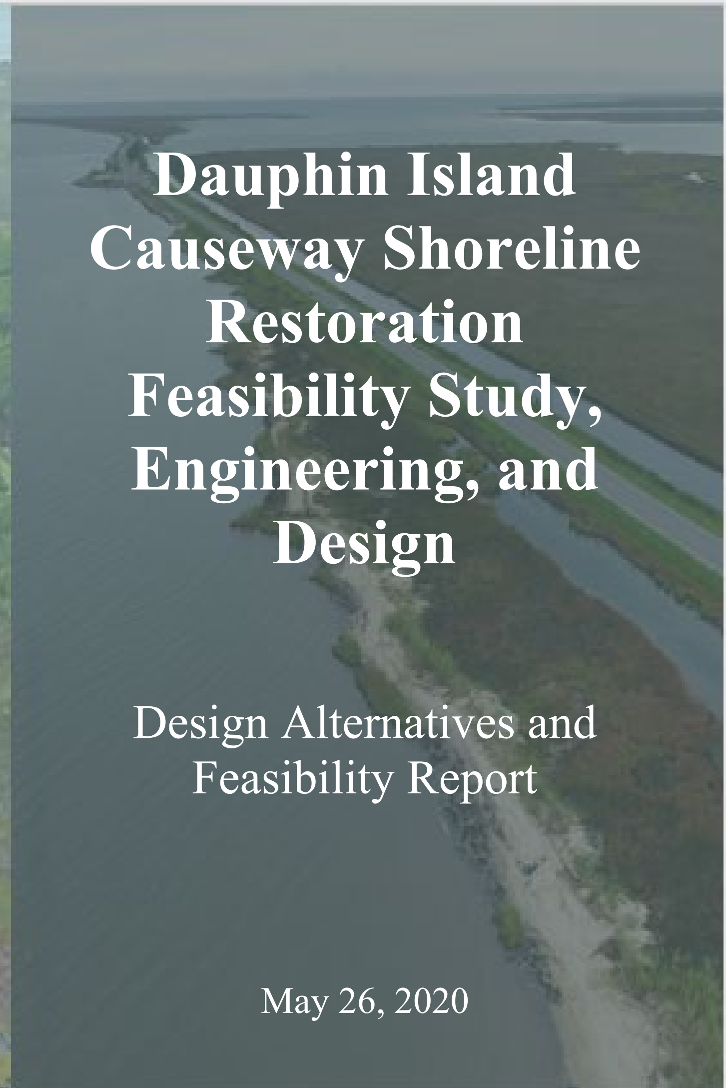
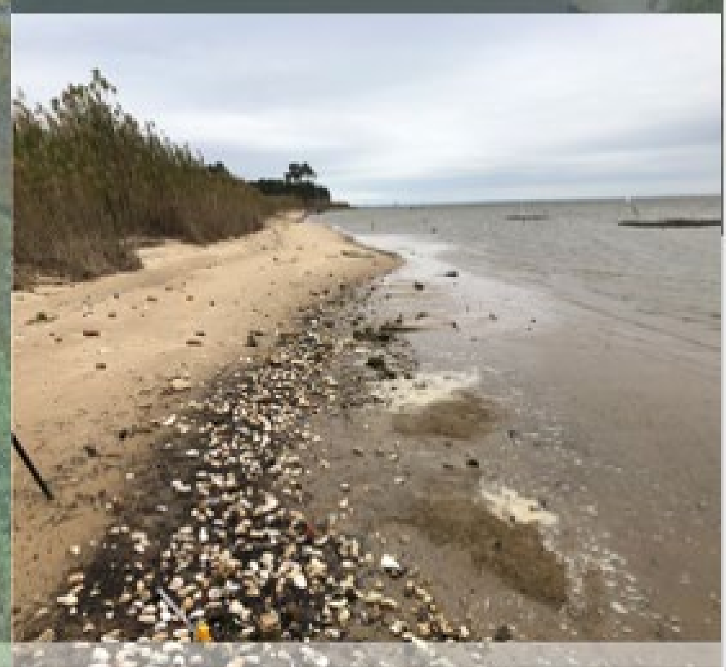


# Dauphin Island Causeway Shoreline Restoration Feasibility Study, Engineering, and Design

## Design Alternatives and Feasibility Report

May 26, 2020

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May 26, 2020

# TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

## LIST OF APPENDICES

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| CUDEM | Continuously Updated Digital Elevation Model |
| DEM | Digital Elevation Model |
| DMMA | Dredged Material Management Area |
| FEMA | Federal Emergency Management Agency |
| FIRM | Flood Insurance Rate Map |
| FM | Flexible Mesh |
| GEV | Generalized Extreme Value |
| GRR | Mobile Harbor Integrated General Reevaluation Report (USACE, 2019) |
| MBNEP | Mobile Bay National Estuary Program |
| MHW | Mean High Water |
| MLW | Mean Low Water |
| MPSRA | Marine Protection, Research, and Sanctuaries Act |
| MsCIP | Mississippi Coastal Improvements Program |
| NCDC | National Climatic Data Center |
| NCEI | National Centers for Environmental Information |
| NFWF | National Fish and Wildlife Federation |
| NOAA | National Oceanic and Atmospheric Administration |
| NRCS | Natural Resources Conservation Service |
| NRDA | Natural Resources Damage Assessment |
| ODMDS | Ocean Dredge Material Disposal Site |
| SWAN | Simulating Waves Nearshore (Modeling Software) |
| USACE | United States Army Corps of Engineers |
| WRDA | Water Resource Development Act |
| XBEACH | eXtreme Beach (Modeling Software) |

# 1. PROJECT OVERVIEW

## 1.1 Project Authorization and Background

The design alternatives and feasibility report is a 30 percent design level report. Geosyntec anticipates authorization of an additional phase (60 to 100 percent design) that includes a Design Report to capture later refinements in the design and analysis.

The Dauphin Island Causeway Shoreline Restoration Project aims to successfully implement a vibrant and sustainable living shoreline through a partnership with Mobile County, The Mobile Bay National Estuary Program (MBNEP), and other stakeholders. A living shoreline protects infrastructure and incorporates natural aesthetic elements to support both ecological functions (including oyster habitat), and human uses (including recreation opportunities such as fishing). The goals of the project are to stabilize the shoreline along the Bayside of the Dauphin Island Causeway and to protect infrastructure, enhance resiliency, create/enhance aquatic and wetland habitat to the greatest extent possible (Mobile County, 2019). Funding for the project was secured from the Natural Resource Damage Assessment (NRDA) program through the Alabama Department of Conservation and Natural Resources (NRCS) and with funding from the National Fish and Wildlife Foundation (NFWF) National Coastal Resilience Award and NFWF Gulf Environmental Benefit Fund through the Mobile Bay National Estuary Program.

Historically, sea level rise, extreme weather events, and increased wave energy have eroded the wetland habitat along the Dauphin Island Causeway. Since the roadway is only approximately four feet above the existing ground and there is little to no buffering wetland, the Causeway can be closed to traffic during periods of storm surge and wave action. In addition to dampening the effects of wave energy, thereby reducing erosion, marshes along the natural shoreline of the Causeway provide critical habitat to fisheries resources. Figure 1 shows the existing conditions of the project site.


**Figure 1: Existing site conditions.**

## 1.2 Basis of Design

As part of the data collection and design process, Geosyntec presented design basis metrics to Mobile County and project stakeholders during a Steering Committee Meeting. A Basis of Design document (Appendix B) outlines the assumptions made in the design of the project features with a 20-year project design life. The following sections provide highlights of the key parameters used for design.

### 1.2.1 Water Levels

A water-level analysis used the Dauphin Island Tide Gauge (NOAA Station 8735180) to determine datums, relative sea level rise, and extreme statistics. The tidal range is approximately 1.2 ft with a Mean High Water (MHW) are of +0.68 ft, NAVD88, and Mean Low Water (MLW) of -0.49 ft, NAVD88. The design of project features considers the intermediate to intermediate-high sea level rise scenarios, which translates to approximately 0.3-0.6 feet over 20-years (Letetrel, 2015). A water level analysis was performed on the measured gauge data to calculate the extreme statistics. Data from FEMA Flood Insurance Rate Maps (FIRM) confirm the calculated values and provide a basis for translating the Dauphin Island values to the project site. The 25-year reoccurrence design water level at the site is 5.1 ft, NAVD88.

### 1.2.2 Wind

Extreme statistics for winds and the direction from which the winds use the National Climatic Data Center (NCDC) station present on Dauphin Island. Return intervals use the ESE wind direction since winds from that direction would affect the project site more than other directions.

Significant wave heights and wave periods, essential to design the project features, use the 25-year ESE wind.

### 1.2.3 1917 Shoreline

The initial target for the seaward construction limits was the historic 1917 shoreline. The consensus among the design team and owner is that this configuration represents the maximum feasible marsh creation area. The scale of the project also matches the team's initial assumptions that the ideal marsh creation project is in the order of one million cubic yards. Presentations during early steering committees offered the various historical shoreline positions, and the committee provided positive feedback regarding the positioning. The steering committee ranked beneficial reuse of material, enhanced community resilience, shoreline protection, and benefit per unit cost among the most critical elements of the multi-criteria decision matrix. Due to the size of the marsh creation area with the 1917 shoreline configuration, more landward alternatives (with less marsh fill) did not score as high using the factored aspects of the decision matrix. Positive feedback from funding agencies also suggests that the configuration is fundable. Due in part to the facts noted above, we are recommending the 1917 shoreline as the preferred alternative.

# 2. COASTAL MODELING

## 2.1 Hydrodynamic Modeling

Hydrodynamic modeling uses Delft3D Flexible Mesh Modeling Suite (Delft3D FM). Deltares developed this modeling suite with the capacity to simulate storm surges, typhoons/hurricanes, tsunamis, detailed flows and water levels, waves, sediment transport and morphology, water quality, and ecology and is capable of handling the interactions between these processes. The hydrodynamic modeling estimates flows in and around the site. Delft3D couples directly with both the wave and sediment/morphodynamic models. This coupling allows the model to collectively consider changes in wind, wave, sediment transport, and morphological conditions.

Delft3D FM uses an unstructured mesh for its computational domain consisting primarily of triangles. Table one includes the characteristics of both the north and south meshes.

**Table 1: Mesh Characteristics for North and South Sites**

| Site | Number of Nodes | Number of Edges | Number of Faces | Minimum Resolution [m] |
|---|---|---|---|---|
| **North** | 43,789 | 131,018 | 87,230 | 3 |
| **South** | 40,047 | 119,793 | 79,747 | 5 |

Figure 2 shows the modeling domain. Also shown on the figure are the boundaries: discharge at the Mobile-Tensaw River and water levels at Dauphin Island and Pascagoula.

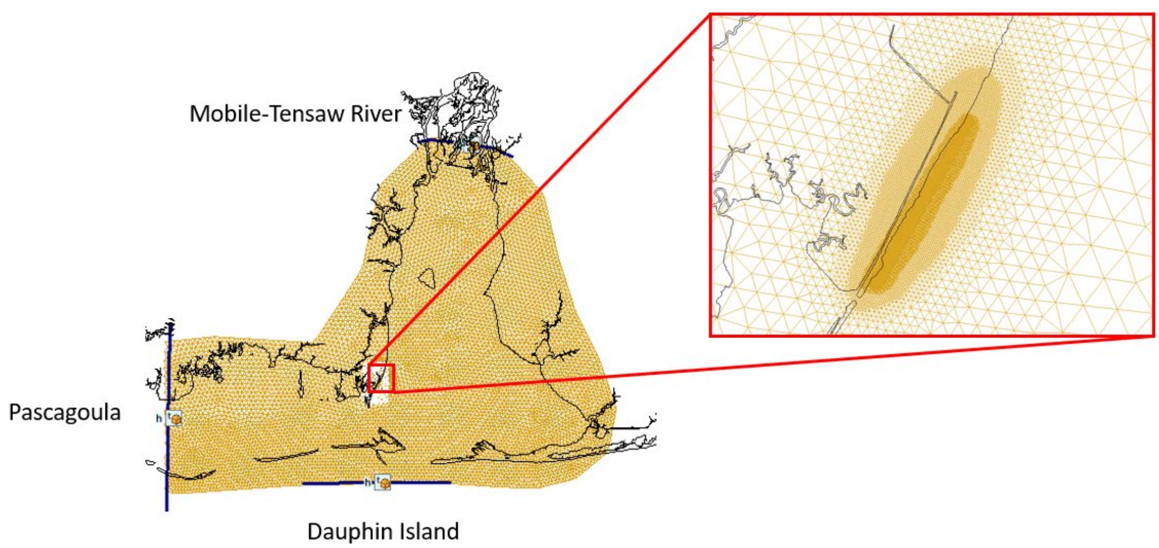


**Figure 2: Modeling domain.**

The model bathymetry used was derived from the National Centers for Environmental Information (NCEI) 1/9$^{th}$ arcsecond (approximately 3-m, or 10-feet) resolution digital elevation models (DEM) that comprise the Continuously Updated Digital Elevation Model (CUDEM) of select coastal areas in the USA. The model boundaries included wind data from the National Data Buoy Center Dauphin Island Station and water level data from the NOAA Dauphin Island (southern boundary of model domain) and Pascagoula Station (western boundary of model domain). The northern model boundary included input from the Mobile-Tensas River. Though the Mobile-Tensas River is gauged at several locations, its braided nature of the delta and the reverse tidal flows through the system make estimating total discharge problematic. Flows from the Mobile-Tensas River were therefore derived from scaling the drainage basin area of the nearby Escambia River, which is gauged by the United States Geological Survey (USGS) Station #02376033.

#### 2.1.1 Design Event

In consultation with the owner, project advisor, and steering committee analysis for the project uses a 25-year design storm. This 25-year storm includes both 25-year return level winds and water levels. Standard extremal statistical methods for fitting extreme data to the Generalized Extreme Value (GEV) distribution determine the return level water levels and winds. Calculations include return levels at 2-, 5-, 10-, 20-, 25-, 50-, and 100-yr return periods. A synthetic hydrograph was developed by analyzing known storms. The hydrograph was scaled by maximum 25-yr water levels at both Dauphin Island and Pascagoula to simulate a 12-hour design storm event. The 25-yr wind was forced over the design event to produce waves at the site. In terms of marsh erosion, storms smaller than the design event can be more damaging. Therefore, the analysis also includes storms of lesser water levels (scaled to the elevation of the road and elevation of the berm).

Analysis of the two preferred alternernatives also includes a sensitivity analysis. Sensitivity analysis for the modeling runs focus on the effect changes in water levels have on the on wave energy and erosion.

#### 2.1.2 Morphological Event

September 2019 was used as a representative month of observed wind, water level, and extrapolated flow conditions to model morphological change (day-to-day long-term effects). Morphological changes typically occur over larger timeframes than sediment transport processes. For this reason, the model uses a morphological factor (morfac). This factor accelerates the morphodynamic response to external forces, such as flow and waves, on the sediment in the system. The model uses a morfac value of 100, producing a morphological response 100-times as fast as the model run time. Therefore a model run over a month corresponds to 100-months of morphological evolution or about 3.25-years over “typical” conditions.

### 2.2 Wave Modeling

Wind and wave modeling was conducted using SWAN (Simulating Waves Nearshore), a state-of-the-art third-generation wave model developed at Delft University of Technology. It computes random, short-crested wind-generated waves in coastal regions and inland waters. The model is fully spectral in frequencies and directions and is non-phase resolving.

The model contains two grids – a coarse grid covering all Mobile Bay and a finer grid in the proximity of the site. Both grids are curvilinear. The coarse grid allows the evolution of waves from across the Bay while the finer grid permits smaller bathymetric features in the model to be resolved and influence the resulting wave field.

The only environmental forcing condition in the wind/wave model is wind speed and direction. Extremal analyses include 16 wind directions in 22.5° increments with 90° windows – N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, and NNW. The design event uses the worst-case wind direction and speed for the 25-year return period event.

The most wind extreme condition for the 25-year storm is from NNW. Given the location of the site and its orientation, however, the storm event from ESE was chosen. Table 2 shows the results of the return period analysis for ESE winds.

**Table 2: Return Period Levels for Winds at Dauphin Island**

| Return Period (years) | ESE Wind Speed (mph) |
|---:|---:|
| 2 | 38.9 |
| 5 | 47.9 |
| 10 | 54.5 |
| 20 | 61.1 |
| 25 | 63.3 |
| 50 | 70.3 |
| 100 | 77.8 |

The XBeach model used these results for the design event shoreline response.

## 2.3 Sediment and Morphodynamic Modeling

In addition to hydrodynamic modeling, sediment and morphodynamic modeling also used Delft3D FM. As with the wave model, the sediment and morphodynamic model was fully coupled with the hydrodynamic model so that changes in bathymetry, for example, fed into both the hydrodynamic and wind/wave models. The observed value of $D_{50}$=0.00033-m was used as the existing sediment size across the whole domain based on the results of sediment samples from the North Segment. The model uses the road, and the proposed in-water structures crest elevations, crest widths, and horizontal layouts.

Figure 3 shows a difference plot of the bed elevation at the end and the beginning of the model run for the existing condition for the north site. Blue (positive) indicates deposition, and red (negative) indicates erosion. The model results show depositon directly around the existing shore except for the area of the existing oyster structures, 2000-feet south of Bayfront Park, where some localized scour takes place. Figure 4 shows the same results for the design sill condition.

The depositional trends are the same as the existing conditions but have been pushed offshore to the 1917 shoreline. The sill design maintains the shoreline under the modeled condition.

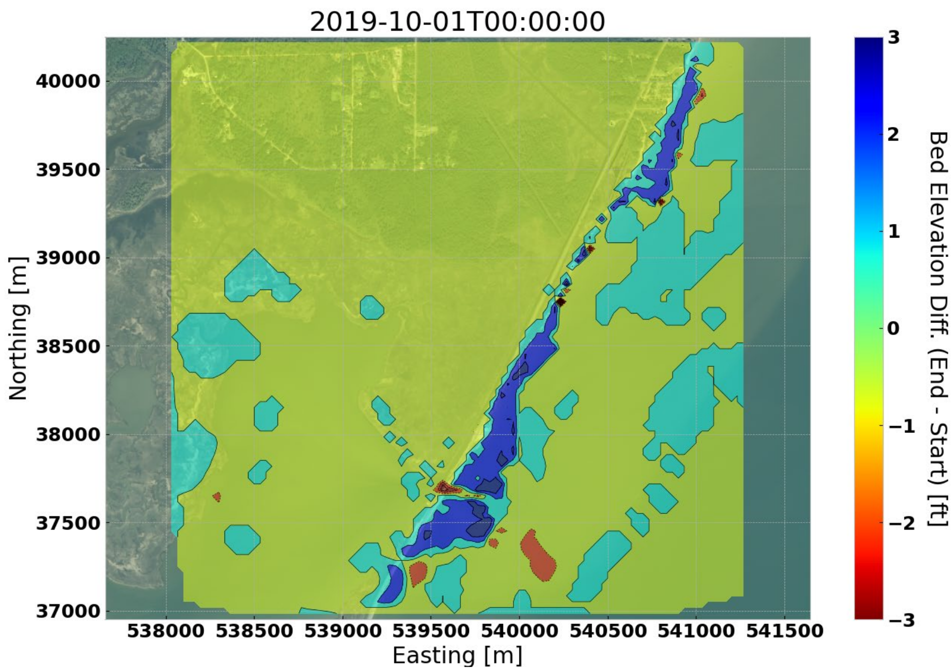


**Figure 3: Morphological Results for Existing North Conditions**

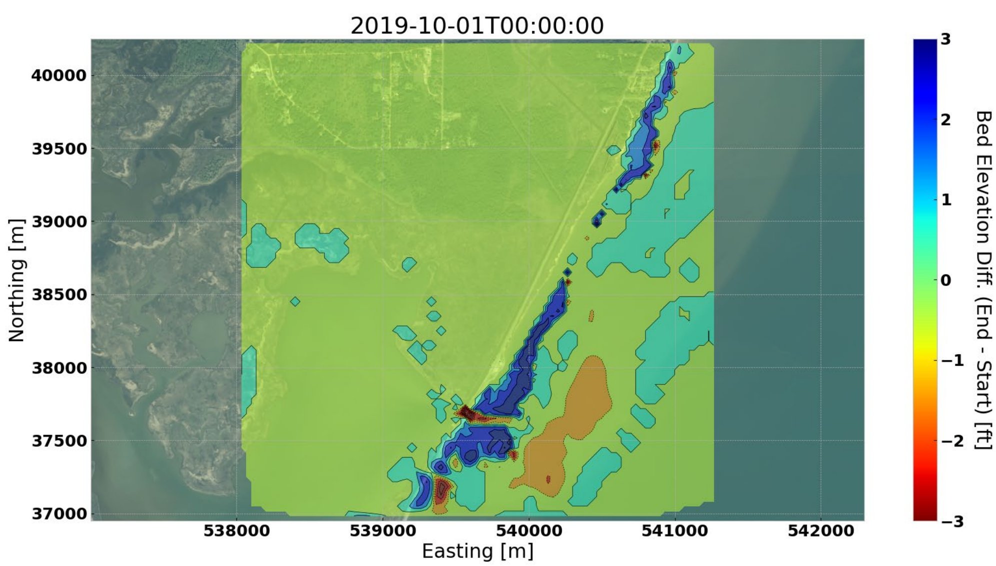


**Figure 4: Morphological Results for North Sill Conditions**

Figure 5 shows a difference plot of the bed elevation at the end and the beginning of the model run for the existing condition for the south site. The modeled condition shows erosion just offshore of the road with deposition directly to the east of the road. In areas where the bathymetry currently dips toward the road, energy funnels toward the road, and the depositional and erosional patterns move landward. Figure 6 shows the same results for the design sill/breakwater combination. The same erosional and depositional patterns exist as with the existing conditions, but they have moved offshore to the 1917 shoreline. The sill/breakwater structures maintain the stability of the material placed between the sill/breakwater and the existing road.

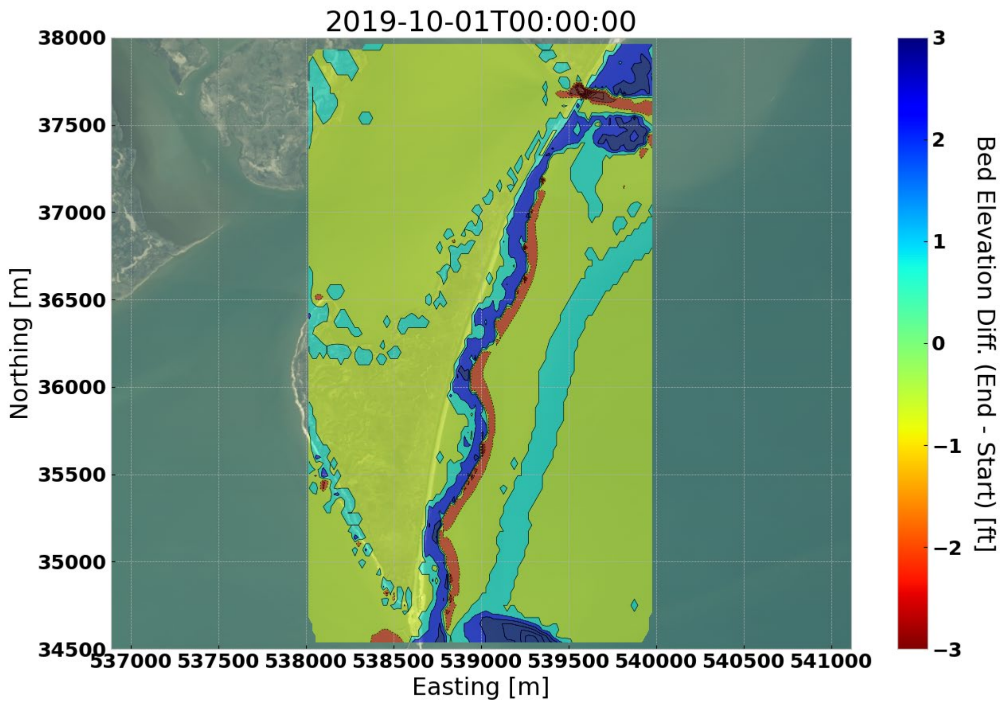


**Figure 5: Morphological Results for Existing South Conditions**

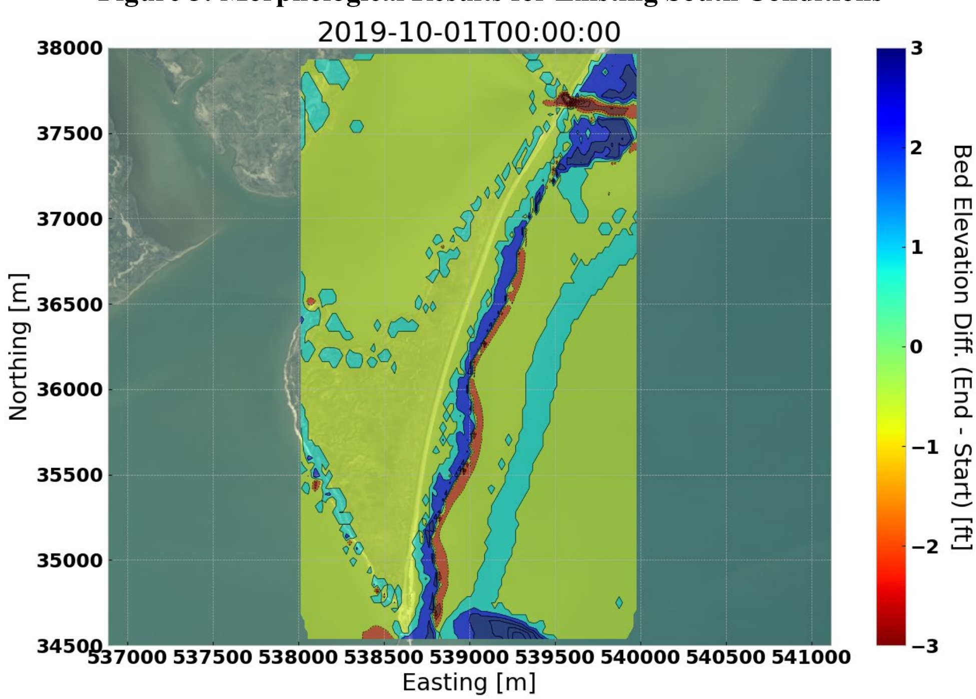


**Figure 6: Morphological Results for South Sill Conditions**

The current model results show substantial erosion through the cutoff. Updated bathymetry has been collected around and through Heron Bay Cutoff. Further modeling efforts, therefore, will be conducted in order to evaluate the impact of the updated bathymetry around the cutoff on circulation, sediment transport, and morphology around the site.

## 2.4 XBeach

The eXtreme Beach behavior model (XBeach) is a process-based numerical model that simulates morphological changes of complex systems due to high energy events (Roelvink et al., 2009). XBeach was chosen for this project because the 2D-horizontal model is capable of simulating hydrodynamics and sediment transport around structures allowing the behavior of alternative designs during storm conditions to be modeled at the project site.

XBeach has been shown to accurately simulate morphological changes on natural (e.g., McCall et al., 2010) and urbanized (e.g. Smallegan et al., 2016) coasts, where structures in urban areas are defined as "non-erodible" layers. The computer model is uniquely capable of seamlessly simulating all four storm impact regimes as defined by Sallenger (2000): the swash, collision, overwash, and inundation regimes. The depth-averaged model resolves infragravity waves, which are important during storm conditions (Roelvink et al., 2009; Van Thiel de Vries, 2009), rather than resolving individual waves. XBeach is incapable of solving three-dimensional processes since it is depth-averaged. Instead, these processes are parameterized in the model, reducing computational time considerably[1].

### 2.4.1 Methods

The Dauphin Island Causeway Project area divides into two regions based on the wave energy along its extent (Figure 7). The north region extends from the Heron Bay Cutoff Inlet to Bayfront Park and has a "moderate" wave energy climate. The south region extends from the Heron Bay Cutoff inlet to Cedar Point and has a "high" wave energy climate.

[1] The main limitations of XBeach that correspond to this study include: morphological changes due to storm conditions only can be simulated because the model does not resolve individual waves; structures cannot be destroyed in the model regardless of the forces acting on them; the results are limited to two-dimensional depth-averaged values; computational time for XBeach is very high relative to many other models so grid size and resolution are the result of this compromise.

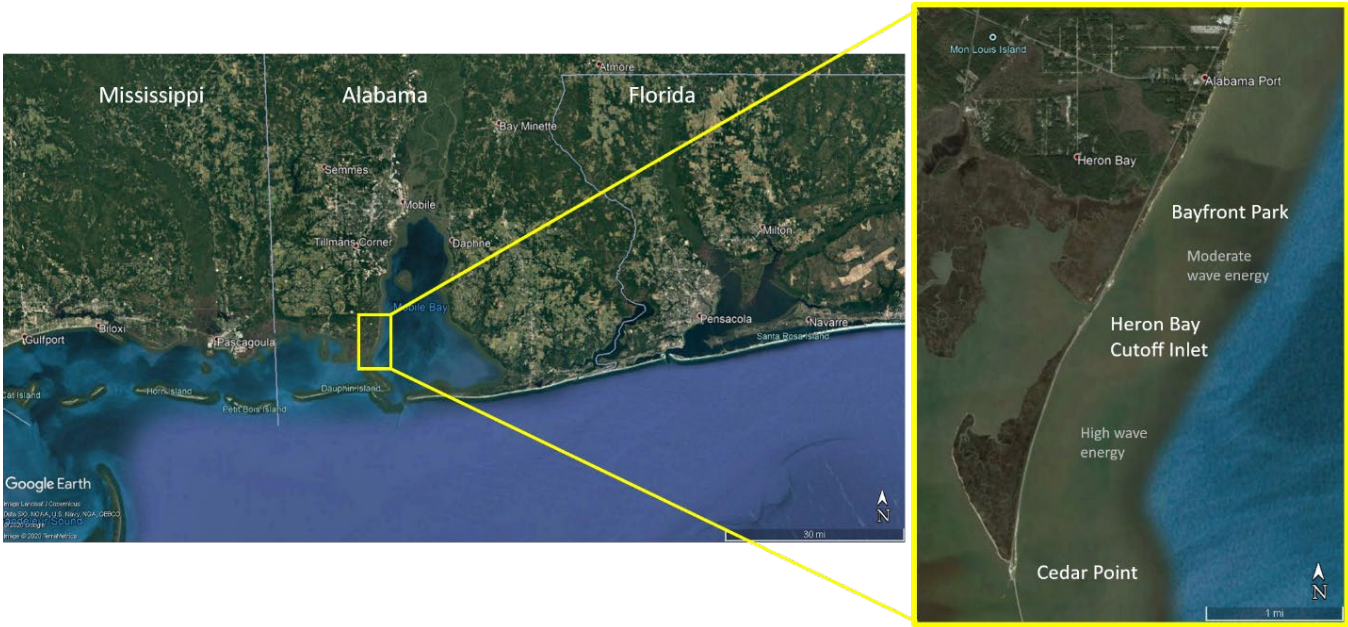


**Figure 7: Map of Project Site and moderate and high energy regions.**

Existing conditions and design alternatives one and two in each region (Table 3) use two-dimensional XBeach grids. Figure 8 and Appendix A show representative cross-shore profiles. Alternative one for the north region and alternative two for the south region are identical and characterized as sill designs. The sill alternative includes a dune located 100 ft from the shoreline, an offshore breakwater/sill located 300 ft from the shoreline with marsh between the shoreline and dune, and sloping marsh from the dune to the breakwater/sill. The dune is 2 ft tall with a 6-ft top width[2], and 1/10 side slopes to match existing conditions where small "dunes" are present in the project site. The breakwater/sill is 0.68 ft tall with a 6-ft top width and 2:1 side slopes. Model parameters set the breakwater/sill as a non-erodible layer in XBeach such that it is not destroyed or eroded in the simulations. Manning's *n* coefficients differentiate ground covers within the model grid. These parameters affect hydrodynamics as the site inundates during storm simulations. The model uses an *n* of 0.5 to represent vegetated regions corresponding to emergent estuarine wetland, an *n* of 0.3 to represent sand dune corresponding to the unconsolidated sandy shore, and an *n* of 0.12 to represent the roadway and breakwater corresponding to development (Passeri et al., 2017).

Alternative two for the north region and alternative one of the south region includes segmented breakwaters backfilled with a sloping marsh. The north region design positions the breakwater 300 ft from the shoreline, and the breakwater is 3 ft tall, has a 6-ft top width, and a 2:1 side

[2] The 6-ft top width corresponds to two grid cells in the XBeach grid. It is important to note that the elevations and design values reported herein may not represent actual design calculations and may change. All design values reported herein are *estimated* in the model since the final grid is an interpolation of a high-resolution representation of each design alternative. The interpolation is necessary to reduce the grid size, thereby reducing computational time.

slope. The model designates north breakwaters as non-erodible and includes 300 ft long sections with 75-ft gap widths. The backfill behind the breakwaters forms a sloping marsh (1-ft drop over 300 ft). In the south region, the breakwater is set 200 ft from the shoreline, is 3 ft tall with a 6-ft top width, and a 2:1 side slope. The model designates south breakwaters also as non-erodible and includes 200 ft long sections with 50-ft gap widths. The backfill behind the south breakwaters forms a sloping marsh (1-ft drop over 200 ft). The Manning's *n* values are specified as described above for the marsh, roadway, and breakwater.

In all XBeach grids, an artificial offshore slope is imposed at the offshore boundary so that the offshore boundary water depth equals the water depth from extracted waves. This technique is common practice in morphological modeling when there is a need to reduce computational time and when the offshore bathymetry is (at least mostly) uniform. The artificial slope allows waves to transform appropriately in the model as they enter shallower water but reduces the grid size since the offshore slope at this project area is very mild. Also, in every XBeach simulation, the mean grain size, $D_{50}$, was specified as 0.3 mm corresponding to geotechnical analysis at the project site. The model uses a *facua* of 0.01 (default value is 0.1), a value determined by XBeach studies of surrounding areas, to account for wave skewness that affects onshore sediment transport (Deltares, 2017).

During a preliminary analysis, the project team chose the breakwater plus fill design as the recommended alternative for the south region due to the higher wave energy present in that region.

**Table 3: XBeach Simulation runs**

| Region | Alternative 1 | Alternative 2 |
|---|---|---|
| North | Sill: breakwater+marsh+dune | Breakwater+fill |
| South | Breakwater+fill | Sill: breakwater+marsh fill+dune |

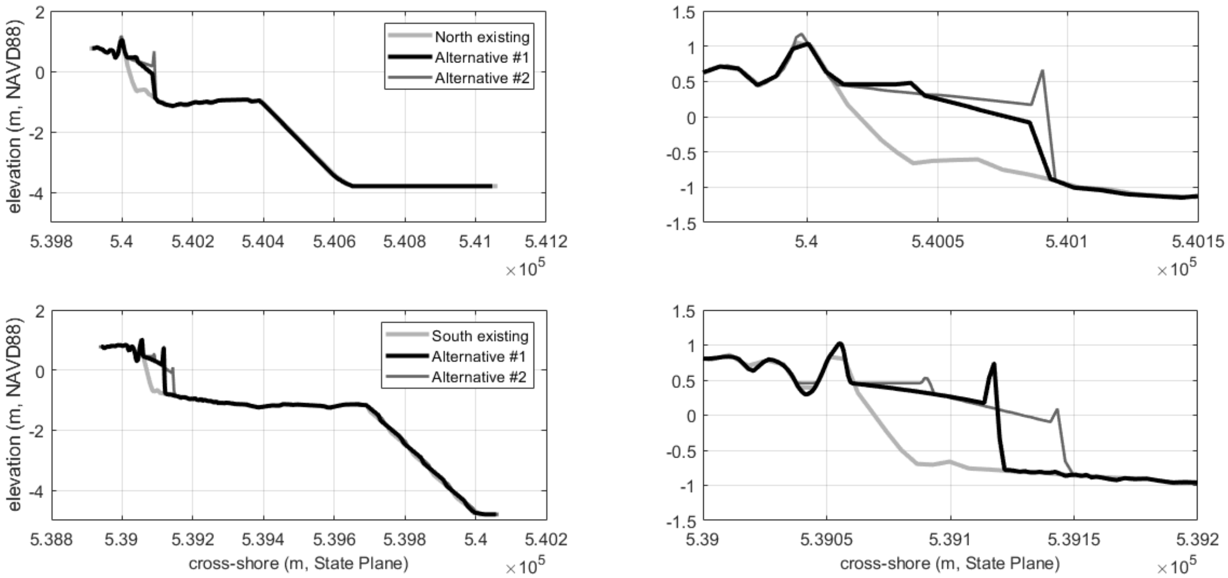


**Figure 8: Representative cross-shore profiles.**

Using SWAN, a wave model, the 25-year storm condtions were simulated for 25- year return period wind speeds assuming a southeast approach (winds coming from/going to angle 135). Figure 9 shows the water level, and Figure 10 shows wave conditions for each region within the project site at the 3.8 m and 4.8 m depth contours for the moderate and high wave energy regions, respectively. A sensitivity analysis includes scaled-down 25-year water levels such that the peak water level equaled the road and dune elevations (Figure 9). Note, the wave conditions were not changed in this sensitivity analysis. The model forces the hydrodynamic conditions at the offshore boundary of the XBeach grids for each region.

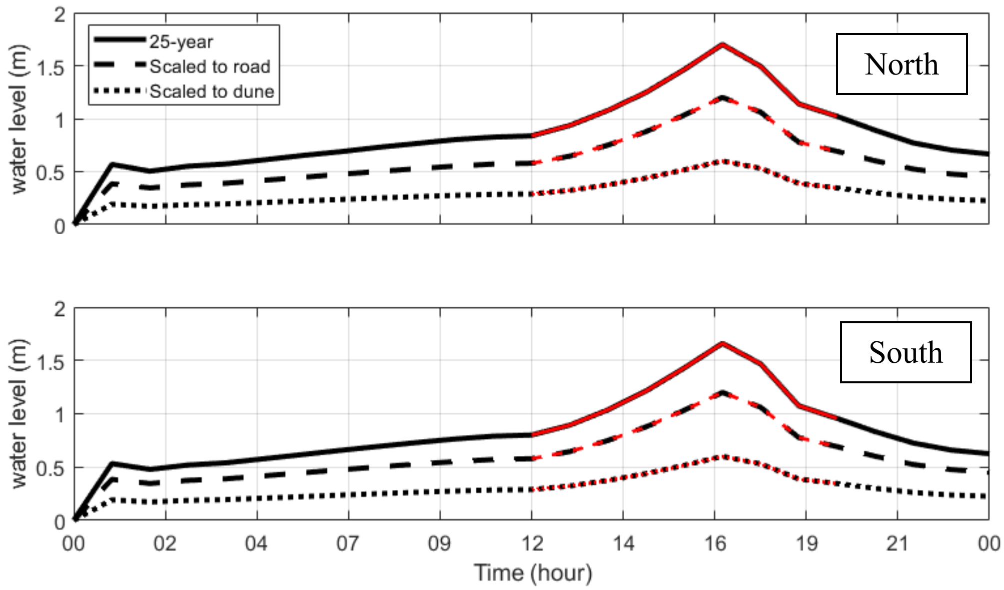


**Figure 9: Water levels for 24-hour storm (black lines) and XBeach storm (red lines).**

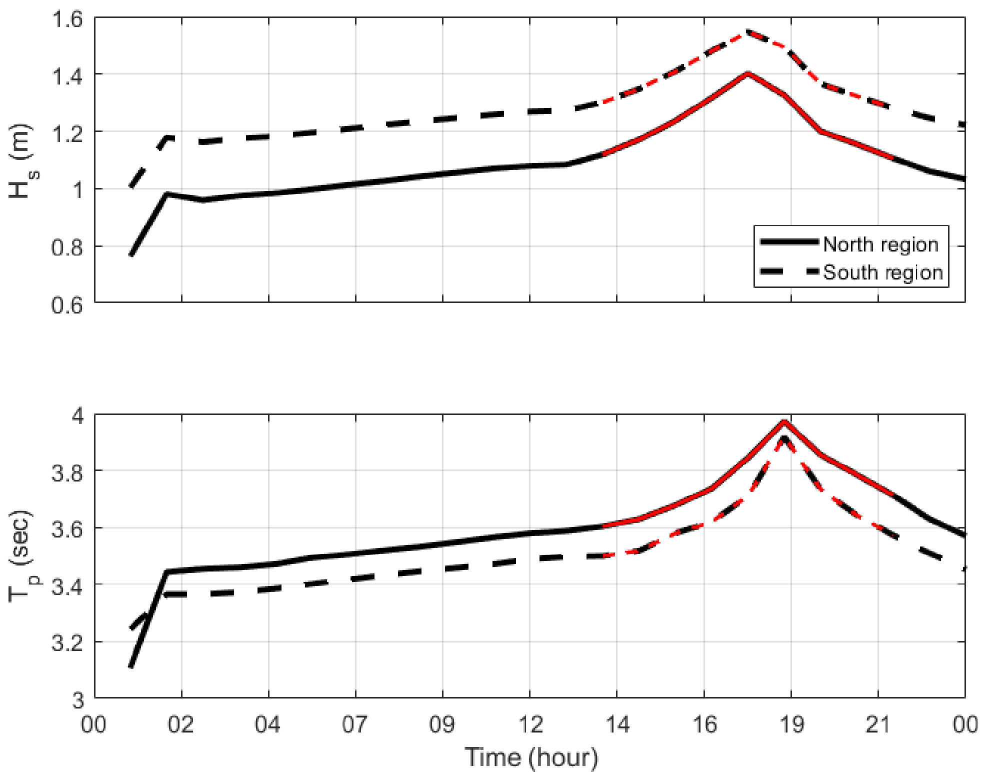


**Figure 10: Significant wave height and peak wave periods.**

### 2.4.2 Results and Discussion

The model forces 25-year storm wave and water level conditions and the scaled water levels at the offshore boundary for the existing and design alternative grids resulting in 18 total XBeach simulations. In the simulations, the 25-year design storm water levels inundated the entire project site at the peak of the storm. Since the effects on the project features are minimal once they inundate, the scaled water levels illustrate the impacts of waves at lower water levels. Appendix A contains the results from the 25-year design storm and all scaled water level scenarios. The following two subsections present the results using the water levels scaled to the road.

#### *2.4.2.1 North Region*

XBeach results indicate alternatives one and two reduce the amount of erosion at the shoreline at the north site (Figure 11, top). From Figure 11, alternative one experiences relatively small amounts of erosion over the sill. Figure 11c shows erosion and deposition for alternative two at the offshore breakwater. This sediment transport is likely due to erosion of the marsh in the backfilled area behind the breakwater. This sediment deposits just offshore of the breakwater. A limitation of XBeach is that structures are not able to be destroyed during the simulation. This limitation is relevant to the existing shoreline and breakwater revetment. However, the model does simulate erosion at the structure. Severe erosion at the toe of the structure could lead to failure. Alternatives one and two mitigate erosion at the structure, thereby reducing the failure potential due to scour.

Figure 11 (d – f) shows changes in wave energy over the north region. Waves under existing conditions remain relatively large until breaking at the shoreline. As wave energy increases, the wave forces experienced by the shoreline, including the revetment and roadway increase. If water levels elevate enough, catastrophic damage could occur. However, alternative one causes the waves to begin to break at the offshore breakwater indicated in Figure 11b as a gradual decrease in wave energy. This gradual reduction, as simulated by XBeach, leads to a reduction of wave energy at the shoreline for these storm and water level conditions. Alternative two also reduces the amount of wave energy at the shoreline; however, the change in wave energy is not longshore uniform since alternative two includes segmented breakwaters. Directly behind the breakwaters, wave energy is nearly completely dissipated. However, as expected, waves propagate through the breakwater gaps and, due to diffraction, wave energy is not equal to zero everywhere behind the breakwaters.

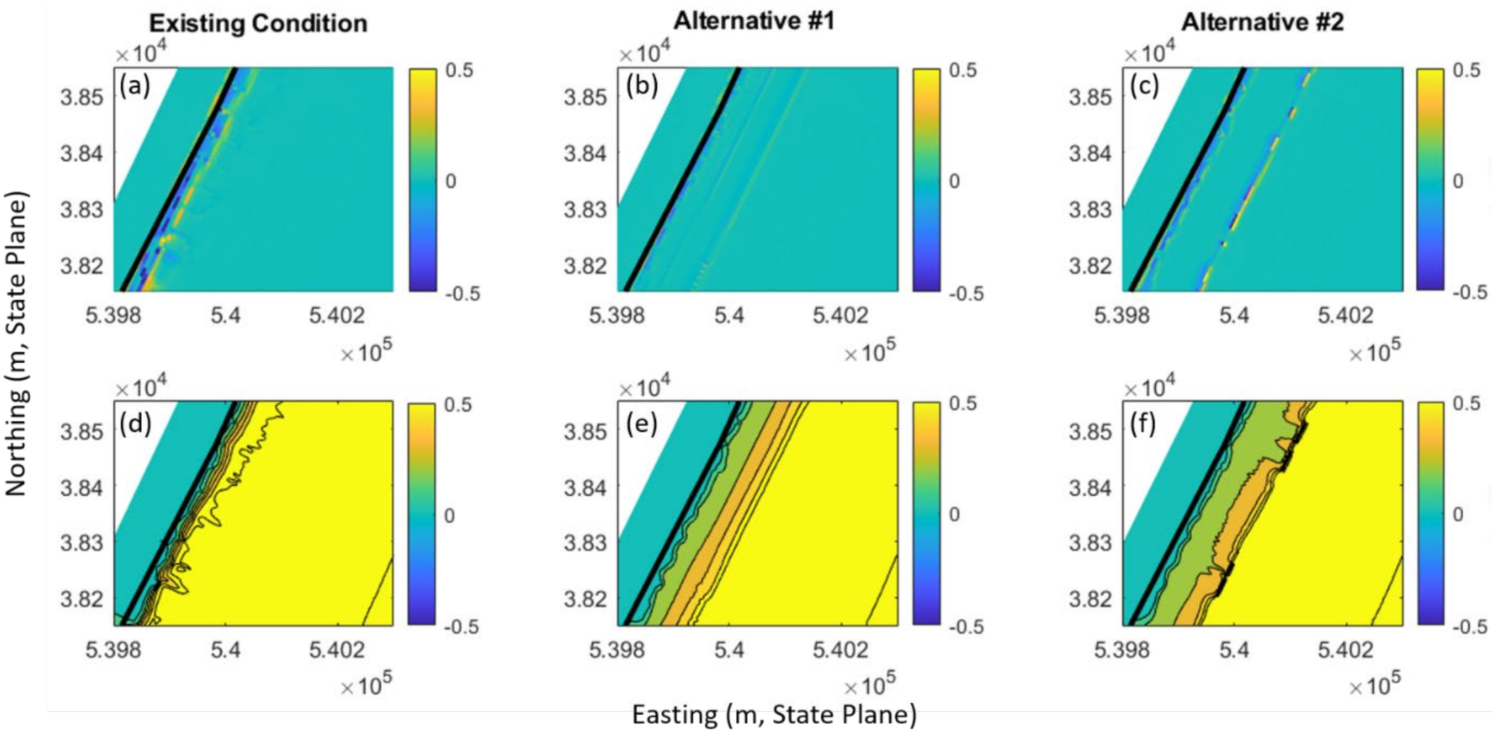


**Figure 11: XBeach North results.**

### *2.4.2.2 South Region*

In the south region, XBeach results indicate alternatives one and two, again, reduce the amount of erosion at the shoreline (Figure 12, top). In Figure 12b, alternative one experiences erosion of the marsh backfill, which is deposited directly offshore of the breakwater, essentially smoothing the transition between the backfill elevations and the water depth at the breakwater. XBeach shows alternative two has the smallest amount of erosion at the shoreline compared to existing conditions and alternative one since the marsh and dune dissipate the energy and deform in response to the forcing (Figure 12c).

Similarly, to the north region, waves break on the shoreline under existing conditions for this storm scenario (Figure 12d), which could lead to damage to the shoreline, existing revetment, and roadway. Alternatives one and two dissipate wave energy either with segmented breakwaters (Figure 12e) or with marsh and dune (Figure 12f).

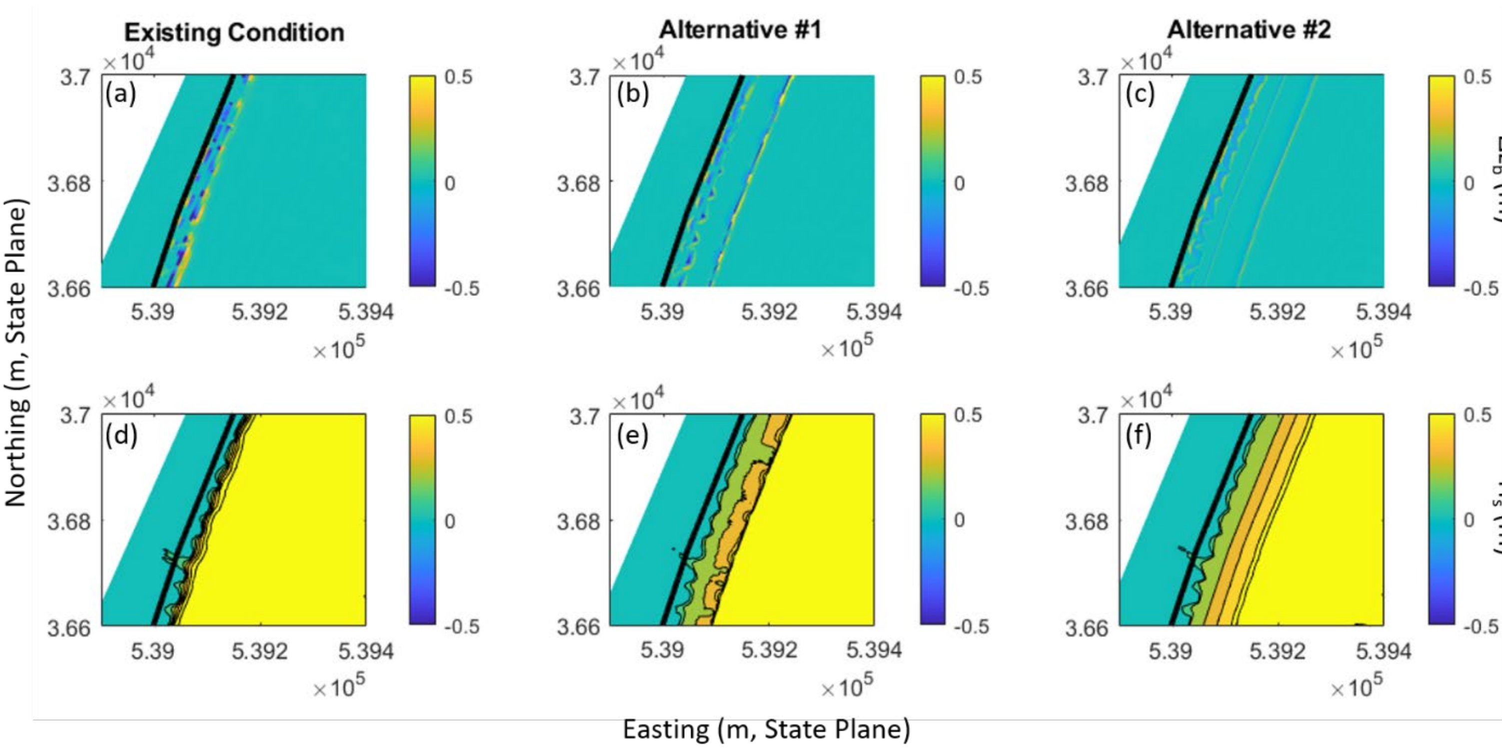


**Figure 12: XBeach South results.**

# 3. SEDIMENT SOURCE EVALUATION

## 3.1 Sediment Source and Delivery Alternatives

The Dauphin Island Causeway Shoreline Restoration project aims to restore critical habitat throughout the project area utilizing material from within the Mobile Bay region. Characteristics of the preferred sediment include predominantly sand with little fine-grained material, median grain size similar to native grain size ($D_{50}$=~0.33mm), and color similar to native soils for aesthetic purposes (if feasible, since no data on color is available).

Nine sediment source alternatives were presented as part of the Concept Design, as shown in Figure 13.

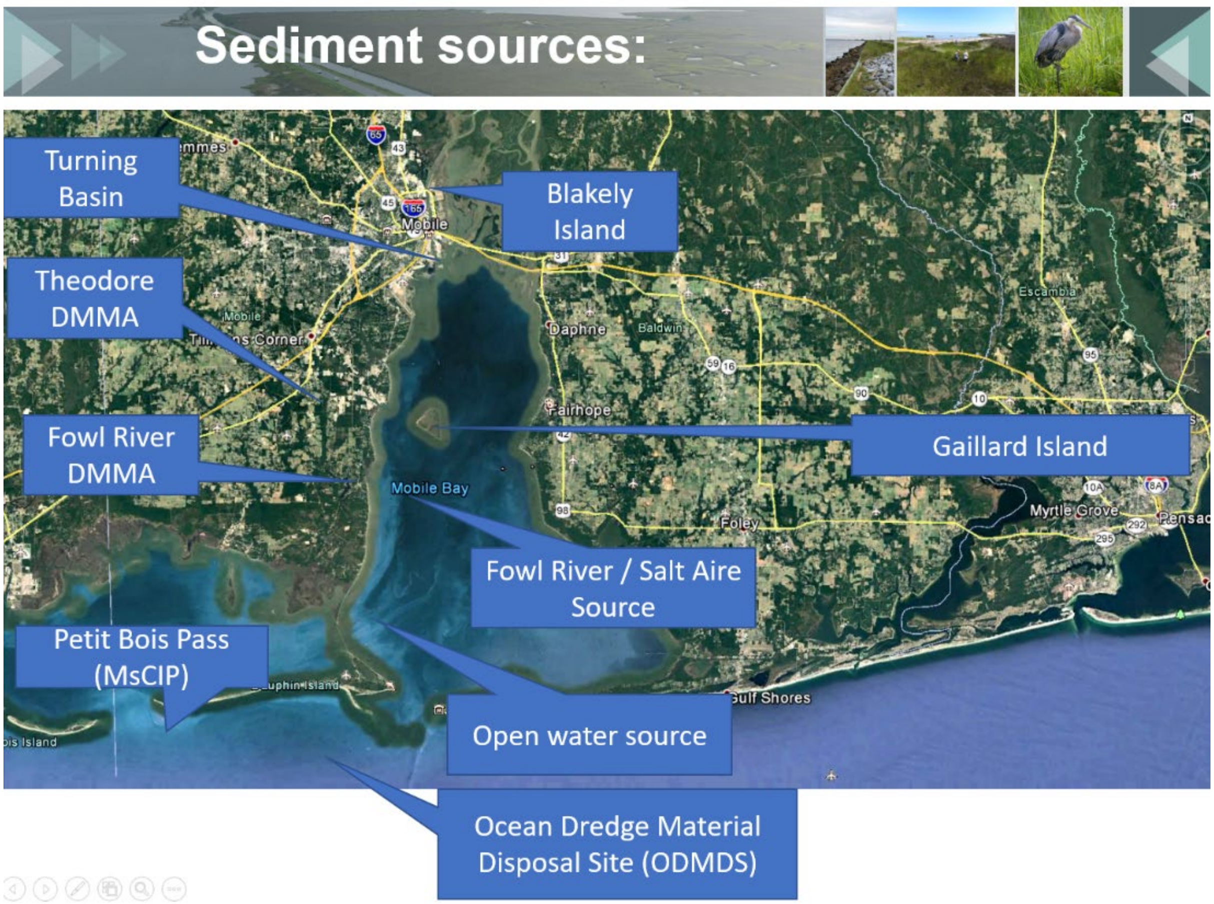


**Figure 13: Sediment Source Alternatives**

### 3.1.1 Turning Basin and Theodore DMMA

The Choctaw Turning Basin near the mouth of the Mobile River is proposed to be deepened and widened as described in the Mobile Harbor Integrated General Reevaluation Report (GRR) prepared by the USACE (USACE, 2019). The expanded area contains predominantly clean sand with pockets of silty sand. Historic borings provided by the USACE show grain sizes in the range preferred. In preliminary coordination with the USACE, they have agreed to place this new work material in the Theodore DMMA for use by the project. At this stage of the project, post-placement processing is unknown. Current cost estimates assume that the material is dried and in a ready to use state.

Conveyance of material from the Theodore DMMA is possible through barging, trucking, or directly pumping material to the project site. Opinions of cost were prepared based on coordination with contractors, USACE, RSMeans, and historical project cost data. Generally, waterside placement of marsh fill (via. barging or pumping) is about twice the cost of landside construction (hauling by truck). Landside construction fill delivery by truck has a higher community impact (due to significant construction traffic) and less potential impact on fishery resources (due to reduced risk of turbidity). The opposite is true of waterside fill delivery (barge or pipeline), which has reduced community impacts, albeit with a higher risk of turbidity concerns.

Temporary construction traffic estimates vary depending on contractor availability and contract requirements. One scenario assumes twenty trailer dump trucks, with a 25-yard capacity, can make a round trip in 90 minutes for eleven hours per day. This scenario anticipates 230 working days to deliver (approximately one truck every four to five minutes) marsh fill for both the north and south projects.

### 3.1.2 Blakely Island

Blakely Island is an upland disposal site along the Mobile River. According to the USACE a range of material is available for use, so the likelihood of the site having compatible material for the project area is high. Initial data collected from the existing material, however, showed a higher percentage of fine-grained material, which is less desirable for use at the project site. Coordination with the USACE revealed that there is a possibility that they could potentially place new work material from the Choctaw Turning Basin at Blakely for future use. However, conveyance of material from Blakely Island would likely require overland hauling or development of a barge loading system. Barging from Blakely Island would be the preferred sediment delivery option because of the distance from the project site, but estimates gathered for this option showed a price per cubic yard of sediment delivery by barging over twice that of trucking.

**Figure 14: Blakely Island Upland Disposal Area**

### 3.1.3 Gaillard Island

Gaillard Island is an upland disposal site within Mobile Bay near the Mobile Ship Channel and the Theodore Industrial Park Complex. This site was considered mainly due to its proximity to the project site. However, it is likely impractical to use due to material availability.

Conveyance of material from here to the project site is only achievable with barges. A barge loading system is not currently in place at Gaillard Island, so loading of material would be difficult and more costly than other methods.

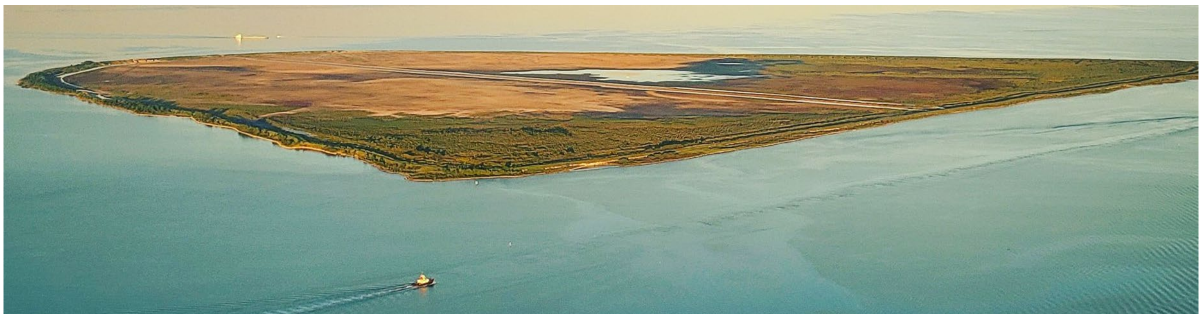

**Figure 15: Gaillard Island Upland Disposal Area (Photo courtesy of Joey Hunsinger)**

### 3.1.4 Fowl River DMMA and Fowl River/Salt Aire Source

The Fowl River DMMA is a dredged material management area and is a consideration because of its proximity to the project site. However, the Salt Aire project is currently utilizing the DMMA to construct the project. Therefore, it is likely impractical to use for the Dauphin Island project due to material availability after the completion of the Salt Aire project.

### 3.1.5 Petit Bois Pass

Sand resources are available in the Petit Bois Pass. According to the USACE, sufficient material exists to complete the Dauphin Island project; however, the site is likely impractical due to the depth in the pass and distance from the project area.

### 3.1.6 Ocean Dredge Material Disposal Site (ODMDS)

The ODMDS is offshore of Dauphin Island in the Gulf of Mexico. While material availability is likely sufficient, depth, and distance to the project site make this option impractical.

### 3.1.7 Open Water Source

Investigation and delineation of an open water source require extensive surveys, sediment sampling, and turbidity control measures. These efforts would likely delay the design timeline, thereby delaying the construction timeline.

### 3.1.8 Preferred Sediment Source and Delivery

Considering the preferred characteristics of the sediment, proximity to the project area, and sediment conveyance feasibility, the Choctaw Turning Basin soils delivered to the Theodore disposal site provides the most cost-effective solution. Conveyance of material from the Theodore DMMA is possible through barging, trucking, or directly pumping material to the project site. As discussed in Section 3.1.1, trucking the material provides the most cost-effective solution. The project team recommends Turning Basin Sediment delivery by truck from the Theodore DMMA.

## 3.2 Choctaw Turning Basin

USACE plans approximately 1.7 MCY of "new work" material from the Choctaw Turning Basin. This work is to comply with the authorized dimensions per Section 201 of the WRDA of 1986, PL 99-662 (USACE, 2019).

### 3.2.1 Turning Basin Sediments

The new work sediment in the turning basin is predominantly clean sand (SP) with some pockets of silty sand (SM). Clean and silty sands are present from elevation -39 feet down to the extent of the proposed deepening at elevation -54 feet. Fat clays (CH) and silts (ML) were also sampled in historical borings, intermixed with sand above elevation -39 feet (USACE, 2019). Borings indicate that the construction of the previous turning basin expansion removed most of the clays and silts. The GRR planned expansion areas on the north and south side of the turning basin has intermittent layers of silt and clay, though predominantly sand (USACE, 2019).

### 3.2.2 Theodore Disposal Area

The USACE identified the Alabama State Docks near the Theodore Industrial Park as a suitable temporary disposal area for the Choctaw Turning Basin sediments. Preliminarily, the USACE has agreed to place the material in this disposal area for dewatering to be available for the Dauphin Island Causeway project. Additional coordination with the USACE is required to understand what is involved in preparing the Theodore Disposal Area.

# 4. DESIGN ALTERNATIVES

## 4.1 Project Goals

The goals of the Dauphin Island Causeway Shoreline Restoration project are to:

- Stabilize the shoreline along the eastern side of the Dauphin Island Causeway and the western shore of Mobile Bay

- Create/enhance aquatic, wetland, and riparian habitat to the greatest extent possible.

The design life of the project features is 20-years.

## 4.2 Multi-Criteria Decision Matrix

In collaboration with the owner and the steering committee, the design team developed a multi-criteria decision matrix to determine, in part, the preferred alternative for the North and South Segments based on pre-determined criteria and weighting. Stakeholders provided input on important parameters in the matrix. The parameters include aspects such as roadway protection, oyster resource protection, habitat creation, and aesthetics. The following sections highlight the main alternatives evaluated.

## 4.3 Alternatives

### 4.3.1 Alternative 1: Beach Nourishment

A beach nourishment project consists of the placement of sand to combat and offset shoreline erosion. The resiliency of inland structures increases without the use of any hard structures. Beach nourishment profiles can vary depending on the dominant coastal processes present in the project area. For the Dauphin Island Shoreline Restoration project area, a potential beach nourishment profile would consist of a dune along the existing shoreline and a beach berm extending from the dune to the historic 1917 shoreline, approximately 200 feet from the dune. This alternative would also include limited plantings along the dune.

Though this alternative achieves the project goal of creating habitat and a natural shoreline, the absence of a shoreline stabilization structure reduces the likelihood the constructed features would survive the 20-year design life without maintenance. It also does not address the desired goal of habitat creation or enhancement. No natural beach/dune systems exist along the Mobile Bay shoreline. Therefore, the team screened this alternative from consideration for the preferred alternative on both the North and the South Segments.

### 4.3.2 Alternative 2: Wetland Creation

The wetland creation alternative considered includes the creation of fully planted wetlands extending to the historic 1917 shoreline. This alternative differs from the beach nourishment alternative in that there is no constructed dune or beach ridge, and the planted marsh extends from the Causeway to the project limits in Mobile Bay.

This alternative achieves the project goal of creating habitat and a natural shoreline, but the absence of a shoreline stabilization structure reduces the likelihood the constructed features would survive the 20-year design life without maintenance or significant loss. The wave climate, especially during storm conditions, would likely not allow the wetland vegetation to survive. Existing wetlands along this region of Bay shoreline are eroding. Therefore, the team screened this alternative from consideration for the preferred alternative on both the North and South Segments.

#### 4.3.3 Alternative 3: Rock Revetment

A rock revetment alternative consists of placement of rock along the shoreline to an elevation that would block wave energy impacting the existing shoreline.

This alternative achieves the shoreline stabilization project goal but completely disregards the habitat restoration component and, in fact, creates a hard edge that interrupts the natural habitat. Therefore, the team screened this alternative from consideration for the preferred alternative on both the North and South Segments.

#### 4.3.4 Alternative 4: Segmented Breakwaters

Segmented breakwaters typically reduce the wave energy to allow for sediment deposition behind the breakwaters and retention of the existing beach. The length of the breakwater, the gap length between the breakwaters, and the distance between the existing shoreline and the breakwater determine whether a tombolo or a salient forms. This alternative assumes the lengths of the breakwater and the distance between the shoreline and the breakwater would allow for tombolo creation.

Since this alternative only includes the segmented breakwaters as a constructed feature, the elevation of the breakwaters needs to be such that it significantly dissipates the wave energy before allowing it to impact the existing shoreline. This alternative has the potential to achieve the shoreline stabilization goal and allows for the possibility to create habitat if tombolos form. The low rates of longshore sediment transport in the project region would likely result in little accretion along the existing shoreline even under reduced wave energy. Since the habitat creation is not guaranteed, the team screened this alternative from consideration for the preferred alternative on both the North and South Segments.

#### 4.3.5 Alternative 5: Segmented Breakwater and Beach Nourishment

This alternative combines the segmented breakwaters described in Alternative 4 and the beach nourishment described in Alternative 1. The segmented breakwaters ensure the retention and stabilization of the beach nourishment component.

This combination of the alternatives achieves the shoreline stabilization goal and provides some habitat creation through the planting of the dune but does not completely fulfill the habitat creation goal. Due to the limited longshore sediment transport in the area, this alternative will likely require period maintenance. Since it does not completely fulfill both project goals, the team screened this alternative from consideration for the preferred alternative on both the North and the South Segments.

### 4.3.6 Alternative 6: Segmented Breakwaters with Wetland Creation

This alternative combines the segmented breakwaters described in Alternative 4 and the wetland creation described in Alternative 2. The wetland would be created from the existing shoreline to the segmented breakwaters and planted.

This combination of the alternatives achieves the shoreline stabilization goal. It provides better habitat creation than Alternative 5, but the wetland creation component does not have the elevation variation of the beach nourishment alternative, does not have the protection of the beach ridge, and is not sloped to adapt to rising sea levels. As a result, the team screened this alternative from the consideration for the preferred alternative on both the North and the South Segments. This alternative is included as an element of some of the alternatives that follow.

### 4.3.7 Alternative 7: Segmented Breakwaters with Beach Nourishment/Wetland Creation Hybrid

This alternative takes the segmented breakwater from Alternative 4 and combines a hybrid of the beach nourishment and the wetland creation alternatives. The breakwater component of this alternative was also evaluated with a lightweight core to reduce settlement, but preliminary analysis of the lightweight core revealed it was cost-prohibitive. The hybrid of the beach nourishment and the wetland creation alternatives include the beach ridge from the beach nourishment alternative and the full planting of the wetland creation alternative. Additionally, varying elevations were included in the wetland creation component to allow for the diversity of plant species to establish and to provide adaptative capacity under sea level rise.

This alternative achieves both the shoreline stabilization goal and the habitat creation goal; therefore, that team considers this alternative a preferred alternative for the both the North and South Segments. It also mimics the existing conditions along the northern portion of the site where a small beach ridge/rack line fronts a wetland that extends to the road. This alternative was modeled using XBeach and Delft3D and compared to existing conditions to determine the reduction of wave energy and changes in morphology.

### 4.3.8 Alternative 8: Sill with Beach Nourishment/Wetland Creation Hybrid

The final alternative considered combines the beach nourishment/wetland creation hybrid described in Alternative 7 and a rock sill rather than a segmented breakwater. The elevation of the rock sill is significantly lower than that of a segmented breakwater.

As with Alternative 7, this alternative achieves both the shoreline stabilization goal and the habitat creation goal but with reduced rock quantities; therefore, the team considers it a preferred alternative for both the North and South Segments. This alternative was also modeled using XBeach and Delft3D and compared to existing conditions to determine the reduction of wave energy and changes in morphology.

## 4.4 Preferred Alternative

The results of the modeling efforts for Alternatives 7 and 8 and the results of the multi-criteria decision matrix scoring informs the selection of the preferred alternative for each segment.

Table 4 summarizes the design alternative analysis.

Table 4: Summary of Design Alternatives

| Alternative | Achieves Shoreline Stabilization Goal | Achieves Habitat Creation Goal | Advantages | Disadvantages | Considered for Preferred Alternative |
|---|---|---|---|---|---|
| 1-Beach Nourishment | Possibly | No | • Natural Shoreline | • No shoreline stabilization feature<br>• Maintenance required to achieve project design life.<br>• Only plantings on dune. | No |
| 2-Wetland Creation | No | Yes | • Natural shoreline<br>• Planting of entire platform | • No shoreline stabilization feature, continues to erode<br>• Maintenance required to achieve project design life. | No |
| 3-Rock Revetment | Yes | No | • Stabilizes shoreline | • Hardened shoreline.<br>• No habitat creation | No |
| 4-Segmented Breakwaters | Yes | Potentially | • Less rock than Alt. 3 while still achieving shoreline stabilization goal.<br>• Allows for some natural processes | • Hardened shoreline.<br>• Habitat creation dependent on coastal processes (i.e. longshore transport). | No |

| Alternative | Achieves Shoreline Stabilization Goal | Achieves Habitat Creation Goal | Advantages | Disadvantages | Considered for Preferred Alternative |
|---|---|---|---|---|---|
| 5-Segmented Breakwaters with Beach Nourishment | Yes | No | • Stabilizes shoreline | • Hardened shoreline<br>• Limited habitat creation | No |
| 6-Segmented Breakwaters with Wetland Creation | Yes | Yes | • Stabilizes shoreline<br>• Creates habitat with planting of marsh platform. | • Partially-Hardened shoreline<br>• Limited plant species diversity due to consistent elevations, susceptible to sea level rise | No (Elements included in Alternatives 7 and 8) |
| 7-Segmented Breakwaters with Beach Nourishment/Wetland Creation Hybrid | Yes | Yes | • Stabilizes shoreline<br>• Creates habitat with planting of beach ridge and wetland.<br>• Varying elevations leading to plant species diversity. | • Unnatural shoreline | Yes |

| Alternative | Achieves Shoreline Stabilization Goal | Achieves Habitat Creation Goal | Advantages | Disadvantages | Considered for Preferred Alternative |
|---|---|---|---|---|---|
| 8-Sill with Beach Nourishment/Wetland Creation Hybrid | Yes | Yes | • Stabilizes shoreline<br>• Creates habitat with planting of beach ridge and wetland.<br>• Varying elevations leading to plant species diversity.<br>• More natural shoreline than Alt. 7. | • Overtopping expected | Yes |

### 4.4.1 North Segment

The comparison of the segmented breakwater and the sill both with a beach nourishment/wetland creation hybrid between the rock feature and the existing shoreline for the North Segment both reduced wave energy impacting the shoreline compared to existing conditions achieving the shoreline stabilization goal. The sill alternative provides a more natural shoreline by allowing some overtopping to help with the diversity of plant species better achieving the habitat creation goal.

The preferred alternative includes the construction of a reshaping beach ridge (just landward of the sill), a salt marsh, and a sill. The limits of the restoration area assume the 1917 historic shoreline. The alternative includes a gently sloping marsh from the beach ridge to the existing shoreline. The sloping marsh allows for species diversity while also increasing the resiliency to future sea level rise. The salt marsh plantings stabilize the surface.

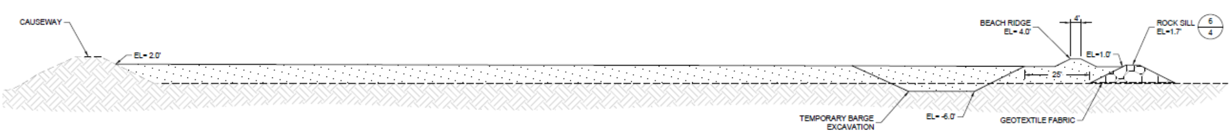


Figure 16: North Segment cross-section.

### 4.4.2 South Segment

The comparison of the segmented breakwater and the sill both with a wetland creation component yielded similar wave reduction results.

Restoration of the South Segment includes the construction of both sill and breakwaters to stabilize the shoreline and marsh between the shoreline stabilization feature and the existing bulkhead along Dauphin Island Causeway. As with the North Segment, the limits of the restoration area is the 1917 shoreline. Due to the higher wave energies in this region, breakwaters and sills alternate along the 1917 shoreline to provide shoreline protection. The salt marsh gently slopes while salt marsh plantings stabilize the surface. The sloping marsh improves the resiliency allowing propogation of the marsh up the slope as sea level rises.

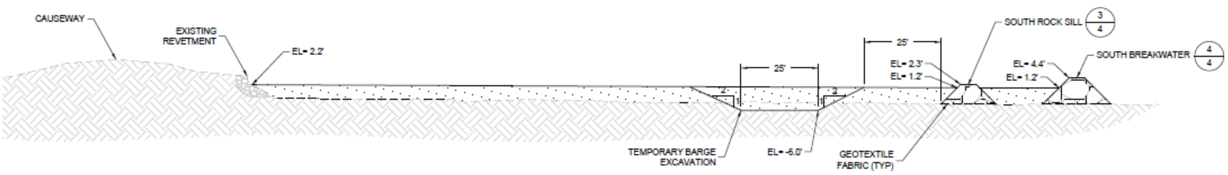


Figure 17: South Segment cross section.

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# APPENDIX A
## Modeling

This appendix provides more details on the existing conditions and design alternatives used in the XBeach simulations.

***North region***

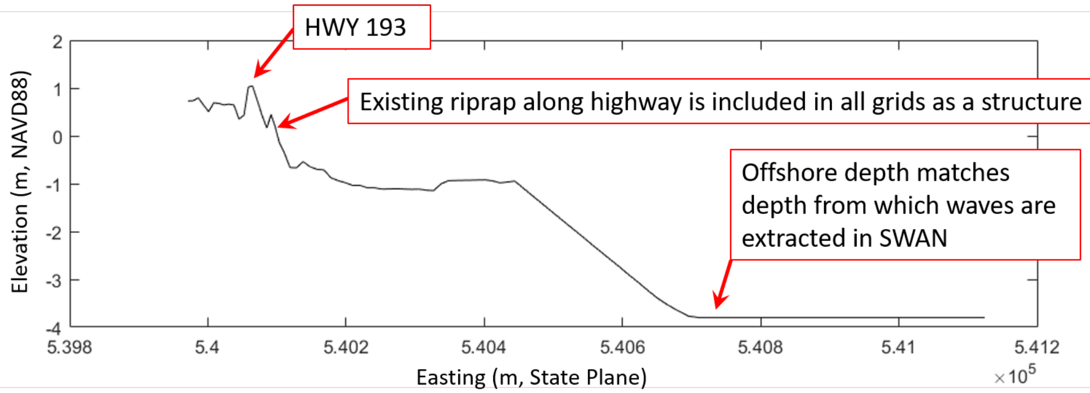



Figure A-1. Cross-shore profile description for the existing condition.

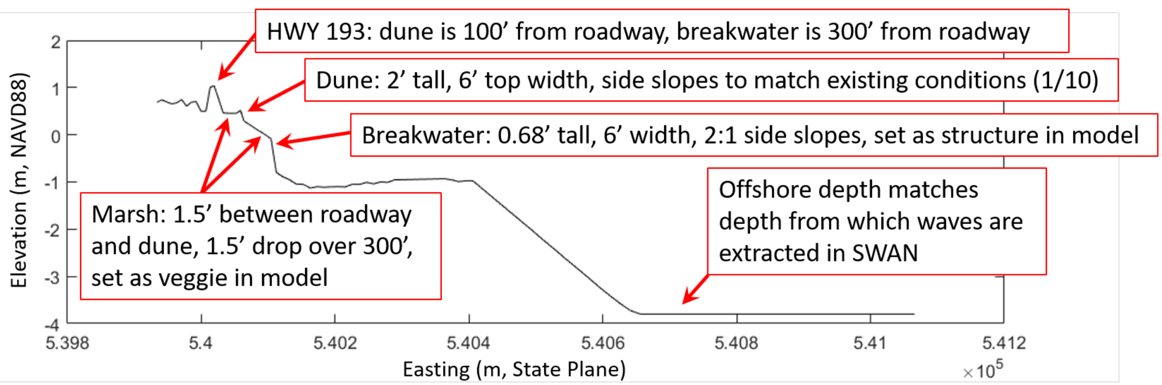



Figure A-2. Cross-shore profile description for Alternative #1 sill design.

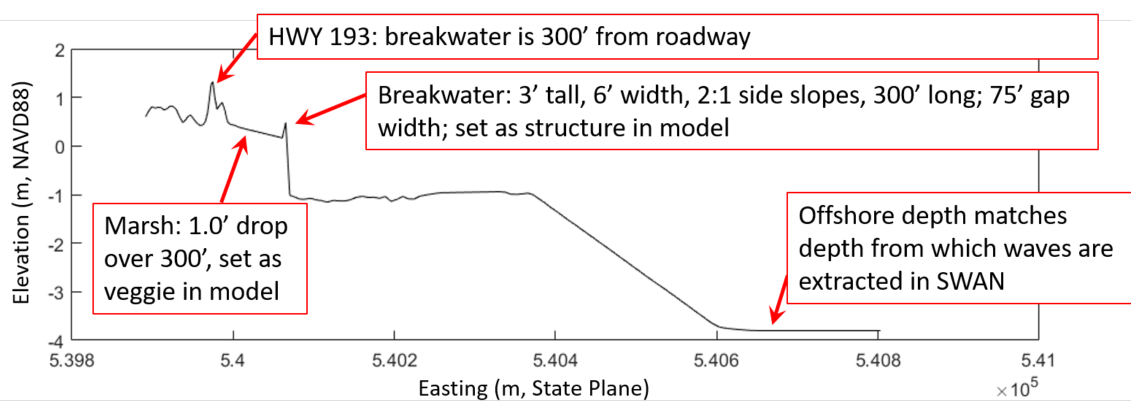



Figure A-3. Cross-shore profile description for Alternative #2 segmented breakwater and marsh design.

### *South region*

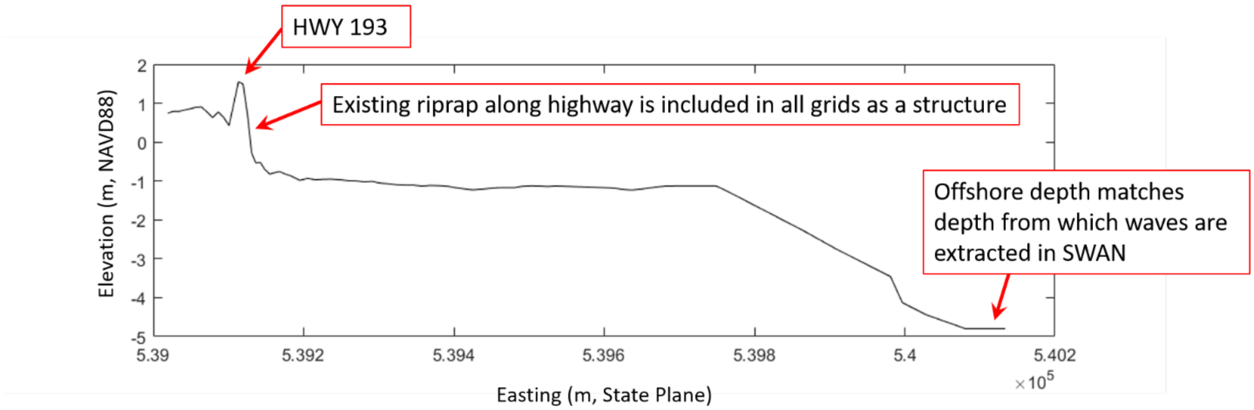



Figure A-4. Cross-shore profile description for the existing condition.

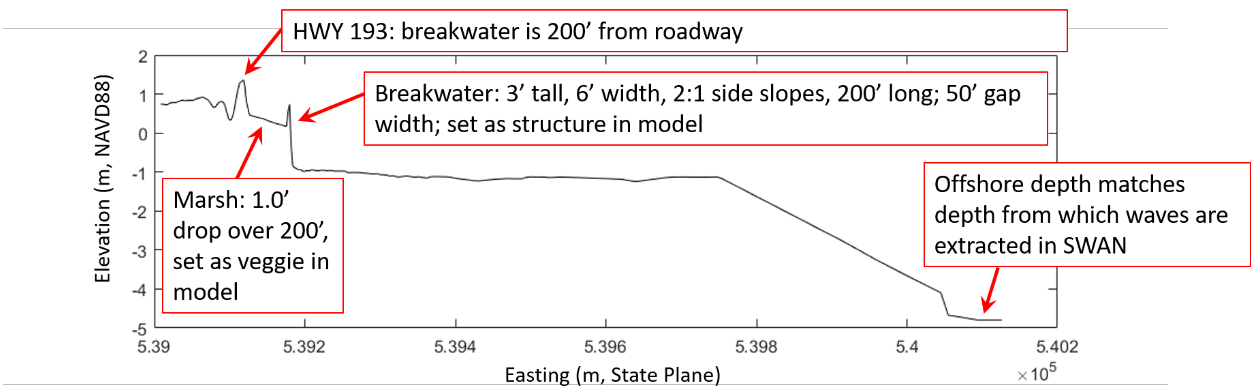



Figure A-5. Cross-shore profile description for Alternative #1 segmented breakwater and marsh design.

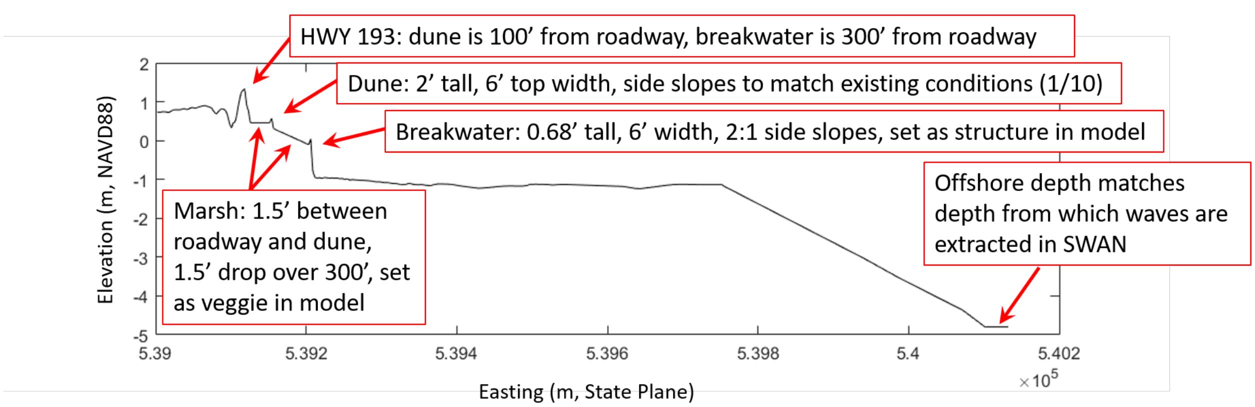



Figure A-6. Cross-shore profile description for Alternative #2 sill design.

This appendix includes additional XBeach simulated results for the north and south regions.

***North region***

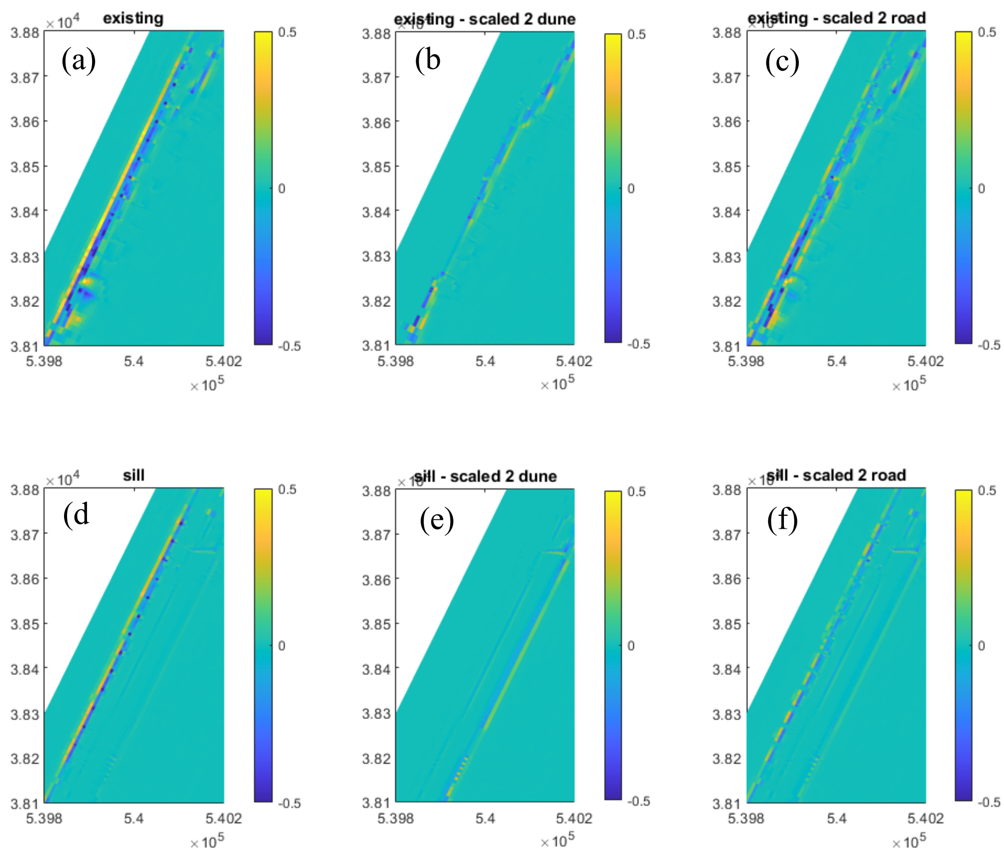



Figure B-1. Erosion, indicated by negative values, for (top) the existing condition and (bottom) Alternative #1 for the (a, d) 25-year design storm water levels, (b, e) water levels scaled to the dune elevation, and (c, f) water levels scaled to the road elevation.

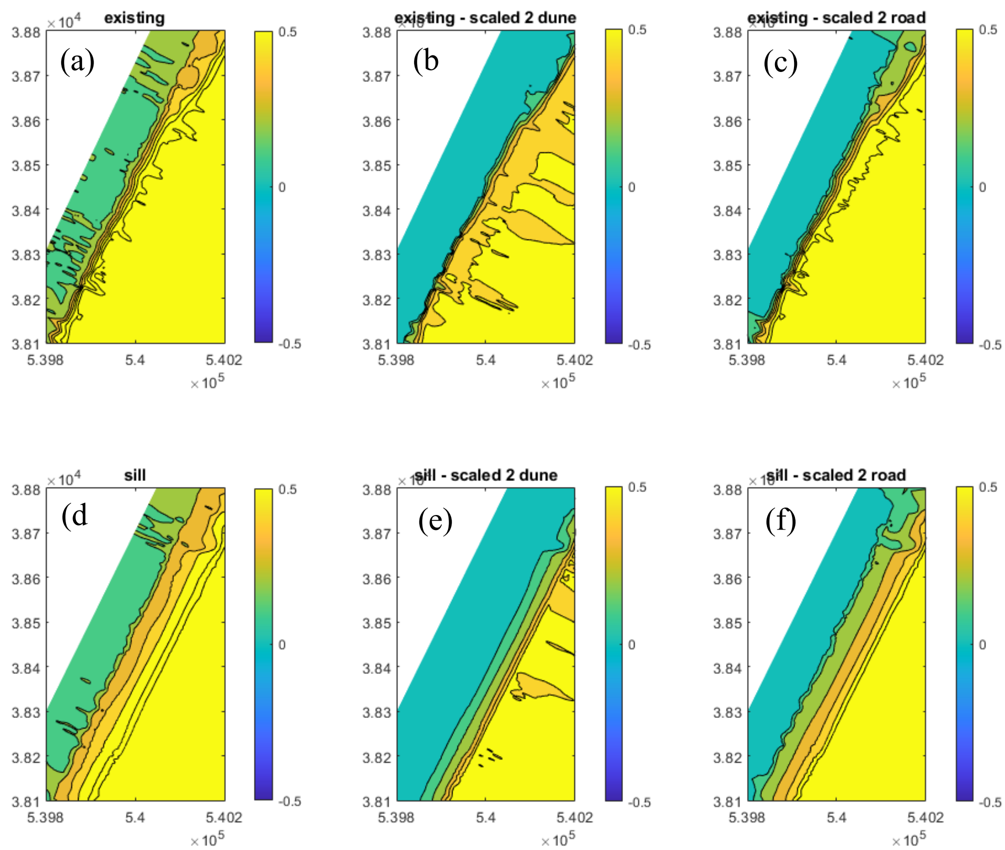



Figure B-2. Wave height for (top) the existing condition and (bottom) Alternative #1 for the (a, d) 25-year design storm water levels, (b, e) water levels scaled to the dune elevation, and (c, f) water levels scaled to the road elevation.

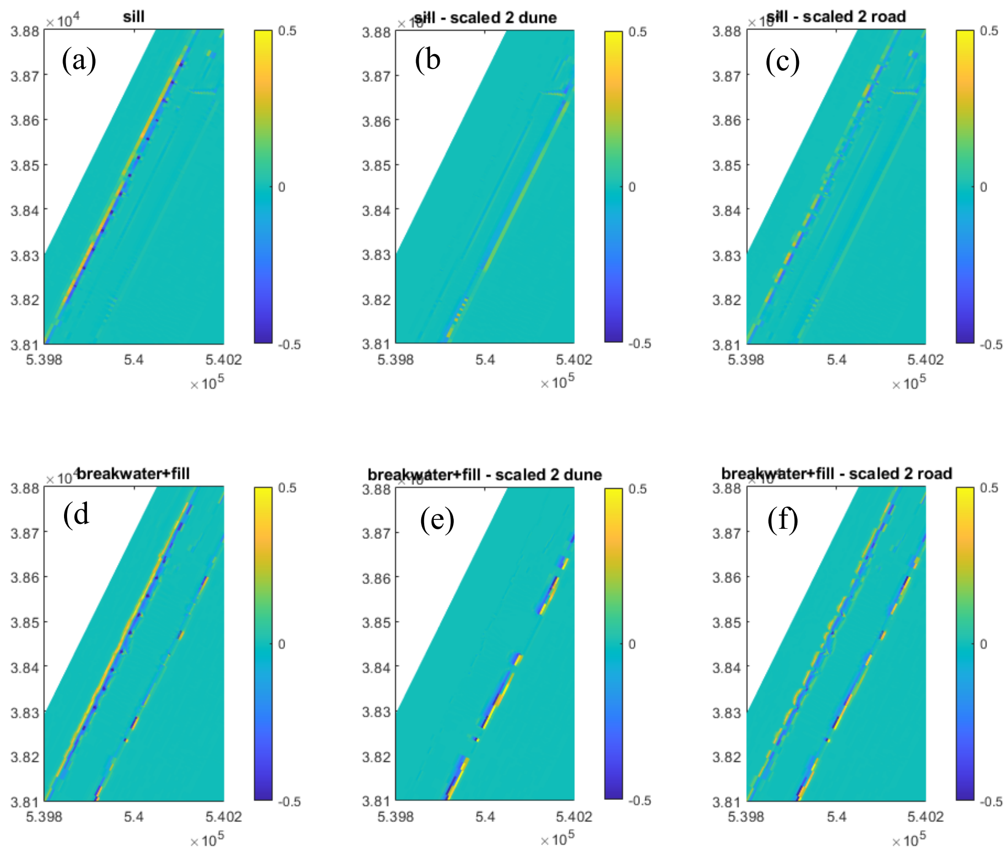



Figure B-3. Erosion, indicated by negative values, for (top) Alternative #1 and (bottom) Alternative #2 for the (a, d) 25-year design storm water levels, (b, e) water levels scaled to the dune elevation, and (c, f) water levels scaled to the road elevation.

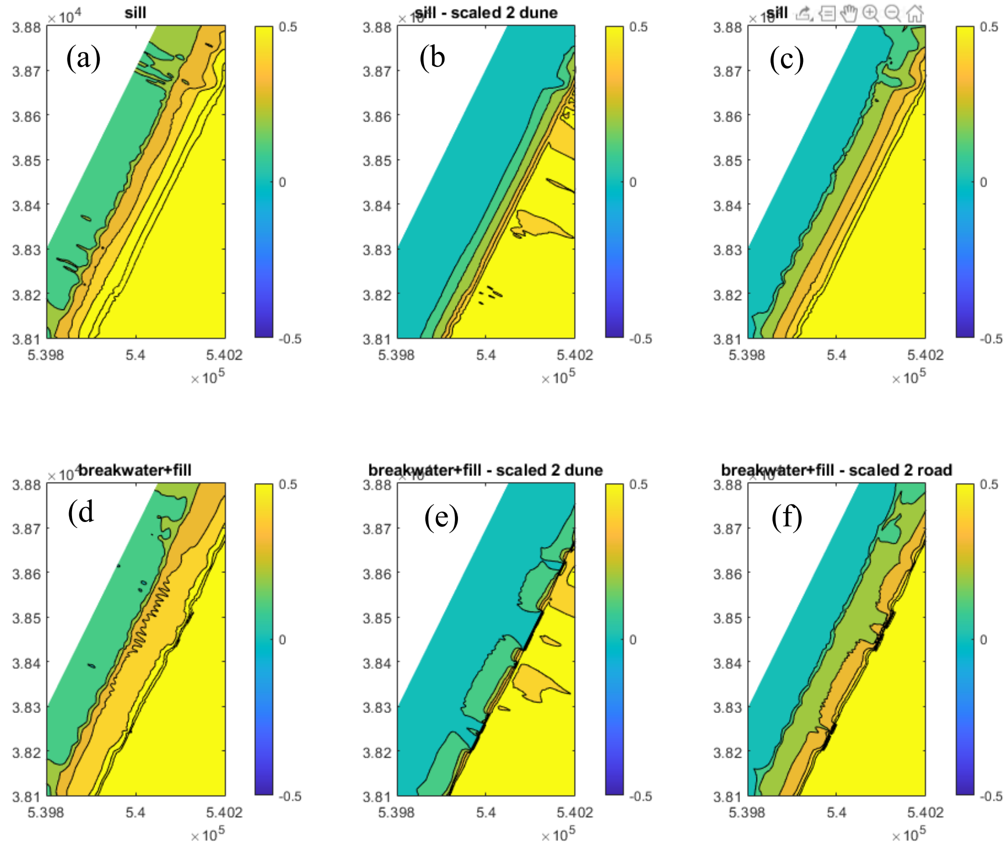



Figure B-4. Wave height for (top) Alternative #1 and (bottom) Alternative #2 for the (a, d) 25-year design storm water levels, (b, e) water levels scaled to the dune elevation, and (c, f) water levels scaled to the road elevation.

### *South region*

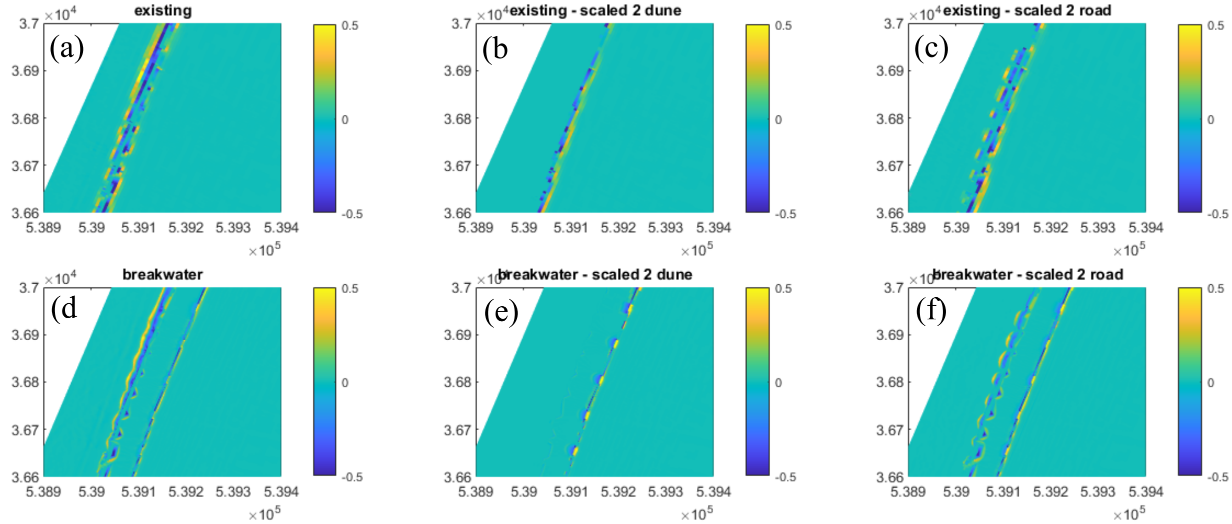



Figure B-5. Erosion, indicated by negative values, for (top) the existing condition and (bottom) Alternative #1 for the (a, d) 25-year design storm water levels, (b, e) water levels scaled to the dune elevation, and (c, f) water levels scaled to the road elevation.

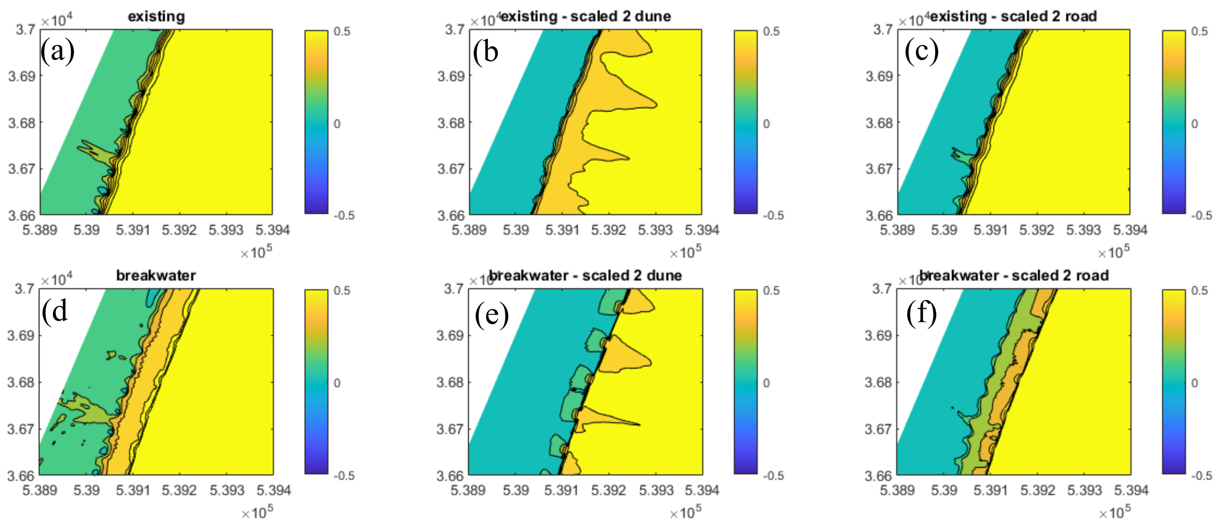



Figure B-6. Wave height for (top) the existing condition and (bottom) Alternative #1 for the (a, d) 25-year design storm water levels, (b, e) water levels scaled to the dune elevation, and (c, f) water levels scaled to the road elevation.

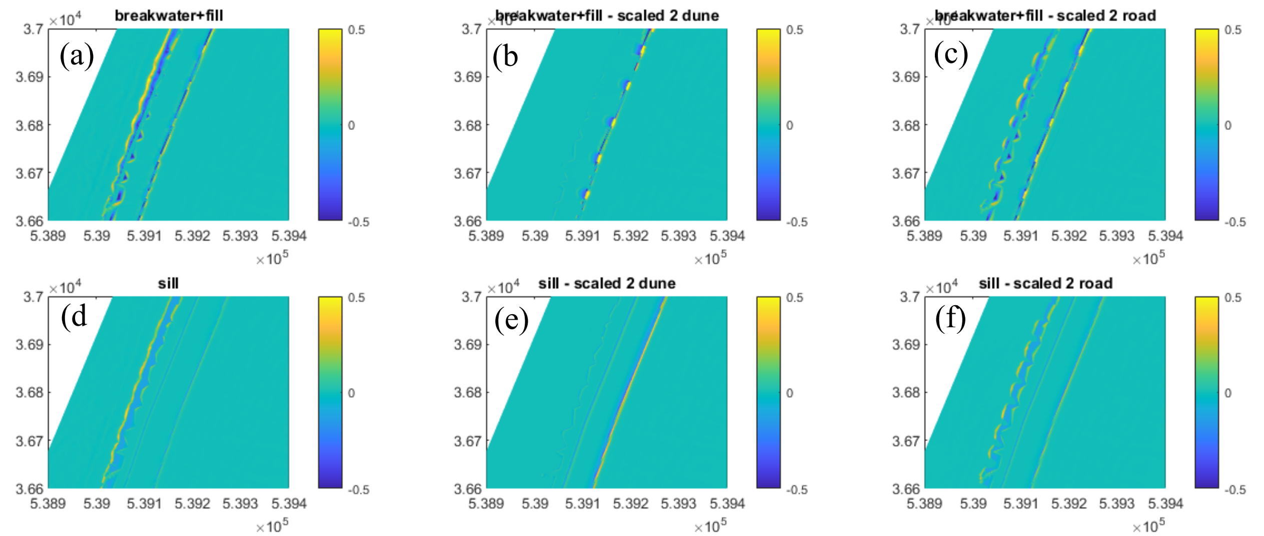



Figure B-7. Erosion, indicated by negative values, for (top) Alternative #1 and (bottom) Alternative #2 for the (a, d) 25-year design storm water levels, (b, e) water levels scaled to the dune elevation, and (c, f) water levels scaled to the road elevation.

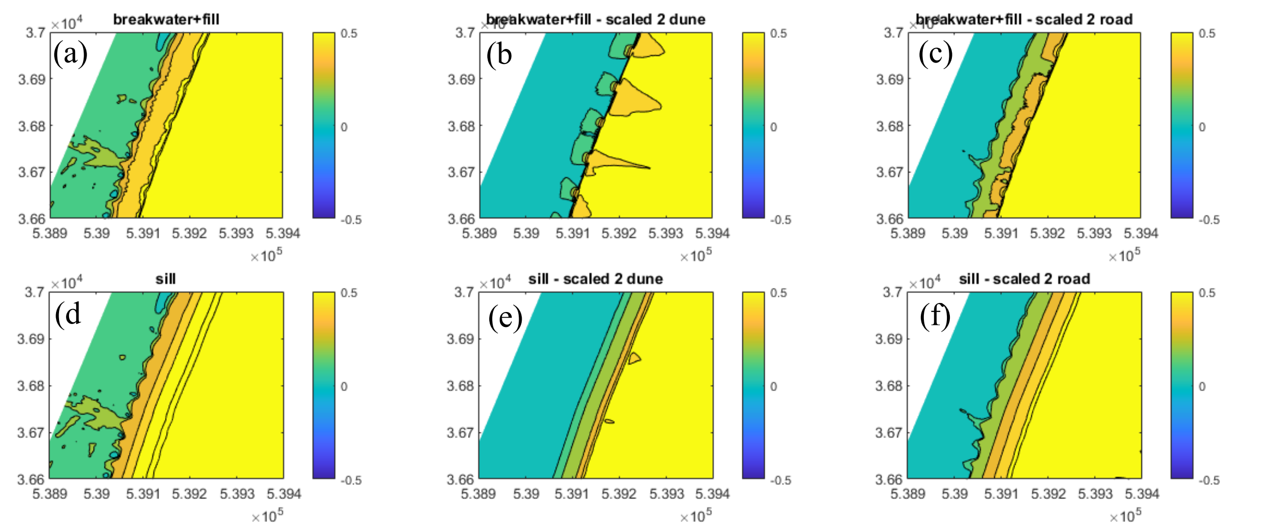



Figure B-8. Wave height for (top) Alternative #1 and (bottom) Alternative #2 for the (a, d) 25-year design storm water levels, (b, e) water levels scaled to the dune elevation, and (c, f) water levels scaled to the road elevation.

# APPENDIX B
Design Basis Report
Revision 2

# 1. PROJECT AUTHORIZATION

The Dauphin Island Causeway Shoreline Restoration Project aims to successfully implement a vibrant and sustainable living shoreline through a partnership with Mobile County and The Mobile Bay National Estuary Program. A living shoreline is one that protects infrastructure and incorporates natural aesthetic elements to support both ecological functions (including oyster habitat), and human uses (including recreation opportunities such as fishing). The goals of the project are to stabilize the shoreline along the Bay side of the Dauphin Island Causeway and to protect infrastructure, enhance resiliency, create/enhance aquatic, wetland, and riparian habitat to the greatest extent possible (Mobile County, 2019).

## 2. EXISTING CONDITIONS

Historically, sea level rise, extreme weather events, and increased wave energy have eroded the wetland habitat along the Dauphin Island Causeway. Since the roadway is only approximately 4 feet above existing ground and there is little to no buffering wetland, the Causeway can be closed to traffic during high periods of wave action. In addition to dampening the effects of wave energy thereby reducing erosion, marshes along the natural shoreline of the Causeway provide critical habitat to fisheries resources. Figure 1 shows the existing conditions of the proposed Project Site.


*Figure 1: Existing conditions*

### 2.1 Shoreline Change

Since 1847, the shoreline has retreated approximately 800 feet due to both natural processes and human intervention. For design purposes, the 1917 shoreline will be used as a basis to rebuild the shoreline.


***Figure 2: Shoreline Change from 1847-present.***

## 2.2 Sediment Dynamics

According to *Sediment Dynamics in Mobile Bay, Alabama: Development of an Operational Sediment Budget* report, Mobile Bay is overall a sediment sink with the Mobile-Tensas River being the primary sediment source. The dominant direction of transport is from north to south with about 40% of the sediment input from the Mobile-Tensas River system migrating to the southern part of Mobile Bay (Byrnes, 2013).

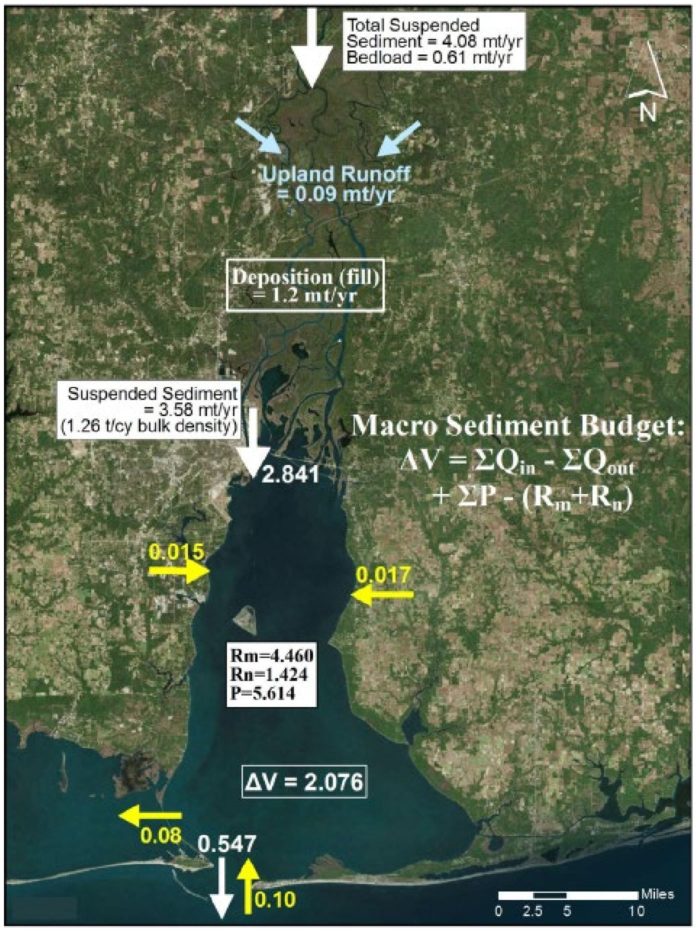



***Figure 3: Overall sediment budget for Mobile Bay, 1917/18 to 1984/2011. Arrows show direction of sediment movement and numbers reflect magnitude of net sediment transport in millions of cy/yr (Byrnes, 2013).***

Locally, sediment transport is bidirectional. Just north of the project area, near Fowl River, the net sediment transport is slightly south to north due to the input from Fowl River, and just south of the project area, near Cedar Point, the sediment transport is north to south.

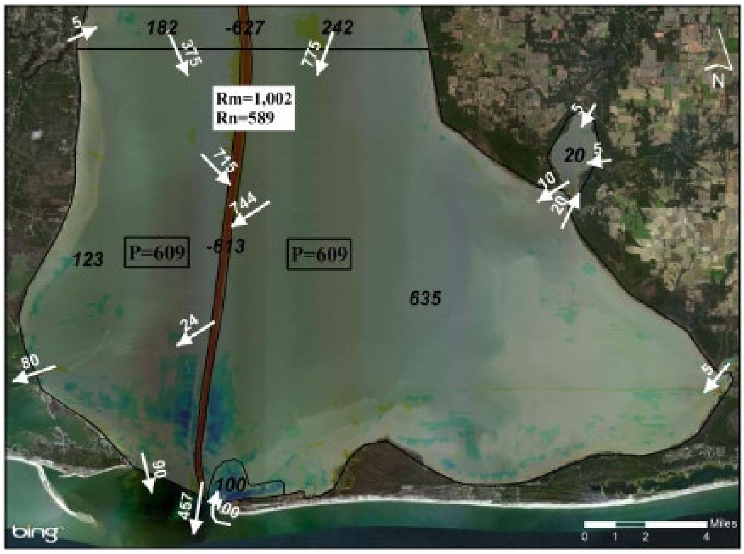



***Figure 4: Sediment dynamics in the project area. Arrows illustrate direction of sediment movement and numbers reflect magnitude in thousands of cy/yr (Byrnes, 2013).***

## 2.3 Existing Soils

Sediment samples were taken from the northern reach of the project area to determine in-situ grain size. Grain size analysis determined the $d_{50}$, which is defined as the median diameter or median value of particle size distribution, of the sediment is approximately 0.33mm; therefore, material targeted for construction of the marsh will have a $d_{50}$ of approximately 0.33mm.

## 2.4 Existing Waves

The Wave Information Studies (WIS) is a US Army Corps of Engineers (USACE) project that generates consistent, hourly, long-term (20+ years) wave climatologies along all US coastlines (USACE, 2010). Three WIS stations are located near the project site as shown in Figure 5. The Wave Information Studies provide coastal wave hindcast using wind fields and the latest wave modeling technology (USACE, 2010).

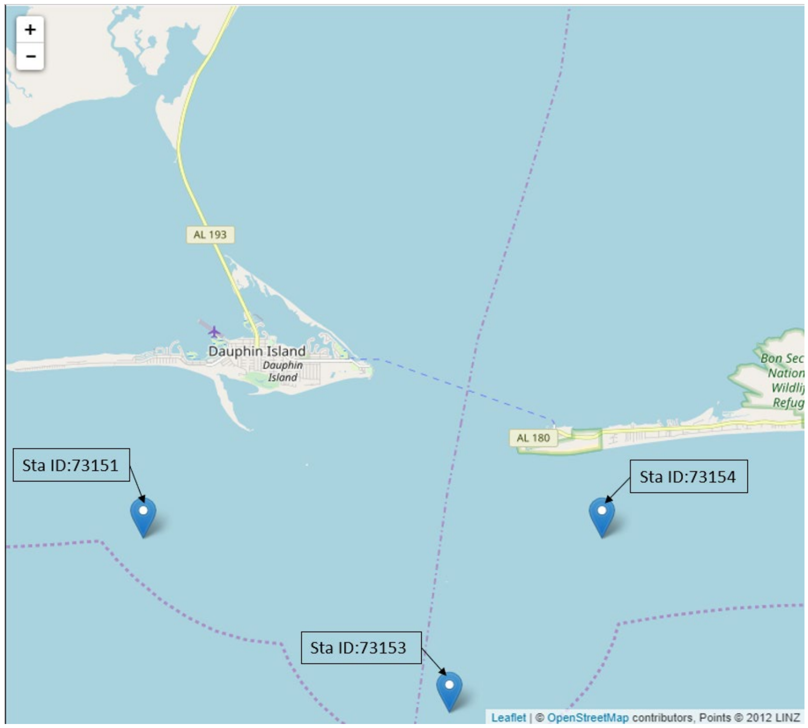



***Figure 5: WIS station locations.***

At least 20-30 years of continuous wave climatology data is included to produce the wave roses in Figure 6.

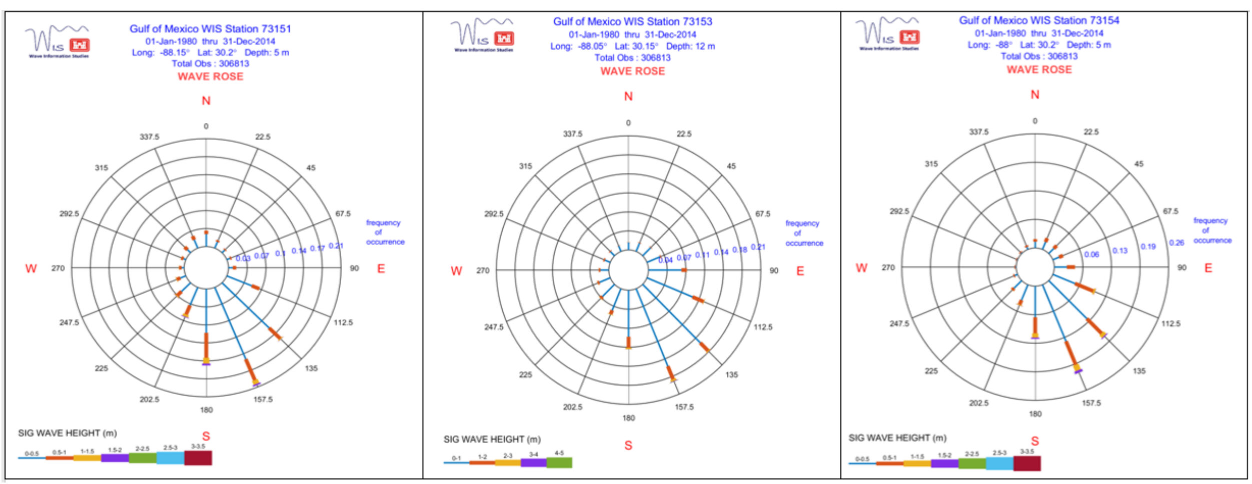



***Figure 6: Wave roses for all historical data.***

Within the Bay, near the project site, waves are mainly wind-driven waves. In addition, Mobile Bay experiences changes in wave conditions due to ship wakes from deep-draft vessels travelling the Mobile Ship Channel. In order to evaluate the effects these vessels have on the wave climate in Mobile Bay, the Alabama Center for Estuarine Studies (ACES) is working on the development of a model to simulate the propagation of vessel wakes (Chen & Douglass, 2003).

# 3. DESIGN BASIS

The following sections detail the assumptions made in the design of the project features. The project design life is assumed to be 20-years.

## 3.1 Water Levels

### 3.1.1 Relative Sea Level Rise

Globally, sea levels have risen an average of about 1.7 mm/year over the past 100 years, but this rate has increased in the past 15 years to around 3.1 mm/year. The Dauphin Island area has experienced a rise in sea levels of 3.94 mm/year (0.0129 feet/year) (NOAA, 2019). Though all SLR scenarios are statistically possible, the intermediate to intermediate-high SLR scenarios were selected for design of the project features. The intermediate to intermediate-high SLR scenarios translates to approximately 0.3-0.6-ft over the project life as shown in Figure 7.

An intermediate-high sea level rise of 0.6-feet over the 20-year project life will be assumed in the design of the project features.

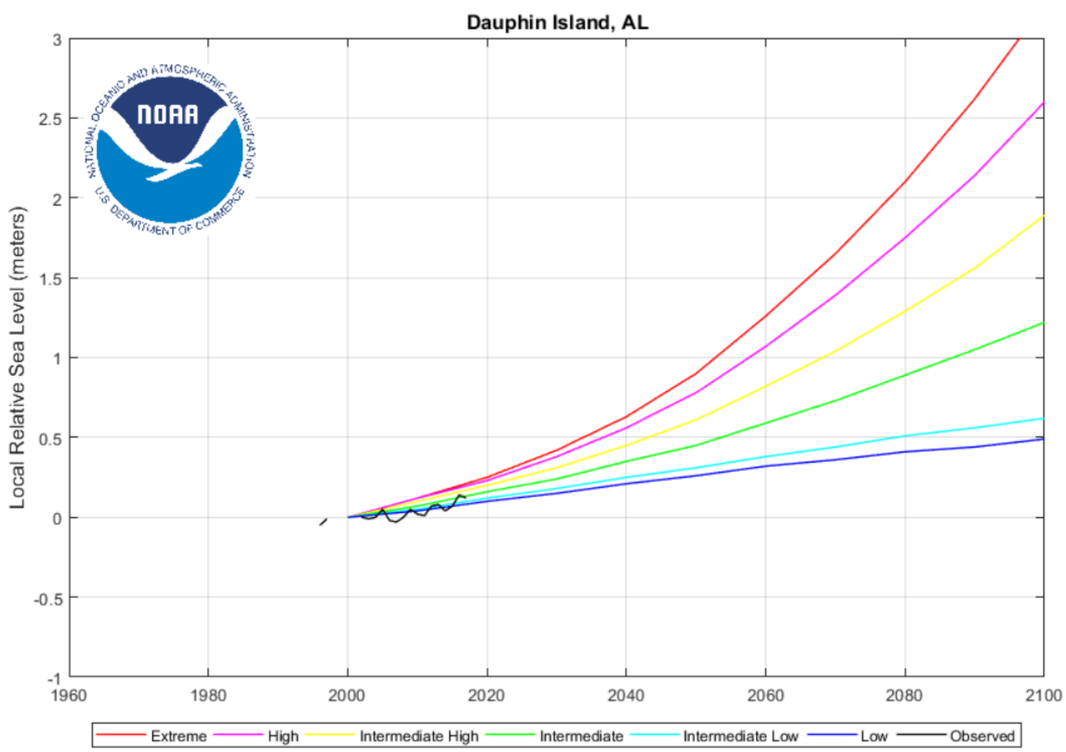



*Figure 7: Regional Sea Level Rise Projections.*

Figure 8 shows the SLR scenarios overlaid on the Dauphin Island Causeway road survey showing within the next 50 years, the probability for parts of Dauphin Island Causeway to be inundated increases.

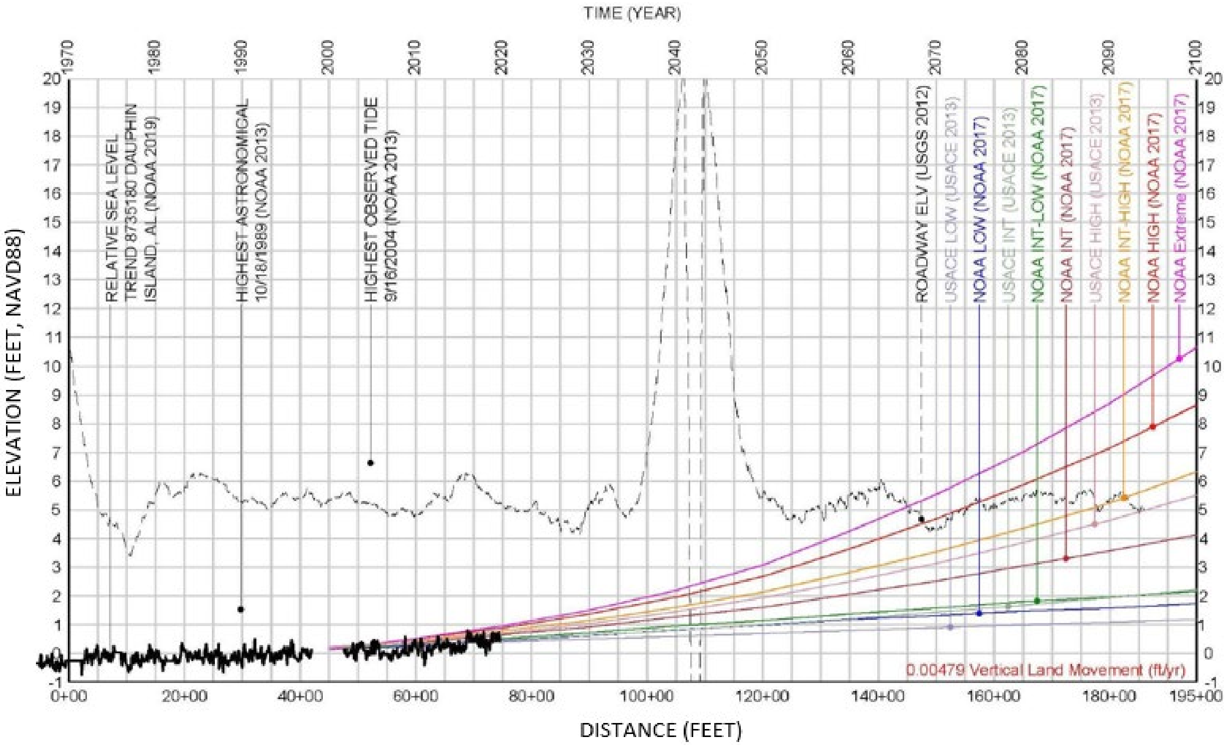



*Figure 8: SLR scenarios overlaid on the Dauphin Island Causeway roadway.*

### 3.1.2 Tidal Datum

Two water level gauges are found in the vicinity of the project area, Cedar Point (CP-001) and Dauphin Island (NOAA Station: 8735180). Though the Cedar Point gauge is closer to the project area, measured water level data from that gauge does not show similar magnitude as other nearby water level gauges as shown in Figure 9 and there is uncertainty as to the gauge elevation. Therefore, the Dauphin Island gauge was utilized for tidal datum calculations.

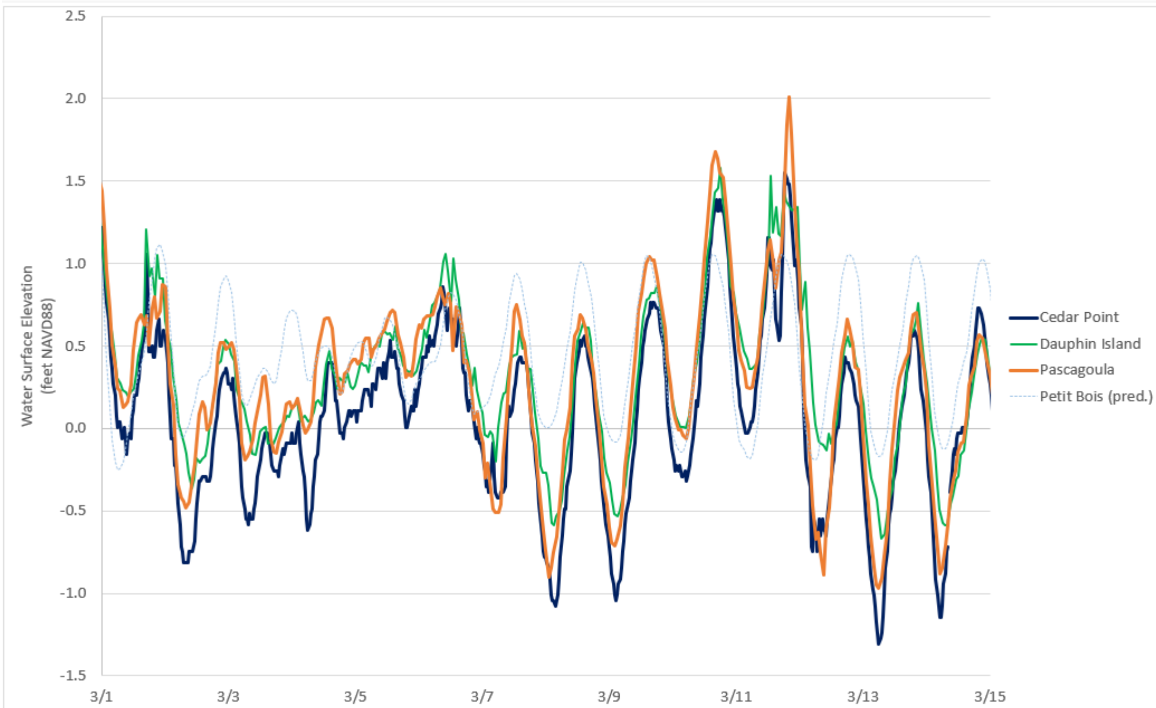



***Figure 9: Cedar Point gauge compared to nearby gauges.***

Tidal data collected from the Dauphin Island gauge was correlated to the most current tidal epoch (1983-2001) utilizing Sta 8729840 in Pensacola, Florida as a control. Figure 10 shows the verified tidal data over the past 20 years. During that time, Hurricanes Ivan and Katrina impacted the Northern Gulf Coast and produced two of the high tide anomalies shown on the graph. Hurricane Ivan's 6.64 ft, NAVD88 tide represents the maximum tide observed at the Dauphin Island gauge.

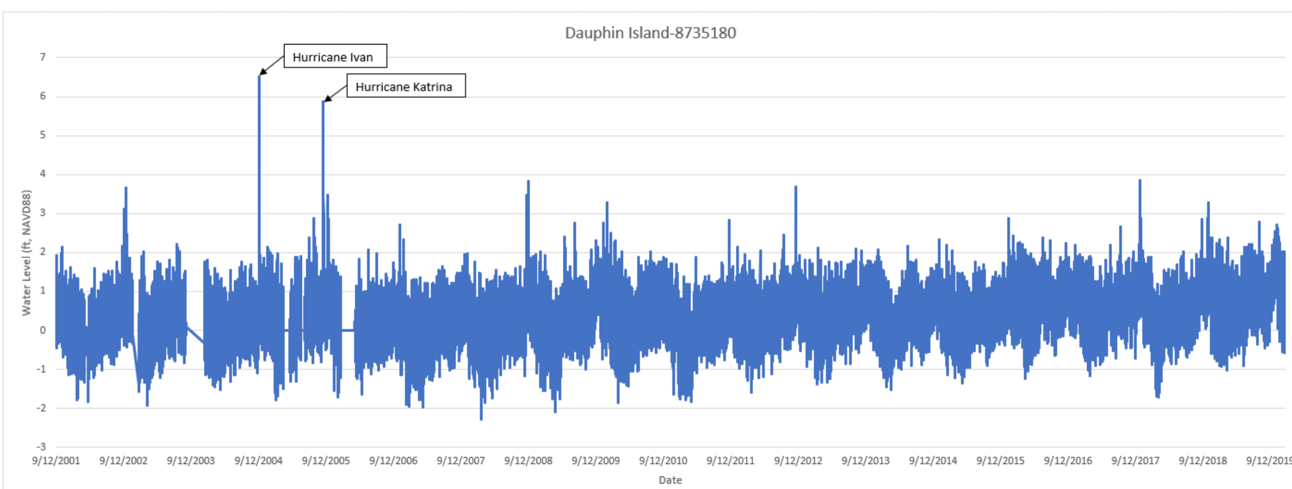



***Figure 10: Dauphin Island tide gauge hourly data from 2000-present.***

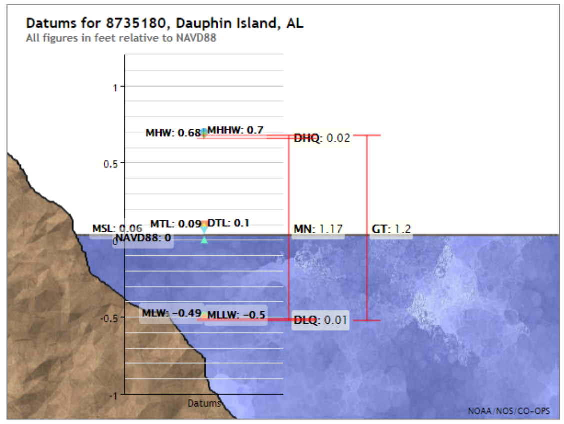
**Elevations on NAVD88**

**Station:** 8735180, Dauphin Island, AL
**Status:** Accepted (Jul 19 2013)
**Units:** Feet
**Control Station:** 8729840 Pensacola, FL
**T.M.:** 0
**Epoch:** 1983-2001
**Datum:** NAVD88

| Datum | Value | Description |
|---|---|---|
| MHHW | 0.70 | Mean Higher-High Water |
| MHW | 0.68 | Mean High Water |
| MTL | 0.09 | Mean Tide Level |
| MSL | 0.06 | Mean Sea Level |
| DTL | 0.10 | Mean Diurnal Tide Level |
| MLW | -0.49 | Mean Low Water |
| MLLW | -0.50 | Mean Lower-Low Water |
| NAVD88 | 0.00 | North American Vertical Datum of 1988 |
| STND | -3.38 | Station Datum |
| GT | 1.20 | Great Diurnal Range |
| MN | 1.17 | Mean Range of Tide |
| DHQ | 0.02 | Mean Diurnal High Water Inequality |
| DLQ | 0.01 | Mean Diurnal Low Water Inequality |
| HWI | | Greenwich High Water Interval (in hours) |
| LWI | | Greenwich Low Water Interval (in hours) |
| Max Tide | 6.64 | Highest Observed Tide |
| Max Tide Date & Time | 09/16/2004 04:06 | Highest Observed Tide Date & Time |
| Min Tide | -2.58 | Lowest Observed Tide |
| Min Tide Date & Time | 01/19/1977 06:00 | Lowest Observed Tide Date & Time |
| HAT | 1.53 | Highest Astronomical Tide |
| HAT Date & Time | 10/18/1989 05:24 | HAT Date and Time |
| LAT | -1.55 | Lowest Astronomical Tide |
| LAT Date & Time | 01/18/1988 14:54 | LAT Date and Time |

**Tidal Datum Analysis Periods**

01/01/1983 - 12/31/1997



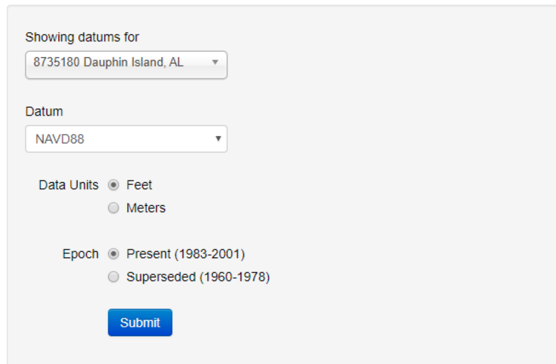




***Figure 11: Dauphin Island tide gauge datum.***

The tidal datum calculated for the project area is, MHW= +0.68 ft, NAVD88 and MLW= -0.49 ft, NAVD88. The astronomical tide range for this station is HAT=1.53 ft, NAVD88 and LAT=-1.55 ft, NAVD88.

Figure 12 shows the calculated tidal range with SLR included over the 20-year project design life.

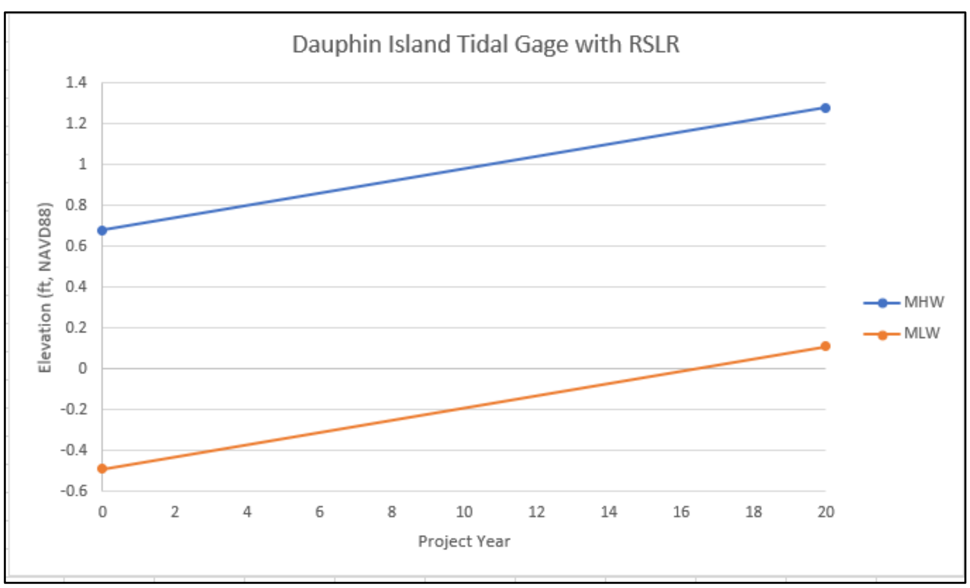



***Figure 12: Dauphin Island tidal range over the 20-year project design life.***

## 3.2 Percent Inundation

Percent inundation refers to the percentage of the year in which a certain elevation of land would be flooded based on the water levels found in that region which directly correlates to marsh health and plant diversity. Brackish marshes, like those found in the project vicinity, are most productive when flooded between 10% and 65% of the year (Snedden and Swenson, 2012). Figure 13 shows the 10% and 65% inundation elevations overlaid on the tidal range for comparison purposes. The brackish marsh optimal inundation range will be used to design the constructed and 20-year target marsh elevation.

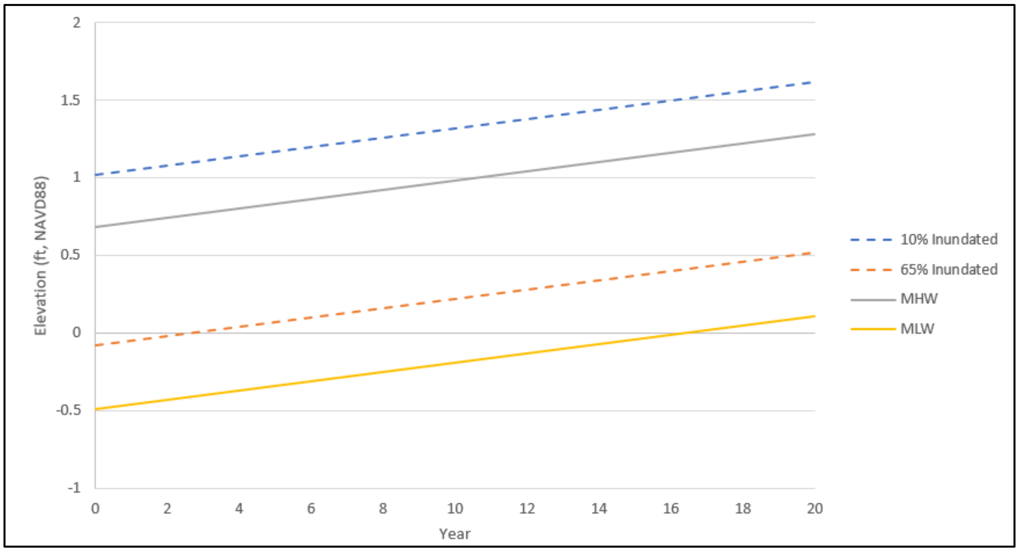



*Figure 13: Optimal inundation range overlain with tidal range.*

## 3.3 Water Level Return Period

In order to determine the design water level conditions, extreme statistics were computed for the Dauphin Island Tide Gauge, and those water levels for the storm return periods are shown in Table 2. Though Dauphin Island is not far from the project area, Flood Insurance Rate Maps (FIRM) produced by FEMA show that the base flood elevation (100-year) is higher at the Dauphin Island Gauge than the project area as shown in Figure 14 (values shown on the FIRM include wave crest elevations in VE zones). In order to determine the project specific water level return period, the Dauphin Island Gauge calculations were translated to reflect the project site base flood elevation, and the results are shown in Table 2. A 25-year return period will be used for design of the project features.

*Table 2: Water Level Return Period for Dauphin Island and Project Site (water elevations not including waves).*

| Return Period (ft, NAVD88) | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|---|
| Dauphin Island Gauge | 3.1 | 4.0 | 4.8 | 5.7 | 6.0 | 7.0 | 8.0 |
| Project Site | 2.6 | 3.4 | 4.1 | 4.8 | 5.1 | 5.9 | 6.8 |

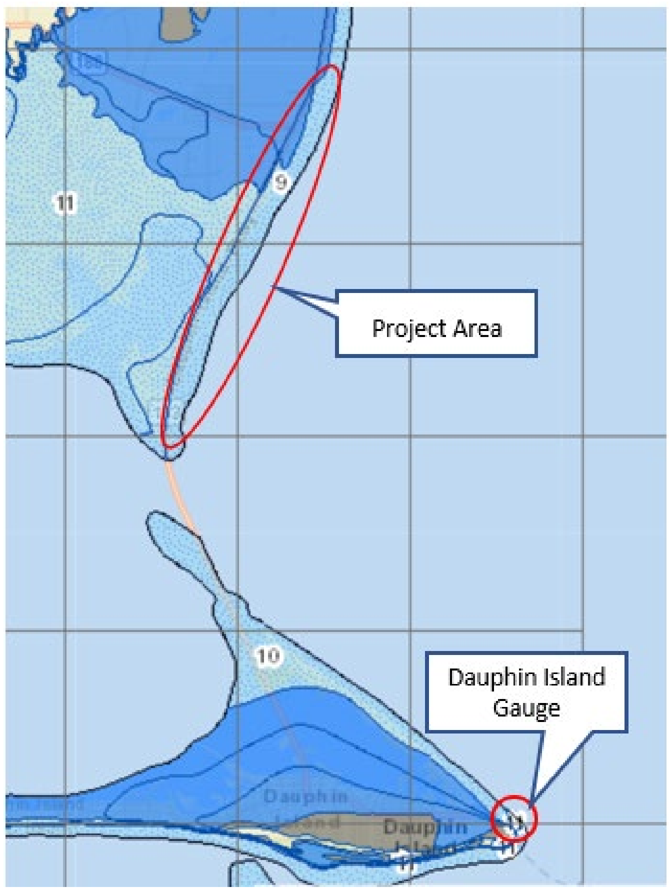



*Figure 14: FEMA FIRM for Dauphin Island and Project Site.*

## 3.4 Wind

The National Climatic Data Center (NCDC) Station 994420 at Dauphin Island was used to determine the annual wind speed return intervals by direction. The period of record for the Dauphin Island Station is 1987- 2019. Figure 15 shows the return analysis and direction of wind speeds from the Dauphin Island station. A 25-year wind return interval will be used to design the project features.

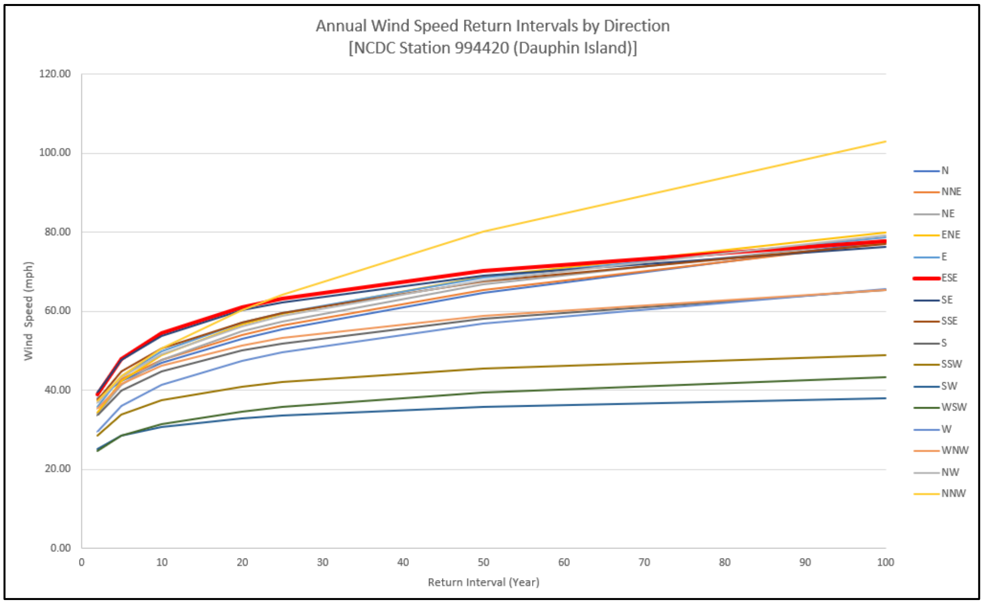



***Figure 15: Dauphin Island Wind Analysis.***

### 3.4.1 Waves

An existing conditions wave model was run utilizing the Delft3D-WAVE model. Utilizing the 25-year wind return period of approximately 64-mph from the ESE direction, significant wave heights and wave periods shown in Table 3 were determined.

***Table 3: Wave outputs based on 25-year wind from ESE.***

| Location | Hsig (ft) | RTpeak (s) | Tm01 (s) |
|---|---|---|---|
| 5 | 5.09 | 5.74 | 3.78 |
| 12 | 5.72 | 5.07 | 3.71 |

Figure 16 corresponds to the model output locations shown in Table 3.


***Figure 16: Wave model output locations.***

## 3.5 Extreme Events

Due to the project's location along the Northern Gulf Coast, many extreme weather events have passed within the vicinity of the project area giving valuable information on winds, tides, and waves. Figure 17 shows named storms which have passed within the vicinity of the project area within the last few decades.

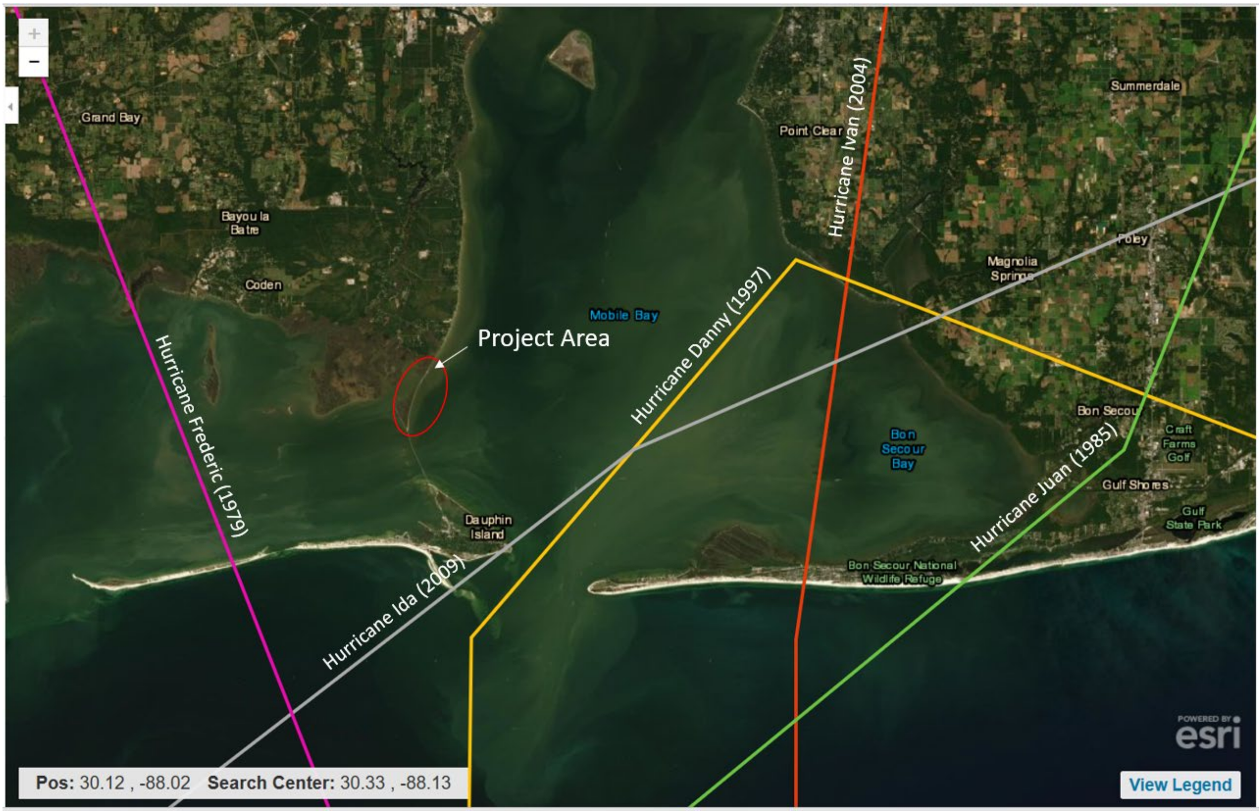



***Figure 17: Named tropical systems passing within the vicinity of the Project Area.***

Extreme water level data for many tropical and non-tropical are archived by SURGEDAT. The data compiled includes the location and heights of more than 700 tropical surge events dating back to 1880 (LSU, 2015). Figure 18 shows storm surge heights near the project area from SURGEDAT data.


*Figure 18: Historic storm surge data in the project vicinity.*

Though extreme events are not the normal wind and water level conditions experienced at the project site, they offer information on the survivability of the system and therefore will be considered in the design of the project features. The track of the approach of the hurricane has a noticeable effect on the water levels near the project site as shown in Figure 19. Though Hurricane Ivan made landfall closer to the project site than Hurricane Katrina, water levels from Hurricane Katrina were higher at the project site than those from Hurricane Ivan. To determine the survivability of the design a hurricane making landfall to the west of the project site like Hurricane Katrina or Hurricane Frederic will be used.

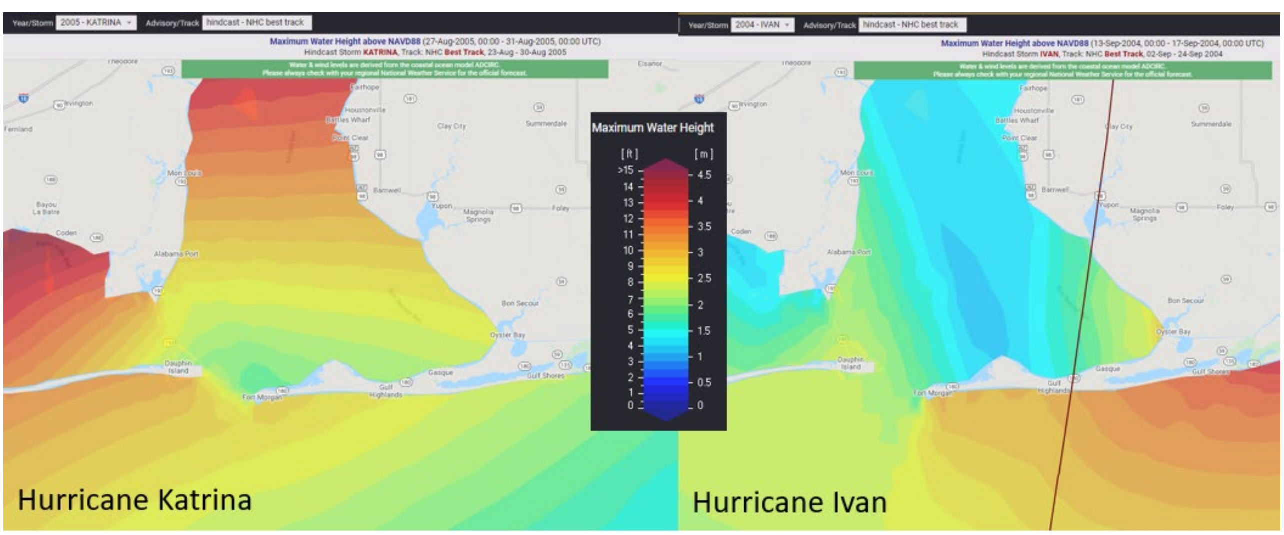



*Figure 19: Hindcast of Hurricanes Ivan and Katrina.*

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