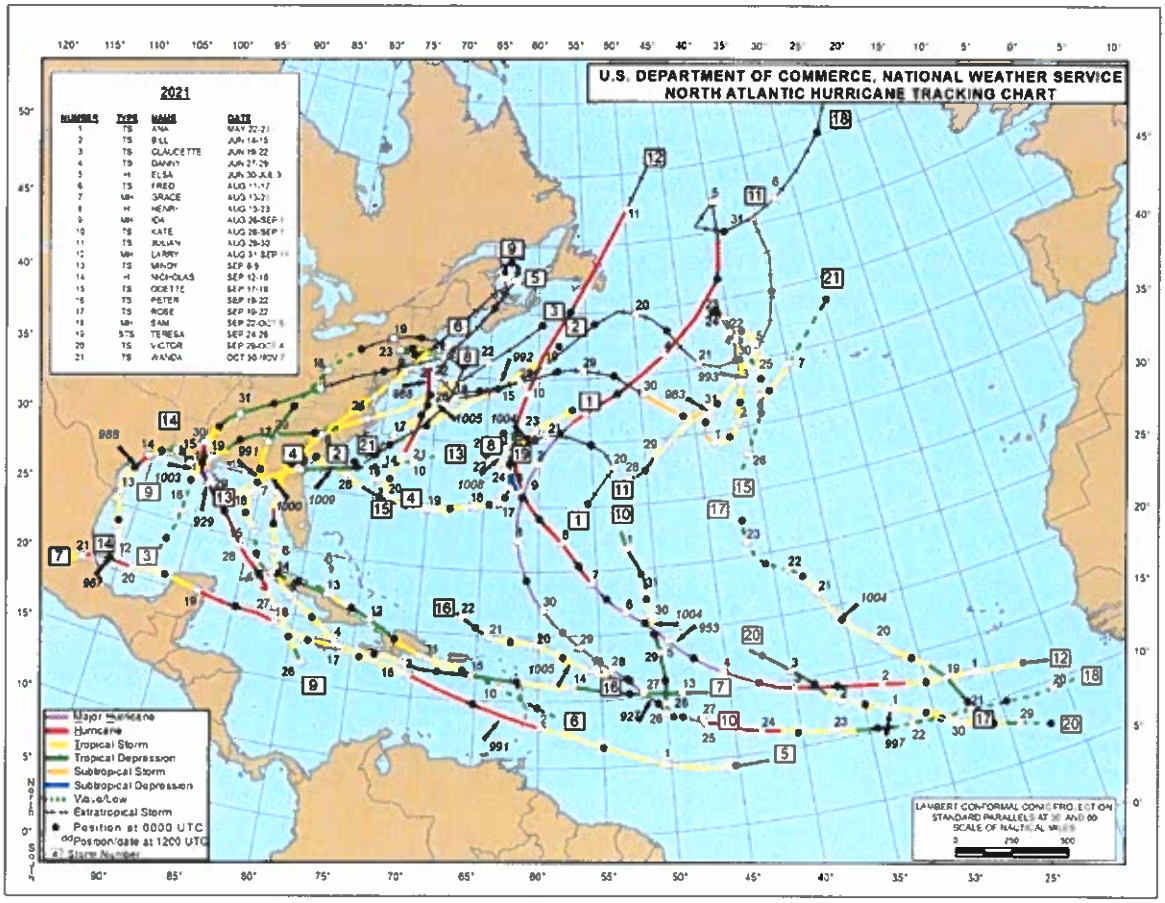


Figure 2-30. 2021 Atlantic Hurricane Summary Overview.

Although the 2021 season was relatively mild, the 2022 hurricane season brought Hurricane Ian which impacted the Holden Beach shoreline in late September of 2022 (see next section for more).

2.8.1 HURRICANE IAN 2022

Hurricane Ian made landfall as a sizable category 1 storm on September 30th in south of Georgetown, SC approximately 65 miles southwest of Holden Beach (see Figure 2-31). Hurricane Ian approached at an unfortunate time during a peak spring high tide, bringing over 4 feet of storm surge for a total water elevation of ~9.4 ft above MLLW (see Figure 2-32).

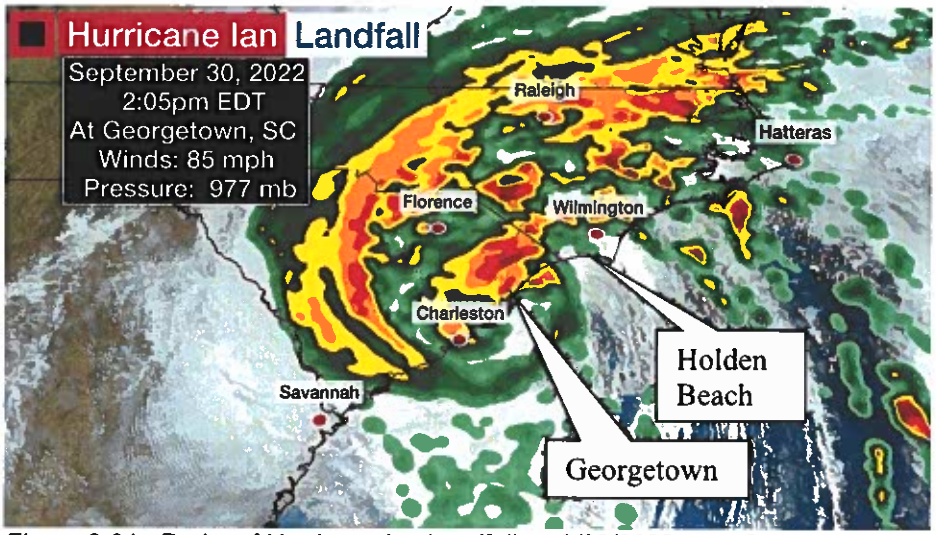


Figure 2-31. Radar of Hurricane Ian Landfall on 9/30/2022 near Georgetown, SC

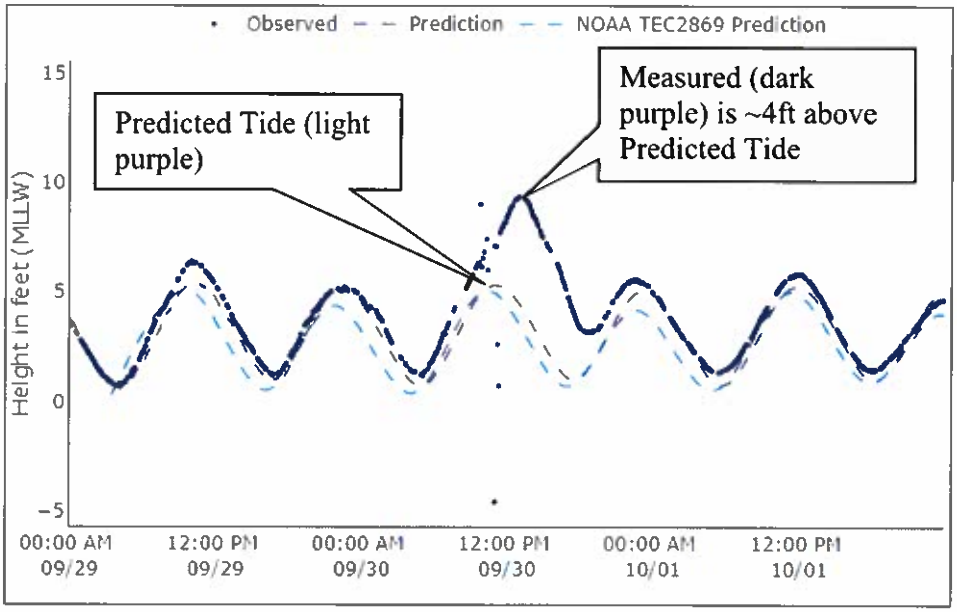


Figure 2-32. Predicted and Measured Water Elevation at Holden Beach during Hurricane Ian 2022 (source: Holden Beach Hohonu real-time gage)

Fortunately only moderate damage and impacts were observed on Holden Beach following Ian. Effects to the Holden Beach shoreline as a result of Hurricane Ian will be assessed in more detail with the next annual monitoring survey effort in April 2023.

2.9 USACE FEDERAL BCB/CSDR POTENTIAL PROJECTS

The USACE Brunswick County Beaches (BCB) project has been re-initiated and is in the early of stages of the Corps study. This is a 50-year coastal storm damage reduction (CSDR) project similar to the USACE CSDR projects up and down the coast (e.g., Ocean Isle, Wrightsville Beach, Carolina Beach, etc.). The BCB project has historically included Holden Beach, Caswell Beach and Oak Island however the current Corps study is only for Holden Beach.

The USACE Wilmington District received additional funding for Hurricane Florence recovery efforts and while Holden Beach restoration was a researched alternative for this funding (as well as other NC beaches), they ultimately were not chosen.

This USACE funding was officially from the "Additional Supplemental Appropriations for Disaster Relief Act, 2019" and more commonly referred to as PL116-20. The Town is currently moving forward alone in this process (i.e., nourishment on Holden Beach only) as are the other historical BCB communities. Town and ATM staff are coordinating with Corps staff to ensure that the Corps are working with the most recent and up-to-date data on the beach and borrow areas.

2.9.1 SACS PROJECT

The USACE South Atlantic Division (SAD) recently released (September 2020) a sand needs summary report for the Southeast. ATM and Town staff have coordinated with researchers. In general, the Sand Availability and Needs Determination (SAND) assessed sand nourishment needs as well as available offshore borrow area sand. A figure showing Brunswick County summary results is provided (Figure 2-33). Overall result for Brunswick County is that the 50-year sand need exceeds known borrow area sand reserves. Much more information can be found here: https://www.sad.usace.army.mil/SACS/

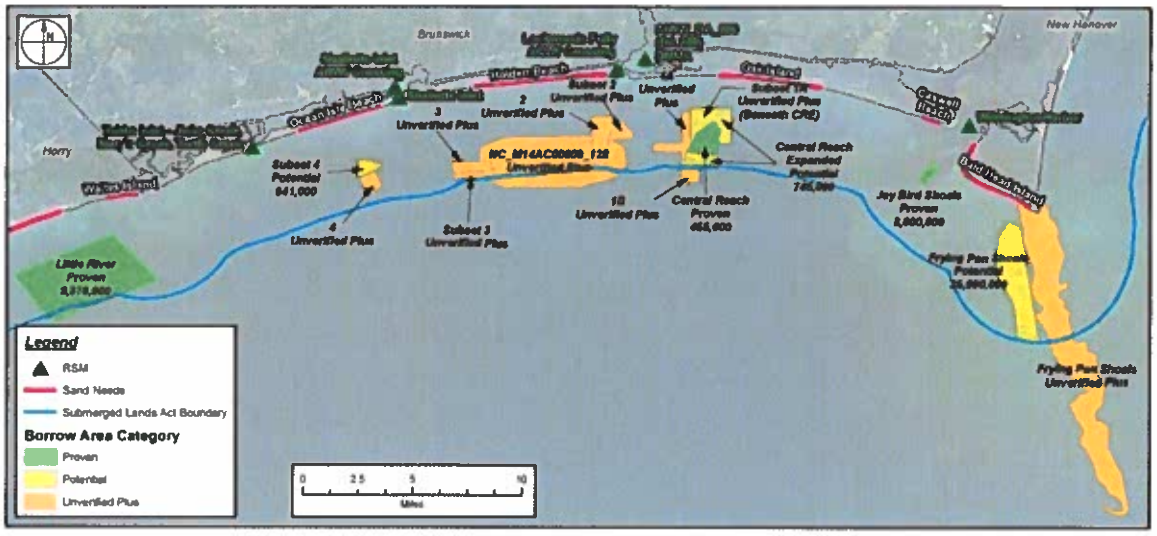


Figure 2-33. SACS summary figure for Brunswick County.

Related to the SACS study, the USACE has approached Holden Beach for interest in using Frying Pan Shoals as a sand borrow area. This would be a multi-beach project including other local islands. Two meetings occurred in 2020 and 2021 with the USACE and other agencies to preliminarily discuss the use of Frying Pan Shoals. Overall, Frying Pan Shoals is too far (~15 miles) for an individual beach nourishment on Holden Beach however additional research into this borrow area source by BOEM is encouraged.

In 2022, BOEM has coordinated with town and ATM staff (among other towns/interests) in collecting data 3 to 8 nautical miles offshore (i.e., in federal waters). This data collection is focused on identifying sand resources. The collection is expected to be underway however it is not known when the data will be available for end-users. Once complete, the offshore data may reveal potential borrow areas (which will then require permitting-level data collection and analysis).

2.9.2 WILMINGTON HARBOR DEEPENING

The State Port Authority (SPA) would like to deepen the Wilmington Harbor by 5 ft (from 42 ft to 47 ft MLLW) to allow for larger vessels and remain competitive with other ports along the eastern seaboard. The SPA recently released a preliminary report on the proposed project. While annual maintenance dredging is typically composed of mud and fines, "new work" dredging can contain beach-compatible material. This was the case for the 2001/2002 Wilmington Harbor deepening, where 525,000 cy of material was placed on

Holden Beach (in addition to other nearby beaches). In reviewing the preliminary report, no official volume of beach-compatible material was provided, however, Town staff have participated in deepening meetings and have made it known that the Town would like to receive beach-compatible sand, if feasible quantities are available. The project is currently slated for construction in 2024.

See the following link for more information:
https://www.saw.usace.army.mil/Missions/Navigation/Dredging/Wilmington-Harbor/WHNIP_203_Study/

2.10 INLET HAZARD AREA UPDATE

DCM has developed new State inlet hazard areas (IHAs) that include Shallotte and LWF Inlets. The current IHAs were established in 1978. IHAs are defined as shorelines especially vulnerable to erosion and flooding, where inlets can shift suddenly and dramatically. IHAs do not affect FEMA flood maps or the National Flood Insurance Program (NFIP), however, they do affect some State regulations related to erosional setbacks.

Revised IHAs were previously introduced around 2010, however, these were never implemented. Similarly, the currently proposed 2019 IHAs were scheduled to be implemented in 2020/2021. However, these also appear to be under additional internal review and have not been implemented (and are listed as "pending" on the DEQ website). The 2019 proposed IHAs are expanded for Shallotte and LWF Inlets (as with most of the IHAs statewide). In general, the new methodology for the IHA determination appears reasonable for the east end of Holden Beach bordering LWF Inlet, however, the west end (adjacent to Shallotte Inlet) is accretional and the IHA methodology is overly conservative. The "hybrid-vegetation" line along the west end is decades old.

Figures 2-34 and 2-35 present the proposed IHAs affecting Holden Beach. More information on this topic is available at https://deq.nc.gov/about/divisions/coastal-management.

Figure 22. Shallotte Inlet at Holden Beach Hybrid-Vegetation Line and the recommended IHA boundary with the 30- and 90-Year Risk Lines. Black dashed line indicates Transect-90 where the IHA boundary was adjusted to match the existing IHA line (yellow dashed line).

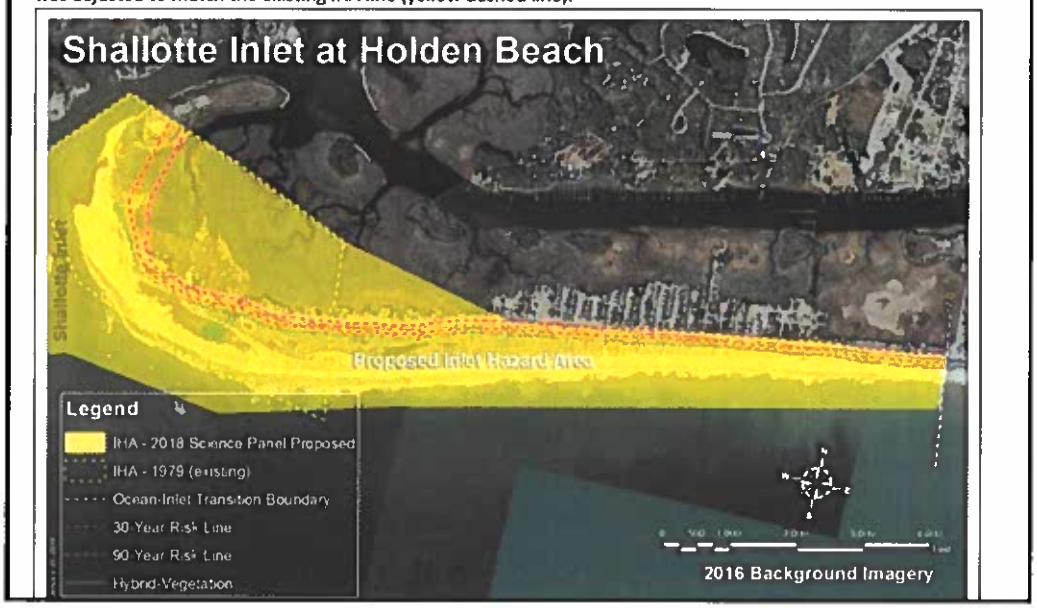


Figure 2-34. Proposed IHA for the west end of Holden Beach (image source: 2019 DCM IHA report)

Figure 26. Lockwood Folly Inlet at Holden Beach Hybrid Vegetation Line and the recommended IHA boundary with the 30- and 90-Year Risk Lines.

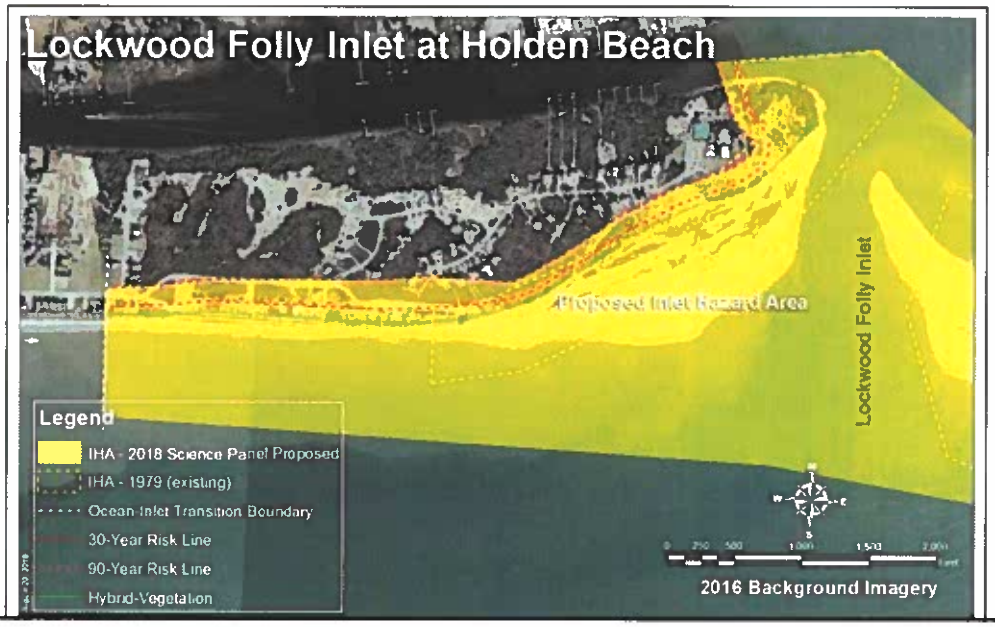


Figure 2-35. Proposed IHA for the east end of Holden Beach (image source: 2019 DCM IHA report)

2.11 BEACH MANAGEMENT PERMITS

The Town currently has several projects that have required or do require permits, including:

- LWFIX and Bend-Widener
- LWF Outer Bar (side-casting, shallow draft hopper)
- Upland Borrow Area
- Central Reach Reimbursement (CRR) Project (using offshore borrow area)

In general, DCM/CAMA prefers to modify the beach nourishment permit initially obtained by the Town in 2002 (permit number 14-02). This follows modifications that included the 2008 and 2009 Town nourishments using the Smith borrow site. The offshore borrow areas are included in this DCM permit. The DCM permit 14-02 expiration date is December 2024.

In contrast to DCM, the USACE typically creates new permits for each project (upland fill, LWFIX, CRP). The USACE permit for the upland borrow area nourishment project (SAW 2005-00935) was extended in 2009 and again last year. This permit now expires on December 31, 2024, and currently allows the placement of 64,000 cy of upland borrow material. Other projects including the offshore borrow area can be requested as a modification under this existing permit where the USACE generally chooses to create a new permit under the programmatic general permit (PGP) mechanism.

The NCDWQ permits are project specific and generally follow the lead of DCM/CAMA. The USACE, DCM and DWQ generally coordinate to avoid any permit condition conflicts. If any future modifications are needed, it is anticipated that coordination will be needed with all these agencies. Agencies have been amenable to permit modifications and extensions related to beach fill placement location and permitted borrow areas (Turkey Trap, Smith Site, Boyd Site, and Central Reach) in the past.

On a similar note, the County's special exception permit to operate a mine in Brunswick County for the Turkey Trap Road borrow area has no expiration date. The Smith borrow site is a water feature for a residential development; therefore, a special exception permit is not needed (although this can be determined by regulatory interpretation). Also note that the Smith upland site could be developed at any time (and of no future use as a borrow source). Upland borrow areas need to be reviewed by the Division of Land Resources, which oversees mining operations in the State. The Town renews the mining permit as necessary.

As discussed in Section 2.5, the Town obtained permits in 2016 to perform SDI projects, including LWFIX dredging and beach placement, as well as outer-channel sidecast dredging. The State permit (DCM 52-16) and USACE permits expire in 2026 (following a few extension requests).

3.0 ANNUAL SURVEY RESULTS

3.1 SURVEY RESULTS

Beach surveys are performed annually as a part of the Town's Beach Management Plan and span from LWF Inlet to Shallotte Inlet. Figure 3-1 presents the stationing and transects established by the monitoring plan. Survey data were collected in April 2022 at 51 transects along Holden Beach, following both the Town CRR and the USACE LWFIX nourishment projects. Beginning with the April 2020 survey, three new Shallotte Inlet transects were established and surveyed along the far west end of Holden Beach for additional monitoring of the west end shoreline and Shallotte Inlet related effects.

This annual survey also included an additional seven transects on western Oak Island. The monitoring of these additional Oak Island transects began with the 2012 survey to more closely monitor inlet-related effects and establish more consistent baseline data. Similar to historical trends on the west end of Holden Beach, the west end of Oak Island is generally stable; however, inlet dynamics and major storms have the potential to affect this area.

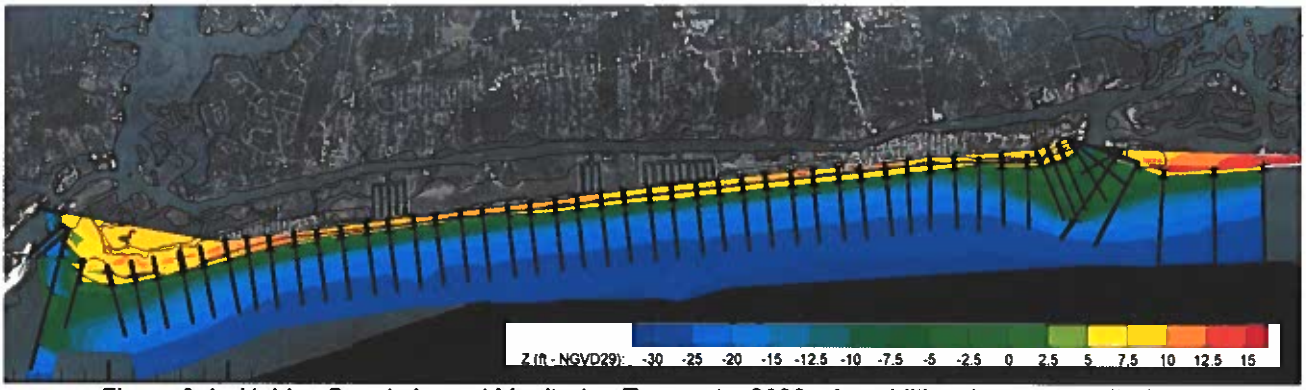


Figure 3-1. Holden Beach Annual Monitoring Transects, 2022. An additional seven monitoring transects have also been added to western Oak Island beginning with the 2012 survey and three additional Shallotte Inlet transects were recently established beginning with the 2020 survey. Note "Z" is in ft-NGVD29.

Figures 3-2 and 3-3 present example transect surveys comparing April 2021 and April 2022 survey data. Figure 3-2 also shows the April 2020 and April 2021 survey comparison to illustrate typical changing sediment transport patterns since the 2020 USACE LWFIX project, and the April 2022 survey shows a typical profile view of the beach following the Town's recent 2022 Central Reach Reimbursement and the USACE 2022 LWFIX project.

The CRR placement extended from Station 40+00 to just east of Station 270+00 and adjoins the USACE 2022 LWFIX on the east end which placed material approximately from Station 40+00 to Station 20+00. Note that CRR placement west of Station 235+00 represented a reduced template due to project logistics with respect to USACE regional South Atlantic Regional Biological Opinion (SARBO) limitations.

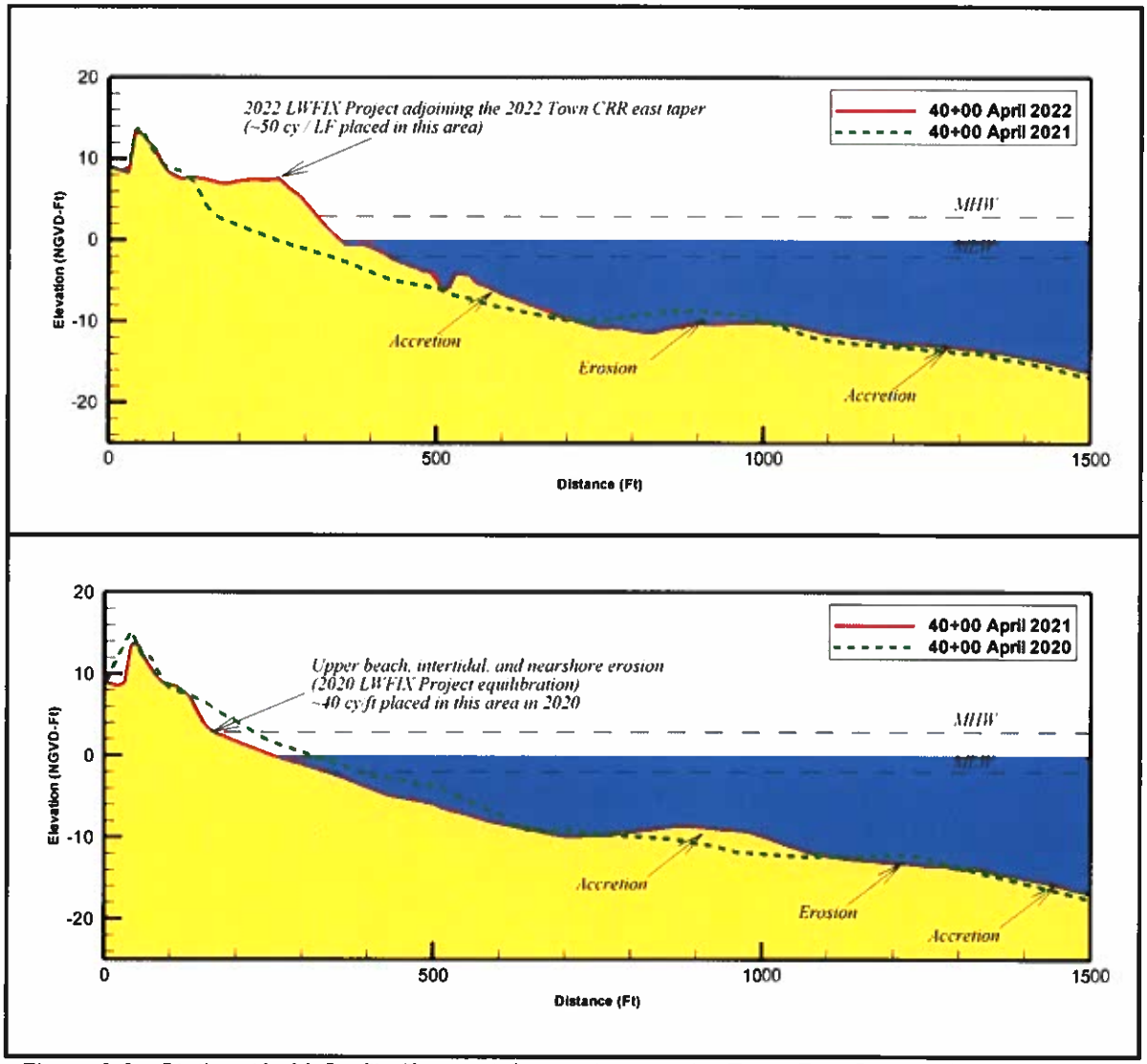


Figure 3-2. Station 40+00 Profile Transect Comparison on the Town East Reach of Holden Beach. Lower panel shows 2020-2021 survey comparison showing a largely erosional beach and continued equilibration of material from the previous USACE LWFIX nourishment in 2020. Upper panel shows 2021-2022 comparison, displaying the recently placed 2022 CRR nourishment and 2022 USACE LWFIX material. This location is near the eastern taper of the CRR template where it adjoined the USACE LWFIX project.

Note that some differences in profiles may be related to recent wave activity and/or nourishment activities and are not necessarily indicative of long-term trends. Appendix A contains all transect data for the 2021 and 2022 annual monitoring surveys.

Figure 3-3 shows a profile view within the Central Reach Reimbursement project area. Building upon the 2017 Central Reach Project, the CRR project has significantly widened the beach within the Central Reach.

Similar to the 2017 CRP, the 2020 CRR nourishment will provide a beneficial sand source for the downdrift shorelines to the west as this material equilibrates. The newly constructed secondary berm along with the vegetation and sand fencing efforts will help to enhance the dune system which had experienced some damage due to Hurricane Isaias in 2020 and again to Hurricane Ian in 2022.

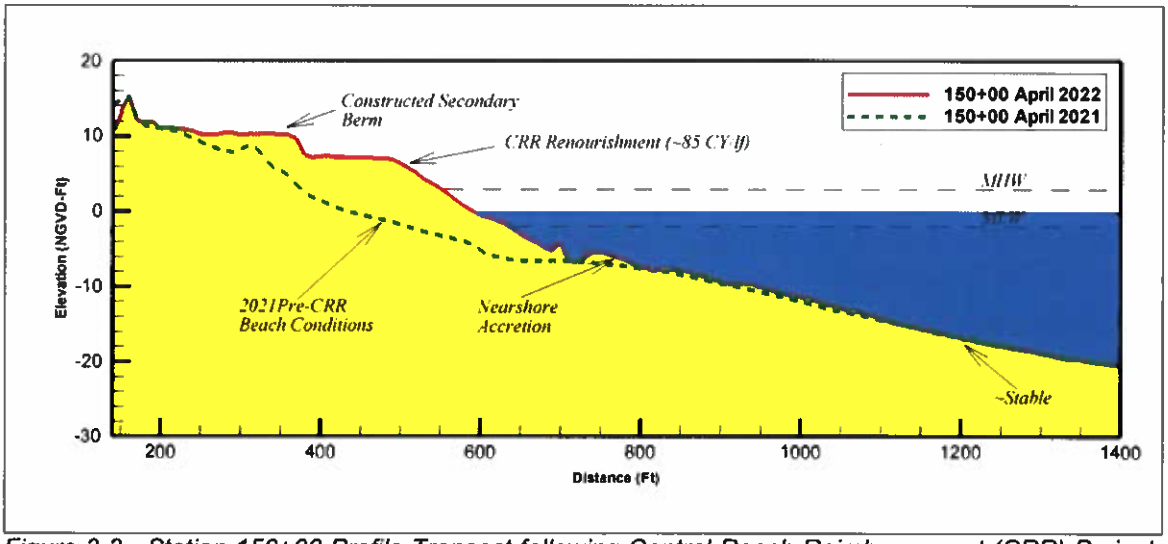


Figure 3-3. Station 150+00 Profile Transect following Central Reach Reimbursement (CRR) Project. Central Reach Reimbursement nourishment placed approximately 85 cy/lf in this area.

In general, comparison of the 2021 and 2022 surveys reveals a stable to mildly erosional beach for areas west of the 2022 Central Reach Reimbursement project area. However, some upper and intertidal beach accretion was observed in the western reaches as the downdrift shoreline continues to benefit from the 2017 Central Reach Project.

Significant accretion was observed within the CRR and USACE LWFIX project areas, as expected. As both projects were completed this past spring, this 2022 survey represents immediate post-construction conditions.

Some nourishment sand from the 2022 projects is expected to move nearshore as the constructed profile "smooths out" approaching an equilibrium beach profile. Longshore transport patterns are generally east to west and therefore lateral spreading of the placed material is expected to benefit the shorelines downdrift (west of) the Central Reach. Future monitoring will help to quantify movement and spreading benefits of the CRR nourishment.

The east end, which historically displays more erosional conditions, was accretional over the past year. This is largely in part due to the USACE LWIFX nourishment of ~115,000 cy of sand placed between stations 20+00 and 40+00 as well as recent shoal movement near Lockwood Folly Inlet.

Figure 3-2 reveals that some minor movement of material has occurred in areas farther offshore and beyond the -12 ft contour. The -12-ft contour has historically been considered the DOC for Holden Beach, barring major hurricanes. Significant changes have been observed beyond the typical DOC in recent years and will continue to be monitored.

Sections 3.2 and 3.3 provide more information on volume and shoreline analysis, respectively.

3.2 VOLUME ANALYSIS

Figure 3-4 presents changes in volumes from April 2021 to April 2022 along the entire beach. Volumes are quantified by comparing profile volumes from successive surveys. The USACE Beach Morphology Analysis Program (BMAP) was used to compute changes in profile volumes for each profile and for all surveys during the monitoring period.

Figure 3-4 shows significant accretion along the eastern half of the shoreline where nourishment activities took place. Erosion is observed in the far western reaches. The most significant erosion over the past year was observed near the inlets, which is not atypical as inlet dynamics often cause significant volumetric fluctuations. Overall, a very healthy beach

is observed over the past year and continued spreading benefits are expected to mitigate the erosional trend seen along the western shorelines.

A mostly stable beach is observed just west of the CRR project area with a pattern of increasing erosion observed moving westward towards Shallotte Inlet, with some variation from station to station. This variation is due to survey precision as well as seasonal variation, and recent wave activity. Additional variation may also be attributed to undulating patterns along the shoreline, which have been documented along nearby beaches[1].

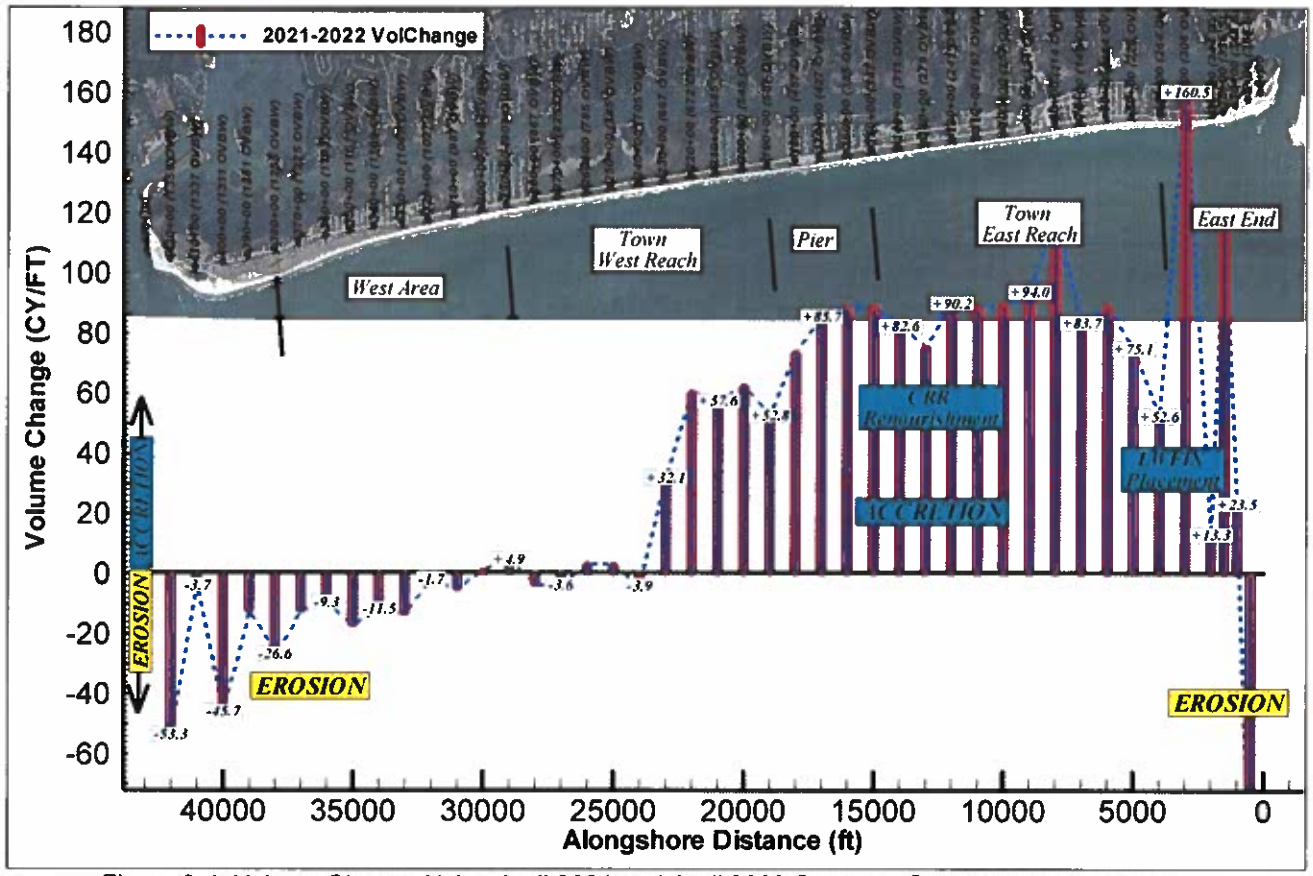


Figure 3-4. Volume Change Using April 2021 and April 2022 Surveys. Positive values indicate accretion, negative values indicate erosion. Note significant accretion observed throughout the Central Reach and East End due to the recent CRR and LWFIX nourishments. A stable beach is observed west of the CRR with a pattern of generally increasing erosion moving westward. The most significant erosion over the past year is seen near the inlets.

[1] PARK, J.-Y.; GAYES, P.T., and WELLS, J.T., 2009. Monitoring beach renourishment along the sediment-starved shoreline of Grand Strand, South Carolina. *Journal of Coastal Research*, 25(2), 336–349. West Palm Beach (Florida), ISSN 0749-0208

The western reaches have been typically more stable and oftentimes accretional in the past. The erosion observed between 2021 and 2022 is likely due to the recent wave and elevated water level conditions brought by winter storms. Noting that Hurricane Ian (which is not captured in the annual survey data herein) did affect the dune to varying degrees along the entire shoreline.

Although erosion was observed in the far western reaches over the past year and has been documented in recent years, the continued beneficial spreading of 2017 nourishment material outside of the Central Reach Project footprints is evidenced by the exhibited volumetric stability and accretion in the areas downdrift / west of the 2017 CRP area, seen particularly in the upper and intertidal beach. The western extent of the 2017 CRP nourishment ended at about Station 260+00.

A trend of beneficial spreading is expected to continue and accretion to the western reaches is anticipated as the recently placed 2022 CRR nourishment material equilibrates and spreads west. The 2022 CRR also ended at about Station 260+00, however, a smaller volume of sand was placed than in 2017.

The volumes calculated in Figure 3-4 are from the dune out to about the -12-ft NGVD contour, which represents the typical (non-hurricane) DOC limit. The DOC essentially represents the depth limit where sand along the seabed stops moving. In general, the vast majority of sand transport and profile change typically occurs in waters shallower than the DOC, such as the surf zone and intertidal beach.

During periods of significant energetic wave conditions, however, changes to the beach profile can occur beyond the DOC limit. Therefore, the DOC can vary annually and seasonally depending on storm activity, and extreme storms can move material out to depths of 30 ft. Past recent surveys have shown more significant changes in locations seaward, deeper than the -12-ft contour and even beyond -20-ft contour as well, due to Hurricanes Florence and Michael in 2018. Note that for FEMA mitigation calculations for Hurricanes Florence and Michael, FEMA representatives did not want to use the -12-ft DOC and a -20-ft DOC was mutually agreed upon and was also used for FEMA mitigation from Hurricanes Dorian (2019) and Isaias (2020).

Changes in these deeper areas (beyond -12 ft, and even beyond -20 ft) will continue to be monitored to assess any potential future volumetric impacts of sediment transport for Holden Beach. In addition to the recent nourishment activities, the beach has shown continued signs of volumetric growth and recovery offshore beyond the surf zone resulting in an overall mostly stable to accretional beach even out to -20 ft.

Figure 3-4 identifies several smaller shoreline reaches (e.g., West Area, Town West Reach, Pier, Town East Reach) along Holden Beach. The east end is historically highly erosional due to Lockwood Folly Inlet dynamics. Over the last 5 years, the east end has benefitted from the eastward spreading of the 2017 CRP and 202 CRR nourishments as well as USACE LWFIX east end nourishments.

As expected, substantial accretion is observed in the Central Reach where the recent nourishment took place, from the Town East Reach to about midway through the Town West Reach. A mostly stable beach and only minor changes are observed in the western half of the Town West Reach, likely due to continued downdrift spreading from the 2017 nourishment.

Erosion occurred in the West Area towards the west end (see Figure 3-4), but the dune system is still over several hundred feet wide in this area and spreading of CRR sand is expected to benefit this area as the recent project equilibrates.

Similar to the extreme east end, more significant erosion is observed near Shallotte Inlet on the west end from inlet dynamics and recent shoal movement. The west end fortunately has a large and wide dune system that can buffer several years of erosion. As with any inlet, this area can be susceptible to episodic erosion.

Additionally, Shallotte Inlet dredging activities have been documented to have adverse impacts on Holden Beach shorelines in the past and, therefore, this area is monitored for any potential impacts related to the borrow area and any continuing erosional patterns. Shallotte Inlet was recently dredged for a nourishment on Ocean Isle (in conjunction with the Ocean Isle terminal groin construction), as reflected in the April 2022 survey transects (refer to Appendix A). Though the Holden Beach shoreline along Shallotte Inlet appears mostly healthy over the past year, the channel was dredged approximately 1,000 ft away from

Holden Beach and could affect sediment processes here. This area will continue to be monitored for potential negative impacts the dredging (or groin) may have on the Holden Beach side. Ocean Isle will submit monitoring related to the terminal groin and nourishment using Shallotte Inlet this spring to the town and ATM staff (among others). More discussion on this topic is presented in Section 3.3.

Volume calculations were also performed from the dune to the -5 ft NGVD contour, which represents the approximate typical surf-zone limit. The -5-ft volume limit is more characteristic of visible/tangible beach conditions than the deeper -12-ft or -20-ft limits that can occur more than a quarter mile offshore.

Figure 3-5 presents the two different boundaries historically used for volume calculations and illustrates some of the intertidal and nearshore erosion in the surf zone that was observed in the West Area at Station 350+00, considerably far downdrift/west of the 2017 CRP and the recent 2022 CRR placements (which both ended near Station 260+00). Figure 3-5 also shows some upper beach accretion is observed in the far western reaches, likely a result of continued downdrift moving of the 2017 CRP material. As previously mentioned, volumes out to -20 ft deep are also calculated.

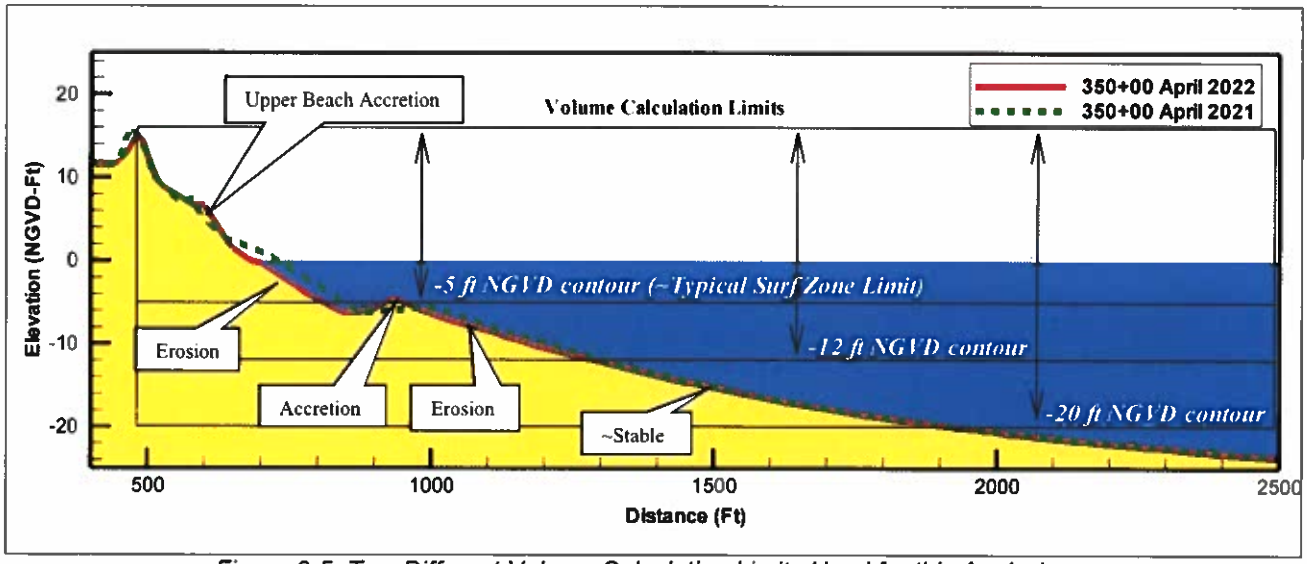


Figure 3-5. Two Different Volume Calculation Limits Used for this Analysis: 1) Dune to -12 ft NGVD and 2) Dune to –5 ft NGVD.

Little movement beyond the -12 ft contour occurred, compared with recent years where large storms (e.g., Hurricane Dorian) caused more significant movement in offshore areas.

Table 3-1 presents volume changes estimated by the reaches identified in Figure 3-4 (i.e., East End, Town East Reach, Pier, etc.) from 2021 to 2022. As expected, accretion was significant for most of the island due to the 2 nourishment projects with an island wide gain island-wide gain of 1,574,000 cy of sand out to the -12-ft DOC limit.

Note that the survey area is not a closed system and identifying sediment transport direction can only be inferred based on measured volume change and engineering judgment.

Table 3-1. Volume Change by Shoreline Reach for 2021 and 2022 Surveys

Reach Averages	Stations Included	**Total Volume Change (cy) (Dune to -12 ft NGVD)**	Dry Beach/Surf Zone Volume Change (cy) (Dune to -5 ft)	Surf Zone/Depth-of-Closure Volume Change (cy) (-5 ft to -12 ft NGVD)*
LWF Inlet	5 to 15	+15,000	+21,000	-6,000
USACE East	15 to 40	+227,000	+149,000	+78,000
Town East	40 to 150	+958,000	+852,000	+106,000
Pier	150 to 190	+319,000	+293,000	+26,000
Town West	190 to 290	+237,000	+233,000	+4,000
West Area	290 to 380	-80,000	-16,000	-64,000
Shallotte Inlet	380 to 420	-102,000	-5,000	-97,000
	TOTAL	**+1,574,000**	**+1,527,000**	**+47,000**
Central Reach	40 to 290	**+1,514,000**	**+1,378,000**	**+136,000**

*Negative values indicate likely sediment movement from surf zone/depth-of-closure area to dry beach/surf zone area and/or nourishment spreading effects.

As Table 3-1 shows, accretion occurred at all depths within the USACE East to the Town West reaches over the past year. The majority of erosion along Holden Beach out to -12 ft occurred within the West Area and Shallotte Inlet reaches, and in general these reaches experienced less erosion (or more accretion) within the dry beach to surf zone area (dune to -5 ft region), likely due to continued spreading of 2017 CRP material. The LWF Inlet reach experienced overall accretion out to -12 ft, though erosion was observed typically in the surf zone to depth of closure limit (-5 ft to -12 ft region), likely due to shoal movement and inlet effects.

Historical volume changes back to 2012 for the Central Reach (Stations 40+00 to 290+00) and the entire Holden Beach shoreline, calculated from the dune to the -12-ft NGVD DOC are provided in Table 3-2a. The most significant volume losses were observed between 2015 and 2016, largely due to a year of higher-than-normal wave activity, as well as

Hurricane Joaquin in October 2015, and between 2019 and 2020 due to Hurricane Dorian in September of 2019.

Of course nourishment activities have considerably ameliorated conditions along the Holden Beach shoreline, as seen following the 2014 east end nourishment, the 2017 Central Reach and Town/USACE LWFIX nourishments, and the recent 2022 Central Reach Reimbursement and USACE LWFIX projects. The 2022 CRR project now represents the largest beach renourishment project on Holden Beach to date and as a result, the Central Reach experienced a gain of 1,514,000 cy over the past year out to the -12 ft DOC.

Table 3-2a. Historic Volume Changes (cy) (Dune to -12 ft NGVD) by Year

Reach Averages	2012-2013 Total Volume Change (cy)	2013-2014* Total Volume Change (cy)	2014-2015 Total Volume Change (cy)	2015-2016 Total Volume Change (cy)	2016-2017* Total Volume Change (cy)	2017-2018 Total Volume Change (cy)	2018-2019 Total Volume Change (cy)	2019-2020 Total Volume Change (cy)	2020-2021 Total Volume Change (cy)	2021-2022 Total Volume Change (cy)
Central Reach	-14,000	94,000	62,000	-238,000	1,386,000	231,000	-142,000	-397,000	92,000	1,514,000
Entire Beach	-73,000	235,000	-11,000	-358,000	1,479,000	440,000	191,000	-821,000	59,000	1,574,000

*2013-2014, 2016-2017, and 2021-2022 show large gains in total volume due to nourishment activities

Table 3-2b presents the 2017 CRP nourishment performance since construction, which now also includes the 2022 CRR. As noted in the table, over 1 million cubic yards was measured to remain in the project area prior to the 2022 CRR. This is largely due to relatively milder years in 2017/2018 and 2021, while LWFIX nourishment activity can also have a positive effect. Fortunately, the CRP has held up well providing a good base of pre-project beach for the 2022 CRR project to expand on and now over 2.6 MCY of material are measured in the Central Reach since 2017 with the two Central Reach nourishments combined.

The effective storm buffer and protection provided by the 2017 CRP has been demonstrated in each of the major storm events over the past few years, and the recent CRR nourishment was conducted with this goal in mind for future storms.

Table 3-2b. Central Reach Volume Change and Volume Remaining (cy) since 2017 Nourishment Project (Dune to -12 ft NGVD)

	2017	2018	2019	2020	2021	2022
Volume Change (cy)	+1,386,000	+231,000	-142,000	-397,000	+92,000	+1,514,000
Central Reach Total Volume Remaining (cy)	+1,386,000	+1,617,000	+1,475,000	+1,078,000	+1,170,000	+2,684,000

As mentioned previously, the east end area (Stations 5+00 to 40+00) is historically erosional especially at the known erosional hotspot near Station 20+00 (near the Town's eastern-most oceanfront house called *Amazing Grace*).

In general, monitoring stations east of Station 40+00 can exhibit highly variable changes based on inlet dynamics and USACE fill activities (timing, volume, placement, etc.). Sidecasting and outer inlet maintenance (or lack thereof) also have an effect.

Several past shoal attachments (documented in previous annual reports) have contributed to localized low-tide beach expanses on the east end in previous years. These shoal attachments have been estimated to be between 5,000 and 50,000 cy and can provide a significant benefit to the sand (littoral) system. These shoals can also create erosional hotspots, depending on their distance from shore, size, attachment location, etc.

Volume change calculations show the USACE East Reach (Stations 15+00 to 40+00) overall is accretional over the entire dune to the DOC zone and exhibited a gain of about 227,000 cy of material. This large addition of material came from the recent 2022 USACE LWIFX project as well as shoal and bar movement within the surf zone to the depth of closure region along the shoreline closer to Lockwood Folly Inlet.

Due to the recent 2022 LWFIX project, this reach of shoreline features a wide and healthy beach (see Figure 3-6) and will fortunately benefit from spreading of the 2022 CRR nourishment as well as additional material in upcoming LWFIX nourishment projects.

The LWF Inlet Reach (Stations 5+00 to 15+00) experienced approximately 15,000 cy of accretion, likely due to spreading of the previous LWFIX project material from 2020 and inlet dynamics. Significant erosion did occur at Station 5+00, however, this was primarily in the

surf zone to DOC limit due to inlet effects and channel shifting. The upper beach experienced relatively minor erosion.

Figure 3-6. Recent Photograph of East End Beach Conditions Taken between Stations 20+00 and 30+00 Looking West (Upper Photo) and East (Lower Photo). 2022 LWIFX Placement Showing Wide Beach Present in What Is Typically an Erosional Hotspot Area (Photos Taken April 2022).

The West Area (Stations 290+00 to 380+00) is historically stable and has never been nourished but passively receives much of the Central Reach nourishment sand as it migrates westward (net sediment transport direction). The 2022 survey showed the West Area overall lost about 80,000 cy of material in the dry beach to the DOC area (dune to -12 ft) over the past year. Significantly less erosion (or more accretion) took place in the dry beach to surf zone area (dune to -5 ft NGVD), as some upper beach accretion and healthy

dune growth has continued over the past year in spite of an overall erosional trend seen in the past year (see Appendix A). This area in the past showed some of the largest observed dry, upper beach growth in the years following the 2017 CRP, which is expected to occur in future years from downdrift spreading of 2022 CRR material.

The beach west of Station 380+00 to Shallotte Inlet is subject to episodic erosion, typically with the largest fluctuations along the shoreline closest to the inlet. This reach experienced volumetric erosion between 2021 and 2022, with a total loss of 102,000 cy. Fluctuations in volumes in this region can be attributed to net westerly sand transport, shoreline undulations, inlet-related processes (including shoreline orientation/curvature and shoal formation), and extreme storm conditions. This reach also passively receives migrating CRP sand and will benefit from the 2022 CRR material as well as in future years.

3.3 SHORELINE ANALYSIS

In addition to a volumetric analysis, shoreline analyses were also performed as another useful metric in gauging beach health. Figure 3-7 was developed to view annual changes in the mean high water (MHW) shoreline contour along Holden Beach.

Average MHW shoreline change by reach is presented in Table 3-3. Similar to the volumetric analysis, the MHW shoreline reveals a largely accretional shoreline where the nourishment projects have vastly widened the beach. Within the Central Reach, the MHW shoreline accreted by approximately 142 ft overall. Figure 3-8 presents recent drone photos documenting Central Reach beach conditions showing the newly constructed wide berm and secondary berm with sand fencing and plantings.

The east end along Lockwood Folly Inlet shows erosion, which is typical in this area due to inlet effects. Accretion and mostly only minor erosion of the MHW shoreline was seen in the Western Reaches. The reaches west of the Central Reach show a generally stable MHW shoreline over the past year with some accretion occurring due to downdrift / westward alongshore spreading. The west end experienced variable erosion and large accretion close to Shallotte Inlet, due to inlet dynamics and shoal movement.

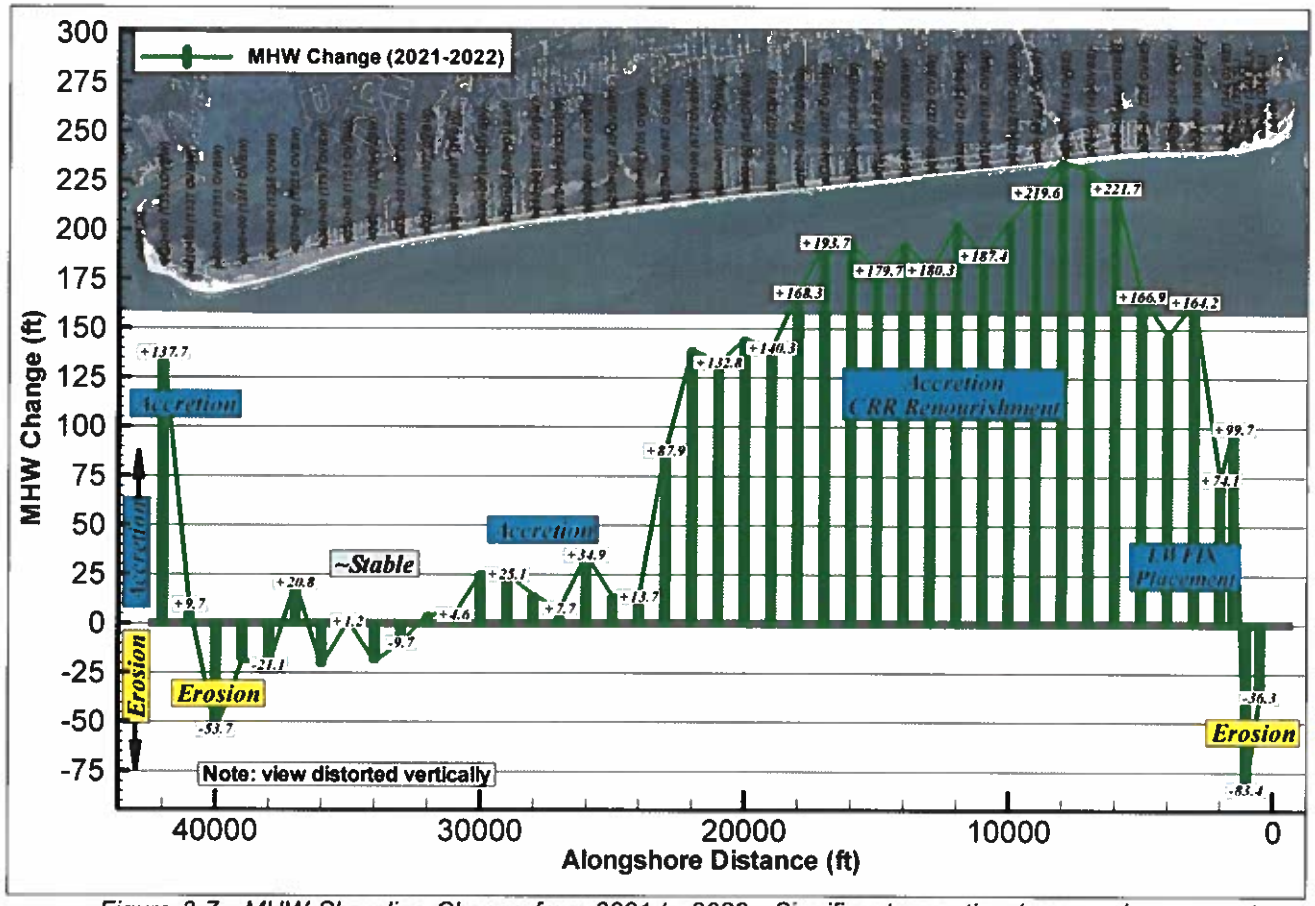


Figure 3-7. MHW Shoreline Change from 2021 to 2022. Significant accretion / seaward movement of the MHW shoreline within nourishment placements. A mostly stable to accretional MHW shoreline occurred along the western half of Holden Beach, with the exception of erosion / landward movement observed along the west end likely due to winter storm wave activity. Accretion observed at the far west end near Shallotte Inlet and erosion observed on the east end near Lockwood Folly Inlet (large fluctuations at the extreme east and west ends due to inlet dynamics).

Table 3-3. MHW Shoreline Change by Reach for 2021 and 2022 Surveys

Reach Averages	Stations Included	2021 to 2022 MHW Change (ft)
LWF Inlet	5 to 15	-6.7
USACE East	15 to 40	+128.5
Town East	40 to 150	+197.6
Pier	150 to 190	+175.1
Town West	190 to 290	+68.7
West Area	290 to 380	+1.1
Shallotte Inlet	380 to 420	-20.9
Central Reach	40 to 290	+141.6

Figure 3-8. Central Reach April 2022 Aerial Photos Taken Near Station 200+00 Looking West Towards Shallotte Inlet in Upper Panel and East Towards the Pier and LWF Inlet in the Lower Panel.

The western portions closer to Shallotte Inlet show mostly MHW shoreline erosion, though some accretion occurred particularly at the far west end due to inlet dynamics. Figure 3-9 presents the changes in the MHW position from 2021 to 2022 along the westernmost shorelines of Holden Beach. Appendix B provides figures of the 2022 survey MHW results for the entire Holden Beach shoreline.

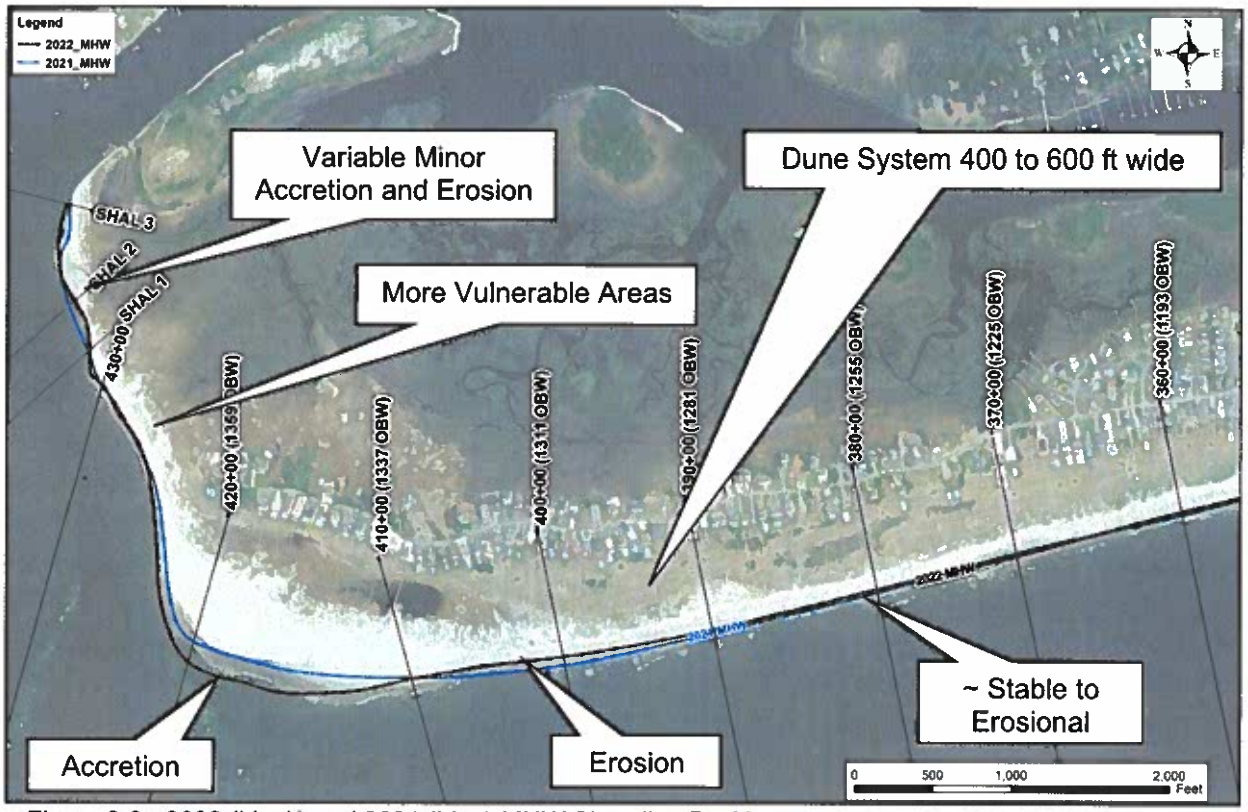


Figure 3-9. 2022 (black) and 2021 (blue) MHW Shoreline Positions along the West End of Holden Beach near Shallotte Inlet. "SHAL 1" begins at the same location as 430+00. (2021 aerial shown).

Despite volumetric losses observed in this area, the MHW line here has generally remained relatively stable and experienced mostly only mild erosion over the past year, with the exception of 420+00 which saw larger landward movement of the MHW line. The localized erosion is possibly due to sediment movement during energetic wave conditions and/or inlet related processes.

Although the MHW shoreline here was relatively stable over the past year, more significant erosion has been documented in recent years, and some significant dune scarping, dune walkover damage and vegetation loss was observed near this area following Hurricane Ian in 2022. Dune system widths in the West Area can be up to 600 ft; therefore, large fluctuations in volume and/or shoreline position in this area are still several hundred feet from residential structures. Ground photographs of recent conditions in West End are presented in Figure 3-10 showing a healthy upper beach and significantly wide vegetated dune system.

Figure 3-10. Recent Photographs of West End Beach Conditions Taken between Stations 350+00 and 360+00. Lower Photo shows view from beach looking west and Upper Photo shows upland view from walkover looking east over healthy wide vegetated dune system. (Photos Taken November 2022).

This area will continue to be closely monitored and future efforts to enhance vegetation may be implemented as a proactive measure to mitigate erosion. Beach scraping following a major storm event to rebuild the dune is also an option. Also, the substantial addition of material into the system from the 2017 CRP now combined with the 2022 Central Reach Reimbursement Project is expected to promote beach growth in this region as nourishment material continues downdrift spreading in years to come.

Several homes on the extreme western end of the Holden Beach, near Station 420+00 (approximately 1359 OBW) are close enough to Shallotte Inlet that close monitoring of inlet migration and USACE/Ocean Isle dredging activities in Shallotte Inlet is warranted.

Three additional monitoring transects (SHAL 1, 2, and 3) have been established along the west end of Holden Beach for detailed monitoring of Shallotte Inlet, which began with the April 2020 survey.

As previously discussed, the Ocean Isle nourishments typically use Shallotte Inlet as a borrow area. The most recent of these nourishment events occurred this past winter/spring (2021/2022) as part of the USACE Federal Coastal Storm Risk Management (CSRM) project, which coincided with construction of Ocean Isle Beach's terminal groin project (see Figure 3-11). This project included dredging about 700,000 cy from Shallotte Inlet and placement onto the eastern shoreline of Ocean Isle, west of the newly built structure. No noticeable changes to the Holden Beach shoreline have been observed based on April 2022 survey data, however, shoreline monitoring will continue to assess any potential effects of this and future activities on the Holden Beach shoreline. Groin-related monitoring of Shallotte Inlet (including the Holden Beach west end) will occur by Ocean Isle as required by permits.

Smaller (~50,000 cy) Shallotte Inlet AIWW dredging projects also place material on Ocean Isle when dredged material is beach compatible. These smaller dredging projects occur about every two years.

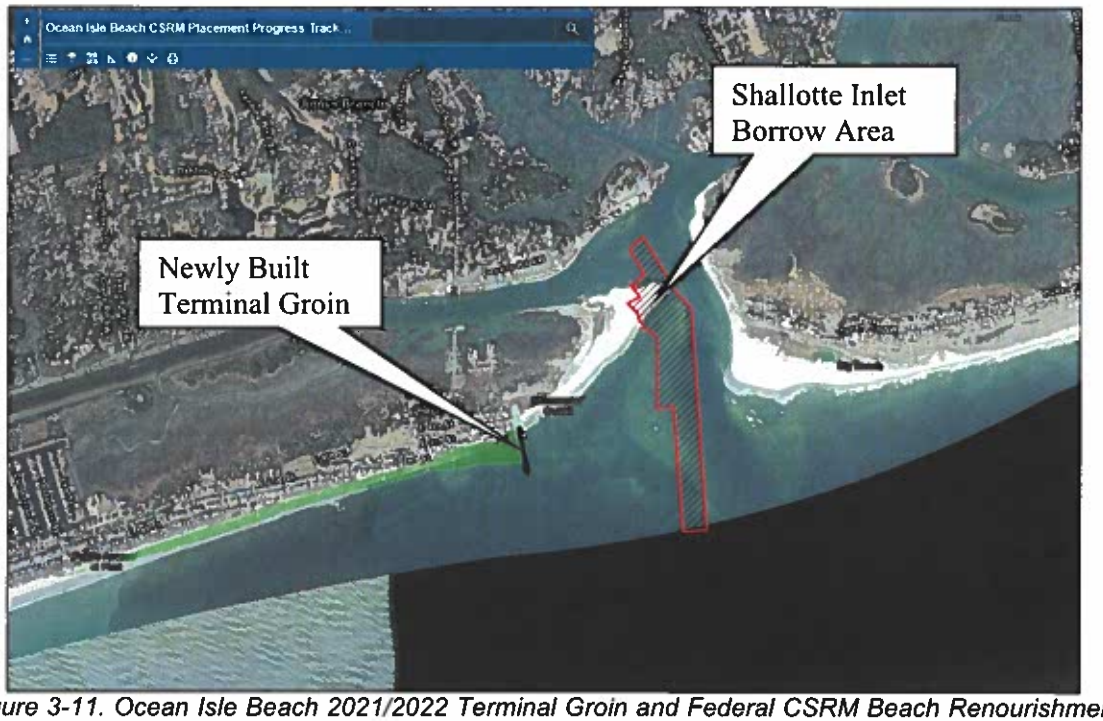


Figure 3-11. Ocean Isle Beach 2021/2022 Terminal Groin and Federal CSRM Beach Renourishment Projects. Shallotte Inlet Borrow Area and Placement Area Shown (USACE Ocean Isle Beach CSRM Placement Progress Tracker)

Similar to the volumetric analysis, the eastern end near LWF Inlet shows large MHW changes occurred in this area as a result of the recently completed renourishment projects. Figure 3-12 presents the changes in the MHW position from 2021 to 2022 along the easternmost shorelines of Holden Beach. The extreme east end, east of the 2022 LWFIX placement area, shows variable landward and seaward movement of the MHW shoreline from LWF Inlet dynamics, and the shoal attachment between Station 0+00 and Station 5+00 (documented in the 2019 monitoring report). The 2022 survey and more recent aerials and site observations reveal this shoal continues to be flattening and spreading out, which is benefitting the east end. Lateral spreading from equilibration of the 2022 nourishments will also benefit the far east end.

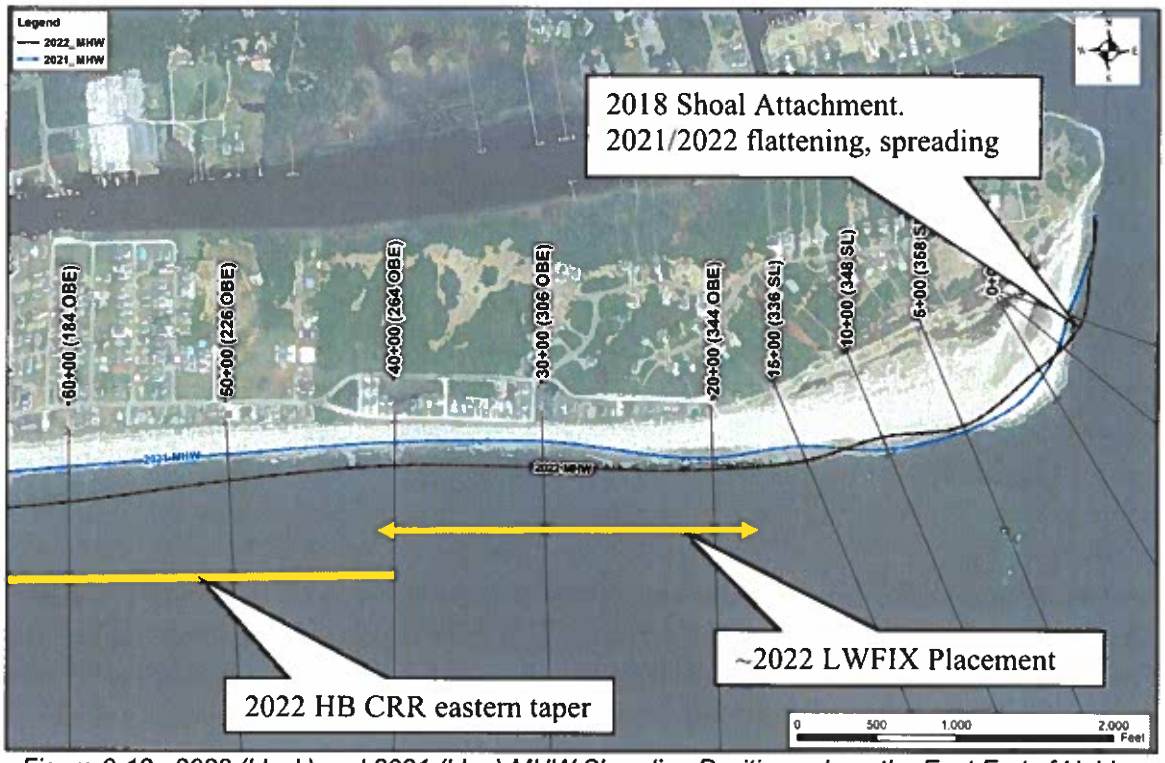


Figure 3-12. 2022 (black) and 2021 (blue) MHW Shoreline Positions along the East End of Holden Beach near Lockwood Folly Inlet. (2021 aerial shown).

The toe-of-dune (TOD) shoreline (7 ft NGVD contour) is shown on Figure 3-13 and generally represents the seaward edge of the dune. The TOD shoreline change shows some variable erosion and accretion changes on the east and west ends, but overall a mostly accretional trend, which was expected due to the CRR construction which included a secondary berm to promote dune growth. Areas of observed erosion can likely be attributed to wave activity over the past year. The west end dunes also suffered damage during Hurricane Ian and this recovery (or lack thereof) will be monitored.

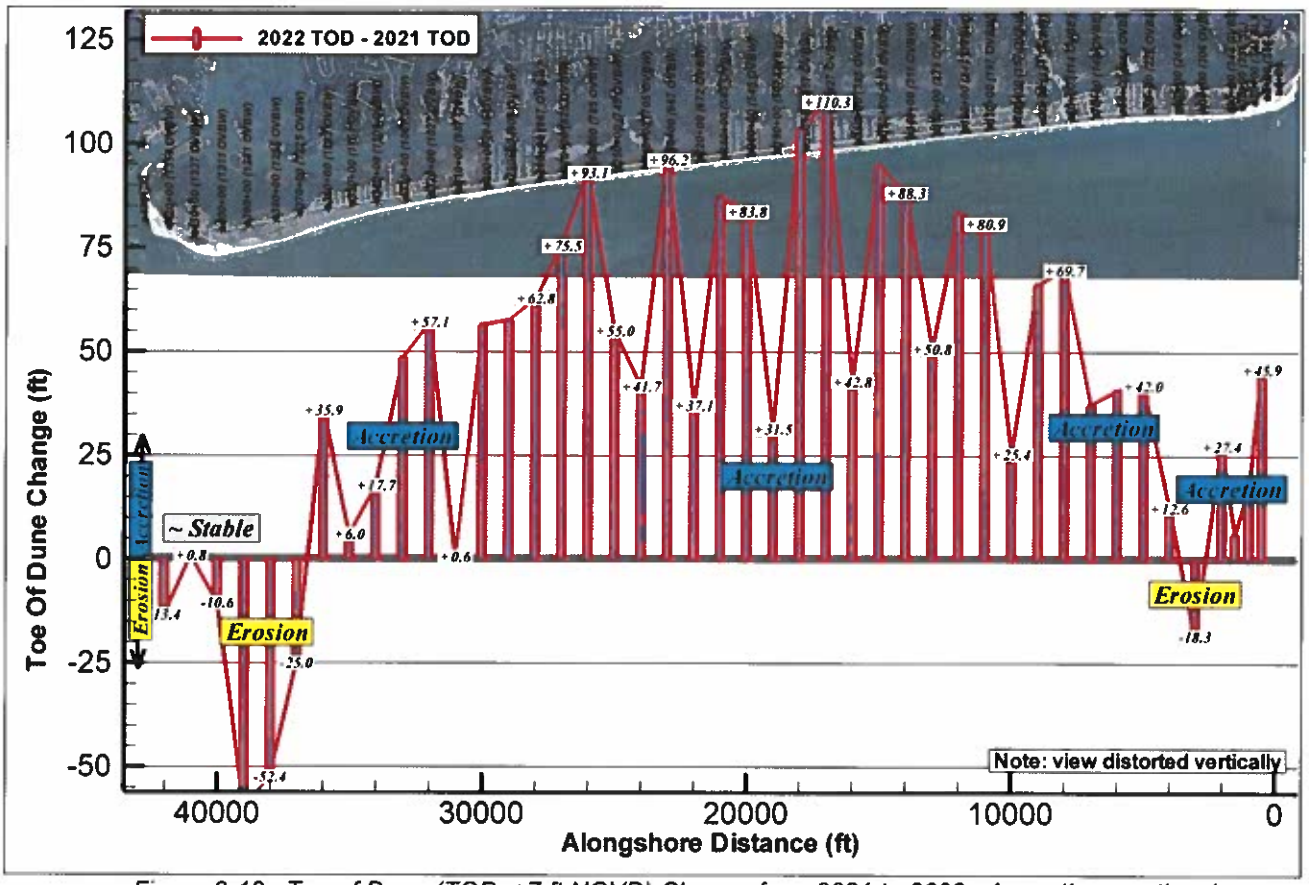


Figure 3-13. Toe of Dune (TOD, +7 ft NGVD) Change from 2021 to 2022. A mostly accretional beach trend is exhibited, though with variability and erosion near the east and west ends.

Figure 3-14 presents maximum dune heights for each Holden Beach station. Dune heights are generally healthy and were mostly stable over the past year. Proactive dune enhancements, discussed in Section 2.7, are an important activity related to maintaining a healthy dune system.

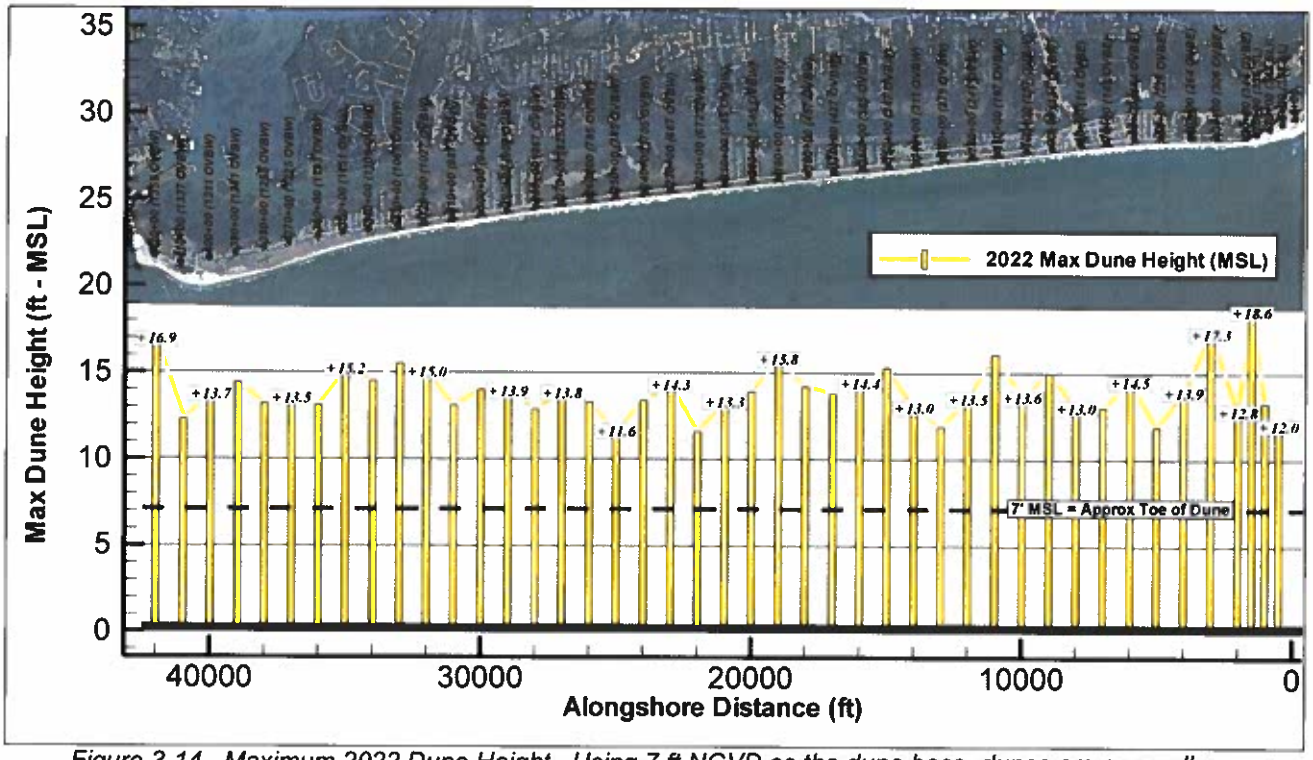


Figure 3-14. Maximum 2022 Dune Height. Using 7 ft NGVD as the dune base, dunes are generally 5' to 8' high.

3.4 HISTORICAL ANALYSIS

Figure 3-15 presents an approximately 22-year MHW shoreline comparison using 2000 and 2022 survey data. The 2000 survey represents a significantly erosional condition. A general accretional trend of 50 to 280 ft is exhibited for the MHW shoreline between 2000 and 2022 (not including the more variable inlet shorelines and east end nourishments).

The most recent DCM long-term background erosion rates from 2019 are included in Figure 3-15 for comparison purposes (DCM assigns a minimum long-term erosion of -2 ft/year). DCM 2019 erosion rates consider recent fill activities and, therefore, reflect lower erosion rates. This is a benefit in terms of reduced setback distances for several areas of the island (when compared to the older 2004 or 2011 DCM erosion rates). The 2019 DCM erosion rate was converted to the same time span (January 2000 to April 2022) as the survey data in Figure 3-15.

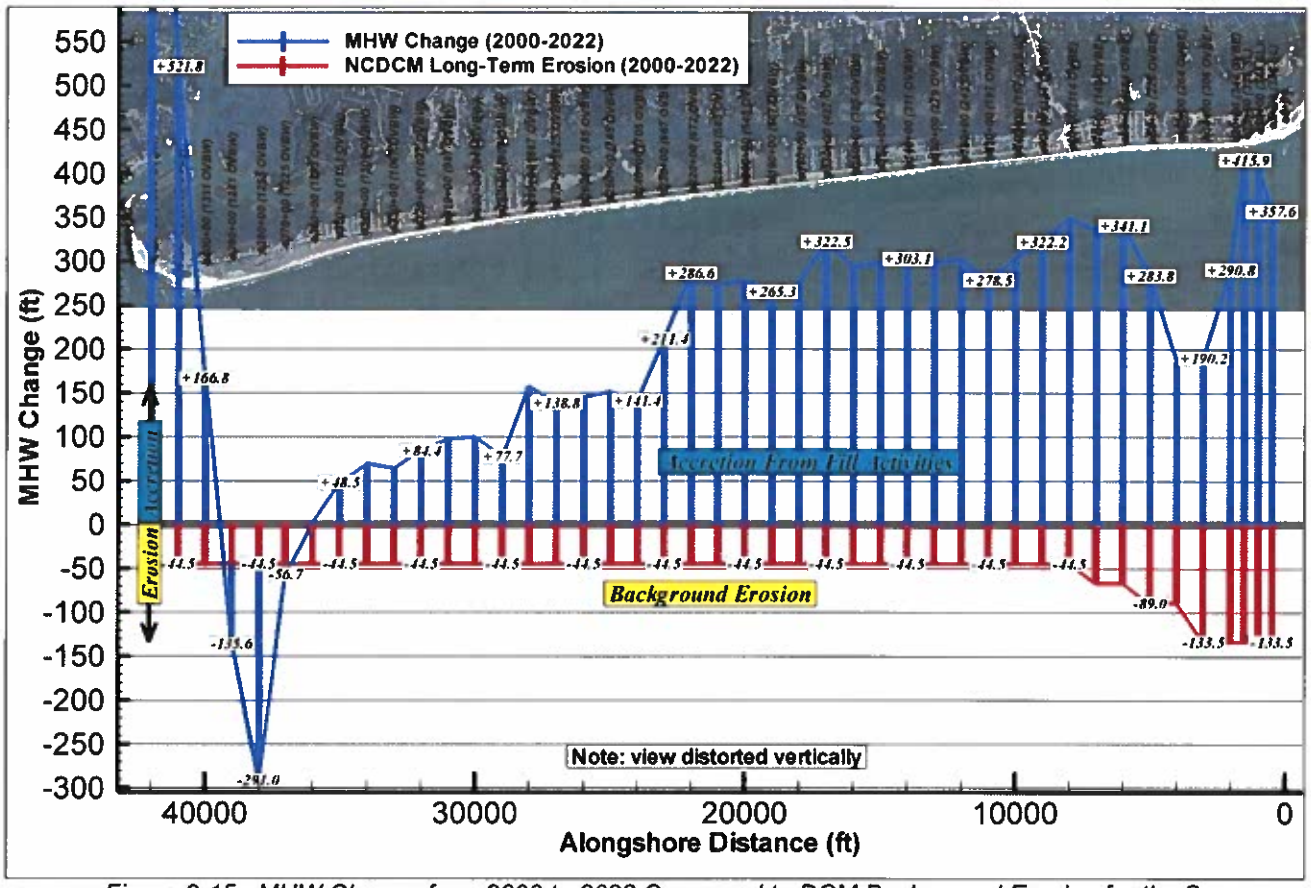


Figure 3-15. MHW Change from 2000 to 2022 Compared to DCM Background Erosion for the Same Period

Table 3-4 presents average MHW change by reach over the last 22 years. Results show that Town and USACE fill and dune enhancement activities have been successful in combating erosion over the last 22 years. The 2017 CRP and the recent 2022 CRR were constructed with this goal in mind.

As a result of the 2022 nourishment the Town East Reach exhibits the largest increases in MHW change over the last 22 years, excluding inlet reaches. Similarly, the USACE East, Pier, and Town West reaches show large increases as well and an increase is observed in the West Area as well from the continued equilibration and progression of the 2017 nourishment

The increases within the inlet reaches can be attributed to inlet dynamics and channel maintenance activities.

Table 3-4. Historical MHW Shoreline Change by Reach (2000 to 2022)

Reach Averages	Stations Included	Historical MHW Change (2000 to 2022) (ft)
LWF Inlet	5 to 15	+392.7
USACE East	15 to 40	+222.4
Town East	40 to 150	+300.3
Pier	150 to 190	+291.1
Town West	190 to 290	+193.4
West Area	290 to 380	+19.8
Shallotte Inlet	380 to 420	+65.5
Central Reach	40 to 290	+254.7

Figure 3-16 compares a 1993 aerial of Holden Beach with a 2021 aerial. The 2022 MHW line is shown on both aerials for comparison purposes. Figure 3-15 clearly shows that the overall health of the Holden Beach shoreline is better than it was decades ago.

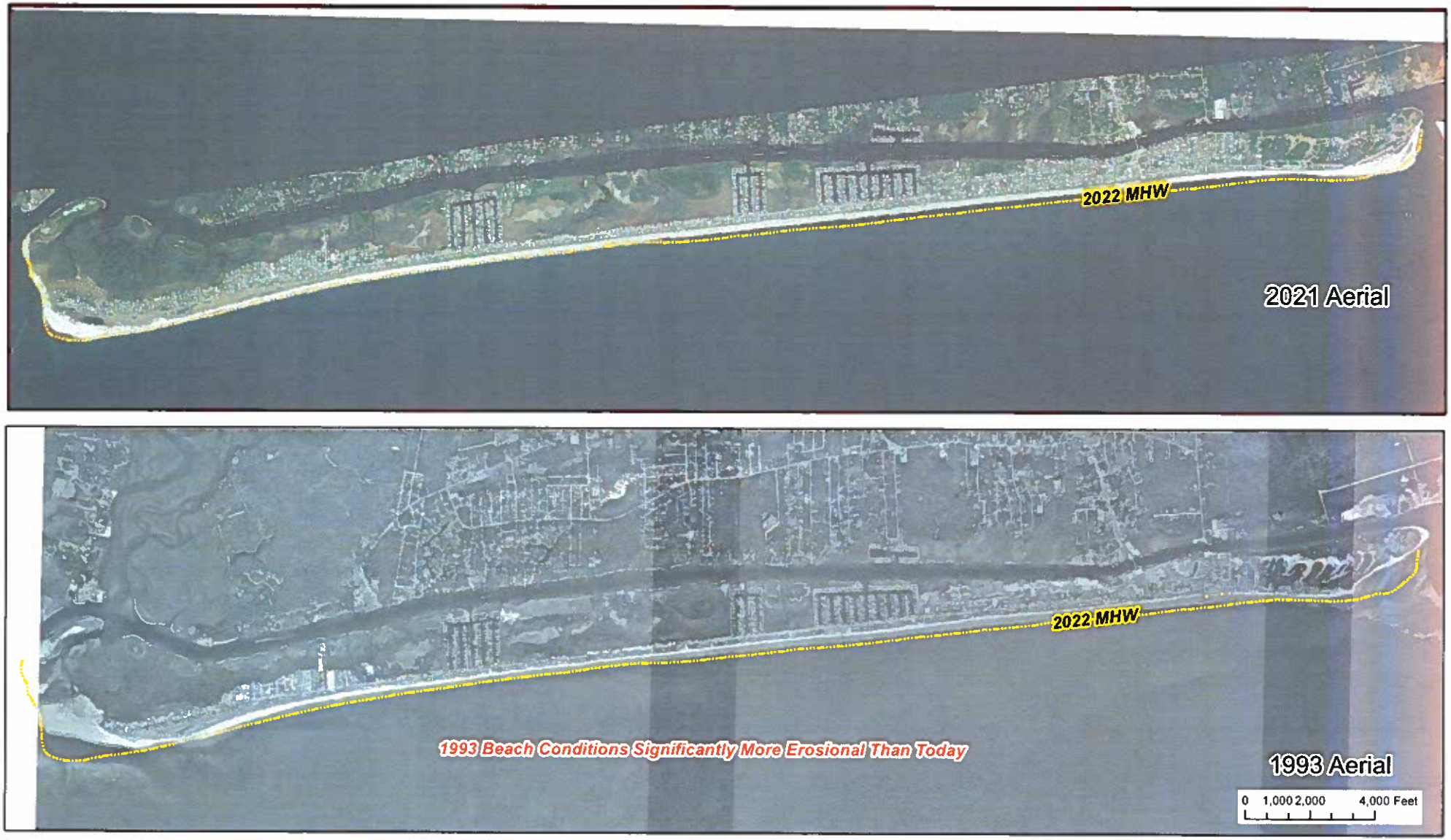


Figure 3-16
1993 and 2021 Aerial Comparison with 2022 Mean High Water (MHW) line.
2021 aerial and 2022 MHW Line shows overall accretion in comparison wth 1993 conditions.

ATM DESIGN ENGINEERING CONSULTING

3.5 OAK ISLAND TRANSECTS

The Town has been collecting additional survey data on the western end of Oak Island to establish baseline conditions for this area. Additionally, because regional sediment transport is from east to west in this area, any changes in this area have the potential to affect Holden Beach shorelines (i.e., downdrift). Surveying was needed because Oak Island only performed annual surveys down to the mean low water (MLW) from 1998 to 2013, which is not sufficient to completely capture sediment movement. More recently, Oak Island has conducted some surveys to DOC.

Oak Island monitoring transects are shown in Figure 3-17. As with the Holden Beach inlet transects, the Oak Island inlet transects 1 through 4 (i.e., not shoreline perpendicular) are excluded from some volume calculations. The west end of Oak Island has more development closer to the active beach than the west end of Holden Beach (where the dune system is up to 600 feet wide) and, therefore, is more vulnerable to short-term erosional episodes (both west ends are stable/accretional in the long term).

Similar to the inlet-influenced transects on the west end of Holden Beach, large variation is typically exhibited for Oak Transects 1 through 4. Oak Transects 5 and 6 are transitional (i.e., partially inlet-influenced), while Oak Transect 7 is generally removed from inlet effects and has historically shown less variability and more stability.

The Town of Oak Island recently completed their "FEMA Phase II: Hurricane Florence Nourishment Project" this past spring (2022) around the same time of the CRR project on Holden Beach. This was a large nourishment project (~800,000 cy) to restore material lost from recent hurricanes and included placement of sand along the western half of the Town of Oak Island's engineered beach and the placement ended just west of Transect 6 (see Figure 3-17). Additionally, the most recent Oak Island west end nourishment project occurred in the spring of 2021, as part of the USACE LWFIX Inlet dredging (see Figures 3-17 and 3-18) which, in the past, had solely been used to replenish the habitually eroding east end of Holden Beach. It is estimated approximately 120,000 cy of material was placed on the west end of Oak Island during the 2021 LWFIX project. Note that LWFIX dredging for 2023 is scheduled for placement on Oak Island.

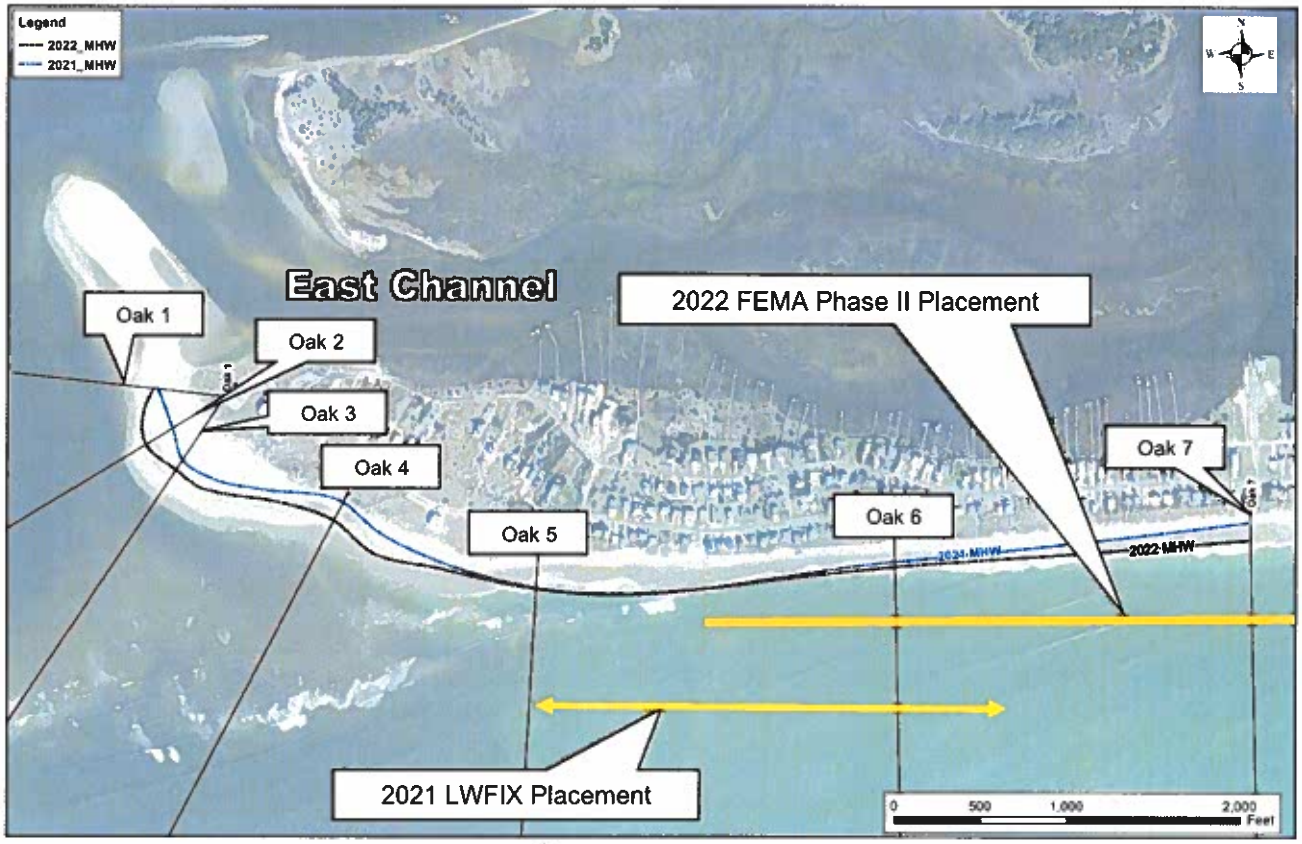


Figure 3-17. Oak Island Transects and approximate 2022 FEMA Phase II Renourishment Placement Location (western taper) Shown with 2021 MHW (blue) and 2022 MHW (black) Lines. "Oak 2" and "Oak 3" transects begin at the same location as "Oak 1." 2021 USACE LWFIX Placement Location also Shown for Reference. (2020 aerial shown).

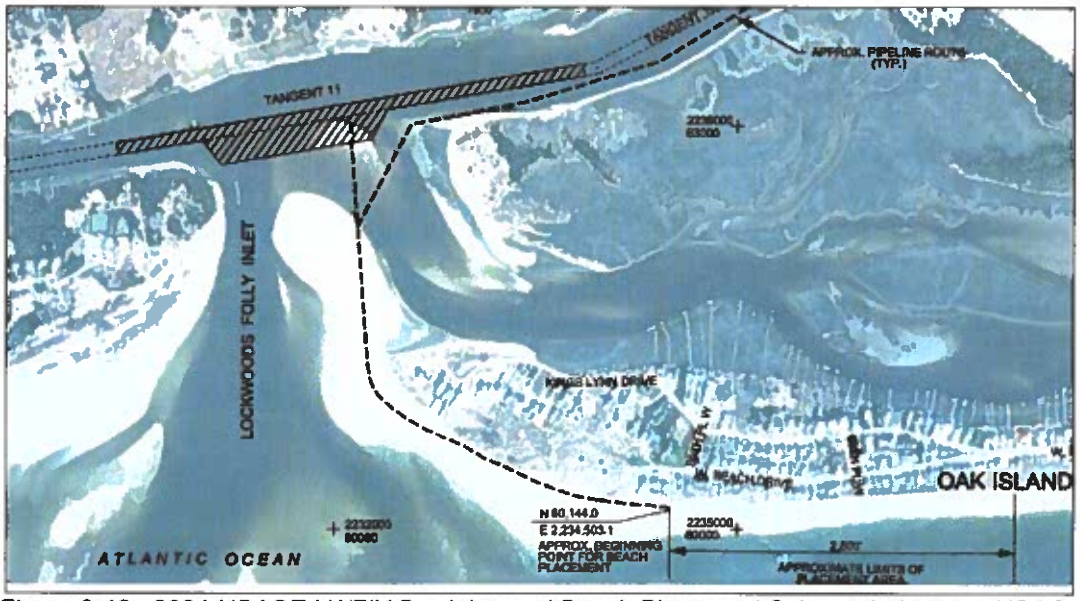


Figure 3-18. 2021 USACE LWFIX Dredging and Beach Placement Schematic (source: USACE request for dredging proposal).

As Figure 3-17 shows, Oak Island Transects 6 and 7 are located within the western taper of the recently completed FEMA Phase II Renourishment and therefore show accretion of the MHW line over the past year. Transects 1-4 are just downdrift of the 2021 LWFIX nourishment template and showed MHW line accretion over the past year, likely due to spreading benefits and inlet related effects (shoal movement). A mostly stable MHW shoreline between 2021 and 2022 is seen near Transect 5.

Table 3-5 presents the volume changes for the Oak Island transects between the 2021 and 2022 surveys, and Table 3-6 presents the annual MHW shoreline changes since the spring 2012 survey.

Table 3-5. Oak Island Transect Volume Analysis from 2021 to 2022

Station	Distance to Next Monument (ft)	Volume Change (cy/lf) (Dune to -12 ft*)	Volume Change (cy/lf) (Dune to -5 ft)	Notes
Oak 1	0	-48.5	-18.1	LWF Inlet
Oak 2	0	+9.7	+28.3	LWF Inlet
Oak 3	890	+94.7	+73.7	LWF Inlet
Oak 4	1100	+14.4	+19.3	LWF Inlet Shoulder
Oak 5	2000	+4.0	+9.2	Oceanfront
Oak 6	2000	+14.2	+10.5	Oceanfront
Oak 7	-	+40.5	+37.7	Oceanfront

Table 3-6. Oak Island Transect MHW Change

Transect	2012-2013 MHW Change (ft)	2013-2014 MHW Change (ft)	2014-2015 MHW Change (ft)	2015-2016 MHW Change (ft)	2016-2017 MHW Change (ft)	2017-2018 MHW Change (ft)	2018-2019 MHW Change (ft)	2019-2020 MHW Change (ft)	2020-2021 MHW Change (ft)	2021-2022 MHW Change (ft)	Notes
Oak1	+65.4	-51.9	+331.3	-224.8	-103.7	-68.6	+90.8	+89.1	-235.6	+27.6	
Oak2	-432.8	+105.9	+87.0	-27.0	-168.1	-26.4	-8.8	+112.4	-265.2	+180.2	Channel Shoaling
Oak3	-338.2	+19.4	+302.1	-371.5	-57.6	+84.4	-155.6	+145.9	-184.4	+68.8	
Oak4	-75.4	-51.9	-134.4	+91.1	-242.8	+69.7	+89.4	-71.9	-198.3	+118.9	
Oak5	-91.7	-12.6	+94.3	-64.6	+49.7	-110.8	+102.6	-131.4	+108.0	+6.0	2015, 2019, 2021 Nourishments
Oak6	-7.5	-4.0	+163.1	-68.9	-13.1	-112.9	+78.3	-115.4	+79.1	+31.4	2015, 2019, 2021, 2022 Nourishments
Oak7	+13.7	+14.0	-16.9	+37.1	-15.7	-48.6	-26.0	+4.8	-12.0	+102.9	2022 Nourishment

*Nourishment activities to west end of Oak Island occurred in 2015, 2019, and 2021, and 2022

The western-most portions of Oak Island are highly variable from year to year, as with any inlet shoreline. As a result of the recent nourishment activities, the west end of Oak Island appears healthy and shows some significant accretion of the MHW line over the past year.

Similar to the MHW change analysis, overall, the Oak Transects showed volumetric accretion. Significant accretion occurred at Oak Transect 7 due to the 2022 renourishment project. Oak Transects 2 through 4 also showed significant volumetric accretion between 2021 and 2022, from Lockwood Folly Inlet dynamics and spreading of the 2021 LWFIX nourishment sand. Shoaling into the channel was observed to have taken place here, particularly at Oak Transect 2. Oak Transect 1 eroded, though the majority of volumetric erosion occurred within the surf zone to depth-of-closure (DOC) limit further offshore as a result of channel movement and inlet dynamics.

Town staff and ATM will continue to follow shoreline changes and any upcoming nourishments along the western end of Oak Island since these have the potential to affect LWF Inlet and Holden Beach.

4.0 SUMMARY

The Holden Beach shoreline has historically exhibited moderate erosion rates (with the exception of the inlets). As a result, the Town has instituted a nourishment and beach management program to offset this erosion. Dating back to January 2000 (approximately 22 years), the Town and the USACE have placed an average of approximately 230,000 cy/year on the beach. This rate of sand placement has been effective at staying ahead of long-term background erosion.

Holden Beach suffered significant erosion and damage to the upper beach and dune systems from hurricanes over the last 5 years. Similar to "engineered beach" mitigation projects following Hurricanes Hanna (2008), Irene (2011), and Matthew (2016) FEMA assistance was implemented following Hurricanes Florence (2018), Michael (2018), Dorian (2019) and Isaias (2020) which resulted in the Central Reach Reimbursement (CRR) project that occurred this past winter/spring (2022). The CRR project placed a total of about 1.54 mcy of sand primarily funded by FEMA mitigation to replace the Central Reach sand lost in the "engineered beach" that was directly attributed to hurricanes where FEMA was involved. Two offshore borrow areas were used for the CRR nourishment effort.

While the 2021 hurricane season was luckily much milder for Holden Beach and signs of recovery to the upper beach and dune system were observed, Hurricane Ian in late September 2022 impacted the beach and dune system. Note that despite Hurricane Ian's impacts, FEMA was not involved in any mitigation capacity.

Despite the hurricane activity affecting the Holden Beach shoreline, the Town's beach management efforts, including the 2017 Central Reach Project, the 2022 CRR project and LWFIX projects, have helped to provide a significant buffer during these extreme conditions.

As a result, a relatively wide pre-project shoreline was still present to provide a good cumulative base for the 2022 beach fill projects, and conditions have significantly improved as a result of the large-scale CRR project and USACE LWFIX project which both occurred this past winter/spring.

In summary, this past year (2021 to 2022) was very eventful for the Holden Beach shoreline, with the substantial nourishments of the Central Reach Reimbursement (CRR) and the LWFIX east end project, which helped restore and widen significant portions of beachfront.

The most recent annual shoreline survey occurred in April 2022. *In comparing this survey to the April 2021 survey, the entire island experienced a net gain of approximately 1,574,000 cy out to the -12-ft DOC limit.* The CRR and the most recent USACE LWFIX project brought a much-needed addition of material into the Holden Beach littoral system. Historical annual losses have been documented at about 100,000 cy/year for Holden Beach. Fortunately, the two nourishment projects came at a very valuable time to offset this erosion and future beach surveys will monitor the progress, equilibration, and spreading of these nourishments. Erosion did occur in the western half of the island over the past year, however, this was mostly mild and as the CRR equilibrates, material will spread westward to benefit the downdrift shorelines.

From a shoreline contour perspective, approximately the center 5 miles of island (Central Reach STA 40+00 to 290+00) exhibited an average MHW accretion of +142 ft between surveys. The CRR has vastly widened the MHW line along the stations within the project footprint. As the nourishment equilibrates the MHW is expected to show some recession within the project footprint, and over time, accretion will be seen outside of the project area to both the east and west due to spreading effects. The western portions of the island showed a mostly stable MHW line and generally less erosion (or more accretion) was observed compared with the volumetric analysis, indicating a mostly stable and healthy intertidal and dry beach. The observed MHW erosion in the west areas was mostly relatively minor, with more substantial erosion occurring closer to Shallotte Inlet, likely as a result of recent wave and water level activity and inlet dynamics. Fortunately, a healthy and significantly wide dune system is still present in this area.

The toe-of-dune (TOD) line was accretional for the majority of the island, primarily due to the recent nourishment activities (which included a secondary berm and significant dune vegetation planting and enhancement), but also due to continued cumulative benefits from the 2017 CRP and LWFIX projects. Erosion of the TOD line occurred in the west area approaching Shallotte Inlet, which is consistent with the MHW and volumetric analyses.

In comparing the April 2022 survey with the January 2000 survey (22-year span), the MHW shoreline exhibits approximately 210 ft of accretion, largely in part due to this past year's large-scale nourishment activities. The Central Reach Reimbursement project and other future projects of this scale are designed to enhance the beach and dune system which will result in protective, ecological, recreational, and economic benefits.

The Central Reach Reimbursement nourishment project, completed this past April, represents the largest nourishment project on Holden Beach (over twice the size of the 2001-2002 USACE 933 project). The CRR project placed ~1.54 mcy of offshore beach compatible sand from Stations 40+00 to 270+00 (~23,000 linear feet of shoreline), mimicking and expanding upon the 2017 CRP. The purpose of the project, which is a component of the Town's comprehensive beach management program, is to provide beach restoration along eroding sections of shoreline sufficient to maintain the island's restored protective and recreational beachfront and natural dune system. The 2022 survey represents the immediate post-project survey of the nourishment, and continued monitoring will assess the equilibration and movement of the project sand.

The 2022 USACE LWFIX project was similar to recent LWFIX projects, and it came at an opportune time to supplement the CRR nourishment. Due to the close proximity to LWF Inlet, the east end is relatively dynamic and some erosional hotspots have been observed over the years. The 2022 survey showed that the additional ~115,000 cy from the project has created a wide recreational beach and storm buffer to abate future erosion along this stretch of shoreline.

ATM and Town staff will continue to evaluate the potential piggybacking and/or use of the 400-ft bend widener for any future USACE LWFIX projects. The next upcoming LWFIX project with beneficial placement on Holden Beach is scheduled to occur in 2024, as the 2023 project will place material on Oak Island. The NCDEQ Shallow Draft Inlet (SDI) program has provided the Town with permits to dredge the inner and outer portions of LWF Inlet. These permits essentially allow the Town, with potential help from the County and State, to perform the same inlet maintenance activities that the USACE currently performs (i.e., LWFIX dredging, outer channel sidecasting). While the Town has not used these permits since obtaining them in 2016, they remain a potential option for future navigation improvements and beach or nearshore placement.

In summary, the most recent 2016 North Carolina Beaches and Inlets Management Plan (NC BIMP) report estimated the 2013/2014 Beach Recreation Annual Total Impact Output for Holden Beach at $80.4 million, which accounted for 942 jobs. Additionally, the NC BIMP conducted a study of losses attributed to 50 percent beach width loss and found that, for Holden Beach, the 2013/2014 estimated *annual loss* (including output/sales/business activity) would be $12.6 million. The Town's beach management and maintenance program strives to maintain and enhance this important economic and environmental benefit.

Recommendations for future and ongoing beach management activities include the following actions:

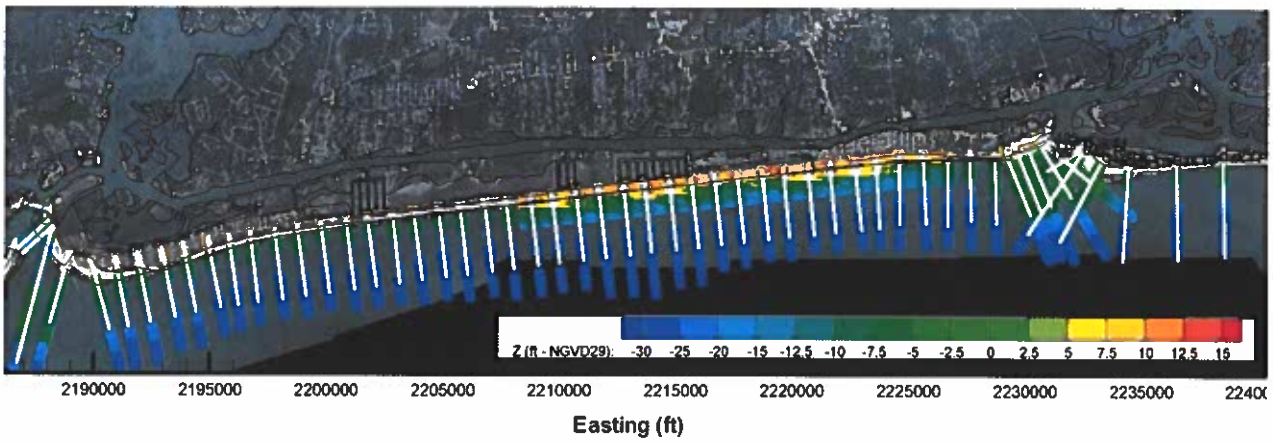
- Continue annual island-wide monitoring with beach profiles
- Continue to coordinate with USACE and NCDEQ on future outer LWF Inlet channel sidecast/hopper dredging and nearshore sand placement
- Continue coordination and support of the State's SDI program and quarterly SDI MOA meetings held by the USACE and NCDEQ/NCDWR (regarding LWFIX, etc.)
- Continue proactive dune enhancement activities (planting, fertilizing, fencing, etc.).
- Work closely with Congressional representatives and lobbyists to assure continued support of future USACE nourishment projects for Holden Beach
- Extend DCM and USACE permits as necessary
- Work with USACE Civil Works staff to aid in developing the 50-year CSDR study
- Continue coordination with BOEM on their sand-related data collection 3-8 miles offshore of Holden Beach
- Continue to monitor nearby Oak and Ocean Isle projects (as well as County efforts)

The Town worked proactively with the USACE to maximize the use of the LWFIX borrow area and bend-widener, even before shallow-draft dredging funds were available from the State. With the State SDI dredging fund now available, Oak Island and Brunswick County have expressed increased interest in using LWF Inlet sand resources. Holden Beach is the downdrift beach to LWF Inlet, therefore, the east end of Holden Beach is the most affected and most vulnerable to LWF Inlet processes (including any manmade changes to this system). Town and ATM staff will continue to actively engage in these projects and monitor their potential effects.

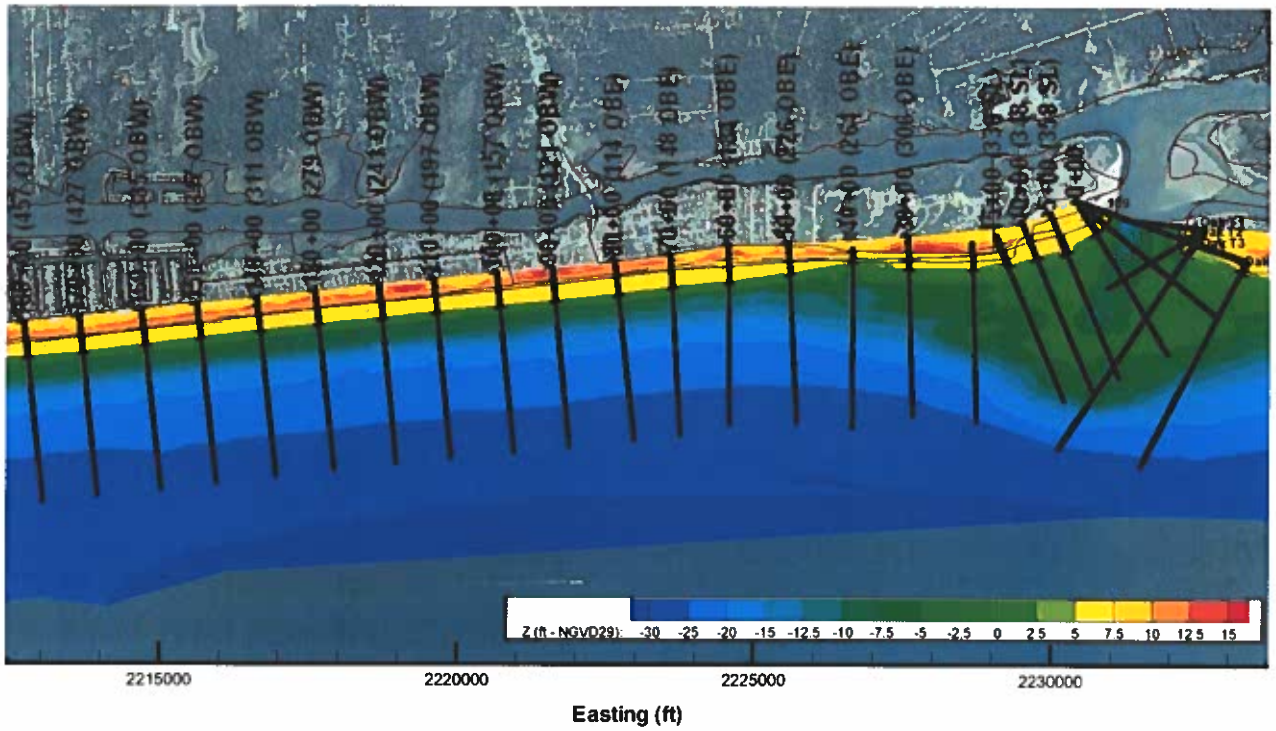
Appendix A

Station Profile Analysis

APPENDIX A – ELEVATION PROFILE TRANSECTS



Survey Stationing Figure. Profile Transect Stationing shown in white and actual survey points shown with color legend on above figure. Plots below are from east (Lockwood Folly Inlet) to west (Shallotte Inlet). Profile plots are zoomed in to nearshore area (typically from the dune to ~-20ft NGVD depth). Oak Island Transects are at the end of the section. Note "Z" is in ft-NGVD29.

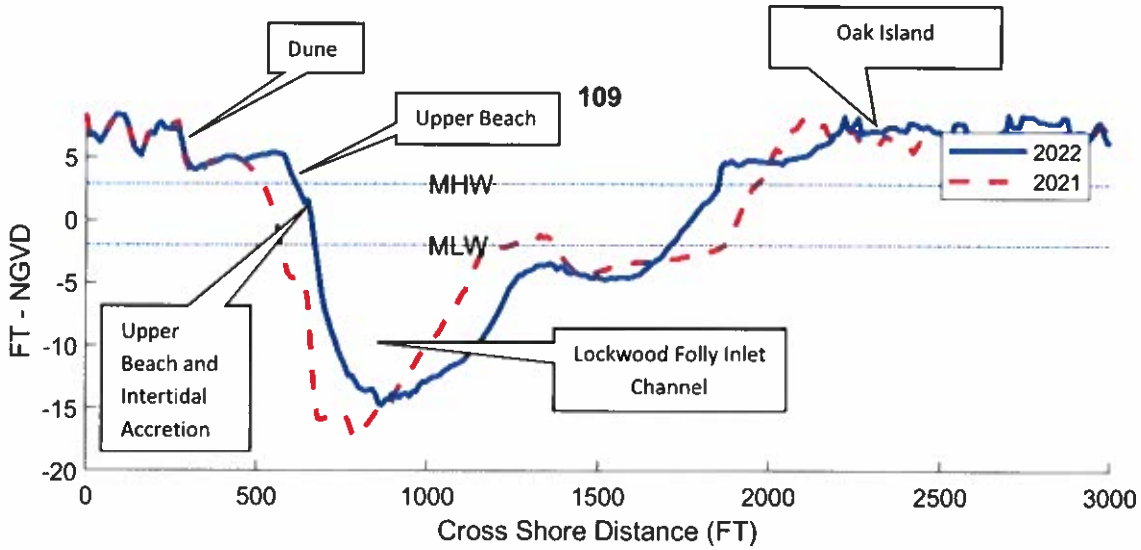


Zoomed in to eastern half of island (station 170+00 is to the left and just east of the pier). Note "Z" is in ft-NGVD29.

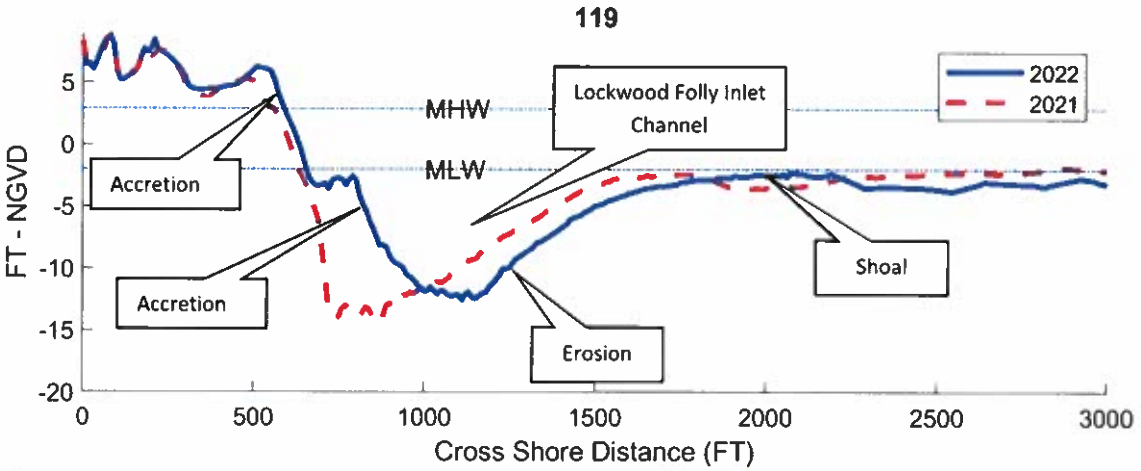
Please Note:

In the following cross sections, the Station Number is shown at the center top of the figure.

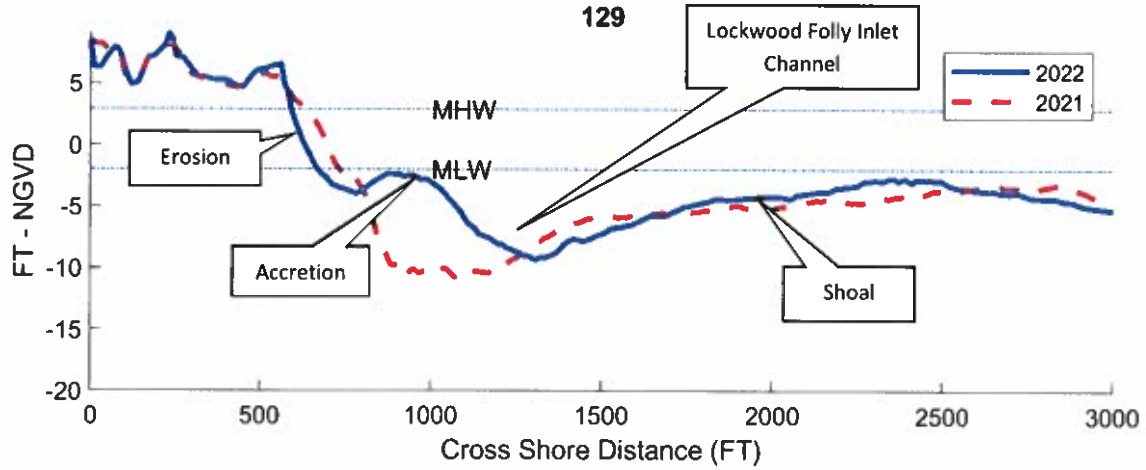
Any notable features are described in "call-outs" or in blue below the figure.



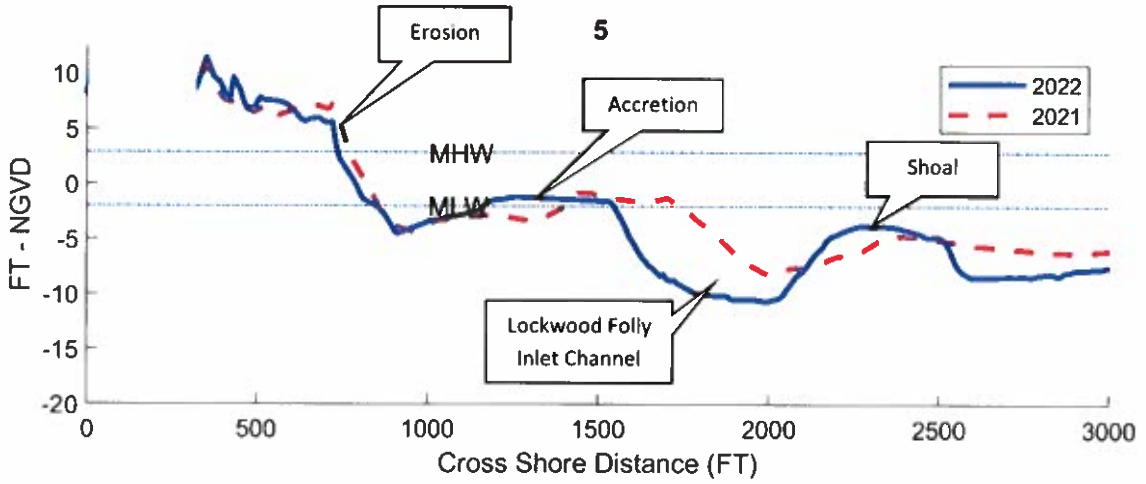
Station 109+00 (far east). Plots typically show from dune (between ~7' and ~15' NGVD) out to ~-20' NGVD. MHW=Mean high water, MLW=mean low water.



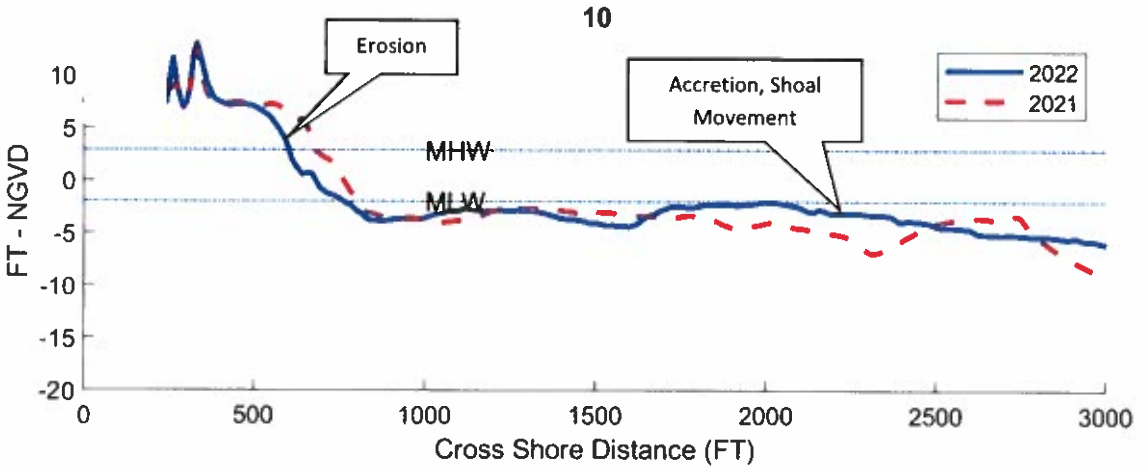
Station 119+00. Upper and intertidal beach showing accretion. Some "filling in" of sand is observed as the LWF Inlet channel has become more shallower since the 2021 survey



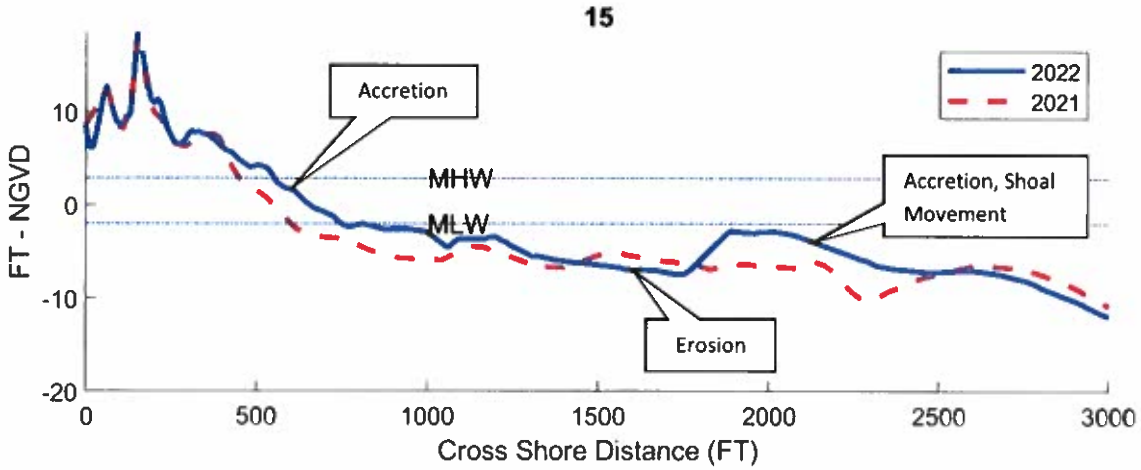
Station 129+00. LWF Inlet Channel Approximately 800 ft from baseline. Intertidal erosion, and movement below MLW into the LWF Inlet Channel is seen since 2021 survey.



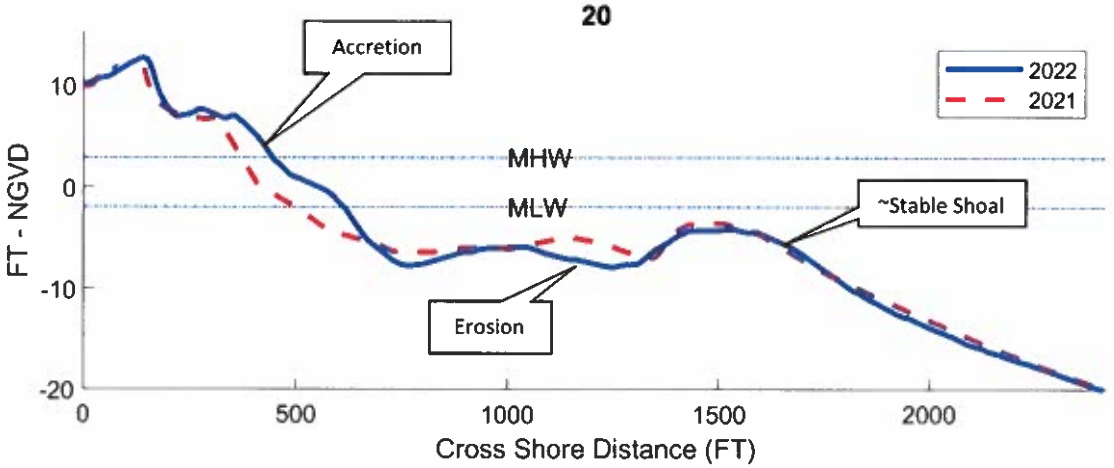
Station 05+00. Upper beach erosion and channel shifting towards Holden Beach observed in this area since 2021 survey.



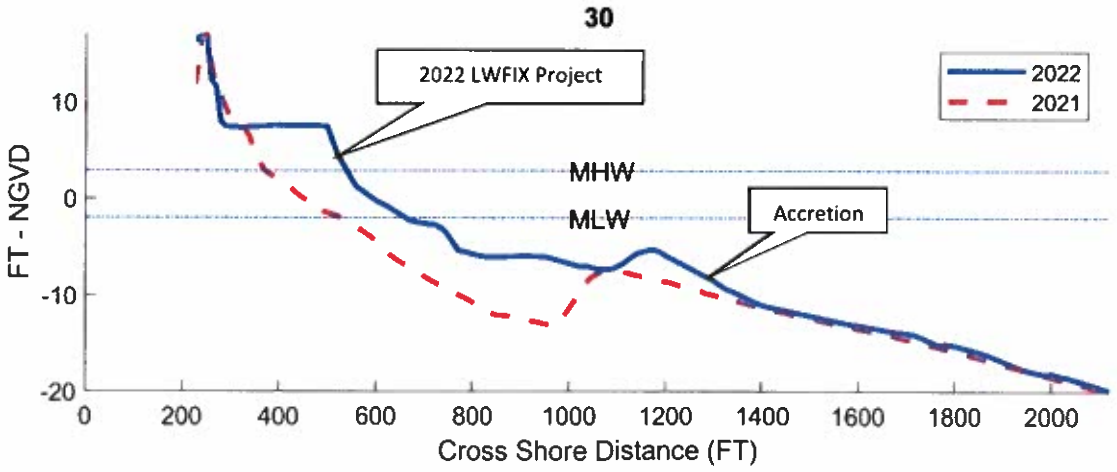
Station 10+00. Upper and intertidal beach erosion has taken place.

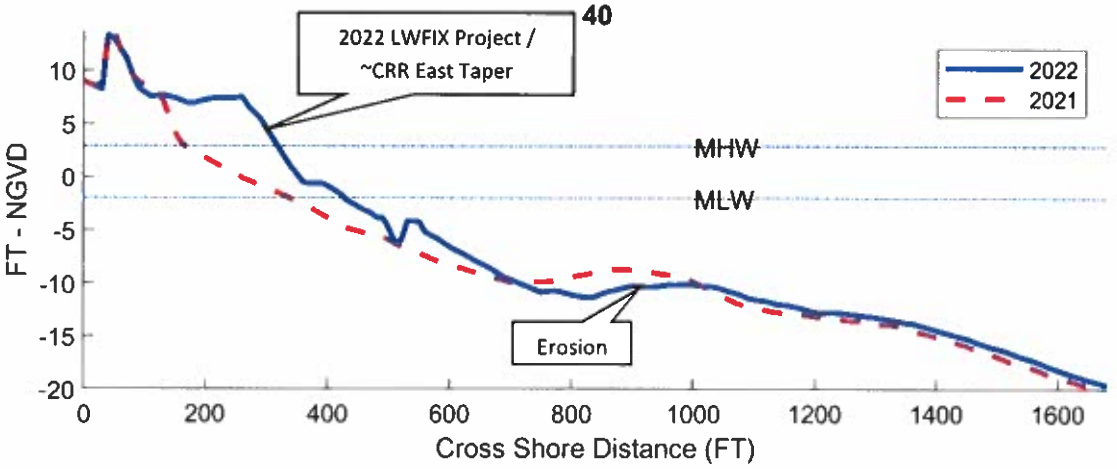


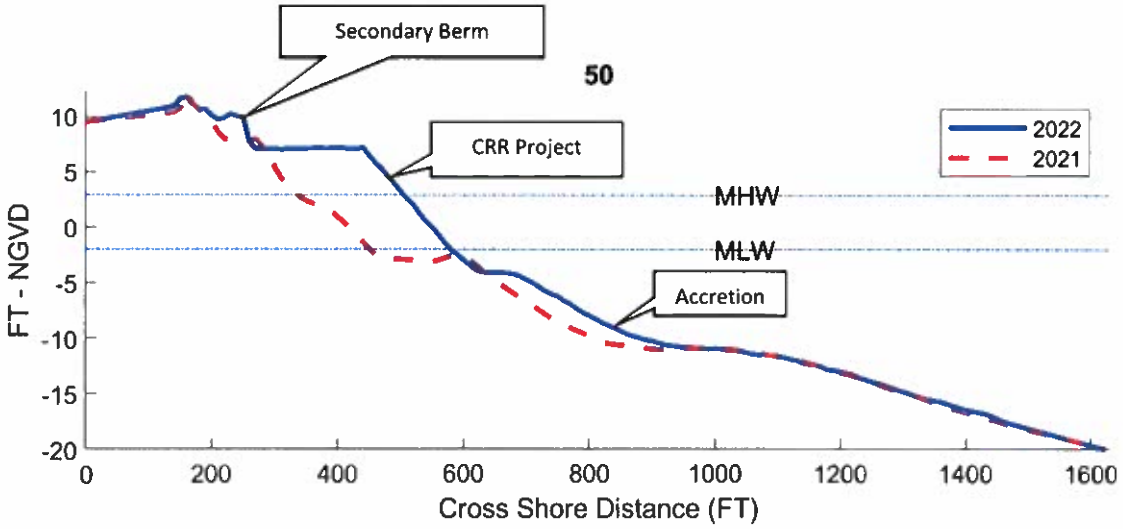
Station 15+00. Upper and intertidal beach accretion has taken place. Accretion also observed farther offshore due to inlet dynamics and nearby shoal movement.



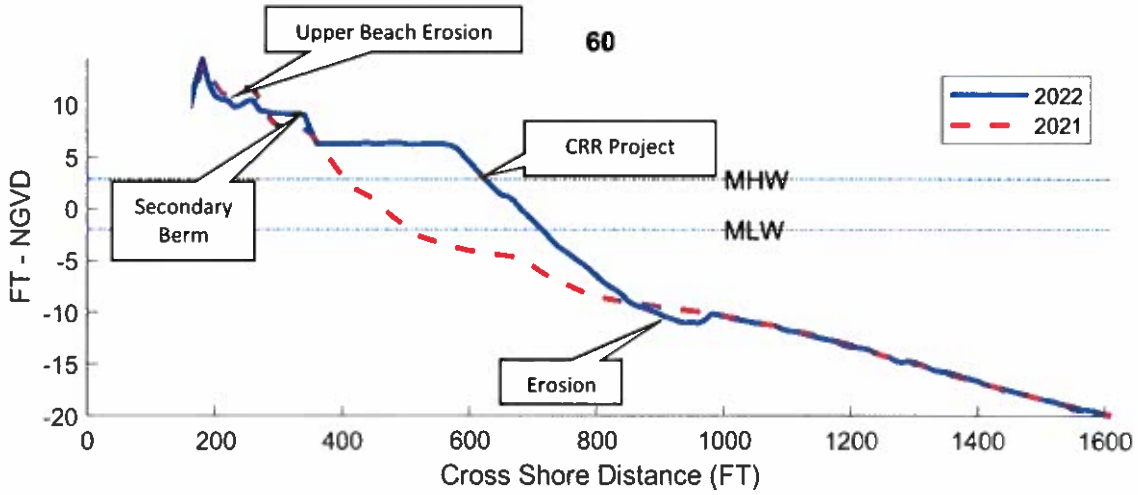
Station 20+00. Some nearshore erosion observed. Upper beach and intertidal accretion occurred since the 2021 survey, due to 2022 LWFIX taper material spreading.

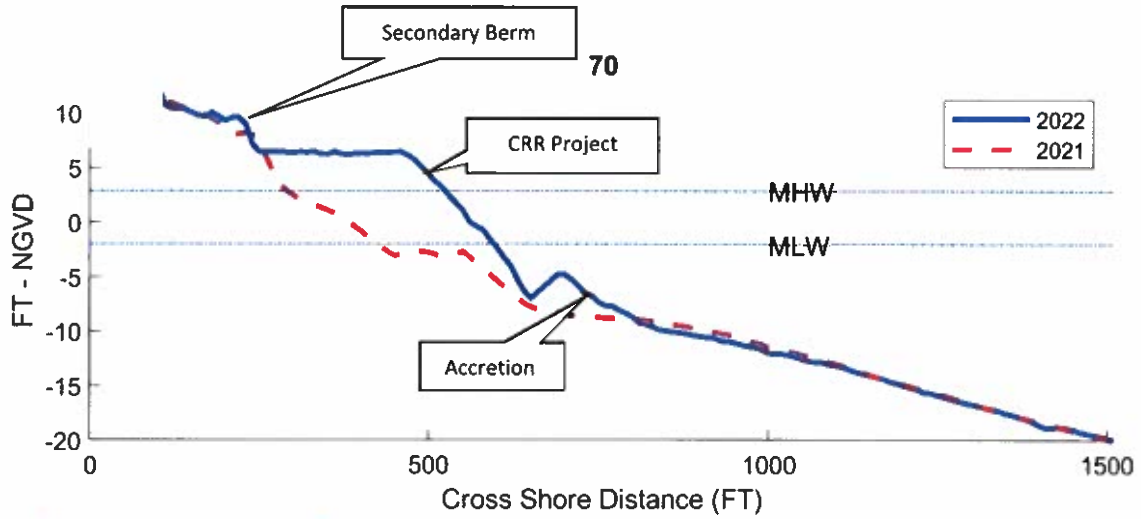

30
2022 LWFIX Project
2022
2021
MHW
MLW
Accretion
FT - NGVD
10
0
-10
-20
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Cross Shore Distance (FT)


40
2022 LWFIX Project /
~CRR East Taper
2022
2021
MHW
MLW
Erosion
FT - NGVD
10
5
0
-5
-10
-15
-20
0
200
400
600
800
1000
1200
1400
1600
Cross Shore Distance (FT)

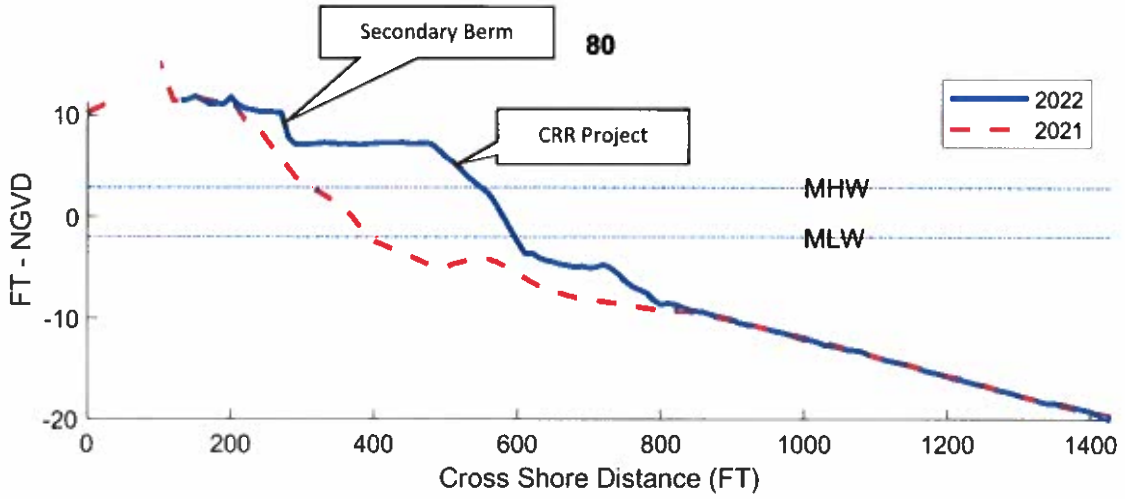


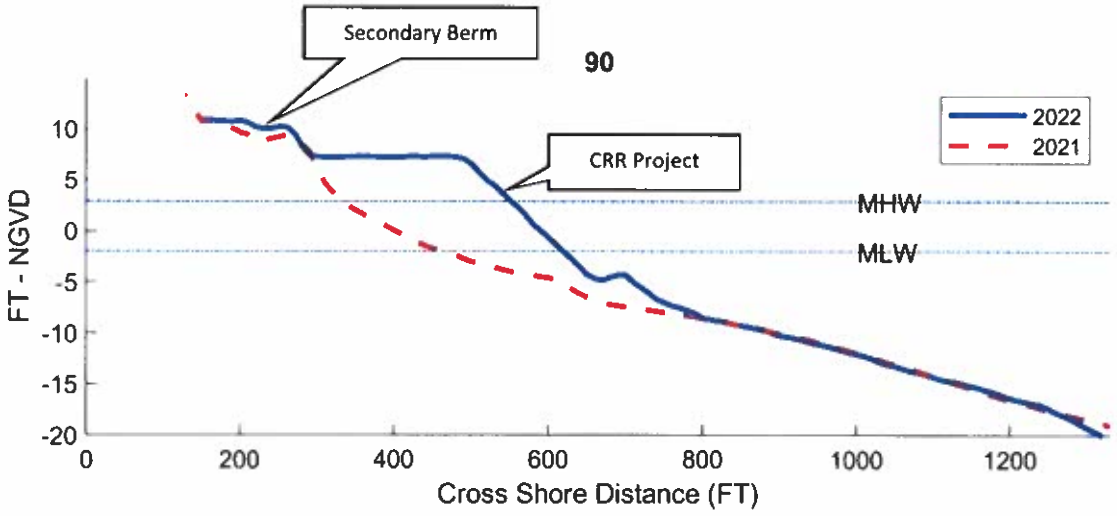
Station 50+00. The Central Reach Reimbursement (CRR) Project was completed in early 2022. Sand placement extended from Station 40+00 to Station 260+00 (ended just east of Station 270+00) and features a primary berm and secondary berm to promote dune growth.

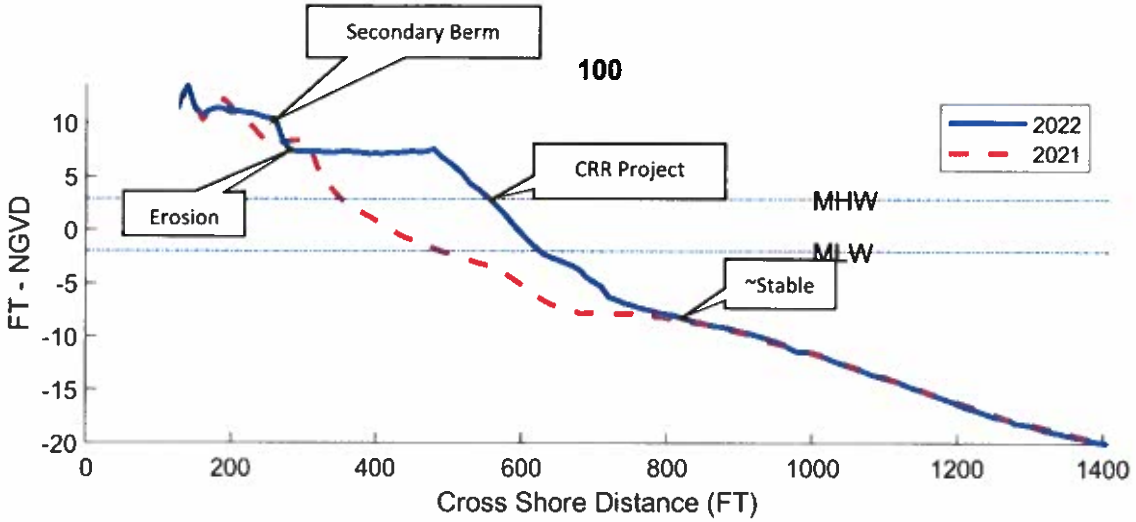




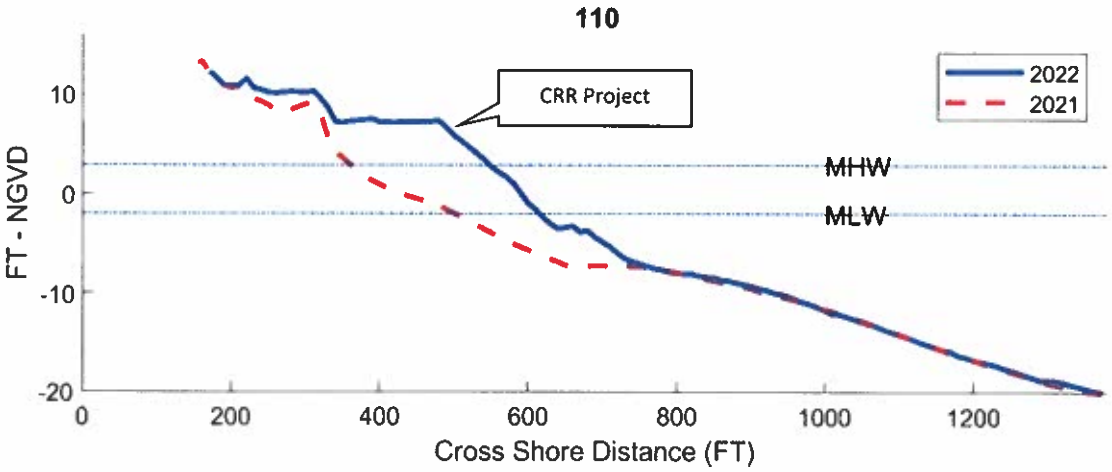
Station 70+00. Wide beach and healthy dune observed in this area due to the 2022 CRR renourishment project. Some nearshore accretion observed due to spreading of placed material.

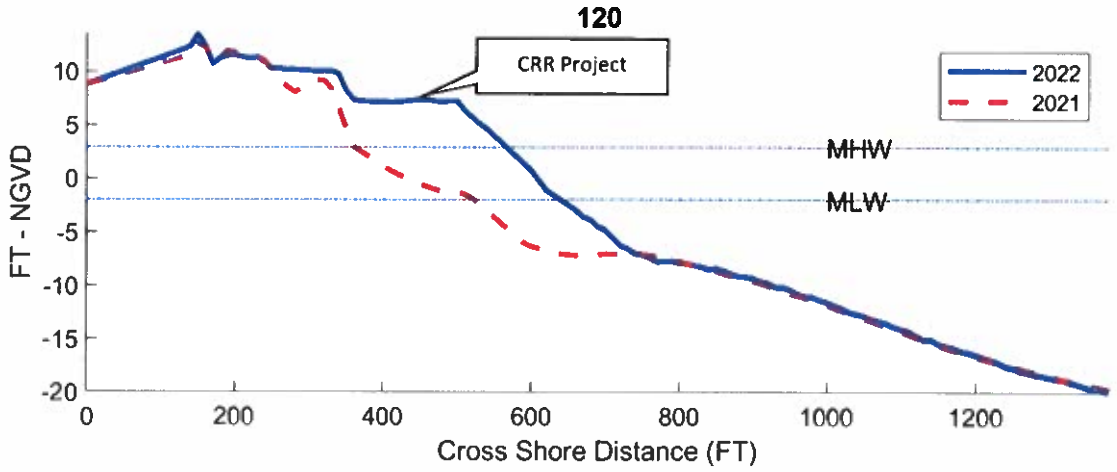


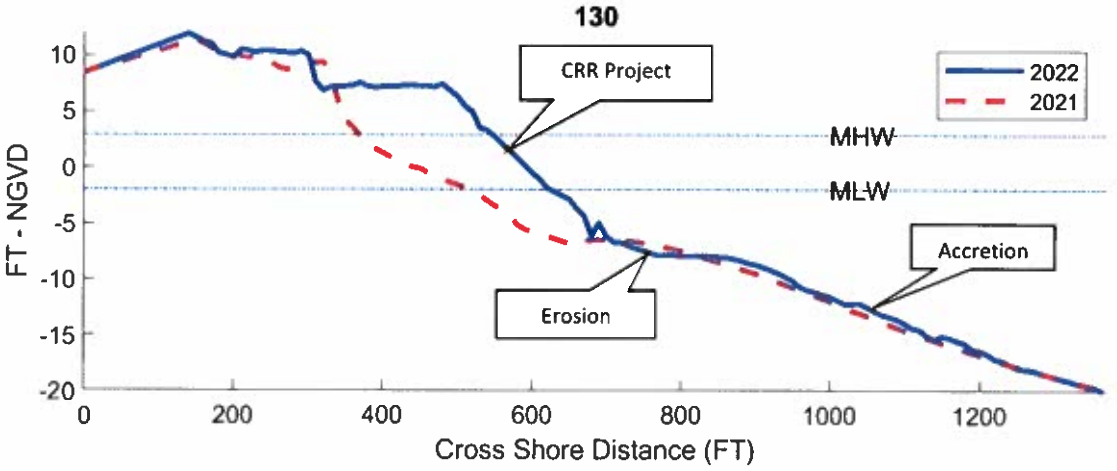


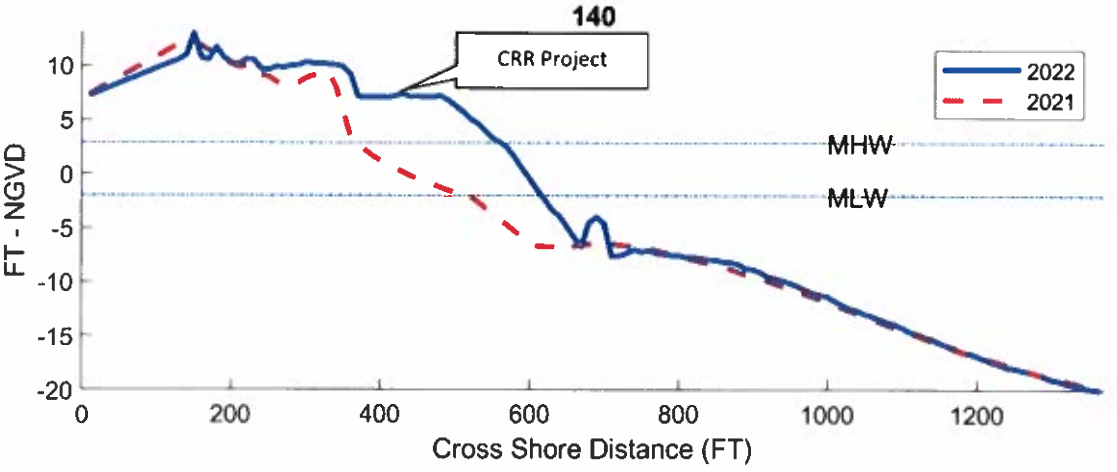


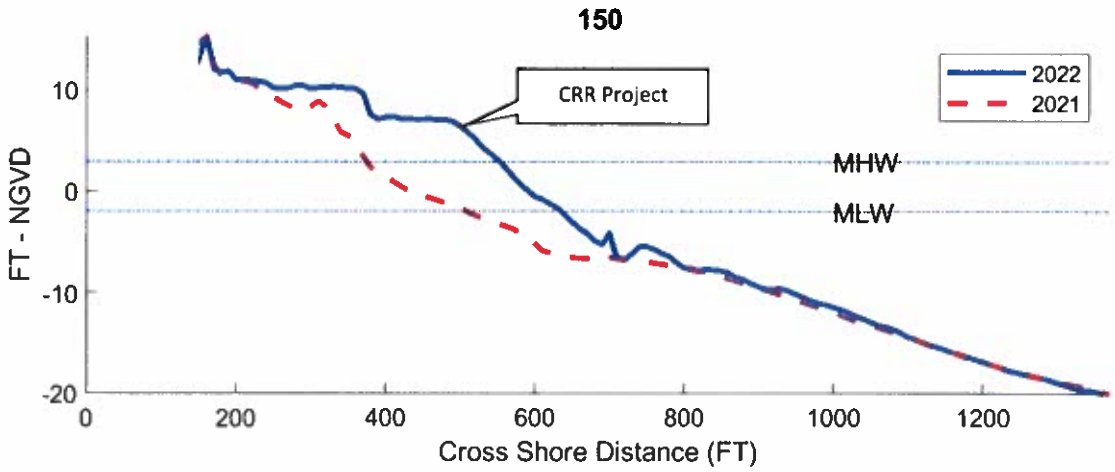
Station 100+00. 2022 survey shows minor upper beach erosion had taken place, however, the secondary berm as part of the CRR template brought additional material here.

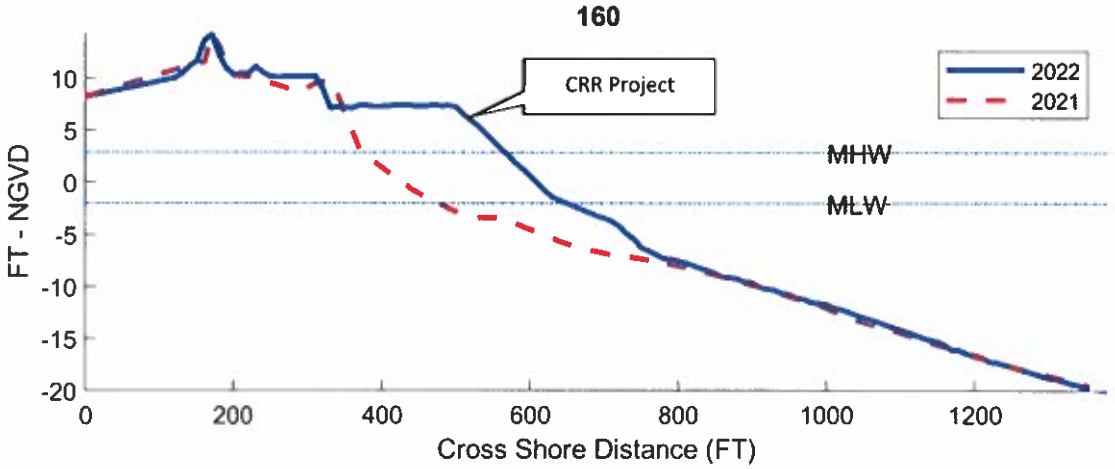


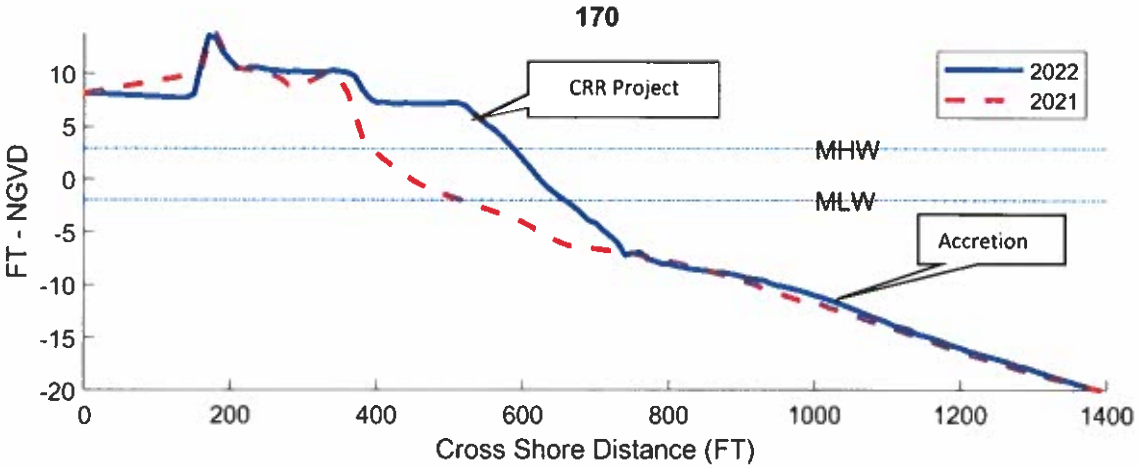

120
CRR Project
2022
2021
MHW
MLW
FT - NGVD
10
5
0
-5
-10
-15
-20
0
200
400
600
800
1000
1200
Cross Shore Distance (FT)

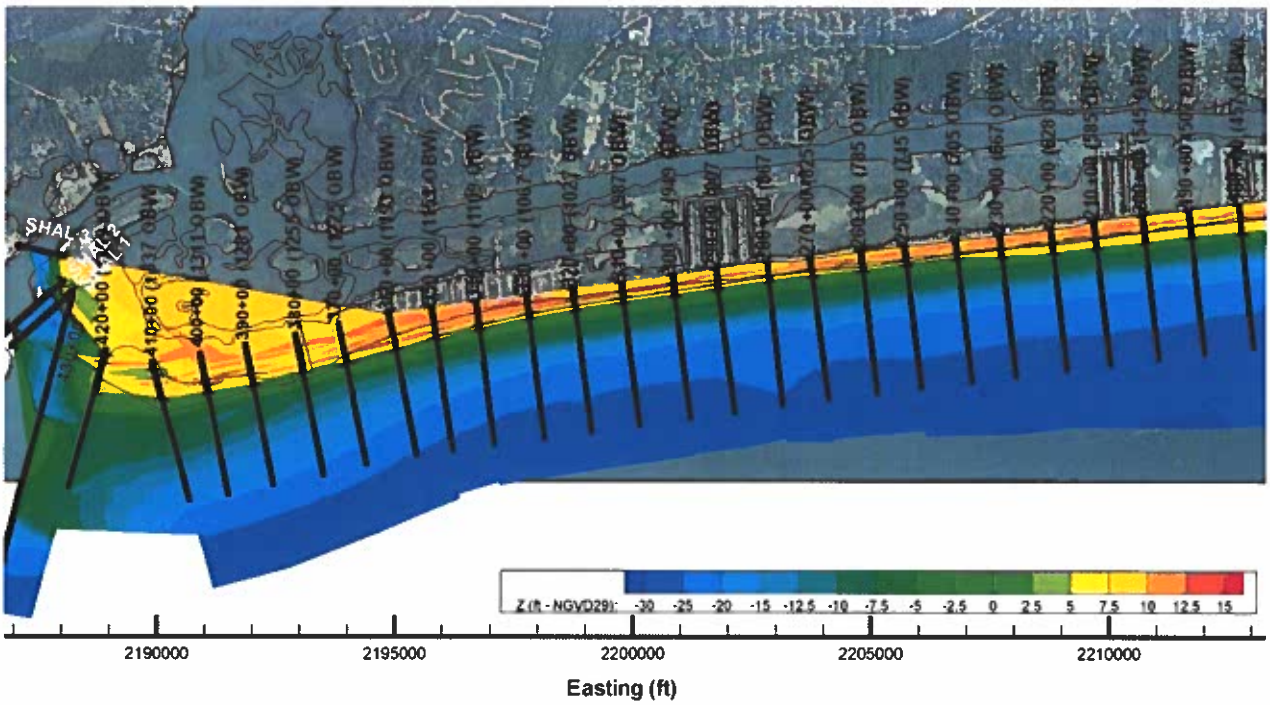

130
CRR Project
2022
2021
MHW
MLW
Accretion
Erosion
FT - NGVD
10
5
0
-5
-10
-15
-20
0
200
400
600
800
1000
1200
Cross Shore Distance (FT)


140
CRR Project
2022
2021
MHW
MLW
FT - NGVD
10
5
0
-5
-10
-15
-20
0
200
400
600
800
1000
1200
Cross Shore Distance (FT)

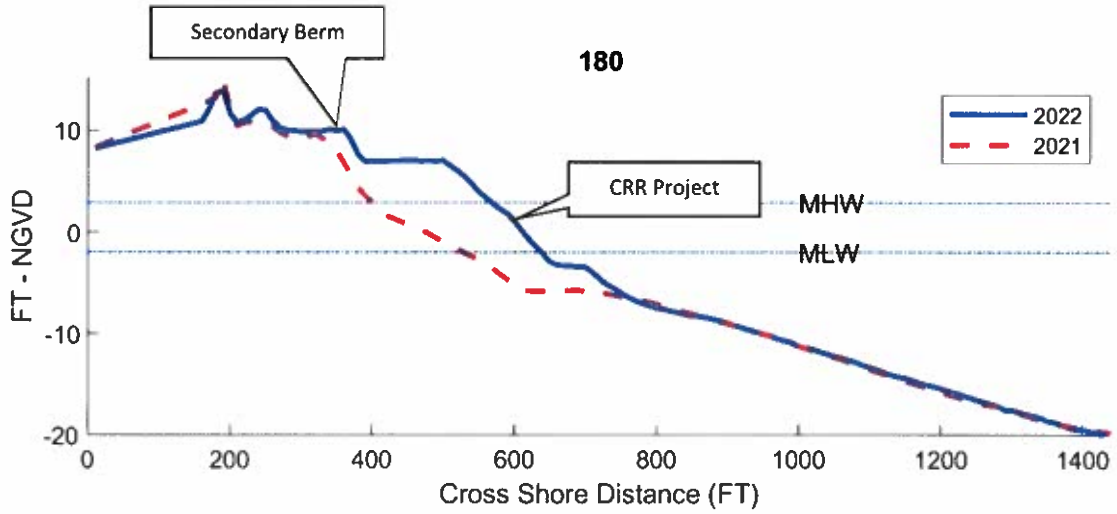

150
CRR Project
2022
2021
MHW
MLW
FT - NGVD
10
0
-10
-20
0
200
400
600
800
1000
1200
Cross Shore Distance (FT)

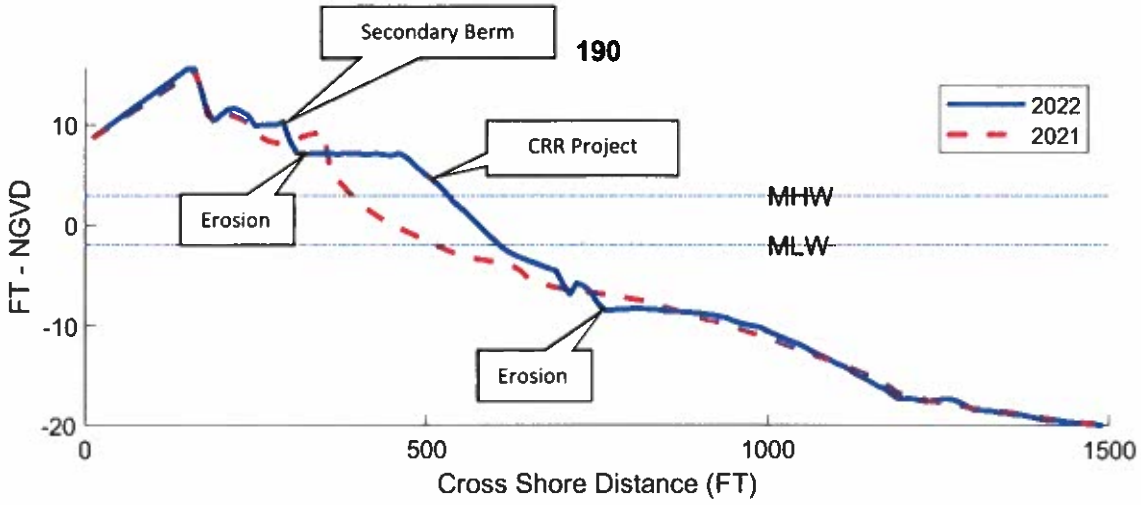

160
CRR Project
2022
2021
MHW
MLW
FT - NGVD
10
5
0
-5
-10
-15
-20
0
200
400
600
800
1000
1200
Cross Shore Distance (FT)

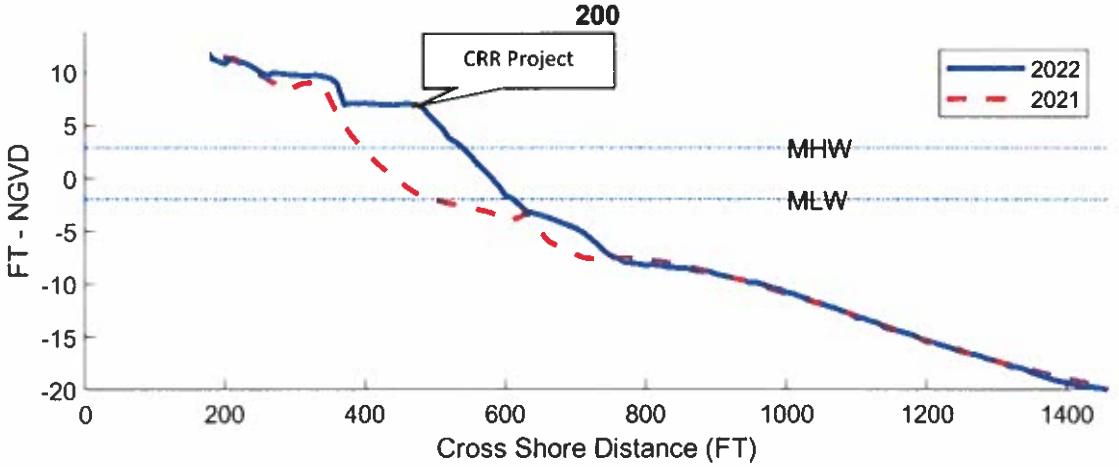

170
CRR Project
2022
2021
MHW
MLW
Accretion
FT - NGVD
10
5
0
-5
-10
-15
-20
0
200
400
600
800
1000
1200
1400
Cross Shore Distance (FT)

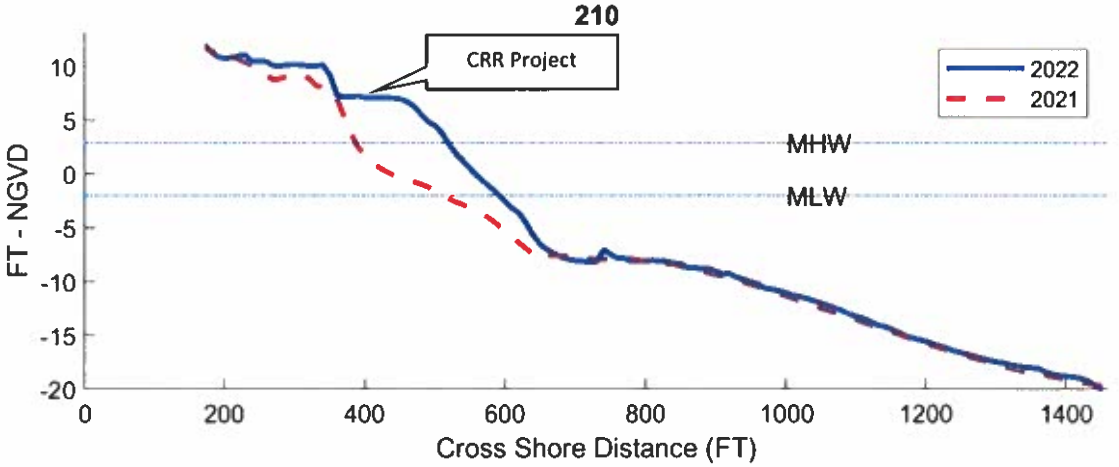


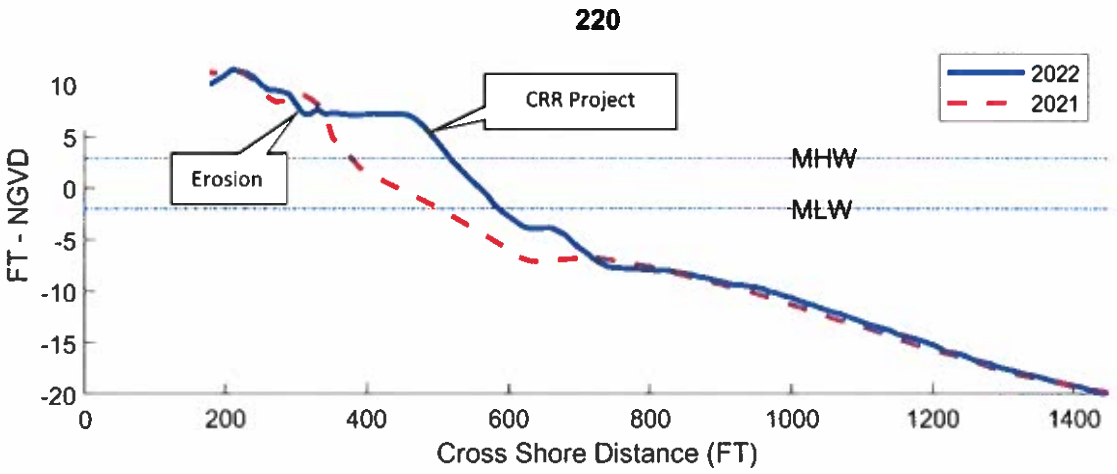
Zoom in of western end (Station 180+00 near the pier to Station 430+00 and newly added Shallotte Inlet Stations beginning with 2020 survey). Note "Z" is in ft-NGVD29.

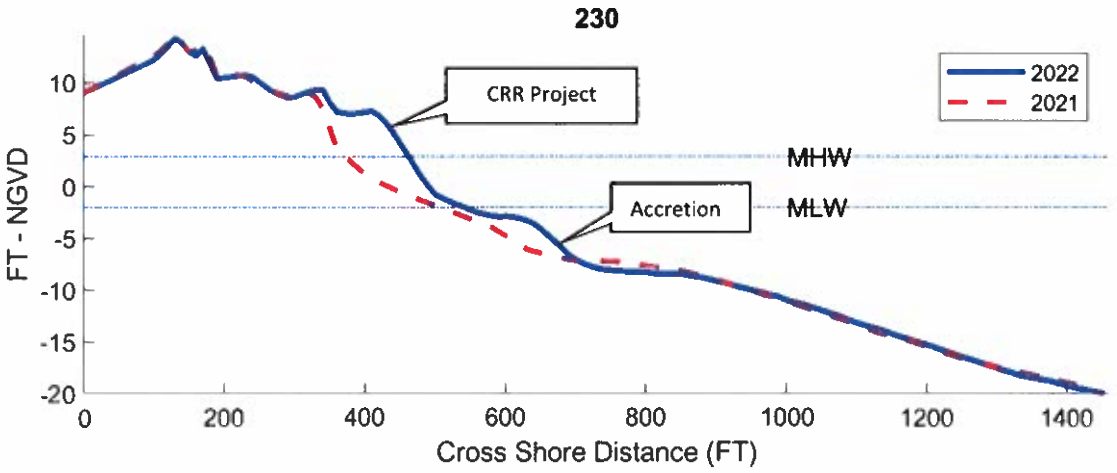



190
Secondary Berm
CRR Project
Erosion
Erosion
MHW
MLW
2022
2021
FT - NGVD
Cross Shore Distance (FT)

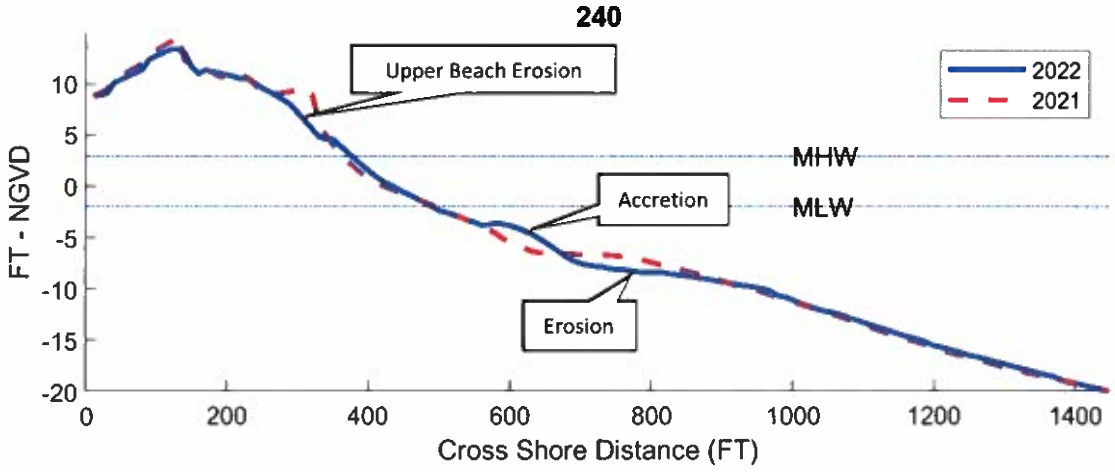

200
CRR Project
MHW
MLW
2022
2021
FT - NGVD
Cross Shore Distance (FT)

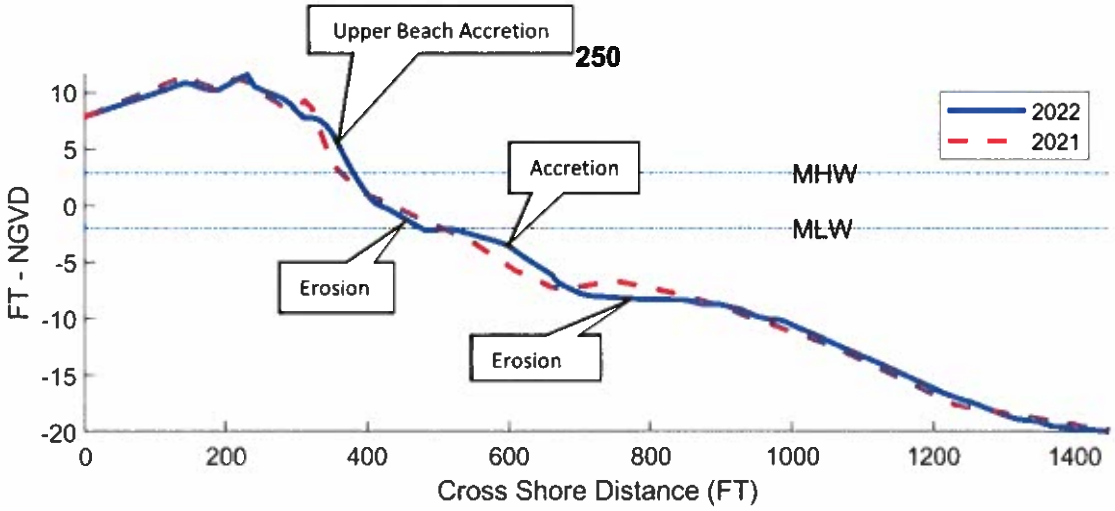

210
CRR Project
MHW
MLW
2022
2021
FT - NGVD
Cross Shore Distance (FT)

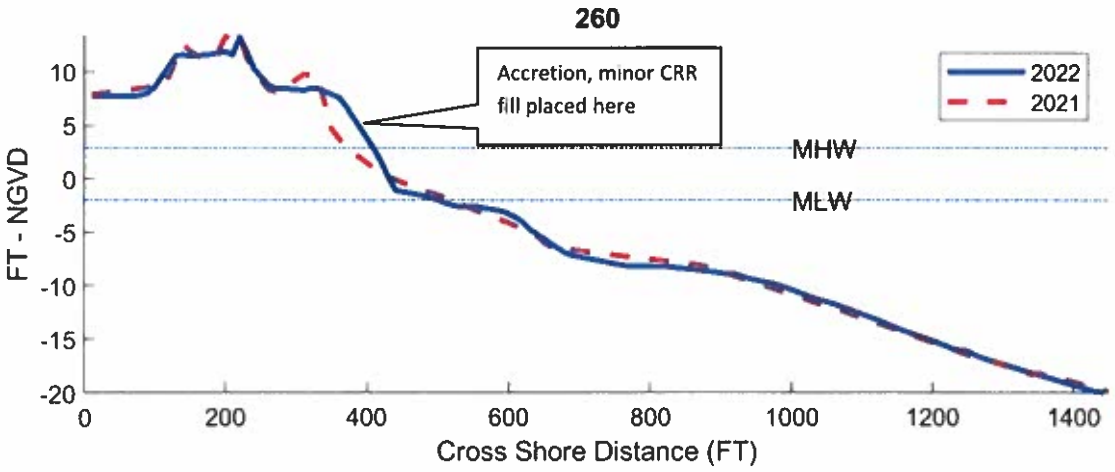


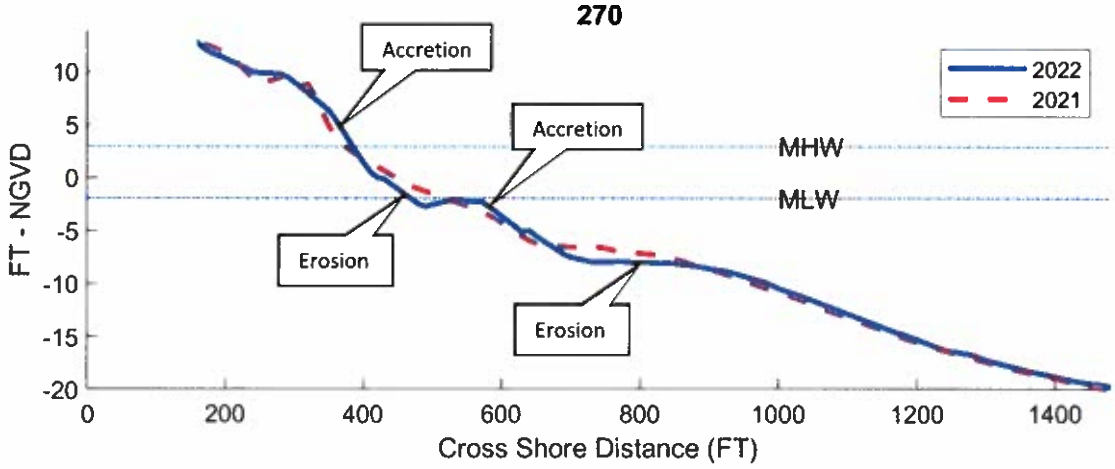


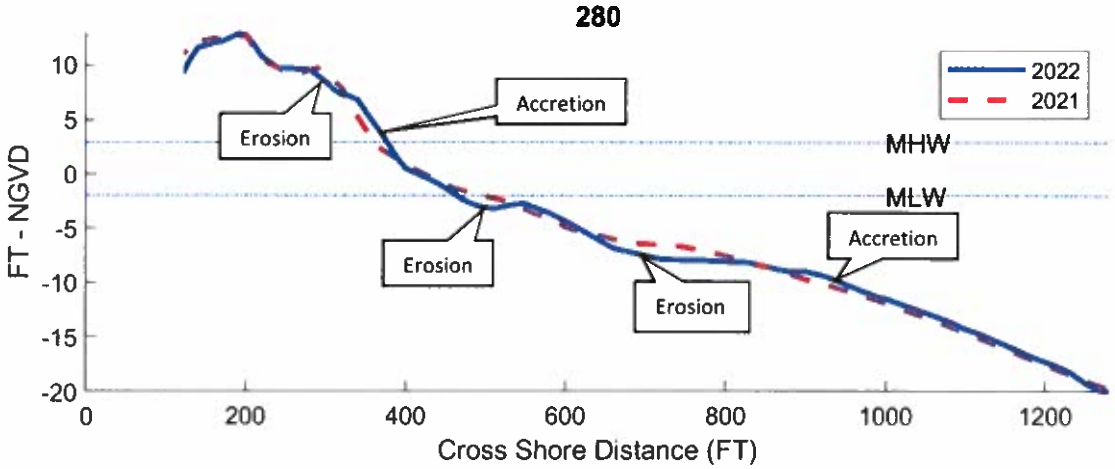
Station 230+00. Approximate west taper of the CRR project, however, minor fill was placed at Station 260+00

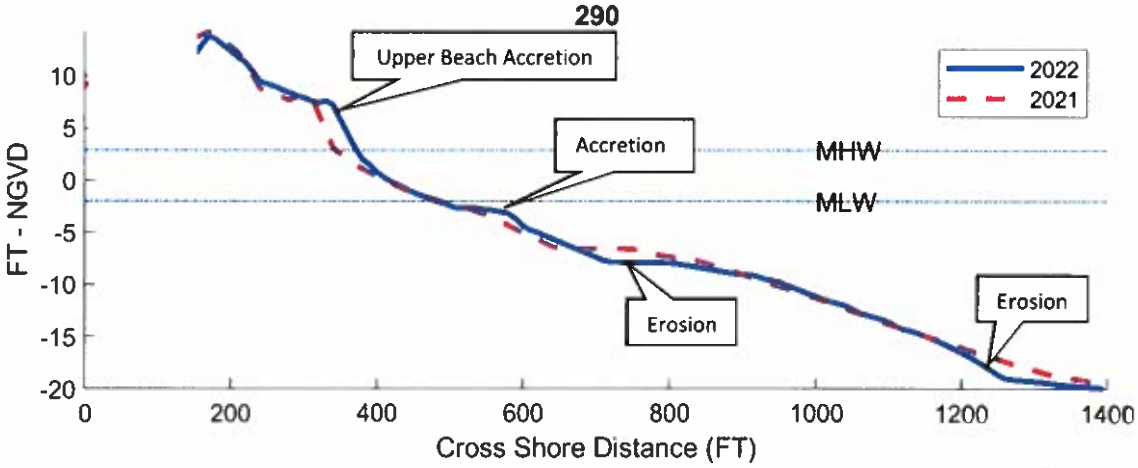

240
Upper Beach Erosion
2022
2021
MHW
MLW
Accretion
Erosion
FT - NGVD
Cross Shore Distance (FT)


Upper Beach Accretion
250
2022
2021
Accretion
MHW
MLW
Erosion
Erosion
FT - NGVD
Cross Shore Distance (FT)

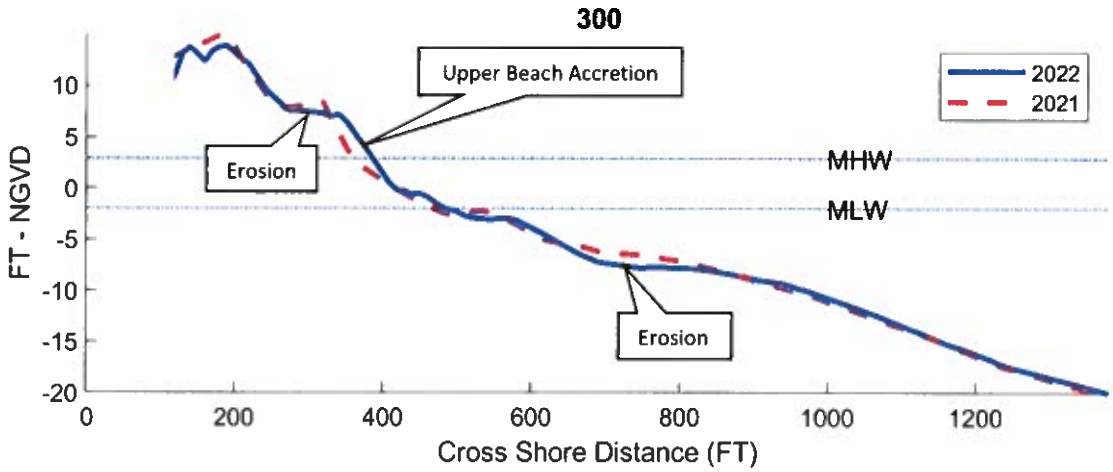

260
Accretion, minor CRR
fill placed here
2022
2021
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)



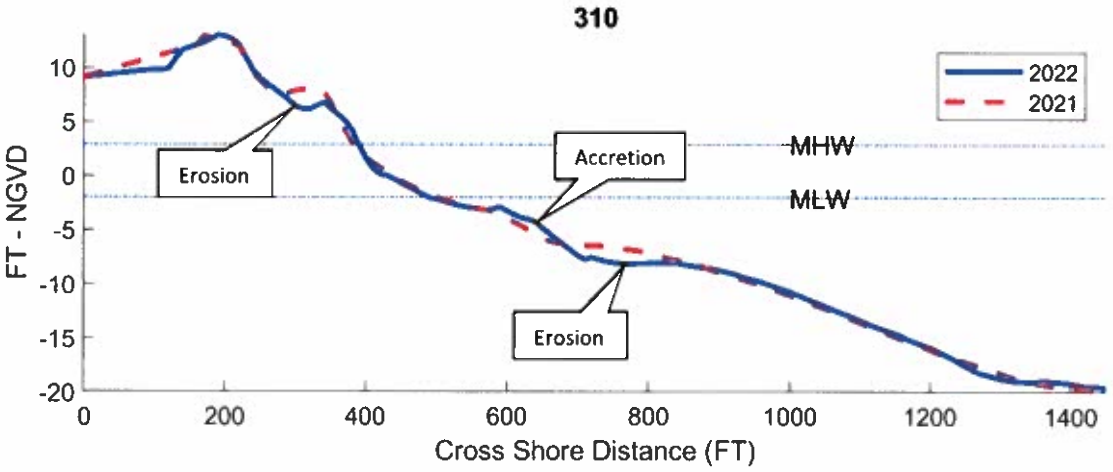


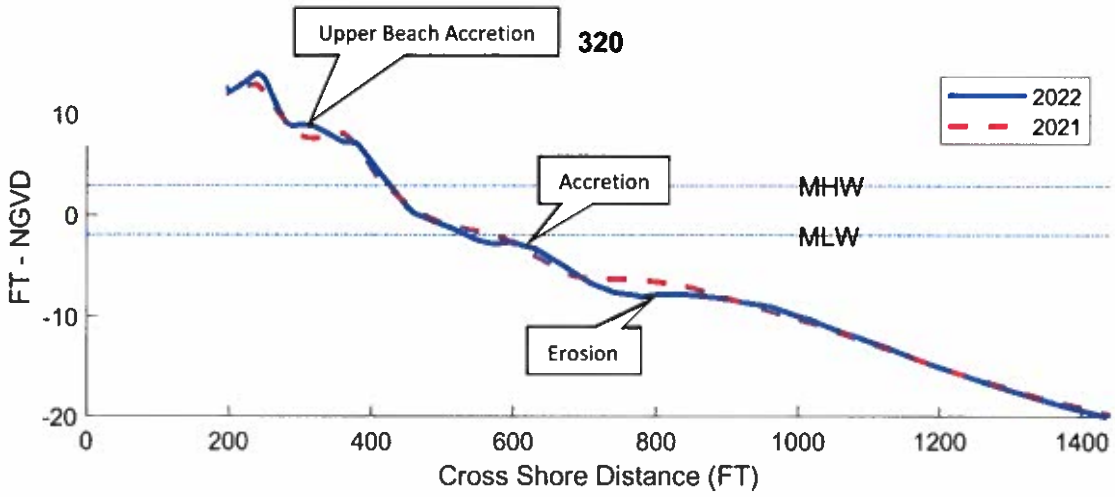


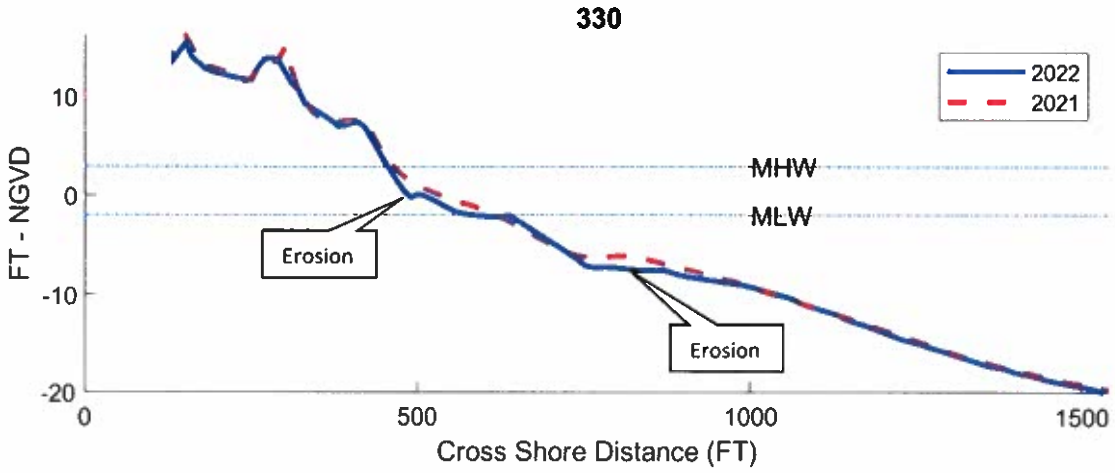
Station 290+00. 2022 survey shows the benefits of continued downdrift spreading of the 2017 Central Reach Project far outside of the original fill template placement. Additional accretional spreading is anticipated in futures years from the 2022 CRR material.

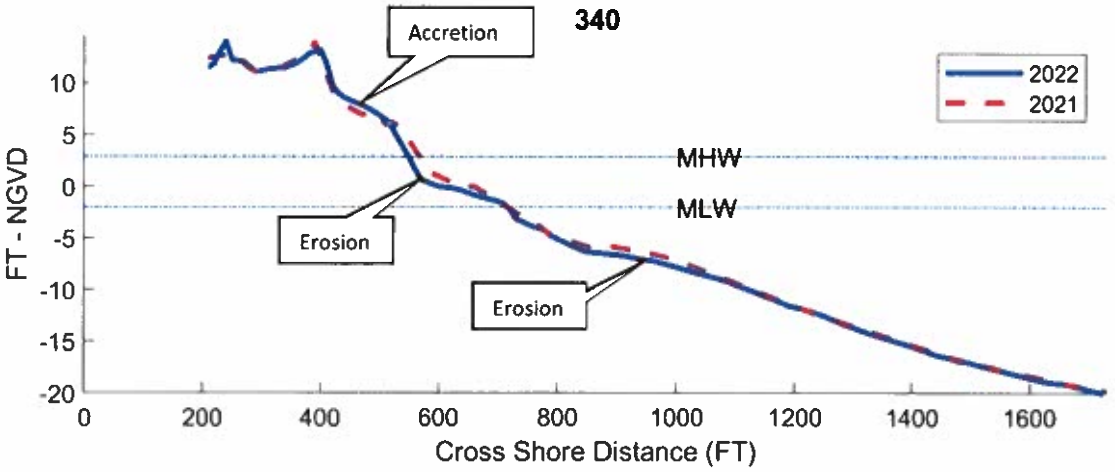


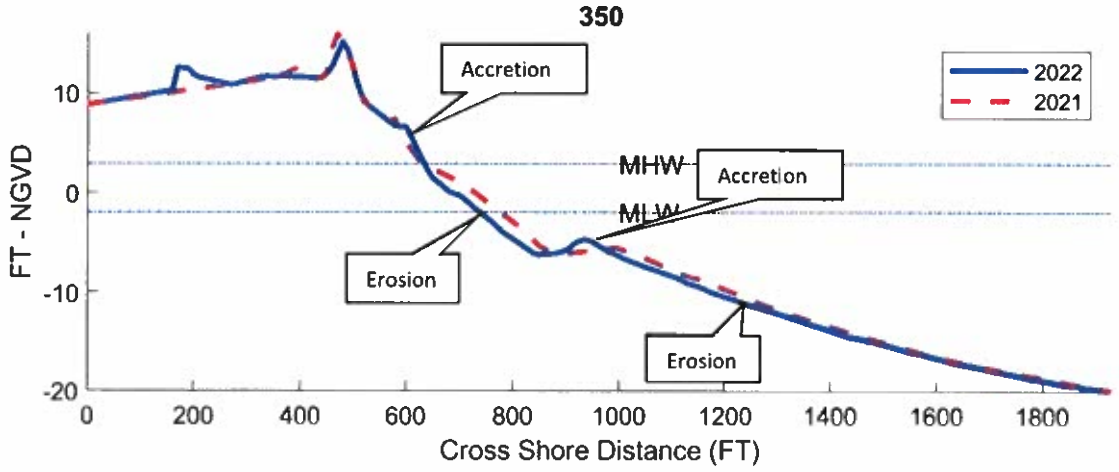
Station 300+00. Intertidal and upper beach accretion is observed over the past year (also observed extending beyond Station 360+00) showing the continued spreading benefits from the 2017 Central Reach nourishment.

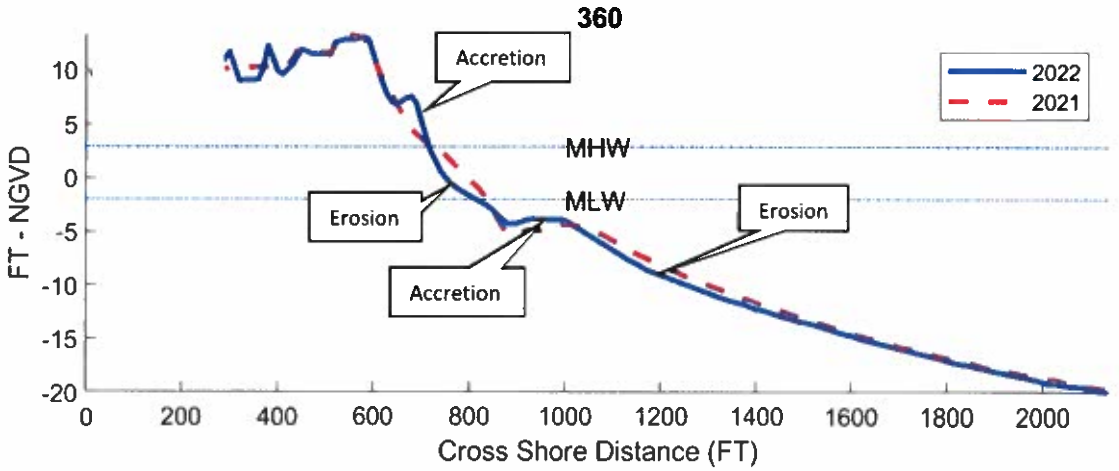



320
Upper Beach Accretion
Accretion
Erosion
MHW
MLW
2022
2021
FT - NGVD
Cross Shore Distance (FT)

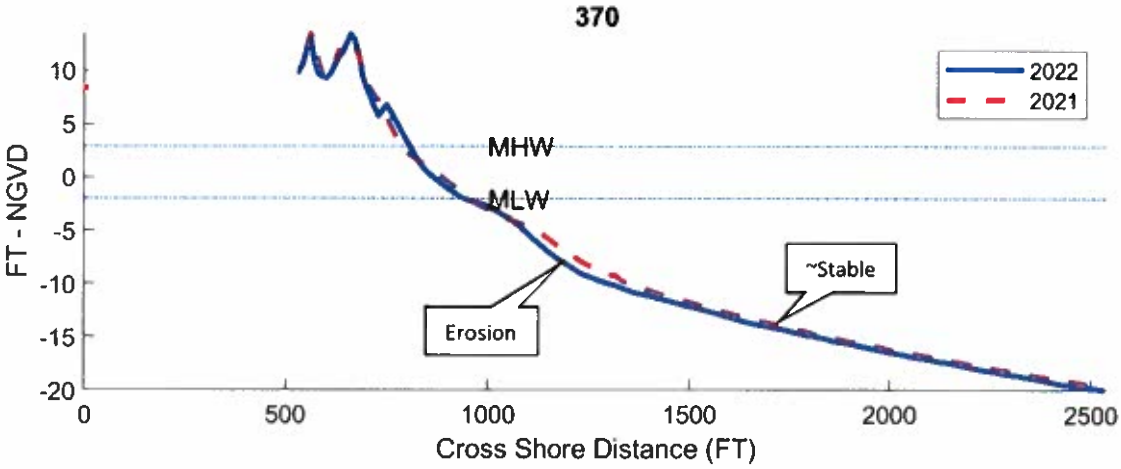

330
Erosion
Erosion
MHW
MLW
2022
2021
FT - NGVD
Cross Shore Distance (FT)

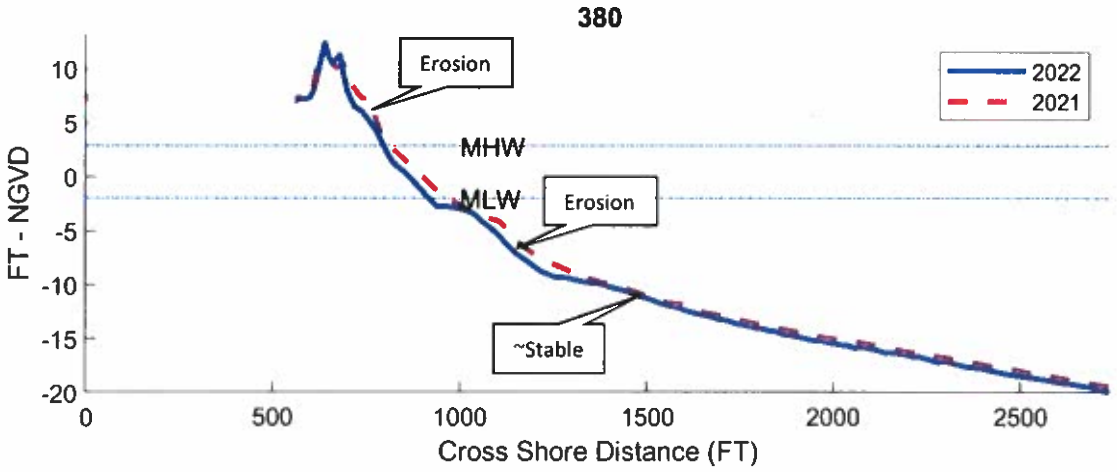

340
Accretion
Erosion
Erosion
MHW
MLW
2022
2021
FT - NGVD
Cross Shore Distance (FT)

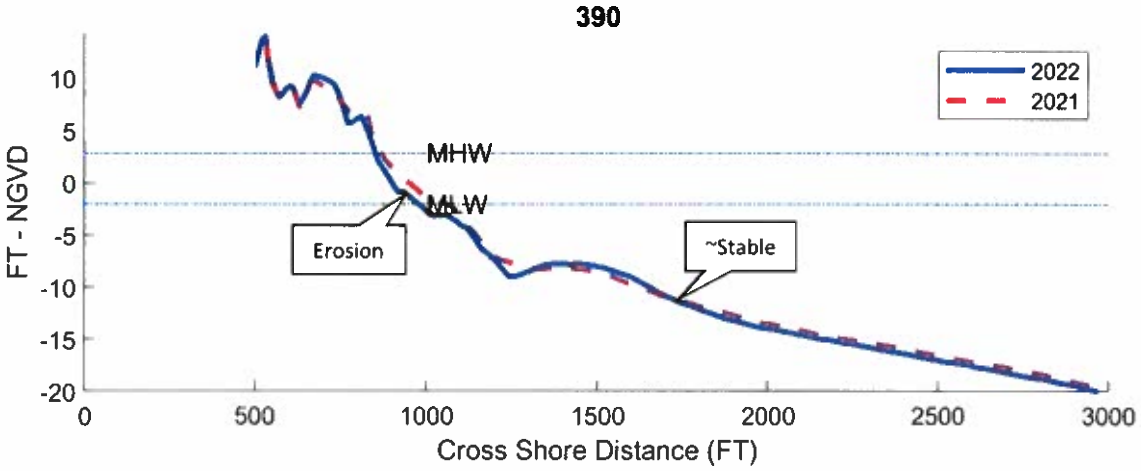


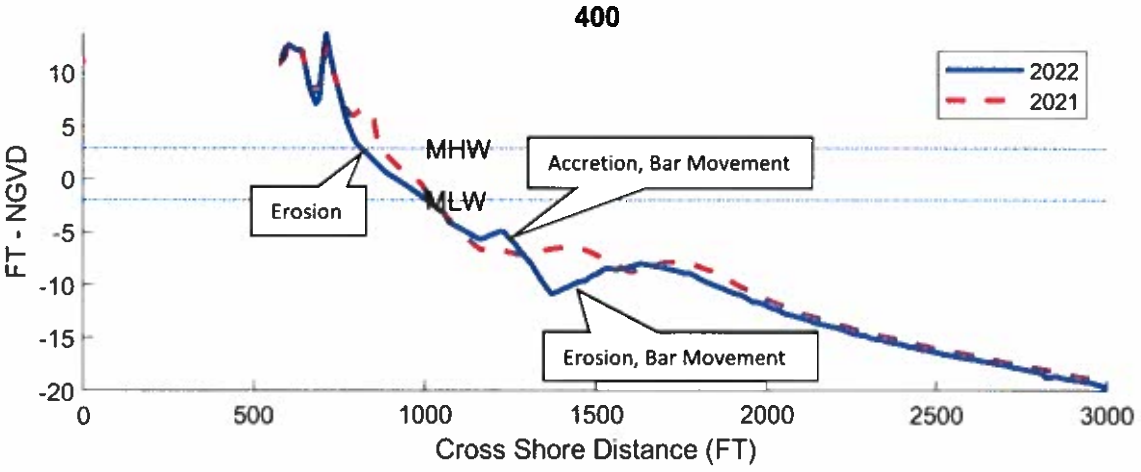


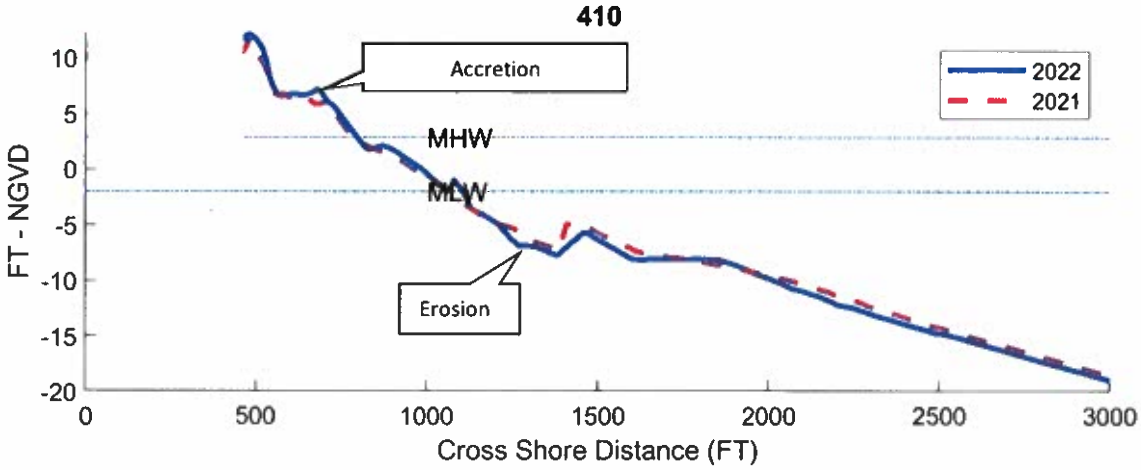
Station 360+00. Intertidal erosion, and upper beach accretion is observed. Dunes are overall very healthy and stable over the past year along the west end continuing towards Shallotte Inlet.

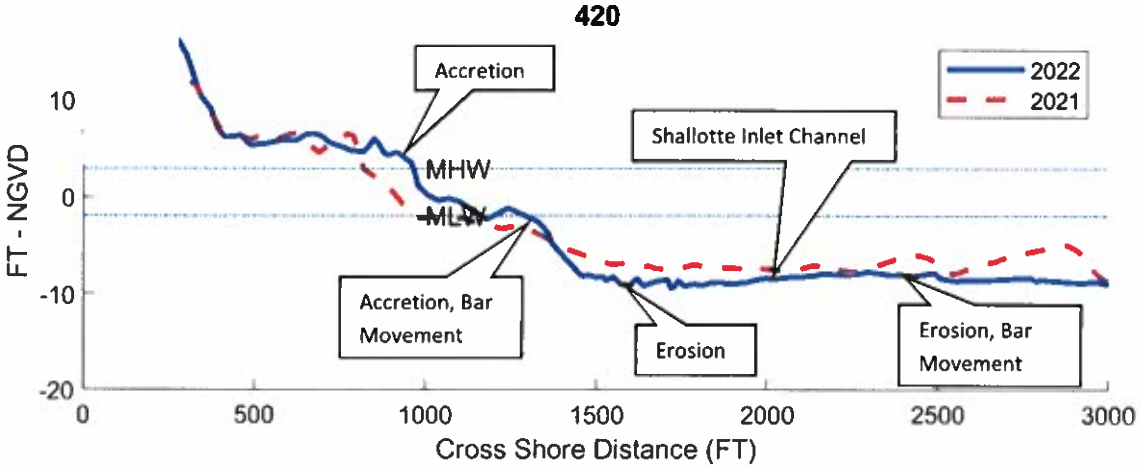



380
Erosion
2022
2021
MHW
MLW
Erosion
~Stable
FT - NGVD
10
5
0
-5
-10
-15
-20
0
500
1000
1500
2000
2500
Cross Shore Distance (FT)

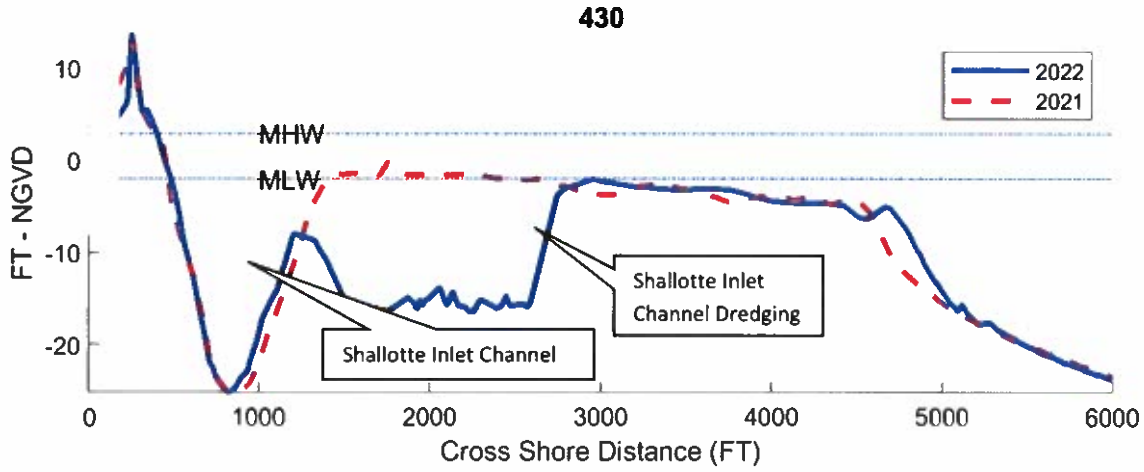

390
2022
2021
MHW
MLW
Erosion
~Stable
FT - NGVD
10
5
0
-5
-10
-15
-20
0
500
1000
1500
2000
2500
3000
Cross Shore Distance (FT)


400
2022
2021
MHW
MLW
Erosion
Accretion, Bar Movement
Erosion, Bar Movement
FT - NGVD
10
5
0
-5
-10
-15
-20
0
500
1000
1500
2000
2500
3000
Cross Shore Distance (FT)

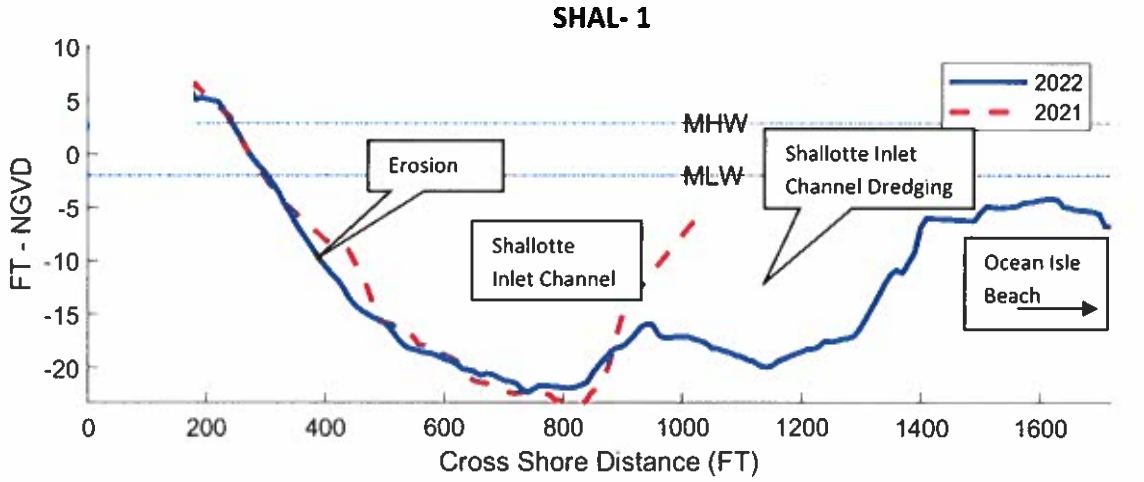




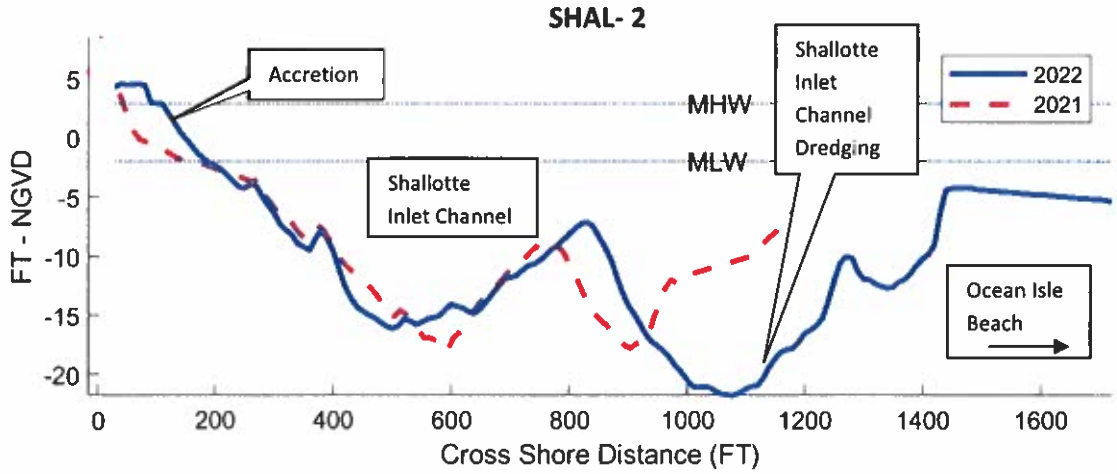
Station 420+00. 2022 survey shows upper and intertidal beach accretion as well as bar movement and channel deepening since 2021.



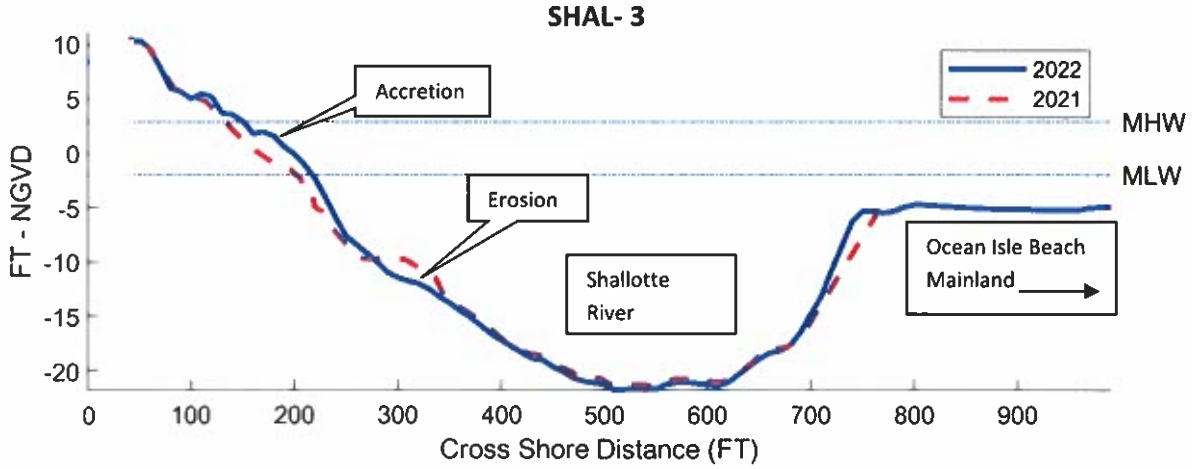
Station 430+00. The beach appears mostly stable on the Holden Beach side of the Shallotte Inlet Channel. Significant changes in offshore depths are observed due to dredging of the Shallotte Inlet borrow area.



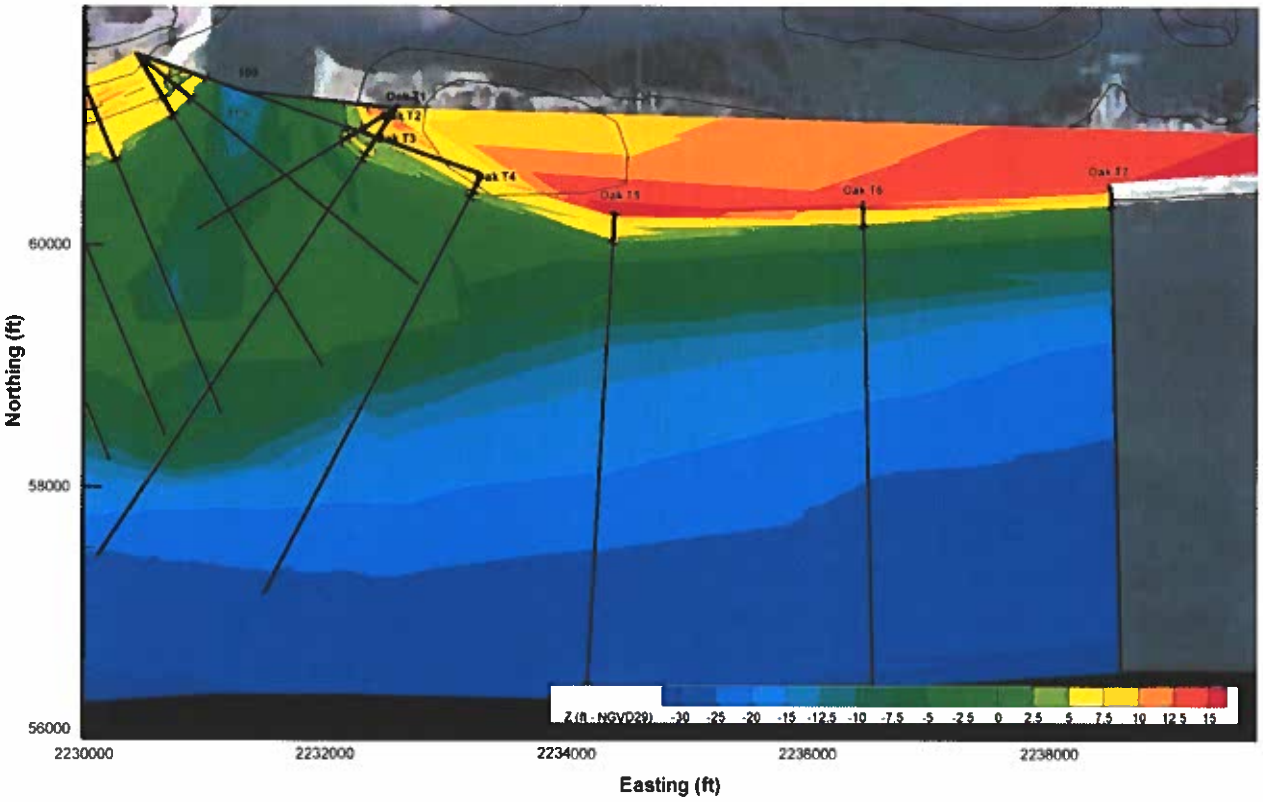
Station SHAL-1. Shallotte Inlet Channel profile shown surveyed for the first time in 2020. Erosion observed here on the Holden Beach side over the past year and channel has widened significantly since 2021 due to the Shallotte Inlet borrow area dredging.



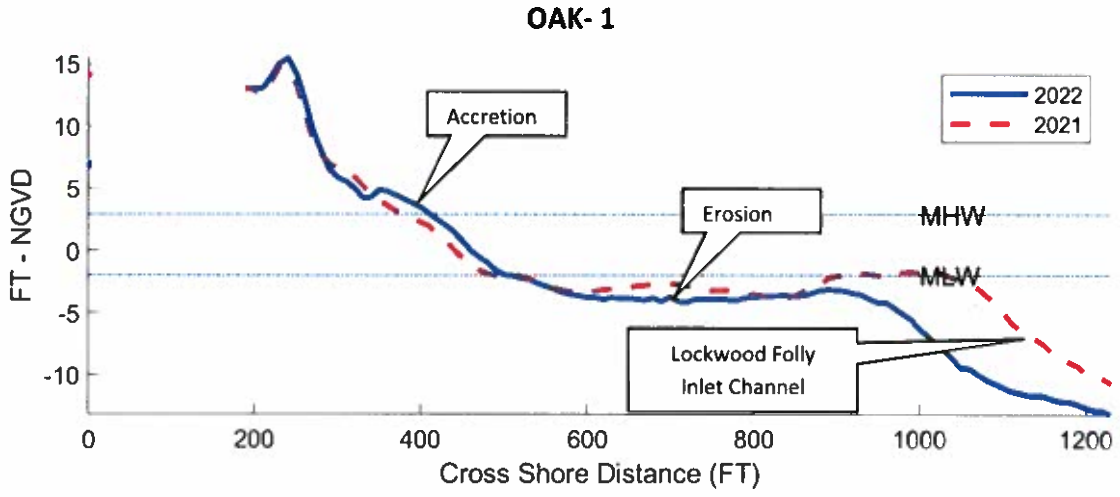
Station SHAL-2. Shallotte Inlet Channel profile shown surveyed for the first time in 2020. Upper and intertidal beach accretion on the Holden Beach side and shoal movement offshore over the past year as well as Shallotte Inlet borrow area dredging.



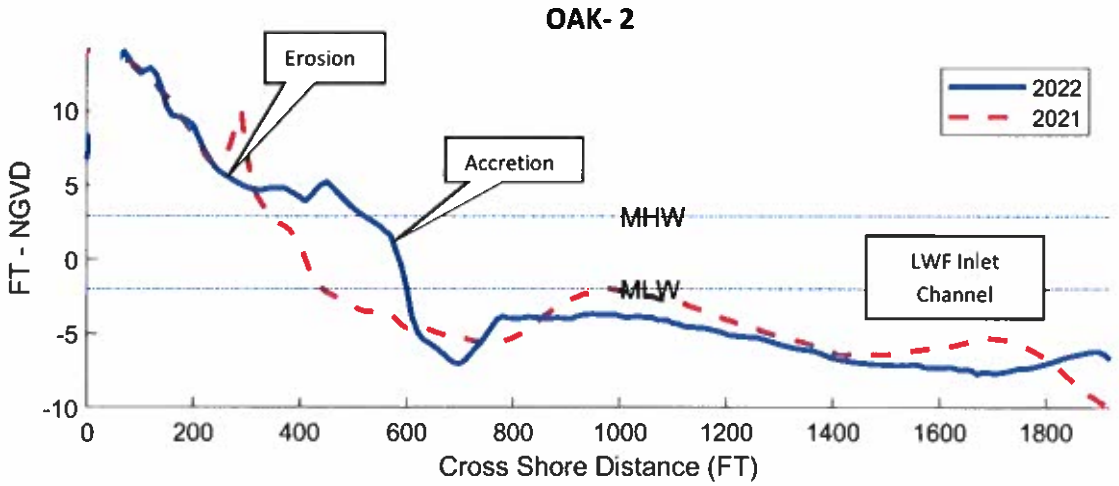
Station SHAL-3. Shallotte Inlet Channel profile shown surveyed for the first time in 2020. A mostly accretional beach on the Holden Beach side and generally stable channel observed over the past year here.



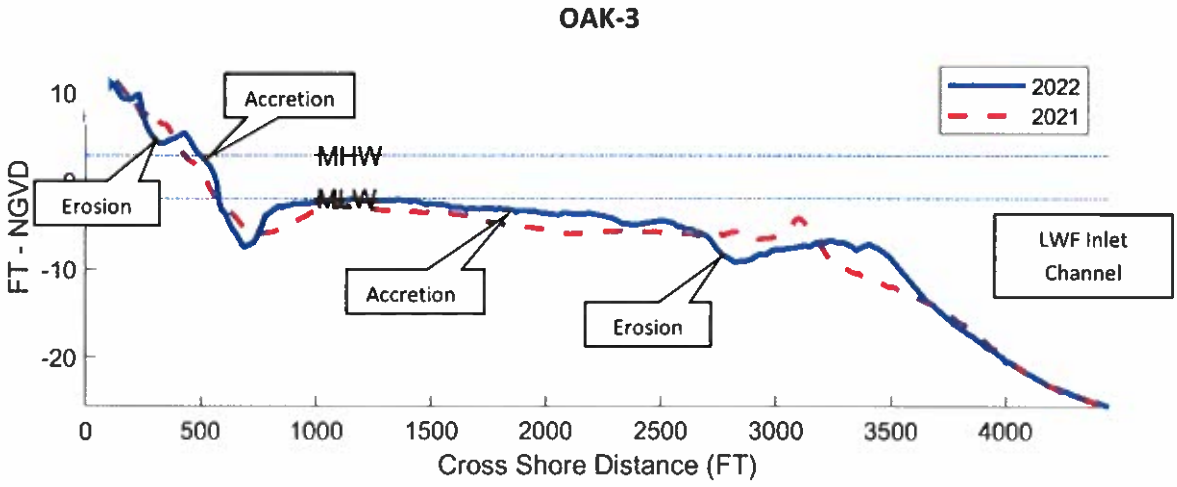
Oak Island Transects

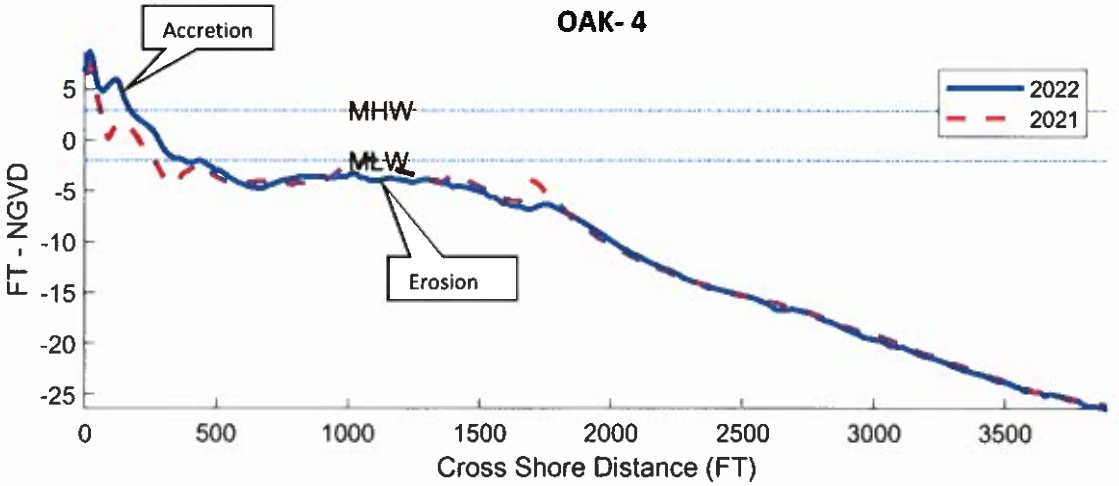


Station OAK- 1. The dune system is healthy and some intertidal accretion is seen along the western-most Oak Island profiles. The LWF Inlet Channel is observed to have deepened since the 2021 survey.



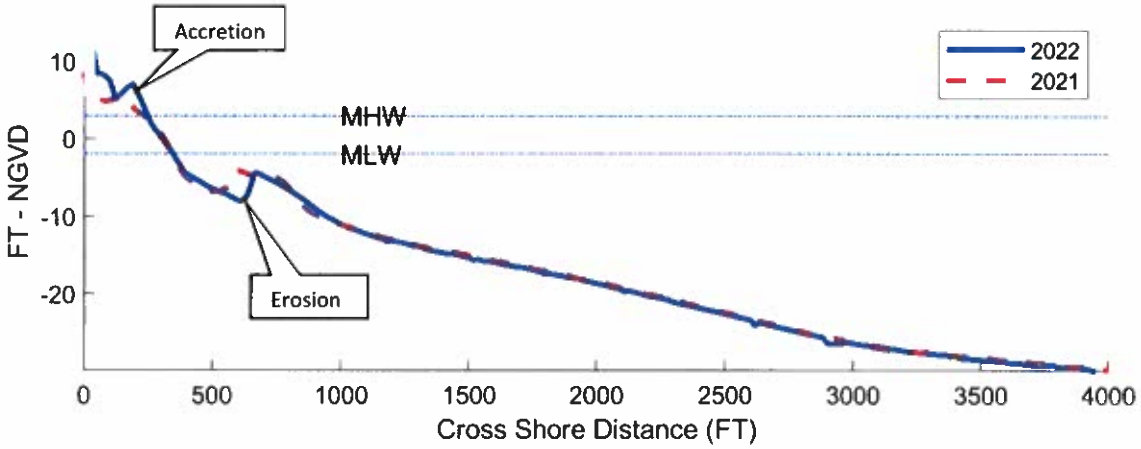
Station OAK- 2. Significant intertidal accretion observed here and offshore erosion and bar movement due to inlet dynamics.



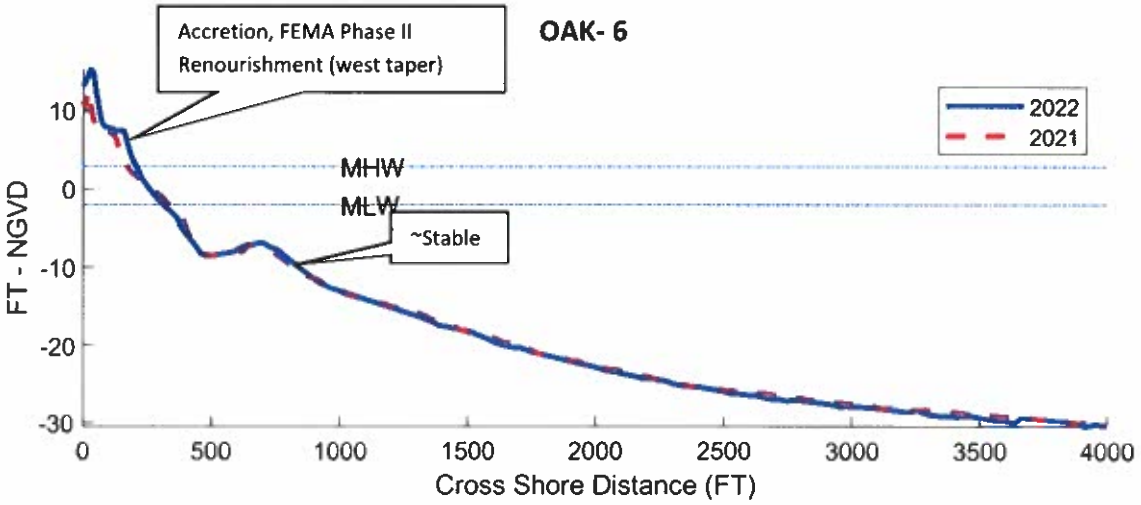


Station OAK-4. Upper beach and intertidal accretion observed here and at OAK-5 through OAK-7 due to equilibration and spreading of the 2021 USACE LWFIX dredging and beach placement and the recent 2022 FEMA Phase II Renourishment placement.

OAK- 5



OAK- 6



OAK- 7

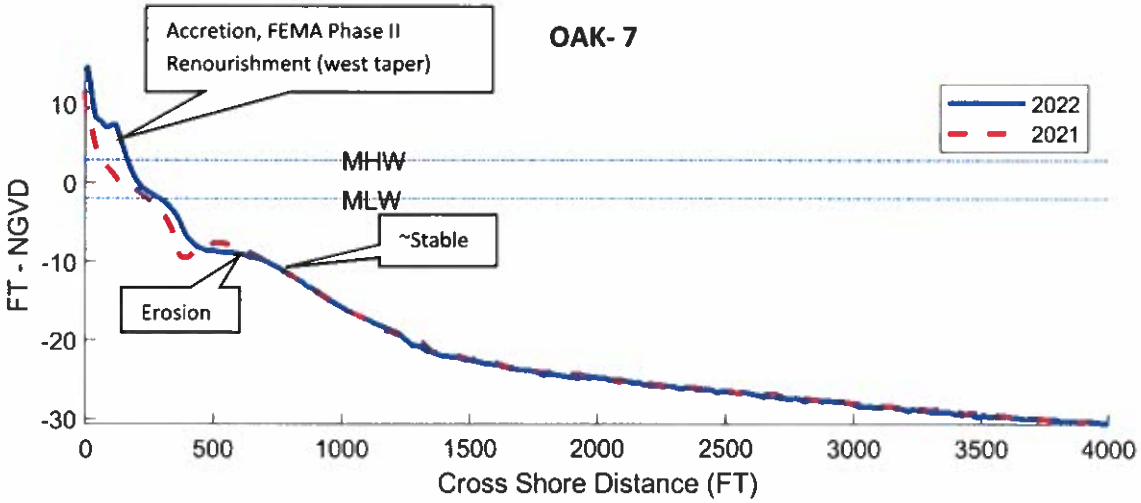


TABLE A-1: 2021 to 2022 Survey Transect Analysis

General Notes –

Transects are primarily oceanfront perpendicular and parallel except for inlets and inlet shoulder transects.

Unit Volume (cy/ft) changes at inlet and inlet shoulder transects cannot use "average end" method for calculating volumes.

MHW change at inlet and inlet shoulder is not necessarily perpendicular to the shoreline due to variable orientation.

*all elevations relative to NGVD29

2021 to 2022 Survey Analysis					
STATION	Distance to Next Monument (ft)	Volume Change (cy/ft) (Dune to -12 ft*)	Volume Change (cy/ft) (Dune to -5 ft)	MHW Change (ft)	Notes
109+00	0	55.5	38.8	98.6	LWF Inlet
119+00	0	49.7	23.9	27.1	LWF Inlet
129+00	500	30.4	1.9	-52.8	LWF Inlet
5+00	500	-104.1	-14.6	-36.3	LWF Inlet Shoulder
10+00	500	23.5	2.4	-83.4	LWF Inlet Shoulder
15+00	440	119.0	91.8	99.7	LWF Inlet Shoulder
20+00	1000	13.3	36.4	74.1	Oceanfront Perpendicular
30+00	1000	160.5	71.4	164.2	
40+00	1000	52.6	54.0	147.2	
50+00	1000	75.1	60.6	166.9	
60+00	1000	89.1	83.4	221.7	
70+00	1000	83.7	75.3	230.6	
80+00	1000	118.8	101.3	235.3	
90+00	1000	94.0	85.3	219.7	
100+00	1000	89.8	78.4	204.9	
110+00	1000	88.6	78.4	187.4	
120+00	1000	90.2	80.0	203.8	
130+00	1000	75.7	69.0	180.3	
140+00	1000	82.6	74.4	193.7	
150+00	1000	89.0	78.2	179.7	
160+00	1000	88.8	80.1	193.5	
170+00	1000	85.7	78.2	193.7	
180+00	1000	73.7	70.0	168.3	
190+00	1000	52.8	51.3	140.3	
200+00	1000	62.6	58.4	144.8	
210+00	1000	57.6	52.7	132.8	

220+00	1000	60.5	51.5	139.4	
230+00	1000	32.1	32.0	88.0	
240+00	1000	-3.9	-0.6	13.7	
250+00	1000	3.2	4.2	14.3	
260+00	1000	3.3	5.9	34.9	
270+00	1000	-3.6	-0.2	7.7	
280+00	1000	-3.6	-0.4	15.0	
290+00	1000	4.9	8.3	25.1	
300+00	1000	1.2	5.6	25.8	
310+00	1000	-5.0	-1.2	4.6	
320+00	1000	-1.7	3.5	4.7	
330+00	1000	-13.3	-6.2	-9.7	
340+00	1000	-11.5	-5.2	-19.2	
350+00	1000	-17.1	-9.5	1.2	
360+00	1000	-9.3	1.1	-21.2	
370+00	1000	-12.3	0.0	20.8	
380+00	1000	-26.6	-15.7	-21.1	
390+00	1000	-12.3	-13.4	-18.6	
400+00	1000	-45.7	-18.3	-53.7	Oceanfront perpendicular
410+00	1000	-3.7	13.2	9.7	Shallotte Inlet Shoulder
420+00	1000	-53.3	42.5	137.7	Shallotte Inlet
430+00	-	-	-	-	Shallotte Inlet
SHAL 1	-	-	-	-	Shallotte Inlet
SHAL 2	-	-	-	-	Shallotte Inlet
SHAL 3	-	-	-	-	Shallotte Inlet
	OAK ISLAND TRANSECTS				
OAK 1	0	-48.5	-18.1	27.6	LWF Inlet
OAK 2	0	9.7	28.3	180.2	LWF Inlet
OAK 3	890	94.7	73.7	68.8	LWF Inlet
OAK 4	1100	14.4	19.3	118.9	LWF Inlet Shoulder
OAK 5	2000	4.0	9.2	6.0	Oceanfront perpendicular
OAK 6	2000	14.2	10.5	31.4	
OAK 7	-	40.5	37.7	102.9	

Appendix B

2022 Survey Plan View Figures

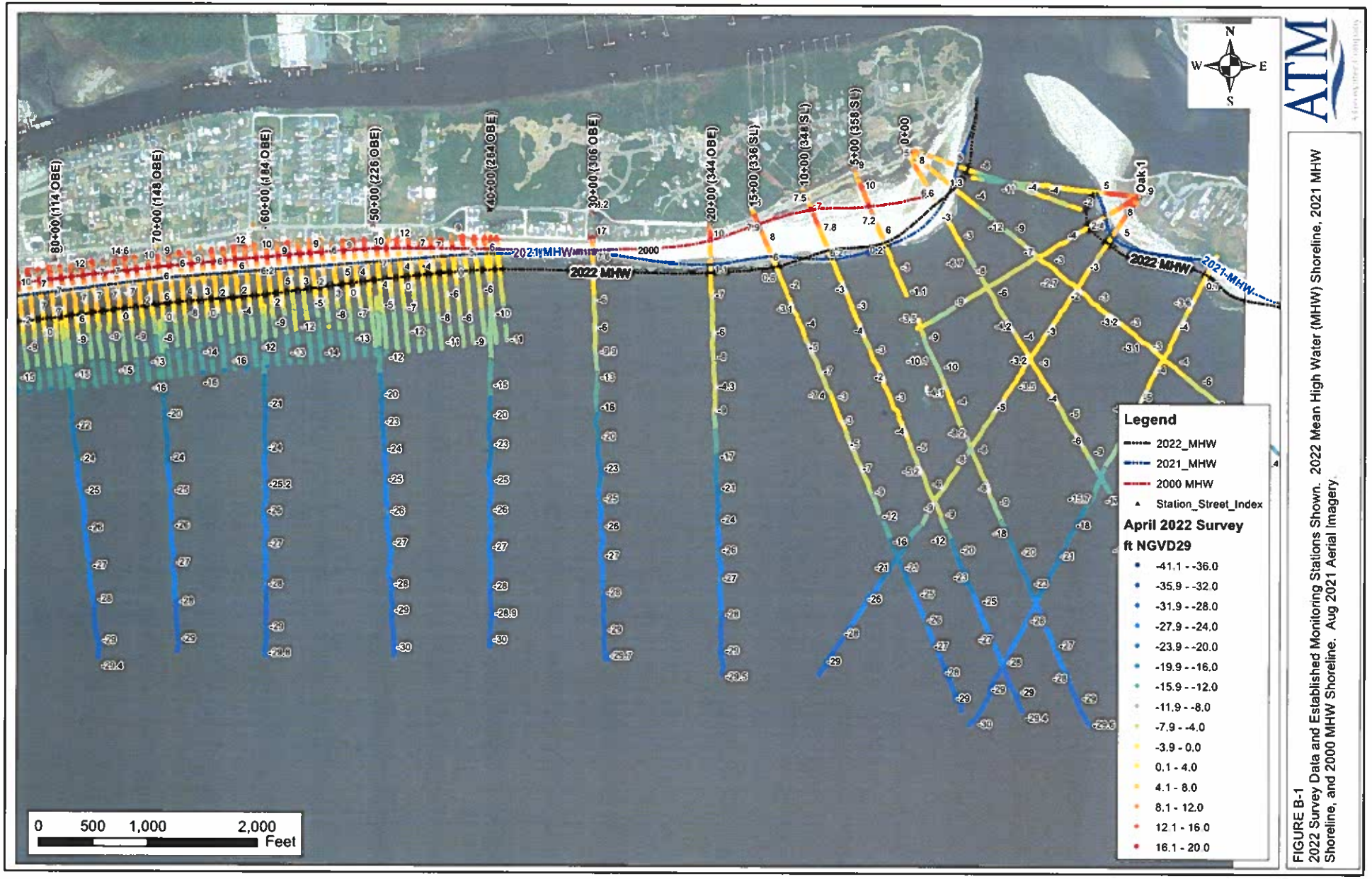


FIGURE B-1
2022 Survey Data and Established Monitoring Stations Shown. 2022 Mean High Water (MHW) Shoreline, 2021 MHW Shoreline, and 2000 MHW Shoreline. Aug 2021 Aerial Imagery.

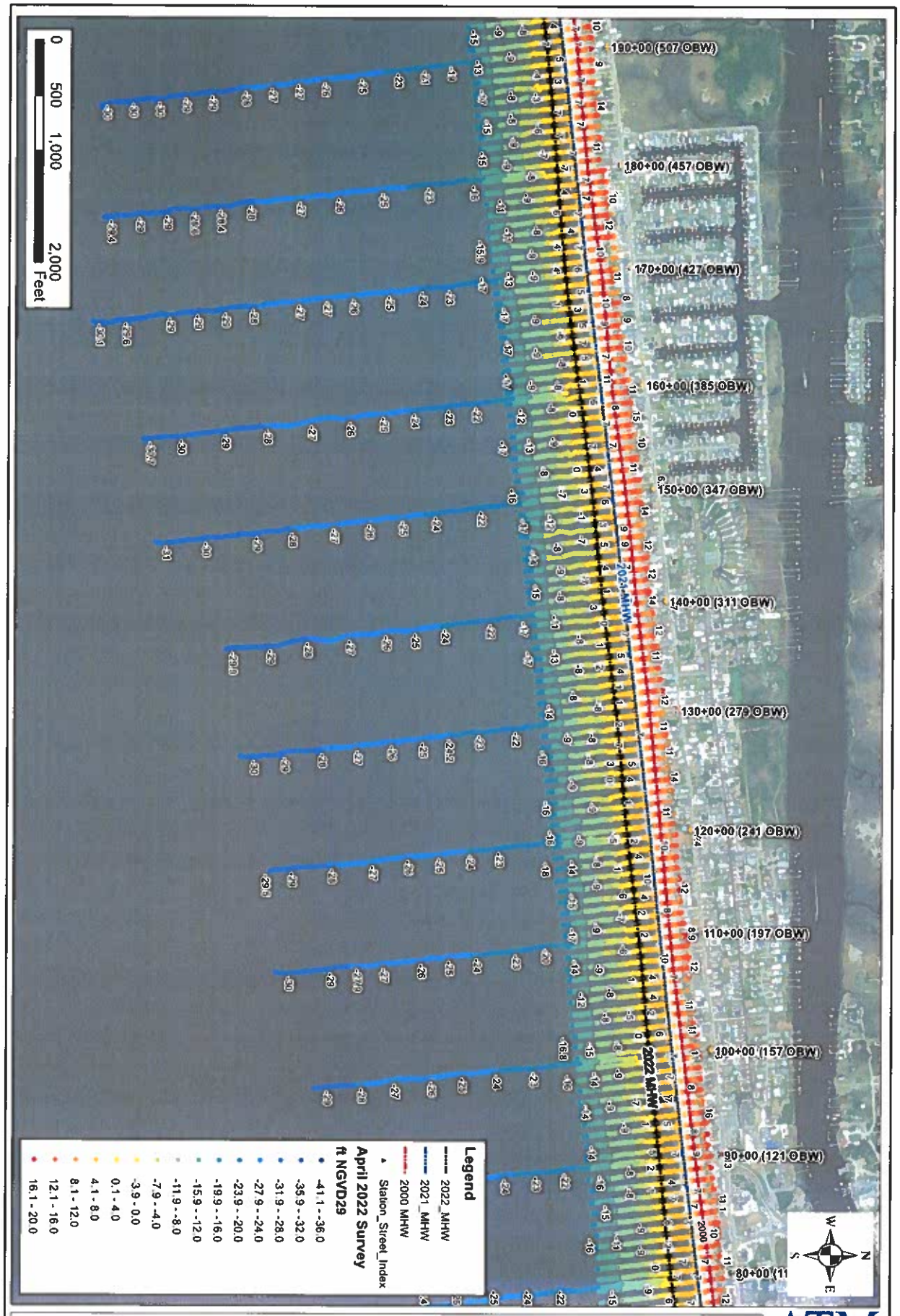


FIGURE B-2
2022 Survey Data and Established Monitoring Stations Shown. 2022 Mean High Water (MHW) Shoreline, 2021 MHW Shoreline, and 2000 MHW Shoreline. Aug 2021 Aerial Imagery.

ATM

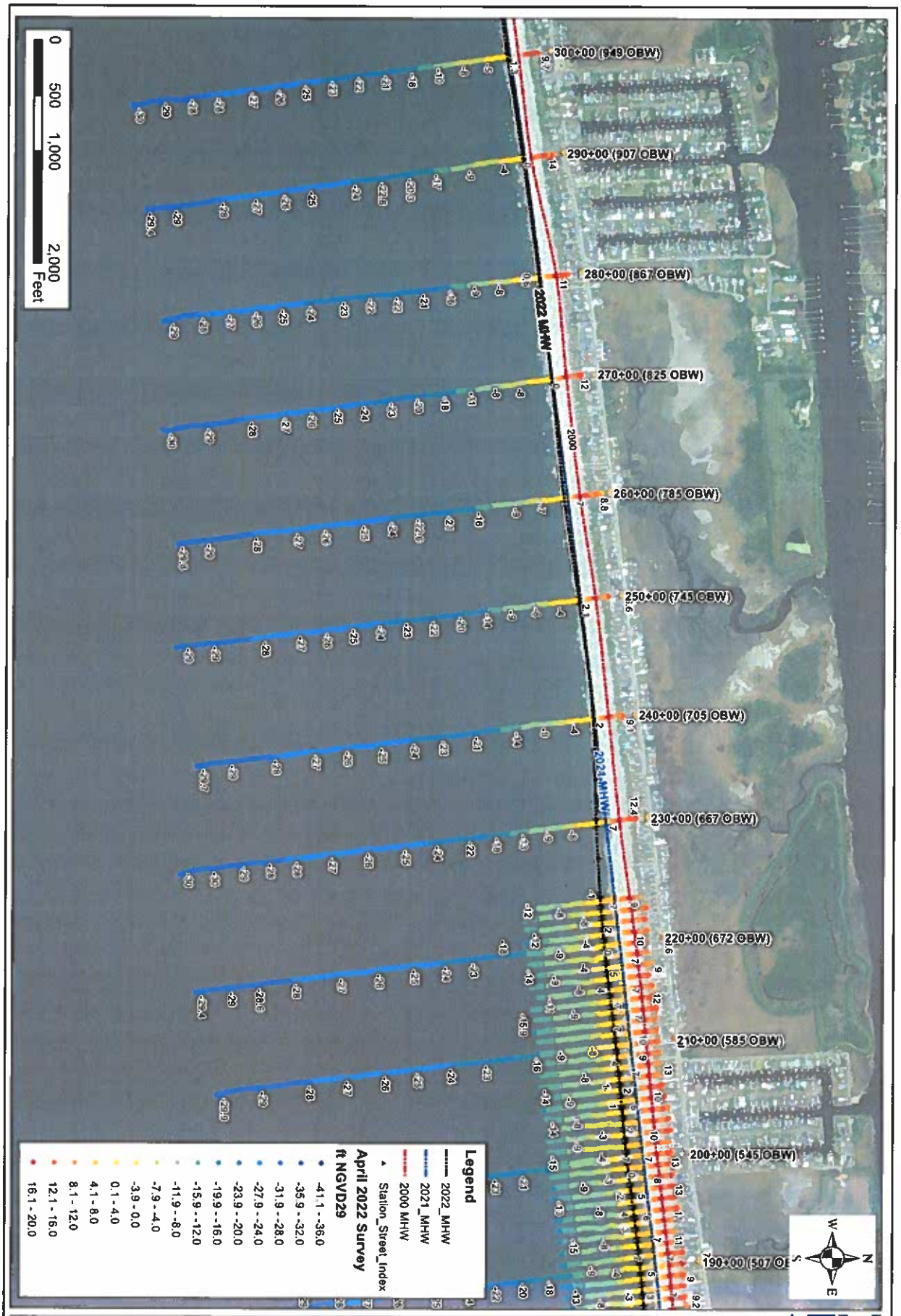


FIGURE B-3
2022 Survey Data and Established Monitoring Stations Shown. 2022 Mean High Water (MHW) Shoreline, 2021 MHW Shoreline, and 2000 MHW Shoreline. Aug 2021 Aerial Imagery.

ATM

FIGURE B-4
2022 Survey Data and Established Monitoring Stations Shown. 2022 Mean High Water (MHW) Shoreline, 2021 MHW Shoreline, and 2000 MHW Shoreline. Aug 2021 Aerial Imagery.

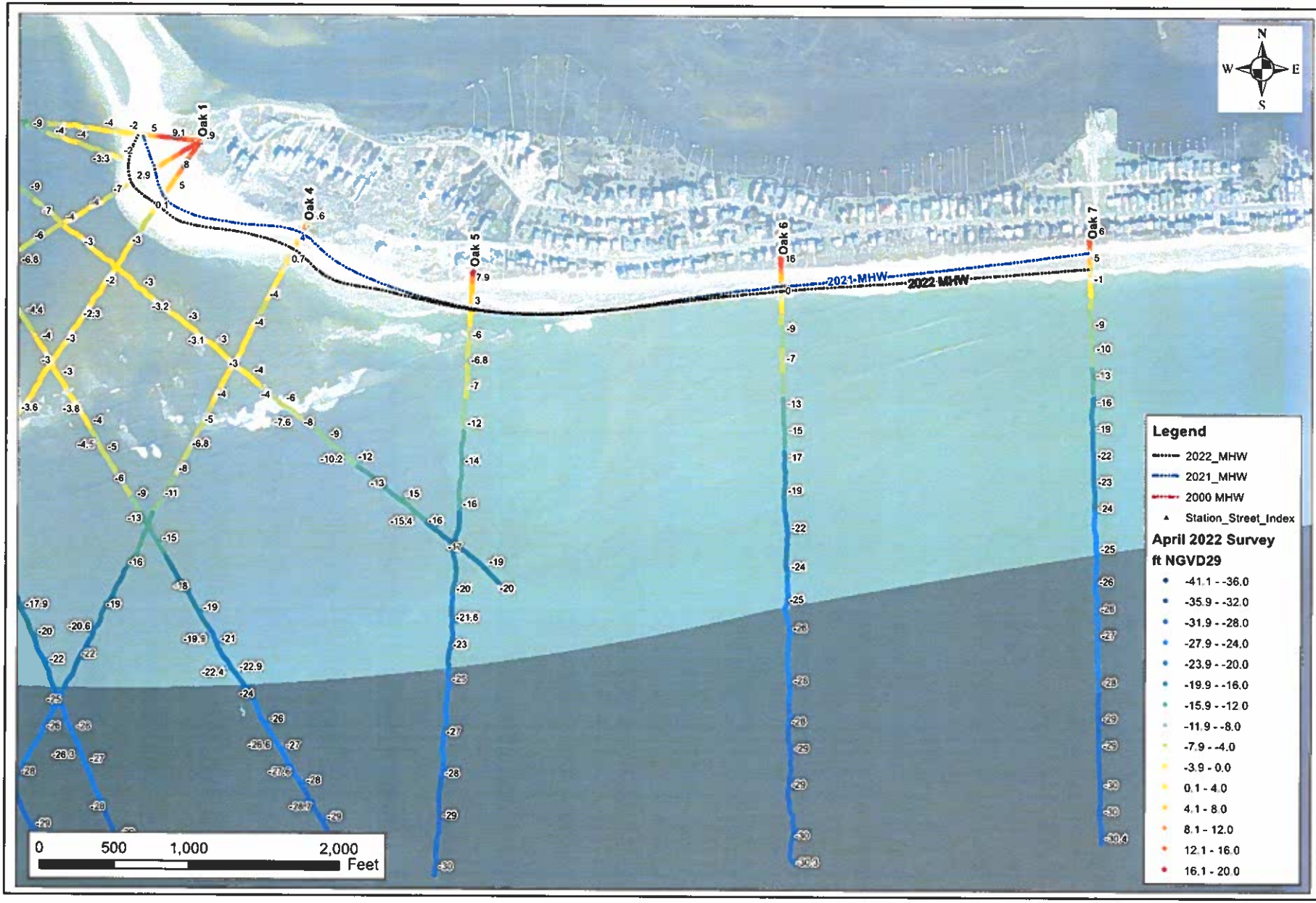


FIGURE B-5
2022 Survey Data and Established Monitoring Stations Shown. 2022 Mean High Water (MHW) Shoreline, 2021 MHW Shoreline, and 2000 MHW Shoreline. 2020 Aerial Imagery.

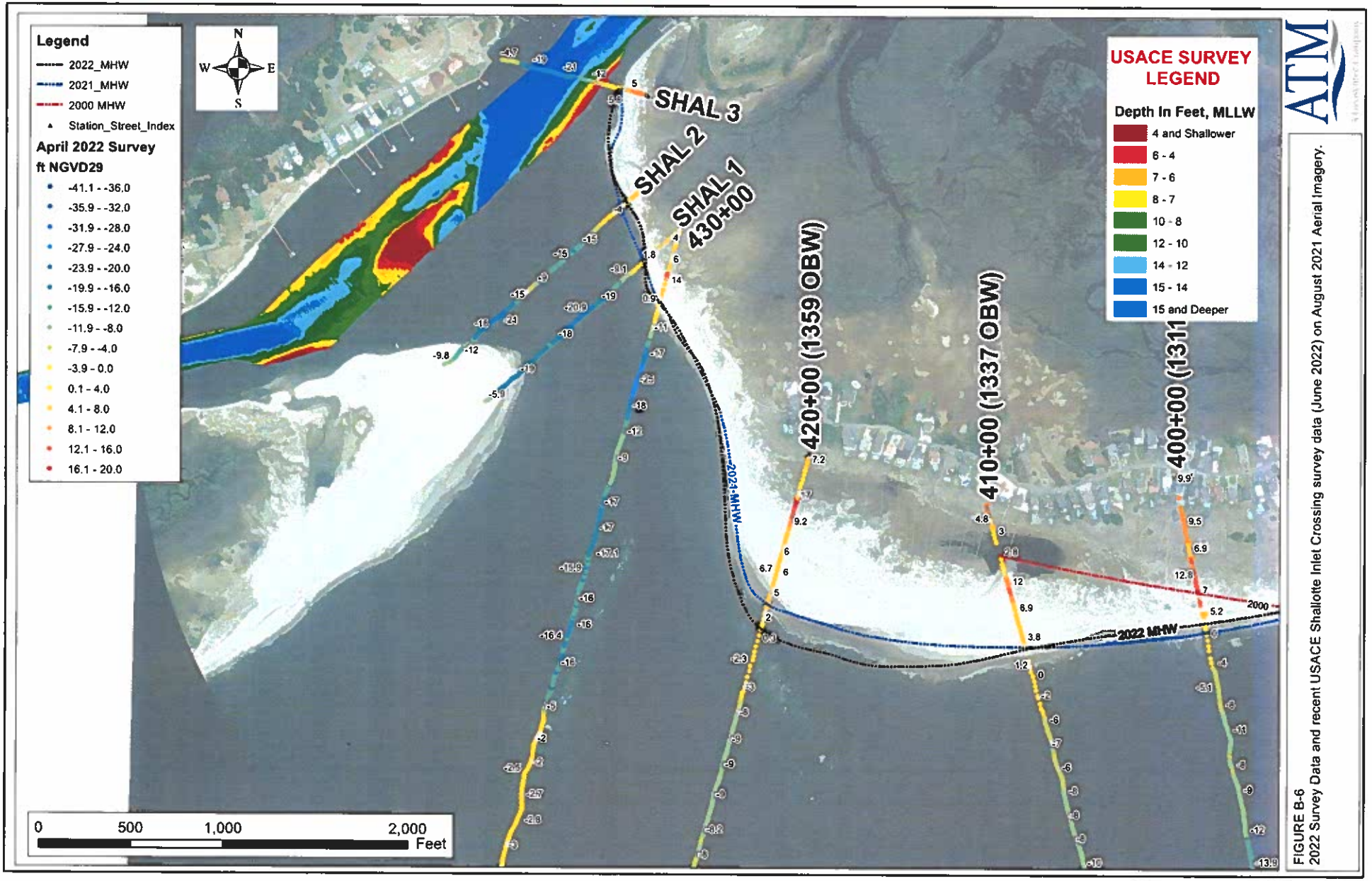


FIGURE B-6
2022 Survey Data and recent USACE Shallotte Inlet Crossing survey data (June 2022) on August 2021 Aerial Imagery.

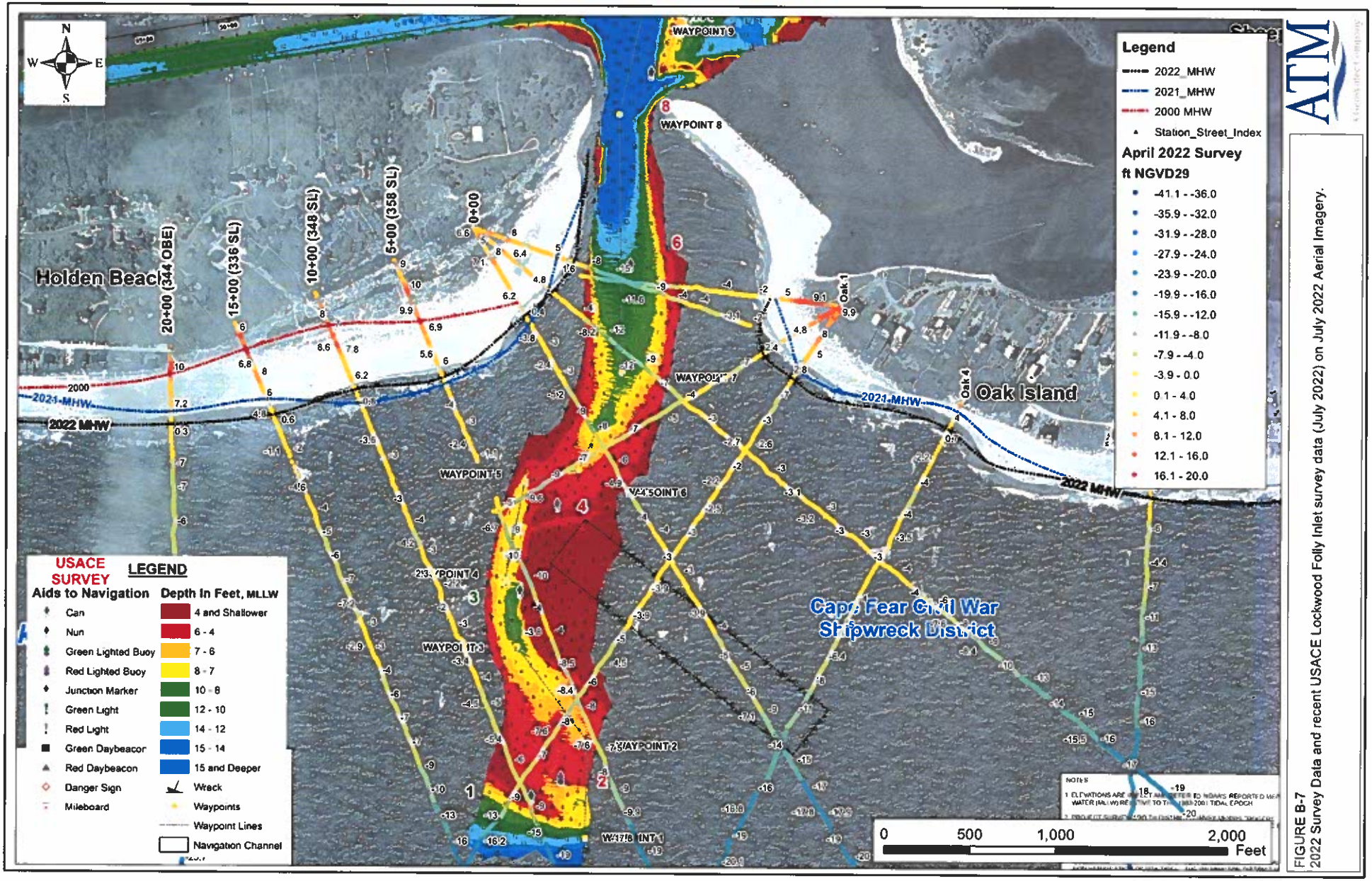


FIGURE B-7
2022 Survey Data and recent USACE Lockwood Folly Inlet survey data (July 2022) on July 2022 Aerial Imagery.