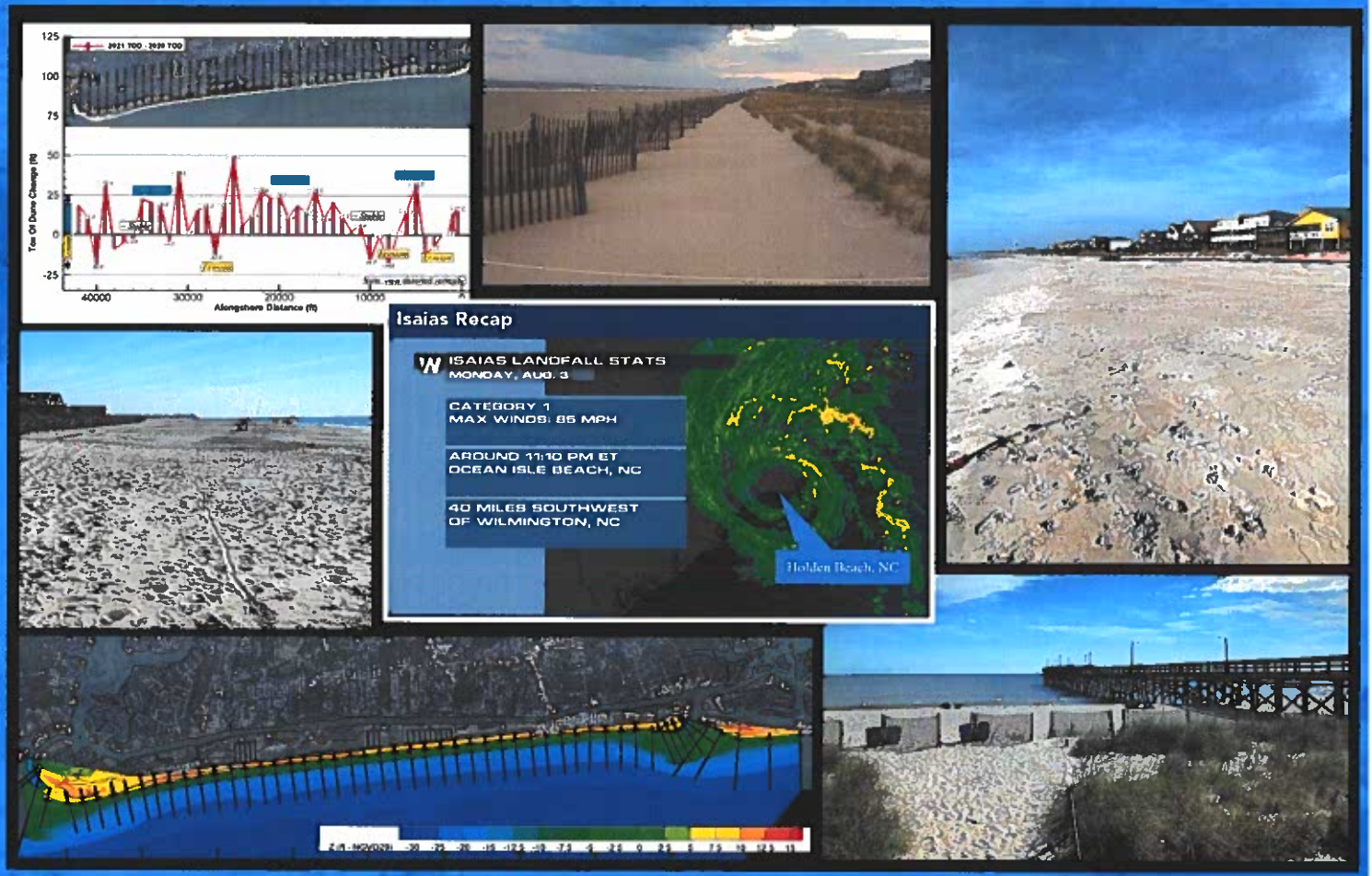
Holden Beach

Annual Beach Monitoring Report

Prepared For:
Town of Holden Beach, North Carolina



December 2021

ATM DESIGN ENGINEERING CONSULTING

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ATM

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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.

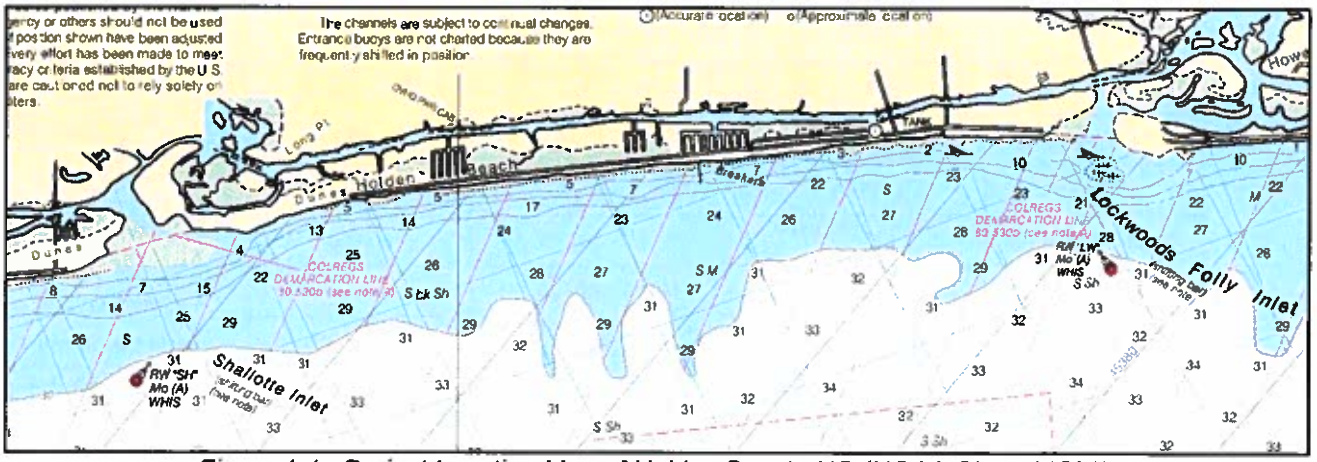

Figure 1-1. Project Location Map of Holden Beach, NC (NOAA Chart 11536)

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 2020 to 2021 beach management activities and compares the most recent annual survey (April 2021) with beach profile surveys collected from 2000 through 2020. 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.

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
		Approximate Total Volume since 2001	**3,482,983**	

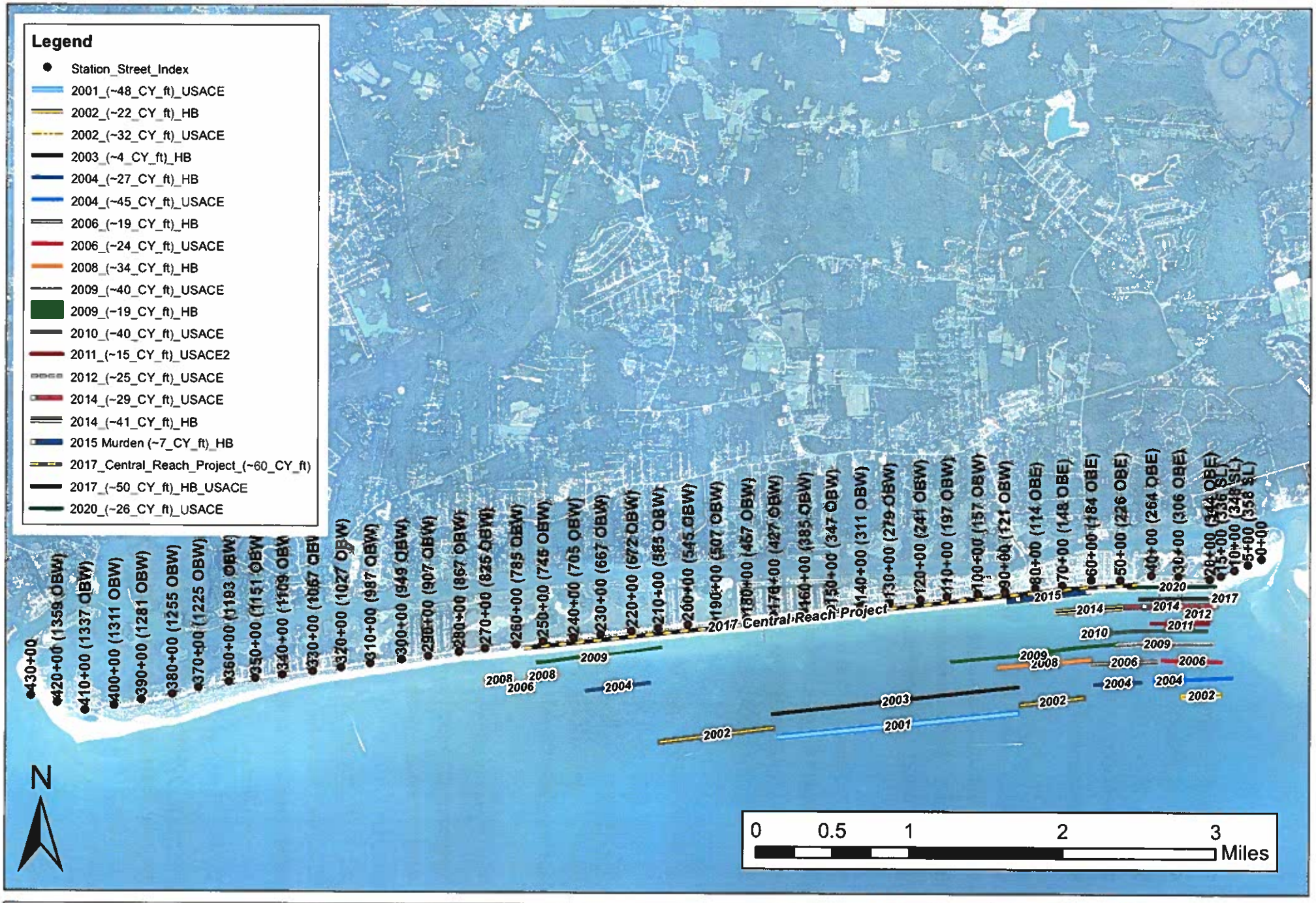

Figure 2-1
Holden Beach nourishments since 2001 and beach stationing for surveying.
Survey stations begin at LWF Inlet (0+00) and are generally at 1,000 foot intervals, ending at Shallotte Inlet (430+00).

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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).

As seen in Table 2-1, the most recent project was completed last spring (2020), when the USACE LWFIX Project placed ~80,000 cy of material along about 3,000 linear feet of shoreline on the eastern end of Holden Beach. No nourishment activity on Holden Beach occurred in 2018, 2019, or 2021.

In March of 2017, the Town 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. Of course, 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.

The 4-year post-project movement and spreading of the fill placements from these two nourishment projects are reflected in the 2021 survey (discussed in Section 3). Further details of these projects are provided in subsequent sections.

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 CENTRAL REACH PROJECT

The Town CRP nourishment occurred in winter/spring 2017 and represents the largest beach fill project to date on the island. Project construction began on January 3, 2017 and was completed on March 17, 2017 (74 days) by Weeks Marine. 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, and Figure 2-5 presents a typical fill cross-section following construction. 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).

Construction was scheduled to begin in mid-December 2016, but winter storms caused some minor delays and the project officially began on January 3, 2017. Fortunately, two hopper dredges were utilized simultaneously for the majority of the project's duration. These dredges were the R.N. Weeks and the B.E. Lindholm (Figure 2-6). The use of two hopper dredges helped move the project along very efficiently and allowed work to progress without delay since the dredges periodically would have to leave the project site and return to the maintenance yard in Wilmington for equipment changes or services.

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 ft of shoreline per day. Despite the minor delays towards the beginning and near the end of the project, the entire nourishment took approximately 74 days and was completed on March 17. Aerial and ground photographs taken during construction are provided in Figures 2-7 and 2-8.

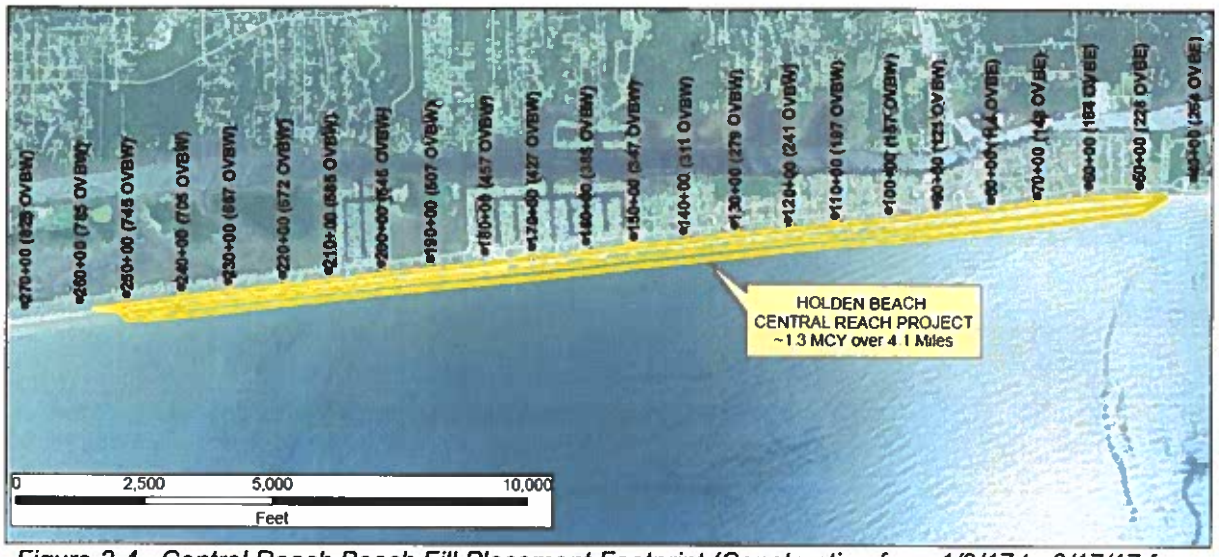

Figure 2-4. Central Reach Beach Fill Placement Footprint (Construction from 1/3/17 to 3/17/17 from Approximately Station 45+00 to Station 257+00)

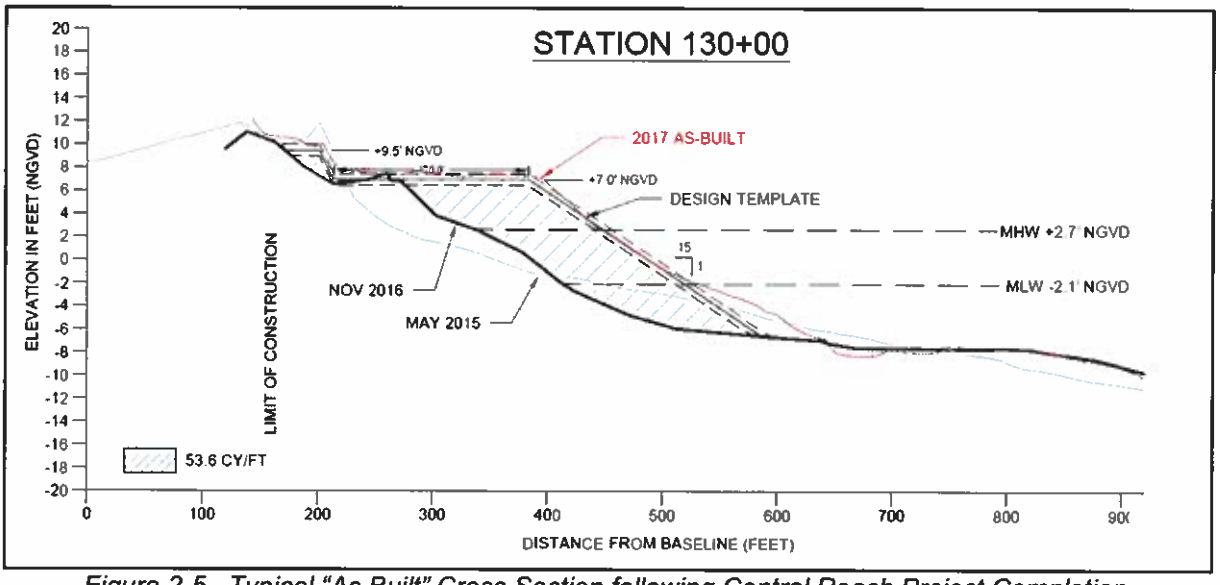

Figure 2-5. Typical "As Built" Cross Section following Central Reach Project Completion

Figure 2-6. Central Reach Construction (ATM photo taken January 2017).

Figure 2-7. Aerial Photograph during Central Reach Construction West of Pier, Approximately Station 180+00 (Weeks Marine/Aerophoto Photo 2/22/17).

Figure 2-8. Central Reach Construction (ATM photo taken 1/26/17).

2.2.1 OFFSHORE BORROW AREAS

The CRP utilized an offshore borrow area approximately 5 miles southeast of the Holden Beach project shoreline. Figure 2-9 presents a figure of the post-project dredge cut depths. Hopper dredges work by making long shallow cuts (typically only 6 inches to 1 ft deep) along the borrow area, and the cut depths shown are typical. 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 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.

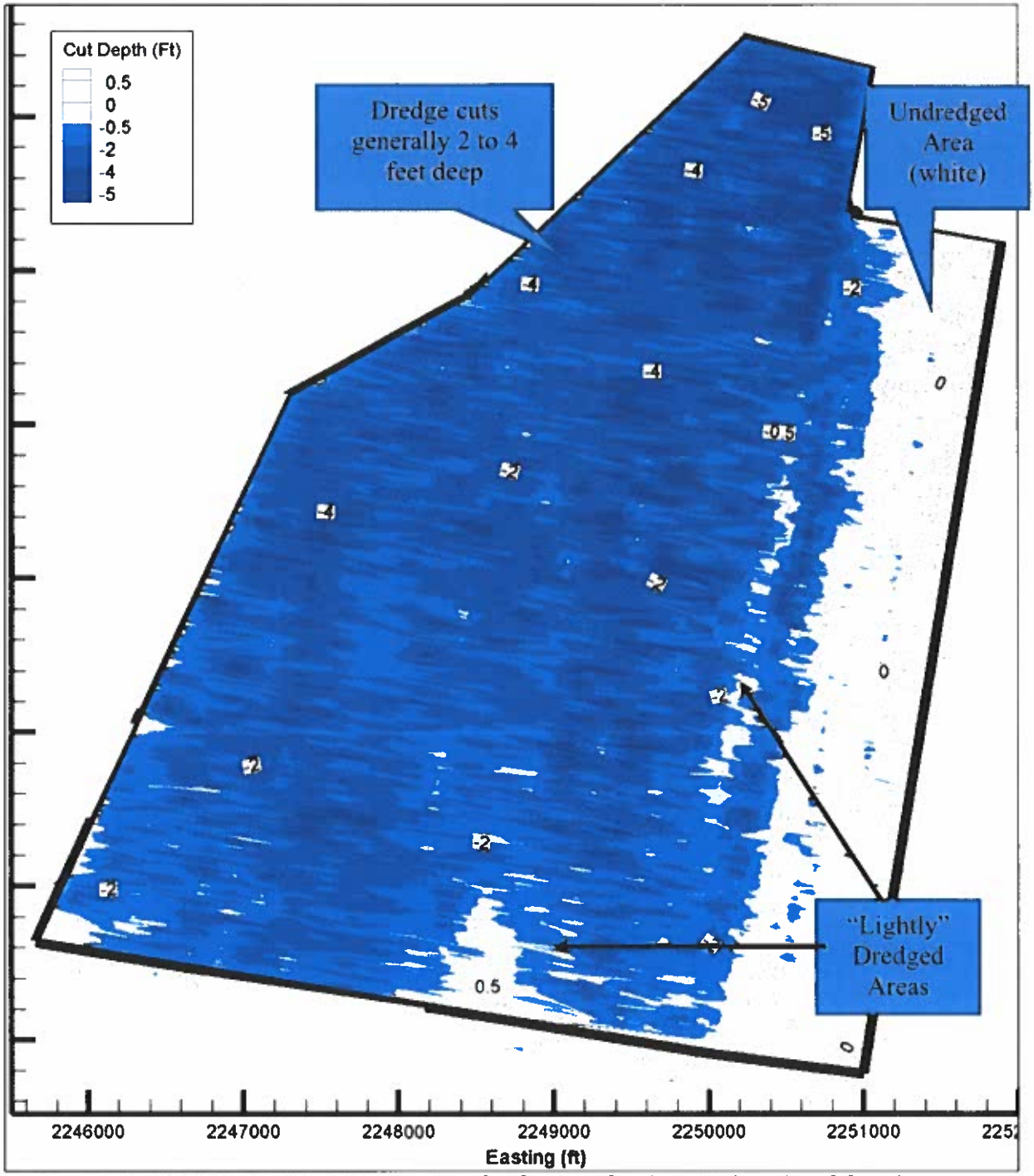

Figure 2-9. 2017 Central Reach Borrow Area Cut Depths. Dredge cuts less than 2 feet deep can likely be used for future nourishments.

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

Additionally, due to the CRP borrow area location offshore (2 to 3 miles) 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, Michael and Dorian, a Central Reach Reimbursement (CRR) project design has begun where the Town can place up to 1.7 mcy in FEMA "engineered beach" mitigation. ATM has completed additional offshore borrow area reconnaissance and has identified/permitted ~1.9 mcy of beach compatible sand (in addition to the CRP borrow area). More discussion on borrow area reconnaissance is provided in Section 2.3. The 2022 offshore borrow area project aims to place between ~1.5 and ~1.7 mcy based on anticipated sand borrow area available.

2.2.2 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 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.

2.2.3 CENTRAL REACH PERFORMANCE

The CRP nourishment took place just months after Hurricane Matthew and vastly revitalized the beach and dune system. The newly constructed beach has and continues to provide added protection from storms. The latest 2021 survey shows that the project has held up well considering impacts from Hurricanes Florence (2018), Michael (2018), Dorian (2019), and Isaias (2020).

Figure 2-10 (A) shows an example profile from the most recent annual survey near the pier (at Station 170+00) illustrating how the beach has changed since the CRP nourishment, and Figure 2-10 (B) presents a photograph of recent beach conditions in this approximate location. Despite anticipated project equilibration, combined with the coastal impacts of several hurricanes, still over 100 feet of dry recreational beach berm remains.

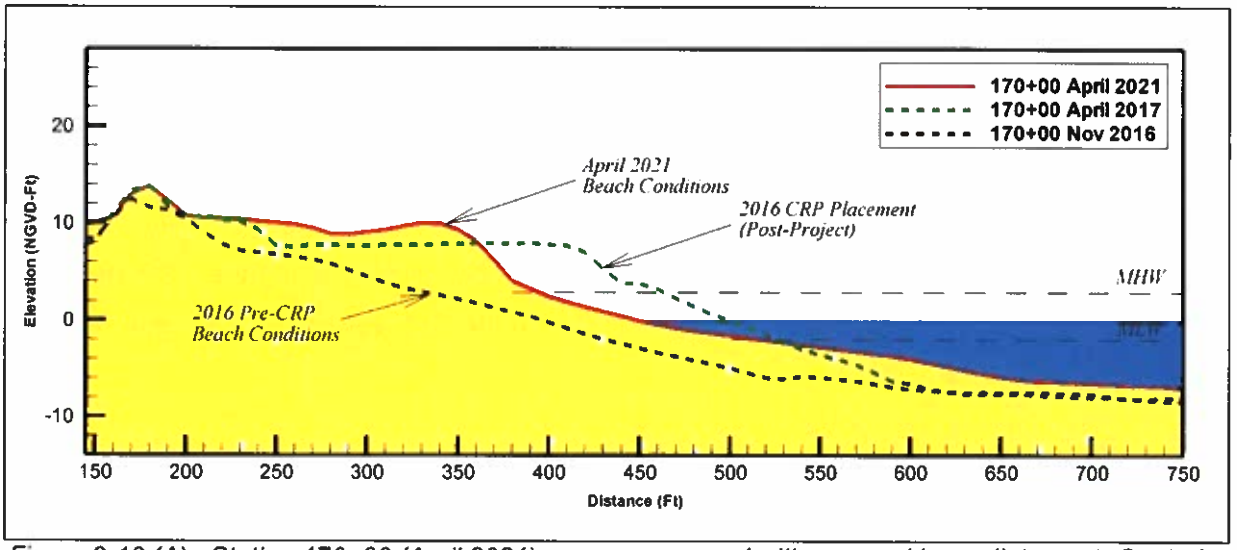

Figure 2-10 (A). Station 170+00 (April 2021) survey compared with pre- and immediate post- Central Reach Project conditions.

Figure 2-10 (B). October 2021 Photograph Taken Near Pier (~Station 170+00) Looking West.

Post-construction monitoring photos are presented in the following figures. Figure 2-11 (A) shows the widened beach conditions immediately following construction. Recent photographs taken 1 to 4 years following construction are presented in Figure 2-11 (B), (C), (D), (E), (F), and (G).

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

Figure 2-11 (A). Central Reach Immediate Post-Construction Approximately Station 50+00 (ATM photo taken January 2017)

Figure 2-11 (B). Central Reach Post-Construction Approximately Station 230+00 (ATM photo taken August 2018). Note sand fencing, starter dune, and plantings.

Figure 2-11 (C). Central Reach Post-Construction Approximately Station 170+00 (ATM photo taken March 2019).

Figure 2-11 (D). Central Reach Post-Construction Approximately Station 170+00 (ATM photo taken September 2019). Note plantings have matured and grown.

Figure 2-11 (E). July 2020 photo. New plantings along the landward dune.

Figure 2-11 (F). October 2021 photo. New plantings along the landward dune (left hand side of photo) have suffered some damage (likely from Isaias in August 2020), but dunes are overall healthy.

Figure 2-11 (G). Central Reach Post-Construction Approximately Station 170+00 looking east (ATM photo taken October 2021). Note plantings have matured and grown (right hand side of photo) and are overall healthy following damage from Hurricane Isaias in August of 2020.

2.3 CENTRAL REACH REIMBURSEMENT (CRR) PROJECT

The CRR project is a direct result of the Town's significant investments in its beach management program. The CRR is a FEMA mitigation project that will place about 1.5 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.

The proposed nourishment involves a FEMA-related beach fill and stabilization plan and mimics the Central Reach Project (CRP) template completed in 2017. The beach nourishment design includes the placement of ~1,510,000 cy of 'in-place' beach quality sand between Stations 40+00 and 280+00 dredged offshore from two different borrow areas (refer to Figures 2-12 and 2-13). The project is slated to begin this upcoming winter/spring environmental window with the potential of up to 1.7 mcy placed (assuming adequate offshore borrow area material is available).

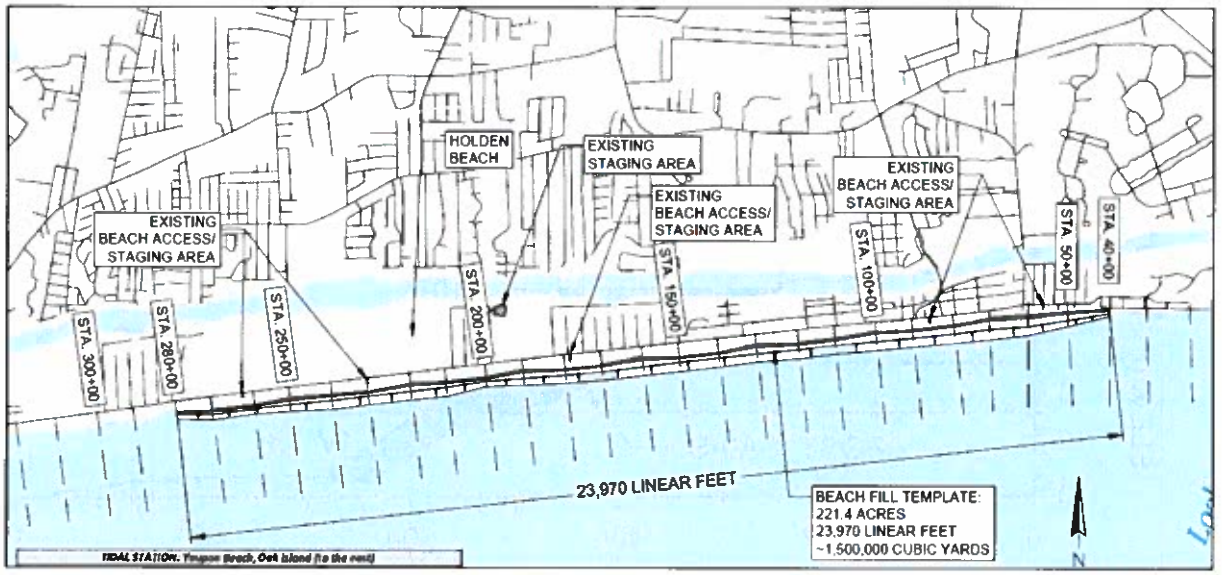

Figure 2-12. CRR Beach Fill Template Between Stations 40+00 and 280+00 (~24,000 Linear Feet from 262 Ocean Boulevard East to 871 Ocean Boulevard West)

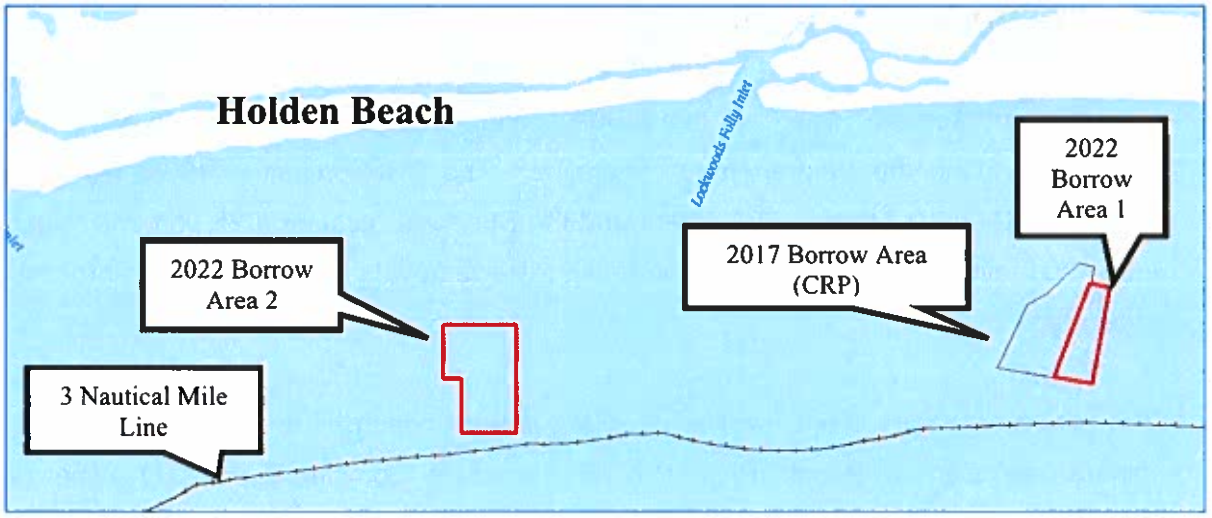

Figure 2-13. CRR Offshore Borrow Areas Outlined in Red.

Taken as a whole, the average fill placement density is ~63 cubic yards per foot along the entire length of the project, including tapers. An example fill template is shown for Station 220+00 on Figure 2-14. The selected design includes a varying dune feature to blend in with existing dunes. The dune system was recently impacted by Hurricane Isaias, which made landfall during a king tide event in August of 2020.

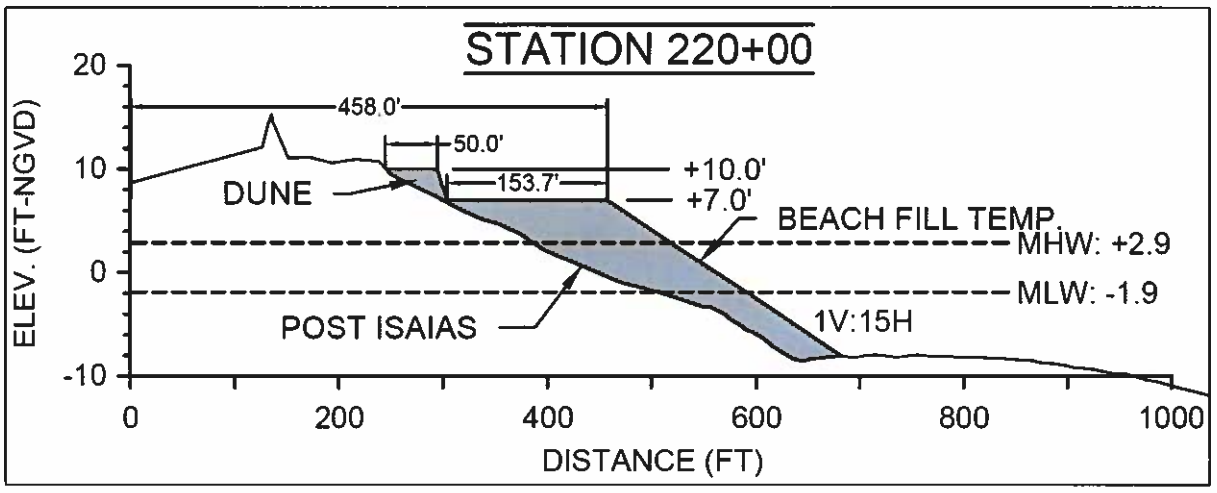

Figure 2-14. CRR Example Beach Fill Template for Station 220+00 Shown Relative to August 2020 Post-Hurricane Isaias Beach Profile.

The two CRR project borrow areas are highlighted in red on Figure 2-13. Borrow Area 1 (BA1) for the proposed CRR project represents the lightly dredged and undredged eastern portions of the previously permitted borrow area for the 2017 CRP, approximately 5 miles

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

Estimated volume yields of beach compatible sand for maximum cut depth for BA1 and BA2 are ~600,000 cubic yards (cy) and ~1.9 million cy, respectively, assuming 100% volume recovery. Of course, 100% volume recovery will not occur due to losses inherent with the hydraulic dredge process and therefore typical buffers/tolerances of ~15-25% will be established to account for losses of excavated to in-place quantities. Similar to the 2017 CRP, a shallow dredge cut using a hopper dredge is planned 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 will be used for the 2022 project.

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 2-15a) to 400 ft wide (Figure 2-15b). 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 2-16 provides an aerial photograph taken during the 2014 LWFIX project.

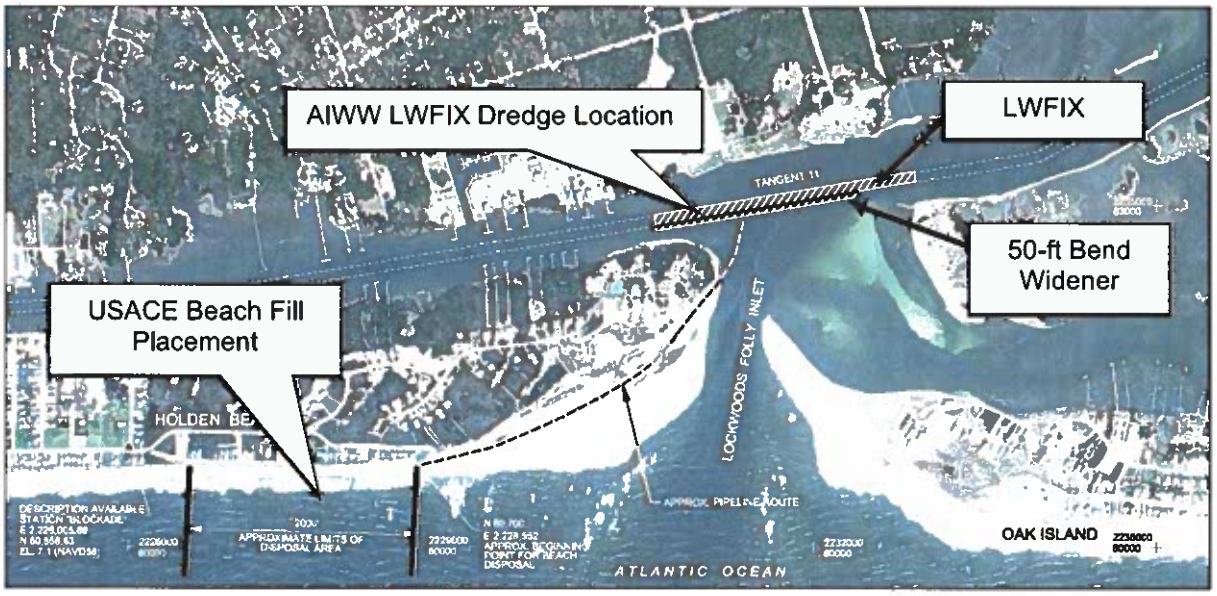

Figure 2-15a. USACE LWFIX Dredging and Beach Placement Schematic (source USACE request for proposal). Placement typically occurs between Holden Beach Stations 20+00 and 40+00.

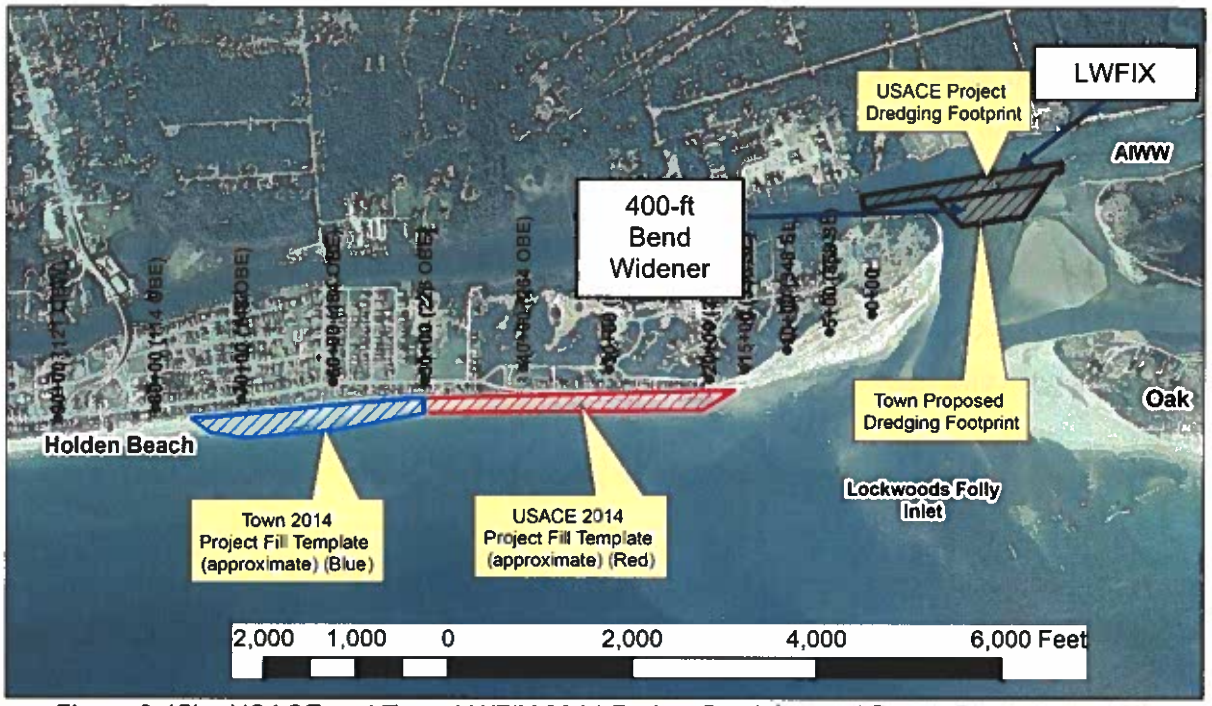

Figure 2-15b. USACE and Town LWFIX 2014 Project Dredging and Beach Placement which included the 400-ft bend widener.

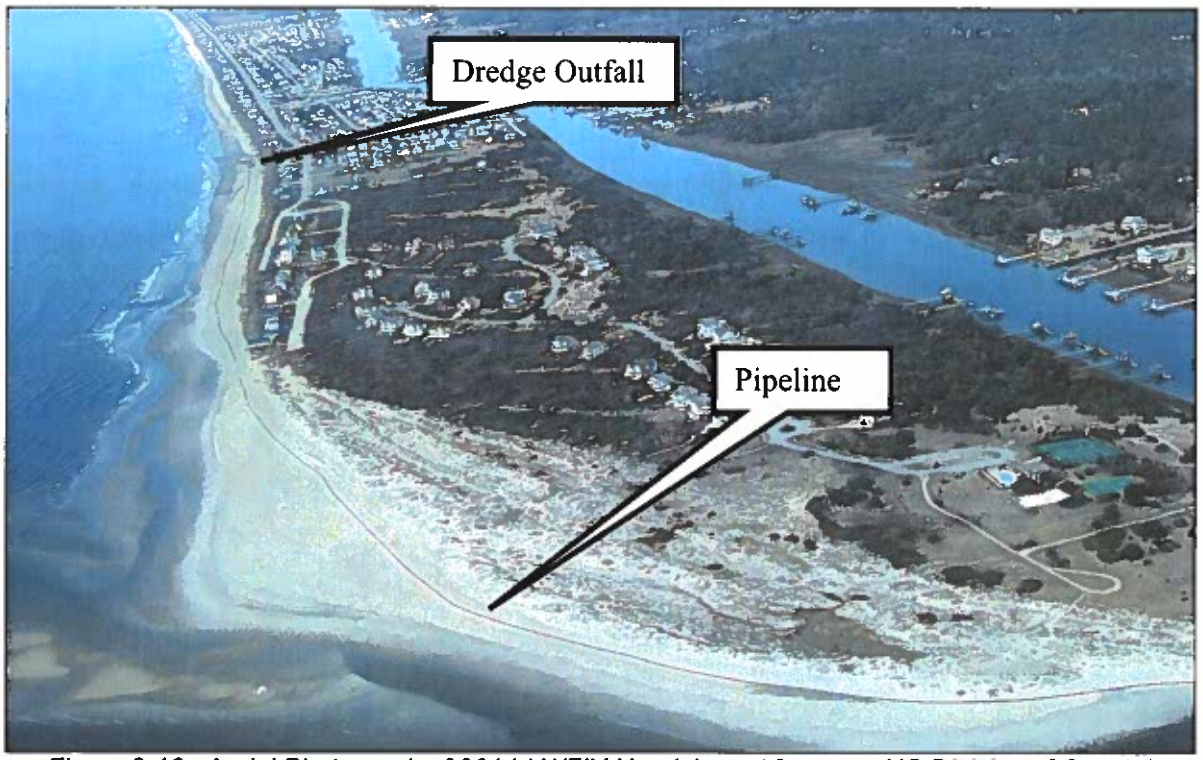

Figure 2-16. Aerial Photograph of 2014 LWFIX Nourishment [source: NC Division of Coastal Management (DCM)].

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 2-17 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.

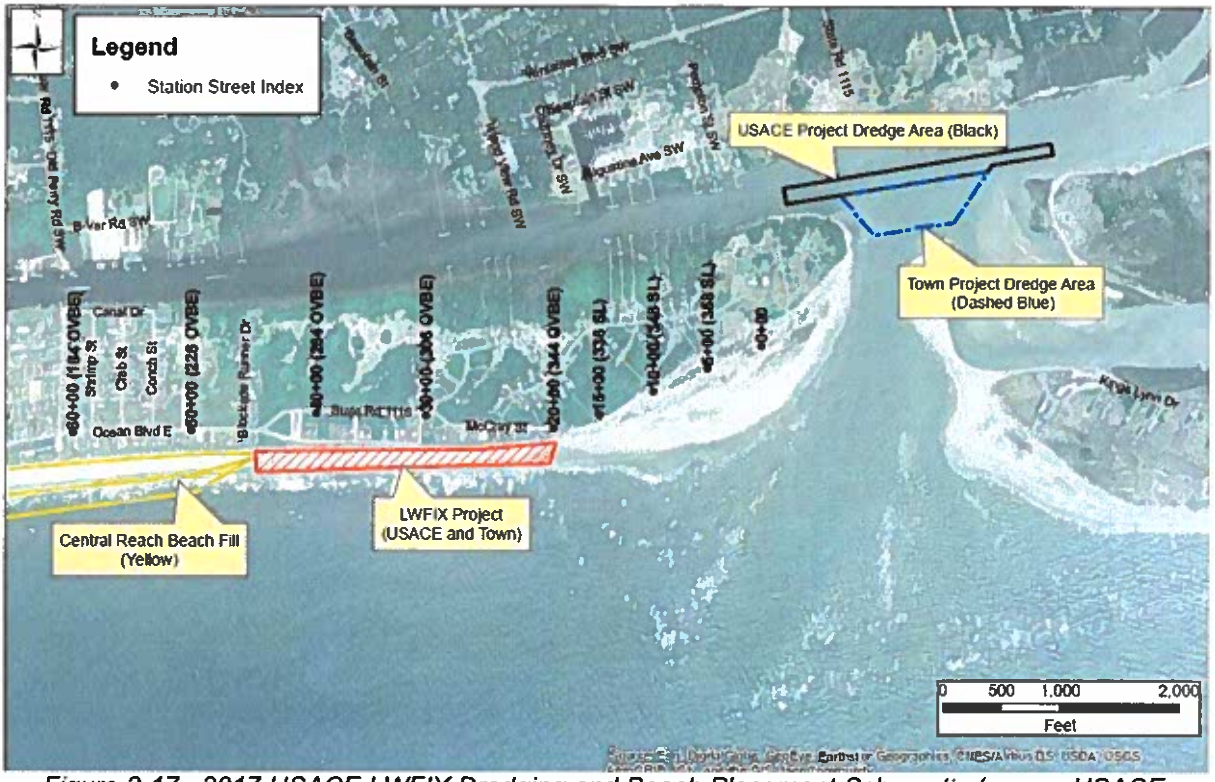

Figure 2-17. 2017 USACE LWFIX Dredging and Beach Placement Schematic (source USACE request for proposal). Placement of Approximately 120,000 cy occurred in March 2017 between Holden Beach Stations 20+00 and 45+00 to meet in with the Central Reach Project.

The Eastern Reach Project was very successful, and photographs taken during construction are presented in Figures 2-18 and 2-19. 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 2-18. Holden Beach POA Photograph Taken near 323 McCray Street (approximately Station 26+00) during 2017 Eastern Reach Project construction.

Figure 2-19. 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 2-20 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 2020 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 2-20. 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 2-21 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.

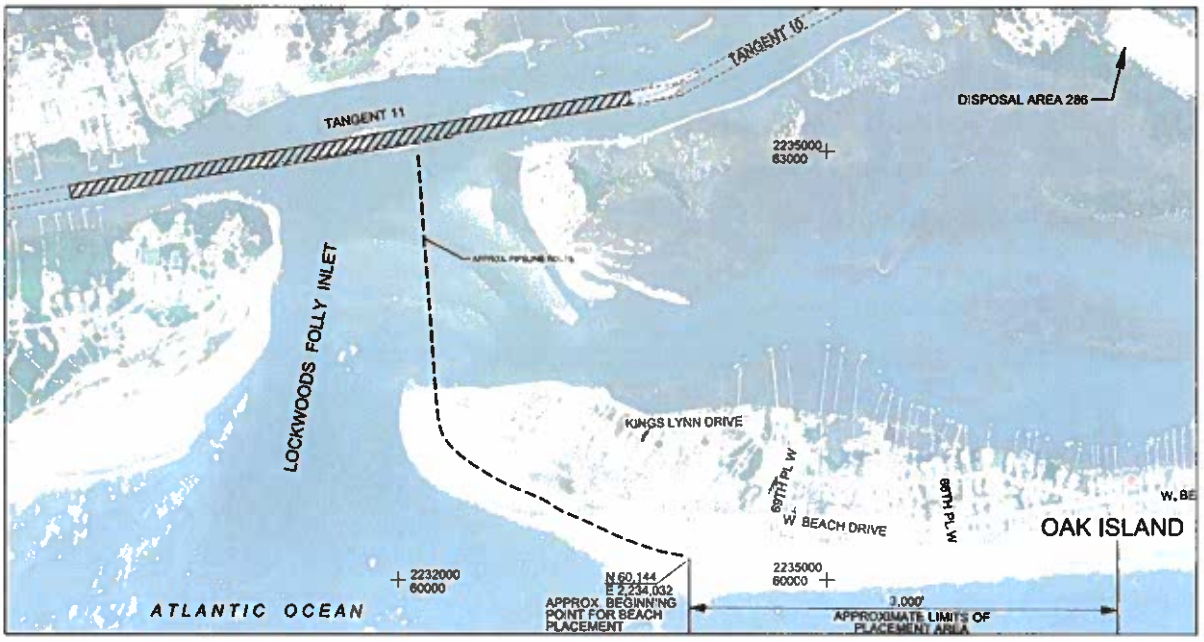

Figure 2-21. Planned 2019 LWFIX Placement on Oak Island. Actual Final Placement Area Approximately 2,500 ft. Refer to Section 3.5 for more information on 2019 LWFIX and Oak Island west end volume changes.

Town and ATM staff have met with USACE and Oak Island staff on several occasions over the past three 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 2-22). Updated easements were obtained in 2019 and placement on the east end can now again occur.

Figure 2-22. 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 2-23). 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 2-24 presents photographs taken during and after construction of the 2020 LWIFX project placement on the east end. Figure 2-24 (d) and (e) present recent photographs of the 2020 LWFIX project area conditions (~1.5-year post project). The east end beach conditions are generally healthy and still a relatively wide, dry recreational beach is present along this vulnerable and historically highly erosional shoreline reach. More detail on east end volume changes and recent accretional/erosional trends are provided in Section 3.

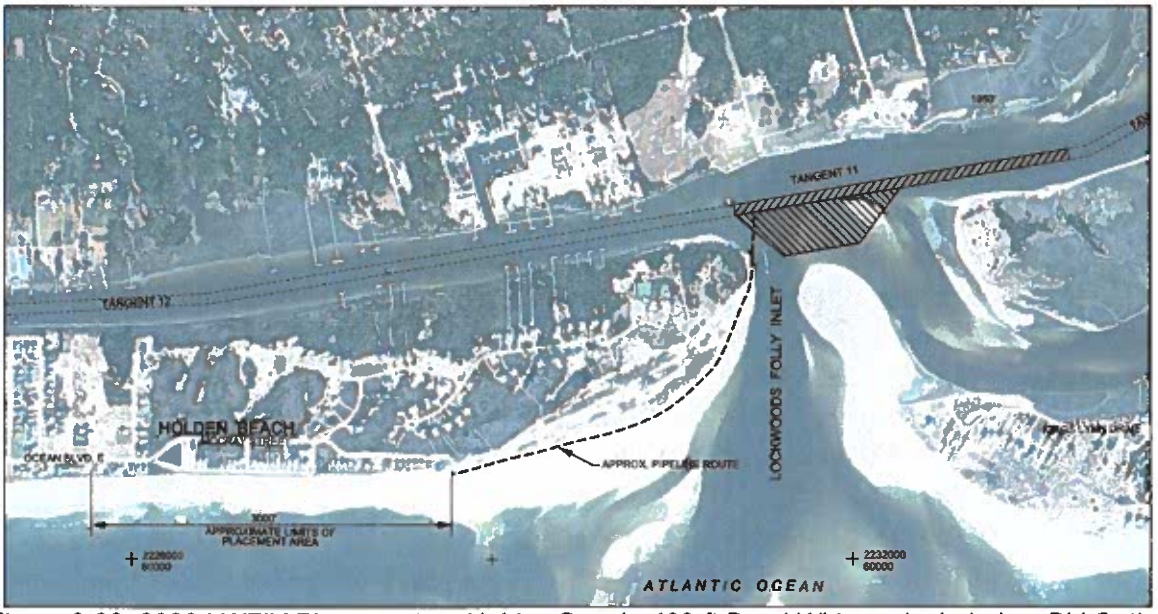

Figure 2-23. 2020 LWFIX Placement on Holden Beach. 400-ft Bend Widener Included as Bid Option Item (Alt) But Was Only Lightly Dredged During Actual Project.

Figure 2-24 (a). Photograph in East End Taken During 2020 LWFIX Construction. (Holden Beach Town Newsletter)

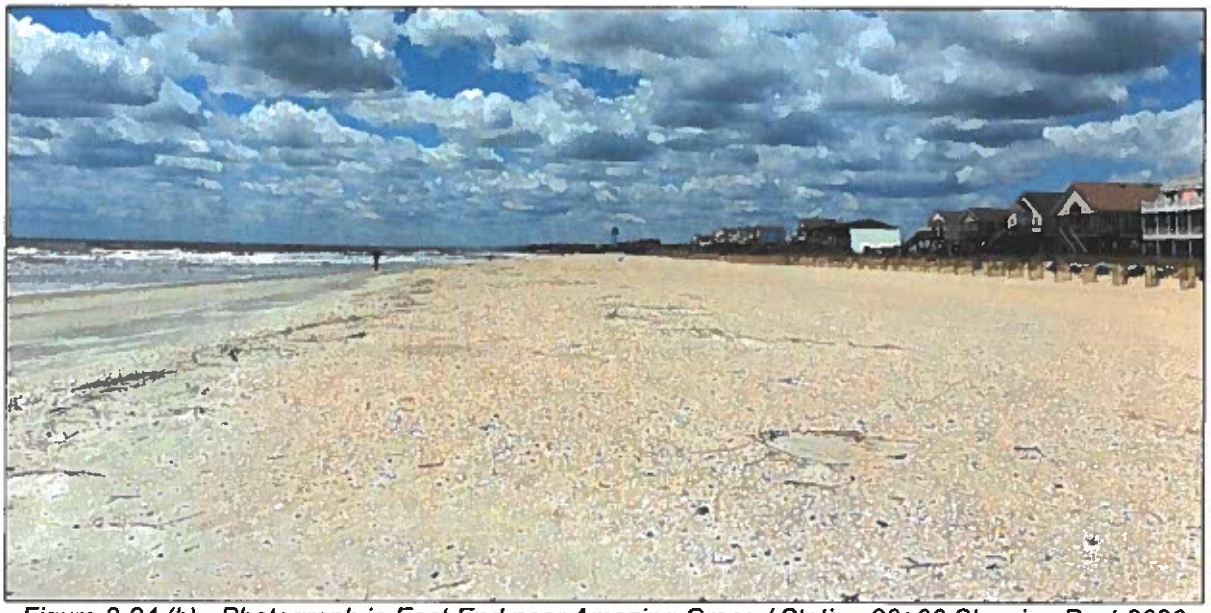

Figure 2-24 (b). Photograph in East End near Amazing Grace / Station 20+00 Showing Post-2020 LWIFX beach conditions (May 1, 2020).

Figure 2-24 (c). July 2020 photograph near Amazing Grace.

Figure 2-24 (d). October 2021 photograph near Station 30+00 looking East.

Figure 2-24 (e). October 2021 photograph near Station 30+00 looking West.

2.4.4 2021 LWFIX PROJECT

The most recent USACE LWIFX occurred this past spring in 2021. Similar to the 2019 LWIFX project, dredging placement 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 2-24e).

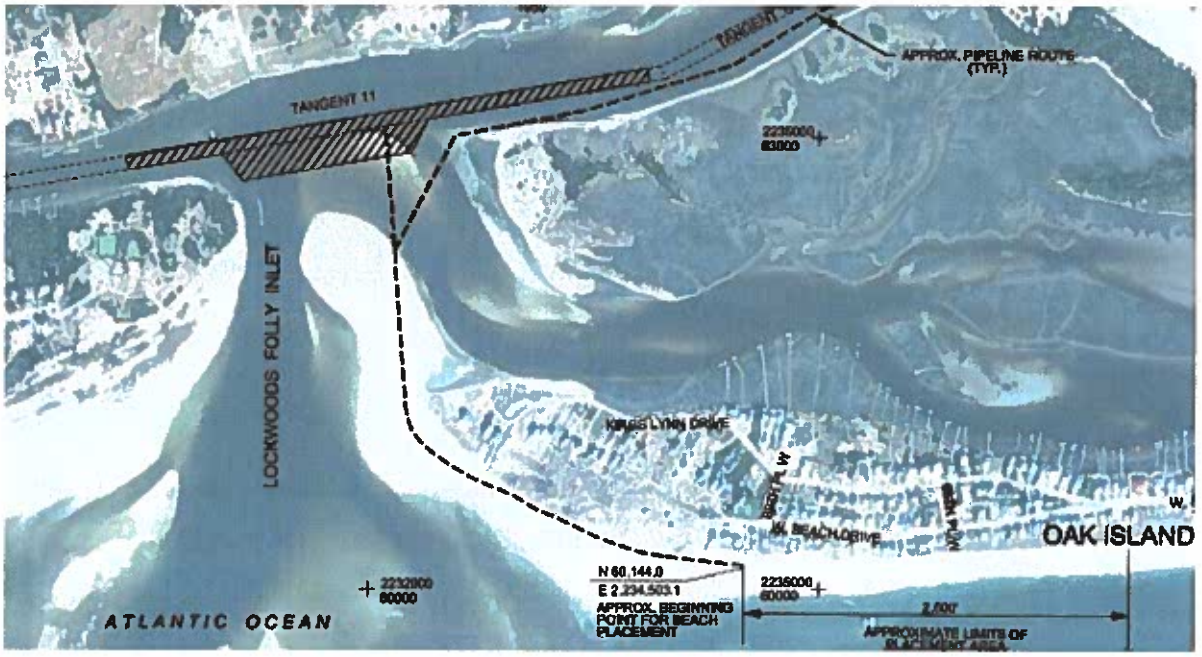

Figure 2-24 (e). LWFIX 2020/2021 bid plans (November 3, 2020 plans).

2.4.5 2022 LWFIX PROJECT

Similar to the 2017 USACE and Town LWFIX Project and the 2017 CRP, the upcoming 2022 USACE LWFIX project will occur in conjunction with the Town's anticipated 2022 Central Reach Reimbursement Project. The 2022 LWFIX project is expected to begin in March of 2022 with placement along ~3,000 linear feet of shoreline on the east end of Holden Beach between (see Figure 2-24f). The Town and ATM staff have been coordinating with USACE-Navigation personnel in order to maximize volume placed on Holden Beach. Anticipated volume placed ranges from 100,000 cy to 175,000 cy (depending on time remaining in the permitting window and pre-project shoaling conditions).

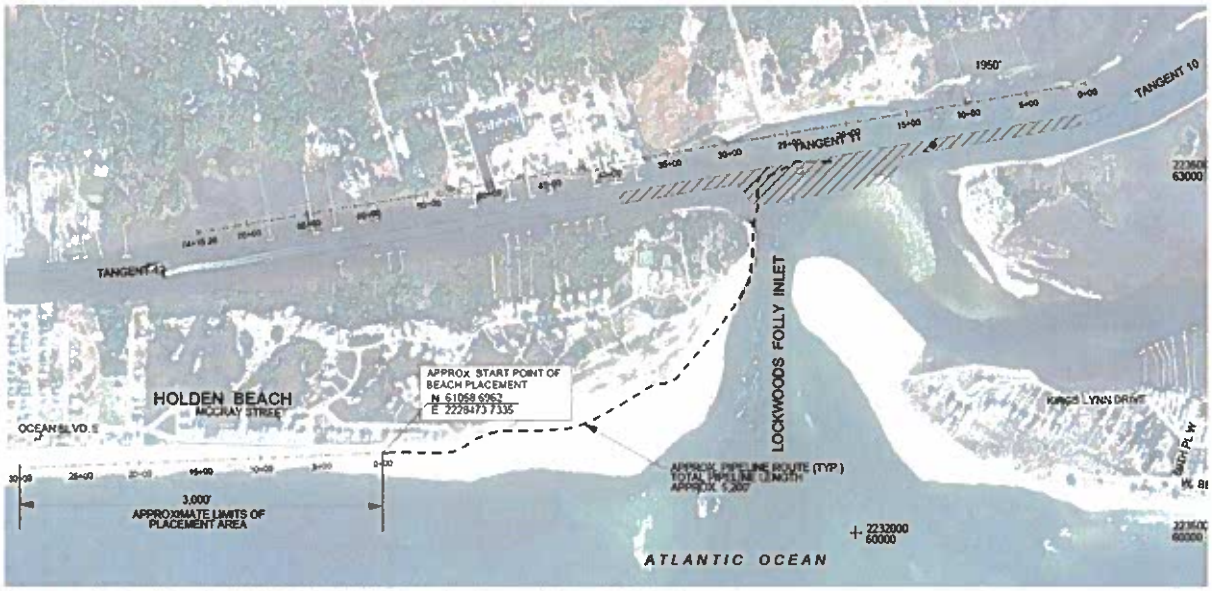

Figure 2-24 (f). LWFIX 2021/2022 bid plans. (July 2021 plans).

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

Dare County and the State have come up with funding to form a public-private partnership with a Dare County contractor to build a shallow draft hopper dredge that would primarily serve Dare County (Oregon and Hatteras Inlets). At a minimum, this dredge will ease demand for other USACE shallow draft dredging projects (i.e., LWF Inlet). It is not known whether this new dredge will be available for future LWF Inlet work.

The State Shallow Draft Navigation Channel Dredging and Aquatic Weed Fund allocated $15,000,000 to Dare County (local partner) to provide a forgivable loan to a private partner for the construction and purchase of the proposed shallow draft hopper dredge.

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.

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 costs between $225,000 and $250,000, including the associated pre-dredging and post-dredging surveys (USACE navigation communication, 2013). 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 is only one sidecast dredge that remains in the Federal government fleet, the refurbished *Merritt*, and 2) Federal funding has been limited/absent and this trend is 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, 2021 and extensions to extend them 1 year have been applied for. 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 2-26a 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.

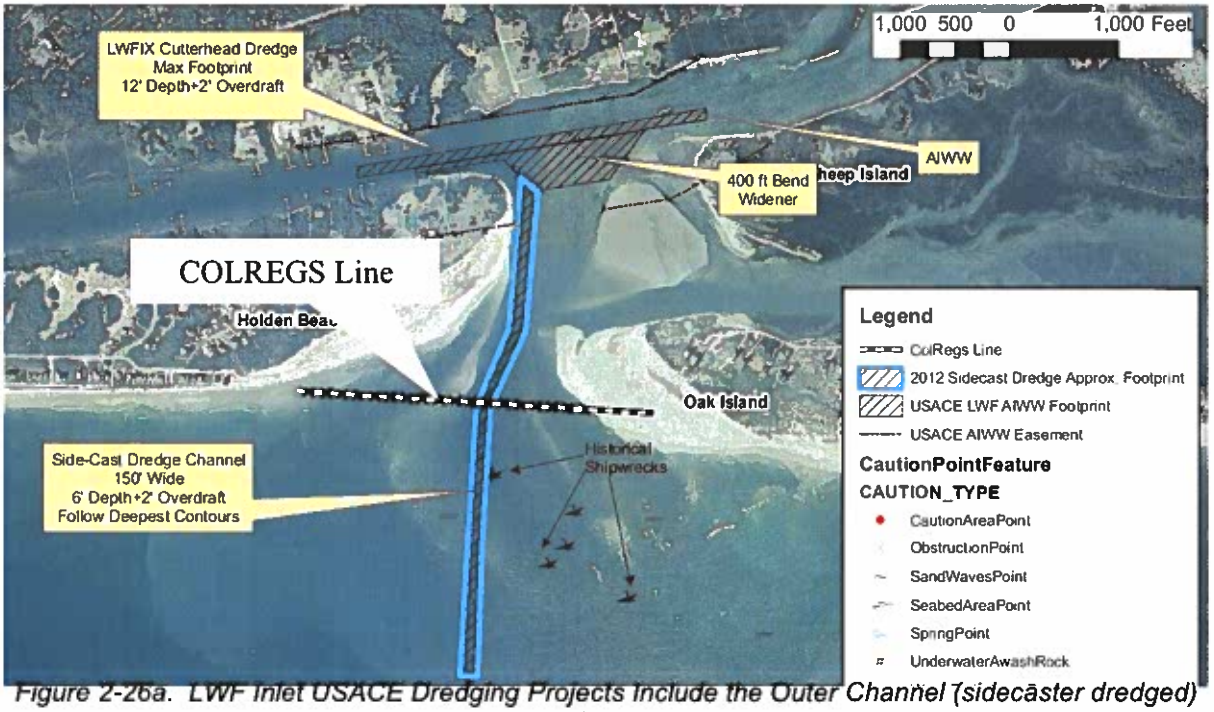

Figure 2-26a. LWF Inlet USACE Dredging Projects Include the Outer Channel (sidecaster dredged) and the LWFIX (cutterhead dredged)

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 2-26b 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.

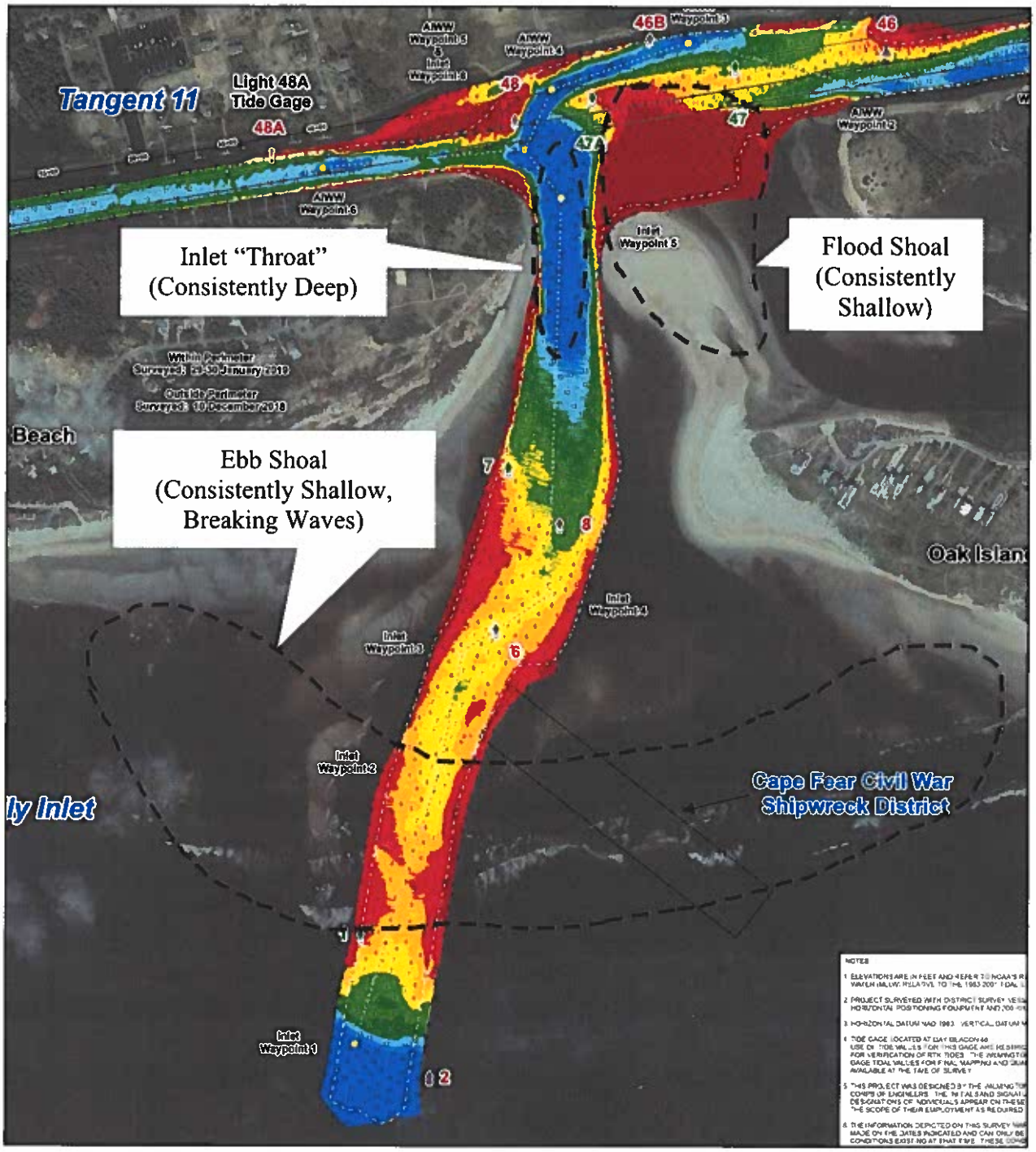

Figure 2-26b. Inlet Throat, Flood Shoal and Ebb Shoal at LWF Inlet (Image Source: USACE Wilmington Navigation Branch)

2.6 LWF OUTER EBB SHOAL DREDGING

Outer ebb shoal (see Figure 2-26b) dredging is typically performed by the *Merritt*, which is the USACE's only remaining sidecaster; however, the *Murden* is 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 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).

Figures 2-29 (A) and (B) present example sections of sand fencing put in place just seaward of the constructed "starter dune" immediately following the 2017 nourishment projects. Post-project monitoring photographs of the starter dunes and plantings are provided in Figures 2-28 (A) - (D). Unfortunately, the observed dune growth over recent years suffered some substantial damage as a result of Hurricane Isaias in August of 2020. More detail is provided in the following section.

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).

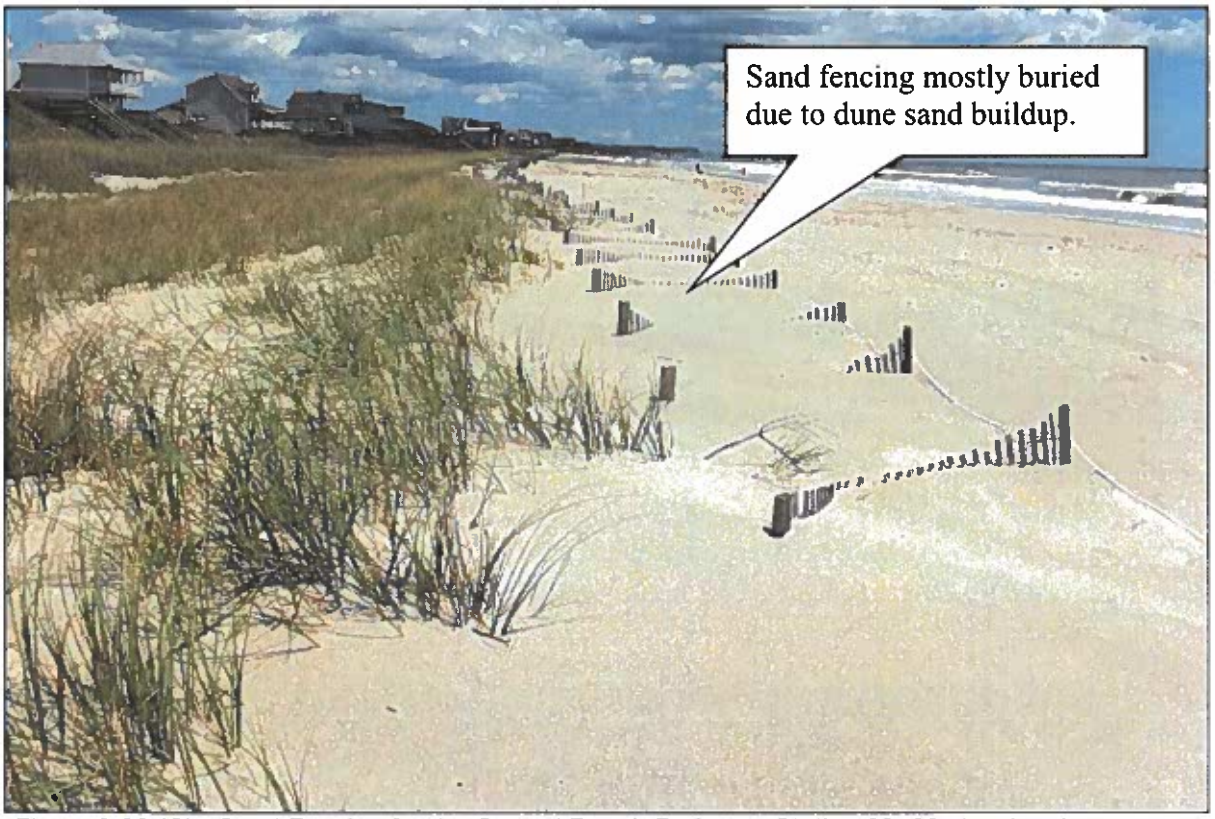

Figure 2-28 (C). Sand Fencing for the Central Reach Project at Station 60+00 showing dune vegetation and continued sand growth about 3.5-years post project. (ATM photo, taken May 2020).

Figure 2-28 (D). November 2021 Station 60+00 where recovery from Hurricane Isaias is ongoing..

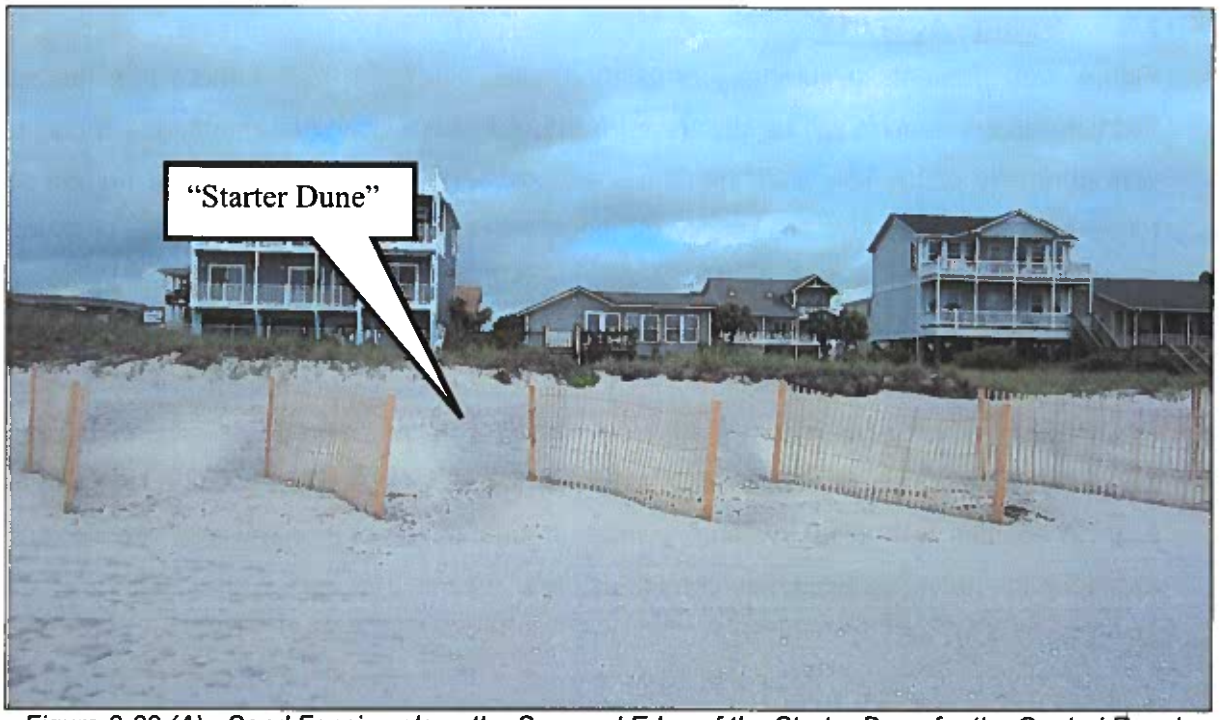

Figure 2-29 (A). Sand Fencing along the Seaward Edge of the Starter Dune for the Central Reach Project at Station ~60+00. Vegetation has been planted on the starter dune since photograph date. (ATM photo, taken May 2017).

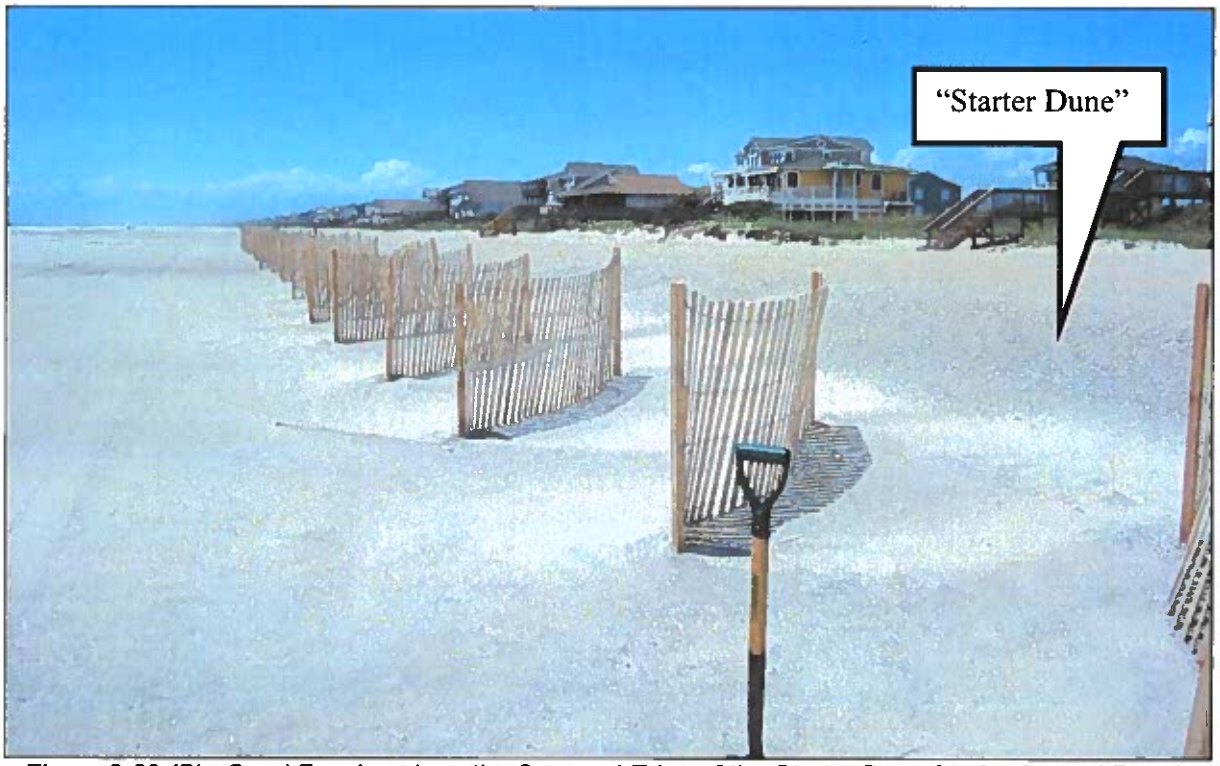

Figure 2-29 (B). Sand Fencing along the Seaward Edge of the Starter Dune for the Central Reach Project at Station ~230+00. Vegetation has been planted on the starter dune since photograph date. (ATM photo, taken May 2017).

2.8 STORM ACTIVITY

Figure 2-30 presents a summary of 2020 Atlantic Hurricane tracks (note that the recent 2021 hurricane season will be discussed in the subsequent annual monitoring report but it was generally mild). The 2020 hurricane season began early, with the first named storm forming in early May and the activity did not slow down. The 2020 hurricane season was incredibly active and had 30 named storms, with 7 storms reaching major hurricane status (i.e., a Category 3 hurricane or greater and noted as "MH" in Figure 2-30).

Fortunately, no major hurricanes affected Holden Beach, however, Hurricane Isaias had direct significant impacts on the Holden Beach shoreline in August of 2020 (see Figure 2-31). In addition to tropical systems, periods of sustained southeast winds and winter Nor-easters can create highly erosive conditions also.

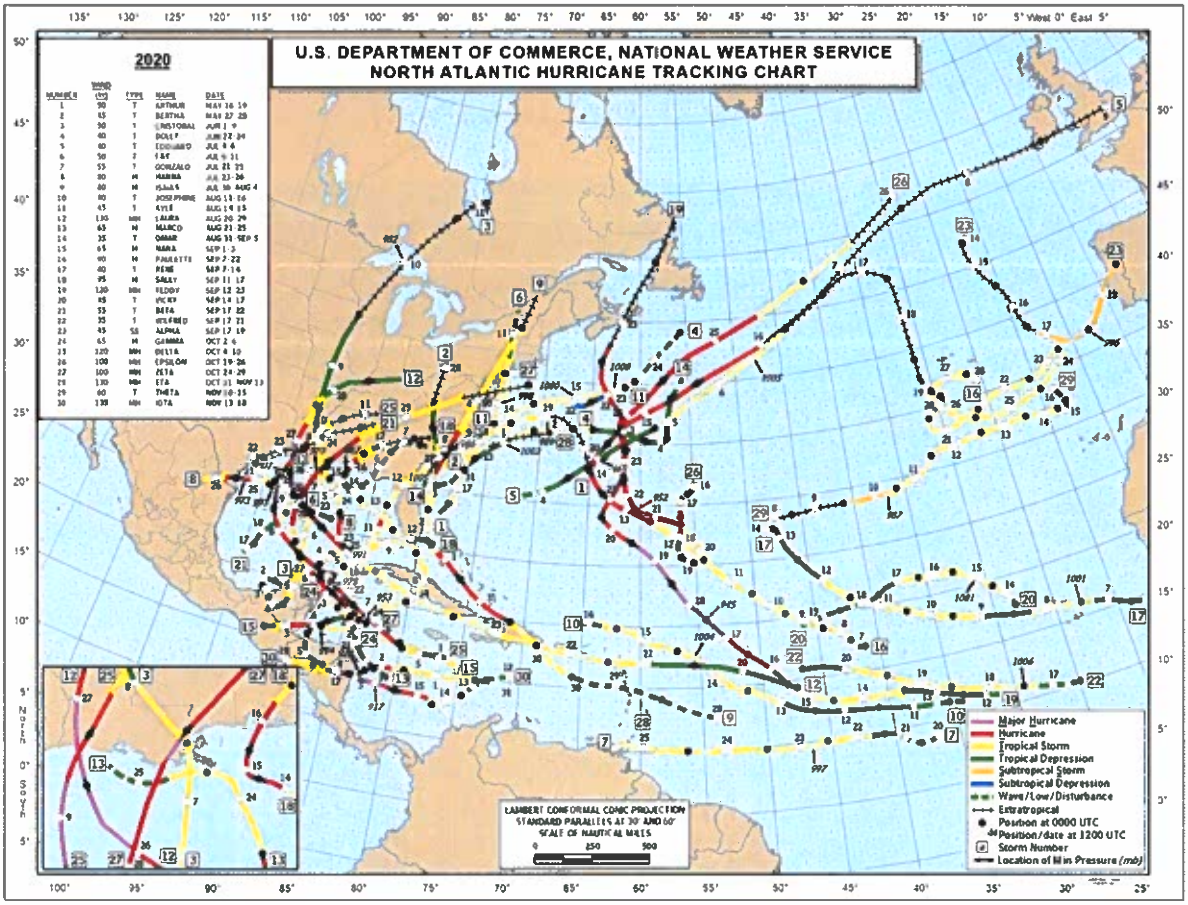

Figure 2-30. 2020 Atlantic Hurricane Summary Overview.

2.8.1 HURRICANE ISAIAS 2020

Hurricane Isaias made landfall as a sizable category 1 storm on August 3rd in Ocean Isle Beach, just west of Holden Beach, and at an unfortunate time during a peak spring high tide (see Figure 2-32 and Figure 2-33).

The NOAA tide gauge at Springmaid Pier (~35 miles SW of Holden Beach) measured a surge of ~4.5 ft above the predicted tide for a combined total storm tide water level measured at over 10 feet above MLLW (Mean Lower Low Water) during Hurricane Isaias, exceeding that of recent large storms which impacted Holden Beach in 2018 and 2019 (Florence, Michael, and Dorian).

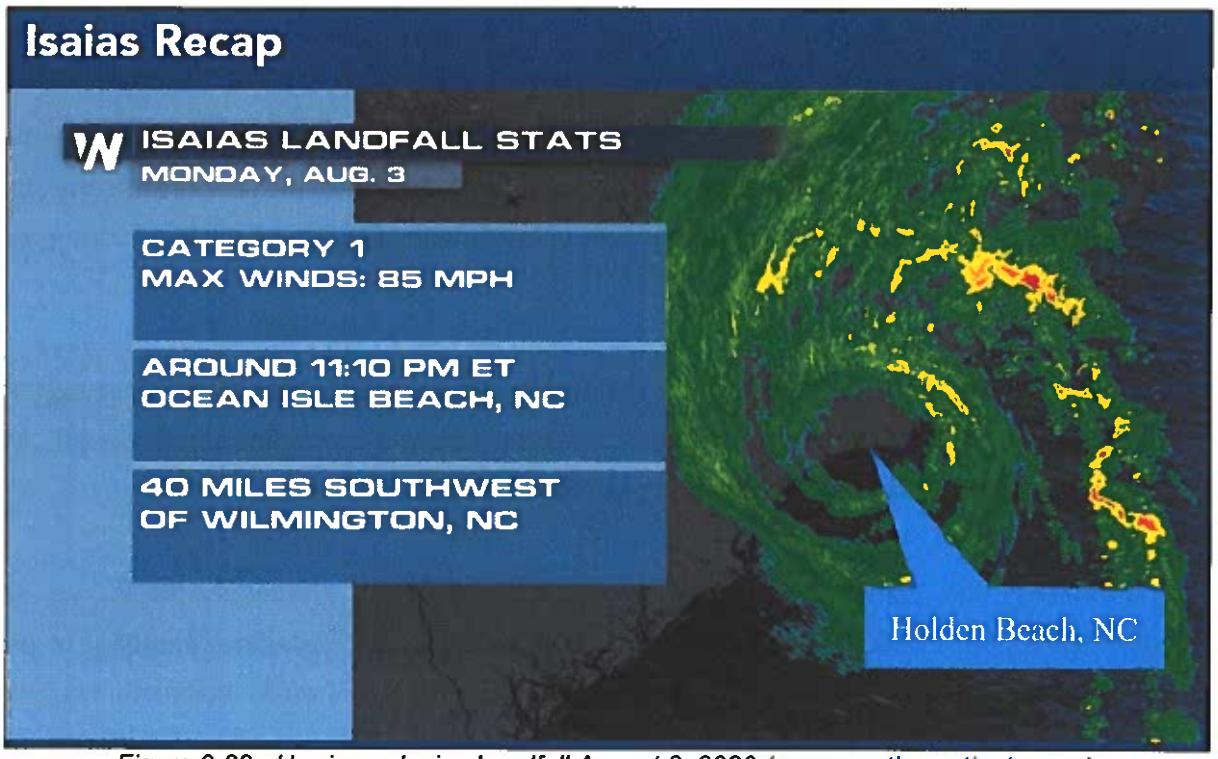

Figure 2-32. Hurricane Isaias Landfall August 3, 2020 (www.weathernationtv.com)

A post-storm beach survey was conducted immediately following Hurricane Isaias and ~67,400 cy of material was lost from the engineered portions of beach above the -20 ft NGVD contour.

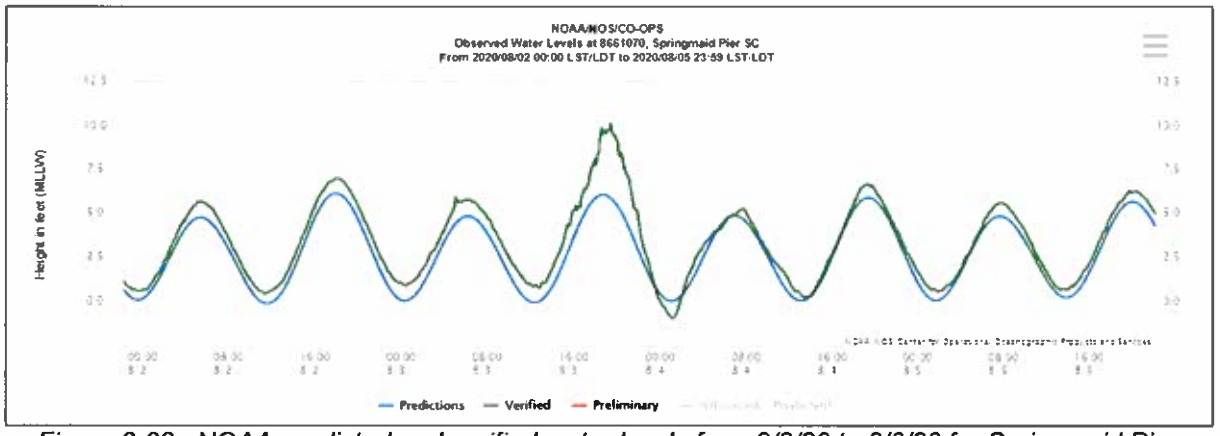

Figure 2-33. NOAA predicted and verified water levels from 8/2/20 to 8/6/20 for Springmaid Pier, Myrtle Beach, SC (~35 miles SW of Holden Beach). Verified water levels ~4.5 ft higher than predicted.

Figure 2-34 presents an example beach profile at Station 160+00 of the April 2020 and April 2021 annual monitoring surveys, compared with the immediate post-Hurricane Isaias August 2020 survey to illustrate the impacts of Isaias and how the beach has changed over the past year.

The extreme storm surge and waves during Hurricane Isaias caused the most significant impacts to occur directly along the upper beach and dune system (see upper panel). Much of the upper beach and emerging dunes suffered damage from Isaias.

Fortunately, the April 2021 survey shows recovery from Hurricane Isaias, as some significant upper beach accretion has occurred since Isaias, back to resembling a profile similar to pre-Isaias conditions (see lower panel), and a generally stable to accretional beach was observed over the past year for the majority of the Holden Beach shoreline (discussed in detail Section 3).

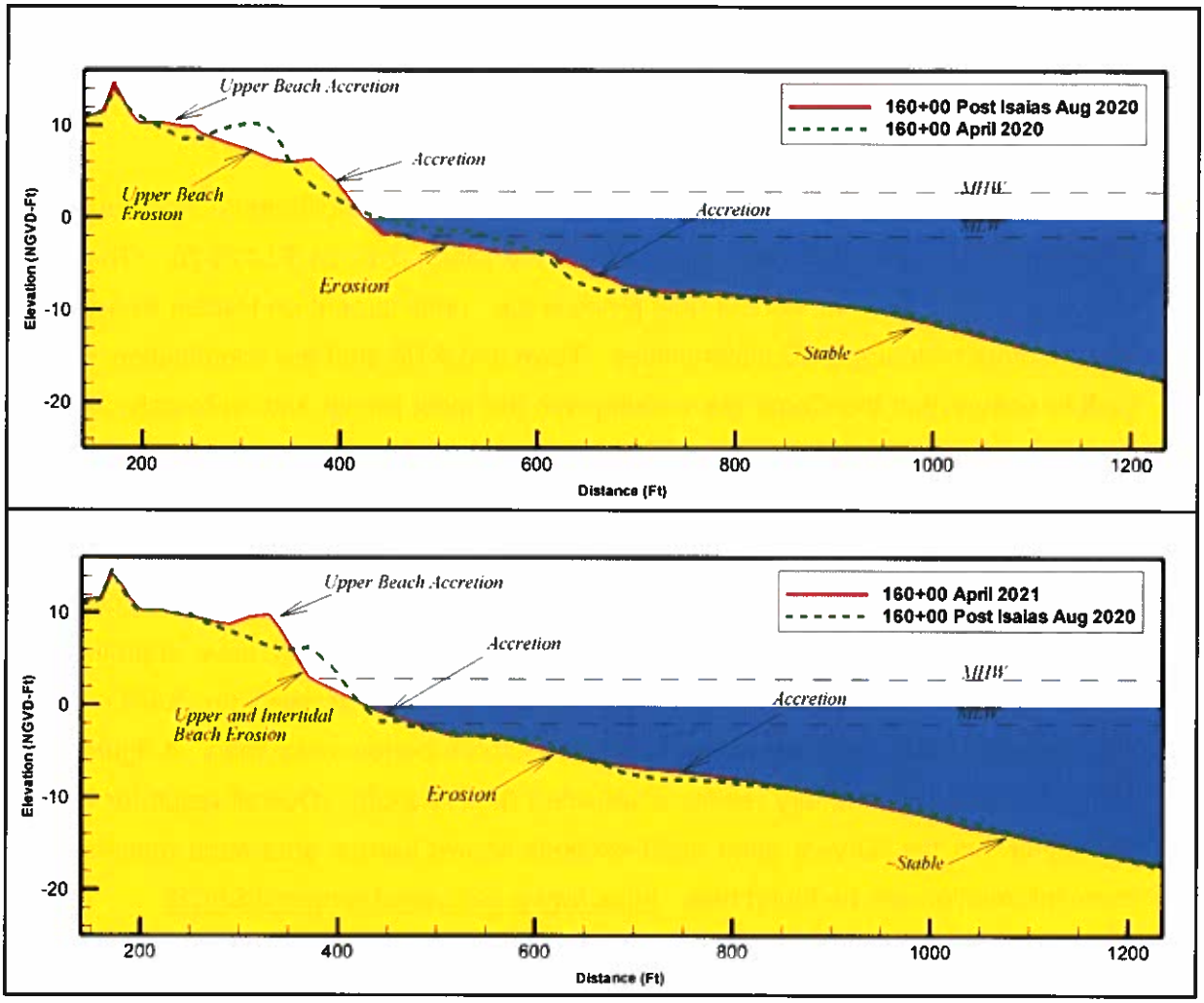

Figure 2-34. (Station 160+00 Beach Profile Comparisons). Upper Panel – Comparison of April 2020 Annual Monitoring Survey/Pre-Hurricane Isaias with August 2020 Post-Hurricane Isaias Survey. Lower Panel – Comparison of August 2020 Post-Isaias Survey and April 2021 Annual Monitoring Survey

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 2-35). 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/

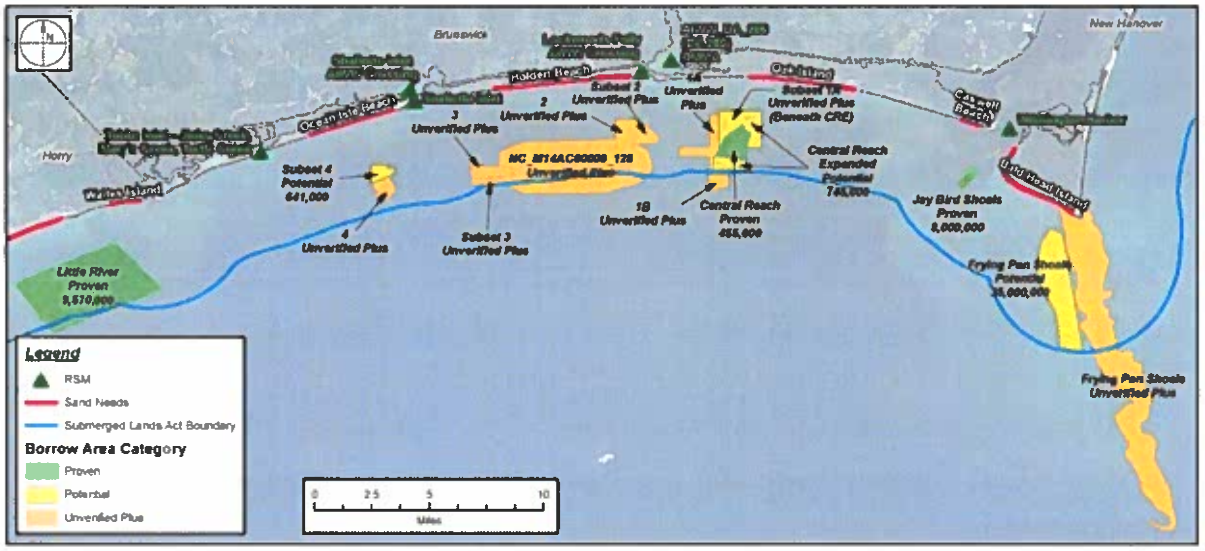

Figure 2-35. SACS summary figure for Brunswick County.

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.

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 under NEPA regulatory review.

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 are more likely to be implemented in 2022 (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 2-36 and 2-37 present the proposed IHAs affecting Holden Beach. More information on this topic is available at https://deq.nc.gov/about/divisions/coastal-management.

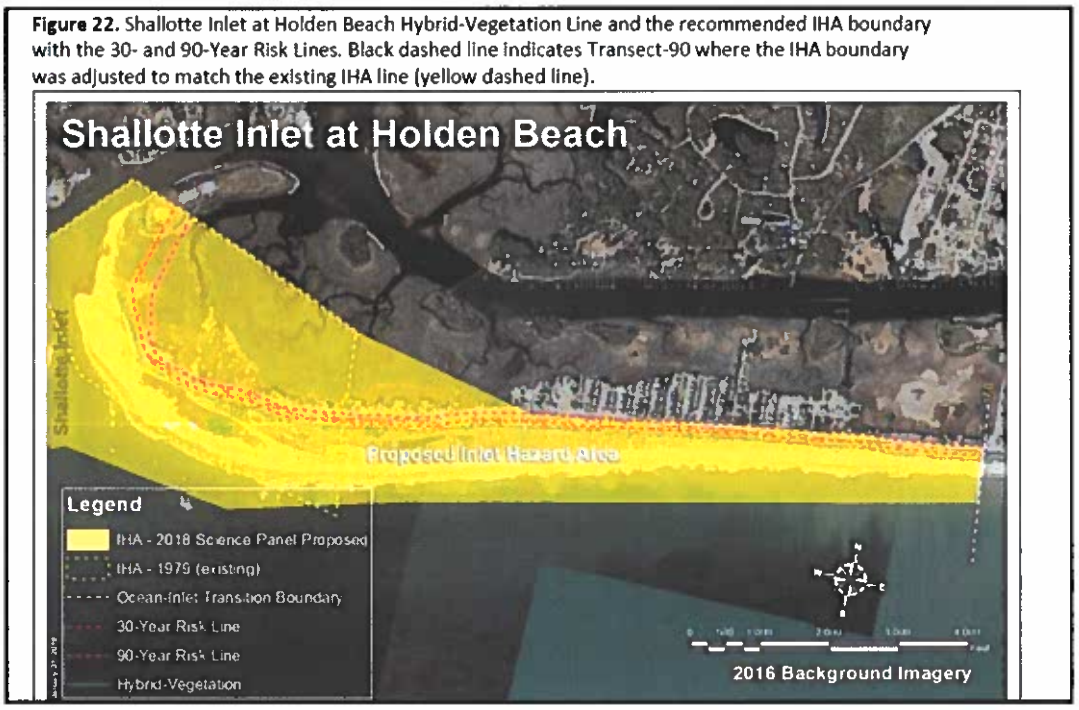

Figure 2-36. Proposed IHA for the west end of Holden Beach (image source: 2019 DCM IHA report)

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

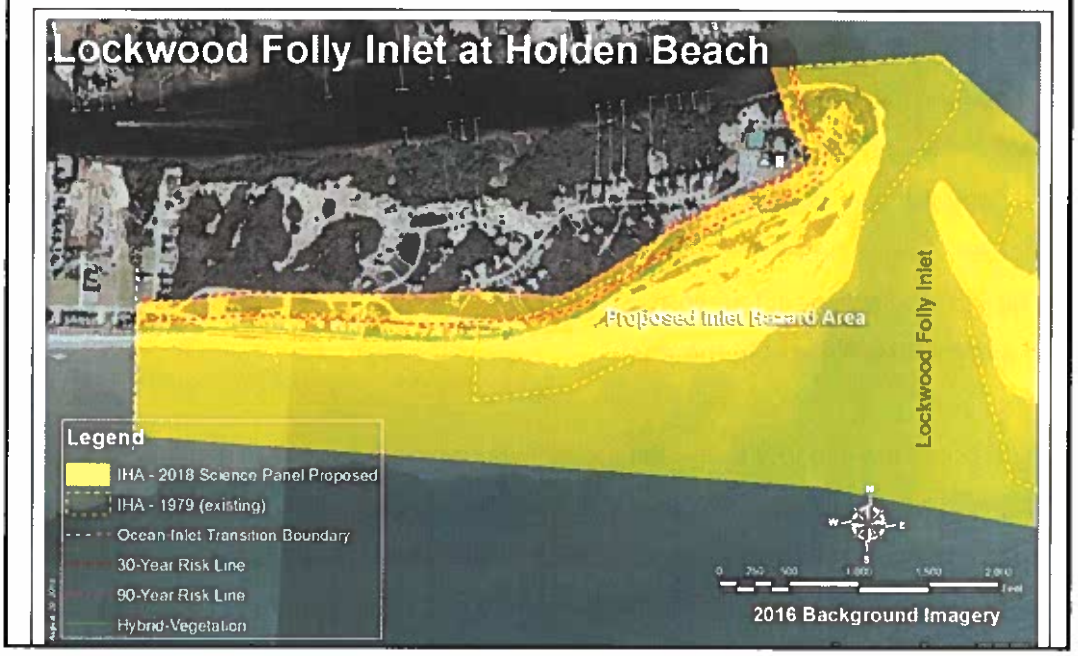

Figure 2-37. Proposed IHA for the east end of Holden Beach (image source: 2019 DCM IHA report)

2.11 BEACH MANAGEMENT PERMITS

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

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

The CRP nourishment has been completed, although some offshore borrow area volume is still available (as planned). DCM chose to modify the beach nourishment permit initially obtained by the Town in 2002 (permit number 14-02) for the CRP. This follows modifications that included the 2008 and 2009 Town nourishments using the Smith borrow site. DCM is now requiring permit extensions every year; therefore, an extension was requested in November 2021.

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.

The NCDWQ permits are project specific and generally follow the lead of DCM. 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 permit extensions were requested in November 2021.

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 2021 at 51 transects along Holden Beach. 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 have the potential to affect this area.

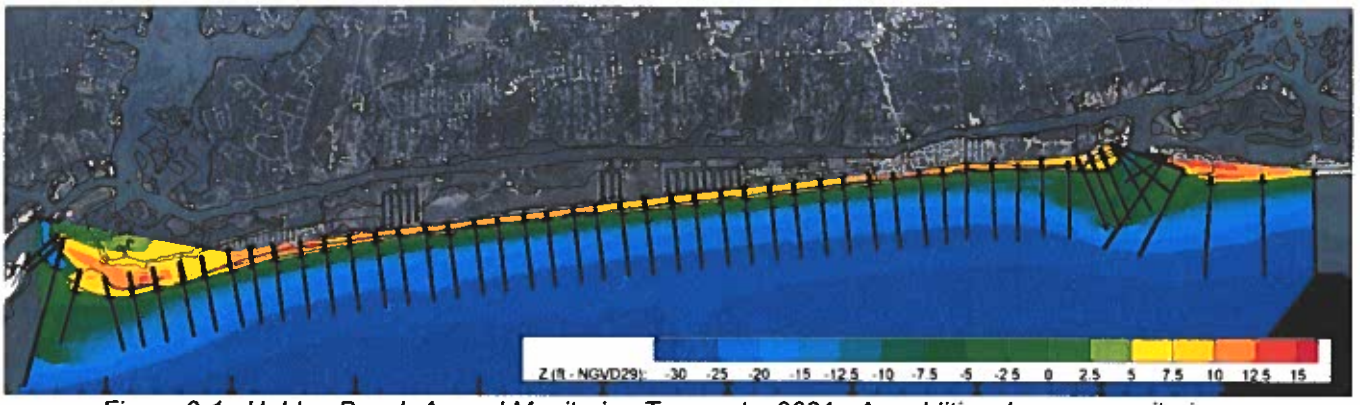

Figure 3-1. Holden Beach Annual Monitoring Transects, 2021. An additional seven monitoring transects have also been added to western Oak Island beginning with the 2012 survey and three additional Shallotte Inlet transects were recently established beginning with the 2020 survey. Note "Z" is in ft-NGVD29.

In general, comparison of the 2020 and 2021 surveys reveals an overall stable to accretional beach along much of the island. Although much of the upper beach and dune system were impacted by Hurricane Isaias in August 2020, the beach has recovered well and some dry upper beach and dune growth occurred along much of the shoreline over the past year despite the damage from Isaias. Additionally, continued downdrift spreading of nourishment material is observed in areas west of the CRP footprint.

Erosion occurred along the east end due to equilibration of the 2020 LWFIX project as well as recent shoal movement, and accretional spreading benefits are observed in areas outside the project limits.

Figures 3-2 and 3-3 present example transect surveys comparing April 2020 and April 2021 survey data. Figure 3-2 also shows the April 2019 and April 2020 survey comparison to illustrate typical changing sediment transport patterns and monitoring of the 2017 nourishment projects and the recent 2020 LWIFX 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 2020 and 2021 annual monitoring surveys.

Since the 2017 Town Eastern Reach Nourishment / USACE LWFIX Project nourishment, the cross-shore changes at Station 40+00 had previously shown the movement of material from the upper beach into the nearshore, forming an equilibrium beach profile in the April 2019 survey. Fortunately, the 2020 LWFIX brought additional material to the east end (approximately 80,000 cy placed from east of Station 20+00 to past Station 40+00 in early spring of 2020). This material has since equilibrated relatively quickly over the past year as shown in the April 2021 survey, as significant movement of upper, intertidal, and nearshore material into the offshore has occurred likely due to Hurricane Isaias.

Figure 3-3 shows a typical profile view within the 2017 CRP (Central Reach Project) area and displays some continued adjustment/equilibration of the nourishment material has taken place, but overall a stable beach is observed. The majority of erosion here took place just below mean low water (MLW), however, accretion took place just offshore in the surf zone.

Additionally, some upper beach accretion occurred near the dune toe, indicating recovery since Hurricane Isaias and healthy growth over the past year. As the CRP was completed in the spring of 2017, the 2021 survey represents 4-year post-construction conditions.

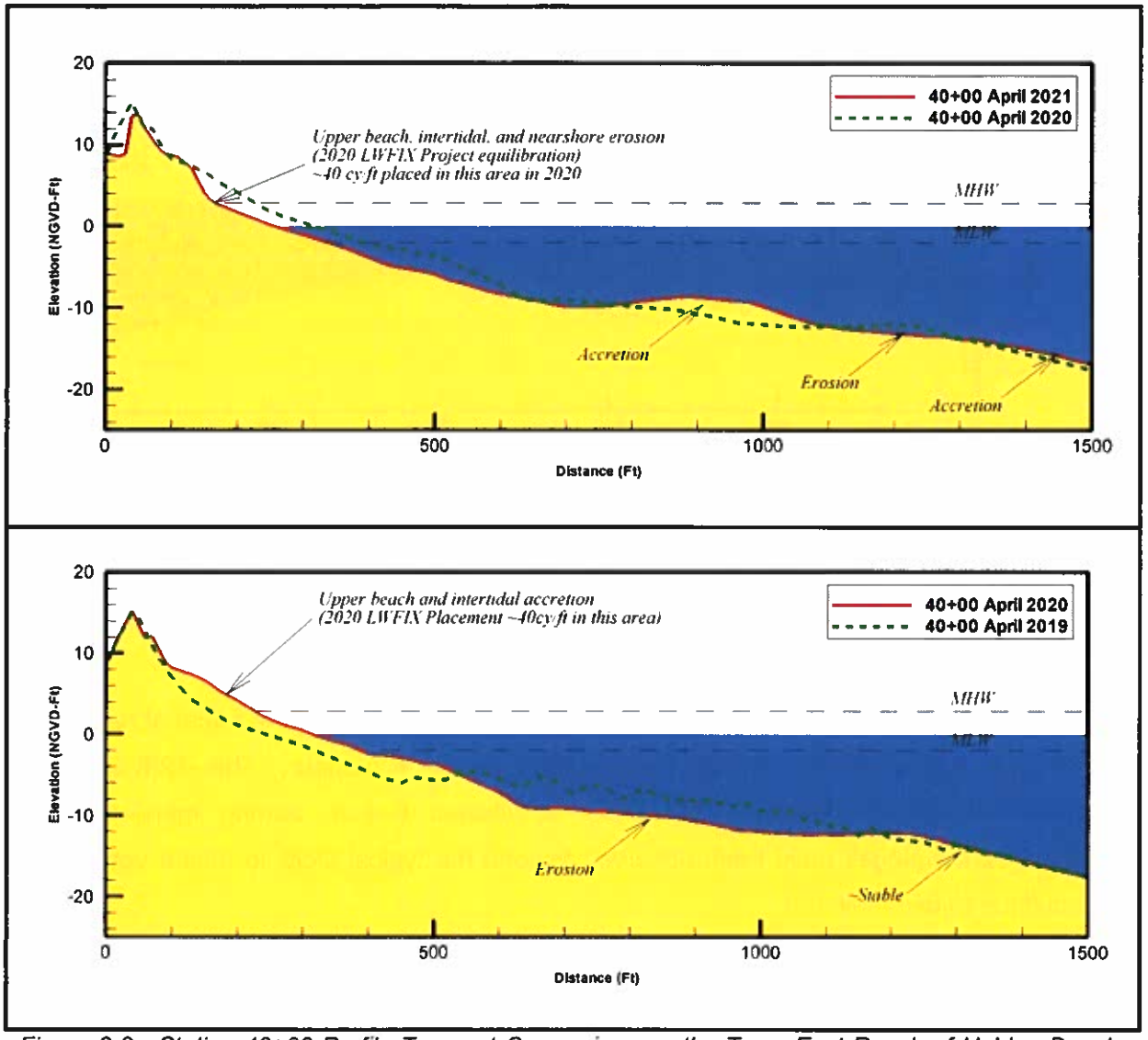

Figure 3-2. Station 40+00 Profile Transect Comparison on the Town East Reach of Holden Beach. Lower panel shows 2019-2020 survey comparison showing the addition of material from the 2020 USACE LWFIX nourishment with additional accretion attributed to lateral spreading of 2017 nourishment material. Placed project volumes typically ranged between 20 and 40 cubic yards / linear foot (cy/lf) in the late winter/early spring of 2020. Upper panel shows 2020-2021 comparison, displaying the adjustment of the 2020 LWFIX / Town Eastern Reach nourishment into an equilibrium beach profile by the 1-year post project profile (April 2021), likely accelerated by Hurricane Isaias in August of 2020.

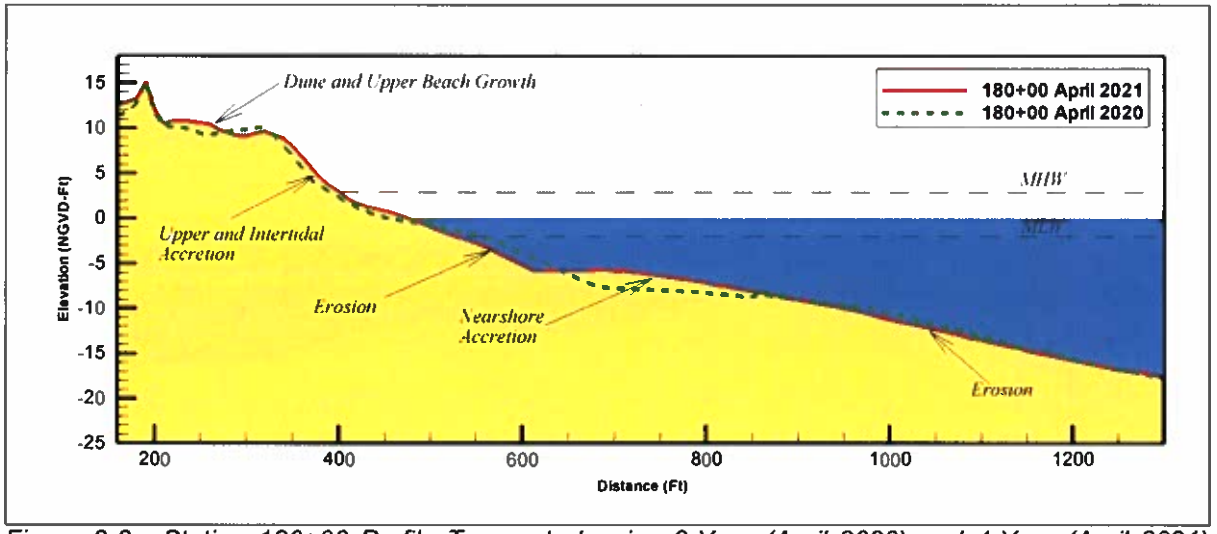

Figure 3-3. Station 180+00 Profile Transect showing 3-Year (April 2020) and 4-Year (April 2021) post-project profiles following the 2017 Town Central Reach Project. Central Reach Nourishment placed approximately 55 cy/lf in this area. Note minor continued project equilibration is observed in intertidal and nearshore areas, but beach is overall stable with some intertidal and upper beach accretion. Accretion in the upper beach indicating recovery since Isaias and dune growth over the past year also noted.

Similar to Station 40+00, Figure 3-3 reveals that some movement of material has occurred in areas farther offshore as well, 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.

In comparing the April 2021 annual survey data with post-storm profile data obtained immediately following Isaias (from August 2020), accretion has occurred in the recovery months following Hurricane Isaias particularly in the upper beach areas which were most impacted from the high water levels during Hurricane Isaias. Despite these impacts from Isaias, over the past year the upper beach has shown good signs of recovery, and growth of the dune system has occurred. This pattern was observed throughout the 2021 survey showing the beneficial spreading occurring in combination with effective sand fencing and dune planting efforts.

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 2020 to April 2021 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.

With the exception of the extreme east and west ends, the majority of the shoreline has been mostly stable to accretional, with some variation from station to station (see Figure 3-4). 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].

Accretion occurred throughout much of the Central Reach shoreline and the most significant erosion over the past year was observed near the inlets and particularly along the east end where equilibration of the 2020 LWFIX project has taken place over the past year.

The stable to accretional beach comes at a good time as recovery is needed since the impacts of Hurricane Dorian in 2019 caused significant volumetric losses to the entire beach (refer to 2020 Annual Monitoring Report). Although Hurricane Isaias likely slowed this recovery to some degree, a healthy beach is observed which overall showed a positive accretional trend over the past year.

Continued beneficial spreading of the nourishment material outside of the combined 2017 project footprints is evidenced by the exhibited volumetric accretion in the areas downdrift / west of the CRP area. The western extent of the 2017 CRP nourishment ended at about Station 260+00.

The volumes calculated in Figure 3-4 are from the dune out to about the -12-ft NGVD contour, which represents the typical 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.

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[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

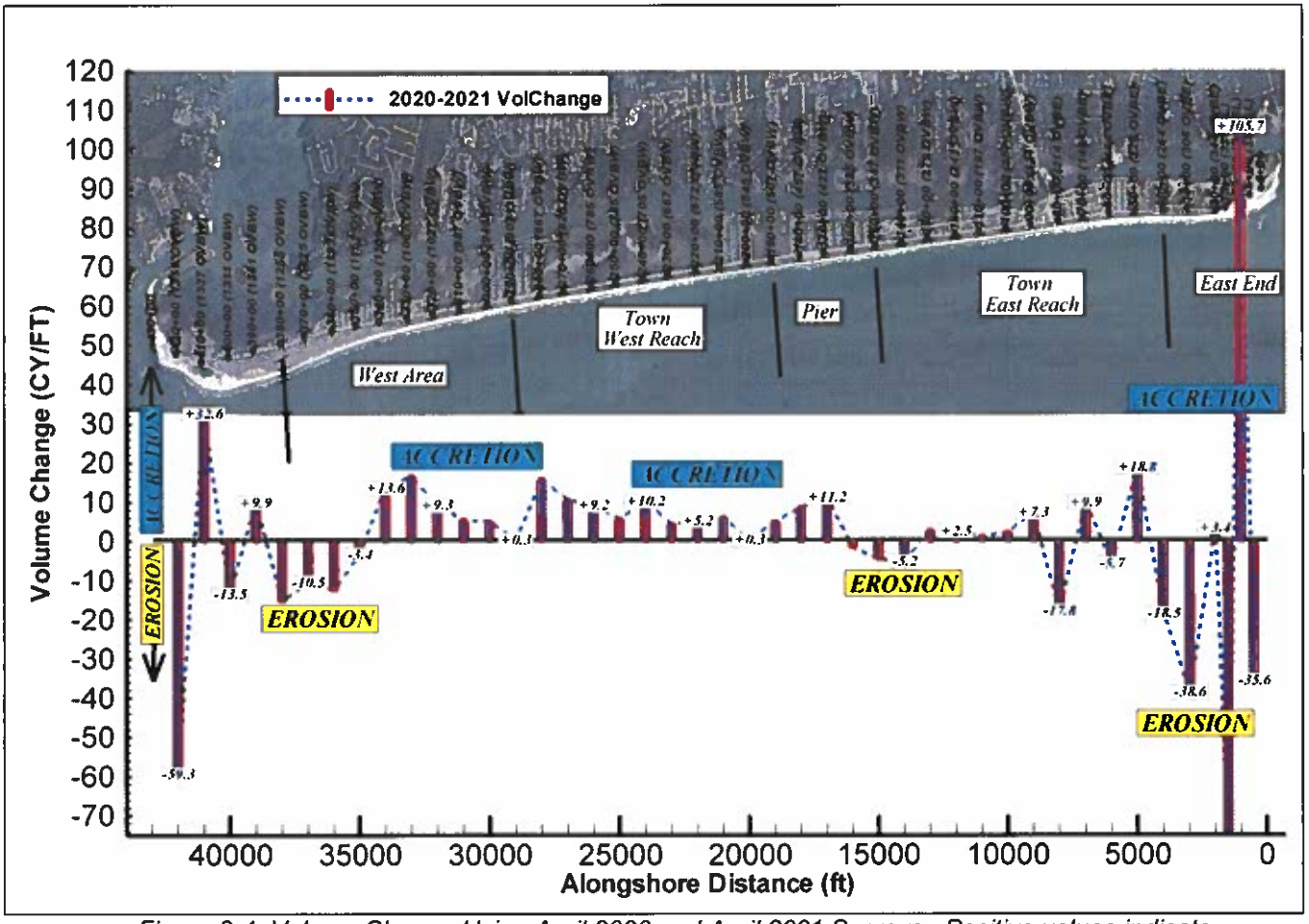


Figure 3-4. Volume Change Using April 2020 and April 2021 Surveys. Positive values indicate accretion, negative values indicate erosion. Note mostly accretion and some minor erosion observed throughout most of Central Reach and continued accretional/spreading of the 2017 CRP nourishment project can be observed to the west area. Minor erosion observed in the west area and the most significant erosion is seen near the inlets, and particularly the east end where equilibration of the 2020 LWFIX project has taken place.

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 or greater. 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 and Isaias in 2019 and 2020, respectively.

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. The beach has shown signs of growth and recovery since the 2020 hurricane season 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. In recent years, the east end had been accreting and benefitting from the eastward spreading of the 2017 nourishment sand (refer to 2018 and 2019 Annual Monitoring Reports), and of course accreted in 2020 due to the spring 2020 LWIFX placement. However, erosion occurred over the past year within the East End Reach as the 2020 LWIFX project has equilibrated. This equilibration may have been accelerated by Hurricane Isaias, but it appears spreading has benefitted the downdrift areas, west of the 2020 LWFIX project area.

Variable areas of erosional and accretional trends are observed moving closer to Lockwood Folly Inlet over the past year due to eastward spreading of nourishment project material and inlet-related effects / shoal movement.

Mostly accretion and some mild to moderate erosion is observed from the Town East Reach to the Town West Reach. Consistent accretion took place from the pier to the eastern half of the West Area, likely due to continued spreading of the CRP nourishment material moving westward alongshore. Some 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.

Similar to the east end, larger variability and 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 will be monitored for any potential impacts related to the borrow area and any continuing erosional patterns.

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 upper beach accretion and some loss near the dune toe observed at Station 350+00, considerably far downdrift/west of the 2017 CRP placement which ended near Station 260+00. As previously mentioned, volumes out to -20 ft deep are also calculated.

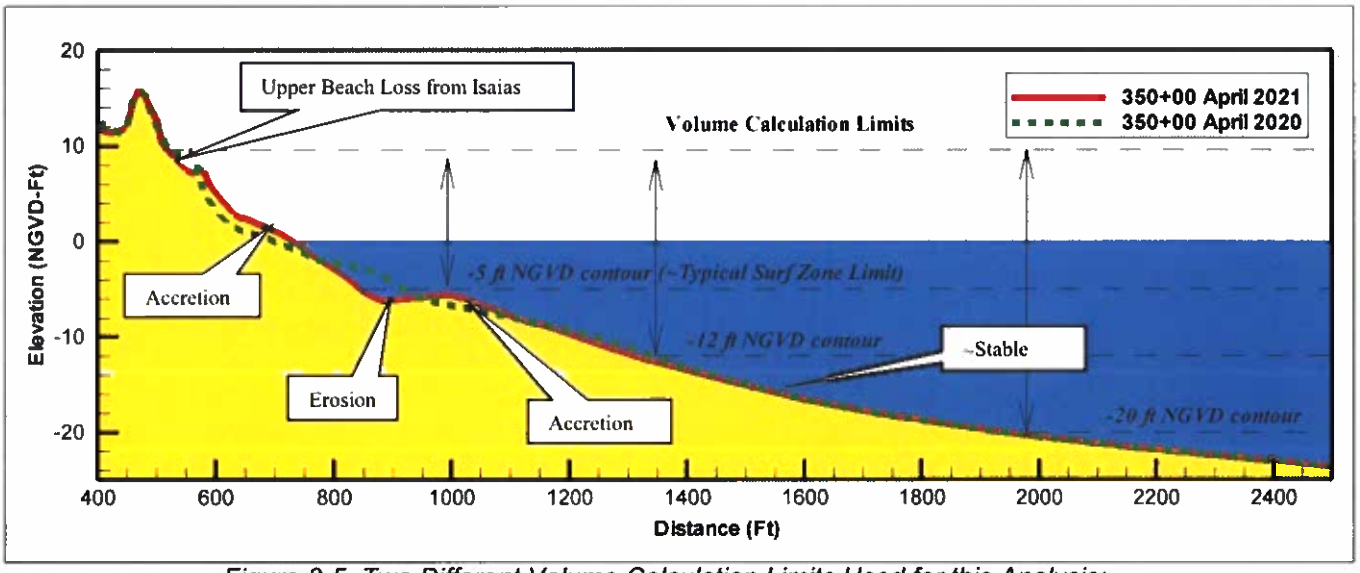


Figure 3-5. Two Different Volume Calculation Limits Used for this Analysis: 1) Dune to -12 ft NGVD and 2) Dune to –5 ft NGVD.

The predominant cross-shore sediment transport pattern observed over the past year showed material eroding from the intertidal area and surf zone and accreting in the nearshore just beyond the surf zone. This cross-shore movement can be attributed primarily to the 2020 hurricane season (Hurricane Isaias) and winter storms as well as continued nourishment equilibration. Compared with the immediate post-Isaias conditions, considerably less erosion is observed in the intertidal and surf zone area over the past year indicating sediment has been moving onshore in the months following Isaias.

Additionally, cross-shore movement in the upper beach was commonly observed between the 2020 and 2021 annual surveys with some variable upper beach berm loss and accretion

due to Hurricane Isaias and recovery in recent months, as well as observed dry beach and dune growth over the past year.

Little movement beyond the -12 ft contour occurred, compared with recent years where larger 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 2020 to 2021. Accretion was observed out to the -12-ft DOC limit, with an island-wide gain of 59,000 cy. The Central Reach gained 92,000 cy of sand out to the -12-ft DOC limit. These accretional gains are relatively minor but having occurred in a year without any nourishments, fortunately do indicate a stable, healthy beach recovering from significant losses due to Hurricane Dorian in 2019, despite the impacts from Hurricane Isaias in August of 2020.

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 2020 and 2021 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	+24,000	+18,000	+6,000
USACE East	15 to 40	-66,000	-65,000	-1,000
Town East	40 to 150	+4,000	-66,000	+70,000
Pier	150 to 190	+18,000	-4,000	+22,000
Town West	190 to 290	+70,000	+13,000	+57,000
West Area	290 to 380	+17,000	+31,000	-14,000
Shallotte Inlet	380 to 420	-8,000	-16,000	+8,000
	TOTAL	**+59,000**	**-89,000**	**+148,000**
Central Reach	40 to 290	**+92,000**	**-57,000**	**+149,000**

*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, the majority of erosion along Holden Beach out to -12 ft occurred within the dry beach/surf zone area (dune to -5 ft region), which aligns with the cross-shore transport patterns observed as a direct result of Isaias. Relatively significant erosion took place in the USACE East reach reflecting the 2020 LWFIX project sand equilibration.

In general, over the past year the most significant accretion (or least amount of erosion) occurred within the surf zone/depth of closure area (-5 ft to -12 ft region) and specifically within the Town East, Pier, and Town West reaches. This is indicative of cross-shore movement of material from the intertidal and upper beach into the surf zone as a result of Isaias impacts, as well as spreading and beach recovery as sediment which had moved offshore from recent storms has begun making its way back into the surf zone during calmer conditions. Additionally, some accretion of the upper beach occurred between the April 2020 and April 2021 surveys, likely a result of beneficial spreading of nourishment sand and ongoing upper beach and dune system growth observed over the past year.

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. Although the accretion observed over the past year is relatively minor, as no nourishment activities took place on Holden Beach between 2020 and 2021, this accretion indicates a favorable recovery of the beach from recent storm impacts.

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)
Central Reach	-14,000	94,000	62,000	-238,000	1,386,000	231,000	-142,000	-397,000	92,000
Entire Beach	-73,000	235,000	-11,000	-358,000	1,479,000	440,000	191,000	-821,000	59,000

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

Table 3-2b presents the 2017 nourishment performance since construction. As noted in the table, over 1 million cubic yards is measured to remain in the project area. This is largely due to relatively milder years in 2017/2018 and this past year, while LWFIX nourishment activity can also have a positive effect.

Table 3-2b. Central Reach Volume Change (cy) Since 2017 nourishment project (Dune to -12 ft NGVD)

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

Fortunately, the CRP has held up well. Moreover, the effective storm buffer and protection provided by the CRP has been demonstrated in each of the recent major storm events.

As mentioned previously, the east end area (Stations 5+00 to 40+00) is historically highly 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) can and 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 erosional over the entire dune to the DOC zone and exhibited loss of about 66,000 cy of material. This area recently benefitted from the 2020 LWIFX project, and as expected experienced some of the largest erosion over the past year as this material has equilibrated, which was likely exacerbated by Hurricane Isaias.

This reach of shoreline still features a relatively wide and generally healthy beach (see Figure 3-6 and other recent post-2020 LWFIX project east end photographs in Section 2.4) and will fortunately benefit from additional material in the upcoming 2022 CRR and 2022 LWFIX nourishment projects.

Figure 3-6 Recent Photograph of East End Beach Conditions Taken near Station 30+00 Looking East. 2020 LWIFX Placement Equilibrated and Erosion Seen Over Past Year, But Still Wide Beach Present in What Is Typically an Erosional Hotspot Area (Photo Taken October 2021).

The LWF Inlet Reach (Stations 5+00 to 15+00) experienced approximately 18,000 cy of accretion, likely due to spreading of the 2020 LWFIX material and inlet dynamics. Significant erosion did occur at Station 15+00, however, this was primarily in the surf zone to DOC limit due to inlet effects and the 2021 survey also shows a much more stable upper beach with some dry beach accretion seen at Station 15+00.

The West Area (Stations 290+00 to 380+00) is historically stable and has never been nourished but passively receives much of the CRP sand as it migrates westward (net sediment transport direction). The 2021 survey showed the West Area overall gained about 17,000 cy of material in the dry beach to the DOC area (dune to -12 ft) over the past year.

Additionally, more accretion took place in the dry beach to surf zone area (dune to -5 ft NGVD) as approximately 31,000 cy of material was gained and the West Area experienced some of the largest observed dry, upper beach growth (refer to Appendix A). This can be attributed to downdrift, westward spreading of material from the CRP area and continued healthy dune growth.

In addition to causing significant cross-shore movement, Hurricane Isaias likely caused continued alongshore movement and equilibration of the CRP sand, similar to Hurricanes Florence and Michael in 2018 and Hurricane Dorian in 2019.

The beach west of Station 380+00 to Shallotte Inlet is subject to episodic erosion. This reach experienced some moderate volumetric erosion between 2020 and 2021, with a total loss of 8,000 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.

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.

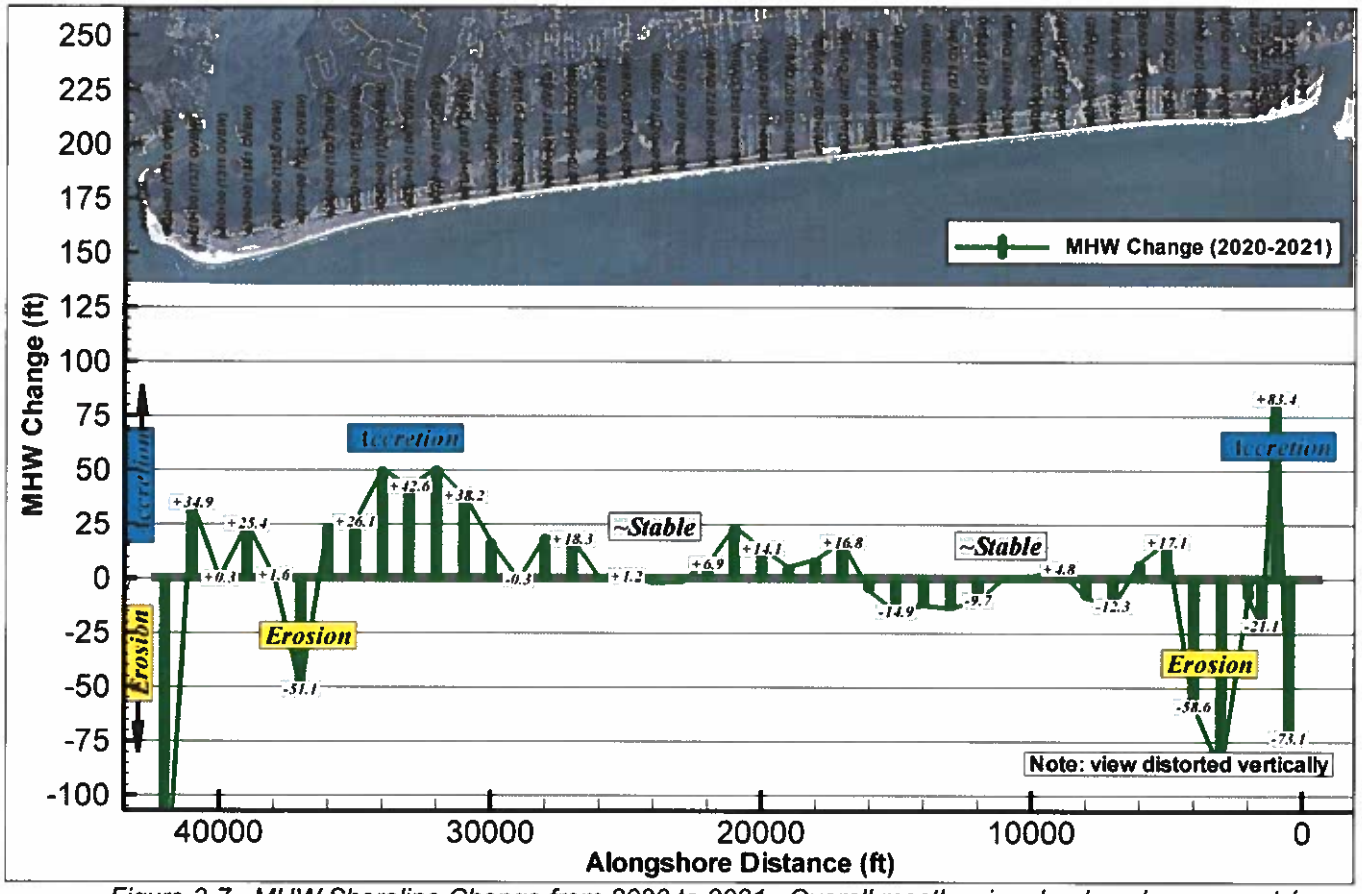


Figure 3-7. MHW Shoreline Change from 2020 to 2021. Overall mostly minor landward movement / erosion and seaward movement / accretion of the MHW shoreline is observed throughout the Central Reach indicating a largely stable Central Reach shoreline over the past year. Accretion / seaward movement is observed primarily in western reaches of Holden Beach and erosion / landward movement occurred in the eastern reach.

Average MHW shoreline change by reach is presented in Table 3-3. Accretion of the MHW shoreline was observed along the western reaches of Holden Beach, where continued spreading of the 2017 CRP material benefitting the western shoreline is evident.

As expected, erosion of the MHW shoreline is observed near the east end in the vicinity of the 2020 LWFIX project, due to cross-shore movement of material from the upper portions of beach into the nearshore as the project is approaching an equilibrium beach profile one year following placement. However, a healthy wide dry beach can still be seen in these areas (refer to Figure 3-6 in the previous section). Additionally, significant accretion is observed just east of the project area, likely from 2020 LWFIX material spreading and inlet dynamics. Hurricane Isaias likely accelerated the equilibration movement. The east end close to Lockwood Folly Inlet shows high variability, which is typical in this area due to inlet effects.

Table 3-3. MHW Shoreline Change by Reach for 2020 and 2021 Surveys

Reach Averages	Stations Included	2020 to 2021 MHW Change (ft)
LWF Inlet	5 to 15	-3.6
USACE East	15 to 40	-51.8
Town East	40 to 150	-8.2
Pier	150 to 190	+2.2
Town West	190 to 290	+7.8
West Area	290 to 380	+19.9
Shallotte Inlet	380 to 420	+15.6
Central Reach	40 to 290	+0.3

Over the past year, the majority of the beach experienced varying degrees of erosion and accretion of the MHW shoreline, with more substantial accretion observed in the western half of the beach. Hurricane Isaias caused erosional impacts in the dry upper beach and intertidal zone, eroding the MHW shoreline landward along much of the island. The April 2021 surveys the MHW shoreline has recovered well and reveals a mostly stable shoreline as generally only minor erosion/accretion occurred over the past year along the majority of Holden Beach.

This pattern was observed most notably in the Central Reach, where recovery since the 2020 hurricane season reveals a MHW shoreline similar to pre-Isaias conditions. Landward

and seaward movement of the MHW line was relatively minor (typically less than 15 ft) in the Central Reach. In general, more accretion was observed in the western portions of the Central Reach than the eastern portions due to downdrift / westward alongshore spreading.

Figure 3-8 (A) presents recent oblique aerial photographs in the Central Reach, and a ground photograph is shown on Figure 3-8 (B). Despite recent storms, a wide, healthy dry beach and dune system still characterizes the Central Reach shoreline from the large nourishment effort in 2017 and sand fencing and dune plantings in the years after.

Figure 3-8 (A). Central Reach October 2021 Aerial Photos Taken Near Station 90+00 Looking West towards the pier in the Upper Panel and East toward LWF Inlet in the Upper Panel.

Figure 3-8 (B). Central Reach October 2021 Photo Taken Near Station 230+00 Looking East.

Stations west of the Central Reach to about Station 360+00 generally experienced some of the most substantial MHW shoreline accretion as lateral spreading of the CRP has contributed to some significant upper beach growth and accretion of the MHW line. Figure 3-8 (C) presents a photograph near Station 280+00 exhibiting an overall very healthy beach and dune system which showed some additional growth over the past year.

Figure 3-8 (C). October 2021 Photo Taken Near Station 280+00 Looking East.

The western portions closer to Shallotte Inlet show mostly MHW shoreline accretion, with some erosion, particularly at the far west end due to inlet dynamics. Figure 3-9 presents the changes in the MHW position from 2020 to 2021 along the westernmost shorelines of

Holden Beach. Appendix B provides figures of the 2021 survey MHW results for the entire Holden Beach shoreline.

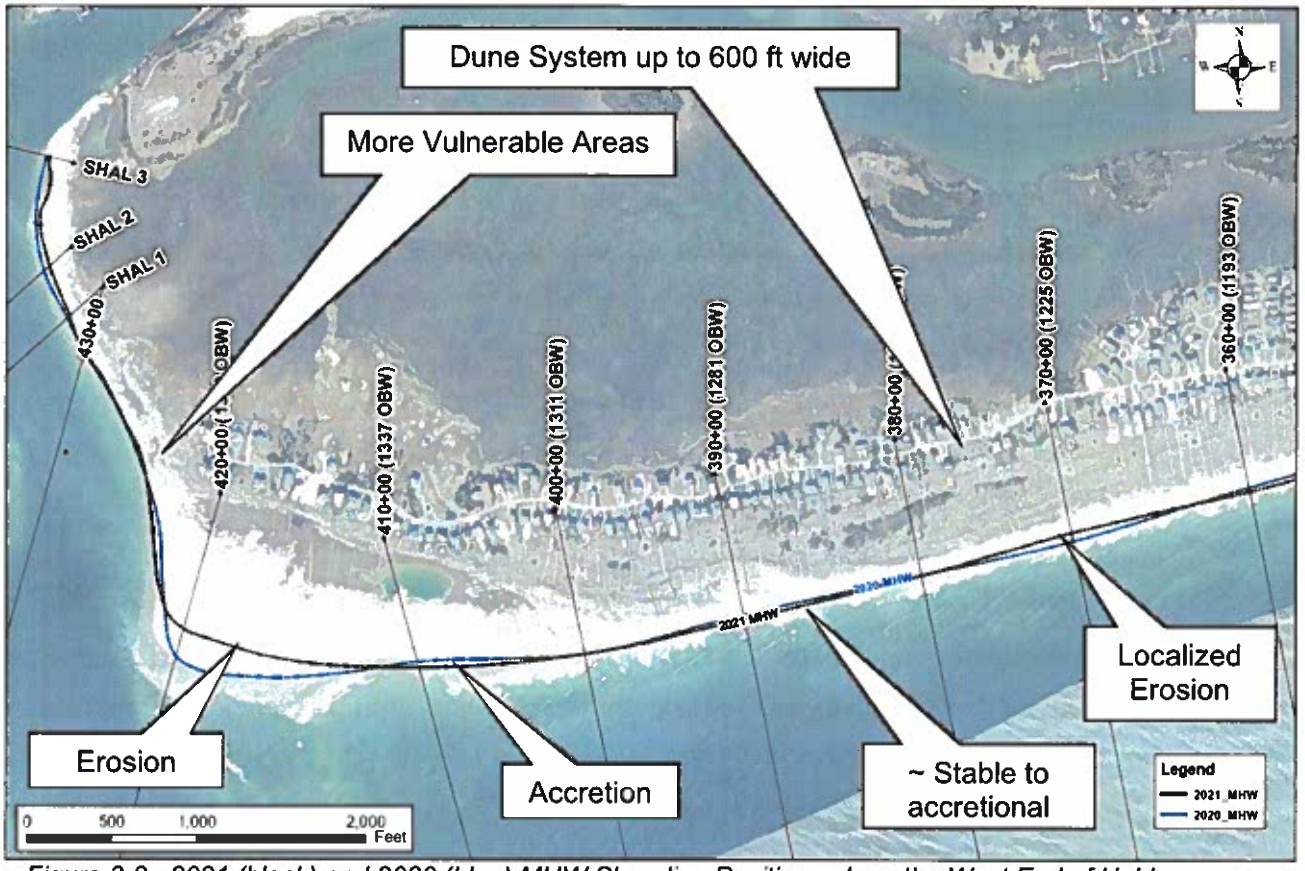


Figure 3-9. 2021 (black) and 2020 (blue) MHW Shoreline Positions along the West End of Holden Beach near Shallotte Inlet. "SHAL 1" begins at the same location as 430+00. (2020 aerial shown).

Despite volumetric losses observed in this area, the MHW line here has generally remained relatively stable over the past year, with the exception of Stations 370+00 and 420+00 which eroded. The localized erosion in these areas 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, 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 Michael in 2018. 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.

This area will continue to be closely monitored and future efforts to enhance vegetation may be implemented as a proactive measure to mitigate erosion. Also, the substantial addition of material into the system from the 2017 CRP (along with the upcoming 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.

The Ocean Isle nourishments typically use Shallotte Inlet as a borrow area. The most recent of these nourishment events occurred in April 2018 as part of the USACE Federal CSDR project, which involved dredging about 370,000 cy from Shallotte Inlet and placement onto the eastern shoreline of Ocean Isle. No noticeable changes to the Holden Beach shoreline have been observed based on April 2021 survey data, however, shoreline monitoring will continue to assess any potential effects of this and future activities on the Holden Beach shoreline. Another Ocean Isle nourishment is planned this winter along with construction of a terminal groin. Groin-related monitoring of Shallotte Inlet (including the Holden Beach west end) will occur by Ocean Isle as required by permits.

Similar to the volumetric analysis, the eastern end near LWF Inlet shows some of the largest MHW changes occurred in this area. Figure 3-10 presents the changes in the MHW position from 2020 to 2021 along the easternmost shorelines of Holden Beach. Stations 60+00 and 50+00 are mostly stable, and consistent landward movement of the MHW shoreline of over can be observed from Stations 40+00 to 15+00 due to equilibration of the 2020 USACE LWFIX project.

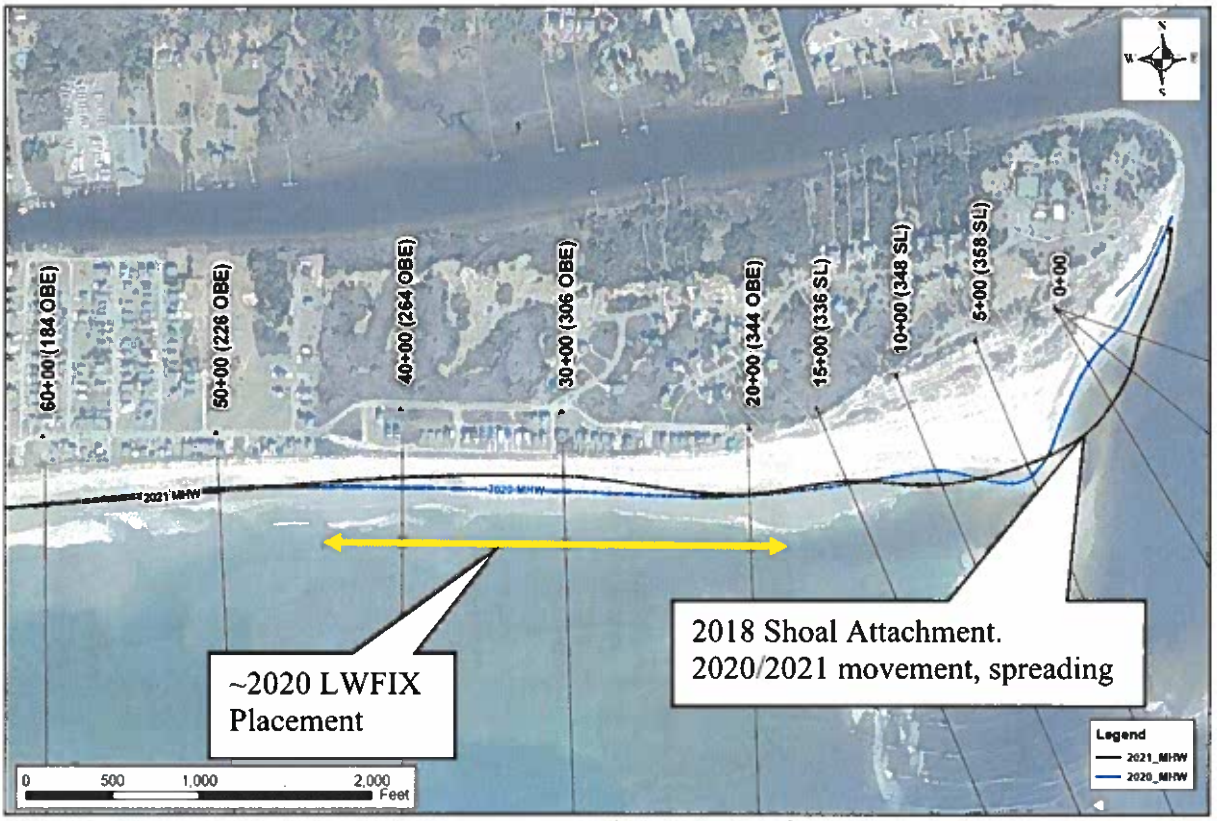


Figure 3-10. 2021 (black) and 2020 (blue) MHW Shoreline Positions along the East End of Holden Beach near Lockwood Folly Inlet. (2020 aerial shown).

The extreme east end shows large seaward movement / accretion of the MHW shoreline from alongshore movement from the 2017 and 2020 nourishment projects, LWF Inlet dynamics, and the shoal attachment between Station 0+00 and Station 5+00 (documented in the 2019 monitoring report). The 2021 survey and more recent aerials and site observations reveal this shoal continues to be flattening and spreading out, which is benefitting the east end.

The toe-of-dune (TOD) shoreline (7 ft NGVD contour) is shown on Figure 3-11 and generally represents the seaward edge of the dune. The TOD shoreline change shows some variable erosion and accretion changes, but overall a mostly accretional trend. Areas of observed erosion can likely be attributed to Hurricane Isaias, which impacted the beach and dunes with extreme water levels and wave action in August of 2020.

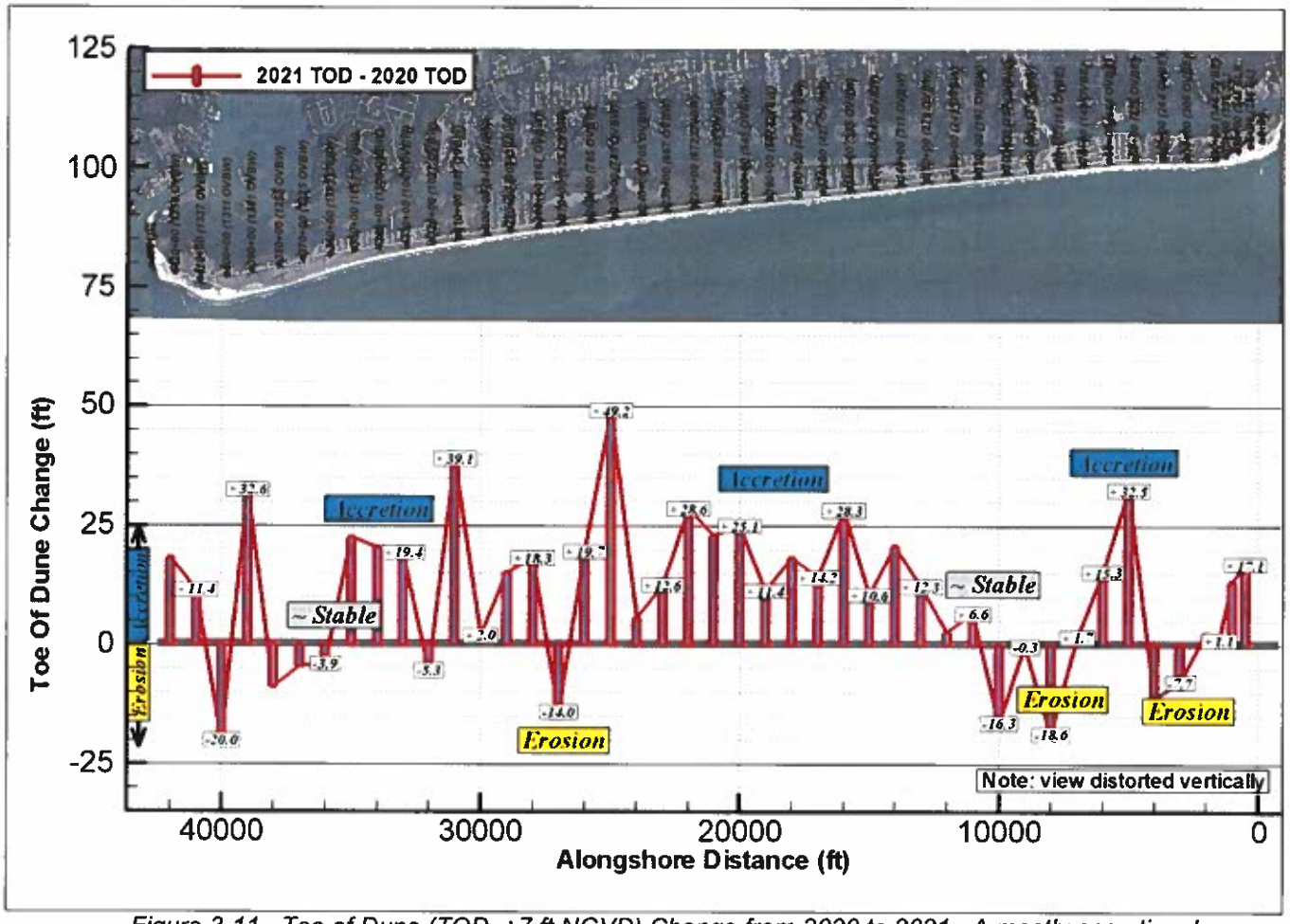


Figure 3-11. Toe of Dune (TOD, +7 ft NGVD) Change from 2020 to 2021. A mostly accretional beach trend is exhibited, though with variability throughout the reaches.

However, the observed changes show that although Hurricane Isaias caused damage to the upper beach and dune system, several areas of healthy growth and vegetation emergence occurred over the past year pushing the TOD shoreline seaward along much of the Holden Beach shoreline.

Figure 3-12 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.

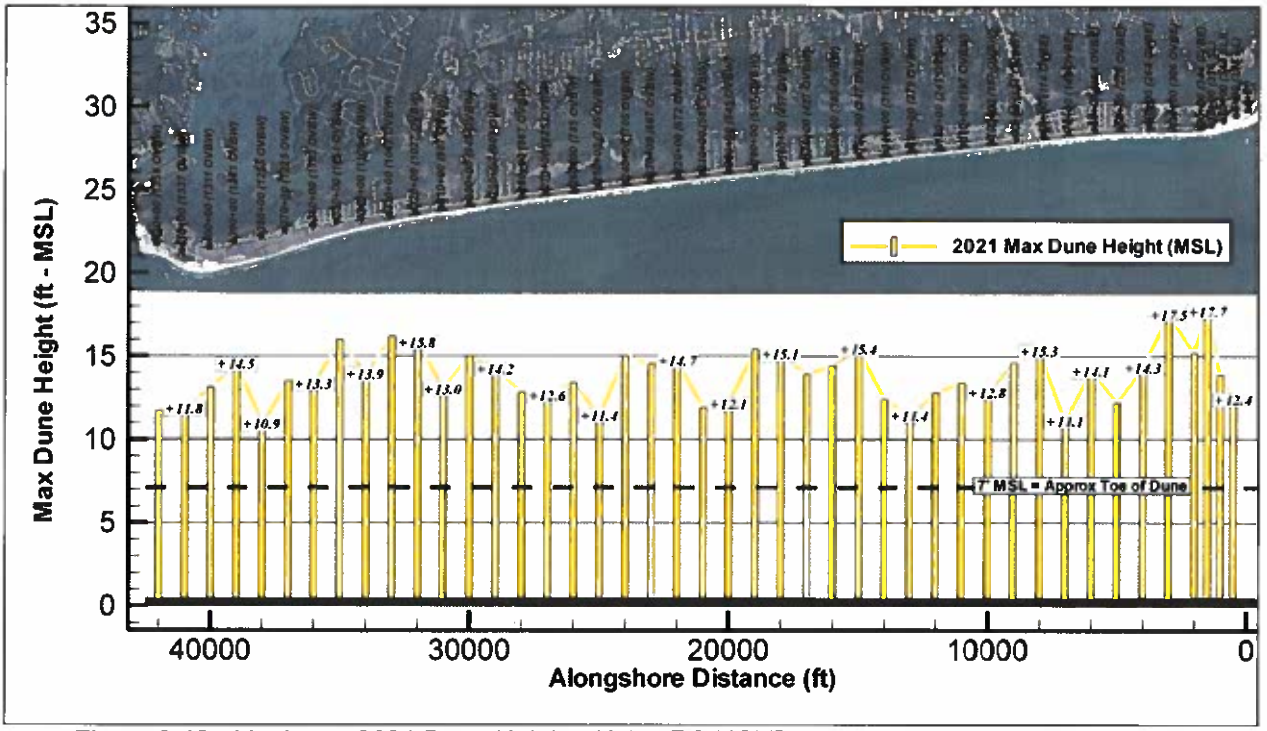


Figure 3-12. Maximum 2021 Dune Height. Using 7 ft NGVD as the dune base, dunes are generally 5' to 8' high.

3.4 HISTORICAL ANALYSIS

Figure 3-13 presents an approximately 21-year MHW shoreline comparison using 2000 and 2021 survey data. The 2000 survey represents a significantly erosional condition. A general accretional trend of 50 to 130 ft is exhibited for the MHW shoreline between 2000 and 2021 (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 3-13 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 2021) as the survey data in Figure 3-13.

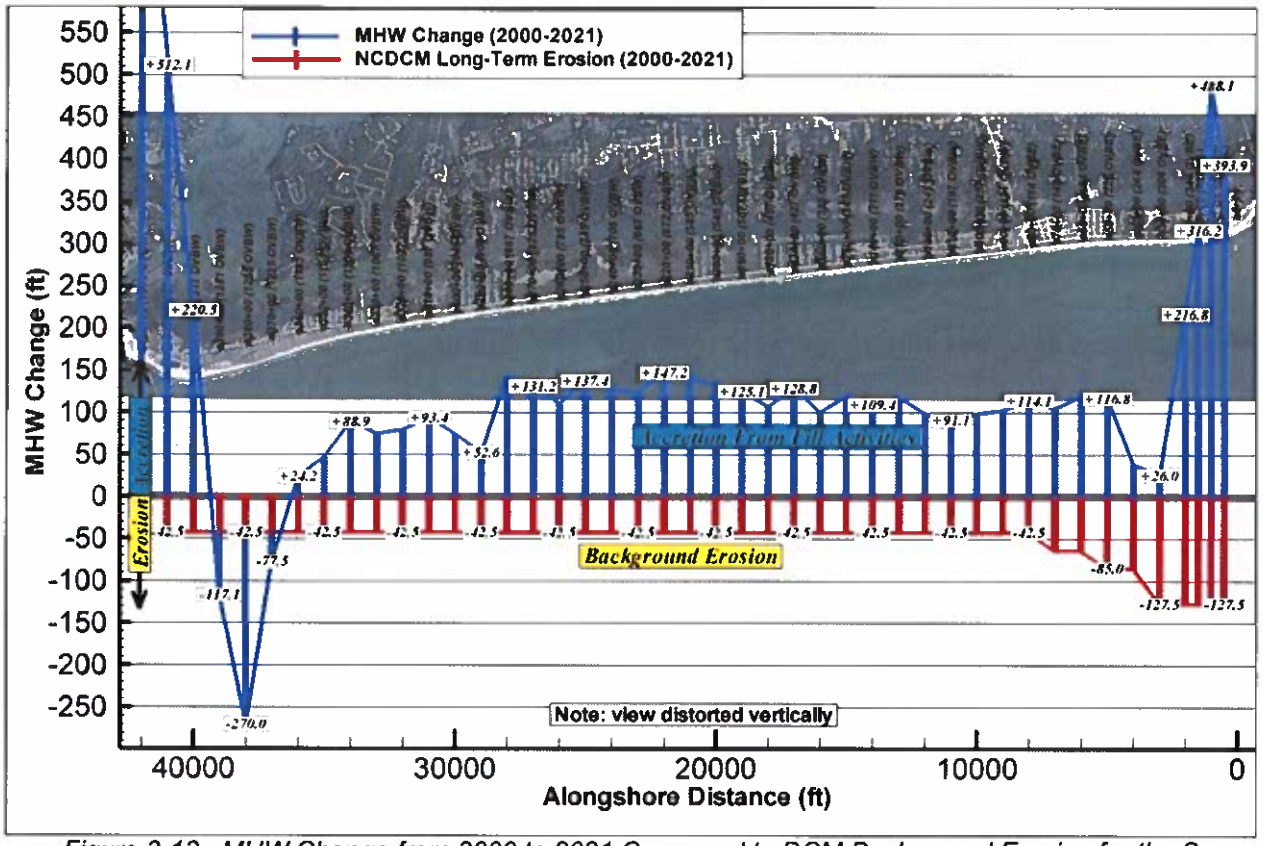


Figure 3-13. MHW Change from 2000 to 2021 Compared to DCM Background Erosion for the Same Period

Table 3-4 presents average MHW change by reach over the last 21 years. Results show that Town and USACE fill and dune enhancement activities have been successful in combating erosion over the last 21 years and the CRP was constructed with this goal in mind.

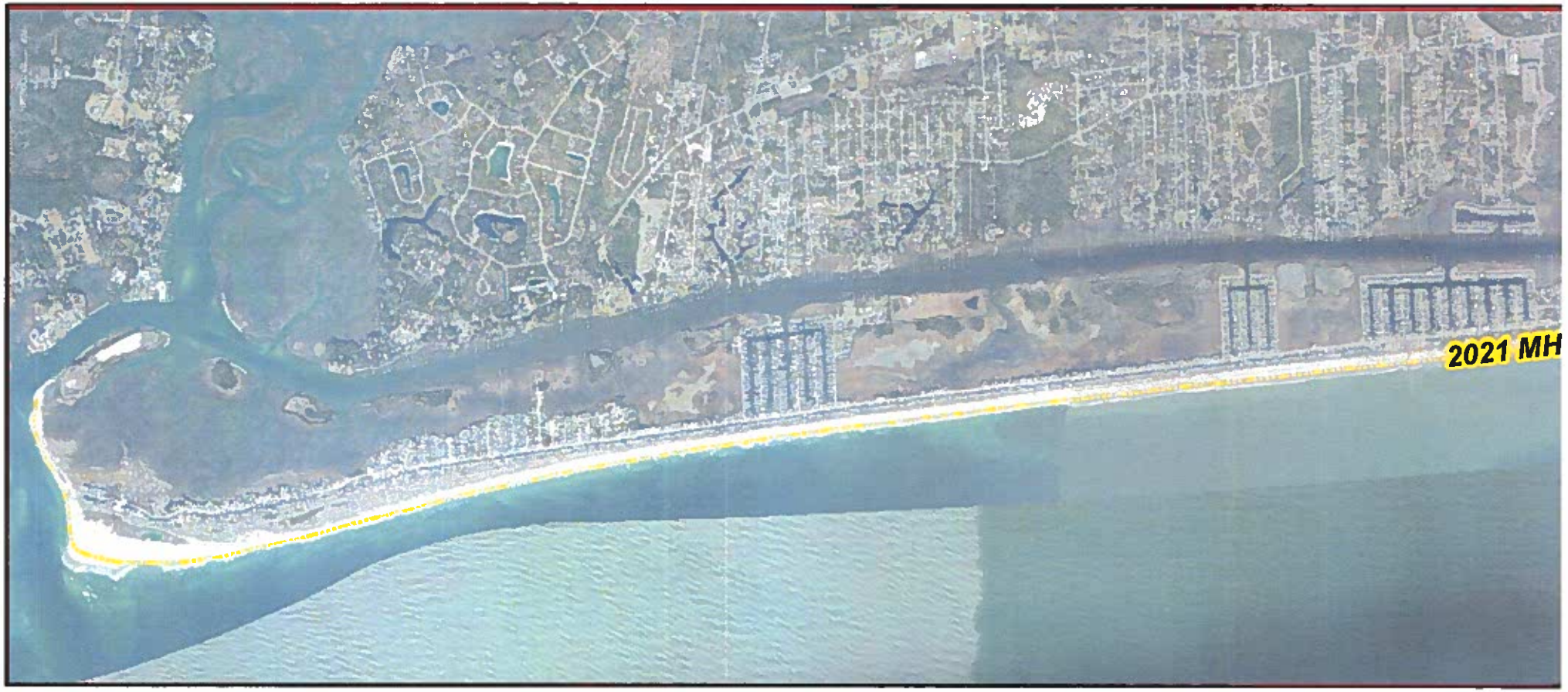
Excluding inlet reaches, the Town West reach exhibits the largest increases in MHW change over the last 21 years, as a result of the continued equilibration and progression of the 2017 nourishment. Similarly, the Town East and Pier reaches show large increases as well.

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 2021)

Reach Averages	Stations Included	Historical MHW Change (2000 to 2021) (ft)
LWF Inlet	5 to 15	+399.4
USACE East	15 to 40	+94.0
Town East	40 to 150	+102.7
Pier	150 to 190	+116.1
Town West	190 to 290	+124.7
West Area	290 to 380	+18.7
Shallotte Inlet	380 to 420	+86.4
Central Reach	40 to 290	+113.0

Figure 3-14 compares a 1993 aerial of Holden Beach with a 2020 aerial. The 2021 MHW line is shown on both aerials for comparison purposes. Figure 3-14 clearly shows that the overall health of the Holden Beach shoreline is better than it was decades ago.


2021 MH


2021 MH

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 3-15. 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 most recent Oak Island west end nourishment project occurred in the spring of 2021, as part of the USACE LWFIX Inlet dredging (see Figure 3-16), which, in the past, had solely been used to replenish the habitually eroding east end of Holden Beach. The placement location is shown also on Figure 3-15 for reference. It is estimated approximately 120,000 cy of material was placed on the west end of Oak Island during the 2021 LWFIX project.

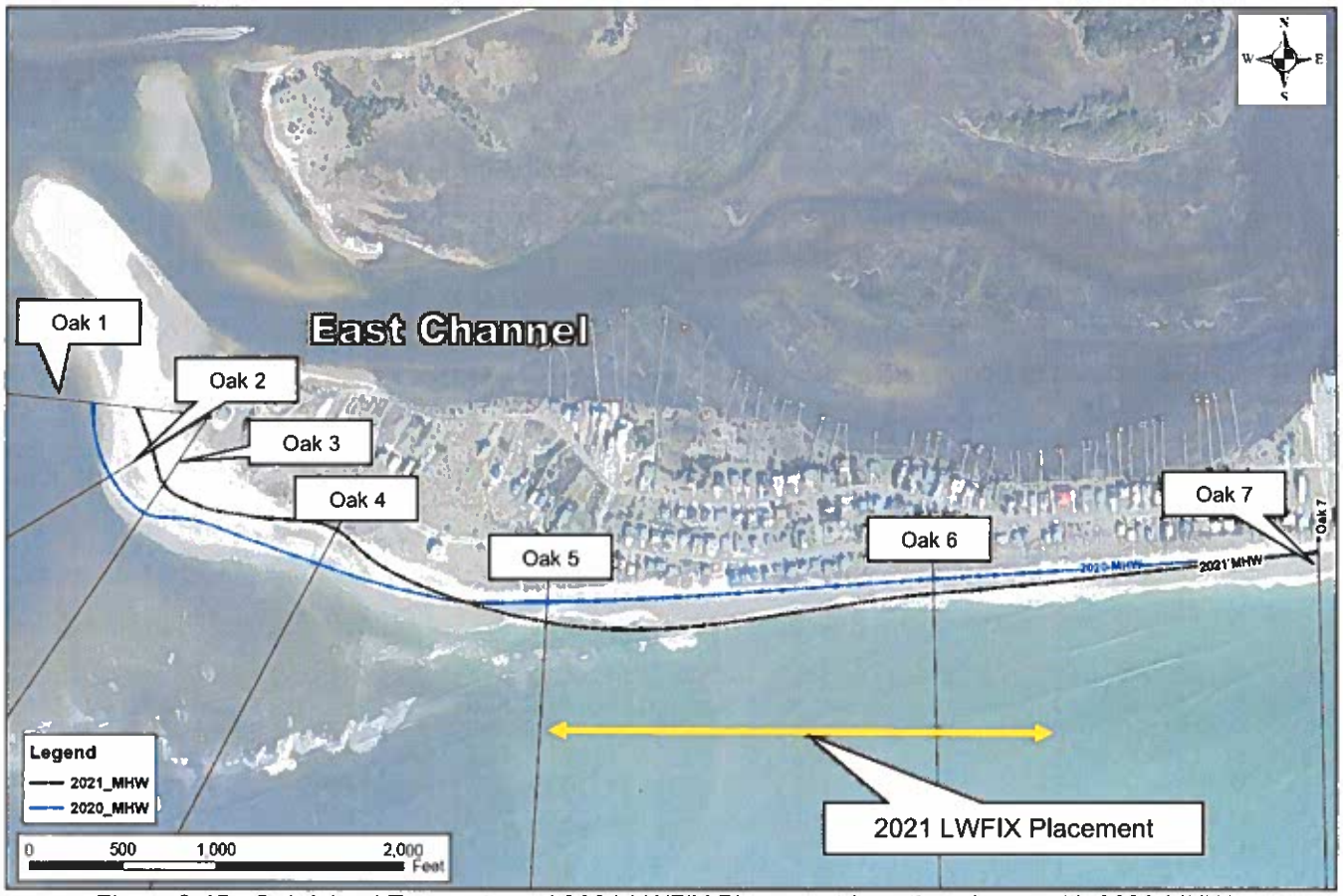


Figure 3-15. Oak Island Transects and 2021 LWFIX Placement Location shown with 2020 MHW (blue) and 2021 MHW (black) Lines. "Oak 2" and "Oak 3" transects begin at the same location as "Oak 1." (2020 aerial shown).

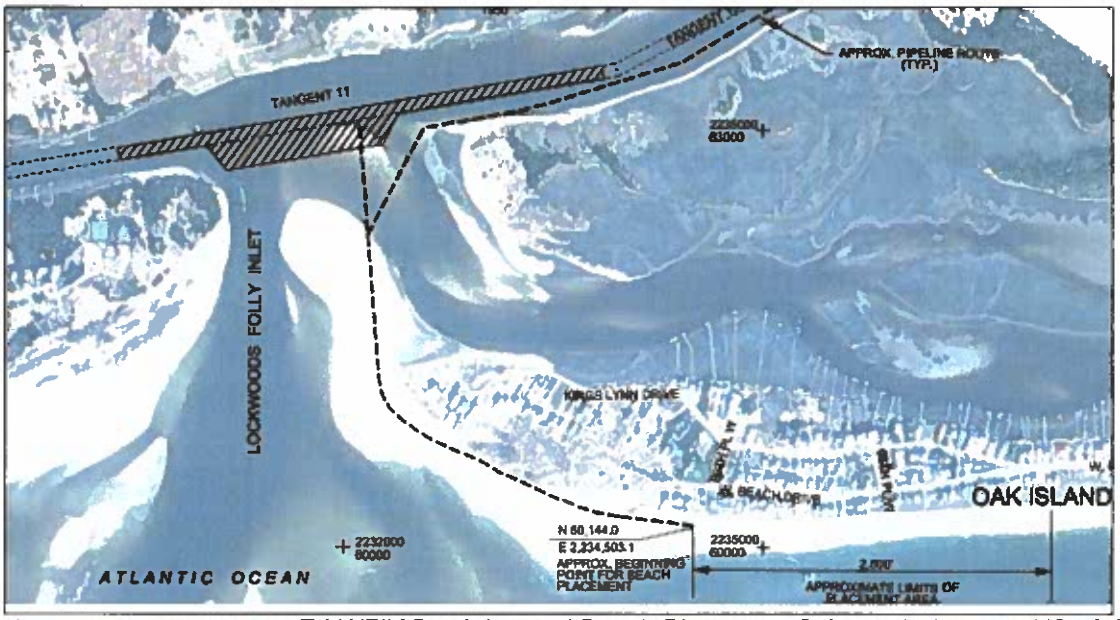


Figure 3-16. 2021 USACE LWFIX Dredging and Beach Placement Schematic (source: USACE request for dredging proposal).

As Figure 3-15 shows, Oak Island Transects 5 and 6 show accretion of the MHW line over the past year, from the 2021 LWFIX nourishment. Downdrift of the nourishment template, the MHW shoreline Transects 1-4 showed MHW line erosion over the past year due to inlet dynamics and wave activity. Transect 7, located updrift/east of the sand placement and less influenced by Lockwood Folly Inlet dynamics, showed a stable MHW shoreline between 2020 and 2021.

Table 3-5 presents the volume changes for the Oak Island transects between the 2020 and 2021 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 2020 to 2021

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	+17.6	-25.4	LWF Inlet
Oak 2	0	-12.3	-56.7	LWF Inlet
Oak 3	890	-151.1	-124.7	LWF Inlet
Oak 4	1100	-16.2	-9.6	LWF Inlet Shoulder
Oak 5	2000	+21.7	+29.2	Oceanfront
Oak 6	2000	+48.5	+32.2	Oceanfront
Oak 7	-	-7.4	-5.0	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)	Notes
Oak1	+65.4	-51.9	+331.3	-224.8	-103.7	-68.6	+90.8	+89.1	-235.6	
Oak2	-432.8	+105.9	+87.0	-27.0	-168.1	-26.4	-8.8	+112.4	-265.2	Channel Shoaling
Oak3	-338.2	+19.4	+302.1	-371.5	-57.6	+84.4	-155.6	+145.9	-184.4	
Oak4	-75.4	-51.9	-134.4	+91.1	-242.8	+69.7	+89.4	-71.9	-198.3	
Oak5	-91.7	-12.6	+94.3	-64.6	+49.7	-110.8	+102.6	-131.4	+108.0	2015, 2019, 2021 Nourishments
Oak6	-7.5	-4.0	+163.1	-68.9	-13.1	-112.9	+78.3	-115.4	+79.1	2015, 2019, 2021 Nourishments
Oak7	+13.7	+14.0	-16.9	+37.1	-15.7	-48.6	-26.0	+4.8	-12.0	

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

The western-most portions of Oak Island are highly variable from year to year, as with any inlet shoreline. Similar to the MHW change analysis, Oak Transects 5 and 6 showed the most substantial volumetric accretion as benefits from the recent project as a result of the 2021 nourishment. Volumetric accretion out to the -12 ft depth-of-closer limit is also observed at Oak Transect 1, due to recent shoal movement and LWF Inlet dynamics.

Oak Transects 2 through 4 showed mostly volumetric erosion between 2020 and 2021, though some accretion and shoaling into the channel was observed to have taken place here, particularly at Oak Transect 2. Minor erosion is observed at Oak Transect 7, east of the 2021 LWFIX project, but will likely receive material from the project as it equilibrates and spreads outside of the template.

The Town of Oak Island is slated to continue their "FEMA Phase II: Hurricane Florence Nourishment Project" this upcoming spring 2022. This is a large nourishment project (between ~700,000 cy and ~1 MCY) to restore material lost from recent hurricanse and will include placement of sand along the western half of the Town of Oak Island's engineered beach.

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 21 years), the Town and the USACE have placed an average of approximately 200,000 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 Florence and Michael in September and October 2018. Similar to "engineered beach" mitigation projects following Hurricanes Hanna (2008), Irene (2011), and Matthew (2016) FEMA assistance was implemented following the 2018 hurricane season and a Central Reach Reimbursement (CRR) project is planned for the 2022 winter/spring dredging window. The CRR project represents a total of about 1.5 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 Florence, Michael and potentially Dorian. Two offshore borrow areas will be used for this effort.

Holden Beach was impacted Hurricane Isaias in August of 2020 and again was subjected to widespread erosion and damage to the upper beach. Isaias impacts were much less severe (compared with recent storms - Florence, Michael, and Dorian), however, some of the most significant impacts were to the upper beach and emergent dunes.

The beach is slowly recovering from these storms and fortunately the upper beach has been improving since Isaias and healthy new dune growth was observed in several areas over the past year. The 2017 CRP and LWFIX / Town Eastern Reach Project and the recent 2020 LWFIX project helped to provide a significant buffer during the extreme conditions the beach was subject to through the past few hurricane seasons.

The most recent annual shoreline survey occurred in April 2021. *In comparing this survey to the April 2020 survey, the entire island experienced a net gain of approximately 59,000 cy out to the -12-ft DOC limit. The upper portions of the beach and surf zone (i.e., from the*

dune out to -5 feet), however, show a net loss of only ~89,000 cy over the entire Holden Beach shoreline due to the impact of Hurricane Isaias.

The April 2021 survey overall shows a mostly stable to accretional beach over the past year which is welcomed following the losses from Dorian in 2019 and fortunately the 2020 Hurricane season and Isaias (along with winter storms) appear to have not hindered this recovery too much. Although accretional gains are relatively minor, observed accretion over the past year is favorable considering no nourishment activity occurred over this time span.

The majority of erosion along Holden Beach occurred within the dry beach/surf zone area (dune to -5 ft region). Considerably more accretion (and less erosion) took place beyond the surf zone limit. This reflects the cross-shore movement of material from Isaias impacts, as well as alongshore spreading and signs of beach recovery as sediment which had moved offshore from recent storms (e.g., Dorian) has begun making its way back into the surf zone. Some accretion of the upper beach also occurred between the April 2020 and April 2021 surveys in spite of Isaias, likely a result of beneficial spreading of nourishment sand and ongoing upper beach and dune system growth observed over the past year.

Volumetric erosion occurred near the east end over the past year as the 2020 LWFIX nourishment project is equilibrating, and some nearby accretion occurred from eastward and westward spreading. Inlet dynamics and the spreading of a recent shoal attachment on the far east end have been contributing to dry beach accretion along the east end shoreline also, however, these trends have been known to quickly reverse in the absence of nourishment activities.

The CRP and the 2017 LWFIX Eastern Reach Project brought a much-needed addition of material into the Holden Beach littoral system in 2017 (~1.5 million cubic yards combined). A mostly accretional beach was observed in the center approximately 5 miles of island (Central Reach STA 40+00 to 290+00) in comparing the 2020 and 2021 surveys. Over the past year, a total net gain of approximately 92,000 cy of sand was observed in the Central Reach out to the -12 ft DOC limit. This is in large part due to natural beach recovery during a relatively calmer year, continued healthy dune and upper beach growth, and both eastward and westward lateral spreading of nourishment material.

Due to the anticipated continued lateral/longshore spreading of the project sand, the movement of material from the Central Reach has mitigated erosional losses from storms along the shorelines outside of the Central Reach and contributed to accretion and dry upper beach growth seen in these areas in the 2021 survey. Overall, approximately 70% of the CRP can still be accounted for within the CRP footprint.

From a shoreline contour perspective, the majority of the island can be characterized as stable to accretional. The Central Reach experienced overall relatively minor changes to the mean high water (MHW) shoreline. The MHW shoreline showed signs of recovery in the months following Hurricane Isaias as the 2021 survey shows MHW shoreline conditions similar to pre-Isaias conditions. More consistent substantial seaward MHW movement was observed in the western reaches from spreading of 2017 nourishment material, and some localized erosion is observed in the far west end closer to Shallotte Inlet likely due to Hurricane Isaias and/or inlet dynamics and shoal movement.

Erosion / landward movement of the MHW line occurred along the east end near LWF Inlet as equilibration of the 2020 LWFIX project took place over the past year moving intertidal beach sand into the nearshore and surf zone. This cross-shore movement was likely accelerated by the energetic wave and high-water level conditions experienced during Hurricane Isaias. Some MHW accretion is observed along the far east end where the spreading and flattening of a recent shoal attachment has been benefitting this area. Without nourishment activities the east end is typically erosional, and fortunately the upcoming 2022 LWFIX project will provide additional sand to this reach to mitigate future erosion. ATM and Town staff will continue monitoring this movement (and shoal attachments) as it progresses.

The toe-of-dune (TOD) line within the Central Reach was generally accretional. Additionally, dune heights are healthy, and despite damage to the upper portions of beach from Hurricane Isaias in August of 2020, recovery and continued growth of the starter dunes and planted vegetation as part of the CRP was observed over the past year. Significant sand fencing and dune vegetation planting occurred following the 2017 nourishment projects, which have helped mature and enhance these dunes in recent years.

In comparing the April 2021 survey with the January 2000 survey (21-year span), the beach width based on the MHW shoreline location is on average approximately 135 ft wider for the entire island now than it was 21 years ago. This increased beach width is in large part due to the recent 2017 large-scale nourishment activities, along with the 2020 LWFIX project on the east end. The CRP and other future planned projects of this scale are designed to enhance the beach and dune system, which will result in protective, ecological, recreational, and economic benefits.

The CRP nourishment, completed in March of 2017, represents the largest nourishment project on Holden Beach (more than twice the size of the 2001-2002 USACE 933 project). 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 2021 survey represents the 4-year post-project survey of the 2017 CRP nourishment for monitoring the continued equilibration and movement of the project sand.

The planned Central Reach Reimbursement (CRR) project aims to mimic and expand upon the 2017 CRP. The project will place ~1.5 mcy of offshore beach compatible sand from Stations 40+00 to 280+00 (~24,000 linear feet of shoreline).

The most recent nourishment on Holden Beach came from the spring 2020 USACE LWFIX project with the usual placement along Holden Beach's east end, which is historically highly erosional. The 2021 survey showed that the additional 80,000 cy from the 2020 LWFIX has equilibrated over the past year and this was likely accelerated by Hurricane Isaias. Still a relatively wide recreational beach is present and the upcoming CRR and LWFIX projects will create additional beach and storm buffer width to abate future erosion along this stretch of shoreline.

The 2020 LWFIX project was not as large as those in 2017 and 2014. Some dredging of the 400-ft bend widener did occur, though the full amount was not dredged due to scheduling/timing constraints or other logistical issues. Alternative/optional bid items are given less priority than the base items and are not required to be completed, whereas base bid items are.

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 most recent LWFIX project placement was for the west end of Oak Island in spring of 2021, and the upcoming LWFIX project with beneficial placement on Holden Beach is scheduled to occur this March 2022, concurrently with the upcoming CRR project.

The NCDEQ 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 planning and perform CRR re-nourishment project
- 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

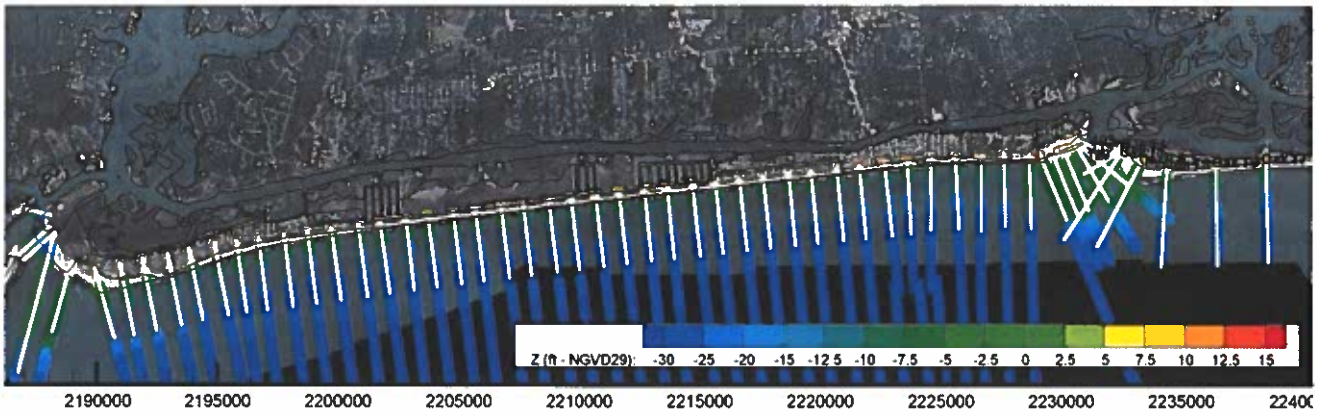
Specific needs regarding ongoing beach management in the near future are related to the upcoming CRR project as well as the LWFIX project.

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.

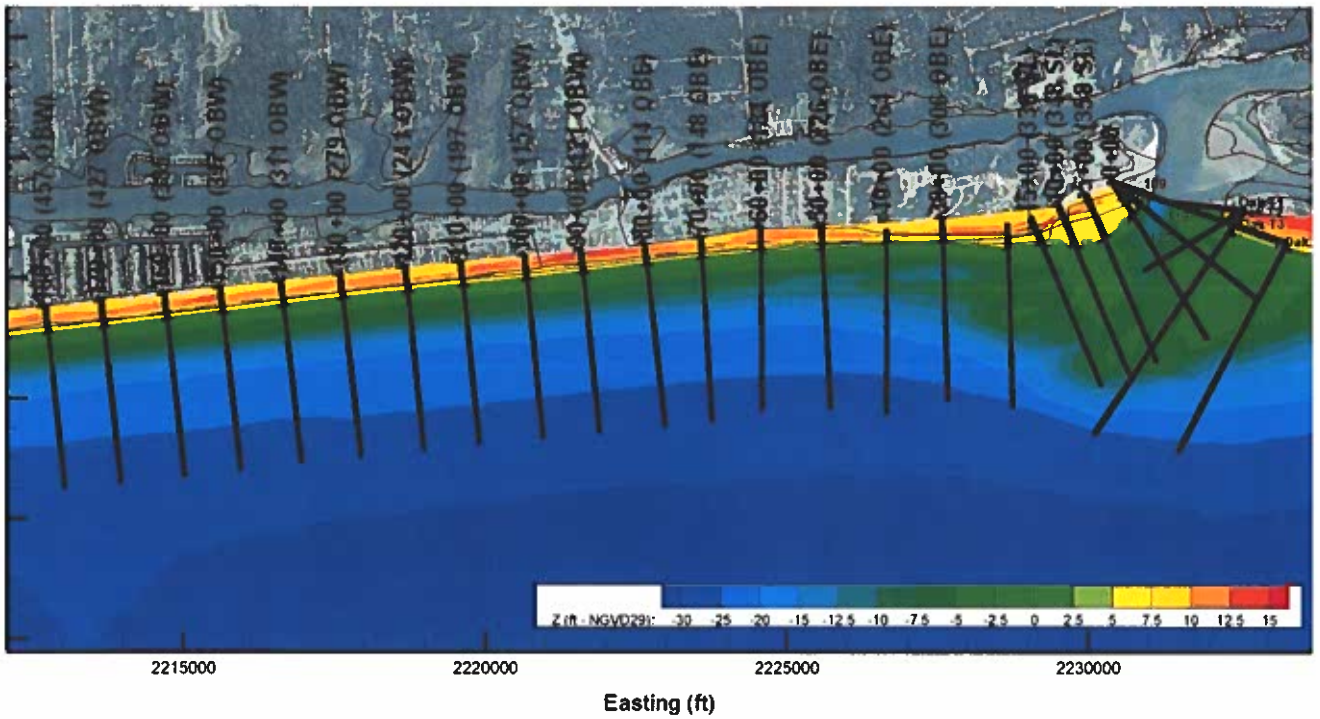
Appendix A

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.

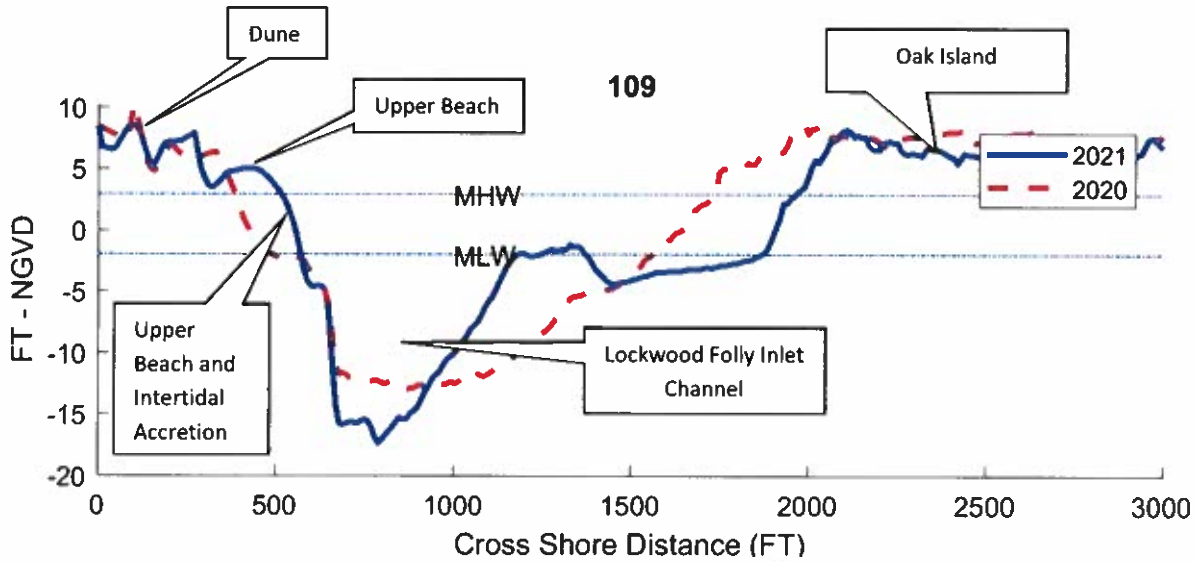


Zoomed in to eastern half of island (station 170+00 is to the left and just east of the pier). Note "Z" is in ft-NGVD29.

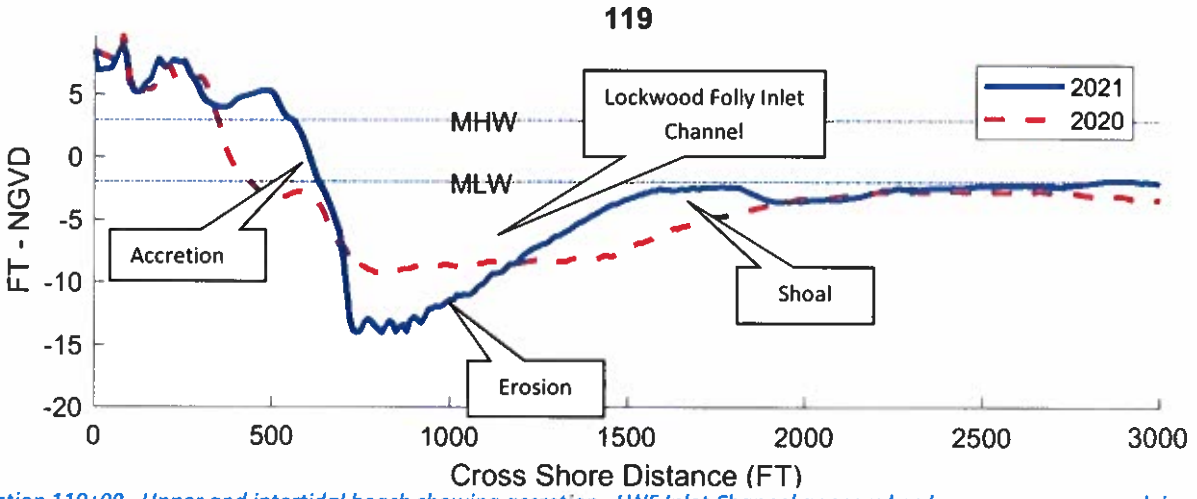
Please Note:

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

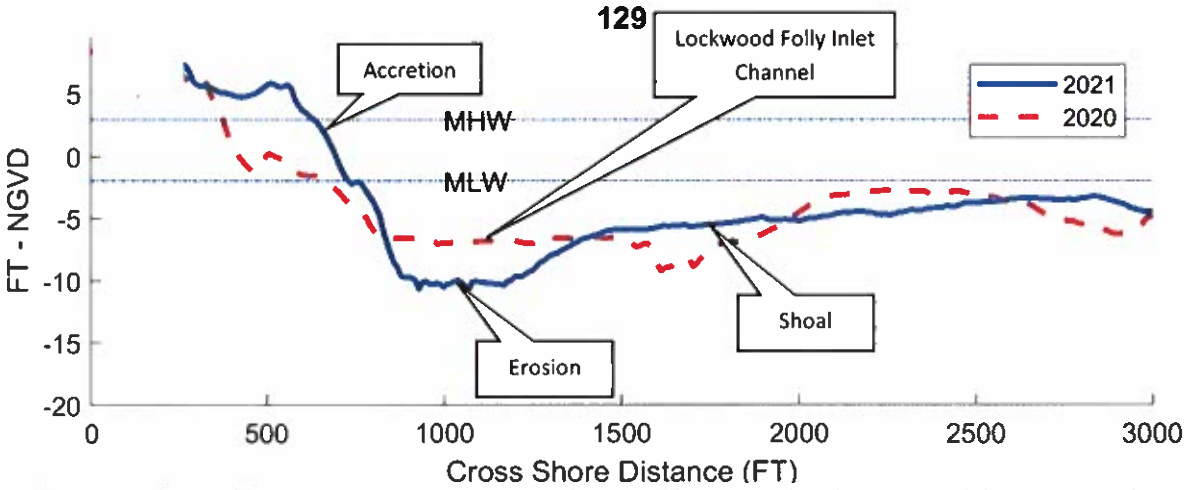
Any notable features are described in "call-outs" or in blue below the figure.



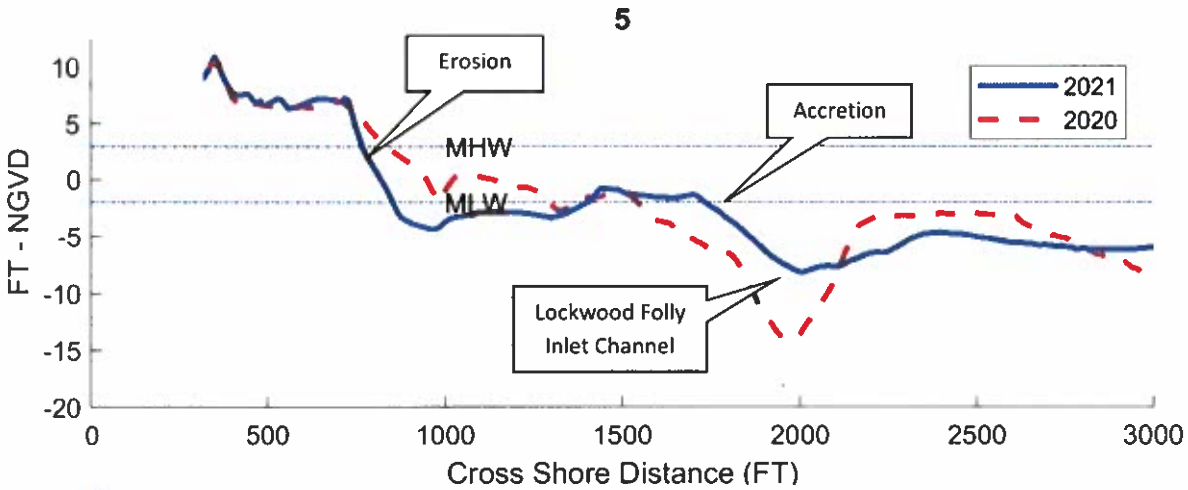
Station 109+00 (far east). Plots typically show from dune (between ~7' and ~15' NGVD) out to ~-20' NGVD. MHW=Mean high water, MLW=mean low water. LWF Inlet Channel appears relatively stable since the 2019 survey.



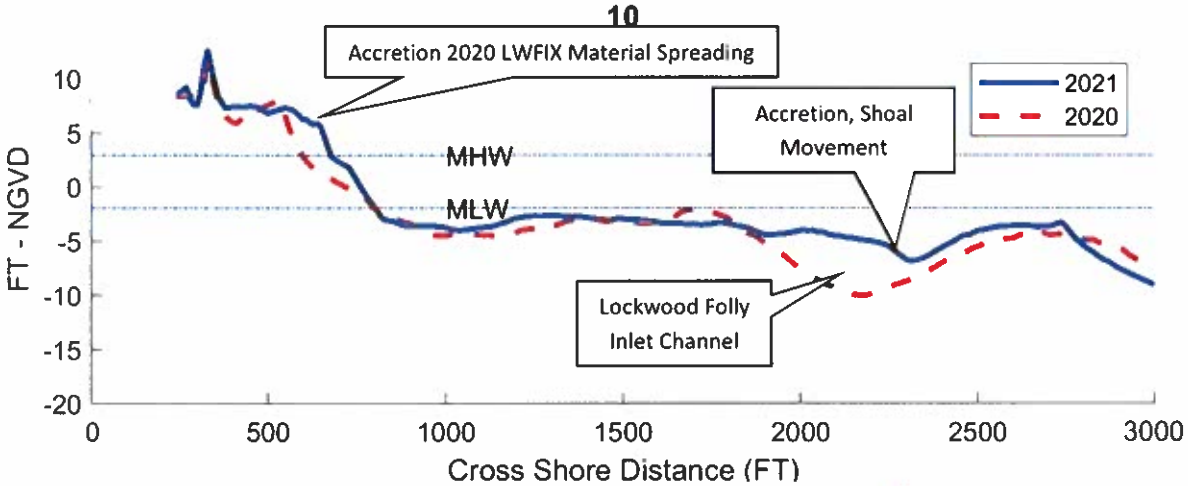
Station 119+00. Upper and intertidal beach showing accretion. LWF Inlet Channel appears has become narrower and deeper since the 2020 survey.



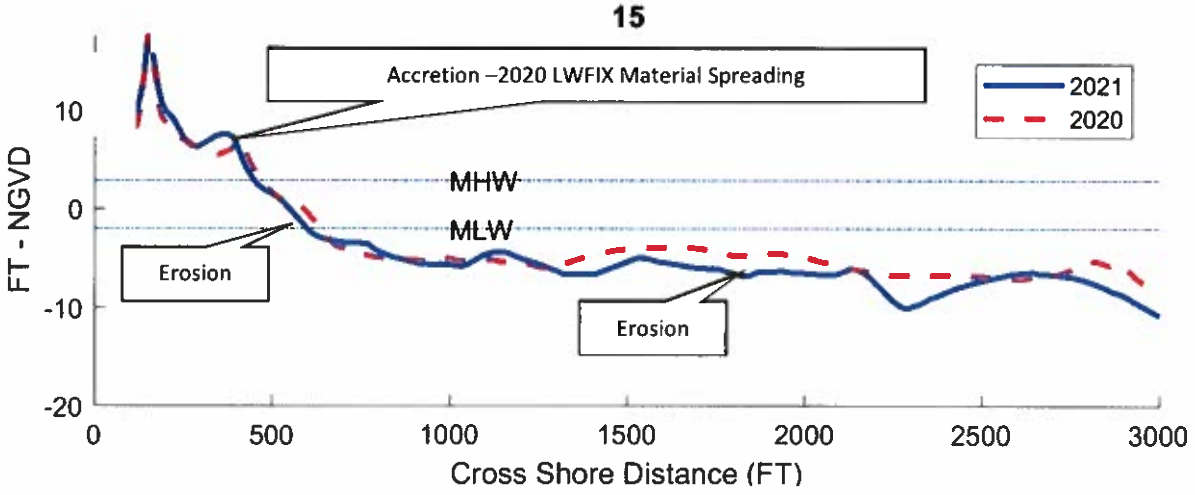
Station 129+00. LWF Inlet Channel Approximately 800 ft from baseline. Upper beach and intertidal accretion, and movement below MLW into the LWF Inlet Channel is seen since 2020 survey.



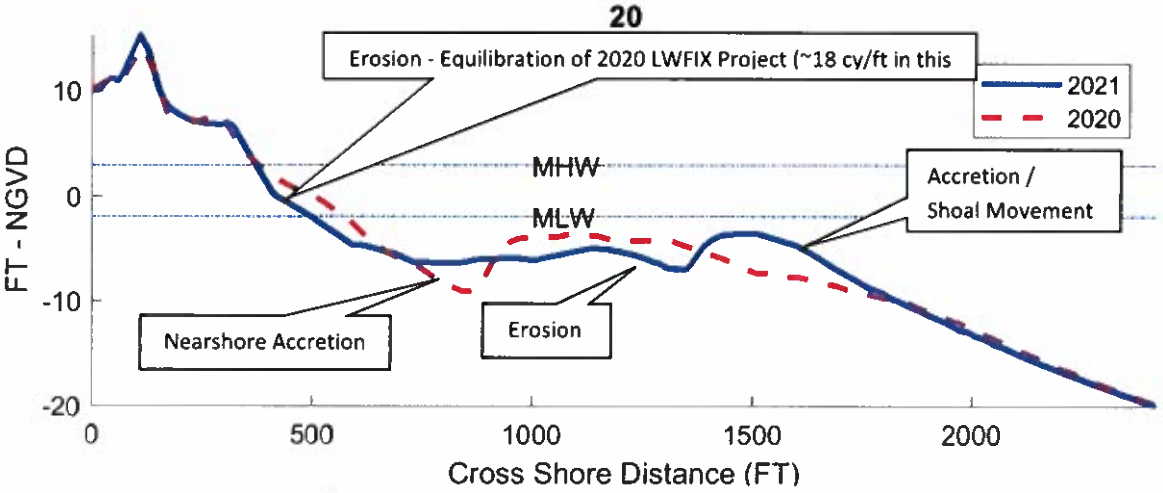
Station 05+00. Upper beach and intertidal erosion and channel shallowing observed in this area since 2020 survey.



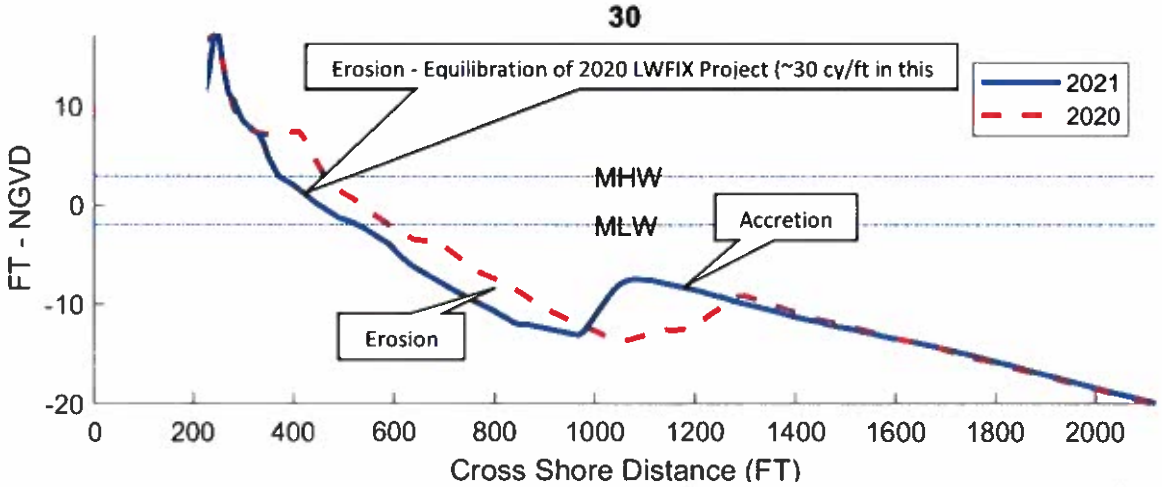
Station 10+00. Upper beach and intertidal accretion has taken place likely due to continued spreading of the 2020 LWFIX project.



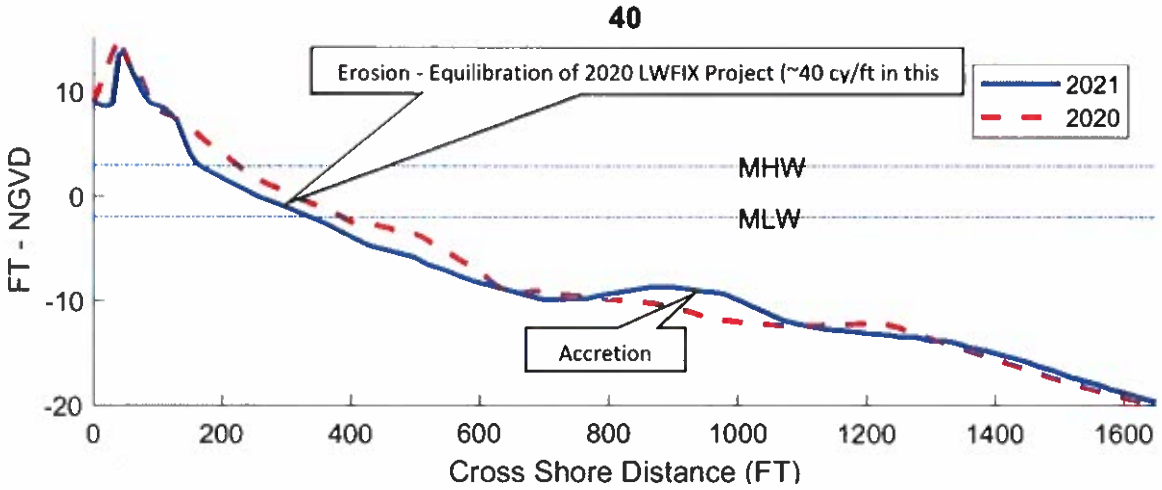
Station 15+00. Upper beach accretion has taken place, and erosion is observed throughout the nearshore and extending offshore beyond 2500ft due to inlet dynamics and nearby shoal movement.

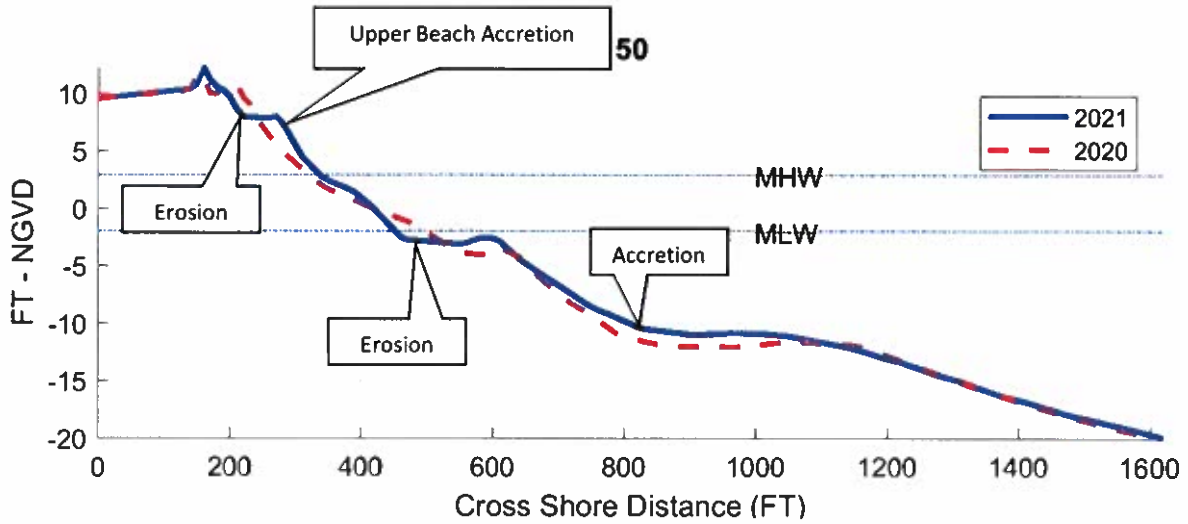


Station 20+00. Note some intertidal and nearshore erosion and accretion / shoal movement towards shore since 2020 survey. Intertidal erosion due to equilibration of 2020 LWFIX Project.

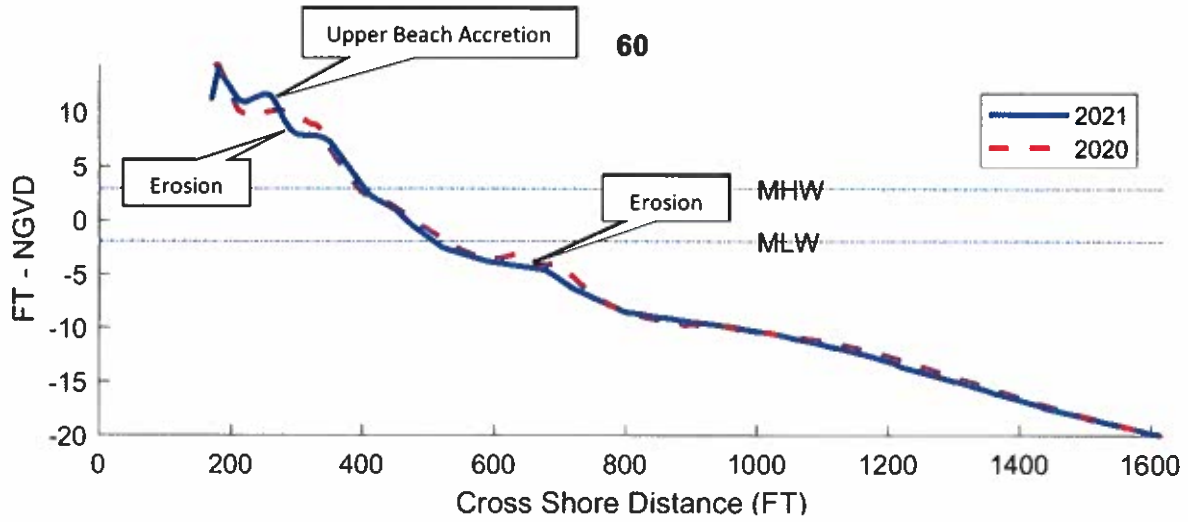


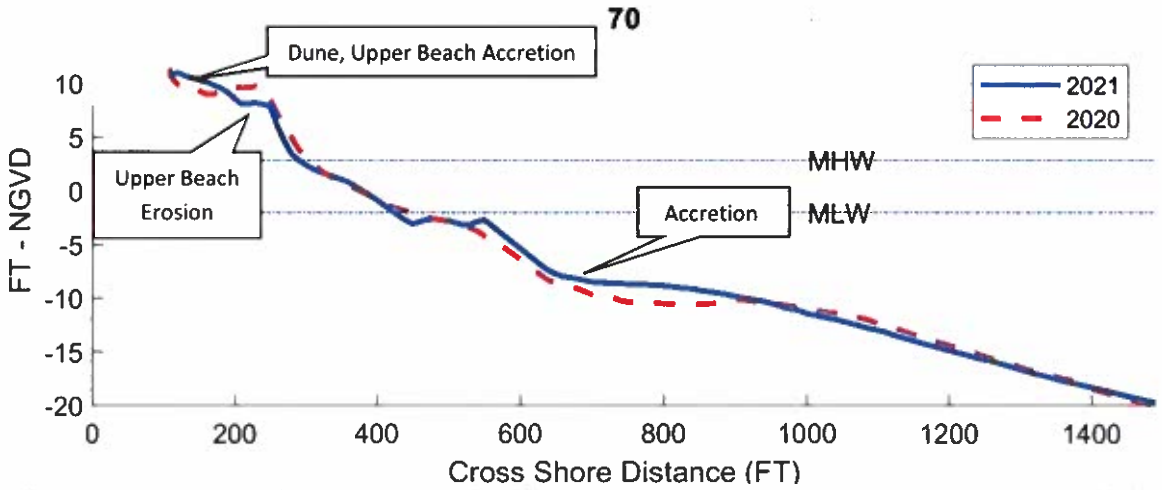
Station 30+00. Upper beach, intertidal , and nearshore erosion. Accretion observed farther offshore. This pattern is due primarily to equilibration of 2020 LWFIX Project.



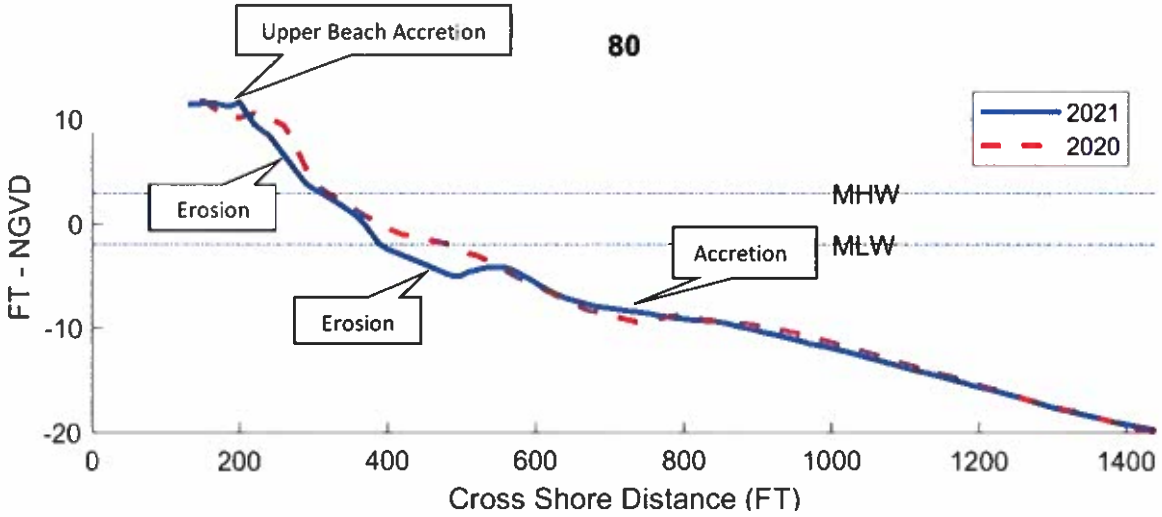


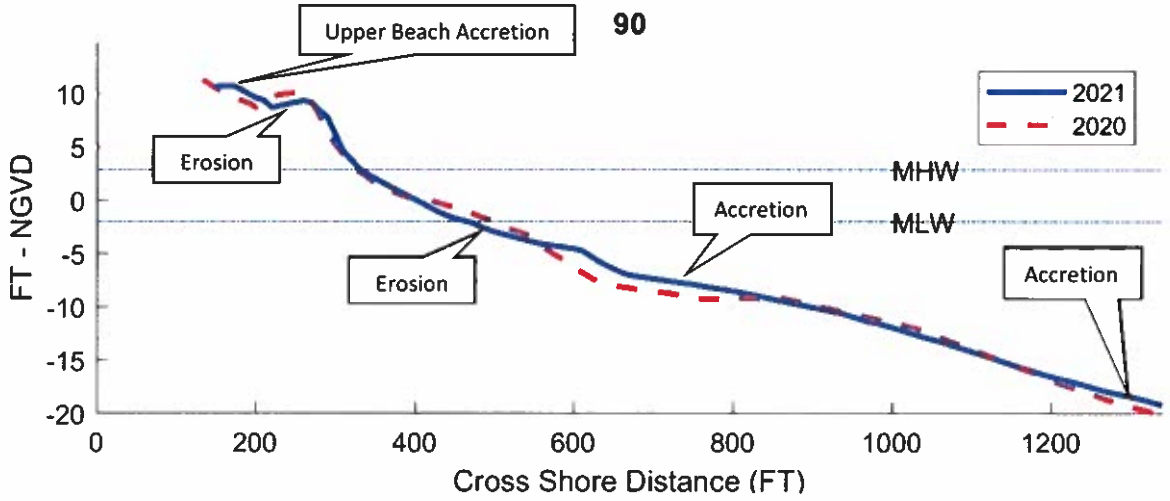
Station 50+00. Note some upper beach movement and a mostly stable to accretional intertidal beach, near the east taper of the 2017 Central Reach Nourishment Project (CRP). Accretion due likely to spreading of the 2020 LWFIX Project.

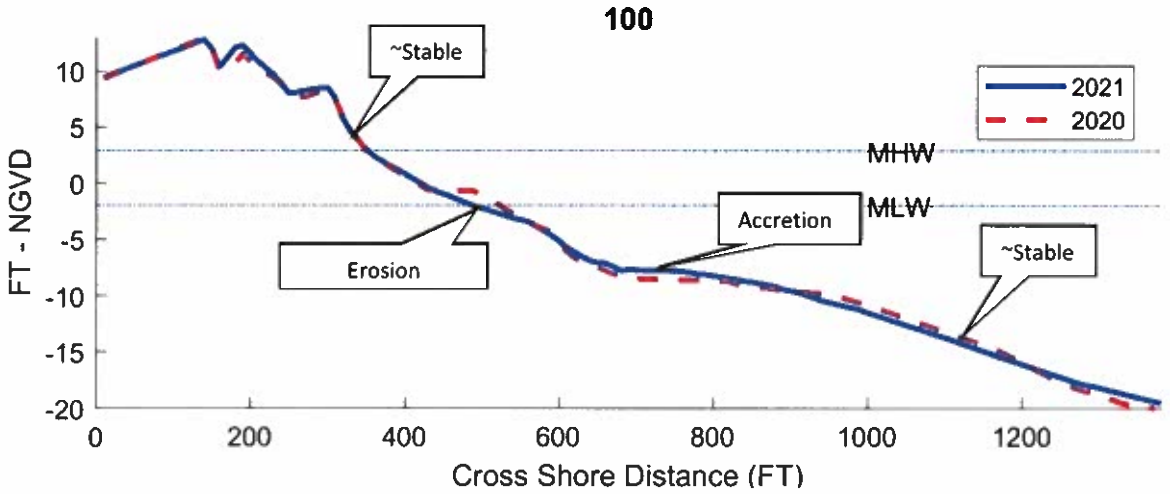




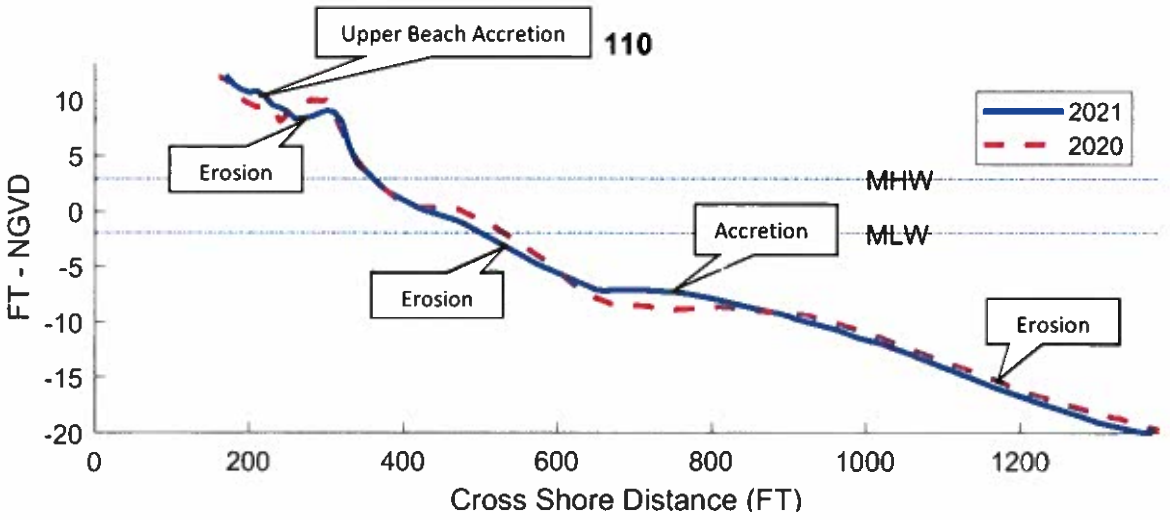
Station 70+00. Dune growth / upper beach accretion observed here and throughout many of the 2021 survey profiles reflecting the positive benefits of the dune plantings and sand fencing. Over the past year, the pattern of mostly relatively minor erosion within portions of the upper beach and intertidal zone along with nearshore accretion is observed to have taken place here and along much of the Holden Beach shoreline, showing continued movement and equilibration of the 2017 nourishment.

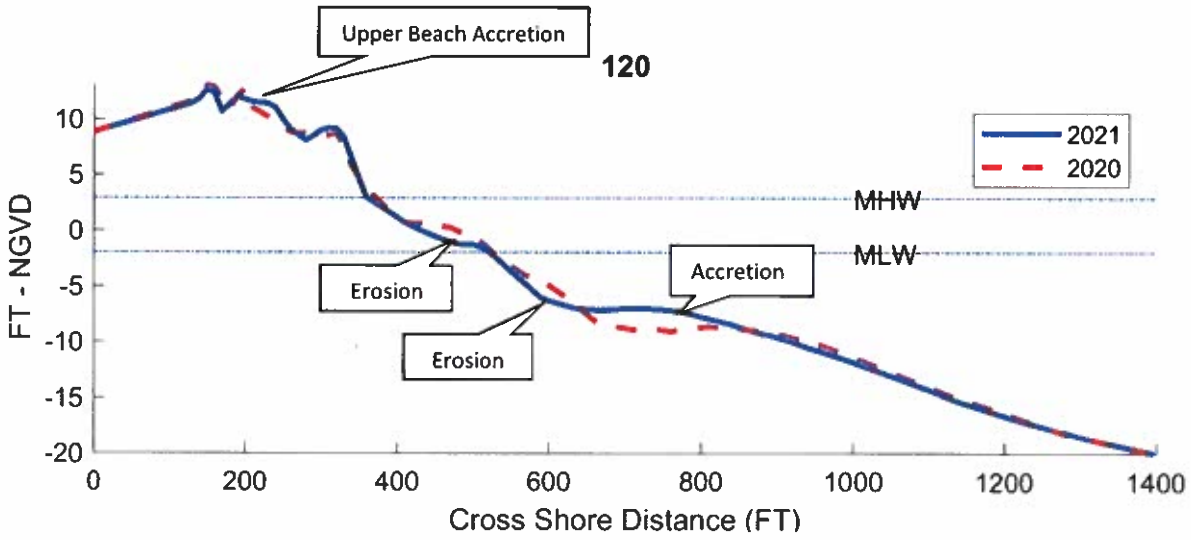


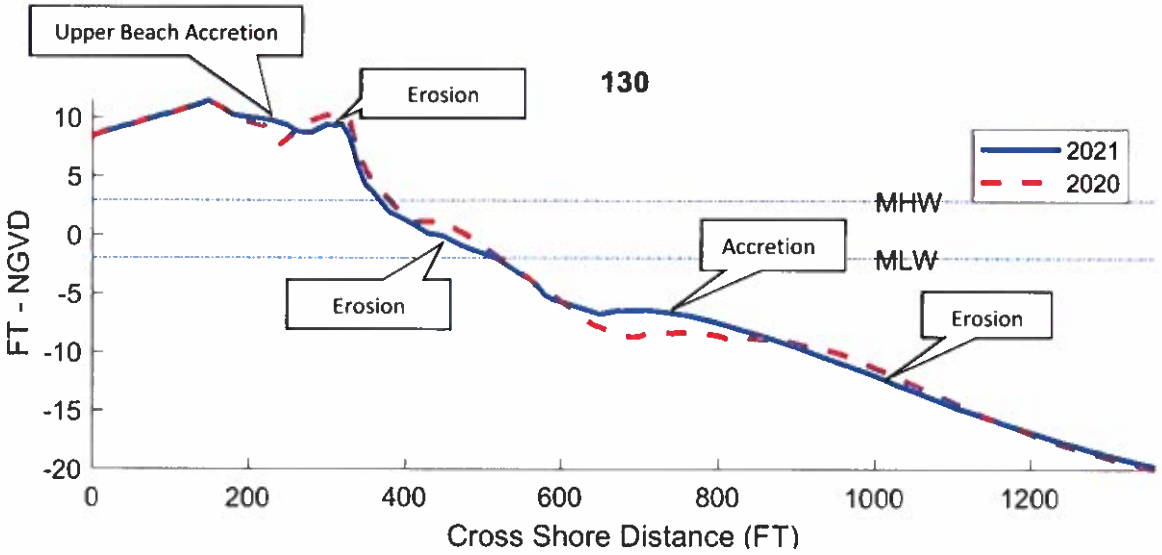


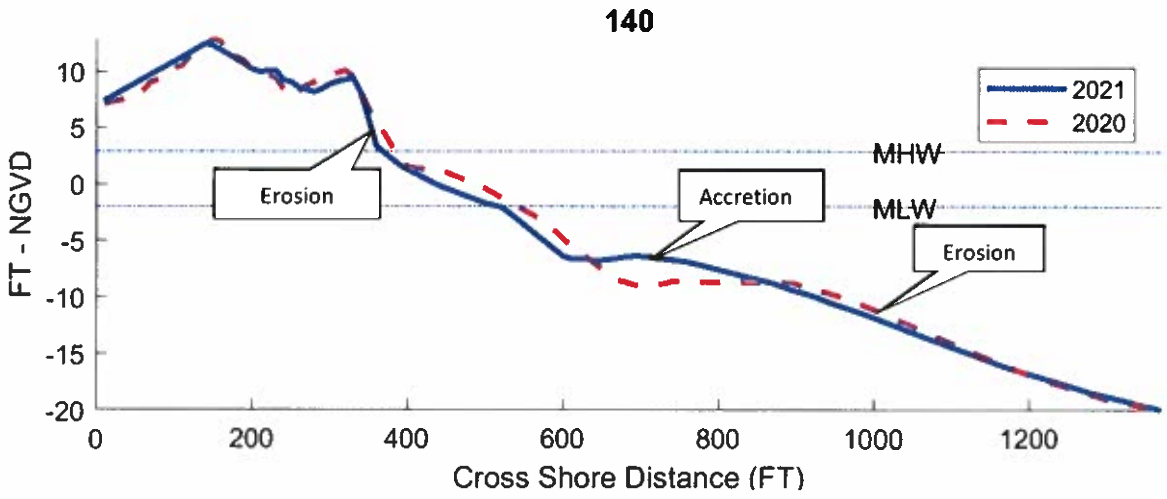


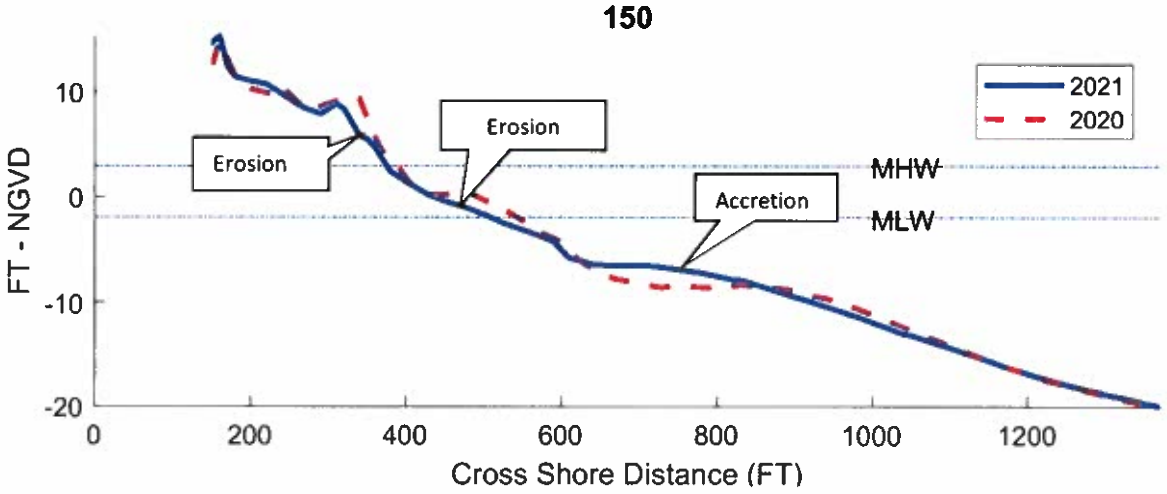
Station 100+00. 2021 survey shows a generally stable beach profile with some intertidal and nearshore movement of sand.

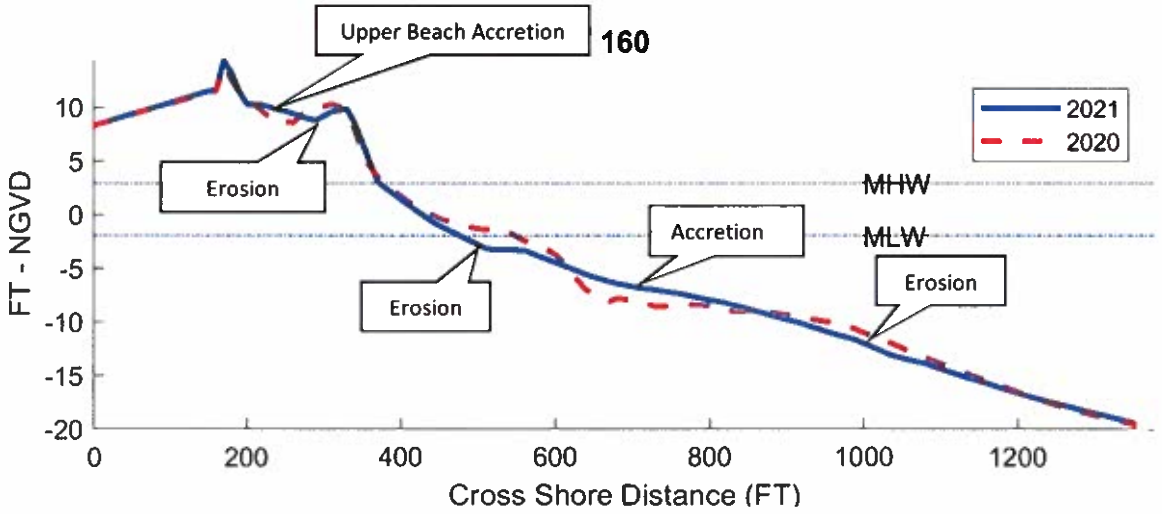


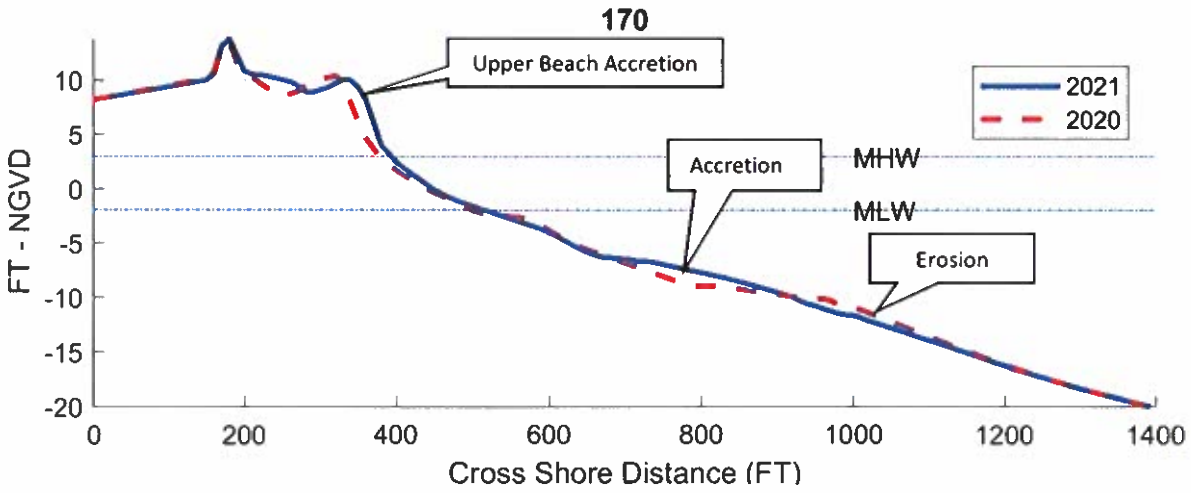

Upper Beach Accretion
120
Erosion
Erosion
Accretion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)

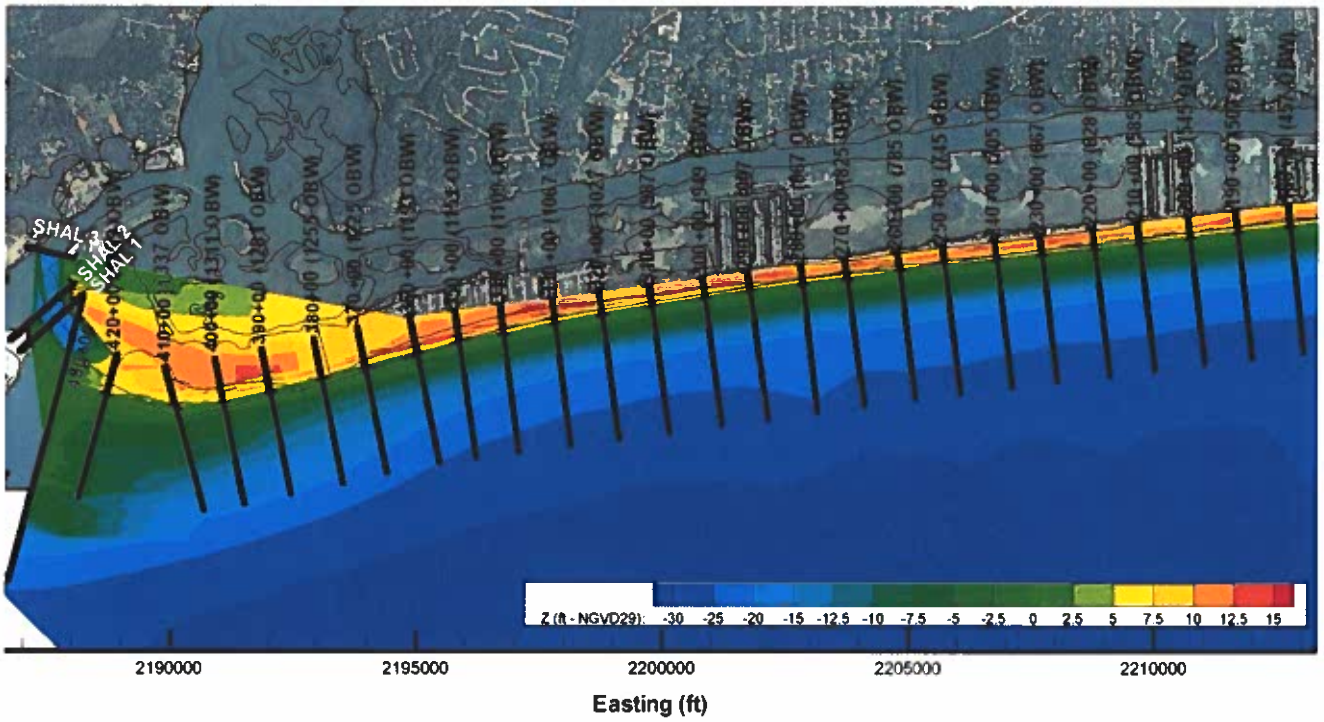

Upper Beach Accretion
Erosion
130
Erosion
Accretion
Erosion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)


140
10
5
0
-5
-10
-15
-20
FT - NGVD
0
200
400
600
800
1000
1200
Cross Shore Distance (FT)
2021
2020
MHW
MLW
Erosion
Accretion
Erosion

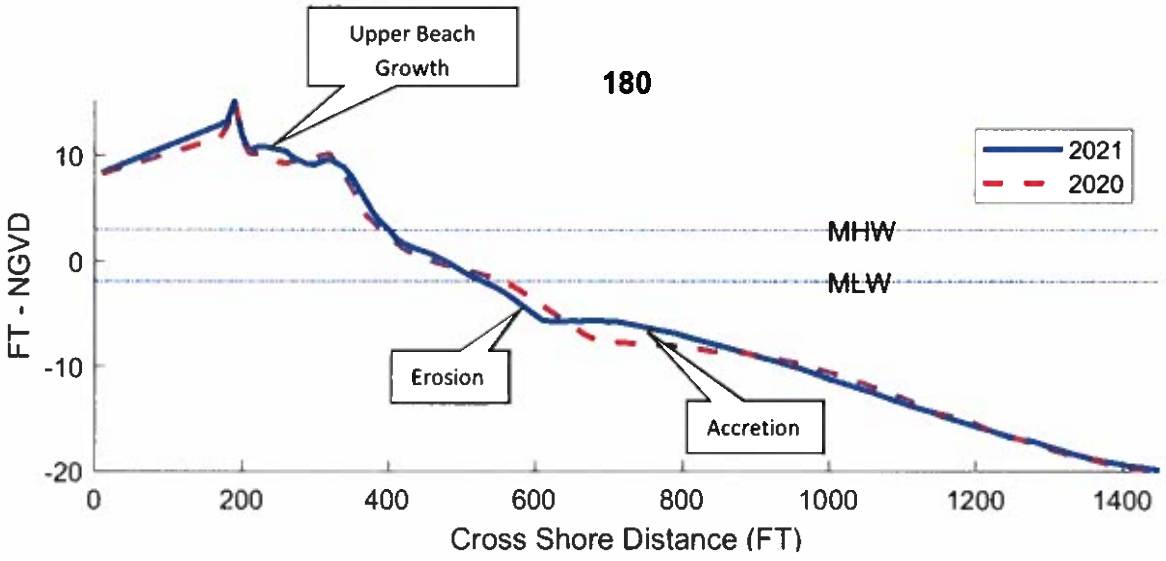

150
10
0
-10
-20
FT - NGVD
0
200
400
600
800
1000
1200
Cross Shore Distance (FT)
2021
2020
MHW
MLW
Erosion
Erosion
Accretion

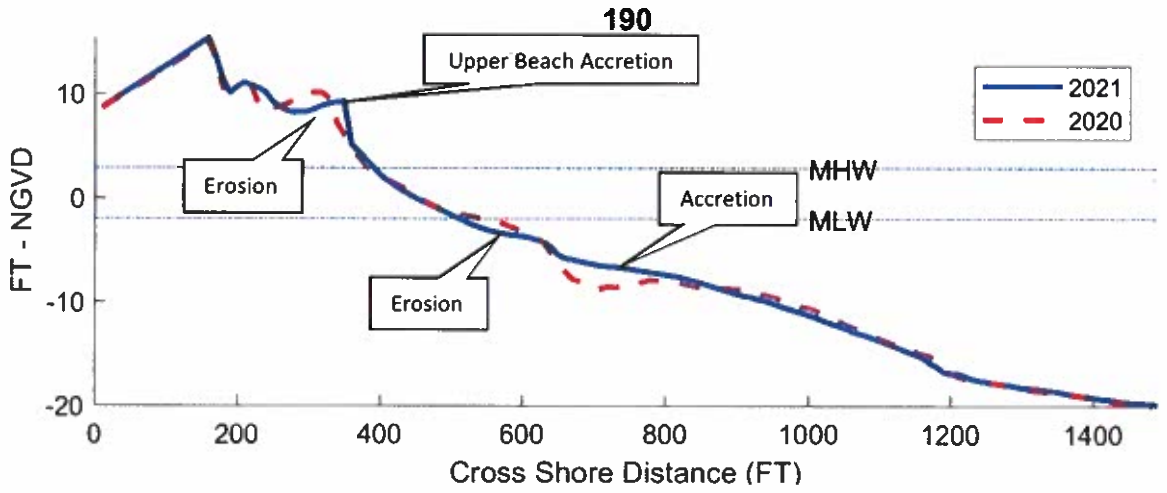

160
Upper Beach Accretion
Erosion
Erosion
Accretion
Erosion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)

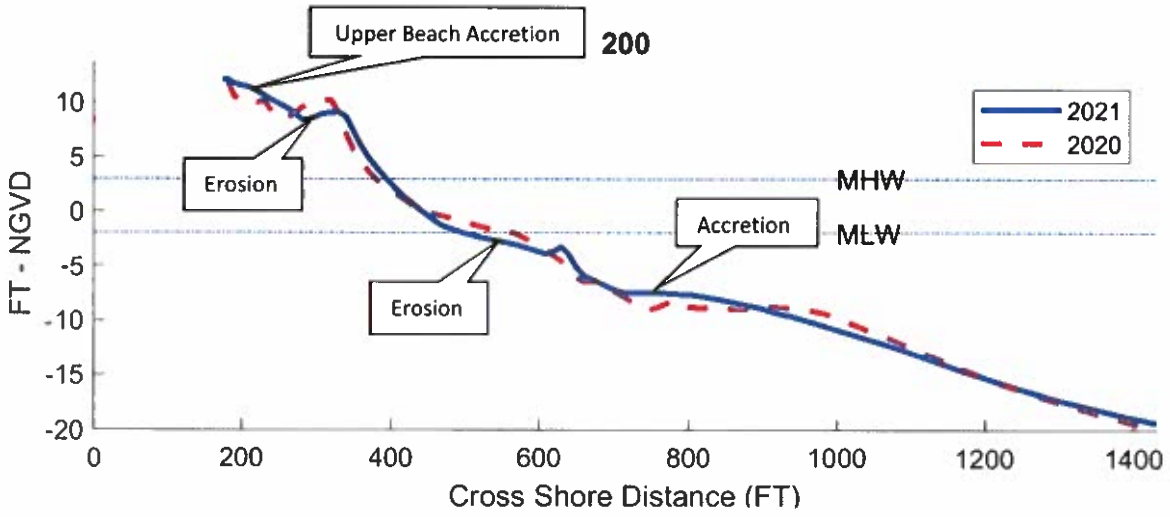

170
Upper Beach Accretion
Accretion
Erosion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)

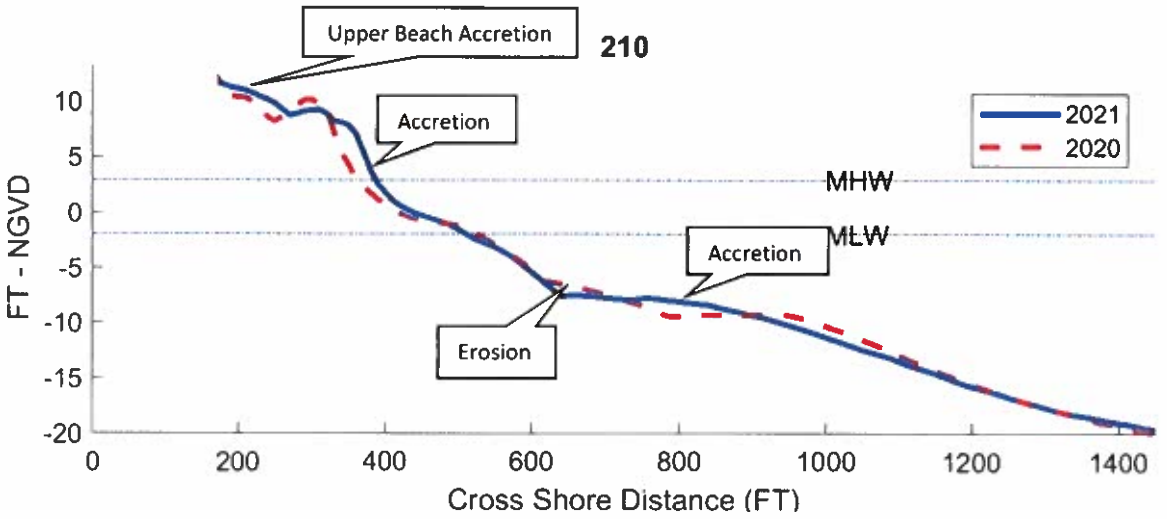


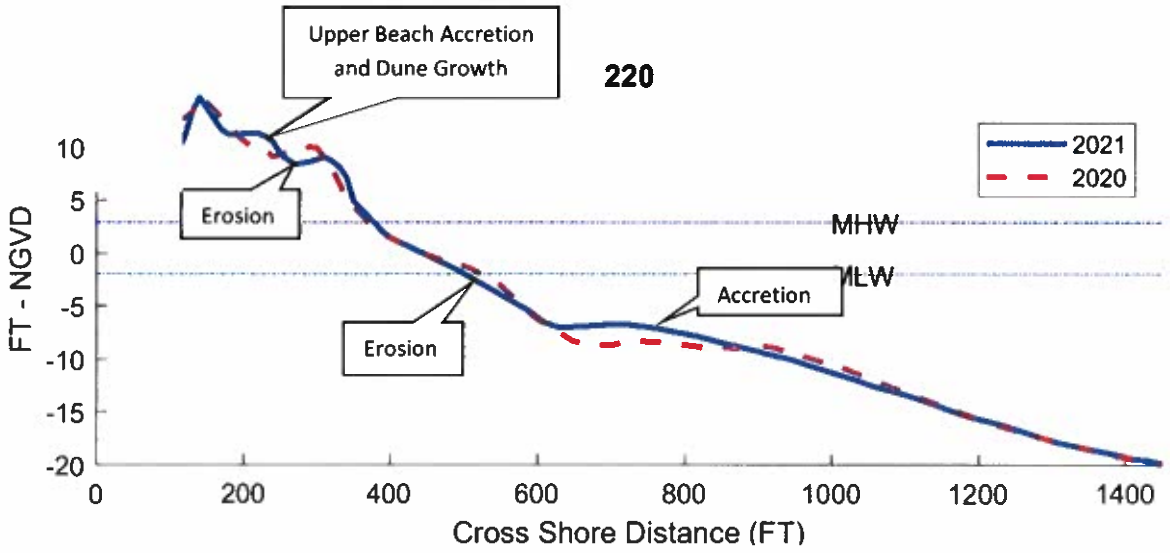
Zoom in of western end (Station 180+00 near the pier to Station 430+00 and newly added Shallotte Inlet Stations beginning with 2020 survey). Note "Z" is in ft-NGVD29.

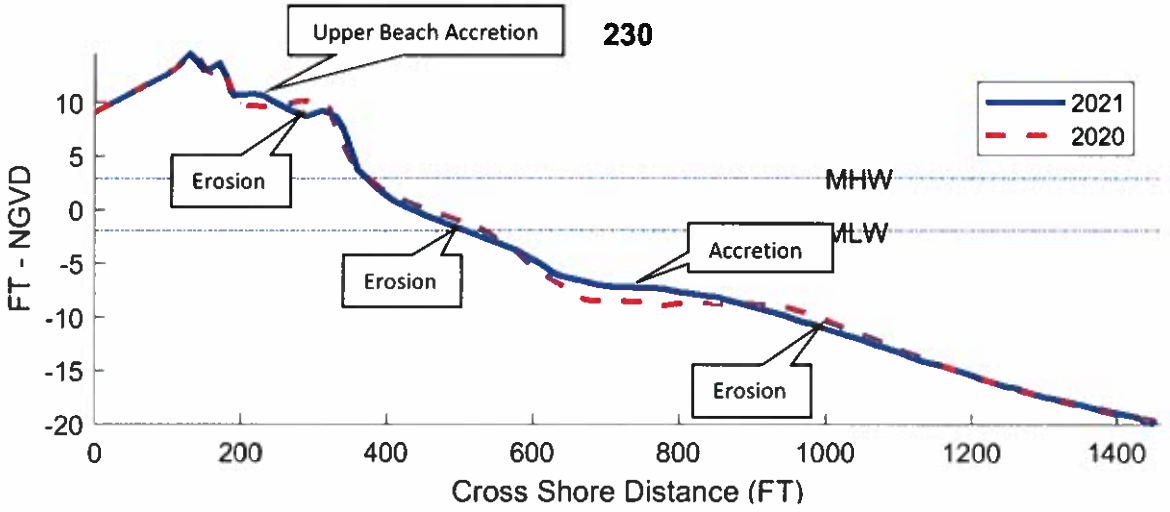


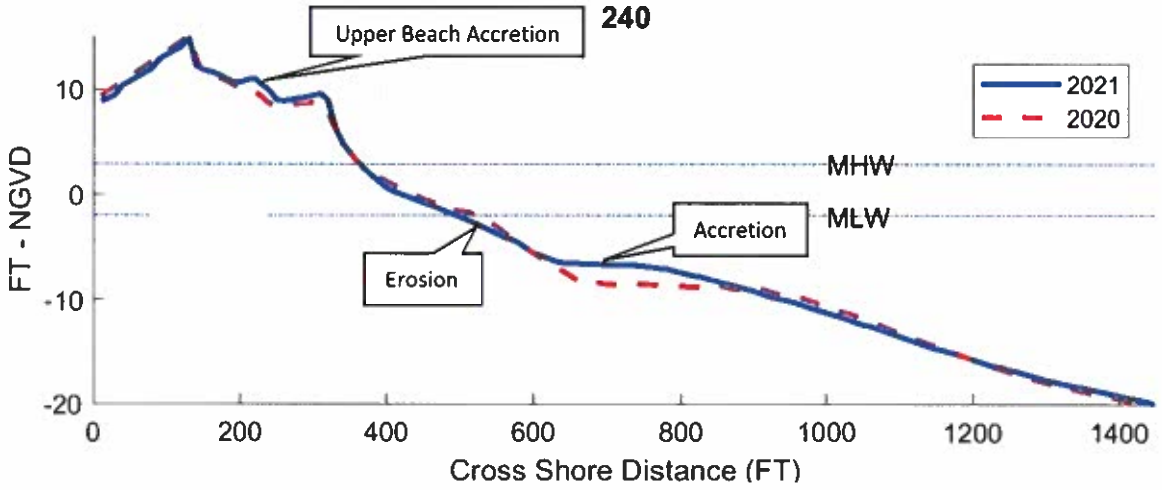

190
Upper Beach Accretion
Erosion
Accretion
Erosion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)

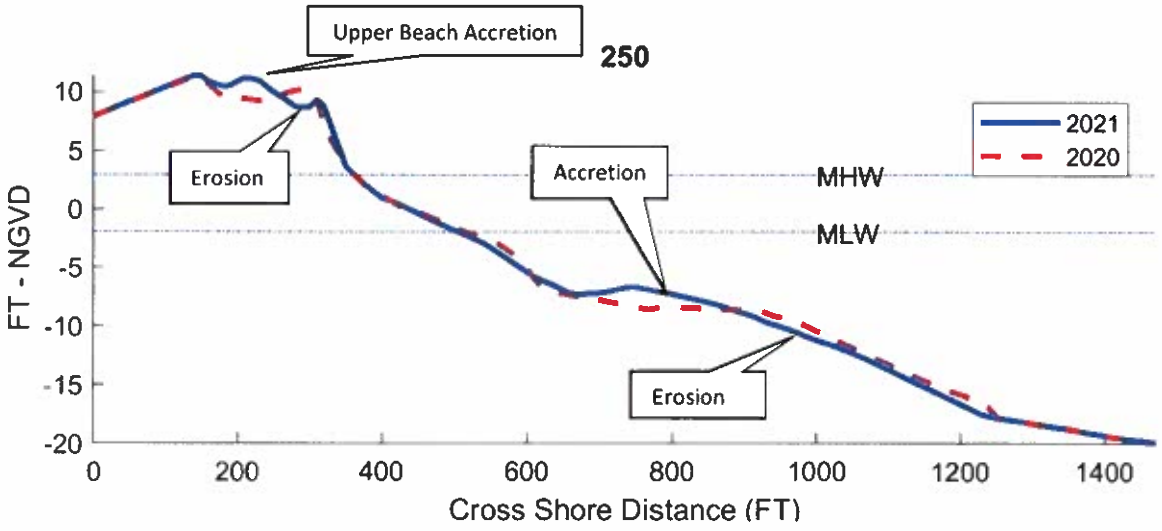

Upper Beach Accretion
200
Erosion
Accretion
Erosion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)

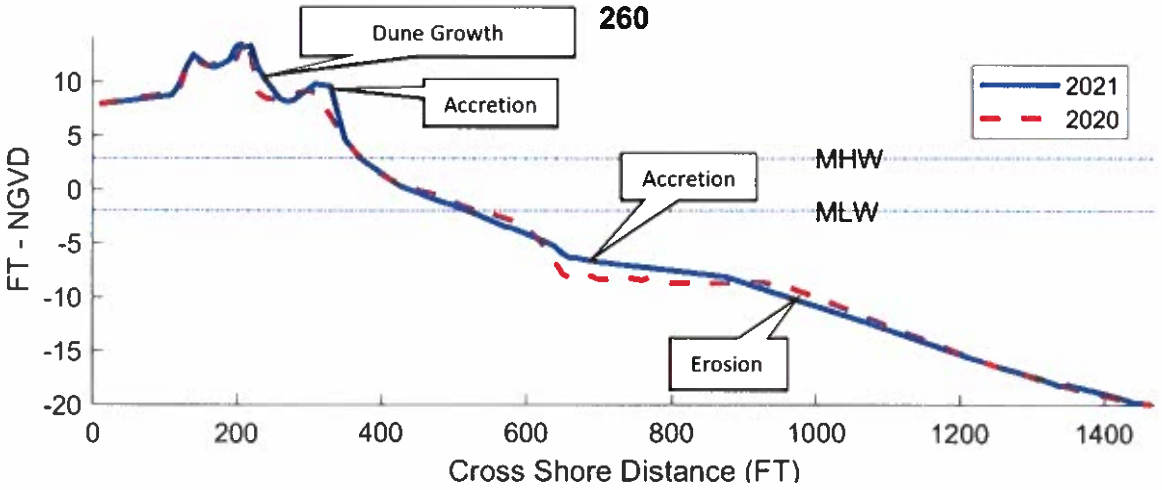

Upper Beach Accretion
210
Accretion
Accretion
Erosion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)

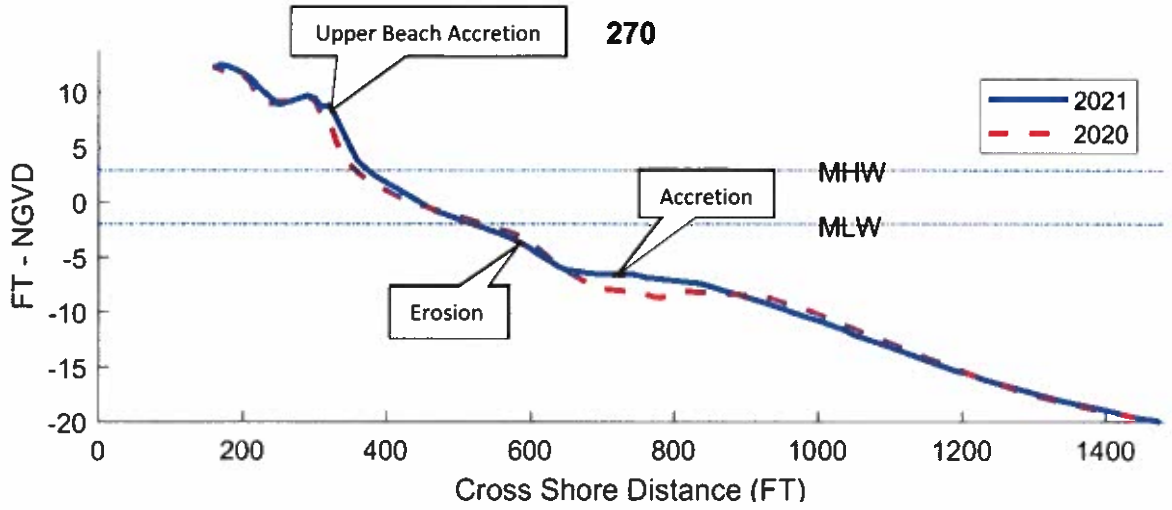

220
Upper Beach Accretion and Dune Growth
Erosion
Erosion
Accretion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)

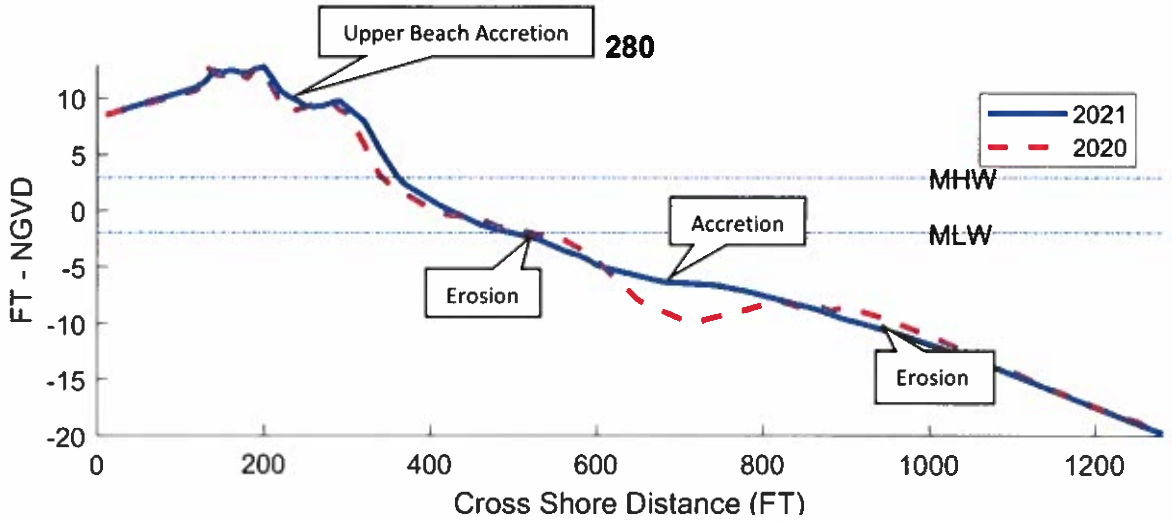

230
Upper Beach Accretion
Erosion
Erosion
Accretion
Erosion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)


240
Upper Beach Accretion
Erosion
Accretion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)

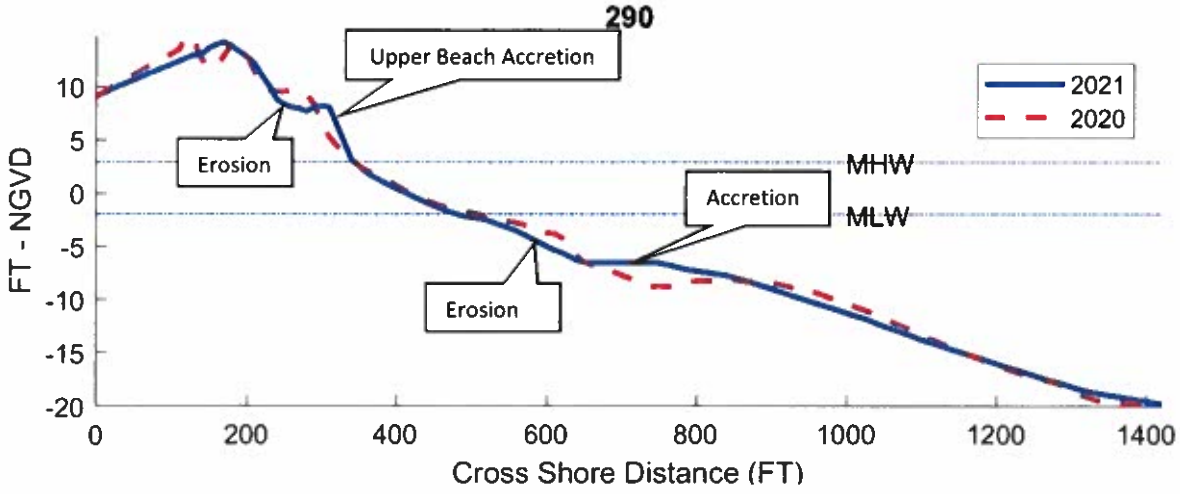

250
Upper Beach Accretion
Erosion
Accretion
Erosion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)

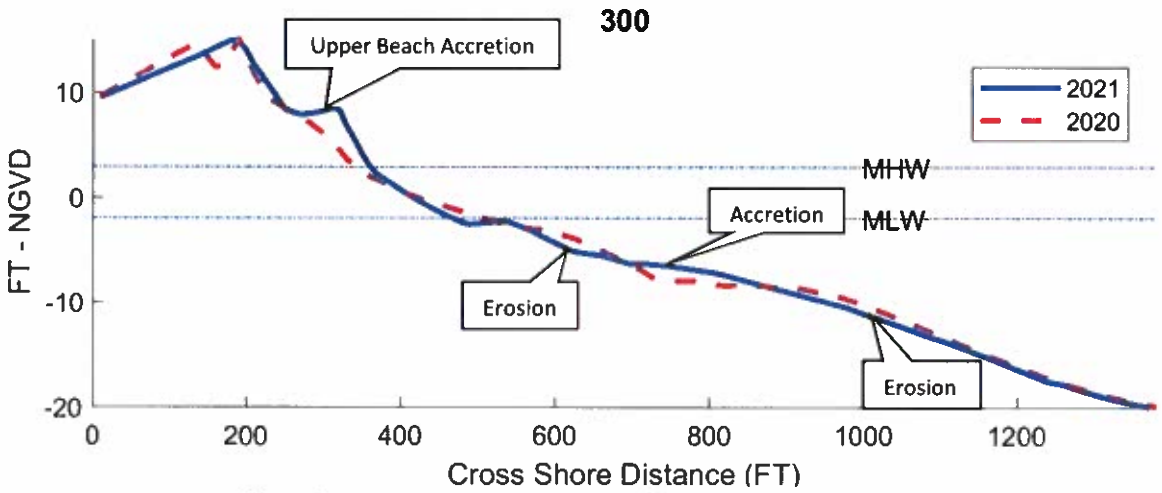

260
Dune Growth
Accretion
Accretion
Erosion
MHW
MLW
2021
2020
FT - NGVD
Cross Shore Distance (FT)



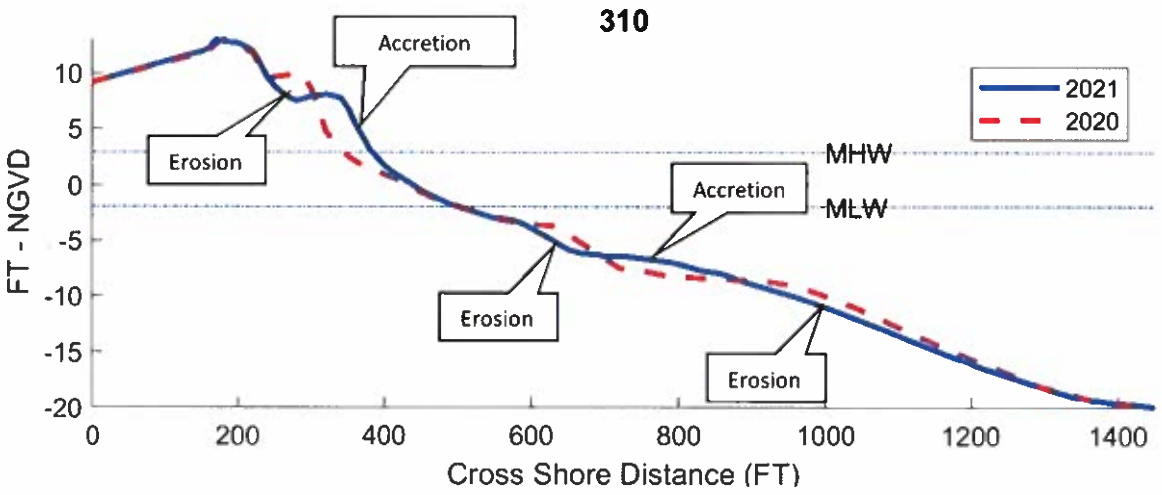


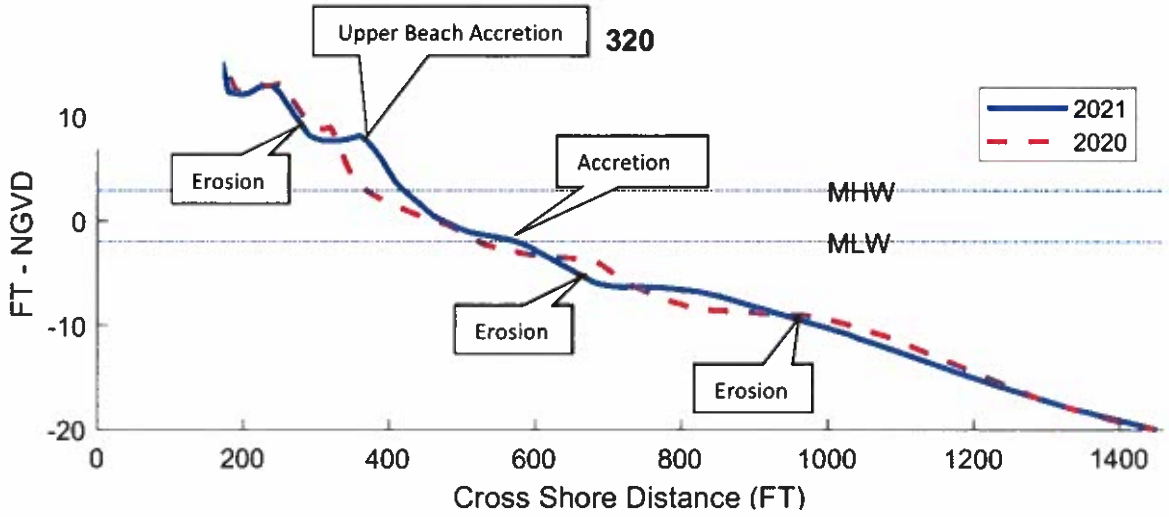
Station 280+00. 2021 survey shows the benefits of continued downdrift spreading of the 2017 Central Reach Project far outside of the original fill template placement.

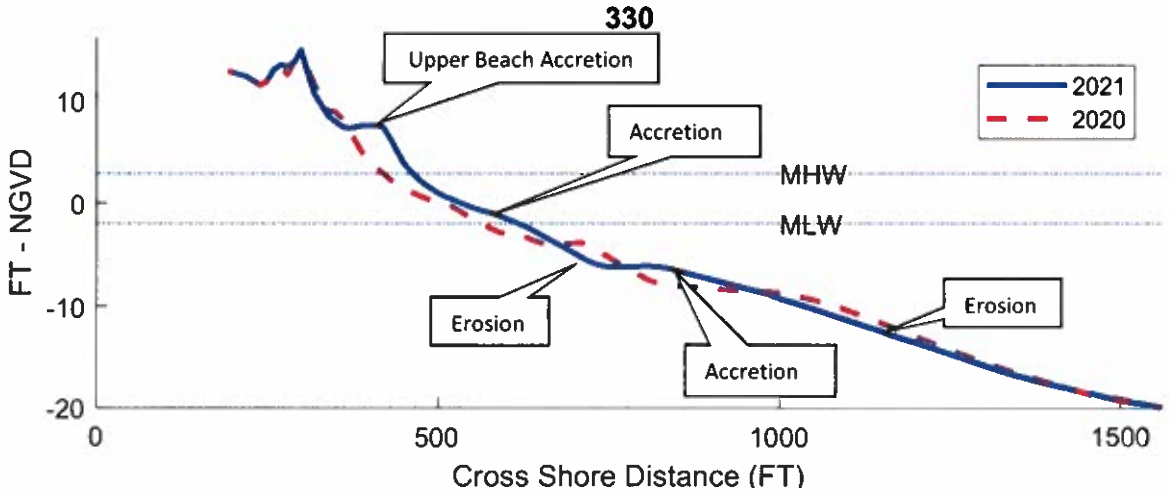


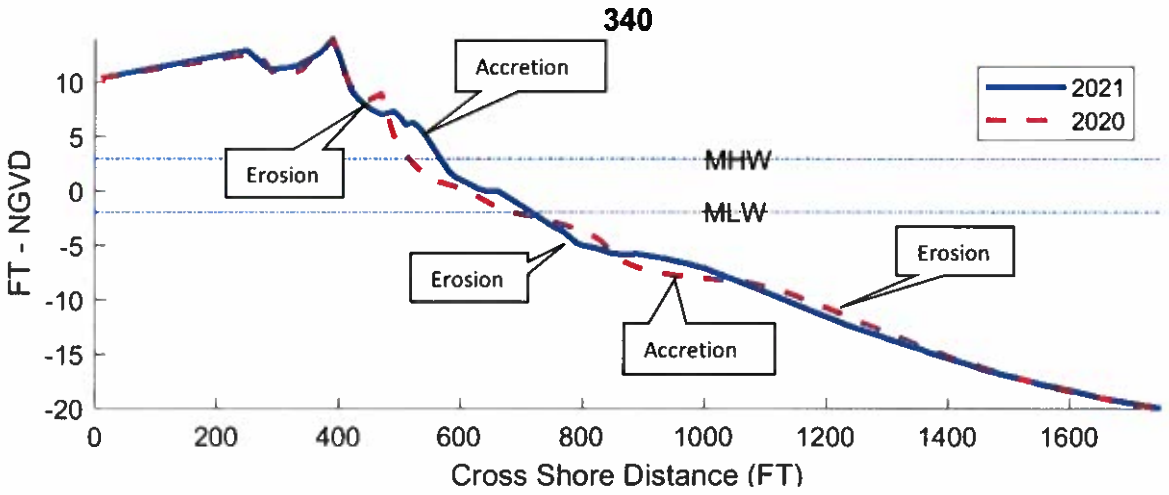


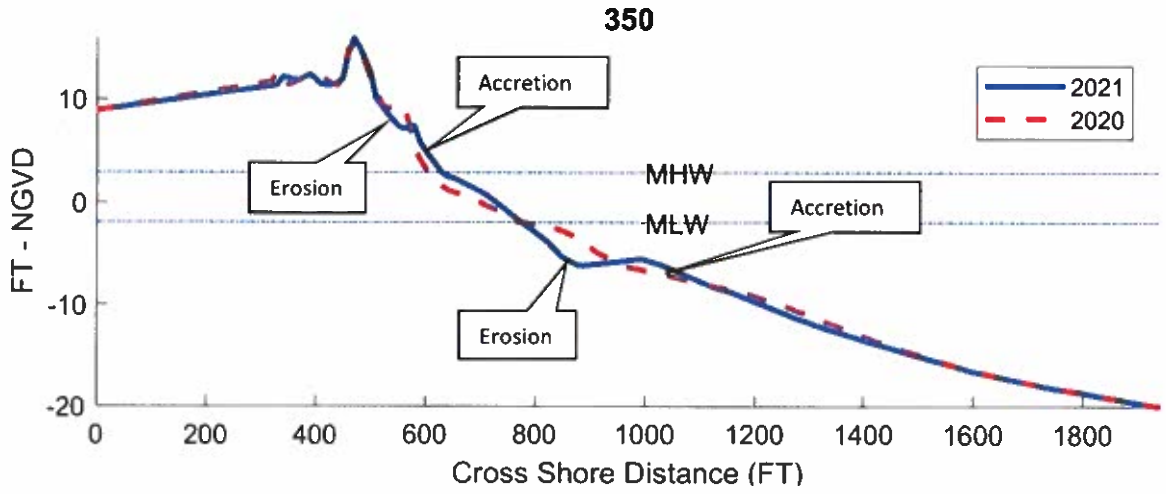
Station 310+00. Some significant intertidal and upper beach accretion and dune growth is observed over the past year (extending beyond Station 340+00) showing the continued spreading benefits from the 2017 Central Reach nourishment.

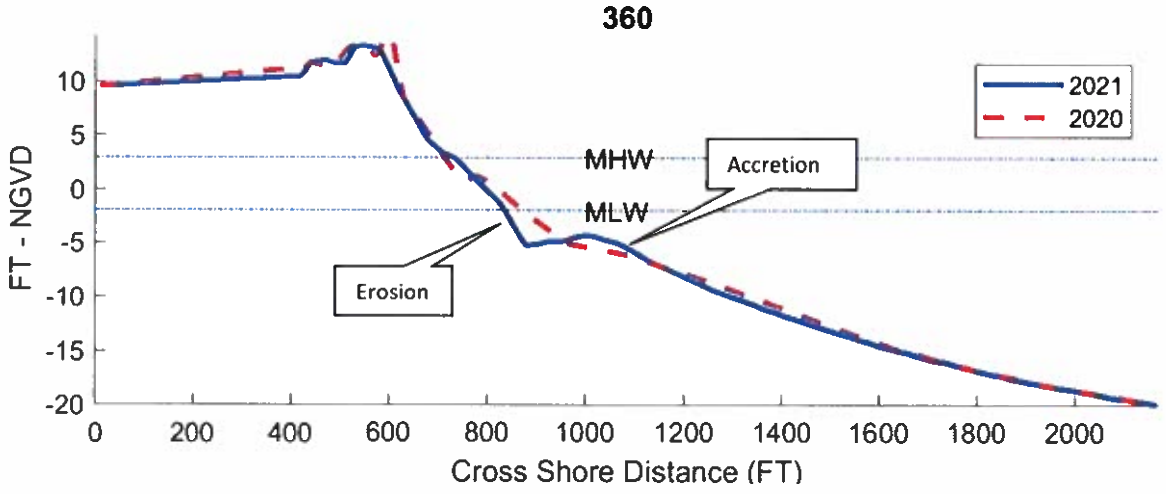


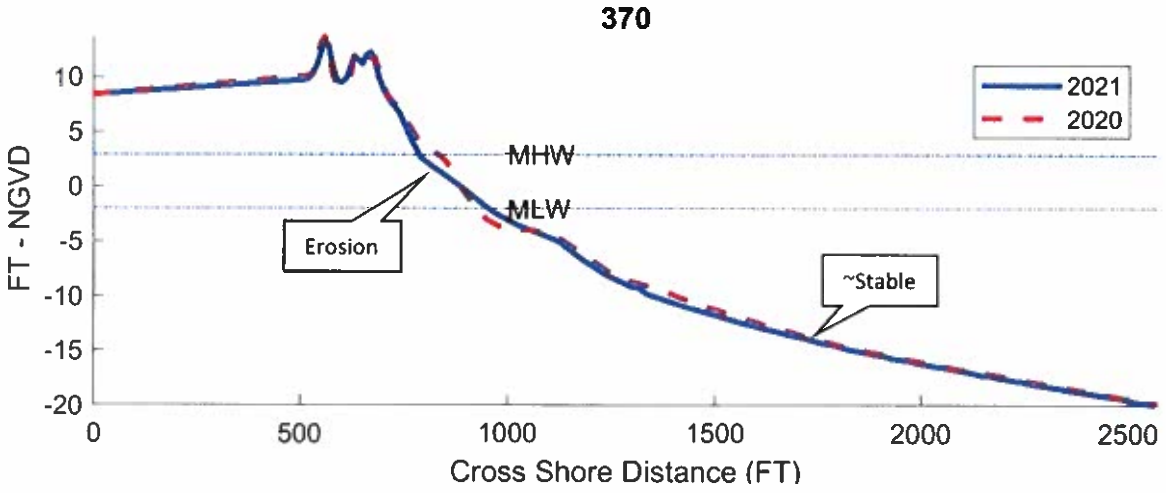

320
Upper Beach Accretion
Erosion
Accretion
Erosion
Erosion
MHW
MLW
2021
2020
FT - NGVD
10
0
-10
-20
0
200
400
600
800
1000
1200
1400
Cross Shore Distance (FT)

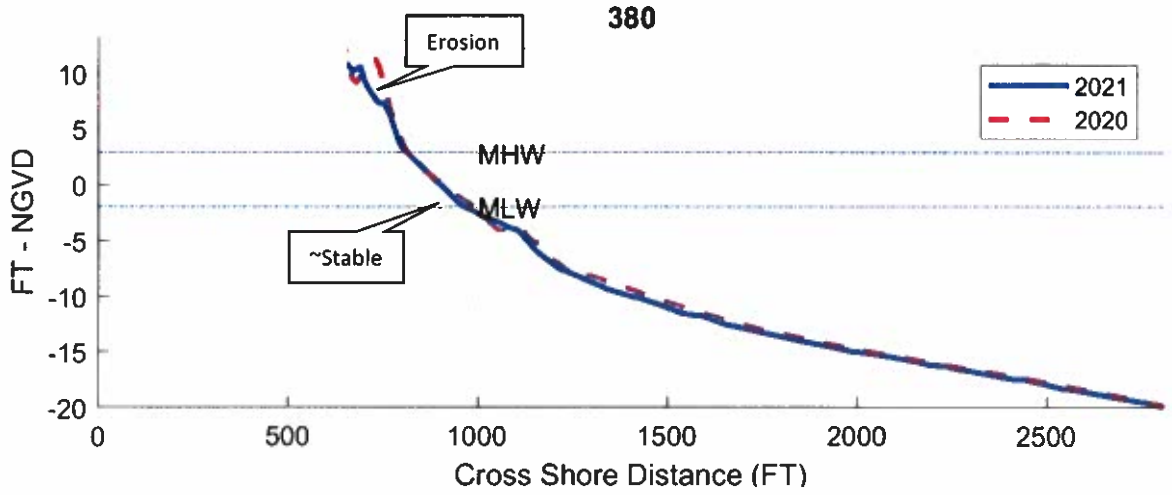

330
Upper Beach Accretion
Accretion
Erosion
Accretion
Erosion
MHW
MLW
2021
2020
FT - NGVD
10
0
-10
-20
0
500
1000
1500
Cross Shore Distance (FT)

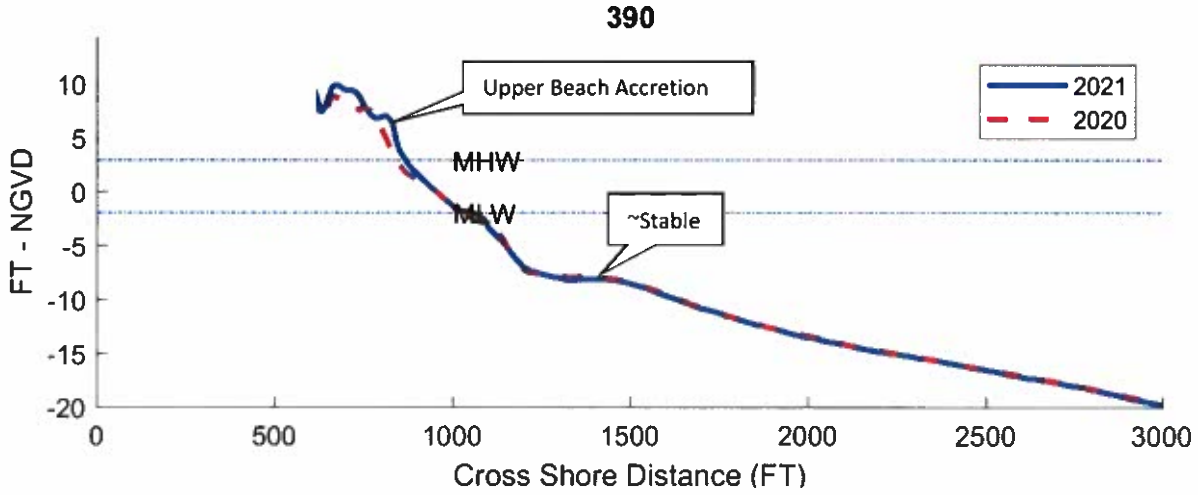

340
Accretion
Erosion
Erosion
Accretion
Erosion
MHW
MLW
2021
2020
FT - NGVD
10
5
0
-5
-10
-15
-20
0
200
400
600
800
1000
1200
1400
1600
Cross Shore Distance (FT)

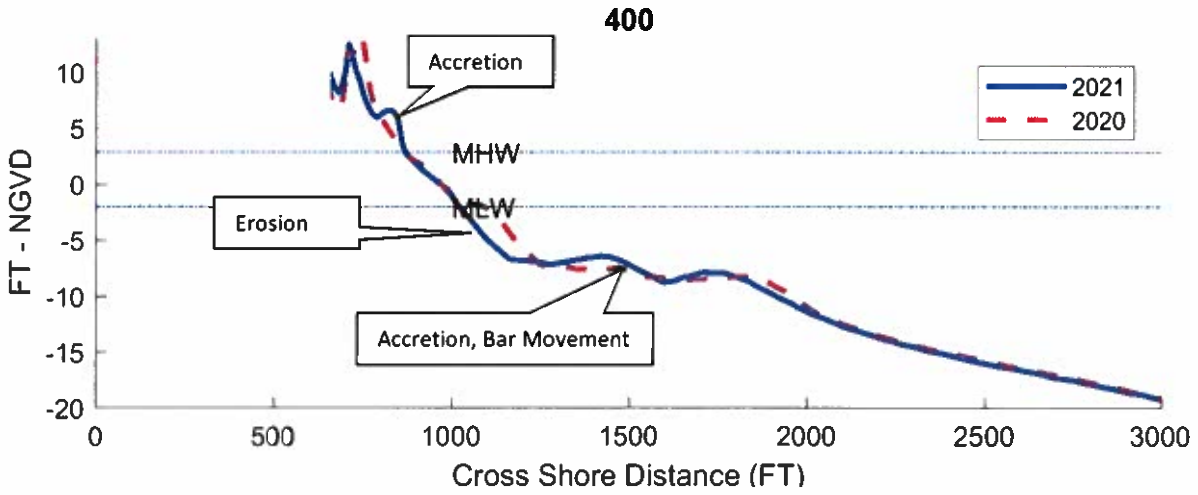

350
Accretion
Erosion
MHW
MLW
Accretion
Erosion
2021
2020
FT - NGVD
Cross Shore Distance (FT)

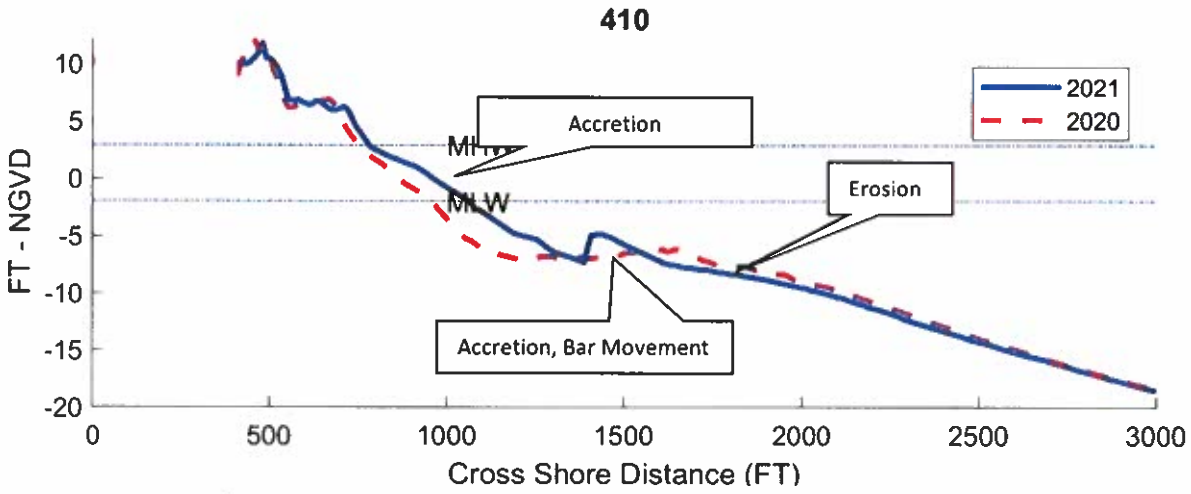

360
MHW
Accretion
MLW
Erosion
2021
2020
FT - NGVD
Cross Shore Distance (FT)


370
MHW
MLW
Erosion
~Stable
2021
2020
FT - NGVD
Cross Shore Distance (FT)

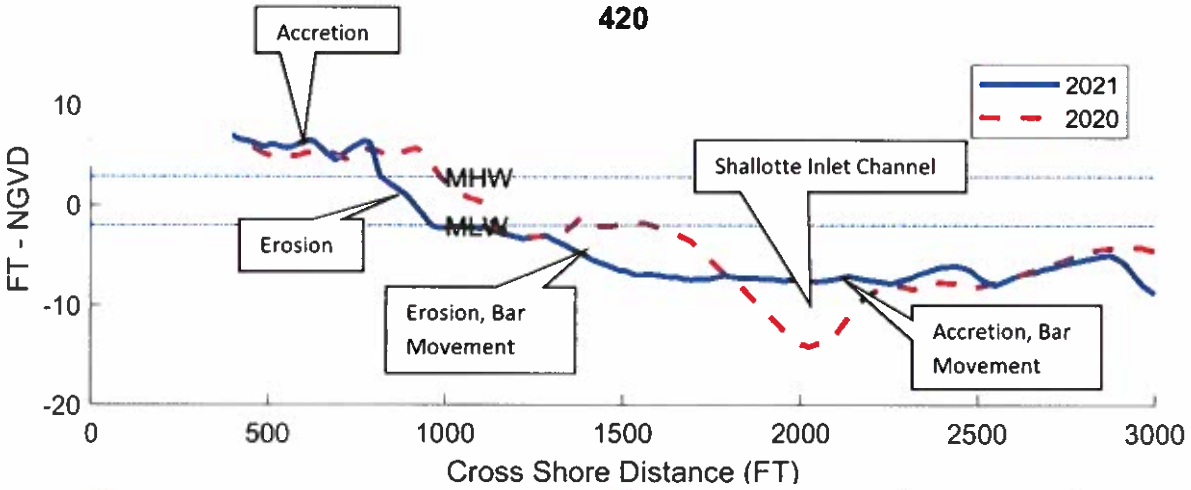

380
Erosion
2021
2020
MHW
MLW
~Stable
FT - NGVD
10
5
0
-5
-10
-15
-20
0
500
1000
1500
2000
2500
Cross Shore Distance (FT)


390
Upper Beach Accretion
2021
2020
MHW
MLW
~Stable
FT - NGVD
10
5
0
-5
-10
-15
-20
0
500
1000
1500
2000
2500
3000
Cross Shore Distance (FT)

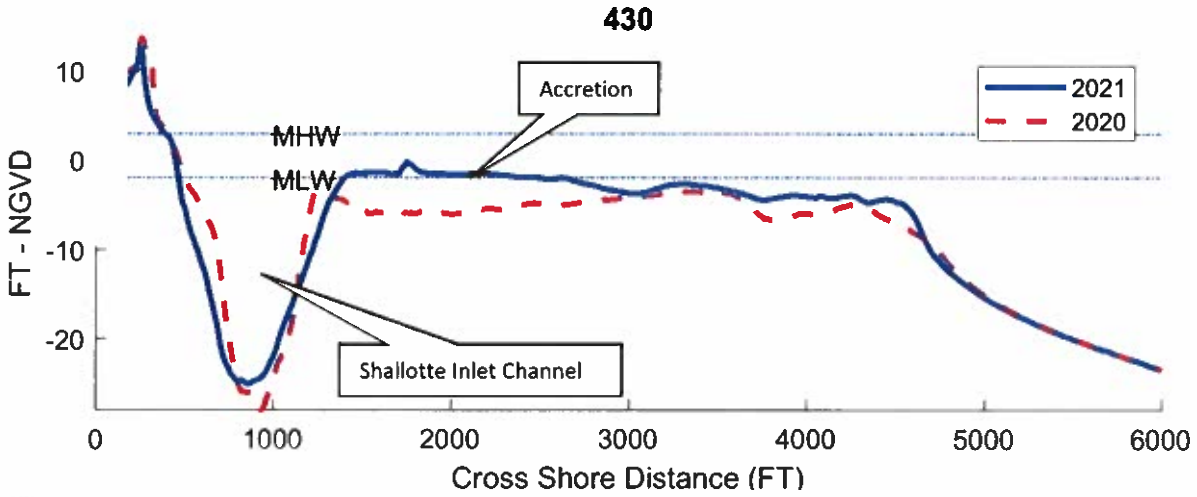

400
Accretion
2021
2020
MHW
MLW
Erosion
Accretion, Bar Movement
FT - NGVD
10
5
0
-5
-10
-15
-20
0
500
1000
1500
2000
2500
3000
Cross Shore Distance (FT)



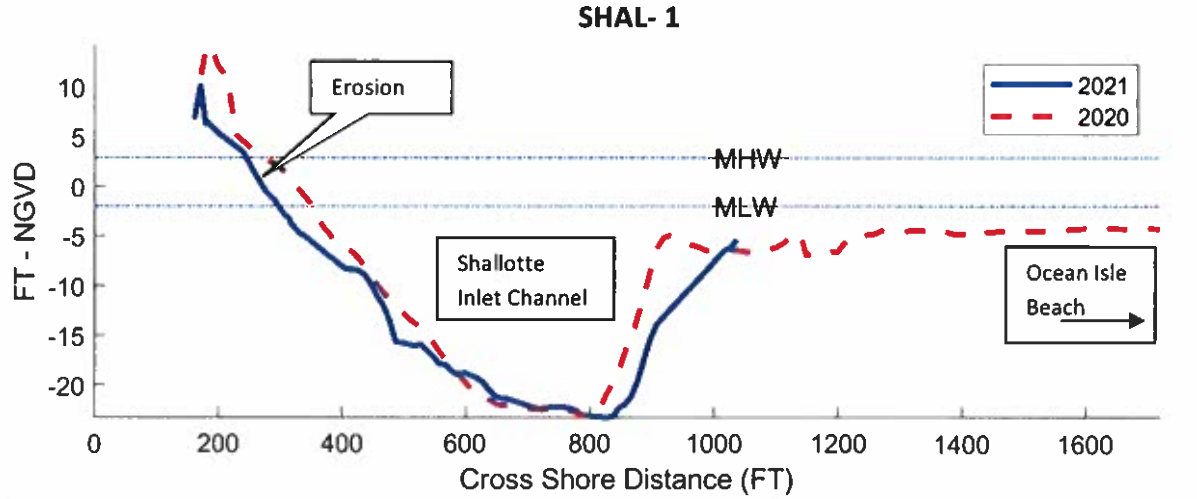
Station 410+00. 2020 survey shows some significant erosion / bar movement since 2019.



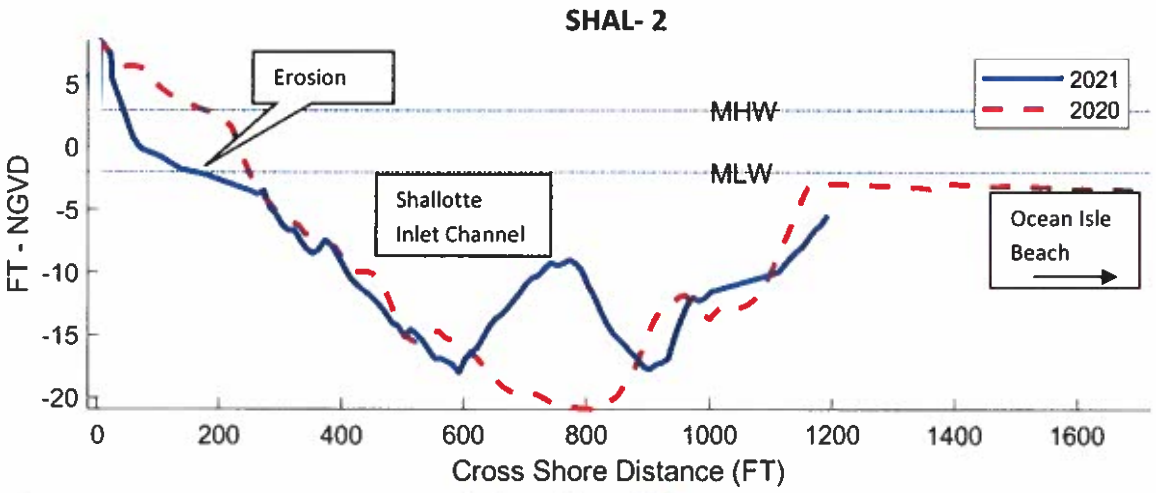
Station 420+00. 2021 survey shows some significant bar movement and channel infilling/migration since 2020.



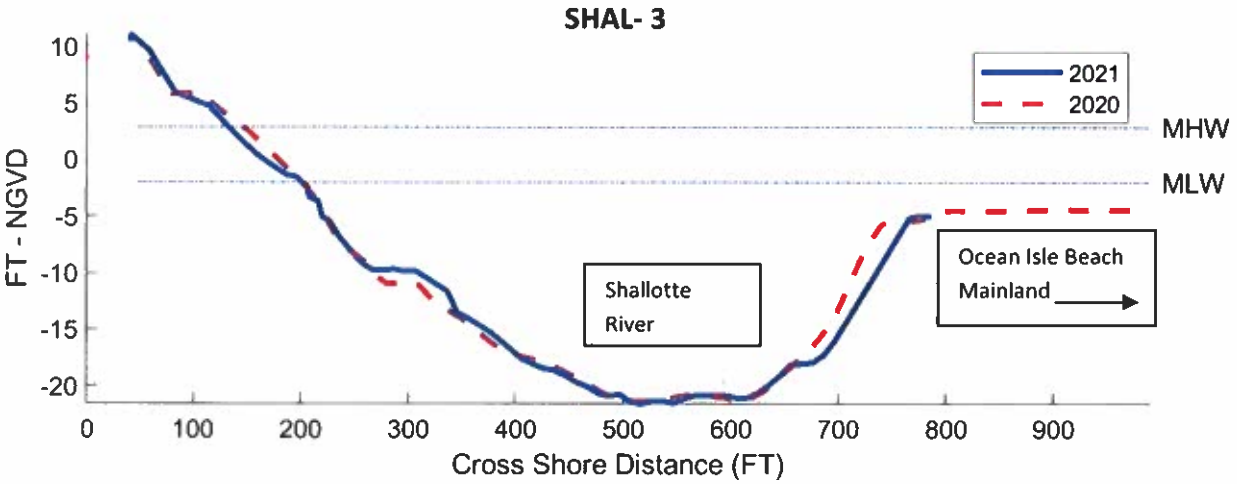
Station 430+00. The beach appears mostly stable on the Holden Beach side of the Shallotte Inlet Channel. The nearshore shoal has shallowed and widened some over the past year in this location.



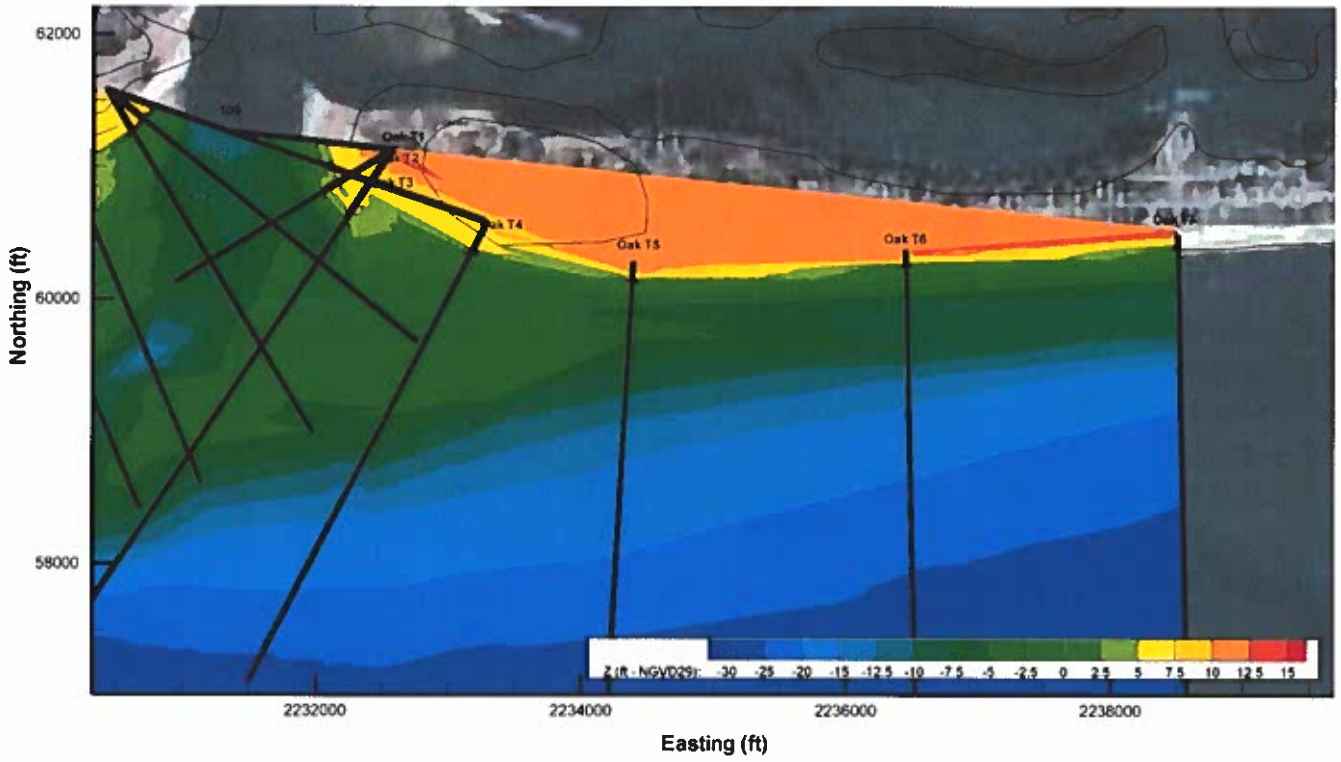
Station SHAL-1. New Shallotte Inlet Channel profile shown surveyed for the first time in 2020. Erosion observed here on the Holden Beach side over the past year and channel has widened slightly since 2020.



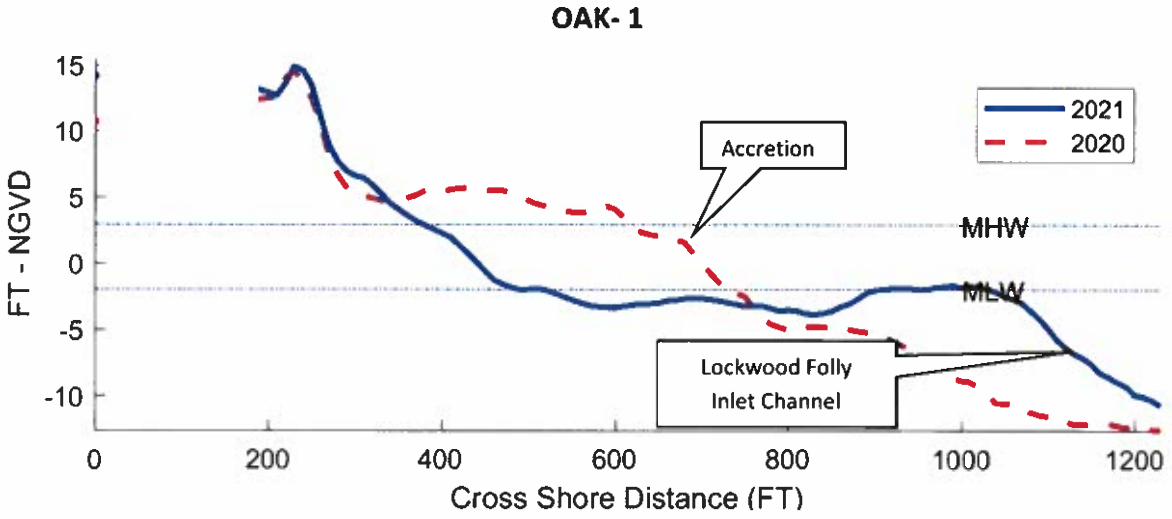
Station SHAL-2. New Shallotte Inlet Channel profile shown surveyed for the first time in 2020. Upper and intertidal beach erosion on the Holden Beach side and shoal movement / channel infilling over the past year.



Station SHAL-3. New Shallotte Inlet Channel profile shown surveyed for the first time in 2020. A mostly stable upper beach and channel observed over the past year here.

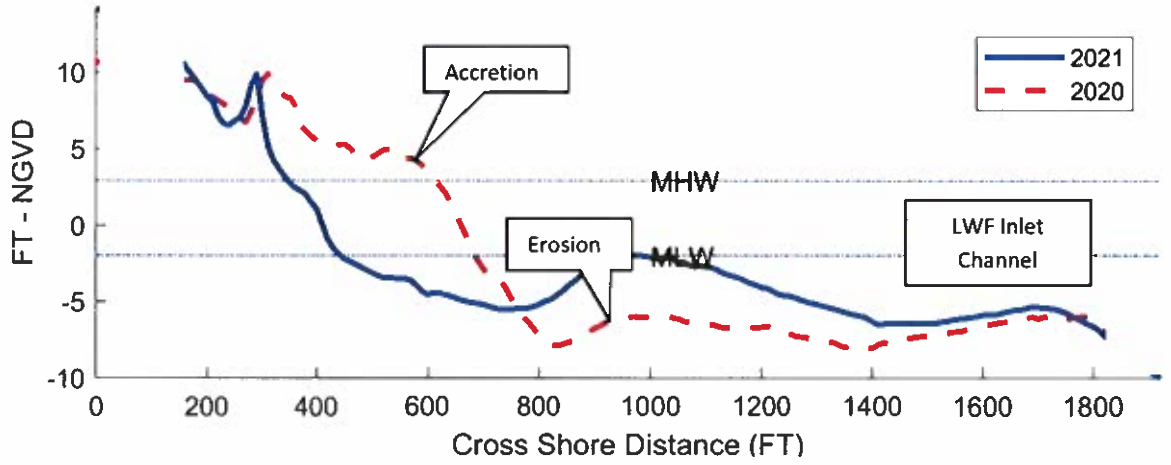


Oak Island Transects

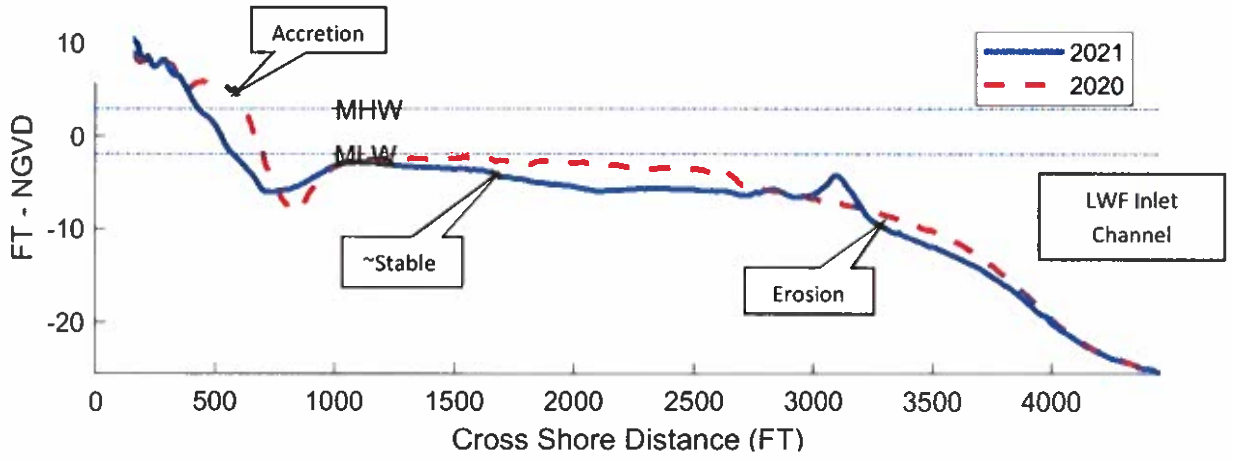


Station OAK- 1. The dune system is healthy and some significant accretion is seen along the western-most Oak Island profiles in the upper beach and intertidal zones possibly due to spreading from the USACE LWFIX dredging and beach placement in 2019. The LWF Inlet Channel is observed to have shallowed some since the 2019 survey.

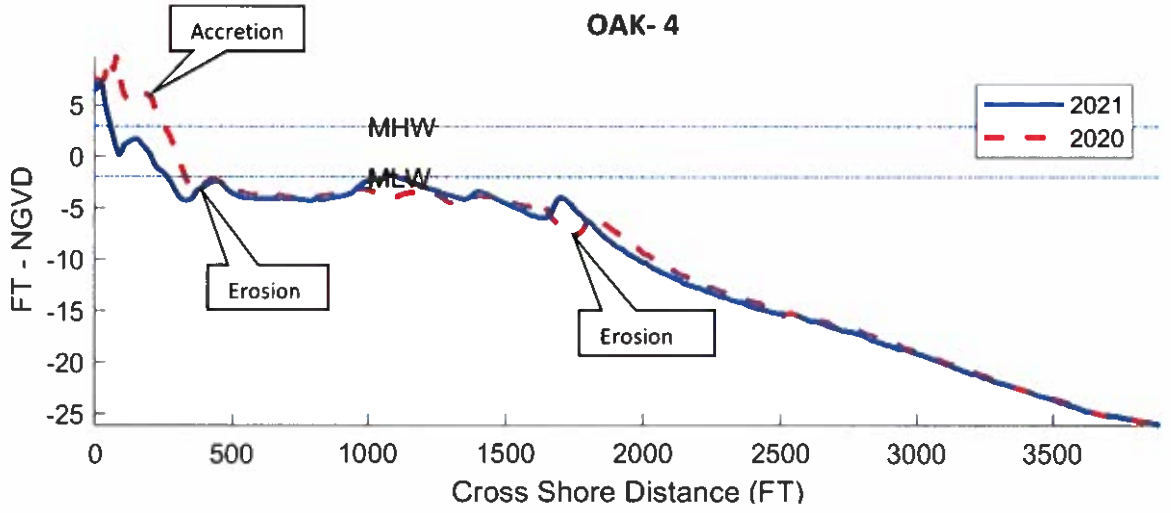
OAK- 2



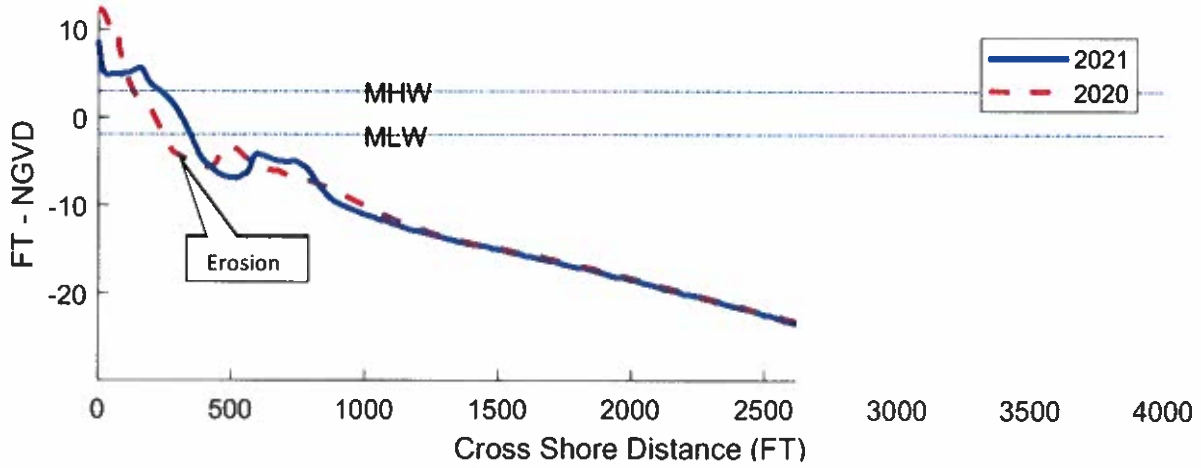
OAK-3



OAK- 4

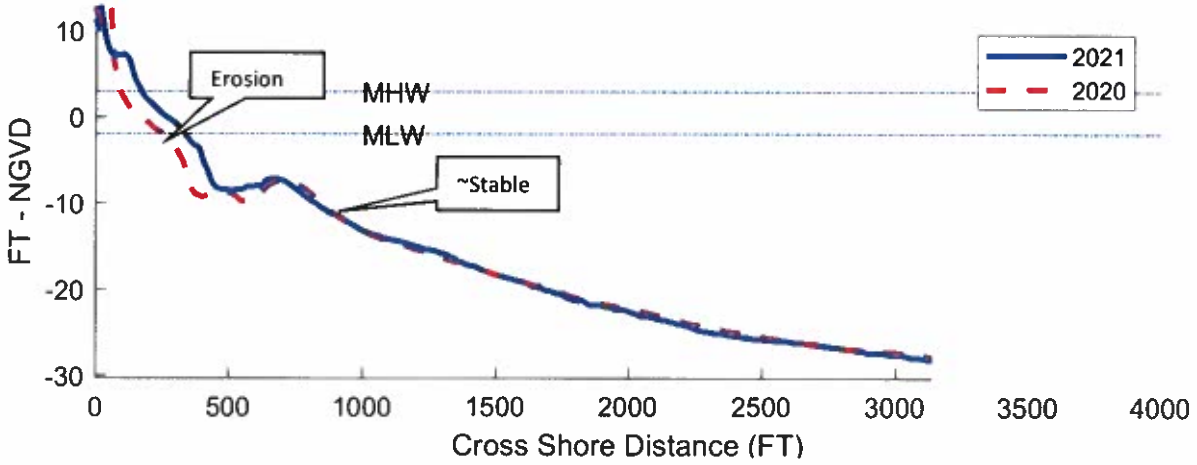


OAK- 5



Station OAK- 5. Upper beach and intertidal erosion observed here and at OAK-6 primarily due to equilibration of the 2019 USACE LWFIX dredging and beach placement along with Hurricane Dorian effects.

OAK- 6



OAK- 7

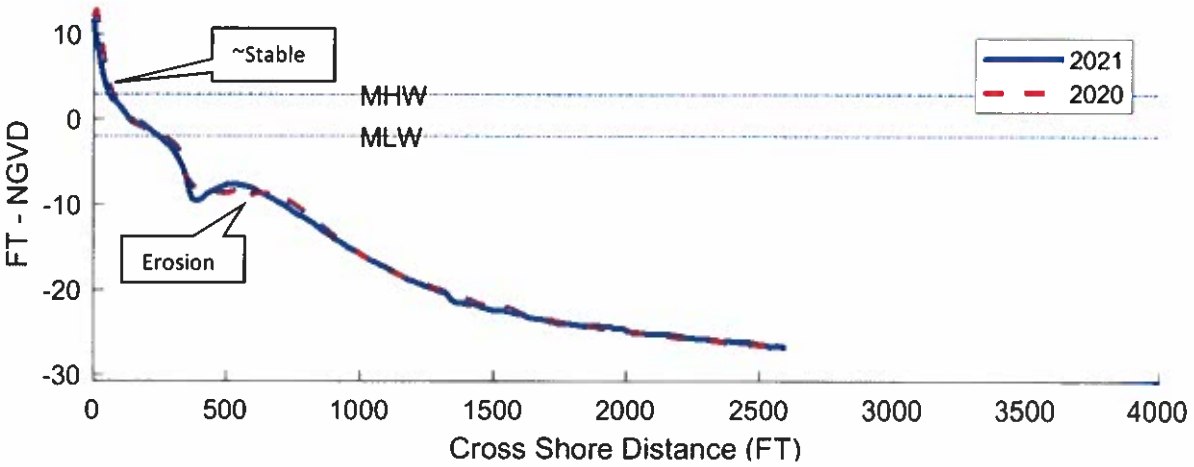


TABLE A-1: 2020 to 2021 Survey Transect Analysis

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

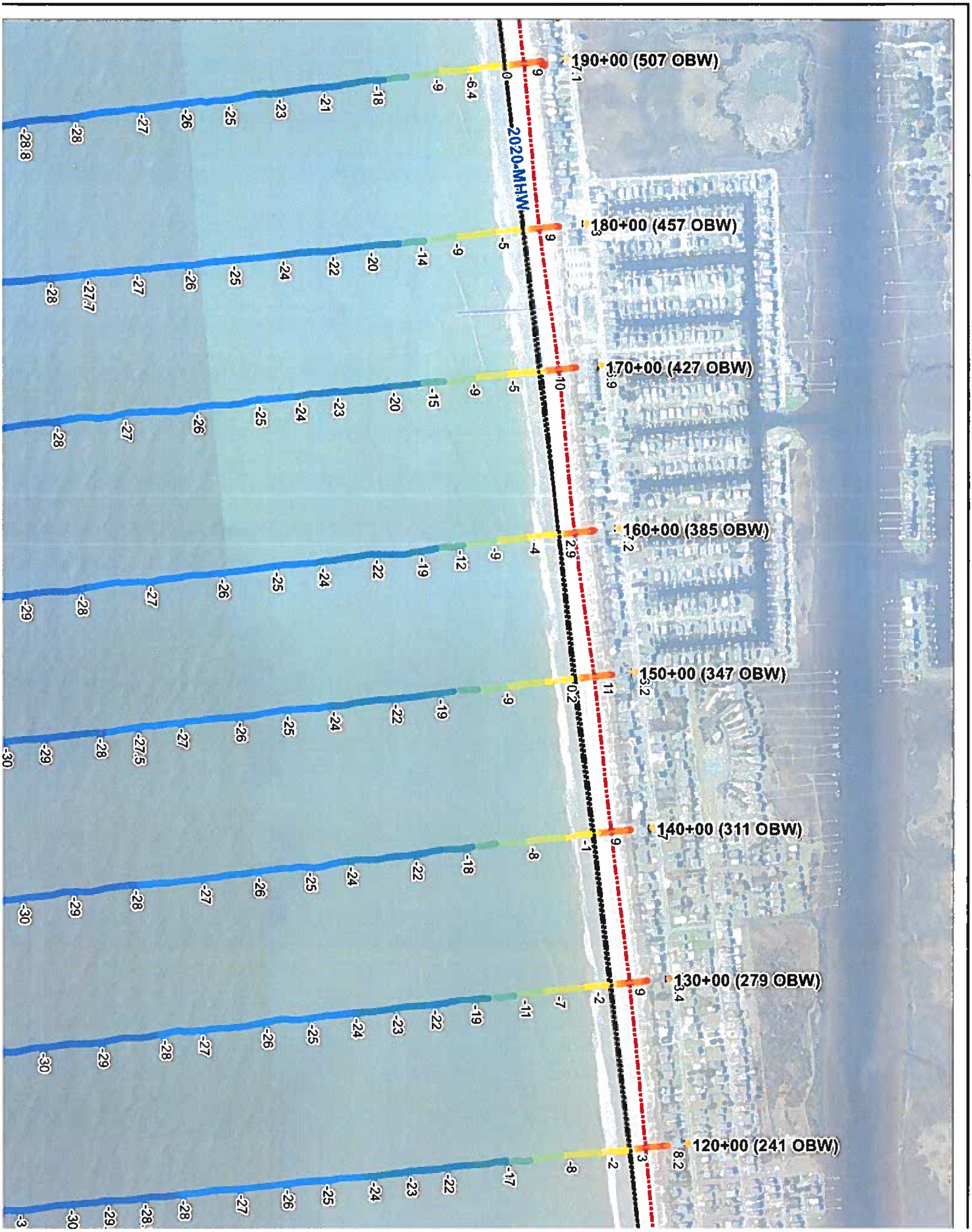
2020 to 2021 Survey Analysis					
STATION	Distance to Next Monument (ft)	Volume Change (cy/ft) (Dune to -12 ft*)	Volume Change (cy/ft) (Dune to -5 ft)	MHW Change (ft)	Notes
109+00	0	27.5	29.1	131.2	LWF Inlet
119+00	0	52.2	62.2	214.8	LWF Inlet
129+00	500	55.7	71.8	267.0	LWF Inlet
5+00	500	-35.6	-38.4	-73.1	LWF Inlet Shoulder
10+00	500	105.7	56.5	83.4	LWF Inlet Shoulder
15+00	440	-81.7	-3.8	-21.2	LWF Inlet Shoulder
20+00	1000	3.4	-19.1	-8.6	Oceanfront Perpendicular
30+00	1000	-38.6	-37.0	-88.2	
40+00	1000	-18.5	-26.1	-58.6	
50+00	1000	18.8	4.8	17.2	
60+00	1000	-5.7	-4.2	7.7	
70+00	1000	9.9	-2.6	-12.3	
80+00	1000	-17.8	-17.9	-8.5	
90+00	1000	7.3	-1.3	4.8	
100+00	1000	2.2	-0.6	1.1	
110+00	1000	1.2	-5.0	0.9	
120+00	1000	2.5	-3.0	-9.7	
130+00	1000	2.7	-6.2	-13.7	
140+00	1000	-5.2	-11.5	-12.3	
150+00	1000	-4.6	-10.4	-14.9	
160+00	1000	-1.6	-6.8	-5.4	
170+00	1000	11.2	7.8	16.8	
180+00	1000	8.7	1.6	8.9	
190+00	1000	5.1	-1.9	5.6	
200+00	1000	0.3	-0.9	14.1	
210+00	1000	6.1	7.0	24.1	

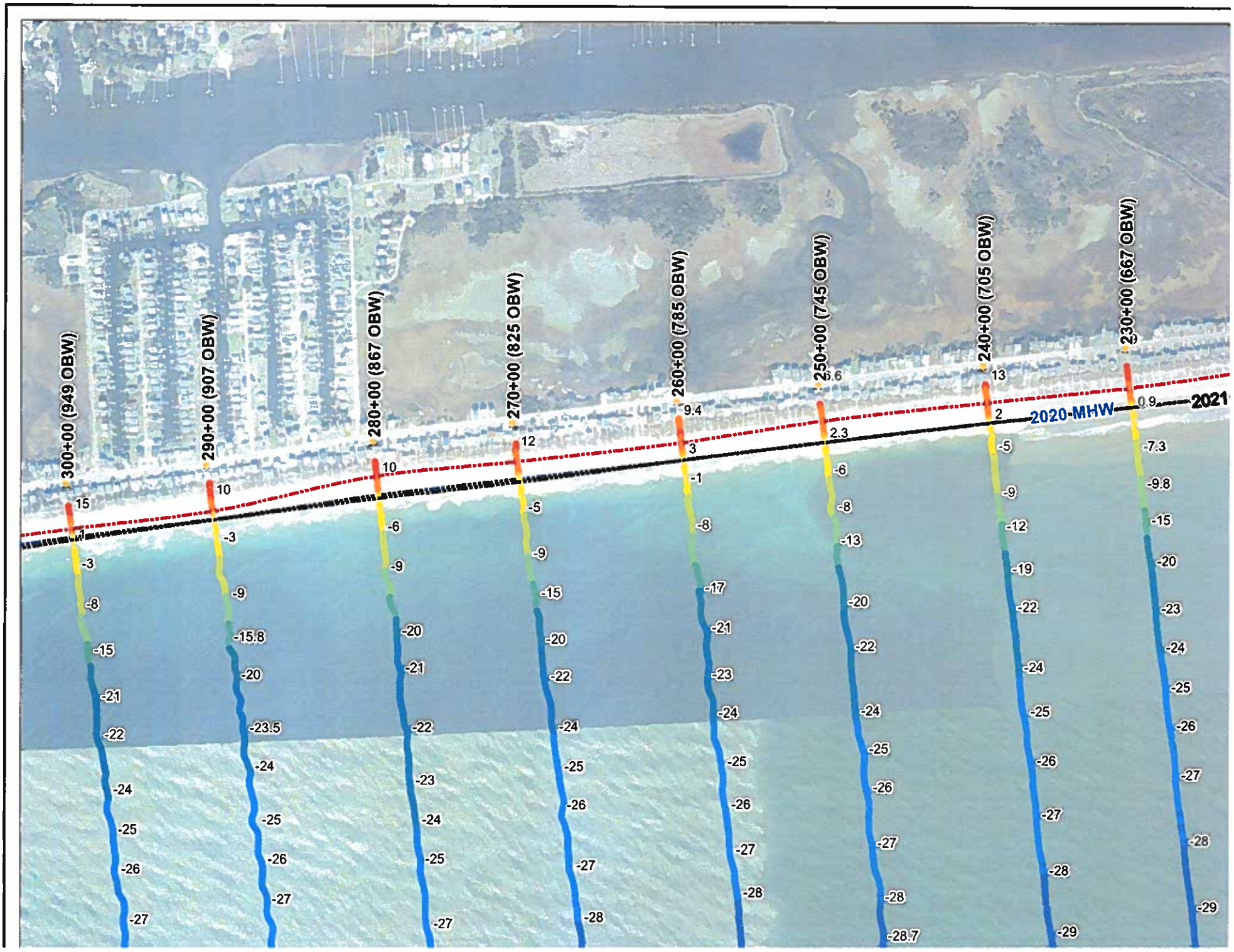
220+00	1000	5.2	-1.6	6.9	
230+00	1000	4.4	-2.4	-1.5	
240+00	1000	10.2	0.5	-1.8	
250+00	1000	5.8	1.3	1.2	
260+00	1000	9.2	1.7	0.3	
270+00	1000	10.6	4.9	18.3	
280+00	1000	15.8	4.7	19.4	
290+00	1000	0.3	-2.5	-0.3	
300+00	1000	5.1	4.6	17.1	
310+00	1000	5.5	6.3	38.2	
320+00	1000	9.3	9.1	50.8	
330+00	1000	16.7	16.6	42.6	
340+00	1000	13.6	11.3	50.3	
350+00	1000	-3.4	-0.3	26.1	
360+00	1000	-12.4	-9.9	23.9	
370+00	1000	-10.5	-2.0	-51.1	
380+00	1000	-15.2	-6.9	1.6	
390+00	1000	9.9	11.8	25.4	
400+00	1000	-13.5	-12.4	0.3	Oceanfront perpendicular
410+00	1000	32.6	32.2	34.9	Shallotte Inlet Shoulder
420+00	1000	-59.3	-89.1	-163.5	Shallotte Inlet
430+00	-	-	-	-	Shallotte Inlet
SHAL 1	-	-	-	-	Shallotte Inlet
SHAL 2	-	-	-	-	Shallotte Inlet
SHAL 3	-	-	-	-	Shallotte Inlet
	OAK ISLAND TRANSECTS				
OAK 1	0	17.6	-25.4	-235.6	LWF Inlet
OAK 2	0	-12.3	-56.7	-265.2	LWF Inlet
OAK 3	890	-151.1	-124.7	-184.4	LWF Inlet
OAK 4	1100	-16.2	-9.6	-198.3	LWF Inlet Shoulder
OAK 5	2000	21.7	29.2	108.0	Oceanfront perpendicular
OAK 6	2000	48.5	32.2	79.1	
OAK 7	-	-7.4	-5.0	-12.0	

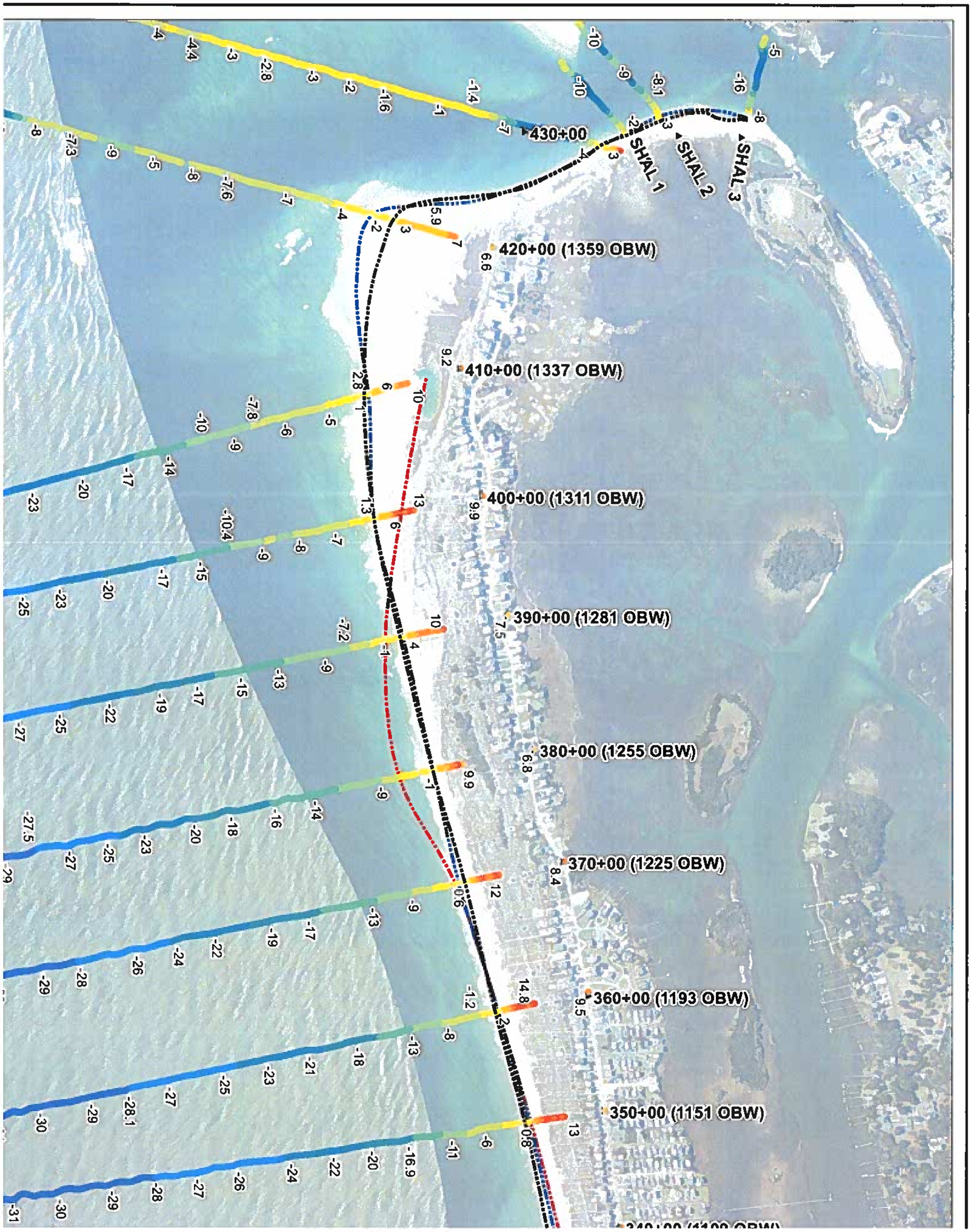
Appendix B

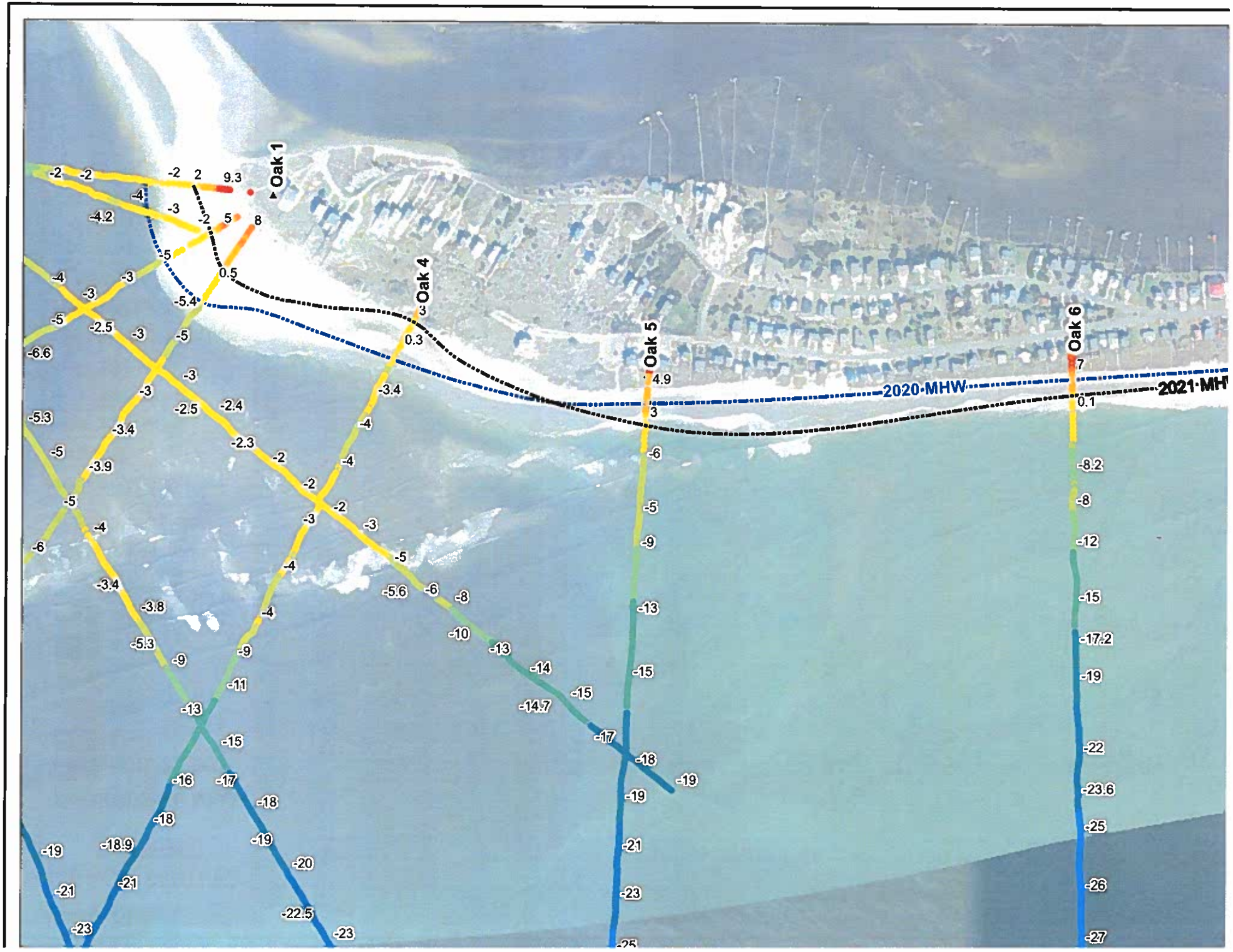
2021 Survey Plan View Figures

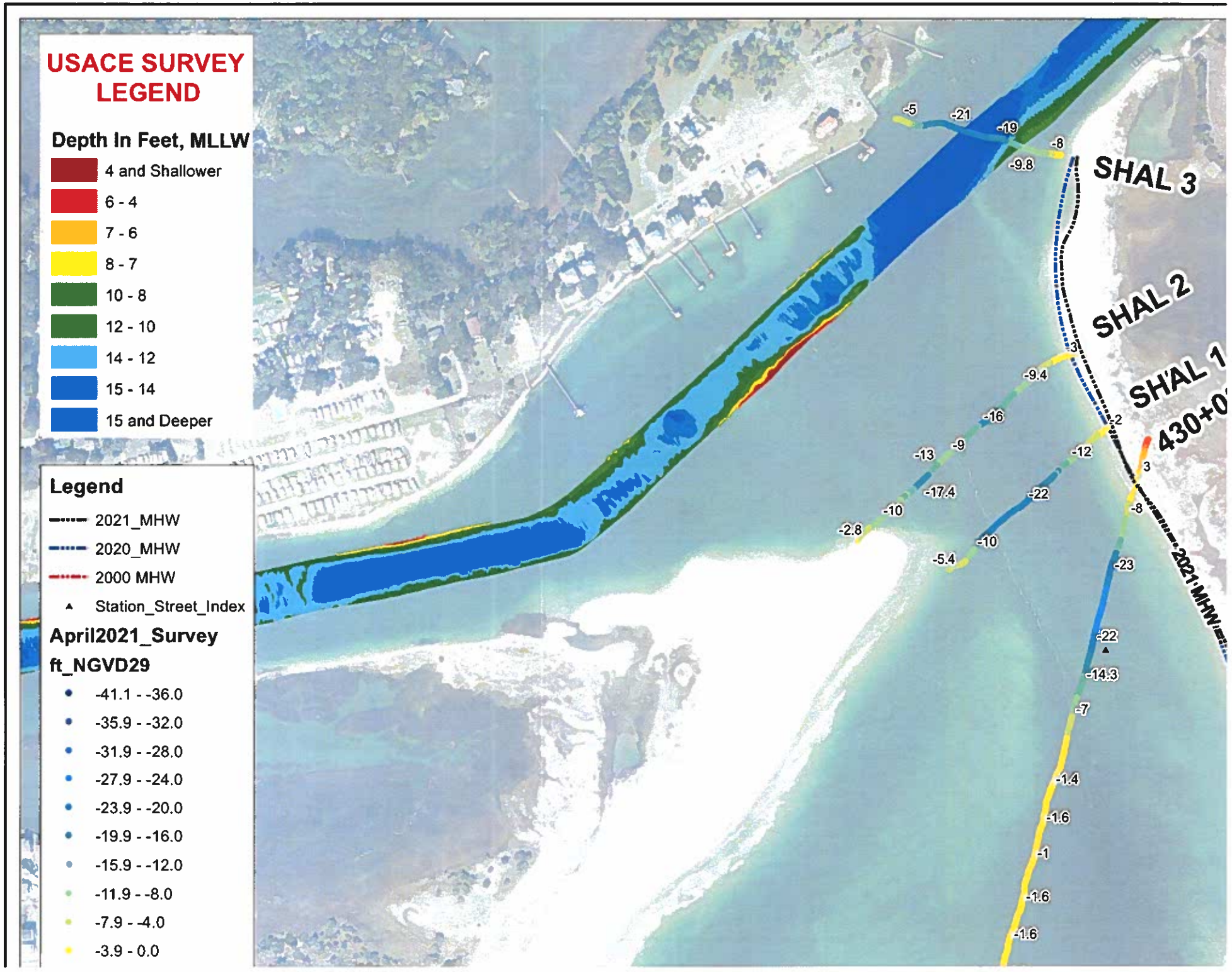

80+00 (114 OBE)
70+00 (148 OBE)
60+00 (184 OBE)
50+00 (226 OBE)
40+00 (264 OBE)
30+00 (306 OBE)
20+00 (344 OBE)
15+00 (336 SL)
10+00 (348 SL)
5+00 (358 SL)
2021 MHW
2020 MHW
2000

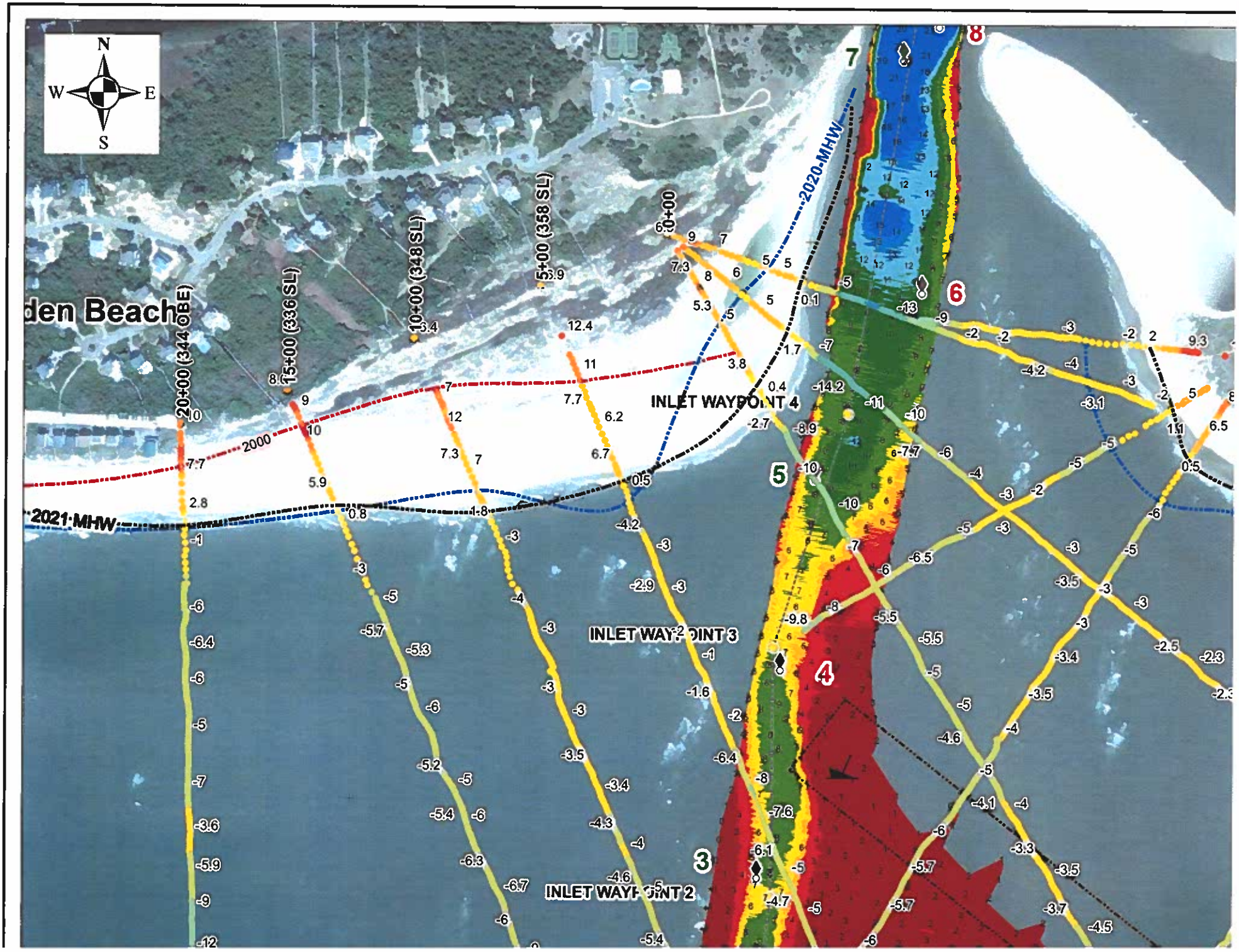

190+00 (507 OBW)
180+00 (457 OBW)
170+00 (427 OBW)
160+00 (385 OBW)
150+00 (347 OBW)
140+00 (311 OBW)
130+00 (279 OBW)
120+00 (241 OBW)
2020-MHW


300+00 (949 OBW)
290+00 (907 OBW)
280+00 (867 OBW)
270+00 (825 OBW)
260+00 (785 OBW)
250+00 (745 OBW)
240+00 (705 OBW)
230+00 (667 OBW)
2020-MHW
2021


430+00
SHAL 1
SHAL 2
SHAL 3
420+00 (1359 OBW)
410+00 (1337 OBW)
400+00 (1311 OBW)
390+00 (1281 OBW)
380+00 (1255 OBW)
370+00 (1225 OBW)
360+00 (1193 OBW)
350+00 (1151 OBW)


Oak 1
Oak 4
Oak 5
Oak 6
2020 MHW
2021 MHW


USACE SURVEY LEGEND
Depth In Feet, MLLW
4 and Shallower
6 - 4
7 - 6
8 - 7
10 - 8
12 - 10
14 - 12
15 - 14
15 and Deeper
Legend
2021_MHW
2020_MHW
2000 MHW
Station_Street_Index
April2021_Survey
ft_NGVD29
-41.1 - -36.0
-35.9 - -32.0
-31.9 - -28.0
-27.9 - -24.0
-23.9 - -20.0
-19.9 - -16.0
-15.9 - -12.0
-11.9 - -8.0
-7.9 - -4.0
-3.9 - 0.0
SHAL 3
SHAL 2
SHAL 1
430+0
2021 MHW
-5
-21
-19
-8
-9.8
-9.4
-16
-13
-9
-12
-17.4
-22
-10
-2.8
-10
-5.4
-23
-22
-14.3
-7
-1.4
-1.6
-1
-1.6
-1.6


N
W
E
S
den Beach
20+00 (344 OBE)
15+00 (336 SL)
10+00 (348 SL)
5+00 (358 SL)
0+00
2020-MHW
2021-MHW
2000
INLET WAYPOINT 4
INLET WAYPOINT 3
INLET WAYPOINT 2
8
7
6
5
4
3