Saving the Integrity of Keller Bay and Sand Point Peninsula

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Executive Summary

The Sand Point Peninsula is at a tipping point in its geological history. Soon, this peninsula will fully breach and Keller Bay will cease to exist as a separate body of water from West Matagorda Bay. Keller Bay is worth protecting for ecological and economic reasons, as it provides ~500 acres of estuarine emergent wetlands, many oyster reefs, and protected boating and recreational access for citizens. Keller Bay's wetlands also support endangered whooping cranes, and the bay waters provide great fishing opportunities for anglers to catch spotted sea trout, redfish, and black drum. If we want to save Keller Bay, we must act soon.

The overarching goal of this project was to identify a path forwards to stop the Sand Point Peninsula from breaching. Our strategy was to develop a "nature-based" solution, coordinate this strategy among various project partners, and deliver shovel-ready and permitted plans for construction.

Specifically, we: (1) measured and monitored the existing hydrodynamic and morphodynamic conditions in the field, (2) used Delft 3D software to model how different solutions could prevent the breach, (3) designed and produced engineering plans, obtained permits for these plans, and (4) led a large number of federal, state, and local agencies, non-profit organizations, private landowners, legislators, and other stakeholders towards implementing a solution.

The final designs incorporated the construction of a living shoreline with staggered, T-shaped rock structures arrayed along the most rapidly eroding portion of the peninsula. It also incorporated a protection reef to catch sand and build the beach at the tip of the peninsula. This design was submitted for funding to the Texas General Land Office as a short-term emergency solution. It also tied into opportunities for a broader and longer-term regional sediment management strategy for using the resources of the Matagorda Ship Channel to create a "sand engine".

In summary, this project brought together stakeholders, identified nature-based solutions to prevent the peninsula from breaching, and delivered engineering designs and permits for its implementation.

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1.0 Introduction

The Sand Point Peninsula is at a tipping point in its geological history. Soon, this peninsula will fully breach and Keller Bay will cease to exist as a separate body of water from West Matagorda Bay (Fig. 1). Today, an abandoned caliche road is all that prevents water from mixing across the lowest point of the breach during fortnightly spring tides. With a storm surge of a few feet, these waters already fully mix (Fig. 2).

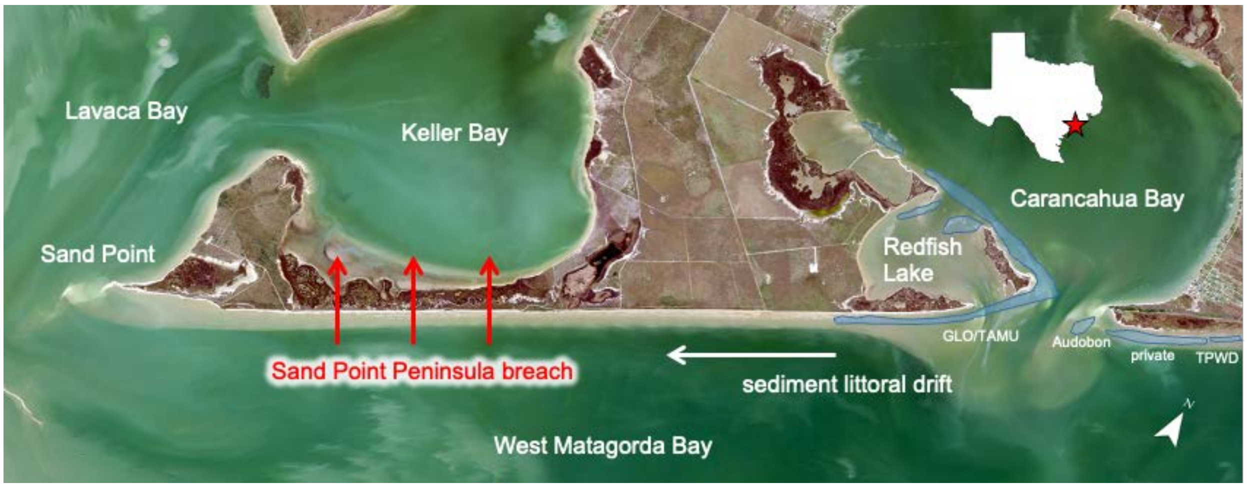

Figure 1. Once the Sand Point Peninsula is fully breached, Keller Bay will become a part of West Matagorda Bay. Several other “living shoreline” projects are on-going in the area (blue polygons).

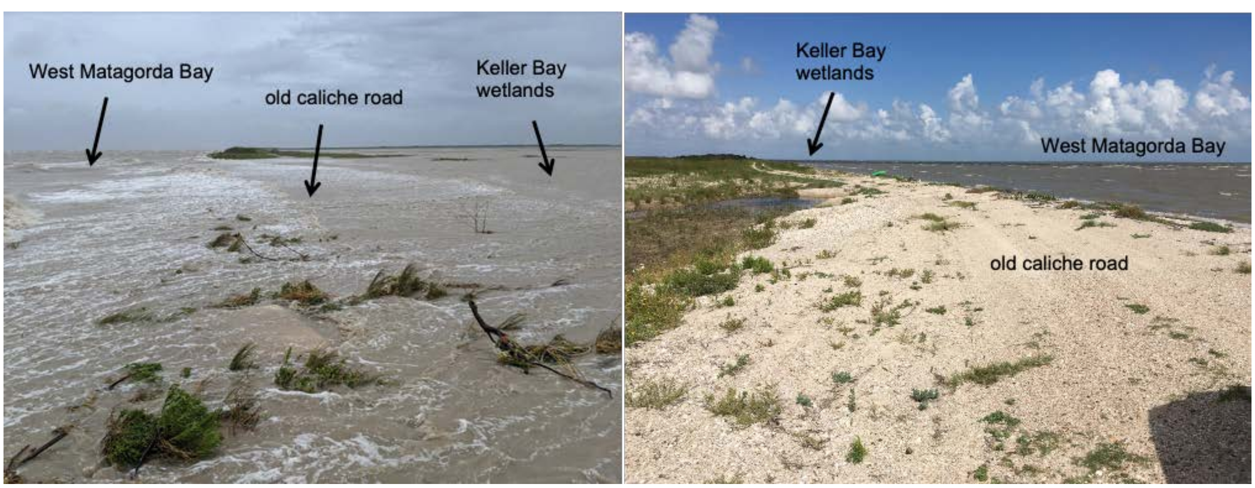

Figure 2. Left side panel: Hurricane Hanna surge of 3 feet, July 2020. View is looking down the Sand Point Peninsula at the breach towards the southwest. Right side panel: On even a normal day, the tidal water in Keller Bay wetlands is separated by only a few yards from West Matagorda Bay. The remnants of an old caliche road are the only factor preventing a complete breach. View is looking towards the northeast.

Keller Bay is worth protecting for ecological and economic reasons. Its ecosystem is unique in terms of water clarity and low wind fetch. The shoreline along Keller Bay includes up to ~500 acres of wetlands, ~250 acres of seagrass, and a large quantity of oyster mounds (Fig. 3). This bay is particularly known for spotted sea trout among anglers (Figs. 4-5). Recreational fishing and boating in this bay deliver tourism dollars and enhance property values for the communities of Olivia, Port Alto, Port Comfort, and Port Lavaca.

Figure 3. Several hundred acres of wetland and seagrass habitat, and several square miles of aquatic habitat in Keller Bay, are currently sheltered by the Sand Point Peninsula. Data from (Feagin et al. 2021).

If we want to save Keller Bay, we must act soon. Once the Sand Point Peninsula fully breaches, Keller Bay will become dangerous for recreational boating and fishing. Its unique role as a nursery and refuge, off-limits to commercial fishing and shrimping, will fade as the bay becomes part of the larger West Matagorda Bay basin. The Olivia boat ramp and bulkhead will become unusable, and the wetlands will be increasingly exposed to potential oil and pollutant exposure arriving from the Gulf Intracoastal Water Way, the proposed dredging of deep-draft channels to petrochemical facilities at Port Comfort and Port Lavaca, and offshore production facilities. The entire bay will be exposed to severe wave erosion and an altered hydrological, salinity, and biological regime.

Figure 4. Upper left side panel: *Spartina alterniflora*-dominated salt marsh on the Sand Point Peninsula in Keller Bay. Lower right side panel: *Batis maritima*-dominated salt flats.

Figure 5. Sea trout catch from fishing the oyster mounds in Keller Bay.

1.1 Project location

The Sand Point Peninsula (Fig. 6) is located in the Central Texas Coast in the Gulf Prairies and Marshes ecoregion. The peninsula divides Keller Bay from West Matagorda Bay. Keller Bay is currently a tertiary bay to Lavaca Bay, which itself is a secondary bay to the much larger West Matagorda Bay. Keller Bay has its own distinct circulation patterns and biological production. The bay is fed inflowing freshwater by Keller Creek. It lies in Texas Congressional District 27 in Calhoun County. Related studies on the erosion in this area include those by Osting et al. (2019), Feagin (2021), Feagin et al. (2022), and Huff et al. (2022).

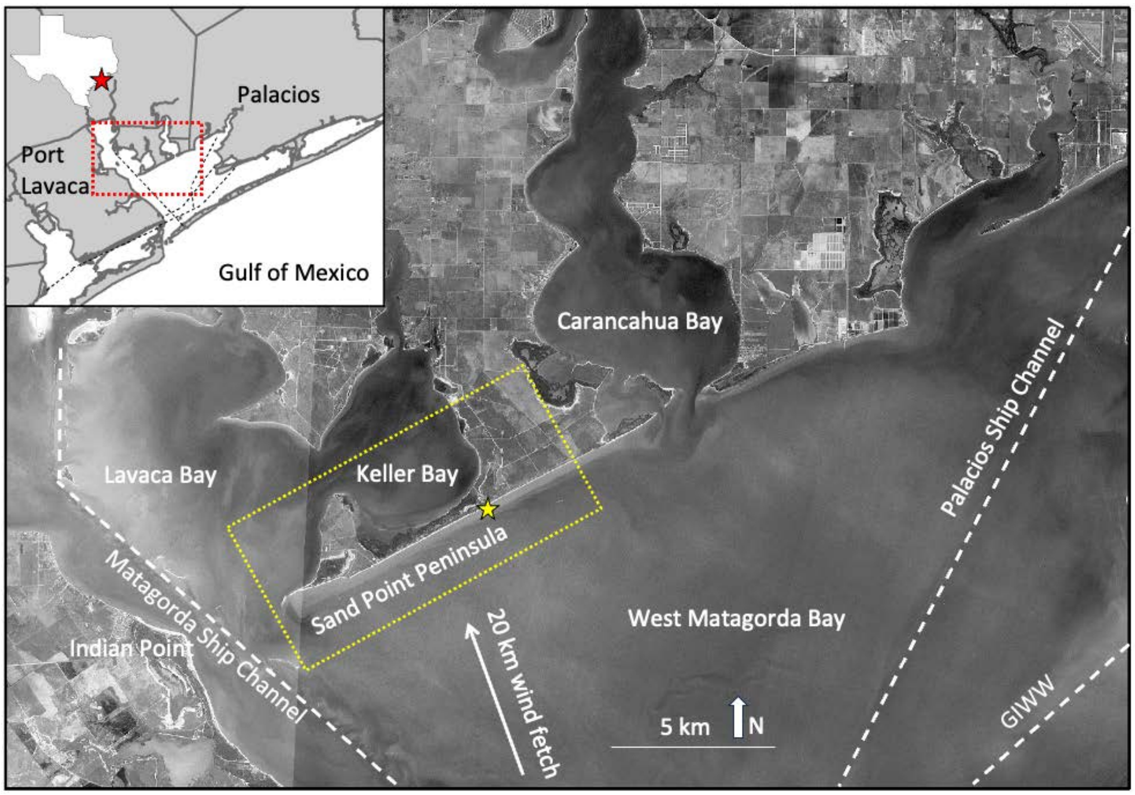

Figure 6. The Sand Point Peninsula and Keller Bay are located within the broader context of Lavaca Bay and West Matagorda Bay. GIWW = Gulf Intracoastal Water Way. Yellow dotted line denotes primary study area and yellow star denotes tripod sampling location.

The ~500 acres of estuarine emergent wetlands in Keller Bay are composed of *Spartina alterniflora* low marsh with some *Batis maritima, Salicornia virginica*, and *Avicennia germinans*, extensive algae-covered salt flats, and *Spartina spartinae* high marsh. The 250 acres of seagrass beds on the south side of the bay are composed of *Halodule wrightii* with some *Ruppia maritima*. There are oyster reef mounds in the bay as well (*Crassostrea virginica*).

Keller Bay is well-regarded by recreational anglers for fish such as spotted sea trout (*Cynoscion nebulosus*), redfish (*Sciaenops ocellatus*), and black drum (*Pogonias cromis*). The bay is a nursery bay for shrimp, and it is legally off-limits to all commercial fishing. Several species of waterfowl utilize the various types of wetlands, including the endangered whooping crane (*Grus americana*). The marshes are visited to hunt ducks. Birding is another common recreational activity and the wetlands lie along the Central Flyway of the US. The nearby communities of Olivia, Port Alto, Port Comfort, Port Lavaca, and Palacios are home to many anglers, hunters, birders, kayakers, boaters, nature lovers, and coastal citizens who use the bay for recreation.

1.2 Project Need

The specific location of the current project was prioritized as a *Tier 1 Project in the Texas Coastal Resiliency Master Plan 2023*, which outlines select restoration and protection project locations as priorities for the State of Texas (Commissioner Dawn Buckingham, Executive Summary, Texas General Land Office [GLO] 2023). The Master Plan process was a multi-year effort led by the GLO, composed of many scientists and agency personnel. Specifically, this document refers to identified needs as the “Sand Point Peninsula Living Shoreline (9245)”.

The specific location is also listed in the US Army Corps of Engineers (USACE) and GLO’s *Coastal Texas Protection and Restoration Feasibility Study* (USACE 2021). The Coastal Texas Study was a multi-year effort led by the USACE and partnered with the GLO to identify coastal protection and restoration needs. Specifically, this document refers to identified needs as “CA5 - Keller Bay Restoration.”

In addition, conservation and management plan objectives that are supported by this project include:

1. North American Waterfowl Management Plan (2012)
2. U.S. Shorebird Conservation Plan (2001)
3. U. S. Ocean Action Plan (2004)
4. National Marine Protected Areas Center Strategic Plan (2010-2015)
5. Gulf Coast Prairies and Marshes Ecoregional Conservation Plan, The Nature Conservancy (2002)
6. Mottled Duck Conservation Plan, Gulf Coast Joint Venture (2007)
7. Waterbird Conservation for the Americas: The North American Waterbird Conservation Plan, (Kushlan et. al. 2002)

8. Coastal Program – Texas Regional Strategic Work Plan: 2017-2021. Draft (2017 USFWS)
9. Texas Conservation Action Plan 2012 – 2016: Gulf Coast Prairies and Marshes Handbook (Texas Parks and Wildlife Department [TPWD] 2012)
10. The Flounder Fishery of the Gulf of Mexico, United States: A Management Plan, Gulf States Marine Fisheries Commission (2000)
11. The Oyster Fishery of the Gulf of Mexico, Untied States: A Regional Management Plan, Gulf States Marine Fisheries Commission (2012)
12. The Blue Crab Fishery of the Gulf of Mexico, Untied States: A Regional Management Plan, Gulf States Marine Fisheries Commission (2015)
13. The Black Drum Fishery of the Gulf of Mexico, Untied States: A Regional Management Plan, Gulf States Marine Fisheries Commission (1993)
14. Texas Shrimp Fishery Management Plan, TPWD (1989)
15. Texas Oyster Fishery Management Plan, TPWD (1988)

1.3 Project Collaborators

The current project is led by Texas A&M AgriLife Research, using funds from the Matagorda Bay Mitigation Trust (MBMT). The consortium of partners is involved in the current project include:

-Texas A&M AgriLife Research/Texas A&M University (TAMU) – project lead, grant writing, scoping, field data collection, modeling, stakeholder communication

-Aqua Strategies, Inc. (ASI) – field data collection, engineering and design, permitting

-WEST Consultants, Inc. – field data collection, stakeholder communication

-Matagorda Bay Mitigation Trust (MBMT) – funding the current project, to meet priority needs of “Environmental Research” and “Habitat Restoration” by Trustee mandate

The current project takes place on state-owned lands (open waters of Texas) and on private lands (Fig. 7). Several state, federal, non-governmental entities, and citizens groups have been involved during the current project and within the context of the larger management strategy for the general study area. Some of these partners have participated in current project meetings on occasion, and whereas others have been consulted with at other times. These entities include:

-Matagorda Bay Foundation (MBF) – lease on bay bottom, USACE permittee, potential project lead for construction

-Texas General Land Office (GLO) – potential project lead for construction

-US Fish & Wildlife Service (USFWS) –funded TAMU for scoping efforts on habitat in Keller Bay from 2017 to 2021

-Texas Water Development Board (TWDB) – equipment provision to TAMU for study

-National Oceanic and Atmospheric Administration (NOAA) - general support and consultation, information regarding fish gap passage requirements for structure

-Texas Department of Transportation (TXDOT) - general support and consultation, advice on Matagorda Ship channel and Gulf Intracoastal Water Way (GIWW) traffic

-Texas Parks & Wildlife Dept. (TPWD) – general support and consultation; funding living shoreline construction upstream in littoral drift, to the east

-Calhoun County - general support and consultation

-Calhoun County Port Authority - general support and consultation

-an informal group of local anglers – organized by MBF, informal leaders include Matt Glaze and the Prasek family

-local boat marina owners – provision of boat ramp access for TAMU, MBF

-Coastal Conservation Association (CCA) – stakeholder coordination

-Audubon Society – development of plans with GLO-Coastal Management Program (CMP) program on construction of Bird Rookery Island structure in updrift direction

-Anchor QEA – involved in planning potential dredge spoil usage in general study area, funded by Natural Resource Damage Assessment (NRDA) funds

Private landowners have been consulted during the project:

-Sand Point Ranch Limited Partnership (SPRLP) – owns immediately adjacent parcels on the Sand Point Peninsula and Keller Bay shorelines.

-John Willis Holdings, LLC – Mr. Willis owns immediately adjacent parcels on the Sand Point Peninsula and Keller Bay shorelines.

-Bill Bauer and family – owns nearby parcels on the Sand Point Peninsula

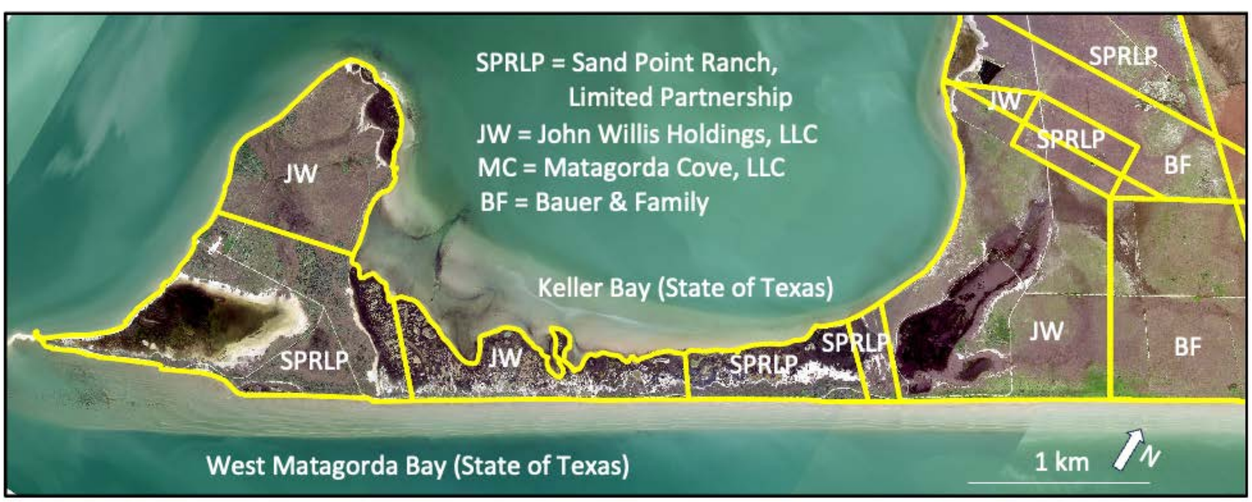

Figure 7. Property ownership in the Sand Point Peninsula area.

1.4 Project Objective

Our overarching goal is to protect the unique estuarine resources of Keller Bay by stopping the Sand Point Peninsula from breaching. Our strategy is to develop a “nature-based” solution. We seek to coordinate this strategy among various project partners, while also delivering shovel-ready and permitted plans a possible solution. Specific objectives funded by MBMT include to:

(1) Identify and model the best actions to stop the peninsula from breaching
(2) Engage a working group, composed of stakeholders and agencies, to help design and identify a preferred action plan
(3) Produce engineering/design plans and obtain permits for these designs

The current project ties into a larger management strategy for the entire West Matagorda Bay system. Once the permits are obtained, the shovel-ready solutions can be implemented.

2.0 Existing Field Conditions

We collected in-situ hydrodynamic, bathymetric, and sedimentary datasets for three purposes: (1) to understand how waves and currents drive erosion and accretion on the peninsula, (2) serve as validation datasets for modeling purposes, and (3) provide input into the development of designs.

2.1 Methods

To gather in-situ hydrodynamic data, we deployed a sensor-equipped tripod in West Matagorda Bay (Figs. 8-9). This tripod included a wave sensor (Ocean Sensor Systems Sonic Xbees (XB)) and an Acoustic Doppler Current Profiler (ADCP) (Nortek Aquadopp HR). The sensor deployments spanned two separate sampling periods: 8/5/2022 to 1/11/2023, and 2/26/2023 to 3/1/2023.

To monitor wave and water level data, the XB wireless sensor was mounted onto the tripod and an onshore computer received and stored the transmitted datasets. The XB was set to sample at 16 Hz for 120 seconds, at the beginning of every hour. Significant wave height (H_s) was extracted from the XB wave data using the zero-up-crossing method to determine individual waves and then extract the largest third of the waves. H_s was then combined with wind data from the NOAA Port Lavaca gauge #8773259. The wave energy within West Matagorda Bay is dictated by the wind speed and direction and is limited in overall amplitude by the friction caused by interacting with the bay bottom. To show this effect, H_s was matched with wind direction and then plotted.

To simultaneously monitor the velocity of the passing waves and the tidal currents, the ADCP was deployed. This ADCP was deployed in an upward-looking configuration used to measure water velocity through the water column. The ADCP had a blanking distance of 0.2 m, and measured up to 2 m in distance, with records averaged within every 10 cm of the water column. The ADCP was set to sample at 16 HZ for 120 seconds, at the beginning of every hour. ADCP-derived flow velocities and directions were then mapped using polar plots.

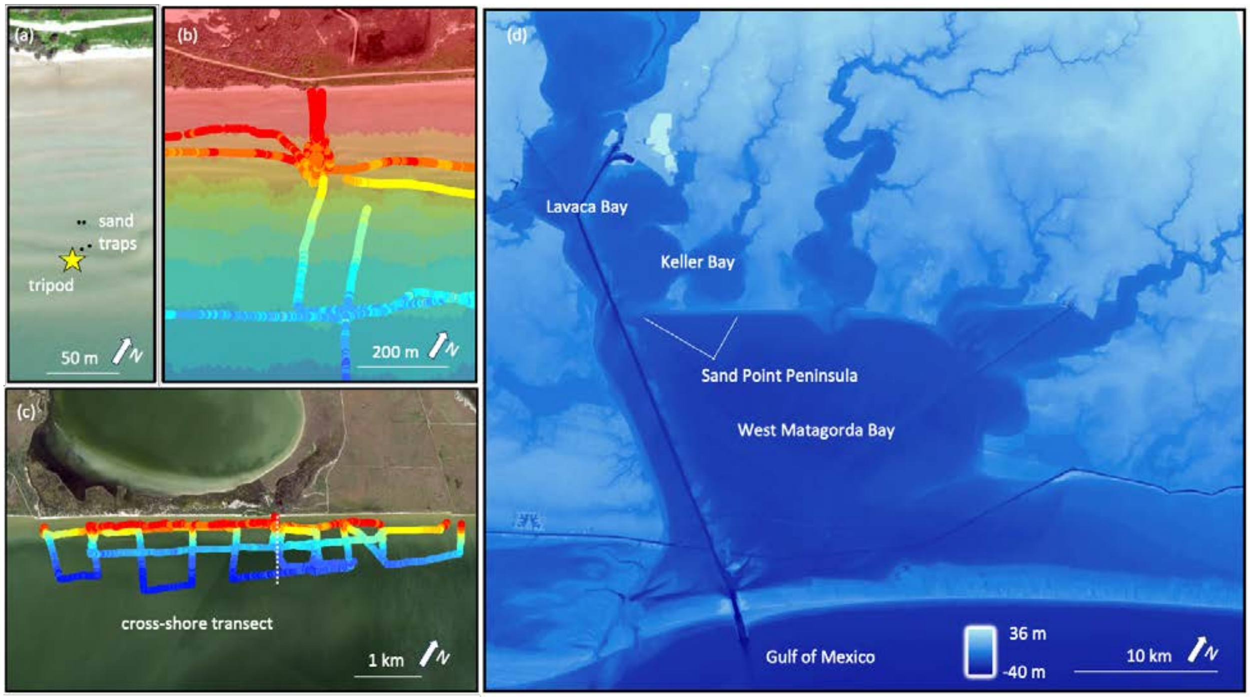

Figure 8. (a) The sensor tripod (yellow star) and sand traps were located 150 to 180 m offshore in West Matagorda Bay. (b-c) The topo-bathymetric point dataset for the immediate study area surrounding the tripod (colored dots), with 1 km long cross-shore transect (dotted white line), and (d) bathymetric dataset of the wider region, used for modeling purposes.

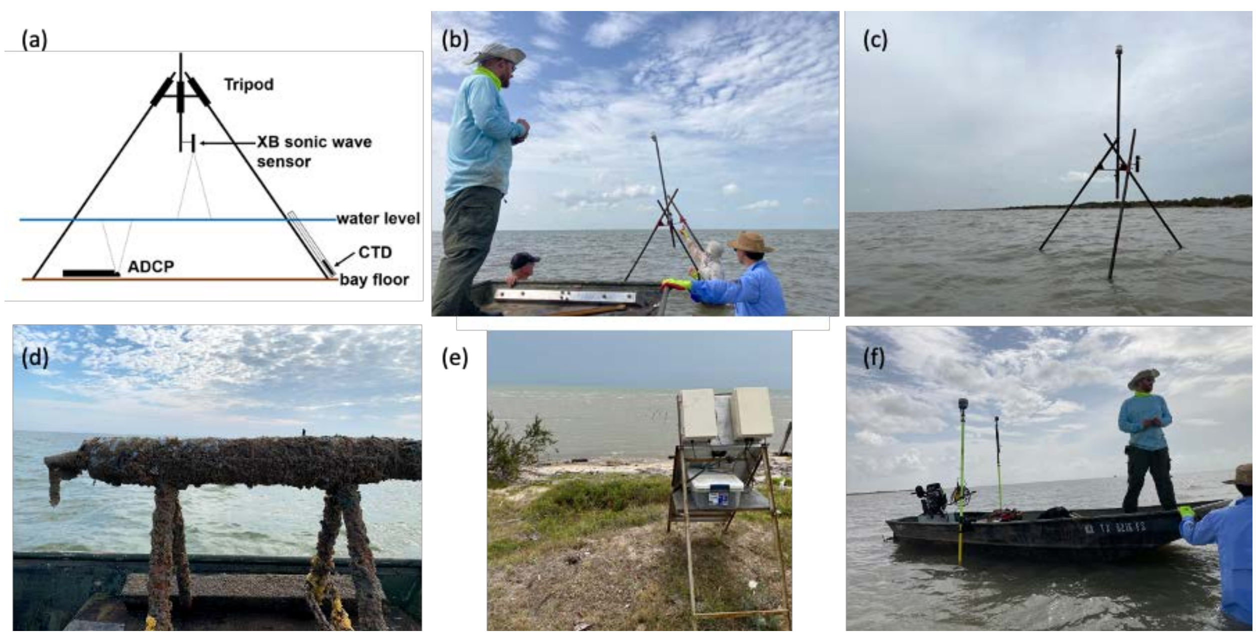

Figure 9. (a) Sensor set up on the tripod, (b) the tripod during deployment, (c) the tripod after deployment, (d) the ADCP velocity sensor post-deployment, (e) the computer station used to

communicate with the X-bee wave sensors, and (f) the linked sonar and survey-grade GNSS system, attached to the side of the boat.

We next surveyed around the tripod using a survey-grade Global Navigations Satellite System (Trimble R10 GNSS, 0.04 vertical precision, 0.02 m horizontal precision, RMS of 0.02 m) and integrated this survey data into a broader topo-bathymetric dataset for West Matagorda Bay (Fig. 8a-c). For locations landward of the tripod, the shallow water depths and complex sand bar structures precluded the use of sonar, and so we recorded the bathymetry along several transects, using only the GNSS.

For locations seaward of the tripod, we linked the GNSS with a sonar (OHMEX Instruments SonarMite v5 Echo Sounder, 0.03 m precision) for a total vertical accuracy of ~0.10 m due to boat-induced motion. The final bathymetric product was vertically referenced to the NAVD88 datum and covered an area offshore from the Sand Pont Peninsula shoreline approximately 1 km out into West Matagorda Bay. We also harmonized this near-shore product with a National Center for Environmental Information topo-bathymetric digital elevation model that covered all of West Matagorda Bay (Fig. 8d) and its adjacent large basins (derived from airborne LIDAR and high resolution side-scan sonar measurements of the Keller Bay and Lavaca Bay areas (TPWD 2023).

We then collected sediment grab samples along the main cross-shore transect (Fig. 8c). Each sample came from the upper 5 cm of sediment. Samples collected in the field were later processed to determine the dry weight of all samples and the bulk density and grain size analysis of select samples.

We also deployed four sediment streamer traps along this same transect (Fig. 10). Two traps were deployed facing the cross-shore direction and two were deployed facing the longshore direction. A pair of each trap orientation was deployed in two different sand bar troughs, hereby labelled Trough #1, and Trough #2. Each trap consisted of two rectangular PVC brackets each measuring 8”x8” at its opening attached to a 50 µm polyester streamer bag. The streamer bags extended 24” deep where it was sewn closed with an 8”x8” square piece of material. The 50 µm polyester mesh captures sediment larger than a very fine silt.

The sediment traps were deployed in 12-hour intervals starting at 19:00 February 26th, 2023 and ending at 19:00 on February 28th, 2023. The sediment captured by the traps was later processed to determine the dry weight, bulk density, and grain sizes. The existing sensor tripod was used to measure flow velocities, significant wave heights, and water level. Bins 3 – 6 (30 – 70 cm above the sensor head) were selected for analysis to ensure sufficient distance from the sensor head as well as ensuring the selected bins were always underwater.

Figure 10. Two sediment streamer traps. Each trap had an upper and lower catchment trap.

2.2 Results

We found distinct patterns in how the waves and alongshore currents affected the Sand Point Peninsula, that differed based on the wind direction (Figs. 11-12). In contrast, the tides did not noticeably alter these patterns.

During typical summer conditions (Fig. 11), H_s approached 0.4 m with southerly direction winds (90 to 270 degrees) at around 10 kts/hr. The alongshore current moved in a southwesterly direction when the winds had any easterly direction to them (0 to 180 degrees), and this movement most strongly increased during the early daytime. During evenings to early nighttime, the current direction switched to the northeast and the winds had westerly directional components (180 to 360 degrees).

During typical winter conditions and prior to the approach of a cold front (Fig. 12), there were strong southerly direction winds (90 to 270 degrees) that typically approached around 15-20 kts/hr and H_s approached 0.6 m in height. Again, the alongshore current moved in a southwesterly direction when the winds had any easterly direction to them (0 to 180 degrees). Immediately after a cold front passed, the winds switched to a northerly direction (270 to 90 degrees). Because the Sand Point Peninsula sheltered this portion of the bay waters from the northerly fetch directions, H_s became quite small particularly with northwesterly wind directions. The current direction immediately switched during these times to the northeast, whenever the winds had westerly directional components to them (180 to 360 degrees).

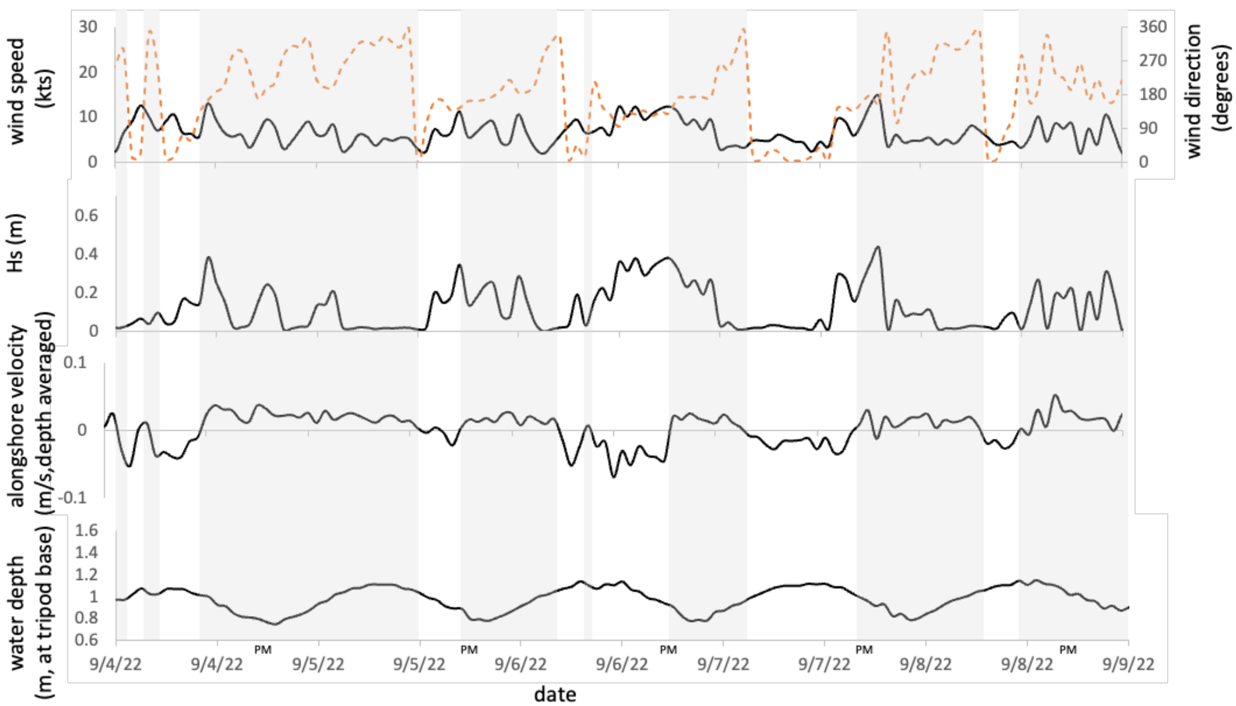

Figure 11. The alongshore current direction switched to the northeast when there were northerly or westerly quadrant winds (180 to 360 degrees), in the summer months. Northeasterly movement generally occurred during evenings to early nighttime in the summer, whereas southwesterly movement occurred when the winds were southerly or easterly (0 to 180 degrees) and picked up during the early daytime. Positive alongshore velocities (moving to the northeast) are shaded.

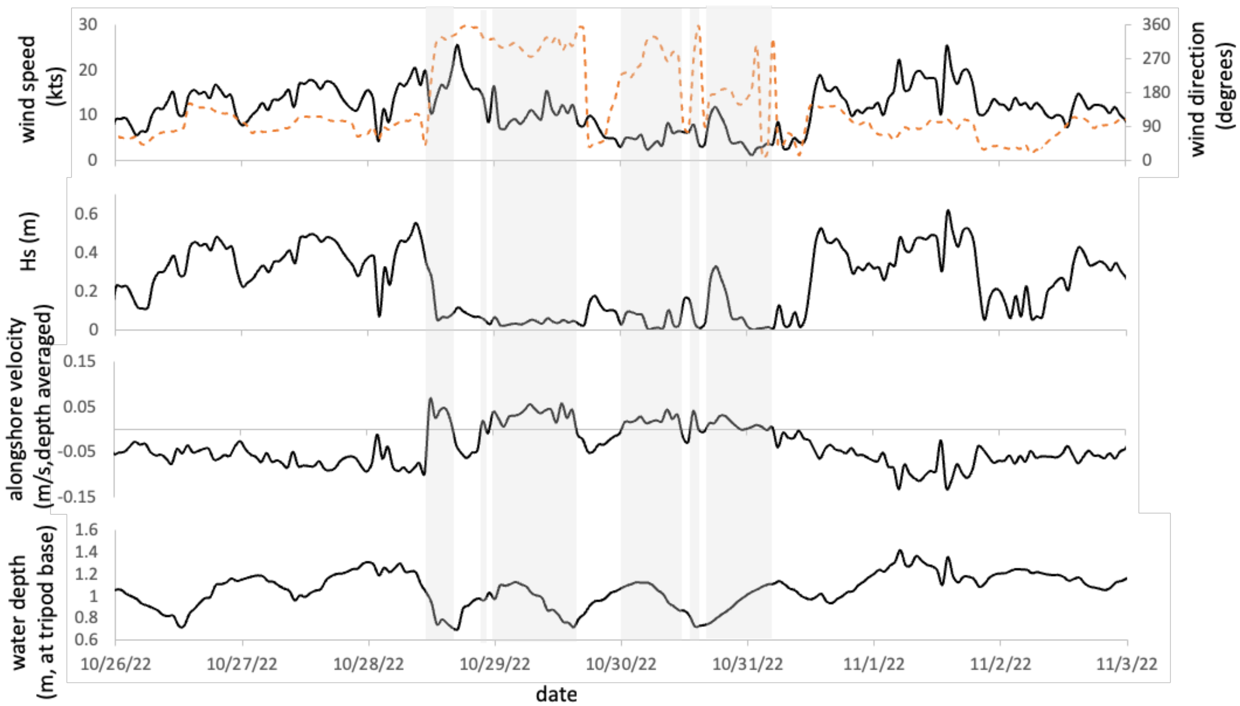

Figure 12. The alongshore current direction switched to the northeast when there were northerly or westerly quadrant winds (180 to 360 degrees) during winter cold fronts. The direction was to the southwest in between these fronts, when the winds were southerly or easterly (0 to 180 degrees). Positive alongshore velocities (moving to the northeast) are shaded.

We also found that the net water flow direction moved to the southwest over weekly and greater time periods (Fig. 13), and that the flow velocities tended to be stronger when moving in this direction.

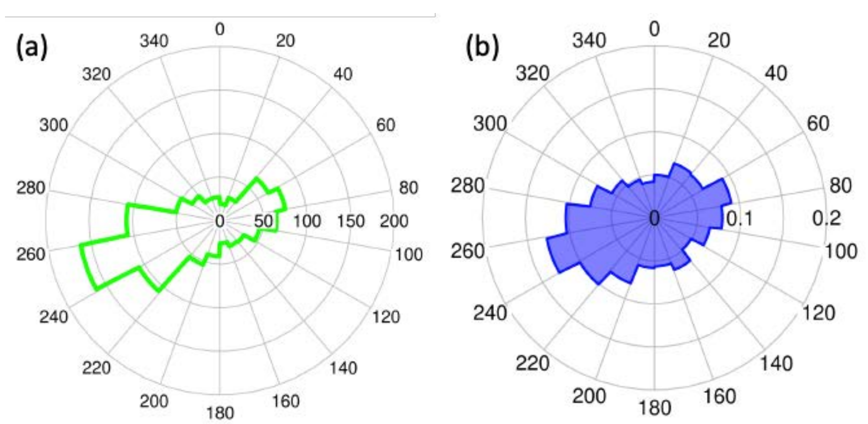

Figure 13. (a) Accumulated hours for each current direction, during a 1000 hour period starting on 8/5/2022. (b) mean water velocity in m/s, by current direction, over the same time period.

We also found that a series of sand bars extended roughly 180 meters offshore from the mean water line (Fig. 14a), out to elevation of roughly -0.8 m (NAVD88), or 1.17 m of depth below the mean water level (MWL). These bars were composed of sand and were superimposed onto an underlying muddy silt bottom. In the gaps between the bars, this silt was exposed. Seaward of the bars, the profile slope graded slowly downwards to reach a depth of 3.17 m below MWL at 1,000 m offshore.

These bars migrated in the cross-shore dimension, presumably as they responded to shifting wave conditions (Fig. 14b). For example, the ADCP and its stand were buried by a migrating bar in at least 0.4 m of sand, in only 70 days as recorded by our datasets between August 8, 2022 and October 17, 2022.

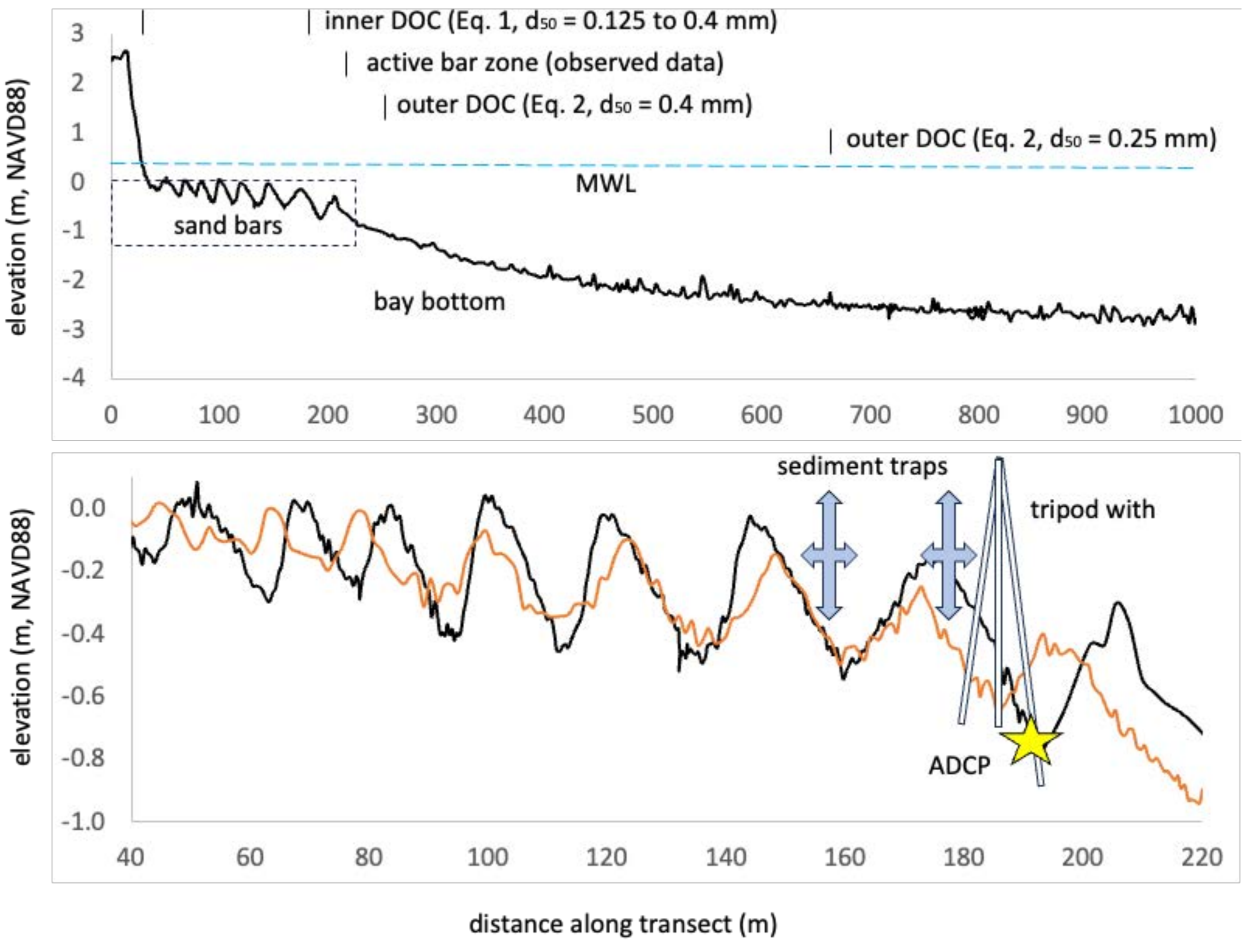

Figure 14. (a) Cross-shore transect profile, running from the upland out to 1,000 m in the offshore direction, and (b) Zoom-in of the profile and data collection stations, from the MWL at 40 m out to the edge of the active wave zone at 220 m. Black lines show transect profile recorded on Aug. 8, 2022. Orange line shows profile recorded on October 17, 2022. DOC refers to the depth of closure, as calculated using our observed wave data, sediment grain size data, and Brutsche et al. (2016) Eqs. 1 and 2.

We found that the existing shoreline was composed of various materials, with strong zonation according to location in the cross-shore dimension. The beach was coarse sands with some shell hash. The subtidal nearshore had sand bars perched on top of fine to very fine sands. The deeper nearshore had a flatter and silty sand bottom.

On the beach, the material was a medium sand with mean grain size of 0.40 mm, a bulk density of 1.21 g/cm^3, an organic matter composition of 1.60%, and a water composition of 17.09%. For the beach only, we also obtained the critical sheer stress (1.15 Nm^2) and mean velocity for erosion to occur (0.545 m/s). Within the subtidal bottom in the active wave zone, the material was a fine to very fine sand, with a mean grain size of 0.125 mm. This material had a low bulk density (0.31 g/cm3) and organic matter composition (0.97%), yet a high water composition (73.63 %). In summary, the beach was composed of medium sands and the subtidal bottom of fine to very fine sand.

During the measurement of the sand flux using the traps, we found that the absolute cross-shore flow velocities averaged 0.03 m/s but reached a maximum velocity of 0.13 m/s, coinciding with the greatest H_s of 0.4 meters (Fig. 15). Absolute longshore flow velocities averaged 0.09 m/s but reached an even greater maximum velocity of 0.43 m/s, coinciding with the maximum cross-shore velocity, H_s, and an increasing water level. The average H_s during the study period was 0.25 m and the average water level was 0.19 NAVD88 m. To generalize, the collection period was quite windy from the southeast and with much wave energy.

Across all deployments and sediment traps, the average sediment flux rate was 2.3 kg/hr/m^2. However, most of the sediment was captured by one sediment trap in the cross-shore direction, where the bottom bracket trap captured an average of 9.6 kg/hr/m^2. Sediment flux in the cross-shore direction greatly outpaced sediment flux in the longshore direction, 3.5 kg/hr/m^2 compared to 0.8 kg/hr/m^2. Of the samples selected for testing, the average bulk density was 1.17 g/cm^3. Of these samples, approximately 80% of the sediment fell in the size class between 0.1255 – 0.25, indicating fine sand. The next most abundant size class was from 0.063 – 0.125, indicating very fine sand.

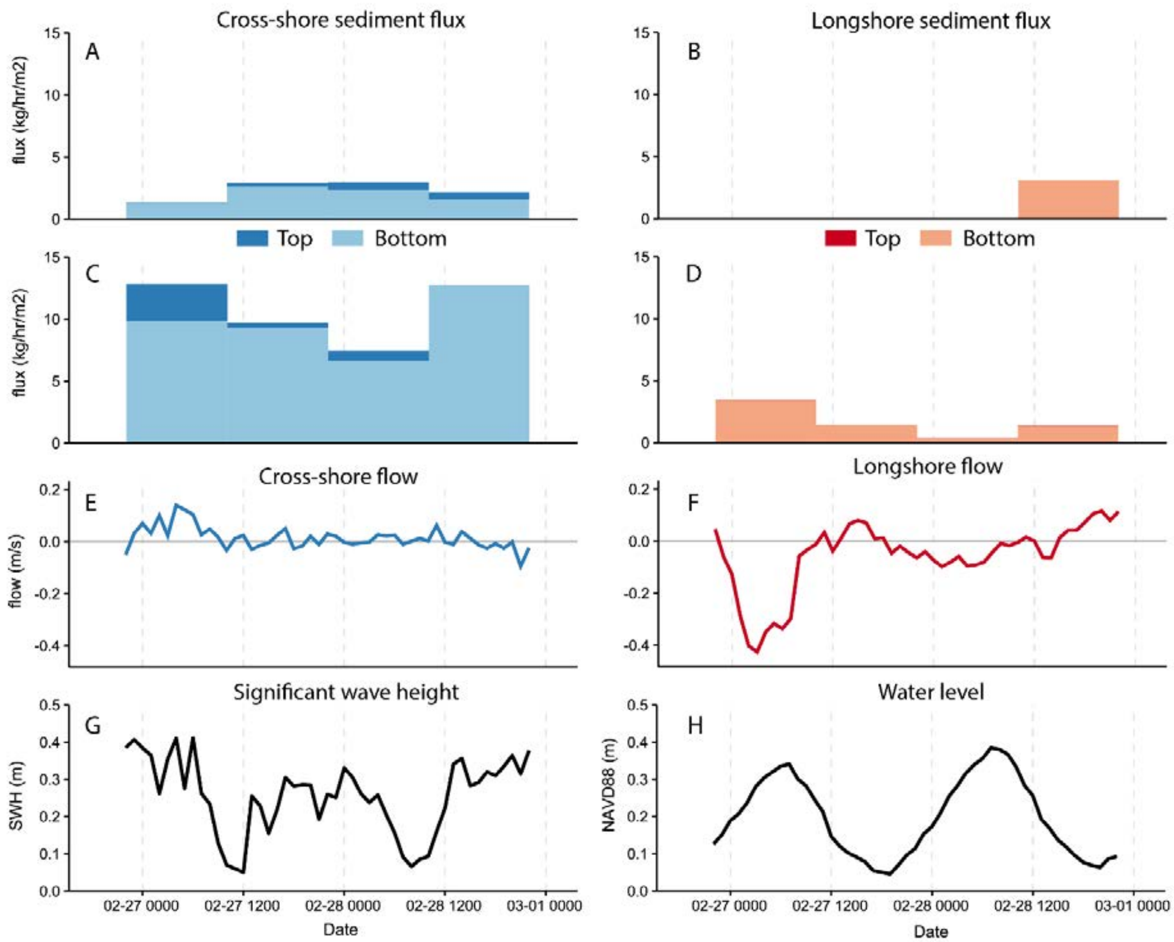

Figure 15. (a) Cross-shore sediment flux, and (b) longshore sediment flux for Trough #1, and similarly for Trough #2 (c-d). Cross-shore (e) and longshore (f) flow velocities. (f) Significant wave height (g) and water level (h). All data from the period from 2/26/2023 to 2/28/2023.

3.0 Modeling the Solutions

In order to identify a solution for the Sand Point Peninsula, we sought to predict hydrodynamic responses to several living shoreline designs. We accordingly created a Delft3D model to guide the development of these designs and explore several relevant questions.

3.1 Base Model and Inputs

The base model was created with DELFT3D-FM software (Deltares 2024). Its starting and reference date were set to August 1, 2020 at 00:00, and the end date was set to August 1, 2022 at 23:00. All simulations occurred within these dates and as mentioned, the time step was set to 3 minutes.

Tidal water level data was obtained for Port Aransas to drive the tides from the ocean (NOAA 2025, station #8775241). This data series was hourly and in meters (NAVD88 units). The "predicted" data series values were used as they represented the astronomical contribution to the tides only; the wind contribution towards water level fluctuation was to be simulated by DELFT3D-FM and we did not want to "double-dip" this effect. Wind data was acquired from the Port Lavaca station, as it was closest to the area of interest (NOAA station #8773259). This data series was hourly and in meters per second, with the direction in degrees. The daily inflows were obtained from USGS river flow gauges, for the Colorado River (USGS 2025, #08162501), Lavaca River (#08164000), and Tres Palacios River (#08612600). This data series was daily and in cubic feet per second, then converted into cubic meters per second, and then apportioned to the discharge per grid cell by dividing by the number of cells where it was input. All other freshwater inflow sources were ignored as they were a factor of several times lower.

To create the base model, a coarse-scale model was run first to simulate the entirety of West Matagorda Bay and its sub-bays, extending out into the Gulf of Mexico (Fig. 16a). The aforementioned bathymetry (Fig. 16b) and tidal, wind, and freshwater inflow data streams were used as inputs and the model was run. Over several iterations, we compared this model's outputs with our observed field data at the tripod location, and then re-calibrated the model. Over these iterations, we made the following adjustments: increased the wind drag co-efficient to 0.007, added 1 knot per hour to the wind data upon entry into the model, and shifted the water level forward by 2 hours.

This model's output data was extracted at several key observation points and then used as inputs along the boundaries of an embedded finer-scaled model (Fig. 16c). This "model within a model" set up allowed us to simulate the proper hydrodynamics at the whole basin scale, while also simulating meter-scaled scouring around living shorelines, over the entirety of the simulated two year period. Both the coarser and finer model grids were created with varying density using the flexible mesh function in Delft3D-FM, with the highest grid resolution in the finer-scaled model set to 5 m.

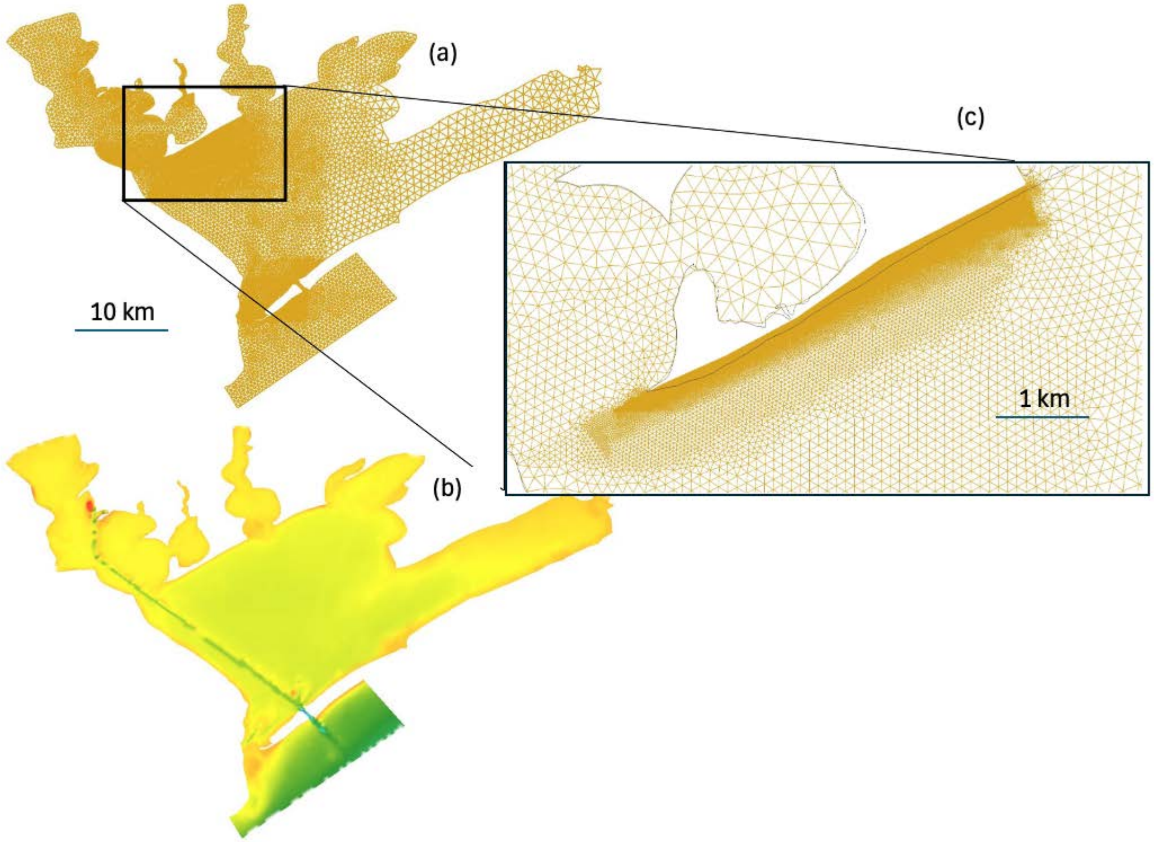

Figure 16. (a) The coarser-scale model domain, (b) the bathymetry layer, and (c) the finer-scale model domain.

3.2 Base Model Validation

To validate the final base model (to make sure that it correctly approximated reality), we matched the modeled versus the observed hydrodynamic data at the tripod location. We compared this data statistically over several months (Table 1) and graphed it over seven day time intervals to better visualize its detail (e.g., Fig. 17). Overall, the modeled water levels and significant wave heights, H_s, matched the observed field data quite well in magnitude and timing.

The modeled water flow velocities also matched the observed data quite well in terms of their temporal synchronicity, as caused by tidal cycling and wind wave events. Sometimes however, the modeled alongshore velocities changed their direction too early or too late by 1-2 hours, as visually compared to the observed data (Fig. 17). In addition, the model slightly under-predicted the net alongshore motion towards the southwest over time, while it slightly over-predicted net cross-shore motion towards the offshore direction (Table 1). Still, the absolute magnitude of the modeled cross-shore and alongshore velocities matched the observed data quite well, and so the model was considered a valid approximation for our purposes.

Table 1. Averaged modeled versus observed datasets at the tripod location, from August 5 to November 13, 2022. Negative cross-shore velocities are in the offshore direction, and negative alongshore in the southwesterly direction.

	Modeled	Observed
water level (mean, NAVD88, m)	0.39	0.37
H_s (mean, m)	0.25	0.26
Cross-shore velocity (mean, m/s)	-0.02	0.00
Cross-shore velocity (mean of absolute value, m/s)	0.04	0.04
Alongshore velocity (mean, m/s)	-0.01	-0.03
Alongshore velocity (mean of absolute value, m/s)	0.08	0.08

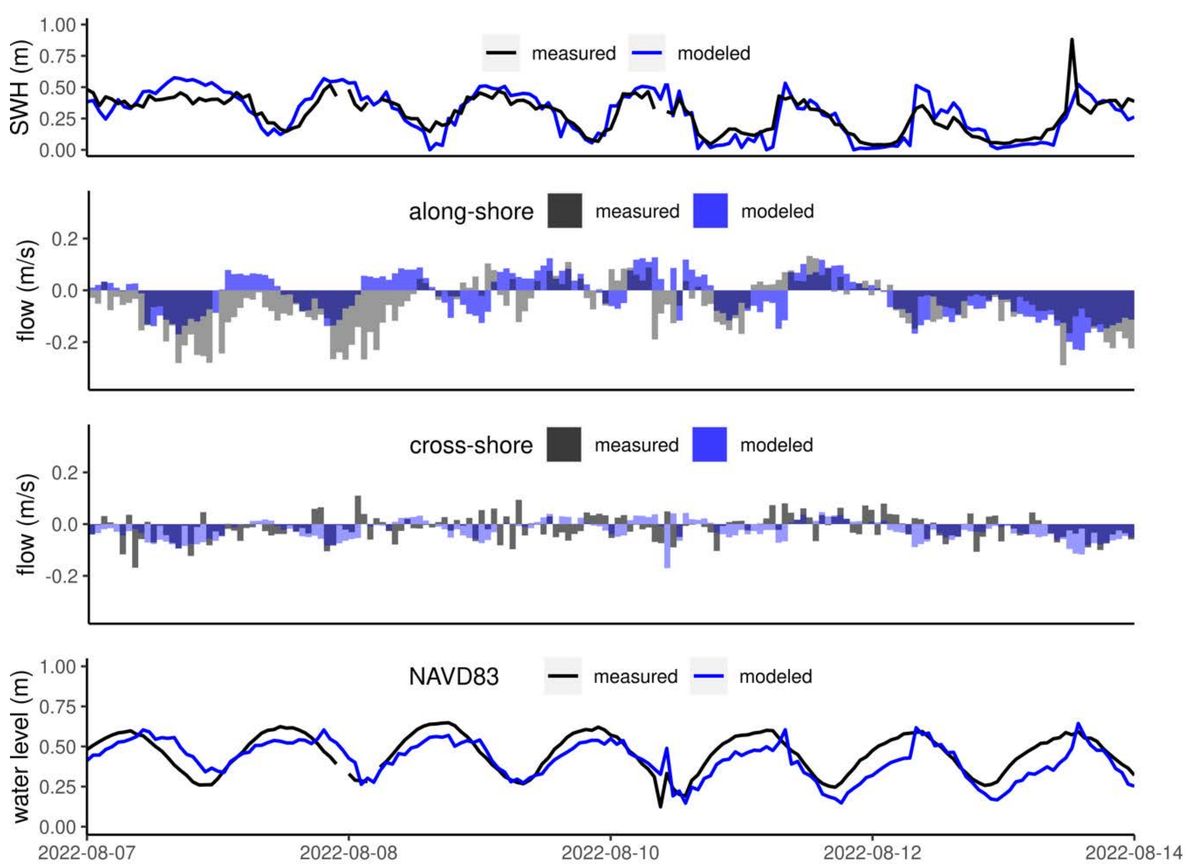

Figure 17. Example of the modeled versus observed measured results, at the tripod location for dates August 7, 2022 through August 14, 2022.

The baseline model results also matched the general circulation patterns of alongshore current flow that we visually observed in the study area, during the many times that we had visited in the field (Fig. 18). Net littoral flow along the shoreline moved towards the southwest.

Fig. 18. An example of current flow tracks over time, generated by mapping flow velocities every hour iteratively. The origin is denoted by the small pink circles at the head of the orange line. The track around the tripod is shown in the zoom-in panel. The net tracks along the peninsula generally moved to the southwest due the most common wind and tidal conditions.

3.3 Simulating the Design Alternatives

We used the validated model to test several designs to meet the overall objective of reducing wave energy onto the shorelines of the Sand Point Peninsula and thus prevent the likelihood of its breaching. The performance of each design was evaluated based on its effects on significant wave heights, water velocities, and potential for sediment accumulation.

Several separate models were designed, but not all were simulated. We note which were simulated below. In addition, we note that as a part of the larger design process, we also conducted an alternatives analysis that considered many possible courses of action that were later removed and not simulated (see Appendix 1).

At first, the simulated designs included six unique design alternatives (Appendix 2) and one baseline scenario. The design alternatives can be grouped into three general categories (Fig. 19): a "living shoreline" for the purpose of reducing wave erosion and current velocities on the peninsula's shorelines, a "spit protection reef" for the purpose of catching and accumulating sediment at the tip of the peninsula, and a "sand engine" for the purpose of adding new sediment to the peninsula from upstream in the littoral drift. The "sand engine" (Stive et al. 2013 Escudero et al. 2020) could be particularly useful in the event that the USACE has dredge sediment from the Matagorda Ship Channel (MSC) for beneficial use (USACE 2018).

During our simulations, we found no hydrodynamic interaction between the structures from one category to the next, and so we present the results for each design separately. These alternatives included:

Alt 1: "Beach Nourishment". This design was for ~ 186,581 yds^3 of sediment placement along the immediately shoreline of the eroding portion of the peninsula. Not simulated.

Alt 2: "Sand Engine". This design was for the placement of ~ 682,924 yds^3 of sediment in a large area, immediately offshore of the shoreline and upstream in the littoral drift from the eroding portion of the peninsula.

Alt 3A: "Sand Berms". This design was for the placement of ~ 258,767 yds^3 of sediment into staggered linear berms, set at +2 ft above mean sea level. It was however run at +7, or infinite height.

Alt 3B: "Continuous Breakwater". This design was for a continuous rock breakwater of ~ 142,426 yds^3 of material, running the length of the eroding shoreline, set at +7 ft above mean sea level.

Alt 3C: "Living Shoreline". This design was for a continuous living shoreline, running the length of the eroding shoreline, composed of ~ 35,892 yds^3 of base rock material with oyster balls placed atop to +2 ft above mean sea level. The simulation for this was the same as 3A because Delft 3D was run with the barrier at an infinite height.

Alt 3D: "Spit Protection Reef". This design was for a spit protection reef, placed at the tip of the peninsula, generally in parallel to the shoreline, composed of ~ 9,010 yds^3 of base rock material with oyster balls placed atop to +2 ft above mean sea level. It was however run at +7 or infinite height.

Fig. 19. The three general categories of the alternatives and their locations (orange objects) and relevant observation points (yellow stars).

The results showed that the sand engine (Alt 2) strongly affected the waves and current velocities in its immediate vicinity (Table 2), around observation points 7 and 8. However, it did not greatly affect them anywhere else.

The various forms of living shorelines (Alt 3A, 3B, and 3C) reduced the wave heights and current velocities for the observation points both in front of and behind these structures. Alt 3A and 3C were particularly effective. Alt 3B was less effective and increased y velocities (generally alongshore direction) at observation point #2.

The spit protection reef (Alt 3D) reduced the wave heights at locations behind the structure (observation point #5) and only minimally affected wave heights at other locations. However, it strongly reduced the x velocities (generally cross-shore) and y velocities (generally alongshore) for locations behind and in front of the structure (#4 and #5) but increased them for those near its seaward tip (#6).

More details on the simulations can be found in Appendix 3. Videos of the simulation runs can be viewed within the data file folders delivered to MBMT, or by contacting the authors of this report.

Table 2. The effects of various design alternatives on significant wave height (hourly average of Hs, m), x velocity (hourly average of absolute values, m/s), and y velocity (hourly average of absolute values, m/s). Dark shading represents a 50-100% reduction, and light shading represents 1-49% reduction in each measured attribute. Red text indicates an increase in the measured attribute. The observation points locations are shown in Fig. 19.

	Obs Pt 1			**Obs Pt 2**			**Obs Pt 3**		
	Hs	x velocity	y velocity	Hs	x velocity	y velocity	Hs	x velocity	y velocity
Alt 2	-1%	0%	0%	-1%	0%	0%	-1%	0%	0%
Alt 3A/C	-88%	-100%	-99%	-9%	-66%	-54%	-81%	-38%	-41%
Alt 3B	-2%	7%	-3%	-2%	-9%	24%	-81%	-63%	-63%
Alt 3D	0%	0%	0%	0%	0%	0%	0%	0%	0%

	Obs Pt 4			**Obs Pt. 5**			**Obs Pt 6**		
	Hs	x velocity	y velocity	Hs	x velocity	y velocity	Hs	x velocity	y velocity
Alt 2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Alt 3A/C	-1%	0%	0%	0%	0%	0%	0%	0%	0%
Alt 3B	0%	0%	0%	0%	0%	0%	0%	0%	0%
Alt 3D	-3%	-33%	-40%	-62%	-73%	-25%	-1%	21%	2%

	Obs Pt 7			**Obs Pt 8**		
	Hs	x velocity	y velocity	Hs	x velocity	y velocity
Alt 2	-2%	-66%	-68%	-4%	-41%	-53%
Alt 3A/C	-2%	-9%	-20%	-81%	-92%	-95%
Alt 3B	0%	0%	15%	-85%	-91%	-93%
Alt 3D	0%	0%	0%	0%	0%	0%

After initial simulations of the above designs, we came up with two improved designs and then simulated them:

Alt 3D-2: “Spit Protection Reef, Perpendicular”. This design was for a spit protection reef, placed at the tip of the peninsula, generally perpendicular to the shoreline, composed of ~ 9,010 yds^3 of base rock material to +2 ft above mean sea level. The purpose of rotating the reef was to better catch sediment and reduce scouring close to shore, for example at the original Alt 3D tip near observation point #6. This alternative was simulated to its correct height by embedding the structure into the bathymetry within DELFT 3D-FM.

Alt 3E: “Living Shoreline, Staggered T’s”. This design was for a series of staggered living shoreline structures, placed along the most quickly eroding portions the peninsula, with T-shaped rock structures, composed of ~ 25,628 yds^3 of base rock material to +2 ft above mean sea level. This alternative was also simulated to its correct height by embedding the structure into the bathymetry within DELFT 3D-FM.

From the perpendicular spit protection reef 3D-2 (Fig. 20), we found that the potential for scour was pushed offshore towards the tip of the structure and away from the peninsula itself. For the staggered T’s of Alt 3E, (Fig. 21) waves and current velocities were greatly reduced behind the long linear structure and at the tripod location.

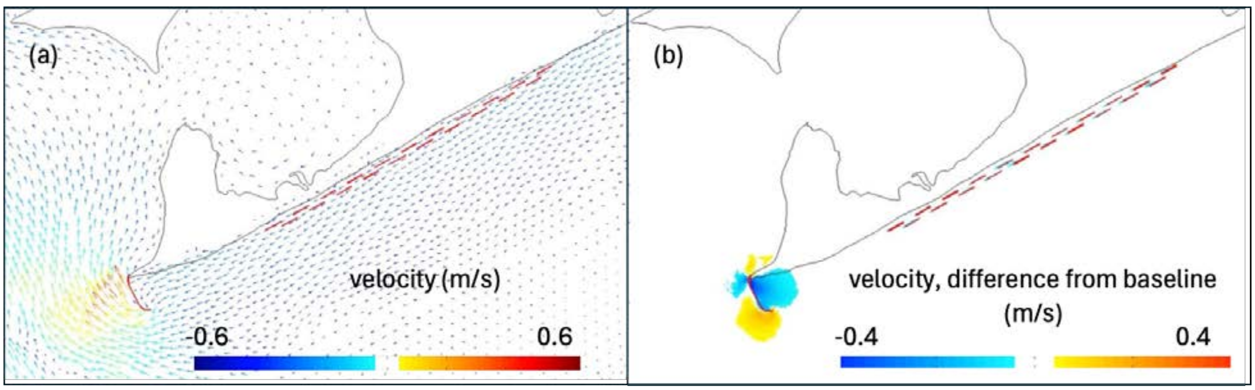

Figure 20. An example of velocities around the Alt 3D-2 structure (a), and as compared to the baseline scenario (b). In Alt 3D-2, the spit protection reef is rotated such that it is generally perpendicular to the shoreline. Date shown is Sept. 9, 2020 at 22:00 local time.

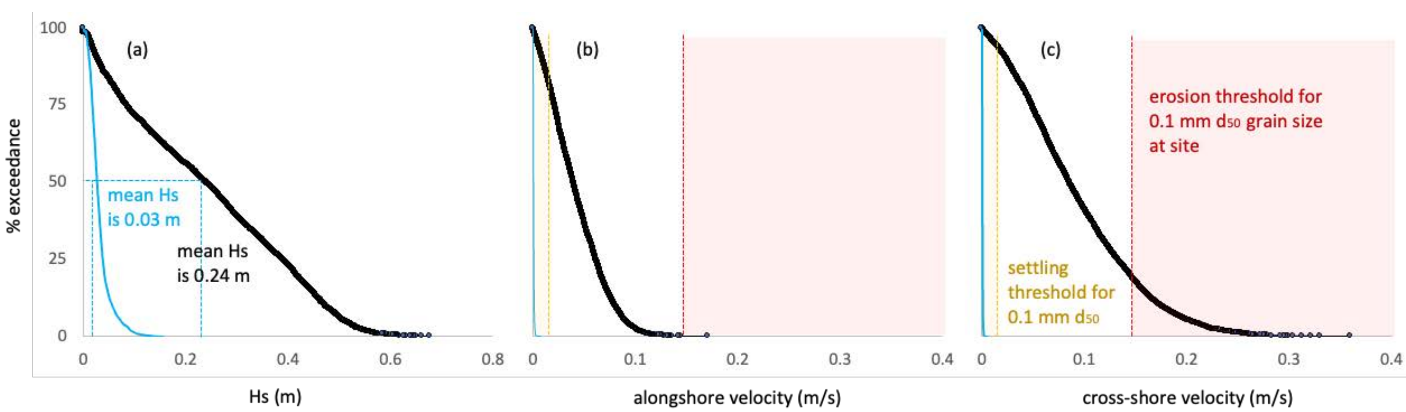

Fig. 21. (a) Exceedance probability for the baseline scenario (black line) versus the Alt 3E scenario (blue line) at observation point #1 (the tripod location): (a) significant wave height (Hs), (b) alongshore water velocity, and (c) cross-shore water velocity. Orange and red shaded areas represent the settling velocity thresholds for a 0.1 mm grain size. Data from 8/5/2022 to 12/31/22.

Based on these follow up simulations, we then developed a final design and limited the extent of the living shoreline due to cost considerations as mentioned in Section 4.0 Engineering and Design. The final design is shown in Fig. 22 and the relevant final design plans can be found in Appendix 4. Note that volume of rock material listed in the final designs (Appendix 4) are lower than those found in the earlier draft versions (Appendix 2).

Figure 22. The final design that was sent to permitting, as described further in Section 4.0 Engineering and Design and Appendix 4.

4.0 Engineering & Design (E&D) and Permitting

The Engineering & Design (E&D) process occurred in tandem with the modeling process described in Section 3.0 and the stakeholder communication process described in Section 5.0. Based on these experiences, our team decided to take the "best" E&D products to the USACE for permitting. Our choice of what was best was based on the ability of the designs to:

(1) reduce wave heights and velocities, while avoiding the potential for scour and poor hydrodynamic circulation, as demonstrated by the modeling results,
(2) minimize the volume and cost of the required material, while also ensuring its longevity by allowing sediment bypass over the structure and allowing oyster growth to occur vertically
(3) meet NOAA/NMFS requirements for gap widths on living shorelines, and biological needs of passing fish and other marine organisms
(4) meet adjacent private landowner concerns regarding overly tall protection structures that could obscure views of the bay
(5) allow placement of the protection structures offshore of the peninsula within state-owned and federally-regulated waters, so as to enable public funding to be used while also protecting the resources of the peninsula, West Matagorda Bay, and Keller Bay
(6) remain under the funding size cap requirements for various GLO and USACE funding programs

The E&D for all alternatives listed under Section 3.0 can be found in Appendices 1, 2, and 4.

However, we submitted only two of them to the USACE Joint Evaluation Meeting (JEM), based on the above logic. These were the Alt 3D: "Spit Protection Reef, Perpendicular" and Alt 3F: "Living Shoreline, Staggered T's".

During the USACE permitting process, we then revised the plans based on the comments of several federal and state agencies that attended the JEM. We also submitted extensive documentation on threatened and endangered species to the National Marine Fisheries Service (NMFS) and the USFWS. The documents submitted for final USACE Permitting, including the E&D, can be found in Appendix 5.

We additionally sought a Texas Antiquities Act Permit and submitted documents to the Texas Antiquities Committee of the Texas Historical Commission. We conducted a magnetometer survey, an oyster and seagrass survey, and received Archeology Permit #32055. These documents can be found in Appendix 6.

We additionally collaborated with the Matagorda Bay Foundation to submit a GLO Application for a Surface Lease of the State's ownership on the bay bottom (Appendix 7), as well for GLO Coastal Management Plan consistency (Appendix 8).

In summary, several permits were submitted. After their final approval, the project will be "shovel-ready" for state and federal entities to fund.

5.0 Stakeholder Participation and Support

Several online meetings, in-person meetings, and site visits were held among the project participants and associated stakeholders. These included presenting to private landowners to receive their support, meetings with federal, state, and local agency personnel, and meetings with elected officials. Several hundred informal phone calls among project personnel also occurred, as well as hundreds of email exchanges. Only the formal and informal meeting dates are documented in Appendix 9.

While talking with stakeholders, we obtained letters of support for the project. The letters of support are documented in Appendix 10.

We also generated an easy-to-use legislative hand out, as shown in Appendix 11. We created a large number of slide show presentations that were given at research conferences and meetings with stakeholders. These documents can be found in the large files that were submitted to the MBMT or by contacting the authors of this report.

6.0 Conclusion

We developed a “nature-based” solution to prevent the Sand Point Peninsula from breaching into Keller Bay, and delivered shovel-ready and permitted engineering and design plans. The final design incorporated the construction of a living shoreline with staggered, T-shaped rock structures arrayed along the most rapidly eroding portion of the peninsula. It also incorporated a spit protection reef to catch sand and build the beach at the tip of the peninsula. This design was developed and optimized after conducting hydrodynamic and sedimentary data collection and Delft 3D-FM modeling.

The design is permitted and supported by state and federal agencies, and has strong support from the local community and its elected representatives. The design is now ready to be funded and constructed.

As a follow on effort to this project, we have already submitted two applications for construction funding to the GLO. In 2024, we submitted to the GLO’s Coastal Management Program Project of Special Merit program (see Appendix 12). This project was not awarded as the program did not disburse any funds for any projects due to changing agency priorities in 2024.

In 2025, we submitted to the GLO’s Coastal Erosion Planning and Response Act (CEPRA) program (see Appendix 13). The GLO is currently exploring ways to potentially build or modify this project as well as exploring a other possible solutions in concert with the USACE, and members of the large team of stakeholders are continuing to collaborate with them.

In summary, this project identified potential solutions and delivered shovel-ready and permitted engineering and design plans.

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