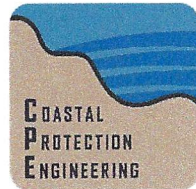


**TOWN OF DUCK NORTH CAROLINA  
2025 SHORELINE & VOLUME CHANGE  
MONITORING REPORT**

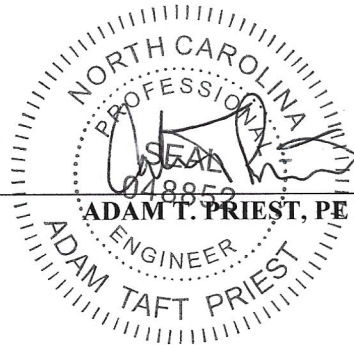


**SUBMITTED TO:  
TOWN OF DUCK**

**SUBMITTED BY:**



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



**ADAM T. PRIEST, PE NO. 048852**

12/17/25

**DATE**

**November 2025**

## EXECUTIVE SUMMARY

The Town of Duck has implemented a long-term beach management program to sustain the beaches that support a significant portion of their local economy and maintains the tax base of the Town. In May and June 2017, the Town constructed its initial beach nourishment project that placed approximately 1.26 million cubic yards of fill along 1.6 miles of oceanfront between Skimmer Way (station D-10) and the northern boundary of the USACE Field Research Facility (FRF) property (station D-19). Between April and May 2023, the Town constructed the first maintenance of the beach nourishment project along the same area nourished in 2017, placing approximately 576,800 cubic yards of fill.

As part of its long-term beach management program, the Town has implemented an annual monitoring program to assess both the performance of the beach renourishment project and to track the overall health of the beach along the entire Town. The annual monitoring focuses on analyzing shoreline and volume changes. The beach is divided into three areas designated as the Central Reach Project Area (station D-10 to D-19); the North Monitoring Area (D-01 to D-10), which extends south from the Town limit to Skimmer Way; and the South Monitoring Area (D-19 to D-34), which extends from the northern boundary of the FRF property south to the Town boundary with Southern Shores.

### Shoreline Change:

A shoreline change analysis was completed to assess shoreline advance and recession along the Central Reach Project Area and both North and South Monitoring Areas. The contour used to monitor shoreline change throughout the Town of Duck is the +6.0 ft. NAVD88 contour, which is the design berm elevation used when the nourishment projects are constructed.

The following table summarizes the average shoreline change rates (ft./yr) in the position of the +6.0 ft. NAVD88 contour measured between the recent and long-term periods used to evaluate the Central Reach Project Area and North and South Monitoring Areas. Average shoreline change rates are shown for the periods from September 2013 to June 2025, which represents long-term changes that include the construction of the 2023 beach nourishment project, May 2023 (Post-construction) to June 2025 (changes since project construction), and June 2024 to June 2025 (recent changes).

**Table ES-1  
Summary of Average Shoreline Change Rates (ft./yr.) Measured Along the Town of Duck.**

MONITORING AREAS	Sept. 2013 (Baseline) to June 2025 (Year-2)	May 2023 (Post-Con) to June 2025 (Year-2)	June 2024 (Year-1) to June 2025 (Year-2)
<b>NORTH MONITORING AREA</b> (D-01 TO D-10)	-0.5	4.7	13.1
<b>CENTRAL REACH PROJECT AREA</b> (D-10 TO D-19)	2.9	-57.6	-48.5
<b>SOUTH MONITORING AREA</b> (D-19 TO D-34)	-0.3	-0.5	-18.8

The longest timeframe extends from the September 2013 survey to the most recent survey (June 2025). This period is most applicable to tracking long-term shoreline change in the North and South Monitoring Areas where no nourishment has been implemented. As shown in Table ES-1, the average long-term rates in the North Monitoring Area (-0.5 ft./yr.) and South Monitoring Area (-0.3 ft./yr.) have been relatively

stable over the approximately 11.75-year period. Over the long-term, the Central Reach Project Area had a positive rate of 2.9 ft./yr, which is indicative of the construction of the beach fill projects in 2017 and 2023.

The second timeframe extends from May 2023 to June 2025, which represents the time since the construction of the 2023 beach renourishment project. This period represents the performance of the 2023 project over the first 2 years following the 2023 maintenance event. As shown in Table ES-1, the average shoreline change rate measured along the Central Reach Project Area during this period between the 2023 and the 2025 surveys was -57.6 ft./yr. While this period represents project performance in the first two years since construction it is not uncommon to see higher rates of shoreline change over the first few years of a project due to the concept of equilibration of the fill. Future monitoring data will provide a more representative rate of shoreline change as it relates to project performance.

The third timeframe extends from June 2024 to June 2025 and represents the shoreline changes measured over the most recent 12-month period of monitoring. The average rates listed in Table ES-1 suggest a positive rate in the North Monitoring Area, a high negative rate in the Central Reach Project Area, and a negative rate in the South Monitoring Area. In the North Monitoring Area, the rate was positive compared to the slightly negative rate measured in the previous monitoring year. Additionally, the trend in the South Monitoring reversed, with a negative rate this year compared to last year’s positive rate. The consistent relatively high rate of negative shoreline change measured along the Central Reach Area is primarily associated with the post-construction equilibration of the beach fill placed in May 2023.


**Volume Change:**

In addition to the shoreline change analysis, volumetric change analyses were also conducted along the Town of Duck oceanfront. Volumetric change was evaluated using the same three timeframes and the same three Monitoring Areas of the Town as those used in the shoreline change analysis. Volumetric change and volumetric change rates are computed based on the volumetric change measured along each beach profile survey transect out to a depth of -24 feet NAVD88. Average volumetric change rates calculated (cubic yards/ft./year) for the North Monitoring Area, Central Reach Project Area, and South Monitoring Area are provided in Table ES-2.

**Table ES-2  
Summary of Average Volumetric Change Rates (cy/ft./yr.) Measured along the Town of Duck.**

MONITORING AREAS	Sept. 2013 (Baseline) to June 2025 (Year-2)	May 2023 (Post-Con) to June 2025 (Year-2)	June 2024 (Year-1) to June 2025 (Year-2)
<b>NORTH MONITORING AREA</b> (D-01 TO D-10)	1.9	7.7	6.6
<b>CENTRAL REACH PROJECT AREA</b> (D-10 TO D-19)	8.9	-11.4	-21.7
<b>SOUTH MONITORING AREA</b> (D-19 TO D-34)	3.4	7.7	6.8

**Central Reach Project Area:** The long-term average volumetric change rate, covering the period from September 2013 to June 2025 and reported in Table ES-2, indicates a positive rate of 8.9 cy/ft./yr. This positive rate is indicative of the benefits of the 2017 and 2023 beach nourishment projects on the Central Reach Project Area. The 2023 beach nourishment project placed a total of 576,800 cubic yards of fill along



the Duck shoreline between stations D-10 and D-19 (Central Reach Project Area). Approximately 870,000 more cubic yards of sand were measured within the Central Reach Project Area in June 2025 than were measured at the time of the baseline survey conducted in September 2013, prior to any nourishment.

A rate of -12.3 cy/ft./yr. was measured between December 2017 and January 2023, which represents the performance of the 2017 beach nourishment project over an approximate 5-year interval (CPE, 2024). As shown in Table ES-2, a rate of -11.4 cy/ft./yr. was measured between May 2023 and June 2025, which represents the 2-year rate of performance of the 2023 beach nourishment project. The desired outcome is that the 2023 project will continue to outperform the 2017 beach nourishment project. This is expected due in part to the optimized beach fill design developed for the 2023 beach nourishment project, as well as the often-seen trend of erosion rates stabilizing after multiple nourishment cycles.


As shown in Table ES-2, the rate measured from June 2024 to June 2025 was -21.7 cy/ft./yr., representing a loss of approximately 180,000 cy during the most recent monitoring year. Adding this to the volume loss recorded between May 2023 and June 2024 (approx. -23,300 cy) shows that, 25 months after completion, the Central Reach Project Area has retained approximately 65% of the sand placed during the 2023 project. With that said, it is noteworthy that the general trend in the North and South Monitoring Areas were more positive than the long-term average, indicating that overall, the entire Town experienced lower erosion rates since the September 2013 baseline survey.

**North Monitoring Area:** The long-term average volumetric change rates (Sept. 2013 to June 2025) shown in Table ES-2 for the North Monitoring Area, reflect a positive volumetric rate of 1.9 cy/ft./yr. Although discrete periods of volumetric losses have been observed along the North Monitoring Area between 2013 and 2025, the overall volumetric trend over this period has been positive. Despite the absence of direct sand placement within the North Monitoring Area during the 2017 and 2023 beach nourishment projects, a cumulative net gain of approximately 196,500 cubic yards was measured over the 11.75-year monitoring period. Of this total, approximately 52,700 cubic yards of sediment accretion occurred between June 2024 and June 2025.

Historically, the determination of whether a reasonable level of storm damage reduction is being maintained for public and private development along the Town's oceanfront has been based on the results of a storm simulation model known as SBEACH. The SBEACH model is used to simulate storm scenarios equivalent to a modern-day version of Hurricane Isabel, which impacted the Town in 2003, to determine impacts based on current conditions. Simulations conducted in 2019, based on May 2019 beach conditions, identified only one (1) oceanfront structure and no oceanfront pools along the North Monitoring Area that would have been impacted based on the SBEACH analysis. That SBEACH analysis was then updated in 2023 using May 2023 beach conditions and the results of that analysis indicated no oceanfront houses or pools in the North Monitoring Area would have been impacted by the design storm.

The short-term (June 2024 to June 2025) average volumetric change measured along the North Monitoring Area was a gain of approximately 52,700 cy. This equates to a change rate of +6.6 cy/ft./yr., which indicates an above average period of positive volumetric change along the North Monitoring Area over this most recent period. While the SBEACH analysis was not updated based on the June 2025 conditions, the fact that this area continues to experience a volumetric gain suggests that a reasonable level of storm damage reduction to public and private development existed along the North Monitoring Area as of June 2025.

**South Monitoring Area:** The long-term average volumetric change rates (Sept. 2013 to June 2025) shown in Table ES-2 for the South Monitoring Area, reflect a positive volumetric rate of 3.4 cy/ft./yr. Although discrete periods of volumetric losses have been observed throughout the South Monitoring Area between 2013 and 2025, the overall volumetric trend over this period has been positive. Although no sand was



directly placed in the South Monitoring Area through beach nourishment during the long-term period, a net increase of approximately 544,500 cy of sand was measured over the 11.75-year monitoring interval.

The short-term (June 2024 to June 2025) average volumetric change measured along the South Monitoring Area was a gain of approximately 92,700 cy. This equates to a change rate of +6.8 cy/ft./yr., which indicates an above average period of positive volumetric change along the South Monitoring Area over this most recent period.

As previously stated, the determination of whether a reasonable level of storm damage reduction along the oceanfront is being maintained is based on the results of a storm simulation model known as SBEACH. Simulations conducted in 2019, based on May 2019 beach conditions, identified 28 oceanfront structures and 40 oceanfront pools along the South Monitoring Area, particularly south of the USACE Field Research Facility, that would have been impacted based on the SBEACH analysis. That SBEACH analysis was then updated in 2023 using May 2023 beach conditions and the results of that analysis indicated no oceanfront structures and nine (9) oceanfront pools in the South Monitoring Area would have been impacted by the design storm.

The decrease in the number of oceanfront structures and pools identified as impacted through the SBEACH Analysis, between May 2019 and May 2023, coincides with a volumetric gain of approximately 202,000 cy between station D-23, which is located just north of the southern boundary of the USACE Field Research Facility, and D-34, which is located at the southern Town boundary. While the SBEACH analysis was not updated based on the June 2025 conditions, this same stretch of the Town from near the southern boundary of the USACE Field Research Facility to the southern Town Boundary experienced a volumetric gain of approximately 47,000 cy between June 2024 and June 2025. This positive volumetric change suggests that a reasonable level of storm damage reduction to public and private development existed along the South Monitoring Area as of June 2025.

### **Recommendations:**

CPE recommends the Town continue to monitor the beach along the entire Town oceanfront to assess 1) the performance of the May 2023 beach renourishment project and 2) shoreline and volume change trends along the portions of the Town outside the Central Reach Project Area. For continued monitoring of the Central Reach Project Area, the May 2023 survey should represent the post-construction conditions. Future annual monitoring reports should reference shoreline and volume changes in the Central Reach Project Area relative to the May 2023 condition to track the short- and long-term performance of the 2023 project and aid in the determination of when additional nourishment is needed in the Central Reach Project Area and surrounding beaches. Continued annual monitoring of the project will also provide a pre-storm condition survey that can be used to estimate damages if the project is impacted by a significant storm.

Continued monitoring of the North and South Monitoring Areas is vital to achieving the Town's goal of providing a reasonable level of storm damage reduction to public and private development along the entire Town oceanfront. This continued monitoring will allow the Town to evaluate future areas of concern and longshore transport trends, and to develop successful shoreline management strategies to deal with issues as they arise.

**TOWN OF DUCK, NORTH CAROLINA  
2025 SHORELINE & VOLUME CHANGE  
MONITORING REPORT**

**TABLE OF CONTENTS**

I.	INTRODUCTION.....	1
II.	PROJECT LOCATION.....	1
III.	SURVEY DATA COLLECTION.....	4
IV.	SHORELINE CHANGE ANALYSIS .....	6
V.	VOLUMETRIC CHANGE ANALYSIS .....	13
VI.	DISCUSSION .....	21
VII.	RECOMMENDATIONS .....	24
VIII.	REFERENCES.....	24

**LIST OF FIGURES**

Figure No.

Figure 1.	Project Location Map .....	2
Figure 2.	Detailed Project Area Map showing the North Monitoring Area, Central Reach Project Area, South Monitoring Area, and the location of the Monitoring Stations .....	3
Figure 3.	Long-term Shoreline Positions (+6.0 ft. NAVD88) Relative to September 2013.....	9
Figure 4.	Cumulative Average Shoreline Changes in the +6.0 ft. NAVD88 Contour Position since September 2013 in the Central Reach Project Area and North and South Monitoring Areas..	12
Figure 5.	Volume Change Rates (cubic yards/foot/year) measured between Sept. 2013 to June 2025, June 2024 to June 2025, and May 2023 to June 2025. ....	16
Figure 6.	Cumulative Volumetric Changes above the -24 ft. NAVD88 contour since September 2013 in the Central Reach Project Area and the North and South Monitoring Areas .....	17
Figure 7.	Profile D-21 showing progression of nearshore changes measured during the May 2023, June 2024, and June 2025 surveys. ....	20

**LIST OF TABLES**

Table No.

Table 1.	Dataset Descriptions .....	4
Table 2.	Monitoring Survey Baseline and Azimuth.....	5
Table 3.	Summary of Shoreline Changes (ft.) .....	7
Table 4.	Summary of Shoreline Change Rates (ft./yr.).....	8
Table 5.	Volumetric Change Rates (cy/ft./yr.) along Duck above -24 ft. NAVD88.....	14
Table 6.	Volumetric Changes along Duck (CY), above -24 ft. NAVD88 .....	15

**LIST OF APPENDICES**

Appendix No.

- A 2025 Town of Duck Beach Profile Cross Section Plots
- B 2025 Dare County Data Acquisition Survey Report



**DRAFT: TOWN OF DUCK  
2025 SHORELINE & VOLUME CHANGE  
MONITORING REPORT**

**I. INTRODUCTION**

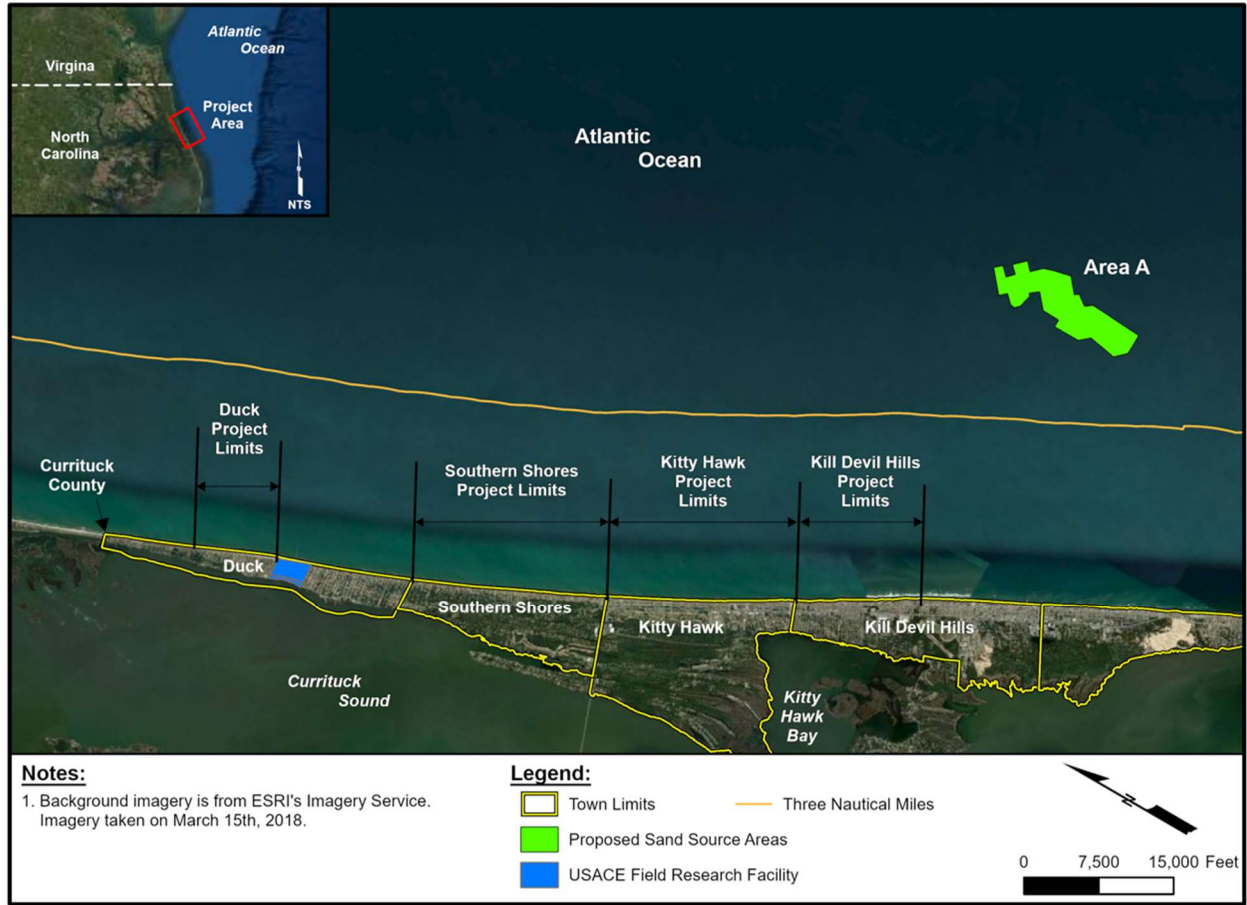
The Town of Duck has implemented a long-term beach management program to sustain the beaches that support a significant portion of their local economy, maintain the tax base of the Town, retain existing recreational resources, and protect existing natural resources. To accomplish these stated goals, the Town is taking steps to maintain and monitor its oceanfront beach and dune to a configuration that provides a reasonable level of storm damage reduction to public and private development and mitigates long-term erosion impacts.

As part of the long-term shoreline management program, the Town of Duck, in cooperation with Dare County, constructed a large beach nourishment project in 2017 that placed approximately 1.26 million cy of sand along approximately 1.6 miles of the Town’s shoreline. This area, referred to as the Central Reach project, extends from near station D-10 in the north, which is located near 128 Skimmer Way, to near station D-19 in the south, which is located at the south property line of 137 Spindrift Lane (northern boundary of the USACE FRF property). The beach fill design for the 2017 project in the Town of Duck included a 20-foot wide dune at elevation +20.0 feet NAVD88 fronted by a variable width berm at elevation +6.0 feet NAVD88. In 2023, the Town completed its first renourishment of the Central Reach project. Approximately 576,800 cy were placed along the same area as the 2017 project. The beach fill design for the 2023 Central Reach project included a variable width berm at elevation +6.0 feet NAVD88 and augmentation of portions of the dune that varied in elevation between +14.0 and +19.0 feet NAVD88 along the southern 1 mile of the Central Reach Project Area.

The Town has implemented a beach monitoring program to track both the performance of the Central Reach Project Area and the overall health of the beach along the entire Town. This monitoring report describes shoreline changes and volume changes measured along the Town’s oceanfront shoreline.

**II. PROJECT LOCATION**

The Town of Duck is located on the Outer Banks of North Carolina roughly 27 miles south-southeast of the North Carolina and Virginia border. The Town encompasses 5.5 square miles extending along 5.9 miles of Atlantic Ocean shoreline from the Dare County and Currituck County line south-southeast to the Town of Southern Shores. The USACE Field Research Facility (FRF) is located within the Town limits between station D-19 and D-23 and is approximately 2.3 miles north of the southern limit and 3.6 miles south of the northern limit. A Location Map is provided in Figure 1. This location map also shows the limits of the Duck nourishment project (Central Reach), built along a 1.6-mile section of the Town’s oceanfront shoreline.



**Figure 1. Project Location Map**

For the purpose of monitoring, the oceanfront beach of Duck was separated into three areas: namely, the Central Reach Project Area, the North Monitoring Area, and the South Monitoring Area. These areas are depicted on Figure 2. The Central Reach Project Area includes the beach between the northern FRF property line, located near station D-19, through station D-10, which is near the northern end of Skimmer Way. The section referred to as the North Monitoring Area extends from station D-10 (northern end of Skimmer Way) north to the Duck town limits (station D-01). The area designated as the South Monitoring Area extends from station D-19 south to D-34 (located near the Duck town boundary with the Town of Southern Shores) and includes the shoreline along the USACE FRF property. Figure 2 also depicts the monitoring stations where the beach profile surveys were conducted.

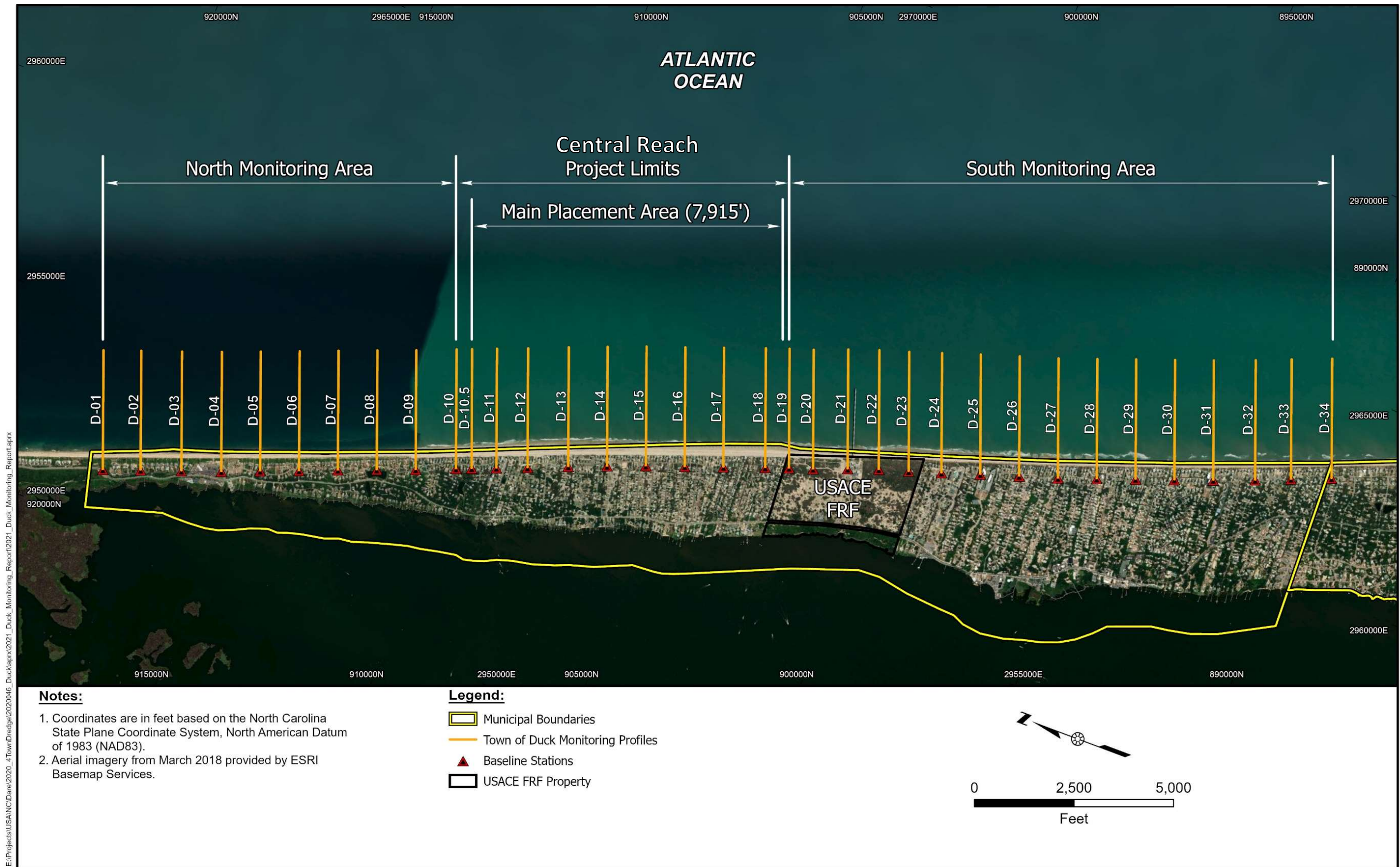


Figure 2. Detailed Project Area Map showing the North Monitoring Area, Central Reach Project Area, South Monitoring Area, and the location of the Monitoring Stations

### III. SURVEY DATA COLLECTION

Data used in this study included twelve (12) different data sets collected from September 2013 to June 2025. See Table 1 below for dates and description of the datasets that were used.

**Table 1. Dataset Descriptions**

Agency/Firm	Survey Type	Date	Transects
CPE (APTIM)	Profile Survey	September 2013	D-01 to D-34
CPE (APTIM)	Profile Survey	May 2015	D-01 to D-34
CPE (APTIM)	Profile Survey	December 2017	D-01 to D-34
CPE (APTIM)	Profile Survey	June 2018	D-01 to D-34
CPE (APTIM)	Profile Survey/Offshore Bathymetry	May 2019	D-01 to D-34
CPE (APTIM)	Profile Survey	December 2019	D-10 to D-19
CPE	Profile Survey	June 2020	D-01 to D-34
CPE	Profile Survey	April 2021	D-01 to D-34
TI Coastal	Profile Survey	October 2022	D-10 to D-19
TI Coastal	Profile Survey	January 2023	D-10 to D-19
TI Coastal	Profile Survey	May 2023	D-01 to D-34
CPE	Profile Survey	June 2024	D-01 to D-34
CPE	Profile Survey	June 2025	D-01 to D-34

In April 2021, CPE began surveying one additional station (D-10.5) that had not been surveyed in previous years and has continued to survey this station during subsequent monitoring events. Most monitoring stations are spaced approximately 1,000 feet apart along the Town’s oceanfront beach. CPE only collected survey data along the upland portion of the profiles located at stations D-19, D-20, D-21, D-22, and D-23 due to the USACE FRF request not to approach the shoreline in this area with survey vessels. Offshore data was obtained by the USACE FRF staff who regularly survey the offshore portions of those profiles. The USACE FRF data for the 2025 monitoring was collected on May 30, 2025.

Beach profile data were collected along each of the monitoring stations listed in Table 2. Coordinates shown in Table 2 are referenced to the North Carolina State Plane coordinate system in feet NAD83 and the profile azimuth refers to degrees referenced to true north. Cross section plots of the beach profiles surveyed in June 2025 at each station are included in Appendix A – 2025 Town of Duck Beach Profile Cross Section Plots. The survey data from the June 2025 survey is provided in Appendix B – 2025 Dare County Data Acquisition Survey Report.

Beach profile surveys extended landward until a structure was encountered or to a range of 25 feet beyond the landward toe of dune, whichever was more seaward. Elevation measurements were also taken seaward along the profile to at least the -30-foot NAVD88 contour. Upland data collection included 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 records along individual profiles was 25 feet. The upland survey extended into wading depths sufficiently to allow the offshore portion to overlap the upland portion by a minimum of 50 feet.

**Table 2. Monitoring Survey Baseline and Azimuth**

<b>Monitoring Station</b>	<b>Easting</b>	<b>Northing</b>	<b>Azimuth</b>
D-01	2951387.5	918267.7	70
D-02	2951733.8	917384.4	70
D-03	2952103.0	916429.4	70
D-04	2952464.0	915495.3	70
D-05	2952849.3	914598.0	70
D-06	2953224.4	913696.9	70
D-07	2953607.3	912798.8	70
D-08	2953983.0	911897.9	70
D-09	2954356.7	910994.8	70
D-10	2954759.1	910066.7	70
D-10.5	2954914.2	909703.5	70
D-11	2955158.1	909133.1	70
D-12	2955461.4	908412.5	70
D-13	2955874.3	907478.4	70
D-14	2956252.1	906578.3	70
D-15	2956628.6	905677.8	70
D-16	2956978.7	904767.7	70
D-17	2957333.7	903863.9	70
D-18	2957718.8	902886.5	70
D-19	2957932.5	902331.0	70
D-20	2958139.7	901760.7	70
D-21	2958472.1	900958.7	70
D-22	2958754.0	900228.8	70
D-23	2958992.7	899515.6	70
D-24	2959267.2	898739.8	70
D-25	2959601.7	897824.3	70
D-26	2959928.6	896902.3	70
D-27	2960250.6	895981.9	70
D-28	2960604.1	895073.0	70
D-29	2960963.6	894166.2	70
D-30	2961317.7	893257.6	70
D-31	2961676.7	892350.7	70
D-32	2962078.1	891379.4	70
D-33	2962439.4	890553.2	70
D-34	2962839.6	889616.1	70



#### IV. SHORELINE CHANGE ANALYSIS

A shoreline change analysis was completed to assess shoreline advance and recession along the monitoring area. The shoreline is typically defined as a specified elevation contour. For this study, the shoreline was defined as the +6.0 ft. NAVD88 contour, which represents the beach nourishment project design berm elevation (CPE-NC, 2015A). Shoreline change is calculated by comparing shoreline position along shore perpendicular stations or profiles. Typically, shoreline change is then annualized to describe recession and advance rates per year. Average shoreline changes for the monitoring areas were determined by computing a weighted average based on distance between the monitoring stations relative to the overall distance of the area. Annualized change rates computed for the monitoring were calculated using a linear regression method. The rate is calculated by determining the slope of the linear trendline for a certain shoreline position (+6 ft. NAVD88) for all available survey events. All available data for each survey listed in Table 1 were used in the linear regression calculation. These changes are described in terms of positive (“+”) or advance (shoreline moving seaward) and negative (“-”) or recession (shoreline moving landward).

The May 2023 survey has been adopted to represent the post-construction condition within the Central Reach Project Area. Future annual monitoring reports will reference shoreline changes in this area relative to the May 2023 condition to evaluate the performance of the 2023 project. This report also includes a comparison to the baseline survey, which represents the initial survey conducted by CPE during the project planning process. The first survey of the Duck shoreline by CPE was completed in September 2013, and the data from that survey were used to define the existing condition for the berm and dune design associated with the initial Central Reach Project construction in 2017. The shoreline changes measured between September 2013 (baseline survey) and June 2025 (Year-2 Post-construction) represent the cumulative changes that have occurred since the initial baseline survey and include the effects of the 2017 and 2023 beach nourishment projects. The changes measured between May 2023 (Post-construction) and June 2025 represent the post-project changes that have taken place within the Central Reach Project Area following completion of the 2023 nourishment project, including the short-term shoreline changes of the +6.0 ft NAVD88 contour measured during the most recent survey interval between June 2024 and June 2025.

Table 3 provides the measured shoreline changes between various surveys for each station where data exists and provides averages for the various areas monitored. All values in Table 3 represent actual changes and not rates. Table 4 shows rates of change determined using a linear regression method that considers each of the data sets available for the long-term period between September 2013 (baseline survey) and June 2025, the Post-project period between May 2023 (Post-construction) and June 2025, and the recent period from June 2024 to June 2025.

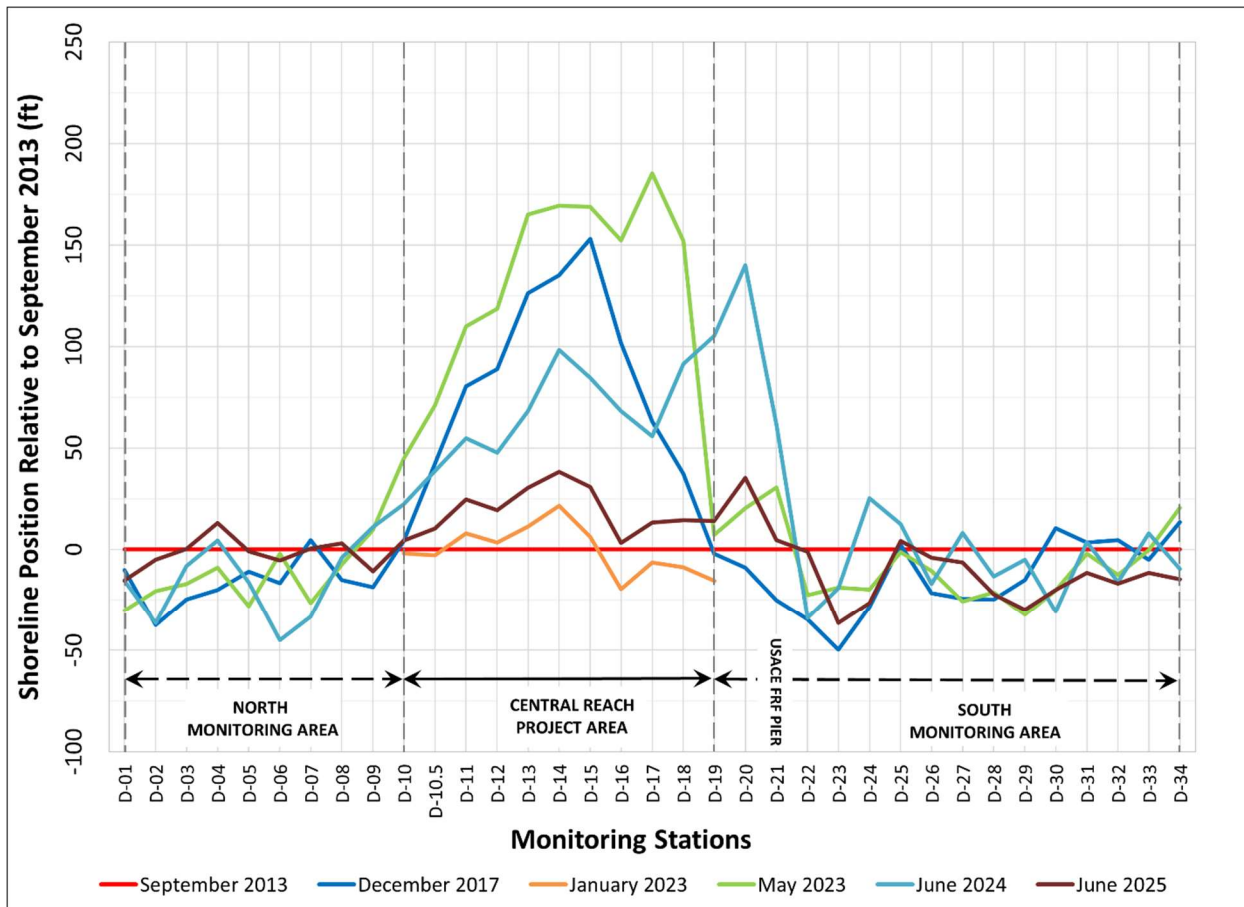
**Table 3. Summary of Shoreline Changes (ft.)**

MONITORING STATION		Sept. 2013 (Baseline) to June 2025 (Year-2)	May 2023 (Post-Con) to June 2025 (Year-2)	June 2024 (Year-1) to June 2025 (Year-2)
North Monitoring Area	D-01	-15.3	15.0	0.3
	D-02	-5.1	15.6	31.5
	D-03	0.2	17.5	8.5
	D-04	13.1	22.2	8.8
	D-05	-1.0	27.2	15.2
	D-06	-5.5	-3.3	39.7
	D-07	0.3	26.9	33.8
	D-08	3.0	10.6	7.2
	D-09	-10.9	-20.5	-21.8
Central Reach Project Area	D-10	4.4	-40.3	-17.9
	D-10.5	10.3	-60.6	-28.3
	D-11	24.6	-85.3	-30.1
	D-12	19.3	-99.4	-28.5
	D-13	30.2	-134.8	-37.9
	D-14	38.2	-131.2	-60.1
	D-15	30.8	-138.0	-53.8
	D-16	3.2	-149.1	-64.9
	D-17	13.1	-172.3	-42.6
	D-18	14.5	-137.7	-77.0
South Monitoring Area	D-19	13.9	6.9	-91.2
	D-20	35.3	14.9	-104.8
	D-21	4.4	-26.2	-57.1
	D-22	-1.1	21.6	32.9
	D-23	-36.6	-17.7	-17.3
	D-24	-26.6	-6.7	-51.9
	D-25	4.2	5.5	-8.2
	D-26	-4.1	6.5	13.0
	D-27	-6.5	19.3	-14.5
	D-28	-22.3	-1.0	-8.9
	D-29	-29.9	2.5	-24.7
	D-30	-20.0	0.3	10.9
	D-31	-11.7	-9.4	-15.2
	D-32	-16.9	-4.2	-0.7
	D-33	-11.6	-11.2	-19.6
D-34	-14.8	-35.3	-5.1	
<b>NORTH MONITORING AREA (D-01 TO D-10)</b>		-1.3	10.0	13.1
<b>CENTRAL REACH PROJECT AREA (D-10 TO D-19)</b>		20.1	-120.0	-48.5
<b>SOUTH MONITORING AREA (D-19 TO D-34)</b>		-10.5	-1.6	-18.8

**Table 4. Summary of Shoreline Change Rates (ft./yr.)**

MONITORING STATION		Sept. 2013 (Baseline) to June 2025 (2-Year)	May 2023 (Post-Con) to June 2025 (Year-2)	June 2024 (Year-1) to June 2025 (Year-2)
North Monitoring Area	D-01	-1.8	7.3	0.3
	D-02	-1.9	7.2	31.5
	D-03	1.3	8.4	8.5
	D-04	1.1	10.7	8.8
	D-05	0.8	13.0	15.2
	D-06	-1.7	-2.1	39.7
	D-07	-1.8	12.6	33.8
	D-08	-0.5	5.1	7.2
	D-09	-1.5	-9.7	-21.8
Central Reach Project Area	D-10	2.6	-19.3	-17.9
	D-10.5	2.5	-29.0	-28.3
	D-11	3.4	-41.0	-30.1
	D-12	1.0	-47.9	-28.5
	D-13	1.8	-64.9	-37.9
	D-14	4.1	-62.9	-60.1
	D-15	1.7	-66.3	-53.8
	D-16	3.4	-71.5	-64.9
	D-17	3.7	-83.1	-42.6
	D-18	4.5	-65.8	-77.0
South Monitoring Area	D-19	2.7	4.6	-91.2
	D-20	6.1	8.6	-104.8
	D-21	2.5	-11.9	-57.1
	D-22	-0.6	10.0	32.9
	D-23	-2.6	-8.4	-17.3
	D-24	-1.0	-2.6	-51.9
	D-25	0.0	2.8	-8.2
	D-26	0.4	3.0	13.0
	D-27	1.3	9.6	-14.5
	D-28	-1.5	-0.4	-8.9
	D-29	-1.9	1.5	-24.7
	D-30	-4.7	0.0	10.9
	D-31	-0.4	-4.4	-15.2
	D-32	-1.6	-2.0	-0.7
	D-33	0.3	-5.2	-19.6
D-34	-0.1	-17.1	-5.1	
<b>NORTH MONITORING AREA (D-01 TO D-10)</b>		-0.5	4.7	13.1
<b>CENTRAL REACH PROJECT AREA (D-10 TO D-19)</b>		2.9	-57.6	-48.5
<b>SOUTH MONITORING AREA (D-19 TO D-34)</b>		-0.3	-0.5	-18.8

Figure 3 graphically displays the position of +6.0 ft. NAVD88 contour for the December 2017, January 2023 (Pre-construction), May 2023 (Post-construction), June 2024 (Year-1 Post-construction), and June 2025 (Year-2 Post-construction) surveys along the entire monitoring area relative to the September 2013 +6.0 ft. NAVD88 contour position.



**Figure 3. Long-term Shoreline Positions (+6.0 ft. NAVD88) Relative to September 2013**

A review of Figure 3 illustrates several notable trends throughout the different years and monitoring areas. In the Central Reach Project Area, the shoreline positions in December 2017 and May 2023 are significantly seaward of the shoreline position in September 2013 due to the beach nourishment projects constructed in 2017 and 2023. The shoreline position observed in May 2023 is actually seaward of the shoreline position in December 2017. However, this is primarily due to the timing of when the post-construction surveys were completed following construction. In 2017, the Central Reach Project was completed in June 2017 with post-construction surveys completed 6 months later in December. In 2023, the post-construction surveys were conducted within 2 weeks following beach fill placement. In the year following the 2023 project, the Central Reach Project Area showed recession, with notable landward movement between stations D-13 and D-17, which is primarily attributed to the equilibration of the beach fill that typically occurs within 6 to 12 months following construction along the Outer Banks. The June 2025 shoreline position relative to June 2024 shows the shoreline continued a trend of recession throughout the Central Reach Project Area, with notable recession between stations D-14 and D-19. Similarly, the majority of the North and South Monitoring Area shorelines remain consistently landward of the 2013 position; however, on average, the shoreline along South Monitoring Area is further landward than the North Monitoring Area shoreline. In comparison of the June 2025 shoreline to the June 2024 shoreline positions, the North Monitoring Area shows mostly seaward movement, while the South Monitoring Area is mostly landward movement. Outside the Central Reach Project Area, the June 2025 monitoring data shows the most seaward shoreline position was in the North Monitoring Area at station D-04, whereas the landward most shoreline position was in the South Monitoring Area at station D-23.




Figure 3 also highlights the landward retreat of the June 2025 shoreline relative to September 2013, in the South Monitoring Area along the approximately 2,500 ft. of shoreline immediately south of the Central Reach Project Area and within the USACE FRF property. The data clearly indicates notable retreat of the shoreline between stations D-23 and D-24 in contrast to moderate shoreline recession observed along the remainder of the South Monitoring Area between stations D-25 and D-34. This is also apparent in the average shoreline change values shown in Table 3. Table 3 also shows the position of the +6.0 ft. contour between stations D-23 and D-24 moved landward by an average 31.3 ft. between September 2013 and June 2025. In contrast, during the same time period the average shoreline change measured along the South Monitoring Area from station D-25 to station D-34 (Town boundary with Southern Shores) was -13.3 ft.


Another noteworthy observation from Figure 3 is the landward retreat of the June 2025 shoreline in the South Monitoring Area along the 1,500 ft. of shoreline immediately south of the Central Reach Project Area and within the USACE FRF property. The data between June 2024 and June 2025 clearly indicates notable recession of the shoreline between stations D-19 and D-21 in contrast to shoreline recession observed to the south within the remainder of the South Monitoring Area. This is also apparent in the average shoreline change values shown in Table 3. Table 3 shows the position of the +6.0 ft. contour between stations D-19 and D-21 moved landward by an average -81.5 ft. between June 2024 and June 2025, which is likely associated with the continued spreading of the beach fill placed along the Central Reach Project Area in May 2023. In contrast, during the same time period the average shoreline change measured along the remainder of the South Monitoring Area from station D-22 to station D-34 (Town boundary with Southern Shores) was -8.9 ft. In this regard, the characterization of shoreline changes within the monitoring areas is best represented by averaging shoreline trends for multiple stations within certain sections. As discussed below, average shoreline trends were computed for the three subareas within the overall monitoring area, namely, North Monitoring Area, the Central Reach Project Area, and South Monitoring Area.

### **Central Reach Project Area (D-10 to D-19)**

The construction of the 2023 beach renourishment project extended the +6 ft. NAVD88 contour seaward an average of 139.3 ft. (stations D-10 through D-19). This number reflects the change in the position of the +6 ft. NAVD88 contour based on the placement of mostly unequibrated fill within the construction beach fill template.

Beach profile data indicated that between December 2017 and January 2023, the average shoreline change of the +6 ft. NAVD88 contour within the Central Reach Project Area was -88.3 ft., which is equivalent to a rate of change of -15.7 ft./yr. These values are provided as they reflect the measured shoreline change trend between the 2017 project and the 2023 project. A profile-by-profile comparison shows the rate of change in the position of the +6.0 ft. NAVD88 contour varied across the Central Reach Project Area as shown in Table 4. The greatest shoreline changes were measured in the central portion of the Central Reach Project Area. The average shoreline change measured from station D-13 through D-16 was -124.1 ft. The average shoreline changes between December 2017 and January 2023, in the northern portion of the Central Reach Project Area from stations D-10 (Skimmer Way) through D-12 (Sound Sea Ave.) was -52.3 ft.; whereas the average shoreline change in the southern part of the Central Reach Project Area measured from stations D-17 (located at the south end of Buffell Head Rd.) through D-19 (northern USACE FRF boundary) was -43.1 ft.

The changes measured between May 2023 (Post-construction), and June 2025 represent post-project changes that occurred within the Central Reach Project Area over the approximate 2-year period since the 2023 beach nourishment project was constructed. The average shoreline change measured along the Central Reach Project Area during this period between the May 2023 and June 2025 surveys was -120.0 ft. The average shoreline change rate measured between May 2023 and June 2025 was -57.6 ft./yr. While this

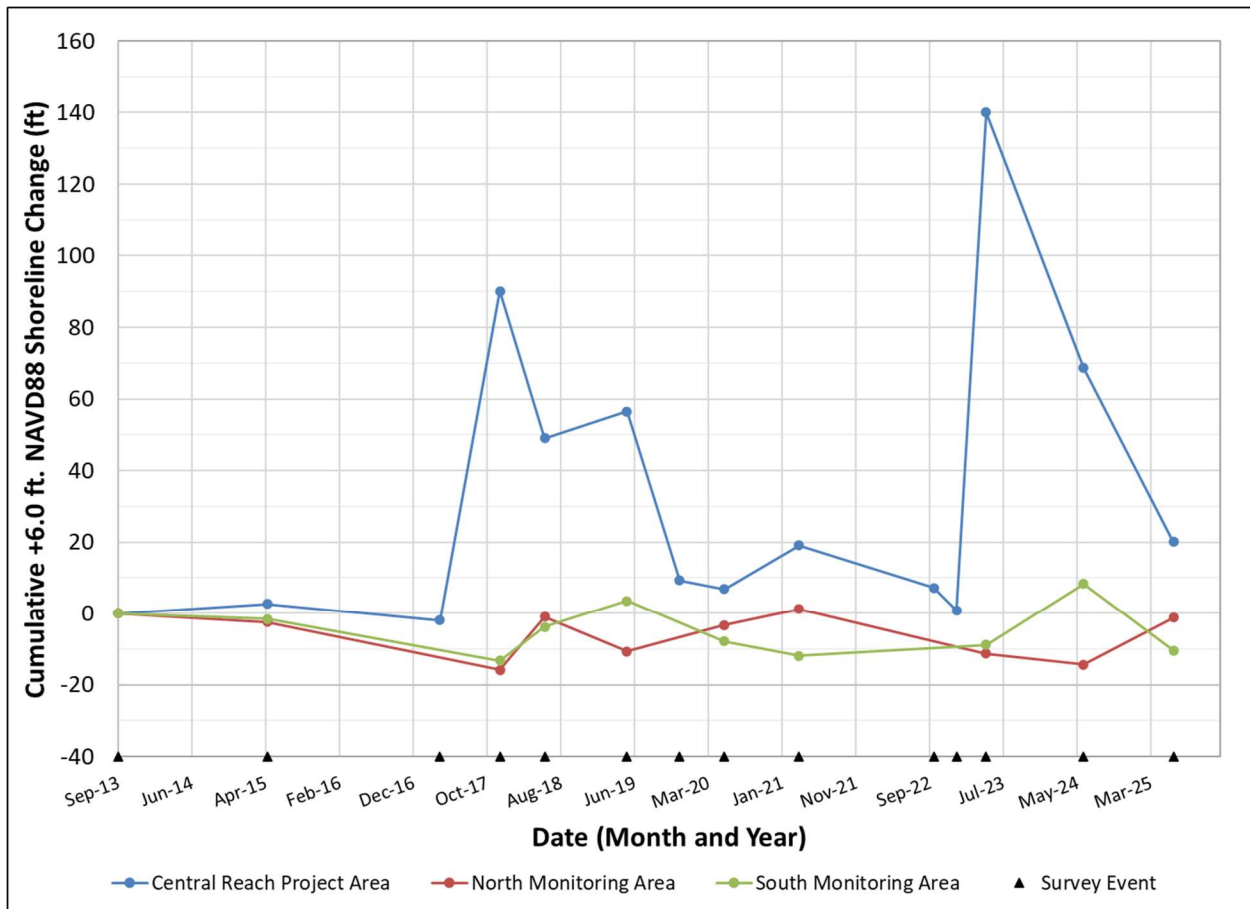


average rate is considerably higher than the average rate measured between the 2017 and 2023 projects, it is not uncommon to see considerable shoreline change retreat immediately following the construction of a beach fill project as the fill equilibrates, and it is expected that future monitoring data will provide a more representative comparison of the rate of project performance.

In the most recent monitoring period between June 2024 and June 2025, beach profile data indicates that the average shoreline change of the +6 ft. NAVD88 contour within the Central Reach Project Area moved -48.5 ft. landward in the second year following completion of the 2023 project. The greatest shoreline change rates were experienced between D-14 (Dianne St.) and D-19 (located at the south end of Spindrift Lane.), averaging recession at a rate of -60.9 ft./yr. The northern portion of the Project Area between D-10 (Skimmer Way) and D-13 experienced less recession at an average rate of -30.4 ft./yr.

The long-term shoreline changes within the Central Reach Project Area calculated from Sept. 2013 to June 2025, which are provided in Table 3 and Table 4 are influenced by both the 2017 and 2023 projects. In the Central Reach Project Area, the shoreline experienced an average positive shoreline change rate of 2.9 ft./yr.

Figure 4 depicts the average cumulative change in the position of the +6.0 ft. NAVD88 contour within the Central Reach Project Area (i.e. average change of stations D-10 to D-19) between September 2013 and June 2025, identified by the blue line. The large increase in the cumulative average shoreline change in the Central Reach Project Area between April 2017 and December 2017 reflects the average shoreline seaward advance associated with the 2017 project. The variation in the location of the average +6 ft. NAVD88 contour between December 2017 and January 2023 reflects the changes in the average shoreline position that occurred during the nourishment interval between the 2017 and 2023 projects. The large seaward advance between January 2023 and May 2023 reflects the seaward advance associated with the 2023 project. For the most recent period, Figure 4 depicts the Project Area shoreline experienced an average negative cumulative shoreline change between June 2024 and June 2025. As previously stated, this relatively dramatic decrease in width since the May 2023 project is associated with the equilibration process.



**Figure 4. Cumulative Average Shoreline Changes in the +6.0 ft. NAVD88 Contour Position since September 2013 in the Central Reach Project Area and North and South Monitoring Areas**

### **North Monitoring Area (D-01 to D-10)**

From the baseline survey in September 2013 to the recent monitoring in June 2025, the average position of the +6.0 ft. NAVD88 contour along the North Monitoring Area moved landward 1.3 feet (Table 3). An average rate of -0.5 ft./yr was measured when annualized over the 11.75-year period (Table 4). This trend for the North Monitoring Area (red line) is illustrated in Figure 4. The North Monitoring Area experienced negative shoreline change between September 2013 and December 2017. Between December 2017 and June 2018, the shoreline position experienced a positive change resulting in a similar average position of the +6.0 ft. NAVD88 contour to what was measured in September 2013. Though moderate recession was observed between June 2018 and May 2019, an average shoreline advance was observed between May 2019 and April 2021 resulting in a similar average position as was measured in September 2013 and June 2018. Between April 2021 and May 2023, the average position of the +6.0 ft. NAVD88 contour retreated. Similarly, from May 2023 to June 2024, the recession trend continued. In contrast, from June 2024 to June 2025, the trend reversed, with a positive average shoreline change of 13.1 ft. over the 12-month monitoring period. As a result of the positive change measured between June 2024 and June 2025, the June 2025 cumulative shoreline position was similar to the average position of the +6.0 ft. NAVD88 contour to what was measured in September 2013, June 2018, and April 2021.

While Figure 4 depicts the average shoreline change, Table 3 shows variability at each profile in the short and long term. For example, between September 2013 and June 2025, the shoreline change rate at station D-10 (Skimmer Way) has experienced the greatest positive trend advancing at 2.7 ft./yr. whereas the

greatest negative trend of -1.9 ft./yr. was measured at station D-02 (N. Baum Trail). On the other hand, from June 2024 to June 2025, station D-06, experienced the greatest positive (seaward) shoreline change rate (39.7 ft./yr.). Station D-09 experienced the greatest negative (landward) shoreline change rate of 21.8 ft./yr.

### **South Monitoring Area (D-19 to D-34)**

Since the initial baseline survey of the Duck shoreline in September 2013 to June 2025, the average position of the +6.0 ft. NAVD88 contour along the South Monitoring Area (D-19 to D-34) moved landward 10.5 ft. (Table 3). The average shoreline change rate measured between September 2013 and June 2025 was -0.3 ft./yr. when annualized. As shown in Figure 4, between September 2013 and December 2017, the South Monitoring Area experienced negative shoreline change. Between December 2017 and May 2019, the area experienced an average positive shoreline change followed by a general trend of shoreline recession between May 2019 and May 2023. Between May 2023 and June 2024, the shoreline change was positive, whereas the trend reversed between June 2024 and June 2025 with a negative shoreline change relatively comparable to the positive change measured between May 2023 and June 2024.

Table 3 and Table 4 demonstrate the variability in shoreline change on a profile-to-profile basis. Between September 2013 and June 2025, the greatest negative change in the position of the +6.0 ft. NAVD88 contour was observed at station D-30 (approximately 100 ft. north of LaLa Ct. beach access) which experienced shoreline recession at a rate of -4.7 ft./yr. Over the same time, the greatest positive shoreline change was observed at station D-20 (approximately 1,000 ft. north of the FRF pier), which experienced shoreline advance at an annualized rate of +6.1 ft./yr. over the 11.75-year period.

During the recent monitoring period from June 2024 to June 2025 the average shoreline change in the South Monitoring Area was -18.8 ft. Between June 2024 to June 2025, the greatest positive change in the position of the +6.0 ft. NAVD88 contour was observed at station D-26 (Cook Dr.) of 13.0 ft. over the approximate 12-month period. Over the same time, the greatest negative shoreline change was observed at station D-20 (1,000 ft. north of FRF pier), which experienced -104.8 ft. of change in the position of the +6.0 ft. NAVD88 contour. The average shoreline change measured within the FRF property between station D-19 (northern boundary of FRF property) and D-21 (130 ft. north of FRF pier) was -81.5 ft. (landward movement) between June 2024 to June 2025. During this same 12-month period, an average shoreline change of -8.9 ft. was measured between stations D-22 (630 ft. south of FRF pier) and D-34 (southern Town boundary).

## **V. VOLUMETRIC CHANGE ANALYSIS**

Volumetric changes measured over the entire monitoring area for various time periods are provided in Table 5, given in terms of cubic yards/foot of shoreline/year (cy/ft./yr.) and Table 6, given in term of cubic yards (cy). The beach profile data is used to compute volumetric change out to the depth of closure, which has been established as -24 ft. NAVD88 for the sake of this monitoring program (CPE-NC, 2015a). Volume changes were evaluated for the periods from September 2013 to June 2025, May 2023 to June 2025, and June 2024 to June 2025. The September 2013 to June 2025 surveys present the long-term volume changes. These changes are mainly focused on evaluating the changes outside of the Central Reach Project Area since the volumes in the Central Reach Project Area are heavily influenced by the construction of the 2017 and 2023 projects. The May 2023 to June 2025 surveys show changes occurring since the beach nourishment project was completed whereas the June 2024 to June 2025 surveys present the most recent volume changes. Future annual monitoring reports will reference volume changes in the Central Reach Project Area relative to the May 2023 condition to track the performance of the 2023 project. Table 5 and Table 6 provide the volume change rates (cy/ft./yr.) and volumes (cy), respectively, at each monitoring station along the Town of Duck for each of the monitoring periods. Figure 5 graphically depicts the

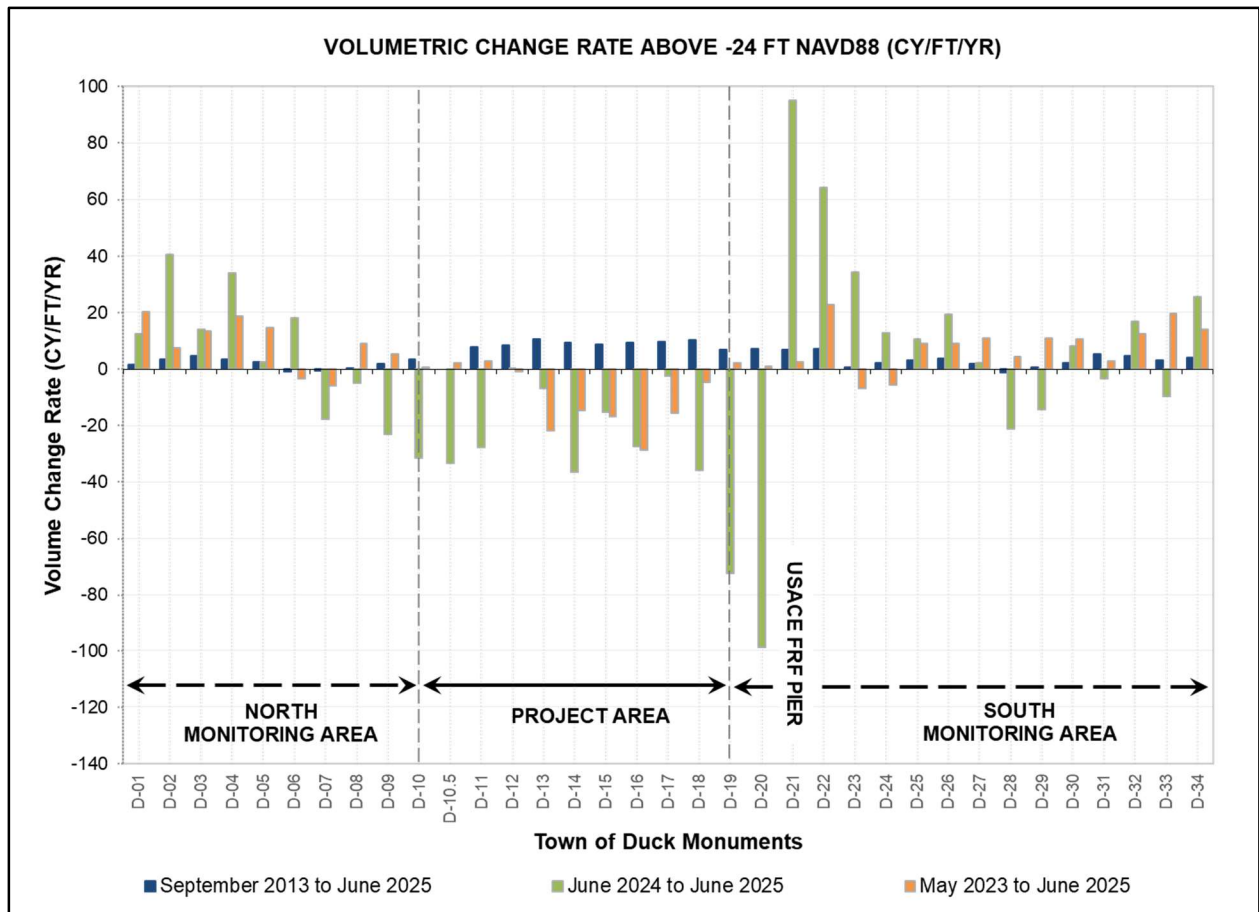
volumetric changes calculated above -24 ft. NAVD88 between September 2013 and June 2025 as well as changes measured following the 2023 construction from May 2023 to June 2025.

**Table 5. Volumetric Change Rates (cy/ft./yr.) along Duck above -24 ft. NAVD88**

MONITORING STATION		Sept. 2013 (Baseline) to June 2025 (2-Year)	May 2023 (Post-Con) to June 2025 (Year-2)	June 2024 (Year-1) to June 2025 (Year-2)
North Monitoring Area	D-01	1.6	20.3	12.6
	D-02	3.4	7.4	40.5
	D-03	4.6	13.4	14.2
	D-04	3.5	18.7	33.9
	D-05	2.5	14.7	2.4
	D-06	-0.9	-3.3	18.2
	D-07	-0.6	-5.9	-17.9
	D-08	0.0	9.2	-5.1
	D-09	1.9	5.3	-23.0
	D-10	3.4	0.5	-31.5
Central Reach Project Area	D-10.5	-	2.1	-33.3
	D-11	7.7	2.8	-27.9
	D-12	8.6	-0.9	0.2
	D-13	10.7	-21.9	-6.8
	D-14	9.4	-14.7	-36.6
	D-15	8.9	-16.8	-15.2
	D-16	9.2	-28.8	-27.4
	D-17	9.6	-15.7	-2.6
	D-18	10.2	-4.5	-35.9
	D-19	7.0	2.2	-72.2
South Monitoring Area	D-20	7.3	1.1	-98.9
	D-21	7.0	2.4	95.1
	D-22	7.3	22.7	64.2
	D-23	0.6	-7.0	34.2
	D-24	2.2	-5.4	12.8
	D-25	3.0	8.9	10.5
	D-26	3.9	8.9	19.3
	D-27	2.0	10.8	2.2
	D-28	-1.2	4.4	-21.3
	D-29	0.5	11.0	-14.4
	D-30	2.1	10.7	8.0
	D-31	5.3	2.9	-3.3
	D-32	4.6	12.4	17.0
	D-33	3.2	19.6	-9.5
	D-34	4.0	13.9	25.7
<b>NORTH MONITORING AREA (D-01 TO D-10)</b>		1.9	7.7	6.6
<b>CENTRAL REACH PROJECT AREA (D-10 TO D-19)</b>		8.9	-11.4	-21.7
<b>SOUTH MONITORING AREA (D-19 TO D-34)</b>		3.4	7.7	6.8

**Table 6. Volumetric Changes along Duck (CY), above -24 ft. NAVD88**

MONITORING STATION		Sept. 2013 (Baseline) to June 2025 (2-Year)	May 2023 (Post-Con) to June 2025 (Year-2)	June 2024 (Year-1) to June 2025 (Year-2)
North Monitoring Area	D-01 to D-02	27,800	25,200	27,300
	D-02 to D-03	48,000	28,000	22,200
	D-03 to D-04	47,400	24,100	33,400
	D-04 to D-05	33,900	17,700	33,900
	D-05 to D-06	9,100	10,100	11,600
	D-06 to D-07	-8,600	100	-9,300
	D-07 to D-08	-3,500	-11,200	3,300
	D-08 to D-09	11,000	-13,700	14,700
	D-09 to D-10	31,300	-27,500	6,100
	Central Reach Project Area	D-10 to D-10.5	25,700	-12,800
D-10.5 to D-11		40,400	-18,900	3,200
D-11 to D-12		74,800	-10,800	1,600
D-12 to D-13		115,500	-3,300	-24,200
D-13 to D-14		115,300	-21,100	-37,100
D-14 to D-15		104,700	-25,200	-32,000
D-15 to D-16		103,600	-20,800	-46,300
D-16 to D-17		107,500	-14,600	-45,000
D-17 to D-18		122,200	-20,200	-22,200
D-18 to D-19		60,000	-32,100	-1,400
South Monitoring Area	D-19 to D-20	51,100	-51,900	2,100
	D-20 to D-21	72,800	-1,700	3,200
	D-21 to D-22	65,600	62,300	20,500
	D-22 to D-23	34,800	37,000	12,300
	D-23 to D-24	13,500	19,400	-10,700
	D-24 to D-25	30,000	11,400	3,500
	D-25 to D-26	39,700	14,600	18,200
	D-26 to D-27	33,800	10,500	20,100
	D-27 to D-28	4,700	-9,300	15,500
	D-28 to D-29	-3,900	-17,400	15,700
	D-29 to D-30	14,900	-3,100	22,000
	D-30 to D-31	42,300	2,300	13,800
	D-31 to D-32	61,200	7,200	16,700
	D-32 to D-33	41,300	3,400	30,000
	D-33 to D-34	42,800	8,200	35,500
<b>NORTH MONITORING AREA (D-01 TO D-10)</b>		196,500	52,700	143,200
<b>CENTRAL REACH PROJECT AREA (D-10 TO D-19)</b>		869,700	-180,000	-202,400
<b>SOUTH MONITORING AREA (D-19 TO D-34)</b>		544,500	92,700	218,500



**Figure 5. Volume Change Rates (cubic yards/foot/year) measured between Sept. 2013 to June 2025, June 2024 to June 2025, and May 2023 to June 2025.**

### 2017 Beach Fill Volumes

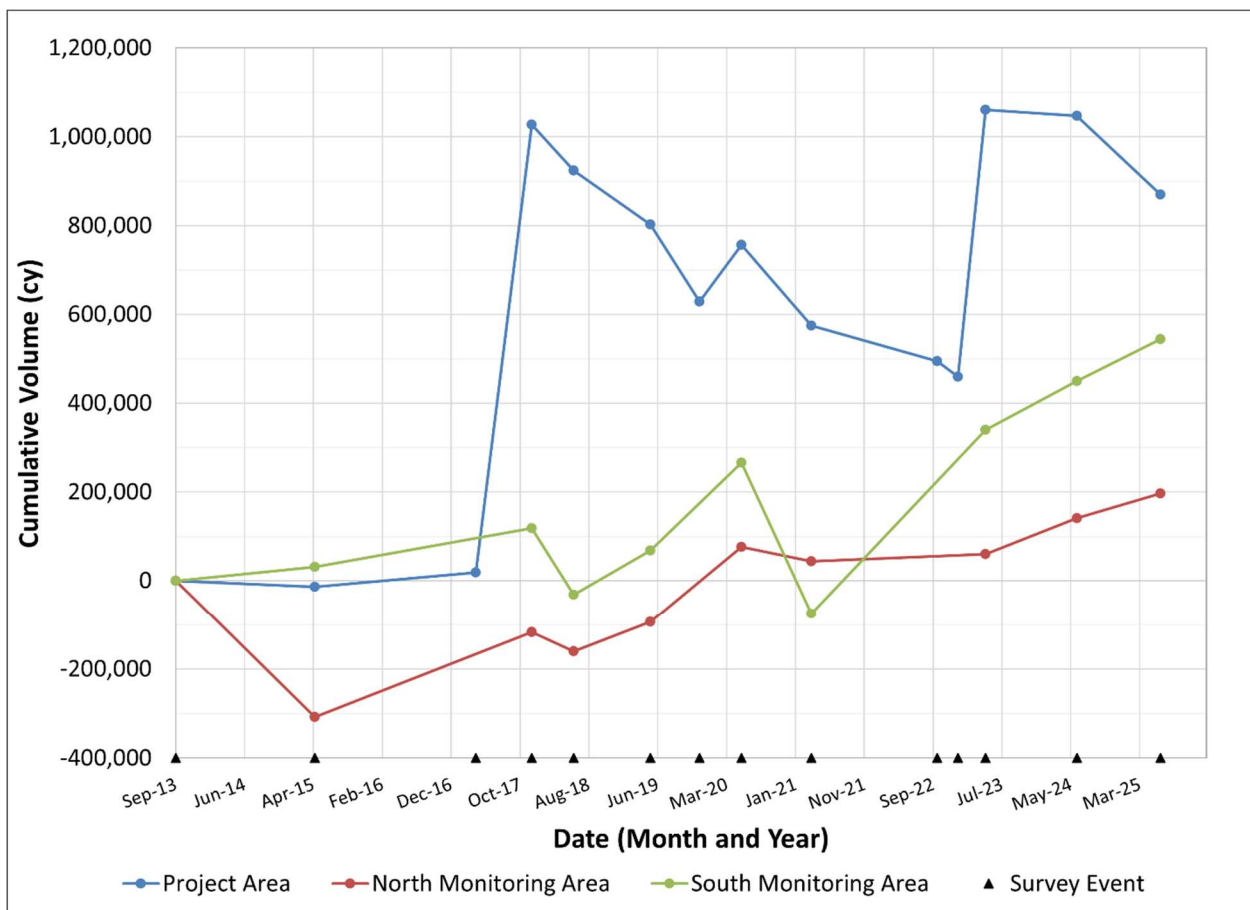
Based on comparisons of Before Dredge (BD) and After dredge (AD) surveys, between May and June 2017, a total of 1.26 million cubic yards of fill were placed along the Duck shoreline between stations D-10 and D-19 (Central Reach Project) (APTIM, 2020). Based on volume changes computed between April 2017 (Pre-con) and December 2017 (Post-con), a volume change of approximately 963,100 cubic yards was measured on the active profile (above the -24-foot NAVD88 contour) within the Project Area (APTIM, 2020). For more information on why this method of assessing volume was used, please refer to the 2018 Shoreline and Volume Change Monitoring Report (APTIM, 2018).

### 2023 Beach Fill Volumes

Between April and May 2023, the 2023 beach renourishment project placed a total of 576,800 cubic yards of fill along the Duck oceanfront within the Central Reach Project Area. The May 2023 survey has been adopted to represent the post-construction conditions within the Central Reach Project Area. Future annual monitoring reports will reference volume changes in the Central Reach Project Area relative to the May 2023 condition to track the performance of the 2023 project.

### Central Reach Project Area (D-10 to D-19)

Beach profile monitoring surveys indicate a volume change within the project area of -202,400 cubic yards between May 2023 (Post-construction) and June 2025 (Table 6). This equates to a rate of -11.4 cy/ft./yr. when annualized. This average rate is heavily influenced by the negative volume changes experienced on the central 4,00 ft. of the beach fill project between stations D-13 and D-17 as seen in Figure 5. The average volume change from D-13 south to D-17 was calculated to be a loss of -19.8 cy/ft./yr., equivalent to 160,500 cubic yards, or 79% of the total volume lost since May 2023. **As of June 2025, the analysis indicates that the Town of Duck beach nourishment project had approximately 65% of the initial fill volume remaining as measured above the -24-foot NAVD88 contour.** Figure 6 shows the cumulative volumetric changes for the Town of Duck measured since the baseline survey was conducted in September 2013. Cumulative volumetric changes are displayed for the Central Reach Project Area, North Monitoring Area, and South Monitoring Area. The large increases in the Central Reach Project Area (blue line) between April 2017 and December 2017, and between January 2023 and May 2023 reflects the volume gain associated with the 2017 and 2023 projects. In the intermittent period between the projects, December 2017 and January 2023, the project area mainly experienced erosion. After approximately 576,800 cy of sand were added to the beach between April and May 2023, the June 2024 data shows a volume loss of approximately 23,300 during the first monitoring year, followed by a loss of approximately 180,000 cy between D-10 and D-19 from June 2024 to June 2025.



**Figure 6. Cumulative Volumetric Changes above the -24 ft. NAVD88 contour since September 2013 in the Central Reach Project Area and the North and South Monitoring Areas**

From September 2013 to June 2025 the Central Reach Project Area experienced a net positive volumetric change of approximately 869,700 cy (Table 6). This change is equivalent to an annual average density change rate of +8.9 cy/ft./yr. when annualized over the 11.75-year period. This positive trend shown in Figure 5 is reflective of both the 2017 and 2023 beach nourishment projects.

Over the 12-month period between June 2024 and June 2025, the volume of material within the Central Reach Project Area decreased by approximately 180,000 cubic yards (Table 6). The average volume change measured along the profiles from D-10 to D-19 was -21.7 cy/ft. However, as shown in Figure 5 and Table 5 there is considerable variation in the volume changes measured along the project area. The only positive volume change was measured along Profile D-12 (0.2 cy/ft.); whereas the greatest negative volume change was measured along Profile D-19 (-72.2 cy/ft.).

The relatively high losses along the southern end of the Project Area between stations D-18 and D-19 occurred during the same period in which substantial gains were recorded on the profiles at stations D-21, D-22, and D-23 south of the Project Area, as can be seen in Figure 5. The analysis shows a significant buildup of sand on profiles between stations D-21 and D-23, located immediately north and south of the pier, compared to the changes measured between May 2023 and June 2024. In that regard, during the period from June 2024 to June 2025, a check of the wave conditions measured by Gage 630 operated by the USACE FRF indicates there was a predominance of wave energy out of the southern quadrants that would have tended to move littoral sediment to the north. During this time, the waves out of the southern quadrants accounted for 65% of the wave energy with 35% coming from the northern quadrants. More discussion is included regarding the sediment transport in the subsequent section of this report under the heading South Monitoring Area (D-19 to D-34).

The overall changes measured in the Project Area show a moderate trend of volume loss along the northern portion of the project between D-10 and D-11, whereas the southern portion of the project between D-14 and D-19 exhibited slightly higher trends during the recent 12-month period. The higher trend of erosion in the southern portion of the project may be influenced by the continued profile adjustments following the beach nourishment project as a result of additional material that was placed along the southern portion of the project in order to allow wave action to naturally form the southern transition. As discussed below, some of the material lost out of the Project Area may have been transported to the north and south.

#### **North Monitoring Area (D-01 to D-10)**

From September 2013 to June 2025 the North Monitoring Area experienced a net positive volumetric change of approximately 196,500 cy, as shown in Table 6. This equates to an annual average density change rate of +1.9 cy/ft./yr and is reflective of relative stability within the area over the 11.75-year period. As shown in Table 5, the rates of change varied from profile to profile within the North Monitoring Area ranging from a positive rate of 4.6 cy/ft./yr. at station D-03 (South Baum Trail) to a negative rate of -0.9 cy/ft./yr at station D-06 (Martin Lane). Consequently, the volume change measured within the North Monitoring Area from May 2023 (Post-construction) to June 2025 was a positive average volume change rate of 7.7 cy/ft./yr. Over the 12-month period between June 2024 and June 2025, a positive trend in volume change of 6.6 cy/ft./yr. was measured.

In the previous monitoring report (CPE, 2024), the analysis of the changes along the 3,000 ft. of shoreline immediately north of the Project Area between Waxwing Ln. and Skimmer Way (stations D-07 and D-10) from May 2023 to June 2024 measured a gain of 24.6 cy/ft. (+22.7 cy/ft./yr.) or approximately 74,000 cubic yards. However, the recent trends measured between June 2024 and June 2025 show this 3,000 ft. section lost an average 16.9 cy/ft., equivalent to approximately -52,400 cubic yards during the 12-month period. Some of the gains may still be associated with the northward spreading of the nourishment material during

the recent 12-month period and attributed to the predominance of wave energy out of the southern quadrants (65%) that would have tended to move littoral sediment to the north for the time period between June 2024 and June 2025.

In contrast, the area along the northern approximately 5,000-foot section of the monitoring area from D-06 through D-01, gained an average of 21.3 cy/ft. during the same 12-month period between June 2024 and June 2025, which equates to a gain of approximately 105,000 cubic yards. However, most of the accretion within the 5,000-ft section is attributable to anomalously high gains of 40.5 cy/ft. at station D-02 and 33.9 cy/ft. at station D-04. Even when the gains at stations D-02 and D-04 are excluded, the 5,000-foot section still shows an average gain of 10.7 cy/ft.

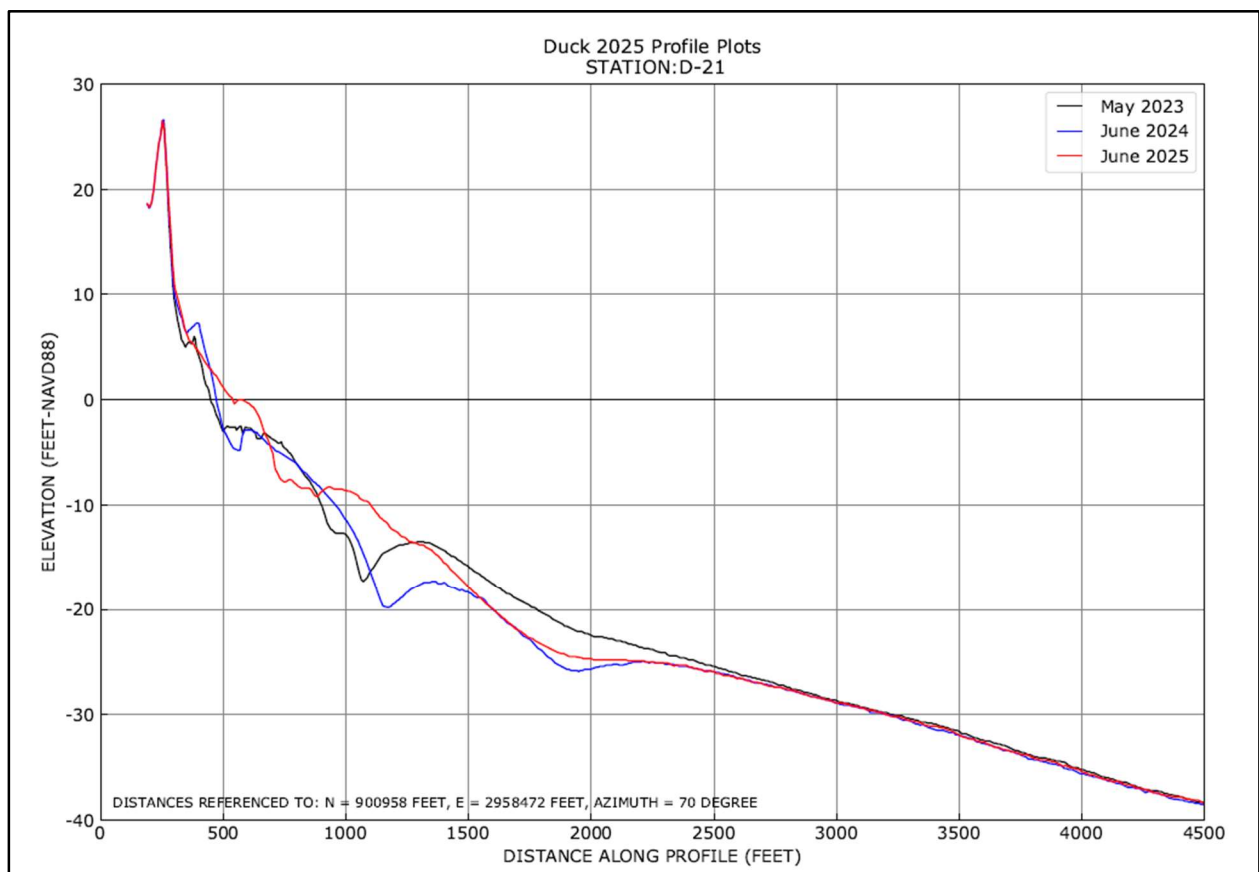
In Figure 6, the cumulative volumetric changes in the North Monitoring Area (red line) indicates a relatively steep erosional trend between September 2013 and May 2015, prior to the 2017 Central Reach Project. This erosional trend represents a negative volumetric change of approximately 308,000 cy. A positive volumetric trend was measured between May 2015 and June 2020 which more than offset the losses measured between September 2013 and May 2015 and resulted in a cumulative positive volumetric change of approximately 76,000 cy in June 2020, relative to the September 2013 condition. Figure 6 also shows that the cumulative volume change trend along the North Monitoring Area between June 2020 and May 2023 remained relatively stable with a modest increase in volume between May 2023 and June 2024. The positive trend continued through June 2025. As of June 2025, the North Monitoring Area had approximately 196,500 cy more volume than measured at the time of the September 2013 baseline survey.

#### **South Monitoring Area (D-19 to D-34)**

From September 2013 to June 2025 the South Monitoring Area experienced a net positive volumetric change of approximately 544,500 cy above the -24 ft. NAVD88 contour (Table 6). This equates to an annual average density change rate of +3.4 cy/ft./yr. over the 11.75-year period. As shown in Table 5, the rates of change varied from profile to profile within the South Monitoring Area ranging from a positive rate of 7.3 cy/ft./yr. at station D-20 (approximately 1,000 feet north of the FRF pier) and station D-22 (approximately 600 feet south of the FRF Pier) to a negative rate of -1.2 cy/ft./yr. at station D-28 (Duck Landing Ln). Of the 16 profiles included in the South Monitoring Area, the four profiles most proximate to the Central Reach Project Area (D-19 through D-22) experienced the greatest positive density change rates, averaging 7.2 cy/ft./yr. This is likely associated with the spreading beach fill placed in the Central Reach Project Area. During the 25-month period from May 2023 to June 2025, since the construction of the beach nourishment project, the South Monitoring Area gained an average of 7.7 cy/ft./yr. During the recent 12-month period from June 2024 to June 2025 the South Monitoring Area gained an average rate of 6.8 cy/ft./yr.

In Figure 6, the cumulative volumetric changes in the South Monitoring Area (green line) illustrates a relatively modest accretional trend between September 2013 and May 2015, prior to the construction of the project. This accretional trend resulted in a positive volumetric change of approximately 31,000 cy. A negative volumetric change was measured between December 2017 and June 2018, to the degree that in June 2018, the net volumetric change from the baseline survey in September 2013 to June 2018 was negative. From June 2018 to June 2020, the South Monitoring Area experienced a positive volumetric change of approximately 298,000 cy. The South Monitoring Area experienced a considerable negative volumetric change between June 2020 and April 2021. However, between April 2021 and June 2024, the Area experienced a positive volumetric change. The South Monitoring Area continued to gain volume between June 2024 and June 2025. As of June 2025, the South Monitoring Area had approximately 544,500 cy more volume than measured at the time of the baseline survey in September 2013.

During the 12-month period from June 2024 to June 2025, the South Monitoring Area experienced positive volume change at an average rate of 6.8 cy/ft./yr., which is equivalent to a gain of approximately 92,700 cubic yards. However, an examination of volume changes in the 1,500 section between stations D-21 and D-23 (the FRF pier is located approximately 150 ft. south of station D-21), shows this area experienced an average 65.0 cy/ft./yr. gain over the 12-month period. In contrast, the adjacent profiles at stations D-19 and D-20 (located north of the FRF pier) measured losses of -72.2 cy/ft./yr. and -98.9 cy/ft./yr., respectively. The losses at stations D-19 and D-20 were due to erosion of the berm and nearshore slope down to the -8 ft. NAVD88 contour and the deflation of the offshore bar. An examination of volume changes measured station to station shows anomalous volume gains of 95.9 cy/ft./yr., 64.2 cy/ft./yr., and 34.2 cy/ft./yr. at stations D-21, D-22, and D-23, respectively (Table 5). The anomalous changes between D-21 and D-23 appear to be influenced by an increase of material on the berm and by the formation of a bar that was not present on the profiles at those stations in June 2024 as shown on Figure 7. The USACE FRF Pier may play a part in the sediment transport patterns that have been observed along the FRF property and may at times impact the southern portion of the Town’s project. A previous analysis completed by APTIM in 2013, using wave data from (1998 to 2008), found that based on the results of an Even-Odd Analysis, the USACE FRF pier had a limited longshore transport barrier effect that was limited to the FRF property.



**Figure 7. Profile D-21 showing progression of nearshore changes measured during the May 2023, June 2024, and June 2025 surveys.**

## VI. DISCUSSION


This monitoring report evaluated shoreline and volumetric changes along the Town of Duck over three timeframes. The longest timeframe ranges from the initial baseline survey conducted in September 2013 and spans through the most recent survey conducted in June 2025. Shoreline and volume change analyses were also performed for the entire Town of Duck oceanfront between the two most recent survey events, conducted in June 2024 and June 2025. Additionally, changes were evaluated for the period between May 2023 and June 2025 to quantify the changes following completion of the 2023 nourishment project.

### Shoreline Change Analysis

**Central Reach Project Area.** During the period between December 2017 and January 2023, the position of the +6 ft. NAVD88 contour receded landward by an average of 88.3 ft. within the Central Reach Project Area. While this period is used to evaluate project performance between the construction of the initial 2017 beach nourishment project and the 2023 renourishment project, it is important to note that the December 2017 survey represents the beach condition approximately 6 months after completion of the 2017 Central Reach Project in Duck. This is an important consideration given a beach nourishment project experiences dramatic shoreline change in the months following construction as the profile equilibrates (Willson et al., 2017). Compared to the immediate After Dredge (AD) surveys that were conducted during the 2017 construction project, the January 2023 survey indicates an average shoreline change of approximately -229 feet. The shoreline changes associated with equilibration are also evident through comparison of the May 2023 and June 2025 surveys. While the 2023 beach renourishment project extended the position of the +6 ft. NAVD88 contour seaward an average of 139.3 ft. based on comparisons of the Before Dredge (BD) and After Dredge (AD) surveys, in the 25 months following the construction (June 2025), an average shoreline recession of 120.0 ft. was measured.

**North Monitoring Area.** The +6.0 ft. NAVD88 long-term shoreline changes north of the project (stations D-01 to D-10) were predominantly negative and variable from September 2013 to June 2025. The average change was -1.3 ft., equivalent to a rate of -0.5 ft./yr. when annualized, which includes the construction of the two beach nourishment projects constructed in 2017 and 2023. During the Post-project period, the shoreline change measured within the North Monitoring Area from May 2023 to June 2025 shows an average advance of the +6 ft. NAVD88 shoreline at a rate of 4.7 ft./yr. The average shoreline advance measured for the North Monitoring Area was +10.0 ft. Most of the advance was attributed to movement of sediment onto the upper portions of the profile in response to tide and wave conditions. During the period from May 2023 to June 2025, a check of the wave conditions measured by Gage 630 operated by the USACE FRF indicates there was a predominance of wave energy out of the southern quadrants that would have tended to move littoral sediment to the north. The wave data shows that between May 2023 and June 2025, the waves out of the southern quadrants accounted for 56% of the wave energy with 30% coming from the northern quadrants.

**South Monitoring Area.** The long-term average shoreline change rate computed along the South Monitoring Area (stations D-19 to D-34), based on all the various surveys conducted between September 2013 and June 2025, was -0.3 ft./yr. While the average shoreline change rate indicates stability along the South Monitoring Area since September 2013, there is a clear trend of positive changes immediately south of the Project Area and more fluctuation further south. The average long-term shoreline change rate from the southern boundary of the Central Reach Project Area to approximately 130 ft. north of the USACE FRF pier (stations D-19 to D-21) was a positive 4.0 ft./yr. (seaward movement). The positive average shoreline change rate along this section of the Town, directly adjacent to the Central Reach Project Area, may indicate a positive impact on the +6.0 ft. contour location due to the 2017 and 2023 projects. The average long-term shoreline change rate between 600 ft. south of the USACE FRF pier and the southern Town Boundary (station D-22 to D-34) was -1.0 ft./yr. (landward movement).



During the Post-project period, the shoreline change measured along the South Monitoring Area from May 2023 to June 2025 shows an average recession of the +6 ft. NAVD88 shoreline at a rate of -0.5 ft./yr.. The average shoreline recession measured for the South Monitoring Area was -1.6 ft. Similar to the long-term period, the average change indicates stability; however, there is no clear trend with changes ranging from a shoreline advance of 21.6 ft. at station D-22 to a recession of -35.3 ft. at station D-34.

### **Volumetric Change Analysis**

**Central Reach Project Area.** The long-term average volumetric change rate between Sept. 2013 to June 2025 was +8.9 cy/ft./yr. This positive rate reflects the cumulative benefits of the 2017 and 2023 beach nourishment projects implemented within the Central Reach Project Area. The 2023 beach nourishment project placed approximately 576,800 cubic yards of fill along the Duck shoreline between stations D-10 and D-19 (Central Reach Project). As of June 2025, the total volume of sand within the Central Reach Project Area was approximately 870,000 cubic yards greater than the volume measured during the baseline survey conducted in September 2013, prior to any nourishment activities.

Between December 2017 and January 2023, a change rate of -12.3 cy/ft./yr. was recorded and represents the performance of the 2017 beach nourishment project over the initial 5-year maintenance interval. The desired outcome is that the 2023 project will not experience volume change rates greater than the 2017 beach nourishment project. The 2023 project employed an optimized beach fill design intended to reduce the rate of loss from the project compared to the 2017 project. Furthermore, it is not uncommon to observe a reduction in erosion rates along a beach after multiple nourishment cycles.

In the two years since the 2023 nourishment project was completed the Central Reach Project Area experienced an average erosion rate of -11.4 cy/ft./yr. As of June 2025, the 2023 project is exhibiting a slightly lower erosion rate relative to the 2017 nourishment project over the two-year post-construction period. The total volumetric change since May 2023 corresponds to an estimated net loss of approximately 202,400 cubic yards of sand. Overall, after 25 months post-construction, approximately 65 percent of the material placed during the 2023 project remains within the Central Reach Project Area. Beach nourishment projects often exhibit a non-linear pattern of erosion following construction with higher rates of erosion occurring immediately following construction and lower rates experienced in the latter years of a maintenance cycle. This pattern is illustrated in Figure 6 where the cumulative loss of sand between December 2017 and December 2019 was greater than the volumetric change measured between December 2019 and January 2023. Continued monitoring will allow for a better comparison of post-construction performance trends between the 2017 and 2023 nourishment projects.

During the recent period, June 2024 to June 2025, the Central Reach Project experienced an average rate of change of -21.7 cy/ft./yr. This equates to a loss of approximately 180,000 cy, indicating an increase in volume losses from the initial post-construction monitoring period between May 2023 and June 2024 (-23,300 cy). In the 12 months following the completion of the 2023 project, the Central Reach Project experienced positive changes (>+30 cy/ft./yr.) along the northern and southern approximate 1,000 feet of shoreline within the Project Area. This indicates that the project was gaining material at the northern and southern ends of the project rather than losses which are typically experienced following a project due to lateral spreading of the fill to ends of the project, known as diffusion.

**North Monitoring Area.** The long-term average volumetric change rate along the North Monitoring Area (September 2013 to June 2025) was +1.9 cy/ft./yr. While the North Monitoring Area experienced discrete periods of volumetric losses between 2013 and 2025, the overall trend during this time has been positive. Despite no direct sand placement in this area during the 2017 and 2023 beach nourishment projects, the monitoring data shows an increase of approximately 196,500 cy of sand over the 11.75-year period.


The assessment of whether the Town's oceanfront provides a reasonable level of storm damage reduction for public and private development has traditionally relied on the SBEACH storm simulation model. This model simulates storm scenarios equivalent to a modern-day version of Hurricane Isabel, which affected the Town in 2003. In 2019, simulations based on May 2019 beach conditions identified only one oceanfront structure and no oceanfront pools in the North Monitoring Area that would have been affected. An updated SBEACH analysis conducted in 2023, using May 2023 beach conditions, found that no oceanfront houses or pools in the North Monitoring Area would have been impacted by the design storm. Although the SBEACH analysis was not updated using June 2025 conditions, the North Monitoring Area experienced an additional volumetric gain of approximately 143,200 cy between May 2023 and June 2025. This continued positive volumetric change suggests that, as of June 2025, a reasonable level of storm damage reduction for public and private development remained in place along the North Monitoring Area.

In the short-term period between June 2024 and June 2025, the average volumetric change measured along the North Monitoring Area was a gain of approximately 52,700 cy, equivalent to an average change rate of +6.6 cy/ft./yr. These results indicate an above average period of positive volumetric change along the North Monitoring Area given the long-term average volume change rate was reported as +1.9 cy/ft./yr. Although the SBEACH analysis was not updated using the June 2025 conditions, the observed volumetric gain in the area suggests that, as of June 2025, the North Monitoring Area maintained a reasonable level of storm damage reduction for public and private development.

**South Monitoring Area.** The long-term average volumetric change rate along the South Monitoring Area (September 2013 to June 2025) was +3.4 cy/ft./yr. Despite periods of volumetric losses in the South Monitoring Area between 2013 and 2025, the overall trend during this timeframe has been positive. Although no sand was directly placed in the South Monitoring Area during this period as part of beach nourishment projects, the analysis indicates an increase of approximately 544,500 cy of sand over the 11.75-year monitoring period. With the implementation of the Town of Southern Shores beach nourishment project in 2022/2023, the South Monitoring Area is now bound by beach nourishment projects both to the north and the south. As stated above, over the 11.75-year long-term period the South Monitoring Area has experienced positive volume change at a rate of 3.4 cy/ft./yr.; however, since the completion of the 2022/2023 beach nourishment projects in Southern Shores and Duck an average rate of +7.7 cy/ft./yr. was measured as of June 2025. Given that the South Monitoring Area is located between the Southern Shores and Duck beach nourishment projects, it is reasonable to consider that the South Monitoring Area may be experiencing volume changes that are positively influenced by the presence of these adjacent nourishment projects.

Between June 2024 and June 2025, the South Monitoring Area experienced a short-term volumetric gain of approximately 92,700 cy. This corresponds to an average change rate of +6.8 cy/ft./yr., reflecting an above-average period of positive volumetric change for the area given the long-term average rate of +3.4 cy/ft./yr.

As previously noted, the evaluation of whether a reasonable level of storm damage reduction is being maintained along the oceanfront relies on the SBEACH storm simulation model. In 2019, simulations based on May 2019 beach conditions identified 28 oceanfront structures and 40 oceanfront pools in the South Monitoring Area, particularly south of the USACE Field Research Facility, as potentially impacted by the design storm. In 2023, an updated SBEACH analysis using May 2023 conditions showed a significant improvement, with no oceanfront structures and only nine (9) oceanfront pools identified as impacted by the design storm. This decrease in the number of impacted structures and pools aligned with a volumetric gain of approximately 202,000 cy between stations D-23 (just north of the southern boundary of the USACE Field Research Facility) and D-34 (at the southern Town boundary) from 2019 to 2023. Although the SBEACH analysis was not updated using June 2025 conditions, the same stretch of the South



Monitoring Area experienced an additional volumetric gain of approximately 180,400 cy between May 2023 and June 2025. This continued positive volumetric change suggests that, as of June 2025, a reasonable level of storm damage reduction for public and private development remained in place along the South Monitoring Area.

## **VII. RECOMMENDATIONS**

CPE recommends that the Town continue to monitor the entire Town oceanfront to assess 1) the performance of the May 2023 beach renourishment project and 2) shoreline and volume change trends along the beach areas outside of the Central Reach Project Area. For continued monitoring of the Central Reach Project Area, the May 2023 survey should represent the post-construction conditions. Future annual monitoring reports should reference shoreline and volume changes in the Central Reach Project Area relative to the May 2023 condition to track the short- and long-term performance of the 2023 project and aid in the determination of when additional nourishment is needed in the Central Reach Project Area and surrounding beaches. Continued annual monitoring of the project will also provide a pre-storm condition survey that can be used to estimate damages if the project is impacted by a significant storm.

Continued monitoring of the North and South Monitoring Areas is vital to achieving the Town's goal of providing a reasonable level of storm damage reduction to public and private development along the entire Town oceanfront. This continued monitoring will allow the Town to evaluate future areas of concern and longshore transport trends, and to develop successful shoreline management strategies to deal with issues as they arise.

## **VIII. REFERENCES**

APTIM, 2018. Aptim Coastal Planning & Engineering of North Carolina, Inc., *Town of Duck North Carolina 2018 Shoreline & Volume Change Monitoring Report*. Prepared for Town of Duck. Wilmington, NC.

APTIM, 2019. Aptim Coastal Planning & Engineering of North Carolina, Inc., *Town of Duck North Carolina 2019 Shoreline & Volume Change Monitoring Report*. Prepared for Town of Duck. Wilmington, NC.


APTIM, 2020. Aptim Coastal Planning & Engineering of North Carolina, Inc., *Town of Duck Shore Protection Project Beach Maintenance Plan*. Prepared for Town of Duck. Wilmington, NC.

CPE, 2020. Coastal Protection Engineering of North Carolina, Inc. Post-Storm Design Report: Hurricane Dorian Town of Duck Shore Protection Project Repair Dare County, NC. Prepared for Town of Duck. Wilmington, NC.

CPE, 2020. Coastal Protection Engineering of North Carolina, Inc., *Town of Duck North Carolina 2020 Shoreline & Volume Change Monitoring Report*. Prepared for Town of Duck. Wilmington, NC.

CPE, 2021a. Coastal Protection Engineering of North Carolina, Inc., *Town of Duck North Carolina 2021 Shoreline & Volume Change Monitoring Report*. Prepared for Town of Duck. Wilmington, NC.

CPE, 2021b. Coastal Protection Engineering of North Carolina, Inc., *Town of Duck, North Carolina Erosion and Shoreline Management Design Report*. Prepared for the Town of Duck. Wilmington, NC.



CPE, 2023. Coastal Protection Engineering of North Carolina, Inc. Town of Duck North Carolina 2023 Shoreline and Volume Change Monitoring Report Dare County, NC. Prepared for Town of Duck. Wilmington, NC.

CPE, 2024. Coastal Protection Engineering of North Carolina, Inc. Town of Duck North Carolina 2024 Shoreline and Volume Change Monitoring Report Dare County, NC. Prepared for Town of Duck. Wilmington, NC.

CPE-NC, 2013. Coastal Planning & Engineering of North Carolina, Inc., *Erosion and Shoreline Management Feasibility Study*, Wilmington, NC.

CPE-NC, 2015A. Coastal Planning & Engineering of North Carolina, Inc., *Town of Duck North Carolina Erosion & Shoreline Management Design Report*. Prepared for Town of Duck. Wilmington, NC.

CPE-NC, 2015B. Coastal Planning & Engineering of North Carolina, Inc., *Comprehensive Marine Sand Search and Borrow Areas Design Report*. Prepared for the Towns of Duck, Kitty Hawk, and Kill Devil Hills. Wilmington, NC.

CPE-NC, 2016. Coastal Planning & Engineering of North Carolina, Inc., *Town of Duck North Carolina Shoreline & Volume Change Monitoring Report*, Wilmington, NC.

Willson, K.; Thomson, G.; Roberts Briggs, T.; Elko, N; and Miller, J. *Beach Nourishment Profile Equilibration: What to Expect After Sand is Placed on a Beach*. Shore & Beach Vol. 85, No. 2, Spring 2017.

**APPENDIX A**

**2025 TOWN OF DUCK BEACH PROFILE CROSS SECTION PLOTS**

**APPENDIX B**

**2025 DARE COUNTY DATA ACQUISITION SURVEY REPORT**