INDIAN RIVER COUNTY, FL
SECTOR 3 BEACH & DUNE RESTORATION PROJECT

STORM DAMAGE REPORT:
HURRICANES IAN & NICOLE

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EXECUTIVE SUMMARY

This report documents the changes in shoreline width and beach volume to the 6.6-mile Indian River County, FL, Sector 3 Beach and Dune Restoration Project 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 feet offshore of the County's coastline. The result of both storms to the Sector 3 project area was appreciable erosion to the beach berm and dunes. As a regularly maintained local- and State-funded engineered beach restoration project, the Indian River County, FL, Sector 3 Beach & Dune Restoration Project qualifies for post-disaster relief from the Federal Emergency Management Agency (FEMA) Public Assistance Program (Category G).

During the storm inter-survey period, the Sector 3 engineered beach project experienced an average shoreline retreat of -3.4 ft, an average dune retreat of -21.1 ft, and a beach volume loss of -154,300 cy above the depth of closure (average of -4.4 cy/ft). For the 8-month period between the pre-storm survey (May 2022) and post-storm survey (January 2023), a background sand loss of -61,500 cy was estimated for the project area. After removing the background loss from the measured loss, the Sector 3 engineered beach project is estimated to have lost -92,800 cy of sand directly attributed to the impacts of Hurricanes Ian and Nicole. 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 for both project areas 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 damages from the 2022 hurricane season ranges from $7,553,948.10 to $26,610,292.55 (with 10% added for contingency) depending on type of volume losses considered (total profile loss to the depth of closure versus losses from construction template).

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1. INTRODUCTION

This report documents the changes in beach volume to the 6.6-mile Indian River County, FL, Sector 3 Beach & Dune Restoration Project 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 and maintenance of the engineered beach project, Indian River County authorized the collection of post-storm beach profile surveys to document the storm damages. As a regularly maintained local- and State-funded engineered beach restoration project, the Indian River County, FL, Sector 3 Beach & Dune Restoration Project qualifies for post-disaster relief from the Federal Emergency Management Agency (FEMA) Public Assistance Program (Category G).

2. BACKGROUND

2.1 Project Location and History

The Sector 3 Beach and Dune Restoration Project is located on the east coast of Florida within Indian River County (**Figure 1**). The northern boundary of the project is located approximately 3.6 miles south of Sebastian Inlet. The initial project, spanning from R-20 to R-55, was completed in three phases between 2010 and 2012 – Phase 1 (2010), Phase 2 (2011), Phase 2b (2012) and resulted in the placement of approximately 560,600 cubic yards (CY) of upland sand. The project was authorized under the Florida Department of Environmental Protection (FDEP) Joint Coastal Permit No. 0285993-001-JC.

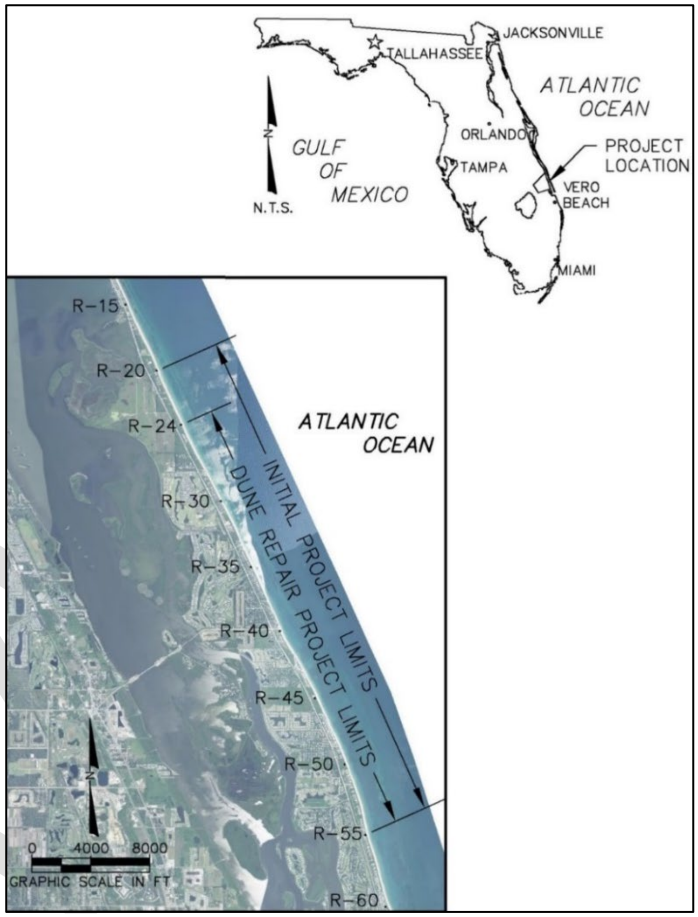


Figure 1. Sector 3 Project Location Map.

Following completion of the initial project, damages were sustained during Hurricane Sandy in October 2012. Subsequently, repairs to the dunes were authorized under FDEP Permit Modification No. 085993-008-JN. The dune repair project, spanning from R-24 to R-55, was constructed during the winter of 2014/15 and resulted in the placement of approximately 173,100 cy of upland sand.

The most recent Sector 3 Beach and Dune Renourishment Project was constructed in two phases between January 2021 and March 2022 under Florida Department of Environmental Protection (FDEP) Permit No. 0285993-009-JC. Phase 1 (2021) spanned from R-20 to R-40 and Phase 2 (2021 – 2022) spanned from R-40 to R-55. The total placement of material in the combined Phase 1 and Phase 2 project area was approximately 552,400 cy of upland sand. Additionally, dune vegetation was installed along the dune crest following sand placement. A total of 713,359 plants were installed, consisting of four plant types including sea oats (80%), dune panic grass (10%), with railroad vine, and beach elder making up the remainder (10%).

2.2 Project Design

In 1998, the County formulated a conceptual plan for maintenance of County beaches as identified in the *Indian River County Beach Preservation Plan* (BPP). In 2007, the County updated the BPP to address the 2004 and 2005 hurricane impacts and to refine the County's overall plan for the beaches (Coastal Tech, 2008a; subsequently updated by CB&I, 2015). As identified in the Sector 3 Project Design and Feasibility Report (APTIM, 2018), the County's goal was to mitigate ongoing and historical erosion of the beach. The Project was designed to partially restore the beach and dune to 1972 conditions to the extent feasible while incurring "no impact" to the nearshore hardbottom communities fronting the project area.

Figure 2 depicts the typical design construction template for the beach restoration project. The key elements of the 2021-2022 project design, as permitted, include sand placement for:

a) restoration of the beach berm from R-20 to R-51.3 from the toe of the restored dune extending seaward at a 1V:10H slope to match the existing grade,
b) restoration of the beach berm from R-51.3 to R-55 from the toe of the restored dune extending seaward at a 1V:10H slope with no material placed seaward of the MHW line,
c) restoration of the dune from R-20 to R-55 to include:
    - a dune crest elevation of +11.0 feet NAVD88 from R-20 to R-24 that tapered up to a +12.0 feet NAVD88 dune crest elevation from R-25 to R-27 that tapered up to a +15.0 feet NAVD88 dune crest elevation from R-28 to R-55 – with native dune vegetation planted on the restored dune crest,
    - a landward slope on the restored dune backslope at 1V:5H – where applicable, and
    - a seaward slope on the restored dune face at 1V:3H from the dune crest to the seaward toe of the restored dune.

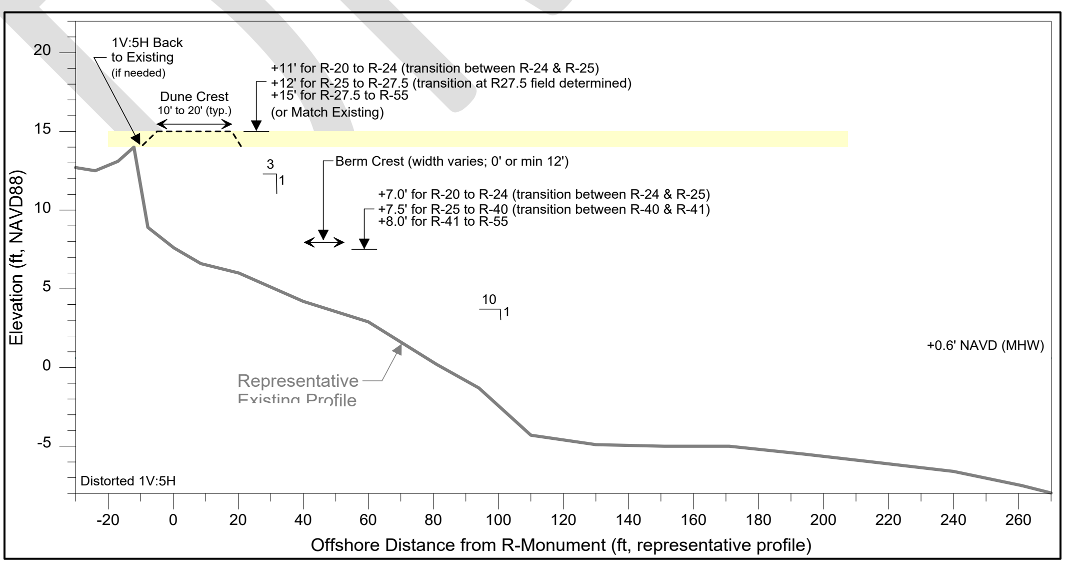


Figure 2. Typical Beach Fill Construction Template.

2.3 Post-Construction Monitoring Program

Physical monitoring for the project is required under the FDEP Permit No. No. 0285993-009-JC, Specific Condition 31. The Physical Monitoring Plan was approved by the FDEP in April 2020, prior to construction of the 2021-2022 project. The plan consists of numerous elements that track the physical performance of the beach restoration project, including analysis of beach profile surveys, aerial photography, and beach sand sampling. Bathymetric surveys of the borrow area are not required due to the project being constructed from an upland source. **Table 1** lists the schedule of events required for physical monitoring. One post-construction monitoring report was completed in July 2022. Post-storm beach profile surveys are not required in the scope of the annual physical monitoring program; however, post-storm profiles were collected by the County to document storm damages following Hurricane Ian and Hurricane Nicole in winter 2022/2023.

Table 1. Physical Monitoring Schedule

Task	Schedule of Events						
Project Construction	▭						
Beach Profile Surveys	▲	▲	▲	▲	▲		▲
Aerial Photography		⊕	⊕	⊕	⊕		⊕
Beach Sand Sampling		+					
Report		★	★	★	★		★
Construction Phase	Pre	Post	Year 1	Year 2	Year 3	Year 4	Year 5

This schedule continues biennially until the next beach nourishment event or the expiration of the project design life, whichever comes first.

2.4 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] Administered by the Federal Emergency Management Agency (FEMA) via its Public Assistance Program,

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

restoration of a damaged public facility is eligible for assistance (Category G for beaches[2]). Section 102(9) of the Stafford Act defines a *public facility*, and Title 44 of the Code of Federal Regulations (CFR), Section 206.201(c) further defines a *facility* as "an improved and maintained natural feature." 44 CFR. § 206.226(j) outlines eligibility criteria for *Beaches* as engineered infrastructure under the following conditions:

- The beach is not a federally constructed shoreline under the specific authority of USACE.
  - The Indian River County, FL, Sector 3 Beach & Dune Restoration Project is a non-Federal project.
- The beach was constructed by the placement of imported sand (of proper grain size) to a designed elevation, width, and slope.
  - The Indian River County, FL, Sector 3 Beach & Dune Renourishment Project has been constructed to design drawings and specifications using imported sand of proper grain size to established elevations, widths, and slopes. Additionally, all imported sand followed and remained in compliance with all permit approved Sediment QA/QC plans.
- The Applicant has established and adhered to a maintenance program involving periodic renourishment with imported sand to preserve the original design.
  - The maintenance program for this project was established in the County's Beach Preservation Plan (CB&I, 2015). The program was optimized to a 7-year renourishment interval with the placement of 301,000 cy of sand during each renourishment event. To track project performance and refine the renourishment interval and volume requirement, annual physical monitoring has taken place continuously since the initial project completion in 2012. To perform the requisite monitoring and maintenance of the beach fill project, Indian River County has been fully committed to utilizing existing taxing mechanisms, including a Tourist Development Tax (a.k.a. "Bed Tax") and potential Local Option Sales Tax, in combination with the cost-sharing contributions of the Florida Department of Environmental Protection Beach Management Funding Assistance Program. Concurrent with the prior commitment, the County has the capability and intent to continue to perform the requisite future monitoring and maintenance of the project. Implicit in the eligibility regulations is the requirement that the applicant regularly document the condition of the project area. To date, numerous reports have been prepared that:
    - Document the post-construction condition – Coastal Tech (2010, 2011, 2012), CB&I (2015), and APTIM (2022).
    - Document the monitoring and performance over the life of the project since construction – Coastal Tech (2011, 2012), CB&I (2013, 2014, 2015, 2016), APTIM (2017, 2018, 2019), and 2023 monitoring scheduled.

[2] To facilitate the processing of PA funding, FEMA separates Emergency Work into two categories and Permanent Work into five categories based on general types of facilities. Permanent work to restore engineered beaches falls under Category G – Parks, Recreation, Other.

In addition, the Public Assistance Program administered by FEMA 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.

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 3** 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 4** plots the track of Hurricane Ian.

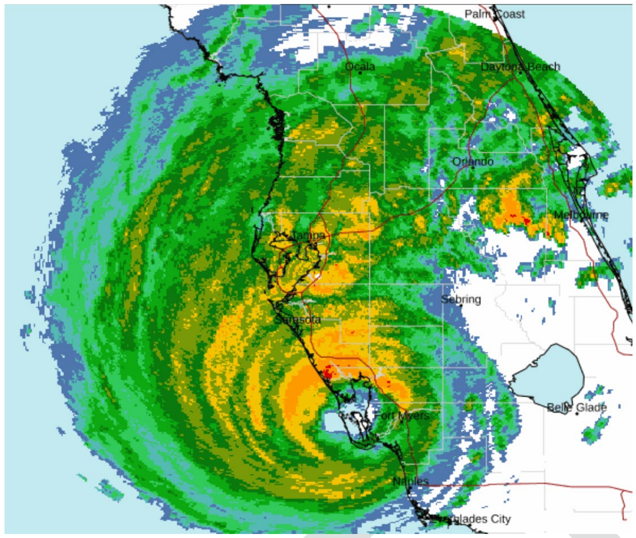


Figure 3. Radar Image of Hurricane Ian on September 28, 2022.
(Source: National Weather Service)

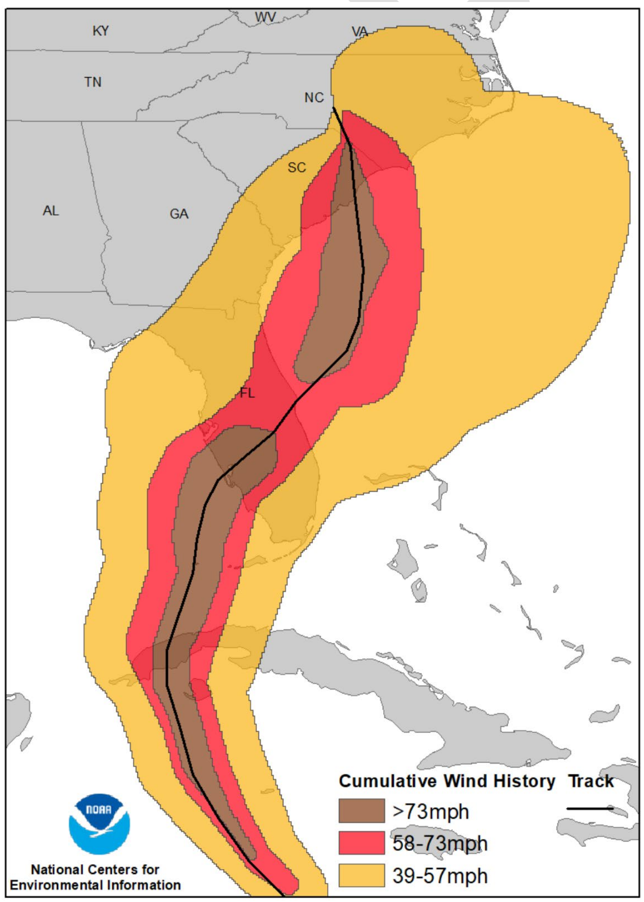


Figure 4. Hurricane Ian's Path and Cumulative Wind History.
(Source: National Oceanic and Atmospheric Administration)

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 3. Post-storm photographs of the Sector 3 shoreline are found in **Appendix B**.

Figure 5 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.

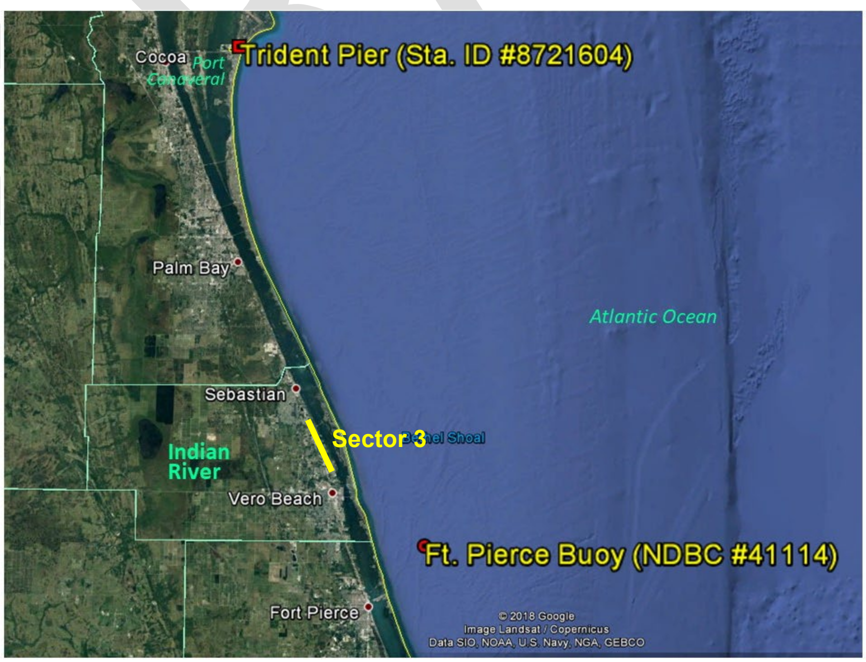


Figure 5. Oceanographic Data Collection Stations near Indian River County.

Figure 6 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.

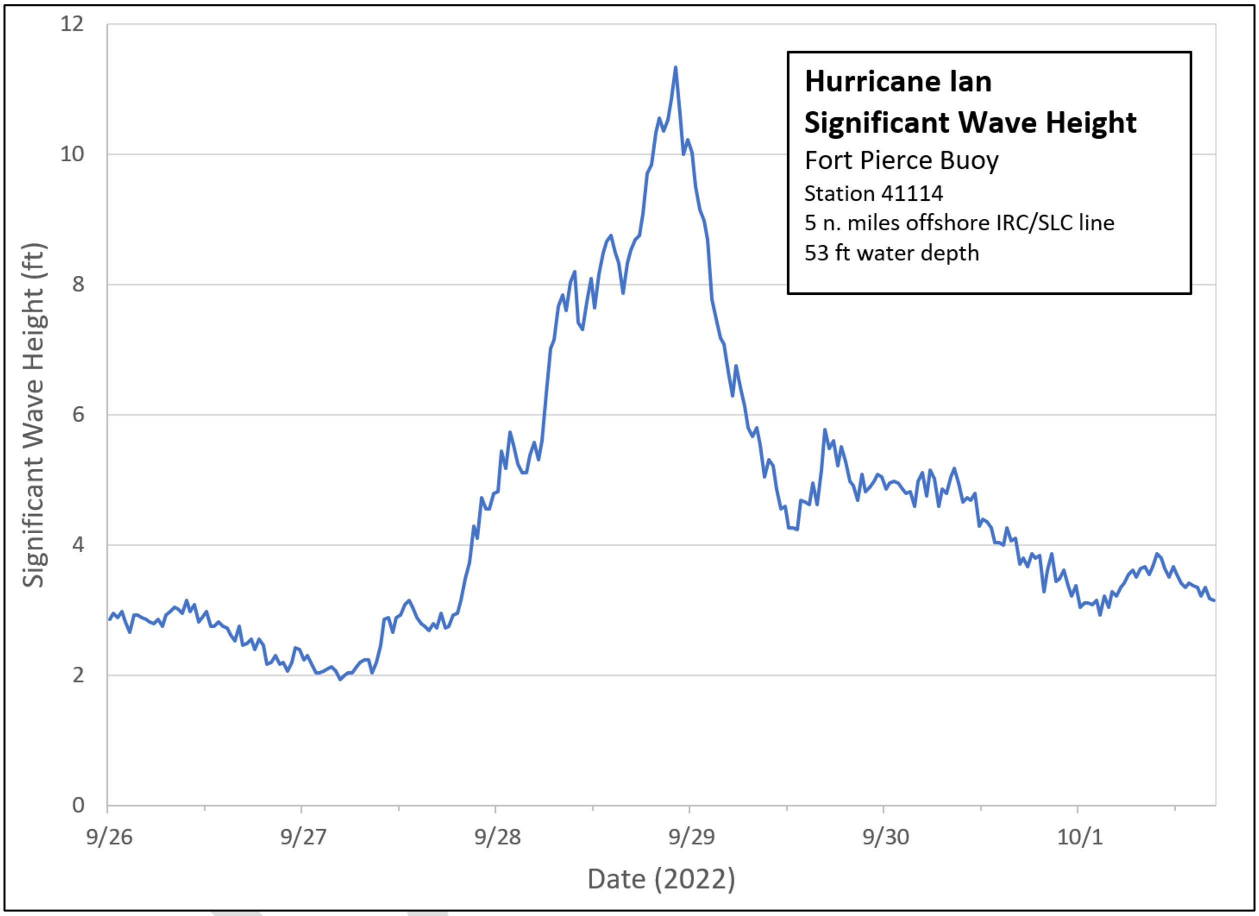


Figure 6. Significant Wave Heights Measured during Hurricane Ian.

Figure 7 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[3] resulted in a storm tide[4] of +3.9 ft NAVD at its peak. Based on pre- and post-storm profile

[3] *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.
[4] *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).

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.

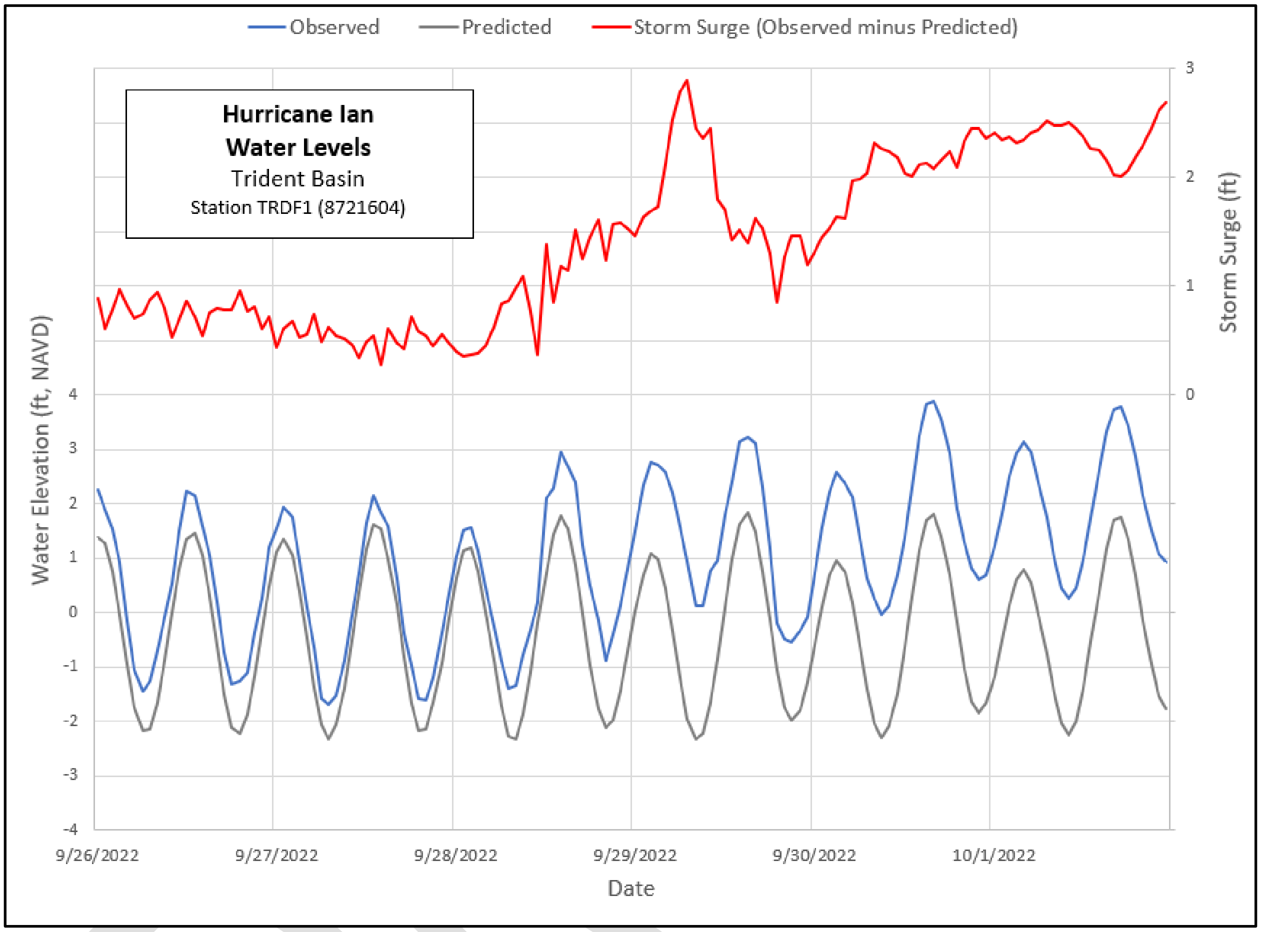


Figure 7. Water Levels Measured during Hurricane Ian.

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 8**.

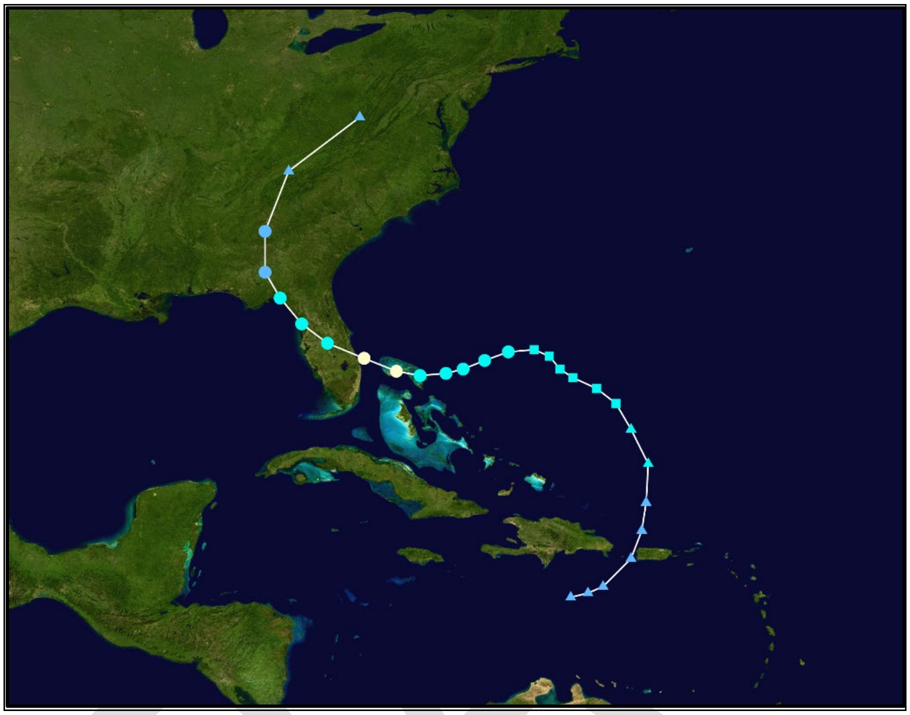


Figure 8. Path of Hurricane Nicole (NOAA 2022).

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 9 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 3. Post-storm photographs of the Sector 3 shoreline are found in **Appendix B**.

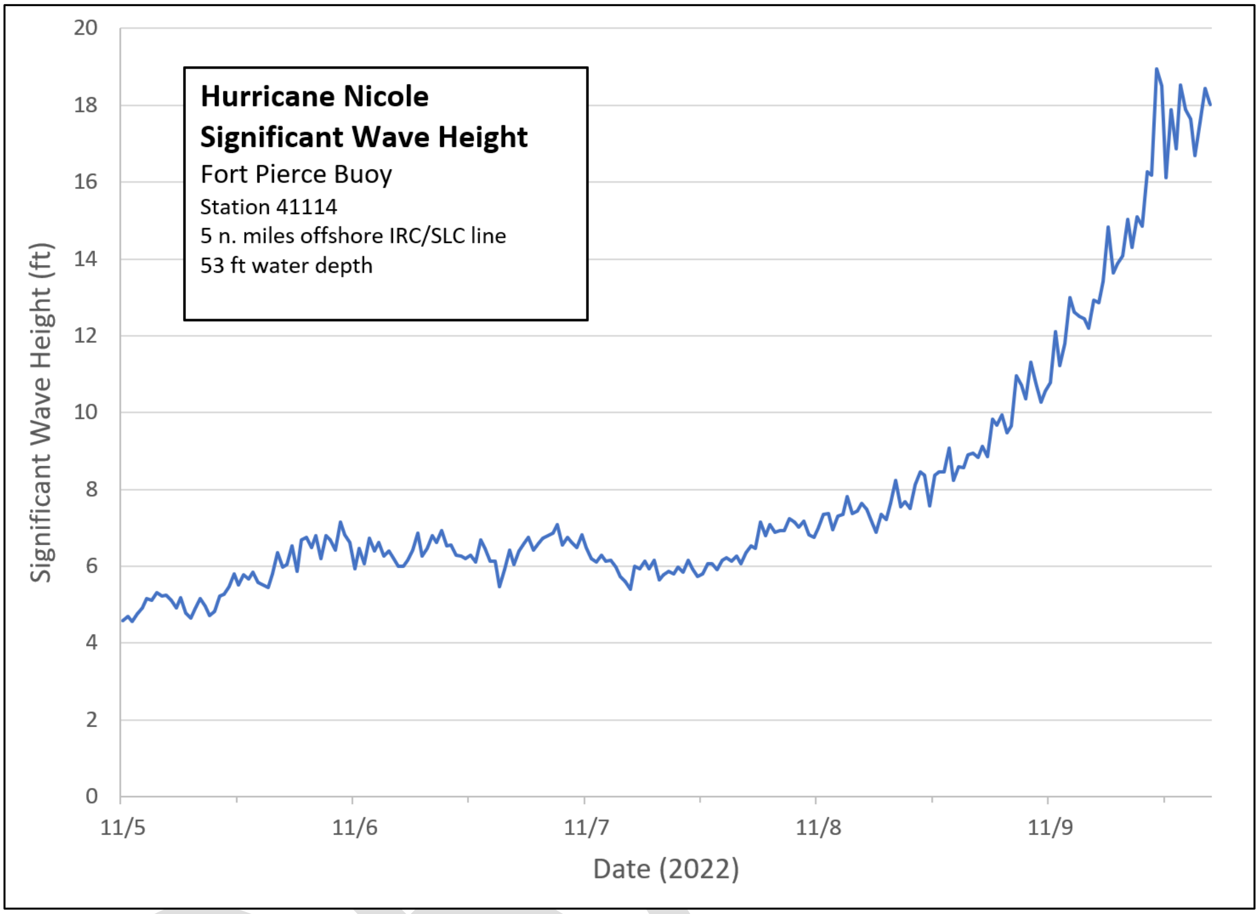


Figure 9. Significant Wave Heights Measured during Hurricane Nicole.

Figure 10 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.

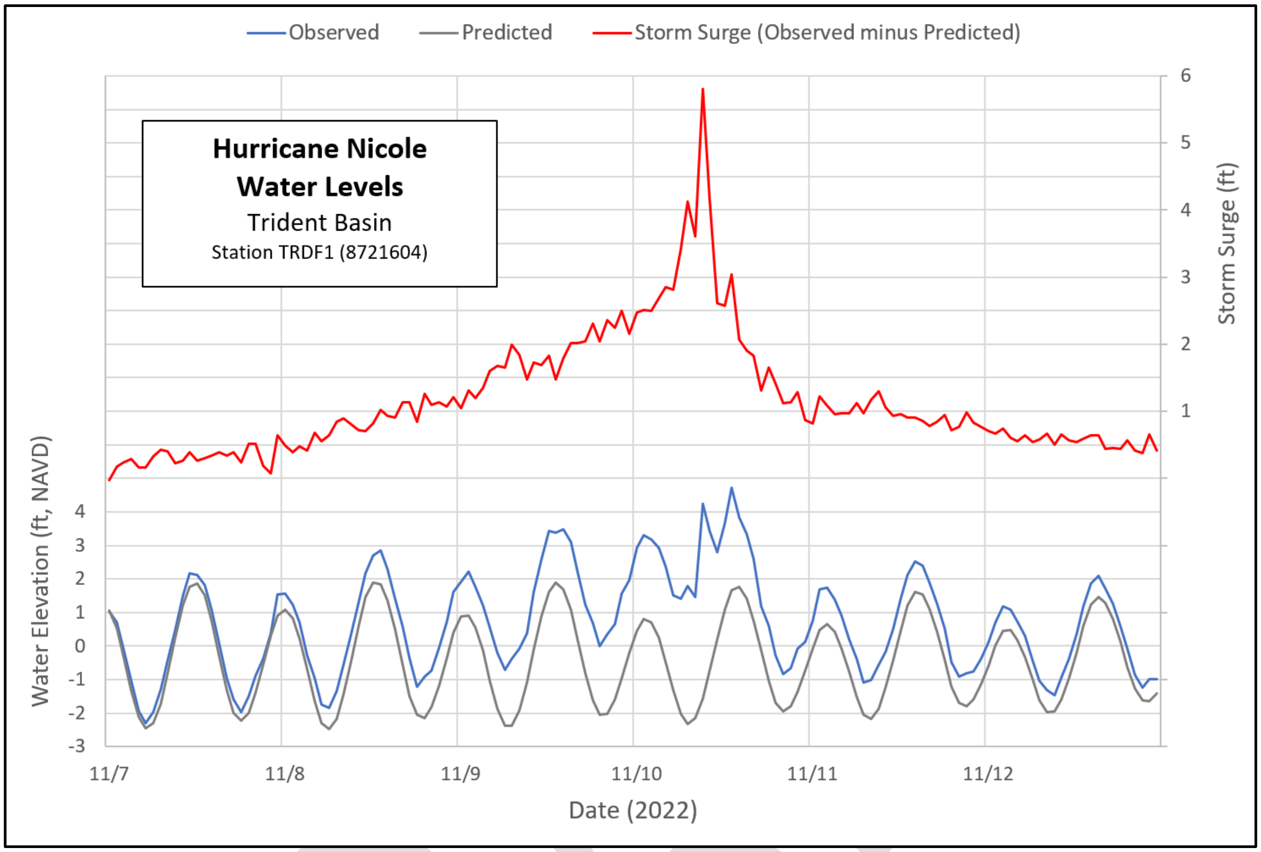


Figure 10. Water Levels Measured during Hurricane Nicole.

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 2** 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 between April 7 and May 7, 2022, by Morgan & Eklund, Inc. as part of the County's 2022 annual physical monitoring effort. The onshore survey was collected between April 7 and May 7, while the offshore survey was collected on May 6.

Post-Ian Survey:
The post-Ian survey was collected in the onshore/nearshore between October 24 and November 1, 2022, by Morgan & Eklund, Inc. The onshore/nearshore surveys are only complete from R-20 to R-37 due to the survey not being completed prior to the passing of Hurricane Nicole. No offshore data was collected, and this dataset only represents a portion of the dry beach within the Sector 3 Project Area.

Post-Nicole Survey:
The post-Nicole survey was collected between December 6, 2022, and January 9, 2023, by Morgan & Eklund, Inc. The onshore survey was collected on December 6 and 7, while the offshore survey was collected on January 5 and 9.

Table 2. Beach Profile Monument Control

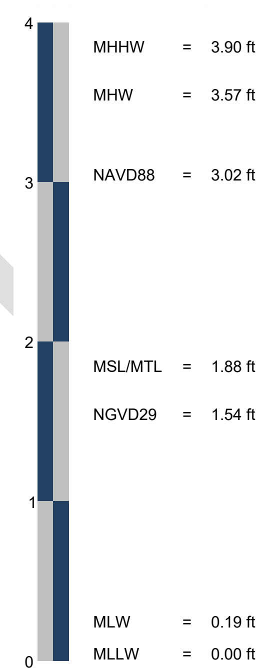
FDEP R-Monument	Easting (ft, NAD83)	Northing (ft, NAD83)	Azimuth (deg. CCW from true N)	Distance (ft, between monuments)
R-20	842,898.8	1,264,643.7	70	
				988.1
R-21	843,254.5	1,263,721.9	70	
				1,026.5
R-22	843,751.7	1,262,823.8	70	
				1,020.0
R-23	844,158.1	1,261,888.2	70	
				998.9
R-24	844,565.8	1,260,976.4	70	
				1,120.2
R-25	845,052.9	1,259,967.6	70	
				961.7
R-26	845,441.6	1,259,087.9	70	
				758.9
R-27	845,818.0	1,258,429.0	70	
				1,046.0
R-28	846,320.8	1,257,511.8	70	
				962.5
R-29	846,807.7	1,256,681.5	70	
				1,019.2
R-30	847,271.1	1,255,773.8	70	
				937.0
T-31	847,677.8	1,254,929.7	70	
				956.8
R-32	848,083.7	1,254,063.2	70	
				990.0
R-33	848,497.9	1,253,164.0	70	
				959.5
R-34	848,869.7	1,252,279.5	70	
				1,055.0
R-35	849,305.2	1,251,318.6	70	
				861.4
T-36	849,634.4	1,250,522.6	70	
				984.3
R-37	850,067.0	1,249,638.4	70	
				973.2
T-38	850,470.1	1,248,752.6	70	
				958.0
R-39	850,813.7	1,247,858.4	70	
				1,011.8
R-40	851,288.1	1,246,964.6	70	
				1,084.8
R-41	851,770.0	1,245,992.7	70	
				996.2
R-42	852,279.9	1,245,136.9	70	
				1,361.2
R-43	852,926.6	1,243,939.1	70	
				672.9
R-44	853,257.5	1,243,353.2	70	
				1,023.8
T-45	853,652.5	1,242,408.6	70	
				931.4
T-46	854,053.3	1,241,567.8	70	
				989.0
R-47	854,515.6	1,240,693.5	70	
				979.3
R-48	854,750.4	1,239,742.8	70	
				1,012.9
R-49	855,298.8	1,238,891.3	70	
				1,034.0
R-50	855,660.9	1,237,922.7	70	
				1,020.4
R-51	856,032.2	1,236,972.3	70	
				984.3
R-52	856,362.9	1,236,045.1	70	
				1,029.8
R-53	856,624.3	1,235,049.1	70	
				1,013.0
R-54	856,897.5	1,234,073.6	70	
				974.8
R-55	857,087.8	1,233,117.6	70	
		TOTAL (R-20 to R-55):		**34,696.8**

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 3**. To conform to previous studies within the County, a MHW elevation of +0.6 ft NAVD is defined in this report. This MHW elevation is consistent with the elevation of the MHW line surveyed in 2009 to establish the Erosion Control Line in Sector 3.

Table 3. 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 seaward face of the dune, and has been used to track the dune position in previous studies, including the County's Beach Preservation Plan (CB&I, 2015). The dune crest is slightly lower along the northernmost portion of the Sector 3 project area; as such, north of and including R-24, the +9-ft contour is identified to define the dune position.

The results of the contour change analysis are summarized in **Table 4** and **Figure 11**. The MHW shoreline experienced an average landward retreat of -3.4 ft between the pre- and post-storm surveys. The greatest retreat, averaging -16.9 ft, occurred along the northern portion of the project between R-20 and R-23. This area also experienced significant deflation of the beach berm, with profile lowering by as much as 3 to 4 ft. The dune position experienced an average landward retreat of -21.1 ft, with at least -30 ft of dune retreat experienced at six monuments throughout the Sector (R-20, R-23, R-40, R-48, R-52, and R-53). These dune impacts are not expected to recover naturally based upon environmental conditions and have diminished the storm protection provided by the dune to upland infrastructure.

Table 4. Contour Changes

FDEP R-Monment	Contour Change (feet) MHWL[1]	DUNE[2]
R-20	-33.7	-31.5
R-21	-4.0	-25.0
R-22	-5.5	-27.1
R-23	-24.3	-30.0
R-24	-15.2	-22.5
R-25	-6.9	-22.8
R-26	-12.1	-16.4
R-27	-5.9	-29.4
R-28	-2.9	-29.7
R-29	-11.0	-24.7
R-30	-5.3	-26.4
T-31	-8.9	-26.7
R-32	-2.7	-18.2
R-33	-3.2	-17.3
R-34	-4.7	-19.4
R-35	-1.5	-24.9
T-36	-0.9	-24.2
R-37	-1.9	-22.7
T-38	-10.5	-0.5
R-39	-4.5	0.6
R-40	-5.8	-33.8
R-41	13.8	-24.5
R-42	-1.9	-22.8
R-43	4.5	-26.4
R-44	18.7	-21.5
T-45	1.1	-15.7
T-46	11.7	-10.4
R-47	6.2	-26.1
R-48	3.9	-31.0
R-49	-3.0	3.6
R-50	2.5	6.8
R-51	-8.1	-22.9
R-52	-8.2	-30.7
R-53	-4.9	-34.8
R-54	8.0	-23.6
R-55	5.0	-8.2
Average:	**-3.4**	**-21.1**

[1]MHWL defined at +0.6 feet NAVD88.

[2]Dune defined at +10.0 ft NAVD88 south of R-24. Dune defined at +9.0 ft NAVD88 north and including R-24.

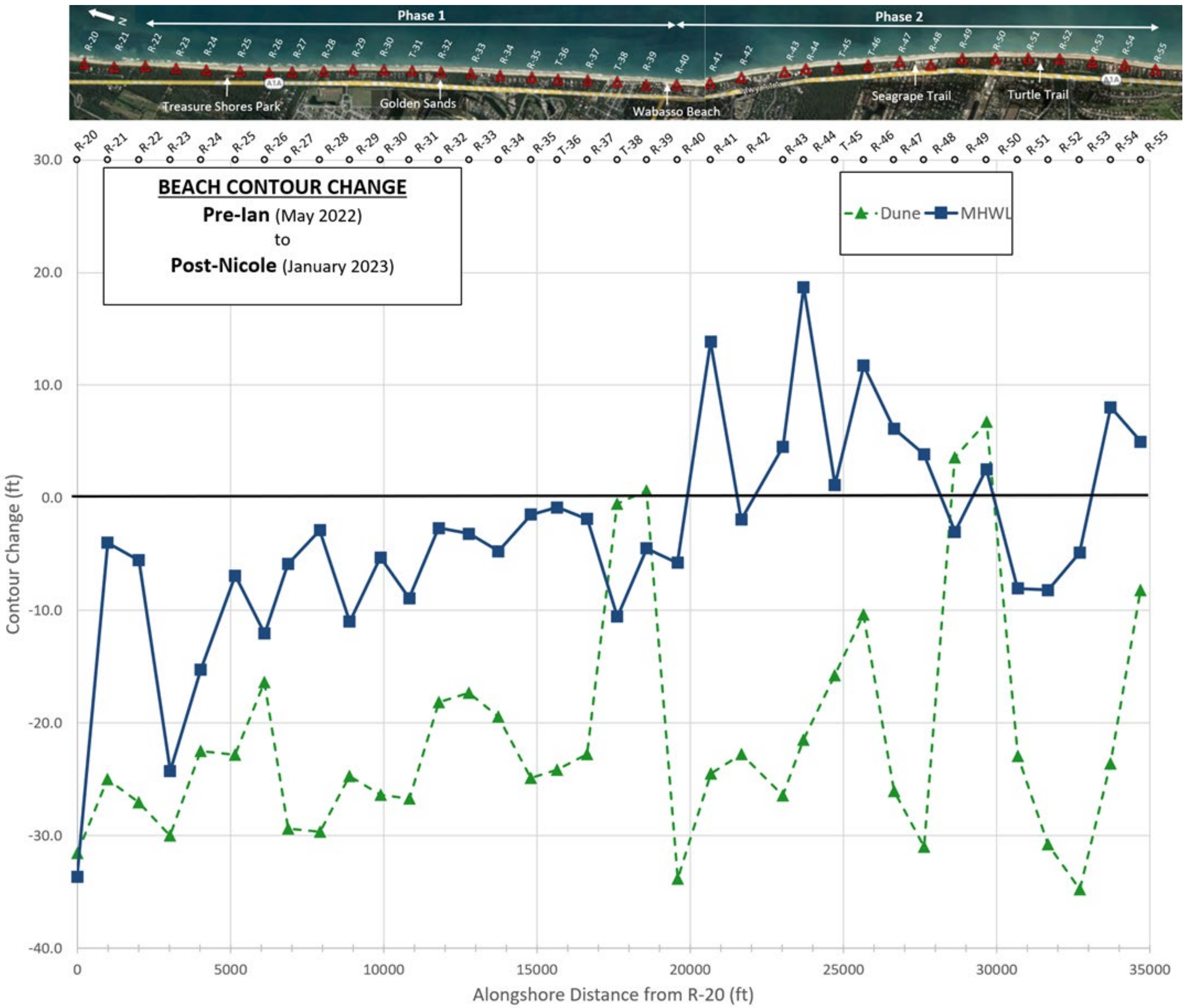


Figure 11. Shoreline and Dune Position Change.

6. BEACH VOLUME CHANGE

Pre- and post-storm beach profile surveys 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.

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

Due to the jagged nature of the nearshore hardbottom found just offshore of the project 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 is specified at each R-monument in both the distance offshore and elevation (**Table 5**). That is, volume changes are not included offshore of a specified distance and not deeper than a specified elevation. The same calculation limits used in previous Sector 3 reports were used in this report for consistency with previous monitoring efforts and storm assessments (described in CB&I, 2014; APTIM, 2018). For clarity of nomenclature within this report, the seaward limit of volumetric analysis is referred to as the *depth of closure* (or *DOC*).

Table 5. Seaward Limit of Volumetric Analysis (Depth of Closure)

FDEP R-Mon.	Dist. (ft)	Elev. (ft, NAVD)	FDEP R-Mon.	Dist. (ft)	Elev. (ft, NAVD)	FDEP R-Mon.	Dist. (ft)	Elev. (ft, NAVD)
R-20	554.7	-15.0	R-32	477.0	-15.0	R-44	551.4	-12.0
R-21	538.9	-15.0	R-33	428.8	-15.0	T-45	493.0	-12.0
R-22	483.3	-15.0	R-34	489.2	-15.0	T-46	635.5	-12.0
R-23	486.8	-15.0	R-35	463.0	-15.0	R-47	446.9	-12.0
R-24	489.0	-15.0	T-36	481.7	-15.0	R-48	690.3	-12.0
R-25	526.7	-15.0	R-37	550.0	-15.0	R-49	460.0	-12.0
R-26	524.5	-15.0	T-38	540.3	-15.0	R-50	459.6	-12.0
R-27	481.2	-15.0	R-39	611.1	-15.0	R-51	462.0	-12.0
R-28	475.5	-15.0	R-40	451.0	-15.0	R-52	476.6	-12.0
R-29	427.1	-15.0	R-41	320.1	-12.0	R-53	516.8	-12.0
R-30	417.7	-15.0	R-42	801.5	-12.0	R-54	368.0	-12.0
T-31	559.3	-15.0	R-43	701.7	-12.0	R-55	395.4	-12.0

- **Determination of Hurricane Ian vs. Hurricane Nicole Impacts**

As the offshore portions of the post-Ian survey in addition to profiles south of R-37 were not completed prior to the passage of Hurricane Nicole, erosion estimates were required to determine losses attributable to both storms. The intent of this evaluation is to establish a reasonable erosion contribution for each of the individual storms. The basis of the analysis follows these steps:

  - Identify volume losses above MHW for the pre-Ian (May 2022) and post-Nicole survey for profiles R-20 to R-37.
  - Identify volume losses above MHW for the pre-Ian (May 2022) and post-Ian survey for profiles R-20 to R-37.
  - Identify volume losses above MHW for the post-Ian and pre-Nicole survey for profiles R-20 to R-37.
  - Develop a prorated distribution for each storm based the ratio of volume losses measured from pre- to post-Ian and pre- to post-Nicole divided by total storm volume losses measured from pre-Ian to post-Nicole.

Using this basis for analysis, each of the individual storm contributions are:

  - Hurricane Ian: 22%
  - Hurricane Nicole: 78%

These prorated distributions were then applied to total beach profile losses to the depth of closure in order to determine Hurricane Ian and Hurricane Nicole losses for the full beach profile, which is required by FEMA. **Table 6** details volume calculation for each time period utilized to determine storm impact contributions.

Table 6. Volume Losses above MHW for Storm Impact Evaluation

FDEP Monument	Distance (ft)	Pre-Ian (May 2022) to Post-Nicole (January 2023) ABOVE MHW (+0.6 ft NAVD) Vol. Density (cy/ft)	Pre-Ian (May 2022) to Post-Nicole (January 2023) ABOVE MHW (+0.6 ft NAVD) Volume (cy)	Pre-Ian (May 2022) to Post-Ian (November 2022) ABOVE MHW (+0.6 ft NAVD) Vol. Density (cy/ft)	Pre-Ian (May 2022) to Post-Ian (November 2022) ABOVE MHW (+0.6 ft NAVD) Volume (cy)	Post-Ian (November 2022) to Post-Nicole (January 2023) ABOVE MHW (+0.6 ft NAVD) Vol. Density (cy/ft)	Post-Ian (November 2022) to Post-Nicole (January 2023) ABOVE MHW (+0.6 ft NAVD) Volume (cy)
R-20		-14.9		-0.6		-14.3	
	988		-11,616		60		-11,685
R-21		-8.6		0.7		-9.3	
	1,027		-9,449		2,975		-12,394
R-22		-9.8		5.1		-14.8	
	1,020		-10,829		773		-11,448
R-23		-11.4		-3.6		-7.6	
	999		-12,036		-3,489		-8,417
R-24		-12.7		-3.4		-9.2	
	1,120		-13,100		-4,286		-8,809
R-25		-10.7		-4.2		-6.5	
	962		-9,704		-3,729		-5,974
R-26		-9.5		-3.5		-5.9	
	759		-9,563		-2,585		-6,978
R-27		-15.7		-3.3		-12.4	
	1,046		-16,134		-2,356		-13,842
R-28		-15.1		-1.2		-14.0	
	963		-13,439		-2,262		-11,277
R-29		-12.8		-3.5		-9.4	
	1,019		-13,004		-3,897		-9,102
R-30		-12.7		-4.2		-8.4	
	937		-12,035		-4,648		-7,311
T-31		-13.0		-5.8		-7.2	
	957		-9,222		-3,466		-5,723
R-32		-6.3		-1.5		-4.8	
	990		-6,350		-350		-5,989
R-33		-6.5		0.8		-7.3	
	960		-7,034		-976		-6,044
R-34		-8.1		-2.8		-5.3	
	1,055		-9,580		-3,537		-6,035
R-35		-10.0		-3.9		-6.1	
	861		-8,387		-3,806		-4,575
T-36		-9.4		-4.9		-4.5	
	984		-7,485		-4,029		-3,446
R-37		-5.8		-3.2		-2.5	
Analysis Limits R-20 to R-55	**Distance 16,646**	**-10.8**	**-179,000**	**-2.4**	**-39,600**	**-8.4**	**-139,400**
					Total Storm Losses:	**-179,000**	
					Total Ian Loss:	**-39,600 (22%)**	
					Total Nicole Loss:	**-139,400 (78%)**	

Note: Analysis limits are different in extent than Project limits due to Post-Ian surveys not being completed south of R-37 prior to the passage of Hurricane Nicole.

- **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 7**. 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-aquas change, from MHW out to the offshore DOC
  - Black Dashed-Line: Total profile change, from the dune to the offshore DOC

Above MHW, the project lost -277,700 cy (average of -8.0 cy/ft) during the storm inter-survey period. Below MHW to the depth of closure, the project gained +123,400 cy (average of +3.6 cy/ft). Measured along the entire profile, from the dunes to the depth of closure, the engineered beach project lost a total of -154,300 cy (average of -4.4 cy/ft). This loss represents approximately 28% of the volume placed during initial construction of the County's Sector 3 renourishment. **Figure 13** illustrates the cross-shore transfer of sand that occurred pre-Ian and post-Nicole. From this plot, it can be observed that a large portion of the sand in the upper beach profile was transferred to the sub-aquas portion.

- **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 2015 and July 2020 (5 years) and then accounting for sand volumes placed during that period. An average background erosion rate of -91,800 cy per year was calculated for the project area, which equates to -7,600 cy per month. The resulting rate compares reasonably well with other sources investigated, such as other monitoring intervals and previous design reports (i.e. CB&I, 2015; APTIM, 2018). Utilizing the background erosion rate of -7,600 cy per month for the 8-month period between the pre-storm survey (May 2022) and the post-storm survey (January 2023), a background change of -61,500 cy was estimated for the project area.

- **Beach Volume Change Attributed to Hurricanes Ian and Nicole**

After removing the background change (-61,500 cy) from the measured change (-154,300 cy), there is a difference of -92,800 cy. As such, it is estimated that the Sector 3 engineered beach fill project lost -92,800 cy of sand above the depth of closure directly attributed to the impacts of Hurricanes Ian and Nicole. Using the prorated distribution percentages described above, it is estimated that Hurricane Ian contributed to a volume loss of approximately -20,416 cy, and Hurricane Nicole contributed to a loss of -72,384 cy.

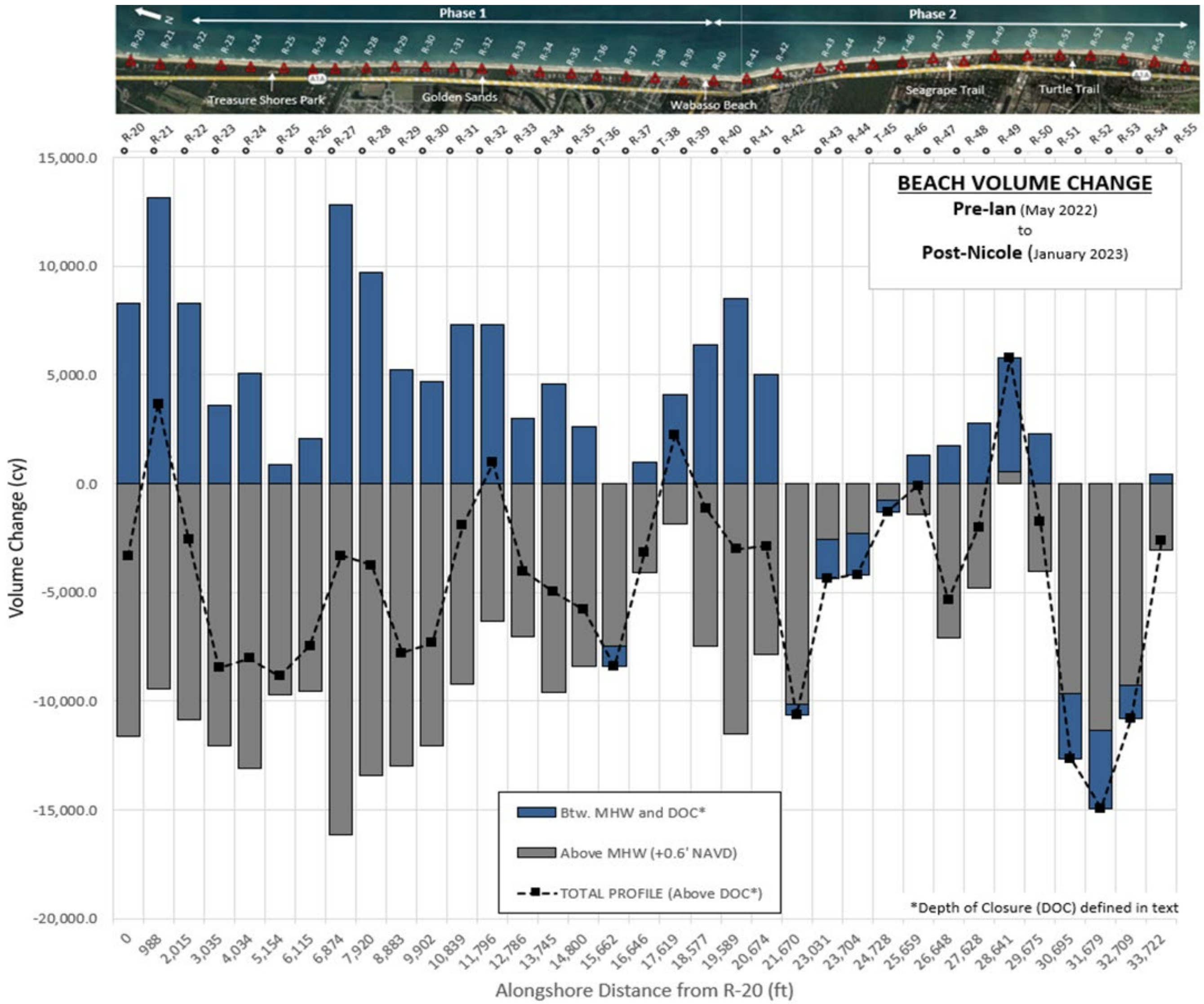


Figure 12. Beach Volume Change.

Table 7. Beach Volume Change

		Pre-Ian (May 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-20		-14.9		4.5		-10.4	
	988		-11,616		8,271		-3,345
R-21		-8.6		12.2		3.6	
	1,027		-9,449		13,120		3,671
R-22		-9.8		13.3		3.5	
	1,020		-10,829		8,282		-2,546
R-23		-11.4		2.9		-8.5	
	999		-12,036		3,576		-8,460
R-24		-12.7		4.3		-8.4	
	1,120		-13,100		5,080		-8,021
R-25		-10.7		4.8		-5.9	
	962		-9,704		847		-8,857
R-26		-9.5		-3.0		-12.5	
	759		-9,563		2,090		-7,472
R-27		-15.7		8.6		-7.2	
	1,046		-16,134		12,829		-3,305
R-28		-15.1		16.0		0.9	
	963		-13,439		9,686		-3,753
R-29		-12.8		4.1		-8.7	
	1,019		-13,004		5,228		-7,775
R-30		-12.7		6.1		-6.6	
	937		-12,035		4,710		-7,325
T-31		-13.0		3.9		-9.0	
	957		-9,222		7,284		-1,938
R-32		-6.3		11.3		5.0	
	990		-6,350		7,302		952
R-33		-6.5		3.5		-3.1	
	960		-7,034		3,015		-4,019
R-34		-8.1		2.8		-5.3	
	1,055		-9,580		4,592		-4,988
R-35		-10.0		5.9		-4.2	
	861		-8,387		2,597		-5,790
T-36		-9.4		0.1		-9.3	
	984		-7,485		-937		-8,421
R-37		-5.8		-2.0		-7.8	
	973		-4,105		958		-3,148
T-38		-2.7		4.0		1.4	
	958		-1,836		4,071		2,234
R-39		-1.2		4.5		3.3	
	1,012		-7,496		6,353		-1,143
R-40		-13.6		8.1		-5.6	
	1,085		-11,534		8,521		-3,013
R-41		-7.6		7.6		0.0	
	996		-7,876		4,992		-2,884
R-42		-8.2		2.4		-5.8	
	1,361		-10,150		-502		-10,652
R-43		-6.7		-3.1		-9.8	
	673		-2,545		-1,835		-4,380
R-44		-0.8		-2.3		-3.2	
	1,024		-2,278		-1,913		-4,191
T-45		-3.6		-1.4		-5.0	
	931		-766		-531		-1,297
T-46		2.0		0.3		2.2	
	989		-1,422		1,313		-108
R-47		-4.8		2.4		-2.4	
	979		-7,110		1,741		-5,369
R-48		-9.7		1.2		-8.5	
	1,013		-4,807		2,797		-2,011
R-49		0.2		4.4		4.5	
	1,034		544		5,221		5,766
R-50		0.9		5.7		6.6	
	1,020		-4,056		2,302		-1,754
R-51		-8.8		-1.2		-10.0	
	984		-9,670		-2,959		-12,629
R-52		-10.8		-4.8		-15.6	
	1,030		-11,353		-3,574		-14,927
R-53		-11.2		-2.2		-13.4	
	1,013		-9,247		-1,552		-10,800
R-54		-7.0		-0.9		-8.0	
	975		-3,042		430		-2,612
R-55		0.8		1.8		2.6	
Project Limits	**Distance**	**ABOVE MHW**		**BTW. MHW & DOC***		**ABOVE DOC***	
R-20 to R-55	**34,697**	**-8.0**	**-277,700**	**3.6**	**123,400**	**-4.4**	**-154,300**
						Estimated Background Change:	**-61,500**
						Change Attributed to Storms:	**-92,800**

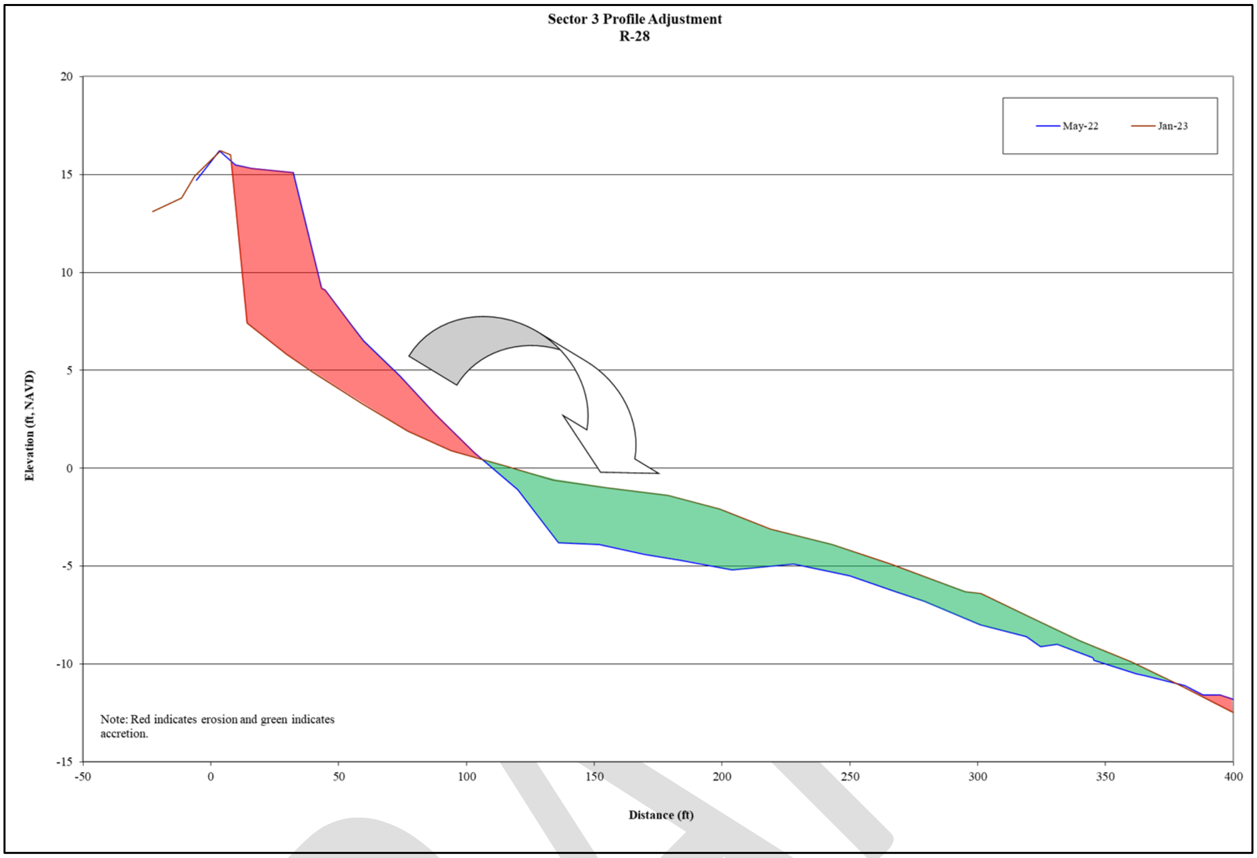


Figure 13. Post-Storm Profile Adjustment.

- **Volume Lost under Design/Construction Template**

Although FEMA only considers losses within the active beach profile from the landward limit of the dune to the depth of closure, it is important to note the impacts to the design/construction template due to the passage of Hurricanes Ian and Nicole. When comparing the post-Nicole profile to the permitted design and construction template, the Sector 3 project area lost 399,500 cy from the design profile, which equates to 72% of the volume placed during the most recent project. These impacts have greatly reduced the storm protection benefit provided by the design profile to neighboring upland infrastructure. **Table 8** summarizes losses observed at each R-monument along the Sector 3 shoreline. Overall, R-30 lost much of its design template and experienced the greatest erosion out of the Sector 3 project area. **Figure 14** depicts the loss of protective dune and beach width following the passage of both storms. As can be seen in the plot, much of the newly constructed dune is no longer present with the post-storm profile.

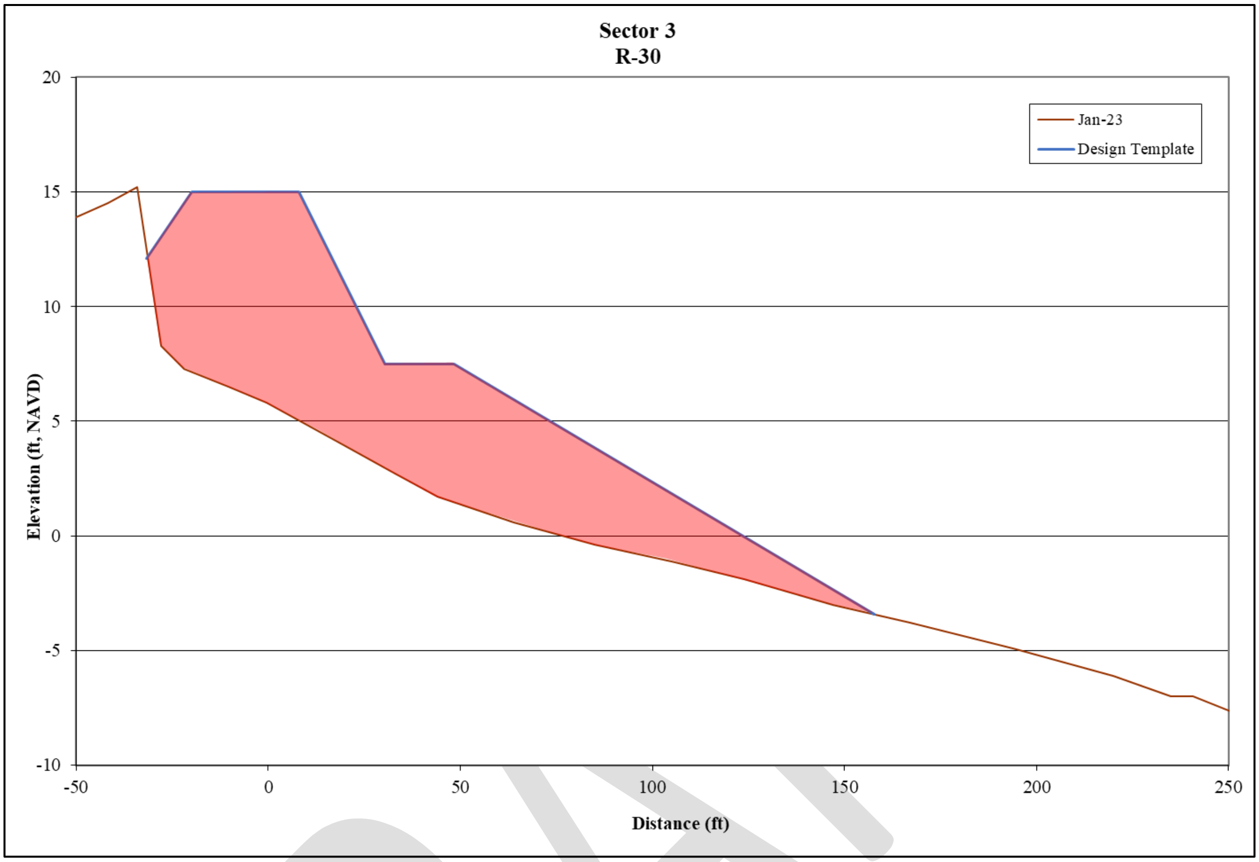


Figure 14. Volume Lost under Design Template.

Table 8. Volume Lost Under Construction Template

FDEP Monument	Distance (ft)	Post-Nicole (January 2023) to 2021/22 Construction Template Vol. Density (cy/ft)	Volume (cy)
R-20		14.8	
	988		11,095
R-21		7.7	
	1,027		11,562
R-22		14.8	
	1,020		13,635
R-23		11.9	
	999		11,178
R-24		10.5	
	1,120		14,106
R-25		14.7	
	962		13,126
R-26		12.6	
	759		13,266
R-27		22.4	
	1,046		26,172
R-28		27.7	
	963		22,018
R-29		18.1	
	1,019		26,346
R-30		33.6	
	937		22,847
T-31		15.1	
	957		11,969
R-32		9.9	
	990		9,668
R-33		9.7	
	960		10,894
R-34		13.1	
	1,055		14,840
R-35		15.1	
	861		13,247
T-36		15.7	
	984		12,418
R-37		9.6	
	973		12,240
T-38		15.6	
	958		12,909
R-39		11.4	
	1,012		14,345
R-40		17.0	
	1,085		13,171
R-41		7.3	
	996		6,434
R-42		5.6	
	1,361		7,875
R-43		5.9	
	673		3,094
R-44		3.3	
	1,024		3,373
T-45		3.3	
	931		2,634
T-46		2.3	
	989		5,439
R-47		8.7	
	979		10,285
R-48		12.3	
	1,013		13,612
R-49		14.5	
	1,034		13,838
R-50		12.2	
	1,020		6,247
R-51		0.0	
	984		28
R-52		0.0	
	1,030		4,650
R-53		9.0	
	1,013		7,241
R-54		5.3	
	975		3,656
R-55		2.2	
Project Limits	**Distance**		
R-20 to R-55	**34,697**	**11.5**	**399,500**

7. DUNE VEGETATION

Indian River County has proactively managed the Sector 3 dune system since the first major restoration project. For each subsequent dune restoration event, including the Sector 3 Phase 1 and 2 Projects constructed in 2021/22, dune vegetation was installed along the newly created habitat **(Figure 15)**.

Figure 15. Newly planted sea oats as part of the Sector 3 Beach and Dune Restoration Project.

The dune vegetation along the Sector 3 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 21 ft. Utilizing dune retreat at each profile within the project area and the average loss of vegetated dune area, approximately 728,633 dune plants are required to fully replant the dune system.

8. COST ESTIMATE

The cost estimate to replace sand lost 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 9**). 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. Engineering, Design, Permitting, and Construction Administration costs are estimated at 10% of the construction cost, which is typical 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 damages from both storms is $7,553,948.10 with 10% added for contingency. The costs associated with Hurricane Ian and Nicole are $1,661,869 and $5,892,080, respectively.

Table 9. Estimated Construction Cost to Replace Volume Change to DOC

ITEM	PROJECT ELEMENT	UNIT	QUANTITY	UNIT COST*	COST
1)	Mobilization & Demobilization	LS	1	$ 275,000.00	$ 275,000.00
2)	Supply/Deliver/Place Sand	CY	92,800	$ 51.35	$ 4,765,280.00
3)	Beach Tilling	LS	1	$ 28,560.00	$ 28,560.00
4)	Environmental Compliance	LS	1	$ 128,315.00	$ 128,315.00
5)	Supply/Deliver/Plant Dune Vegetation	EA	728,633	$ 1.07	$ 779,637.31
6)	Site Restoration	LS	1	$ 26,140.00	$ 26,140.00
7)	Pre- and Post-Placement Surveys	LS	1	$ 240,000.00	$ 240,000.00
8)	Engineering, Design, Permitting, Construction Admin.			10% of Items 1-5	$ 624,293.23
	Subtotal Cost				**$ 6,867,225.54**
	Contingency			10%	$ 686,722.55
	Total Cost				**$ 7,553,948.10**

*Unit cost estimates are based on bidding costs associated with the IRC Sector 3 project conducted in 2021/22

Additionally, construction costs to replace the volume lost under the design template are presented herein as the losses experienced within the dunes and upper contours of the dry beach are not expected to recover naturally **(Table 10)**. As such, the estimated cost to repair the damages to the construction template from both storms is $26,610,292.55 with 10% added for contingency. This methodology will return the project area to its intended storm protection.

Table 10. Estimated Construction Cost to Replace Template Losses

ITEM	PROJECT ELEMENT	UNIT	QUANTITY	UNIT COST*	COST
1)	Mobilization & Demobilization	LS	1	$ 275,000.00	$ 275,000.00
2)	Supply/Deliver/Place Sand	CY	399,500	$ 51.35	$ 20,514,325.00
3)	Beach Tilling	LS	1	$ 28,560.00	$ 28,560.00
4)	Environmental Compliance	LS	1	$ 128,315.00	$ 128,315.00
5)	Supply/Deliver/Plant Dune Vegetation	EA	728,633	$ 1.07	$ 779,637.31
6)	Site Restoration	LS	1	$ 26,140.00	$ 26,140.00
7)	Pre- and Post-Placement Surveys	LS	1	$ 240,000.00	$ 240,000.00
8)	Engineering, Design, Permitting, Construction Admin.			10% of Items 1-5	$ 2,199,197.73
	Subtotal Cost				**$ 24,191,175.04**
	Contingency			10%	$ 2,419,117.50
	Total Cost				**$ 26,610,292.55**

*Unit cost estimates are based on bidding costs associated with the IRC Sector 3 project conducted in 2021/22

9. SUMMARY

During the storm inter-survey period, the Sector 3 engineered beach project experienced an average shoreline retreat of -3.4 ft, an average dune retreat of -21.1 ft, and a beach volume loss of -154,300 cy above the depth of closure (average of -4.4 cy/ft). For the 8-month period between the pre-Ian survey (May 2022) and post-Nicole survey (January 2023), a background sand loss of -61,500 cy was estimated for the project area. After removing the background loss from the measured loss, the Sector 3 engineered beach project is estimated to have lost -92,800 cy of sand directly attributed to the impacts of Hurricanes Ian and Nicole. It is estimated that Hurricane Ian contributed to a volume loss of approximately -20,416 cy, and Hurricane Nicole contributed to a loss of -72,384 cy. The estimated cost to repair the damages from the 2022 hurricane season ranges from $7,553,948.10 to $26,610,292.55 (with 10% added for contingency) depending on type of volume losses considered (total profile loss versus losses from construction template). It is important to note that although FEMA's method of determining losses is minimal, the dune portion of the beach suffered severe damage following the 2022 hurricane season, which reduces the storm protection benefit of the engineered beach system. Due to the normal wave climate within the project area, it is unlikely that the dry beach will recover to pre-storm conditions.

10. 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

Wabasso Beach Park Looking North

Wabasso Beach Park Looking West

Wabasso Beach Park Looking South

Hurricane Nicole Before and After

BEFORE

AFTER

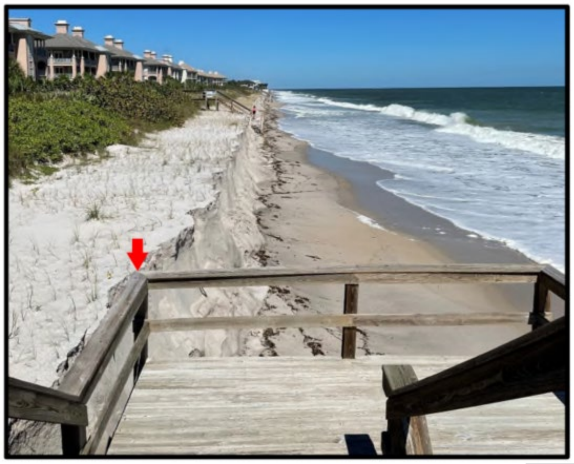
Treasure Shores Beach Park Looking South

BEFORE

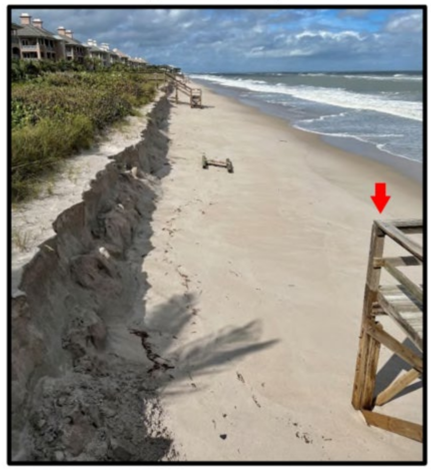
AFTER

Golden Sands Beach Park Looking West

BEFORE 10-5-22

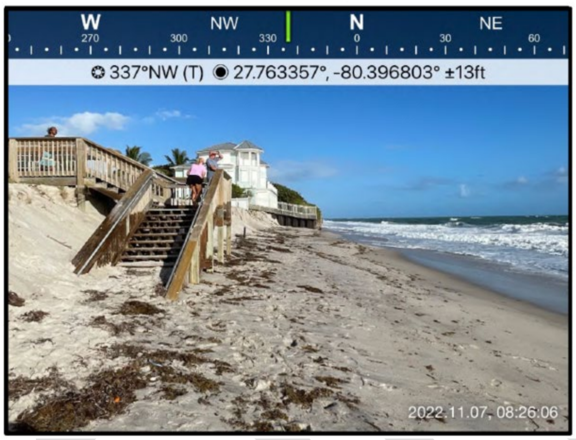


AFTER



Town of Orchid Looking North

BEFORE



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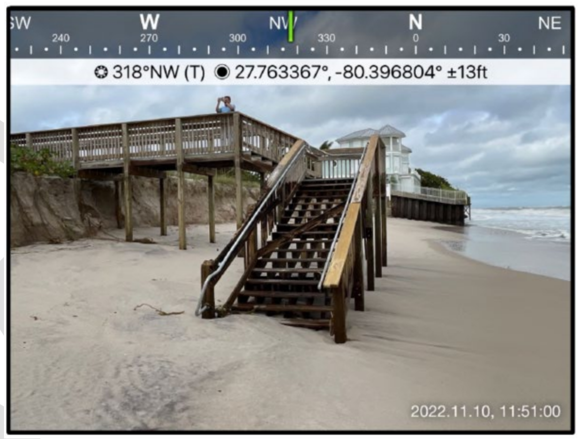
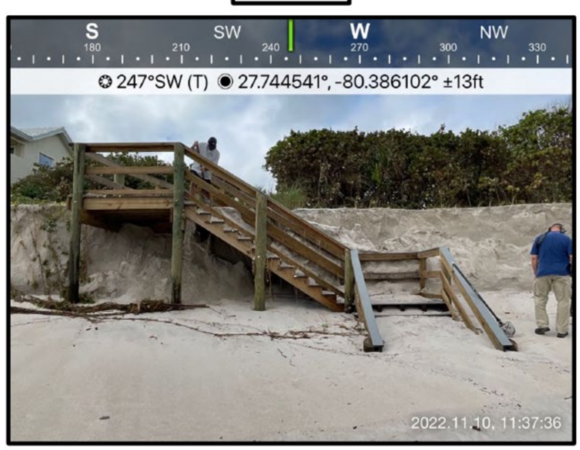


Wabasso Beach Park Looking North

BEFORE

AFTER



Seagrape Trail Beach Access Looking West

BEFORE

AFTER

Turtle Trail Beach Access Looking South