# WEST BELLE PASS HEADLAND GEOMORPHIC AND SEDIMENT TRACER ANALYSIS

*Task Order 97*

**Prepared for and funded by:**

**Louisiana Coastal Protection and Restoration Authority and**

**the National Fish and Wildlife Foundation**

**Prepared by:**

**The Water Institute, University of New Orleans Pontchartrain Institute for Environmental Sciences, and Environmental Tracing**

*February 2026*

## ABOUT THE WATER INSTITUTE



## CONTRIBUTING AUTHORS

**The Water Institute**: Andrew Courtois served as the Institute's project manager, coordinated project activities, and led the writing of this report, and Michael Miner was the Institute's Principal Investigator and contributed to the writing of this report.

**University of New Orleans**: Mark Kulp provided review of this report.

**Environmental Tracing**: Jonathan Marsh provided review and was the primary contributor on sections pertaining to tracer characteristics and analysis methodology.

## ACKNOWLEDGEMENTS

The project scope was shaped by Mike Miner, Ioannis Georgiou, and Andrew Courtois (Amendment I-Topobathy Analysis), along with Mark Kulp and Jon Marsh. Fieldwork efforts were supported by Mike Miner, Emily Miller, Andrew Courtois, Joseph Hankerson, Wilke Coleman, and Martijn Bregman from The Water Institute; Glen Curole and additional staff from CPRA; and Mike Brown, Mark Kulp, and numerous undergraduate and graduate students from the University of New Orleans. Their collective expertise and effort made this work possible.

This report was reviewed by Jordan Fischbach of the Institute and Glen Curole of CPRA. It was edited and formatted by Charley Cameron of the Institute.

## SUGGESTED CITATION

The Water Institute, The University of New Orleans Pontchartrain Institute for Environmental Science, and Environmental Tracing (2026). West Belle Pass Headland geomorphic and sediment tracer analysis. The Water Institute. Prepared for and funded by the Coastal Protection and Restoration Authority. Baton Rouge, LA.

# PREFACE

This study was conducted by The Water Institute (the Institute) for the Coastal Protection and Restoration Authority of Louisiana (CPRA) in support of the Terrebonne Basin Barrier Island and Beach Nourishment Project (TE-0143). Funding for this work was provided by the National Fish and Wildlife Foundation's (NFWF) Gulf Environmental Benefit Fund through a Monitoring and Adaptive Management Grant (MAM). The report is a deliverable under Task Order 97 (TO97).

This report describes the planning, implementation, and results of a sediment tracer study undertaken to evaluate sediment transport dynamics along the West Belle Pass Headland. The study involved the collaboration of the University of New Orleans (UNO) and Environmental Tracing Ltd. (ET), collectively referred to as the Water Institute Team.

The aim of this project was to improve understanding of sediment mobility and geomorphic evolution within this critical restoration area. Findings from this effort support CPRA's broader mission to evaluate the performance and longevity of barrier island and headland restoration projects in coastal Louisiana.

# TABLE OF CONTENTS

# LIST OF FIGURES

## LIST OF TABLES

# 1 INTRODUCTION

The Water Institute of the Gulf (the Institute), in partnership with the University of New Orleans Pontchartrain Institute of Environmental Sciences (UNO PIES) and Environmental Tracing Ltd. (ET), conducted a sediment tracer study to evaluate sediment transport dynamics along the western Caminada Headland between Belle Pass and Raccoon Pass in Lafourche Parish, Louisiana. This location is commonly referred to as West Belle Pass Headland. The study was completed under Task Order 97 (TO97) in support of the Coastal Protection and Restoration Authority (CPRA) Terrebonne Basin Barrier Island Project (TE-0143).

The Operations Division of CPRA is tasked with monitoring, maintaining, and operating restoration projects that protect and sustain Louisiana's coastal wetlands. A critical component of these responsibilities includes evaluating sediment dynamics that influence the geomorphic evolution and long-term performance of barrier island and headland restoration projects. Understanding sediment transport pathways is essential for optimizing design strategies, managing nourishment efforts, and maintaining ecosystem resilience.

The TO97 sediment tracer study was designed to quantify nearshore sediment transport pathways and validate geomorphic trends observed at the West Belle Pass Headland. The study incorporated both field and analytical components, including the purchase, release, and recovery of EcoTrace™ fluorescent sediment tracers, background sampling to assess potential for natural fluorescence interference, and subsequent sampling and laboratory analysis to identify and quantify tracer distribution patterns. The results inform CPRA's understanding of sediment movement, erosion, and accretion processes that shape the restored headland and feeder beach as well as assess coastal system benefits downdrift outside of the project fill template.

## 1.1 OVERVIEW

The objective of this study was to evaluate sediment transport pathways and geomorphic evolution along the West Belle Pass Headland using fluorescent sediment tracers. The project team sought to determine the direction, quantity, and extent of tracer movement resulting from natural hydrodynamic processes and to assess how placed sediments from the feeder beach are redistributed over time.

The central hypothesis of this study is that nourishment material placed along the headland and feeder beach is actively mobilized by longshore transport and contributes to the maintenance of the barrier system west of Belle Pass. The tracer data, coupled with topobathymetric analysis, provide quantitative evidence to test this hypothesis and evaluate restoration performance.

The experimental design incorporated a controlled release of different colored EcoTrace™ tracers at two locations, followed by sequential sampling events to track tracer dispersal spatially and temporally. Three post-release sampling efforts were conducted between 2022 and 2025, supported by geomorphic assessments using multiple topobathy datasets. This combined approach enables a comprehensive understanding of sediment dynamics at the headland scale.

## 1.2 STUDY AREA

The study area is the West Belle Pass Headland located to the southwest of Port Fourchon (Figure 1). This portion of the study area is a part of the larger Caminada Headland, which spans Raccoon Pass to Caminada Pass. Its formation is tied to abandonment of the Lafourche Delta Complex and the past Mississippi River distributaries of Bayou Lafourche and Bayou Moreau (Boyd & Penland, 1988). When the Lafourche Delta was abandoned roughly 300 years ago (Penland, 1990), the region transitioned from a constructive deltaic phase to a transgressive phase characterized by marine reworking (Penland et al., 1981; Roberts, 1997). Longshore transport processes have since redistributed sediment east and west, forming flanking barrier islands such as Grand Isle and the Timbaliers (Kulp et al., 2005). The Caminada Headland is presently evolving through the early stages of transgression following fluvial abandonment, consistent with the conceptual model proposed by (Penland et al., 1988) for conversion of an abandoned deltaic headland to barrier islands and ultimately a transgressive shelf shoal.


*Figure 1. Approximate study area (dashed white rectangle). Port Fourchon is located northwest of study area. Inset map of Louisiana with study area (white X) included. Basemap imagery obtained from Maxar, dated 8/10/24.*

Following delta abandonment, waves, tides, and storms became the dominant geomorphic agents shaping the landscape. Historical analyses indicate shoreline retreat rates averaged 13.3 meters per year between 1887 and 1988, with localized retreat rates of up to 3 kilometers/century (McBride & Byrnes, 1997; Williams et al., 1992). This sustained shoreline erosion has resulted in the loss of interior embayments such as Bay Marchand and Bay Champagne, reflecting a natural process of coastal straightening driven by longshore sediment transport (Miner et al., 2009).

The Caminada Headland fronts Port Fourchon, which is one of the nation's most important coastal ports. Port Fourchon serves as the premier port for the nation's oil and gas industry and currently services approximately 95% of the Gulf of America's deepwater energy production (The Water Institute, 2022). The region is home to several coastal communities, contains critical infrastructure that supports the nation's oil and gas industry, and supports a diverse ecosystem, making it a top priority for the state's restoration efforts.

The construction period for TE-0143 West Belle Reach spanned two hurricane seasons, during which two hurricanes impacted the project area: Hurricane Zeta in 2020 and Hurricane Ida in 2021 (Figure 2). During construction of beach, dune, and marsh geomorphic habitats on the West Belle Pass Headland, Hurricane Zeta forcing resulted in a loss of approximately 2.61 million cubic yards ($yd^3$) of recently placed sand, silt, and clay sediments from the TE-0143 fill template. Post Hurricane Ida satellite imagery showed considerable overwash in the project area (Coastal Engineering Consultants Inc., 2022). The remaining project funds were dedicated to the construction of a 785,000 $yd^3$ feeder beach that was completed in January 2022 (Figure 3).

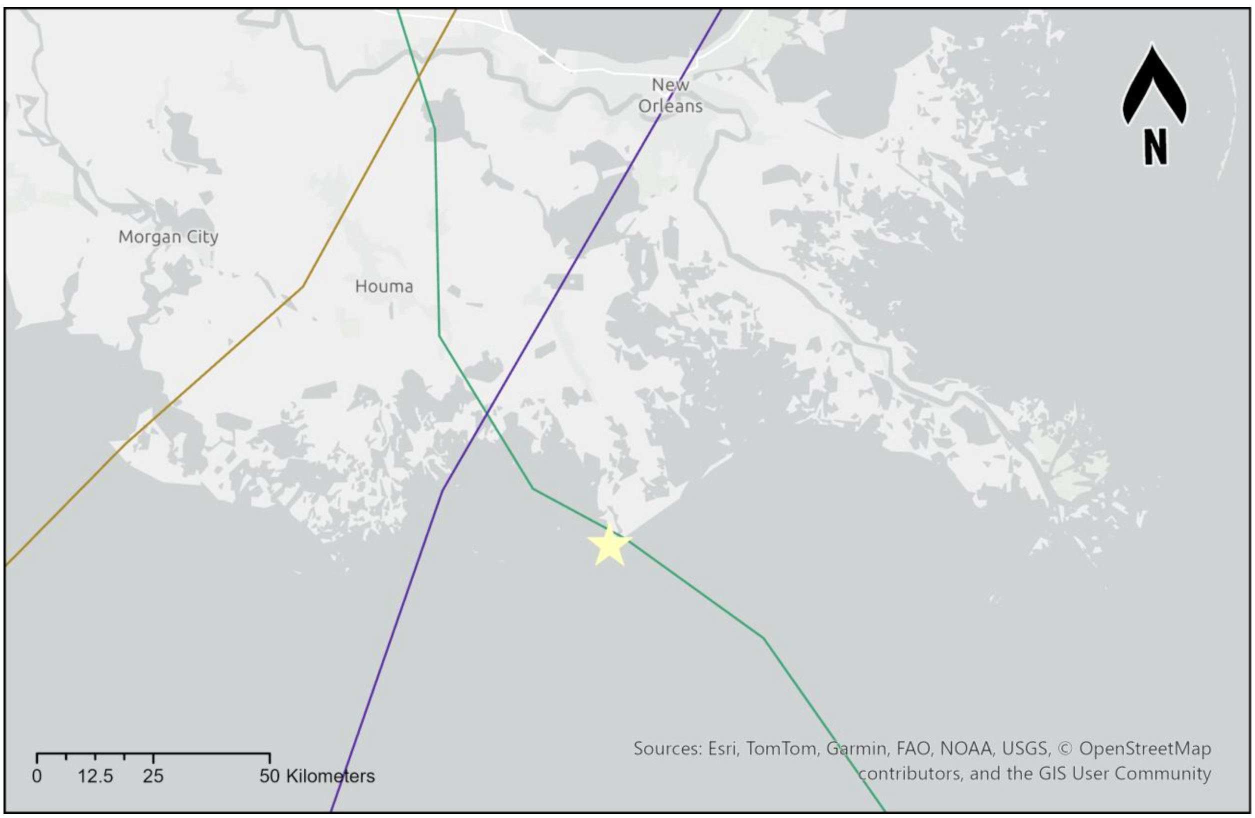


*Figure 2. Hurricane tracks from Ida-2021 (green), Zeta-2020 (purple), and Francine-2024 (gold) with study area location (star).*

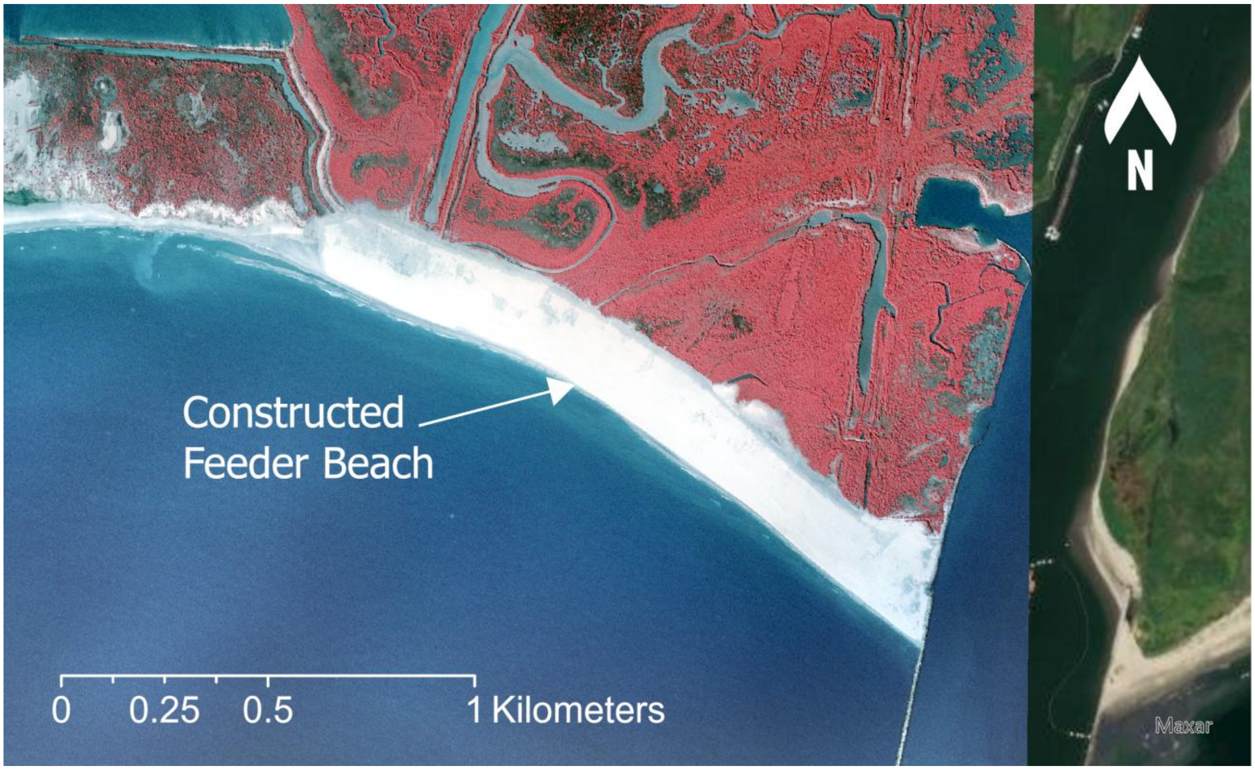


*Figure 3. Post-construction aerial imagery of West Belle Pass feeder beach. Aerial imagery collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). Basemap imagery obtain from Maxar, dated 8/10/24.*

# 2 METHODS

To evaluate sediment transport along the West Belle Pass Headland, an experiment was designed jointly by CPRA, the Institute, UNO PIES, and ET that incorporated collection of field data and analysis to track the movement of introduced sediment tracers through the study area over time. The methodology was designed to characterize spatial and temporal sediment dispersal patterns and quantify relative abundance of tracer particle recovery across multiple sampling events that occurred between November 2022 and July 2025. Key components included background sample analysis, the controlled release of tracer material, establishment of a systematic sampling grid, and implementation of standardized sampling and processing procedures. Details on tracer properties, release conditions, grid configuration, and analytical protocols are provided in the following sections.

## 2.1 GRID SELECTION

### 2.1.1 Background sampling grid

Background sampling was conducted prior to sediment tracer release to establish a baseline to detect any naturally occurring fluorescence. Sampling took place on June 20 and July 8 of 2022. The baseline fluorescence analysis helps to differentiate between the presence of natural background and artificial fluorescence (sediment tracer) for sampling efforts conducted after tracer release. Collectively, the Institute, UNO PIES, and CPRA selected locations for background sampling prior to field collection (Figure 4). Additionally, sediment samples collected within the study area in July, August, October, November, and December of 2021 by UNO PIES for a separate CPRA project (Yocum et al., 2022) were utilized as part of this effort and were included in the decision-making process of selecting background sample sites for this project.

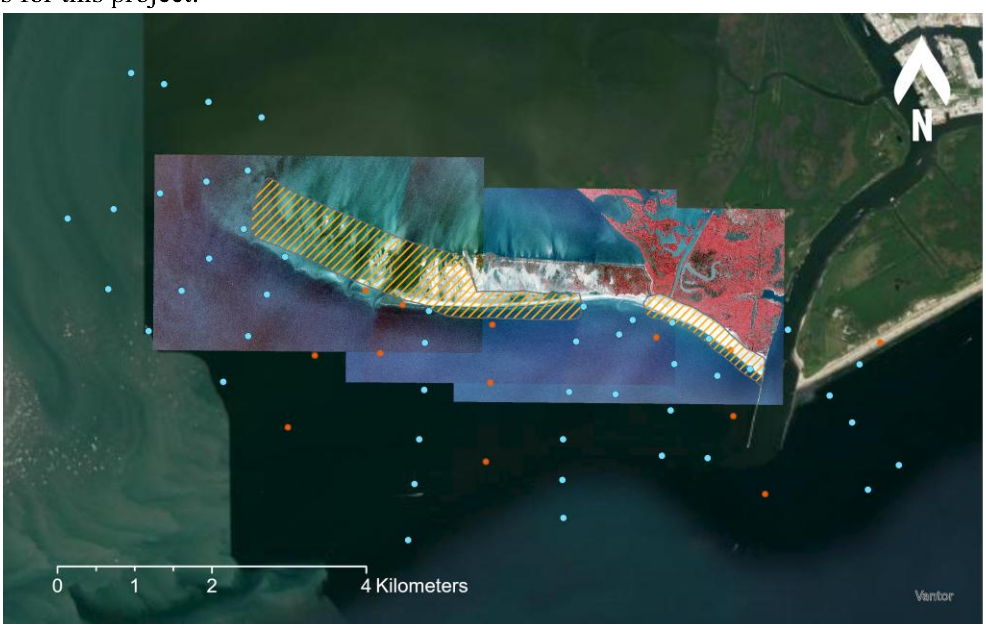


*Figure 4. Sample locations for background sampling collected between June–July 2022 (blue) and July–Dec. 2021 (orange). Orange hatched polygons represent the fill template of TE-0143 West Belle Reach. Post-construction aerial imagery of West Belle Pass feeder beach and West Belle Pass restoration projects included. Aerial imagery collected*

*Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). The horizontal coordinate system is NAD 83 UTM 15N. Basemap sourced from Vantor.*

### 2.1.2 Planned sample location grid

A grid of sampling locations was finalized prior to field sampling through discussions between the Institute, CPRA, and ET (Figure 5). Sample locations were selected based on identified regional sediment transport pathways within the study area (Georgiou et al., 2005; Miner et al., 2009). The final grid consisted of 301 locations: 285 water sample locations and 16 land sample locations. Land sample locations consisted of transects made up of two points: one location in the swash zone and one location at the toe of the dune. In instances where no dunes were present, the location point was placed at the toe of the berm. The grid area was contained within the following boundaries:

- the backbarrier of the West Belle Pass Headland and Raccoon Pass flood tidal delta to the north,
- the approximate area of the 8 m isobath to the south,
- Casse-Tete, Calumet, and East Timbalier Islands to the west, and
- a portion of Caminada Headland (east of Belle Pass).

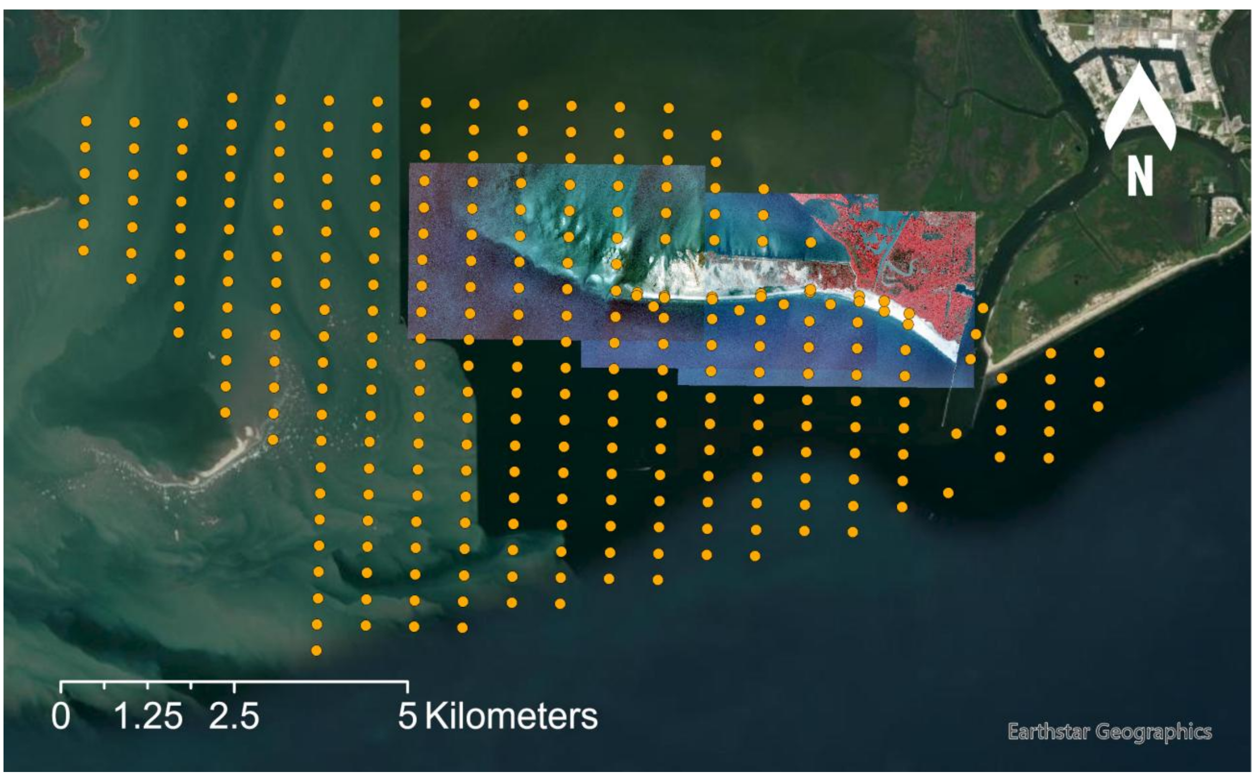


*Figure 5. Original planned sample locations (orange). Post-construction aerial imagery of West Belle Pass feeder beach and West Belle Pass restoration projects included. Aerial imagery collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). The horizontal coordinate system is NAD83 UTM Zone 15. Basemap imagery obtained from Earthstar Geographics.*

The initial sample grid selected by the project team (Figure 5) was intended to remain static throughout the project's field sampling events. However, due to limited movement of the tracer based on results from the first two sampling events and the incorporation of new topobathy datasets that showed geomorphic change along the headland and shoreface (details provided in(The Water Institute, 2025), the project team selected a different grid for the third post-tracer release sampling event. The modified sample location grid constrained the western, southern, and eastern extents of the original grid, but increased the sample density on the upper shoreface and land (Figure 6).

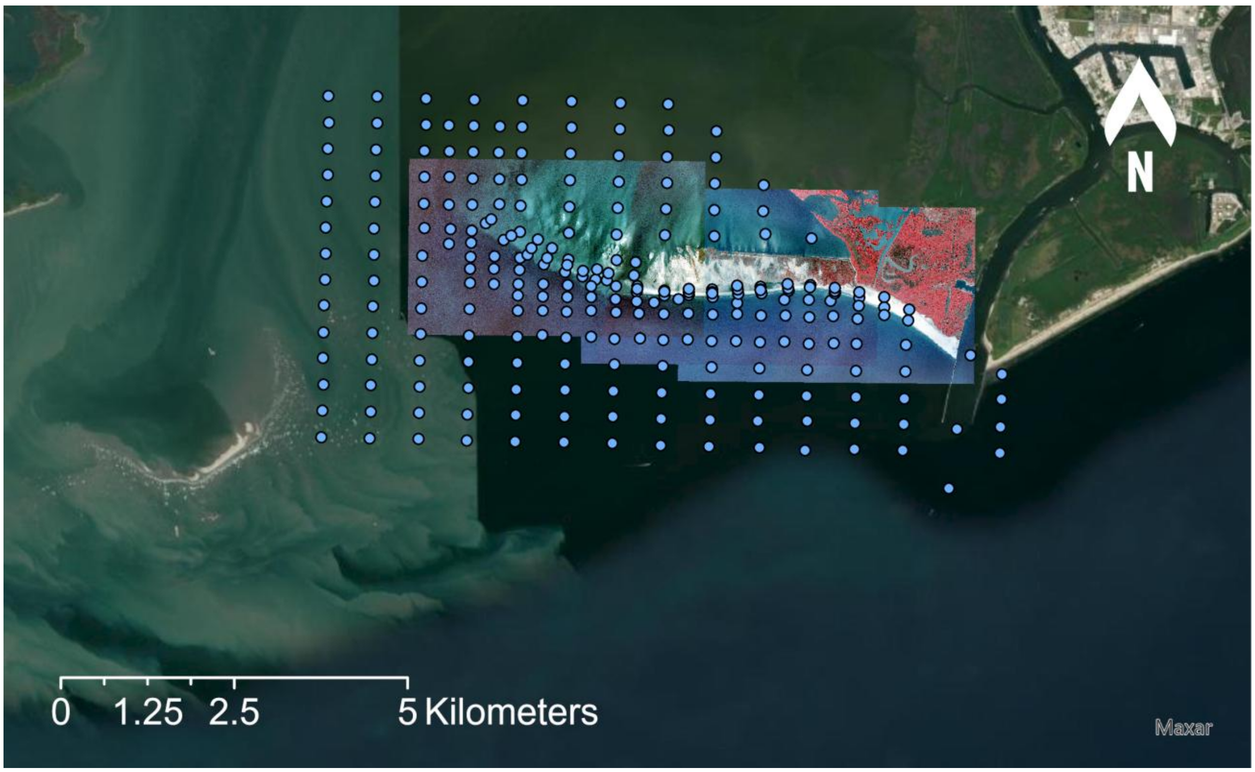


*Figure 6. Sample grid locations (blue) for the third sampling event post tracer release informed by locations where tracer was detected in the previous two sampling events. The same zoom and extent is used as in Figure 3 for comparison. Post-construction aerial imagery of West Belle Pass feeder beach and West Belle Pass restoration projects included. Aerial imagery collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). The horizontal coordinate system is NAD83 UTM Zone 15. Basemap imagery obtained from Maxar.*

## 2.2 SEDIMENT TRACER CHARACTERISTICS

### 2.2.1 Sediment characterization

A key element of this study was to track sand transport using sediment tracers to better understand sediment transport rates and pathways within the study area. In order to ensure that sand tracer movement is representative of the natural sediment dynamics, it is critical that sediment tracer particles have the same physical properties as the native sand (and in this case as the sand placed for beach nourishment). Manufactured tracer grain size was based on the mean grain size in the local area (Figure 7) of 150–300 µm (Bosse et al., 2019).

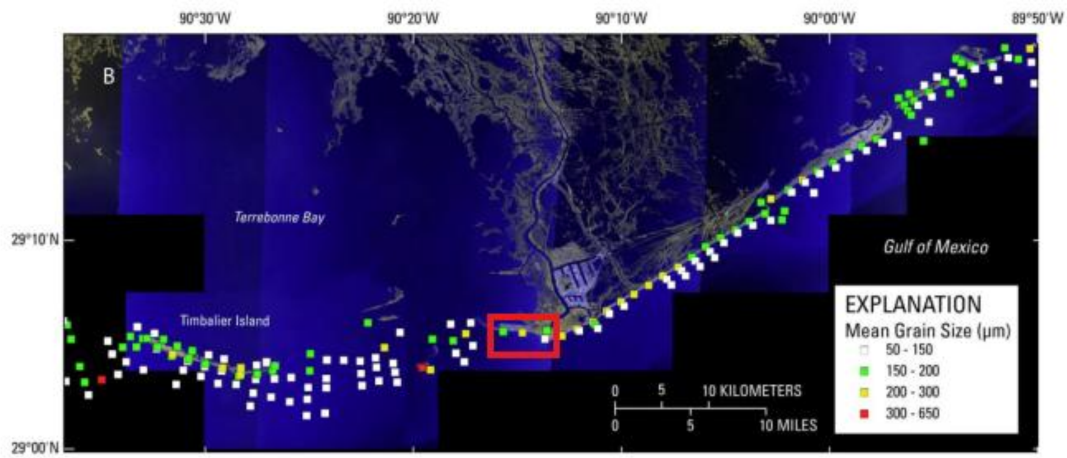


*Figure 7. Regional map showing the mean grain size in µm from various sample sites along the Lafourche Delta Complex from 2015-2016 (Bosse et al., 2019). The study area is within the red outline.*

### 2.2.2 Sand tracers

In terms of analysis, ET does not count any particles smaller than 2 µm due to the increased difficulty and reliability of counting and identifying the color of the particle clearly (see Section 2.3). ET carried out a particle size distribution (PSD) analysis using a standard dry sieving technique (British Standard, 1990). Two sand tracers were manufactured and deployed within the study area: one magenta and one green. The use of two uniquely colored tracers with identical physical characteristics allowed simultaneous tracking of sediment transport from two discrete source locations along the headland, including the constructed feeder beach (Figure 8).

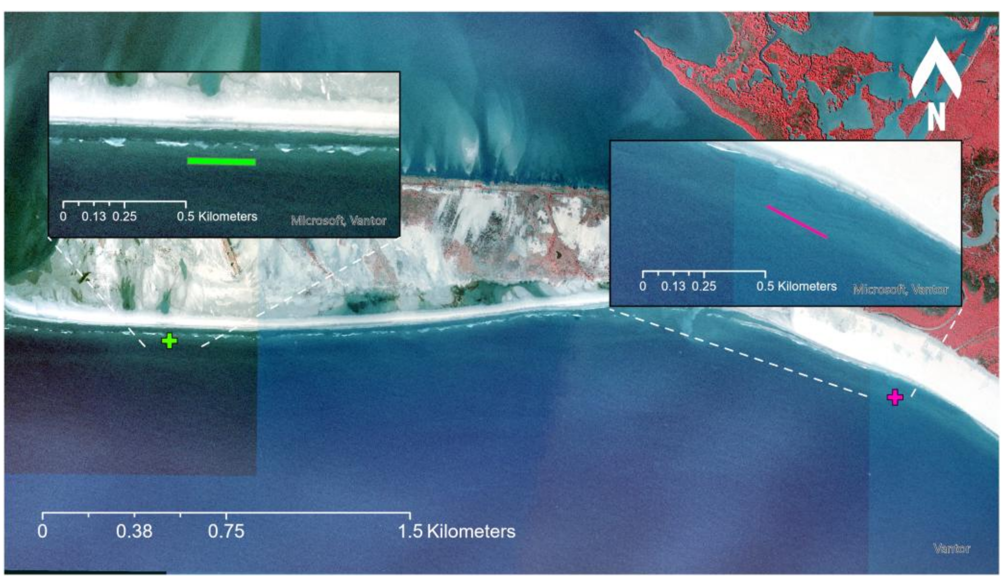


*Figure 8. Zoomed-in view of magenta (top right panel) and green (top left panel) tracer release locations. Tracer polygons are to scale. Green tracer was dispersed over a 10x100 m area and magenta tracer was dispersed over a 5x100 m area.Overview images denotes tracer release locations by crosses (green and magenta). Post-construction aerial imagery of West Belle Pass feeder beach and West Belle Pass restoration projects included. Aerial imagery*

*collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). The horizontal coordinate system is NAD83 UTM Zone 15.*

Deploying both tracers during the same period ensured that sediment movement from each source could be evaluated under identical environmental and metocean conditions in the West Belle Pass area (Figure 8). The PSD results are shown in Figure 9 and summarize the average percentage within each size band for the two sand tracers released (Wentworth scale) as follows:

- Silt and clay: <63 µm
- Very fine sand: >63 – <125 µm
- Fine sand: >125 – <250 µm
- Medium sand: >250 – <500 µm
- Coarse sand: >500 – <1000 µm
- Very coarse sand (and above including shell fragments): >1000 µm

The results of the tracer PSD indicated a strong uniformity between the two tracers selected for this study. For both tracers, the modal size fractions were fine and medium sized particles, accounting for approximately 88–89% of all tracer particles deployed (Table 1).

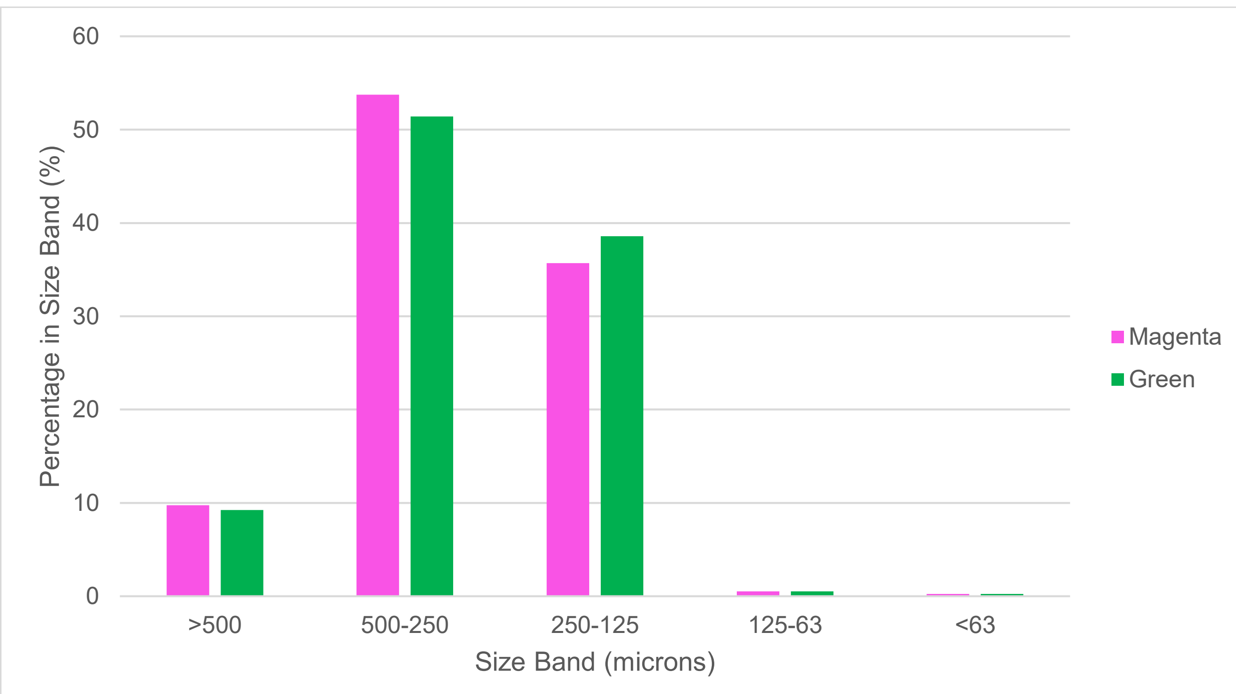


*Figure 9. PSD data for magenta and green sand tracers. Mean grain size for the study site is between 150–300 µm, depending on exact location.*

*Table 1. Tabular representation of the results of the tracer PSD. The modal size fractions are fine (125–250 μm) and medium (250–500 μm) sand.*

| Tracer ID | >500 | 500-250 | 250-125 | 125-63 | <63 |
|---|---|---|---|---|---|
| Magenta | 9.75 | 53.76 | 35.71 | 0.51 | 0.26 |
| Green | 9.23 | 51.42 | 38.57 | 0.53 | 0.25 |

### 2.2.3 Tracer composition

ET's EcoTrace™ fluorescent sand particle tracers were used in this study. These environmentally benign sediment tracers behave and are transported in the same way as natural sediment and assimilate the key sediment transport processes including erosion-resuspension and settling-deposition because of tidal currents, wind-driven currents, waves, and aeolian processes. This gives an integrated assessment of native sediment transport processes, pathways, and patterns of deposition. The tracer particles include fluorescent dyes in a thermoplastic polymer base and, therefore, the whole of each tracer particle contains fluorescence throughout rather than a coating that can wear off or be abraded. Prior to release, tracer particles were pre-wet and mixed with sediment from the site to ensure they adsorb the same electrochemical charge including natural organic coatings as natural sediment particles.

### 2.2.4 Tracer density

It was also necessary to consider the optimum particle density for the sediment tracers prior to ET's manufacturing of the tracers. Factors considered included:

1. Terrigenous sediments make up the majority of the sediment in the area (Van Andel & Poole, 1960).
2. Littoral sediment has a high silica sand content due to its provenance in the Mississippi River Basin (Van Andel & Poole, 1960).
3. Silica sands have been researched more extensively, are well understood, and behave uniformly in terms of key sediment transport processes including erosion, resuspension, transport, and settling-deposition (Madsen & Grant, 1976).
4. The majority of sediment transport models including Delft3D (Deltares, 2019), the empirical formulas used in the models to transport sand (Engelund & Hansen, 1967; Meyer-Peter & Muller, 1948; van Rijn, 2007a, 2007b), and the supporting research for the sand transport functions used in those models, are based on silica grains with a density of 2.65g/cm$^3$. If the sediment tracer data were to be used for model calibration and/or validation, this would be particularly important.

Based on the above, ET manufactured both colors of sand tracer with the same density of 2.65 g/cm$^3$ to represent natural silica-based sediments. This ensured that the results were directly comparable between the different tracers released and with natural silica sand. ET measured the tracer particle density for each of the sediment tracers following procedures set out in British Standard BS812 (British Standard, 1999). Densities were confirmed as 2.65 g/cm$^3$ + 0.01 g/cm$^3$ and were verified by an external accredited laboratory, Element Materials Technology (formerly Exova).

### 2.2.5 Tracer fall velocity

To ensure that the tracer particles behaved in the same way as the target natural sediment from the study site once eroded and resuspended into the water column, ET routinely carries out additional tests to assess the physical behavior of the tracer particles compared with the natural sediment. Fall velocity tests provide a direct comparison of the settling characteristics and behavior of the natural non-cohesive particles collected from the site.

For this study, fall velocity tests were conducted in ET's laboratory to compare sand-sized tracer and natural sediment particles. ET carried out fall velocity tests on the two colors of sand tracer particles (Table 2) and a composite sand sample collected from background samples collected in June–July 2022. The fall velocity tests involved timing an individual (sand or tracer) grain of known size as it falls or settles over a 1-meter (1000 mm) distance. These tests were carried out in seawater at a constant temperature. A total of 10 grains were tested per size band per tracer color/natural sand material. For these tests, water temperature was maintained at 20°C ± 1°C (equivalent to ambient room temperature at the time of the test) and 35.1% salinity (intended to be 35.0%). ET used ambient room temperature since it is difficult to warm the entire 1 m water column consistently and continuously to avoid pocket of warmer and cooler water, which would affect the test results. ET conducts all fall velocity tests at or around 20°C to allow comparison from one tracer/sediment test to another for all project sites tested.

*Table 2. Table of average fall velocity results for strong magenta and green tracer, and natural sediment collected during background sampling.*

| Grain Size (µm) | Average Fall Velocity (mm/s) | | |
|---|---|---|---|
| | Magenta | Green | Natural Sediment |
| Fine (0.125–0.250) | 11.5 | 10.5 | 14.6 |
| Medium (0.250–0.375) | 28.6 | 28.3 | 25.5 |
| Coarse (0.375–0.500) | 69.2 | 68.6 | 61.25 |

For the tests, the two colors (green and magenta) and the natural sand were soaked and wetted in the same way for the same duration from dry. Individual particles were selected by microscope and sized using a microscope eyepiece graticule to ensure comparable grain sizes were chosen. However, it should be noted that sizing particles in this way only allows measurements in two dimensions (X and Y) and not Z, which leads to some variability in the actual grain size in three dimensions. To ensure the tests and results were comparable, the same approach was used for natural sand and sand-sized tracer particles.

Three size bands were compared corresponding to the fine (125–250 µm), medium (250–375 µm) and coarse (375–500µm) particle sizes, tested, and analyzed for tracer grain sizes. Sand and tracer particles smaller than 0.125 µm are more difficult to observe without magnification and have much slower fall velocities and therefore were not tested, although these were counted and recorded in the tracer particle size data.

It should be noted that the individual size bands cover a large range (i.e., 0.125 µm per size band), resulting in substantial variation in particle fall velocities. This variation is particularly important when compared with values reported in the literature, which typically isolate a single particle size, use idealized spherical particles for analytical comparisons, or assume a uniform particle size in numerical models. By comparison, the purpose of these measurements is to ensure that the sand tracers and the natural sand from the study site behave similarly in laboratory conditions using the same methods to select the particles.

For the given size ranges—allowing for the variable grain sizes in three dimensions—the fall velocities for the three size bands were very similar for the sand tracers and the natural sand. Therefore, combined with the other physical characteristics that match (i.e., size and density), the tracer particles were considered to be very likely to behave in the same way in terms of sediment transport processes including erosion-resuspension, transport, and settling-deposition.

## 2.3 TRACER ANALYSIS METHODOLOGY

Tracer sample analysis was conducted by ET on selected background and active ("live") sediment samples. The analytical approach was designed to identify, quantify, and characterize fluorescent sand tracer particles recovered from the study area. A combination of controlled sample preparation, fluorescence imaging, and image-based particle analysis was used to ensure consistent and comparable results across samples.

### 2.3.1 General tracer analysis methodology

This methodology description outlines the procedures undertaken to analyze fluorescent sediment tracers through the utilization of advanced imaging techniques and subsequent image analysis.

All tracer analysis was conducted following Standard Operating Procedures developed by ET over 30 years of sediment tracer analysis. The analysis method can be summarized as follows:

- Overview: Each sample was weighed to provide a total weight of the sample. The sample was then homogenized with a measured weight (~500 g) of wet sediment removed and dried to constant weight; the sample was then re-weighed to provide a wet-to-dry ratio.
- Sand tracer analysis: a sub-sample of the dried sediment was then taken as the "viewing weight" (~300 g) and the total number of sand tracer particles present in the sample (magenta, green) were counted (raw count).
- Image analysis: high-resolution images of the sediment samples were captured under controlled lighting conditions, using a combination of both visible and UV excitation to ensure the correct particles were identified. These images were then transferred to Adobe Photoshop, which was calibrated using reference tracer material to identify the presence of tracer material within the sample. Visible light images were used to measure each individual particle, which were then placed into fine, medium, and coarse size bands 0.125–0.250 µm, 0.250–0.375 µm and 0.375 mm up to 0.600 µm, respectively. Particles below 0.125 µm were not separated out further (i.e., <0.125 µm only) as they were harder to determine the individual size accurately. Therefore, all particles <0.250 µm were classified as fine.
- Sand tracer particles/m$^2$ were calculated using the following formula:

  *((Raw count/viewing weight) x Dry weight of sample) / 0.04 (i.e., grab area in m$^2$)*

- Given the samples collected were potentially varied in terms of size and volume, they were normalized to allow comparison of the results to a constant dry weight. This was based on a known and constant surface area and depth for a grab sample. This allowed all the tracer results to be plotted as tracer counts per $m^2$ of the seabed. In addition, ET determined the distribution of fine, medium, and coarse-sized tracer particles (as listed above) for each sand sample result and plotted proportionally for the total tracer count measured.

### 2.3.2 Quality assurance and quality control (QA/QC)

QA/QC of the image analysis involved various steps, including:

- Repeat Samples: Randomly selected samples were analyzed in triplicate, to ensure consistency in the results produced.
- Instrument calibration and maintenance: Camera systems were regularly cleaned to ensure the image quality was consistent, and the equipment settings were stable throughout the analysis period. Image analysis software was regularly calibrated using reference material, which was captured using the same methods as typical sample analysis.
- Control Experiments: Control experiments were performed using known concentrations of tracer in "spiked" sediment samples, and the expected results were compared with the actual results to identify and address any systematic errors or variations.
- Cross Verification: Randomly selected samples were analyzed using techniques previously developed by ET to establish consistency between the fluorescence imaging results and independent measurements.
- Continuous Feedback Loops: Other QA/QC practices were regularly reviewed to assess their effectiveness.

## 2.4 TRACER RELEASE

Two sediment tracers (magenta, 300 kg; green, 500 kg) were released in the study area at two discrete locations. The magenta tracer was released on the upper shoreface of the newly constructed West Belle Pass feeder beach, while the green tracer was released on the upper shoreface west of the feeder beach. The following criteria for tracer release locations were established in discussions between the Institute, CPRA, and ET:

- The tracer release location should be in the subtidal zone (seaward of bar).
- Based on the amount of tracer to be released, tracer disbursement should be over an area of either 10×100 m or 5×100 m.
- Tracer release location should be outside of wave shadowing area of West Belle Pass jetties for the dominant wave approach.
- Tracer release polygons/areas should be oriented lengthwise in an alongshore direction.

CPRA and Institute personnel conducted a joint field operation on August 17, 2022 to release the two sediment tracers in the study area. The green sediment tracer was dispersed over a 10×100 m area, and the magenta sediment tracer was dispersed over a 5×100 m area. Prior to tracer dispersal, PVC poles were used to mark the boundaries of each polygon so personnel could accurately release sediment tracer in the designated areas. Both the magenta and green tracers were stored and placed in the release areas using 5-gallon buckets. Additionally, separate personnel were used to deploy each of the colors of the tracers to prevent contamination between tracer release locations.

*Figure 10. Photographs of sediment tracer release. Top image showing magenta tracer in bucket. Bottom image showing CPRA (Glen Curole) and Institute (Andrew Courtois) staff conducting sediment tracer release on Aug. 17, 2022.*

## 2.5 SAMPLING METHODS

The methodology for sample collection was adopted from those employed by the Barrier Island Comprehensive Monitoring Sediment Sampling program (Kulp et al., 2015b). The methodology and materials for sample collection consisted of:

- obtaining a geographic position at each sample location from a handheld differential global positioning system,
- logging a waypoint, location, and water depth in field notebook,
- collecting subaqueous sample with a Petite Ponar grab sampler deployed manually from the vessel, and
- transferring sediment sample into waterproof Whirl-Paks labeled with waypoint and water depth.

Upon returning from the field, all digital data were downloaded and underwent QA/QC protocols. Additionally, sample locations were classified by environment. Shoreface and land samples followed the terminology and classifications outlined in Yocum et al. (2022). Terminology and classifications for backbarrier and flood tidal delta environments were adopted from Kulp et al. (2006, 2015a).

## 2.6 TOPOBATHY ANALYSIS

Multiple topobathy datasets were provided to the Institute by CPRA. The objective of this analysis was to identify areas where the seafloor had changed over time to help inform Sampling Event 3, particularly in light of the limited tracer movement observed during Sampling Event 2. It should be noted that no two datasets had coincident survey transects (i.e., repeat surveys along the same transect), survey transect spacing was inconsistent across datasets, and the survey extent for each dataset was unique.

*Table 3. Dates of important events and survey datasets used in topobathy analysis.*

| Events & Surveys | Date |
|---|---|
| TE143 Pre Zeta (Coastal Engineering Consultants Inc., 2022) | 5/19/20–10/26/20 |
| Hurricane Zeta Landfall | 10/28/20 |
| TE143 Post Zeta (Coastal Engineering Consultants Inc., 2022) | 12/2/20–12/11/20 |
| Hurricane Ida Landfall | 8/29/21 |
| Feeder Beach As-Built (Coastal Engineering Consultants Inc., 2022) | 10/1/21–1/22/22 |
| Feeder Beach Post Construction (Coastal Engineering Consultants Inc., 2022) | 3/15/22–6/2/22 |
| Tracer Release | 8/17/2022 |
| Sampling Event 1 (The Water Institute, 2023a) | 11/16/22–12/16/22 |
| Sampling Event 2 (The Water Institute, 2023b) | 6/26/23–7/28/23 |

| Events & Surveys | Date |
|---|---|
| BICM3 (T. Baker Smith, 2023) | 11/29/22–5/3/23 |
| T. Baker Smith Topobathy TE-0143 (T. Baker Smith, 2025) | 7/30/24–8/22/24 |
| Post Francine Reoccupation (T. Baker Smith, 2025) | 12/12/24–3/12/25 |
| Sampling Event 3 (The Water Institute, 2025) | 7/14/25–7/23/25 |

To enable time-series comparison across these multiple datasets, a uniform grid was created at a 75-m resolution (Figure 11). This was done so as spatial interpolation of the data points in each dataset could be conducted using Golden Software Surfer's kriging algorithm to generate digital elevation models (DEMs; NAVD 88, meters). This grid captured the greatest amount of overlap between all survey datasets. The interpolated DEMs were then compared to each other to calculate elevation change at each grid node to produce new DEMs that map zones of erosion and accretion between two time periods. All survey datasets were projected to NAD 1983 UTM Zone 15 and referenced a vertical datum of NAVD 88 meters. Elevations were reported in NAVD 88 (Geoid 12B) for all datasets.

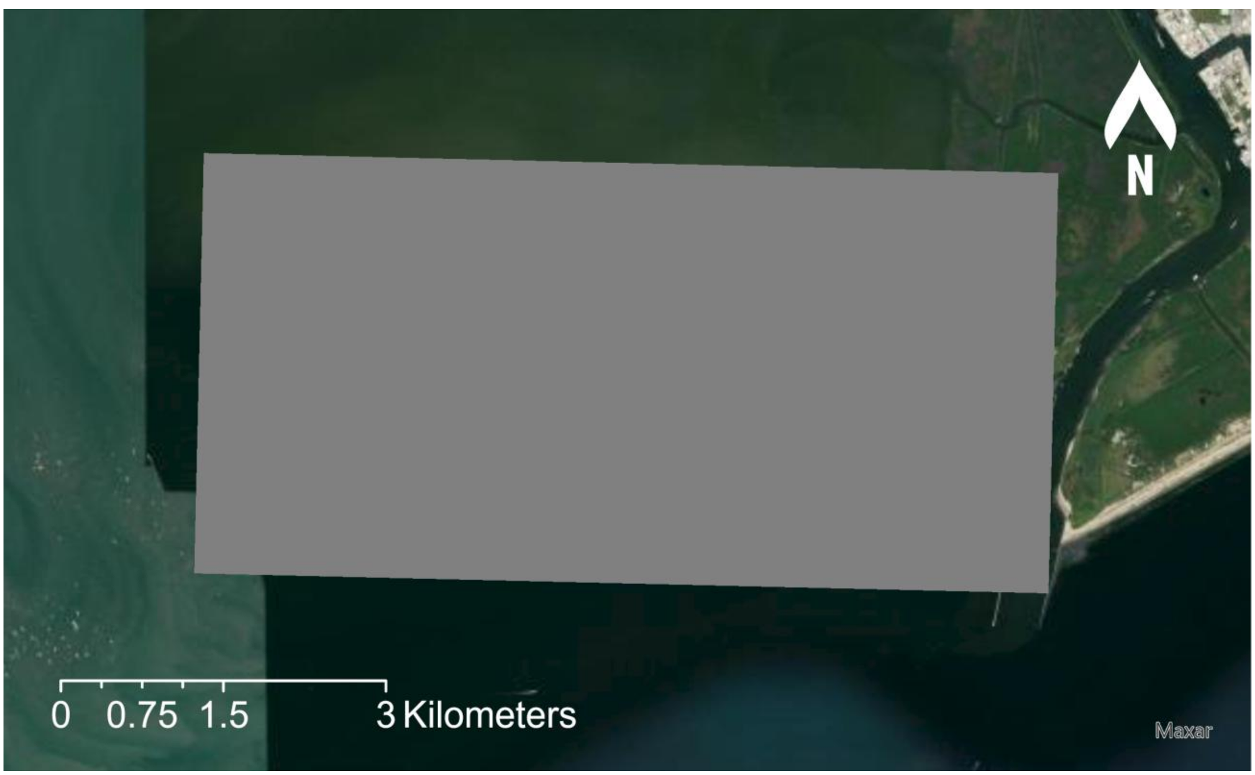


*Figure 11. Constant-value template raster (75-m resolution) used to define the uniform interpolation grid for all survey datasets (extent and cell size). Layer contains a single constant value, rendering as a single color. Horizontal coordinate system is NAD83 UTM Zone 15. Basemap imagery obtained from Maxar.*

# 3 RESULTS

## 3.1 BACKGROUND SAMPLING EVENT

UNO PIES and the Institute conducted background field sampling efforts on June 20 and July 8 of 2022. In total, 60 samples were analyzed by ET for baseline fluorescence (Figure 12). The analysis performed by ET revealed zero fluorescence present in all 60 samples.

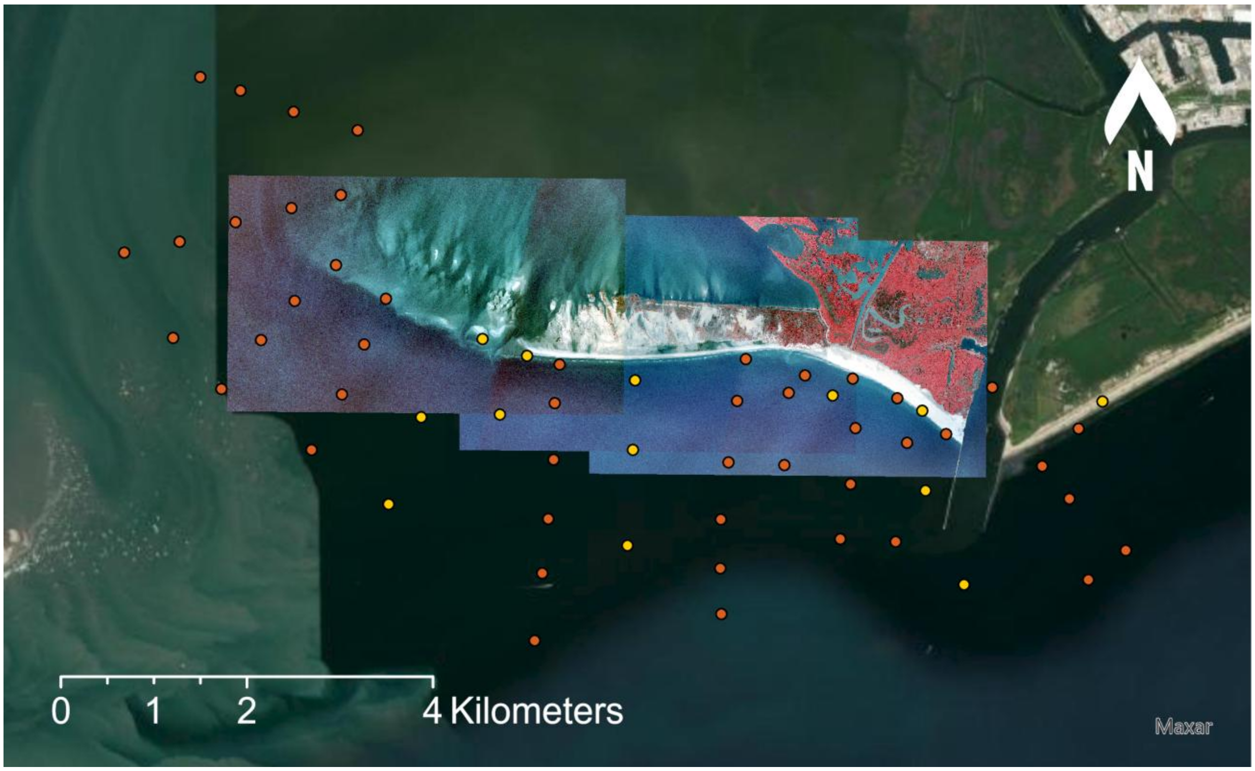


*Figure 12. Samples included for background fluorescence analysis. Background samples collected under TO97 (orange), and subset of samples collected by UNO PIES in fall 2021 (yellow). Post-construction aerial imagery of West Belle Pass feeder beach and West Belle Pass restoration projects included. Aerial imagery collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). The horizontal coordinate system is NAD83 UTM Zone 15. Basemap imagery obtained from Maxar.*

## 3.2 SAMPLING EVENT 1

A total of 295 samples were collected during Sampling Event 1 (Figure 13). Inclement weather and other external factors delayed sample collection at six locations (three in water and three on land). A joint decision between CPRA and the Institute was made to forego the collection of the remaining six samples, due to the extended time that had elapsed since the initial collection of the 295 samples.

Field efforts were conducted jointly by personnel from UNO PIES and the Institute on the following days:

- November 16, 2022

- November 17, 2022
- November 22, 2022
- November 23, 2022
- November 28, 2022
- December 5, 2022
- December 7, 2022
- December 9, 2022
- December 16, 2022

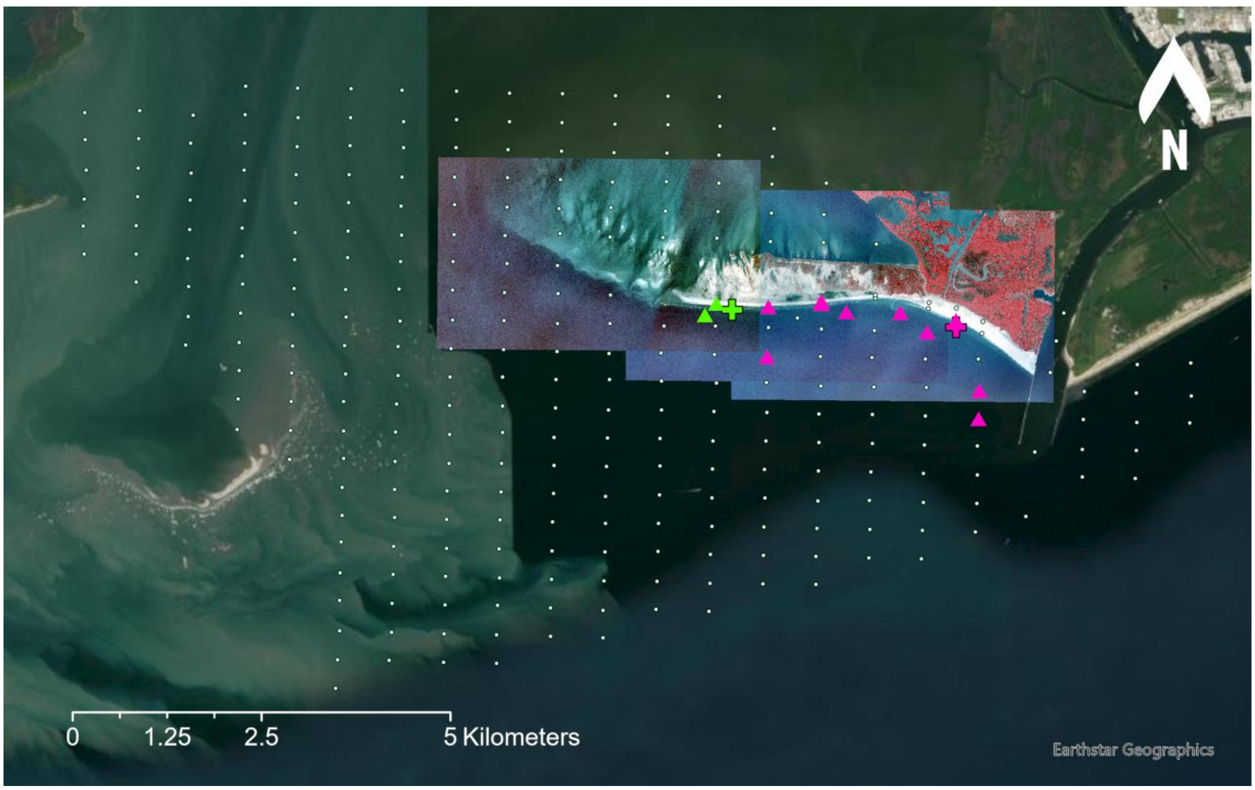


*Figure 13. Actual sample locations for Sampling Event 1 (light teal circles). Tracer hits are denoted by triangles. Green triangles indicate presence of green tracer. Magenta triangles indicate presence of magenta tracer. Colored crosses (green or magenta) indicate the tracer release locations. The horizontal coordinate system is NAD83 UTM Zone 15. Post-construction aerial imagery of West Belle Pass feeder beach and West Belle Pass restoration projects included. Aerial imagery collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). Basemap provided by Earthstar Geographics.*

Following sample collection, QA/QC were performed on all samples, then samples were shipped overseas to ET for analysis. A total of 12 samples contained sediment tracer, with two containing green tracer and 10 containing magenta (Figure 14 and Table 4). Five land locations had the presence of tracer, with the remaining locations restricted to the upper shoreface. The tracer analysis reported the presence of tracer in samples according to three size bins—125–250 µm (fine), 250–375 µm (medium), and 375–500 µm (coarse). Reporting for all sampling events was done using these size bins.

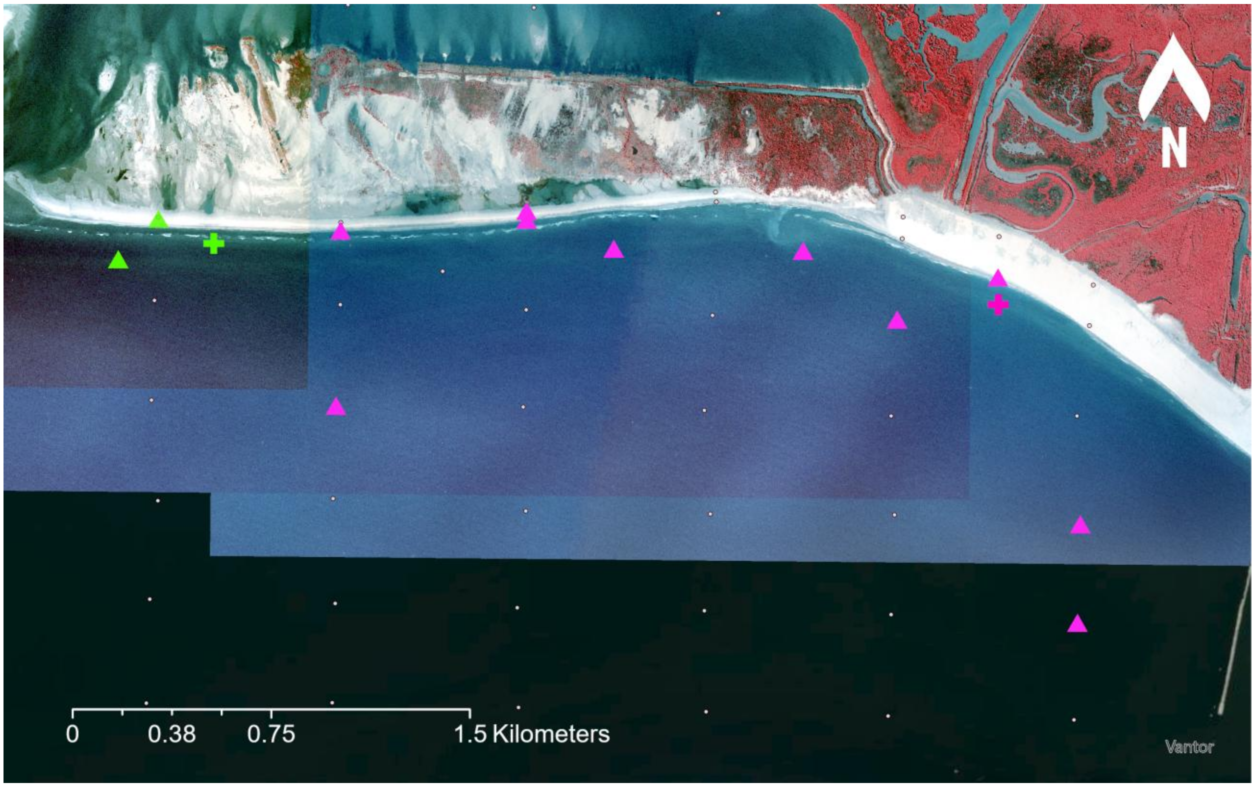


*Figure 14. Locations with tracer present during Sampling Event 1. Points indicate sampling locations. Green triangles indicate presence of green tracer and magenta triangles indicate presence of magenta tracer. Colored crosses (green or magenta) indicate the tracer release locations. The horizontal coordinate system is NAD83 UTM Zone 15. Post-construction aerial imagery of West Belle Pass feeder beach and West Belle Pass restoration projects included. Aerial imagery collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). Basemap provided by Vantor.*

*Table 4. Summary of tracer results for Sampling Event 1. Table includes details on presence of tracer grains by size class: fine (125–250 µm), medium (250–375 µm), and coarse (375–500 µm). Additionally, tracer analysis estimates number of tracer particles per m$^2$.*

| Sample_ID | Environment | Green Tracer per m$^2$ (estimated) | Magenta Tracer per m$^2$ (estimated) | Green_ Fine | Green_ Medium | Green_ Coarse | Magenta_ Fine | Magenta_ Medium | Magenta_ Coarse |
|---|---|---|---|---|---|---|---|---|---|
| WB-1-L-001 | Berm | 51 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| WB-1-L-004 | Swash | 0 | 161 | 0 | 0 | 0 | 1 | 1 | 2 |
| WB-1-L-005 | Berm | 0 | 58 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-1-L-006 | Swash | 0 | 60 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-1-L-013 | Swash | 0 | 244 | 0 | 0 | 0 | 1 | 2 | 1 |
| WB-1-W-084 | Upper Shoreface | 0 | 51 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-1-W-099 | Upper Shoreface | 55 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| WB-1-W-134 | Upper Shoreface | 0 | 40 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-1-W-135 | Upper Shoreface | 0 | 57 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-1-W-153 | Upper Shoreface | 0 | 28 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-1-W-168 | Upper Shoreface | 0 | 40 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-1-W-188 | Upper Shoreface | 0 | 96 | 0 | 0 | 0 | 2 | 0 | 0 |

## 3.3 SAMPLING EVENT 2

A total of 307 samples were collected during Sampling Event 2 (Figure 15). Field teams observed significant changes in the beach profile relative to Sampling Event 1. Six additional samples were collected during Sampling Event 2 due to changes along the headland, which resulted in a change in sampling environments compared to Sampling Event 1. For example, sample locations that were located on the berm during the first sampling event were now located in the upper shoreface. The original static grid was sampled for consistency and additional samples were taken to account for the changing locations of sampling environments (e.g., migrating berm).

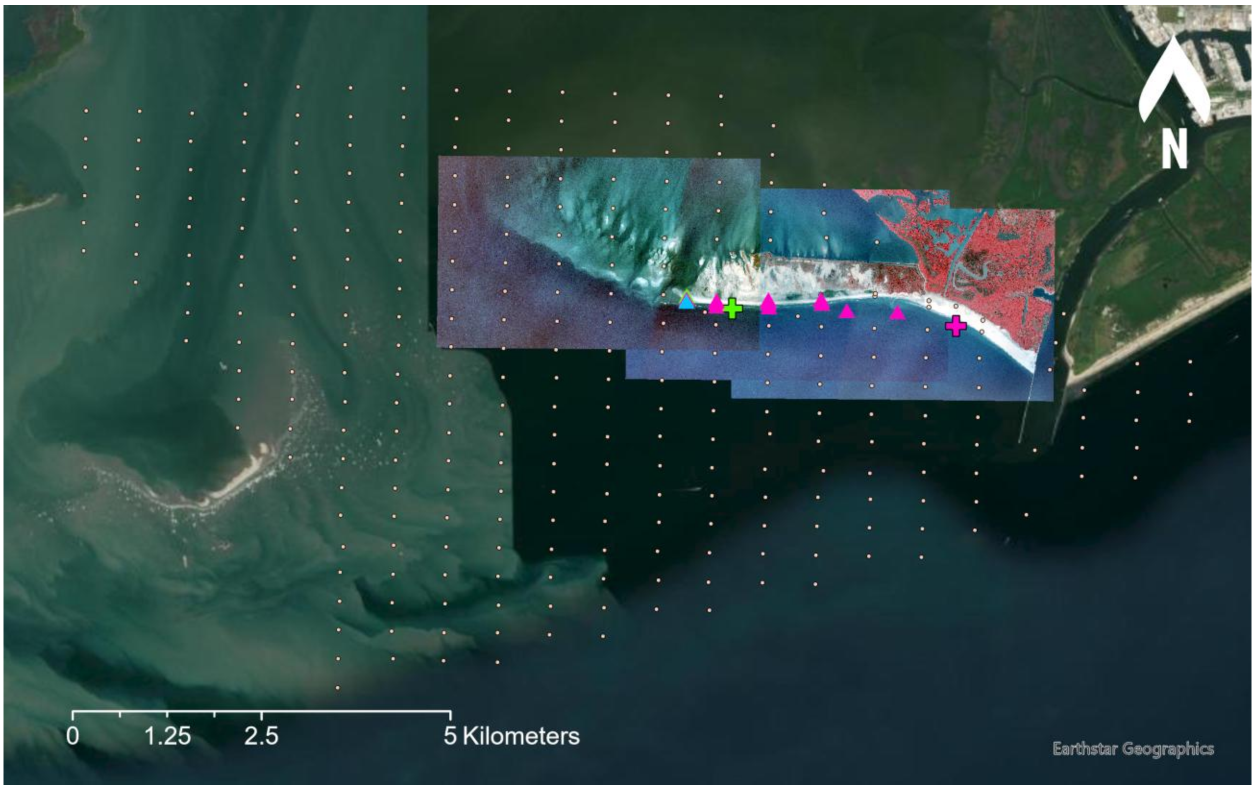


*Figure 15. Actual sample locations for Sampling Event 2 (tan circles). Tracer hits are denoted by triangles. Green triangles indicate presence of green tracer. Magenta triangles indicate presence of magenta tracer. Blue triangle indicates presence of both tracers. Colored crosses (green or magenta) indicate the tracer release locations. The horizontal coordinate system is NAD83 UTM Zone 15. Post-construction aerial imagery of West Belle Pass feeder beach and West Belle Pass restoration projects included. Aerial imagery collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). Basemap provided by Earthstar Geographics.*

Field efforts were conducted jointly by personnel from UNO PIES and the Institute on the following days:

- June 26, 2023
- June 27, 2023
- June 28, 2023
- June 29, 2023

- June 30, 2023
- July 14, 2023
- July 27, 2023
- July 28, 2023

The same protocols used for Sampling Event 1 (i.e., sampling methodology and QA/QC) were used for Sampling Event 2. After sample collection, field samples were sent overseas to ET for tracer analysis.

Field crews observed the landward migration of the shoreline along the West Belle Pass Headland proximal to the western jetties of West Belle Pass, relative to the shoreline location observed during Sampling Event 1. Erosion of the beach face exposed previously buried rocks that were observed fronting the headland during field efforts (Figure 16). This finding was communicated with CPRA, and the Institute was able to obtain the geographic location (in Google Earth .kml format) of the revetment from CPRA. The Institute measured approximately 70 m of shoreline retreat comparing post-construction aerial imagery of the feeder beach to the location of the revetment (Figure 17), highlighting the significant geomorphic changes of the headland between Sampling Events 1 and 2. The timespan between aerial photography and observation of the revetment was approximately 1 year and 4.5 months.


*Figure 16. Drone imagery showing feeder beach construction (top left), feeder beach post-completion detailing longshore sediment transport (bottom left), and evidence of shoreline retreat and revetment exposure immediately west of Belle Pass jetties (top right and bottom right). Imagery provided by CPRA.*

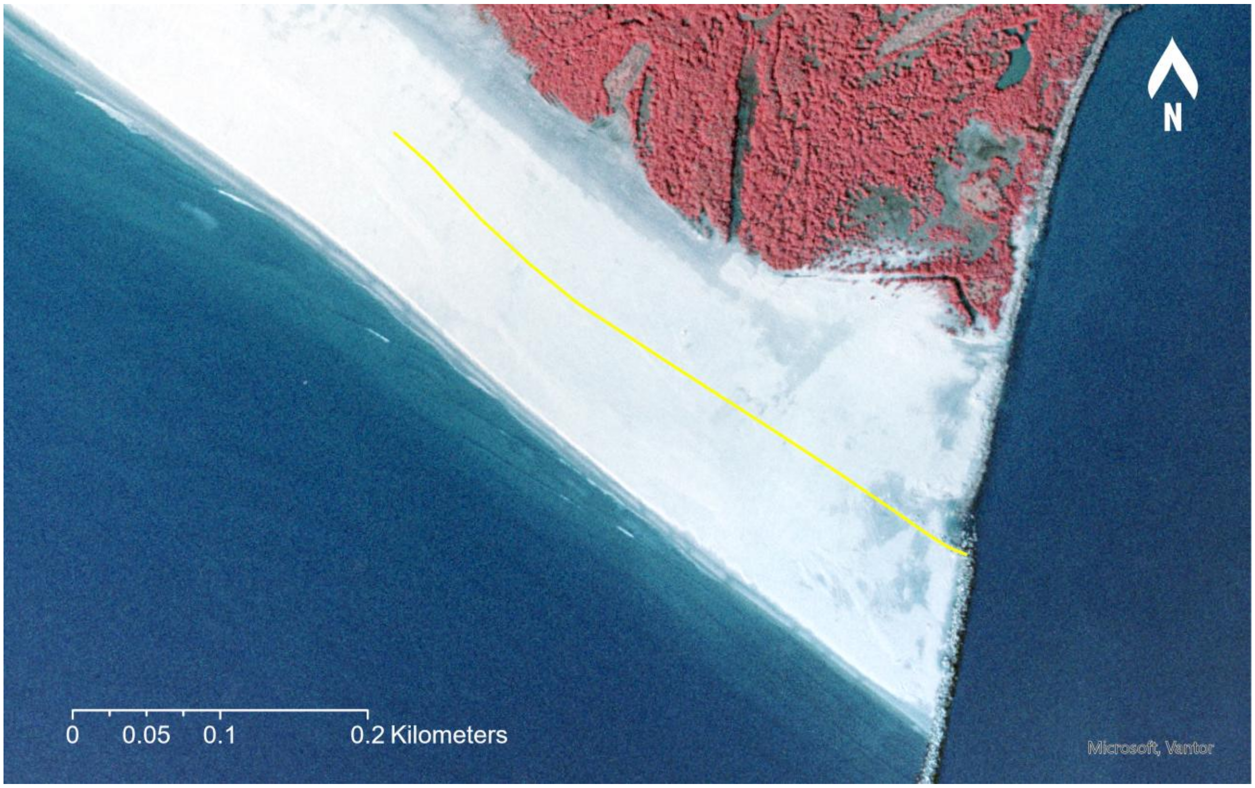


*Figure 17. Revetment (yellow line) located along the West Belle Pass Headland. Post-construction aerial imagery of West Belle Pass feeder beach included. Aerial imagery collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). Revetment location obtained from CPRA.*

The tracer analysis conducted by ET revealed that 15 samples had the presence of tracer. Thirteen samples had the presence of magenta tracer, one sample had the presence green tracer, and one sample had the presence of both magenta and green tracer (Figure 18). Of the samples that had tracers, two were located along the upper shoreface and the remaining samples were located along the headland at various environments.

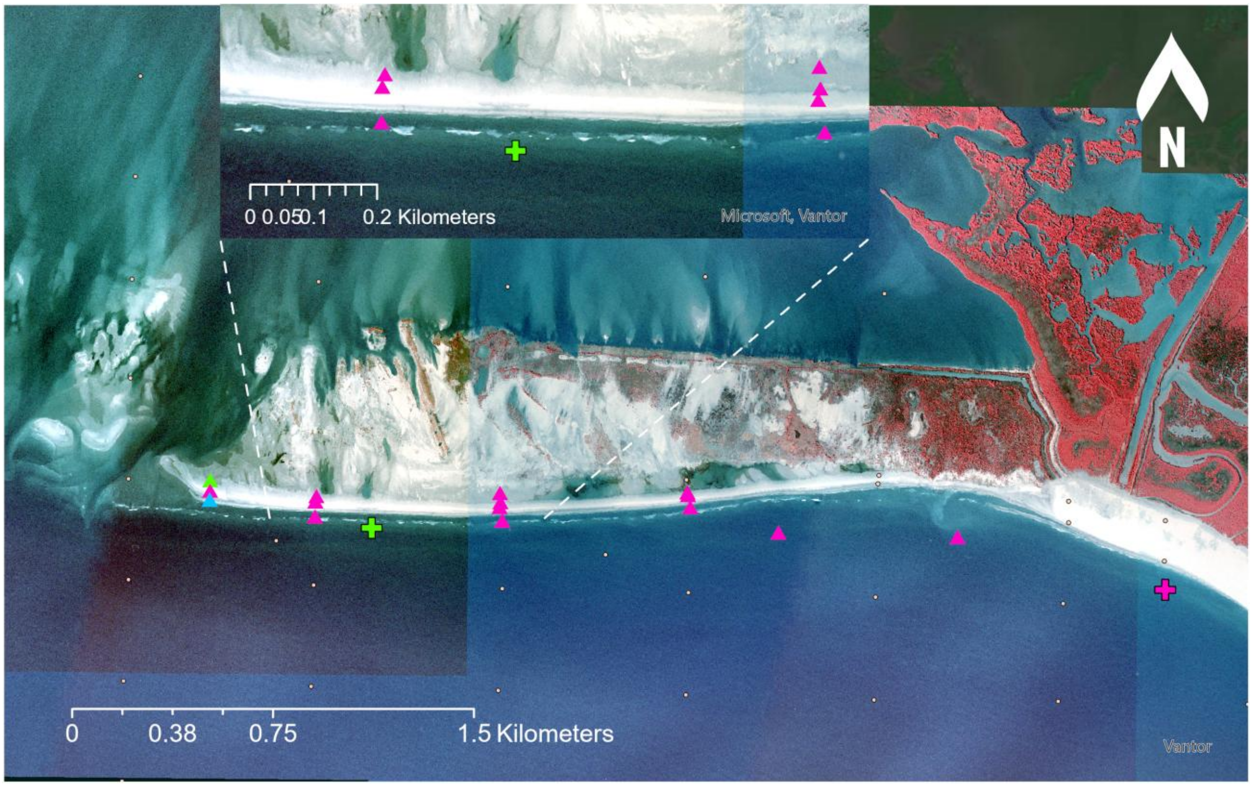


*Figure 18. Locations with tracer present during Sampling Event 2. Green triangles indicate presence of green tracer, magenta triangles indicate presence of magenta tracer, and blue triangle indicates the presence of both green and magenta tracer. Figure includes a zoomed-in panel at top of image to show locations along the headland where tracer was present. Colored crosses (green or magenta) indicate the tracer release locations. The horizontal coordinate system is NAD83 UTM Zone 15. Post-construction aerial imagery of West Belle Pass feeder beach and West Belle Pass restoration projects included. Aerial imagery collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022).*

*Table 5. Summary of tracer results for Sampling Event 2. Table includes details on presence of tracer grains by size class: Fine (125-250 µm), Medium (250-375 µm), and Coarse (375-500 µm). Additionally, tracer analysis estimates number of tracer particles per m$^2$.*

| Sample_ID | Environment | Green Tracer per m$^2$ (estimated) | Magenta Tracer per m$^2$ (estimated) | Green_ Fine | Green_ Medium | Green_ Coarse | Magenta_ Fine | Magenta_ Medium | Magenta_ Coarse |
|---|---|---|---|---|---|---|---|---|---|
| WB-2-001-L | Berm | 0 | 42 | 0 | 0 | 0 | 0 | 1 | 0 |
| WB-2-001-L- ALT(1) | Dune | 0 | 36 | 0 | 0 | 0 | 0 | 1 | 0 |
| WB-2-002-L | Beach face | 0 | 47 | 0 | 0 | 0 | 0 | 1 | 0 |
| WB-2-003-L | Beach face | 0 | 731 | 0 | 0 | 0 | 6 | 6 | 3 |
| WB-2-003-L-ALT(1) | Berm | 0 | 39 | 0 | 0 | 0 | 0 | 1 | 0 |
| WB-2-003-L-ALT(2) | Dune | 0 | 82 | 0 | 0 | 0 | 0 | 1 | 1 |
| WB-2-004-L | Beach face | 0 | 160 | 0 | 0 | 0 | 1 | 2 | 0 |
| WB-2-005-L | Berm | 0 | 102 | 0 | 0 | 0 | 1 | 1 | 0 |
| WB-2-005-L-ALT-(1) | Berm | 0 | 131 | 0 | 0 | 0 | 1 | 2 | 0 |
| WB-2-006-L (W) | Beach face | 0 | 311 | 0 | 0 | 0 | 1 | 3 | 1 |
| WB-2-015-L | Berm | 0 | 34 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-2-015-L-ALT(1) | Dune | 88 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| WB-2-016-W | Beach face | 63 | 126 | 1 | 0 | 0 | 0 | 2 | 0 |
| WB-2-084-W | Upper Shoreface | 0 | 110 | 0 | 0 | 0 | 1 | 1 | 0 |
| WB-2-135-W | Upper Shoreface | 0 | 176 | 0 | 0 | 0 | 1 | 2 | 0 |

## 3.4 TOPOBATHY ANALYSIS

The topobathy analysis was undertaken to inform planning of Sampling Event 3 because Sampling Events 1 and 2 showed very limited tracer movement, making it unclear whether the tracers had remained immobile or whether geomorphic changes in the headland and shoreface had redistributed sediment in ways not captured by the original sampling grid. An assessment of seafloor change using some newly available data was conducted to resolve this uncertainty and design a more targeted and defensible Sampling Event 3.

The objective of the analysis was to identify areas of measurable geomorphic change—erosion, deposition, bar migration, and shoreline movement—to determine which portions of the headland were actively reworking sediment and therefore most likely to transport tracer. By mapping these changes through time, the project team could infer potential tracer pathways, understand where tracer may have moved since the 2022 tracer release, and select sampling locations that maximized the likelihood of tracer detection during Sampling Event 3.

All survey datasets were projected to a common coordinate system (NAD 1983 UTM 15 N), standardized vertically (NAVD 88), and interpolated onto a consistent 75-m grid to ensure node alignment for elevation change calculations (Figure 11). This standardized framework allowed direct comparison between datasets collected under different survey contracts and with different extents/line spacing, providing a coherent basis for identifying change hotspots to guide the revised sampling strategy.

Figure 19–Figure 21 show elevation surfaces of the as-built feeder beach, a post-construction survey of the feeder beach, and the elevation difference between the two (Coastal Engineering Consultants Inc., 2022). The timespan between the as-built and post-construction surveys spans a range of a 2–5 month period, showing >1 m of erosion in some locations of the feeder beach.

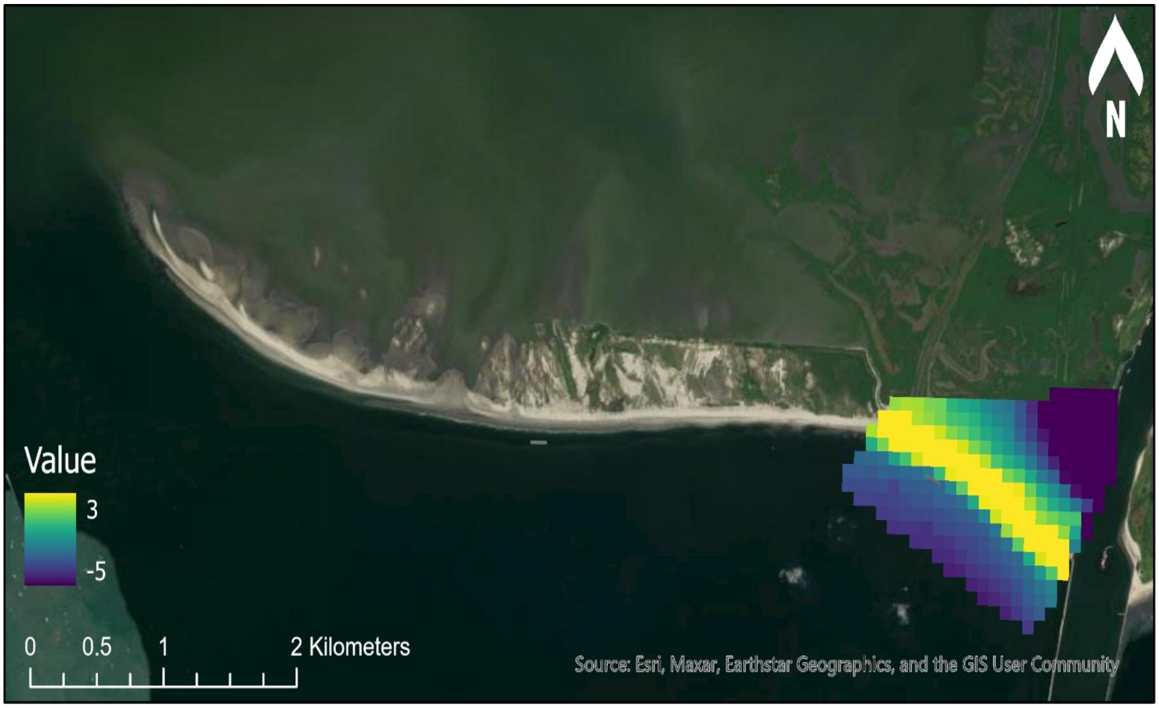


*Figure 19. Elevation surface from as-built survey of feeder beach (Coastal Engineering Consultants Inc., 2022). Survey dates range from 10/1/21-1/22/22. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference. Basemap provided by Maxar.*

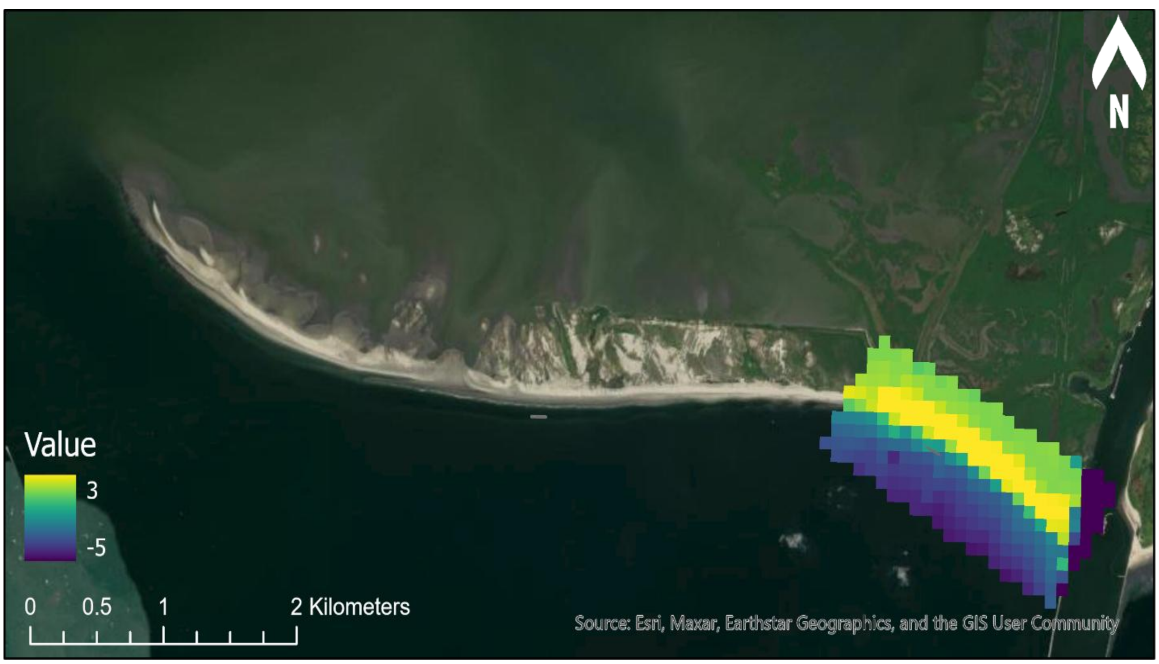


*Figure 20. Elevation surface from post-construction survey of the feeder beach (Coastal Engineering Consultants Inc., 2022). Survey dates range from 3/15/22-6/2/22. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference. Basemap provided by Maxar.*


*Figure 21. Elevation difference between subsequent surveys. Post-construction feeder beach survey minus as-built feeder beach survey (Coastal Engineering Consultants Inc., 2022). Timespan between surveys was approximately a 2–5 month period. Analysis shows clear erosion of the feeder beach over timespan. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

Sequential elevation-change maps showed clear spatial and temporal shifts in geomorphic conditions across the West Belle Pass Headland during the monitoring period. The elevation difference between the as-built feeder beach and post-Hurricane Zeta survey displayed a distinct zone of positive elevation change at the constructed fill (Figure 22), followed in the next interval by measurable upper shoreface and beach-face lowering that indicates post-construction adjustment. Subsequent comparisons revealed a concentrated area of accretion immediately west of the feeder-beach footprint and continued erosion along the upper shoreface, coinciding with spit elongation at the western end of the headland.

Mid-project surveys (T. Baker Smith, 2023, 2025) collected between November 2022 and May 2023 and between July and November 2024, respectively, documented widespread lower shoreface erosion, localized deposition within the mid-headland intertidal zone, and lateral spit accretion to the west. The most recent interval, including the post-Hurricane Francine reoccupation and T. Baker Smith Topobathy TE-0143 surveys (T. Baker Smith, 2025), captures additional upper shoreface retreat, overwash deposition, and backstepping of the headland near the western terminus. These combined datasets provide a comprehensive depiction of elevation change and potential tracer occurrence across the study area and were successful to inform the third sampling strategy that consisted of a more concentrated grid compared to Sampling Events 1 and 2. Remaining figures from the topobathymetric analysis, including elevation surfaces and difference maps, can be found in Appendix A.


*Figure 22. Elevation difference between subsequent surveys. As-built feeder beach survey minus post-Hurricane Zeta survey. Timespan between surveys was approximately two years. Dataset shows clear construction of the feeder beach. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Positive values (blue) indicate deposition and negative values (red) indicate erosion. Areas where tracer release occurred shown as polygons for reference.*

## 3.5 SAMPLING EVENT 3

Results from the topobathy analysis and tracer results from Sampling Events 1 and 2 informed the design of the sample plan that consisted of a new grid with 255 proposed sample locations (Figure 6). A total of 262 samples were collected (Figure 23). Field crews had to move sample locations based on conditions in the field, primarily because the final locations selected were based on outdated imagery of the highly dynamic headland. Examples of moving point locations included shifting land samples to the actual location of targeted environments (i.e., beach face, berm, and dune) and either moving or excluding collection sites for upper shoreface water samples due to their location being in the surf zone, making for unsafe sampling conditions.

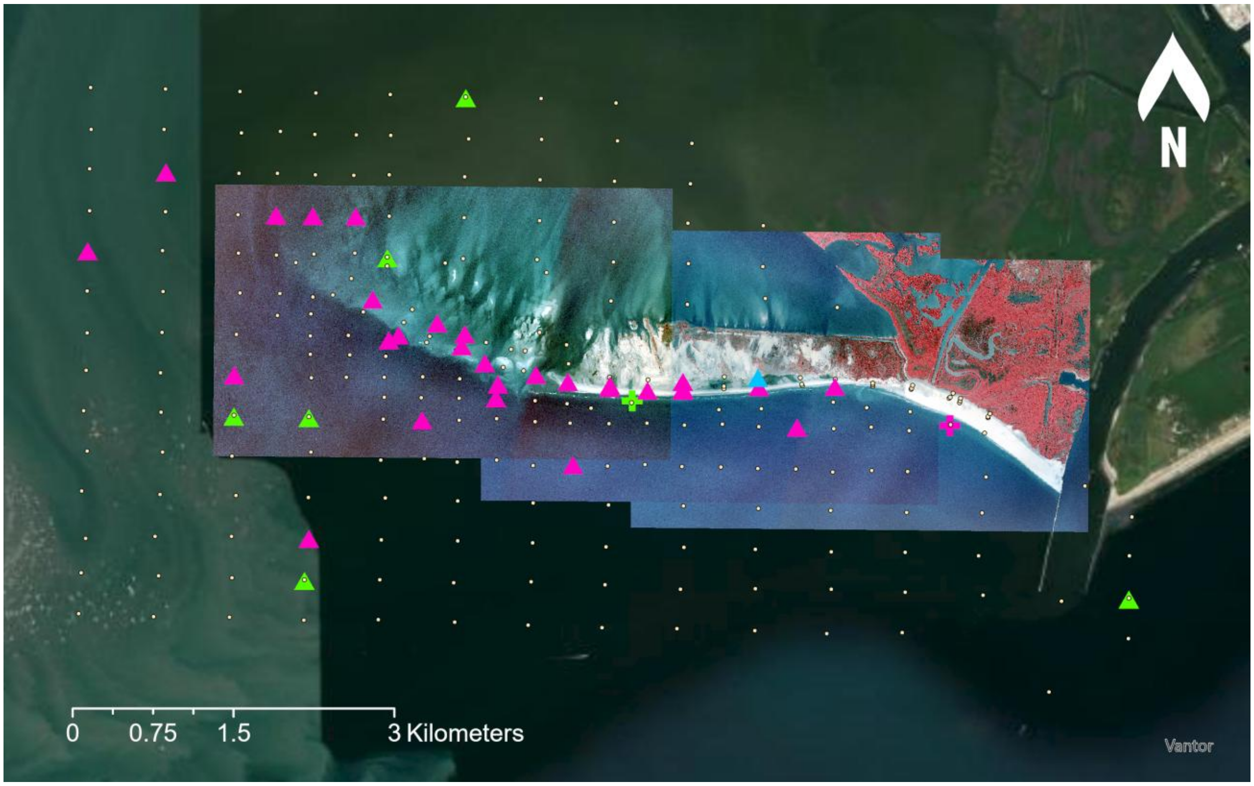


*Figure 23. Actual sample locations for Sampling Event 3 (tan circles). Tracer hits are denoted by triangles. Green triangles indicate presence of green tracer. Magenta triangles indicate presence of magenta tracer. Blue triangle indicates presence of both tracers. Colored crosses (green or magenta) indicate the tracer release locations. The horizontal coordinate system is NAD83 UTM Zone 15. Post-construction aerial imagery of West Belle Pass feeder beach and West Belle Pass restoration projects included. Aerial imagery collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). Basemap provided by Vantor.*

Field teams also collected shallow (1 ft.) subsurface samples on land at select locations that were interpreted as accretional portions of the beach (in the field by a geomorphologist at the time of sampling). Subsurface samples are denoted in the environment attribute of all data files. Active accretionary processes were observed near the western terminus of the headland, with active sandbars welding onshore (Figure 24).

*Figure 24. Photo of West Belle Pass Headland looking west towards the end of the spit. Active sandbar welding onshore captured in the image. Photo credit: Michael Miner.*

Field efforts were conducted jointly by personnel UNO PIES and the Institute on the following days:

- July 14, 2025
- July 15, 2025
- July 16, 2025
- July 21, 2025
- July 22, 2025
- July 23, 2025

The same protocols (i.e., sampling methodology and QA/QC) were used for Sampling Event 3. After sample collection, field samples were sent overseas to ET for tracer analysis.

Tracer analysis conducted by ET revealed the presence of tracer in 35 samples (Figure 23 and Table 6). One sample had both green and magenta tracer present, six samples had green tracer present, and 28 samples had magenta tracer present. Sampling environments with the presence of tracer spanned the upper and lower shoreface, flood tidal delta, backbarrier, and multiple environments along the headland (e.g., beach face, berm, dune, overwash, etc.). Tracer was present in seven subsurface samples.

*Table 6. Summary of tracer results for Sampling Event 3. Table includes details on presence of tracer grains by size class: Fine (125-250 μm), Medium (250-375 μm), and Coarse (375-500 μm). Additionally, tracer analysis estimates number of tracer particles per m².*

| Sample_ID | Environ. | Green Tracer per m² (estimated) | Magenta Tracer per m² (estimated) | Green_ Fine | Green_ Medium | Green_ Coarse | Magenta_ Fine | Magenta_ Medium | Magenta_ Coarse |
|---|---|---|---|---|---|---|---|---|---|
| WB-3-001-ALT-(1)-BF | Beach face | 0 | 59 | 0 | 0 | 0 | 0 | 0 | 1 |
| WB-3-001-BM | Berm | 0 | 56 | 0 | 0 | 0 | 0 | 0 | 1 |
| WB-3-003-ALT(1)-BM SUBSURFACE | Berm subsurface | 0 | 52 | 0 | 0 | 0 | 0 | 1 | 0 |
| WB-3-003-ALT(2)-DN | Dune | 0 | 104 | 0 | 0 | 0 | 0 | 1 | 1 |
| WB-3-004-BF | Beach face | 0 | 102 | 0 | 0 | 0 | 1 | 1 | 0 |
| WB-3-005-ALT (1)-BM SUBSURFACE | Berm subsurface | 0 | 55 | 0 | 0 | 0 | 0 | 1 | 0 |
| WB-3-005-ALT (2)-DN | Dune | 56 | 56 | 1 | 0 | 0 | 0 | 0 | 1 |
| WB-3-007-BF | Beach face | 0 | 52 | 0 | 0 | 0 | 0 | 0 | 1 |
| WB-3-015-ALT-BF | Beach face | 0 | 55 | 0 | 0 | 0 | 0 | 0 | 1 |
| WB-3-107-W | Upper Shoreface | 85 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| WB-3-118-W | Lower Shoreface | 59 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| WB-3-125-W | Upper Shoreface | 0 | 58 | 0 | 0 | 0 | 0 | 0 | 1 |
| WB-3-179-W | Upper Shoreface | 69 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| WB-3-180-W | Upper Shoreface | 66 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| WB-3-194-W | Upper Shoreface | 0 | 71 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-3-198-BF SUBSURFACE | Beach face subsurface | 0 | 48 | 0 | 0 | 0 | 0 | 1 | 0 |
| WB-3-209-W | Upper Shoreface | 0 | 69 | 0 | 0 | 0 | 0 | 1 | 0 |
| WB-3-210-OW/BB SUBSURFACE | Overwash/ba ckbarrier subsurface | 0 | 42 | 0 | 0 | 0 | 1 | 0 | 0 |

| Sample_ID | Environ. | Green Tracer per $m^2$ (estimated) | Magenta Tracer per $m^2$ (estimated) | Green_ Fine | Green_ Medium | Green_ Coarse | Magenta_ Fine | Magenta_ Medium | Magenta_ Coarse |
|---|---|---|---|---|---|---|---|---|---|
| WB-3-233-W | Flood Tidal Delta | 0 | 73 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-3-237-W | Flood Tidal Delta | 67 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| WB-3-251-W | Flood Tidal Delta | 0 | 236 | 0 | 0 | 0 | 1 | 2 | 1 |
| WB-3-264-W | Flood Tidal Delta | 0 | 68 | 0 | 0 | 0 | 0 | 1 | 0 |
| WB-3-293-W | Flood Tidal Delta | 59 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| WB-3-409-OW SUBSURFACE | Overwash subsurface | 0 | 45 | 0 | 0 | 0 | 0 | 0 | 1 |
| WB-3-410-BF SUBSURFACE | Beach face subsurface | 0 | 45 | 0 | 0 | 0 | 0 | 0 | 1 |
| WB-3-428-W | Upper Shoreface | 0 | 59 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-3-431-W | Upper Shoreface | 0 | 76 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-3-434-W | Upper Shoreface | 0 | 70 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-3-439-W | Upper Shoreface | 0 | 51 | 0 | 0 | 0 | 1 | 0 | 0 |
| WB-3-443-W | Flood Tidal Delta | 0 | 133 | 0 | 0 | 0 | 0 | 1 | 1 |
| WB-3-444-W | Flood Tidal Delta | 0 | 62 | 0 | 0 | 0 | 0 | 0 | 1 |
| WB-3-448-BB SHORELINE SUBSURFACE | Backbarrier shoreline subsurface | 0 | 39 | 0 | 0 | 0 | 0 | 0 | 1 |
| WB-3-454-BF | Beach face | 0 | 85 | 0 | 0 | 0 | 0 | 0 | 2 |
| WB-3-463-W | Upper Shoreface | 0 | 48 | | | | 1 | | |
| WB-3-904-OW | Overwash | 0 | 197 | 0 | 0 | 0 | 0 | 0 | 4 |
| WB-3-905-BM | Berm | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 1 |

# 4 DISCUSSION

The tracer and topobathymetric analysis results collectively demonstrate that the West Belle Pass feeder beach is highly dynamic and that placed sediment is rapidly reworked and redistributed along the headland. The magenta tracer (300 kg released in the upper shoreface of the feeder beach) was detected in all three sampling events and across a progressively broader range of geomorphic environments relative to the green tracer, including the upper and lower shoreface, beach face, berm, dune, overwash, backbarrier, and flood tidal delta. In contrast, the green tracer (500 kg released farther west along the headland) was detected in fewer samples and at generally low concentrations. Detected tracer dispersal, coupled with sediment deposition and erosional patterns identified in the topobathymetric change analysis, indicates that nourishment material sourced from the feeder beach has dominated sediment supply along much of the headland during the monitoring period. A summary figure with results from all sampling events is shown in Figure 25.

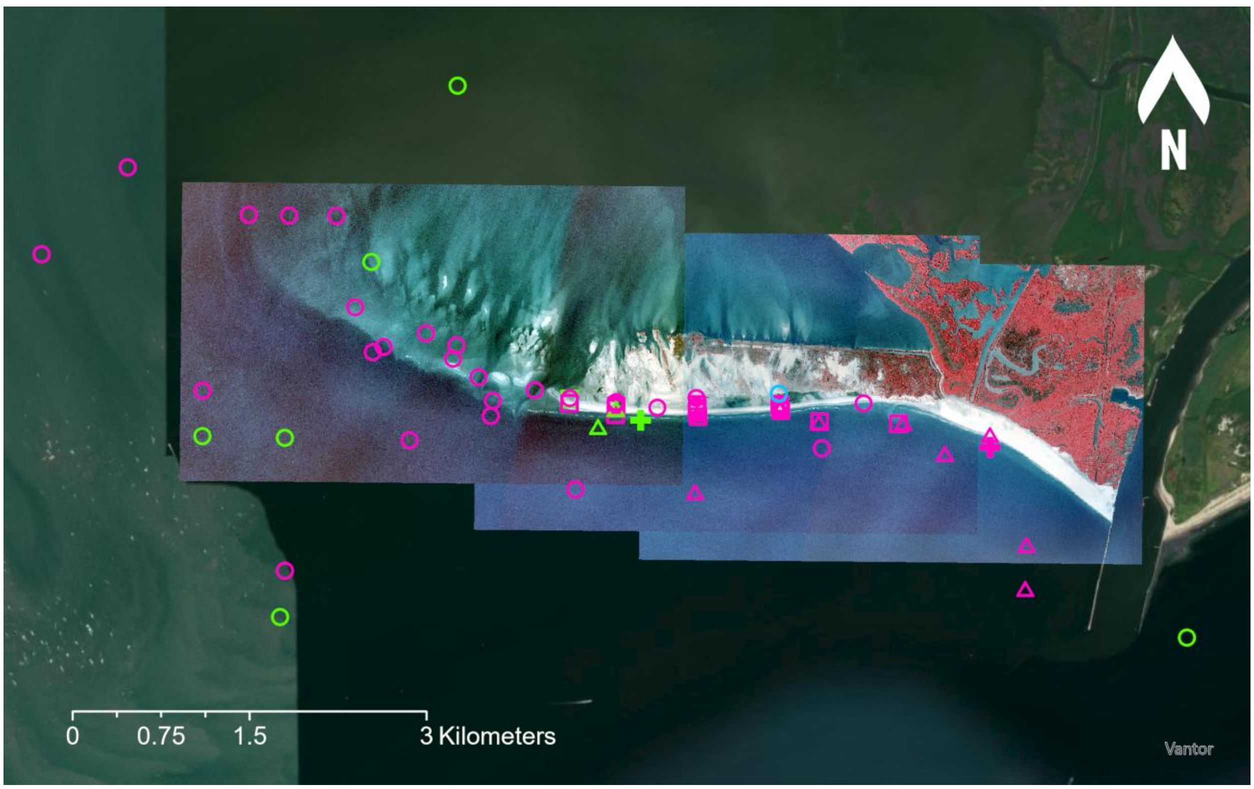


*Figure 25. Summary of tracer results from all Sampling Events. Triangles correspond to Sampling Event 1. Squares correspond to Sampling Event 2. Circles correspond to Sampling Event 3. Symbol color denotes the presence of a particular tracer (green or magenta). Blue symbols indicate the presence of both tracers at a location. Colored crosses (green or magenta) indicate the tracer release locations. The horizontal coordinate system is NAD83 UTM Zone 15. Post-construction aerial imagery of West Belle Pass feeder beach and West Belle Pass restoration projects included. Aerial imagery collected Feb. 14, 2022 (Coastal Engineering Consultants Inc., 2022). Basemap provided by Earthstar Geographics.*

Sampling Event 1 was conducted in November and December of 2022, approximately 3 months after tracer release. This yielded a limited number of detections (12 samples with tracer, predominantly magenta) concentrated along the upper shoreface and at a few land-based locations. At that time, the newly constructed feeder beach was out of equilibrium, and the initial post-release sampling grid emphasized broad spatial coverage rather than targeted high-density sampling in active zones of change. The sparse tracer detections in Sampling Event 1 can be attributed to 1) early-stage dispersal of magenta tracer, potential as transient deposits, on the highly dynamic shoreface, 2) the coarse spatial resolution of the sample grid, which may have missed narrow transport corridors where drift can concentrate along nearshore bars, and 3) burial downdrift by sand shed from the newly constructed feeder beech.

By Sampling Event 2 in June and July 2023, the samples in which tracer was recovered reflect the process of the feeder beach's continued equilibration, which provided for a localized and temporary increase in sand supply downdrift. Field observations and survey comparisons documented ~70 m of shoreline retreat at the feeder beach near the Belle Pass jetties (time period of 1 year and 4.5 months between aerial photography and field observation), exposure of a previously buried revetment, and continued upper shoreface erosion, particularly proximal to the feeder beach. Tracer detections increased modestly (15 samples with tracer), with magenta recovered primarily along the headland in berm, beach-face, and dune environments and a small number of detections in upper shoreface samples. Green tracer detection remained scarce, appearing at only two locations. The combination of pronounced shoreline retreat, upper shoreface lowering, and limited green tracer recovery suggests that the western headland segment is strongly influenced by sediment exported from the feeder beach and that the original green tracer likely underwent rapid burial and/or dilution below detection thresholds as the beach and shoreface adjusted.

The time-series topobathymetric analysis, conducted subsequently to Sample Event 2, provided an additional data source to support the sediment transport trends interpreted from the tracer data. Elevation-change maps developed as part of this study show:

- Construction and subsequent rapid adjustment of the feeder beach, with >1 m of erosion in portions of the fill footprint between the as-built and post-construction surveys.
- Concentrated accretion along the mid- and downdrift (western) headland, coincident with observed spit elongation and evidence of sandbar welding at the western terminus.
- Repeated lower shoreface erosion paired with localized intertidal and supratidal deposition, indicating shoreface retreat and landward transfer of sediment to the nearshore and subaerial spit.
- Overwash and backbarrier deposition in later survey intervals, particularly following storms such as Francine, demonstrating active landward sediment transport pathways (Figure 26).

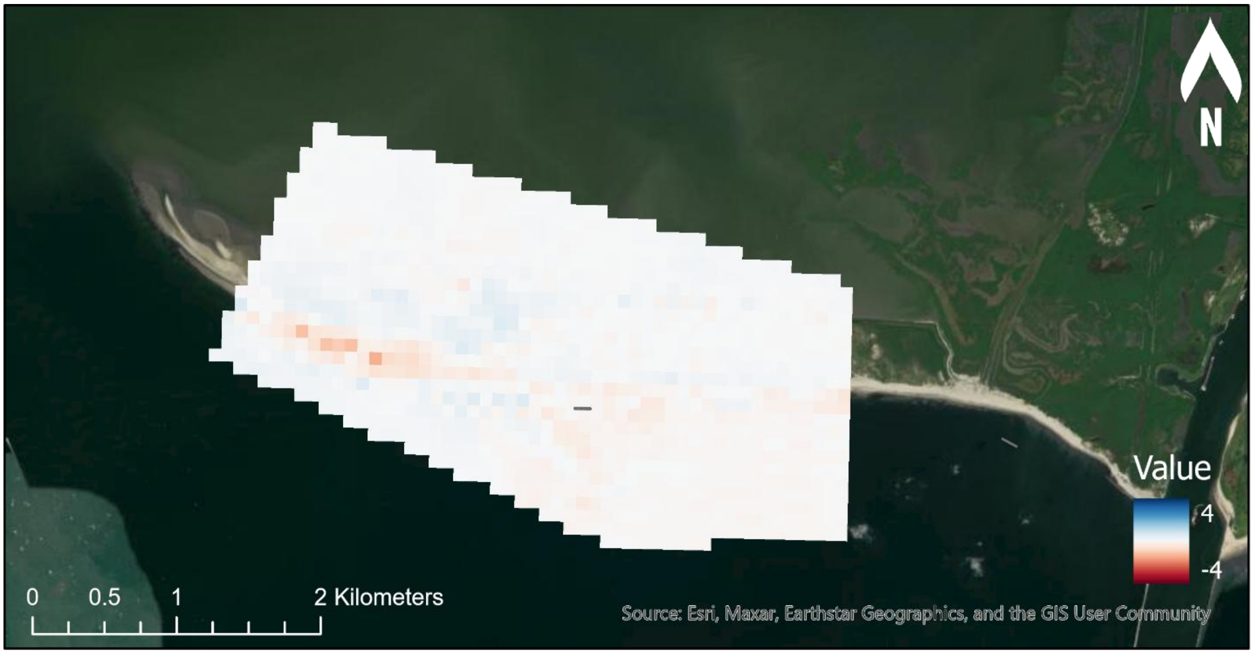


*Figure 26. Post-Francine Reoccupation minus T Baker Smith TE143. Elevation difference- positive values indicate deposition and negative values indicate erosion. T Baker Smith TE143 survey date between 7/30/24-8/22/24. Post Francine reoccupation survey date between 12/12/24–3/12/25. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

Additionally, a land-change analysis conducted for another study (Coastal Engineering Consultants Inc., 2025) used time-series aerial photography to determine Hurricane Francine (Figure 2) impacts to TE-0143 and the West Belle Pass Headland. These results provide independent validation of the sediment transport pathways interpreted from the tracer and topobathymetric change analyses (Figure 27). The Coastal Engineering Consultants (2025) assessment, compared pre-Francine (2022–2023) and post-Francine (2025) conditions, shows substantial net land gain (~95 acres) along the West Belle Pass Headland, most of which can be attributed to lateral spit accretion, and land loss (~67 acres) concentrated at the feeder beach and a narrow zone of shoreline retreat along the central portion of the spit downdrift of the feeder beach.

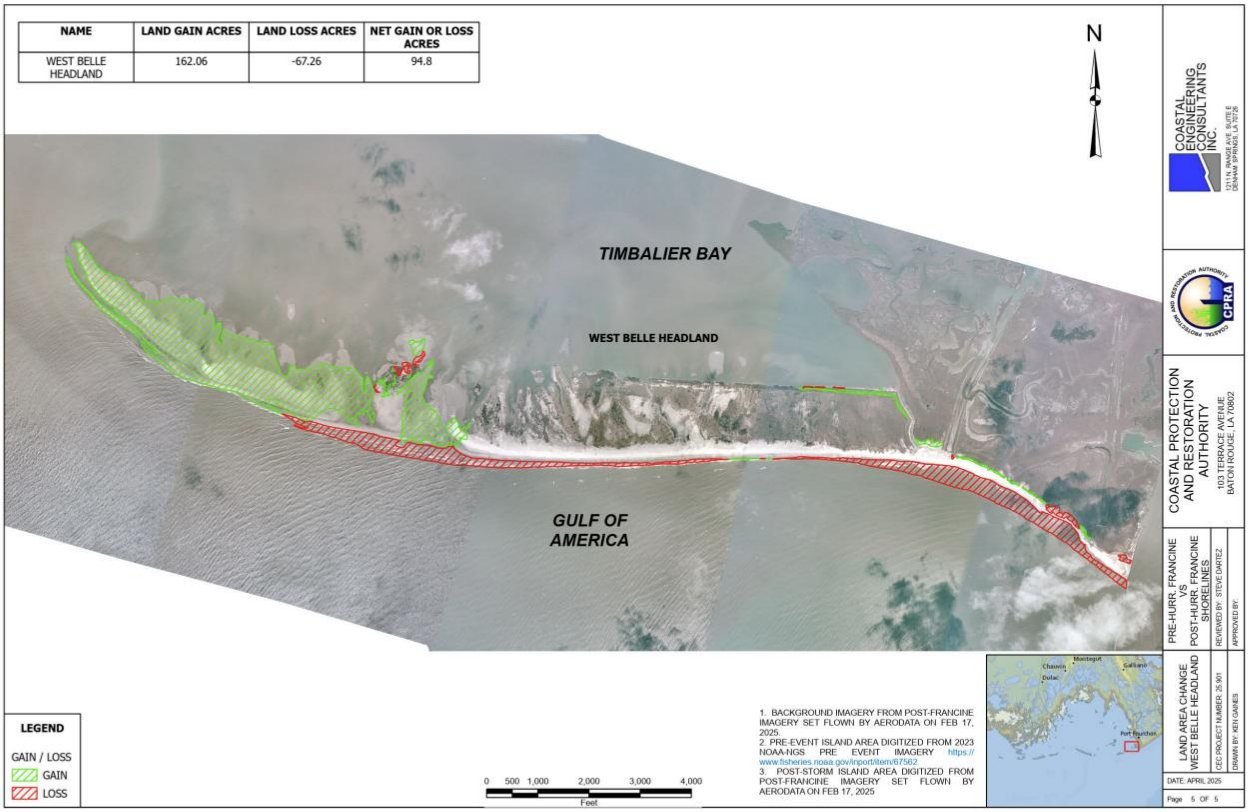


*Figure 27. Land gain (green hashed polygons) and land loss (red hashed polygons) derived from aerial imagery between 2022/2023 to 2025. The 2025 imagery was collected Post Hurricane Francine. Image sourced from (Coastal Engineering Consultants Inc., 2025).*

These sedimentation patterns and geomorphic responses are consistent with a wave- and storm-dominated setting located downdrift of a structure that provides partial wave-sheltering (West Belle Pass jetties), where engineered sediment pulses (i.e., feeder beach nourishment) are redistributed alongshore, driving spit accretion, and episodically across shore into the back-barrier. The tracer results effectively confirm that nourishment material is mobilized and routed through the full spit cross-shore profile (Figure 28), not simply confined to the beach face. Earlier sediment additions to the West Belle Pass headland show a similar migration pattern. Longshore transport dominates under typical conditions, while cross-shore transport is largely confined to the spit and occurs along the headland mainly during extreme storm events, consistent with historical observations of jetty bypassing and storm-driven rollover at Belle Pass and post-construction monitoring from the TE-52 restoration project (Curole et al., 2017; Dantin et al., 1974).

*Figure 28. Drone imagery showing western terminus of the West Belle Pass headland showing the active spit complex, where the majority of tracer was observed. Active sandbar welding onshore is evident. Top image is looking east toward Port Fourchon and bottom image is looking west toward Terrebonne Bay. Imagery provided by CPRA and taken on August 1, 2024.*

Sampling Event 3 occurred in July 2025, and, unlike Events 1 and 2, sample locations were selected using the topobathymetric change analysis and results from the two previous tracer sampling events. The results for Sampling Event 3, coupled with the land change (Coastal Engineering Consultants Inc., 2025) and topobathymetric analysis, produced the most comprehensive picture of sediment pathways. The revised grid increased sampling density along the upper shoreface and beach and added shallow subsurface samples at locations interpreted as depositional (e.g., berm, overwash, and backbarrier). This targeted strategy greatly improved tracer recovery, with 35 samples containing tracer, including 28 with magenta and 7 with green (one of which contained both colors). Magenta tracer was detected across nearly all major environments: upper and lower shoreface, flood tidal delta, beach face, berm, dune, overwash, and backbarrier. The presence of magenta in multiple subsurface samples confirms that feeder beach sediment is not only transported alongshore but is also being buried within accretionary portions of the beach and overwash system.

Green tracer detections in Sampling Event 3, while still relatively minimal, were more spatially consistent than in earlier events, appearing in the upper and lower shoreface, flood tidal delta/tidal inlet, and at one dune site. This pattern supports the hypothesis that green tracer has been mixed and redistributed within the active nearshore system but much of it is probably buried beneath more recent spit, nearshore bar, and overwash deposits. In other words, the tracer signal from the western release site has been “overprinted” by the larger volume of tracer-free sand introduced from nourishment and liberated from the feeder beach as it equilibrates. The limited but meaningful detections of green tracer in the flood tidal delta and backbarrier demonstrate that a portion of the western release sediment is incorporated into the tidal-inlet and backbarrier sediment budget, but likely at concentrations near the lower limit of tracer detectability or most likely buried in the subsurface and potentially some inlet-sediment bypassing to downdrift shorelines.

Collectively, the tracer and topobathy results indicate that: 1) the feeder beach functions as designed: an effective sediment source for the downdrift headland and spit; 2) the majority of sediment tracer experiences multiple cycles of erosion, transport, and deposition across the shoreface, intertidal zone, and backbarrier; and 3) burial in accretional deposits (spit and backbarrier) is a key pathway for long-term storage of sediment sourced from the feeder beach. At the same time, the limited tracer recoveries in Sampling Events 1 and 2, and modest green tracer detection overall, highlight important methodological constraints: the coarse initial grid spacing, the absence of deeper subsurface sampling (vibracores), and the challenge of tracking relatively small tracer masses over multi-year timescales in a storm-dominated system.

Despite these limitations, the study meets its primary objective of clearly identifying sediment pathways and geomorphic response to restoration and storm impacts at the West Belle Pass Headland. The data confirm the success of applying process geomorphic concepts to inform strategic sediment placement to introduce and retain new sand into a sand-starved system. The tracer patterns and elevation changes together provide a robust, process-based understanding that can inform both future nourishment design and system-wide performance monitoring for barrier island restoration programs.

# 5 CONCLUSION

This study demonstrates that the West Belle Pass feeder beach functions as designed, serving as a highly effective sediment source that nourishes the downdrift shorelines well beyond the design fill template, enhances spit elongation (and extent of protective barrier shoreline), and conservation of sand within the system via landward transport as overwash, flood-tidal delta, and recurve spit platform deposits. The combined dataset—tracer results, topobathy results, and independent Coastal Engineering Consultants land-change analysis—reveals a coupled system in which wave-driven transport, storm overwash, and the post-construction restored beach equilibration collectively redistribute placed sediment throughout the barrier complex.

Key conclusions include:

- **Fluorescent sand tracers, coupled with geomorphic change analysis (topobathymetric and shoreline change) are an effective tool to assess barrier restoration success and contributions of placed sediment to the regional barrier system beyond the designed fill template.** This technology could also be adapted to quantify sediment losses from the system versus those retained and derive restoration project benefits (e.g., volume of sand introduced to the sand-starved system, island area, etc.) beyond project lifespan and project area.
- **Feeder beach sediment is rapidly mobilized and widely dispersed along predicted pathways, primarily to beneficial depositional sites that retain sand within the active barrier system**. Magenta tracer confirmed sustained longshore transport and landward-directed cross-shore transport, with detections spanning the full profile from lower shoreface to backbarrier.
- **The feeder beach creates a sand surplus that utilizes natural processes to inject sand to offset a deficit in the regional sand budget.** Throughout the three sampling events, magenta tracer (released near the feeder beach) was consistently detected, primarily migrating westward increasing barrier spit land area.
- **Storms facilitate and accelerate landward transfer of sand via overwash and tidal inlet processes for this study area.** Francine-related overwash and backbarrier deposition align with tracer pathways and burial, providing evidence that sediment sourced from the feeder beach (and potentially the shoreface) and contribute to the long-term barrier evolution.

Building on the findings of this study, focused next steps could strengthen the understanding of sediment pathways on the West Belle Pass Headland and sediment delivery downdrift to East Timbalier Island/Shoal, Raccoon Pass inlet sediment bypassing, and the Calumet and Casse-Tete Islands with findings relevant to improving restoration design, adaptive management approaches, and conservation of limited sand resources for all Louisiana barrier island systems:

1. Collect sediment cores strategically in areas of high deposition to verify burial and storage.
    a) Targeted coring (>1 m length) can be conducted at locations where tracer has been repeatedly detected or where elevation change indicates deposition.
    b) Results can help determine if nourished sediment is incorporated into the barrier system and retained long-term.

2. Deploy additional tracer (new colors) based on the findings of this study to determine key sediment sources and sinks (e.g., release different colors in targeted geomorphic features such as lower shoreface, ebb tidal delta, flood tidal delta, berm).
3. Identify continued reoccupation of existing sample location grid with potential expansion as tracer migrates beyond the study area sampled here.
4. Integrate sampling and tracer analysis with ongoing studies and future restoration activities.
    a. It is the project team's understanding that sediment sampling will be conducted in 2026 along the backbarrier of the West Belle Pass Headland. This provides an opportunity to piggyback on this study with potential cost savings related to mobilization, demobilization, and field efforts.
    b. New sand will be placed from Ship Shoal within the study area with Federal Emergency Management Agency funds to mitigate for hurricanes Ida and Zeta impacts TO-0143.
    c. Expansion of the study area to calibrate results from CPRA's Operational Sediment Budget and Barrier Island Comprehensive Monitoring program tasks focused on overwash and seafloor change.
    d. Future monitoring and adaptive management of TE-0143 and planned restoration of East Timbalier and/or Casse-Tete and Calumet Islands.
5. Use results to inform/refine future nourishment and headland-maintenance designs.
    a. The consistent patterns observed across tracer results, elevation differences from the topobathy analysis, and independent land-change analysis should inform placement strategies and the anticipated downdrift benefits on future projects across the Caminada Headland barrier complex (including Timbalier Islands, Casse-Tete/Calumet, West Belle Pass, Caminada Headland, and Grand Isle) and similar locations across Louisiana. Incorporating these findings to inform design templates can potentially lead to increases in project longevity and retention of sand within the system.
    b. Inform how sediment resources from maintenance of Belle Pass navigation channel might be strategically placed to maximize benefit to the coastal sediment budget.

Together, these actions can close remaining data gaps, strengthen confidence in sediment routing interpretations, and ensure that lessons learned from this tracer study can be incorporated into future restoration projects and system-wide barrier shoreline management to enhance performance and maximize benefits of introducing new sediment into the sand-starved and rapidly disintegrating barrier island system.

# 6 REFERENCES


Bosse, S. T., Flocks, J. G., Bernier, J. C., Georgiou, I. Y., Kulp, M. A., & Brown, M. (2019). Louisiana Coastal Zone sediment characterization; Comparison of sediment grain sizes for samples collected in 2008 and 2015–2016 from the western Chenier plain to the Chandeleur Islands, Louisiana—Louisiana Barrier Island Comprehensive Monitoring (BICM) Program. *US Geological Survey Open-File Report*, *1132*, 17.

Boyd, R., & Penland, S. (1988). A geomorphic model for Mississippi Delta evolution. *Transactions of the Gulf Coast Association of Geological Societies*, *38*, 443–452.

British Standard. (1990). BS 1377-2: 1990. *Methods of Test for Soils for Civil Engineering Purposes-Part*, *2*.

British Standard. (1999). *Testing aggregates: part 2 : methods of determination of density*. London: British Standards Institution.

Coastal Engineering Consultants Inc. (2022). *Terrebonne Basin Barrier Island and Beach Nourishment (TE-143) Project Completion Report*. Coastal Engineering Consultants Inc.

Coastal Engineering Consultants Inc. (2025). *Post-Francine Barrier Island Assessment*.

Curole, G., Hartman, B., & Lee, D. (2017). *2017 Operations, Maintenance, and Monitoring Report for West Belle Pass Barrier Headland Restoration (TE-52)*. Coastal Protection and Restoration Authority.

Dantin, E., Whitehurst, C., & Durbin, W. (1974). *An Investigation of Environmental Factors associated with the Current and Proposed Jetty Systems, at Belle Pass, Louisiana*. Louisiana State University.

Deltares. (2019). *D-Flow Flexible Mesh Suite: User Manual* (Version 1.5.0) (p. 412). Netherlands: Deltares.

Engelund, Frank. A., & Hansen, E. (1967). *Monograph on sediment transport in alluvial streams*. Teknisk forlag.

Georgiou, I. Y., FitzGerald, D. M., & Stone, G. W. (2005). The impact of physical processes along the Louisiana coast. *Journal of Coastal Research*, *Special Issue*(44), 72–89.

Kulp, M. A., FitzGerald, D. M., Penland, S., Motti, J., Brown, M., Flocks, J. G., Miner, M. D., McCarty, P., & Mobley, C. (2006). Stratigraphic architecture of a transgressive tidal inlet-flood tidal delta system: Raccoon Pass, Louisiana. *Journal of Coastal Research*, *Special Issue*(39), 1731–1736.

Kulp, M. A., FitzGerald, D. M., & Penland, Shea. (2005). Sand-rich lithosomes of the Holocene Mississippi River Delta Plain. *SEPM Journal of Sedimentary Research*, 277–294.

Kulp, M. A., Georgiou, I. Y., Marchal, K. L., Kramer, J. N., Adams, A. P., Fitzgerald, D. M., & Yocum, T. E. (2015a). Geomorphic Evolution of the Coupled Raccoon Pass and West Belle Pass Barrier Spit, Louisiana, 57.

Kulp, M., Georgiou, I., Brown, M., Courtois, A., Flocks, J., & Tuten, T. (2015b). *Louisiana Barrier Island Comprehensive Monitoring Program (BICM) Phase 2 - 2015 Characterization of Surficial Sediments in the Early Lafourche Delta, Late Lafourche Delta, Modern Delta, and Chandeleur Islands Regions: Part A - Data Collection, Sample Processing and Products* (p. 16).

Madsen, O. S., & Grant, W. D. (1976). Sediment transport in the coastal environment.

McBride, R. A., & Byrnes, M. R. (1997). Regional variations in shore response along barrier island systems of the Mississippi River Delta Plain: Historical change and future prediction. *Journal of Coastal Research*, *13*(3), 628–655.

Meyer-Peter, E., & Muller, R. (1948). Formulas for Bed-Load transport.

Miner, M. D., Kulp, M. A., FitzGerald, D. M., & Georgiou, I. Y. (2009). Hurricane-associated ebb-tidal delta sediment dynamics. *Geology*, *37*(9), 851–854.

Penland, P. S. (1990). *Barrier Island Evolution, Delta Plain Development, and Chenier Plain Formation in Louisiana.* (Doctor of Philosophy). Louisiana State University and Agricultural and Mechanical College, Louisiana.

Penland, S., Boyd, R., & Suter, J. R. (1988). Transgressive depositional systems of the Mississippi delta plain: A model for barrier shoreline and shelf sand development. *Journal of Sedimentary Petrology*, *58*(6), 932–949.

Penland, S., Nummedal, D., Roberts, H., & Boyd, R. (1981). Deltaic barrier development on the Louisiana coast. *Supplement to Transactions of the Gulf Coast Association of Geological Societies*, *31*, 471–476.

Roberts, H. H. (1997). Dynamic changes of the Holocene Mississippi River Delta plain: The delta cycle. *Journal of Coastal Research*, *13*(3), 605–627.

T. Baker Smith. (2023). Louisiana Barrier Island Comprehensive Monitoring Program (BICM3) 2022 Regional Bathymetric Survey - Sandy Point to Timbalier Island.

T. Baker Smith. (2025). *Topographic and Bathymetric Surveys of Terrebonne Basin Barrier Island and Beach Nourishment (TE-143) Terrebonne and LaFourche Parishes*. T. Baker Smith.

The Water Institute. (2022). *Partnership for Our Working Coast: A Community-Informed Transdisciplinary Approach to Maximizing Benefits of Dredged Sediment for Wetland Restoration Planning at Port Fourchon, Louisiana*. Baton Rouge, LA: The Water Institute of the Gulf. Prepared for and funded by The National Fish and Wildlife Foundation, Shell, Chevron, Danos, and the Greater Lafourche Port Commission.

The Water Institute. (2023a). *Task Order 97 Field Sampling Effort 1* (Technical Memo).

The Water Institute. (2023b). *Task Order 97 Field Sampling Effort 2* (Technical Memo).

The Water Institute. (2025). *Task Order 97 Field Sampling Effort 3* (Technical Memo).

Van Andel, T. H., & Poole, D. M. (1960). Sources of recent sediments in the northern Gulf of Mexico. *Journal of Sedimentary Research*, *30*(1), 91–122.

van Rijn, L. C. (2007a). Unified View of Sediment Transport by Currents and Waves. I: Initiation of Motion, Bed Roughness, and Bed-Load Transport. *Journal of Hydraulic Engineering*, *133*(6), 649–667.

van Rijn, L. C. (2007b). Unified View of Sediment Transport by Currents and Waves. II: Suspended Transport. *Journal of Hydraulic Engineering*, *133*(6), 668–689.

Williams, S. J., Penland, S., & Sallenger, A. (Eds.). (1992). *Louisiana barrier island erosion study: Atlas of shoreline changes in Louisiana from 1853-1989*. Reston, VA: U.S. Geological Survey.

Yocum, T. E., Kulp, M. A., Brown, M. A., & Georgiou, I. Y. (2022). *Caminada Headland Beach and Dune Restoration Increment 1 (BA-0045) and Increment 2 (BA-0143): Restoration Impacts to Sediment Characteristics Part III (Draft).* (p. 67). Pontchartrain Institute for Environmental Sciences.

# APPENDIX A. TOPOBATHY FIGURES

The appendix of this report includes the complete set of images for elevation surfaces and elevation differences for survey data that was available.

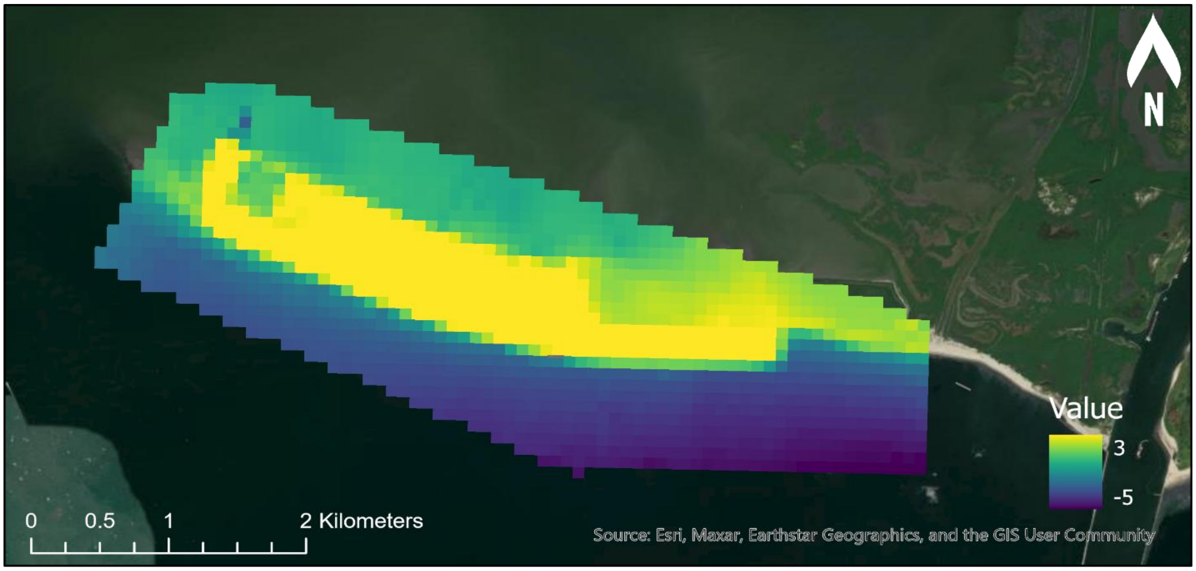


*Figure A-1. Elevation surface from TE143 pre-Zeta survey. Survey dates range from 5/19/20–10/26/20. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

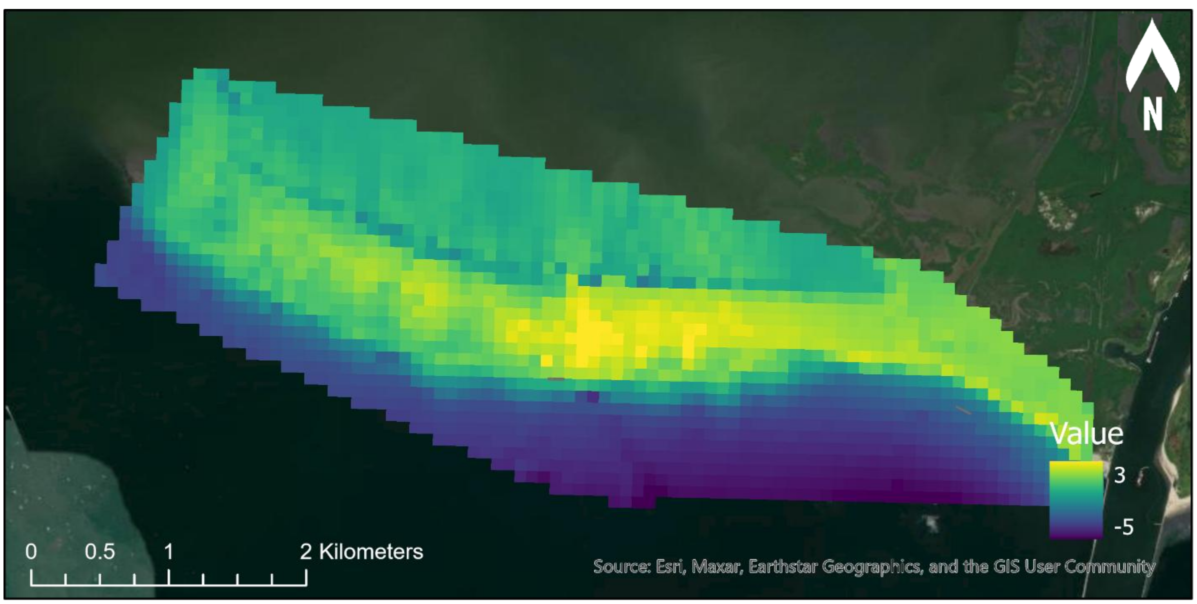


*Figure A-2. Elevation surface from TE143 post-Zeta survey. Survey dates range from 12/2/20–12/11/20. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

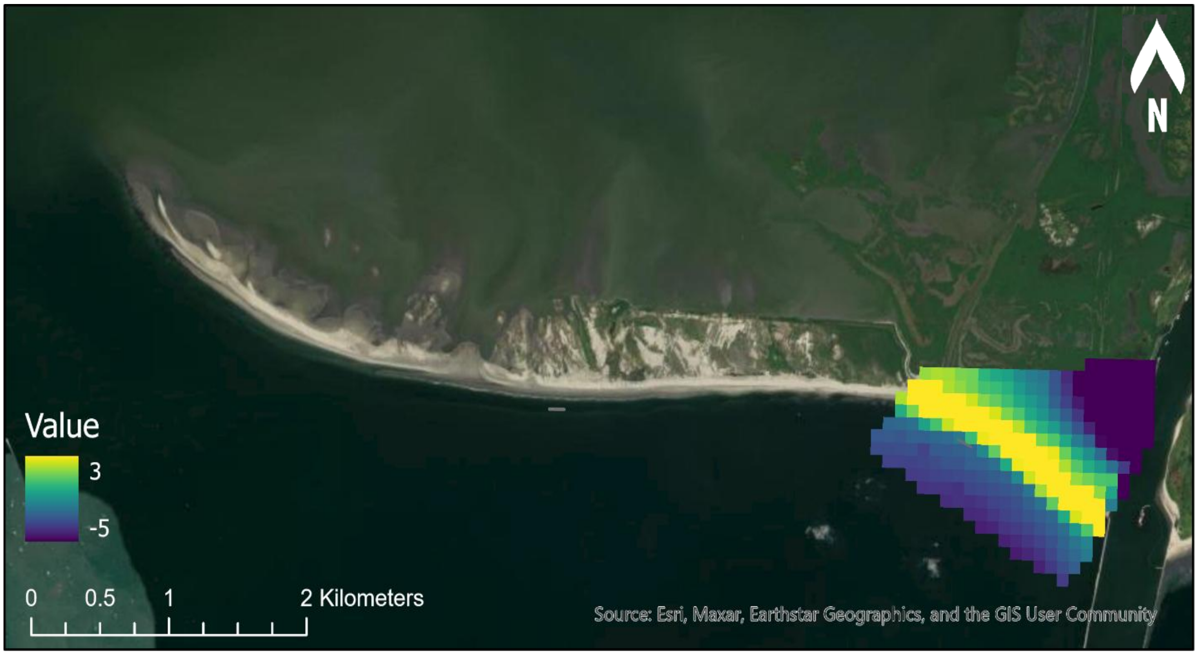


*Figure A-3. Elevation surface from feeder beach as-built survey. Survey dates range from 10/1/21–1/22/22. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

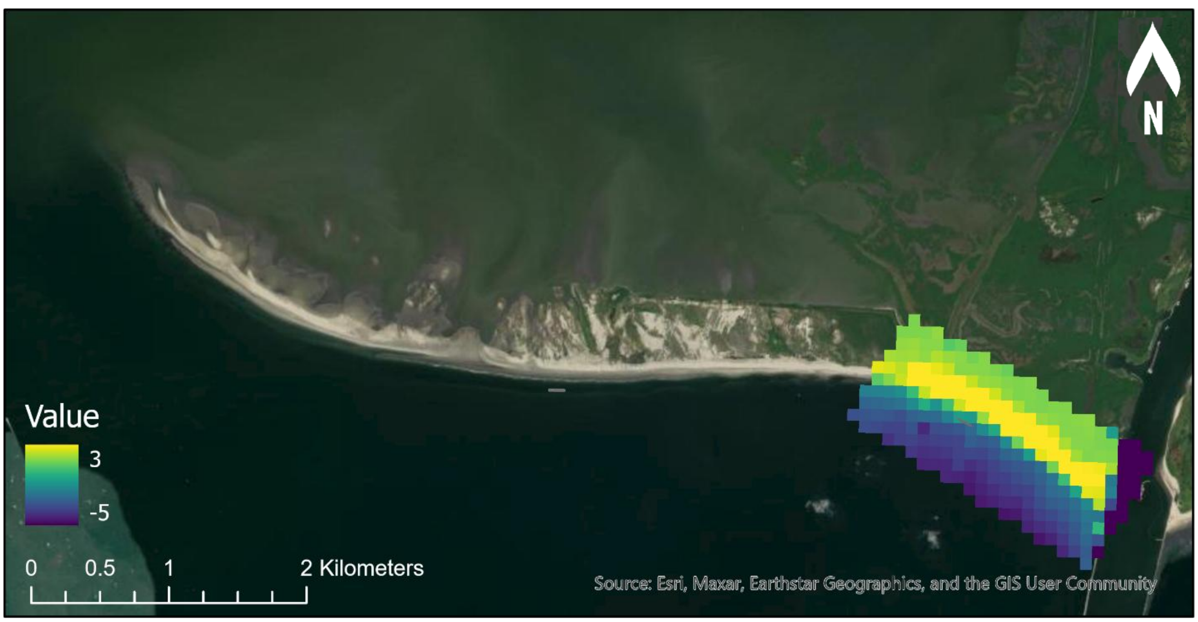


*Figure A-4. Elevation surface from feeder beach post-construction survey. Survey dates range from 3/15/22–6/2/22. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

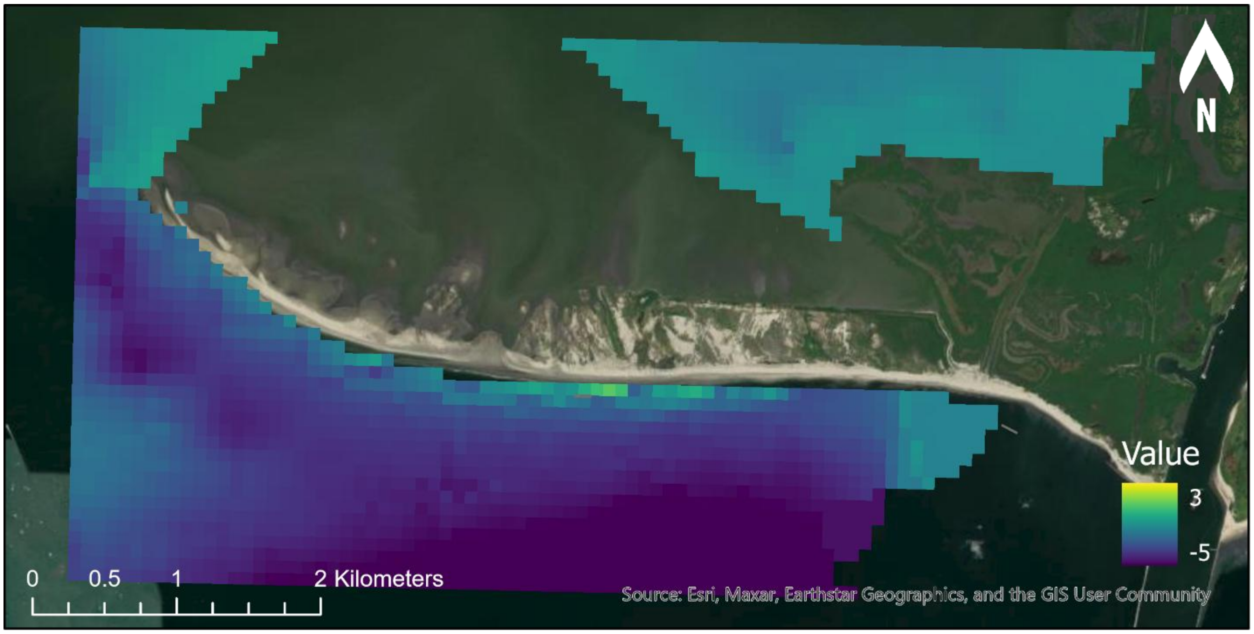


*Figure A-5. Elevation surface from Barrier Island Comprehensive Monitoring survey. Survey dates range from 11/29/22–5/3/23. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

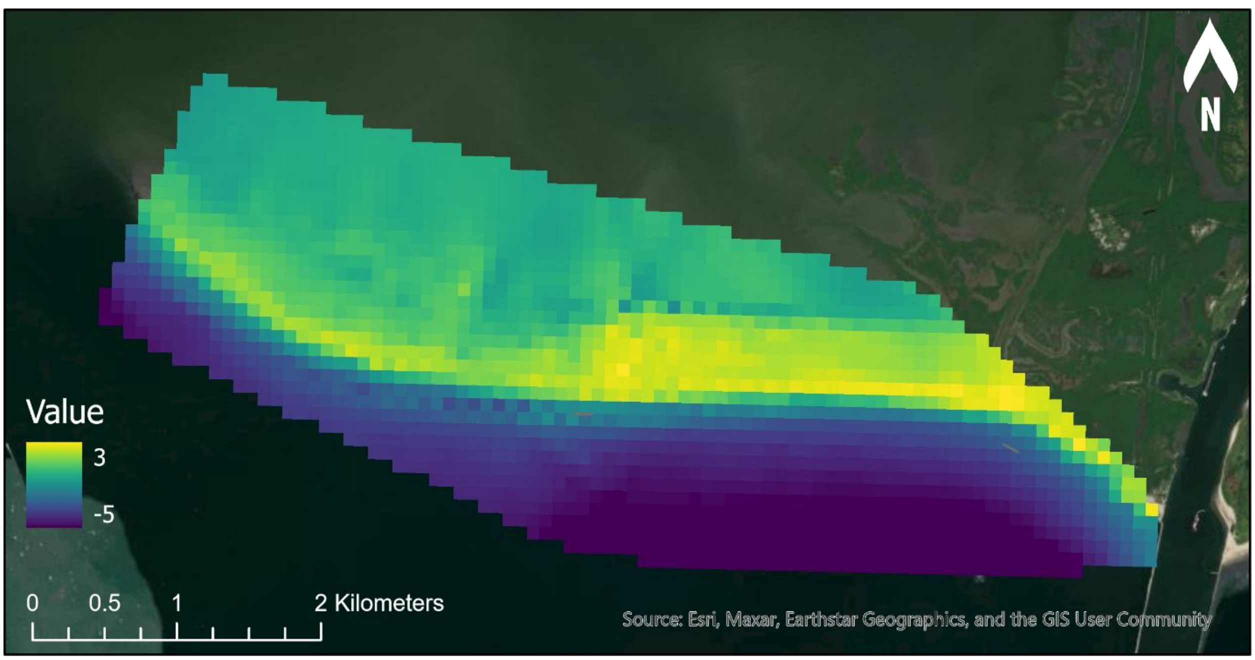


*Figure A-6. Elevation surface from T Baker Smith TE143 survey. Survey dates range from 7/30/24–8/22/24. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

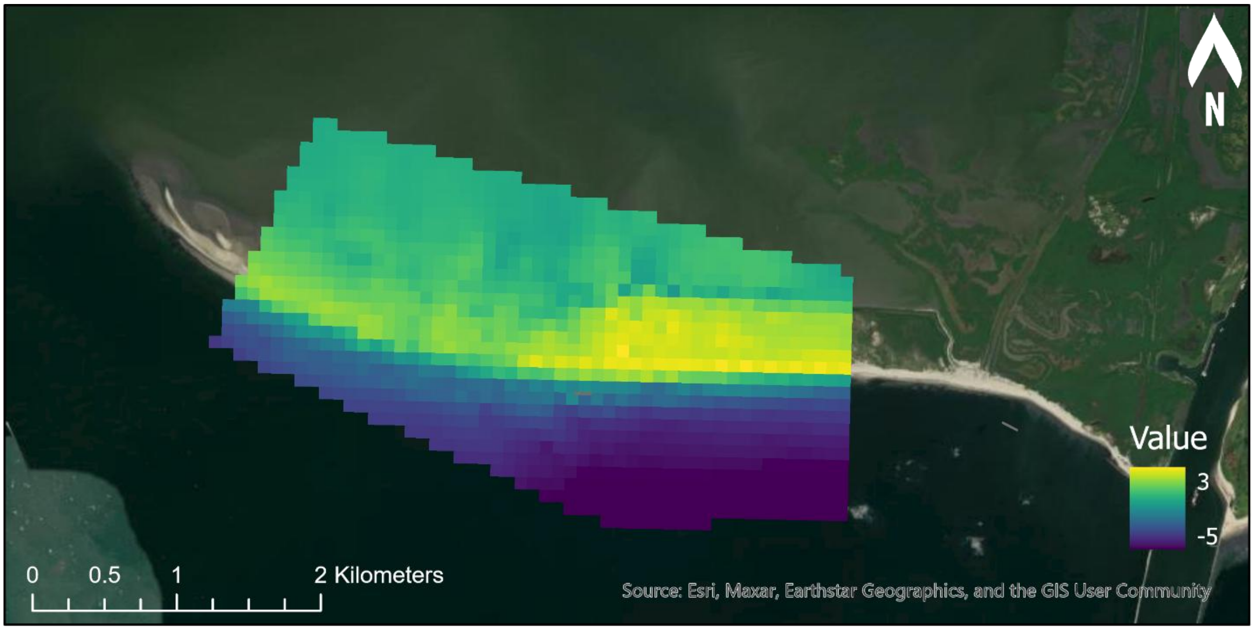


*Figure A-7. Elevation surface from post-Francine reoccupation survey. Survey dates range from 12/12/24–3/12/25. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

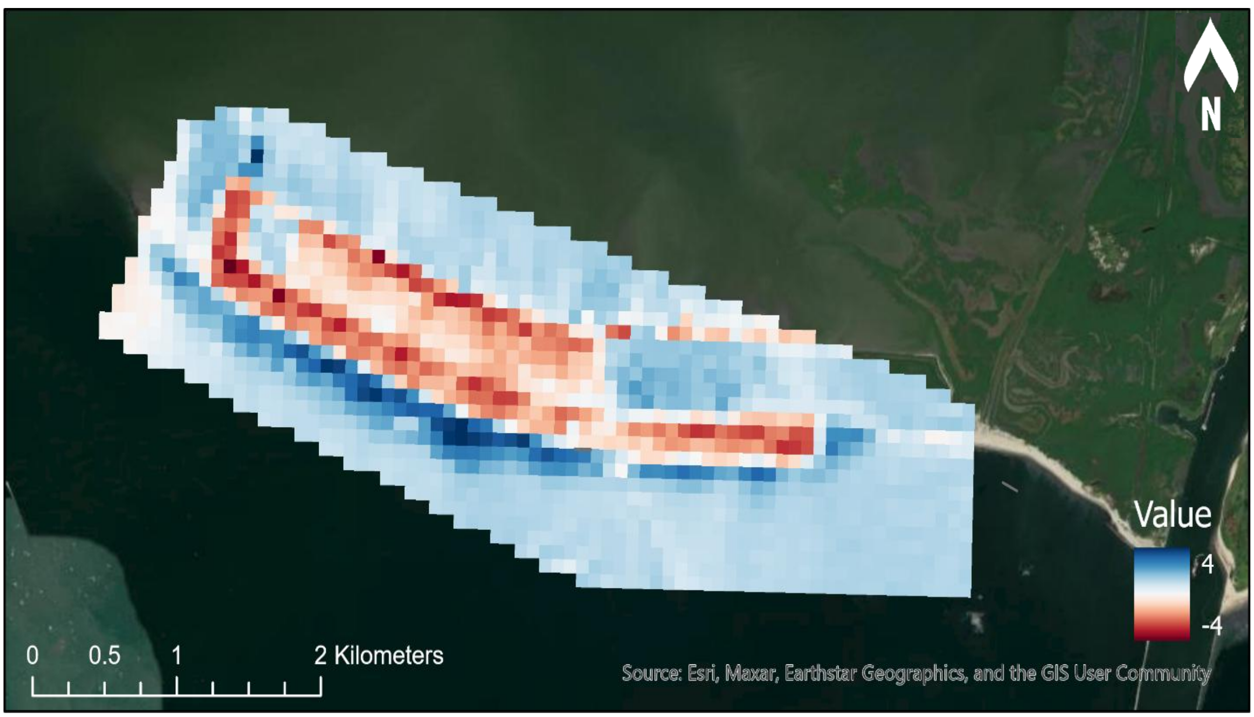


*Figure A-8. Post-Zeta minus pre-Zeta. Elevation difference- positive values indicate deposition and negative values indicate erosion. Pre Zeta survey date between 5/19/20-10/26/20. Post Zeta survey date between 12/2/20–12/11/20. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

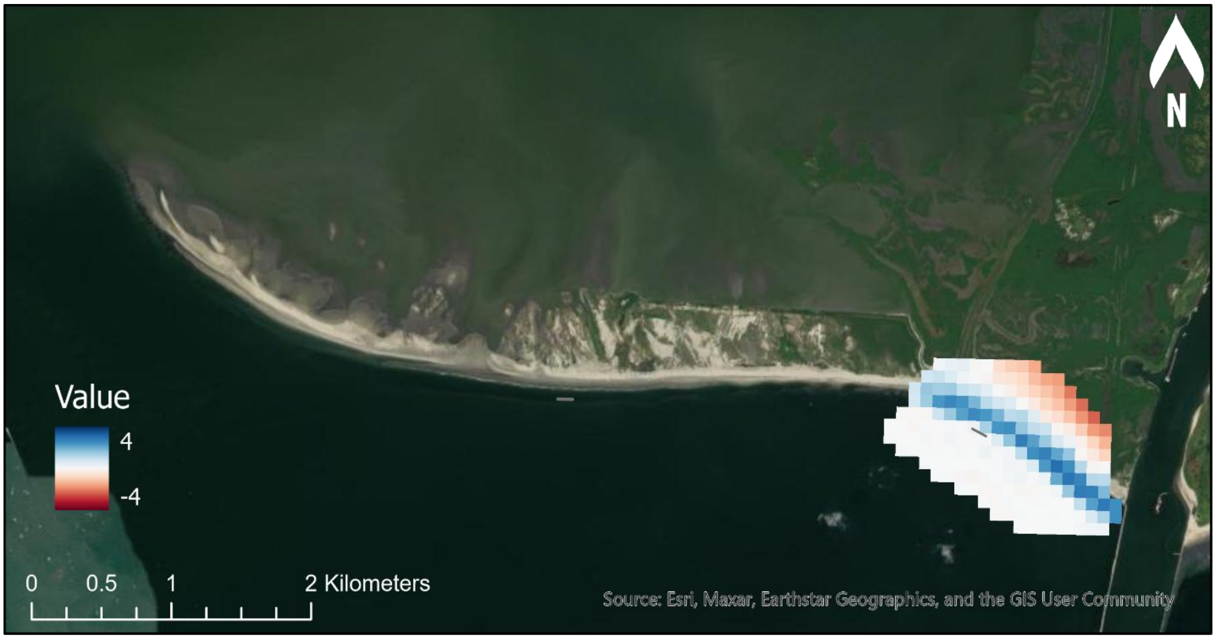


*Figure A-9. Feeder beach as-built minus post-Zeta. Elevation difference- positive values indicate deposition and negative values indicate erosion. Post-Zeta survey date between 12/2/20-12/11/20. Feeder beach as-built survey date between 10/1/21–1/22/22. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

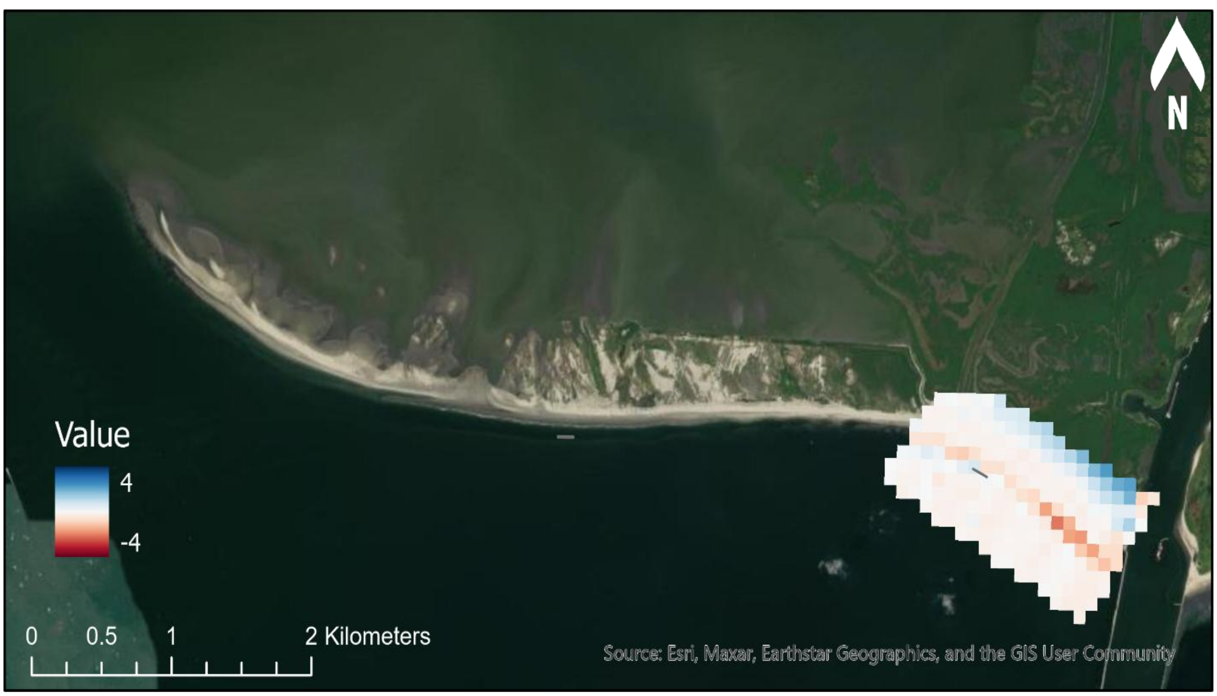


*Figure A-10. Feeder beach post-construction minus feeder beach as-built. Elevation difference- positive values indicate deposition and negative values indicate erosion. Feeder beach as-built survey date between 10/1/21-1/22/22. Feeder beach post-construction survey date between 3/15/22–6/2/22. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*


*Figure A-11. BICM minus feeder beach post-construction. Elevation difference- positive values indicate deposition and negative values indicate erosion. Feeder beach post-construction survey date between 3/15/22-6/2/22. BICM survey date between 11/29/22–5/3/23. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

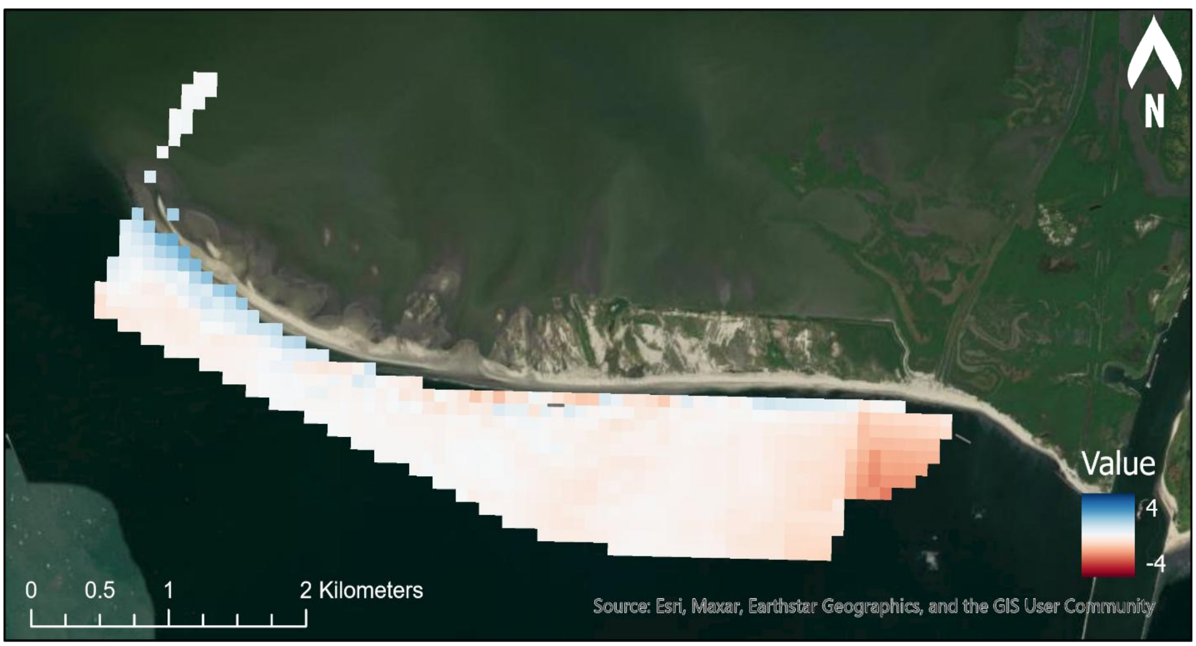


*Figure A-12. T Baker Smith TE143 minus BICM. Elevation difference- positive values indicate deposition and negative values indicate erosion. BICM survey date between 11/29/22-5/3/23. T Baker Smith TE-0143 survey date between 7/30/24–8/22/24. Horizontal coordinate system is NAD 83 UTM 15N and vertical datum is NAVD 88 (meters). Scale in meters. Areas where tracer release occurred shown as polygons for reference.*

THE WATER INSTITUTE

1110 RIVER ROAD S., SUITE 200
BATON ROUGE, LA 70802

(225) 448-2813
**WWW.THEWATERINSTITUTE.ORG**