



Tyndall Pilot Project, Submerged Shoreline Stabilization: 60% Basis of Design Report

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Acronyms and Abbreviations

AFB	Air Force Base
BASH	Bird/Wildlife Aircraft Strike Hazard
BOD	Basis of Design
CRIP	Coastal Resilience Implementation Plan
EWL	extreme water level
FWC	Florida Fish and Wildlife Conservation Commission
Hm0	significant wave height
LMJ	Larry M. Jacobs & Associates, Inc.
m/year	meter(s) per year
MLLW	Mean Lower Low Water
NAVD 88	North American Datum of 1983
NBS	nature-based solutions
No.	number
NOAA	National Oceanic and Atmospheric Administration
RP	return period
s	second(s)
SACS	South Atlantic Coastal Study
SAV	submerged aquatic vegetation
SEARCH	SEARCH, Inc.
SLR	sea level rise
TNC	The Nature Conservancy
T _p	peak period
UF	University of Florida
US-98	U.S. Highway 98
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force

1. Introduction

Tyndall Air Force Base (AFB) in Florida's panhandle is strategic for military preparedness and includes important natural coastal features on and adjacent to the Base. Tyndall AFB was severely damaged by Hurricane Michael in 2018. The Department of Defense is committed to rebuilding Tyndall AFB to make it more resilient to future storms and sea level rise (SLR). The first stages of planning for Tyndall AFB's reconstruction revealed that nature-based solutions (NBS) can play a significant role in making Tyndall AFB more resilient while also providing important ecosystem services.

In March 2022, The Nature Conservancy (TNC), along with Jacobs, the University of Florida (UF), and the Naval Research Lab entered into an agreement with the National Fish and Wildlife Foundation (Grant ID 0318.22.073433) for a \$4.8 million award from the Readiness and Environmental Protection Integration 2021 Challenge. The grant award is being used to design and permit three specific NBS projects as part of Tyndall's layered coastal defenses. The three nature-based design projects, shown on **Figure 1-1**, include a Living Shoreline, an Oyster Reef Breakwater, and a Submerged Shoreline Stabilization.

This Basis of Design (BOD) report focuses on the project site for the Submerged Shoreline Stabilization at Buck Beach, which is situated along the Gulf side of Tyndall AFB in St. Andrew Sound, directly inshore from the gap between barrier islands Crooked Island West and Crooked Island East (**Figure 1-2**). The two barrier islands were formed when Crooked Island was breached in the mid-1970s. Buck Beach is exposed to waves from the Gulf of Mexico and has been identified as erosion prone by the U.S. Air Force (USAF). This pilot project is proposed to shore up an existing ledge of submerged aquatic vegetation (SAV) and increase the resilience of coastal habitat by reducing the wave energy that impacts the shoreline.

This BOD report describes the evaluation and basis of the preliminary (60%) design for the Submerged Shoreline Stabilization pilot project at Tyndall AFB. The objectives of the Submerged Shoreline Stabilization pilot project are to achieve the following:

- Reduce long-term shoreline erosion under operational conditions.
- Enhance the natural coastal habitat, such as existing seagrass and low marsh habitat.

Figure 1-1. Location of the Proposed Nature-based Resilience Projects for Tyndall AFB

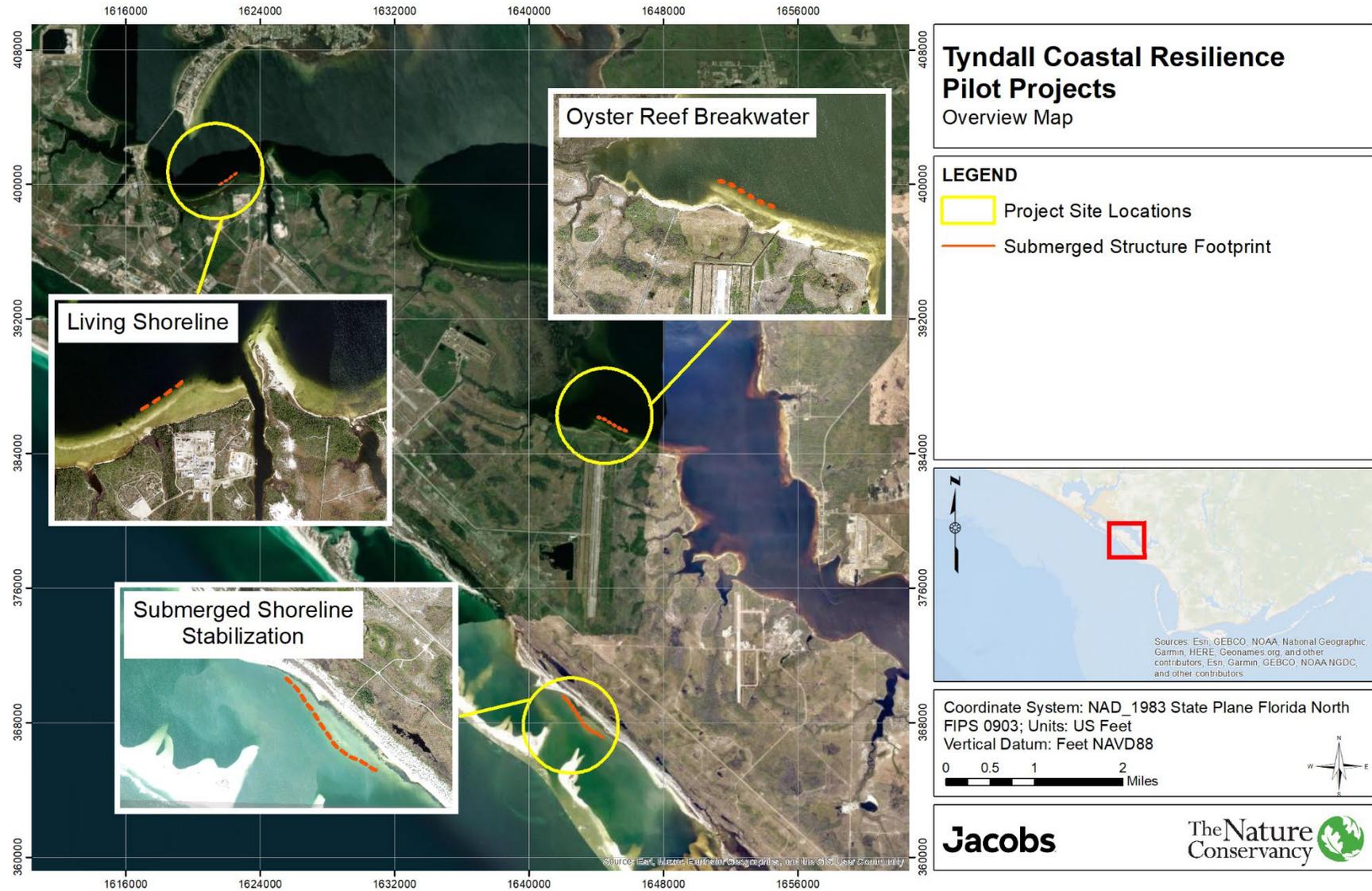
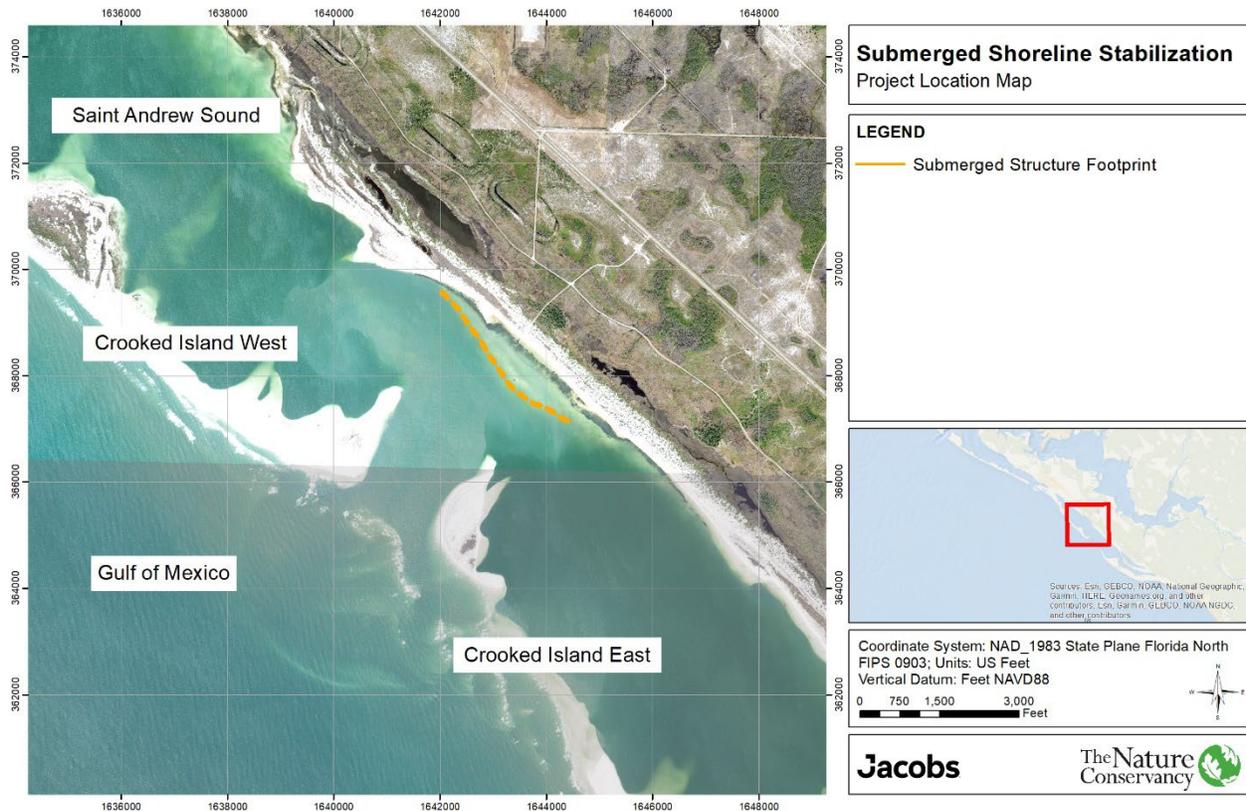


Figure 1-2. Project Location



1.1 Tyndall Pilot Project Design Scope of Work

The pilot projects leverage NBS to lower the risks that arise from coastal processes to improve Tyndall AFB's resilience and enhance its natural environment, which is vital to our national defense. In addition to reducing local wave hazards, NBS offer a range of co-benefits associated with natural habitats by attracting marine life. NBS are potentially less costly than hard defenses and are also self-maintaining.

These pilot projects were also considered as part of the *Coastal Resilience Implementation Plan (CRIP)* (USAF 2022). The CRIP was a USAF-funded project to support mission assurance for Tyndall AFB from severe weather and SLR-related coastal flood inundation. The CRIP provides a roadmap to guide coastal resilience project siting, planning, design, funding, and implementation and the associated timing of these activities based on the evolution of coastal flood risk from climate change.

The Submerged Shoreline Stabilization pilot project was selected to demonstrate how some features could reduce the risk of wave hazards and long-term coastal erosion. The goal was to lower both risks, which are expected to increase over time as sea levels rise, using NBS because they can be less costly than traditional coastal defenses, they can be self-maintaining, and they offer a range of co-benefits associated with natural habitats.

These reductions are the result of both physical and biophysical processes, underscoring the importance of the ecological components of an NBS. A secondary objective is for the solution to be adaptable in the future, allowing more material to be added to increase the structure height if desired, for example, to account for SLR or balance out excessive settlement.

1.2 Report Organization

This BOD report summarizes the 60% design analysis for the proposed Submerged Shoreline Stabilization pilot project at Tyndall AFB. The report is structured as follows:

- **Section 2** presents an existing site overview.
- **Section 3** discusses the general site data.
- **Section 4** presents the BOD conditions.
- **Section 5** provides information regarding the design components and drawings.

The following appendixes are also included:

- **Appendix A.** Bathymetric Survey
- **Appendix B.** Geotechnical Report
- **Appendix C.** Material Alternative Analysis
- **Appendix D.** Cost Estimates
- **Appendix E.** 60% Drawings Package
- **Appendix F.** Specifications

2. Existing Site

2.1 Site Overview

Tyndall AFB is located on a peninsula along Florida's panhandle, southeast of Panama City in Bay County, Florida. It is surrounded by the waters of the Gulf of Mexico to the south, St. Andrew Bay to the west, and East Bay to the north. Tyndall AFB includes the barrier islands of Crooked Island West and East, which form St. Andrew Sound, as well as the barrier island of Shell Island, which makes up the southeastern shoreline of St. Andrew Bay.

Today, Tyndall AFB occupies the site of a former gunnery range known as Tyndall Field, which was opened in 1941. Before its construction, the site was covered with pine and palmetto trees, scrub brush, and swamps. The facility was renamed "Tyndall Air Force Base" in 1948, following the establishment of the USAF in 1947 (USAF 2020).

Tyndall AFB is subject to flooding from coastal surge propagation on both sides of the peninsula and upland rainfall runoff. If the phenomena occur simultaneously, the coastal surge may cause a hydraulic constraint on the surface drainage system of the Base, which outfalls to East Bay and St. Andrew Bay (Jacobs 2020).

Tyndall AFB and Bay County are in a very-high-risk hurricane zone, where 97 tropical storms or hurricanes have been recorded between 1851 and 2022 within a 60-nautical-mile radius. Hurricane Michael is the only Category 5 storm recorded within this 60-mile radius (NOAA 2023a).

In addition to waves entering the St. Andrew Sound from the Gulf of Mexico, waves are generated locally within the Sound; the longest local fetch lengths are southeast and northwest, with lengths of 2.51 and 3.15 miles, respectively.

Based on the CRIP, Tyndall AFB will continue to experience coastal flooding through SLR and event-based storm surge through the year 2100 (Jacobs 2022). In preparation for these conditions, Tyndall AFB is taking measures to protect the mission and support resources around the Base assets. This includes building or enhancing traditional gray infrastructure, such as floodwalls and levees, and promoting NBS such as the Submerged Shoreline Stabilization pilot project.

Buck Beach, the site for the Submerged Shoreline Stabilization pilot project, is located along the northeast shoreline of St. Andrew Sound on the south Tyndall peninsula at the location of the break between Crooked Island West and East. The site is partially sheltered by these two barrier islands for waves out of the west and southeast but is directly impacted by waves from the Gulf out of the southwest.

2.2 Project Site Constraints

Limiting constraints on the siting and design of components of the Submerged Shoreline Stabilization design include the following:

- Work is limited to in-water areas. Structures are not intended to be located in upland areas above the mean high water line.
- Seagrass beds are not to be disturbed, and in-water construction must be located seaward of these beds.

- It is desired that any structures should be below the water surface and not visible to people on the beach.
- During consultation after the 30% design submission, the Bird/Wildlife Aircraft Strike Hazard (BASH) group raised concerns that emerged structure segments would attract birds and, therefore, endanger the aircraft traffic at the Base. Only structures submerged at mean lower low water (MLLW) are to be considered, as discussed further in Section 4.3.

To address the seagrass bed constraint, the structures will be sited at least 25 feet seaward of the existing seagrass beds. To address BASH concerns, structures will be constructed in water depths with bottom elevations of between approximately -3 and -4 feet North American Vertical Datum of 1988 (NAVD 88) and have a crest level at MLLW.

3. General Site Data

3.1 Bathymetry and Topography

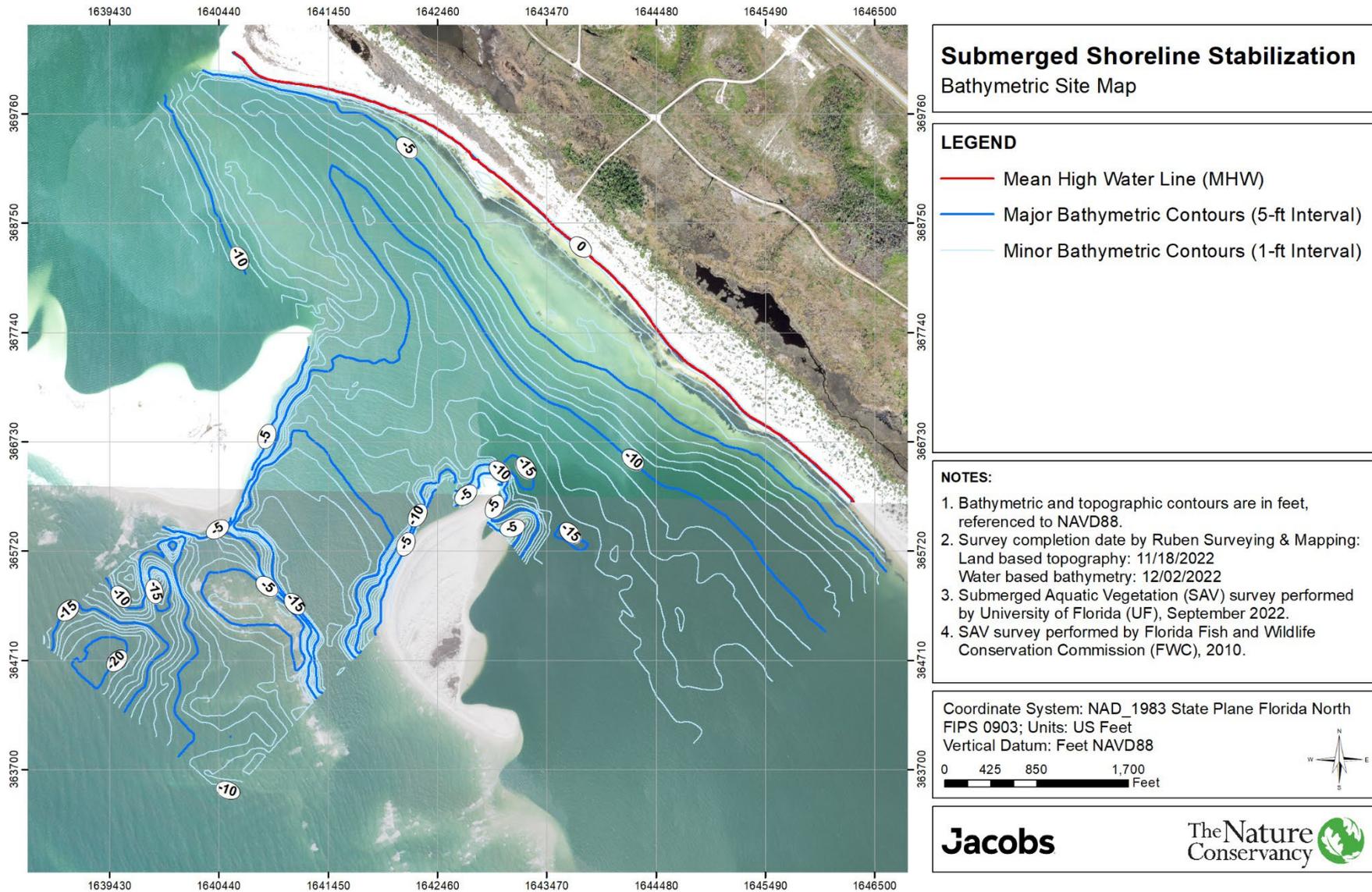
Site-specific topographic and bathymetric data were collected at the Submerged Shoreline Stabilization site in November and December 2022 by Ruben Surveying and Mapping, Inc. These data provide the basis for siting and development of the structures for the pilot project designs. **Figure 3-1** shows bathymetric contours in front of Buck Beach extracted from the site survey. MHW at elevation 0.78 foot NAVD 88 (refer to **Section 3.6.1.1**) is shown on **Figure 3-1** for reference. The bathymetric survey is provided in **Appendix A**.

The bathymetric data on **Figure 3-1** show an ebb-tide shoal offshore of the mouth of the inlet between Crooked Island West and Crooked Island East with water depths as shallow as -4 feet NAVD 88. A channel with bottom depths on the order of -18 feet NAVD 88 enters the inlet between this shoal and the tip of Crooked Island East. The inlet between Crooked Island West and Crooked Island East shallows from approximately -18 feet NAVD 88 at the offshore end to -9 to -11 feet NAVD 88 at the inshore end of the inlet. The data shows a pronounced shallow area directly inshore from the inlet, with bottom elevations less than -5 feet NAVD 88 extending up to 900 feet from the shoreline.

The bathymetry in St. Andrew Sound in the project area should be considered to be dynamic, and the survey conducted in 2022 represents the conditions at the time of the survey. The morphology of a tidal inlet results from a complex response to tidal hydraulics of the system, wave energy characteristics, sediment supply, and the historical pattern of the inlet evolution. It is unclear how stable the inlet is currently; however, it is likely that bathymetric changes do occur regularly over time as a result of sediment over-wash into St. Andrew Sound during significant storms and sediment transport into and out of the inlet due to the action of tides and waves.

Historic aerial photos from 1994 and earlier show the presence of vegetated dunes along the shoreline, roughly in line with the approximate footprint of the shallow area described previously, indicating that a significant amount of recession in this area has occurred over the last 30 years. Due to the lack of historical bathymetric data, it is unclear if the erosion in this area is continuing and, if so, the rate of erosion. Satellite-derived bathymetric data obtained from EOMAP (2022) for 2017 and 2019 suggest that the shallow area along the shoreline may have accreted over this period, at least partially, as a result of sand carried into St. Andrew Sound during Hurricane Michael in 2018.

Figure 3-1. Site Bathymetry



3.2 Shoreline and Submerged Aquatic Vegetation

This section discusses existing and historical shoreline conditions and SAV extents based on available aerial imagery, site photographs, and field data collected between May and December 2022 by UF (UF 2022a).

3.2.1 Existing Shoreline Characteristics

Figure 3-2 and **Figure 3-3** show photographs taken by Jacobs at the Submerged Shoreline Stabilization site during a site visit in October 2022. **Figure 3-2** was taken toward the east, showing the conditions of the site facing inland. **Figure 3-3** presents a view down the beach toward the northwest and shows two “ghost trees” with exposed roots systems, as well as a number of stumps further down the shoreline, which gives an indication of the historical recession of the shoreline in this area.

Results of ecological data collections performed by UF (UF 2022b) document eroded dunes and indicate this is a common feature along this shoreline.

Figure 3-2. Onshore Part of the Project Site, October 2022



Figure 3-3. Dead Trees Along Project Site Shoreline, October 2022



3.2.2 Submerged Aquatic Vegetation

SAV, specifically seagrass, is a principal physical constraint associated with the Submerged Shoreline Stabilization site. Import and placement of material is limited to areas beyond the seaward limits of existing seagrass footprint.

UF performed a survey to record the current extent of SAV at the project site during peak growing season (from June 1 to September 30). The extent of the seagrass at the Submerged Shoreline Stabilization site during the 2022 survey is shown on **Figure 3-5** and compared with its extent in 2010 based on mapping of seagrass habitat in Florida documented by the Florida Fish and Wildlife Conservation Commission (FWC) (FWC 2022). The data suggest that the extent of the seagrass has significantly retreated between 2010 and 2022, with the historical 2010 seagrass footprint extending to the -10 feet NAVD 88 contour and the footprint of the 2020 seagrass footprint only extending from -3 to -4 feet NAVD 88.

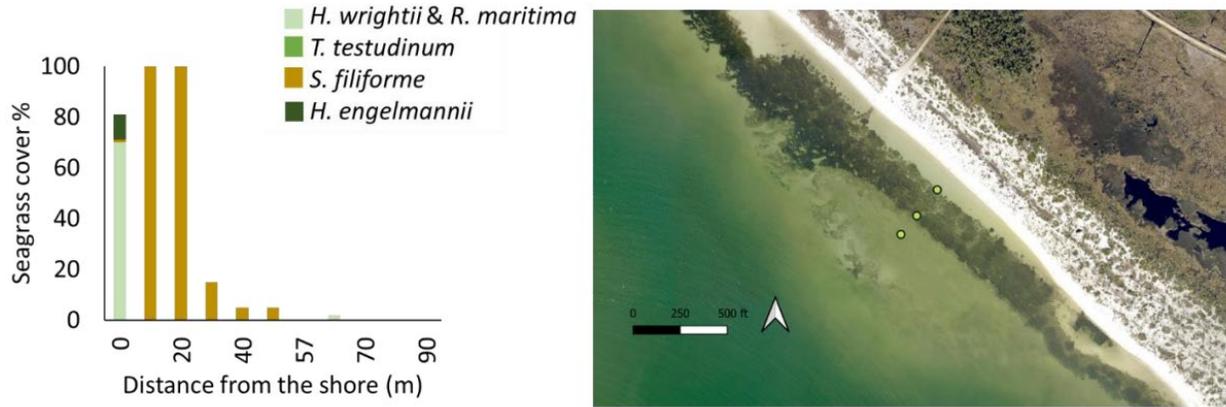
During the survey, UF also recorded the various existing seagrass types and their percent cover along one transect at the Submerged Shoreline Stabilization project site. The location of the transect is illustrated on the right side of **Figure 3-4**. On the left side of **Figure 3-4**, the percent cover is shown over the distance from the shore. The distribution on **Figure 3-4** includes *H. wrightii*, *T. testudinum*, *S. filiforme*, and *H. engelmannii*, which are the most common types of seagrass noted at the project site.

In the ecological surveys, UF (2022b) characterized the seagrass as follows:

"This seagrass meadow had differentiated areas with different seagrass species. The first meters were dominated by *H. wrightii* (~ 80%) and sporadic *S. filiforme* and *H. engelmannii*. The remaining of the transect was dominated by dense *S. filiforme* (100% cover) which started to be grazed from 30 m offshore until the end of the meadow. *T. testudinum* was observed in the meadow but was not present along the surveyed transect. Macroalgae cover was low (15% in one quadrat) and consisted of *Hypnea* spp. Other organisms such as sponges, tubeworms, clams, pen shells, tunicates, sand dollars, sea urchins, blue crabs and mussels were observed within the seagrass meadow. Epiphyte load was clean to light. The most dominant epiphyte were filamentous brown algae and

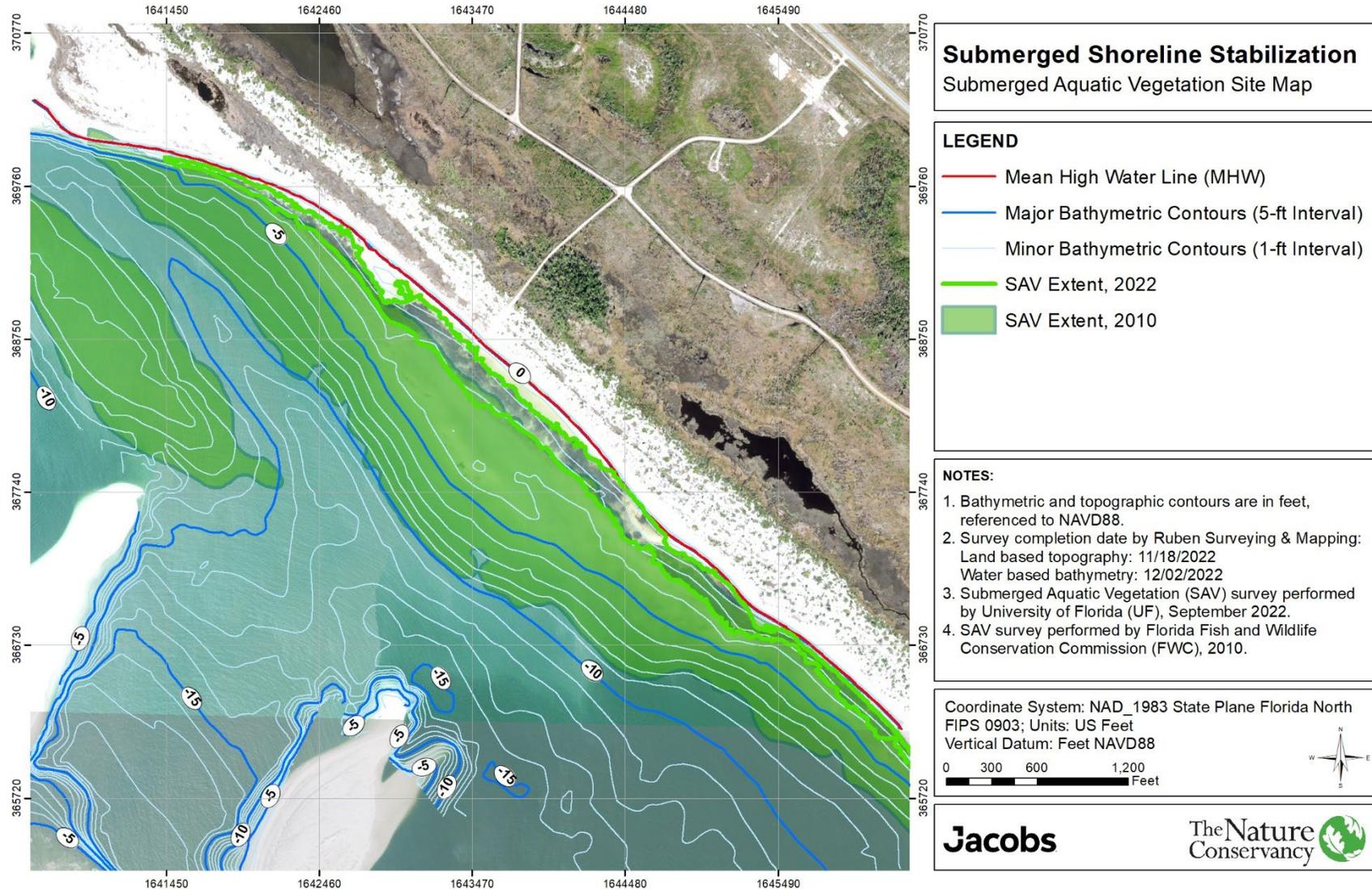
Bittium spp. (small snails). Seagrass shoot length varied between species. *H. wrightii* was longer in the Gulf side than in the Bay side, being ~ 30 cm long. *S. filiforme* was ~ 50 cm long when not grazed and ~ 4 cm when grazed."

Figure 3-4. Seagrass Percent Cover Along the Survey Transect



Source: UF 2022a

Figure 3-5. SAV Extent Based on UF Survey and FWC Database Extent for the Project Site

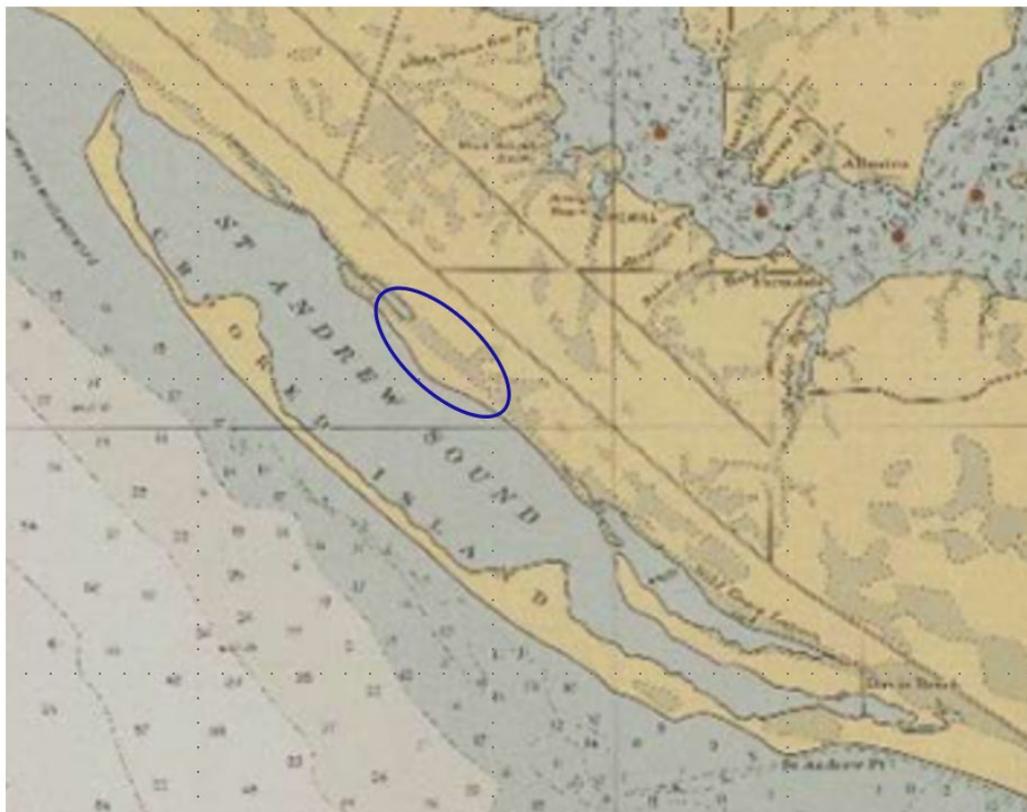


3.3 Shoreline and SAV Evolution

3.3.1 Observed Inlet and Shoreline Changes at Buck Beach

Before 1973, St. Andrew Sound was fronted by Crooked Island, a single contiguous barrier island that sheltered Buck Beach from waves from the Gulf of Mexico. The shoreline in the project area had a small promontory, or ness,¹ along approximately 4,000 feet of the shoreline and extending approximately 800 feet into St. Andrew Sound (refer to **Figure 3-6** from a 1940 nautical chart). No topographical data, other than low-resolution aerial photos and the nautical chart shown on **Figure 3-6**, are available to estimate the initial size of this ness.

Figure 3-6. Ness Coastal Headland, Ness at Buck Beach from 1940 Nautical Chart



Source: U.S. Department of Commerce 1940

Hurricane Eloise made landfall 10 miles northwest of the site as a Category 3 hurricane in 1975. Evidence of breaches splitting Crooked Island into two distinct islands following Hurricane Eloise can be seen in the 1976 aerial photograph shown on **Figure 3-7**.

These breaches began to widen to the southeast by 1983 but remained relatively small. By 1994, a recurve had established at the southeast end of Crooked Island West. Much of the spit on the northwest end of Crooked Island East had been over-washed, resulting in a relatively large inlet (2,500 to 4,000 feet

¹ Nesses are shoreline features that occur where converging tidal flows and alongshore currents create a build-up of material onshore (Holt-Wilson n.d.).

wide). The ness still appears as a prominent feature of the shoreline and appears to include vegetated dunes.

In 1995, Hurricane Opal made landfall approximately 100 miles west of Tyndall AFB as a Category 3 hurricane. Post-Hurricane Opal, much of the spit on the northwest end of Crooked Island East was gone or severely over-washed, widening the inlet to greater than 4,500 feet.

Figure 3-7. Initial Breach into St. Andrew Sound Near Buck Beach



Source: USGS 2020

The spit on the end of Crooked Island West continued to grow to the south, with the inlet roughly centered on the ness. By 1999, this ness had receded significantly from its extent in 1994, and the inlet had widened to greater than 6,000 feet.

Between 1999 and 2004, both spits continued to grow—the recurve on the end of the west island continued to grow, and a well-defined channel within the inlet and extending into the Sound appeared adjacent to the spit on the west island. This channel appears as a darker area on the aerial images between shallower shoals. The spit on the end of the east island continued to recover. The growth of both spits caused the inlet to narrow to approximately 4,500 feet. Over the same period, the ness continued to recede and flatten, and by 2004, it was largely gone as a surface feature.

Hurricane Dennis made landfall approximately 90 miles west of Tyndall AFB in 2005 as a Category 3 storm. Multiple breaches in both spits from over-washing during Hurricane Dennis and erosion of the recurve on the spit from the west island were evident in aerial photographs immediately following the storm. These over-washed areas were largely filled in by 2007. The inlet remained at approximately 4,500 feet wide through this period.

After this time, the inlet narrowed further, with recurves building on each side. The width of the inlet narrowed to approximately 2,700 feet by 2012 and 1,800 feet by 2020.

Hurricane Michael, which made landfall at Tyndall AFB in 2018 as a Category 5 storm, resulted in over-wash and breaching of approximately 3,000 feet of the spit on Crooked Island East, southeast of the inlet, but no significant changes to the width of the inlet were evident. This breach had been largely filled in by the end of 2020.

Further over-wash of the spit on Crooked Island East can be observed in 2022, with an approximately 3,000-foot section affected.

The deeper channel within the inlet also has been reducing in width, from 1,000 feet wide in 1999 to less than 200 feet wide by 2020 and mostly gone by 2022, with sand shoals across most of the mouth of the inlet.

Figure 3-8 shows the change in inlet width over time and the distance between U.S. Highway 98 (US-98) and the shoreline at the location of the ness based on information from open source aerial images.

Figure 3-8. Inlet Width and Shoreline Position with Time

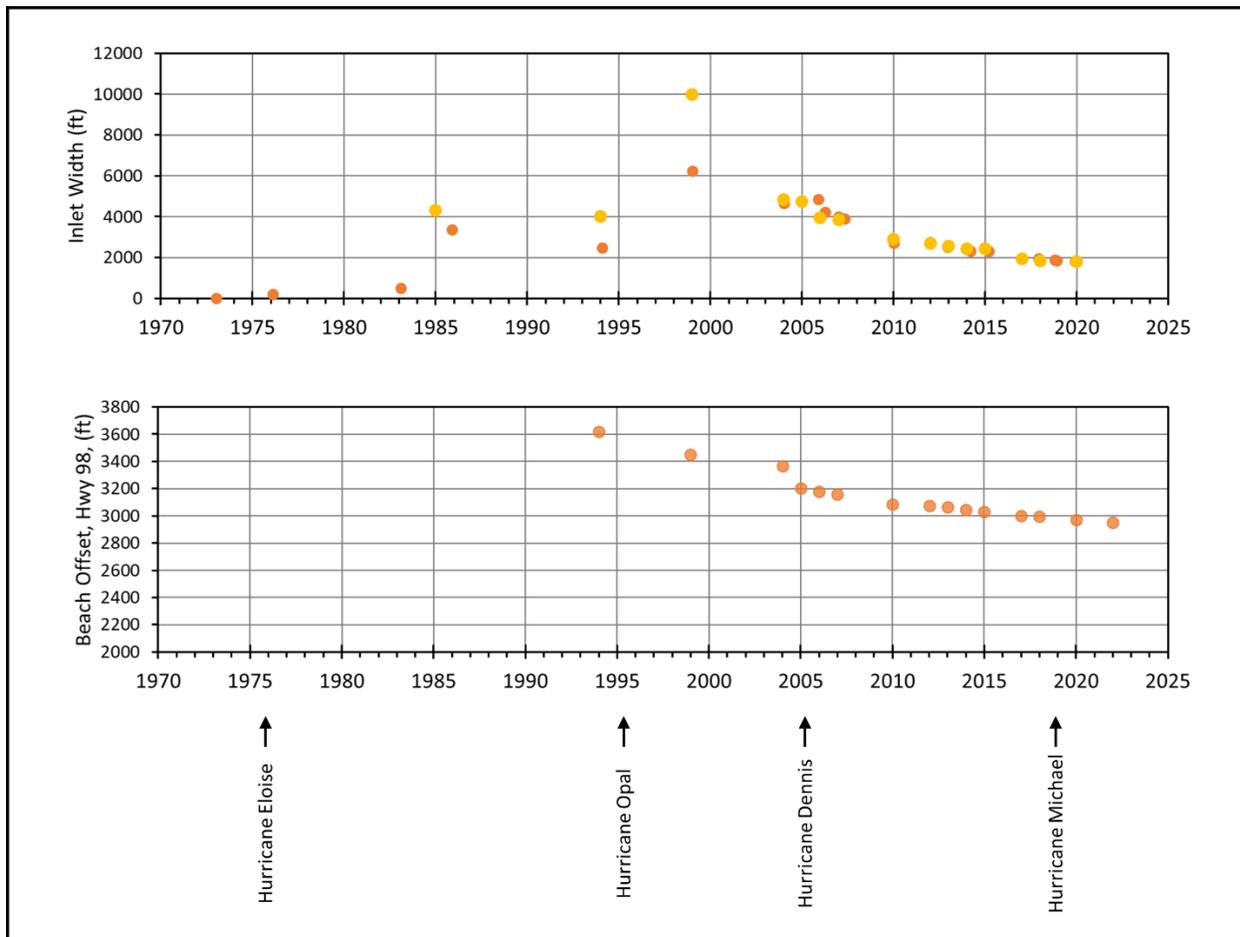
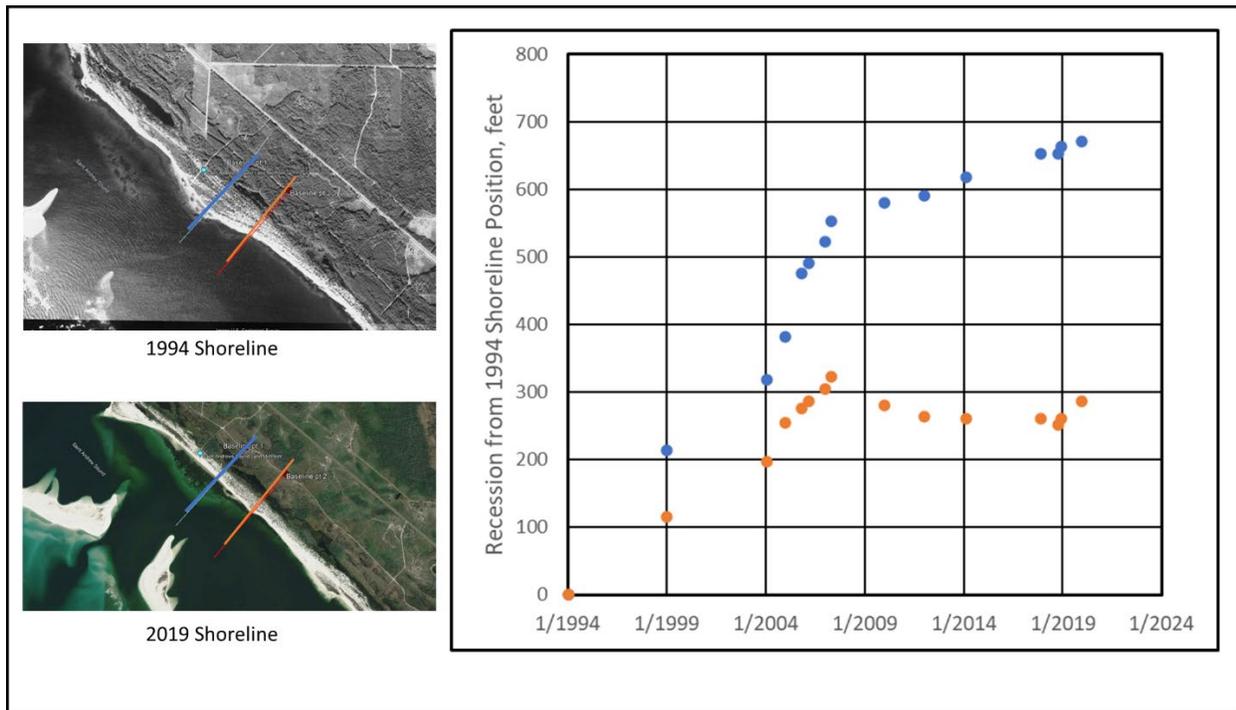


Figure 3-8 shows that the period from 1976 to 1999 saw an expansion of the inlet, followed by a relatively consistent narrowing to the present day. Figure 3-8 also shows erosion rates that generally track the narrowing of the inlet, with higher rates observed when the inlet was the widest and tapering off as the inlet narrowed (and the shoreline began to straighten).

Figure 3-9 shows the recession of the shoreline (as indicated by the waterline on aerial imagery) for two transects from 1994 through 2020 relative to the shoreline position in 1994. Figure 3-9 shows the most rapid recession of the shoreline prior to 2007, with a recession of approximately 40 feet per year along the blue transect and 24 feet per year along the orange transect, based on linear interpolation of the data through 2007. The erosion rates subsequently decreased, with erosion along the blue transect reduced to approximately 9 feet per year and the shoreline even accreting along the orange transect (up to 3 feet of accretion per year) as the mouth of the inlet narrowed such that the shoreline at the orange transect was no longer positioned opposite the inlet opening.

Figure 3-9. Historical Shoreline Position at Buck Beach



3.3.2 SAV Extents at Buck Beach

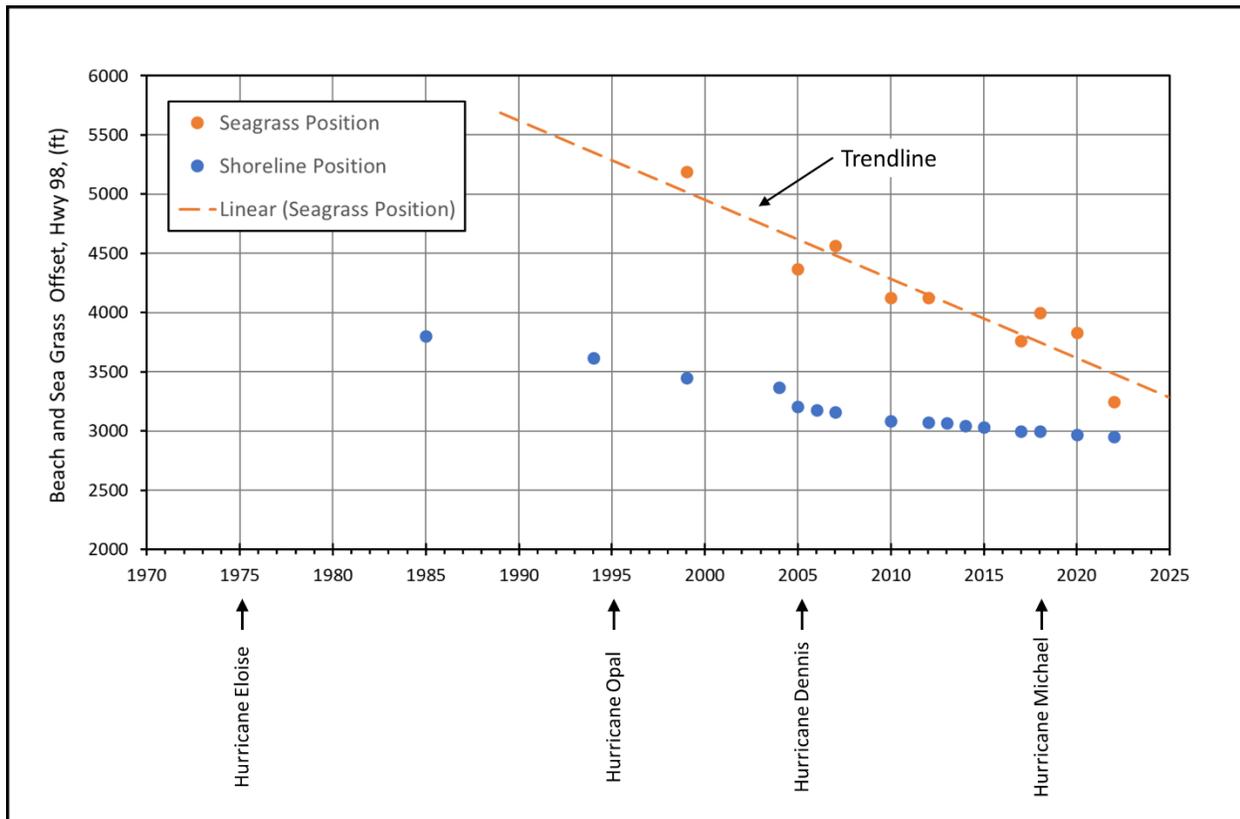
Historical aerial images show SAV, specifically seagrass, as dark areas in shallow-water portions of St. Andrew Sound. Remnants of the historical shoreline ness can be seen as a submerged shoal extending out from the shoreline, with SAV colonization of this area seen in aerial photographs starting in 2004.

The density of SAV within St. Andrew Sound varies from year to year. Available aerial photographs show the density of the SAV on the shoal located in the footprint of the former ness generally increasing from 2004 such that, by 2010, most of this feature that is farther than approximately 150 feet offshore is covered with vegetation.

Figure 3-10 shows a plot of the position of the offshore extent of SAV on this shoal relative to US-98 compared with the shoreline position at Buck Beach. A trend line through the data points indicates that, on average, the seaward end of the SAV is moving inshore at a rate of approximately 67 feet per year.

Changes in SAV coverage can be due to grazing (for example, by sea urchins), wasting (disease), erosion, or deposition (which could result in burial of SAV). Observed changes are likely due to a combination of these factors. The trend seen in the data for the position of the seaward extent of SAV suggests ongoing erosion is a contributor and that the submerged ness is continuing to recede with the increasing water depths over this feature, limiting the area on which the SAV can establish.

Figure 3-10. Position of Offshore Extent of Buck Beach SAV Beds Compared with Shoreline Position



3.3.3 Conceptual Assessment of Processes Affecting the Shoreline at Buck Beach

Based on a review of available information, the following processes are likely driving the shoreline evolution at Buck Beach:

- The present location and width of the inlet allows greater wave energy to enter St. Andrew Sound from the Gulf of Mexico and impact the project site.
- The historical ness in the shoreline serves to refract waves entering St. Andrew Sound and concentrate them on the ness, initially resulting in recession of the ness and, later, as a submerged feature, focusing wave energy on the shoreline behind it, potentially contributing to continued erosion along this stretch of the beach.
- The submerged ness continues to lose material through erosion due to wave action. Evidence of accretion in areas up and down the coast from the project site suggests that, once mobilized, a portion of the sediments at the project site are being moved away from the site by alongshore transport into lower-energy areas that are in the shadow of the barrier islands.
- The inlet location and/or width can change over time such that portions of the shoreline that were previously aligned with the inlet can experience a reduction in wave energy due to increased sheltering from the barrier islands. This reduction in wave energy can result in a decrease in erosion or even accretion along these areas.

3.3.4 Implications of Site Morphology for Submerged Breakwater Design at Buck Beach

Buck Beach, the site for the Submerged Shoreline Stabilization pilot project, is located along the northeast shoreline of St. Andrew Sound on the south Tyndall peninsula at the location of the break between Crooked Island West and East. The site is partially sheltered by these two barrier islands from waves out of the west and southeast but is directly impacted by waves from the Gulf of Mexico out of the southwest.

Data from actual ground and bathymetric surveys are limited, and survey data for assessing long-term trends in the topographic and bathymetric features were not available. Instead, past and present trends related to bathymetry have been inferred based on visual cues, such as limitations on seagrass extent, which may be due to depth limitations for this site. A review of historical aerial images showed how dynamic the area is around Buck Beach. Storm events can result in over-wash of portions of Crooked Island East and Crooked Island West or even generate breaches into St. Andrew Sound. Although the current inlet appears to have stabilized over the last 5 to 10 years, there is the potential for the inlet to widen, close out, move, or reform in another location. A wider or deeper inlet could increase wave action on the site. A change in location of the inlet could move the area impacted up or down the shoreline to a location outside of the project area, potentially resulting in erosion along an area that is not protected.

Based on a review of available information, the following processes are likely driving the shoreline evolution at Buck Beach:

- The present location and width of the inlet allows a greater amount of wave energy to enter St. Andrew Sound and impact the project site.
- The historical ness in the shoreline serves to refract waves entering St. Andrew Sound and concentrate them on the ness, initially resulting in recession of the ness and, later, as a submerged feature, focusing wave energy on the shoreline behind it, potentially resulting in continued erosion along this stretch of the beach.
- The submerged ness continues to lose material through erosion due to wave action. Evidence of accretion in areas up and down the coast from the project site suggests that, once mobilized, the sediments at the project site are being moved away from the site by alongshore transport into lower-energy areas that are in the shadow of the barrier islands.

The potential implications of the shoreline evolution for a submerged breakwater design at Buck Beach are summarized as follows:

- The coastline is dynamic, showing changing position of barrier islands and inlets.
- Significant changes in barrier islands occur during and after hurricanes, when barriers over-wash, and new inlets can be generated.
- Between storms, waves come predominantly from the south and southwest, causing alongshore movement of material, which results in the development of recurved ends of barrier islands. Generally, this causes inlets to narrow.
- The inlet allows increased energy to reach the mainline coast of the Tyndall peninsula along Buck Beach.
- At Buck Beach, the opening of a large inlet in 1999 led to the fairly rapid recession of a ness on the main shoreline. It is likely that the sediment has been pushed alongshore to the northwest and southeast to areas of lower wave energy.
- A remnant of the ness remains as a submerged shoal.

It needs to be considered that the barrier island and inlet configuration could change in the future, changing the patterns of erosion and sediment transport that are the BOD of the structure, shifting the problem to another portion of the shoreline and reducing the effectiveness of the structure. In addition, placing a hard structure, such as a breakwater, could also lead to changes in the sediment transport characteristics in this area. The structure could result in partial reflection of the wave energy entering St. Andrew Sound back toward the inlet, potentially changing the dynamics of the system and causing or increasing erosion at the inlet. With the inlet at its present location, a submerged breakwater could be used to reduce wave energy impacting Buck Beach. This breakwater would likely be located in the shallow water of the footprint of the historical shoreline ness.

3.3.5 Shoreline and SAV Evolution Summary

Section 3.3.3 provides a conceptual assessment of processes affecting the shoreline at Buck Beach based on available information related to past changes at the site. This assessment informs the potential implications of the shoreline evolution for a submerged structure design at Buck Beach, which are summarized as follows:

- The coastline is dynamic, with the barrier islands and inlets to St. Andrew Sound changing over time.
- Changes in barrier islands can occur during and after hurricanes, when barriers over-wash, and new inlets can be generated. With the exception of the present inlet between Crooked Island East and Crooked Island West, areas of over-wash and breaches have historically been temporary; however, they have the potential to become permanent and change the hydraulic characteristics of the Sound.
- Between storms, waves approaching the islands come predominantly from the south and southwest, causing alongshore movement of sand, which can fill in damage caused during earlier storms, resulting in the development of recurved ends of the spits adjacent to the inlet. In general, the growth of these recurves will cause inlets to narrow.
- The inlet between Crooked Island East and Crooked Island West allows increased energy to reach the mainline coast of the Tyndall peninsula along Buck Beach.
- At Buck Beach, the opening of a large inlet in 1999 led to the fairly rapid recession of a ness (promontory) on the main shoreline. It is likely, based on review of historical shoreline changes, that much of the sediment lost from the ness has been pushed alongshore to the northwest and southeast to areas of lower wave energy.
- The most rapid rates of observed shoreline erosion occurred from 1994 through 2007, with the maximum shoreline recession of approximately 40 feet per year occurring due to erosion of the portion of the ness in line with the inlet.
- Since 2007, erosion has continued, but at a reduced rate on the order of 9 feet per year along the portion of the shoreline aligned with the inlet. This reduction coincides with the straightening of the shoreline (that is, the loss of the ness as a shoreline feature) and continued recession of the submerged shoal that remains of the ness, which likely reduces the ability of the shoal to focus waves on the shoreline at this location.
- A remnant of the ness remains as a submerged shoal that has been colonized by SAV.
- The extent of SAV along Buck Beach appears to be related to the presence of this submerged shoal. Over the last 19 years, the offshore extent of seagrass on this shoal has declined (**Figure 3-10**).
- The exact reason for loss of the SAV is unclear, with possible reasons including overgrazing, wasting, erosion, or burial. Depth limitations on seagrass growth can vary by location, with seagrass commonly growing in depths of 6 to 10 feet and even in depths of 30 feet or deeper in some areas of Florida

(Southwest Florida Water Management District 2020). The relatively steady observed movement of the offshore limit of SAV suggests that erosion of the shoal is continuing and contributes to the loss of seagrass at the site as water depths increase.

Based on the shoreline assessment, the design has been undertaken to ensure it is robust in response to the uncertainties for the following reasons:

- There is a lack of quality data to understand ongoing erosional trends.
- Constructing a submerged breakwater in a sandy bed will likely require substantial work and could be exposed to risks of bed erosion and associated risks to the breakwater stability.
- The barrier island and inlet configuration could change in the future, changing the patterns of erosion and sediment transport that are the BOD of the breakwater, shifting the problem to another portion of the shoreline and reducing the effectiveness or negating the need of the structure.

This assessment of the morphology of the shoreline at Buck Beach has been undertaken based on the information available. There is inherent uncertainty due to the limitations of available data. The measurements and values presented are used to inform the overall trends along the shoreline, understanding that they are likely to have errors. For greater confidence, further monitoring data is required, which are currently unavailable.

3.4 Cultural Resources Survey Impact

Jacobs subcontracted SEARCH, Inc. (SEARCH), to perform a maritime archaeological survey to identify known cultural resources in and near the project area and provide a brief historical context to help guide the planning of geotechnical investigations and siting of the project elements. The survey was conducted on March 11 and 12, 2023 (SEARCH 2023).

SEARCH reported that the identified magnetic anomalies and acoustic contacts do not indicate submerged cultural resources of potential significance. Based on the data recorded during the field survey, SEARCH did not recommend any additional archaeological work. If unanticipated archaeological discoveries occur during the construction phase, SEARCH recommends the cessation of work in those portions of the project site.

3.5 Geotechnical Conditions

Jacobs subcontracted Larry M. Jacobs & Associates, Inc. (LMJ), to perform a geotechnical investigation following the cultural resources survey at the project site. The purpose of the geotechnical investigation was to provide information to the design team for the stability of the structure and to refine the preliminary design. The Geotechnical Data Report (LMJ 2023) is provided in **Appendix B**.

The borings at the site of the Submerged Shoreline Stabilization project were conducted between May 20 and 21, 2023. The boring locations are highlighted on **Figure 3-11**. Boring sites B-8, B-9, B-10, and B-11 are located within the project extent of the Submerged Shoreline Stabilization.

For the Submerged Shoreline Stabilization, the borings generally showed tan, brown, and gray sand soils to the bottom of the borings at roughly 9.5 feet below the mudline at the time of drilling. At boring B-9, a layer of brown slightly silty sand with trace clay pockets at roughly 2.5 to 6 feet was encountered below the mudline. Overall, the soils in these borings were mostly loose with occasional very loose and medium dense areas to the bottom of the borings at roughly 9.5 feet below the mudline. The mudline at these locations was roughly 6.5 to 9 feet below the surface of the water at the time of drilling (LMJ 2023).

LMJ performed laboratory tests to assist in soil classification and to document soil properties. The tests included grainsize analysis, hydrometer testing, wash #200 sieve tests, natural moisture content tests, organic content tests, specific gravity, and Atterberg limits tests run on selected split spoon samples. Test results are summarized in the Geotechnical Data Report (**Appendix B**).

Figure 3-11. Geotechnical Investigation Boring Locations



Source: LMJ 2023

3.6 Metocean Conditions

Hydrodynamic conditions at the site are summarized based on data and modeling results presented in *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design – Layout Optioneering and Sediment Transport Modeling* (Jacobs 2024). Parameters of interest for the Submerged Shoreline Stabilization pilot project include:

- Water levels
- Currents
- Waves

Water levels address the existing tidal variations, potential extreme events due to storm surge, and potential for future SLR.

Currents and wave conditions are based on hydrodynamic and wave modeling. The applied models were calibrated based on collected field data. The modeling results are summarized in the **Sections 3.6.2 and 3.6.3** for currents and wave conditions, more-detailed information is documented in the 60% Design Modeling Reports (Jacobs 2023, 2024).

3.6.1 Water Levels

The following sections describe water level information, including tidal environment, extreme water levels (EWLs), SLR, and design total water levels.

3.6.1.1 Tidal Environment

The tidal datums for the project are based on the National Oceanic and Atmospheric Administration (NOAA) gauge station at Panama City Beach (NOAA 2023b), shown on **Figure 3-12** and in **Table 3-1**.

Tidal datums shown in **Table 3-1** are based on the 1983 to 2001 tidal epoch and relative to NAVD 88. The respective levels relative to NAVD 88 are considered to be relevant to the time period during which they were determined. For the purposes of design, SLR that has occurred between 1992 (the mid-point of the 1983 to 2001 tidal epoch) and the present day is considered in the design of the Submerged Shoreline Stabilization pilot project and added to the tidal datums in **Table 3-1**.

Figure 3-12. NOAA Tide Station Location

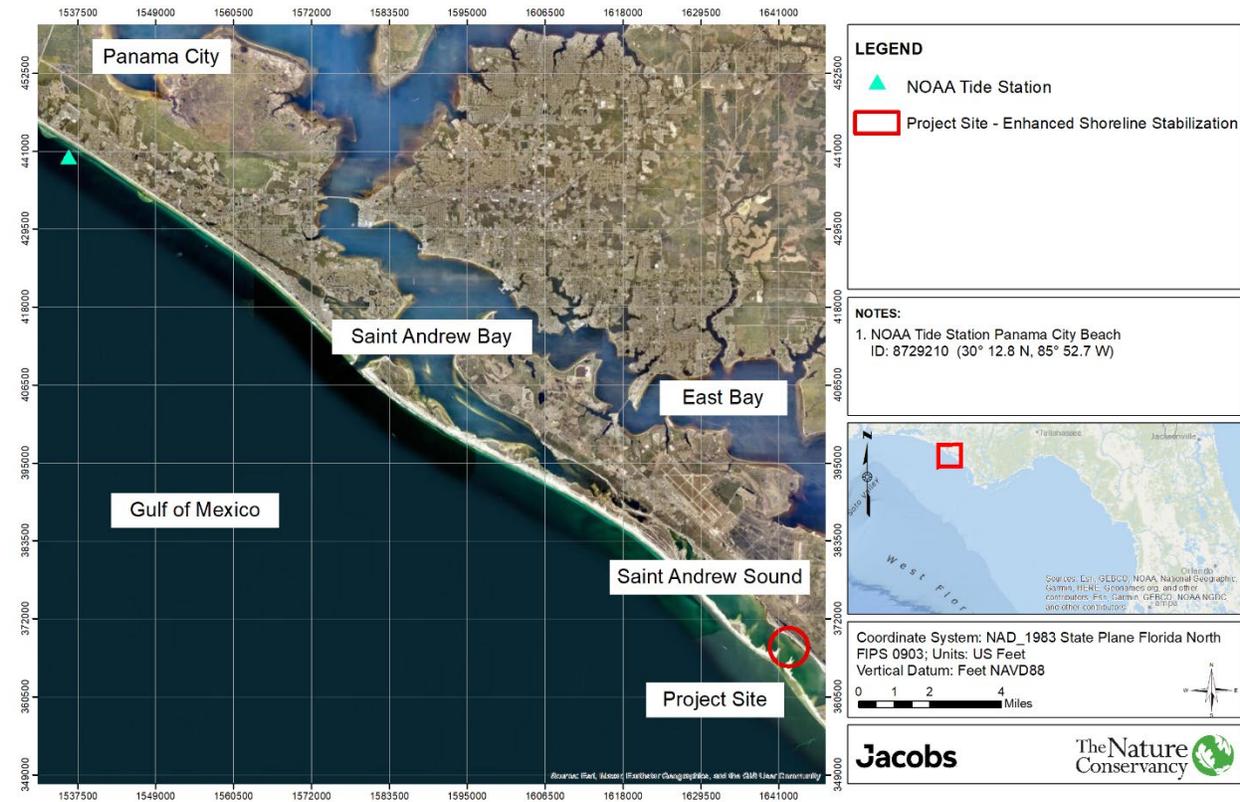


Table 3-1. Panama City Beach Tidal Datums Based on Tidal Epoch 1983–2001

Tidal Datum	Elevation (feet NAVD 88)
Mean Higher High Water	0.86
Mean High Water	0.78
Mean Sea Level	0.13
Mean Low Water	-0.47
MLLW	-0.54

Source: NOAA 2023b

3.6.1.2 Extreme Water Levels

Published EWLs from the *South Atlantic Coastal Study (SACS)* (USACE 2022a) were adopted to inform the design of the Submerged Shoreline Stabilization pilot project. Details can be found in the *Regional Hydrodynamic and Wave Transformation Modeling – 30% Design* (Jacobs 2022). In addition, EWLs were extracted at the Submerged Shoreline Stabilization project site for the 10-, 25-, and 100-year return periods (RPs). The EWL values and corresponding wave parameters are provided in **Table 3-2**.

Table 3-2. Modeling Results from the SACS Extracted at the Submerged Shoreline Stabilization Site

RP (years)	SACS		
	EWL (feet NAVD 88)	Hm0 (feet)	T _p (s)
10	5.58	4.92	11.8
25	6.89	5.58	12.0
100	9.19	6.89	12.4

Hm0 = significant wave height

s = second(s)

T_p = peak period

3.6.1.3 Sea Level Rise

Long-term SLR predictions based on the U.S. Army Corps of Engineers (USACE) Sea Level Change Calculator (USACE 2022b) for the scenarios from NOAA et al. (2017) are illustrated on **Figure 3-13**. While several scenarios are depicted on **Figure 3-13**, the intermediate-high scenario has been adopted for this study. The NOAA 2017 intermediate-high scenarios for selected years are summarized in **Table 3-3**.

SLR values in **Table 3-3** represent the SLR that occurred between 1992 (the mid-point of the tidal epoch used for determining the tidal datums at the site) and each of the given years. Years shown in **Table 3-3** include:

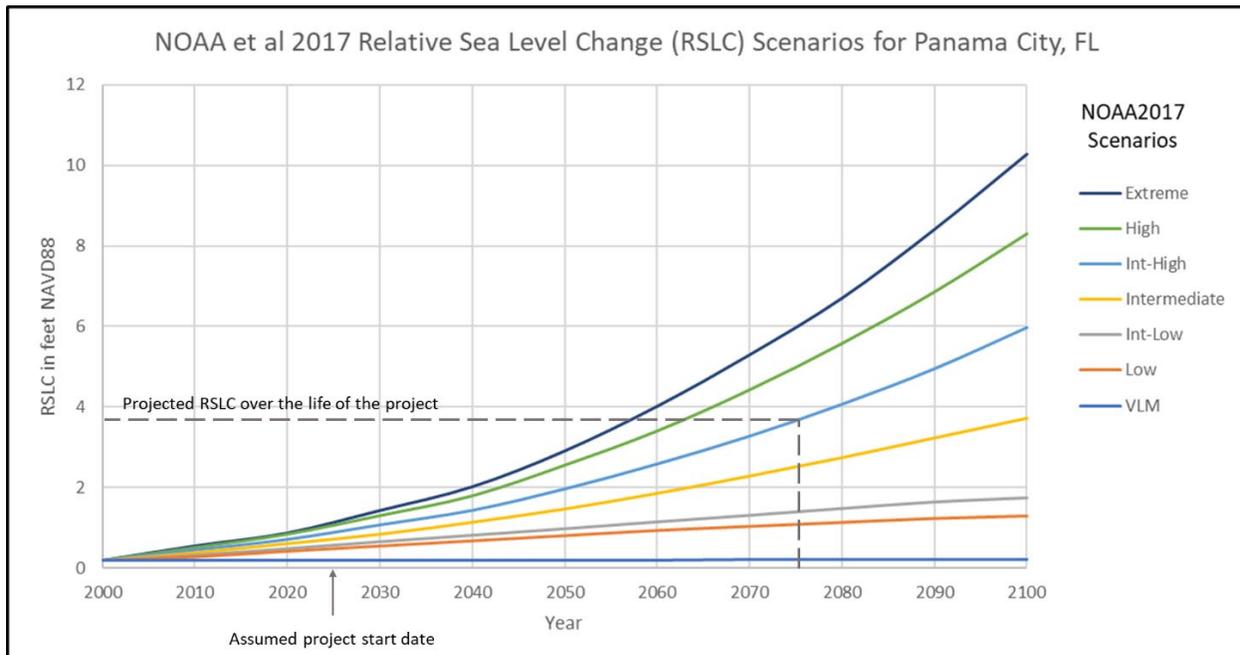
- 2018 – the year of SACS modeling
- 2025 – the year of assumed project start
- 2075 – the year for 50-year project life of the Submerged Shoreline Stabilization pilot project

Table 3-3. Sea Level Change for Panama City, Florida, Intermediate-High Scenario

Year	Sea Level Change (feet)
2018	0.66
2025	0.88
2075	3.67

Source: NOAA 2017

Figure 3-13. Relative Sea Level Change Scenarios for Panama City, Florida



Source: USACE 2022b

3.6.1.4 Design Total Water Levels

Appropriate SLR values to be applied depend on the scenario being addressed. The following values are used for this study:

- An SLR of 0.88 foot is applied to tidal datums shown in **Table 3-1** (based on the 1983–2001 tidal epoch) to obtain tidal datums at the start of the project (2025).
- An SLR of 3.67 feet is applied to tidal datums (1983–2001 tidal epoch) to estimate future tidal datums at the end of the 50-year project life (2075).
- EWLs at the start of the project are adjusted based on the difference in SLR at the anticipated start of the project (2025) and the SLR at the time of the SACS analysis (that is, 0.88 foot – 0.66 foot = 0.22 foot).
- EWLs at the end of the project are adjusted based on the difference in SLR at the end of the project (2075) and the SLR at the time of the SACS analysis (that is, 3.67 feet – 0.66 foot = 3.01 feet).

The design water elevations considered are listed in **Table 3-4**.

Table 3-4. Design Water Levels

Year	MLLW (feet NAVD 88)	Mean Higher High Water (feet NAVD 88)	Total Water Level, 25-year (EWL for 1 in 25-year RP + SLR) (feet NAVD 88)	Total Water Level, 100-year (EWL for 1 in 100-year RP + SLR) (feet NAVD 88)
2025	0.34	1.74	7.11	9.41
2075	3.13	4.53	9.90	12.20

3.6.2 Currents

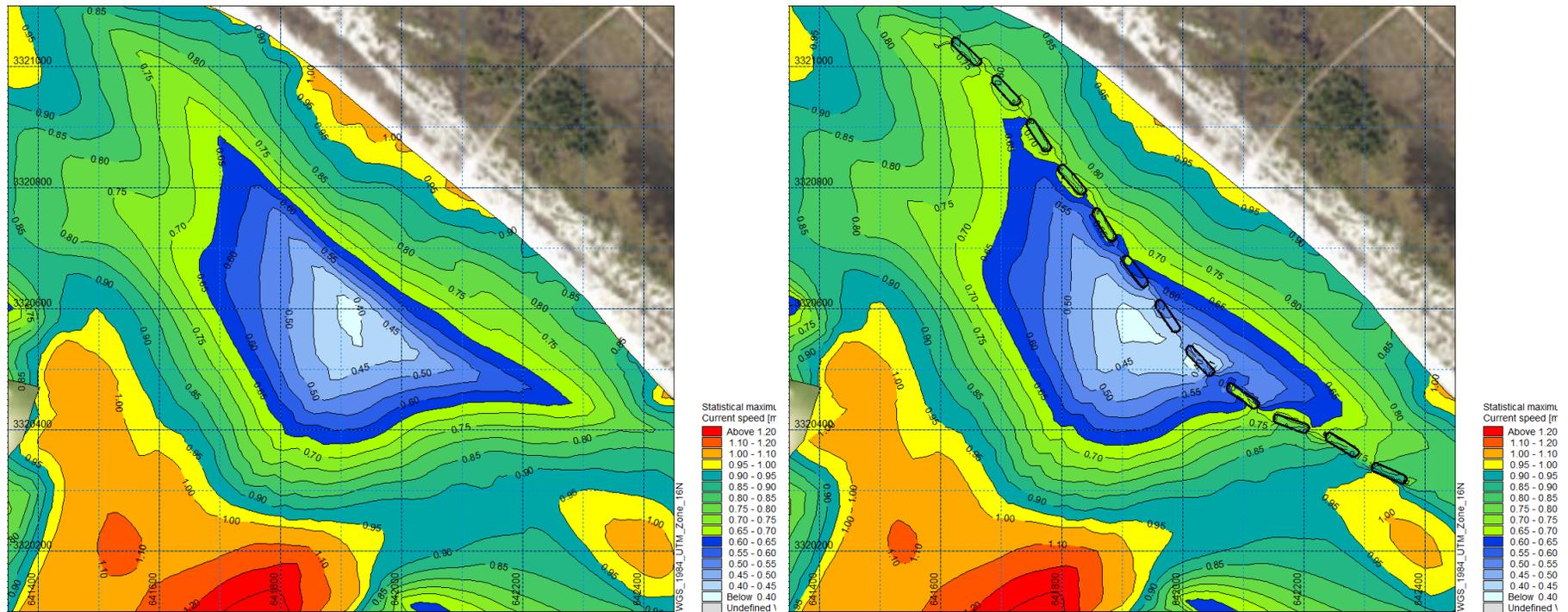
The hydrodynamic model developed during the 30% modeling efforts (Jacobs 2022), which provided a basis for the preliminary assessment, was calibrated with field data during the 60% modeling stage. The 60% model provides current conditions that were considered in the design of the Submerged Shoreline Stabilization site, as documented in *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design- Calibrated Models* (Jacobs 2023).

After incorporating the preferred layout, extreme and operational conditions were analyzed and are summarized in the report *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design – Layout Optioneering and Sediment Transport Modeling* (Jacobs 2024). The modeling included scenarios under present conditions (2025), without SLR, and scenarios under future conditions (2075), including SLR.

The modeling results under future conditions (2075) are shown in **Figure 3-14**, where the figure on the left represents the conditions without structures in place and the figure on the right the conditions with the structural layout in place to investigate the effects of the structure on current patterns.

For the design, a peak current of 2.6 feet per second (0.8 meter per second) was conservatively considered for the scour and stability analysis of the Submerged Shoreline Stabilization. This value represented the maximum current speed near the proposed structures (**Figure 3-14**).

Figure 3-14. Maximum Current Speeds for the 50-year Extreme Event under Future (2075) Conditions without and with Structures in place



Future 2075 conditions without structures

Future 2075 conditions with structures

3.6.3 Waves

The wave transformation model developed during the 30% modeling efforts (Jacobs 2022) was calibrated with field data during the 60% modeling stage. The results of the 60% wave transformation modeling are documented in *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design- Calibrated Models* (Jacobs 2023), which provide insights into the wave conditions for the BOD for the Submerged Shoreline Stabilization site.

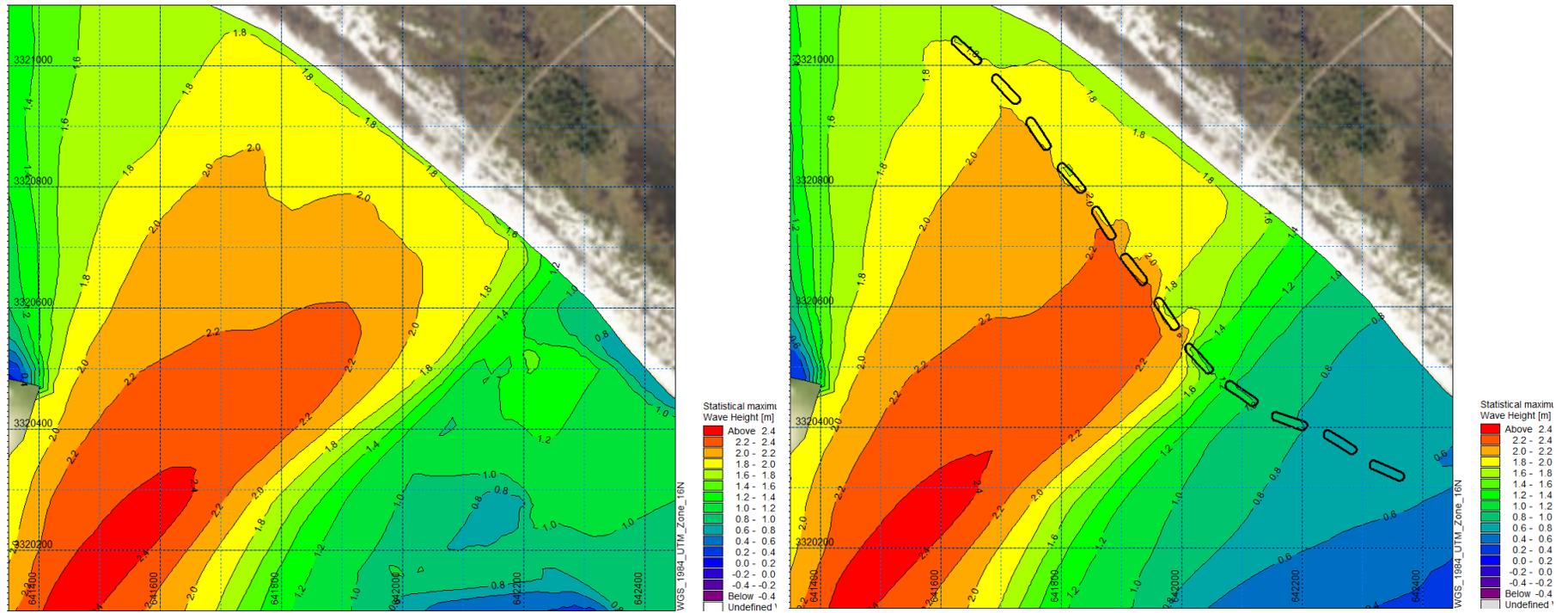
After incorporating the preferred layout, extreme and operational conditions were analyzed and are summarized in the report *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design – Layout Optioneering and Sediment Transport Modeling* (Jacobs 2024). The modeling included scenarios under present conditions (2025), without SLR, and scenarios under future conditions (2075), including SLR.

The modeling results under future conditions (2075) are shown in **Figure 3-15**, where the figure on the left represents the conditions without structures in place and the figure on the right the conditions with the preferred structural layout in place to investigate the effects of the structure on wave patterns.

For the design, a significant wave height of 7.5 feet (2.3 meters) with a peak wave period of 12.3 seconds is considered for the design of the Submerged Shoreline Stabilization. This value represents the maximum wave height near the structures for the future condition including SLR (**Figure 3-15** [right]).

Generally, waves enter St. Andrew Sound during the extreme event from the Gulf by propagating through the inlet and washing over the submerged barrier islands. Waves inside the Sound are limited by wave breaking both on the shoal in front of the inlet as well as over the submerged islands, reducing wave heights considerably compared to waves approaching the site from the Gulf.

Figure 3-15. Maximum Significant Wave Heights for the 50-year Extreme Event under Future (2075) Conditions without and with Structures in place



Future 2075 conditions without structures

Future 2075 conditions with structures

3.6.4 Sediment Transport

An area-wide sediment transport model was developed that uses the results of the hydraulic and wave transformation modeling to assess the annual sedimentation rates in the project vicinity. Sediment data obtained by the geotechnical investigation were implemented in the model, and the model was calibrated by comparing with historical sedimentation. The modeling is documented in *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design – Layout Optioneering and Sediment Transport Modeling* (Jacobs 2024).

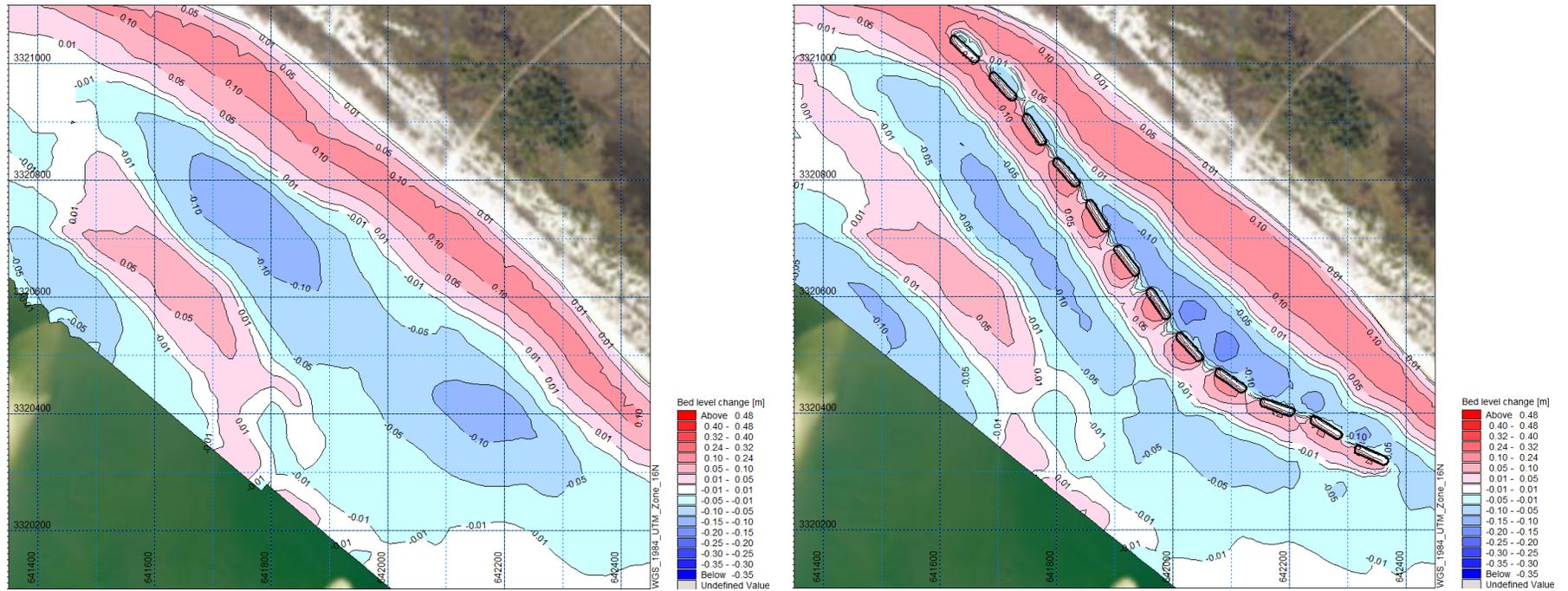
The calibrated model was used to model annual sediment transport at the site without the structures in place (baseline) and after including the preferred layouts to determine sedimentation impacts induced by the structures.

The modeling results without structures in place are shown on the left in **Figure 3-16**. The structure layout was incorporated to model the impact of the structure to the sediment transport; the results from the modeling, including the structures, are shown on the right on **Figure 3-16**.

When comparing these results, the nearshore sedimentation rate is enhanced to 0.1 meter per year (m/year) on average, which is likely due to wave sheltering. The belt of erosion abutting the landward edge of the structure experiences an enhanced erosion rate up to as much of 0.1 meter near the center of the structure line. The preferred layout also leads to a sedimentation strip immediately seaward of the structure line of up to 0.05 meter. A difference plot between preferred layout in places and without structures in place is presented on **Figure 3-17**.

With the structures in place, the model predicted an overall average sedimentation rate for the area behind the submerged breakwaters of 0.09 m/year. This compares with rates of SLR based on the NOAA 2017 intermediate-high scenario of 0.012 m/year at the start of the project and a rate of 0.024 m/year at the end of the 50-year project, suggesting that sedimentation in the area between the breakwaters and the structures could exceed the changes in sea level, reducing the water depth and reducing the potential for increased recession of the shoreline as a result of SLR.

Figure 3-16. Modeled Distribution of Annual Sedimentation Rate without and with Structures in place



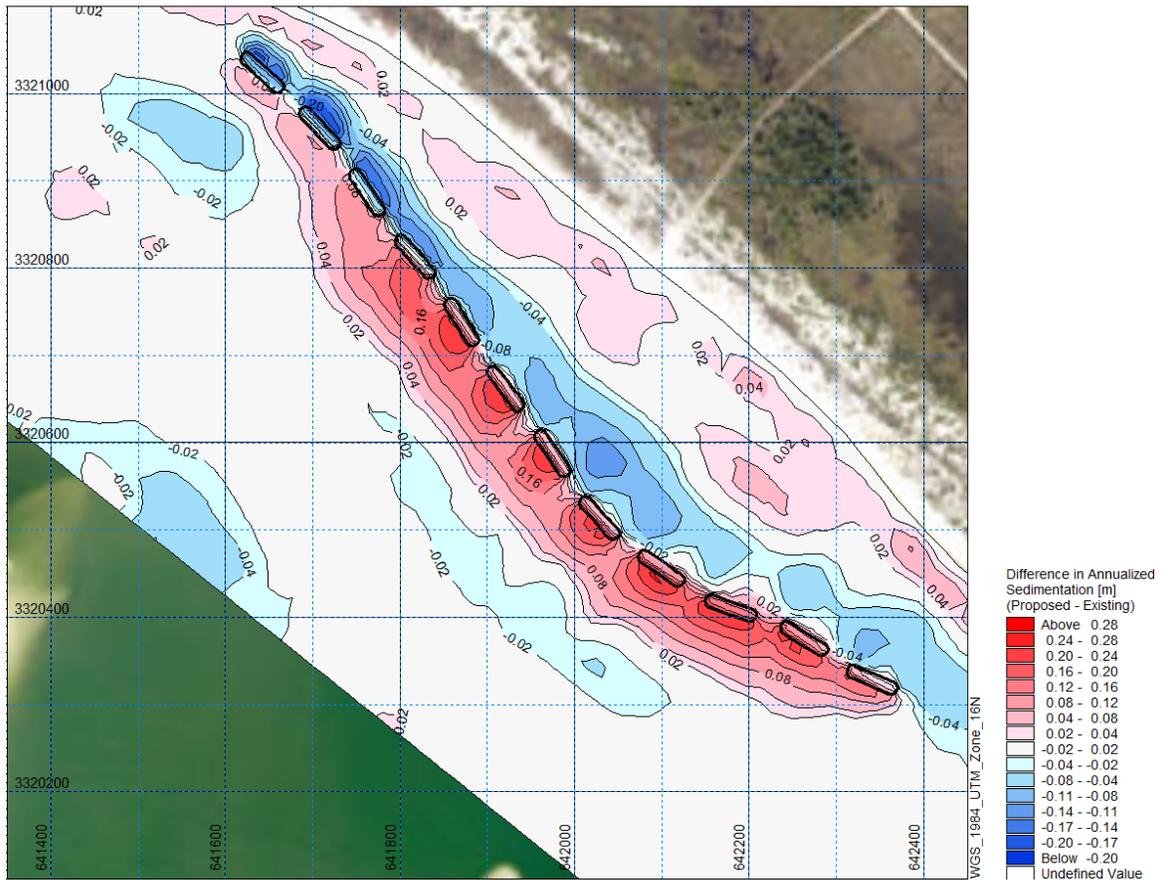
Without structures

With structures

Note: Red color denotes sedimentation; blue denotes erosion.

Figure 3-17. Difference Plot of the Modeled Distribution of Annual Sedimentation Rate between Preferred Layout and without Structures in place

Note: Red color denotes increased sedimentation; blue denotes increased erosion relative to the existing conditions.



4. Basis of Design Conditions

The objectives of the Submerged Shoreline Stabilization pilot project are primarily to reduce local wave hazards, reduce long-term erosion along the shoreline, and enhance seagrass and low marsh habitat. The constraints on the siting and design components are described in **Section 2.2** of this report.

4.1 Design Codes and References

The following codes and references apply to the design of the Submerged Shoreline Stabilization pilot project:

- Stability Design
 - CIRIA, CUR, and CETMEF. 2007. CIRIA C683 - *The Rock Manual: The use of rock in hydraulic engineering (2nd Edition)*.
 - USACE. 2012. *Coastal Engineering Manual: Part VI Design of Coastal Project Elements* (EM 1110-2-1100).
- Geometry Calculations
 - Environment Agency. 2010. *Guidance for outline design of nearshore detached breakwaters on sandy macro-tidal coasts*. Project Summary SC060026/R1. February.
 - USACE. 2008. *Coastal Engineering Manual: Part V Coastal Project Planning and Design* (EM 1110-2-1100).

4.2 Design Life and Design Storm Conditions

A project life of 50 years, from 2025, has been selected for the Submerged Shoreline Stabilization project. Typically, breakwater structures are designed and constructed to deliver coast and shore protection or harbor protection from wave action, and design life is defined as the length of time the structure continues to deliver such functions. However, this project's primary objectives are wave attenuation and enhancement of coastal habitat. Thus, the design life is defined as the length of time the breakwaters are stable in place and continue providing protection from waves while also enhancing coastal habitat.

The design storm defines the conditions that the project must be able to withstand and still function over its design life. Design storms are often defined in terms of their RP, which describes, on average, the frequency that a given event could occur in any given event. The selection of the RP event for a given project should consider potential impacts and risks. For example, a 50-year RP storm has an annual exceedance probability (the probability of being exceeded in any given year) of 2% and will occur, on average, once every 50 years. However, a 50-year event could happen more than once over a 50-year span or not happen at all during that period. The probability that a 50-year event would be exceeded over a 50-year span is approximately 64%.

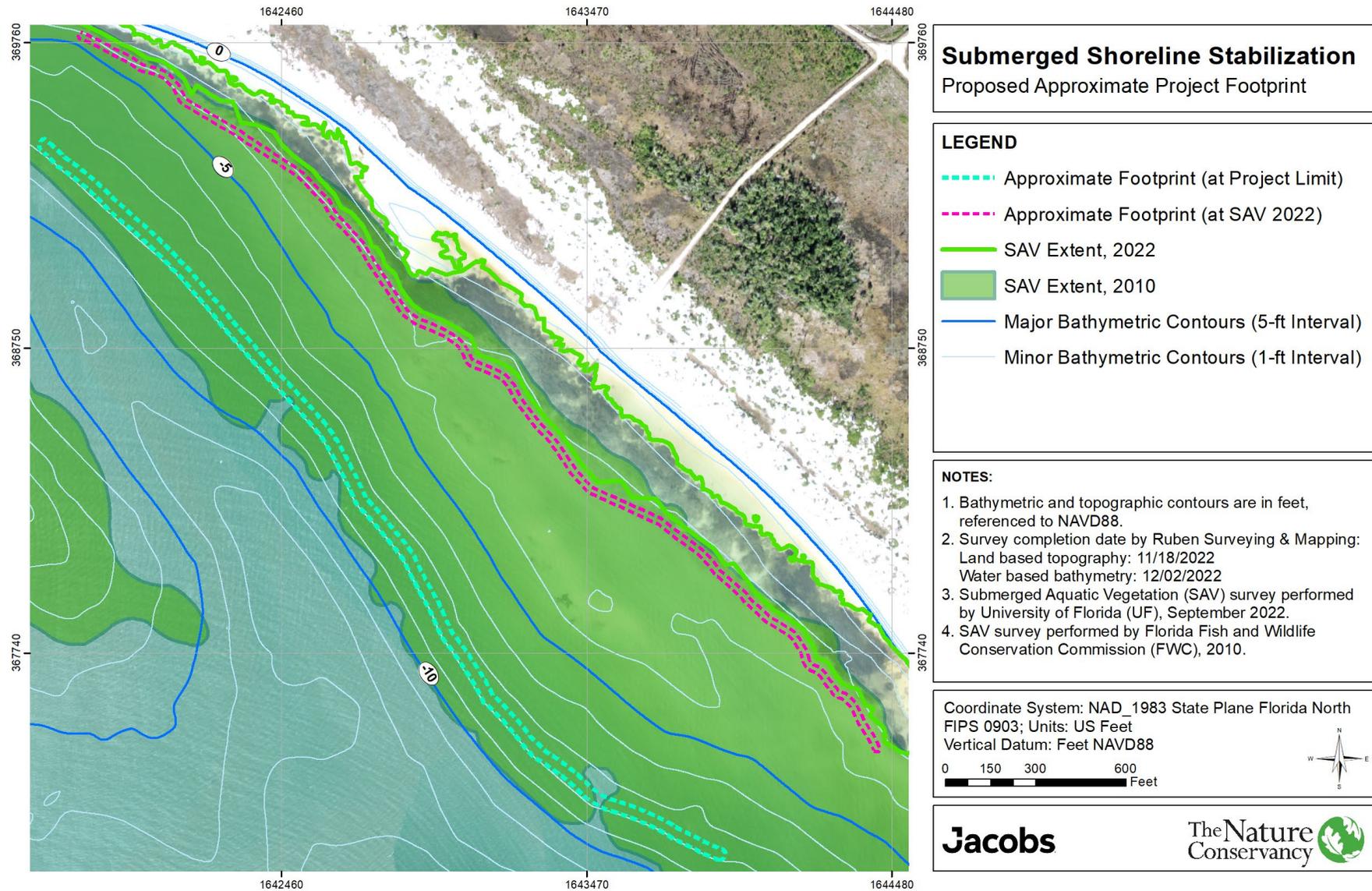
4.3 Preliminary Alternative Option Designs

During the early stages of the project design, various physical characteristics of the Submerged Shoreline Stabilization, including project footprint, cross section, and components, were considered. This section documents the preliminary layout and the considerations that influence the current design configuration.

4.3.1 Preliminary Layout

The approximate footprint of the Submerged Shoreline Stabilization pilot project, at the preliminary design stage, is shown on **Figure 4-1**. The total footprint was intended to cover a length of 3,500 feet (longer if gaps are included) and would be oriented parallel to the shoreline. Two alternative footprints are considered: a deep-water location and a shallow-water location. The preliminary layout structures were designed with the intent to be located in deep water and constructed right at the offshore edge of the defined project area following the -8-foot contour, which will place the structure along the outer edge of the 2010 seagrass extent. The structures located in shallow water would have been constructed no closer than 25 feet from the seaward extent of seagrass based on mapping performed by UF (2022b) to prevent negative impacts to the seagrass during construction. The footprint of the preliminary layout structures of the deep- and shallow-water options is shown on **Figure 4-1**.

Figure 4-1. Proposed Approximate Project Footprint



4.3.2 30% Design Alternatives

Based on the initial feasibility material analysis, three alternatives were considered for the Submerged Shoreline Stabilization pilot project (refer to **Appendix C** for additional details), including two options for a submerged breakwater consisting of limestone and a submerged structure consisting of geobags.

- A submerged breakwater structure with its crest at the 2025 MLLW elevation (0.34 foot NAVD 88) and offshore limit at the proposed project extent (-8 feet NAVD 88 contours) (**Figure 4-2**)
- A submerged breakwater with its crest at the 2025 MLLW elevation (0.34 foot NAVD 88) and onshore limit at the 25-foot buffer from the SAV extent determined by the September 2022 survey (**Figure 4-3**)
- A submerged structure constructed of geotubes with a crest at the 2025 MLLW elevation (0.34 foot NAVD 88) and onshore limit at the 25-foot buffer from the SAV extent determined by the September 2022 survey (**Figure 4-4**)

These alternatives are summarized in **Table 4-1**.

Table 4-1. Design Alternatives Options, Cross-section Parameters

Option No.	Structure Type	Material	Crest Elevation (feet NAVD 88)	Crest Width (feet)	Slope	Footprint (square feet)	Location	Figure No.
1	Submerged Breakwater	Limestone	0.34 (2025 MLLW)	10	1:1.5	131,000	Offshore limit of structure at -8 feet NAVD 88, within the historic SAV extent	Figure 4-2
2 (Selected)	Submerged Breakwater	Limestone	0.34 (2025 MLLW)	10	1:1.5	57,400	Onshore limit of structure at 25-foot offset from 2022 SAV survey	Figure 4-3
3	Submerged Structure	Geotubes	0.34 (2025 MLLW)	6	N/A	72,100	Onshore limit of structure at 25-foot offset from 2022 SAV survey	Figure 4-4

No. = number

All three options were designed to reduce wave energy along the shoreline, providing a potential for reduced long-term erosion and increased accretion, which would provide an added level of resilience to the shoreline during extreme events.

The submerged breakwaters reduce wave energy during non-storm periods, but they would have reduced effectiveness for higher storm surge events and little to no effect for extreme storm surge events. The submerged breakwater would have a minimal visual impact and relatively small footprint for a rubble mound structure.

The rubble mound structures can be modified in the future in response to SLR by adding more stone or armor units to the face and top of the breakwater.

Figure 4-2. Submerged Rubble Mound Breakwater with Toe with a Crest Width of 10 feet and a Crest Elevation at MLLW 2025

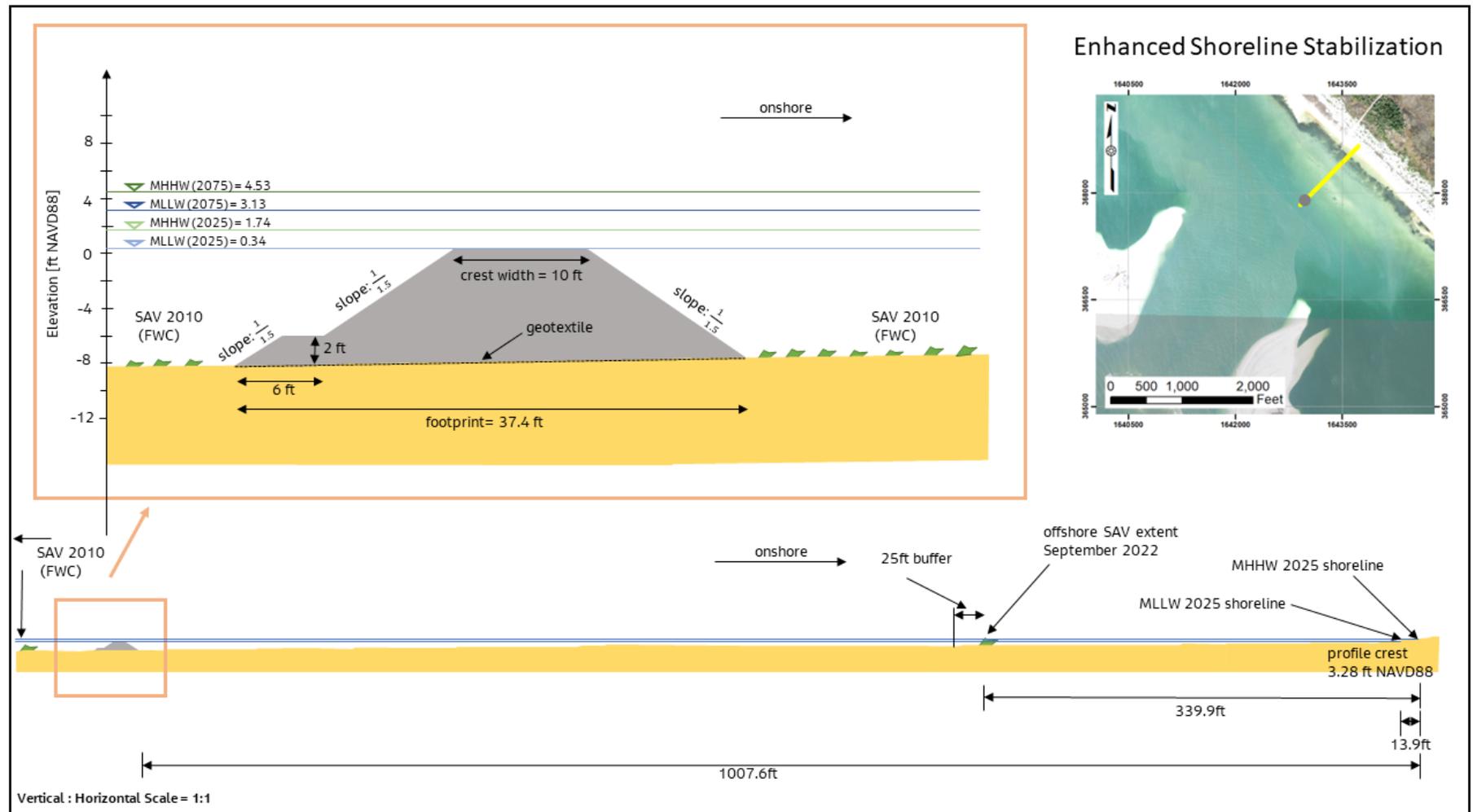


Figure 4-3. Submerged Rubble Mound Breakwater without Toe with a Crest Width of 10 feet and a Crest Elevation at MLLW 2025

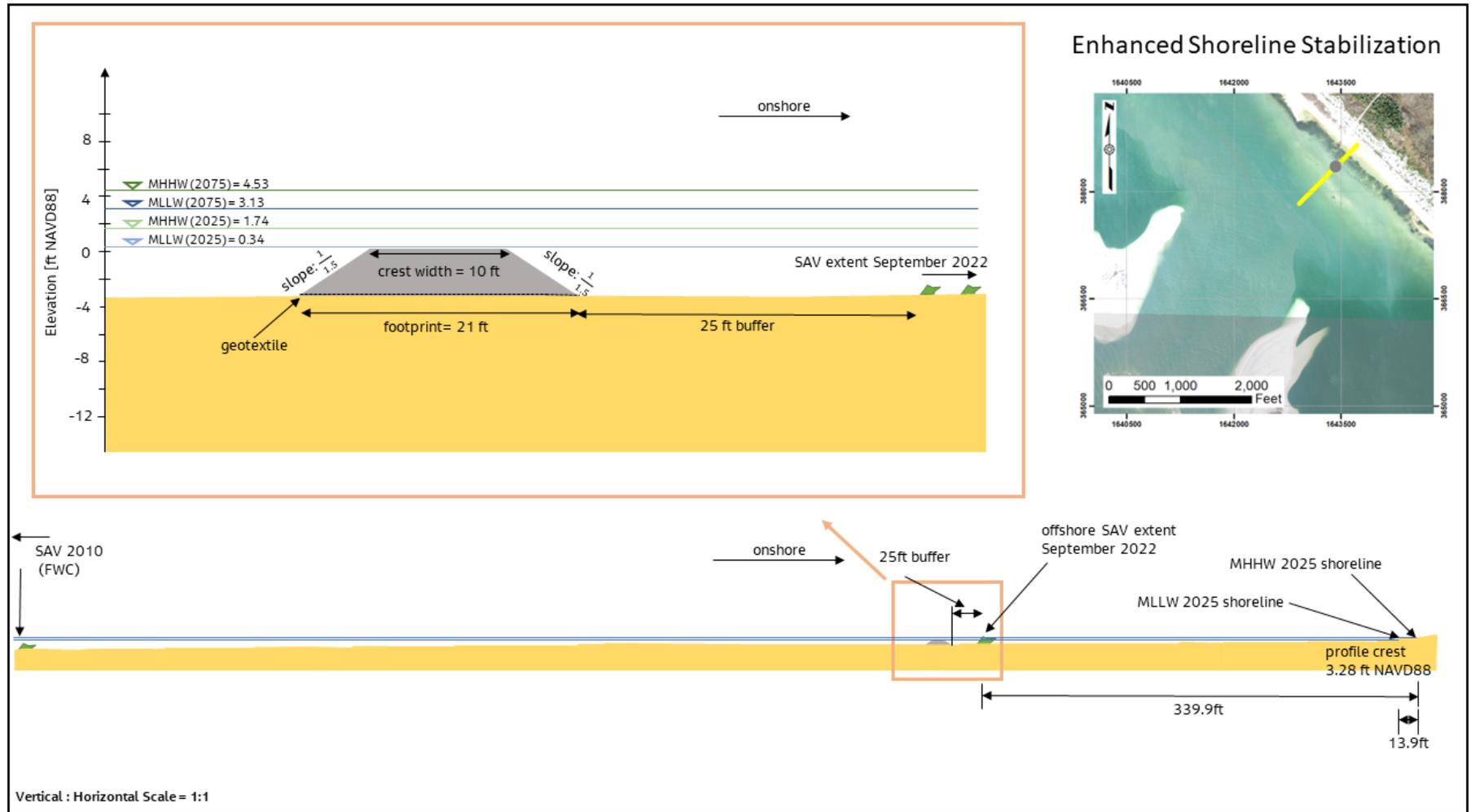
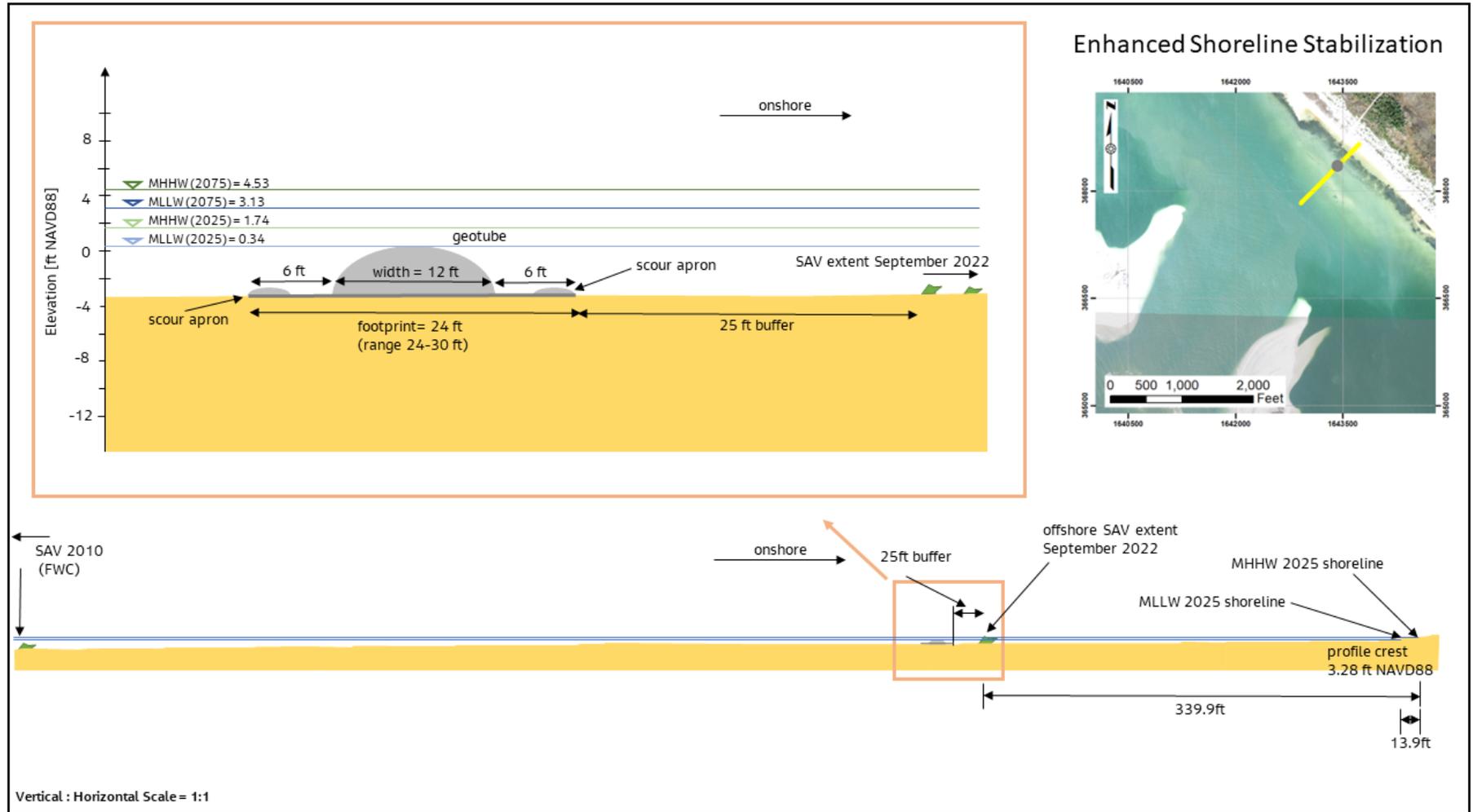


Figure 4-4. Geotubes with a Crest Elevation at MLLW 2025



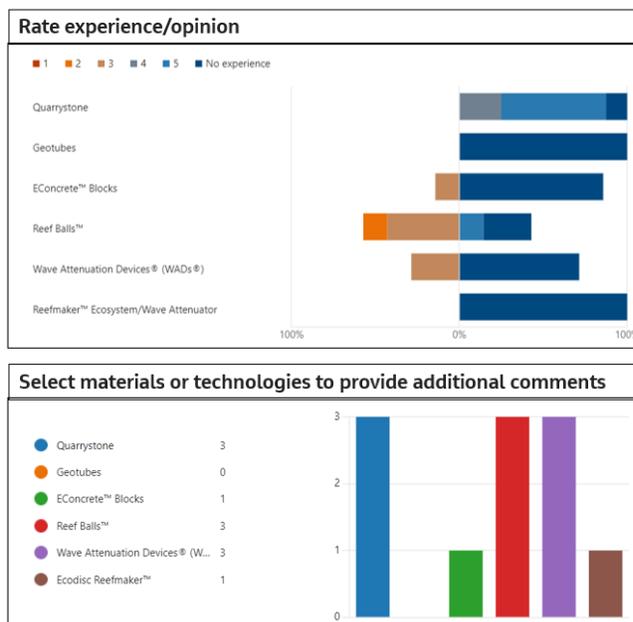
4.3.3 Stakeholder Engagement

A series of stakeholder engagement events were held during the preliminary design phase, including:

- April 20, 2023, Preliminary Design Workshop
- May 4, 2023, Preliminary Design Workshop – T-CRAG
- July 6, 2023, BASH Meeting No. 1
- August 17, 2023, BASH Meeting No. 2

The previously discussed design alternatives were presented during a Preliminary Design Workshop held on April 20, 2023. The meeting invite included a Material Alternatives Analysis Survey to obtain information on material preference and experiences. The results of the survey were presented during the meeting and are shown on **Figure 4-5**.

Figure 4-5. Material Alternatives Survey Summary



During the meeting, the BASH group highlighted that the project alternatives need to be further reviewed due to risks that emerged structure segments could attract birds and, therefore, endanger the aircraft traffic at the Base. On July 6, 2023, a summary of wave attenuation, exposed area, and duration of exposure for all nine alternatives for the three pilot sites was presented during a follow-up meeting with BASH. While the preference from a coastal resilience and shoreline protection viewpoint is for options that offer the highest degree of wave attenuation, BASH highlighted their preference for submerged alternatives over emergent structures. BASH noted that emergent structures present an increased risk of bird attraction that can endanger air traffic due to exposed area and duration of exposure. The Submerged Shoreline Stabilization project is adjacent to airfield Wildlife Exclusion Zones as defined by BASH. The exclusion zones are shown on **Figure 4-6**.

Figure 4-6. Runway and Flightline Operational Constraints (BASH)



During a meeting with BASH on August 17, 2023, it was concluded that, for the 60% Design Optimization described in **Section 4.3.4**, only structures submerged at current MLLW are to be considered. Additional studies are not currently available that assess the potential increase in bird population or site use; therefore, the impact of emergent structures is uncertain. Consequently, emergent structures should be avoided.

4.3.4 60% Design Optimization

Design optimization was undertaken with the purpose of managing the construction cost while maximizing wave attenuation benefits. The layout presented during the preliminary phase was compared to two alternative layouts, summarized in **Table 4-2**. Alternative 2 consisted of 11 reefs instead of 12. The spacing between the individual segments was increased from 100 to 130 feet. For Alternative 3, this altered layout was further changed by decreasing the crest width from 22 to 15 feet.

Table 4-2. Parameters of the Optimization Design Options

Layout Number	Number of Segments	Segment Length (feet)	Number of Gaps	Gap Length (feet)	Crest Width (feet)
1 – Original –Selected	12	200	11	100	22
2	11	200	10	130	22
3	11	200	10	130	15

5. Design Layout and Geometry

This section describes the proposed materials, layout, and location of the proposed Submerged Shoreline Stabilization.

5.1 Materials

The current breakwater design has three main elements. The base, made of geotextile and bedding stone, serves as a foundational layer, providing stability and preventing soil erosion while allowing for efficient drainage. Bedding stone offers additional support and weight distribution to the breakwater structure. The second element, limestone rock, was selected because of its durability and natural composition. Limestone rock will form the bulk of the structure, providing wave attenuation. The breakwaters will be constructed of riprap using a gradation with a median rock size (D_{n50}) of 22 inches or greater, which is sufficient to prevent dispersal of the breakwater structure under storm conditions.

5.2 Layout

The different elements influencing the selected layout are described in the following sections.

5.3 Distance from Shore

The proposed distance from the shoreline was influenced by the following:

- The presence of SAV as a project constraint
- The desired water depth and practicality of installation from water (refer to Section 6 for additional detail)
- Estimated distance from shore within which all sediment movement is contained to aid sediment stabilization
- Locations to tie in up- and downstream and the topography of the existing shoreline

Ultimately, the presence of SAV was the primary driver for the selected distance from shore.

5.4 Reef Length

Reef length is typically determined by selecting the desired shoreline response—no change, growth of salient, tombolo—and the distance from the shoreline where the reefs are intended to be installed. If nourishment of the shoreline is taking place, this will also inform the reef length. Typically, there is a pattern of relative erosion and growth behind the line of reefs. For this project site, the distance between the proposed reefs and the shoreline is determined by the presence of the SAV, and the shoreline response is expected to be “no change.” The selected reef length is 200 feet, primarily influenced by the cost-benefit analysis and wave attenuation response during present operational conditions.

5.5 Reef Spacing

To prevent the structures working as one long reef with limited flushing effect, the minimum reef spacing was selected as five times the wavelength at the reef structure. The wave periods are typically very small, so the wavelength is short; therefore, the minimum spacing is 100 feet, which has been adopted. The

spacing and orientation of the reefs were selected to achieve the optimal level of protection of the shoreline based on both design criteria and modeling results. It is best practice to construct the reefs with a shore-parallel orientation, and therefore, this has been adopted.

5.6 Cross-section and Plan View

Based on the geotechnical investigation, the existing sandy soils are expected to support the weight of a geotextile with manageable settlement. A layer of bedding stone is recommended as an underlayer to act as a separation layer to minimize migration of fines into the rock. Fines displacement would have the same effect as subgrade settlement and consolidation. Geotextile/geogrid, while providing a benefit to project construction (reduced settlement/fines migration), might not be required for the Submerged Shoreline Stabilization project based on early indications. This will be reevaluated during the 90% design stage.

The design crest level is -0.54 foot NAVD 88, which fulfills the BASH requirement for submergent structures. Slopes of 1:1.5 are recommended to limit the footprint, but if there are no concerns about permitting, this could be increased to a shallower slope.

The typical reef cross section and plan view are shown on **Figure 5-1** and **Figure 5-2**.

Figure 5-1. Typical Submerged Shoreline Stabilization Plan View

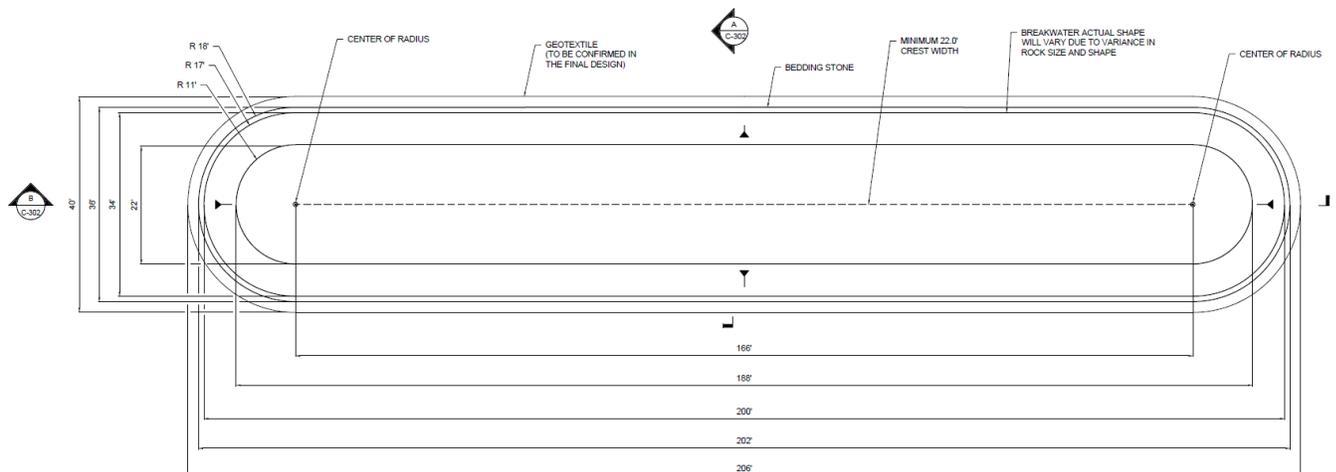
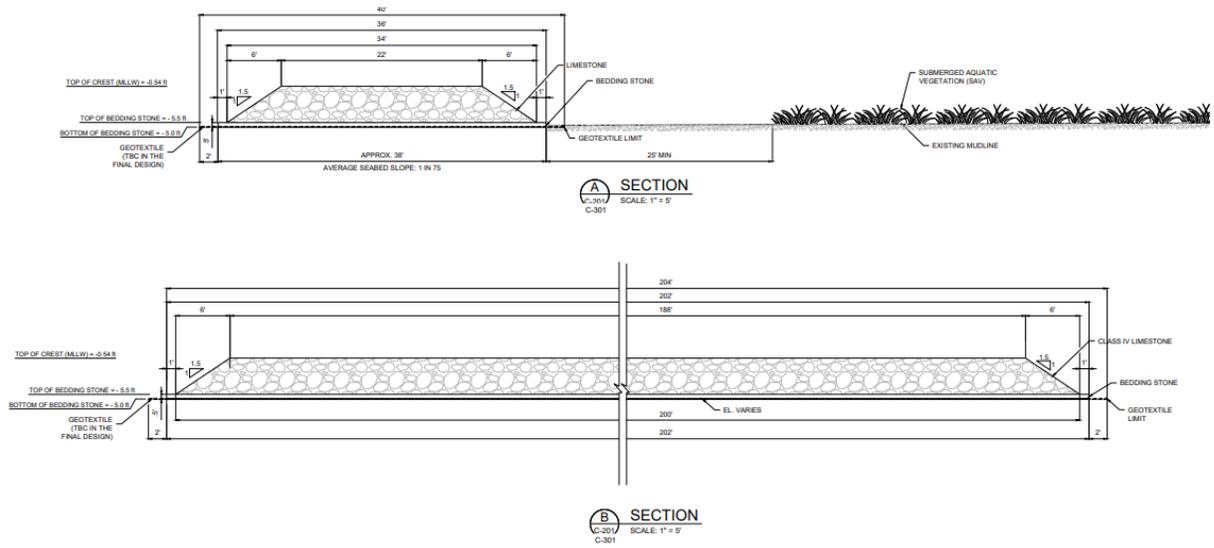


Figure 5-2. Typical Submerged Shoreline Stabilization Structure Profile



6. Constructability

The constructability of the Submerged Shoreline Stabilization is dependent on the depth of water, which will dictate the type of equipment capable of constructing the structures, but also the depth of the inlet at high tide to safely navigate. It is proposed to build the structures using tugboats and barges to transport material to the proposed reef locations. A barge-mounted crane would be used to place the material. With the reefs located along the -5-foot contour, the minimum depth of water anticipated is approximately 4.5 feet (at MLLW). Barges will be positioned seaward of the reef to allow sufficient draft and avoid grounding during construction. Barges will be working in water depths of 4.5 feet or more, depending on the tide. Because the site will be exposed to higher waves going through the inlet, the size of the barge is an assumption and will need to be confirmed by the contractor. The barges might also need to be relocated at night and/or during storm events to a less exposed zone behind the protection of the barrier island. Material and barges might also need to access the site through the Mississippi Road boat ramp inside the Base, which is located northwest of the project site. Constructability options will be refined during the 90% design phase.

Construction Assumptions:

- Anticipated construction timeline: March 2026 to March 2027 to construct all 12 breakwaters.
- Assumed five rock barges (50 feet by 200 feet) for staging and one rock barge (50 feet by 200 feet) and one excavator for placement (**Figure 6-1**).
- Assume some barges would be left overnight at construction site.
- Assume two 25-foot tugboats.
- Barge and other vessel access to the project site from the Gulf and East Bay (refer to drawings package in **Appendix E**).
- Anticipated working hours: Daytime and nighttime, depending on tides.

A construction schedule has not been developed yet. The current assumption is that construction will occur 5 days per week, 5 to 8 hours per day. The ability to transport the stone by barge might necessitate higher tides during the construction period. The summer months have predictably higher tides, with the winter months being subject to cold fronts with northerly winds blowing the water out of the Bay and decreasing the depth of water. The ability to supply the site with stone, expected to be a daily task, will dictate the best construction time frame and equipment to be used.

Figure 6-1. Pensacola East Bay Construction

Photo courtesy of TNC.



7. Adaptive Management

Adaptive management is a process by which future monitoring information may be used to assess the performance of the Submerged Shoreline Stabilization project. Monitoring of the project will be conducted by UF and includes metrics such as:

- Areal dimensions
- Height
- Density of sessile invertebrates
- Percent cover of substrate
- Shoreline position
- Topo-bathymetric profile
- SAV areal extent
- SAV percent cover
- Wave height and currents

Following construction and as monitoring data are evaluated, information may be used to inform future design as well as potential modification to the installed structures. Based on the design intent of the Submerged Shoreline Stabilization, little to no future direct modifications are anticipated. The project is expected to adapt naturally overtime as site conditions change. Minor deviations to the project footprint and geometry are anticipated over the design life. It should be noted, however, that some foreseen, unforeseen, and/ or extreme circumstances may substantially impact the project and modifications to the project may occur. Future potential scenarios that may require direct modifications of the Submerged Shoreline Stabilization include the following:

- Forcing factors (i.e., hurricanes) beyond the design criteria alter the project geometry and create potential navigation hazards. Direct modifications may be performed to address any potential navigation hazards or impacts.
- Future water surface elevation changes outpace physical and biological adaptation rates and project performance is reduced. If considered worthwhile, direct modification may be conducted to reestablish successful performance relative to success criteria, i.e., adding additional materials to increase crest height (without affecting BASH requirements).

Any future direct modification to the Submerged Shoreline Stabilization project will require coordination with Tyndall AFB as well as relevant regulatory permitting agencies.

8. Opinion of Probable Construction Cost

A Class 2 cost estimate, as defined by the Association for the Advancement of Cost Engineering International, is provided in **Appendix D**. The estimating accuracy for 30% to 70% design level is in the range of -15% to +20%. At this level of design, a contingency of 25% is recommended and is included in the total estimated cost. The cost includes escalation.

Table 8-1 provides the low-range, estimate, and high-range cost estimated based on the 60% design. **Figure 8-1** includes additional cost estimate information.

Table 8-1. Summary Cost Estimate

Low Range (rounded) -15%	Estimate Total (rounded)	High Range (rounded) +20%
\$5,238,269	\$6,162,670	\$7,395,204

Figure 8-1. Additional Cost Estimate Details

	On Bid Quantities	%
Direct Cost	3,339,736	54.19%
Indirect Cost	591,387	9.60%
Addons	147,513	2.39%
Bond	73,948	1.20%
Pass Through Cost	1,223,548	19.85%
Direct Markup	667,947	10.84%
Indirect Markup	118,277	1.92%

This estimate was prepared based on the following key assumptions:

- The estimate is based on 60% drawings prepared May 2024.
- Crews work 5 to 8 hours per day, 5 days per week.
- Assumed 60 days for construction.
- Riprap includes delivery, material, and installation.
- Costs are provided in 2024 dollars.

As with all estimates, it represents a snapshot in time of what is known about the project and expected to occur. The commodities and energy markets are currently extremely active. Changes in either will have dramatic effects on this estimate. Therefore, this estimate should be viewed in that light. If more than 90 days have passed, or significant changes in the commodity markets, this estimate should be updated and reevaluated. This estimate does include escalation to address the potential for this to occur.

9. Conclusion and Next Steps

Different preliminary alternative options were considered during the 30% design stage. During that phase, preliminary modeling results were available for the analysis. The options, which were presented during a workshop, raised questions from BASH regarding the attracting of birds by emergent structures. It was decided to only pursue options with a crest elevation at MLLW. During the 30% design stage, field data were collected that included waves, currents, a cultural resources survey, and a geotechnical survey. The field data were used to calibrate the wave, hydrodynamic, and sediment transport models and to inform the design. The results from the calibrated models were applied during the 60% design. Different layout alternatives were analyzed during the optimization. The optimization included weighing function and cost. Ultimately, a layout comprising 12 structure segments was chosen, with a gap with of 100 feet.

The next steps include the review of the 60% design package by TNC and incorporating any consequential comments before advancing to the 90% design stage and developing construction documents. Once the proposed design is chosen, Jacobs will move forward with the detailed design phase of the project. Detailed design will be completed in summer 2024.

The following initial risks were identified at this stage and are offered as an example of best practice and can be used to gauge the level of risk that is applicable to this project. The following is intended to be the start of the risk management process and should be updated regularly:

- Lack of funding for construction and long-term monitoring
- Bathymetry impacts, including potential exposure of cultural resources, from recent hurricanes
- Changes in SAV footprints near the proposed breakwaters
- Inability to secure materials from a reliable and affordable source
- Regulatory changes

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Appendix A

Bathymetric Survey



Appendix B

Geotechnical Report



Appendix C

Material Alternative Analysis



Appendix D

Cost Estimates



Appendix E
Drawing Package



Appendix F

Specifications

