

V. VOLUMETRIC CHANGE RESULTS

Volumetric changes measured over the entire monitoring area for various time periods are provided in Table 4. The volume changes are given in terms of cubic yards/foot of shoreline/year (cy/ft./yr.). Volume change rates were evaluated for the periods from September 2013 to May 2015, December 2017 (Post-construction) to June 2020, and May 2019 to June 2020. The September 2013 to May 2015 rates represent trends occurring prior to construction of the project. The December 2017 to June 2020 surveys show changes occurring since the beach nourishment project was completed whereas the May 2019 to June 2020 surveys present the recent volume changes measured between the last two monitoring events.

The discussion of volume changes focuses on changes occurring within the beach nourishment Project Area (stations D-10 to D-19) as well as changes that are occurring north and south of the Project Area. Figure 5 graphically depicts the volumetric changes calculated above -24 ft. NAVD88 between September 2013 and June 2020 as well as changes measured from May 2019 to June 2020 and between December 2017 and June 2020.

Initial Beach Fill Volumes

Between May and June 2017, the 2017 beach nourishment project placed a total of 1.26 million cubic yards of fill along the Duck shoreline between stations D-10 and D-19 (APTIM, 2018A). However, the performance of the 2017 project along the Town of Duck is based on changes that occur relative to the conditional monitoring survey conducted in December 2017. For purposes of monitoring the performance of the beach fill, the initial volume of material within the limits of the Project Area is defined as the volume change measured between April 2017 and December 2017 (APTIM, 2018B). Based on volume changes computed between the April 2017 and December 2017, a volume change of approximately 963,100 cubic yards were measured on the active profile (above the -24-foot NAVD88 contour) from station D-10 to station D-19 (APTIM, 2018C). For more information on why this method of assessing volume is used, please refer to the 2018 Shoreline and Volume Change Monitoring Report (APTIM, 2018C).

Project Area (D-10 to D-19)

Beach profile monitoring surveys indicate a volume change within the project area of approximately -271,000 cubic yards between December 2017 (Post-construction) and June 2020. This equates to a rate of -12.4 cy/ft./yr. when annualized. **As of June 2020, the analysis indicates that the Town of Duck beach nourishment project had approximately 72% of the initial fill volume remaining as measured above the -24-foot NAVD88 contour.** Figure 6. Figure 6 shows the cumulative volumetric changes for the Town of Duck measured since the initial design survey conducted in September 2013. Cumulative volumetric changes are displayed for the Project Area, North of Project Area and South of Project Area. The large increase in the Project Area curve (blue line) between April 2017 and December 2017 reflects the addition of volume due to the project construction. Since then a relatively linear trend in erosion has been measured from December 2017 to June 2020. Figure 6 also illustrates the volumetric changes between May 2019 and June 2020, specifically the negative volumetric losses attributed to Hurricane Dorian, which impacted the beach in September 2019, and the recovery of the active beach profile between the December 2019 survey and the June 2020 survey.

Table 4. Volumetric Changes (CY/FT./YR.) along Duck above -24 FT NAVD88.

PROFILE		September 2013 to May 2015 (Baseline Surveys)	December 2017 (Post-Con) to June 2020 (Year-3)	May 2019 (Year-2) to June 2020 (Year-3)
Area North of Project	D-01	-10.5	4.4	22.3
	D-02	0.3	6.2	-17.8
	D-03	-33.2	6.4	33.8
	D-04	-16.0	9.5	22.6
	D-05	-52.4	17.3	56.4
	D-06	-18.3	8.8	-3.7
	D-07	-28.4	8.4	29.0
	D-08	-37.2	4.8	0.8
	D-09	25.1	14.9	30.9
Project Area	D-10	-44.6	2.1	-5.9
	D-11	-69.9	-6.9	-1.0
	D-12	30.3	-5.4	-4.8
	D-13	33.1	-13.6	-31.9
	D-14	1.5	-12.8	16.4
	D-15	12.3	-24.9	-26.8
	D-16	-19.5	-17.8	7.5
	D-17	19.5	-10.5	4.4
	D-18	5.2	-18.9	-2.6
	D-19	-4.4	-15.8	-3.6
Area South of Project	D-20	3.9	-3.7	-3.2
	D-21	27.1	8.1	35.8
	D-22	-9.4	13.9	-1.5
	D-23	67.1	9.1	26.8
	D-24	38.0	-4.6	-6.6
	D-25	-1.1	2.0	28.1
	D-26	-28.2	-5.0	-16.4
	D-27	-30.6	1.1	31.5
	D-28	-10.9	6.7	5.6
	D-29	-55.3	2.0	9.5
	D-30	80.2	-0.7	11.1
	D-31	-7.1	13.0	18.1
	D-32	-2.8	7.4	21.8
	D-33	-12.9	22.0	51.6
	D-34	-35.1	0.8	-20.0
AREA NORTH OF PROJECT (D-01 TO D-10)		-21.5	8.3	16.8
PROJECT AREA (D-10 TO D-19)		-3.7	-12.4	-4.8
AREA SOUTH OF PROJECT (D-19 TO D-34)		1.1	3.5	11.8

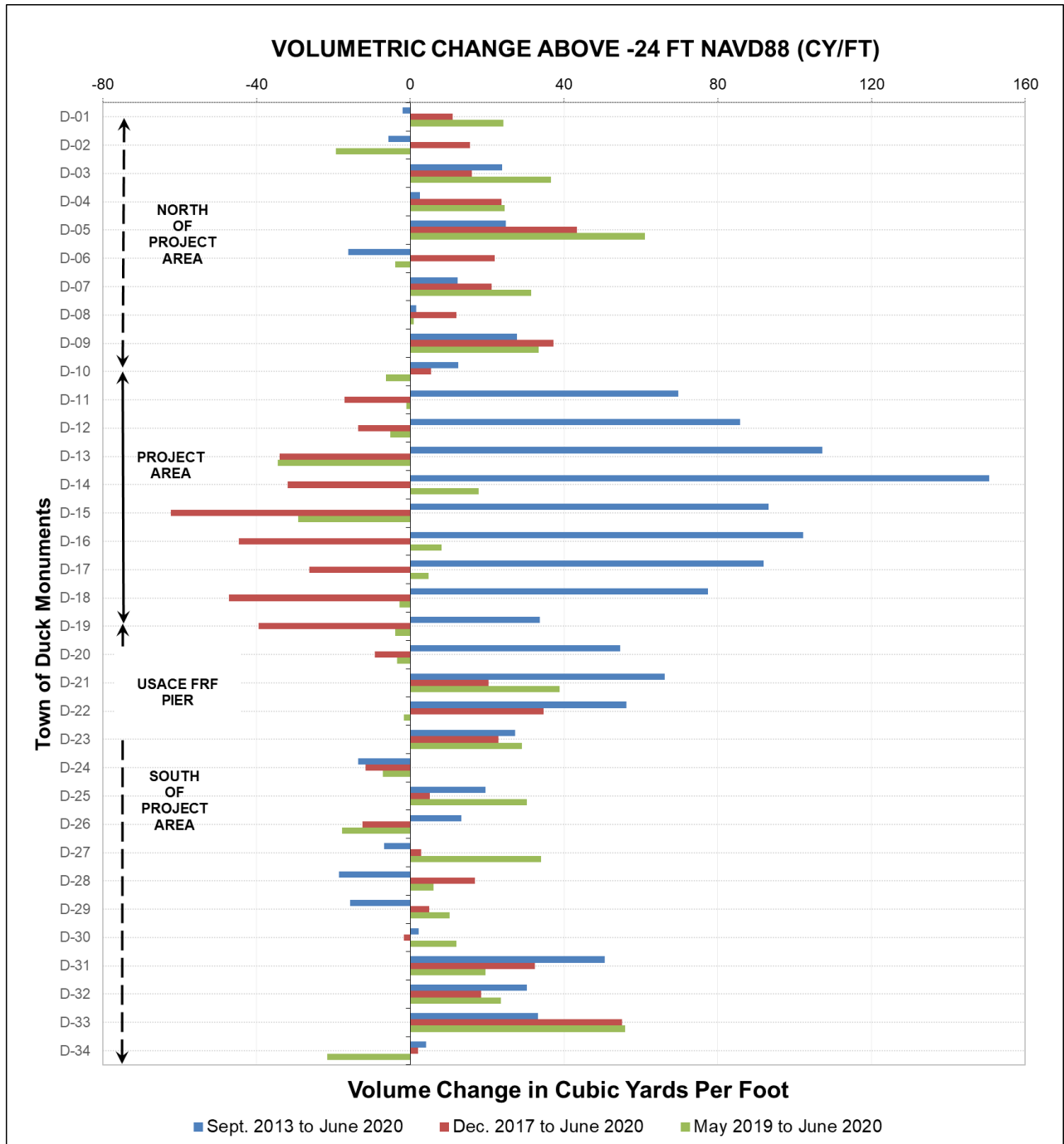


Figure 5. Volume Changes (cubic yards/foot) measured between Sept. 2013 to June 2020, Dec. 2017 to June 2020, and May 2019 to June 2020.

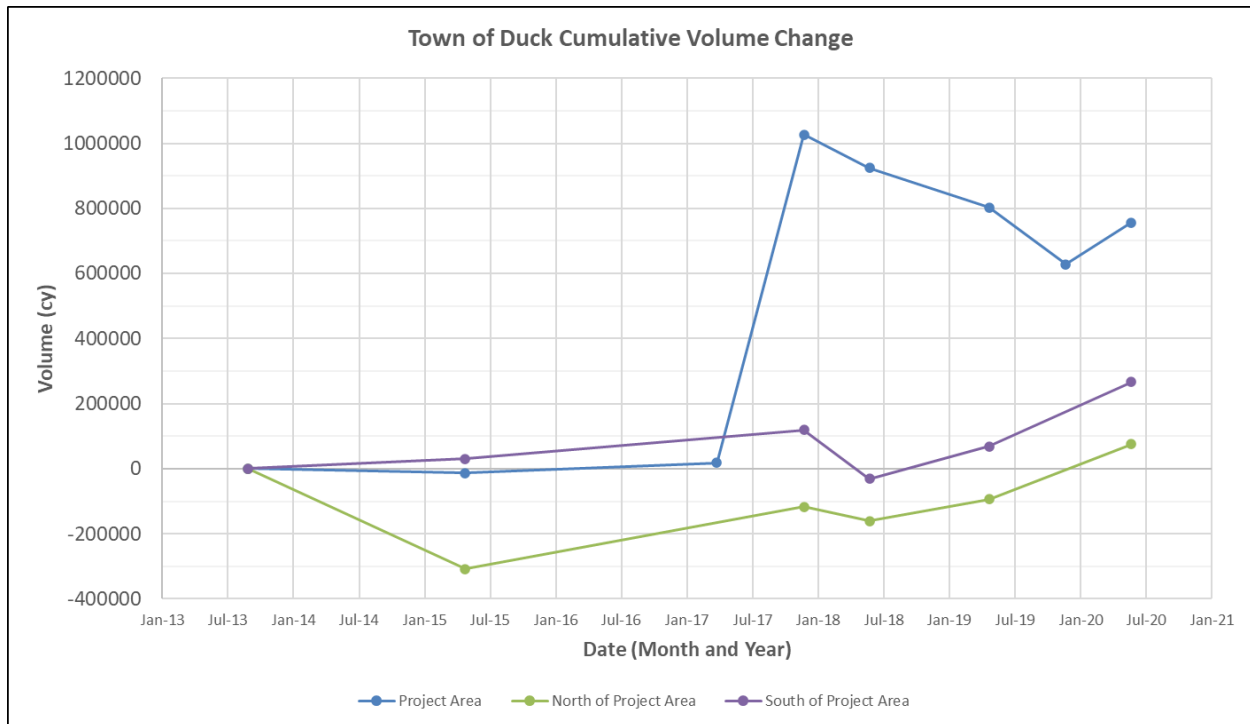


Figure 6. Average cumulative volumetric changes above the -24 ft. NAVD88 contour since September 2013 in the Project Area and in the areas north and south of the Project Area.

The net volumetric change measured from May 2019 to June 2020, was a negative volumetric change of approximately 45,000 cubic yards. This is equivalent to an average loss of approximately -4.8 cy/ft./yr. and equates to approximately 17% of the volumetric change measured between December 2017 and June 2020. The greatest negative volumetric changes were measured along station D-13 (-34.5 cy/ft.), located at Sea Tern Drive E., and station D-15 (-29.1 cy/ft.), located along Bufflehead Road between Springtail and Canvasback Drive. The largest positive volumetric change was measured between these two stations at station D-14 (+17.8 cy/ft), located at Diane St. The four southern profiles within the Project Area (D-16 to D-19) measured an average volume change of approximately +1.6 cy/ft. over the 13-month period. Figure 5 illustrates both the individual short-term volumetric change trends along each profile as well as changes that have occurred since December 2017 and September 2013.

Area North of Project (D-01 to D-10). Volumetric changes in the monitoring Area North of the Project, prior to the construction of the beach nourishment project (September 2013 to May 2015), indicated an average volume change rate of -21.5 cy/ft./yr. Since the project was constructed (December 2017 to June 2020), the average volumetric change rate measured within the area North of the Project was +8.3 cy/ft./yr. The recent period between May 2019 to June 2020 (13-months) measured an average gain of 16.8 cy/ft./yr. within the area. In Figure 6, the curve representing the cumulative volumetric changes north of the Project Area (green) shows the relatively steep erosional trend observed between September 2013 and May 2015, prior to the construction of the project. The next data point for the Area North of the Project is the cumulative volume measured in December 2017, which shows an increase in volume between May 2015 and December 2017. It is noteworthy to report that even after the project, the cumulative volumetric change curve shows less volume in the area north of the project than what was present in September 2013. Between December 2017 and June 2018, the Area North of the Project experienced a modest reduction in volume followed by a 2-year period (June 2018 to June 2020) of

volumetric increase. As of June 2020, the Area North of the Project experienced a net positive volumetric change of approximately 80,000 cy compared to the area in September 2013. Since the project was constructed in 2017, the Area North of the Project experienced a positive volumetric change of approximately 190,000 cy.

In the previous monitoring report (APTIM, 2019), the analysis of the changes along the 4,000 ft. of shoreline immediately north of the Project Area between Martin Ln. and Skimmer Way (stations D-06 and D-10) measured a positive volumetric change of 3.5 cy/ft. between June 2018 and May 2019. The more recent volumetric change trend measured between May 2019 and June 2020 show this 4,000 ft. section gained an average 11.1 cy/ft., equivalent to approximately 60,000 cy.

The area along the northern approximately 5,000-foot section of the monitoring area from D-06 through D-01, experienced a positive average volumetric change of 20.5 cy/ft. between May 2019 and June 2020. This equates to a gain of approximately 111,000 cy.

Area South of Project (D-19 to D-34). Volumetric changes in the monitoring Area South of the Project, prior to the construction of the beach nourishment project (September 2013 to May 2015), were relatively stable indicating modest positive volumetric changes at a rate of 1.1 cy/ft./yr. However, a review of the changes from station to station indicates the behavior of the shoreline was highly variable. Within this area, volume changes between profile stations varied from an accretion rate of 80.2 cy/ft./yr. at station D-30 to an erosion rate of -35.1 cy/ft./yr. at station D-34. During the 30-month period from December 2017 to June 2020, since the construction of the beach nourishment project, this area gained an average of 3.5 cy/ft./yr. During the recent 13-month period, from May 2019 to June 2020, this area accreted at an average rate of 11.8 cy/ft./yr. In Figure 6, the curve representing the cumulative volumetric changes south of the Project Area (purple) illustrates the relatively modest accretional trend observed between September 2013 and May 2015, prior to the construction of the project. The next data point for the area South of the Project is the cumulative volume measured in December 2017, which shows an increase in volume between May 2015 and December 2017. Similar to the trend observed in the area North of the Project, between December 2017 and June 2018, the area South of the Project experienced negative volumetric changes followed by a 2-year period (June 2018 to June 2020) of volumetric increase. As of June 2020, the area South of the Project as a whole experienced a net positive volumetric change of approximately 270,000 cy compared to the area in September 2013. Since the project was constructed in 2017, the area South of the Project experienced a positive volumetric change of approximately 150,000 cy.

During the recent survey interval from May 2019 to June 2020, the 3,000-foot section south of the Project, between stations D-20 and D-23, gained an average of 14.5 cy/ft./yr. An examination of volume changes measured station to station shows the highest volumetric gains of 35.8 cy/ft./yr. and 51.6 cy/ft./yr. at stations D-21 and D-33, respectively while stations D-26 and D-34 to the south exhibited the greatest negative volumetric changes of 16.4 cy/ft./yr. and 20.0 cy/ft./yr., respectively (Table 4). Figure 5 illustrates both the individual short-term volumetric change trends along each profile as well as changes that have occurred since December 2017 and September 2013.