

IV. SHORELINE CHANGES

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 Mean High Water (MHW) contour, which represents the +1.2 feet NAVD elevation (CPE, 2015). Shoreline change is calculated by comparing shoreline position along shore perpendicular transects. Typically, shoreline change is then annualized to describe recession and advance rates. Regardless of whether total or annual shoreline changes are described, positive shoreline change denotes advance (seaward movement) while negative shoreline change indicates recession (landward movement).

The MHW position for each survey was identified along shore perpendicular transects spaced at approximately 1,000-foot intervals at the profiles identified in Table 1 along the monitoring area. The rate of change in the MHW shoreline position measured between the various surveys are provided in Table 2. Within the beach nourishment project (stations D-10 through D-19), shoreline change rates are shown for the period from October 1996 to May 2015, which represents long-term rates prior to construction of the project. Also shown in Table 2, are the changes in the MHW shoreline that occurred between December 2017 and June 2018 as well as an update of the long-term rates measured between October 1996 and June 2018. The updated long-term rates include the impacts of the beach nourishment project.

Outside the beach nourishment project area, shoreline change rates are provided in Table 2 for the period from October 1996 to May 2015, which again, represents long-term rates prior to construction of the project. Table 2 also provides long-term rates from October 1996 to June 2018, which include the effects of the beach nourishment projects on adjacent shorelines. Furthermore, the short-term shoreline change rates (December 2017 to June 2018) are also provided in Table 2 for the area outside of the project area.

The May 2015 survey was the last survey of the entire monitoring area (SS 17 to D-34) conducted prior to the 2017 beach nourishment operation. Even though the 2017 beach nourishment project was completed in June 2017, due to large-scale profile adjustments that normally occur immediately following the placement of a fill, the December 2017 survey has been adopted to represent the post-construction conditions within the project area. This and future annual monitoring reports will reference shoreline changes and volume changes in the project area relative to the December 2017 condition.

Table 2. MHW Shoreline Change Rates

PROFILE	Shoreline Change Rate (FT/YR)		
	OCT. 1996 TO MAY 2015	OCT. 1996 TO JUNE 2018	DEC. 2017 TO JUNE 2018
PI-17	0.3	-0.1	-122.1
PI-18	1.2	0.2	-3.6
D-01	0.9	0.0	-64.3
D-02	1.2	-0.8	-62.7
D-03	-0.6	0.1	-45.4
D-04	-1.0	-2.2	-22.6
D-05	-4.2	-2.3	-48.7
D-06	-1.8	-1.3	-29.2
D-07	-0.4	0.3	-25.3
D-08	0.6	1.4	-27.1
D-09	3.8	2.6	61.5
D-10	0.7	N/A	-20.1
D-11	1.9	N/A	-81.6
D-12	3.9	N/A	-89.8
D-13	1.4	N/A	-132.5
D-14	-2.0	N/A	-197.4
D-15	-0.6	N/A	-185.4
D-16	-5.8	N/A	-156.1
D-17	-5.6	N/A	-106.8
D-18	-3.0	N/A	-70.3
D-19	-2.2	N/A	-70.6
D-20	-2.3	-0.3	-47.2
D-21	-3.7	-1.4	-5.5
D-22	-1.4	0.1	46.1
D-23	3.8	2.1	93.0
D-24	2.1	0.5	1.8
D-25	-1.8	-0.9	15.2
D-26	-4.2	-2.1	-0.3
D-27	-2.0	-1.4	7.5
D-28	0.9	0.5	6.9
D-29	2.0	1.2	1.6
D-30	4.8	0.9	-36.3
D-31	-0.7	0.7	9.7
D-32	-2.2	-1.6	-6.9
D-33	-1.4	-1.5	-23.2
D-34	-0.8	0.0	-31.0

NORTH OF BEACH PROJECT (PI-17 TO D-10)	0.1	0.1	-34.1
PROJECT AREA (D-10 TO D-19)	-1.1	N/A	-111.1
SOUTH OF BEACH PROJECT (D-19 TO D-34)	-0.6	-0.2	-2.4

The linear changes in the shoreline position represented by the MHW contour can vary considerably along the monitoring area and can sometimes differ from volume change trends along sections of a beach. This difference is often due to changes in the slope of the foreshore along the beach from one end of the monitoring area to the other. As shown in Figure 3, the position of the MHW location on the profile can vary greatly depending on the shape of the profile at the time of the survey.

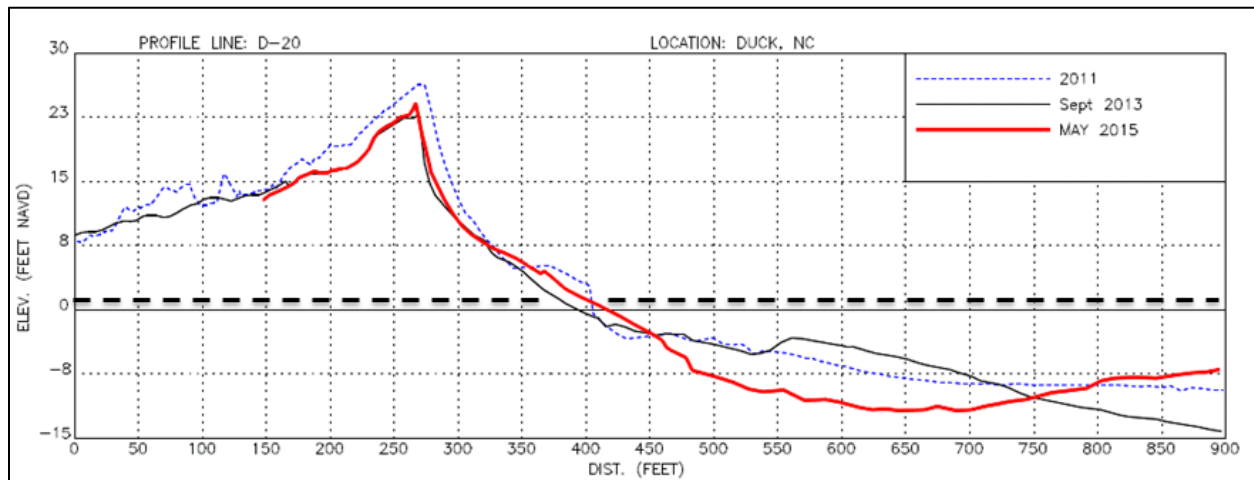


Figure 3. MHW Shoreline Change Variation.

Shoreline change is provided as a rate in an annualized form by dividing the shoreline change by the time period (number of years) between survey events (i.e. feet per year). These rates are described in terms of positive (“+”) or advance (shoreline moving seaward) and negative (“-”) or recession (shoreline moving landward).

For the purpose of monitoring, this report has separated the oceanfront beach of Duck into three areas: namely, the Project Area and the areas North of the Project and South of the Project. These areas are depicted on Figure 3. The Project Area includes the beach between the northern FRF property line, located near profile D-19, through profile D-10, which is near the northern end of Skimmer Way. The section referred to as North of the Project extends from profile D-10 (northern end of Skimmer Way) north to the Duck town limits (profile D-01) plus 2,000 feet on the south end of Pine Island (profiles (PI-17 and PI-18)). The area designated South of the Project extends

from profile D-19 south to D-34. Profile D-34 is located near the Duck town boundary with the Town of Southern Shores.

Figure 4 graphically displays the location of MHW shorelines for the entire monitoring area relative to the October 1996 shoreline. The relative shorelines shown are for May 2015, December 2017 (Post-Construction), and June 2018. As discussed in the feasibility report for the Town of Duck (CPE-NC, 2013) the Duck shoreline is known to be characterized by a series of perturbations, also called “sand waves”, which migrate along the shore. As the sand waves migrate, the behavior of shoreline from one section to the next can experience wide swings from recession to accretion. Therefore, the characterization of shoreline changes within the monitoring area is best represented by averaging shoreline trends for multiple profile lines within certain areas. As discussed below, average shoreline trends were computed for the three subareas within the monitoring area, namely; the Area North of the Project, the Project Area, and the Area South of the Project.

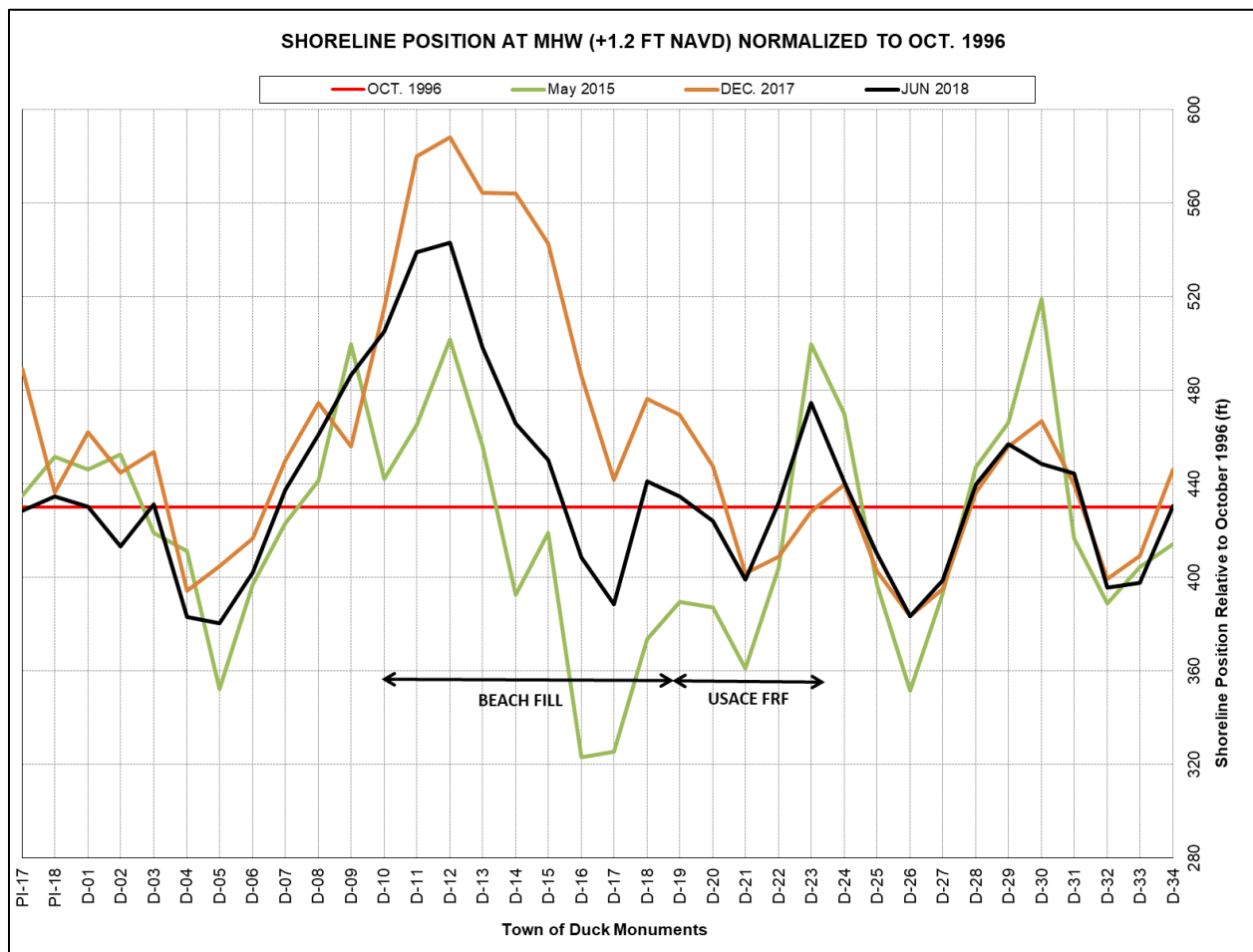


Figure 4. Historical MHW (+1.2 FT NAVD) shoreline position relative to the October 1996 MHW shoreline.

BEACH NOURISHMENT PROJECT AREA (D-10 TO D-19)

The beach nourishment project constructed in 2017 extended the MHW line approximately 241 ft. seaward based on comparisons of the before dredge (BD) and after dredge (AD) surveys (APTIM, 2018B). However, these numbers should not be used in the determination of shoreline change analysis as these numbers represent the condition of the beach prior to any profile equilibration taking place. Based on a comparison of the April 2017 pre-construction survey and the December 2017 survey, the placement of the beach fill within the project area (D-10 to D-19) moved the mean high water (+1.2 ft. NAVD88) contour an average of approximately 111 feet seaward (APTIM, 2018B). This number is more reflective of the movement of the MHW shoreline as a result of the project, as it takes into account profile equilibration that took place between June 2017 and December 2017. From December 2017 to April 2018, the mean high water (MHW) shoreline receded an average of about 55 feet. The recession of the MHW shoreline during this period was associated with continued profile adjustments as material on the upper portion of the profile was moved seaward to deeper portions of the active profile. An example of this offshore movement of material is provided in Figure 5 for Profile D-14.

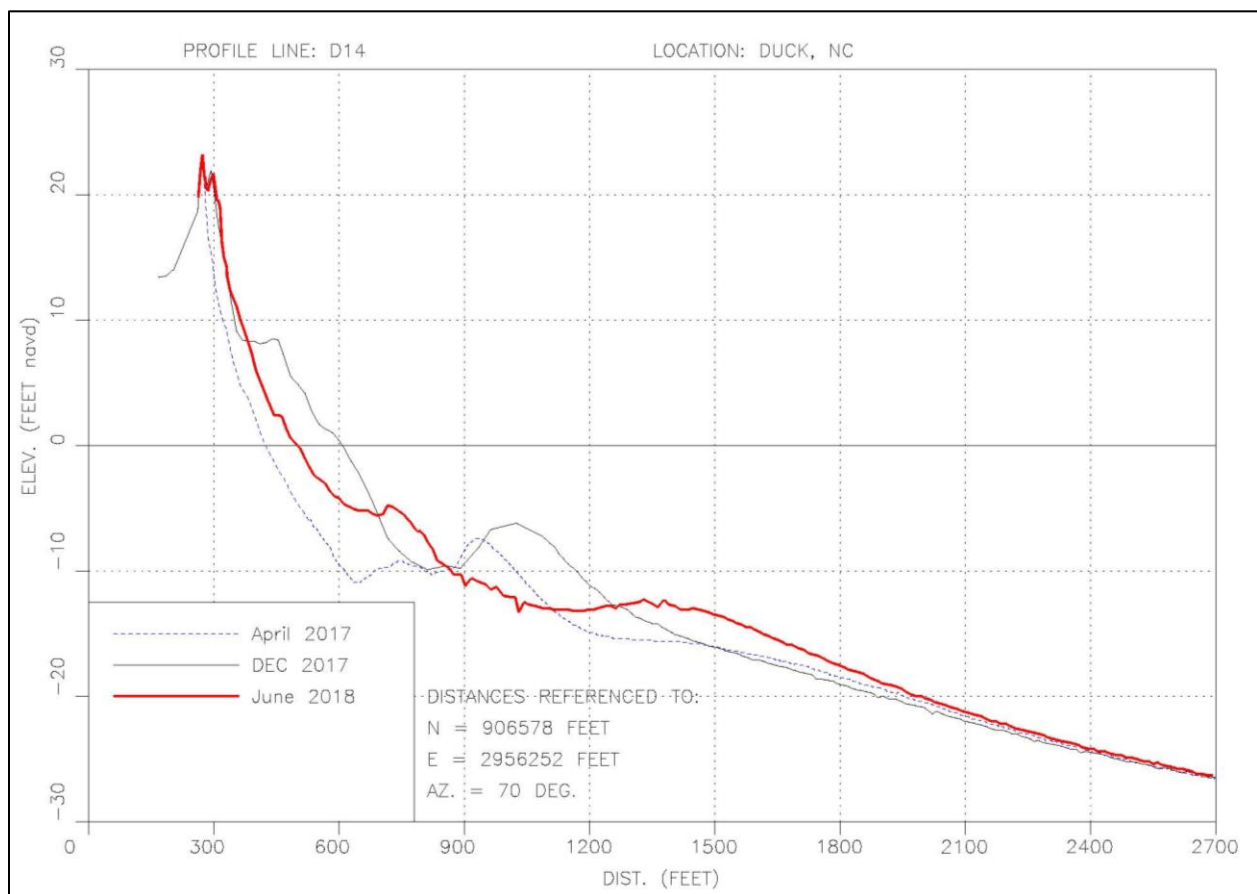


Figure 5. Typical post-fill profile adjustments.

The average cumulative change in the position of the MHW shoreline within the project area (i.e. average of profiles D-10 to D-19) between October 1996 and June 2018 is shown on Figure 6. The shoreline was generally receding up until November 2012 but experienced some recovery (accretion) just prior to the construction of the beach fill project. The cumulative changes in the project area reflects the 111-foot seaward advancement of the shoreline between April 2017 and December 2017 associated with the beach fill project followed by the 55-foot retreat during continued post-fill adjustments that occurred between December 2017 and June 2018.

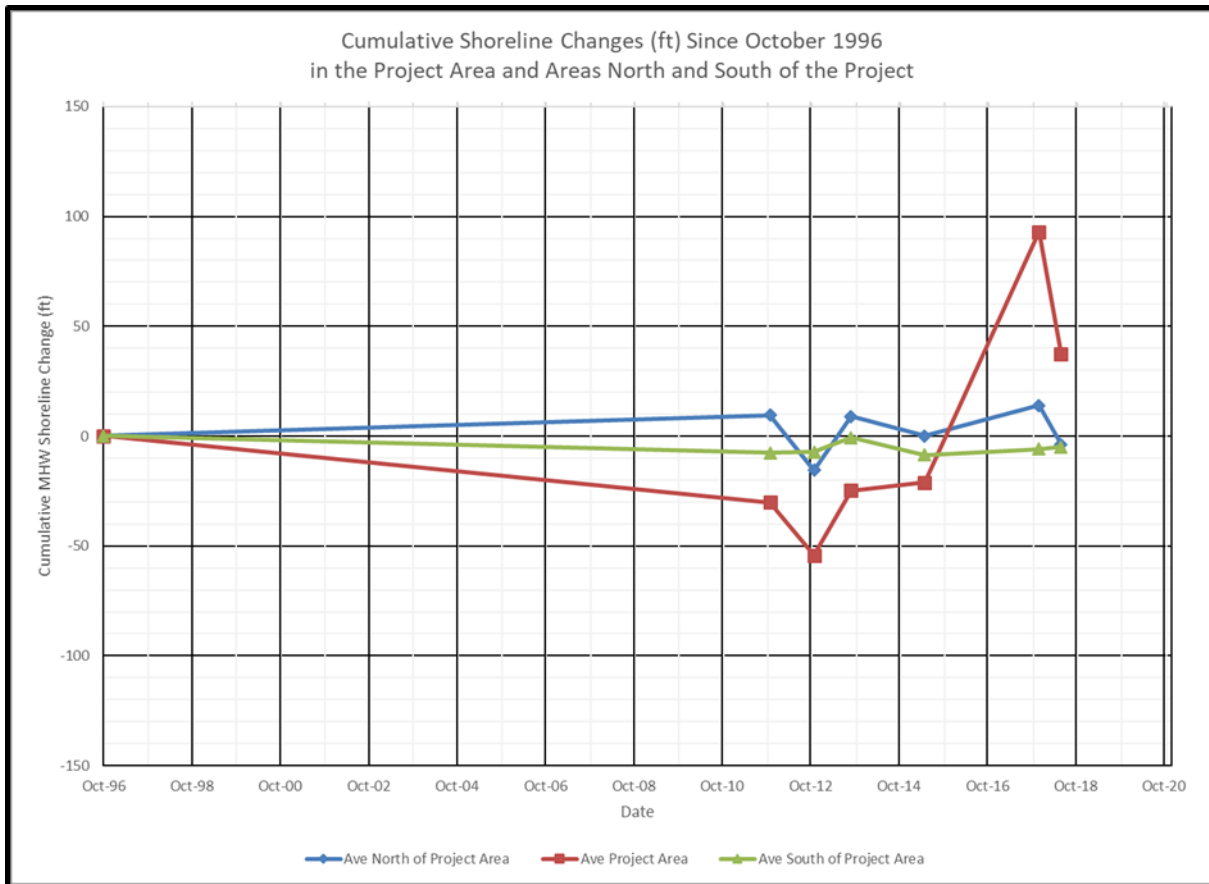


Figure 6. Average cumulative changes in the MHW shoreline position since October 1996 in the Project Area and in the areas north and south of the Project Area.

OUTSIDE THE BEACH NOURISHMENT PROJECT AREA (PI-17 TO D-10 AND D-19 TO D-34)

The average cumulative change in the position of the MHW shoreline in the areas north of the project and south of the project between October 1996 and June 2018 are also shown in Figure 6. Both areas were relatively stable during this period with average shoreline change rates of +0.1 and -0.2 ft./yr., respectively. However, over the long-term period of October 1996 to June 2018, two areas experienced relatively high rates of shoreline recession, one north of the Project Area and one South of the Project Area. In the north area, the shoreline from profile stations D-04 to D-06 (Sanderling Resort to Martin Lane) receded at an average rate of -1.9 ft./yr. between October 1996 and June 2018. South of the Project Area, the shoreline between profile stations D-25 and D-27 (Sea Colony to Wampum Dr.) eroded at an average rate of -1.5 ft./yr. during this period.

A comparison of data collected in September 2013 (CPE-NC, 2015) and June 2018 allows for an evaluation of trends that have occurred over the past 4.75 years. Table 3 shows a comparison of the long-term shoreline change rates outside the project area as measured between October 1996 and June 2018, as well as between September 2013 and June 2018. The average shoreline change rate north of the project areas between September 2013 and June 2018 was -1.9 ft./yr. Similar to the trend seen from 1996 to 2018, the average shoreline change rate in the section between station D-04 and D-06 (-3.0 ft./yr) was higher than the overall average north of the project area (-1.9 ft./yr.). However, the area between station PI-18 and D-03 had a shoreline change rate of -7.2 ft./yr. over the same 4.75-year period.

During the same 4.75-year period from September 2013 to June 2018, the average shoreline change rate south of the project areas between September 2013 and June 2018 was 0.0 ft./yr. This average rate is heavily influenced by the positive shoreline change experienced directly south of the beach fill project along profile D-19 and D-20. The average shoreline change rate from D-21 south along the Duck Shoreline was calculated to be -1.8 ft./yr. Similar to the trend seen from 1996 to 2018, the average shoreline change rate in the section between Station D-25 and D-27 (-2.7 ft./yr) was higher than the overall average south of the project area. However, it appears as though the area with higher shoreline change rates may have migrated south over the past 4.75 years as D-25 had a positive shoreline change rate of +0.5 ft./yr., and the section of beach from D-27 to D-29 had an average shoreline change rate of -3.8 ft./yr.

Table 3. MHW Shoreline Change Rates Outside Project Area

PROFILE	MHW SHORELINE CHANGES (FT/YR)	
	OCT. 1996 TO JUNE 2018	SEPT. 2013 TO JUNE 2018
PI-17	-0.1	-2.5
PI-18	0.2	-11.2
D-01	0.0	-4.9
D-02	-0.8	-6.6
D-03	0.1	-6.2
D-04	-2.2	-1.1
D-05	-2.3	-5.4
D-06	-1.3	-2.3
D-07	0.3	2.2
D-08	1.4	4.0
D-09	2.6	4.8
D-10	3.5	6.5
Beach Nourishment Project Area		
D-19	0.2	13.0
D-20	-0.3	12.1
D-21	-1.4	-1.7
D-22	0.1	-2.3
D-23	2.1	-1.5
D-24	0.5	-1.1
D-25	-0.9	0.5
D-26	-2.1	-1.6
D-27	-1.4	-6.9
D-28	0.5	-2.7
D-29	1.2	-1.9
D-30	0.9	-1.1
D-31	0.7	-0.1
D-32	-1.6	-0.7
D-33	-1.5	-3.2
D-34	0.0	-1.0
NORTH OF BEACH PROJECT (PI-17 TO D-10)	0.1	-1.9
SOUTH OF BEACH PROJECT (D-19 TO D-34)	-0.2	0.0