TOWN OF NAGS HEAD

2024 FALL MONITORING SURVEY EVALUATION

Prepared for:

Rev No	A	B	–	–	–
Issue Purpose	Draft Report				
Date					
By	AK/VS				
Checked	NV				
Approved	NV				

Prepared by:

moffatt & nichol

TOWN OF NAGS HEAD

2024 FALL MONITORING SURVEY EVALUATION

moffatt & nichol

EXECUTIVE SUMMARY

The Town of Nags Head Beach Monitoring and Maintenance Plan is sponsored by the Town of Nags Head (Town) as a continuation of the 2011 monitoring program initiated for assessing beach conditions. The primary purpose of the program is to assess current and historical shoreline conditions, determine shoreline and volumetric changes and evaluate the performance of beach nourishment and other restoration efforts. Evaluating and documenting these changes consistently over successive years provides information necessary to plan for future beach nourishments and to support development of the Town's multi-decadal Beach Nourishment Master Plan.

The latest annual summer survey took place in June 2024 and was carried out by McKim & Creed. Furthermore, a fall survey, prompted by observed scarping along the Town's beachfront, was conducted by McKim & Creed in October 2024. This report outlines the data sources, methodologies, and findings of a survey evaluation conducted by Moffatt & Nichol. The evaluation compares the October 2024 survey to the data from June 2024 survey.

The survey data was used to compute shoreline change at Mean High Water (MHW), which is designated as +1.18 ft NAVD88 for Nags Head, and volume change above +6 ft NAVD88 (berm), MHW, -6 ft NAVD88 (wading depth), -14 ft NAVD88 (outer bar), -19 ft NAVD88 (approximate depth of closure), and -30 ft NAVD88 (offshore). **Table ES-1** and **Table ES-2** provide a summary of the shoreline and volume changes experienced during the observation period.

Table ES-1. Nags Head Shoreline and Average Unit Volume Change Statistics (June 2024 – October 2024)

June 2024 vs. October 2024	Transects	Reach Length	avg shoreline change @ +1.18 ft NAVD88	Change above +6 ft NAVD88	Change above +1.18 ft NAVD88	Change above -6 ft NAVD88	Change above -14 ft NAVD88	Change above -19 ft NAVD88	Change above -30 ft NAVD88
Reach	#	ft	ft	cy/ft	cy/ft	cy/ft	cy/ft	cy/ft	cy/ft
Reach 1	495+00 - 790+00	29,500	-14.1	-1.0	-4.2	4.7	9.6	-1.3	-14.2
Reach 2	790+00 - 920+00	13,000	-15.6	1.8	-0.9	6.6	17.4	3.5	-9.3
Reach 3N	920+00 - 975+00	5,500	-26.1	0.3	-6.2	-0.5	23.0	11.2	1.1
Reach 3S	975+00 - 1010+00	3,500	-43.1	-2.3	-10.9	-9.1	14.5	3.6	-5.2
Reach 4	1010+00 - 1025+00	1,500	2.1	-4.2	-5.7	6.2	30.5	16.5	0.0
	Transects	Reach Length	weighted avg	weighted avg	weighted avg	weighted avg	weighted avg	weighted avg	weighted avg
Nourished Oceanfront	**495+00 - 1025+00**	**53,000**	**-17.2**	**-0.3**	**-4.1**	**3.8**	**13.8**	**2.0**	**-10.4**

Table ES-2. Nags Head Cumulative Volume Change Statistics (June– October 2024)

June 2024 vs. October 2024	Transects	Reach Length	Change above +6 ft NAVD88	Change above +1.18 ft NAVD88	Change above -6 ft NAVD88	Change above -14 ft NAVD88	Change above -19 ft NAVD88	Change above -30 ft NAVD88
Reach	#	ft	cy	cy	cy	cy	cy	cy
Reach 1	495+00 - 790+00	29,500	-28,300	-121,508	137,697	279,228	-38,256	-412,781
Reach 2	790+00 - 920+00	13,000	23,726	-12,065	86,027	226,615	45,887	-120,332
Reach 3N	920+00 - 975+00	5,500	1,623	-33,983	-2,957	126,755	61,465	5,783
Reach 3S	975+00 - 1010+00	3,500	-8,206	-38,109	-31,769	50,576	12,757	-18,103
Reach 4	1010+00 - 1025+00	1,500	-8,485	-11,451	12,496	60,984	32,979	6,610
	Transects	Reach Length	total	total	total	total	total	total
Nourished Oceanfront	**495+00 - 1025+00**	**53,000**	-19,643	-217,115	201,494	744,158	114,832	-538,824

During the June 2024 - October 2024 monitoring period, from Reach 1 to Reach 4, the shoreline retreated -17.2 ft on average. Shoreline retreat was more pronounced in the southern reaches. Reach 3N retreated -26.1 ft, and Reach 3S experienced the greatest retreat rate of -43.1 ft. This erosion allowed waves to reach the dunes, resulting in dune scarping across the Nags Head oceanfront.

The dune scarping and erosion are evidenced by volume loss experienced above +6ft NAVD88 and MHW. Above +6 ft NAVD88, the nourished oceanfront lost -0.3 cy/ft on average in between the summer and fall surveys. The greatest unit volume loss above +6 ft NAVD88 occurred in the southern reaches: Reach 3S (-2.3 cy/ft or -8,206 cy) and Reach 4 (-4.2 cy/ft or -8,435 cy).

During the previous monitoring period, material was deposited above MHW from the nearshore, resulting in a steeper slope. In contrast, during the current observation period (end of July to end of October), all reaches experienced material loss above MHW, with the most significant losses occurring in the southern areas (Reaches 3N, 3S, and 4). The lost material shifted from the subaerial region to the nearshore and sandbar, with deposition occurring above -14 ft NAVD88.

All reaches experienced volume gains above -14 ft NAVD88, with the largest unit volume changes observed at Reach 3N (+23 cy/ft or 126,755 cy) and Reach 4 (+30.5 cy/ft or 60,984 cy). Above -19 ft NAVD88, all reaches experienced volume gains except for Reach 1, which showed minor losses (-38,256 cy or -1.3 cy/ft). However, the gains above -19 ft NAVD88 were less than those observed above -14 ft NAVD88, indicating material loss between -14 ft NAVD88 and -19 ft NAVD88, suggesting offshore material movement.
During the 2019 Beach Nourishment Project approximately 4.0 million cy of material was placed along approximately 10 miles of shoreline. The shoreline position and volume changes above six elevations relative to pre-nourishment conditions (April 2019) along the Nourished Oceanfront (Station 495+00 – 1025+00) were also analyzed.

Figure ES-1 illustrates the shoreline changes relative to pre-nourishment condition (April 2019) along the Nourished Oceanfront. As can be seen from the figure, a significant landward recession has occurred along the Nourished Oceanfront since the completion of the 2019 nourishment project. During the current observation period, the shoreline experienced additional recession, particularly in Reaches 3S and 3N. At Reach 3S, the shoreline has receded substantially landward of the April 2019 pre-nourishment condition, indicating ongoing erosion in this area.

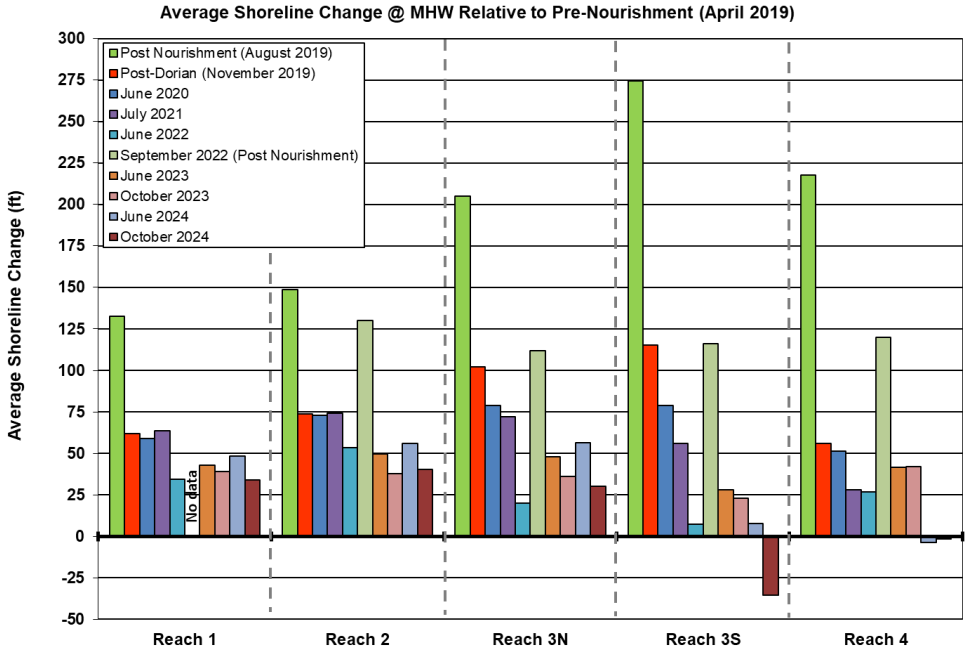

Figure ES-1. Nourished Oceanfront Average Shoreline Change Relative to Pre-Nourishment Conditions

Figure ES-2 illustrates that the overall changes in sand volume vary with the depth above which volumes are assessed. Notably, the Nourished Oceanfront exhibited material losses along the subaerial elevations (+6 ft NAVD88 and MHW) while gaining material above -14 ft NAVD88. The gains above -14 ft NAVD88 indicate some offshore-to-onshore sediment transport, suggesting partial recovery of material losses observed during the previous monitoring period (June 2023 – June 2024). The results indicated a 33% increase of material placed during the 2019 nourishment project above -19 ft NAVD88. The results suggest significant cross-shore shifts of sand across various elevations. Notably, much of the sand has moved to lower elevations near the depth of closure, where it becomes vulnerable to being removed from the system during high-energy wave events.

Figure ES-3 presents the volume changes above -19 ft NAVD88 relative to pre-nourishment conditions (April 2019) along the Nourished Oceanfront. Reach 1, Reach 2 and Reach 3N show volume gains above -19 ft NAVD88 when compared to pre-nourishment levels. In contrast, the remaining reaches experienced material losses, with

Reach 3S and Reach 4 both losing less than 50% of the material placed during the 2019 nourishment.

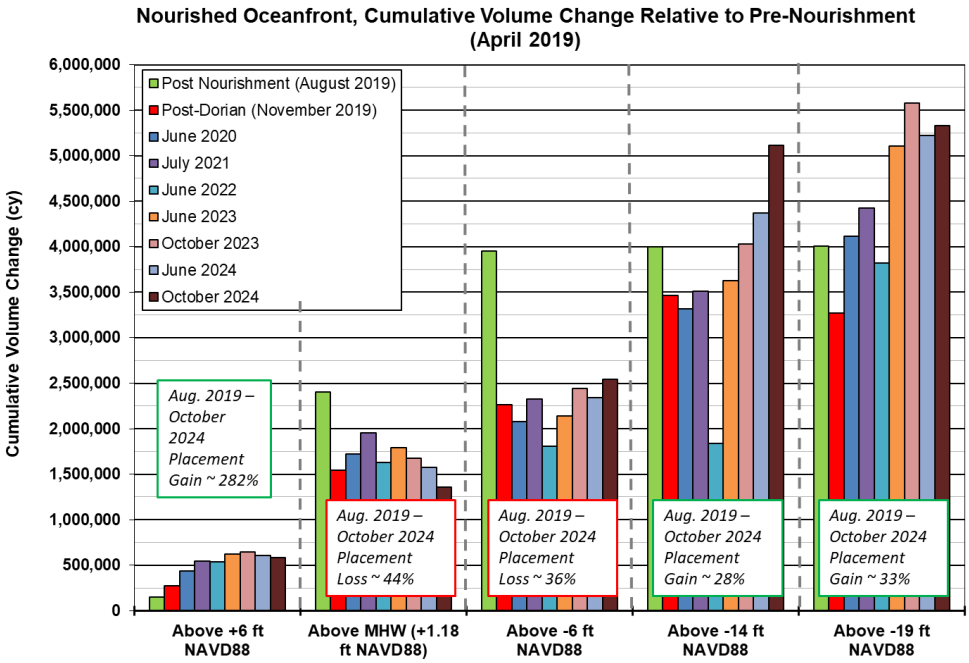

Figure ES-2. Nourished Oceanfront Cumulative Volume Change Relative to Pre-Nourishment

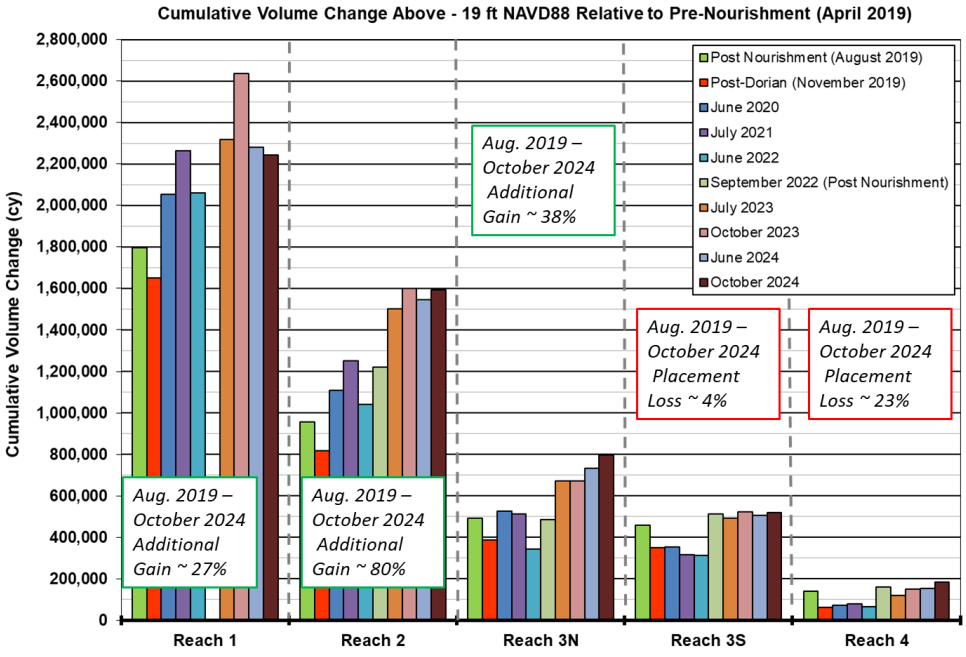

Figure ES-3. Cumulative Volume Change Above -19 ft NAVD88 Relative to Pre-Nourishment

The Town adopted a Multi-Decadal Beach Nourishment Master Plan (Master Plan) in July 2024. This Master Plan included development of volumetric triggers for beach nourishment, based on the profile volume from the landward crest of the primary dune to the outer bar, above the -19 ft NAVD88 elevation. This sand volume was modeled to provide a Level of Protection (LoP) from a 25-year storm. **Figure ES-4** presents the historical and current status of the average profile volumes per reach compared to the volumetric triggers (continuous red and black dashed lines). The volumetric triggers for the reaches have not undergone significant changes since the July survey. Consistent with the observed volume changes, the profile volume has slightly decreased in Reach 1 while increasing in the other reaches.

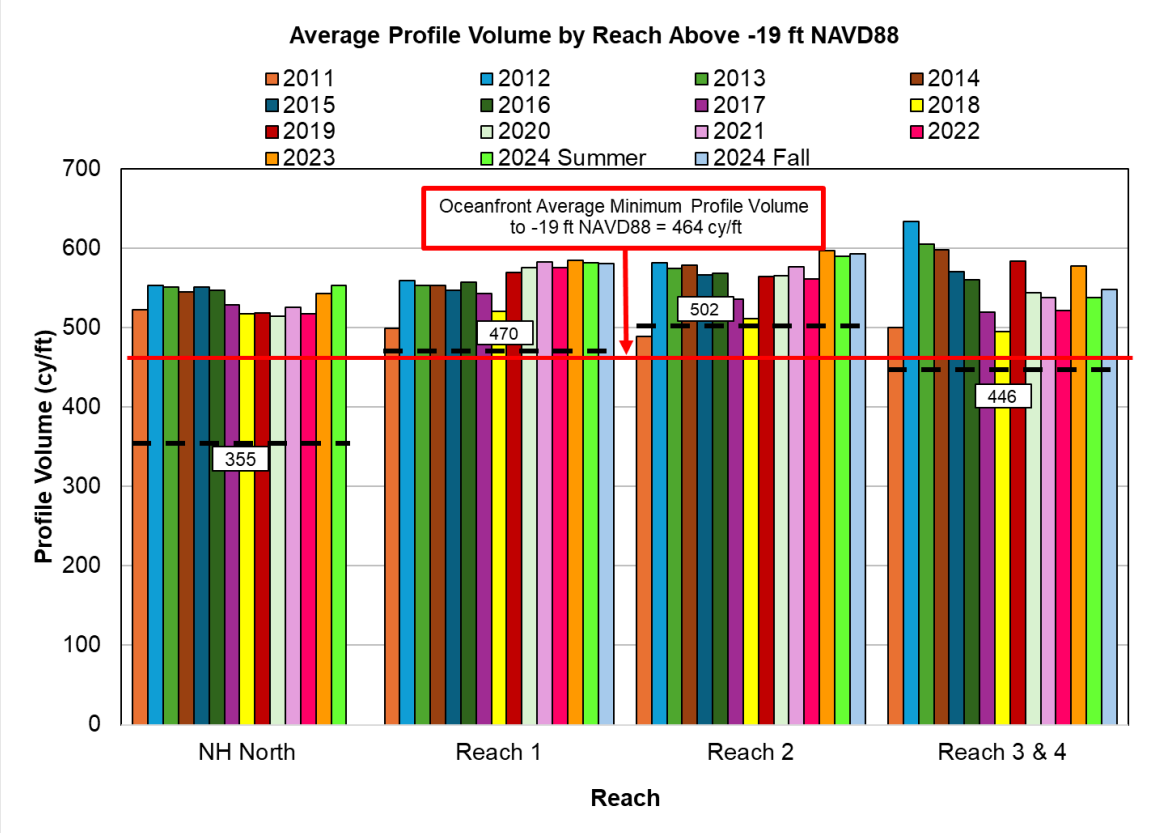

Figure ES-4. Master Plan Nourishment Trigger Volume Comparison

All management reaches currently contain average profile volumes above the nourishment triggers, however, there have been localized erosion hotspots observed along the Town's shoreline in the summer and fall of 2024. To more closely examine the current status of the beach, the profile volumes from all transects as of October 2024 are presented in **Figure ES-5**. Localized segments of Reaches 3 and 4 have profiles below the trigger volumes (red arrows), and additional localized segments of Reaches 1 and 2 are close to the triggers (yellow arrows).

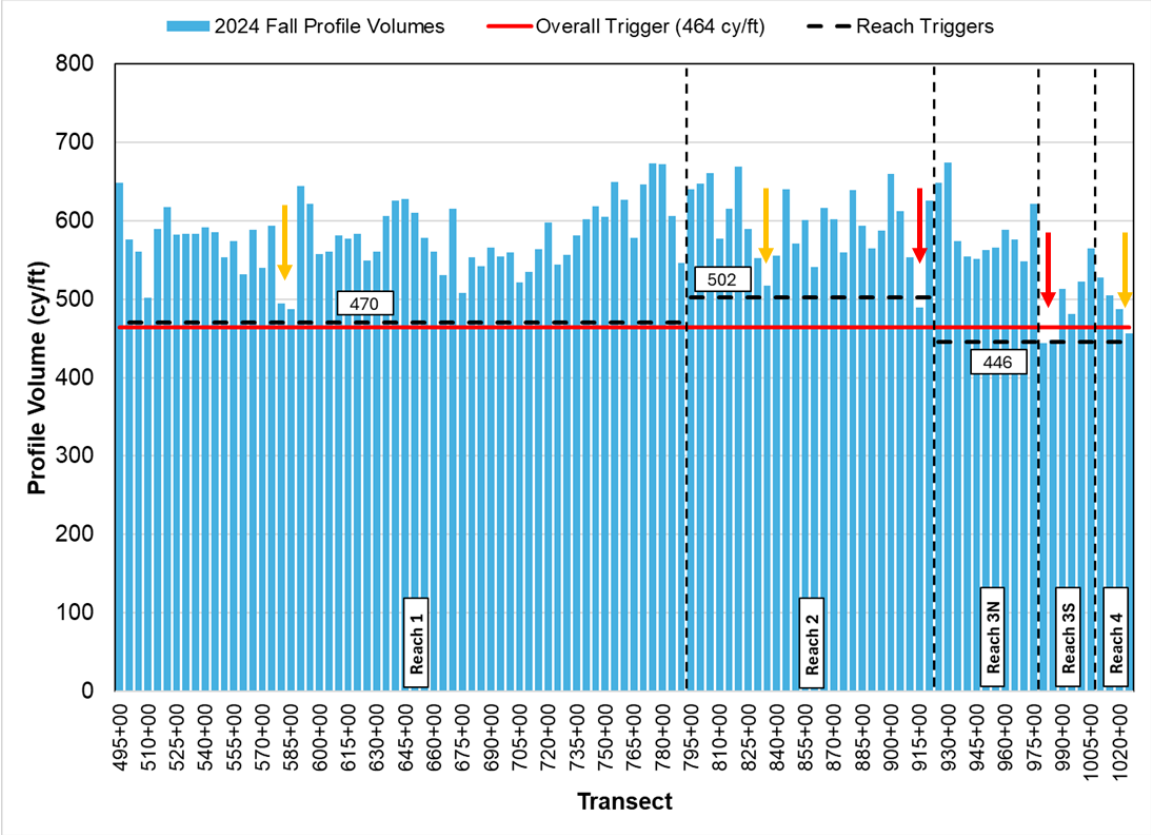

Figure ES-5. 2024 Beach Profile Volumes and Master Plan Trigger Volume Comparison

Due to these results and ongoing erosion across the Town's shoreline, the Town is planning for the option to construct the next project either in summer 2026 or summer 2027.

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

1.0 OBJECTIVE

The Town of Nags Head Beach Monitoring and Maintenance Plan is sponsored by the Town of Nags Head (Town) as a continuation of the 2011 monitoring program initiated for assessing beach conditions. The primary purpose of the program is to assess current and historical shoreline conditions, determine volumetric changes and evaluate the performance of beach nourishment and other restoration efforts. Evaluating and documenting these changes consistently over successive years provides information necessary to plan for future beach nourishments and to support development of the Town's multi-decadal Beach Nourishment Master Plan.

The latest annual summer survey took place in June 2024 and was carried out by McKim & Creed. Subsequently, a fall survey was conducted by McKim & Creed in October 2024 to assess the extent of observed dune erosion and beach narrowing along the Town's beachfront. This report outlines the data sources, methodologies, and findings of a survey evaluation conducted by Moffatt & Nichol. The evaluation compares the June 2024 survey to the data from the October 2024 survey.

2.0 SURVEY PROCEDURES AND DATA PROCESSING

2.1 Survey Transects and Reaches

The present monitoring survey and evaluation continue to use the existing transect lines and origins established by CSE in monitoring periods prior to 2020. **Figure 2-1** shows the survey lines used in the fall 2024 monitoring survey. Notably, the fall survey focused on the nourished town limits and did not cover all transects included in the annual monitoring surveys. As shown, survey transect lines were stationed from north to south along Nags Head. A summary of streets/landmarks present at the start and end of each reach are provided in **Table 2-1**.

Table 2-1. Reach Start and End Points for Fall 2024 Survey

Reach	Stations	Length (ft)	Start Point	End Point
Reach 1	495+00-790+00	29,500	Bonnett Street	Governor Street
Reach 2	790+00-920+00	13,000	Governor Street	James Street
Reach 3 - North	920+00-975+00	5,500	James Street	Limulus Drive
Reach 3 - South	975+00-1010+00	3,500	Limulus Drive	Loon Court
Reach 4	1010+00-1025+00	2,000	Loon Court	National Park Shore “ramp one”

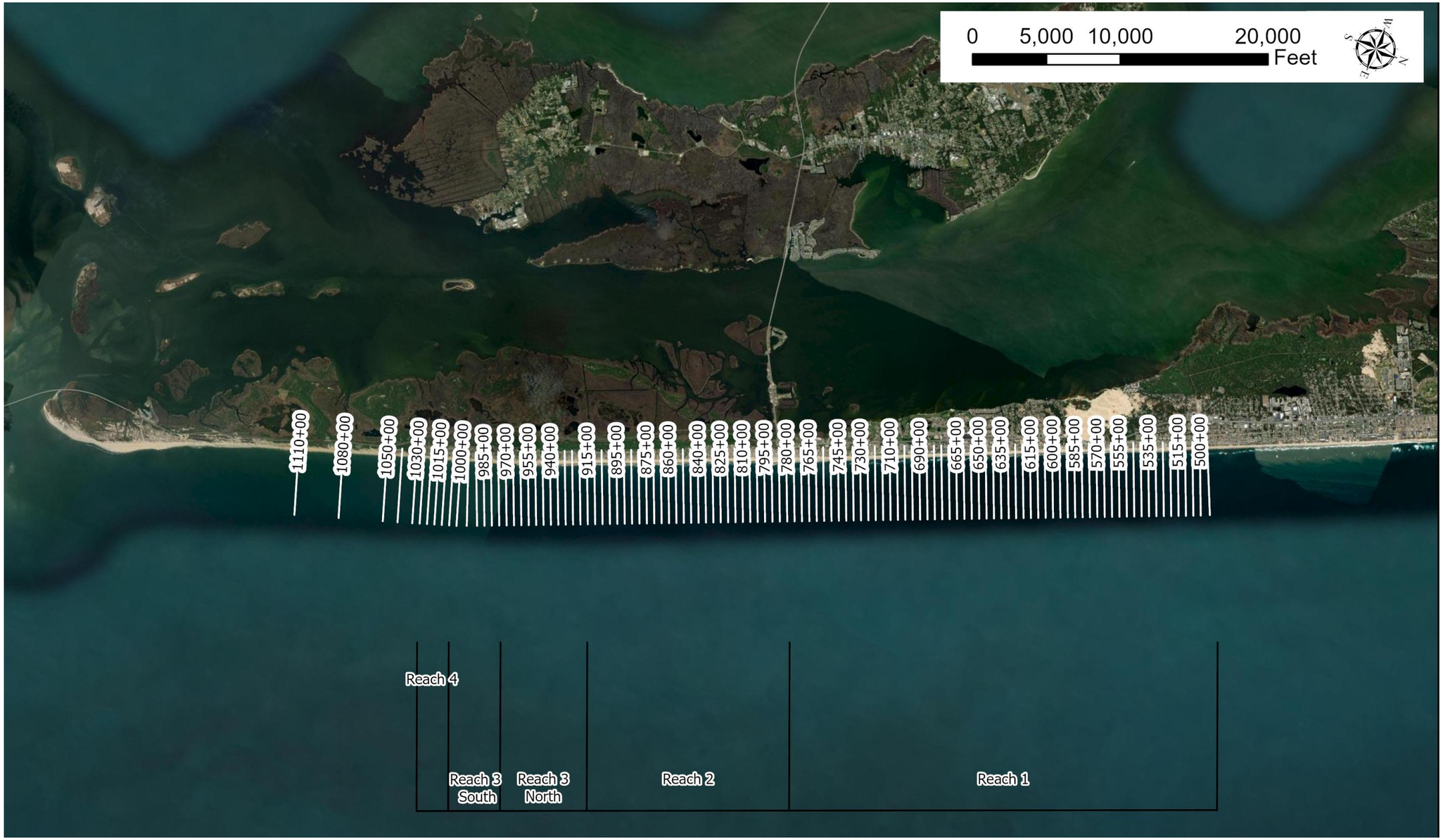

Figure 2-1. Nags Head Fall Monitoring Profile Line Locations

2.2 Survey Data Acquisition

To enable a reproducible and consistent result for the monitoring analysis, the survey events for each shoreline segment are assigned a single date for their completion. Assigning the survey date allows the determination of a consistent timeframe for each monitoring period between survey events for use in calculating shoreline and volumetric change rates. Surveys referenced during the current monitoring analysis include:

2024 Annual Survey
The most recent annual survey data was collected by McKim & Creed between June 18 and July 31, 2024. The crew initially demobilized on June 26 due to a lack of permission to survey within the Cape Hatteras National Seashore. After obtaining the necessary permit, they resumed work on July 29 and completed surveys for the 32 lines within the park, along with re-surveying an additional 7 lines (Reach 4) at the request of the Town of Nags Head by July 31. The date used for the 2024 Nags Head profiles in this report is June 26, 2024, as most of the surveys within the town's boundaries were finished by then (see **Appendix A** for details).

2024 Fall Survey
The present fall survey was conducted from October 30 - November 1. The date used for the 2024 Fall survey is November 1, 2024, when the surveying was completed.

McKim & Creed provided the processed survey data to Moffatt & Nichol in ASCII (xyz), Excel (xyz) and BMAP (free format) formats allowing for compatibility with multiple programs. The data referenced the horizontal North American Datum 1983 (NAD83) State Plane North Carolina (U.S. survey feet) and elevations were provided in feet relative to the North American Vertical Datum of 1988 (NAVD88). A copy of the survey data files is included on the attached USB also containing an electronic copy of the report.

Appendix A contains the McKim & Creed 2024 Fall Survey Field Report which discusses, in detail, the singlebeam (bathymetric) and topographic data acquisition. The field report also provides the associated equipment and quality control procedures (QA/QC) utilized in the data collection and processing tasks.

3.0 SURVEY EVALUATION METHODS

3.1 Shoreline Change

Shoreline change designated at the MHW contour, defined as +1.18 ft NAVD88, was calculated at each transect between the summer and fall 2024 surveys. The MHW elevation is based on a National Oceanic and Atmospheric Administration (NOAA) tidal benchmark at Duck, NC shown in **Figure 3-1**. The resulting values represent the shoreline change (ft) over the time between surveys.

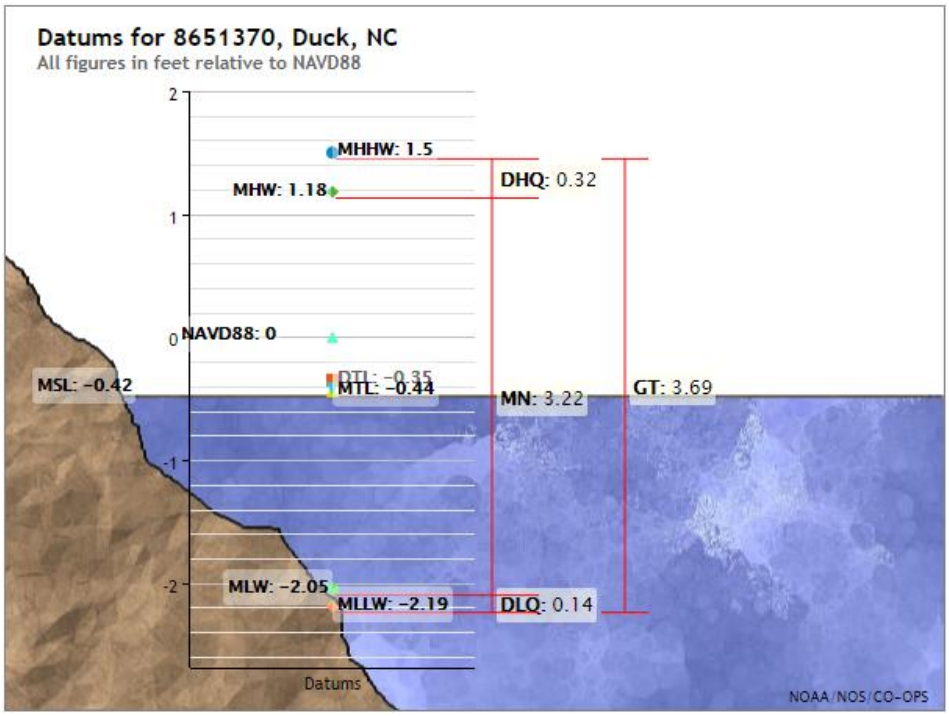

Figure 3-1. Tidal Datum for Duck, NC Station 8651370

3.2 Volume Change

Representative volume changes were calculated at each transect between the summer and fall 2024 surveys. Volume changes were calculated for six different elevations to better understand the processes occurring onshore and offshore of Nags Head. Calculations included volume change above the following elevations:

- above +6 ft NAVD88 (berm),
- above +1.18 ft NAVD88 (MHW),
- above -6 ft NAVD88 (wading depth/recreational beach),
- above -14 ft NAVD88 (outer bar),
- above -19 ft NAVD88 (depth of closure), and
- above -30 ft NAVD88.

For those profiles which did not extend to -30 ft NAVD88, volume calculations were performed above -30 ft NAVD88 out to the extent of the shortest survey. **Figure 3-2** presents a graphical display of the various elevations for which volume change calculations were made.

As with the shoreline change, the results represent volume change (cy/ft) over the period of time between surveys. In addition, the volume changes were converted to cumulative changes over each of the management reaches and for the entire shoreline. This was done by applying the average end area method to the unit volume changes (cy/ft) computed at each transect and summing the total volume changes between each neighboring pair of transects. The resulting value indicated the total loss or gain of material between survey periods based on the applicable profile extents.

It should be noted that the uncertainty in the hydrographic portion of the survey can result in a significant volumetric change in offshore areas where the slope of the seafloor declines gradually. If an uncertainty of ±0.11 ft is applied along the portion of the profile between the seaward side of the depth of closure (approximately 2,050 ft offshore) and a depth of -30 ft NAVD88 (approximately 2,950 ft offshore) along all 77,000 ft of oceanfront shoreline, this lends itself to an uncertainty of approximately ±282,300 cy. For this reason, more attention is given to the volume change calculations at -19 ft NAVD88 and above.

The profile volume calculation lenses (see **Figure 3-2**) were strategically chosen to help understand and track the movement of sand onshore and offshore. Volume changes calculated for portions of the profiles above +6 ft NAVD88 and above MHW are representative of changes in the amount of material in the dune system and on the subaerial beach. These areas of the profile are highly influenced by storm activity, and they are both very significant in the ability of the beach and dune to mitigate storm surge and wave impacts on landward structures and infrastructure. Volume comparisons for portions of the profiles above -6 ft NAVD88, an approximate wading depth, represent changes in the recreational beach area. Volume comparisons above -14 ft NAVD88 help to track sand movement to and from the outer sand bar and are valuable in decision making for future beach nourishment projects. Volume comparisons above -19 ft NAVD88 provide general estimates of the total volumetric change along the respective profile out to the depth of closure. Finally, volume comparisons above -30 ft NAVD88 allow the complete tracking of sand movement offshore. It is noted that, hydrographic survey measurement accuracy may impact these calculations. This is a proven, comprehensive way to assess the impact of storm activity on the subaerial beach and dune system as well as track the movement of sand offshore and quantify total gains and losses in the entire system.

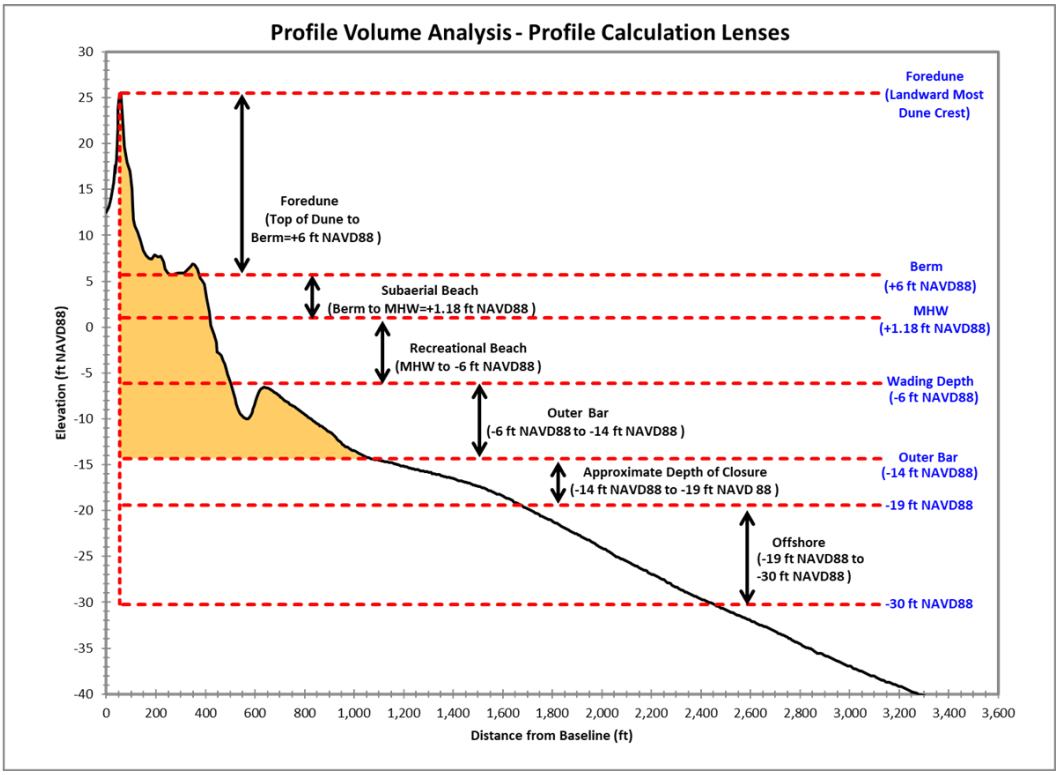

Figure 3-2. Profile Volume Calculation Lenses

4.0 WAVE CLIMATE AND STORM EVENTS DURING REPORTING PERIOD

Wave data from the National Data Buoy Center (NDBC) Station 44056 (USACE Field Research Facility (FRF)), located approximately 15 miles north of the Town, was downloaded for July 2024 through October 2024. The wave data was then plotted to analyze wave activity which may have impacted the Town. **Figure 4-1** shows the location of the buoy while **Figure 4-2** presents a plot of the wave heights during the reporting period.

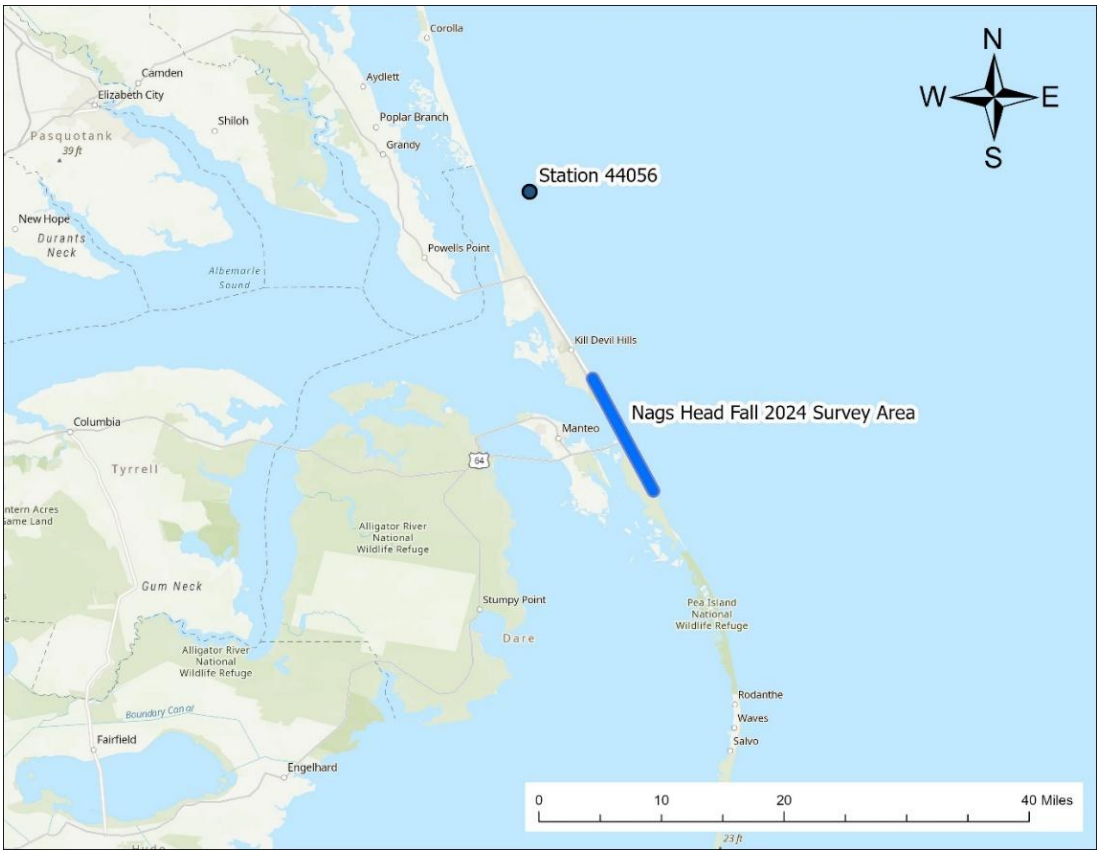

Figure 4-1. USACE FRF Buoy Location

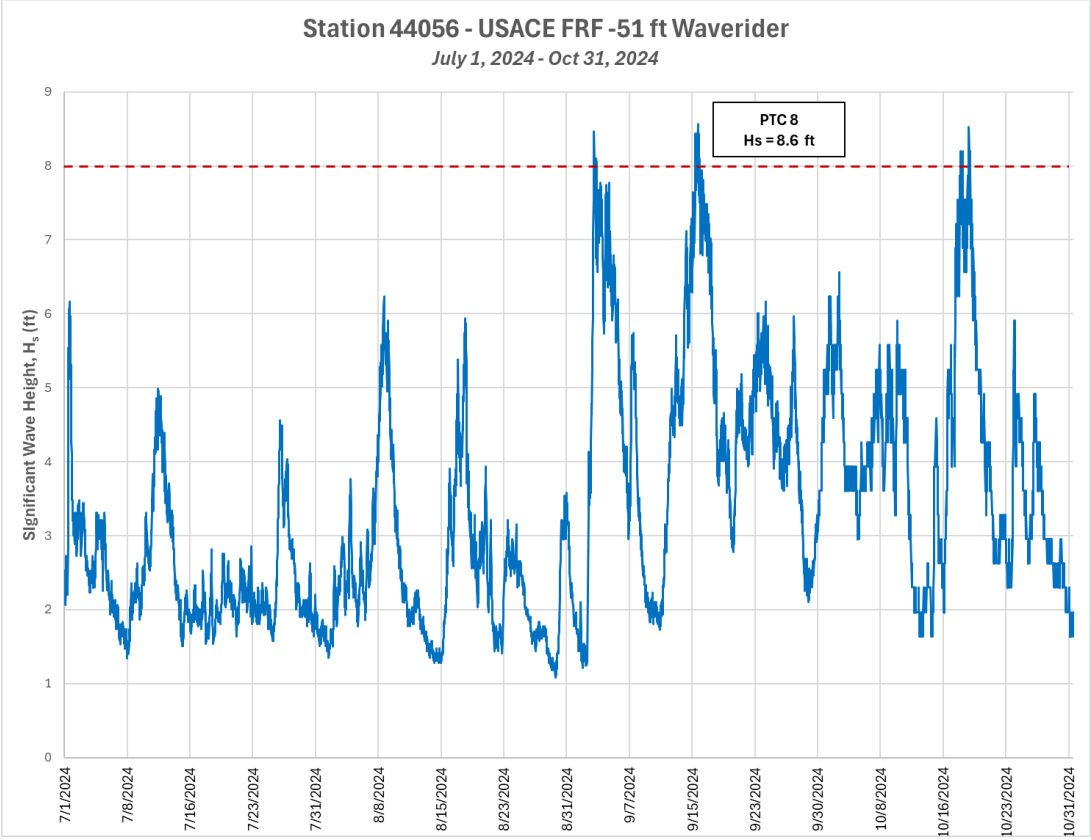

Figure 4-2. USACE FRF Station 44056 Wave Height

The data highlights relatively calm summer conditions followed by increased wave heights throughout the fall. From July 1 to September 1 of 2024 the average significant wave height was 2.5 ft, with only two wave events exceeding 6 ft. From September 1 to October 31 of 2024, the average significant wave height increased to 4.2 ft. Three wave events exceeded 8 ft, with the highest recorded during Potential Tropical Cyclone #8 (PTC#8) (8.6 ft). Wave conditions during this observation period were milder compared to the summer-fall 2023 period, which experienced two storms with significant wave heights exceeding 12 ft.

Figure 4-3 depicts the directional wave rose for July – October 2024, the time between the summer and fall surveys. **Figure 4-4** shows the directional wave rose for the months of July through October for the years 1997 – 2024, for historical comparison. Statistical analysis reveals that for both time spans, prevailing waves originate from east-northeast to east-southeast directions. Compared to previous years, the percentage of waves coming from east-northeast slightly increased in 2024 (~3%), while the percentage of waves coming from the east-southeast slightly decreased. This shift may result in a slight increase of north-to-south transport of material compared to historical trends.

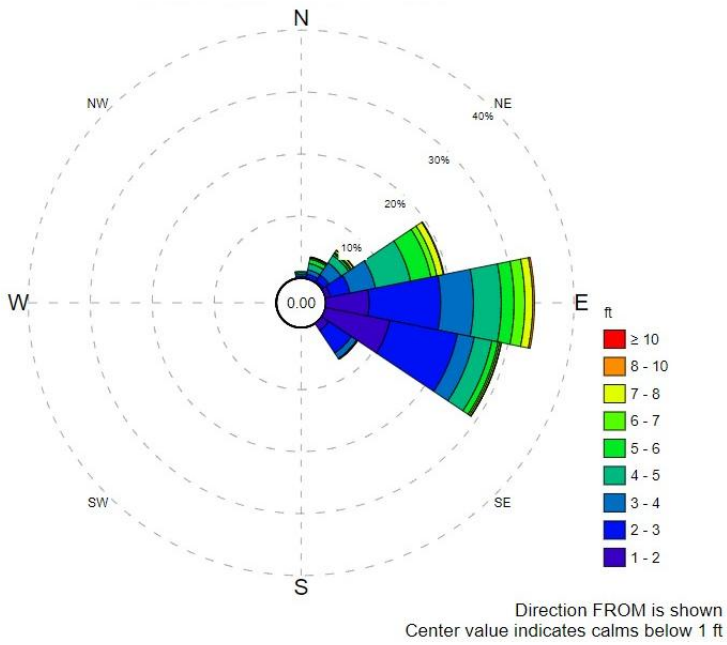

Figure 4-3. Station 44056 Significant Wave Height Rose from 2024 for the months of July – October

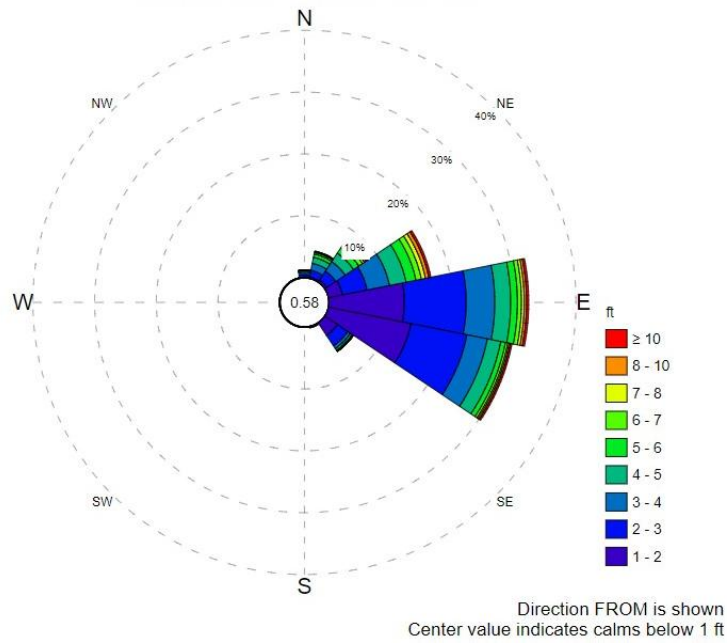

Figure 4-4. Station 44056 Significant Wave Height Rose from 1997 – 2024 for the months July – October

5.0 DISCUSSION OF MONITORING SURVEY EVALUATION

5.1 Nags Head Annual Shoreline and Volume Change Analysis (June 2023 – June 2024)

This section discusses the results of the shoreline and volume change analysis for the defined monitoring reaches along Nags Head (see **Figure 2-1**). Key statistics were calculated to quantify average shoreline and volume changes for individual monitoring reaches as well as the entire nourished oceanfront shoreline for Nags Head. The computed statistics include average shoreline change, average unit volume change, and cumulative volume change (e.g. total volume of material lost or gained along a section of shoreline). Evaluation of the computed statistics considers volume changes computed for portions of the profile above the berm (+6 ft NAVD88), above MHW (+1.18 ft NAVD88), above -6 ft NAVD88, above -14 ft NAVD88, above -19 ft NAVD88, and above -30 ft NAVD88 to better understand onshore and offshore processes.

Appendix B presents profile comparison plots for individual transects. These plots compare the June 2023, October 2023, June 2024, and October 2024 surveys. **Appendix C** provides the computed shoreline changes and volume changes measured at each transect between the June 2024 and the October 2024 surveys in tabular format.

Table 5-1 and **Table 5-2** provide a summary of the shoreline and volume changes. For Nags Head, since each reach consists of a different length of shoreline, the calculations provide a weighted average for unit shoreline change (ft) and unit volume change (cy/ft) along the Nags Head oceanfront. The weighted average also accounts for differences in the shoreline length between each transect. **Appendix B** contains plots of the shoreline and volume changes between June 2024 and the fall 2024 surveys at each transect along Nags Head.

Table 5-1. Nags Head Shoreline and Average Unit Volume Change Statistics (June 2024 – October 2024)

June 2024 vs. October 2024	Transects	Reach Length	avg shoreline change @ +1.18 ft NAVD88	Change above +6 ft NAVD88	Change above +1.18 ft NAVD88	Change above -6 ft NAVD88	Change above -14 ft NAVD88	Change above -19 ft NAVD88	Change above -30 ft NAVD88
Reach	#	ft	ft	cy/ft	cy/ft	cy/ft	cy/ft	cy/ft	cy/ft
Reach 1	495+00 - 790+00	29,500	-14.1	-1.0	-4.2	4.7	9.6	-1.3	-14.2
Reach 2	790+00 - 920+00	13,000	-15.6	1.8	-0.9	6.6	17.4	3.5	-9.3
Reach 3N	920+00 - 975+00	5,500	-26.1	0.3	-6.2	-0.5	23.0	11.2	1.1
Reach 3S	975+00 - 1010+00	3,500	-43.1	-2.3	-10.9	-9.1	14.5	3.6	-5.2
Reach 4	1010+00 - 1025+00	1,500	2.1	-4.2	-5.7	6.2	30.5	16.5	0.0
	Transects	Reach Length	weighted avg	weighted avg	weighted avg	weighted avg	weighted avg	weighted avg	weighted avg
Nourished Oceanfront	**495+00 - 1025+00**	**53,000**	**-17.2**	**-0.3**	**-4.1**	**3.8**	**13.8**	**2.0**	**-10.4**

Table 5-2. Nags Head Cumulative Volume Change Statistics (June 2024 – October 2024)

June 2024 vs. October 2024	Transects	Reach Length	Change above +6 ft NAVD88	Change above +1.18 ft NAVD88	Change above -6 ft NAVD88	Change above -14 ft NAVD88	Change above -19 ft NAVD88	Change above -30 ft NAVD88
Reach	#	ft	cy	cy	cy	cy	cy	cy
Reach 1	495+00 - 790+00	29,500	-28,300	-121,508	137,697	279,228	-38,256	-412,781
Reach 2	790+00 - 920+00	13,000	23,726	-12,065	86,027	226,615	45,887	-120,332
Reach 3N	920+00 - 975+00	5,500	1,623	-33,983	-2,957	126,755	61,465	5,783
Reach 3S	975+00 - 1010+00	3,500	-8,206	-38,109	-31,769	50,576	12,757	-18,103
Reach 4	1010+00 - 1025+00	1,500	-8,485	-11,451	12,496	60,984	32,979	6,610
	Transects	Reach Length	total	total	total	total	total	total
Nourished Oceanfront	**495+00 - 1025+00**	**53,000**	-19,643	-217,115	201,494	744,158	114,832	-538,824

During the June 2024 - October 2024 monitoring period, from Reach 1 to Reach 4, the shoreline retreated -17.2 ft on average. Reaches 1 and 2 experienced an average shoreline retreat rate of -14.1 ft and -15.6 ft, respectively. Moving southward, shoreline retreat increased. Reach 3N retreated -26.1 ft, and Reach 3S experienced the greatest retreat rate

of -43.1 ft. This erosion allowed waves to reach the dunes, resulting in dune scarping across the Nags Head oceanfront. Although Reach 4 experienced a slight seaward advancement in the shoreline position (2.1 ft), it also experienced dune scarping because this area was already narrow prior to the June 2024 survey.

The dune scarping and erosion are evidenced by volume loss experienced above +6ft NAVD88 and MHW. Above +6 ft NAVD88, the nourished oceanfront lost -0.3 cy/ft on average in between the summer and fall surveys. The greatest unit volume loss above +6 ft NAVD88 occurred in the southern reaches: Reach 3S (-2.3 cy/ft or -8,206 cy) and Reach 4 (-4.2 cy/ft or -8,435 cy).

During the previous monitoring period, material was deposited above MHW from the nearshore, resulting in a steeper slope. In contrast, during the current observation period (end of July to end of October), all reaches experienced material loss above MHW, with the most significant losses occurring in the southern areas (Reaches 3N, 3S, and 4).

As shown in the profile plots in Appendix B, the lost material shifted from the subaerial region to the nearshore and sandbar, with deposition occurring above -14 ft NAVD88. This material redistribution contributed to a recovering and growing sandbar, which also gained additional sediment from offshore sources. As a result, the nearshore slope became milder.

All reaches experienced volume gains above -14 ft NAVD88, with the largest unit volume changes observed at Reach 3N (+23 cy/ft or 126,755 cy) and Reach 4 (+30.5 cy/ft or 60,984 cy). Above -19 ft NAVD88, all reaches experienced volume gains except for Reach 1, which showed minor losses (-38,256 cy or -1.3 cy/ft). However, the gains above -19 ft NAVD88 were less than those observed above -14 ft NAVD88, indicating material loss between -14 ft NAVD88 and -19 ft NAVD88, suggesting offshore material movement.

Losses continued below -19 ft NAVD88, with Reach 1, Reach 2, and Reach 3S experiencing volume losses of -14.2 cy/ft, -9.3 cy/ft, and -5.2 cy/ft above -30 ft NAVD88, respectively. **Figure 5-1** to **Figure 5-6** provide example profiles for each reach, illustrating the described volume change trends.

The survey transects at National Seashore exhibited trends similar to those in Reach 4. While average volume calculations were not conducted due to the spacing of the transects, individual profile plots still reveal a discernible pattern. These profiles indicate erosion in subaerial locations, with sandbar growth occurring above -14 ft NAVD88.

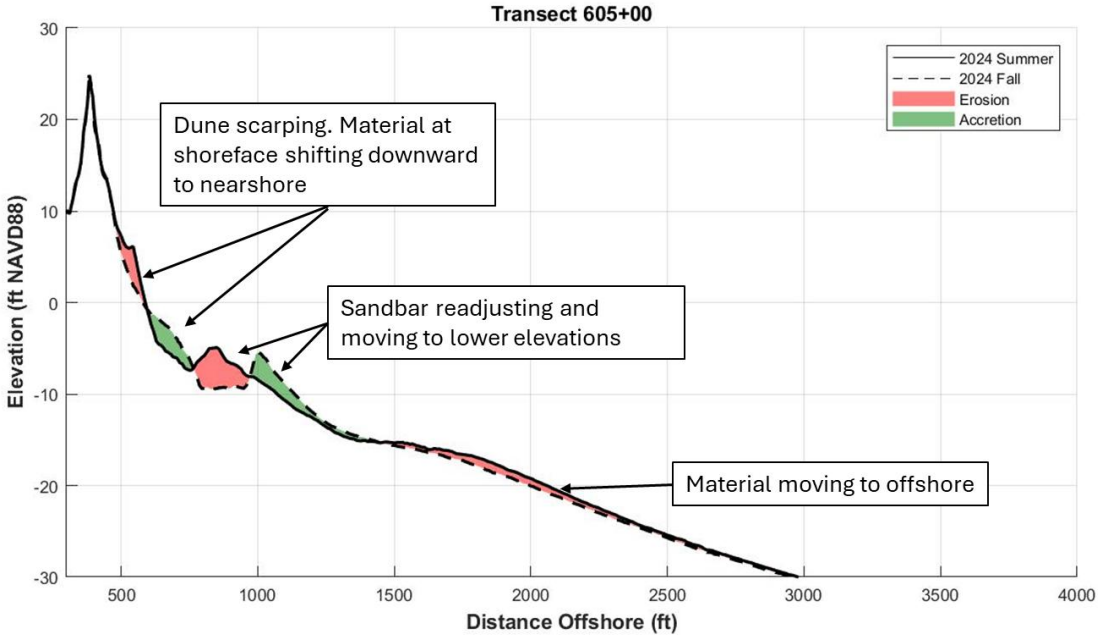

Figure 5-1. Example Reach 1 Station 605+00 (E Dune St.)

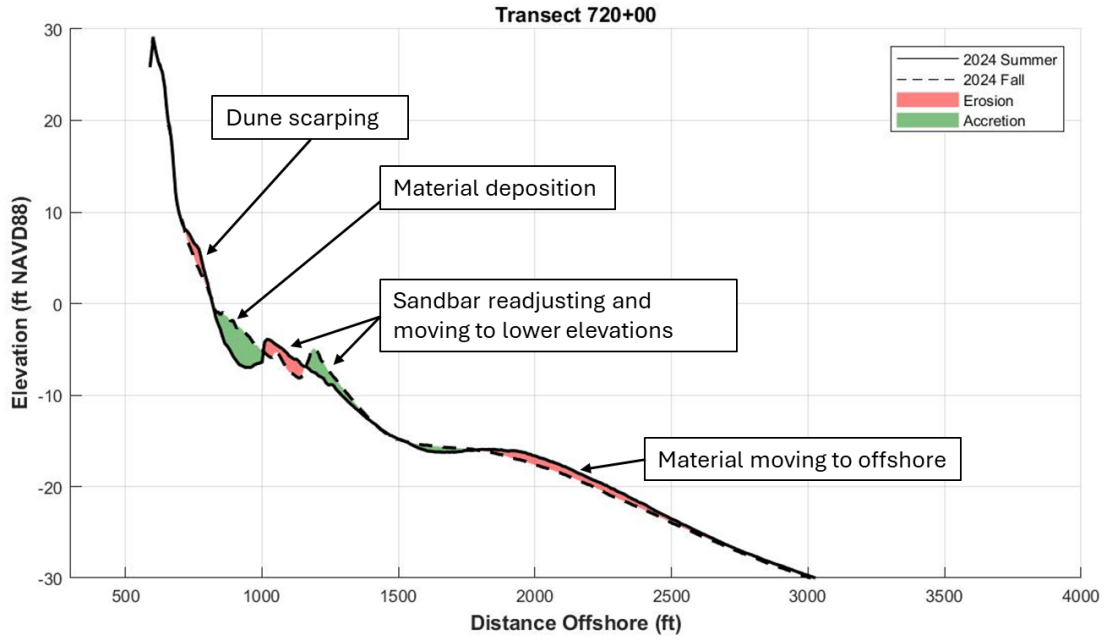

Figure 5-2. Example Reach 1 Station 720+00 (Forrest St. Beach Access)

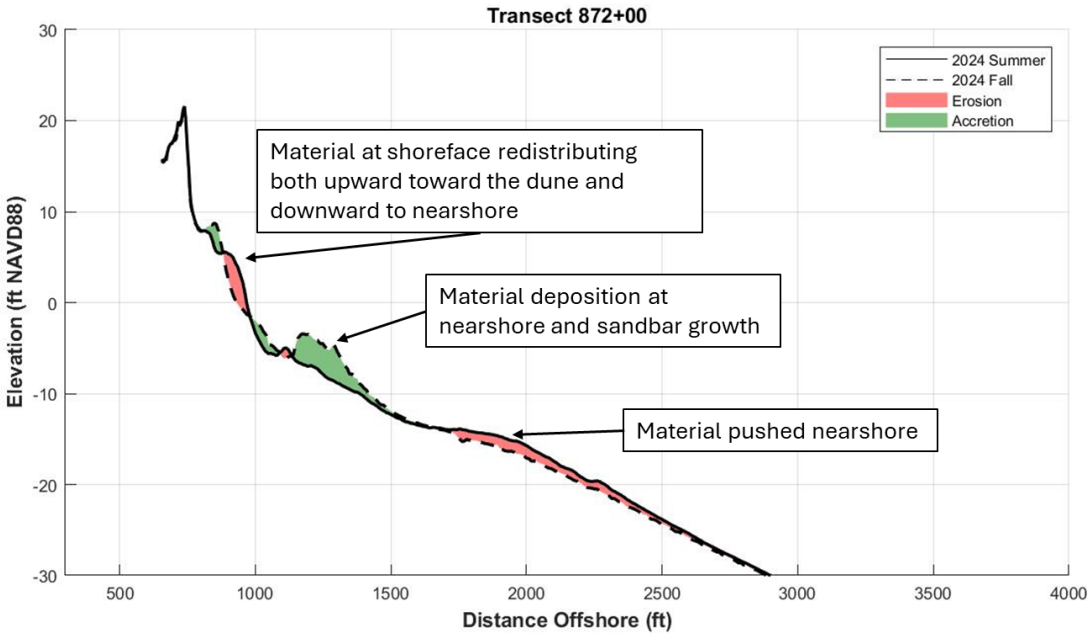

Figure 5-3. Example Reach 2 Station 872+00 (Outer Banks Fishing Pier)

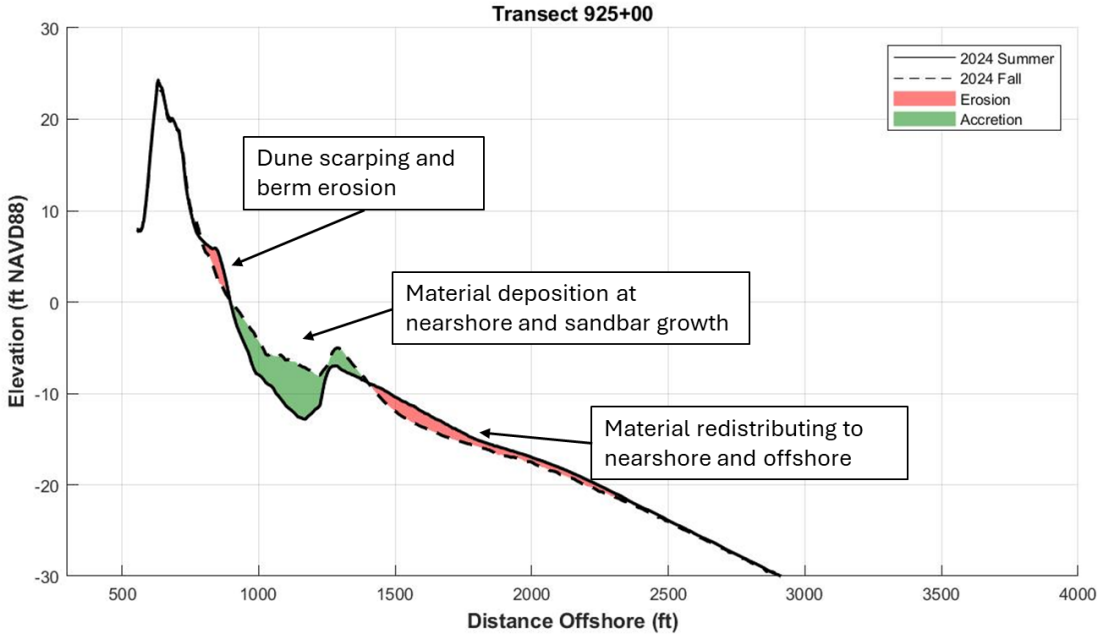

Figure 5-4. Example Reach 3 – North Profile Station 925+00 (East Jacob St.)

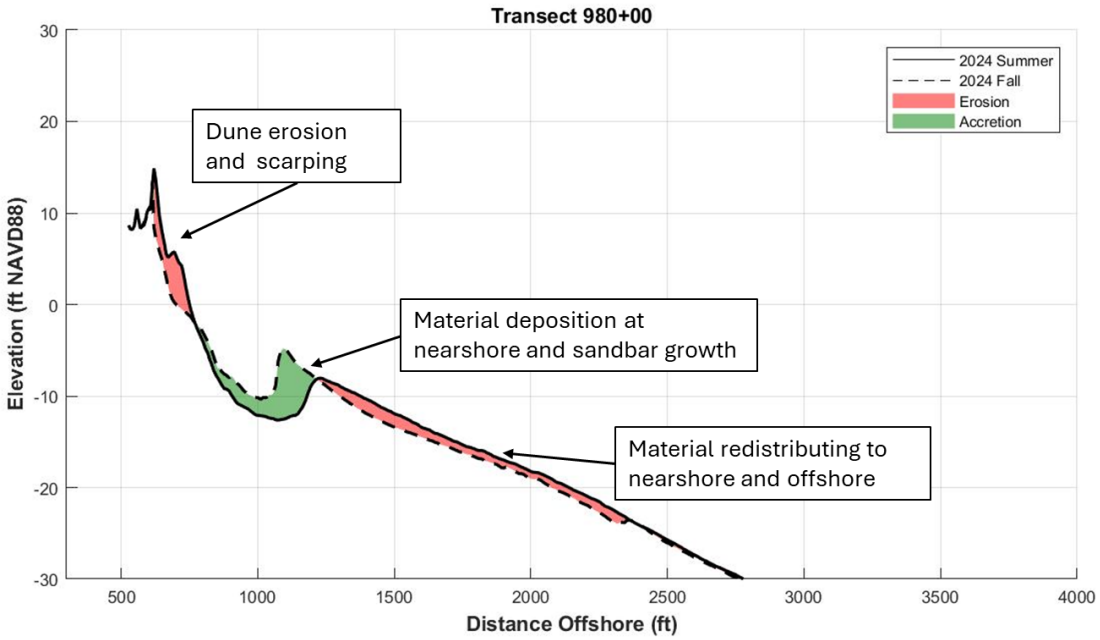

Figure 5-5. Example Reach 3 – South Profile Station 980+00 (E Altoona St.)

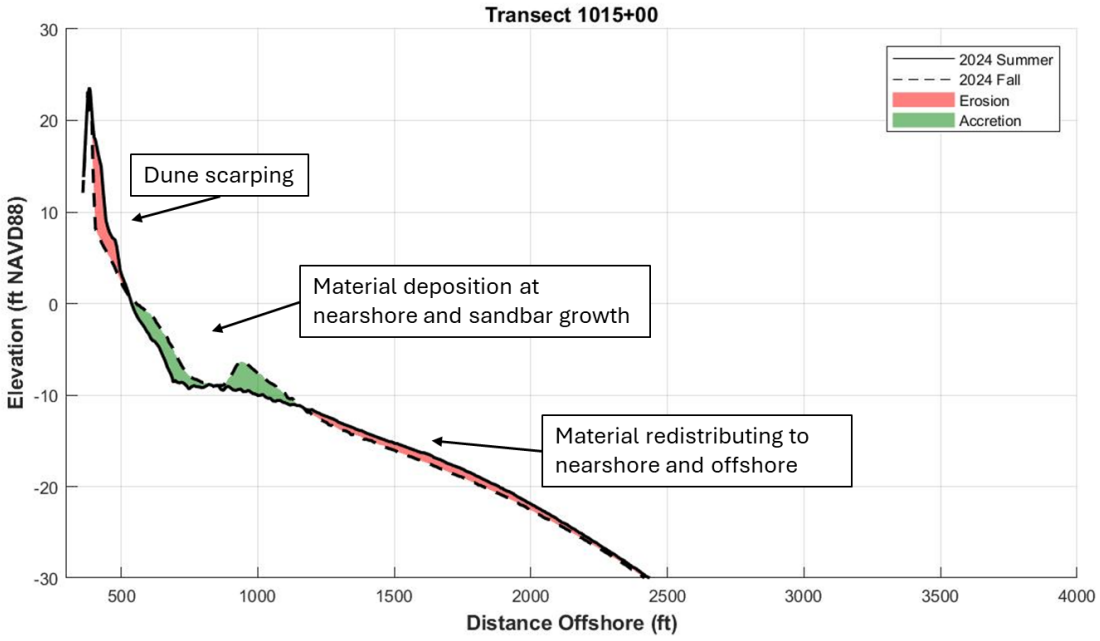

Figure 5-6. Example Reach 4 – South Profile Station 1015+00 (S. Colony South Dr.)

Figure 5-7 and **Figure 5-8** display the trends seen in **Table 5-1** and **Table 5-2** through bar plots of average unit volume changes and total cumulative volume changes for each sub-reach. These visualizations highlight the changes across the nourished oceanfront as a whole and compare the magnitude of changes between individual reaches.

The narrowing of the beach resulted in waves reaching the dunes, causing scarping in most reaches except for Reach 2 and Reach 3N. Both figures indicate volume losses above +1.18 ft NAVD88 across all monitored shoreline reaches. However, nearly all reaches experienced volume gains above -14 ft NAVD88 and -19 ft NAVD88, with the exception of Reach 1, which recorded minor volume losses above -19 ft NAVD88. These findings suggest that sediment was transported from the subaerial zones offshore to the nearshore area and sandbars above the depth of closure.

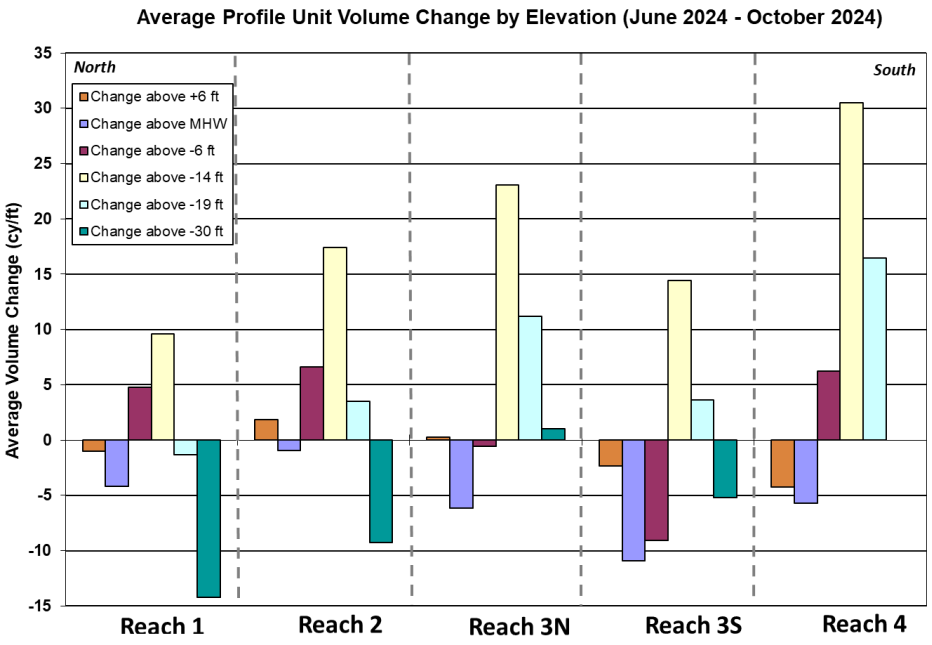

Figure 5-7. Average Unit Volume Change Within Each Reach (June 2024 – October 2024)

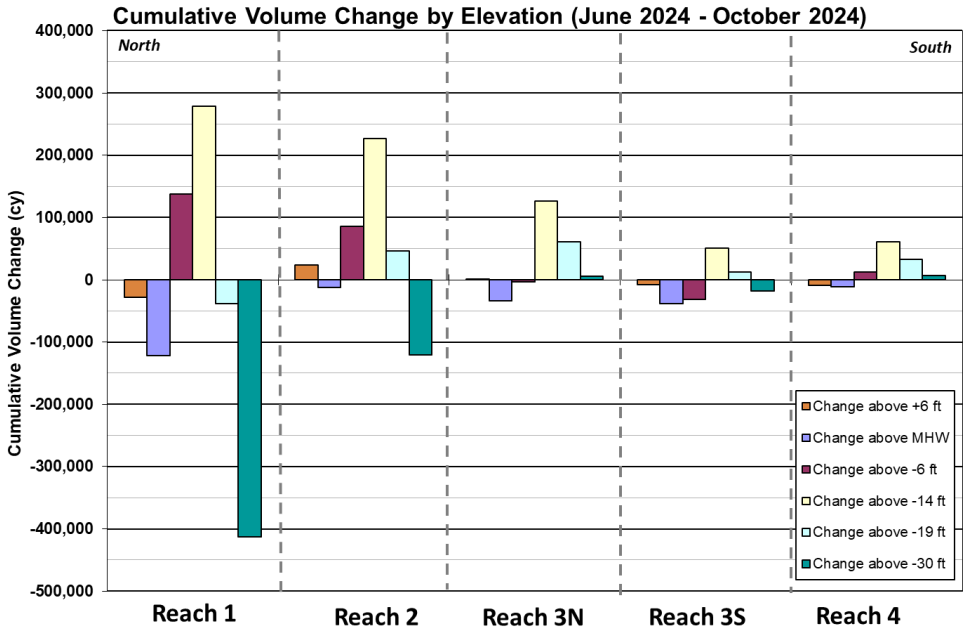

Figure 5-8. Cumulative Volume Change Within Each Reach (June 2024 – October 2024)

5.2 Nourished Oceanfront Performance Relative to Pre-Nourishment

Construction of the 2019 Nags Head Beach Nourishment Project was carried out between May 1, 2019 and August 18, 2019. During the project, a total of 4 million cy of material was placed along approximately 10 miles of shoreline. To quantify the performance of the nourishment project, the volume changes between the pre-nourishment survey and the subsequent monitoring surveys were analyzed.

Figure 5-9 illustrates the shoreline changes relative to pre-nourishment condition (April 2019) along the Nourished Oceanfront. As can be seen from the figure, a significant landward recession has occurred along the Nourished Oceanfront since the completion of the 2019 nourishment project. During the current observation period, the shoreline experienced additional recession, particularly in Reaches 3S and 3N. At Reach 3S, the shoreline has receded substantially landward of the April 2019 pre-nourishment condition, indicating ongoing erosion in this area.

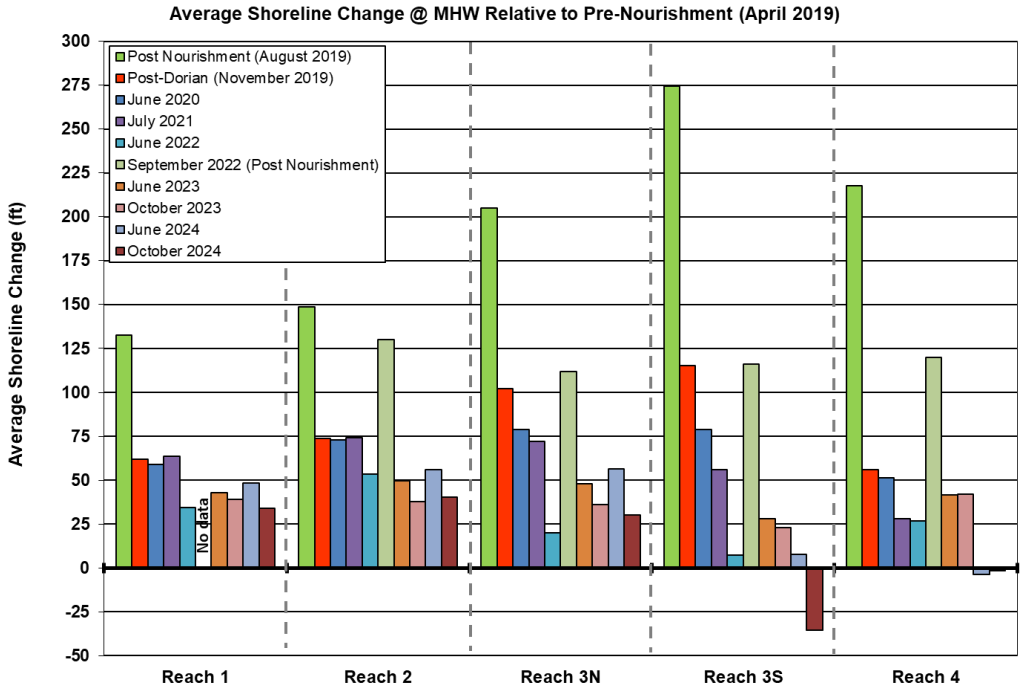

Figure 5-9. Nourished Oceanfront Average Shoreline Change Relative to Pre-Nourishment Conditions

Figure 5-10 presents the volume changes relative to pre-nourishment conditions (April 2019) above six elevations along the Nourished Oceanfront. Notably, the Nourished Oceanfront exhibited material losses along the subaerial elevations (+6 ft NAVD88 and MHW) while gaining material above -14 ft NAVD88. The gains above -14 ft NAVD88 indicate some offshore-to-onshore sediment transport, suggesting partial recovery of material losses observed during the previous monitoring period (June 2023 – June 2024).

The results indicated a 33% increase of material placed during the 2019 nourishment project above -19 ft NAVD88. It's important to highlight that 614,106 cubic yards of material which corresponds to 15% of the material gain were placed during the 2022 Post-Dorian Renourishment project.

The results suggest significant cross-shore shifts of sand across various elevations. Notably, much of the sand has moved to lower elevations near the depth of closure, where it becomes vulnerable to being removed from the system during high-energy wave events.

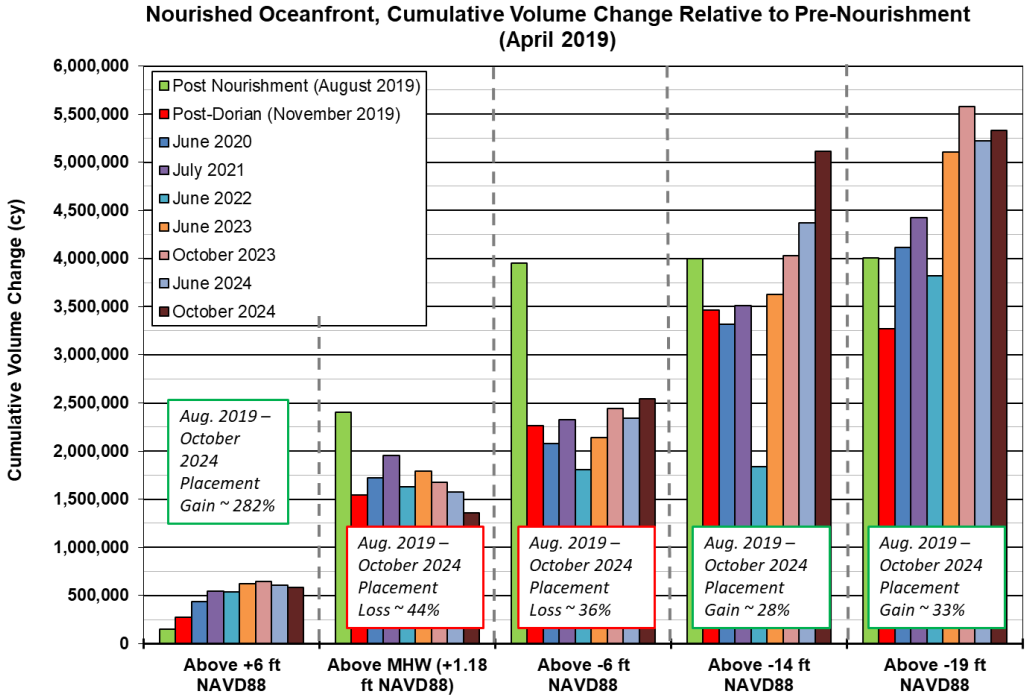

Figure 5-10. Nourished Oceanfront Cumulative Volume Change Relative to Pre-Nourishment

Figure 5-11 illustrates the volume changes relative to pre-nourishment conditions (April 2019) above +6 ft NAVD88 along the Nourished Oceanfront. Reach 1, Reach 2 and Reach 3N experienced a gain in material above +6 ft NAVD88. In contrast, Reach 3S, which experienced significant shoreline recession and recent dune scarping, lost 6% of the material originally placed above +6 ft NAVD88 during the 2019 Nourishment Project. Reach 4 experienced the most substantial losses above +6 ft NAVD88, losing all material placed during the project.

Figure 5-12 presents the volume changes above -19 ft NAVD88 relative to pre-nourishment conditions (April 2019) along the Nourished Oceanfront. Reach 1 and Reach 2 and Reach 3N show volume gains above -19 ft NAVD88 when compared to pre-nourishment levels. In contrast, the remaining reaches experienced material losses, with Reach 3S and Reach 4 both losing less than 50% of the material placed during the 2019 nourishment.

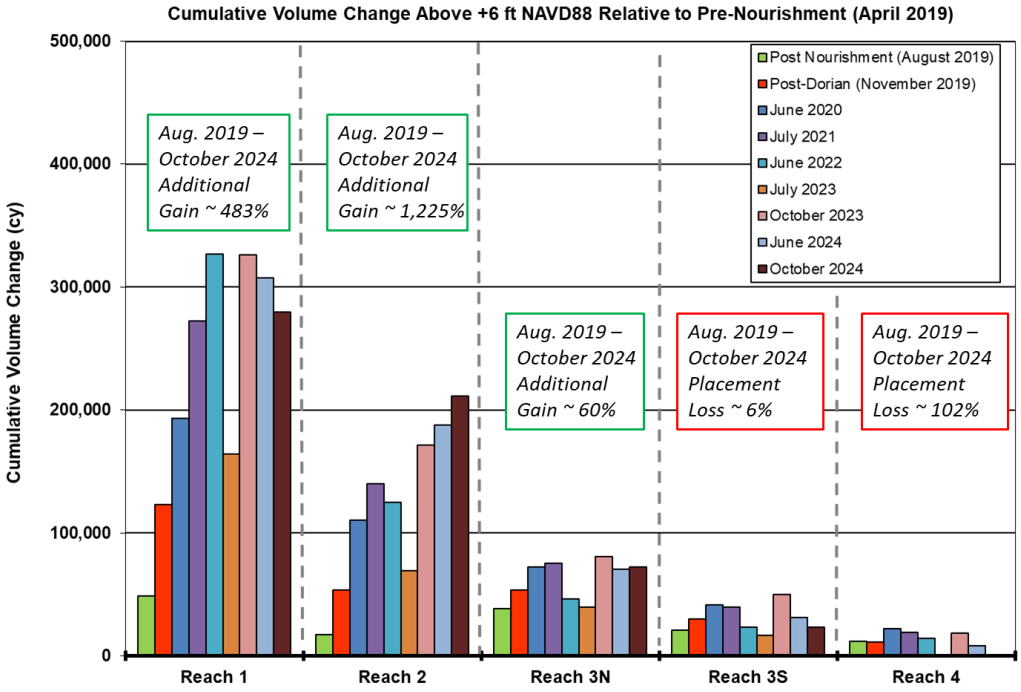

Figure 5-11. Cumulative Volume Change Above +6 ft NAVD88 Relative to Pre-Nourishment

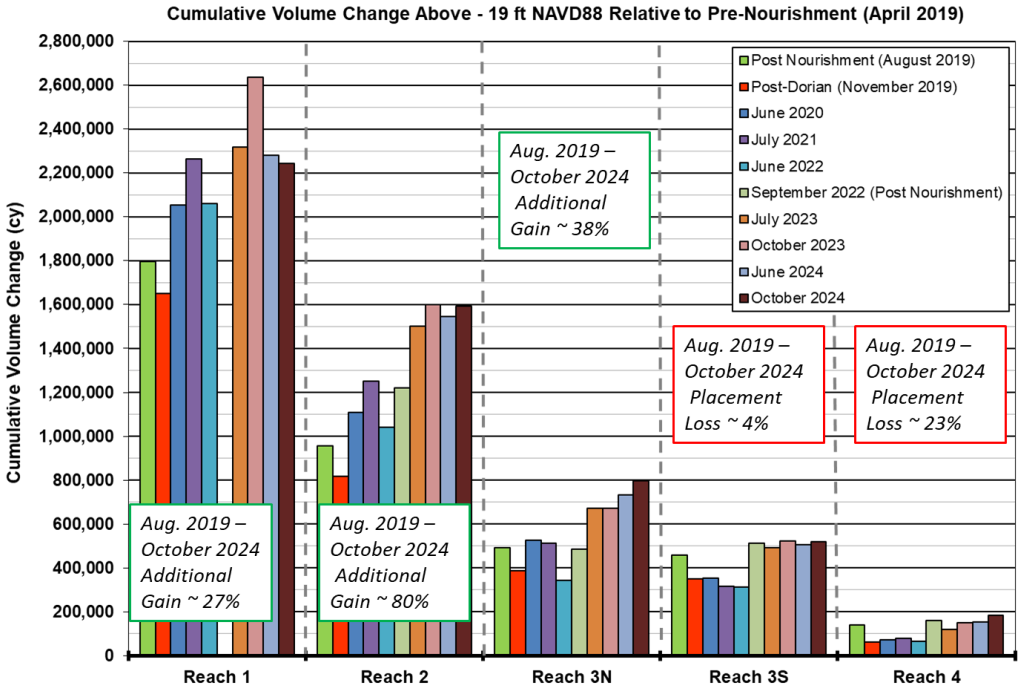

Figure 5-12. Cumulative Volume Change Above -19 ft NAVD88 Relative to Pre-Nourishment

5.3 Multi-Decadal Beach Nourishment Master Plan

The Town of Nags Head has developed a Multi-Decadal Beach Nourishment Master Plan (Master Plan), adopted in July 2024, to provide a framework to plan and conduct beach maintenance and storm response projects over a 50-year timeframe. With this framework in place, the Town will be able to efficiently plan the permitting, financing, and construction of future beach nourishment projects.

The annual monitoring efforts guide the timing and scope of beach nourishment projects by tracking the average profile volume within each management reach. These volumes are compared to nourishment triggers, which define the minimum profile volumes required to maintain an equivalent level of protection along the Nags Head shoreline.

The volumetric triggers, established as part of the Master Plan, are based on the profile volume measured from the foredune (landward crest of the primary dune) to the outer bar above the -19 ft NAVD88 elevation. These triggers are designed to ensure consistent protection along the oceanfront. Engineering analysis, combined with historical data and projected funding levels, determined that the Town can maintain a Level of Protection (LoP) against a 25-year return period storm event.

To determine the required sand volume above -19 ft NAVD88 for this LoP, detailed CSHORE modeling (a 1-D cross-shore numerical model) was conducted for each management reach. The triggers vary by reach due to differences in existing dune height, berm width, and other profile characteristics. **Table 5-3** outlines the management reaches and their respective nourishment triggers, with the Town-wide average trigger set at 464 cubic yards per foot (cy/ft).

Table 5-3. Trigger Volumes Above -19 ft NAVD88 for 25-yr Event

Reach	Stations	Length (ft)	Reach Trigger for 25-yr event (cy/ft)
Nags Head - North	430+00- 495+00	6,500	355
Reach 1	495+00- 790+00	29,500	470
Reach 2	790+00- 920+00	13,000	502
Reach 3 - North	920+00- 975+00	5,500	446
Reach 3 - South	975+00- 1010+00	3,500	
Reach 4	1010+00- 1025+00	1,500	
Town Limits		59,500	464

All profile data from 2011 to present was re-evaluated considering these volumetric triggers, as shown in **Figure 5-13**. Notably, the starting position for volumetric computations in the trigger evaluation differs from the *Xon* (computation start) location used in historical volume change analyses in this and previous reports. For trigger evaluation, volumes are calculated from the approximate dune crest to the offshore location

of the -19 ft NAVD88 contour. As shown in **Figure 5-13**, the volumetric triggers for the reaches have not undergone significant changes since the July survey. Consistent with the observed volume changes, the profile volume has slightly decreased in Reach 1 while increasing in the other reaches.

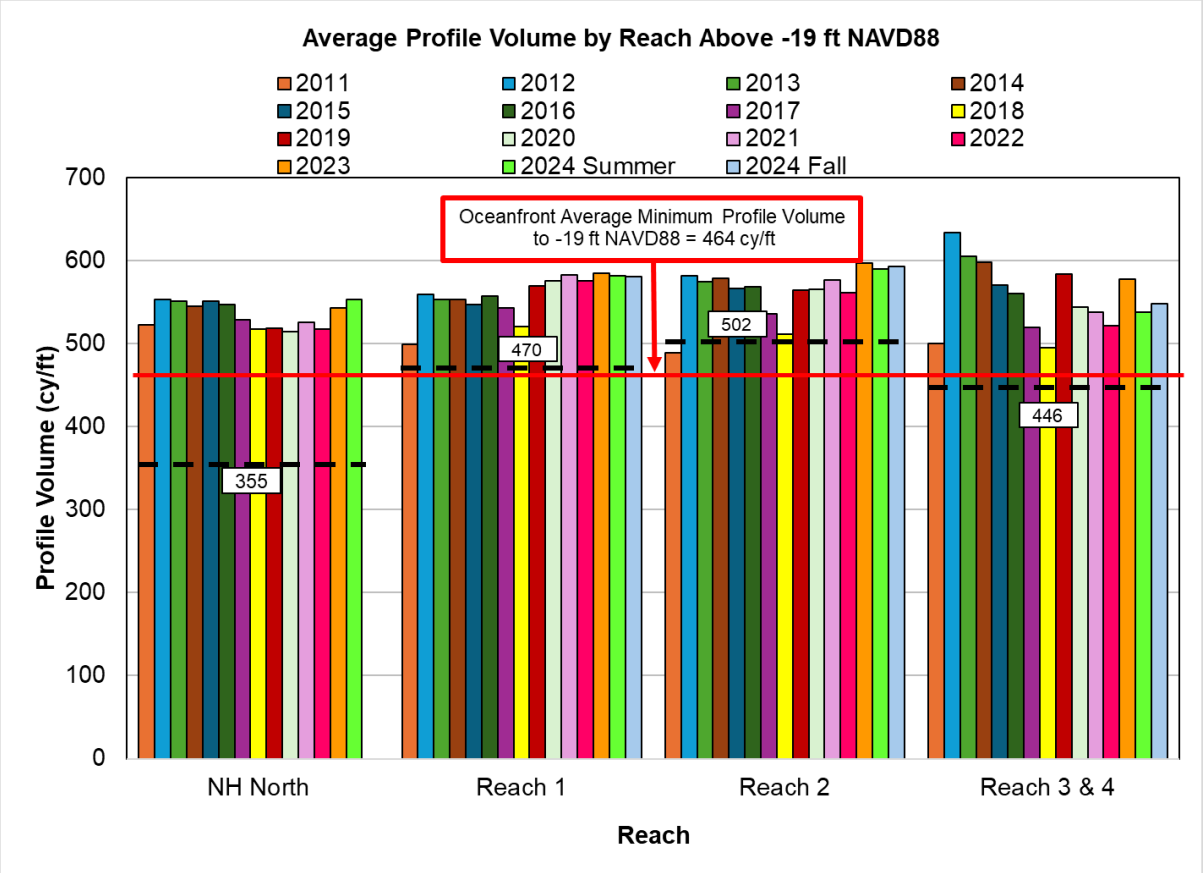

Figure 5-13. Master Plan Nourishment Trigger Volume Comparison

All management reaches currently contain average profile volumes above the nourishment triggers, however, there have been localized erosion hotspots observed along the Town's shoreline in the summer and fall of 2024. To more closely examine the current status of the beach, the profile volumes from all transects as of November 2024 are presented in **Figure 5-14**. Localized segments of Reaches 3 and 4 have profiles below the trigger volumes (red arrows), and additional localized segments of Reaches 1 and 2 are close to the triggers (yellow arrows).

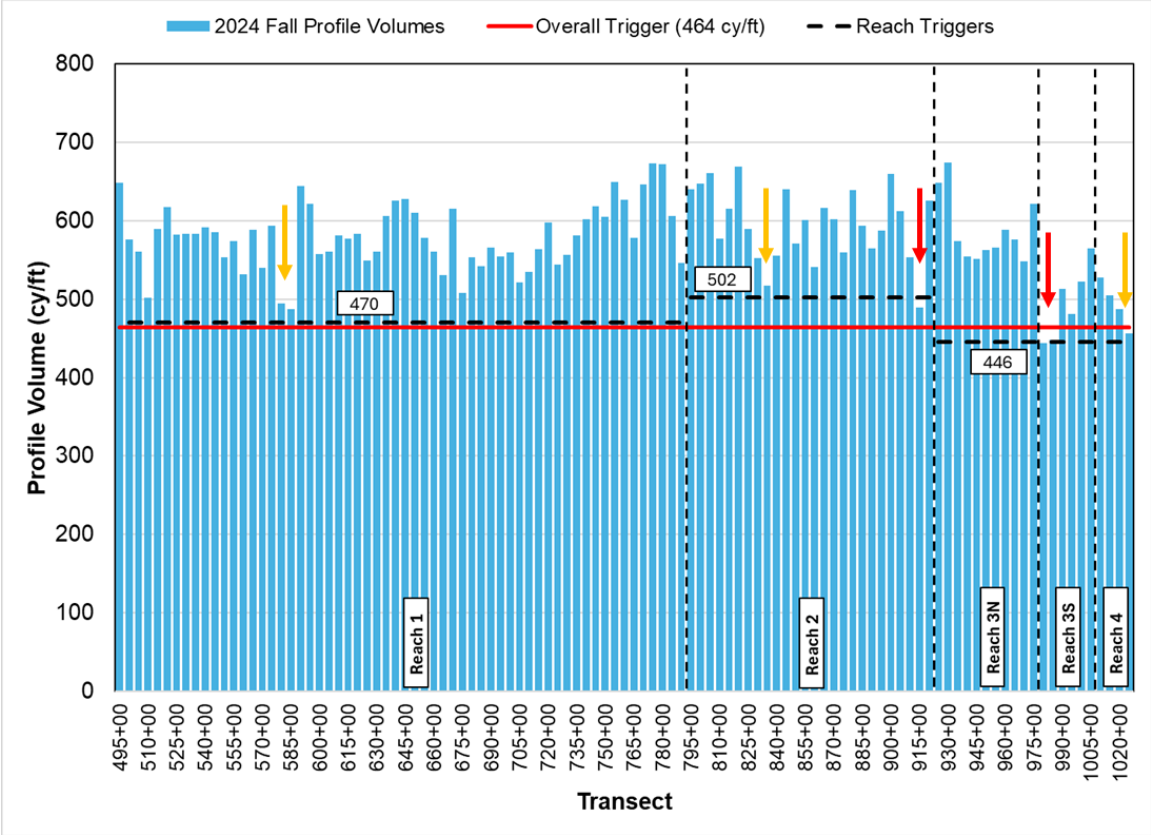

Figure 5-14. 2024 Fall Beach Profile Volumes and Master Plan Trigger Volume Comparison

Due to these results and ongoing erosion across the Town's shoreline, the Town is planning for the option to construct the next project either in summer 2026 or summer 2027.

6.0 SUMMARY

The Town of Nags Head Beach Monitoring and Maintenance Plan is sponsored by the Town of Nags Head (Town) as a continuation of the 2011 monitoring program initiated for assessing beach conditions. The primary purpose of the program is to assess current and historical shoreline conditions, determine shoreline and volumetric changes and evaluate the performance of beach nourishment and other restoration efforts. Evaluating and documenting these changes consistently over successive years provides information necessary to plan for future beach nourishments and to support development of the Town's multi-decadal Beach Nourishment Master Plan.

The latest annual summer survey took place in June 2024 and was carried out by McKim & Creed. Furthermore, a fall survey, prompted by observed scarping along the Town's beachfront, was conducted by McKim & Creed in October 2024. This report presented the data sources, methodologies, and findings of a survey evaluation conducted by Moffatt & Nichol. The evaluation compares the October 2024 survey to the data from June 2024 survey.

The survey data was used to compute shoreline change at Mean High Water (MHW), which is designated as +1.18 ft NAVD88 for Nags Head, and volume change above +6 ft NAVD88 (berm), MHW, -6 ft NAVD88 (wading depth), -14 ft NAVD88 (outer bar), -19 ft NAVD88 (approximate depth of closure), and -30 ft NAVD88 (offshore). **Table 6-1** and **Table 6-2** provide a summary of the shoreline and volume changes experienced during the observation period.

Table 6-1. Nags Head Shoreline and Average Unit Volume Change Statistics (June 2024 – October 2024)

June 2024 vs. October 2024	Transects	Reach Length	avg shoreline change @ +1.18 ft NAVD88	Change above +6 ft NAVD88	Change above +1.18 ft NAVD88	Change above -6 ft NAVD88	Change above -14 ft NAVD88	Change above -19 ft NAVD88	Change above -30 ft NAVD88
Reach	#	ft	ft	cy/ft	cy/ft	cy/ft	cy/ft	cy/ft	cy/ft
Reach 1	495+00 - 790+00	29,500	-14.1	-1.0	-4.2	4.7	9.6	-1.3	-14.2
Reach 2	790+00 - 920+00	13,000	-15.6	1.8	-0.9	6.6	17.4	3.5	-9.3
Reach 3N	920+00 - 975+00	5,500	-26.1	0.3	-6.2	-0.5	23.0	11.2	1.1
Reach 3S	975+00 - 1010+00	3,500	-43.1	-2.3	-10.9	-9.1	14.5	3.6	-5.2
Reach 4	1010+00 - 1025+00	1,500	2.1	-4.2	-5.7	6.2	30.5	16.5	0.0
	Transects	Reach Length	weighted avg	weighted avg	weighted avg	weighted avg	weighted avg	weighted avg	weighted avg
Nourished Oceanfront	**495+00 - 1025+00**	**53,000**	**-17.2**	**-0.3**	**-4.1**	**3.8**	**13.8**	**2.0**	**-10.4**

Table 6-2. Nags Head Cumulative Volume Change Statistics (June– October 2024)

June 2024 vs. October 2024	Transects	Reach Length	Change above +6 ft NAVD88	Change above +1.18 ft NAVD88	Change above -6 ft NAVD88	Change above -14 ft NAVD88	Change above -19 ft NAVD88	Change above -30 ft NAVD88
Reach	#	ft	cy	cy	cy	cy	cy	cy
Reach 1	495+00 - 790+00	29,500	-28,300	-121,508	137,697	279,228	-38,256	-412,781
Reach 2	790+00 - 920+00	13,000	23,726	-12,065	86,027	226,615	45,887	-120,332
Reach 3N	920+00 - 975+00	5,500	1,623	-33,983	-2,957	126,755	61,465	5,783
Reach 3S	975+00 - 1010+00	3,500	-8,206	-38,109	-31,769	50,576	12,757	-18,103
Reach 4	1010+00 - 1025+00	1,500	-8,485	-11,451	12,496	60,984	32,979	6,610
	Transects	Reach Length	total	total	total	total	total	total
Nourished Oceanfront	**495+00 - 1025+00**	**53,000**	-19,643	-217,115	201,494	744,158	114,832	-538,824

During the June 2024 - October 2024 monitoring period, from Reach 1 to Reach 4, the shoreline retreated -17.2 ft on average. Shoreline retreat was more pronounced in southern reaches. Reach 3N retreated -26.1 ft, and Reach 3S experienced the greatest retreat rate of -43.1 ft. This erosion allowed waves to reach the dunes, resulting in dune scarping across the Nags Head oceanfront.

The dune scarping and erosion are evidenced by volume loss experienced above +6ft NAVD88 and MHW. Above +6 ft NAVD88, the nourished oceanfront lost -0.3 cy/ft on average in between the summer and fall surveys. The greatest unit volume loss above +6 ft NAVD88 occurred in the southern reaches: Reach 3S (-2.3 cy/ft or -8,206 cy) and Reach 4 (-4.2 cy/ft or -8,435 cy).

During the previous monitoring period, material was deposited above MHW from nearshore, resulting in a steeper slope. In contrast, during the current observation period, all reaches experienced material loss above MHW, with the most significant losses occurring in the southern areas (Reaches 3N, 3S, and 4). The lost material shifted from the subaerial region to the nearshore and sandbar, with deposition occurring above -14 ft NAVD88. This material redistribution contributed to a recovering and growing sandbar, which also gained additional sediment from offshore sources. As a result, the nearshore slope became milder.

All reaches experienced volume gains above -14 ft NAVD88, with the largest unit volume changes observed at Reach 3N (+23 cy/ft or 126,755 cy) and Reach 4 (+30.5 cy/ft or 60,984 cy). Above -19 ft NAVD88, all reaches experienced volume gains except for Reach 1, which showed minor losses (-38,256 cy or -1.3 cy/ft). However, the gains above -19 ft NAVD88 were less than those observed above -14 ft NAVD88, indicating material loss between -14 ft NAVD88 and -19 ft NAVD88, suggesting offshore material movement.

During the 2019 Beach Nourishment Project approximately 4.0 million cy of material was placed along approximately 10 miles of shoreline. The shoreline position and volume changes above six elevations relative to pre-nourishment conditions (April 2019) along the Nourished Oceanfront (Station 495+00 – 1025+00) were also analyzed.

Figure 6-1 illustrates the shoreline changes relative to pre-nourishment condition (April 2019) along the Nourished Oceanfront. As can be seen from the figure, a significant landward recession occurred along the Nourished Oceanfront since the completion of the 2019 nourishment project. During the current observation period, the shoreline experienced additional recession, particularly in Reaches 3S and 3N. At Reach 3S, the shoreline has receded substantially landward of the April 2019 pre-nourishment condition, indicating ongoing erosion in this area.

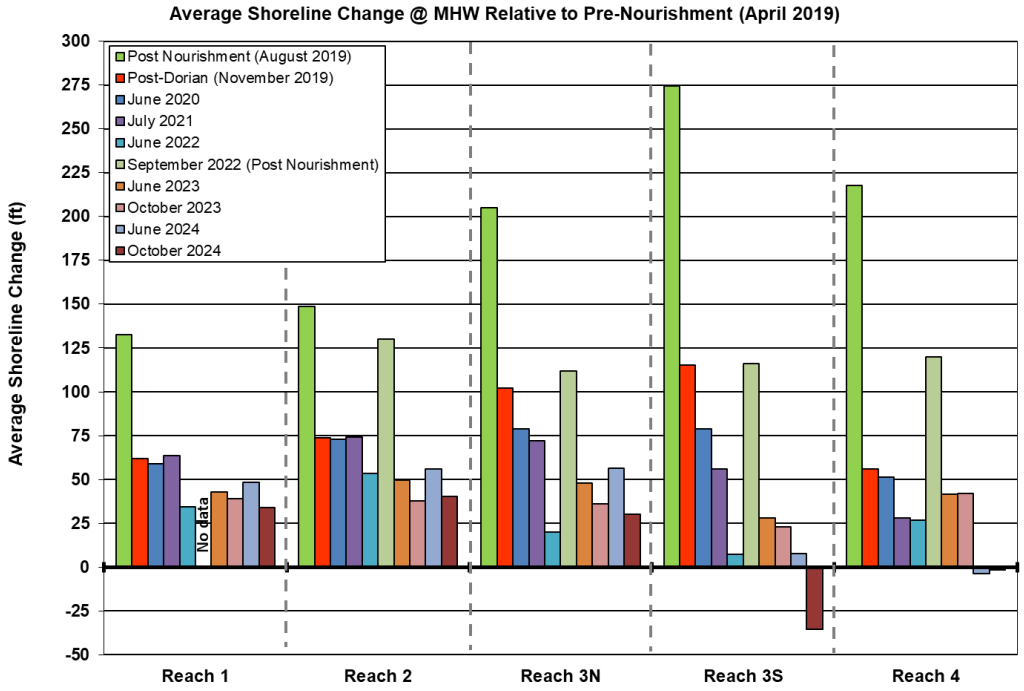

Figure 6-1. Nourished Oceanfront Average Shoreline Change Relative to Pre-Nourishment Conditions

Figure 6-2 illustrates that the overall changes in sand volume vary with the depth above which volumes are assessed. Notably, the Nourished Oceanfront exhibited material losses along the subaerial elevations (+6 ft NAVD88 and MHW) while gaining material above -14 ft NAVD88. The gains above -14 ft NAVD88 indicate some offshore-to-onshore sediment transport, suggesting partial recovery of material losses observed during the previous monitoring period (June 2023 – June 2024). The results indicated a 33% increase of material placed during the 2019 nourishment project above -19 ft NAVD88. The results suggest significant cross-shore shifts of sand across various elevations. Notably, much of the sand has moved to lower elevations near the depth of closure, where it becomes vulnerable to being removed from the system during high-energy wave events.

Figure 6-3 presents the volume changes above -19 ft NAVD88 relative to pre-nourishment conditions (April 2019) along the Nourished Oceanfront. Reach 1 and Reach 2 and Reach 3N show volume gains above -19 ft NAVD88 when compared to pre-nourishment levels. In contrast, the remaining reaches experienced material losses, with Reach 3S and Reach 4 both losing less than 50% of the material placed during the 2019 nourishment.

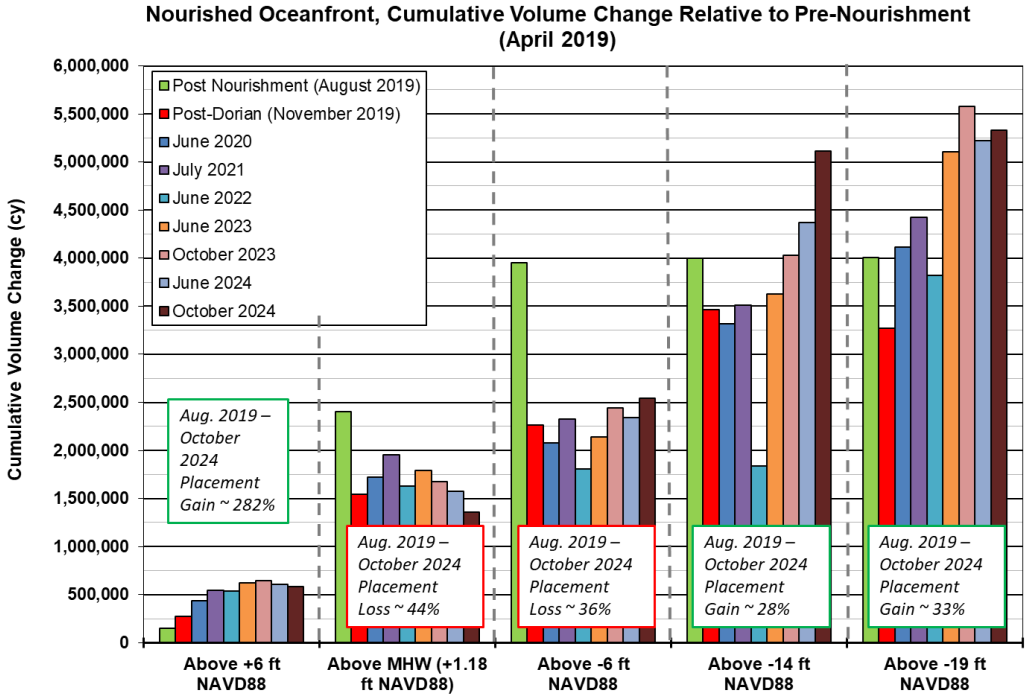

Figure 6-2. Nourished Oceanfront Cumulative Volume Change Relative to Pre-Nourishment

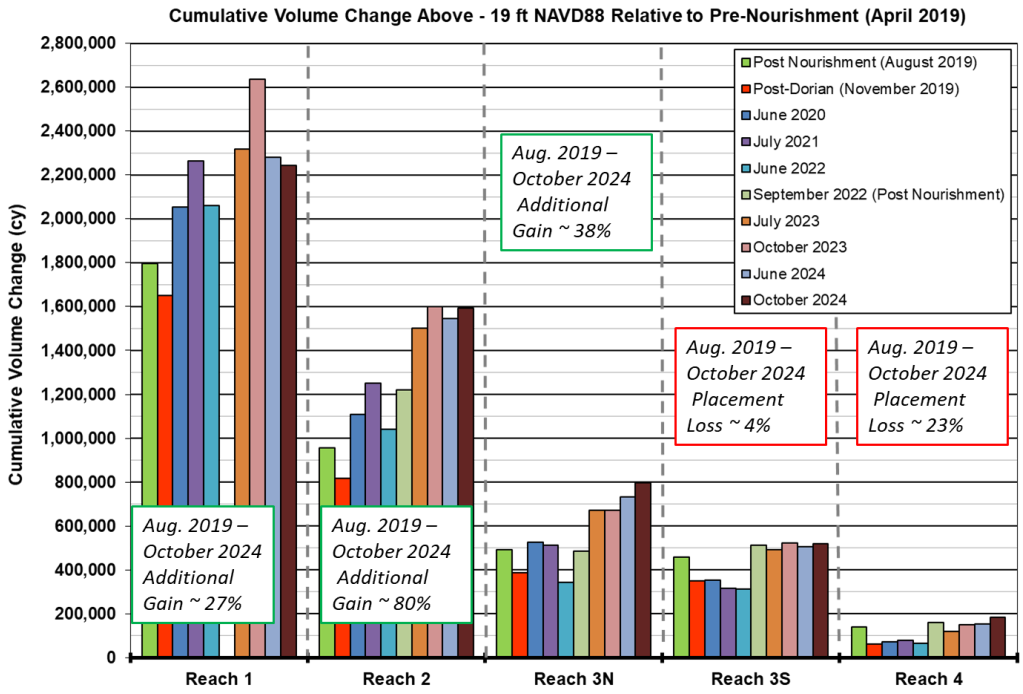

Figure 6-3. Cumulative Volume Change Above -19 ft NAVD88 Relative to Pre-Nourishment

The Town adopted a Multi-Decadal Beach Nourishment Master Plan (Master Plan) in July 2024. This Master Plan included development of volumetric triggers for beach nourishment, based on the profile volume from the landward crest of the primary dune to the outer bar, above the -19 ft NAVD88 elevation. This sand volume was modeled to provide a Level of Protection (LoP) from a 25-year storm. **Figure 6-4** presents the historical and current status of the average profile volumes per reach compared to the volumetric triggers (continuous red and black dashed lines). The volumetric triggers for the reaches have not undergone significant changes since the July survey. Consistent with the observed volume changes, the profile volume has slightly decreased in Reach 1 while increasing in the other reaches.

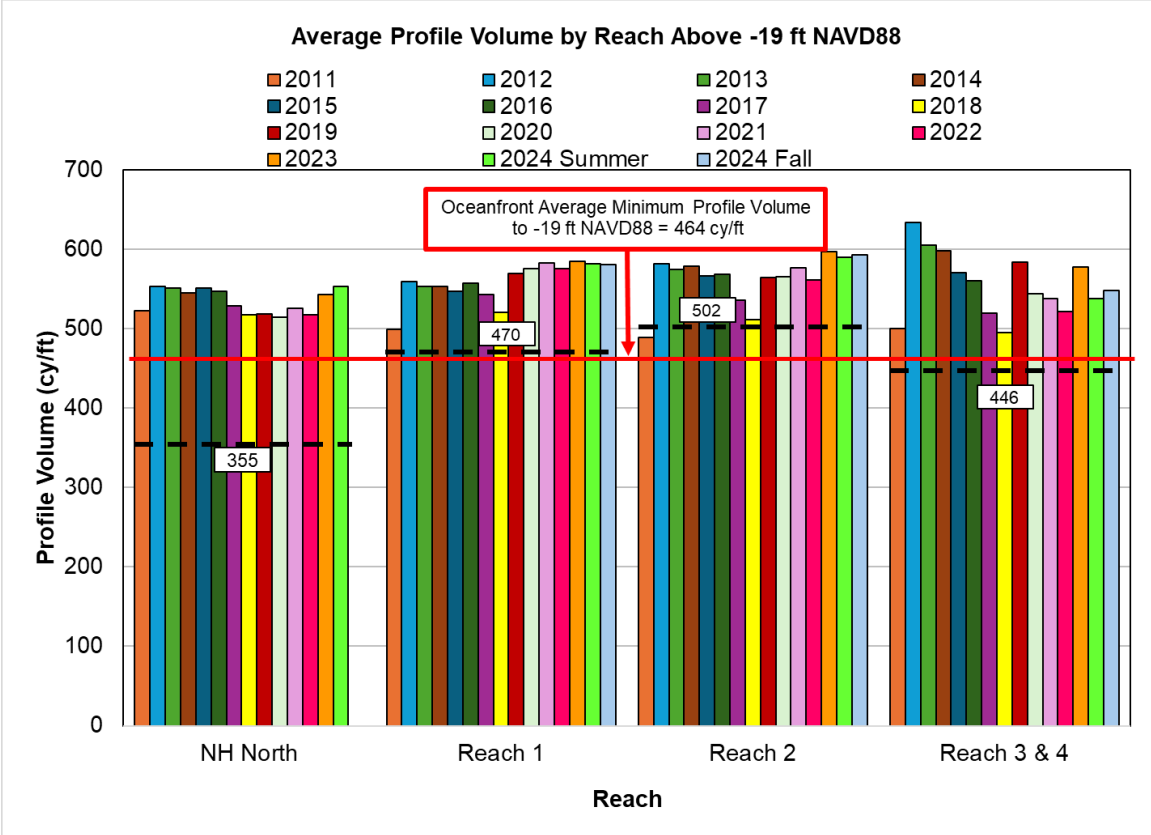

Figure 6-4. Master Plan Nourishment Trigger Volume Comparison

All management reaches currently contain average profile volumes above the nourishment triggers, however, there have been localized erosion hotspots observed along the Town's shoreline in the summer of 2024. To more closely examine the current status of the beach, the profile volumes from all transects as of October 2024 are presented in **Figure 6-5**. Localized segments of Reaches 3 and 4 have profiles below the trigger volumes (red arrows), and additional localized segments of Reaches 1 and 2 are close to the triggers (yellow arrows).

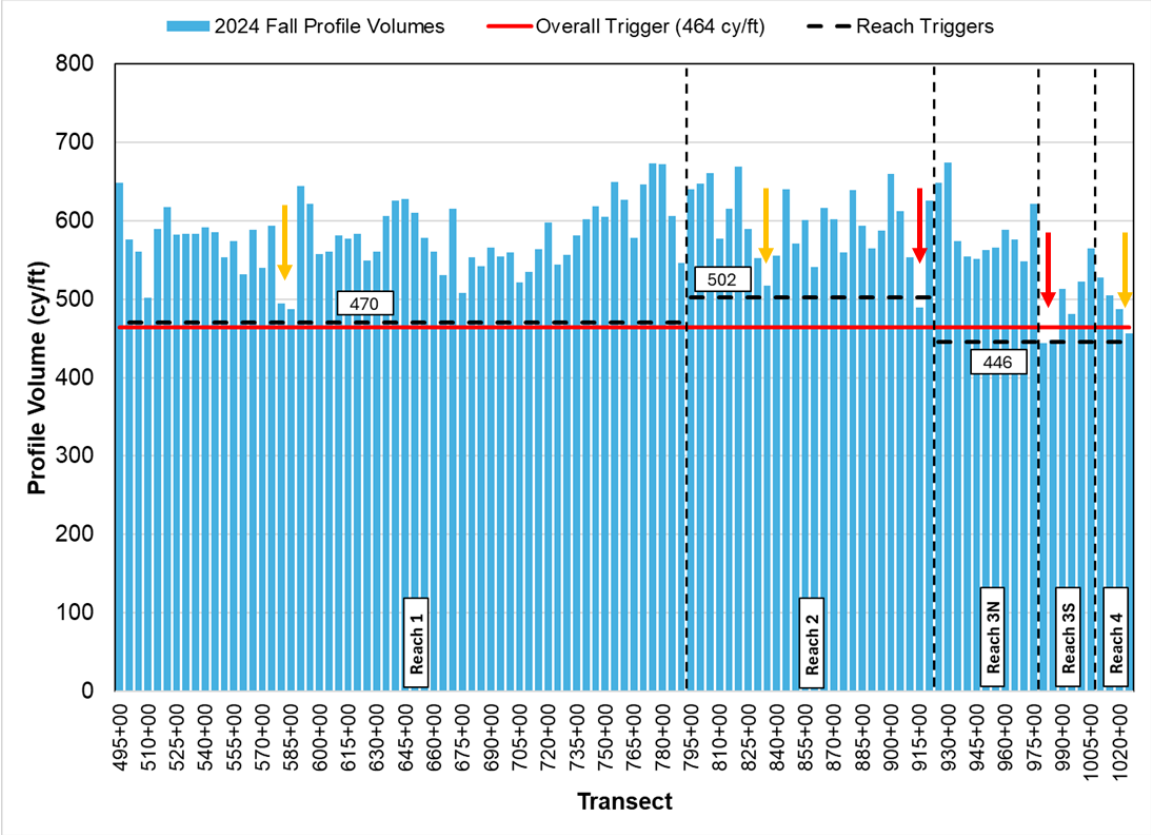

Figure 6-5. 2024 Beach Profile Volumes and Master Plan Trigger Volume Comparison

Due to these results and ongoing erosion across the Town's shoreline, the Town is planning for the option to construct the next project either in summer 2026 or summer 2027.

7.0 REFERENCES

Coastal Science & Engineering Inc. (CSE), 2018. Monitoring and Analyses of the 2011 Nags Head Beach Nourishment Project. Year 7 (2018) Beach Monitoring Report for Town of Nags Head., NC. Columbia, SC. October 2018.

Moffatt & Nichol (MN), 2024. Town of Nags Head Beach Monitoring Analysis Program. 2024 Summer Annual Monitoring Survey Evaluation. Raleigh, NC. October 2024.