South Padre Island Beach and Dune Assessment Project

August 2021 Progress Update

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Summary Overview:

Task 2

- Conducted coastal erosion assessment using XBeach modeling for 6 CBI Profiles
- Simulated storm scenarios for 2, 10, and 100 year return period storms

Progress Narrative: Coastal Erosion Assessment

A major technical task of this study was to evaluate the potential for coastal erosion of SPI beaches for a range of projected storm events in addition to the future sea level rise scenarios. Overall, the methods to conduct this coastal erosion analysis included assessment of site topographic and nearby bathymetric conditions, the regional wave climate and wave refraction to the shoreline adjacent to the site, and then the XBeach modeling to predict coastal erosion potential. This report summarizes the methods used and provides some examples of the results.

Coastal Erosion and Accretion: Different recurrence intervals help better understand the frequency over time that the beach-dune system may be exposed to. Erosion and accretion along the SPI beaches from projected storm conditions associated were calculated for the following recurrence frequencies:

- 2-year, also referred to as a 50% annual chance storm event
- 10-year, also referred to as a 10% annual chance storm event
- 100-year, also referred to as a 1% annual chance storm event

Analysis Transects

Six shoreline profiles were selected from the available profiles along SPI to perform XBeach simulations and evaluate the coastal erosion potential. The selected profiles were CBI-03, CBI-06, CBI-13, CBI-17, CBI-22, and CBI-24 (Figure 1). These profiles were selected using the June 2021 survey data and based on unique shoreface features to be a subset that is representative of the entire width of SPI. The explanation for the profile selection was included in the July 2021 Progress Report. CBI-22 was undergoing nourishment during the June 2021 survey and the profile did not cover the entire beach-dune system. Therefore, the elevation data for profile CBI-22 were derived from the May 2020 survey.

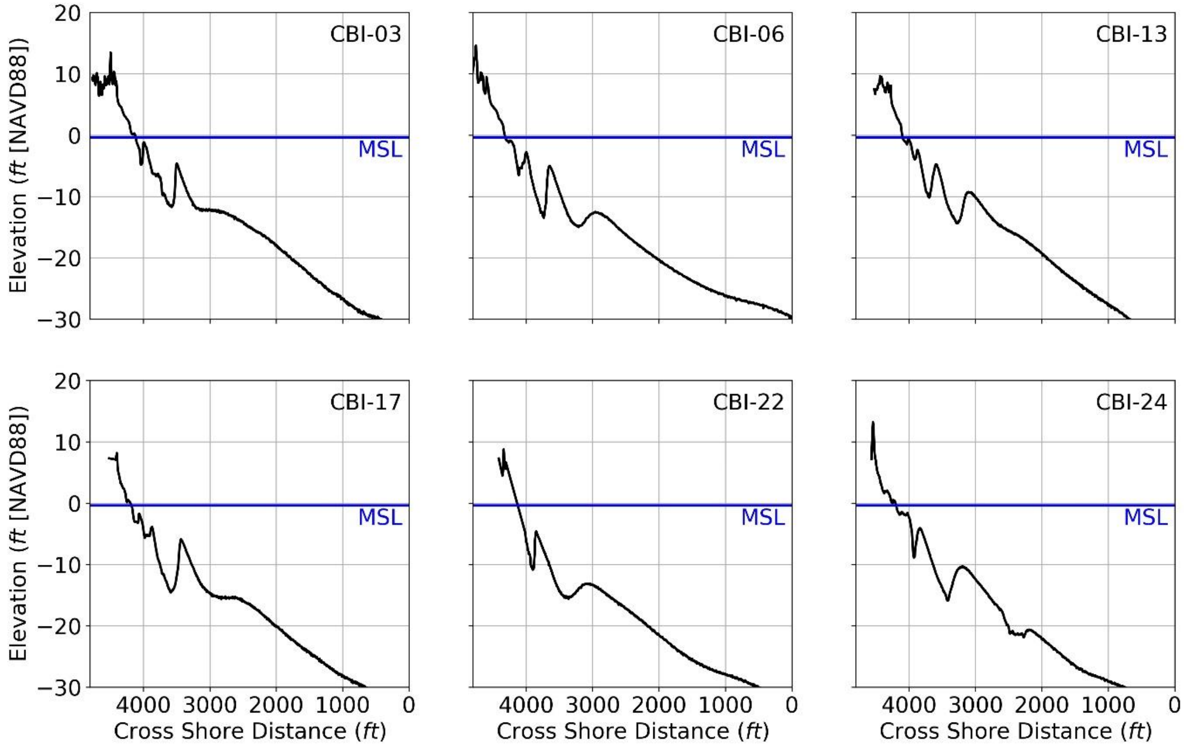

Figure 1. Selected SPI Shoreline Profiles with Mean Sea Level Line

XBeach Modeling

XBeach was used to model coastal erosion potential along a selected set of beach profiles under a range of storm wave conditions. XBeach is particularly suited for modeling coastal erosion (e.g. volume, width, elevation) processes on timescales of single storm and wave events, as it simulates tidal and wave driven sediment transport and coastal erosion, and is a readily available free open-source model.

XBeach is a numerical model used to predict coastal erosion and accretion. This model assesses the interaction of waves with the bathymetry and topography. XBeach is particularly suited for modeling the impacts of waves along a coastline on timescales of single storm and wave events.

Extreme Value Analysis

The Extreme Value Analysis was conducted early in the project and the results were summarized in the Phase 1 Report. The information is repeated here because it is essential to the XBeach modelling workflow, and the return period for the 2-year storm is also included here. The range of wave processes in response to the wide sloping continental shelf along the coast of the GoM necessitates a qualitative and quantitative understanding of existing wave conditions. In an effort to summarize the existing wave conditions along SPI, the full data record from the closest NOAA wave buoy was reviewed. This NOAA buoy, station 42020, is located ~68 mi northeast of the Brazos Santiago Channel and the south end of SPI, and has a data record from 1990 – present (Figure 2). The NOAA buoy is in 280 ft of water near the edge of the continental shelf and is equipped with sensors to collect meteorological data, water temperature, and directional wave data. Over the full data record at this NOAA buoy, the mean wave height is 4.3 ft, the mean wave period is 6.3 s, and the median wave direction is 120°. The median is defined as the middle wave direction of the entire record. To determine the impact of extreme storm events on the coastal resiliency of SPI beaches and dunes, extreme values of wave height, representative of an array of storm events, were computed to be used as inputs in the XBeach model. This extreme value analysis (EVA) provided the highest wave heights for various return periods (e.g., 2, 10, 100-years) from a 30 year measured data record (Table 1).

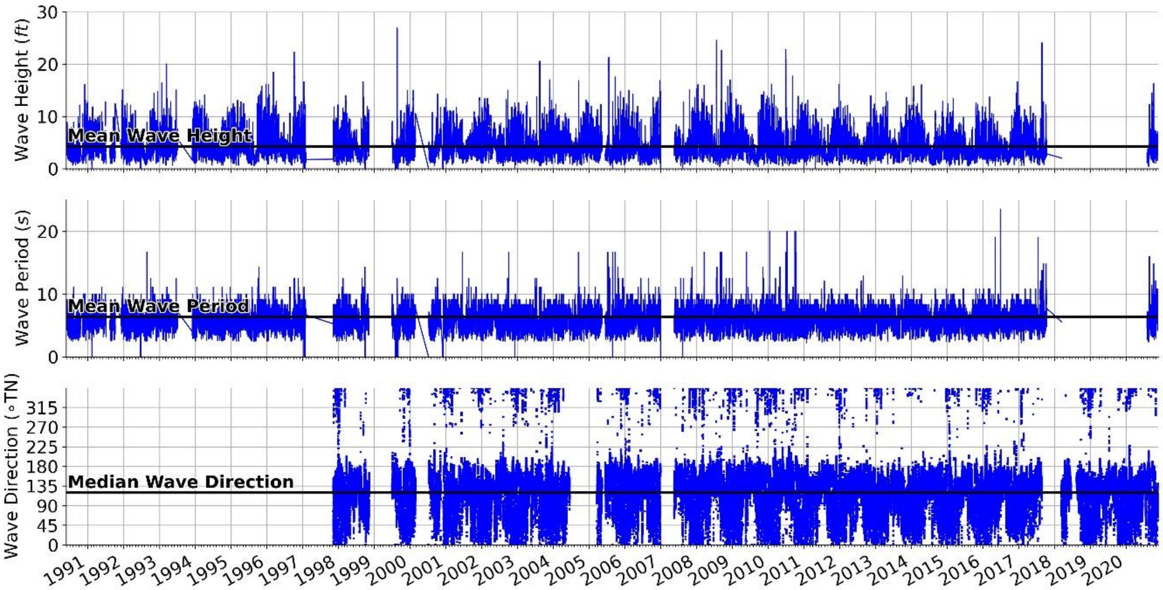

Figure 2. Full Record of Wave Height, Wave Period, and Wave Direction including Average Values from NOAA Buoy 42020.

Table 1.Wave Height Return Period Values from EVA for the Offshore NOAA Buoy

Return Period	Offshore Sig. Wave Height (feet)
1-year	16.2
10-year	22.9
100-year	41.7

The NOAA buoy measurements used in the EVA are typically in deep water where the influence of the bathymetry and local nearshore bathymetric features do not affect the waves. Thus, it is critically important to transform the waves from the deep water to the nearshore zone to evaluate a site specific wave exposure. Linear Airy wave theory was used to transform the deep water waves into the nearshore region, taking into account the effects of local bathymetry and profile slope. These transformed wave heights were used as the XBeach boundary conditions for all six selected profiles (Table 2). As it can been seen, these nearshore wave heights along with the offshore wave heights derived from the EVA sequentially increase for the 2-, 10-, and 100-year return periods, and contribute to increased wave run-up and the potential for erosion and accretion. This resulted in 18 separate XBeach model simulations representing three different significant storm events along the six selected profiles. The wave period was held constant across the 18 XBeach simulations, set as

16 seconds, a typical wave period generated from an offshore storm event in the GoM. XBeach was setup to run for 30 hours, representative of a typical storm event duration. During this 30 hour period, constant wave and time varying water level boundary conditions were applied.

Table 2. Nearshore Significant Wave Height used for Selected Profiles (feet)

Return Period	Offshore Sig. Wave Height (feet)	Nearshore Sig. Wave Height (feet)
2-year	16.2	13.2
10-year	22.9	17.8
100-year	41.7	22.9

In addition to the wave conditions at the offshore boundary, a time varying water level was applied. A time varying water level provided a more realistic storm impact, as it would occur over a tidal cycle, and the higher tides would increase the probability of erosion and accretion along the shoreface. These data were selected from the measured data record at NOAA station # 8779749, SPI Brazos Santiago, TX (Figure 3) and subset to a transition from a neap to spring tide. This simulates an increasing water level resulting from storm surge, along with the constant wave conditions.

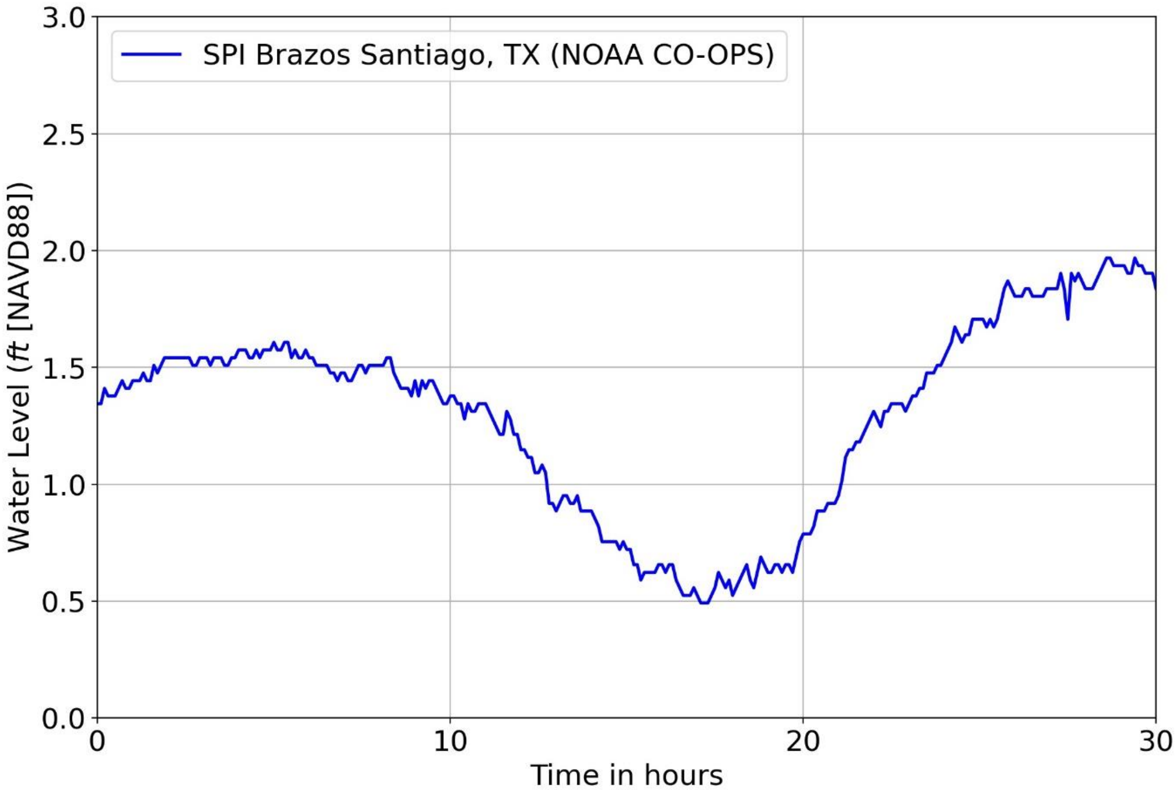

Figure 3. Time Varying Water Level Boundary Condition Applied to XBeach Simulations

In addition to the wave and water level boundary conditions, vegetation and sediment physical characteristics were defined along each of the selected profiles. The location of the vegetation line was defined from the vegetation survey data. This feature in XBeach provides additional roughness for predicting the wave run up and erosion of the dunes. The sediment physical characteristics, i.e. D50, D90, porosity, and bulk density, were defined based on typical sandy beaches along the Gulf Coast region. These model parameters provide a more realistic sediment bed when simulating erosion and accretion.

XBeach Results

The model predictions provide an evaluation of coastal erosion and accretion potential along each of the selected profiles due to defined storm events. Figure 4 illustrates the initial condition of one of the profiles, CBI-03, before the impact of a single storm event. A line for the mean sea level (MSL) elevation was added for reference. The still water level (SWL), at the start of each simulation, was derived from the NOAA water level data shown in Figure 3.

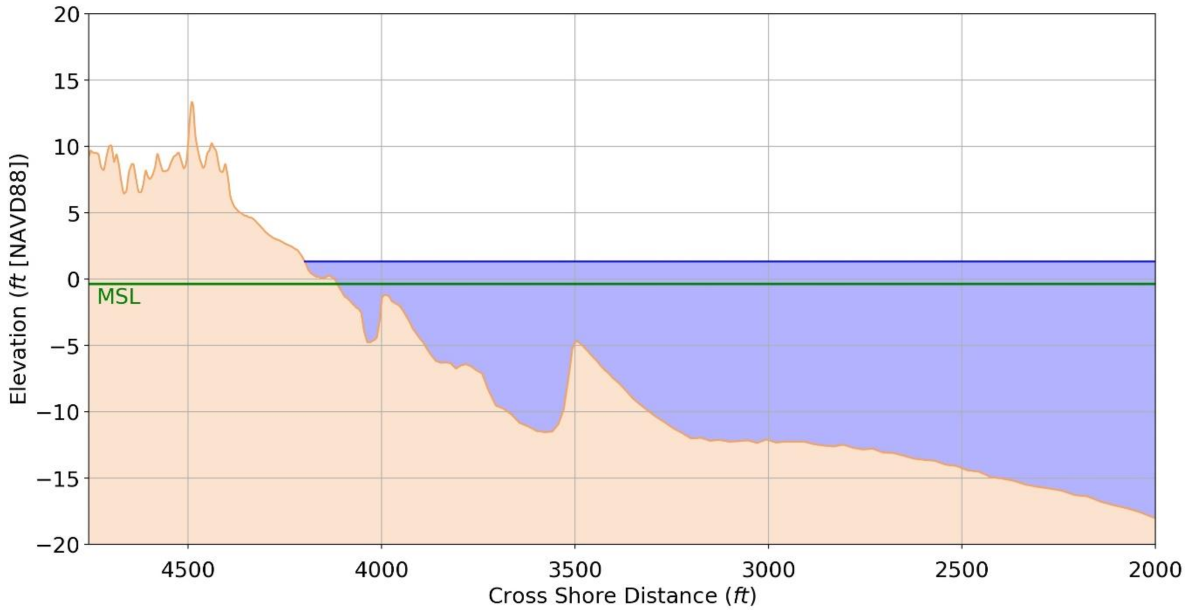

Figure 4. Initial Still Water Level and Bed Elevation for Profile CBI-03. MSL Datum Shown for Reference.

CBI-3, 6, 13, and 17

For CBI-3, 6, 13, and 17, the beach responded similarly to each storm scenario. The model predictions after 30 hours exposed to a 2-year wave event over a neap to spring tidal cycle are shown as erosion and accretion along the CBI-03 profile (Figure 5) as an example. Below ~10 feet NAVD88, the model did not predict a change in the bottom elevation in either the 2 or 10-year storm scenario. Closer inshore, especially along the steeper bottom features, up to 2 ft of erosion was predicted and areas of accretion occurred adjacent to the erosional areas. Between MSL and below 5 ft NAVD88, erosion of between 1.5 – 2 ft was predicted, the specific value depending on the profile. After the 10-year storm event, some accretion occurs in the deeper bathymetric features in the nearshore zone (Figure 6). For the 100-year storm event, erosion was predicted higher on the beach, up to an elevation of 5 ft above NAVD88 (Figure 7). A large length of the beach above MSL was predicted to erode for the 100-year storm event as compared to the 2 and 10-year events.

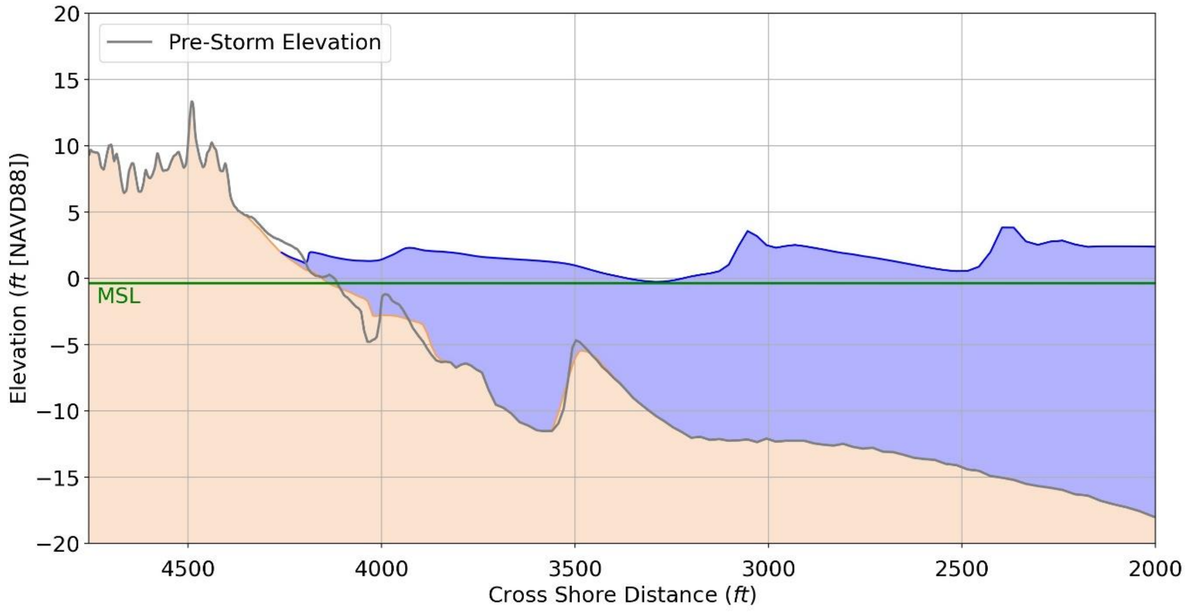

Figure 5. Predicted Shoreline Elevation for CBI-03 after 30 Hours of Exposure to a 2-Year Storm Event

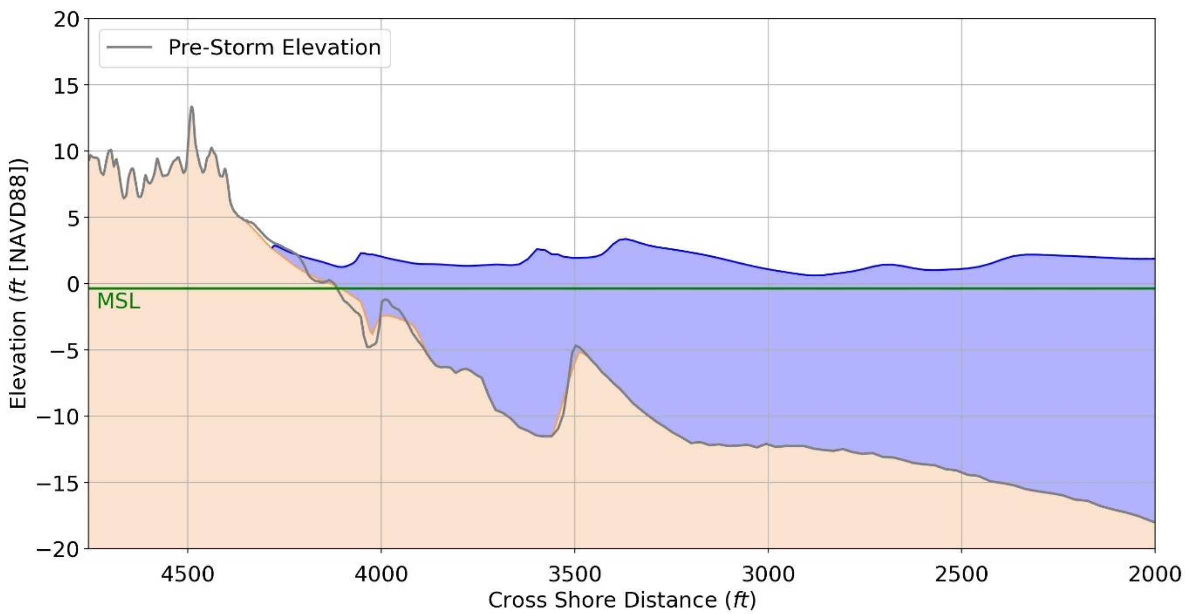

Figure 6. Predicted Shoreline Elevation for CBI-03 after 30 Hours of Exposure to a 10-Year Storm Event

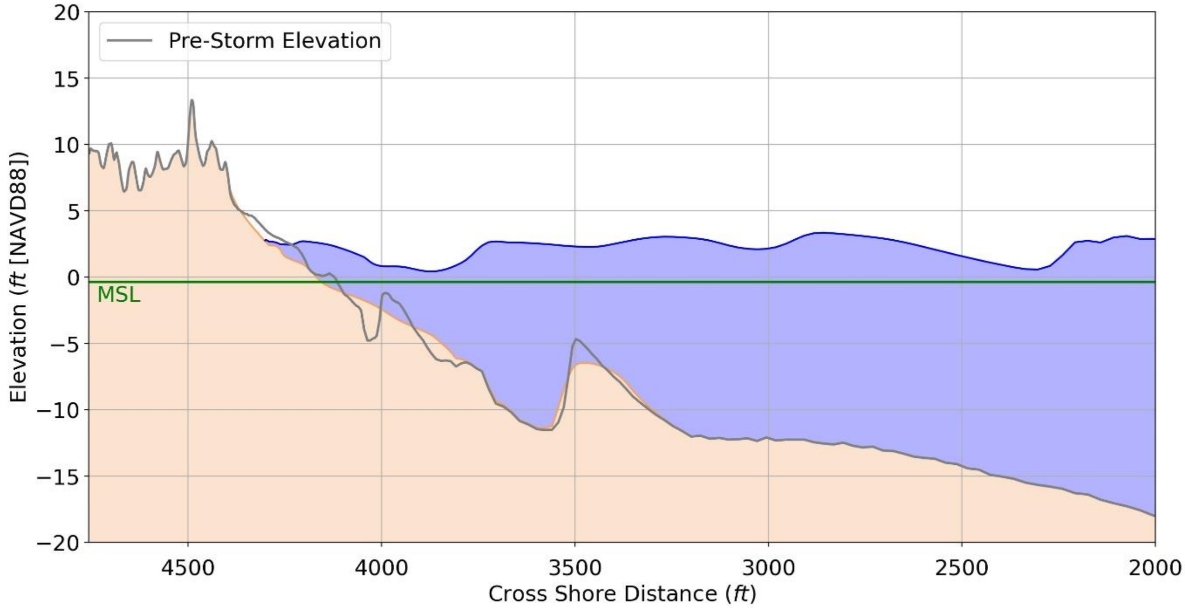

Figure 7. Predicted Shoreline Elevation for CBI-03 after 30 Hours of Exposure to a 100-Year Storm Event

CBI-22 and 24

For CBI-22 and 24, the model predictions after 30 hours exposed to a 2-year wave event over a neap to spring tidal cycle are shown as erosion and accretion. The results for CBI-22 are shown as an example in Figure 8. Below ~10 feet below NAVD88, the model did not predict a change in the bottom elevation. Closer inshore, especially along the steeper bottom features, up to 2 ft of erosion was predicted and areas accreted adjacent to the erosional areas. A large length along the beach face, above MSL and below 5 ft NAVD88, with erosion of up to 2 ft was predicted with some accretion predicted along the beach above 5 ft NAVD88. For the 10-year and 100-year storm event scenarios, the predicted magnitude of erosion and accretion increased up to 3 ft (Figures 9 and 10). For CBI-22, during the 10 and 100-year storm events, erosion was predicted along the foredune face, to the top of the dune at ~8 ft NAVD88. This feature is steeper along this profile as compared to other profiles, which likely contributed to the increased erosion.

Interestingly, for CBI-22, the 10-year storm event predicted a larger amount of erosion along the foredune face as compared to the 100-year storm event. This is a result of the influence of bathymetry and topography on the wave energy. Smaller waves can travel closer to shore before breaking, especially with varying water levels. While at the offshore point of the profile, the 100-year wave height is higher than the 10-year wave height (Table 2), the larger offshore wave of the 100-year event comes in contact with the sea floor at a deeper depth and will break, expelling its energy before rushing up to the foredune, thus reducing the potential for erosion. The 10-year offshore wave will break closer to the shoreline, thus increasing the potential for erosion. The importance of this finding is that more frequent wave events could cause increased potential for coastal erosion, however, the occurrence of this is dependent on the local bathymetry as most of the other modeled profiles were predicted to have larger amounts of erosion during the 100-year storm event.

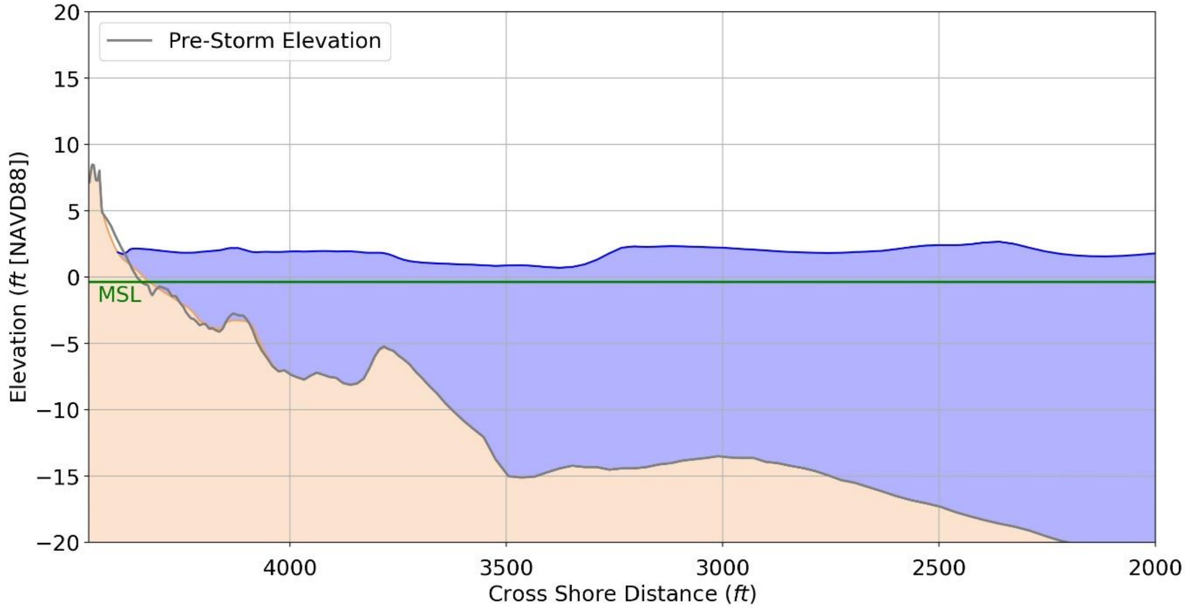

Figure 8. Predicted Shoreline Elevation for CBI-22 after 30 Hours of Exposure to a 2-Year Storm Event

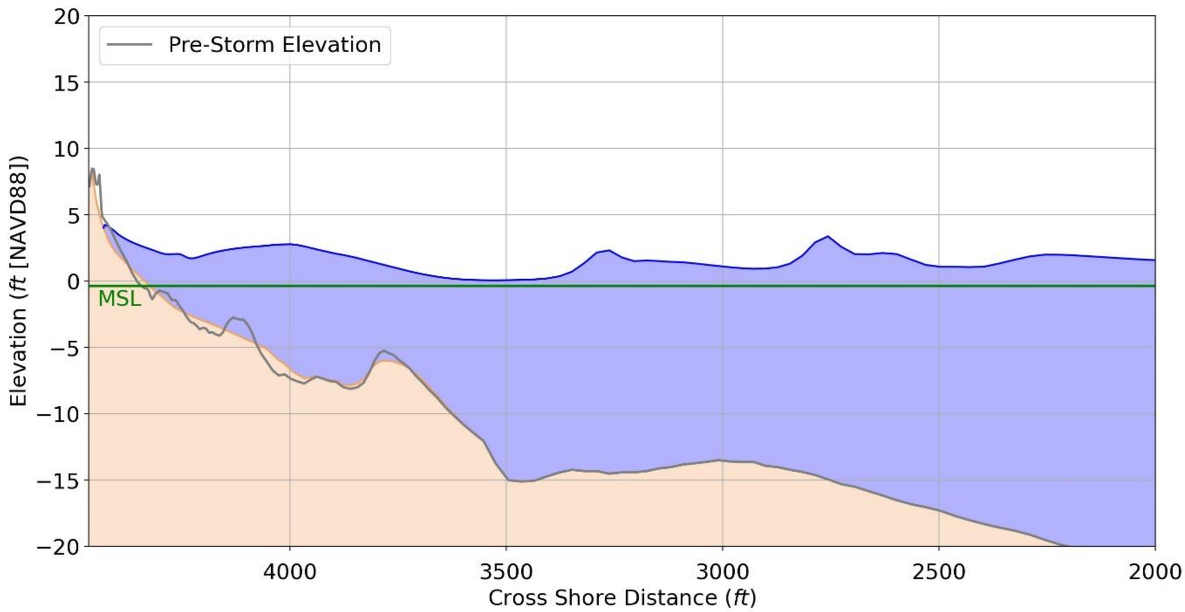

Figure 9. Predicted Shoreline Elevation for CBI-22 after 30 Hours of Exposure to a 10-Year Storm Event

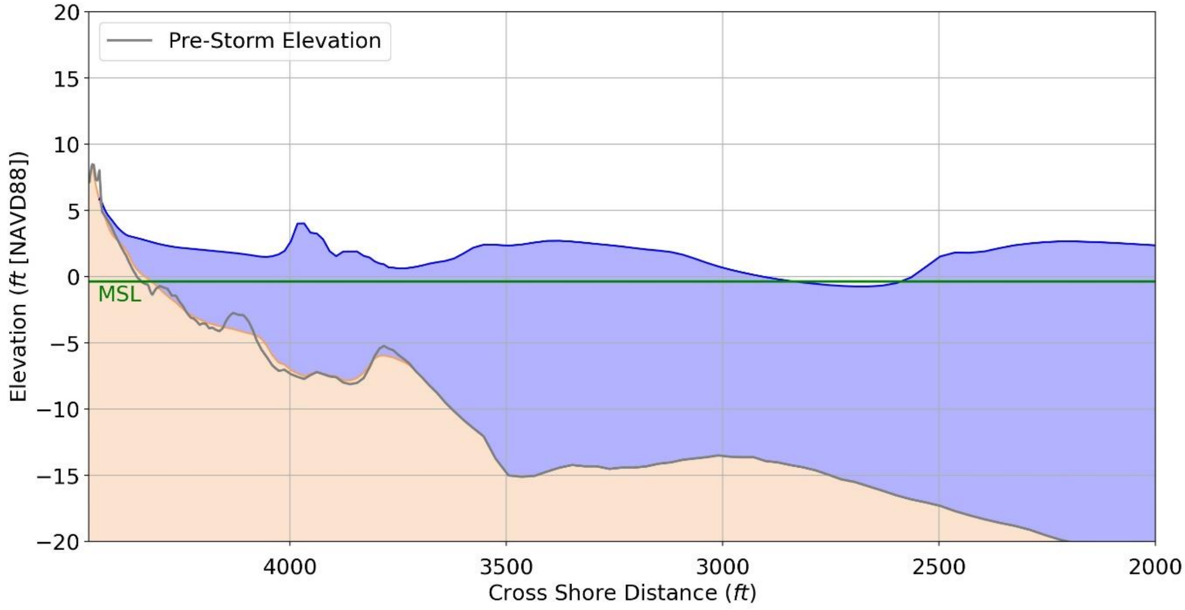

Figure 10. Predicted Shoreline Elevation for CBI-22 after 30 Hours of Exposure to a 100-Year Storm Event

Model Uncertainty

Model grid resolution and bathymetry interpolation lead to potential sources of model uncertainty. Modeled bathymetry within a grid cell, while reflective of the mean bathymetry measured using an echo sounder, might be shallower or deeper in certain regions of the cell, leading to enhanced sub-grid-scale erosion/deposition in nature that is not captured by the model.

In addition, uncertainties can arise assigning values to the sediment bed properties. Sediment bed properties were defined uniformly and containing primarily sand. Variability of these properties within a reach can lead to variability in predicted erosion and accretion, and hence uncertainty in model predictions. The effect of this variability can be evaluated by undertaking sensitivity tests that vary the sediment bed composition during the selected storm events.

However, the net effect of these uncertainties on the short-term sediment transport along each of the profiles is assumed minimal relative to the predictions of erosion and accretion and will meet the needs of the scope of this project.

Recommendations and Next Steps

The coastal hazard analysis of six selected profiles along South Padre Island, TX identifies some key areas of future concern for the shoreline. In short, this task has documented the expected impacts of potential erosion and accretion along SPI. The next steps are to model future conditions under specific sea level rise scenarios and the then integrate the findings to informing coastal planning decisions.