TOWN OF SOUTHERN SHORES NORTH CAROLINA
2020 BEACH ASSESSMENT REPORT

SUBMITTED TO:

TOWN OF SOUTHERN SHORES

SUBMITTED BY:

COASTAL PROTECTION ENGINEERING OF NORTH CAROLINA, INC.
ENGINEERING LICENCE CERTIFICATE #: C-2331

ADAM T. PRIEST, PE NO. 048852

DATE 01/28/21

January 2021

Coastal Protection Engineering of North Carolina, Inc.

EXECUTIVE SUMMARY

The Town of Southern Shores authorized this study to update long-term and short-term shoreline and volumetric changes. This study provides updated erosional and accretional trends; updated assessment of the volume envelope density, which relates to the level of storm damage reduction provided by the existing beach; and updated information on the "useable beach" width, particularly in the northern portion of the project. All of this information is provided to aid the Town in assessing needs to sustain the beaches that support a significant portion of their local economy and maintains the tax base of the Town.

For monitoring purposes, the Town was divided into three areas: namely, the Northern, Central, and Southern Areas. The Northern Area includes the portion of the Town north of 3rd Avenue, which includes stations -197+12 through -150+00. The Central Area, previously referred to as the "Main Fill" area in the Beach Management Plan, spans from station -150+00 to -50+00, which is located approximately 450 feet south of Chicahauk Trail. The Southern Area includes the portion of the Town from station -50+00 to 0+00, which is the boundary between the Town of Southern Shores and Kitty Hawk.

Shoreline Change Analysis: Average long-term MHW shoreline change rates measured along the southern 15,000 feet of the Town's oceanfront (South of 3rd Ave.) and along the northern 2,000 ft. of oceanfront (north of 8th Ave.) were -1.3 ft./yr. This rate suggests the shoreline has been relatively stable along these portions of the beach for the respective 12.4 and 5.7-year periods.

The average MHW shoreline change rate measured along the Town's oceanfront between December 2017 and May 2020 was -4.1 ft./yr. However, extensive variability in the measured shoreline changes at each profile was observed. The Northern and Central Areas experienced a negative shoreline change rate of -2.3 ft./yr., while the Southern Area had an average shoreline change rate of -10.8 ft./yr.

Useable Beach Width: The term "useable beach", as it relates to the monitoring of the Southern Shores beach, was defined as the distance between the +12.0 ft. NAVD88 and +4.0 ft. NAVD88 contours on any given beach profile. The catalyst for evaluating the useable beach width, was feedback provided to Coastal Protection Engineering of North Carolina, Inc. (CPE) by the Town in 2019. This input suggested the area from the northern Town limit to approximately 5th Avenue (station 197+12 to 157+41) was an area in which useable beach was insufficient.

In a previous assessment conducted by CPE, the useable beach width was calculated along the Town of Southern Shores south of station -150+00 (located near 3rd Avenue), to serve as a proxy for an area of beach with sufficient beach width. The evaluation of data collected in May 2019 indicated that the average useable beach width along Southern Shores, south of 3rd Avenue, was approximately 84 ft. In this regard, the average useable beach width measured along this portion of the Town's oceanfront north of 5th Avenue was 57 ft. in May 2019. Evaluation of data collected in June 2020 indicated the average useable beach width north of 5th Avenue has increased by approximately 12 feet on average between May 2019 and June 2020.

Volumetric Change Analysis: Volumetric changes derived from repeated beach profile surveys are the preferred method of tracking the changes taking place along a beach. The overall average

volumetric change rate, computed along the Town of Southern Shores over the 2.5-year period between December 2017 to June 2020, was -1.7 cy/lf/yr. The overall average rate is considered manageable over the long term with regards to beach nourishment. The average rate over the 13-month period between May 2019 and June 2020 was -2.9 cy/lf/yr., which is slightly higher than the rate measured over the 2.5-year period.

Although the overall average rate along the Town is manageable, there are considerable differences in the measured rates with respect to the Northern, Central and Southern Areas. Volumetric changes along the Southern Area indicated the highest erosion rates. Over the 2.5-year period between December 2017 and June 2020, the average volumetric change rate was measured to be -15.3 cy/lf/yr., resulting in a measured volumetric change of approximately -202,100 cy. The volumetric change rate over the 13-month period between May 2019 and June 2020 was slight less, measuring -10.6 cy/lf/yr., or a measured volumetric change of approximately -53,100 cy.

Along the Central Area, the rate over the 2.5-year period was -0.3 cy/lf/yr., which essentially suggests no net volumetric change along this 10,000-foot stretch of beach. However, over the 13-month period between May 2019 and June 2020, the measured volumetric change rate averaged -6.8 cy/lf/yr.

The overall average volumetric change rate along both the Central and Southern Areas (Town oceanfront south of 3rd Ave.), measured between December 2017 and June 2020 was -5.2 cy/lf/yr. This is significant because the rate of volumetric change measured along this section (Central and Southern Areas) between December 2017 and May 2019 was used to determine the background erosion rate used to compute the "advanced fill" volume for the proposed beach fill options. Advanced Fill is a volume of sand estimated to account for typical background erosion that will take place between beach nourishment intervals. This is in excess of the "design volume", which is the volume required to achieve a stated design level of protection. The *2019 Beach Assessment Report* used a volumetric change rate of -3 cy/lf/yr. to determine advanced fill. The increase in the rate from -3 cy/lf/yr. to -5.2 cy/lf/yr., would require additional material for the construction of a beach fill project along the Towns oceanfront. Currently, CPE is evaluating beach fill alternatives using a combination of these monitoring results and a numerical model used to simulate beach fill performance. Results of these analyses will be used to recommend optimal beach fill densities for the proposed 2022 project constructed along the Central and Southern Areas.

Between December 2017 and June 2020, the Northern Area experienced net volumetric increases. The average rate along this portion of the Town between the northern Town limit and 3rd Avenue, was +6.1 cy/lf/yr. The net volumetric increase measured over this 2.5-year period was 75,700 cy. Positive volumetric changes were measured along each profile located north of 5th Avenue over this same period. Between May 2019 and June 2020, the average volumetric change rate along the Northern Area was also positive (7.0 cy/lf/yr.). The vulnerability analyses completed for the Town of Southern Shores suggested the volume density within the Volume Envelope along the Northern Area would provide sufficient storm damage reduction for the design storm, which was a storm similar in characteristics to Hurricane Isabel, which impacted the area in 2003. The

volumetric increases measured along the Northern Area, suggests the storm damage reduction along this portion of the Town has increased over the past 2.5-years.

Volume Envelope: The total volume measured along each profile above the -24 ft. NAVD88 contour and seaward of the +20 ft. NAVD88 contour, on the landward side of the dune, is referred to as the volume envelope. Previous analyses have established a volume envelope density of 846 cy/lf as the design volume needed within the volume envelope to provide sufficient storm damage reduction for a storm with comparable physical characteristics of Hurricane Isabel. The *2019 Beach Assessment* indicated that the average density within the Volume Envelope along the Central Area and Southern Area was less than 846 cy/lf, based on May 2019 data. This prompted the recommendation of beach fill along this portion of the Town to achieve a sufficient level of storm damage reduction. Negative volumetric changes were measured on average in the Central and Southern Areas between May 2019 and June 2020. Therefore, more material may be required to establish the design level of protection within the Central and Southern Areas. CPE is currently conducting design level analysis using both cross shore storm modeling (SBEACH) and a 3-D morphology numerical model (Delft3D), to update recommendations on beach fill configuration within the Central and Southern Areas.

In the Northern Area, the *2019 Beach Assessment* found that the average volume envelope density along this section of beach was in excess of the 846 cy/lf established design density. As has been discussed in this report, positive volumetric changes were measured on average in the Northern Area between May 2019 and June 2020. The average volume envelope density along the Northern Area, as of June 2020, was approximately 33 cy/lf higher than the design density of 846 cy/lf.

Recommendations: Regular monitoring of beaches is instrumental for the Town to evaluate both past project performance and to monitor rates of change for long-term beach management. The frequent repeating of surveys is pivotal to the adaptive management strategy that must be part of the successful long-term maintenance of a beach management program. The Town should continue monitoring the oceanfront project area in 2021. Not only will the survey allow for updating of the project design, but it will also serve as the conditional survey to develop construction documents to bid the proposed project. The monitoring surveys should be conducted in the same timeframes from year to year to mitigate the influence of seasonal differences.

CPE continues to develop updated recommendations for the beach fill configuration. The Town should continue to provide feedback to CPE during the design process regarding the Town's overall goals for the project. As described in this report, sufficient volume may be in place in the Northern Area to provide sufficient storm damage reduction for the design storm. However, the Town has also expressed concerns about the width of "useable beach" along the Northern Area. As described in this report, the useable width measured in June 2020 along the portion of the Town north of 5th Avenue, was approximately 12 feet wider on average than the width measured in May 2019.

DRAFT: TOWN OF SOUTHERN SHORES NORTH CAROLINA
2020 BEACH ASSESSMENT REPORT

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TOWN OF SOUTHERN SHORES

I. INTRODUCTION

In February 2018, APTIM completed the development of a Beach Management Plan for the Town of Southern Shores, to be used for future planning. The Beach Management Plan provided beach nourishment options for the Town to consider, which aimed to 1) provide a reasonable level of storm damage reduction to public and private development, 2) mitigate long-term erosion that could threaten public and private development, recreational opportunities, and biological resources, and 3) maintain a healthy beach that provides sufficient useable beach and supports valuable shorebird and sea turtle nesting habitat.

In May 2020, the Town authorized CPE to collect an updated set of beach profile data and to update shoreline and volumetric change rates. In June 2020, the Town Council of Southern Shores unanimously passed a motion to pursue beach nourishment. In July 2020, the Town entered into an agreement with Coastal Protection Engineering of North Carolina, Inc. (CPE) to provide permitting and design services for the proposed beach nourishment project.

This report provides updated shoreline and volumetric change rates based on data collected in June 2020. The report specifically provides measured shoreline and volume changes that occurred over the long-term period, since the 2017 project was constructed along the South end of the Town, and over the short-term period between the last two data sets (May 2019 to June 2020). There are also periods that are referred to in the report as historic rates based on longer timeframes. The historic rates are dependent on available data for particular sections of Town. For example, along the southern 15,000 feet of the Town south of 3rd Avenue (station -150+00 to 0+00), the historic rates and values were measured between October 2006 and June 2020. Along the northern 2,000 feet of the Town from 9th Avenue north (station -197+12 to -177+13), the historic rates and values were measured from September 2013 to June 2020. For the section of Town between 9th Avenue and 3rd Avenue (stations -170+56 and -157+41), the earliest set of beach profile data is the one collected by CPE in December 2017.

II. PROJECT LOCATION

The Town of Southern Shores is located on the Outer Banks of North Carolina approximately 29 miles south-southeast of the North Carolina and Virginia border. The Town encompasses approximately 9.9 square miles extending along 3.7 miles of Atlantic Ocean shoreline from the Town of Duck south-southeast to the Town of Kitty Hawk. A location map is provided in Figure 1.

For the purpose of monitoring, the analysis described in this report separated the oceanfront beach of the Town of Southern Shores into three areas: namely, the Northern, Central, and Southern Areas. These areas are depicted on Figure 2. The Northern Area includes the portion of the Town north of 3rd Avenue, which includes stations -197+12 through -150+00. The Central Area, previously referred to as the "Main Fill" area in the Beach Management Plan, spans from station -150+00 to -50+00, which is located approximately 450 feet south of Chicahauk Trail. The Southern Area includes the portion of the Town from station -50+00 to 0+00, which is the boundary between the Town of Southern Shores and Kitty Hawk.

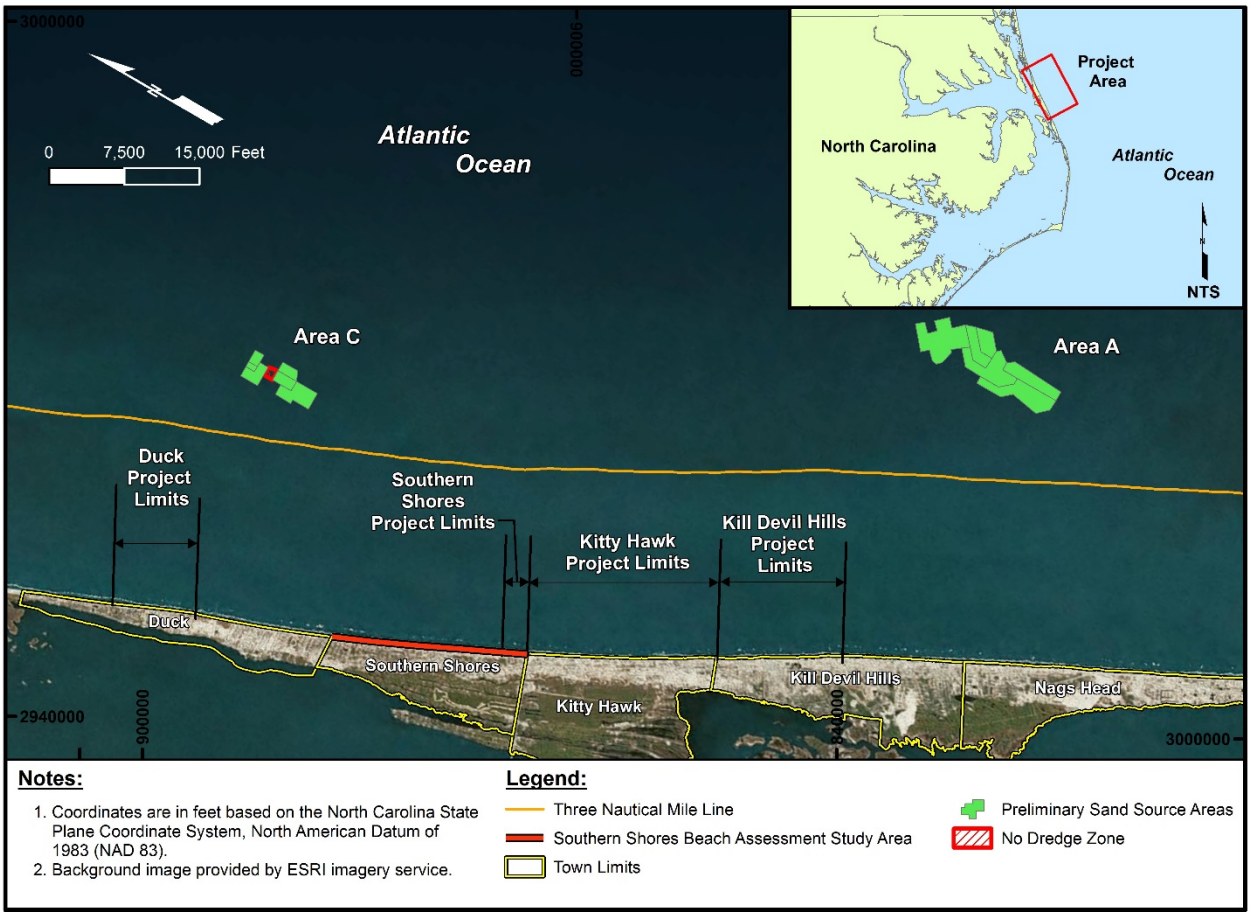

Figure 1. Project Location Map.

III. DATA COLLECTION

The data collection process entailed acquiring beach profile data along the entire oceanfront beach of Southern Shores. Beach profile data collected by CPE in June 2020 were compared to datasets previously compiled and described in the initial Beach Assessment (APTIM, 2018A) to update long-term and short-term shoreline and volumetric trends. Figure 2 shows the locations of the beach profile stations along the Town of Southern Shores oceanfront. The previous data sets used include:

- Beach profile data collected by the USACE Field Research Facility (FRF) in 2006 along the southern 15,000 ft. of the Town of Southern Shores (stations -150+00 to 0+00);
- Beach profile data collected by CPE in 2013 along the northern 2,000 ft. of the Town of Southern Shores (stations -197+12 to -177+13);
- Beach profile data collected by CPE in December 2017 (post-construction) and May 2019, along the entire oceanfront of the Town of Southern Shores (stations -197+12 to 0+00).

The beach profile data acquired by CPE in June 2020 represent the third Town-wide beach profile survey. These three data sets (December 2017, May 2019, and June 2020) consist of a total of 22 profiles with a spacing of roughly 1,000 feet (stations -197+12 to 0+00). Coordinates and azimuths of these profiles are provided in Table 1. Coordinates shown in Table 1 are referenced to the North Carolina State Plane coordinate system in feet NAD83 and the profile azimuth refers to degrees referenced to true north. Transects listed in Table 1 are shown graphically in Figure 2. The complete survey report, which includes detailed plan view maps and comparative profile cross sections, is included as Appendix A (*2020 Town of Southern Shores Topographic and Hydrographic Survey Report*).

Table 1. Profile Survey Baseline and Azimuth

Profile[(1)]	Easting	Northing	Azimuth
-197+12	2962840	889616.1	70
-187+14	2963230	888697.7	70
-177+13	2963619	887775.8	70
-170+56	2963880	887172.9	66.6
-163+99	2964142	886569.9	66.6
-157+41	2964403	885966.9	66.6
-150+00	2964665	885364.0	65.3
-140+00	2965116	884444.0	65.3
-130+00	2965239	883452.0	65.3
-120+00	2965920	882604.0	65.3
-110+00	2966366	881697.0	62.6
-100+00	2966790	880778.0	62.6
-90+00	2967110	879895.0	62.6
-80+00	2967533	878988.0	62.6
-70+00	2967951	878106.0	62.6
-60+00	2968381	877175.0	62.6
-50+00	2968838	876228.0	62.6
-40+00	2969249	875440.0	62.6
-30+00	2969732	874496.1	62.6
-20+00	2970190	873607.2	62.6
-10+00	2970653	872721.0	62.6
0+00	2971224	871890.8	62.6

[(1)]Southern Shores transects (stations 0+00 to -197+12) based on USACE baseline

Notes:

1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, FIPS 3200, North American Datum of 1983 (NAD 83).
2. 2019 Background imagery is provided by NOAA.

Legend:

Southern Shores
Kitty Hawk
Duck
Profiles

0 1,500 3,000 Feet

Title:

Profile Map
Southern Shores
Dare County, NC

COASTAL PROTECTION ENGINEERING OF NORTH CAROLINA, INC.
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Date: 11/16/20 By: FMM

Figure 2. Map showing the location of the beach profiles along the Town of Southern Shores.

The June 2020 data included a topographic survey of the dune, berm, and foreshore section of the beach and a bathymetric survey of the offshore portion of the profile. Beach profiles extended landward from the beach toward the baseline until a structure was encountered or a range of 25 feet beyond the dune was reached, whichever was more seaward. Elevation measurements were also taken seaward along the profile to a range of 2,500 feet beyond the shoreline or to the -30 ft. NAVD88 contour, whichever was more landward.

Land-based or "upland" data collection includes all grade breaks and changes in topography to provide a representative description of the conditions at the time of the work. The maximum spacing between data points along individual profiles is 25 feet. The upland work extended into wading depths sufficiently to provide a minimum 50-foot overlap with the offshore data. This overlap between the topographic and bathymetric surveys provides quality control and quality assurance of the survey.

The bathymetric data or "offshore" portions of the beach profiles were acquired using an Odom Hydrotrac depth sounder at 200 kHz and RTK GPS systems. Tide corrections were obtained redundantly through the use of RTK GPS and the tide station located at the USACE FRF in Duck, North Carolina. Offshore data points were collected with a maximum spacing of 25 feet.

Horizontal and vertical positioning checks were conducted at the beginning and end of each survey day to confirm that survey control was undisturbed and met the accuracy standards of this project with a horizontal limit of 0.66 feet and a vertical limit of 0.16 ft. for all electronic equipment. Vertical positioning checks for depth measuring equipment were conducted at 5 ft. increments between the minimum and maximum depths expected. These specifications meet the Minimum Performance Standards for the U.S. Army Corps of Engineers (USACE) (EM 1110-2-1003).

IV. SHORELINE CHANGE ANALYSIS

Using available beach profile data, a shoreline change analysis was conducted to assess shoreline advance and recession where data were available along the study area. As it relates to shoreline change, the "shoreline" is typically defined as a specified elevation contour. For this study, the shoreline was defined as the Mean High Water (MHW) contour, which represents the +1.2 ft. NAVD88 elevation. Shoreline change is calculated by comparing shoreline position along shore perpendicular transects. Figure 3 shows a typical comparison plot of two beach profile surveys conducted approximately 2 years apart along station -10+00, illustrating graphically how the shoreline change is measured. Shoreline change is provided in terms of the actual linear change measured between surveys and as a rate in an annualized form. The rate is calculated by dividing the measured distance of shoreline change by the time period (number of years) between survey events (i.e. feet per year). These rates are described in terms of positive ("+") or advance (shoreline moving seaward) and negative ("-") or recession (shoreline moving landward).

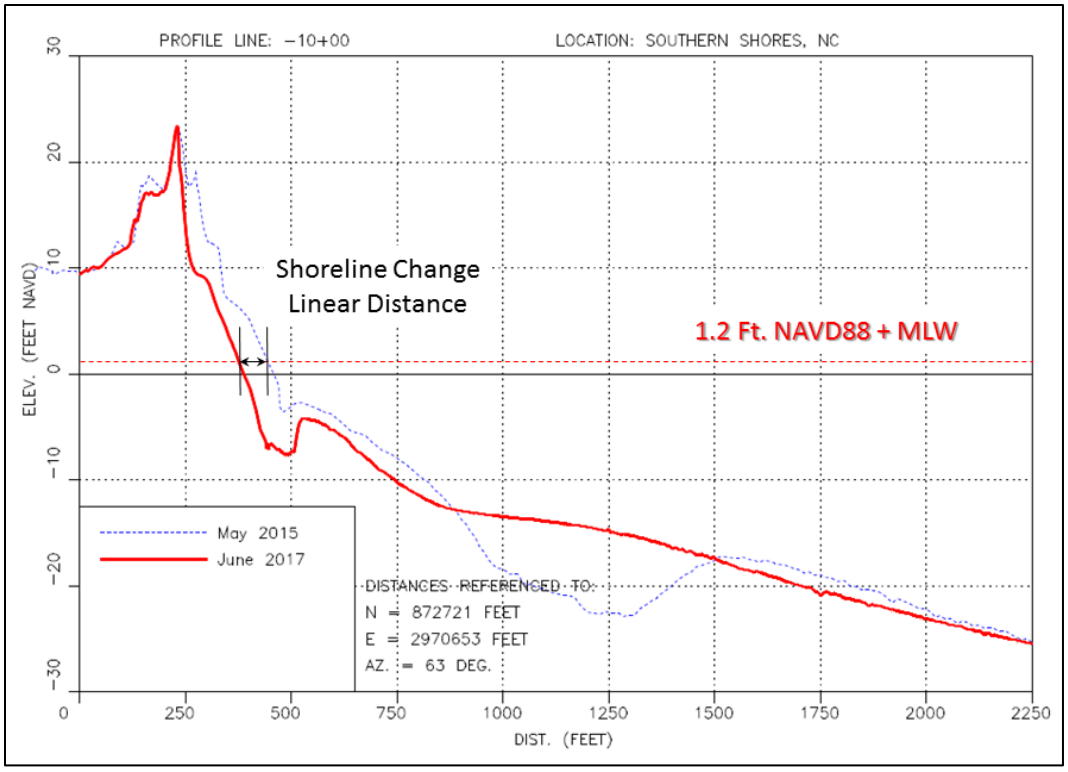

Figure 3. Beach profile cross section illustrating shoreline change.

As part of the original Beach Assessment completed in 2018, the position of the MHW shoreline measured in December 2017 along the portion of beach between 3rd Ave. (station -150+00) and the southern Town boundary (station 0+00), was compared to the position of the MHW shoreline at the time of the October 2006 USACE survey. An average MHW shoreline change of -5.0 ft. was measured over the approximately 11.2-year period, which equates to an average MHW shoreline change rate of -0.4 ft./yr. (APTIM, 2018A). The average shoreline change measured from October 2006 to June 2020 indicates a landward migration of -18 ft., which is equivalent to a slightly higher shoreline change rate of -1.3 ft./yr. over the 13.7-year period. Table 2 provides the individual shoreline change rates computed for each station between October 2006 and June 2020, as well as rates along the approximate northern 2,000 feet of the Town between September 2013 and June 2020. A profile by profile comparison of rates measured between October 2006 and June 2020 shows that a negative shoreline change rate between -0.1 ft./yr. and -4.2 ft./yr. was measured along all but three of the 16 profiles surveyed in both 2006 and 2020. A rate of 0 ft./yr. was measured along station -130+00 and a positive shoreline change rate of 1.6 and 0.1 ft./yr. were measured along stations -140+00 and 0+00.

The position of the MHW shoreline measured in June 2020 along the northern 2,000 feet of Southern Shores (stations -197+12 to -177+13), was compared to the position of the MHW shoreline measured during a survey conducted in September 2013 for the Town of Duck. An average MHW shoreline change of -9.0 ft. was measured over the approximately 6.75-year period. This equates to an average MHW shoreline change rate of -1.3 ft./yr. In the span of 6.75 years the shoreline change ranged from -1.9 ft./yr. at station -187+14 (located at the end of 11th Ave.) to -0.8 at station -177+13 (approximately 200 ft. south of 9th Ave). The average negative shoreline

change rate is a reversal in the trend of positive shoreline change measured between September 2013 and December 2017 (+1.3 ft./yr.). This reversal of the trend was influenced by recent negative shoreline changes measured between December 2017 and June 2020.

Table 2. MHW Shoreline Change Rates for Historic, Long-Term, and Short-Term time periods

PROFILE	Oct. 2006 to June 2020 (FT/YR)	Sep. 2013 to June 2020 (FT/YR)	Dec. 2017 to June 2020 (FT/YR)	May 2019 to June 2020 (FT/YR)
-197+12	-	-1.2	-7.6	-13.3
-187+14	-	-1.9	-6.8	-7.8
-177+13	-	-0.8	-2.6	8.2
-170+56	-	-	9.1	33.5
-163+99	-	-	-0.2	4.1
-157+41	-	-	0.3	19.1
-150+00	-1.5	-	-8.7	-12.0
-140+00	1.6	-	0.8	-13.6
-130+00	0.0	-	-5.6	-22.8
-120+00	-2.5	-	-5.7	0.1
-110+00	-2.0	-	-2.4	-2.1
-100+00	-1.1	-	13.0	-4.7
-90+00	-3.6	-	-10.2	-36.7
-80+00	-0.7	-	7.7	7.2
-70+00	-3.3	-	-3.9	6.7
-60+00	-1.2	-	-3.1	-4.2
-50+00	-0.1	-	-7.5	-15.9
-40+00	-0.2	-	-8.1	-15.9
-30+00	-1.3	-	-7.5	-33.8
-20+00	-4.2	-	-9.2	-19.6
-10+00	-0.8	-	-20.4	-15.4
0+00	0.1	-	-12.1	-6.9
OVERALL AVERAGE	-1.3	-1.3	-4.1	-6.6
NORTHERN AREA (-197+12 to -150+00)	N/A	N/A	-2.3	4.5
CENTRAL AREA (-150+00 to -50+00)	-1.3	N/A	-2.3	-8.9
SOUTHERN AREA (-50+00 to 0+00)	-1.1	N/A	-10.8	-17.9

During the 2.5-year period between December 2017 and June 2020, the average shoreline change rate measured along the extent of the Town of Southern Shores was -10.3 ft., or -4.1 ft./yr. Profile by profile comparison of the changes that occurred between December 2017 and June 2020 show extensive variability, with majority of the movement being landward (Table 2). The greatest positive change rate (shoreline moving seaward) was measured at station -100+00 located at

Dolphin Run (13.0 ft./yr.); whereas the greatest negative change rate (shoreline moving landward) was measured at station -10+00 located within the area where beach nourishment occurred in August 2017 (near Sea Bass Circle) (-20.4 ft./yr.). As indicated in Table 2, the Southern Area experienced a much greater rate of shoreline change than the Central and Northern Areas over the 2.5-year period. This was primarily due to the changes at the stations within the construction area (-20+00 to 0+00) that exhibited negative shoreline change rates (landward movement) with an average shoreline change of -13.9 ft./yr. Over the same period, the average shoreline change rate measured in the Northern and Central Areas were the same at -2.3 ft./yr.

Figure 4 provides a comparison of long-term shoreline change rates (October 2006 to December 2020 along the Central and Southern Areas and September 2013 to June 2020 along the northern approximate 2,000 feet), with rates measured between December 2017 and June 2020. Stations -170+56 to -157+41 had no associated data until the surveys conducted in December 2017. With the exception of stations -100+00 (Dolphin Run) and -80+00 (located near the beach access at the south end of Ocean Blvd.), where the shoreline change trend reversed between 2017 and 2020 when compared to the long-term 2006 to 2020 trend, most stations along the project area show a higher negative shoreline change rate during the more recent period of 2017 to 2020. While this could indicate an increase in the rate of erosion along the project area over the more recent period between December 2017 and 2020, this could also be due to the variability associated in tracking shoreline change rates over a shorter period of time.

Shoreline change and shoreline change rates were also computed between the two most recent data sets, which are May 2019 and June 2020. Over the most recent 13-month period from May 2019 to June 2020, the average shoreline change measured along the Town's oceanfront was a recession (landward movement) of -6.8 ft. This equates to an average shoreline change rate of -6.6 ft./yr. Table 2 shows that the Southern Area experienced the greatest average negative shoreline change. Over the 13-month period, an average shoreline change of -19.4 ft. was measured, which equates to an annual average rate of -17.9 ft./yr. In the Central Area, the average rate measured was -8.9 ft./yr. In the Northern Area, the average rate was actually a positive rate of +4.5 ft./yr. The greatest positive change rate measured was +33.5 ft./yr. at station -170+56 (8th Ave.). The greatest negative shoreline change rate measured was -36.7 ft./yr. at station -90+00 (approximately 300 feet south of Trout Run).

Figure 5 provides a profile by profile comparison of shoreline change rates measured between December 2017 and June 2020 and rates measured over the 13-month period between May 2019 and June 2020. With the exception of a few stations were reversals in the shoreline change trend were observed, most beach profiles showed an increase in the rate of shoreline recession observed between 2017 and 2020 when compared to changes measured over the 13 months between May 2019 and June 2020. This trend of observing higher change rates when comparing shorter periods of time is consistent in what is observed in Figure 4. While this could indicate an increase in the rate of change along the project area over the more recent period between May 2019 and June 2020, this could also be due to the variability associated in tracking shoreline change rates over a shorter period of time.

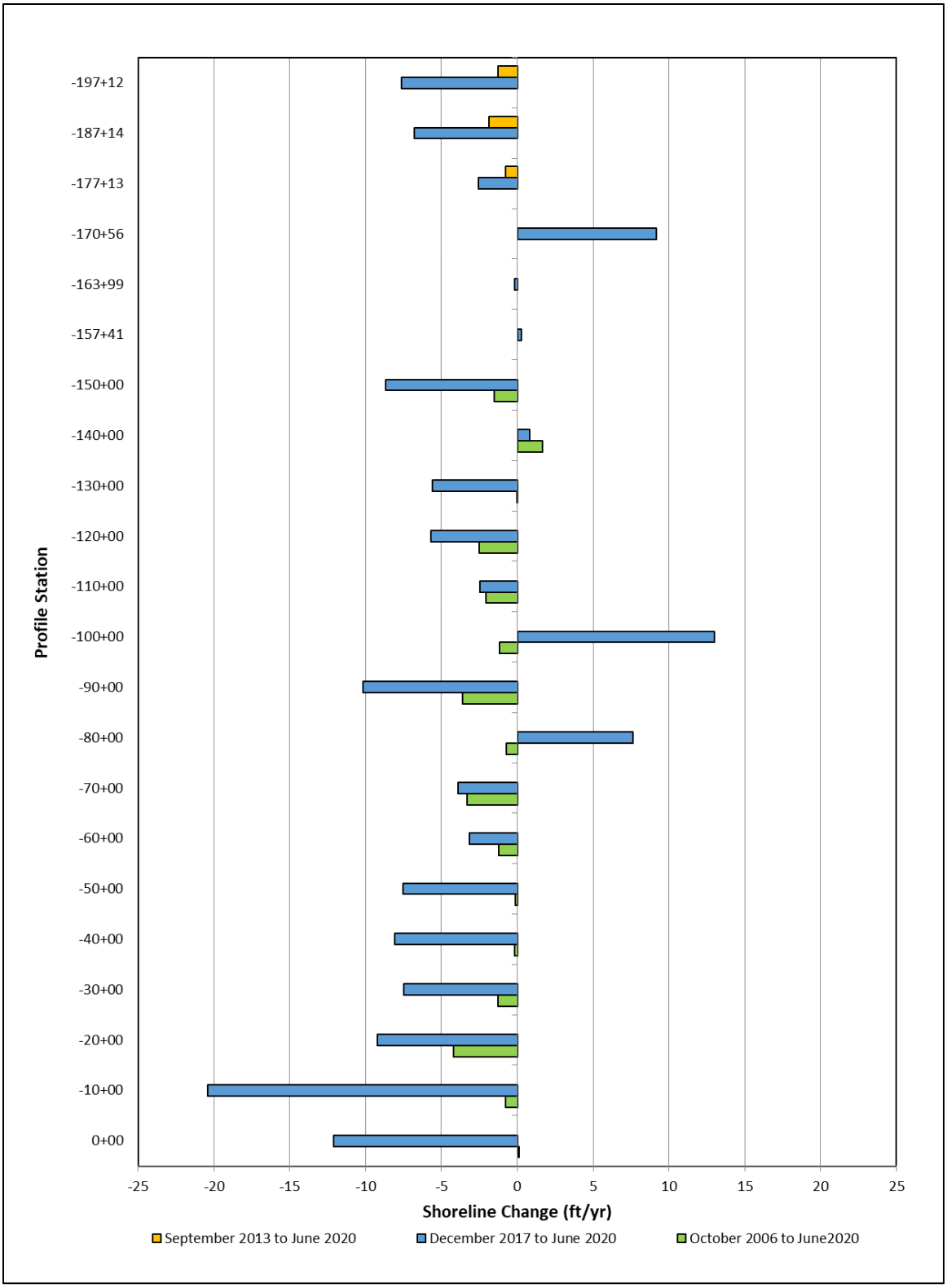

Figure 4. MHW Shoreline Change Rates measured from October 2006 and September 2013 to June 2020 and from December 2017 to June 2020 (FT/YR).

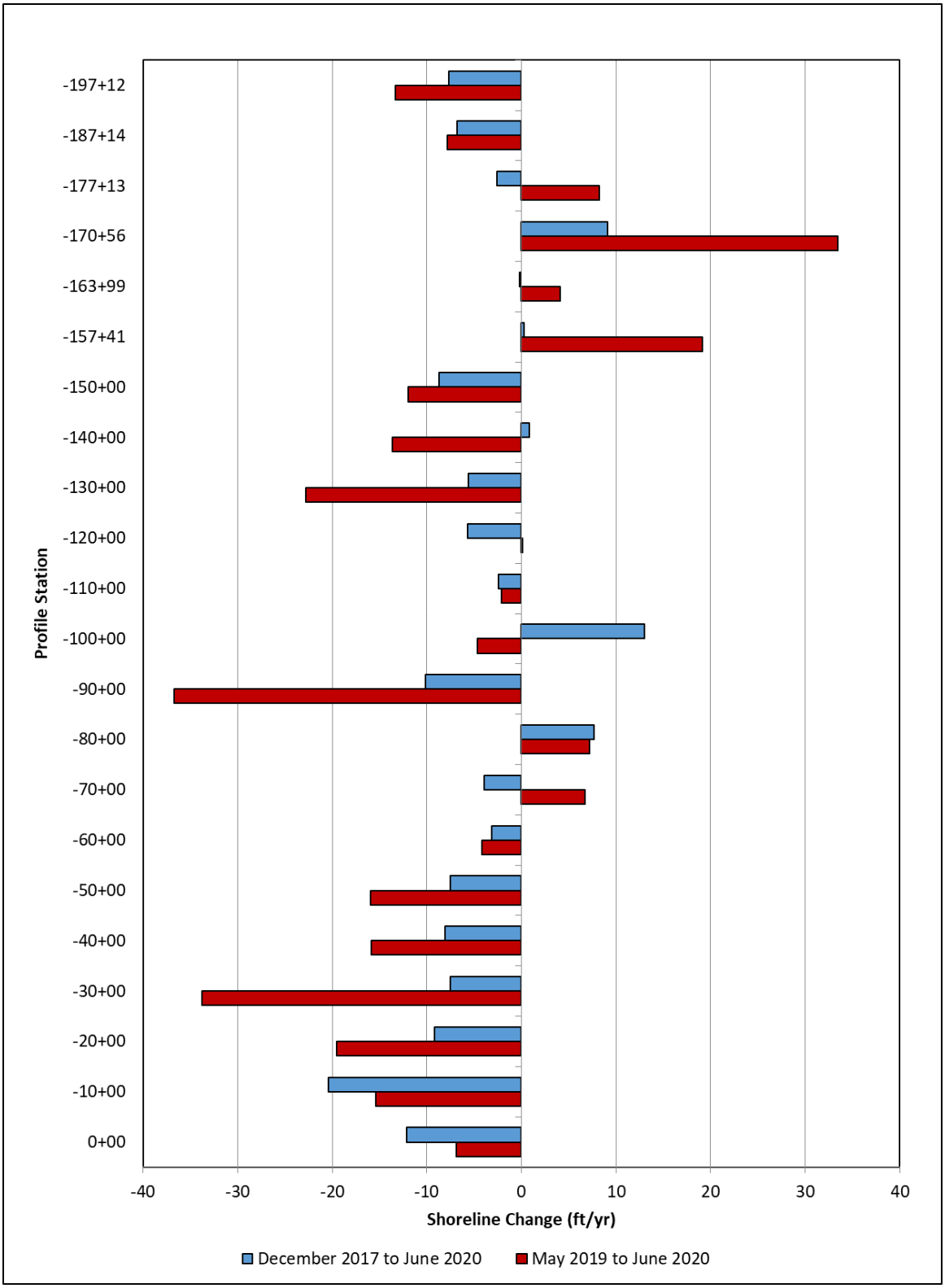

Figure 5. MHW Shoreline Change Rates measured from December 2017 to June 2020 and from May 2019 to June 2020 (FT/YR).

V. USEABLE BEACH WIDTH ANALYSIS

An addendum (Addendum A) to the Beach Management Plan was provided by CPE to the Town on January 29, 2020. Included in the addendum was an analysis of "useable beach". In order to define the term "useable beach", the profile plots were evaluated to determine representative elevation contours that would represent the "dry sand beach". Based on this examination, the +12.0 ft. NAVD88 contour was used as the landward limit of the "dry sand beach"; whereas the +4.0 ft. NAVD88 contour was used as the seaward limit of the "dry sand beach". Figure 6 shows a beach profile plot for data collected in May 2019 at station -100+00, which is located at Dolphin Run. The orange vertical lines cross the profile at the +12.0 ft. NAVD88 and +4.0 ft. NAVD88 contours and the distance between would be considered the "useable beach".

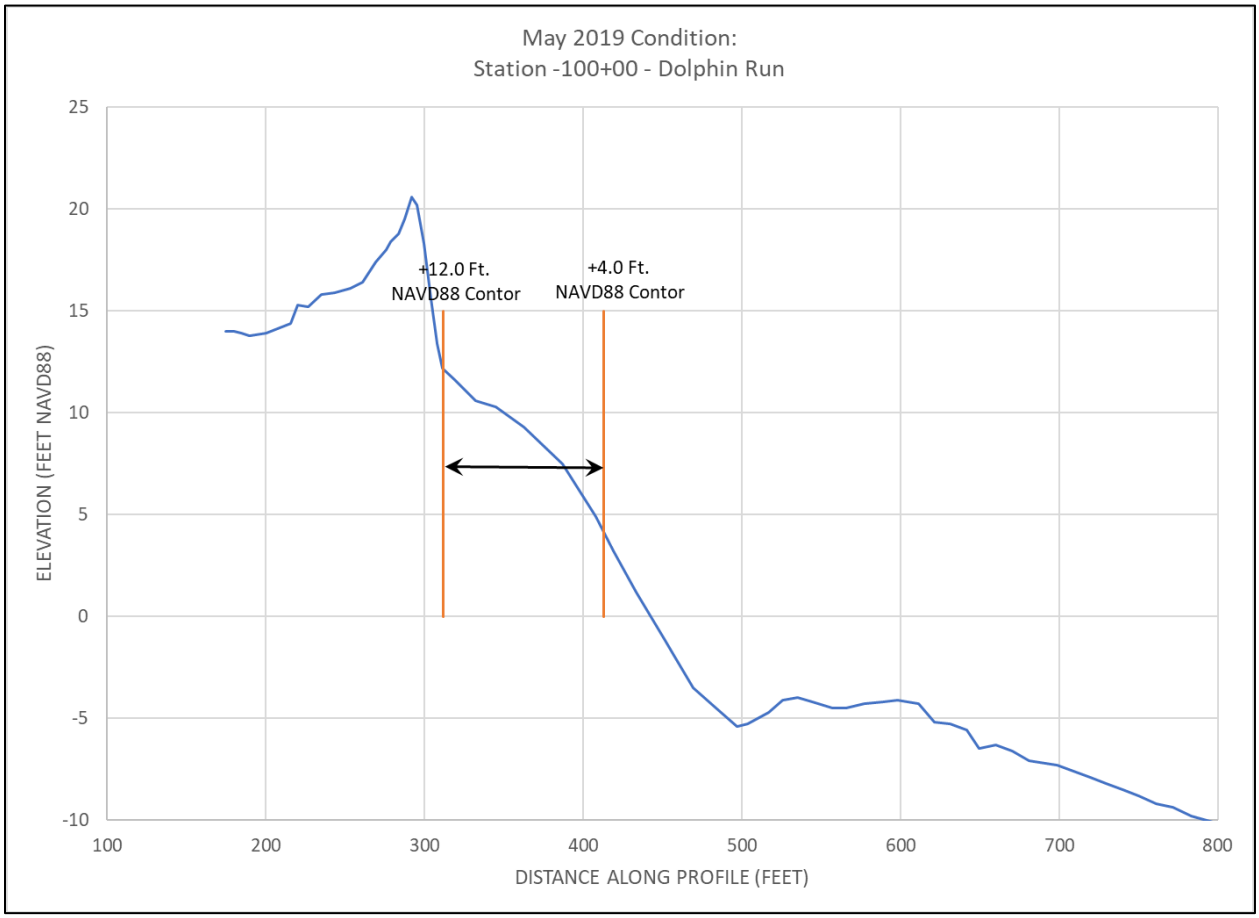

Figure 6. Cross section plot of beach profile data illustrating the defined "useable beach" along Station -100+00 located at Dolphin Run.

Once this term was defined, CPE examined the beach conditions along the Town of Southern Shores south of station -150+00 (located near 3rd Avenue), as well as those portions of Kitty Hawk and Kill Devil Hills that were nourished in 2017 to define what might be considered "sufficient". Average useable beach widths as defined herein were computed along the portion of Southern Shores from 3rd Avenue (station -150+00) south to the southern Town limit (station 0+00) and along the combined portion of Southern Shores, Kitty Hawk, and Kill Devil Hills that received

sand during the 2017 beach nourishment project. This area extends from around Skyline Road (station -20+00) in Southern Shores, south to a point approximately 200 ft. south of the public beach access in Kill Devil Hills at Asheville Street (station 320+00). Based on data collected in May 2019, the average useable beach width along Southern Shores south of 3rd Avenue to the southern Town limit (station 0+00) was 84 ft. The average useable beach width along the portion of Southern Shores, Kitty Hawk, and Kill Devil Hills, where sand was placed in 2017, was 103 ft., as measured in May 2019. These values, which were provided for general comparison purposes, are shown in Table 3.

Table 3. Comparison of the average useable beach width computed for various portions of Southern Shores, Kitty Hawk, and Kill Devil Hills in May 2019 and June 2020.

Beach Section	Profile Stations	May 2019 Average Useable Beach Width	June 2020 Average Useable Beach Width
Town of Southern Shores from 3rd Avenue South to Southern Town Limit	-150+00 to 0+00	84	69
2017 Sand Placement Area (Skyline Road to Asheville Street)	-20+00 to 320+05	103	87
Northern Section of Southern Shores from 5th Avenue North to Northern Town Limit	-197+12 to -157+41	57	69

Using the June 2020 beach profile data, beach width (as previously defined) was calculated along the same portions of the Town of Southern Shores and the 2017 beach nourishment project. Table 3 includes a comparison of the average useable beach width in May 2019 and June 2020. The average beach width along the portion of the Town south of 3rd Ave decreased from 84 feet to 69 feet. Furthermore, the average useable beach throughout the entire area nourished in Southern Shores, Kitty Hawk, and Kill Devil Hills in 2017, decreased from 103 feet in May 2019 to 87 feet in June 2020. The useable beach width along the Town's oceanfront north of 5th Ave., increased from 57 feet to 69 feet between May 2019 and June 2020.

Table 4 includes the individual measured beach width at each profile as well as the overall average and averages for the Northern, Central, and Southern Areas. The beach width in both the Central and Southern Areas have decreased between May 2019 and June 2020; however, the beach width along the Northern Area increased between May 2019 and June 2020 by an average of approximately 9 feet. Figure 7 shows a graphical comparison of the beach width calculated along the Town's oceanfront in May 2019 and June 2020.

Table 4. Useable Beach Width based on May 2019 and June 2020 profile data.

PROFILE	October 2006 Beach Width (LF)	September 2013 Beach Width (LF)	May 2019 Beach Width (LF)	June 2020 Beach Width (LF)
-197+12		65	76	68
-187+14		68	50	61
-177+13		64	50	66
-170+56			56	81
-163+99			61	69
-157+41			49	69
-150+00	90		63	54
-140+00	58		84	72
-130+00	81		81	66
-120+00	102		54	63
-110+00	102		62	60
-100+00	80		100	78
-90+00	91		91	58
-80+00	84		103	92
-70+00	100		56	61
-60+00	70		65	61
-50+00	58		81	62
-40+00	61		75	56
-30+00	85		99	54
-20+00	115		105	76
-10+00	60		120	96
0+00	63		102	92
OVERALL AVERAGE	81	66	76	69
NORTHERN AREA (-197+12 to -150+00)	N/A	N/A	58	67
CENTRAL AREA (-150+00 to -50+00)	83	N/A	76	66
SOUTHERN AREA (-50+00 to 0+00)	74	N/A	97	73

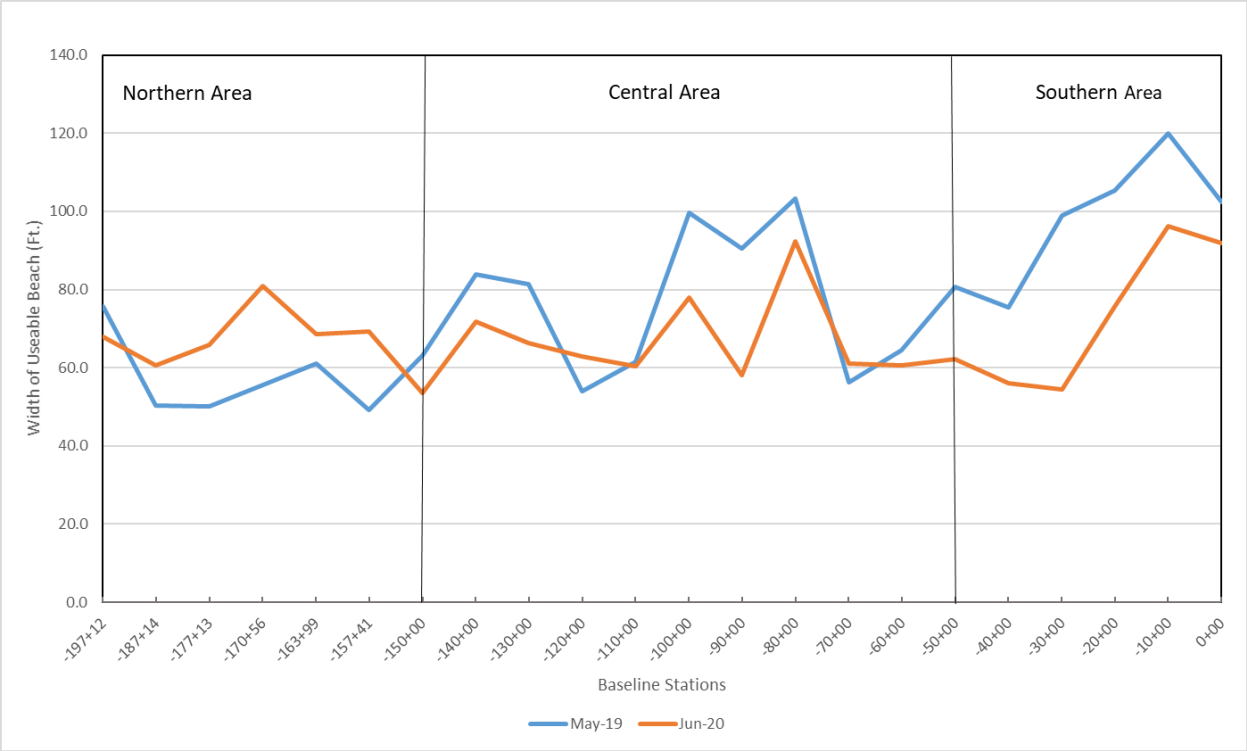

Figure 7. Graph showing the useable beach width measured along Southern Shores in May 2019 and June 2020.

VI. VOLUMETRIC CHANGE ANALYSIS

Sand on the beach is distributed by wind and wave action over the entire active profile (from the dunes/vegetation out to the depth of closure). The dry beach often observed above the water represents only a fraction of the active beach profile. Therefore, the volume of sand measured on the entire profile is an important parameter to track in an effort to gauge the sediment budget, the health of the beach, and the performance of nourishment projects. The volume of sand in place is the metric that defines the three-dimensional beach, which provides storm protection. Volumetric changes are measured cross-shore along the entirety of the profile from the depth of closure (-24 feet NAVD88 contour) to the most landward point at which overlapping data exists. To illustrate this concept, Figure 8 shows the same two profiles shown in Figure 3 with areas between the profiles color-coded to show volumetric gains (green-accretion) and volumetric losses (red-erosion) along the profile. The net difference between these volumetric gains and losses is referred to as volumetric change.

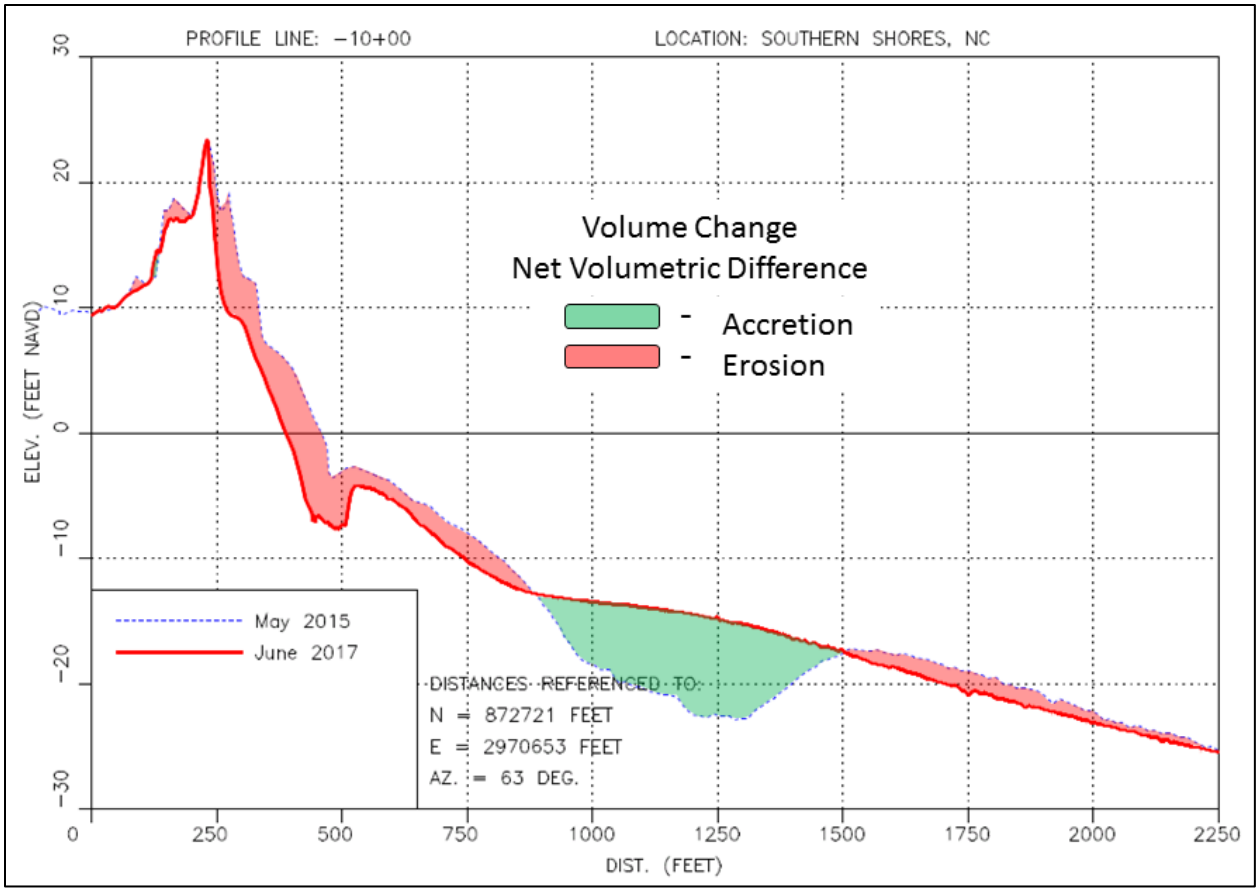

Figure 8. Beach profile cross section illustrating volume change.

All volumetric changes measured along a profile or averaged along multiple profiles are provided in terms of cubic yards per linear foot (cy/lf). At times, this report also provides total volume in cubic yards measured between certain profiles. These volumes are computed using the average end area method; whereby the average volumetric change between adjacent profiles is multiplied by the distance between stations. Volumetric change rates are given in cubic yards per linear foot of shoreline per year (cy/lf/yr.).

This report provides volumetric changes measured between the same data sets used to report shoreline changes. Volumetric changes and rates were computed along each profile between December 2017 and June 2020, as well as over the 13-month period between May 2019 and June 2020. The long-term change rates previously reported were updated based on the June 2020 data. Given the geographic limits of various historic data sets, long-term rates were calculated along the southern 15,000 feet of the Town south of 3rd Avenue (station -150+00 to 0+00) for the 13.7-year period between October 2006 and June 2020. Along the northern 2,000 feet of the Town from 9th Avenue north (station -197+12 to -177+13), the long-term rates and values were measured from September 2013 to June 2020. Table 5 includes rates calculated for each of the periods and along each of the profiles. Average rates for the entire Southern Shores oceanfront as well as the Northern, Central, and Southern Areas are also provided.

The average volumetric change measured over the 2.5-year period between the initial Town-wide monitoring survey (station -197+12 to station 0+00), conducted in December 2017, and the most recent data, collected in June 2020, was -4.4 cy/lf. This equates to a volumetric change rate of -1.7 cy/lf/yr. The volumetric changes measured along the three (3) distinct Areas of the Town varied considerably. In the Northern Area (stations -197+12 to -150+00), the average volume change rate over the 2.5-year period was a positive +6.1 cy/lf/yr. Of the seven (7) profiles included along the Northern Area, all but one (1) experienced positive volumetric changes as shown in Table 5. The average volume change rate along the Central Area (stations -150+00 to -50+00) was -0.3 cy/lf/yr. The relatively low average rate is a factor of having both positive and negative volumetric changes occurring within this Area. Primarily negative volumetric changes were measured between stations -150+00 and -120+00 (from 3rd Ave to the southern boundary of the property at 226 Ocean Blvd), and likewise between station -60+00 and -50+00 (approximately 600 feet north of Chicahauk Trail to 450 feet south of Chicahauk Trail. In the central portion of the Central Area between stations -110+00 and -70+00 (approximately 330 feet south of E. Dogwood Trail to approximately 500 feet south of where Ocean Blvd. and Duck Rd. meet), positive volumetric changes were measured along each of the five (5) beach profiles (Table 5). The Southern Area (stations -50+00 to 0+00) experienced the greatest negative volumetric changes. The average volumetric change measured along these six (6) beach profiles over the 2.5-year period was -38.3 cy/lf, which equates to a rate of -15.3 cy/lf/yr. Rates along the Southern Area ranged from -8.2 cy/lf/yr. at station 0+00 to -20.8 cy/lf/yr. at station -20+00 located approximately 150 feet south of Skyline Road (Table 5). The area in which beach fill was placed in 2017, (Stations 0+00 to -20+00) experienced some of the greatest negative volumetric changes during this 2.5-year period, averaging -40.5 cy/lf or -16.2 cy/lf/yr.

Table 6 provides the total volumetric change, and volumetric change measured between each adjacent set of beach profiles, measured over the 2.5-year period between December 2017 and June 2020. During this period, a net total volumetric change of -117,700 cy was measured along the Town's oceanfront beach. The Northern Area and Central Area had net positive volumetric changes of 75,700 cy and 8,700 cy, respectively. A negative volumetric change of -202,100 cy was measured along the Southern Area, including a negative volumetric change of approximately -110,100 cy along the southern 2,500 feet of the Town where beach fill was placed during the 2017 project.

Table 5. Volume Change Rates (CY/LF/YR) measured above -24 ft. NAVD88.

PROFILE	Oct. 2006 to June 2020 (CY/LF/YR)	Sep. 2013 to June 2020 (CY/LF/YR)	Dec. 2017 to June 2020 (CY/LF/YR)	May 2019 to June 2020 (CY/LF/YR)
-197+12	--	0.8	1.3	-17.2
-187+14	--	-0.7	2.3	16.5
-177+13	--	-0.8	2.3	-21.8
-170+56	--	--	17.3	41.7
-163+99	--	--	2.1	-11.7
-157+41	--	--	18.8	50.0
-150+00	2.9	--	-1.2	-8.4
-140+00	8.2	--	13.4	20.2
-130+00	2.3	--	-10.1	-56.2
-120+00	0.7	--	-8.8	-19.3
-110+00	2.4	--	4.1	-1.1
-100+00	2.1	--	6.7	-6.2
-90+00	0.9	--	1.8	-9.9
-80+00	4.3	--	3.7	37.0
-70+00	0.6	--	0.5	-4.5
-60+00	1.5	--	-0.6	-10.0
-50+00	3.7	--	-13.2	-16.8
-40+00	1.3	--	-11.3	8.6
-30+00	-1.8	--	-18.8	-35.6
-20+00	-2.7	--	-20.8	-8.3
-10+00	1.2	--	-19.6	2.3
0+00	-0.3	--	-8.2	-14.1
TOTAL AVERAGE	1.7	-0.2	-1.7	-2.9
NORTHERN AREA (-197+12 to -150+00)	N/A	N/A	6.1	7.0
CENTRAL AREA (-150+00 to -50+00)	2.7	N/A	-0.3	-6.8
SOUTHERN AREA (-50+00 to 0+00)	0.3	N/A	-15.3	-10.6

Table 6. Volumetric Change (CY) between December 2017 and June 2020 and between May 2019 and June 2020, above -24 ft. NAVD88.

PROFILE			Dec. 2017 to June 2020 (CY)	May 2019 to June 2020 (CY)
-197+12	to	-187+14	4,400	-400
-187+14	to	-177+13	5,700	-2,900
-177+13	to	-170+56	16,100	7,100
-170+56	to	-163+99	16,000	10,700
-163+99	to	-157+41	17,200	13,700
-157+41	to	-150+00	16,300	16,800
-150+00	to	-140+00	15,200	6,400
-140+00	to	-130+00	4,100	-19,600
-130+00	to	-120+00	-23,700	-41,100
-120+00	to	-110+00	-5,900	-11,100
-110+00	to	-100+00	13,600	-4,000
-100+00	to	-90+00	10,700	-8,800
-90+00	to	-80+00	6,900	14,700
-80+00	to	-70+00	5,200	17,600
-70+00	to	-60+00	-100	-7,900
-60+00	to	-50+00	-17,300	-14,600
-50+00	to	-40+00	-27,300	-4,000
-40+00	to	-30+00	-39,900	-15,600
-30+00	to	-20+00	-49,600	-23,900
-20+00	to	-10+00	-50,500	-3,200
-10+00	to	0+00	-34,800	-6,400
TOTAL VOLUMETRIC CHANGE			-117,700	-76,500
NORTHERN AREA (-197+12 to -150+00)			75,700	45,000
CENTRAL AREA (-150+00 to -50+00)			8,700	-68,400
SOUTHERN AREA (-50+00 to 0+00)			-202,100	-53,100

Over the 13-month period between May 2019 and June 2020, an average volumetric change of -3.2 cy/lf was measured along the Town's oceanfront. This equates to an average volumetric change rate of -2.9 cy/lf/yr. The volumetric changes measured along the Northern and Southern Areas of the Town followed similar trends as observed over the 2.5-year period from December 2017 to June 2020. In the Northern Area (stations -197+12 to -150+00), the average volume change rate over the 13-month period was a positive +7.0 cy/lf/yr. Although the overall average along the Northern Area was positive, considerably more variation was observed along the seven (7) profiles in the Area as seen in Table 5. Rates measured along the Northern Area ranged from

+41.7 cy/lf/yr. at station -170+56 (8th Avenue) to -21.2 cy/lf/yr. at station -177+13 (approximately 200 feet south of 9th Avenue). The Southern Area (stations -50+00 to 0+00) experienced the greatest negative volumetric changes. The average volumetric change measured along these six (6) beach profiles over the 13-month period was -11.6 cy/lf, which equates to a rate of -10.6 cy/lf/yr. Although the Southern Area saw the highest average negative volume changes, positive volume changes were measured along station -40+00 (northern boundary of the property at 72 Ocean Blvd.) and -10+00 (approximately 300 feet north of Pelican Watch Way). The other four profiles ranged from -8.3 cy/lf/yr. to -35.6 cy/lf/yr. (Table 5). The area in which beach fill was placed in 2017, (stations 0+00 to -20+00) experienced less of a negative volumetric change on average than the overall average of the Southern Area. Over the 13-month period, this particular area averaged a rate of -6.7 cy/lf/yr. compared to -10.6 cy/lf/yr. for the entire Southern Area.

Along the Central Area (stations -150+00 to -50+00), the average volume change rate was -6.8 cy/lf/yr. over the 13-month period. This is considerably higher than the rate measured over the 2.5-year period from December 2017 to June 2020. With the exception of the profiles at station -140+00 (located approximately 200 feet south of 1st Avenue) and station -80+00 (located near the beach access at the south end of Ocean Blvd.), negative volumetric changes were measured along each profile along the Central Area (Table 5). These negative volumetric change rates ranged from -1.1 cy/lf/yr. at station -110+00 (approximately 330 feet south of E. Dogwood Trail) to -56.2 cy/lf/yr. at station -130+00 (approximately 25 feet north of Sandpiper Ln.).

Table 6 provides the total volumetric change, and volumetric change measured between each adjacent set of beach profiles, over the 13-month period between May 2019 and June 2020. During this period, a net total volumetric change of approximately -76,500 cy was measured along the Town's oceanfront beach. The Northern Area had net positive volumetric change of approximately 45,000 cy. Negative volumetric changes were measured along the Central and Southern Areas of -68,400 cy and -53,100 cy, respectively. Over the 13-month period, a volumetric change of -21,550 cy was measured along the southern 2,500 feet of the Town where beach fill was placed during the 2017 project.

In addition to the volumetric change rates measured between December 2017 and June 2020, Table 5 includes updated long-term volume change rates in those areas where beach profile surveys had been conducted prior to 2017. A profile by profile comparison of the historic volumetric change rates measured between 2006 and 2020 (south of 3rd Avenue), between 2013 and 2020 (northern 2,000 feet of Town), and the rates measured between Dec. 2017 and June 2020, are provided in Figure 9. The average volumetric change rate measured from 3rd Ave. (station -150+00) to the southern Town boundary (station 0+00) over the approximate 13.7-year period was +23.5 cy/lf, or +1.7 cy/lf/yr. An average volumetric change of -1.5 cy/lf (erosion) was measured over the approximate 6.75-year period along those profiles initially surveyed in 2013 by CPE along the northern 2,000 feet of the Town (stations -197+12 through -177+13). This equates to an average volumetric change rate of -0.2 cy/lf/yr.

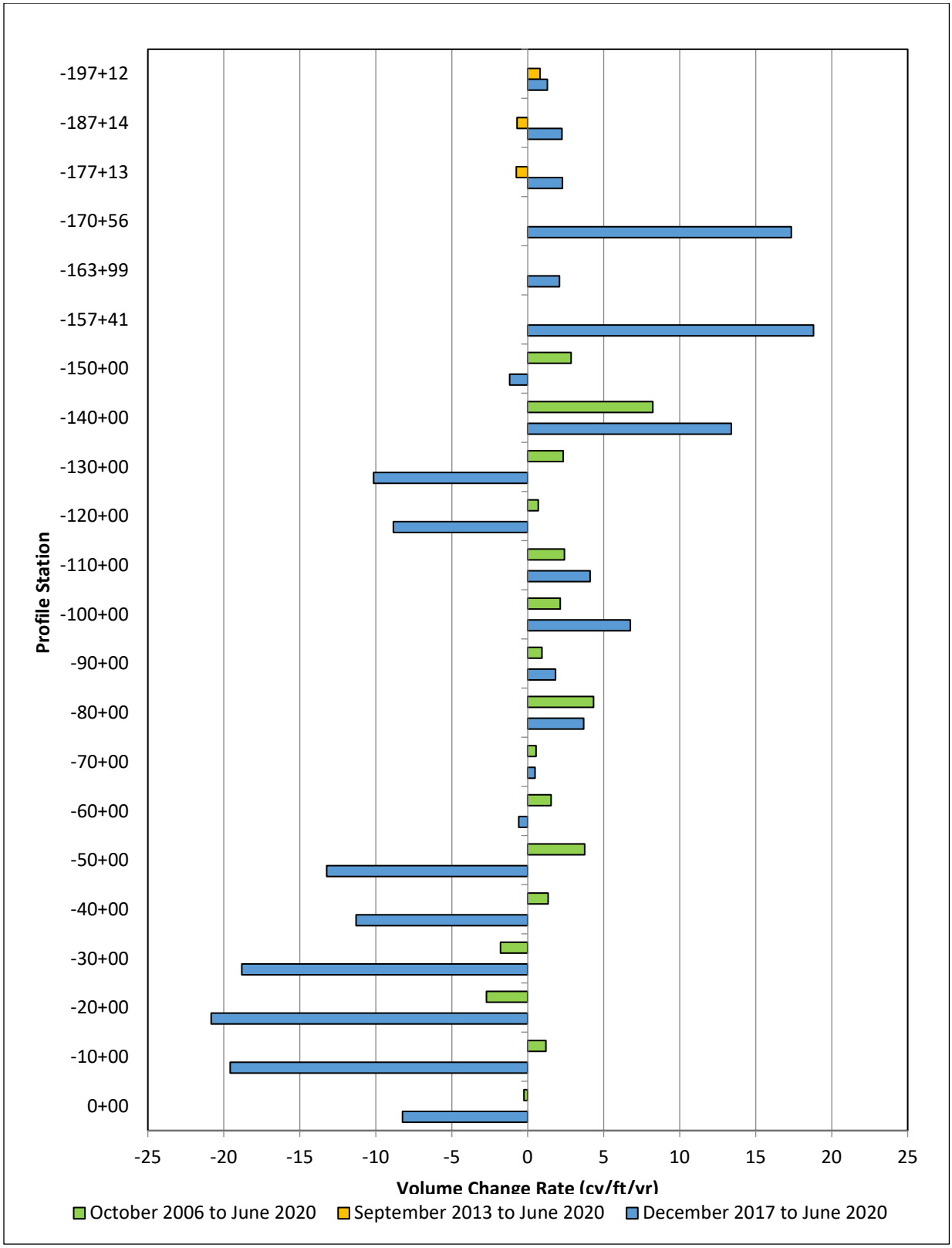

Figure 9. Long-Term Annual Volumetric Change Rate above -24 FT NAVD88 (CY/FT/YR).

VII. VOLUME ENVELOPE ANALYSIS

The total volume measured along each profile was calculated from the +20 ft. NAVD88 contour, on the landward side of the dune, seaward and above the -24 ft. NAVD88 contour at each profile surveyed. This area of the profile is referred to in this report as the volume envelope. Figure 10 shows a cross section of the profile at station -10+00, which graphically depicts the volume envelope. Comparing the volume measured in the volume envelope along the Town's oceanfront allows for the relative comparison of each profile and was used extensively in the development of the beach fill options included in the Beach Management Plan.

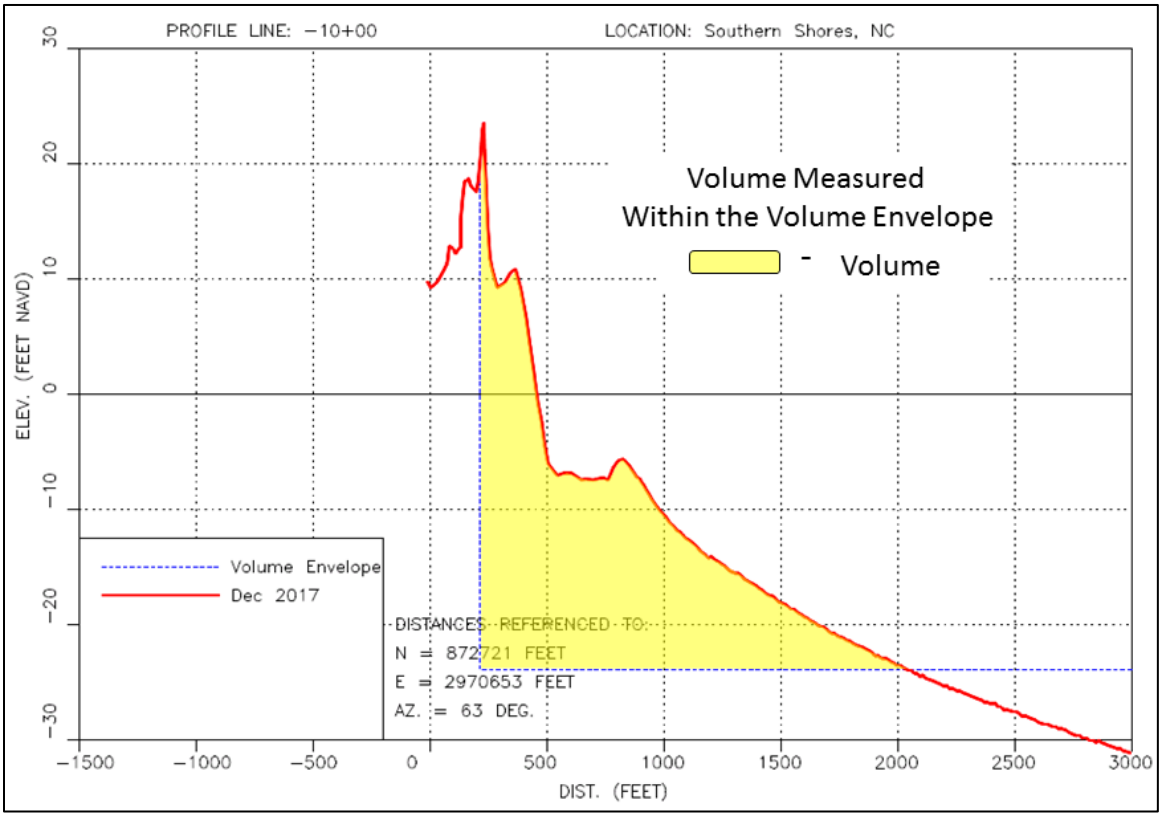

Figure 10. Beach profile cross section illustrating the volume envelope.

The Beach Management Plan (APTIM, 2018B), established a volume envelope density of 846 cy/lf as the design volume needed to protect the beach from a design storm with comparable physical characteristics of Hurricane Isabel using water levels updated to 2018. Figure 11 shows the volume measured within the volume envelope along each of the 22 profiles surveyed in June 2020 along Southern Shores compared to the design volume of 846 cy/lf indicated by the solid red line. The average volume within the envelope measured along all 22 profiles in June 2020 was 826 cy/lf. The average volume envelope density along the Northern Area is 879 cy/lf, which is 33 cy/lf higher than the design volume of 846 cy/lf. The average volume envelope density in the Central and Southern Areas were similar measuring 800 cy/lf and 806 cy/lf, respectively. These averages are 46 cy/lf and 40 cy/lf less than the design volume of 846 cy/lf, respectively.

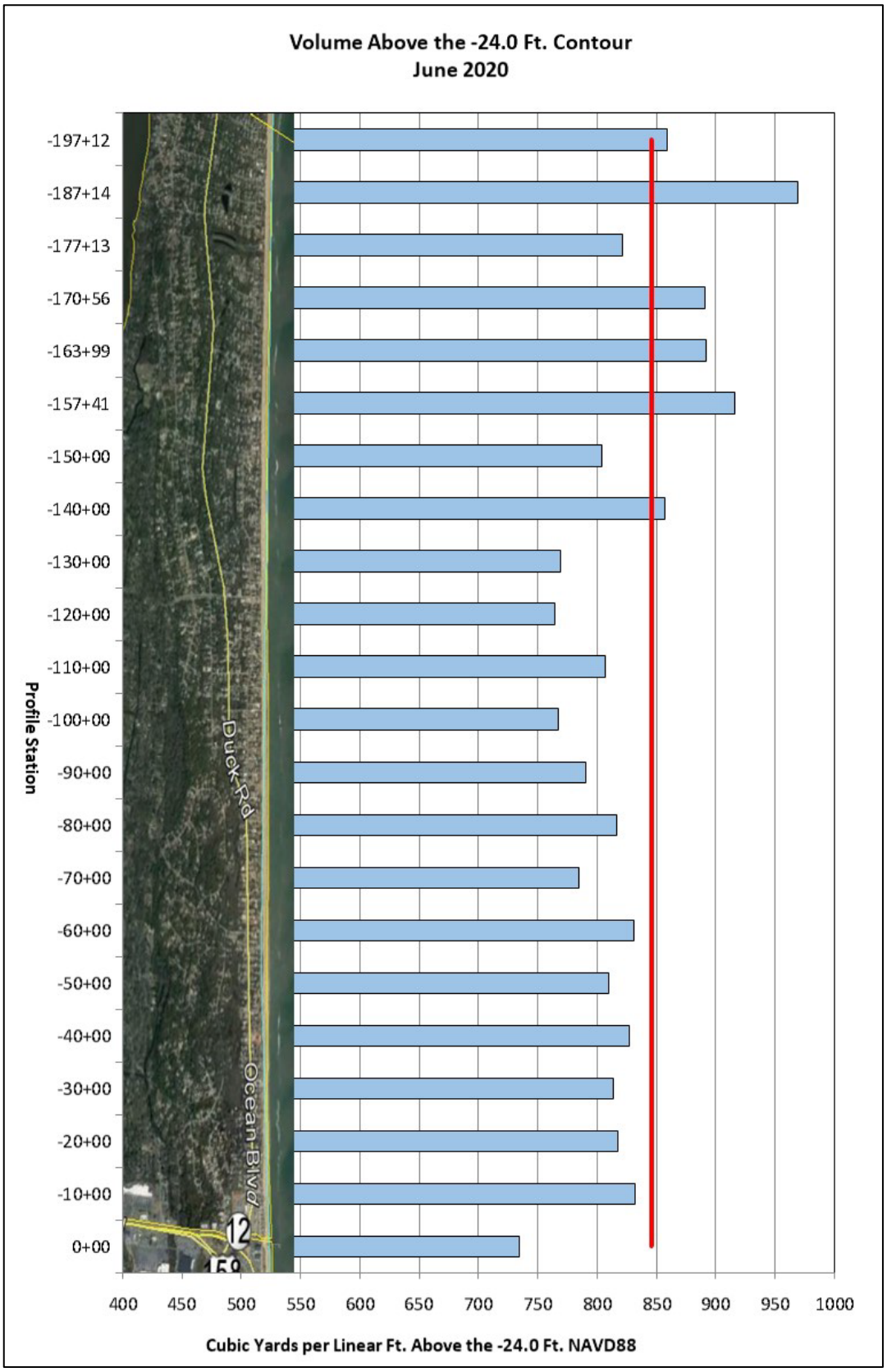

Figure 11. Volume envelope calculations across all Southern Shores profiles.

VIII. DISCUSSION

This monitoring report evaluated shoreline and volumetric changes along the Town of Southern Shores. Data collected in June 2020 was used to update the shoreline and volumetric change rates over long-term and short-term periods based on data availability. The June 2020 data were also used to evaluate useable beach width and in place volume densities (volume envelope).

For monitoring purposes, the Town was divided into three areas: namely, the Northern, Central, and Southern Areas. The Northern Area includes the portion of the Town north of 3rd Avenue, which includes stations -197+12 through -150+00. The Central Areas, previously referred to as the "Main Fill" area in the Beach Management Plan, spans from station -150+00 to -50+00, which is located approximately 450 feet south of Chicahauk Trail. The Southern Area includes the portion of the Town from station -50+00 to 0+00, which is the boundary between the Town of Southern Shores and Kitty Hawk.

Shoreline Change Results

Shoreline change monitoring tracks the location of the MHW (+1.2 ft. NAVD88) contour. Over the 13-month period between the May 2019 and June 2020 data collection, an average annualized shoreline change rate of -6.6 ft./yr. was observed. This rate is higher than the rate of -4.1 ft./yr., which is the average rate measured over the 2.5-year period (Dec. 2017 to June 2020) that CPE has been conducting beach profile surveys along the entire Town.

The Southern Area, which runs from approximately 450 feet south of Chicahauk Trail to the southern Town limit, has had the highest average negative shoreline rate of the three (3) areas. This is the case for both the 2.5-year between December 2017 and June 2020, and the most recent 13-month monitoring period between May 2019 and June 2020. Though each of the six (6) profiles that fall along the Southern Area showed negative shoreline change, the higher rates seem to be driven by shoreline changes that occurred along the three (3) profiles located within the portion of the Town along which beach fill was placed in 2017. However, between May 2019 and June 2020, the highest negative shoreline change rate measured along the Southern Area was measured along station -30+00, which is just outside of where beach fill was placed in 2017. Though shoreline change does not always correlate to volumetric change, in this case, the Southern Area was also found to have the highest negative volumetric changes both over the 2.5-year and 13-month monitoring periods.

The average rates measured throughout the Northern (northern Town Limit to approximately 3rd Ave.) and Central (3rd Avenue to approximately 450 feet south of Chicahauk Trail) Areas over the 2.5-year period between December 2017 and June 2020 were both -2.3 ft./yr. However, over the 13-month period between the last two (2) monitoring events, the average rate measured along the northern area was a positive 4.5 ft./yr., whereas the average rate for the Central Area was -8.9 ft./yr. This is of particular interest given the Northern Area is the area in which concerns have been voiced about the loss of dry sand beach and the generally narrow width of the beach along this portion of the Town.

Useable Beach Width

As previously described, the term "useable beach", as it relates to the monitoring of the Southern Shores beach, was defined as the distance between the +12.0 ft. NAVD88 and +4.0 ft. NAVD88 contours on any given beach profile. In previous assessments, the useable beach width was calculated along the Town of Southern Shores south of station -150+00 (located near 3rd Avenue), to determine an average useable beach width along this portion of the Town's beach. Based on data collected in May 2019, the average useable beach width along Southern Shores, south of 3rd Avenue, was 84 ft.

The catalyst for conducting this analysis was feedback provided to CPE by the Town in 2019 suggesting the area from the northern Town limit to approximately 5th Avenue (station 197+12 to 157+41) was an area in which the useable beach was insufficient. In May 2019, the average useable beach width along this portion of the Town's oceanfront was 57 ft. This width was compared to the average width measured along the Central and Southern Areas, which was determined to be 84 ft. A beach fill option was designed by CPE and provided in the 2020 Addendum to the Beach Maintenance Plan, which estimated the volume of sand needed to widen the beach sufficiently to achieve an 84 ft. useable beach width along the portion of the Town north of 5th Avenue.

A review of the June 2020 data shows that the area from the northern Town Limit to approximately 5th Avenue (station 197+12 to 157+41) has seen a gain in the average beach width from 57 feet in May 2019 to 69 feet in June 2020, which is an approximate 12 ft increase in average beach width over the 13-month period. Coincidentally, the average useable beach width measured along the Central and Southern Area using the June 2020 data, was also 69 feet.

Volume Change Results

As has been discussed previously, tracking the position of a particular shoreline contour over time can provide general information on the trend of the changes occurring along a beach, but shoreline contours can be highly dependent on sea conditions that occurred immediately prior to or during data acquisition. Volumetric changes derived from repeated beach profile surveys are typically a more reliable method of tracking the changes taking place along a beach. The overall average volumetric change rate, computed along the Town of Southern Shores over the 2.5-year period CPE has been conducting beach profile surveys along the Town (December 2017 to June 2020), was -1.7 cy/lf/yr. The overall average rate would be considered manageable over the long term with regards to beach nourishment. The average rate over the 13-month period between May 2019 and June 2020 was -2.9 cy/lf/yr., which is slightly higher than the rate measured over the 2.5-year period.

Although the overall average rates along the Town are manageable, there are considerable differences in the measured rates with respect to the Northern, Central and Southern Areas. Similarly, to the shoreline change trends discussed previously, the trend in volumetric change rates measured along the Southern Area were similar to the shoreline change trends previously discussed. In that regard, volumetric changes along the Southern Area indicated the highest erosion rates. Over the 2.5-year period, between December 2017 and June 2020, the average

volumetric change rate for the Southern Area was measured to be -15.3 cy/lf/yr., resulting in a measured volumetric change of approximately -202,100 cy. This includes baseline stations -20+00 through 0+00, along which beach fill was placed as part of the 2017 project. The average rate measured along this particular portion of the Southern Area was -16.4 cy/lf/yr. The volumetric change rate over the 13-month period between May 2019 and June 2020 along the Southern Area (stations -50+00 to 0+00) was -10.6 cy/lf/yr., or a measured volumetric change of -53,100 cy.

Along the Central Area, the rate over the 2.5-year period was -0.3 cy/lf/yr., which essentially suggests no net volumetric change along this 10,000-foot stretch of beach. However, over the 13-month period between May 2019 and June 2020, the measured volumetric change rate averaged -6.8 cy/lf/yr. This rate appears to be strongly influenced by the volumetric loss measured along station -130+00, which was calculated to be equivalent to an annualized rate of -56.2 cy/lf/yr. A closer examination of the profile data for this particular station indicates that between December 2017 and May 2019, this station experienced volumetric changes equivalent to +25.3 cy/lf/yr., which was considerably higher than the overall average for the Central Area of +4.6 cy/lf/yr. The large negative volumetric change observed between May 2019 and June 2020 may have been a compensation for the uncharacteristically large buildup of volume on the profile between December 2017 and May 2019.

The overall average volumetric change rate along both the Central and Southern Areas (Town oceanfront south of 3rd Ave.), measured between December 2017 and June 2020 was -5.2 cy/lf/yr. This is significant because the rate of volumetric change measured along this section (Central and Southern Areas) between December 2017 and May 2019 was used to determine the background erosion rate used to compute the "advanced fill" volume for the proposed beach fill options. Advanced fill is the volume of sand estimated to account for typical background erosion that will take place between beach nourishment intervals. This is in excess of the "design volume", which is the volume required to achieve a stated design level of protection. The *2019 Beach Assessment Report* (APTIM, 2019) used a volumetric change rate of -3 cy/lf/yr. to determine advanced fill. The increase in the rate from -3 cy/lf/yr. to -5.2 cy/lf/yr., would require additional material for the construction of a beach fill project along the Towns oceanfront. Currently, CPE is evaluating beach fill alternatives using a combination of these monitoring results and a numerical model used to simulate beach fill performance. Results of these analyses will be used to recommend optimal beach fill densities for the proposed 2022 project.

Between December 2017 and June 2020, the Northern Area experienced net volumetric increases. The average rate along this portion of the Town between the northern Town limit and 3rd Avenue, was +6.1 cy/lf/yr. The net volumetric increase measured over this 2.5-year period was 75,700 cy. Positive volumetric changes were measured along each profile located north of 5th Avenue over this same period. Between May 2019 and June 2020, the average volumetric change rate along the Northern Area was also positive (7.0 cy/lf/yr.); however, a pattern of gains on one profile with losses on the adjacent profile is evident in the results provided in Table 5. The vulnerability analyses completed for the Town of Southern shores suggested the volume density within the Volume Envelope along the Northern Area would provide sufficient storm damage reduction for the design storm, which was a storm similar in characteristics to Hurricane Isabel, which impacted the area in 2003 (APTIM, 2019). The volumetric increases measured along the Northern Area,

suggests the storm damage reduction along this portion of the Town has been increased over the past 2.5-years.

Volume Envelope Results

The total volume measured along each profile above the -24 ft. NAVD88 contour and seaward of the +20 ft. NAVD88 contour on the landward side of the dune is referred to as the volume envelope. Previous analyses have established a volume envelope density of 846 cy/lf as the design volume needed within the volume envelope to provide sufficient storm damage reduction for a storm with comparable physical characteristics of Hurricane Isabel. The *2019 Beach Assessment Report* (APTIM, 2019) indicated that the average density within the volume envelope along the Central Area and Southern Areas was less than 846 cy/lf, based on May 2019 data. Therefore, beach fill was recommended along this portion of the Town to achieve a sufficient level of storm damage reduction. As has been discussed in this report, negative volumetric changes were measured on average in the Central and Southern Areas between May 2019 and June 2020. Therefore, more material may be required to establish the design level of protection within the Central and Southern Areas. CPE is currently conducting design level analysis using both cross shore storm modeling (SBEACH) and a 3-d morphology numerical model (Delft3D), to update recommendations on beach fill configuration.

In the Northern Area, the *2019 Beach Assessment Report* found that the average volume envelope density along this section of beach was in excess of the 846 cy/lf established design density. As has been discussed in this report, positive volumetric changes were measured on average in the Northern Area between May 2019 and June 2020. The average volume envelope density along the Northern Area, as of June 2020, was approximately 33 cy/lf higher than the design density of 846 cy/lf.

IX. RECOMMENDATIONS

Regular monitoring of beaches is instrumental for the Town to evaluate both past project performance and to establish baseline rates of change for long-term beach management. The frequent repeating of surveys is pivotal to the adaptive management strategy that must be part of the successful long-term maintenance of a beach management program. CPE recommends that the Town continue monitoring the oceanfront project area in 2021. Not only will the survey allow for updating of the project design, but it will also serve as the survey used to develop construction documents to bid the proposed project. The monitoring surveys should be conducted in the same timeframes from year to year to mitigate the influence of seasonal differences.

CPE continues to develop updated recommendations for the beach fill configuration. The Town of Southern Shores should continue to provide feedback to CPE during the design process regarding the Town's overall goals for the project. As described in this report, sufficient volume may be in place in the Northern Area to provide sufficient storm damage reduction for the design storm. However, the Town has also expressed concerns about the width of "useable beach" along the Northern Area. As described in this report, the useable width measured in June 2020 along the portion of the Town north of 5th Avenue, was approximately 12 feet wider on average than the width measured in May 2019.

X. REFERENCES

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