

III. SURVEY DATA COLLECTION

As previously stated, beach profile surveys were conducted along the Town's shoreline by CPE in September 2013, May 2015, December 2017, June 2018, May 2019, June 2020, and April 2021. Each of these surveys include the 34 profile transects shown in Figure 2. In April 2021, CPE surveyed one additional transect (D-10.5) than had not been surveyed in previous years. The profile transects are spaced 1,000 feet along the Town's oceanfront beach. CPE also conducted an additional survey in December 2019 following Hurricane Dorian. The December 2019 survey included only the profiles within the project area (D-10 to D-19). Beach profile data was collected along transects listed 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 Appendix A – 2021 Town of Duck Topographic and Hydrographic Data Acquisition Report. Appendix A also includes detailed survey methodology, monument information, profile plots, profile digital photography, and field book notes.

Beach profile surveys extended landward until a structure was encountered or to a range 50 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 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 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.


Data along profiles D-19, D-20, D-21, D-22, and D-23 were only be collected by CPE for the upland portion of the profiles due the USACE FRF request not to approach the shoreline with survey vessels. Offshore data was obtained from the USACE FRF who regularly surveys the offshore portions of those profiles. The USACE FRF data was collected on April 28, 2021.

IV. SHORELINE CHANGE RESULTS

A shoreline change analysis was completed to assess shoreline advance and recession along the study 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 transects or profiles. Typically, shoreline change is then annualized to describe recession and advance rates. Annualized shoreline change rates are calculated by dividing the shoreline change by the time period (number of years) between survey events (i.e. feet per year). These changes are described in terms of positive (“+”) or advance (shoreline moving seaward) and negative (“-”) or recession (shoreline moving landward).

Table 1. Profile Survey Baseline and Azimuth

Profile	Easting	Northing	Azimuth
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



The analysis discussed in this report for the Town of Duck evaluated the +6.0 ft. NAVD88 contour positions measured during the September 2013, May 2015, December 2017, June 2020, and April 2021 beach profiles surveys. Even though the 2017 beach nourishment project was completed in June 2017, the December 2017 survey has been adopted to represent the post-construction conditions within the project area due to large-scale profile adjustments that normally occur immediately following the placement of beach fill. This and future annual monitoring reports will reference shoreline changes and volume changes in the project area relative to the December 2017 condition. This report also includes a shoreline comparison of what are referred to as baseline surveys, which represent the initial surveys conducted by CPE during the planning process for the projects. The first survey of the Duck shoreline by CPE, was conducted in September 2013. The September 2013 data were used as the existing condition in the design of the berm and dune design for the Town's first beach nourishment project. The last survey conducted prior to the 2017 beach nourishment operation by CPE was conducted in May 2015. The +6.0 ft. NAVD88 contour position for each survey was identified along shore perpendicular transects spaced at approximately 1,000-foot intervals at the profiles along the monitoring area identified in Table 1.

The changes in the position of the +6.0 ft. NAVD88 contour measured between the September 2013 baseline survey and April 2021 are provided in Table 2. Short-term measured changes of the +6.0 ft. NAVD88 contour that occurred between June 2020 and April 2021 are also provided in Table 2. These values represent actual changes and not rates.

Table 3 shows rates of change for the +6.0 ft. NAVD88 contour between September 2013 (baseline survey) and April 2021, December 2017 (Post-Construction) to April 2021, and June 2020 to April 2021. The September 2013 to April 2021 time period represents long-term rates since CPE began monitoring the Town's Shoreline.

Figure 3 graphically displays the position of +6.0 ft. NAVD88 contours for May 2015, December 2017 (Post-Construction), June 2020, and April 2021 along the entire monitoring area relative to the position of the +6.0 ft. NAVD88 contour in September 2013. A review of Figure 3 shows the +6.0 ft. contour along the Project Area moved seaward between June 2020 and April 2021. During the same time period from June 2020 to April 2021 the shoreline north of the Project Area (stations D-01 and D-10) alternated between landward and seaward shoreline movements. South of the Project Area, the shoreline between stations D-20 and D-22 moved seaward, while the shoreline between stations D-23 and D-26 moved landward and the shoreline between stations D-27 and D-34 fluctuated between landward and seaward movements. In this regard, the characterization of shoreline changes within the monitoring areas is best represented by averaging shoreline trends for multiple profile lines within certain sections. As discussed below, average shoreline trends were computed for the three subareas within the monitoring area, namely, North of the Project, the Project Area, and South of the Project.

Table 2. +6.0 ft. NAVD88 Shoreline Changes (ft.)

PROFILE		September 2013 (Baseline) to April 2021 (Year-4)	June 2020 (Year-3) to April 2021 (Year-4)
Area North of Project	D-01	12.3	57.9
	D-02	-37.8	5.3
	D-03	11.1	20.7
	D-04	6.9	22.9
	D-05	29.2	-16.3
	D-06	-9.1	-13.4
	D-07	-4.7	3.8
	D-08	15.9	20.9
	D-09	-3.9	-39.7
Project Area	D-10	-8.8	12.4
	D-11	12.7	9.4
	D-12	4.3	0.5
	D-13	15.2	8.8
	D-14	22.8	-0.4
	D-15	46.7	25.6
	D-16	16.9	16.6
	D-17	13.0	5.6
	D-18	32.2	21.6
	D-19	41.1	56.6
Area South of Project	D-20	39.1	38.8
	D-21	4.0	30.2
	D-22	-16.3	13.0
	D-23	-64.3	-71.3
	D-24	-41.6	-18.0
	D-25	-14.0	-24.5
	D-26	-19.2	-4.8
	D-27	-10.3	8.3
	D-28	-37.6	-19.4
	D-29	-23.0	-3.5
	D-30	12.7	27.5
	D-31	-20.7	-38.6
	D-32	-22.4	-23.9
	D-33	-18.2	-30.1
	D-34	-1.8	0.5
AREA NORTH OF PROJECT (D-01 TO D-10)		1.1	7.5
PROJECT AREA (D-10 TO D-19)		19.6	15.7
AREA SOUTH OF PROJECT (D-19 TO D-34)		-12.0	-3.7

Table 3. +6.0 ft. NAVD88 Shoreline Change Rates (ft./yr.)

PROFILE		September 2013 (Baseline) to April 2021 (Year-4)	December 2017 (Post-Con) to April 2021 (Year-4)	June 2020 (Year-3) to April 2021 (Year-4)
Area North of Project	D-01	1.6	6.8	69.5
	D-02	-5.0	0.0	6.4
	D-03	1.5	10.8	24.9
	D-04	0.9	8.1	27.4
	D-05	3.9	12.1	-19.6
	D-06	-1.2	2.3	-16.0
	D-07	-0.6	-2.8	4.6
	D-08	2.1	9.3	25.1
	D-09	-0.5	4.4	-47.6
	D-10	-1.2	-3.9	14.9
Project Area	D-11	1.7	-20.3	11.3
	D-12	0.6	-25.4	0.6
	D-13	2.0	-33.3	10.5
	D-14	3.0	-33.7	-0.5
	D-15	6.2	-31.9	30.7
	D-16	2.2	-25.4	20.0
	D-17	1.7	-15.0	6.7
	D-18	4.2	-1.5	25.9
	D-19	5.4	13.0	67.9
	D-20	5.2	14.4	46.5
Area South of Project	D-21	0.5	8.8	36.2
	D-22	-2.1	5.6	15.6
	D-23	-8.5	-4.4	-85.5
	D-24	-5.5	-3.9	-21.6
	D-25	-1.8	-4.8	-29.5
	D-26	-2.5	0.8	-5.7
	D-27	-1.4	4.2	9.9
	D-28	-5.0	-3.9	-23.3
	D-29	-3.0	-2.4	-4.2
	D-30	1.7	0.7	33.0
	D-31	-2.7	-7.2	-46.3
	D-32	-3.0	-8.1	-28.7
	D-33	-2.4	-3.9	-36.2
	D-34	-0.2	-4.6	0.7
AREA NORTH OF PROJECT (D-01 TO D-10)		0.1	4.7	8.9
PROJECT AREA (D-10 TO D-19)		2.6	-17.7	18.8
AREA SOUTH OF PROJECT (D-19 TO D-34)		-1.6	0.3	-4.4

* Average MHW shoreline change rates provided as a reference only.

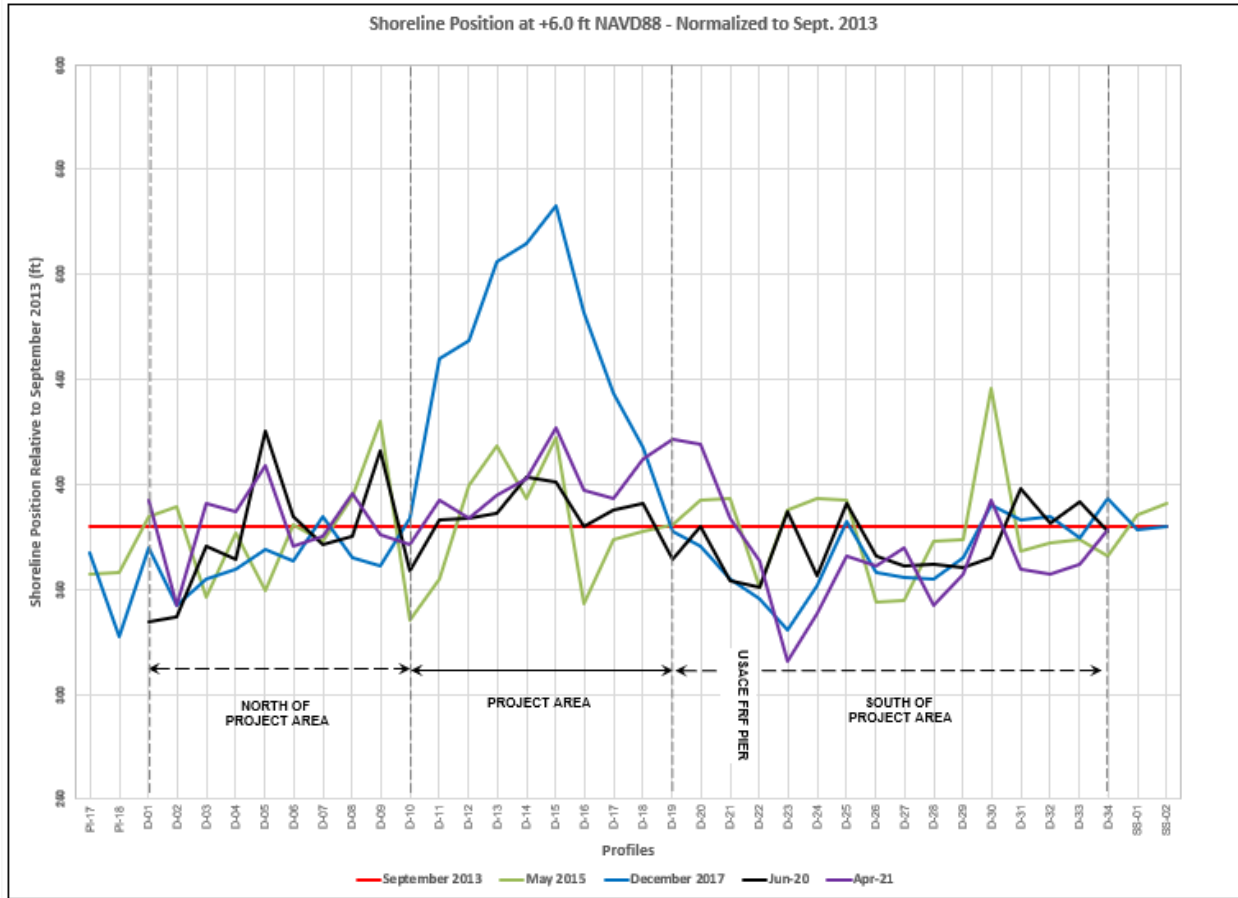


Figure 3. Historical +6.0 ft. NAVD88 Position Relative to the September 2013 +6.0 ft. NAVD88 Position

Project Area (D-10 to D-19)

With the construction of the beach nourishment project in 2017, the +6 ft. NAVD88 contour was extended seaward +183 ft. based on comparisons of the before dredge (BD) and after dredge (AD) surveys. However, these numbers reflect the change based on the placement of the unequibrated beach fill construction template. Between April 2017 and December 2017, the beach fill underwent immediate post-fill adjustments which reduced the initial advancement of the +6.0 ft. NAVD88 contour to an average of +89.5 feet. Note, this average does not include D-19 as this profile was not surveyed during the April 2017 pre-construction survey. The project average includes D-10 through D-18. This seaward advance of the +6.0 ft. NAVD88 contour is more reflective of the effective advance as a result of the project.

Beach profile data indicated that between December 2017 and April 2021, the average shoreline change of the +6 ft. NAVD88 contour within the Project Area was -59.1 ft., which is equivalent to a rate of change of -17.7 ft./yr. A profile-by-profile comparison shows a wide range of rates of change in the position of the +6.0 ft. NAVD88 contour (Table 3). The greatest shoreline changes measured appear to be taking place in the central portion of the project between Station D-13 (Sea Tern Dr.) and D-16 (Pintail Dr.). The average shoreline change along those 4 profiles was -103.6 ft. The average shoreline change between December 2017 and April 2021, in the northern portion of the Project Area from D-12 (Sound Sea Ave.) to D-10 (Skimmer Way) was -55.0 ft.; whereas, the average shoreline change in the southern part of the Project Area from D-17 (located at the south end of Buffell Head Rd.) to D-19 (northern USACE FRF boundary) was -3.9 ft. Table 2 includes measured shoreline change for each profile as well as the average shoreline

change for the beach nourishment project and the monitored areas outside the project. Table 3 includes rates of change of the +6.0 ft. NAVD88 contour for each profile as well as the average rate of change along the Project Area and the Areas to the North and South.

Figure 4 depicts the average cumulative change in the position of the +6.0 ft. NAVD88 contour within the Project Area (i.e. average change of stations D-10 to D-19) between September 2013 and April 2021. The large increase in the cumulative average shoreline change in the Project Area between May 2015 and December 2017 reflects the 89-foot seaward advance of the average shoreline position associated with the beach fill project completed in June 2017. After an initial shoreline recession measured between December 2017 and June 2018, the shoreline change appeared to stabilize somewhat and even advance seaward on average, between June 2018 and May 2019. Between May 2019 and December 2019, a significant shoreline recession was observed associated with Hurricane Dorian. Recession continued at a lower rate between December 2019 and June 2020. Between June 2020 and April 2021, the position of the +6.0 ft. NAVD88 contour moved an average 15.7 ft. seaward along the Project Area.

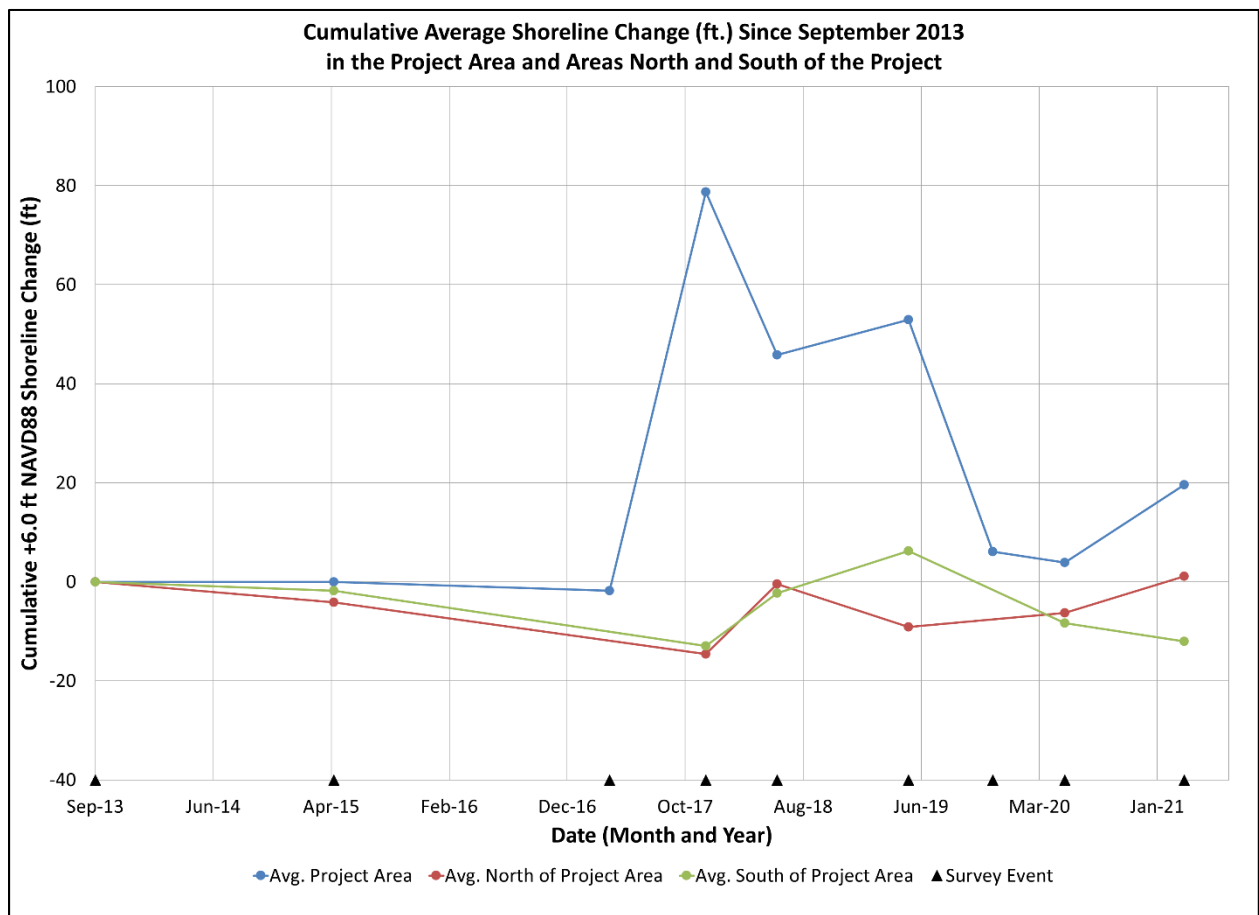


Figure 4. Cumulative Average Changes in the +6.0 ft. NAVD88 Contour Position since September 2013 in the Project Area and in the Areas North and South of the Project Area

Area North of Project (D-01 to D-10)

The average position of the +6.0 ft. NAVD88 contour north of the beach nourishment project (stations D-01 to D-10) is nearly the same as the average position measured in September 2013. As shown in Figure 4, between September 2013 and December 2017, the Area North of the Project experienced negative shoreline change. Between December 2017 and June 2018, the shoreline position experienced a positive change resulting in a similar average position of 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.

As seen in Table 2, the individual measurements from profile to profile vary considerably. Between September 2013 and April 2021, the shoreline change at station D-05 (S. Station Bay Dr) has experienced the greatest positive change of +29.2 ft. whereas the greatest negative change of -37.8 ft. was measured at station D-02 (N Baum Trail).

During the recent survey interval, from June 2020 to April 2021, the shoreline moved seaward an average 7.5 ft. Although the average change was positive, the measured shoreline change varied throughout the area. In general, the northernmost profiles at stations D-01 and D-04 had an average shoreline change of 26.7 ft. (seaward). The average shoreline change measured from station D-05 to D-09 (south end of S. Baum Trail to Pelican Way) was -8.9 feet (landward movement). Station D-01, located at Station 1 Ln, which is considered the northern boundary of the Area North of Project, experienced the greatest positive (seaward) shoreline change between June 2020 and April 2021 (57.9 ft.) Station D-09, located at Pelican Way, which is considered the first profile north of the Project Area, experienced the greatest negative (landward) shoreline change between June 2020 and April 2021 (-39.7 ft.)

Area South of Project (D-19 to D-34)

The average shoreline change of the +6.0 ft. NAVD88 contour south of the Project Area between September 2013 and April 2021 was -12.0 ft. (landward movement). This is equivalent to a rate of -1.6 ft./yr. when annualized. As shown in Figure 4, between September 2013 and December 2017, the Area South of the Project experienced negative shoreline change. As shown in Figure 4, between December 2017 and May 2019, the area experienced an average positive shoreline change. However, between May 2019 and April 2021, the average shoreline change has been negative, resulting in little overall change in the average shoreline position between December 2017 and April 2021.

As seen in Table 2 and Table 3, the individual measurements from profile to profile vary considerably. The average shoreline change measured from D-19 (northern boundary of FRF property) and D-22 (200 ft. north of FRF pier) was 34.6 ft. (seaward movement) between June 2020 and April 2021. All of these stations fall within the FRF property, including D-19 which showed shoreline change of +56.6 feet. Between stations D-23 (800 ft. south of FRF pier) and D-33 (Bias Ln E), the average shoreline change was -18.0 ft. between June 2020 and April 2021. All of these stations fall south of the FRF pier, including D-23 which showed shoreline change of -71.3 feet.