VIII. SUMMARY

This monitoring report evaluated shoreline and volumetric changes along the portions of shoreline nourished in 2017 within the Town of Duck as well as portions of the adjacent shorelines to the north and south. The monitoring area extends south from station D-01, located at the northern limits of the Town of Duck, to station D-34, located near the Town of Duck town limits with the Town of Southern Shores. With the construction of the beach nourishment project in June 2017, the monitoring area was divided into three sections, namely; the Project Area (D-10 to D-19), the Area North of the Project (D-01 to D-10), and the Area South of the Project (D-19 to D-34). Data collected in May 2019 was used to evaluate shoreline and volumetric changes that have occurred following the 2017 beach nourishment project.

Shoreline Change Analysis:

Project Area. In general, the shoreline change measured within the Project Area from December 2017 to May 2019 shows an average retreat of the +6 ft. NAVD88 shoreline since construction of the beach nourishment project. The average shoreline retreat measured for the project area was -25.8 ft. as the constructed beach profile adjusted to tide and wave conditions. Most of the retreat was attributed to movement of sediment from the upper portions of the profile, to deeper portions of the active beach profile in response to tide and wave conditions. The short-term shoreline change trend between the recent survey interval (June 2018 and May 2019) was a seaward advance of +7 ft. on average within the project area.

The average position of the +6.0 ft. NAVD88 shoreline is +52.9 feet seaward of the September 2013 baseline survey as of May 2019. All stations surveyed in May 2019 show positive seaward positions compared to the September 2013 baseline survey.

Area North of the Project. The +6.0 ft. NAVD88 long-term shoreline changes north of the project (stations D-01 to D-10) were predominantly negative and highly variable from September 2013 to May 2019. The average change was -9.1 ft. (landward movement), equivalent to a rate of -1.6 ft./yr. when annualized. In particular, the shoreline from stations D-03 to D-07 (S. Baum Trail to Waxwing Ln.) experienced the highest rates of shoreline recession, averaging -18.3 ft., equivalent to an annualized rate of -3.2 ft./yr. over the 5.7-year period. A similar trend of increased landward movement between stations D-05 and D-09 (S. Station Bay Dr. to Pelican Way) was also observed during the recent period (June 2018 to May 2019). However, the area from D-01 to D-04 (Town of Duck northern limit to the Sanderling) experienced an average seaward movement of +7.4 ft. during the recent 11-month period.

Area South of the Project. Long-term shoreline changes computed between September 2013 and May 2019, which includes the construction of the beach nourishment project, averaged +6.2 ft. (seaward movement), equivalent to a rate of +1.1 ft/yr. However, one section of the shoreline located between Wampum Dr. to Four Season Ln. (stations D-27 and D-30) has experienced a higher trend of landward movement, with an average shoreline change of -18.2 ft., or a rate of -3.2 ft./yr. when annualized for the September 2013 to May 2019 period. Comparison of the recent surveys (June 2018 and May 2019) indicated the section of shoreline in the southern portion of this area between stations D-29 and D-33 experienced a landward movement of -11.7 ft. The

average +6.0 ft. NAVD shoreline change for the Area South of the Project was +8.5 ft. (seaward) during the 11-month period. This average appears to have been heavily influenced by positive shoreline changes south of the project area between stations D-21 to D-24 (approximately 200 ft. north of the FRF pier to Shipwatch). The shoreline change analysis indicates that the section of shoreline between station D-29 to D-33 should be closely monitored to see if this trend persists. Monitoring of this shoreline change trend can be accomplished through the use of the UAS monitoring program the Town has implemented.

Volume Change Analysis:

Project Area. Beach profile surveys indicate that during the most recent survey interval (June 2018 to May 2019), a volumetric loss of 126,200 cubic yards was measured. The highest losses occurred along the southern 2,600 ft. of the Project Area between Pintail Dr. and the northern border of the FRF property (D-16 to D-19). Some of the volume loss from the Project Area may have resulted from spreading losses, typical of a beach nourishment project. Since the completion of Town of Duck beach nourishment project, the Project Area has lost a total of 225,900 cubic yards (December 2017 to May 2019). This equates to approximately 23% of the fill measured in the Project Area in December 2017. As of May 2019, the analysis indicates that the Town of Duck beach nourishment project had 77% of the initial fill volume remaining as measured above the -24-foot NAVD88 contour.

Area North of the Project. The average volume change in the area north of the project, measured between September 2013 and May 2019, was -1.8 cy/ft./yr. In general, the northern approximately 6,000 feet of the area has seen negative volume changes, while the southern approximately 3,000 feet of the area, adjacent to the beach nourishment project, has seen positive volume changes. The average volume change measured from stations D-01 to D-07 was -2.9 cy/ft./yr. The southern portion of the area experienced a positive average volume change of +0.9 cy/ft./yr. The positive volumetric changes measured along the southern portion of the area is likely related to spreading losses that have occurred as a result of the construction and equilibration of the beach nourishment project. Between June 2018 and May 2019, the average volumetric change measured along the Area North of the Project was +8.0 cy/ft./yr.

Area South of the Project. As previously reported in the September 2018 monitoring report (APTIM, 2018), the average long-term volume change between stations D-19 to D-34, measured between September 2013 and June 2018, was a loss of -0.6 cy/ft./yr. The updated long-term trend for this area, based on the September 2013 and May 2019 surveys, indicates an average volumetric change of +1.5 cy/ft./yr. This change in the long-term trend was highly influenced by changes that were measured between June 2018 and May 2019 that exhibited average gain of 6.8 cy/ft./yr. during the recent 11-month survey interval.

In June 2018, an anomalous wide and deep trough was identified just offshore at station D-21. In May 2019, changes on the profile measured at stations D-21 and D-22 exhibited large gains between the -6 ft. and -24 ft. NAVD88 contours that filled in much of the trough observed in June 2018. With stations D-21 and D-22 located immediately north and south of the FRF pier the configuration of the project and recent changes could have been influenced by waves interacting with the pier's piles. Changes on the profiles at stations D-21 and D-22 will be closely examined

following the next monitoring survey to determine if the accretion on the profiles is still present or if it was just an ephemeral feature associated with wave conditions during the recent survey interval.

Nearshore Bathymetric Analysis:

In May 2019, APTIM conducted a supplemental bathymetric survey offshore of the Town of Duck oceanfront shoreline and within the limits of the Town's beach nourishment project from Baseline Station D-08 (south end of Blue Heron Lane) to Baseline Station D-19 (the northern boundary of the USACE FRF property). The survey was performed to determine whether or not anomalous offshore features similar to what has been observed offshore of the Kitty Hawk and Kill Devil Hills projects were present offshore of the Town of Duck. An examination of the nearshore bathymetry data collected during the May 2019 survey showed offshore contours running parallel to the shoreline and generally uniformly spaced throughout the extent of the area surveyed. The data did not show the presence of any anomalous seafloor features, depressions, or troughs similar to what was identified offshore of the Kitty Hawk and Kill Devil Hills project areas.

Storm Damage Vulnerability Analysis Update:

Using the previously calibrated SBEACH model and the May 2019 beach profile survey data, an updated storm vulnerability analysis was conducted of the oceanfront beach and dune system along the Town of Duck. The updated SBEACH analysis indicated that of the 90 structures and 29 pools previously identified as vulnerable within the Project Area based on 2015 data, none of those structures or pools were determined to be vulnerable based on the May 2019 conditions. Additionally, there were no new structures or pools identified to be vulnerable within the Project Area. Along the entire northern 3.3 miles of oceanfront within the Town of Duck (stations D-01 to D-19) there was only 1 structure identified to be vulnerable. This represents a 99% reduction in the number of structures identified as vulnerable between stations D-01 and D-19. The updated analysis also indicated a 35% reduction in the number of vulnerable structures south of the USACE FRF property (D-24 to D-34) based on the May 2019 conditions.

In terms of storm vulnerability, the 2017 beach fill project has performed as expected and has added a layer of protection to upland development against damage associated with long-term erosion and has reduced the damage potential due to coastal storms.

IX. RECOMMENDATIONS

APTIM recommends the Town continue to monitor the beach along the entire Town oceanfront in order to assess if shoreline and volume change trends identified in this report persist. Future monitoring will be instrumental for the Town to evaluate future areas of concerns and to develop successful shoreline management strategies to deal with issues as they arise. The monitoring program will continue to provide valuable information on the performance of the 2017 beach fill project and aid in the determination as to when additional nourishment is needed in the project area. The measured performance of the beach fill will also serve as a valuable tool to aid in the development and design of future beach nourishment projects the Town may consider.

The surveys will also be used to evaluate losses associated with coastal storms that are designated as natural disasters. In this regard, post-disaster relief programs available through the Federal Emergency Management Agency (FEMA) for "improved or engineered beaches", specifically Category G, may allow the Town to be reimbursed for the cost to replace sand lost due to a declared disaster. In order to be eligible for Category G assistance, the project must have a maintenance plan that includes periodic re-nourishment. The Town of Duck has a documented maintenance plan.

Based on the analysis of the supplemental nearshore bathymetric survey data collected in May 2019 offshore of the project area, no future supplemental bathymetric surveys are warranted. The offshore contours appear to follow a regular shore parallel pattern, which indicates 1,000-foot spaced profiles should be sufficient to evaluate volume change trends throughout the project area.

The monitoring program serves as the basis for determining when and what volume of additional nourishment is needed in the project area. Initial monitoring of the project over the first 2 years following construction indicates the Duck beach nourishment project appears to be performing as expected. However, given these results are based on only two years of survey data, APTIM does not believe an accurate assessment of updated volume needs for the anticipated 2022 project can be determined at this time.