INDIAN RIVER COUNTY, FL
SECTOR 4 STORM DAMAGE REPORT:

HURRICANES IAN & NICOLE

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EXECUTIVE SUMMARY

This report documents the changes in beach volume to the 3.3-mile Indian River County, FL, Sector 4 beach and dune caused by the effects of Hurricanes Ian and Nicole. On September 28, 2022, Hurricane Ian made landfall in the United States on Cayo Costa in Lee County. One day later, the eye passed over Brevard County, immediately north of Indian River County as a tropical storm, generating wave heights over 11 feet offshore of the County's coastline. The storm's path relative to Indian River County resulted in elevated storm surge and large waves impacting the County's beaches for several days while the storm approached and passed. On November 10, 2022, Hurricane Nicole made landfall just south of Vero Beach in Indian River County as a Category 1 hurricane. The large wind field and direct impact with the County generated wave heights of nearly 19 ft offshore of the County's coastline. Although Sector 4 is not currently designated as a critically eroded area (62B-36.002(5), F.A.C.) and is not a regularly maintained local- and State-funded engineered beach, the Sector experienced appreciable erosion to the berm and dunes as a result of Hurricanes Ian and Nicole and is seeking assistance from the Federal Emergency Management Agency (FEMA) Public Assistance Program (Category B).

During the storm inter-survey period, the Sector 4 beach experienced an average dune retreat of -19.2 ft and a loss of sand above Mean High Water of 50,200 cubic yards (cy). Portions of immediate beachfront infrastructure are also in a vulnerable state following the passage of the storms. Although a significant loss of sand due to the dune erosion was measured, hydrographic surveys performed after Hurricane Nicole showed an average shoreline gain of 9.9 ft and a beach volume gain of 800 cy above the depth of closure (average of 0.05 cy/ft). For the four (4) to eight (8) month period between the pre-storm survey (May /September 2022) and post-storm survey (January 2023), a background sand loss of -10,900 cy was estimated for the Sector. Although the storm caused significant damage to the dry beach, the measured net volume over the entire active profile (to the depth of closure) was relatively moderate. It is unlikely that the dry beach will recover to pre-storm conditions based on the normal wave climate of the area. The changes due to Hurricane Ian and Hurricane Nicole are described herein to provide FEMA with data needed to develop the Project Worksheets (PW). The estimated cost to repair the dune damages from the 2022 hurricane season is $5,093,666.71 with 10% added for contingency.

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HURRICANES IAN & NICOLE

Table of Contents

List of Figures

INDIAN RIVER COUNTY, FL
SECTOR 4 STORM DAMAGE REPORT:
HURRICANES IAN & NICOLE

Table of Contents

Cont'd

List of Figures

Figure No.

List of Tables

Table No.

List of Appendices

Appendix No.

INDIAN RIVER COUNTY, FL
SECTOR 4 STORM DAMAGE REPORT:
HURRICANES IAN & NICOLE

1. INTRODUCTION

This report documents the changes in beach volume to the 3.3-mile Indian River County, FL, Sector 4 beach caused by the effects of Hurricanes Ian and Nicole on September 28-29, and November 10, 2022, respectively. The eye of Hurricane Ian passed immediately north of Indian River County as a tropical storm with wind gusts up to 65 mph and offshore wave heights of 11 ft. Hurricane Nicole directly impacted Indian River County as a Category 1 hurricane with maximum sustained winds of 75 mph and offshore wave heights of nearly 19 ft. Elevated storm surge and large waves from both storms, resulted in appreciable erosion to the berm and dunes. As part of the monitoring of the beaches within the County as identified in the County' Beach Preservation Plan (2019), Indian River County authorized the collection of post-storm beach profile surveys to document the storm damages. Although Sector 4 is not currently designated as a critically eroded area (62B-36.002(5), F.A.C.) and is not a regularly maintained local- and State-funded engineered beach, the Sector experienced appreciable erosion to the berm and dunes as a result of the 2022 hurricane season and is seeking funding from the Federal Emergency Management Agency (FEMA) Public Assistance Program (Category B).

2. BACKGROUND

2.1 Location and History

Indian River County's Sector 4 Beach is located on the east coast of Florida (**Figure 1**). The northern boundary of the project is located approximately 10.2 miles south of Sebastian Inlet. The Sector spans from R-55 to T-72 and is currently not an engineered beach. The nourishment history of Sector 4 is comprised of one large dune maintenance from 2005 to 2006 and a series of small dune maintenance projects in response to erosional storm events from 2012 to 2017. After Hurricanes Jeanne and Frances in 2004, approximately 72,000 cy of sand was placed in Sector 4. After Hurricane Sandy in October 2012, approximately 1,500 cy of sand was placed in Sector 4. In 2017, in response to Hurricane Matthew (October 2016) and a nor'easter (January 2017), a series of nourishments totaling 7,400 cy were constructed. Additionally, a small 500 cy nourishment was conducted following Hurricane Irma (September 2017). The Sector has shown long-term erosional trends observed along the shoreline since 2002.

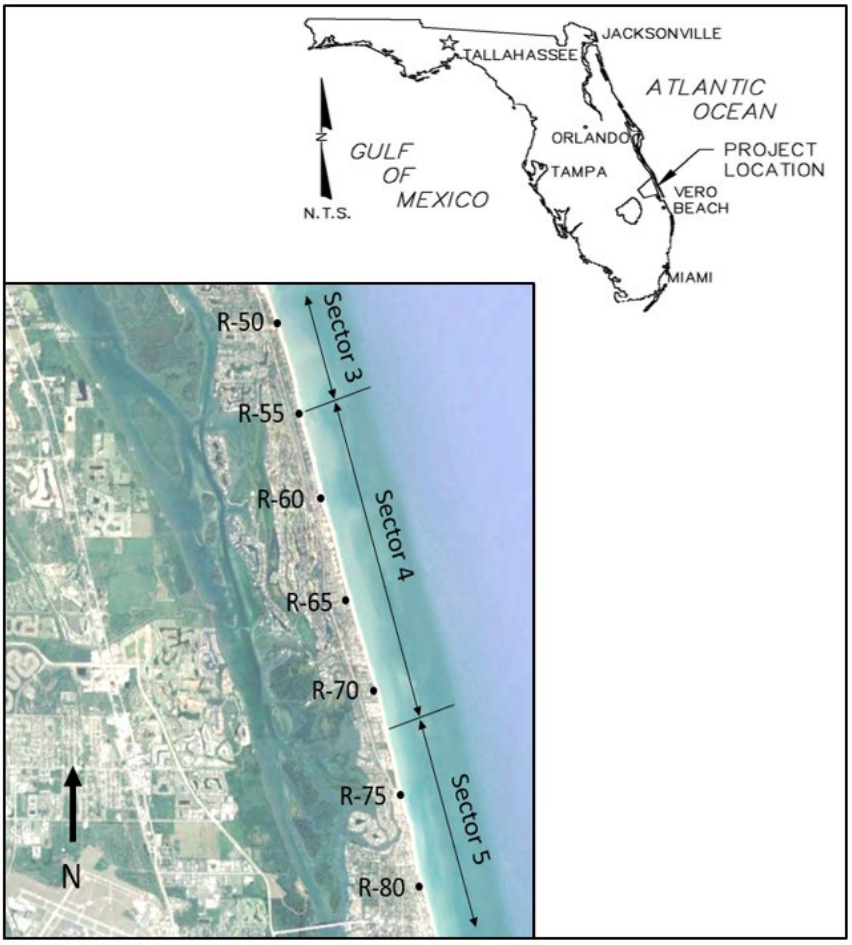


Figure 1. Sector 4 Location Map.

2.2 Public Assistance Eligibility

The Robert T. Stafford Disaster Relief and Emergency Assistance Act, as Amended (Stafford Act), Title 42 of the United States Code § 5121 et seq., authorizes the President to provide Federal assistance when the magnitude of an incident or threatened incident exceeds the affected State, Territorial, Indian Tribal, and local government capabilities to respond or recover.[1] This process is administered by the Federal Emergency Management Agency (FEMA) via its Public Assistance Program.

The Public Assistance Program provides assistance for emergency work on beaches under the Emergency Protective Measures (Category B) program. Category B assistance is available if "a natural or engineered beach has eroded to a point where a 5-year flood could damage improved property, cost effective emergency protective measures on the beach that protect against damage from that flood are eligible." Eligible emergency work measures include:

- Construction of emergency sand berms to protect against additional damage from a 5-year flood. Emergency berms may be constructed with sand recovered from the beach or with imported sand. If imported sand is chosen to repair the berm, FEMA will only provide public assistance funding if the sand is from a source that meets applicable environmental regulations and one of the following circumstances exists:
    - Recoverable quantities are insufficient; or
    - State, Territorial, Tribal, or local government regulations prohibit placement of the recovered sand.

The Emergency Protective Measures will cover the following work based on the expected erosion for a 5-year flood:

- Provide funding for emergency berms constructed with up to 6 cy per linear foot of sand above the 5-year stillwater elevation or the berm's pre-storm profile, whichever is less.
- Placement of sand below the 5-year stillwater elevation is also eligible as part of the emergency protective measure if it is necessary to provide a base for the berm.
- Placement of dune grass on an emergency berm is eligible only if it is required by permit and is an established, enforced, uniform practice that applies to the construction of all emergency berms within the applicant's jurisdiction.

[1] For the Federal government to provide assistance, the President must declare that an emergency or major disaster exists (Emergency Declaration).

3. 2022 HURRICANE SEASON

3.1 Hurricane Ian

On September 26, 2022, Hurricane Ian developed into a Category 1 hurricane approximately 300 miles south of Cuba. On the morning of September 27, 2022, Hurricane Ian had strengthened into a Category 3 hurricane, and hit Cuba, causing nationwide power outages. Hurricane Ian moved north and strengthened to a Category 4 while moving across the Gulf of Mexico.

Hurricane Ian made landfall on the United States in Lee County on September 28 around 3 p.m. as a Category 4 hurricane, delivering hurricane force winds and causing massive storm surge to the southwest coast of Florida. **Figure 2** shows a radar image of Ian's wind field after landfall in Florida. The cyclone slowly moved west across the Florida peninsula and weakened to a tropical storm. After reaching the Atlantic Ocean, it again intensified into a Category 1 hurricane before making landfall once more near Georgetown, South Carolina, on September 30. Hurricane Ian then weakened to a post-tropical cyclone as it moved into North Carolina. **Figure 3** plots the track of Hurricane Ian.

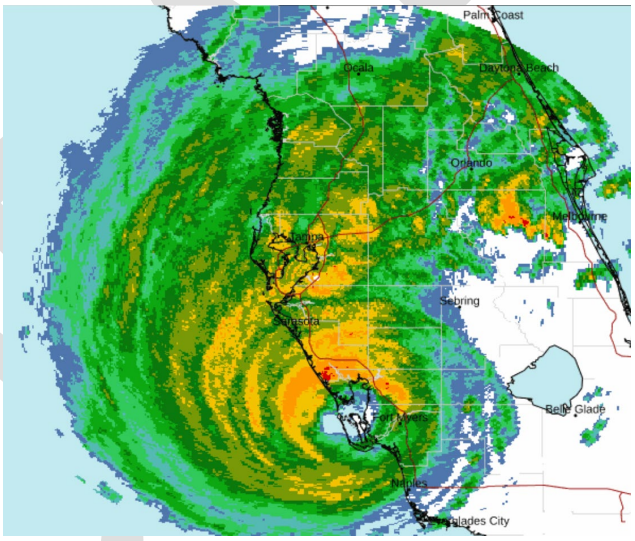


Figure 2. Radar Image of Hurricane Ian on September 28, 2022.
(Source: National Weather Service)

Hurricane Ian was a tropical storm when it hit Indian River County and developed into a Category 1 hurricane shortly after moving off the County's coast. The large wind field produced wave heights over 11 ft offshore of the County's coastline. The storm's path relative to Indian River County resulted in elevated storm surge and large waves impacting the County's beaches for several days while the storm approached and passed offshore. The result was appreciable erosion to the beach berm and dunes of Sector 4. Post-storm photographs of the Sector 4 shoreline are found in **Appendix B**.

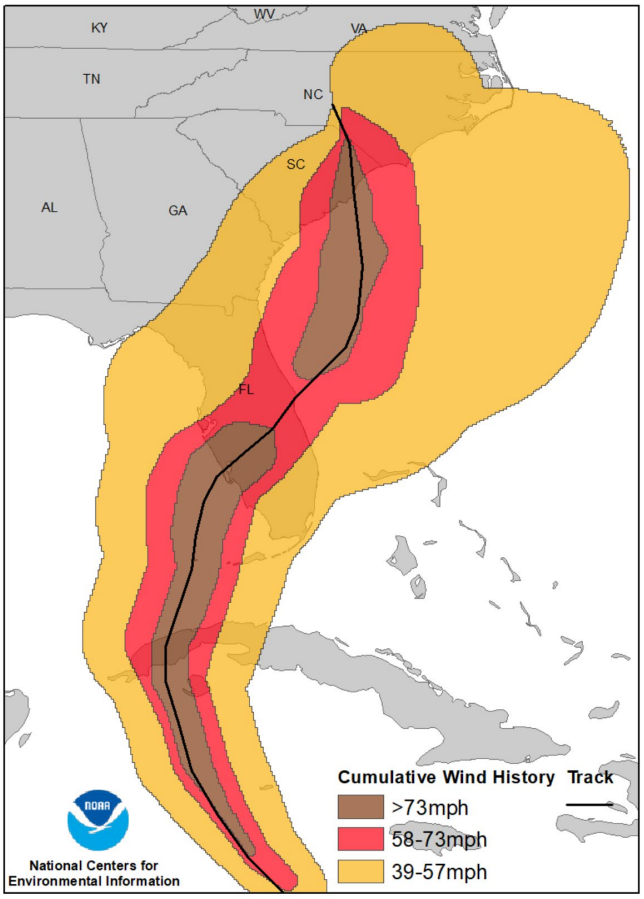


Figure 3. Hurricane Ian's Path and Cumulative Wind History.
(Source: National Oceanic and Atmospheric Administration)

Figure 4 displays the location of oceanographic data collection stations in the vicinity of Indian River County. The wave climate offshore of Indian River County is assumed to be representative of data collected by an offshore waverider buoy, Station 41114 – Fort Pierce, FL (134), published by the National Data Buoy Center (NOAA, 2022a). The buoy is located about 5 nautical miles offshore of the Indian River County / St. Lucie County line, in a water depth of approximately 53 ft. Data collection from the buoy includes significant wave height, wave period, wave direction, and other standard oceanographic and meteorological data.

Water levels near the coast of Indian River County are assumed to be representative of data collected by a tidal station located in the Trident Basin of the interior of Port Canaveral; Trident Pier, FL – Station ID: 8721604 (NOAA, 2022b). The station is located about 35 nautical miles north of the northern Indian River County boundary. It is noted that the tide gage is not located on the open Atlantic Ocean coast. Rather, the station is somewhat sheltered and does not experience the dynamic storm surge (including wave setup) that occurs on the open coast.

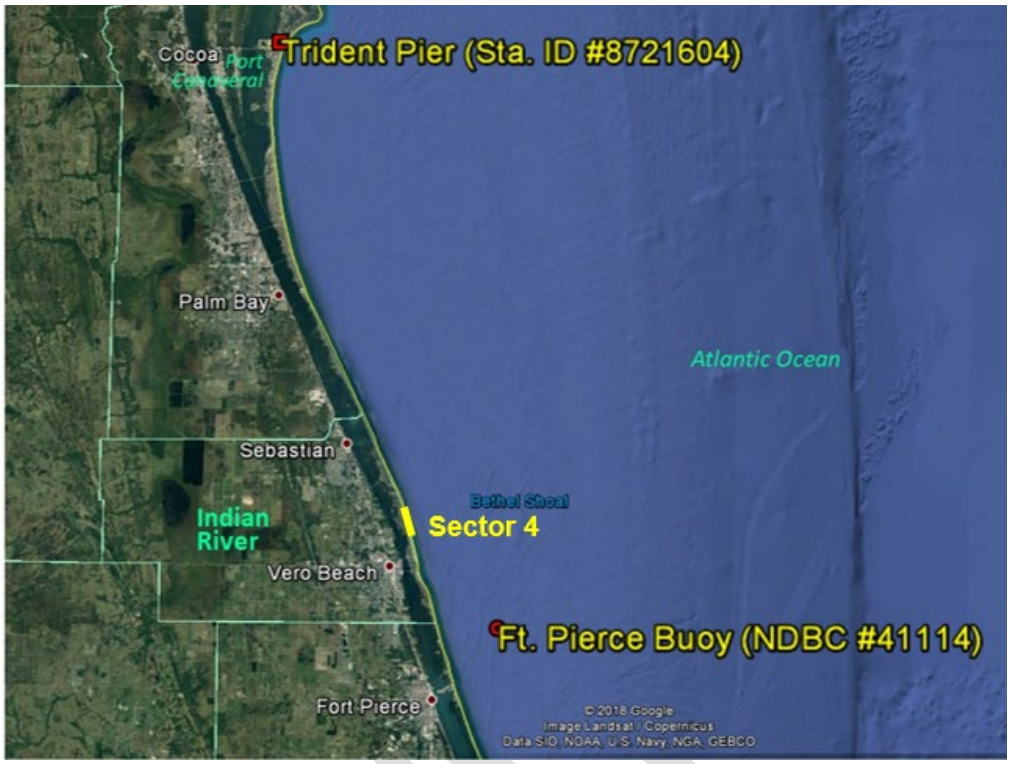


Figure 4. Oceanographic Data Collection Stations near Indian River County.

Figure 5 displays the time series of significant wave height measured at the Fort Pierce Buoy as Hurricane Ian impacted the area. The significant wave heights reported at the buoy are an average of the largest 1/3rd of all wave heights during a 20-minute sampling period (thus, there were waves that passed the buoy during the 20-minute period that were larger than the reported height). Significant wave heights peaked at approximately 11 ft in the morning of September 29, as the storm passed offshore of the County.

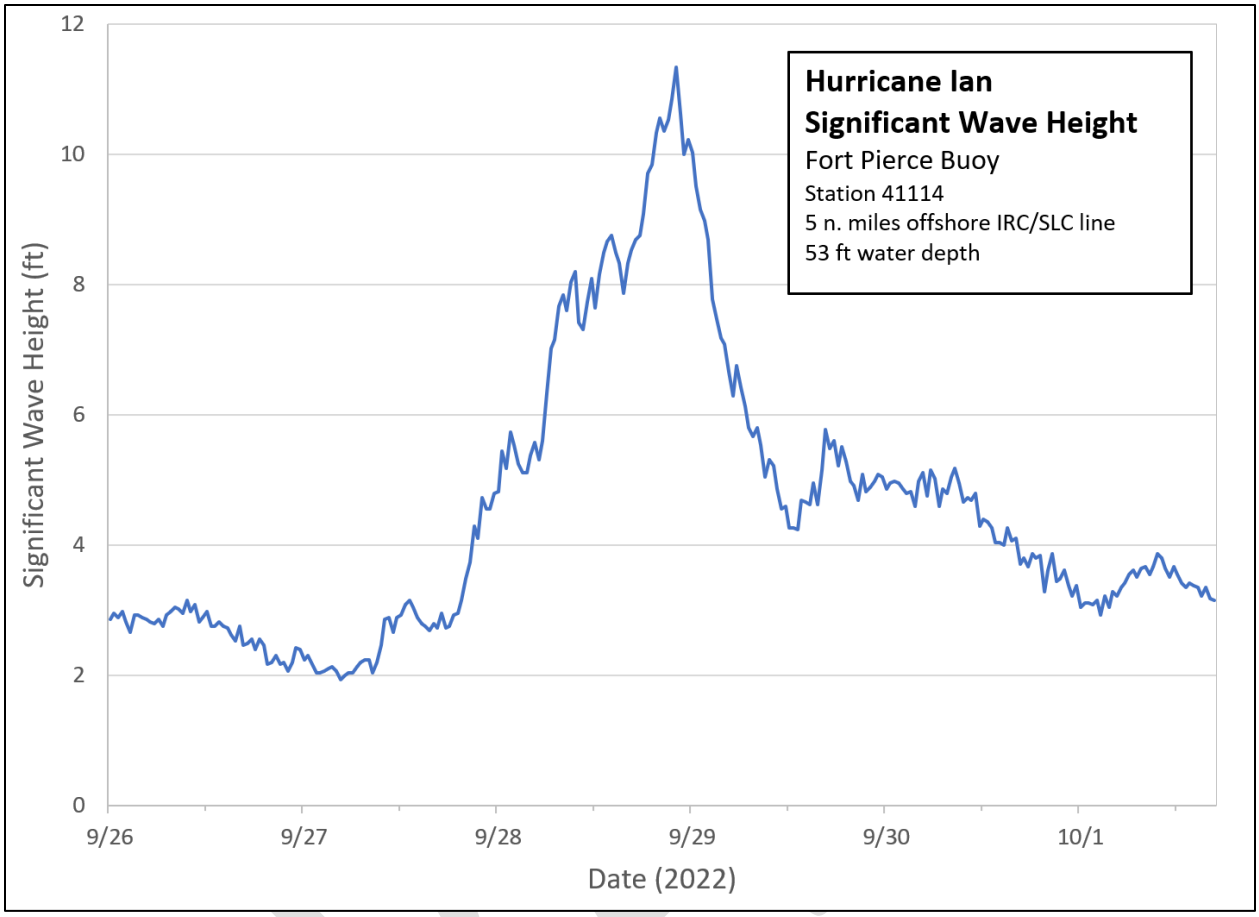


Figure 5. Significant Wave Heights Measured during Hurricane Ian.

Figure 6 displays the time series of water levels measured at the Trident Basin station as Hurricane Ian impacted the area. The greatest storm surge, calculated as the difference between the observed water level and the predicted tide, was +2.9 ft during the morning of September 29. The storm surge[1] resulted in a storm tide[2] of +3.9 ft NAVD at its peak. Based on pre- and post-storm profile inspection, wave impacts and runup reached the toe of the dune in many places, which resides at around +7.5 ft NAVD along most of the County's coast.

[1] *Storm surge* is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tide, and is expressed in terms of height above normal tide levels. Because storm surge represents the deviation from normal water levels, it is not referenced to a vertical datum.

[2] *Storm tide* is defined as the water level due to the combination of storm surge and the astronomical tide, and is expressed in terms of height above a vertical datum, i.e. the North American Vertical Datum of 1988 (NAVD88).

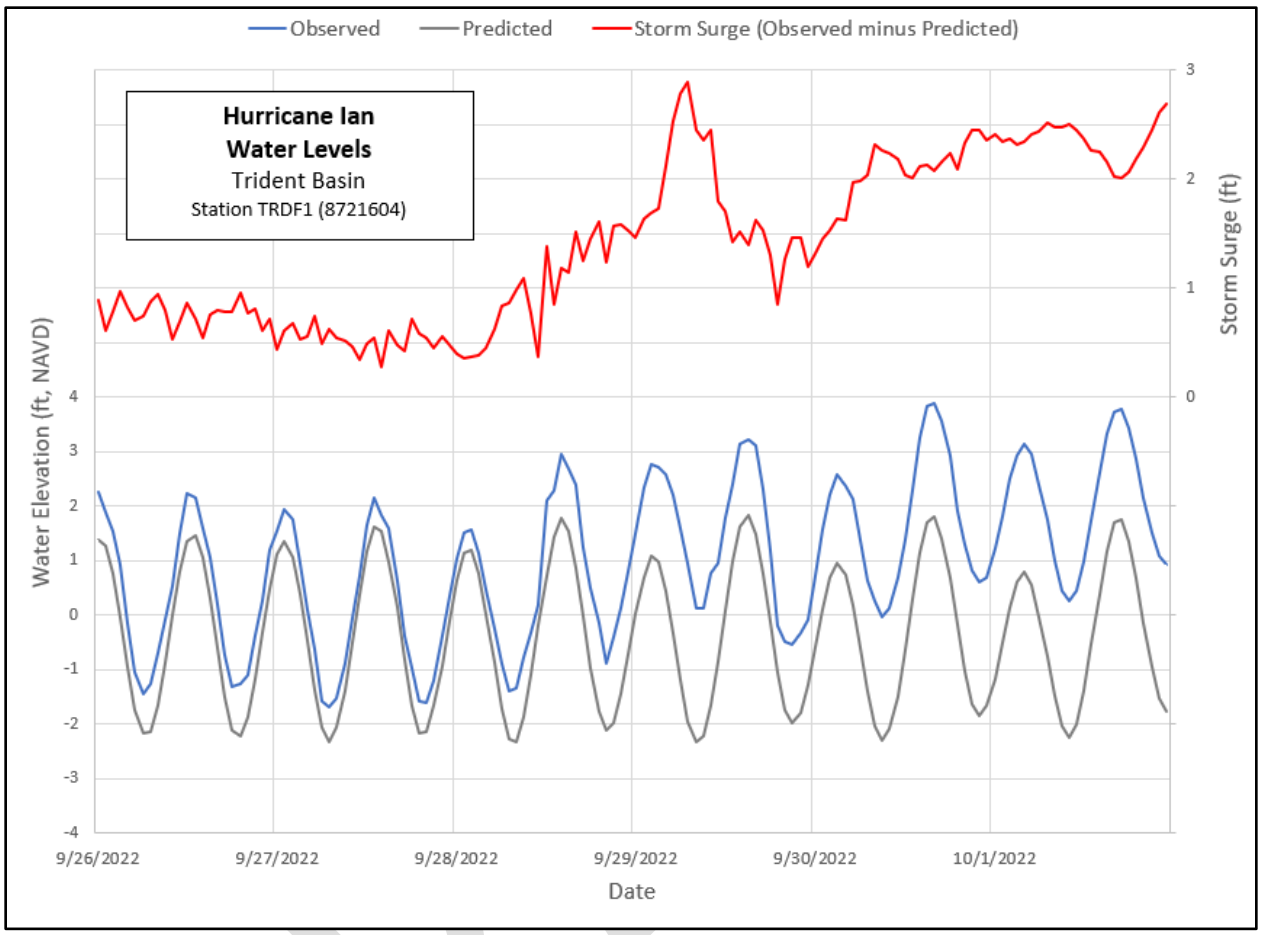


Figure 6. Water Levels Measured during Hurricane Ian.

3.2 Hurricane Nicole

Hurricane Nicole was a sprawling late-season Category 1 hurricane in November 2022, with storm-force winds extending approximately 970 miles in diameter. Nicole was the fourteenth named storm and eighth hurricane of the 2022 Atlantic hurricane season. Nicole formed as a subtropical cyclone on November 7, from a non-tropical area of low pressure near the Greater Antilles and transitioned into a tropical cyclone the next day. On November 9, Hurricane Nicole made landfall on Great Abaco Island, where it strengthened into a Category 1 hurricane with sustained winds of 70 mph (110 km/h). On November 10, Hurricane Nicole made landfall on North Hutchinson Island, just south of Vero Beach, Florida, with 75 mph winds. The storm made a direct impact with Indian River County as a Category 1 hurricane. Nicole subsequently made its second landfall at Cedar Key after briefly emerging over the Gulf of Mexico. Nicole then weakened to a depression while moving over the Florida Panhandle, and then was absorbed into a mid-latitude trough and cold front over extreme eastern Tennessee the following day. The storm path is shown in **Figure 7**.

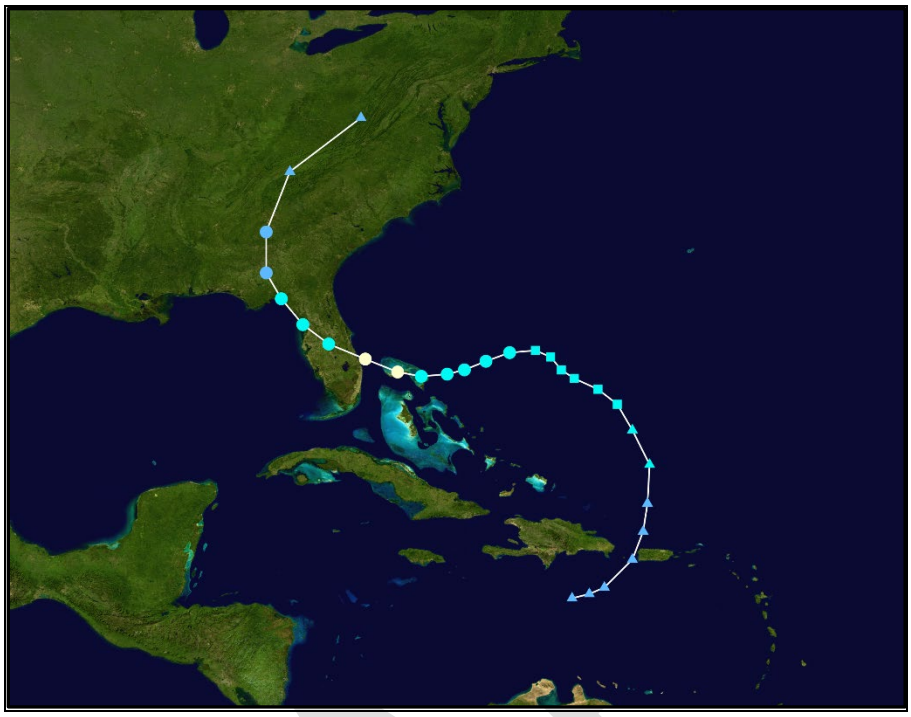


Figure 7. Path of Hurricane Nicole (NOAA 2022).

Nicole crossed the same region in Florida devastated six weeks earlier by Hurricane Ian, and was the first hurricane to make landfall on Florida's east coast since Katrina in 2005. Despite being relatively weak, Nicole's large size produced widespread heavy rainfall and strong winds across the Greater Antilles, the Bahamas, and Florida, knocking out power and inflicting significant damage in many areas. Days of strong onshore wind flow onto the east coast of Florida produced severe beach erosion, especially in Indian River County.

Figure 8 displays the time series of significant wave height measured at the Fort Pierce Buoy (NDBC #41114) as Hurricane Nicole impacted the area. Significant wave heights peaked at approximately 19 ft on November 9. The wave height readings went out shortly after the peak height was recorded. The storm's path relative to Indian River County resulted in elevated storm surge and large waves impacting the County's beaches for several days while the storm approached and impacted the County. The result was appreciable erosion to the beach berm and dunes of Sector 4. Post-storm photographs of the Sector 4 shoreline are found in **Appendix B**.

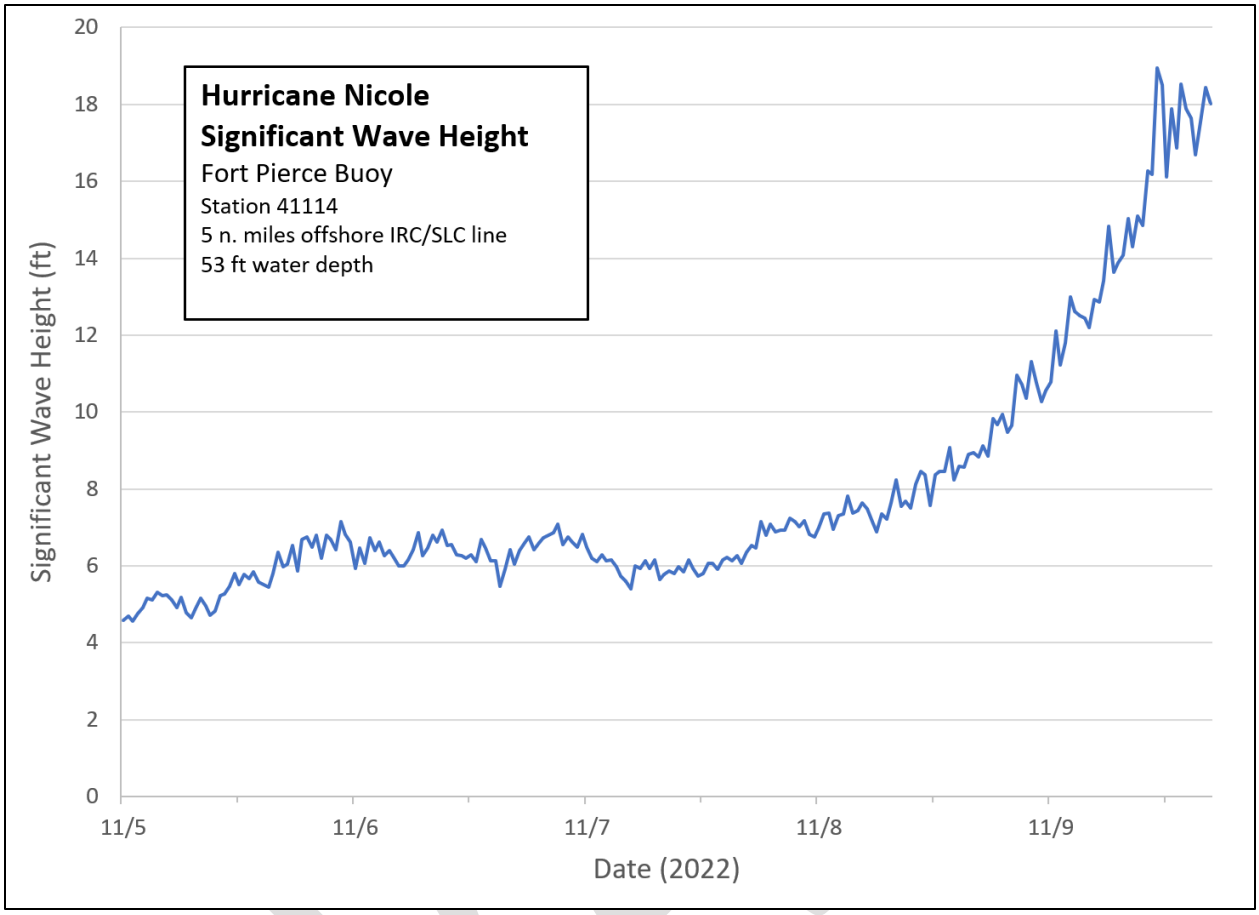


Figure 8. Significant Wave Heights Measured during Hurricane Nicole.

Figure 9 displays the time series of water levels measured at the Trident Basin station as Hurricane Nicole impacted the area. The greatest storm surge, calculated as the difference between the observed water level and the predicted tide, was +5.8 ft during the morning of November 10. The storm surge resulted in a storm tide of +4.7 ft NAVD at its peak. Based on pre- and post-storm profile inspection, wave impacts and runup reached the toe of the dune in many places and further exacerbated the conditions from Hurricane Ian.

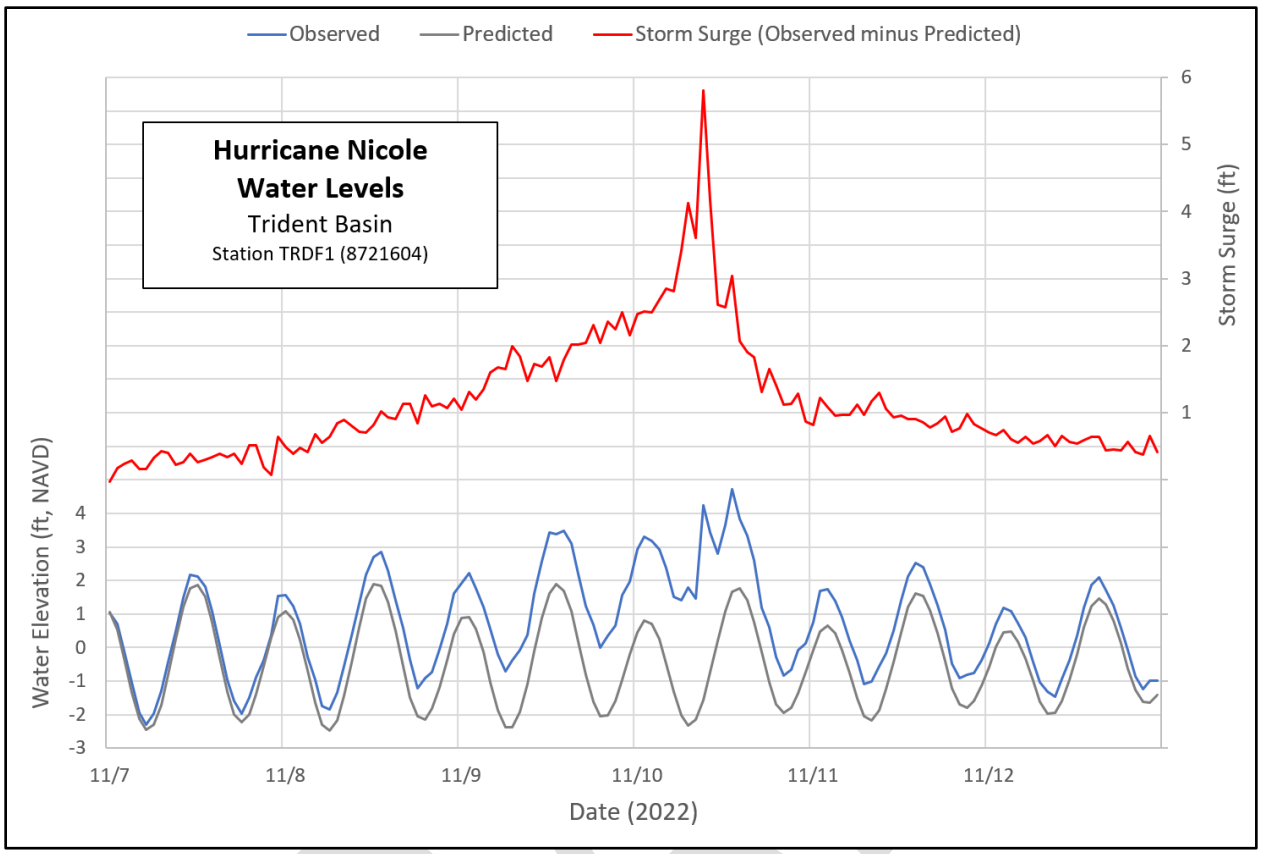


Figure 9. Water Levels Measured during Hurricane Nicole.

4. BEACH PROFILE DATA COLLECTION

Beach profile surveys collected before the passing of Hurricane Ian and after the passing of Hurricane Nicole were utilized to represent pre- and post-storm conditions. These profile sets are listed and described below. **Table 1** lists the survey control of the profiles. Cross section plots of the surveyed profiles are displayed in **Appendix A**.

Pre-Ian Survey:
The pre-Ian survey was collected in two separate surveys for Sector 4. The first survey included R-monuments R-55 to R-60 and was collected between April 7 and May 7, 2022, by Morgan & Eklund, Inc. as part of the Sector 3 Renourishment Project post-construction monitoring requirements. The onshore survey was collected between April 7 and May 7, while the offshore survey was collected on May 6. The second survey included R-monuments R-61 to R-72 and was collected between September 9 and 20, 2022, by Morgan & Eklund, Inc. as part of the County's 2022 annual physical monitoring effort. The onshore survey was collected between September 9 and 20, while the offshore survey was collected on September 15 and 16, 2022.

Post-Nicole Survey:
The post-Nicole survey was collected between December 6, 2022, and January 11, 2023, by Morgan & Eklund, Inc. following both storms. The onshore survey was collected between December 6 and January 11, while the offshore survey was collected between January 5 and 10, 2023.

Table 1. Beach Profile Monument Control

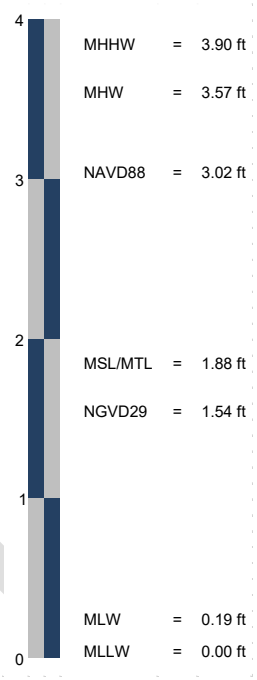
FDEP R-Monument	Easting (ft, NAD83)	Northing (ft, NAD83)	Azimuth (deg. CW from true N)	Distance (ft, between monument)
R-55	857,087.8	1,233,117.6	70	
				994.0
R-56	857,375.8	1,232,166.5	70	
				932.0
R-57	857,607.1	1,231,263.2	70	
				983.0
R-58	857,909.7	1,230,327.8	70	
				992.0
T-59	858,175.9	1,229,372.2	70	
				1,160.0
T-60	858,453.0	1,228,246.0	70	
				965.0
R-61	858,834.3	1,227,359.4	70	
				1,005.0
R-62	859,117.8	1,226,395.4	70	
				990.0
R-63	859,435.0	1,225,458.1	70	
				1,453.0
R-64	859,833.5	1,224,061.0	70	
				573.0
R-65	859,998.8	1,223,512.1	70	
				1,029.0
R-66	860,267.8	1,222,518.6	70	
				936.0
R-67	860,402.5	1,221,592.2	70	
				1,023.0
R-68	860,982.1	1,220,749.1	70	
				1,131.0
R-69	861,335.7	1,219,675.3	70	
				1,036.0
R-70	861,681.3	1,218,698.6	70	
				1,108.0
R-71	861,861.7	1,217,604.9	70	
				1,017.0
T-72	862,167.6	1,216,634.7	70	
			TOTAL (R-55 to R-72):	**17,327.0**

Unless otherwise stated, the vertical datum utilized in this report is the North American Vertical Datum of 1988 (referred to as NAVD88 or NAVD). Tidal datums for the ocean shorefront of Vero Beach (Station ID 8722105) were obtained from NOAA Tides & Currents (NOAA, 2022b), and are summarized in **Table 2**. To conform to previous studies within the County, a MHW elevation of +0.6 ft NAVD is defined in this report.

Table 2. Tidal Datums Established at Vero Beach (Ocean), FL

Datum	Elevation (ft-NAVD)	Elevation (ft-MLLW)
Mean Higher-High Water (MHHW)	+0.88	+3.90
Mean High Water (MHW)	+0.55	+3.57
North American Vertical Datum of 1988 (NAVD88)	0	+3.02
Mean Sea Level (MSL)	-1.14	+1.88
Mean Tide Level (MTL)	-1.14	+1.88
National Geodetic Vertical Datum of 1929 (NGVD29)	-1.48	+1.54
Mean Low Water (MLW)	-2.83	+0.19
Mean Lower-Low Water (MLLW)	-3.02	0

VERO BEACH (OCEAN), FL - Station ID: 8722105; Latitude 27° 40.2' N, Longitude 80° 21.6' W; Epoch: 1983-2001



5. SHORELINE AND DUNE POSITION CHANGE

Beach profile surveys collected before and after the 2022 hurricane season were analyzed to quantify the change in the location of the Mean High Water Line (MHWL) and dune position.

- **MHW Shoreline:** The MHW tidal datum for the ocean shorefront of Indian River County is identified by NOAA Tides & Currents (Station ID 8722105) to be at +0.55 ft NAVD. FDEP's Land Boundary Information System (LABINS) also provides interpolated MHW elevations along the County's ocean shorefront at approximate one-mile intervals. At the County's northernmost location, the MHW is specified at +0.63 ft NAVD, while it is +0.54 ft at the southernmost County location. Considering typical vertical survey accuracy (typically ± 0.2 ft), and to conform to previous studies within the County, a MHW elevation of +0.6 ft NAVD is used to define the shoreline location.

- **Dune Position:** The dune position is defined as the seaward-most cross-shore location of the +10-ft contour. This contour typically corresponds to the average seaward face of the dune throughout the County, and has been used to track the dune position in previous studies, including the multiple iterations of the County's Beach Preservation Plan (CB&I, 2015; Stantec, 2019).

Figure 10 illustrates the extent of dunes lost within the monitoring area. As can be seen from the photograph, the dune has suffered severe erosion and the associated dune overwalk structure has been completely washed out. Irrigation lines, which were once installed along the top of the dune, are also exposed in the photograph to the left of the palm tree. Losses to the dune system, like shown in **Figure 10**, are not expected to naturally recover to their pre-storm conditions and will likely need restored to protect upland infrastructure. The results of the contour change analysis are summarized in **Table 3** and **Figure 11**. The MHW shoreline experienced an average seaward advance of 9.9 ft between the pre- and post-storm surveys. The greatest retreat, averaging -2.1 ft, occurred along the southern portion of the project between R-70 and R-72. The dune position experienced an average landward retreat of -19.2 ft, with at least -20 feet of dune retreat experienced at eight (8) monuments throughout the Sector (R-56, R-57, R-58, R-63, R-69, R-70, R-71, and R-72).

Figure 10. Post-Nicole Conditions in Indian River Shores.

Table 3. Contour Changes

FDEP R-Monment	Contour Change	
	MHWL[1] (ft)	Dune[2] (ft)
R-55	5.0	-8.2
R-56	4.5	-24.1
R-57	14.1	-26.3
R-58	24.0	-20.2
T-59	23.8	-10.5
T-60	10.6	-18.2
R-61	8.6	-12.9
R-62	25.5	-16.1
R-63	5.9	-25.2
R-64	15.3	-10.8
R-65	14.1	-18.9
R-66	9.1	-15.7
R-67	1.9	-11.8
R-68	15.3	-8.2
R-69	6.8	-37.8
R-70	-6.0	-24.2
R-71	6.6	-29.3
T-72	-7.0	-28.0
Average:	**9.9**	**-19.2**

[1]MHWL defined at +0.6 feet NAVD88.
[2]Dune defined at +10.0 ft NAVD88 .
[3]R-55 to T-60 pre-storm shoreline and dune positions were determined using May 2022 survey data.

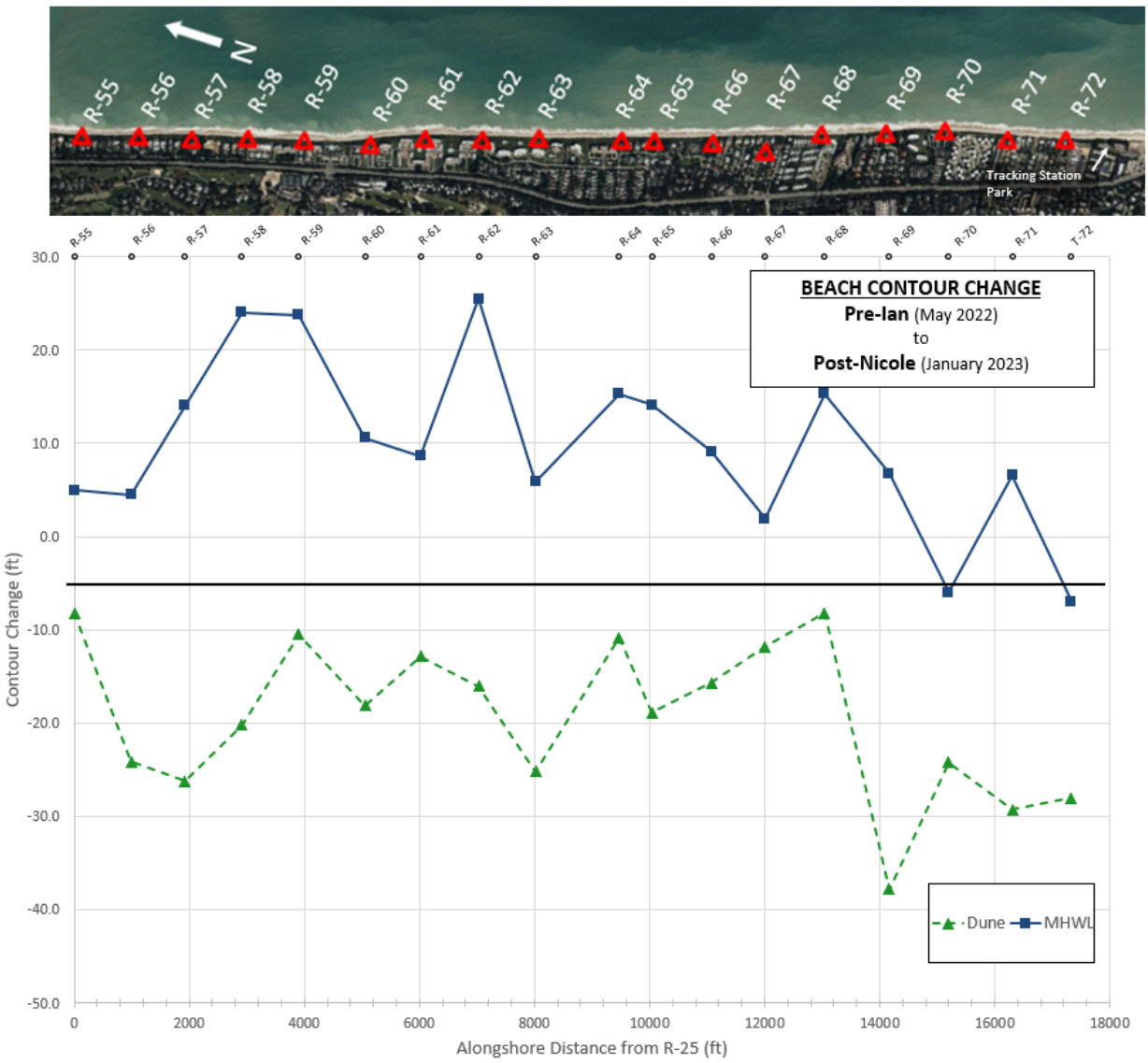


Figure 11. Shoreline and Dune Position Change.

6. BEACH VOLUME CHANGE

Beach profile surveys collected before the passing of Hurricane Ian and after the passing of Hurricane Nicole were directly compared to estimate volumetric changes. Volume changes at the profile transects are described in terms of volume density change, reported in cubic yards per alongshore foot of beach (cy/ft). Volume change between the roughly 1000-ft spaced transects are calculated by using the average-end-area method and reported in cubic yards (cy). Volume changes were calculated from the landward side of the dune out to an offshore depth of closure (DOC) in order to include the entire active beach profile and multiple contours along the dry beach to capture dune losses. As FEMA Category B losses are viewed as cumulative and not additive by storm, losses measured between pre-Ian and post-Nicole are presented within this section.

- **Seaward Limit of Volumetric Analysis (Depth of Closure)**

Due to the jagged nature of the nearshore hardbottom found just offshore of the Sector 4 beach, volume calculations are unreliable along this substrate; therefore, volume changes along the profiles are terminated at the landward extent of the hardbottom. Due to the highly variable nature of the offshore location of the hardbottom, a seaward limit of volume calculation is specified for each R-monument profile within the study area. As such, volume calculations represent seabed changes landward of the location at which movement of sediment could reasonably be estimated, while discounting the naturally irregular hardbottom seafloor. The seaward limit was calculated as the distance from the R-monument to 430 ft seaward of the MHWL (Stantec, 2019). The 2022 post-storm survey was used to determine the location of the MHWL at each monument. The seaward limit is specified at each R-monument in distance offshore (**Table 4**). That is, volume changes are not included offshore of a specified distance and not deeper than a specified elevation. For clarity of nomenclature within this report, the seaward limit of volumetric analysis is referred to as the *depth of closure* (or *DOC*).

Table 4. Seaward Limit of Volumetric Analysis (Depth of Closure)

FDEP R-Mon.	Distance (ft)	FDEP R-Mon.	Distance (ft)	FDEP R-Mon.	Distance (ft)
R-55	566.9	R-61	625.0	R-67	851.7
R-56	572.9	R-62	627.0	R-68	531.5
R-57	631.2	R-63	574.4	R-69	557.2
R-58	562.0	R-64	609.9	R-70	583.6
T-59	562.3	R-65	607.4	R-71	654.5
T-60	654.1	R-66	659.0	T-72	590.3

- **Total Volume Change During the Storm Inter-Survey Period**

The results of the volume change analysis are shown graphically in **Figure 12** and summarized in **Table 5**. Volume changes are computed above different vertical datums in order to assess the cross-shore changes in beach volume. The volume changes are plotted in bar chart form as interpolated volume changes between each profile transect. The bars indicate the volume changes measured between different vertical segments of the beach profile, while the black dashed-line represents the total profile volume change.

- Grey Bar: Sub-aerial change, from the dune to above MHW (+0.6 ft NAVD)
- Blue Bar: Sub-aqueous change, from MHW out to the offshore DOC
- Black Dashed-Line: Total profile change, from the dune to the offshore DOC

Above MHW, Sector 4 lost -50,200 cy (average of -2.9 cy/ft) during the storm inter-survey period. Below MHW to the depth of closure, the Sector gained +51,000 cy (average of +2.9 cy/ft). Measured along the entire profile, from the dunes to the depth of closure, the 3.3 miles of beach gained a total of 800 cy (average of 0.05 cy/ft). **Figure 13** illustrates the cross-shore transfer of sand from the dune and dry beach portion of the beach to the sub-aqueous zone. Due to this process, sand from the dune system was transported to the offshore portion of the profile and resulted in an approximate no-net loss within the coastal system. However, although the total volume change to the depth of closure was minimal, substantial impacts occurred to the dry beach area and dunes, which are not anticipated to recover naturally. In order to further quantify dune losses, the next section details impacts to the dune portion of the beach profile.

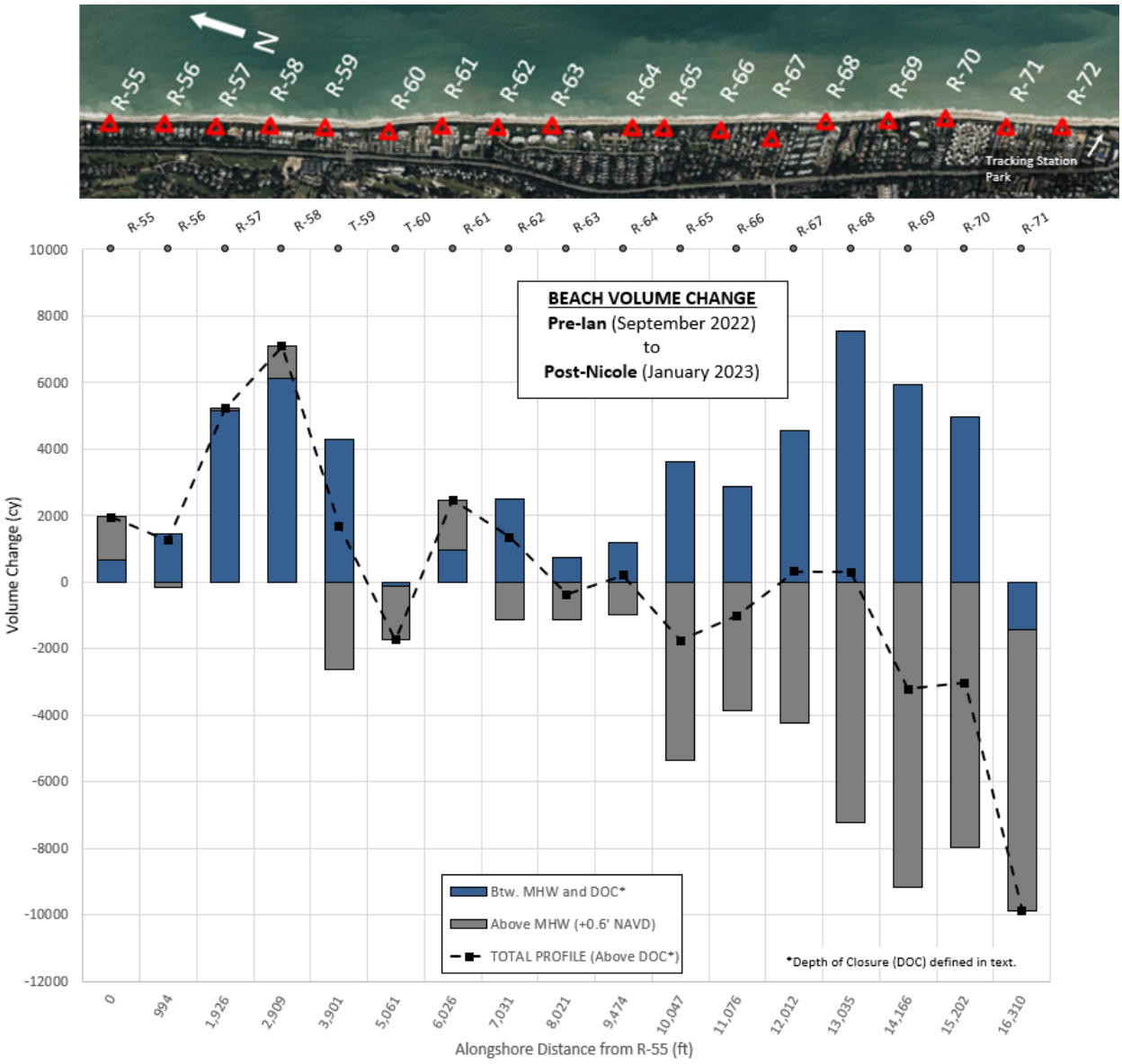


Figure 12. Beach Volume Change.

Table 5. Beach Volume Change

		Pre-Ian (September 2022) to Post-Nicole (January 2023)					
		ABOVE MHW (+0.6 ft NAVD)		BETWEEN MHW AND DOC*		TOTAL ABOVE DOC*	
FDEP Monument	Distance (ft)	Vol. Density (cy/ft)	Volume (cy)	Vol. Density (cy/ft)	Volume (cy)	Vol. Density (cy/ft)	Volume (cy)
R-55		0.8		1.8		2.6	
	994		1,307		649		1,956
R-56		1.8		-0.5		1.3	
	932		-172		1,434		1,262
R-57		-2.2		3.6		1.4	
	983		51		5,161		5,212
R-58		2.3		6.9		9.2	
	992		972		6,121		7,093
T-59		-0.3		5.4		5.1	
	1,160		-2,625		4,302		1,677
T-60		-4.2		2.0		-2.2	
	965		-1,612		-135		-1,747
R-61		0.8		-2.3		-1.5	
	1,005		1,481		983		2,464
R-62		2.1		4.3		6.4	
	990		-1,146		2,497		1,351
R-63		-4.4		0.8		-3.6	
	1,453		-1,131		750		-381
R-64		2.9		0.2		3.1	
	573		-992		1,205		213
R-65		-6.3		4.0		-2.4	
	1,029		-5,367		3,615		-1,752
R-66		-4.1		3.1		-1.0	
	936		-3,879		2,877		-1,002
R-67		-4.2		3.1		-1.1	
	1,023		-4,236		4,563		327
R-68		-4.1		5.8		1.7	
	1,131		-7,239		7,536		297
R-69		-8.7		7.5		-1.2	
	1,036		-9,159		5,943		-3,216
R-70		-9.0		4.0		-5.0	
	1,108		-7,993		4,961		-3,032
R-71		-5.4		5.0		-0.5	
	1,017		-8,469		-1,414		-9,883
T-72		-11.2		-7.8		-19.0	
Project Limits	**Distance**	**ABOVE MHW**		**BTW. MHW & DOC**		**ABOVE DOC**	
R-55 to R-72	**17,327.0**	**-2.9**	**-50,200**	**2.9**	**51,000**	**0.0462**	**800**
						Estimated Background Change:	**-10,900**
						Change Attributed to Storms:	**11,700**

*R-55 to R-60 volumes were calculated using May 2022 (pre-storm) survey data.

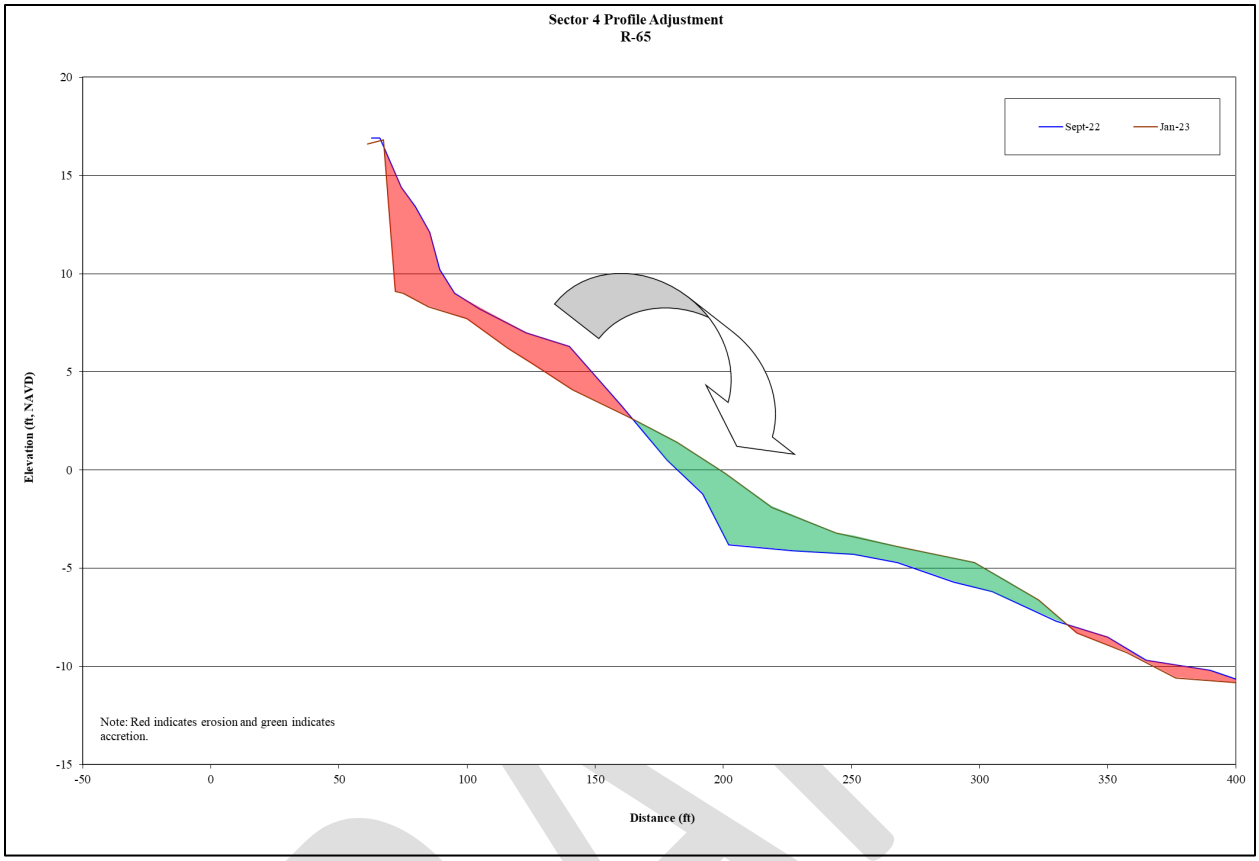


Figure 13. Beach Volume Change.

➢ **<u>Dune Volume Change During the Storm Inter-Survey Period</u>**

The results of the dune/dry beach volume change analysis are shown graphically in **Figure 14** and summarized in **Table 6**. Volume changes are computed above different vertical datums in order to assess the cross-shore changes in beach and dune volume. The volume changes are plotted in bar chart form as interpolated volume changes between each profile transect. The bars indicate the volume changes measured above different vertical elevations of the beach profile.

- Orange Bar: Above 2.5' NAVD
- Blue Bar: Above 5.0' NAVD
- Green Bar: Above 7.5' NAVD

Above 2.5' NAVD, Sector 4 lost -78,700 cy (average of -4.5 cy/ft) during the storm inter-survey period. Above 5.0' NAVD, the Sector lost -87,700 cy (average of -5.1 cy/ft) during the storm inter-survey period. Above 7.5' NAVD, Sector 4 lost -72,100 cy (average of -4.2 cy/ft) during the storm inter-survey period. When comparing pre- to post-storm profiles, the apparent dune losses commence at approximately +5' NAVD and continue to the most landward portion of the dune. **Figure 15** depicts the magnitude of dune erosion experienced within the Sector 4 project and the associated impact to upland infrastructure. As previously detailed, the dune system is currently in

a vulnerable state and future storms could impact upland infrastructure due to the loss of its protective value. Volume necessary to rebuild the dune to its pre-storm conditions should be consider by funding partners as a means to restore storm protection.

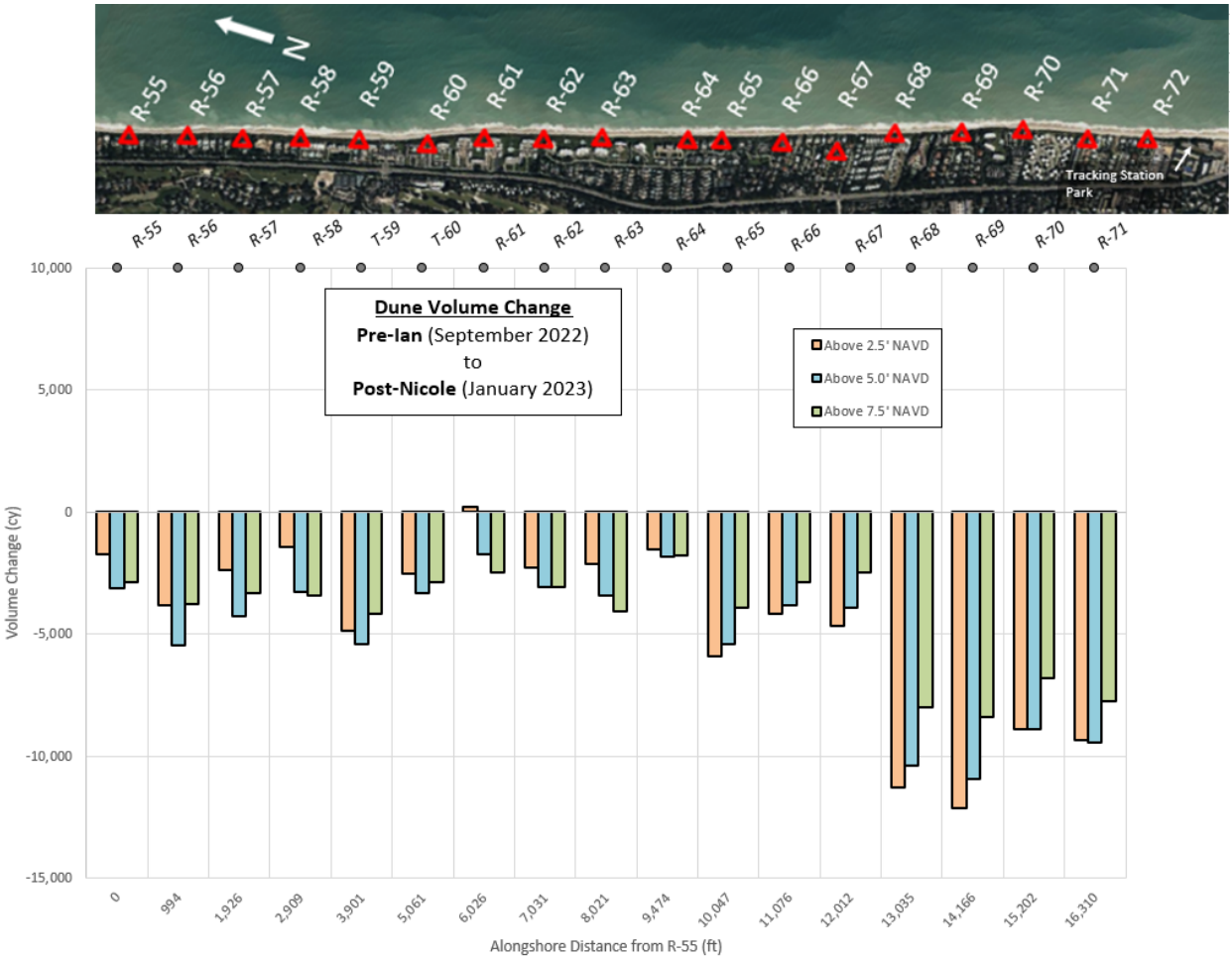


Figure 14. Dune Volume Change.

Table 6. Dune Volume Change

		Pre-Ian (September 2022) to Post-Nicole (January 2023)					
		ABOVE 2.5' NAVD		ABOVE 5.0' NAVD		ABOVE 7.5' NAVD	
FDEP Monument	Distance (ft)	Vol. Density (cy/ft)	Volume (cy)	Vol. Density (cy/ft)	Volume (cy)	Vol. Density (cy/ft)	Volume (cy)
R-55		0.1		-0.6		-1.1	
	994		-1,711		-3,119		-2,894
R-56		-3.5		-5.7		-4.8	
	932		-3,799		-5,441		-3,786
R-57		-4.7		-6.0		-3.4	
	983		-2,380		-4,252		-3,328
R-58		-0.2		-2.6		-3.4	
	992		-1,416		-3,295		-3,411
T-59		-2.7		-4.0		-3.5	
	1,160		-4,855		-5,411		-4,185
T-60		-5.7		-5.3		-3.7	
	965		-2,508		-3,321		-2,891
R-61		0.5		-1.6		-2.3	
	1,005		213		-1,712		-2,472
R-62		-0.1		-1.9		-2.7	
	990		-2,291		-3,054		-3,090
R-63		-4.5		-4.3		-3.6	
	1,453		-2,121		-3,402		-4,066
R-64		1.6		-0.4		-2.0	
	573		-1,512		-1,823		-1,771
R-65		-6.9		-6.0		-4.2	
	1,029		-5,911		-5,403		-3,916
R-66		-4.6		-4.5		-3.4	
	936		-4,143		-3,840		-2,851
R-67		-4.3		-3.7		-2.6	
	1,023		-4,661		-3,916		-2,490
R-68		-4.8		-4.0		-2.2	
	1,131		-11,266		-10,406		-7,992
R-69		-15.1		-14.4		-11.9	
	1,036		-12,131		-10,953		-8,382
R-70		-8.3		-6.7		-4.3	
	1,108		-8,913		-8,909		-6,811
R-71		-7.8		-9.4		-8.0	
	1,017		-9,320		-9,439		-7,734
T-72		-10.6		-9.2		-7.2	
Project Limits	**Distance**	**ABOVE 2.5' NAVD**		**ABOVE 5.0' NAVD**		**ABOVE 7.5' NAVD**	
R-55 to R-72	**17,327.0**	**-4.5**	**-78,700**	**-5.1**	**-87,700**	**-4.2**	**-72,100**

*R-55 to R-60 volumes were calculated using May 2022 (pre-storm) and January 2023 (post-storm) survey data.

Figure 15. Sector 4 Dune Impacts.

- **Background Erosion**

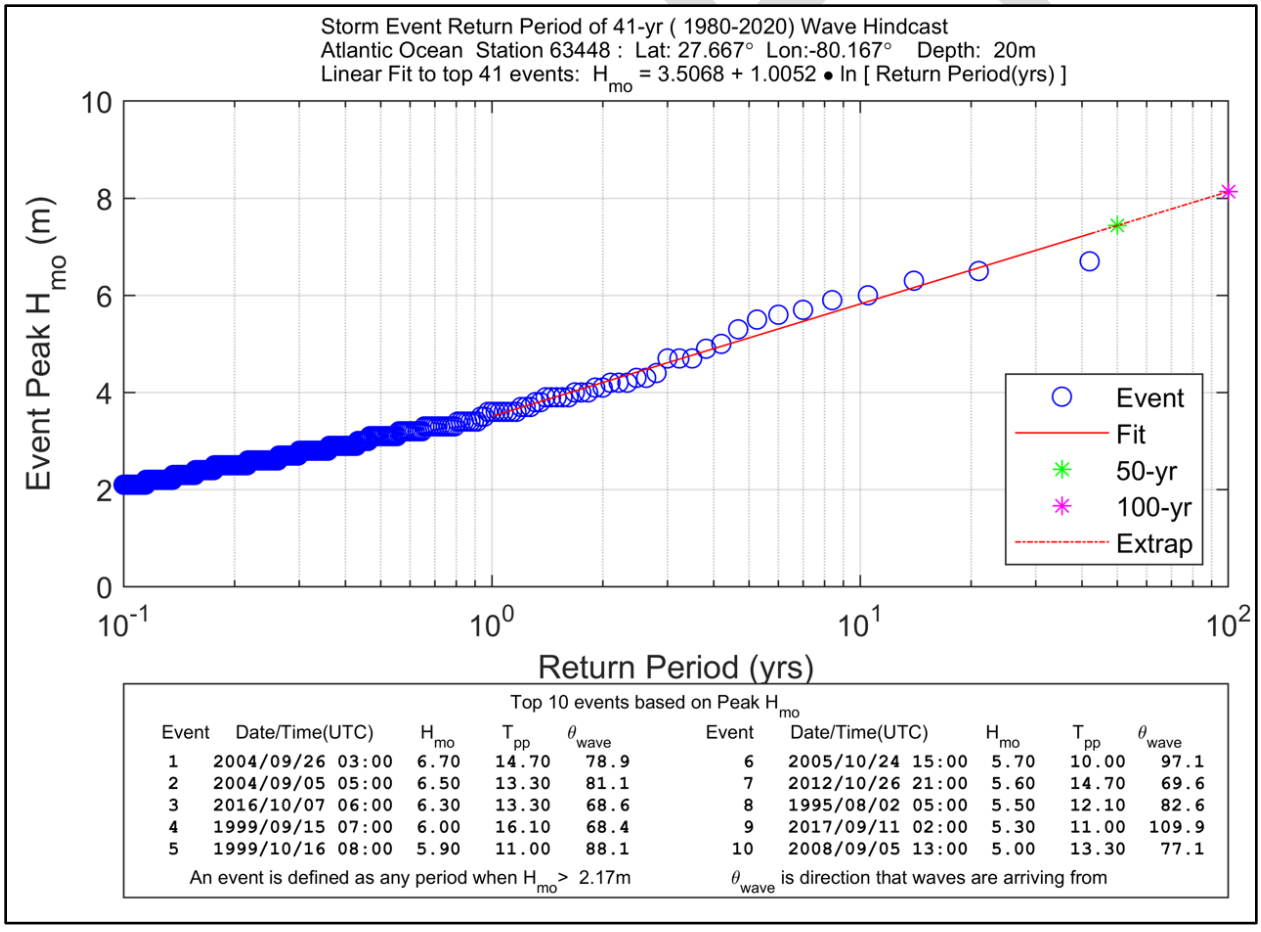
Background erosion was estimated to account for the beach volume changes other than losses due to Hurricanes Ian and Nicole that may have occurred during the time period between the pre- and post-storm surveys. Background erosion was analyzed in the study by calculating volume changes due to average wave conditions and storm events that occurred between July 2013 and summer 2022 (9 years) and then accounting for sand volumes placed during that period. Background erosion rate was calculated separately for R-55 to T-60, due to the difference in date of the summer 2022 survey. The background erosion for section of beach from R-55 to T-60 was calculated over a time period of 8.83 years from July 2013 to May 2022, and equaled 8,300 cy/yr. The background erosion for section of beach from T-60 to T-72 was calculated over a time period of 9.16 years from July 2013 to September 2022, and equaled 16,200 cy/yr. Utilizing the background erosion rates of 8,300 cy per year and 16,200 cy per year for the 4-month and 8-month periods, respectively, between the pre-storm survey (summer 2022) and the post-storm survey (January 2023), a background change of -10,900 cy was estimated for the project area.

7. RUN-UP CALCULATIONS

7.1 Hurricanes Ian and Nicole

The following assumptions and calculations were performed in order to determine if Sector 4 is at risk for damage to improved property from a 5-year flood or storm event. Post-Hurricane Nicole survey data was collected by Morgan & Eklund surveyors in January 2023. The profile surveys were collected along the published azimuth and extended from the dune offshore beyond the depth of closure (DOC).

Wave characteristics were taken from Wave Information Station (WIS) 63448 **(Figure 16)**. This station is located offshore directly east of Sector 5 and is the best representative of deepwater conditions necessary for calculations. An equation was determined for the best linear fit to the top 41 events from 1981 to 2020. This equation was used to determine the H_{mo} for a 5-year return period. A T_p value was determined by averaging the 7th through the 10th largest storm events from the same data set.



Top 10 events based on Peak H_{mo}

Event	Date/Time(UTC)	H_{mo}	T_{pp}	θ_{wave}	Event	Date/Time(UTC)	H_{mo}	T_{pp}	θ_{wave}
1	2004/09/26 03:00	6.70	14.70	78.9	6	2005/10/24 15:00	5.70	10.00	97.1
2	2004/09/05 05:00	6.50	13.30	81.1	7	2012/10/26 21:00	5.60	14.70	69.6
3	2016/10/07 06:00	6.30	13.30	68.6	8	1995/08/02 05:00	5.50	12.10	82.6
4	1999/09/15 07:00	6.00	16.10	68.4	9	2017/09/11 02:00	5.30	11.00	109.9
5	1999/10/16 08:00	5.90	11.00	88.1	10	2008/09/05 13:00	5.00	13.30	77.1

An event is defined as any period when H_{mo} > 2.17m

θ_{wave} is direction that waves are arriving from

Figure 16. WIS Station 73300 Data.

7.2 Calculations and Results

The 2% runup values were determined using the following equation (1) (Stockdon et al., 2006). The surf similarity parameter, ξ, was determined using equation (2). In all calculations the deepwater wave height, Ho, was determined from the zero moment wave height, H_{mo}, using equation (3). The deepwater wavelength, L_o, was calculated using equation (4) with the wave period, Tp, from the seventh event in WIS data, and β is the slope of the active beach profile from the -5 foot contour to the +8 foot contour (Appendix A).

$$R_{2\%} = 1.1\left[0.35 \tan\beta (H_O L_O)^{\frac{1}{2}} + \frac{[H_O L_O (0.563 \tan\beta^2 + 0.004)]^{\frac{1}{2}}}{2}\right] \quad (1)$$

$$\xi = \tan\beta \left(\frac{H_o}{L_o}\right)^{-\frac{1}{2}} \quad (2)$$

$$H_o = \frac{H_{mo}}{(2)^{1/2}} \quad (3)$$

$$L_o = \frac{gT^2}{2\pi} \quad (4)$$

The maximum storm-induced water-surface elevation was determined from using historic water levels near the coast of Indian River County collected by a tidal station located in the Trident Basin of the interior of Port Canaveral; Trident Pier, FL – Station ID: 8721604 (NOAA, 2022b). The station is located about 35 nautical miles north of the northern Indian River County boundary. It is noted that the tide gage is not located on the open Atlantic Ocean coast. Rather, the station is somewhat sheltered and does not experience the dynamic storm surge (including wave setup) that occurs on the open coast. The monthly high storm surge values were obtained from NOAA CO-OPS in feet above MHW at the gauge. A return period analysis was performed on the data and determined that a 5-year storm caused the water level to rise approximately 3.1 ft above MHW. MHW in Indian River County is 0.6 ft NAVD and the additional storm surge would cause the still water elevation to rise to approximately 3.7 ft NAVD.

The calculated runup value was then added to the 3.7-ft stillwater elevation to determine the total runup elevation for Sector 4 which is equal to 11.1 ft NAVD. The results of the calculations can be seen in **Figure 17**. The maximum dune elevation was determined for each profile from the Morgan & Eklund survey from January 2023. In Sector 4, the dune height at each R-monument is greater than the runup experienced with a 5-year storm. The Sector 4 profiles can be found in **Appendix A**. Although the maximum post-storm dune height minimally exceeds the total runup elevation, it is important to note the large loss of dune width within the project area and scarping of the dune due to wave action, which has already impacted an upland residence in the vicinity of

R-67. There is potential risk for damage to improved property if the total runup elevation is solely considered by FEMA for Category B funding within this area.

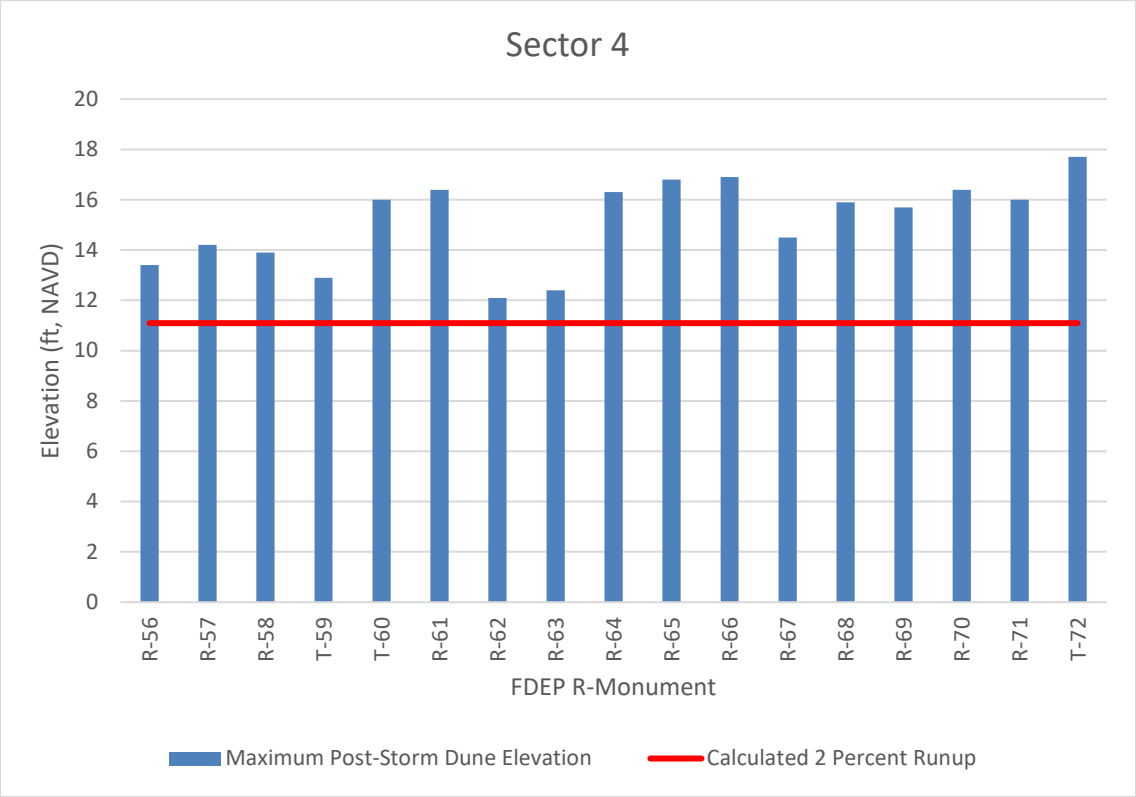


Figure 17. Sector 4 Max Dune Elevation and Total Runup Elevation.

8. DUNE VEGETATION

The dune vegetation along the Sector 4 shoreline is in need of rehabilitation due to impacts from Hurricanes Ian and Nicole. The dune system provides valuable protection to coastal infrastructure in addition to serving as habitat. Based upon an analysis of the pre- and post-storm landward vegetation extents, there was an average overall cross-shore loss of vegetation of 19 ft. Utilizing dune retreat at each profile within the project area and the average loss of vegetated dune area, approximately 329,213 dune plants are required to fully replant the dune system.

9. COST ESTIMATE

The cost estimate to replace sand lost above MHW (+0.6' NAVD) due to impacts from the 2022 hurricane season is based on obtaining material from upland sand mine(s) and transporting it to the project site via truck-haul method (**Table 7**). This was the method of construction utilized for the initial 2010-2012 project, the 2014/15 dune repair project, and the 2021/22 renourishment. The

itemized cost estimates are based on bids received for the 2021/22 project and the Emergency repair projects conducted by the County post-Ian and Nicole. Engineering, Design, Permitting, and Construction Administration costs are estimated at 10% of the construction cost, which is typically based on previous project experience. A 10% contingency is included to account for uncertainties such as inflation and fuel prices. The estimated cost to repair the dune damages from both storms could be up to $5,093,666.71 with 10% added for contingency. The costs presented within the table assume a November 1, 2023 commencement date.

Table 7. Estimated Construction Cost

ITEM	PROJECT ELEMENT	UNIT	QUANTITY	UNIT COST*	COST
1)	Mobilization & Demobilization	LS	1	$ 137,500.00	$ 137,500.00
2)	Supply/Deliver/Place Sand	CY	87,700	$ 41.42	$ 3,632,534.00
3)	Beach Tilling	LS	1	$ 14,280.00	$ 14,280.00
4)	Supply/Deliver/Plant Dune Vegetation	EA	329,213	$ 1.07	$ 352,257.91
5)	Site Restoration	LS	1	$ 13,070.00	$ 13,070.00
6)	Pre- and Post-Placement Surveys	LS	1	$ 60,000.00	$ 60,000.00
7)	Engineering, Design, Permitting, Construction Admin.			10% of Items 1-5	$ 420,964.19
	Subtotal Cost				**$ 4,630,606.10**
	Contingency			10%	$ 463,060.61
	Total Cost				**$ 5,093,666.71**

*Unit cost estimates are based on bidding costs associated with the IRC Sector 3 project conducted in 2021/22 and Emergency post-storm repairs

10. SUMMARY

During the storm inter-survey period, the Sector 4 beach project experienced an average dune retreat of -19.2 ft and volumetric loss within the dune system of 87,700 cy. Due to sand being deposited near the MHW from the upper beach, the measured MHW shoreline change was +9.9 ft and a total beach volumetric change of +800 cy above the depth of closure (average of 0.05 cy/ft). As detailed above, the associated MHW shoreline and beach volume gain is attributable to the large amount of volume lost from the upper beach (dune) and deposited at and below the waterline. It is unlikely that the dry beach will recover to pre-storm conditions based on the normal wave climate of the area. There is potential risk for damage to improved property if the total runup elevation is solely considered for FEMA Category B funding within this area. The estimated cost to fully repair the damages to the dunes from the 2022 hurricane season is $5,093,666.71, which includes 10% added for contingency.

11. REFERENCES

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APPENDIX A

Beach Profile Cross-Sections

APPENDIX B

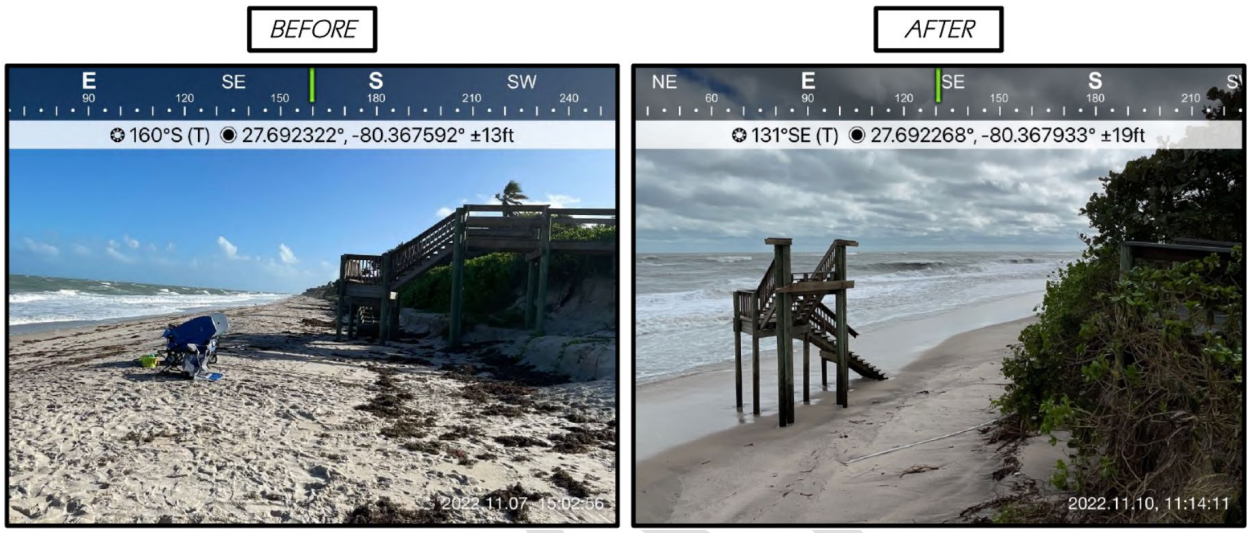
Pre- and Post-Storm Photographs

These photos are from Indian River County's Beach Observation Reports for Hurricanes Ian and Nicole (IRC, 2022)

Hurricane Ian Before and After

Beachcomber Lane Beach Access

Hurricane Nicole Before and After



Beachcomber Lane Beach Access