Tyndall Pilot Project, Oyster Reef Breakwater – 60% Basis of Design Report

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The Nature Conservancy
Tyndall Pilot Project Design and Permitting

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Tyndall Pilot Project, Oyster Reef Breakwater – 60% Basis of Design Report

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Acronyms and Abbreviations

°C	degree(s) Celsius
AFB	Air Force Base
BASH	Bird/Wildlife Aircraft Strike Hazard
BOD	Basis of Design
CRIP	Coastal Resilience Implementation Plan
DARPA	Defense Advanced Research Projects Agency
EWL	extreme water level
FWC	Florida Fish and Wildlife Conservation Commission
Hm0	significant wave height
MLLW	mean lower low water
NAVD 88	North American Datum of 1988
NBS	nature-based solutions
NOAA	National Oceanic and Atmospheric Administration
RP	return period
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
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 significantly make 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 AFB's layered coastal defenses. The three nature-based design projects shown on **Figure 1-1**, include a living shoreline, an oyster reef, and a submerged shoreline stabilization.

This Basis of Design (BOD) report focuses on the project site for the Oyster Reef Breakwater, which is situated along the East Bay in the northeast portion of Tyndall AFB. The location is shown on **Figure 1-2**. This pilot project is proposed to enhance coastal habitat by introducing reef structures allowing the growth of oysters. The Oyster Reef Breakwater structures will improve the overall resilience against wave-induced coastal erosion near the Tyndall AFB runway by reducing the potential wave heights reaching the shore under operational conditions.

This document describes the evaluation and basis of the detailed (60%) design for the Oyster Reef Breakwater project at Tyndall AFB. The objectives of the Oyster Reef Breakwater project are as follows:

- Enhance the natural coastal habitat to preserve and restore oyster population.
- Reduce long-term shoreline erosion trends at the Tyndall AFB runway.

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

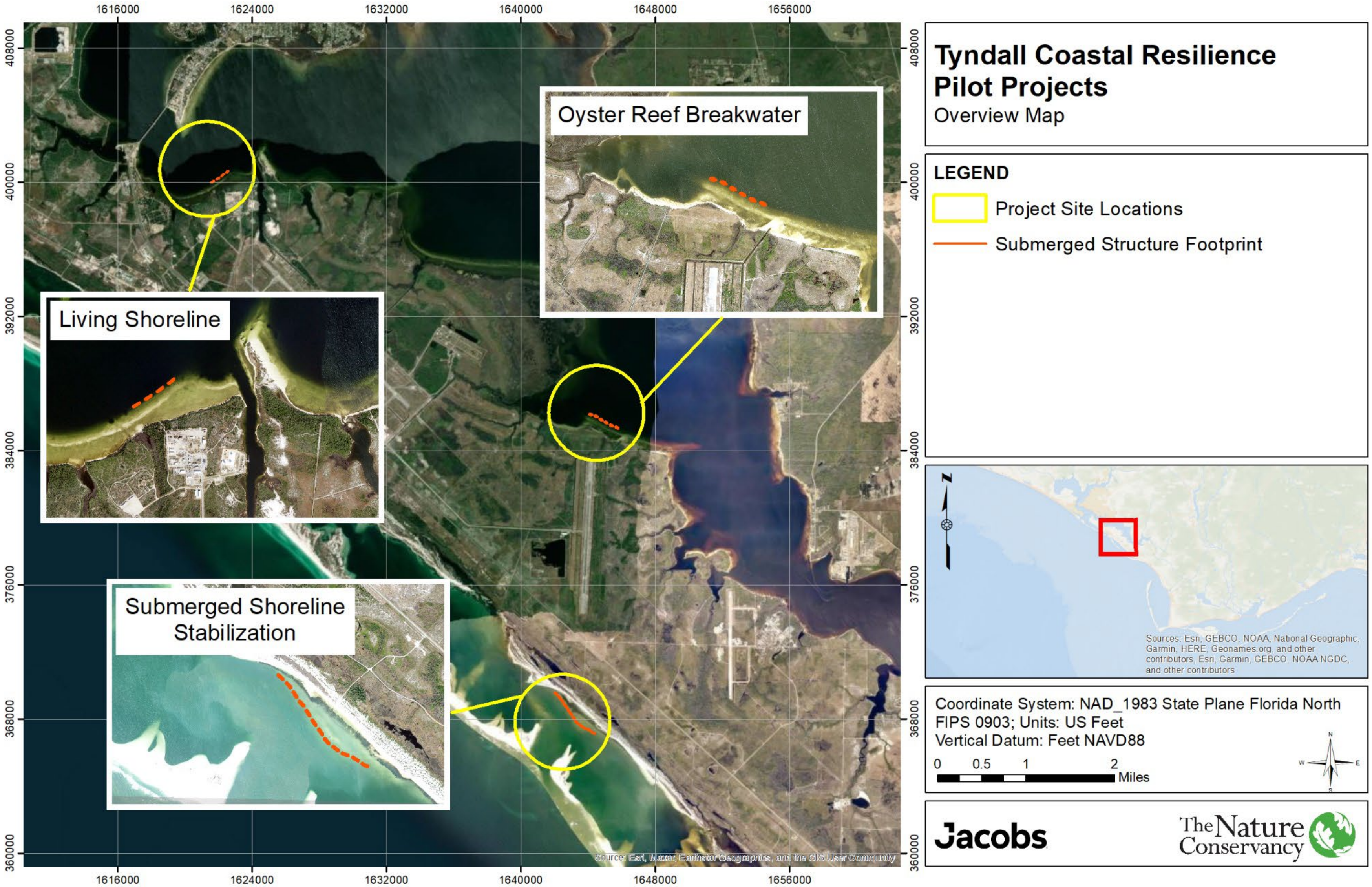
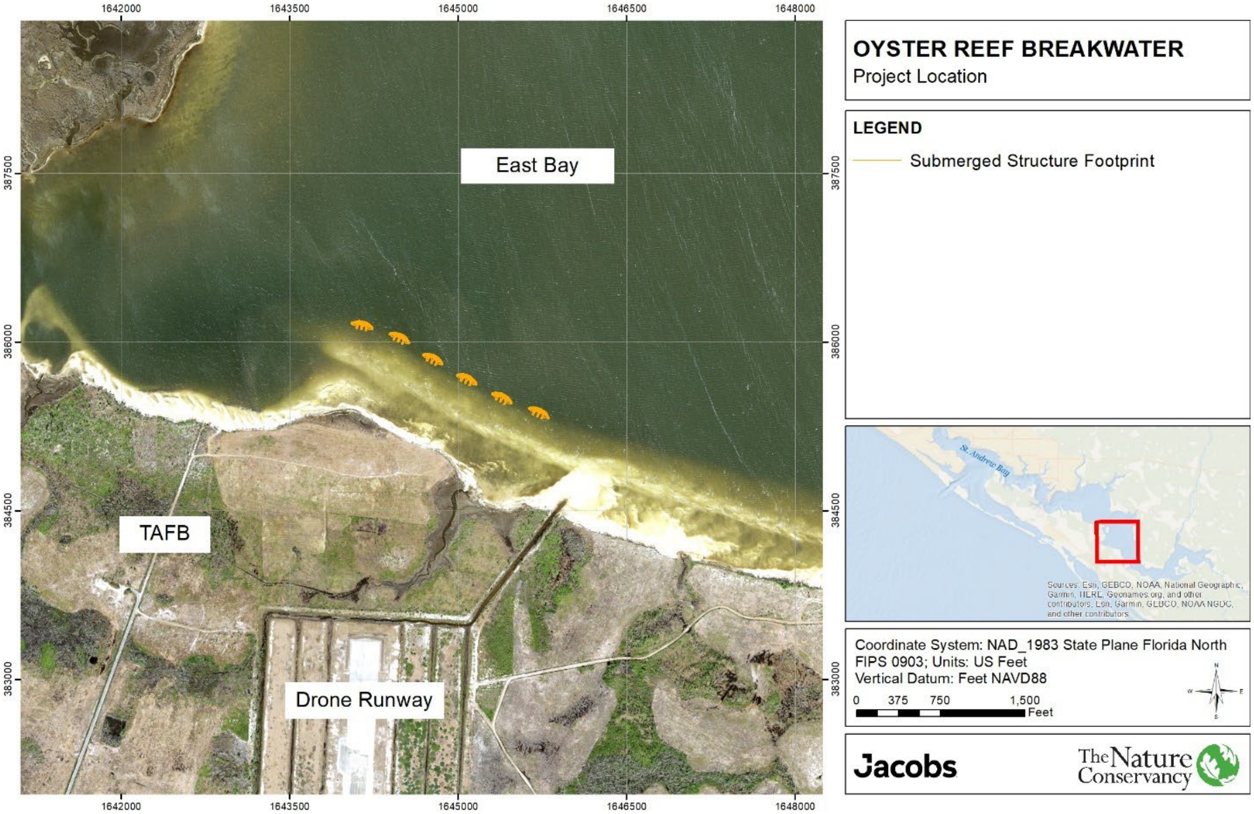


Figure 1-2. Project Location



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, improving water quality, and fostering biodiversity. NBS can be 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 U.S. Air Force (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 Oyster Reef Breakwater project was selected to demonstrate how some features, such as reefs, could reduce the risk of wave hazards and long-term coastal erosion. The project is located directly adjacent to the drone runaway (**Figure 1-2**), which is a critical asset for Tyndall AFB. Its location will create indirect benefits by improving the long-term resilience of this asset.

The primary objective of the Oyster Reef Breakwater project is to provide risk-reduction benefits to the shoreline by reducing wave heights and long-term wave-induced erosion. These risk reductions result from both physical and biophysical processes, underscoring the importance of an NBS's ecological components.

A secondary objective is for the reefs 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.

From an ecological standpoint, the primary goal is to design an oyster reef habitat that promotes settlement of oyster larvae and sustained recruitment of adult oysters. The project was designed using a substrate suitable for oyster larvae to settle and colonize.

1.2 Report Organization

This BOD report summarizes the 60% design analysis for the proposed Oyster Reef Breakwater 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 preliminary design components and drawings.

As series of appendixes used for the design are also provided in the form of appendices:

- **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 Overview

Tyndall AFB is located on a peninsula along Florida's panhandle, southeast of Panama City in Bay County. 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, and 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 currently subject to flooding from coastal surge propagation on both sides of the peninsula, as well as upland rainfall runoff. If the phenomena occur simultaneously, the coastal surge can cause a hydraulic constraint on the surface drainage system of the base, which outfalls to East Bay and St. Andrew (Jacobs 2020).

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

Based on the CRIP, Tyndall AFB will continue to experience coastal flooding through SLR and event-based storm surge through the year 2100 (USAF 2022). In preparation for these conditions, Tyndall AFB is taking measures to protect the mission as well as supporting resources around the base assets. This includes building or enhancing traditional gray infrastructure, such as flood walls and levees, and promoting NBSs, such as the Oyster Reef Breakwater project.

The Oyster Reef Breakwater project site is located along the southern side of the East Bay, between Camp Eagle Lane and the stormwater discharge outlet located southeast of Tyndall AFB. The project site is exposed to waves coming from the north side of the East Bay with a maximum fetch of 2.7 miles. The shoreline consists of dense and sparse seagrass and sand within the intertidal area. Some woody vegetation, including trees, was observed during a site visit in October 2022 (**Figure 2-1**).

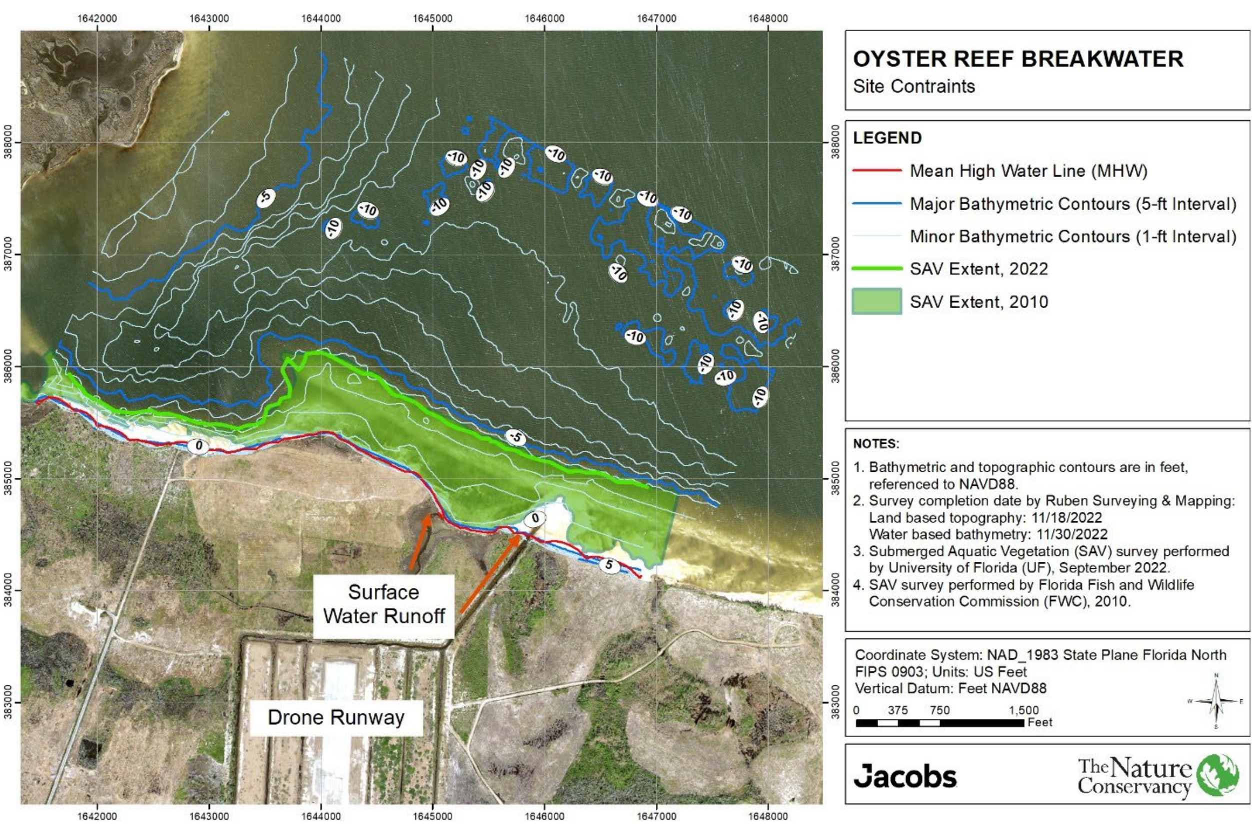
Figure 2-1. Site Photograph of the Project Site Shoreline, October 2022

2.1 Project Site Constraints

Several physical constraints associated with the project site impact the proposed solution that can be implemented. These are summarized on **Figure 2-2** and include the following:

- Submerged aquatic vegetation (SAV) (specifically, seagrass) is present between the shoreline and seabed elevation from approximately -4 feet, North American Vertical Datum of 1988 (NAVD 88). This prevents the import and placement of material directly on the shoreline and between the shoreline and the seaward side limits of the existing seagrass. Placement of the material seaward side of the seagrass limits the overall shoreline management strategies available at this site.
- Surface water runoff is present at this site between the stormwater drainage canal and the shoreline. The Oyster Reef Breakwater project is not expected to reduce shoreline erosion near this area.
- Drone flight runway restrictions limit access to the site.
- 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; refer to **Section 4.6** for further discussion.

Figure 2-2. Oyster Reef Breakwater Constraints Plan



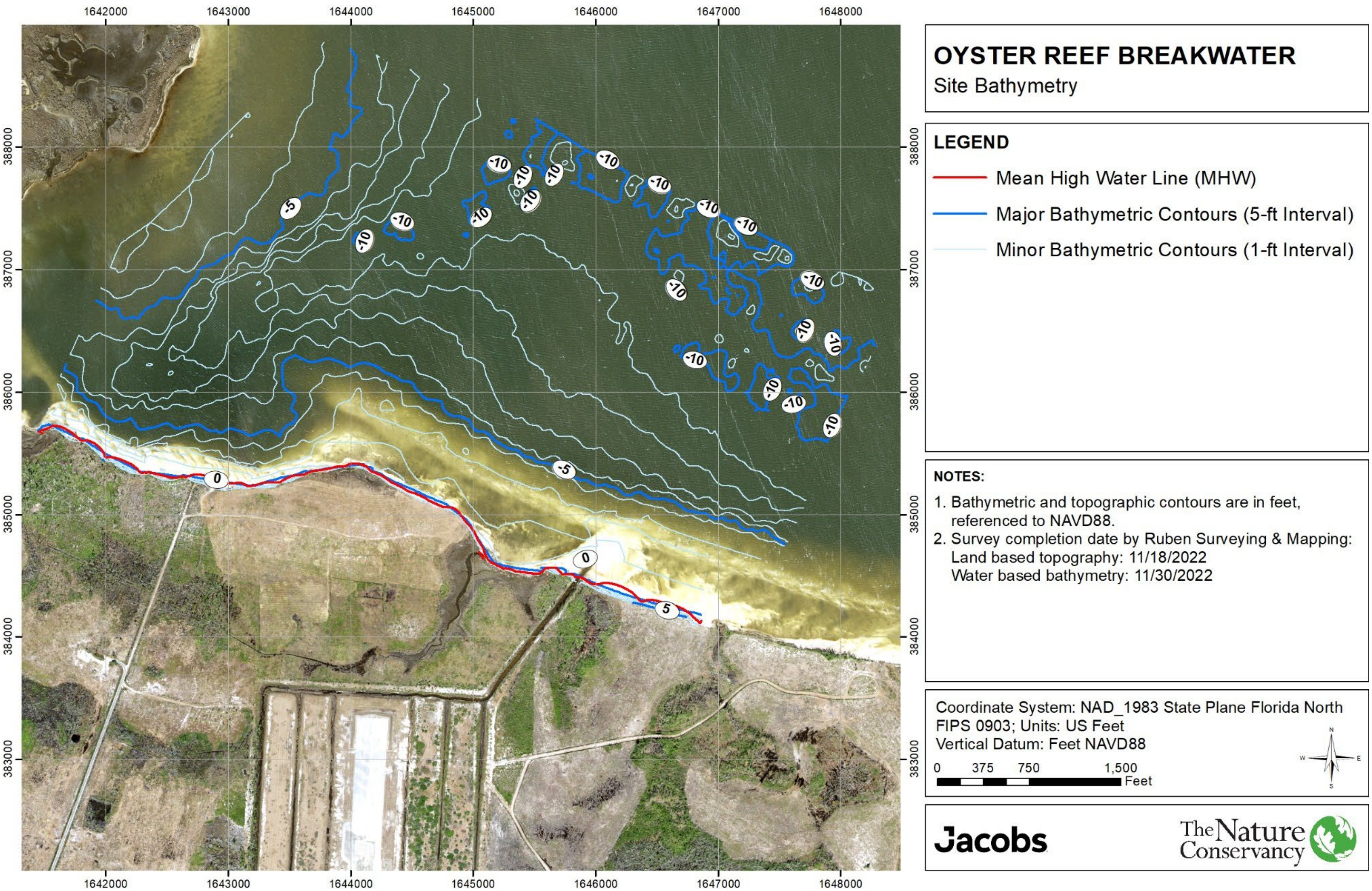
3. General Site Data

3.1 Bathymetry and Topography

Ruben Surveying and Mapping, Inc., collected site-specific topographic and bathymetric data at the Oyster Reef Breakwater project site in November 2022 (**Appendix A**). These data provide the basis for the siting and development of the structures for the pilot project designs.

The data collected show that the project area is typified by shallow nearshore water depth with a gentle nearshore gradient. The seaward side boundary of the existing seagrass lies between approximately 350 feet (to the north) and 800 feet (to the south) from the shoreline with water depths ranging between -3 to -4 feet, NAVD 88 (**Figure 3-1**).

Figure 3-1. Site Bathymetry



3.2 Shoreline and Submerged Aquatic Vegetation

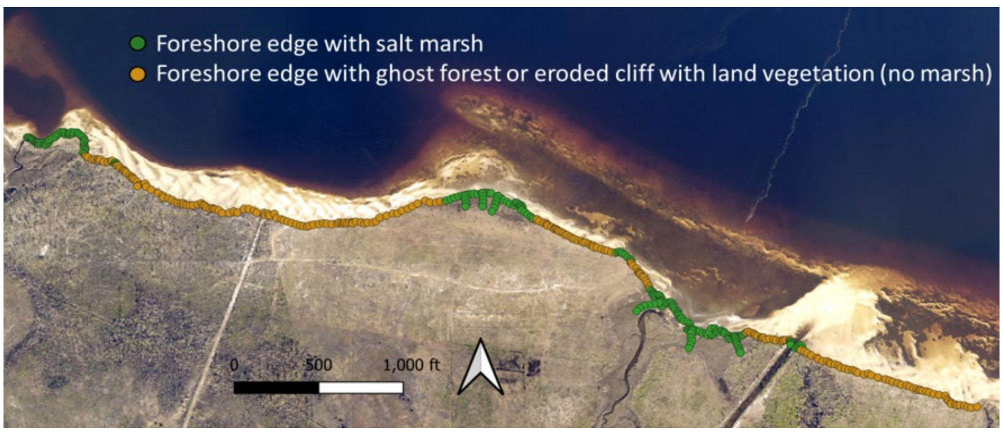
This section discusses existing and historic shoreline conditions and SAV extents that are based on available aerial imagery, site photographs, and field data collected between May and December 2022, as documented by UF (UF 2022a).

3.2.1 Shoreline Conditions

Data on characteristics of the shoreline/saltmarsh habitats are documented by UF (UF 2022b). These are summarized on **Figure 3-2** and **Figure 3-3**.

The Oyster Reef Breakwater site is located inside the East Bay in St. Andrew Bay. It consists of continuous seagrass meadows (mainly subtidal and few intertidal) and marshes in the higher tidal elevations. A high-level review of aerial imagery datasets from 2007 to 2020 was undertaken, which showed that the shoreline had not measurably retreated between 2007 and 2015. **Figure 3-3** indicates isolated and localized marsh erosion. Future SLR will likely increase this erosion and impact the currently stable foreshore.

Figure 3-2. Foreshore Characterization Along the Project Site Shoreline



Source: UF 2022b

Figure 3-3. Foreshore Characterization Photographs Along the Project Site Shoreline

Source: UF 2022b

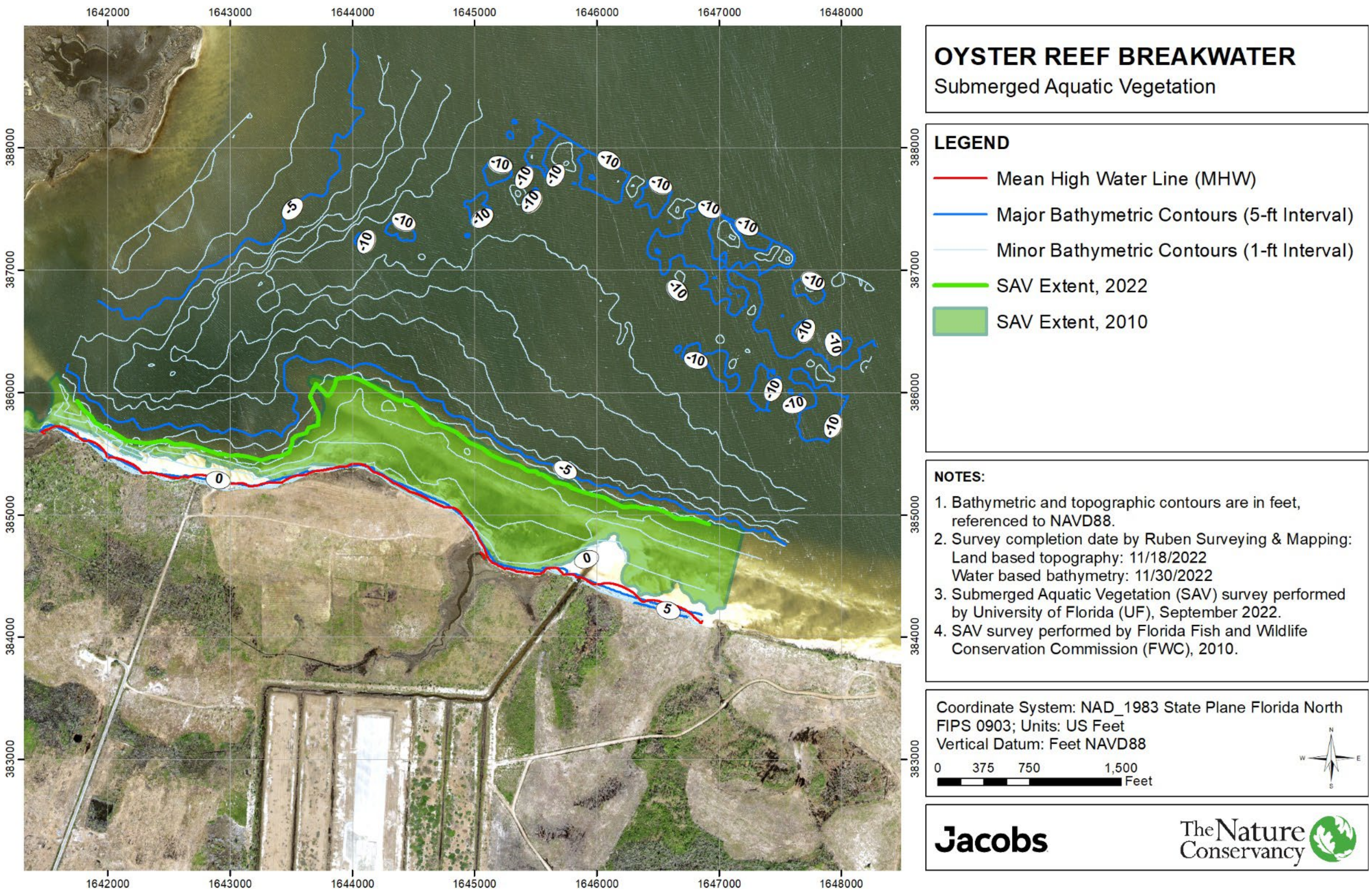
3.2.2 Submerged Aquatic Vegetation

SAV, specifically seagrass, is a principal physical design constraint but also one of the main resources to be protected. Therefore, the import and placement of material are limited to areas beyond the seaward limits of the existing seagrass footprint.

UF performed a survey to record the current extent of SAV at the project site during the peak growing season (from June 1 to September 30). The extent of the seagrass at the Oyster Reef Breakwater site during the 2022 survey is shown on **Figure 3-4** and compared with its extent based on a mapping of seagrass habitat in Florida documented by the Florida Fish and Wildlife Conservation Commission (FWC) (2022). The data suggest that the seagrass is stable, with little change in the extent of the seagrass between 2010 and 2022.

Figure 3-4. Oyster Reef Breakwater - SAV Extent Based on UF Survey and FWC Database Extent

UF survey taken September 2022 and FWC database extent dated 2010.

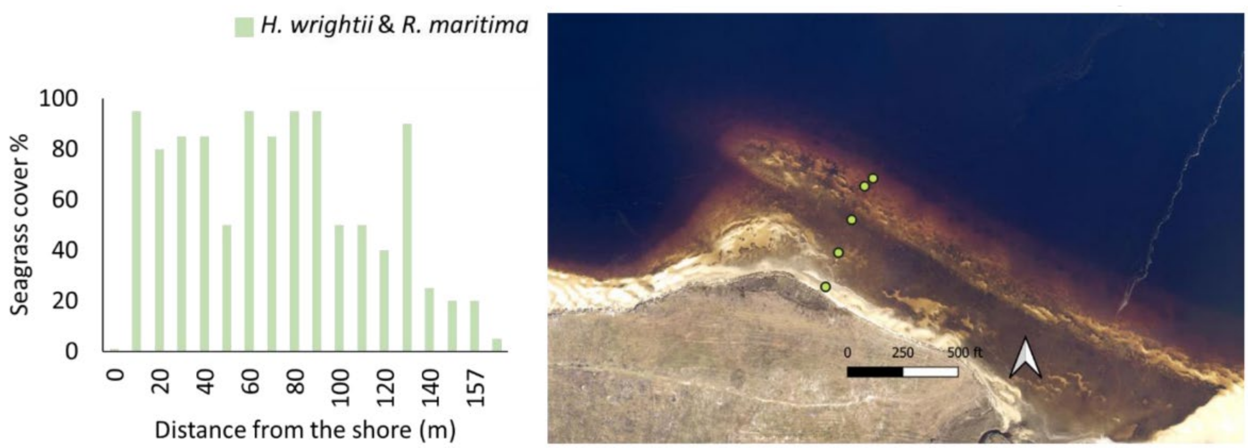


During the survey, UF also recorded the various existing seagrass types and their percent cover along one transects at the Oyster Reef Breakwater project site. The location of the transect is illustrated on the right side of **Figure 3-5.** On the left side of **Figure 3-5**, the percent cover is shown over the distance from the shore.

In the ecological surveys, UF characterized the seagrass as follows:

> *"At the OBR, SAV percent coverage was measured along one transect, 167m long, lain perpendicular to the shoreline (Fig. 3-5). SAV cover was dominated by a mix of H. wrightii and R. maritima, with overall SAV percent cover ranging from 20 to 90%. T. testudinum was observed in the meadow but was not present along the surveyed transect. The water in this location was the most turbid and with more tannins. Macroalgae cover was 0%. Overall, other organisms such as sponges were not found but a few oysters were found attached to woody debris. The epiphyte load was moderate to heavy, mainly composed by filamentous brown algae and Bittium spp. (small snails). Average SAV shoot length was ~ 20 cm. (UF, 2022a).*

Figure 3-5. Oyster Reef Breakwater- Seagrass Percent Cover Along the Survey Transects



Source: UF 2022b

3.3 Ecological Conditions

There are several ecological conditions that can affect the suitability of oyster growth promotion. Data from January 2013 to January 2023, obtained from the Florida Department of Environmental Protection DearSpa Portal (near station IDs: 12SEAS959, 12SEAS964), were inspected to derive the following for the Oyster Reef Breakwater site location:

- Salinity: Average monthly values from 8 to 30 parts per thousand, which is typical of a brackish water environment
- Dissolved Oxygen (DO): Average monthly values from 2 to 15 milligrams per liter
- Temperature: Average monthly values from 10 degrees Celsius (°C) to 30 °C

3.4 Cultural Resources 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 historic context to 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 stated 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 geotechnical investigation aimed to provide information to the design team for the stability of the structure and to refine the preliminary design (**Appendix B,** LMJ 2023).

The borings at the Oyster Breakwater Reef project site were conducted between May 18 and May 19, 2023. The locations of the borings at the Oyster Reef Breakwater site (#2) are highlighted on **Figure 3-6**. Borings B-4 through B-7 are located within the project extent of the Oyster Reef Breakwater.

For the Oyster Reef Breakwater, the borings generally showed gray, tan, and brown sand soils to roughly 2 to 4 feet and varied erratically thereafter with mostly gray and brown silty and slightly silty sand soils with occasional clayey sand layers/pockets to the bottom of the borings at roughly 9.5 to 11.5 feet below mudline at the time of drilling. Boring B-7 also encountered layers of clay with various amounts of sand at roughly 8.5 to 11.5 feet below mudline. The soils in these borings were generally loose to roughly 2 to 4 feet and mostly very loose and very soft with occasional loose areas to the bottom of the borings at roughly 9.5 to 11.5 feet below mudline. Mudline at these locations was roughly 4 to 5.5 feet below the surface of the water at the time of drilling (refer to Geotechnical Data Report in Appendix B).

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

Figure 3-6. Boring Locations of Geotechnical Investigation

Source: LMJ 2023

3.6 Metocean Conditions

Hydrodynamic conditions at the site are summarized based on data and modeling results presented in the *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design Report* (Jacobs 2023a). Parameters of interest for the Oyster Reef Breakwater project include:

- Water levels
- Currents
- Waves

Water levels address the existing tidal variations, potential extreme events due to storm surges, and the 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 Sections 3.6.2 and 3.6.3 for current and wave conditions, more detailed information is documented in the 60% Design Modeling report (Jacobs 2023a).

3.6.1 Water Levels

The following subsections 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, shown on **Figure 3-7** and listed in **Table 3-1**. Tidal datums are based on the 1983 to 2001 tidal epoch and relative to the NAVD 88. The respective levels relative to NAVD 88 are considered to be relevant to the time period during which they were determined.

Figure 3-7. Location of NOAA Tide Station

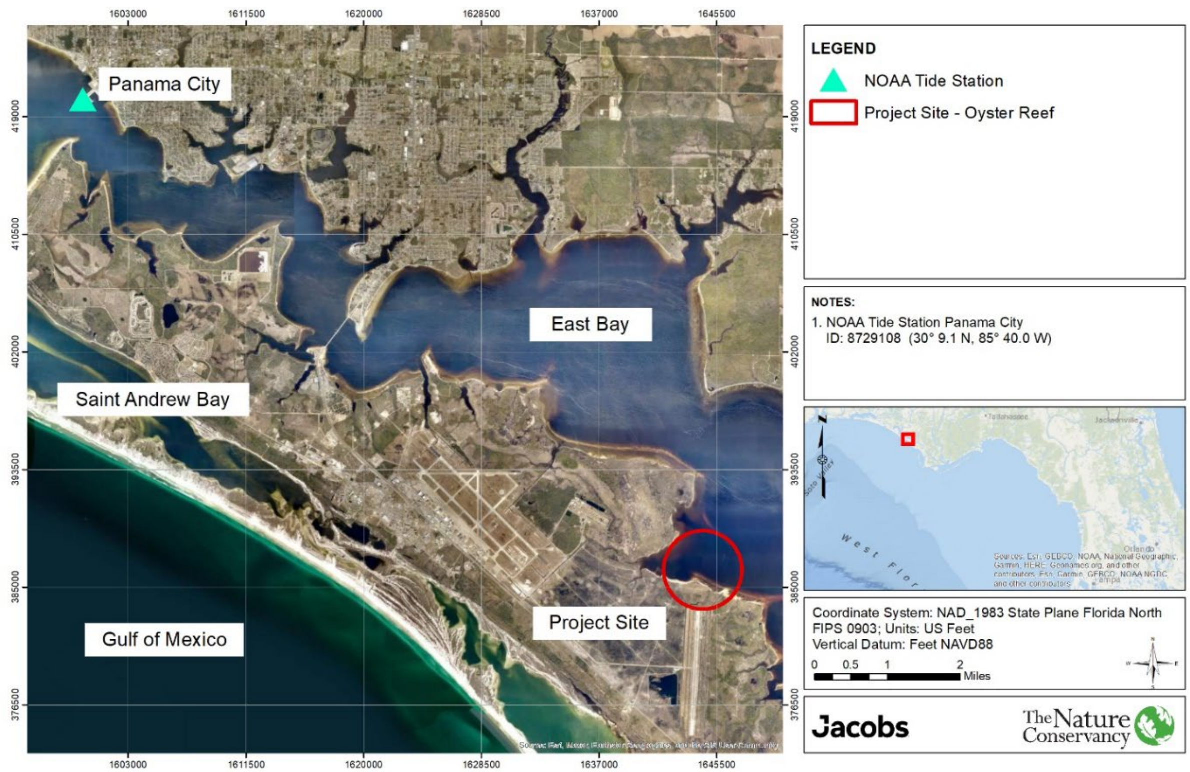


Table 3-1. Panama City Tidal Datums Based on the Tidal Epoch of 1983 to 2001 (Station ID 8729108)

Tidal Datum	Elevation (feet NAVD 88)
Mean Higher High Water	0.78
Mean High Water	0.74
Mean Sea Level	0.11
Mean Low Water	-0.51
MLLW	-0.56

Source: NOAA 2023b

3.6.1.2 Extreme Water Levels

Published EWLs from the *South Atlantic Coastal Study* (SACS) (USACE 2022a) were adopted to design the Oyster Reef Breakwater project. Details can be found in the Modeling Report (Jacobs 2022). In addition, EWLs were extracted at the project site of the oyster reef breakwater for the return periods (RPs) 10-, 25-, and 100-year. The EWL values and corresponding wave parameters are listed in **Table 3-2**.

Table 3-2. Modeling Results from the SACS Extracted at the Oyster Reef Breakwater Project Site

RP (year)	SACS		
	EWL (feet NAVD 88)	Hm0 (feet)	T_p (s)
10	4.27	1.64	2.9
25	5.25	1.97	2.9
100	6.89	2.62	3.1

Hm0 = significant wave height

s = second(s)

Tp = peak period

3.6.1.3 Sea Level Rise

Long-term SLR predictions based on U.S. Army Corps of Engineers' (USACE's) Sea Level Change Calculator (USACE 2022b) for the scenarios from NOAA et al. (2017) are illustrated on **Figure 3-8**. While several scenarios are depicted on **Figure 3-8**, 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 center 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:

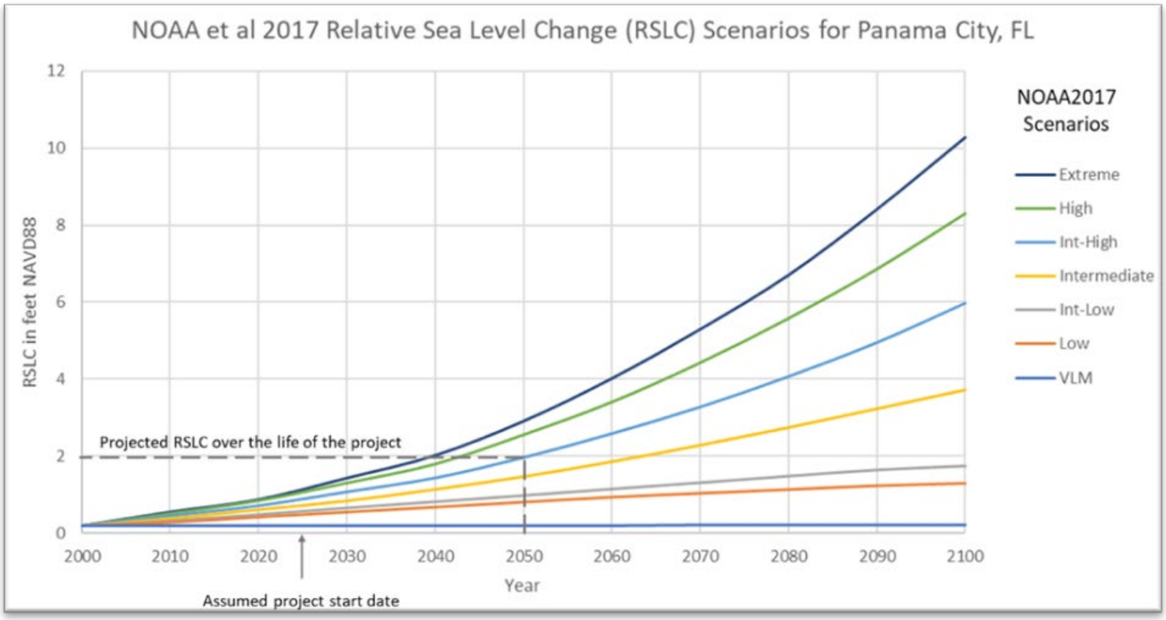
- 2018 – the year of SACS modeling
- 2025 – the year of assumed project start
- 2050 – the year for 25-year project life of the Oyster Reef Breakwater project

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

Year	Sea Level Change, feet
2018	0.66
2025	0.88
2050	1.96

Source: NOAA 2017

Figure 3-8. Relative Sea Level Change Scenarios for Panama City, FL



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 were used for this study:

- A SLR of 0.85 foot was applied to tidal datums (which are based on the 1983 to 2001 tidal epoch) to tidal datums at the start of the project (2025).
- A SLR of 1.96 feet was applied to tidal datums to estimate future tidal datums at the end of the 25-year project life (2050).
- 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 to 0.66 foot = 0.22 foot).
- EWLs at the end of the project were adjusted based on the difference in SLR at the end of the project (2050) and the SLR at the time of the SACS analysis (that is, 1.96 feet to 0.66 foot = 1.3 feet).

For the purposes of design, SLR that has occurred between 1992 and the present day was considered in the design of the initial Oyster Reef Breakwater crest elevation and added to the mean higher high water shown in the previous **Table 3-1**, **Section 3.6.1.1**. However, during the 60% design stage, the crest elevation criteria of the structure was limited to MLLW to fulfil the requirements set by BASH. The design water elevation considered for the stability analysis and the crest elevation are summarized in **Table 3-4.**

Table 3-4. Design Water Levels

Year	MLLW Tidal Epoch of 1983–2001 (feet NAVD 88)	Total Water Level (SACS EWL for 1 in 25-year RP + SLR)
2025	-0.56 (Design Crest Elevation)	5.47
2050	0.78	6.55 (Stability Analysis)

3.6.2 Currents

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

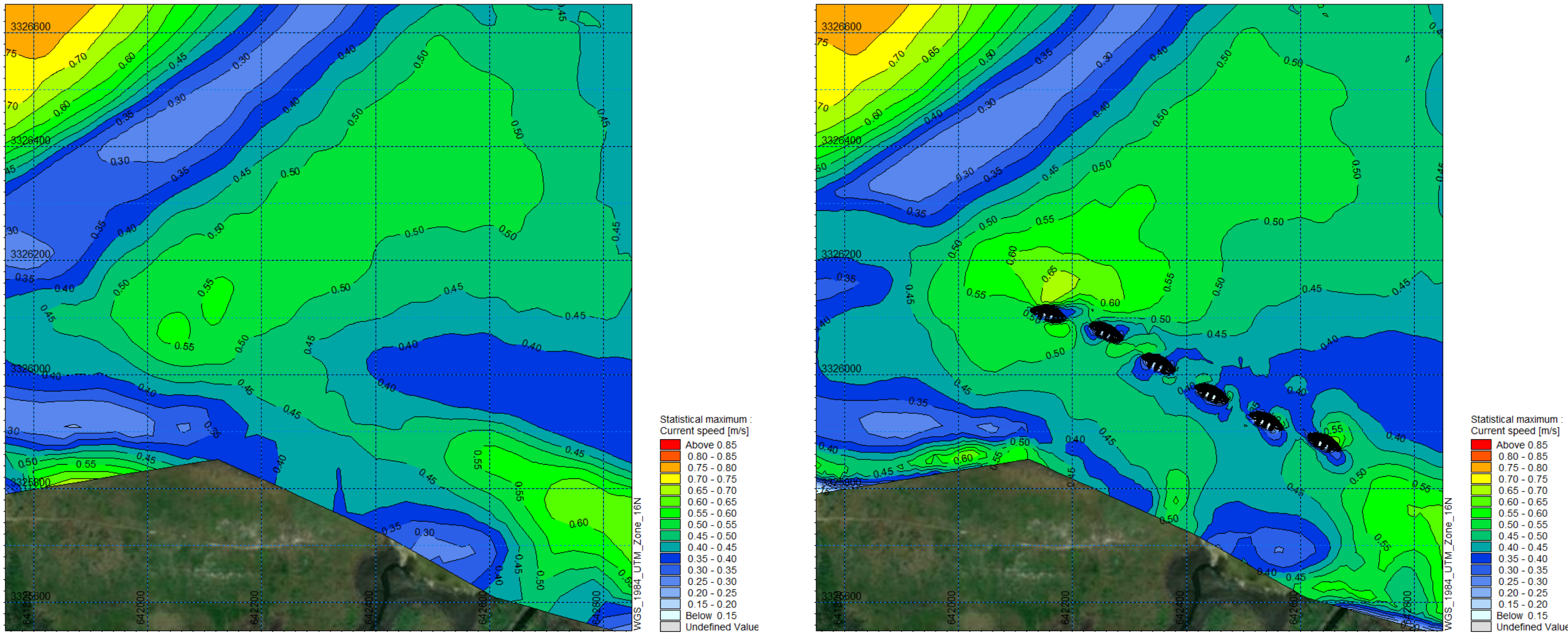
After incorporating the preferred layout, extreme and operational conditions were analyzed and are summarized in the report *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design – Layout Optioneering and Sediment Transport Modeling* (Jacobs 2024). The modeling included scenarios under present conditions (2025), without SLR, and scenarios under future conditions (2050), including SLR.

For each of the modeled cases, the peak current speeds were based on an incoming storm tide. As the storm surge receded, the flow reversed as water drained from the bay, and circulation patterns changed with lower current velocities along the eastern end of the site due to sheltering by the spit east of Fred Bayou and higher currents along the western portion as flows filled in the eddy that was present during the incoming storm tide.

The modeling results under future conditions (2050) are shown in **Figure 3-9**, 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 current patterns.

For the design, a peak current of 3.8 feet per second (1.17 meters per second) was conservatively considered for the scour and stability analysis of Oyster Reef Breakwater. This value represented the maximum current speed near the proposed structures **(Figure 3-9).**

Figure 3-9. Maximum Current Speeds for the 25-year Extreme Event under Future (2050) Conditions without and with Structures



Future 2050 conditions without structures

Future 2050 conditions with structures

3.6.3 Waves

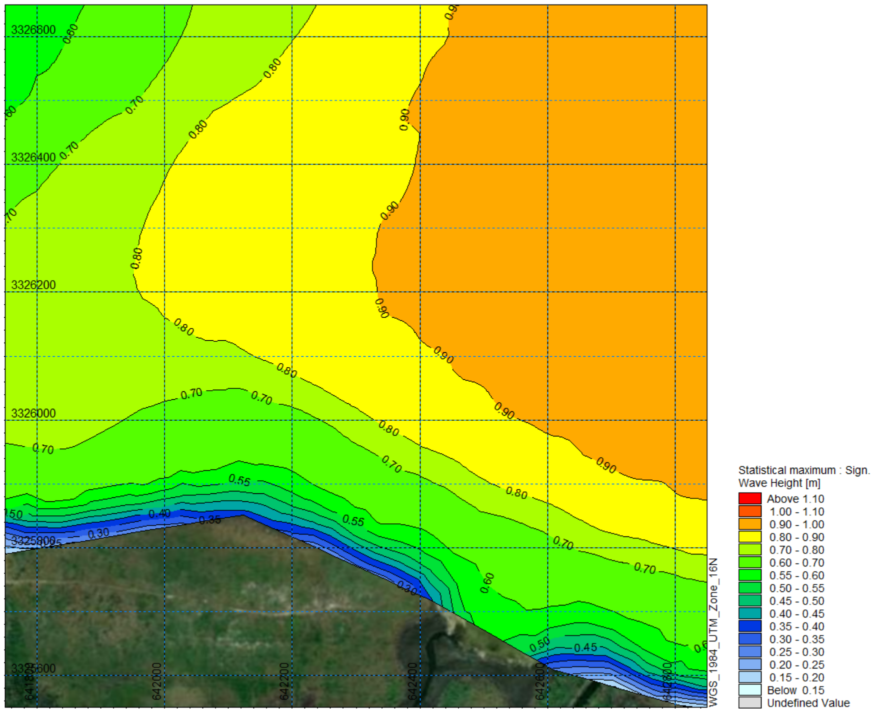
The wave transformation model developed during the 30% modeling efforts was calibrated with field data during the 60% modeling stage (Jacobs 2022). The results of the 60% wave transformation modeling are documented in *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design- Calibrated Models*, which provide insights into the wave conditions for the BOD for the Oyster Reef Breakwater site (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 (2050), including SLR.

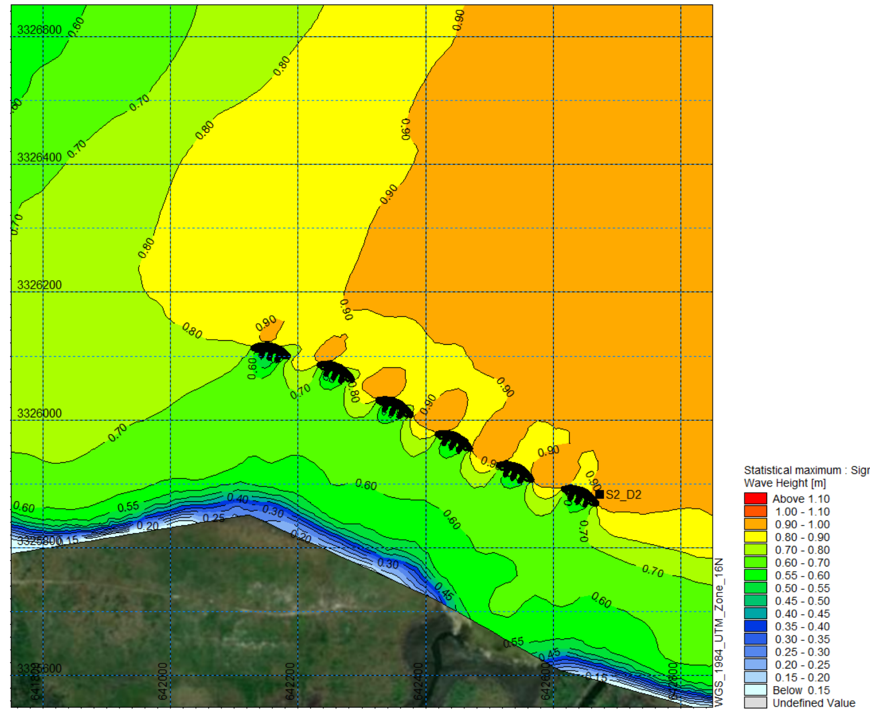
The modeling results under future conditions (2050) are shown in **Figure 3-10**, where the figure on the left represents the conditions without structures in place and the figure on the right the conditions with the preferred structural layout in place to investigate the effects of the structure on wave patterns.

For the design, a significant wave height of 3.2 feet (0.96 meter) with a peak wave period of 3.0 seconds is considered for the design of Oyster Reef Breakwater. The value represented the maximum wave height near the structures **(Figure 3-10)**.

Figure 3-10. Maximum Significant Wave Height for the 25-year Extreme Event under Future (2050) Conditions without and with Structures



Future 2050 conditions without structures



Future 2050 conditions with structures

3.6.4 Sediment Transport

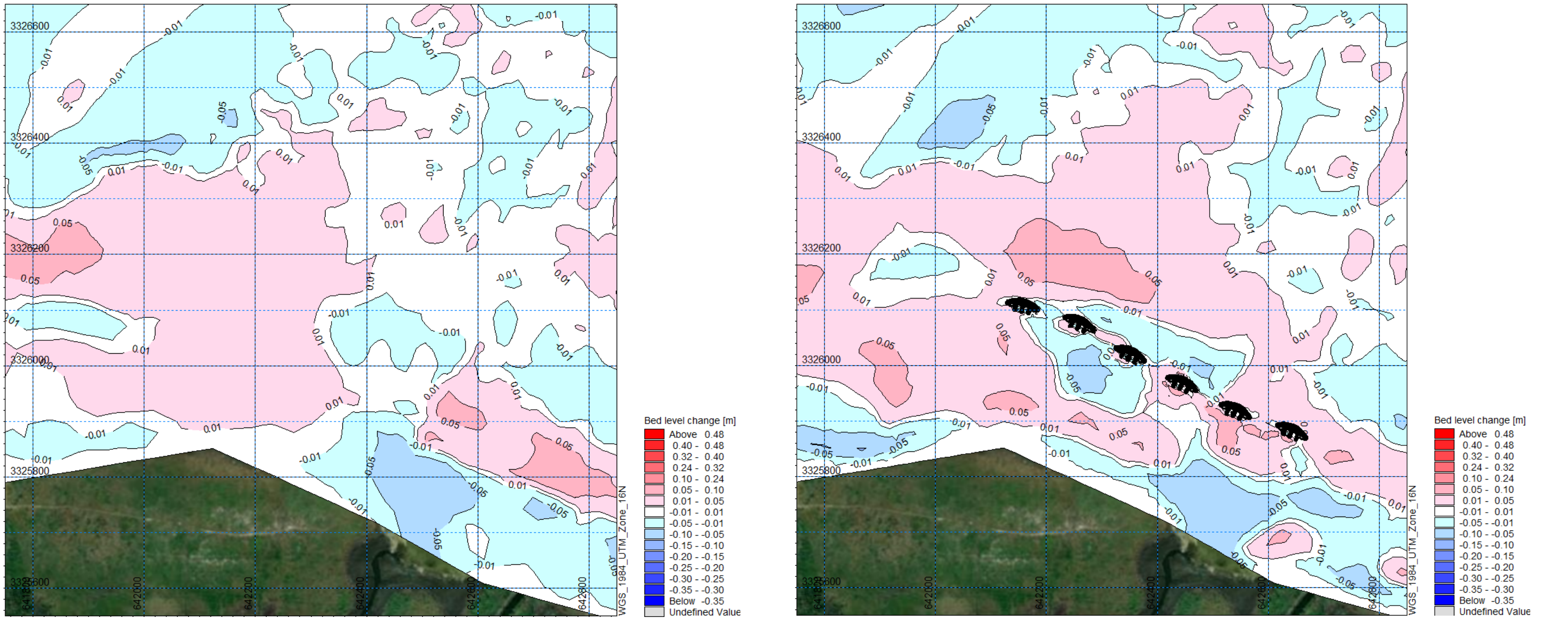
An area-wide sediment transport model was developed, which uses the results of the hydraulic and wave transformation modeling to assess the annual sedimentation rates near the project. Sediment data obtained by the geotechnical investigation were implemented in the model, and the model was calibrated by comparing with historical sedimentation. The modeling is documented in the report *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 3-11**. The structure layout was incorporated to model the impact of the structures to the sediment transport; the results from the modeling, including the structures, are shown on the right on **Figure 3-11**.

When comparing these two results, the overall changes due to the structures are minimal. There is some sediment movement in discrete zones around the structure line, with sedimentation and erosion. However, the same annual rates of +/- 0.05 meter is maintained. A difference plot between the preferred layout in place and without structures is presented in **Figure 3-12**.

Figure 3-11. Modeled Distribution of Annual Sedimentation Rate without and with Structures in place

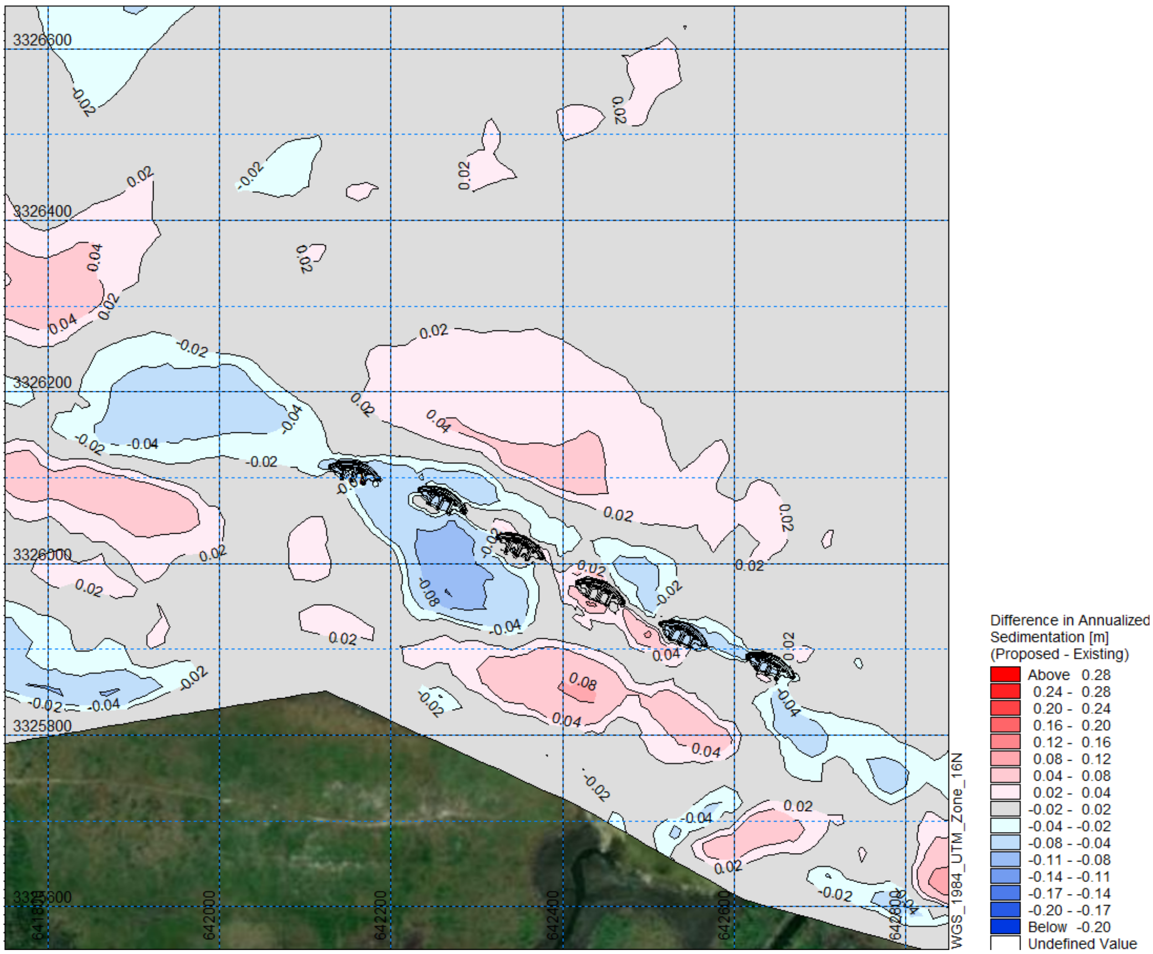


Without structures *With structures*

Note: Red color denotes sedimentation; blue denotes erosion.

Figure 3-12. 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

Design criteria and performance criteria for the Oyster Reef Breakwater project site were defined to achieve wave attenuation and the ability to foster oyster growth and habitat creation at the project site, using design solutions that are adaptive to SLR.

Breakwaters can be divided into two types depending on their function and position relative to the shoreline. Beach/coastal breakwaters are placed within the surf zone and are generally used for shoreline management by providing shelter from waves and modifying the littoral transport behind and adjacent to the structures. Offshore breakwaters are located relatively far outside the surf zone and are typically used to attenuate wave energy for various reasons (that is, to protect a ship wharf or reduce wave-induced flooding).

For this specific project site, the following constraints were identified:

- Work is limited to in-water areas. Structures are not to be located in the upland areas above the mean high-water line.
- In-water construction shall be to be located seaward of the seagrass beds.
- BASH group raised concerns that emerged structure segments would attract birds and therefore endanger the aircraft traffic at the base. Only structures submerged at MLLW are to be considered.

During the 60% design stage, the structure's crest elevation criteria were limited to current MLLW to fulfil the requirements set by BASH.

4.1 Design Codes, Standards, and References

The following codes and references apply to the design of the Oyster Reef Breakwater 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).
  - Preliminary 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 25 years, from 2025, has been selected for the Oyster Reef Breakwater project.

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 25-year RP storm has an annual exceedance probability (the probability of being exceeded in any given year) of 4% and will occur, on average, once every 25 years. However, a 25-year event could happen more than once over a 25-year span or not happen at all during that period. The probability that a 25-year event would be exceeded over a 25-year span is approximately 64%.

Typically, reefs and 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 oyster reefs are stable in place and continue providing protection from waves while also providing suitable oyster habitat.

4.3 Oyster Habitat Suitability

Several physical characteristics that can affect suitability of oyster growth promotion were considered during design. The factors that can enhance habitat creation and resiliency for Oyster Reef Breakwaters are summarized in **Table 4-1.**

Table 4-1. Oyster Reef Breakwater Resiliency Design Guide

<table>
<tr><th>Parameter</th><th>Concerns</th><th>Effect on Oysters</th><th>Solutions</th></tr>
<tr><td>Salinity</td><td>▪ Droughts reduce freshwater input to bays and estuaries causing a spike in salinity.
▪ SLR creates new hydraulic connections with higher salinity in the Gulf of Mexico.</td><td>Dermo infection and mortality rates increase with salinities above 12 to 15 parts per thousand</td><td rowspan="2">▪ Selected site with high circulation to reduce susceptibility to salinity fluctuations.</td></tr>
<tr><td>Temperature</td><td>▪ Increasing annual temperatures.
▪ Runoff from precipitation events causing localized water temperature spike.</td><td>Dermo infection and mortality rates increase with temperatures above 20°C and rapidly intensify above 25°C</td></tr>
<tr><td>DO</td><td>▪ Higher water temperatures hold less oxygen.
▪ Nutrient-rich runoff can cause algal blooms, leading to excess oxygen consumption during decomposition of the phytoplankton.</td><td>▪ Oxygen is necessary for oyster survival
▪ Dermo infection and mortality rates increase in low oxygen waters</td><td>▪ Lowest oxygen rates occur near bottom of water column; reef is designed to maintain healthy populations above hypoxic zone.</td></tr>
<tr><td>Depth</td><td>▪ SLR shifts the tidal range upwards.</td><td>▪ Oyster growth rates decrease when oysters remain submerged</td><td>▪ Intertidal oysters should naturally maintain pace with increasing sea level up to a rate of 11 centimeters per year.</td></tr>
<tr><td>Harvesting</td><td>▪ Harvesting rates exceed oyster colonization and growth rates.</td><td>▪ Depletion of self-sustaining oyster population</td><td>▪ Consider prohibiting[1] oyster harvesting.</td></tr>
</table>

[1] The Oyster Reef Breakwater pilot project site may be designated as a no-harvest zone in Florida law after the project is completed.

Parameter	Concerns	Effect on Oysters	Solutions
Sedimentation	▪ Runoff from precipitation events. ▪ Coastal storms causing erosion and suspension of seabed. ▪ Harvesting practices suspending sediment.	▪ Runoff from precipitation events ▪ Coastal storms causing erosion and suspension of seabed ▪ Harvesting practices suspending sediment	▪ Reef crest at MLLW due to BASH requirement, refer to Section 4.4.3 - Stakeholder Engagement. Slope and material size selection to prevent sedimentation on the structure. ▪ Arrangement of reef rows perpendicular to predominant flow directions are less prone to sedimentation.
Predation	▪ Oysters may be quite sensitive to some types of predations, such as crabs, snails and starfish.	▪ Reduction of oyster population size ▪ Reduction of reproduction success rates	▪ Predation can be limited for example by introducing natural predators of oyster predators, such as certain species of fish or through selective and approved harvesting. ▪ Material size and associated interstitial spacing.
Ocean Acidification	▪ Increase in atmospheric carbon concentrations largely absorbed by the ocean (approximately 30%). ▪ Decreasing pH (increasing acidification) in coastal waters.	▪ Reduction in the availability of carbonate ions used by calcifying and shell-building organisms ▪ Adversely impacts survival, growth, and physiology	▪ Reefs near seagrass beds should buffer pH of surrounding water.

Source: Modified from Texas General Land Office 2023

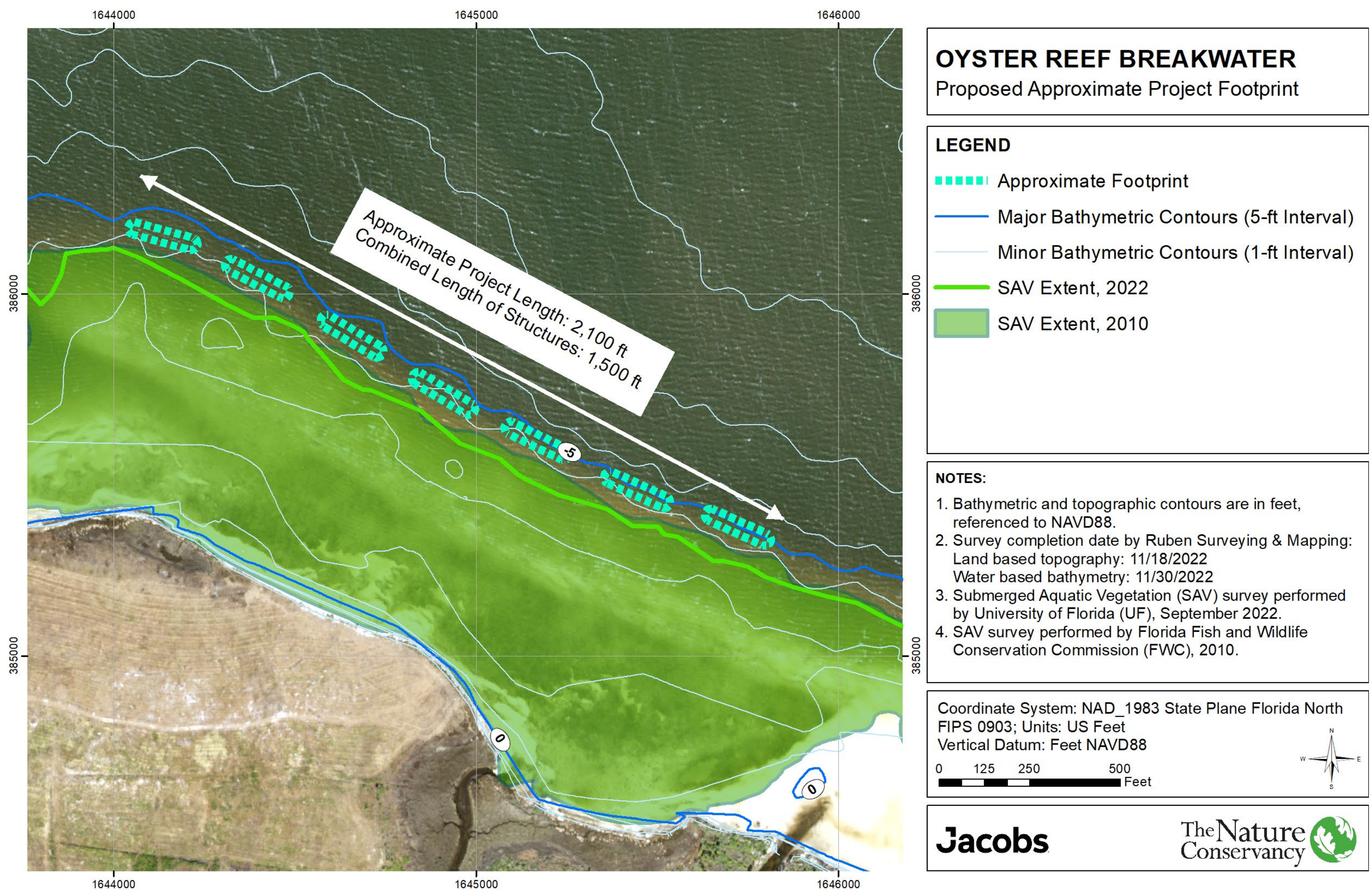
4.4 Preliminary Alternative Option Design

The physical characteristics of potential oyster reef breakwater design alternatives, including the project footprint, cross-section, and components, are discussed in the following subsections.

4.4.1 Preliminary Layout

The preliminary footprint of the Oyster Reef Breakwater project is shown on **Figure 4-1**. The reef footprints were intended to cover a total length of approximately 1,500 feet. The total length of protected shoreline was larger than 1,500 feet (including gaps between each reef). Structures were assumed to be constructed no closer than 25 feet from the seaward extent of seagrass based on mapping performed by UF (2022) to prevent negative impacts to the seagrass during construction. Minimum reef spacing (gaps) was set to be 5 times the wavelength at the reef structure to prevent the structures working as one long reef and creating a potential flushing effect. Minimum gaps for this site were assumed to be 120 feet. Each of the seven segmented reefs was approximately 200 feet long. The orientation of the reefs was selected based on the best practice to construct the reefs with a shore-parallel orientation.

Figure 4-1. Preliminary Layout



4.4.2 30% Design Alternatives

Based on the initial feasibility material analysis, three design alternative options were considered for the Oyster Reef Breakwater project (**Table 4-2),** (refer to **Appendix C** for more details).

Table 4-2. Design Alternatives, Cross-section Parameters

Option No.	Structure Type (-)	Shoreline/ Resilience Benefits	Adaptability	Constructability	Resources Impacts/ Permitting	Cost	Figure No. (-)
1 (Selected)	Quarrystone	Mitigate wave energy and potential future impacts on the Tyndall AFB area. Enhance and protect natural coastal habitat by stabilizing sediments. Support marine species growth and adaptation to SLR.	High	Routine	Medium to larger footprint	Lower	Figure 4-2
2	Precast units		Medium	Routine	Medium to larger footprint	Medium	Figure 4-3
3	Reefmaker EcoDisk		Medium	Routine, additional geotechnical investigations are required	Smaller footprint; noise from pile driving	Higher	Figure 4-4

Due to their costs and ease of construction, the top two rated materials were quarry stone and precast units. Quarrystone was selected to be the overall highest-rated material due to its high adaptability for further adaptation in the future. Quarrystone is also the most adaptive solution as suitable material should be available in the future, whereas supplier-designed solutions such as Eco-disks may no longer be available. Bedding stone and a geotextile were not included in the material alternatives assessment (**Appendix C,** Jacobs 2023b) as they have a supporting function only.

The preferred option advanced during the 60% design phase was a modified version of the preliminary design alternative Option 1. This option was selected based on the stakeholder engagement and design optimization, which is discussed in the following sections.

Figure 4-2. Loose Material – Reef – Limestone

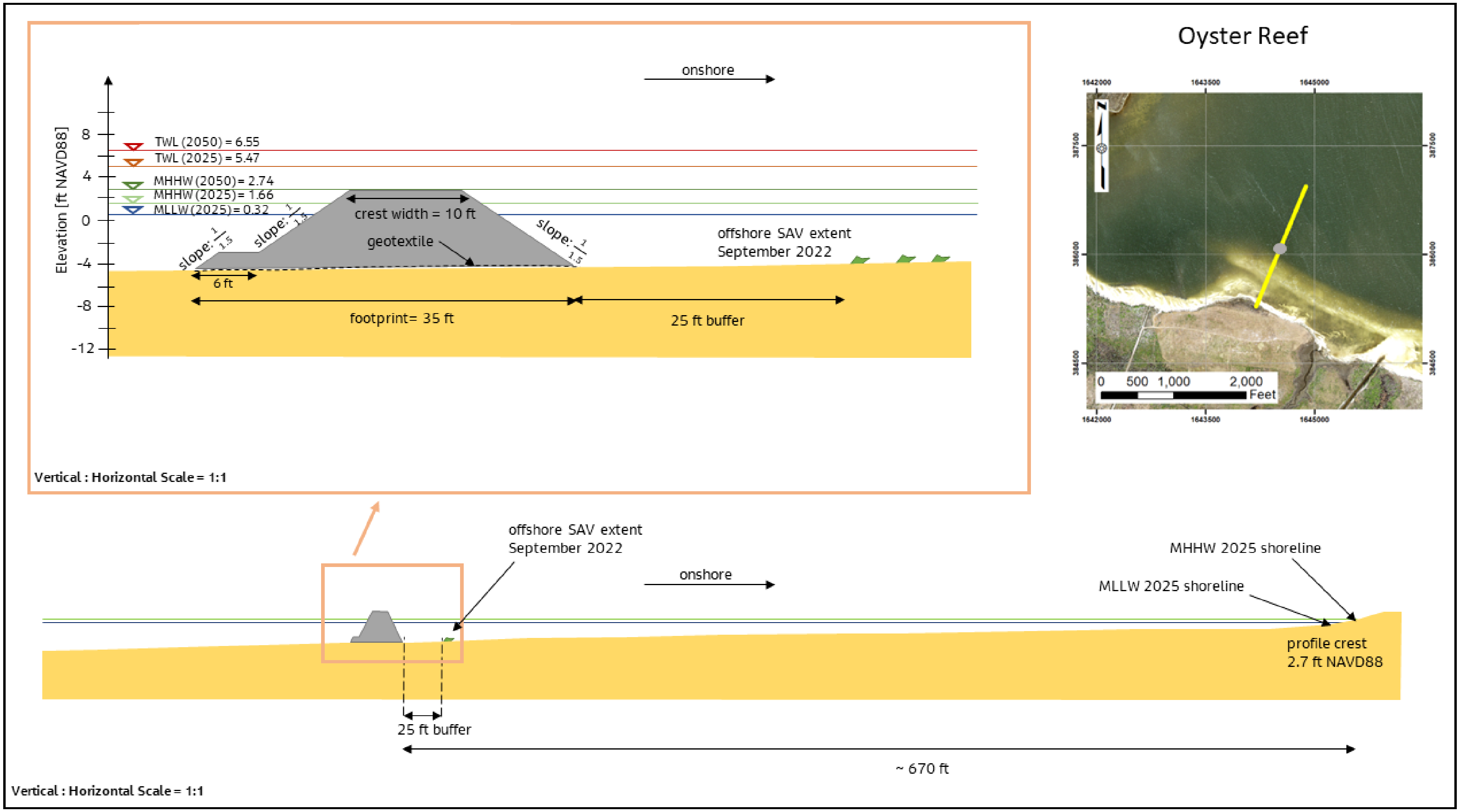


Figure 4-3. Precast Units – Reef

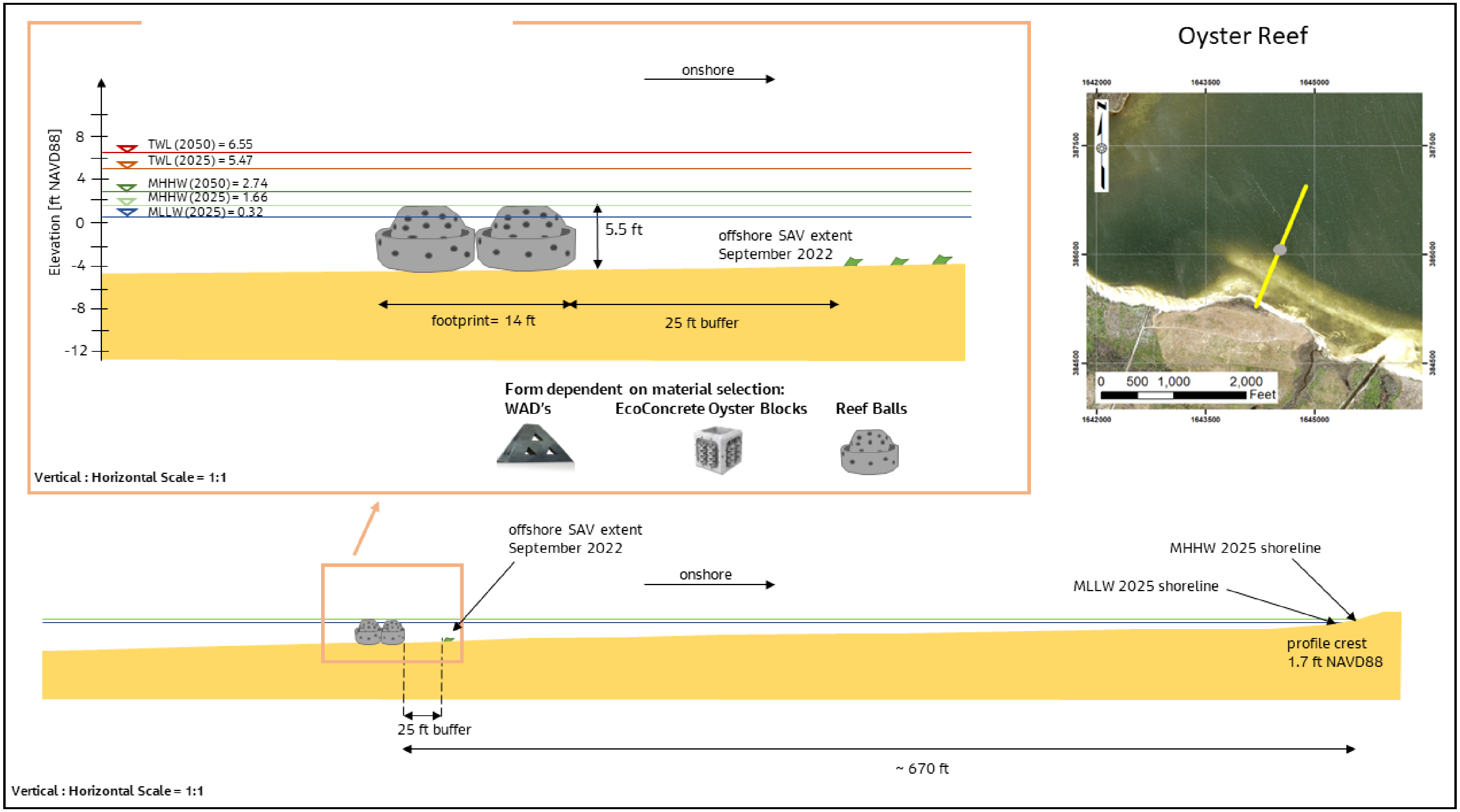
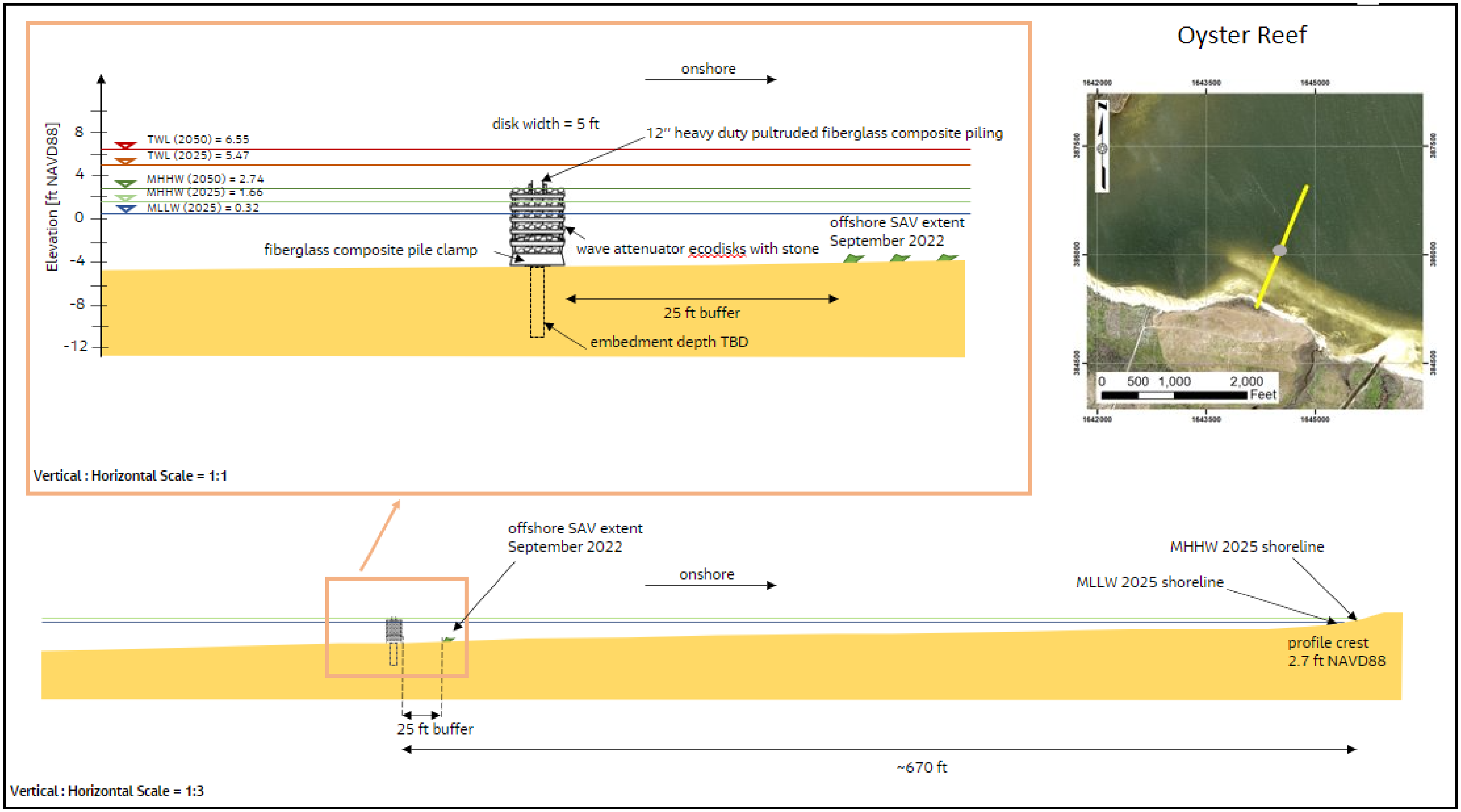


Figure 4-4. Precast Units – A Pile-supported Reef



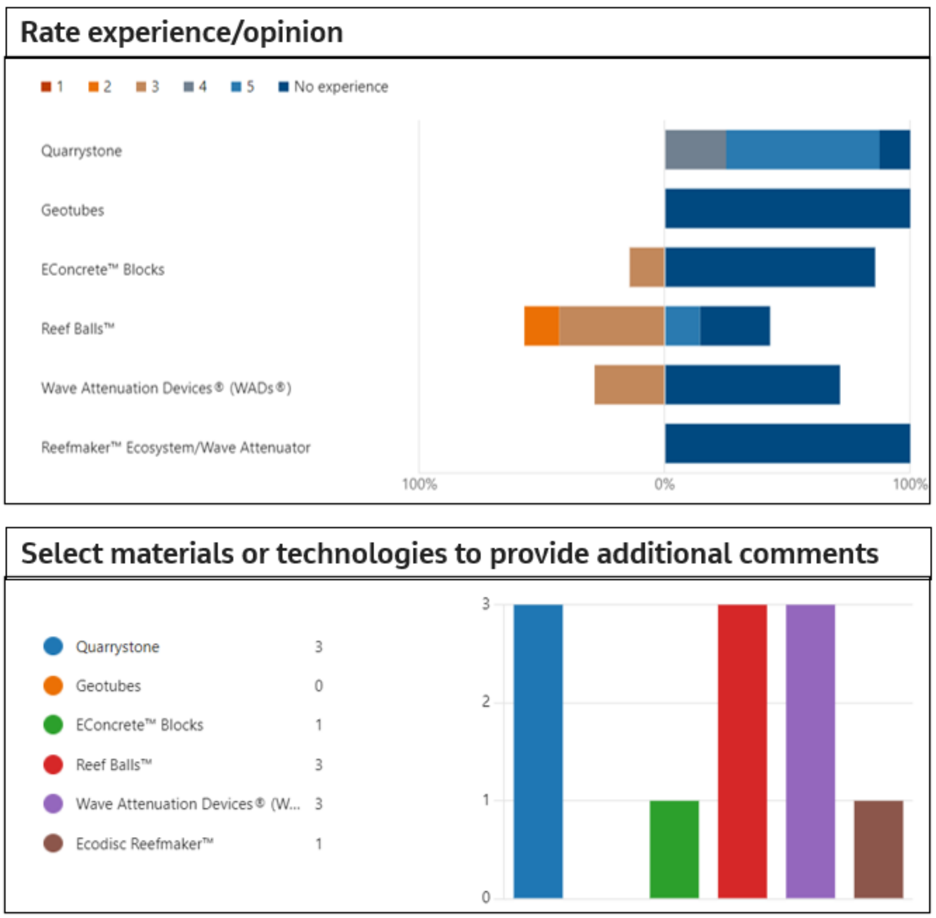
4.4.3 Stakeholder Engagement between 30% and 60% Design Phases

A series of stakeholder engagement events were held, including:

- April 20, 2023, Preliminary Design Workshop
- May 4, 2023, Preliminary Design Workshop – T-CRAG
- July 6, 2023, BASH Meeting Number 1
- August 17, 2023, BASH Meeting Number 2

The Preliminary Design Alternative Options were presented during a Preliminary Design Workshop held on April 20, 2023. The meeting participants were asked to respond to 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, a summary of wave attenuation, exposed area, and duration of exposure of the in total nine alternatives for the three pilot sites were presented during a follow-up meeting with BASH. While the preference from a coastal resilience and shoreline protection viewpoint is for other options that offer the highest degree of wave attention regardless of the exposed area or duration of exposure to emergent structures, BASH highlighted their preference for submerged alternatives over emergent structures. They noted that emergent structures present an increased risk of bird attraction that can endanger air traffic. The Oyster Reef Breakwater 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, it was concluded that for the 60% Design Optimization described in **Section 4.5**. Only structures submerged at the 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.

4.5 Design Optimization 60%

Design optimization was undertaken with the purpose of reducing construction costs, maximizing wave attenuation benefits, and providing a substrate for oyster settlement. The original layout presented during the preliminary phase was compared to three alternative layouts, summarized in **Table 4-3**. Layout alternative 2 consisted of 6 reefs instead of 5. The spacing between the individual segments was increased from 100 feet to 150 feet to decrease the number of reef segments from 7 to 6. Layout alternative 3 was further changed by using breakwater sections with a complex geometry. Alternative 4 is similar to alternative 3, except for decreasing the crest width to 5 feet.

Table 4-3. Parameters of the Optimization Design Options

Layout No.	Number of Segments (-)	Segment Length (feet)	Number of Gaps (-)	Gap Length (feet)	Crest Width (feet)	Geometry
1 – Original	7	210	6	100	17	Simple
2	6	210	5	150	5	Simple
3	6	210	5	150	17 (Averaged)	Complex
4 – Selected	6	210	5	150	5	Complex

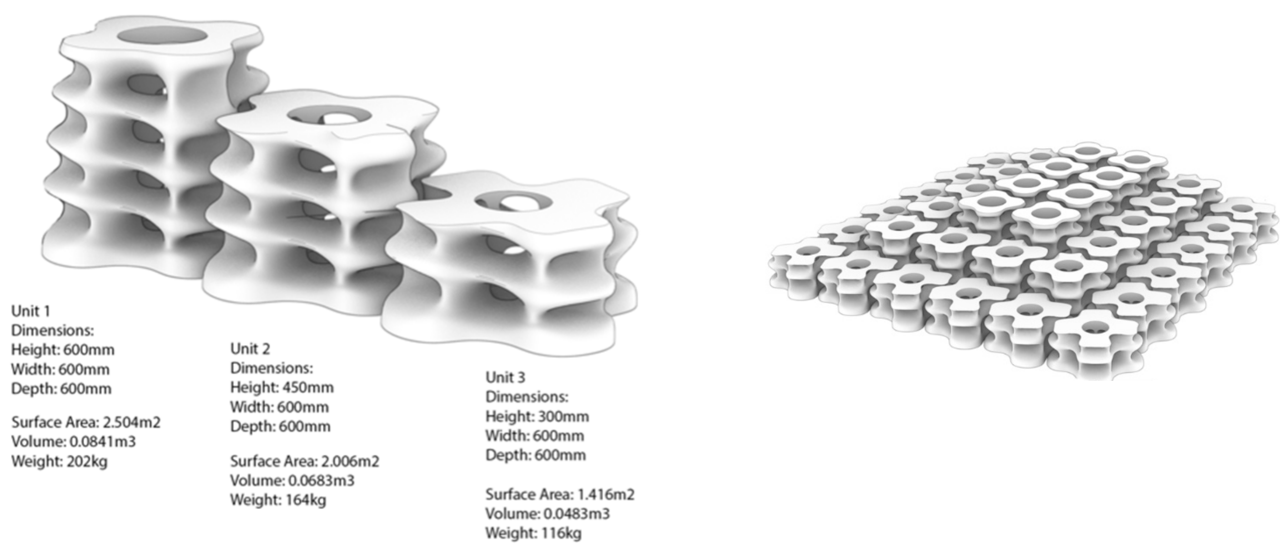
A comprehensive cost-benefit analysis and considerations regarding wave attenuation effectiveness primarily influenced the decision to select layout No. 4 over the others. While all alternatives offered viable solutions for shoreline protection and habitat enhancement, layout 4 was selected as preferred choice due to its lower construction cost and comparable wave attenuation performance.

The original layout and the selected layout were implemented into the calibrated 60% wave transformation model to analyze the difference in wave attenuation and to inform an optimized decision between cost and function. For more details refer to the modeling results presented in the *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design Report* (Jacobs 2023a).

4.5.1.1 Precast Concrete (DARPA) Units

The integration of innovative technologies such as Defense Advanced Research Projects Agency (DARPA) Units. DARPA Units use cutting-edge materials to provide attachment surface for marine organism as well as foster the development of diverse habitats. Their modular design allows to create adjustable configurations, allowing to suit site-specific habitat requirements. Units' shape and height is controlled by filling existing mold, which can be scaled down or up to meet the project specific requirements. Typical dimensions and weights are shown on **Figure 4-7**.

Figure 4-7. DARPA Units



5. Design Layout and Geometry

5.1 Materials

The construction of the oyster reef entails a carefully selected combination of materials to ensure structural integrity, environmental sustainability, and ecosystem enhancement. The current reef 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 reef structure. As a second element—limestone rock with a medium size (Dn50) of 1 foot—was selected because of its durability and natural composition, which is suitable for oyster recruitment and stability under wave and current forces. Limestone rock will form the primary bulk of the reef, providing wave attenuation and substrate for oyster settlement and growth. The third and last element is made of precast concrete units, also referred to as DARPA Units. These units are strategically integrated into the design to promote oyster colonization, offering shelter and protection for marine life.

5.2 Layout

The different elements influencing the modeled layout are described in the following subsections.

5.2.1 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 further 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.

5.2.2 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 210 feet, primarily influenced by the cost-benefit analysis and wave attenuation response during present operational conditions.

5.2.3 Reef Spacing

To prevent the structures working as one long reef with limited flushing effect[2], the minimum reef spacing was selected as 5 times the wavelength at the reef structure. The wave periods are typically very small so the wavelength is short (approximately 24 feet); therefore, the minimum spacing is 120 feet. However, to balance the material costs required, a spacing of 150 feet 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.

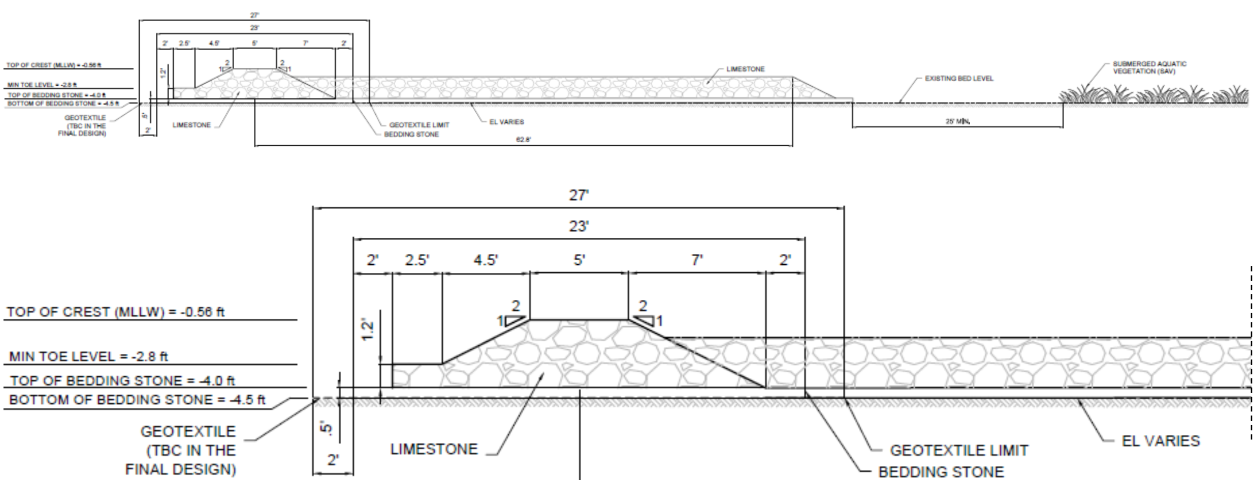
5.2.4 Cross-section and Plan View

The subgrade of the reef, according to the geotechnical investigation, consists primary of loose sandy material that is expected to undergo some minor settlement upon installation. While significant settlement is not expected, placement of a granular layer will evenly distribute the load and counteract potential differential settlement. A layer of bedding stone and geotextile 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.

Due to the ground conditions, a toe berm is required on all seaward side faces of the reef and roundheads to ensure the stability of the rock. This detail allows the rock to counteract scour at the toe without reducing the crest level or width.

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

Figure 5-1. Typical Oyster Reef Breakwater Cross Section A-A



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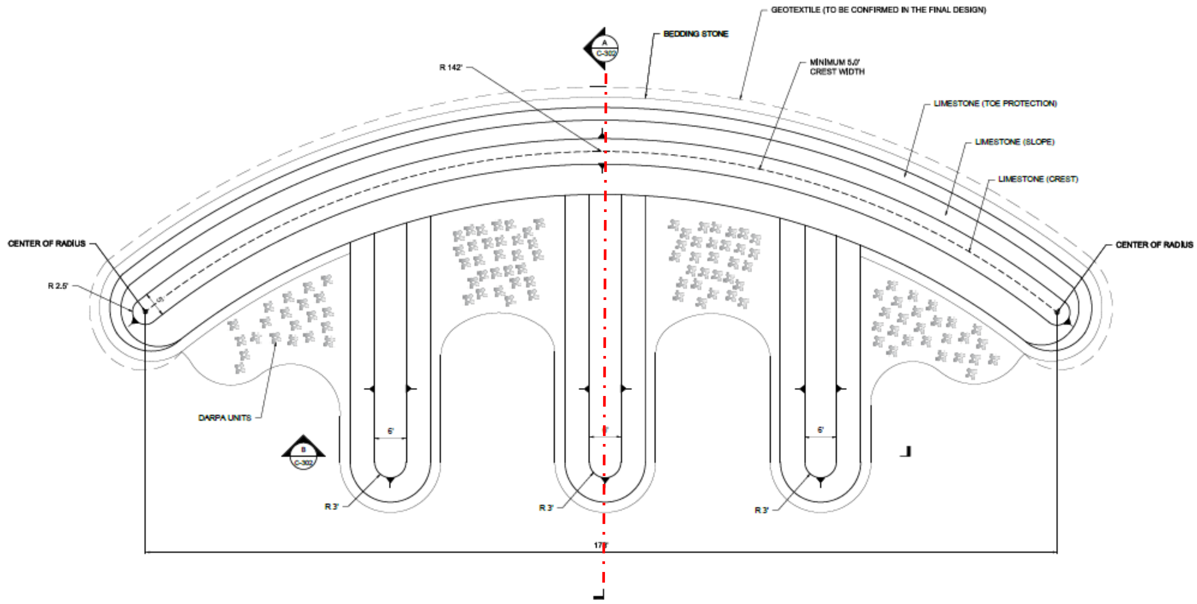
2 Design that enhances water circulation and promotes flushing of stagnant areas to mitigate issues such as hypoxia, nutrients buildup, and pollutant accumulation.

Figure 5-2. Typical Oyster Reef Breakwater Plan View



6. Constructability

The constructability of the Oyster Reef Breakwater is dependent on the depth of water, which will dictate the type of equipment capable of constructing the reefs. 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 -4.5-foot contour, the minimum depth of water anticipated is approximately 4 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 feet or more depending on the tide.

Construction Assumptions:

- Anticipated construction timeline: 2026 through 2027 to construct all six breakwaters.
- Assumed five rock barges (50 feet by 200 feet) for staging, 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 project site from Gulf and East Bay. Refer to drawings package (**Appendix E**) for more information.
- Anticipated working hours daytime and nighttime depending on tides.

Figure 6-1. Pensacola East Bay Construction

Photo courtesy of TNC.

Figure 6-2 illustrates the type of equipment considered possible for construction of the reefs.

Figure 6-2. Potential Construction Equipment

Construction schedule has not been developed yet. Current assumption is that construction will occur 5 days per week, with 10- to 12-hour work days. The ability to bring in 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 timeframe and equipment to be used.

7. Adaptive Management

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

- Areal dimensions
- Height
- Rugosity
- Oyster density and shell height
- Density of sessile invertebrates
- Percent cover of substrate
- Water quality
- Shoreline position
- Topo-bathymetric profile
- Marsh areal extent
- Percent cover of emergent marsh vegetation
- 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 Oyster Reef Breakwater, few 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 Oyster Reef Breakwater 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 Oyster Reef Breakwater project will require coordination with Tyndall AFB as well as relevant regulatory permitting agencies.

8. Opinion of Construction Costs

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 estimate cost. Cost includes escalation.

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

Table 8-1. Summary Cost Estimate

Low Range (rounded) -15%	Estimate Total (rounded)	High Range (rounded) +20%
$3,479,530	$4,093,565	$4,912,278

Figure 8-1. Additional Cost Estimate Details

	On Bid Quantities	%
Direct Cost	2,223,296	54.31%
Indirect Cost	373,367	9.12%
Addons	97,550	2.38%
Bond	49,126	1.20%
Pass Through Cost	831,143	20.30%
Direct Markup	444,659	10.86%
Indirect Markup	74,673	1.82%

This estimate was prepared based on the following key assumptions:

- The estimate is based on 60% drawings prepared May 2024
- Crews work 5 to 10 hour per days and 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 there have been significant changes in the commodity markets, this estimate should be updated and reevaluated.

9. Conclusions 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 by BASH regarding the attraction of birds by emergent structures. It was decided to only pursue options further with a crest elevation at MLLW. During the 30% design stage, field data was collected that included waves, currents, cultural resources survey, and geotechnical survey. The field data was used to calibrate the wave, hydrodynamic and sediment transport models and to inform the design. The results from the calibrated modeled were applied during the 60% design. Different layout alternatives were analyzed during the optimization. The optimization included weighing function and cost. Ultimately, a layout with six complex structure segments and DARPA Units was chosen.

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 process that is applicable to this project. It is intended to be the start of the risk management process and should be updated regularly, as follows:

- 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 reefs
- 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
60% Drawings Package

Appendix F
Specifications