Village of North Haven
Comprehensive Shoreline Management Plan
Report

Final
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Prepared by:

RACE COASTAL ENGINEERING

Project No. 2020061

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Executive Summary

As outlined in our Scope of Services, authorized by the Village of North Haven, effective June 11, 2020, **RACE Coastal Engineering (RACE)** has prepared this Comprehensive Shoreline Management Plan Report and Policy Statement summarizing the Phase 1: Shoreline Condition Assessment, Phase 2: Coastal Analysis, and multiple soft and hard stabilization alternatives for the North Haven shoreline.

Phase 1 included review of existing reports prepared by others for the Village as well as visiting the North Haven peninsula to document the existing conditions of the shoreline. Physical details such as the shoreline type, structure type and condition of the shoreline were observed, documented and used to complete Phase 2.

Phase 2 involved conducting a detailed coastal engineering analysis to determine the wave climate surrounding the North Haven peninsula and to predict locations that are susceptible to persistent erosion and storm damage. Findings throughout Phase 1 and Phase 2 were used to provide soft and hard erosion control solution alternatives to the Village of North Haven. A variety of alternatives have been presented along with detailed descriptions of design attributes. "Failure triggers" of soft structural solutions have also been presented to assist the Village in determining if continued failure of a soft solution warrants the design and construction of a hard solution.

1. Introduction

RACE Coastal Engineering (RACE), at the request of the Village of North Haven ("The Village") located in Sag Harbor, NY, performed a condition assessment and a coastal engineering analysis of the shoreline. The review included the assessment of the existing shoreline along the North Haven peninsula and the associated wave climate and environmental conditions at various locations along the shore. Existing shoreline management, erosion, and coastal analysis reports previously prepared for the Village were reviewed and relevant information was utilized for this report. The purpose of this study is to provide the Village with a summary of potential solutions that may be used to reinforce sections along the dynamic shoreline of North Haven peninsula. It is anticipated that these solutions and associated design components will be used by the Village as recommendations for written policies to be incorporated into the Village Code for when a structural solution may be allowable under the local permitting process. This report is intended to provide a comprehensive shoreline management plan for the Village to utilize as a guidance document for future stabilization solutions along the dynamic shoreline of the peninsula.

This document provides the Village with a summary of the existing conditions along the North Haven peninsula, key findings of the coastal engineering analysis and a summary of hard and soft stabilization measures that the Village may consider implementing along the shoreline. This document recommends the property owner first attempt to stabilize their site with a soft solution and monitor its performance in most locations. "Failure triggers" of soft solutions are outlined in this report. If these triggers are met or exceeded during the monitoring of the site, RACE suggests that it should be permissible to then install a hard solution (through proper permitting requirements).

1.1 Study Objective

The project involves a comprehensive review of the shoreline along the North Haven peninsula and broad-based recommendations to reinforce the shoreline and protect against existing and potential erosion. Various sections of the shoreline along the peninsula experience erosion during typical as well as infrequent, large, storm surge and wave events. Locations of critical erosion are dependent upon site specific features and exposure and must be individually analyzed. Reinforcement measures recommended to mitigate erosion on the bluffs, beaches and dunes around the peninsula consist of hard, soft and/or hybrid structures. Many of these structure types are present along the shoreline today and vary in their design, condition and amount of erosion protection they provide.

"Hard" structures protect the shoreline by using impermeable materials such concrete, rock, steel, etc. They are typically constructed in areas that experience medium to high wave action and should be designed to withstand destructive forces associated with significant storm events. Although enticing due to their protective capabilities, if placed in an undeveloped area or designed poorly, they can have negative environmental and geological consequences. In certain environments a "soft" solution may be used to protect the shoreline with decreased impacts. Soft solutions are typically comprised of materials such as coir logs (coconut fibers), sand, vegetation, and biodegradable fabrics or other natural features. Soft solutions perform best in areas that experience low wave action. The resilience of soft solutions decreases when they are placed in an area that experiences medium to high wave energy. When constructed in the appropriate environment, soft solutions provide protection against erosion while also integrating with the surrounding environment to provide ecological habitat value.

The data collected during the site investigation, literature review and coastal analysis were used to determine a variety of hard and soft flood and erosion control recommendations for the Village of

North Haven. The North Haven Peninsula is displayed below in Figure 1: Google Earth Aerial 9/19/2019. The project area is displayed in the red outline in Figure 1.

Figure 1: Google Earth Aerial 9/19/2019 (Google Earth 2019)

2. Historic Literature Review

The Village has had numerous studies and reports prepared over the years. Under Phase 1: Shoreline Condition Assessment, **RACE** reviewed the three reports listed below:

- Comprehensive Shoreline Management Report – On the Bluff Properties (Draft), Village of North, New York, First Coastal Consulting, February 2015
- North Haven Erosion Mitigation Report, Woods Hole Group, Inc. dated February 2016
- The Comprehensive Plan for Docks, Woods Hole Group, March 2016

Review of these reports provided **RACE** with a broad understanding of the peninsula conditions and issues prior to performing the site investigation. Although the reports were produced 4+ years ago, many of the assessments and associated conclusions are still relevant along the shoreline today. As such, **RACE** incorporated relevant data, coastal analysis methods and conclusions into the current study.

2.1 First Coastal Consulting - Comprehensive Shoreline Management Report, 2015 - Report Summary

The Comprehensive Shoreline Management Report provides the Village of North Haven and On the Bluff property owners with an overview of shoreline erosion at the time the report was written. Shoreline conditions at individual property parcels were reviewed with a common set of criteria in order to relate site conditions. The report proposed a variety of stabilization alternatives centered around those which are most effective as well as environmentally sustainable for each typical condition. The objective of the report is to provide alternatives to create a consistent plan of action, preserve beach dynamics, beach access, and bluff preservation.

The study focused specifically on the high bluffs along the northwestern portion of the North Haven peninsula. It reviewed seventeen (17) property parcels which were analyzed and extended along 3,000± linear feet of shoreline. The study noted that the shoreline consists of a high bluff with a vegetated crest, a steep sloping face and a moderately sloping, narrow beach. The sediment of the site is a combination of sand and cobble with random boulders scattered along the beach. Weak littoral transport occurs in the northern and southern directions because of the high wave energy climate that impacts the site. It also reviewed bluff failure mechanisms and documented a constant loss of sediment. **RACE's** review of this portion of the peninsula is consistent with First Coastal Engineering's findings. Additional details are explained in Sections 3 and 4 below.

Due to the eroding nature of the northwestern property parcels and loss of sediment along the bluff, the Comprehensive Shoreline Management Report recommended three stabilization alternatives as outlined below.

2.1.1. Vegetation

The soft solution would entail using coir logs, erosion control matting, native vegetation, etc. along the toe, face, or crest of the bluff to reduce erosion. The vegetation alternative should only be considered in areas where there is minimal threat to infrastructure as well as a mild slope along the face of the bluff. It is anticipated that the vegetation planted along the bluff would act as an erosion inhibitor as the roots would secure the sediment of the bluff together.

2.1.2. Vegetation with Beach and/or Bluff Fill

Adding beach and/or bluff fill assists with the erosive nature of the bluff because it replenishes sediment that was lost during erosive events. It is most effective when paired with vegetation and should be considered prior to placing a hard structure along the shoreline. However, it is key to note that in areas with repeated erosion, it can be very costly and continued maintenance may be required.

2.1.3. Vegetation with Fill and Toe Protection

In locations where bluffs have experienced chronic erosion and soft solutions have been previously ineffective, property owners may opt for a stabilization alternative that is more robust. Adding toe protection to the design should be considered when soft solutions are proven ineffective. Vegetation should always be considered when implementing a stabilization solution and may provide habitat to the surrounding ecosystem.

While protecting the bluff against erosion is the objective of the On the Bluff property owners and the Village of North Haven, the report also discusses the negative side effects of disrupting the natural erosive nature of the bluff. It is key to note that reducing erosion of the bluff will in turn decrease the amount of sediment in the dynamic littoral system. If beach/bluff fill is used to combat this negative side effect, it is crucial that sediment compatibility to the existing sediment on site is consistent.

2.2 North Haven Erosion Mitigation Report, Woods Hole Group, Inc., February 2016 – Report Summary

The North Haven Erosion Mitigation Report discusses a shoreline characterization analysis that was performed along the northwestern portion of the North Haven peninsula. Property parcels ranging from 1 On the Bluff to 52 On the Bluff were characterized and the coastal climate was analyzed to determine potential hard and soft stabilization solutions that may stabilize the erosive nature of the bluff. The northwestern project area was divided into three (3) reaches based on sediment composition, bluff orientation, and the elevation of the bluff crest. Each reach has locations which are in stable condition as well as locations that have experienced critical erosion. The erosion that has taken place has progressed from the beach and toe of the bluff, up along the bluff face, and to the crest of the bluff.

The report describes a variety of hard and soft shoreline protection alternatives that may be considered to stabilize the bluffs. For each alternative, a description of the design is provided, and the potential positive and negative impacts are addressed. Hard engineering alternatives that are discussed are: rock revetment, vertical bulkhead, nearshore sill/perched beach, groin, and a variety of toe protection designs. Soft engineering alternatives that are discussed are: beach nourishment, bank revegetation and placement of biodegradable support. Of the soft solutions, preferred alternatives discussed include stabilizing the toe of the coastal bank with coir, stabilizing the coastal bank face with plantings, and stabilizing the top of the coastal bank.

The report provides suggested guidelines to assist the property owners and the Village during the design of the shoreline protection measure as well as permitting the design. Guidelines consist of, but are not limited to, the proposed location, height, and anchoring method of coir logs/blocks; a description of the where/what/when plant species will be placed along the bluff; if irrigation is proposed and if so where it will be located; and the location/quantity of beach nourishment.

2.3 The Comprehensive Plan for Docks, Woods Hole Group, Inc., March 2016 – Report Summary

The overall objective of the Comprehensive Plan for Docks report produced by Woods Hole Group was to provide the Village with a summary of the existing physical conditions observed along the North Haven shoreline, to assess the positive and negative impacts from the usage and construction of docks, and to provide a series of recommendations to be used during dock construction. The Comprehensive Plan for Docks evaluates the entirety of the peninsula shoreline.

As part of this study, a site investigation team visited the North Haven peninsula to gather the existing physical conditions of the shoreline and to locate/quantify how many docks are located around the peninsula at the time of the report. The peninsula was separated into eight (8) regions depending on their direction (ex. North, South, East, West, Northeast, etc.). The nearshore slopes and water depths within these regions were documented and used to complete a detailed coastal analysis. Nearshore resources and the location of existing docks were observed and documented. In 2016, at the time the report was written, forty-six (46) docks lined the shoreline of North Haven peninsula. The docks ranged in length from approximately 30 feet to 235 feet and were examined based on their impact on the four primary coastal resource values: public access, shoreline aesthetics, water quality and nearshore habitat.

While the dock information itself is less relevant to the comprehensive shoreline management study at hand, Woods Hole Group completed a detailed coastal analysis of the physical processes affecting the shoreline as part of the study that is extremely relevant and useful when evaluating the suitability of shoreline protection structures. Historic wind and wave exposure were explored and attributed to the shoreline for storm events ranging from 5-year to 100-year return periods. An extremal analysis was conducted to determine the design wind speeds for 5-, 10-, 25-, 50-, 100-year return periods. With the given physical inputs, a SWAN model was created to calculate the wave heights that would impact the shoreline during the chosen design storm event. The SWAN model was run to depict a normal condition simulation as well as a 50-year return period simulation. A storm with a 100-year return period was not considered because it was considered an extreme condition and therefore not practical for the dock study.

Based on the coastal analysis and model outputs from the 50-year design storm, it was concluded that the construction of docks along the eastern, western, and northwestern shores are not favorable due to large wave heights. As such, the report recommends that the Village shall not place new docks in high wave intensity areas, the location of a new dock should be properly sited in regards to benthic resources and property lines and that new docks should meet a variety of construction standards pertaining to, but not limited to, water depth, length/width/height, float size, open grate decking, etc. While not the focus of the dock study, RACE believes it can be inferred that locations determined by Woods Hole Group to be unsuitable for docks because of wave energy would likewise be unsuitable for soft solutions.

3. Existing Site Conditions

RACE preformed a site investigation under Phase 1: Shoreline Condition Assessment, to document the physical site conditions that currently exist along the shoreline of the North Haven peninsula. The literature review provided the site investigation team with a baseline understanding of the shoreline prior to visiting the peninsula. Site conditions observed during the site investigation are documented and summarized in the following section. The data collected and described in this section was used to classify the existing shoreline and verify the input parameters for the coastal model described in Section 4.

3.1 Description of Project Site

The project site consists of the shoreline along the North Haven peninsula in Sag Harbor, New York. Due to its location within Sag Harbor Cove, the southern shoreline of the peninsula has limited site exposure to wind-driven waves and was not analyzed during this study (See Figure 1). The portions of the peninsula that are considerably exposed are surrounded by Shelter Island Sound which consists of Noyack Bay located along the western shoreline of the peninsula and the Peconic River located along the northern and eastern shorelines. The peninsula is normally exposed to winds and waves originating from the southwestern direction during the summer months and from the northwestern direction during the winter months. The shoreline is subject to semi-diurnal tidal fluctuations. The storm events most typically associated with the project site include hurricanes and nor’easters.

The shoreline type along the coast of the project site changes from the southwestern portion, clockwise to the northern portion and continues to the southeastern portion (Approx. 210°-150°). The primary types of shorelines that can be found along the peninsula are a series of high bluffs, low bluffs, beaches, and marsh lands. High bluffs are primarily located along the northwestern shoreline whereas the medium to low bluffs are located along the western, northeastern and eastern shorelines. The physical state of the shoreline is dynamic and can be altered depending on the site exposure to an active wind and wave climate, resulting in mild to severe erosion in some areas. Critically eroded areas can be found along stretches of both high and low bluff shorelines and is a direct result of a varying wave climate and existing adjacent structures.

Owners have historically and are currently constructing shoreline stabilization structures along various portions of exposed high bluff, low bluff, beach, and marsh lands to mitigate erosion and protect their upland property. Both hard and soft stabilization structures are located along the peninsula including: bulkheads, revetments, living shorelines, and a variety of other structures such as seawalls and non-engineered rock toe protection. In addition, some properties along the shoreline are simply "natural" and do not have any placed erosion protection. These properties may either not be experiencing erosion and do not need a solution at this time are in the process of seeking a solution, or the properties are vacant lots which are owned by persons who have not pursued erosion protection yet.

3.2 Site Investigation

A site investigation was performed by **RACE** on August 6, 2020 during a period of high water transitioning to a period of low water. The site visit was performed to document the existing conditions of the shoreline with a focus on the shoreline type, shoreline condition and the structure types that can be found along the project site. The investigation was carried out by a **RACE** field team consisting of a NY State licensed PE/Coastal Engineer and a Field Technician /Engineer walking along the southwestern, western, northwestern, northeastern, and eastern shorelines. While traversing the shore, **RACE** personnel took field notes, site specific geolocated data, and ground and drone photographs/videos. Due to restricted access of deep-water channels and small waterfront beaches, the northern and southeastern shorelines were not accessible to walk. As such, personnel utilized the DJI Mavic 2 Zoom drone to capture photographs and videos of the northern and southeastern shore.

3.3 Site Investigation Findings

RACE found that the shoreline type, shoreline condition and structure type varied considerably across the project site. For instance, a shoreline type characterized as "high bluff" may extend across long stretches of properties, while the structure type that extends over the same stretch of properties varied across the property lines. As such, the shoreline type, shoreline condition and structure type along the project site was analyzed based on individual property parcels along the shore in order to have a site specific understanding about what is currently occurring along the shoreline of North Haven peninsula. Property parcels were identified and extracted from the NYS GIS Clearinghouse for Suffolk County, NY.

3.3.1. Shoreline Type

The shoreline type that can be found along the shore of the North Haven peninsula is dynamic and can noticeably vary between two abutting property parcels. Depending on the orientation of the shoreline to the Shelter Island Sound, the peninsula varies between long stretches of high bluff to long stretches of marsh lands and beaches. High/low bluffs along the shoreline consist of a steep section of natural sediment with a crest elevation that ranges between approximately +5 feet NAVD 88 to +40 feet NAVD 88. The steep bluff face transitions into a moderately sloping beach at the toe of the bluff. Beaches can be found waterward of high/low bluffs as well as existing structural solutions such as bulkheads. Beaches provide property parcels with an area that can be used to dissipate wave energy prior to impacting bluffs/structures. Marsh lands are found along inland wetlands and channels which allow water from Shelter Island Sound to enter the peninsula. Marsh lands are comprised of low-lying dunes and thick vegetation. A graphic depicting the shoreline types along the North Haven peninsula can be found in Appendix A, Sheet 1. The quantity and percentage of the properties depicted in Appendix A, Sheet 1 have been tabulated and are shown below in Table 1. Shoreline types are separated based on property parcel boundaries and trends can be identified.

Table 1: North Haven Property QTY: Shoreline Type

North Haven Property QTY: Shoreline Type		
Shoreline Type	Number of Properties	Percentage of Properties
High Bluff	31	26
Medium Bluff	19	16
Low Bluff	29	24
Beach	25	21
Marsh	4	3
Beach/Marsh	7	6
Other	5	4
Total	120	100

The classification of shoreline type around the peninsula, shows the shoreline type varies drastically between the western portion to the eastern portion of the project site. Most of the peninsula is comprised of high bluffs (approximately 26%), low bluffs (approximately 24%), and beach environments (approximately 21-27%). The southwestern to western portion of the project site gradually transitions from a beach environment to a low/medium bluff environment. As the shoreline progresses north, the western low/medium bluffs transition into high bluffs along the On the Bluff properties. The high bluff scenario continues until it is intersected by the change in orientation of the shoreline along the northern coast. Marsh lands and low bluffs/beaches span the northern shoreline. The crest elevation of the bluff changes along the northeastern shoreline and varies between high to low bluff in areas and quickly transitions to a beach environment for most of the northeastern and eastern shorelines. The southeastern shoreline varies considerably between all the shoreline types. Long stretches of high bluffs are bounded by medium/small bluffs. Marsh lands account for approximately 3-9% of the shoreline and are primarily located along the long stretches of non-residential properties with coastal inlets, with beach environments sporadically located in between.

3.3.2. Structure Type

The classification of structures that are found along the North Haven peninsula vary between hard and soft structures and locations which are naturally vegetated. Hard structures are located along both the western and eastern shorelines and include bulkheads, rock revetment, seawalls, and non-engineered rock. Soft structures such as living shorelines are comprised of coir logs, erosion control matting and vegetation and are also present along both shorelines. Unlike the shoreline type that is a direct result of natural processes, the structures present along the shoreline vary in type, condition, age and apparent design (or lack thereof) and are generally inconsistent between properties. A graphic depicting the structural solutions along the peninsula can be found in Appendix A, Sheet 2. The quantity and percentage of the properties depicted in Appendix A, Sheet 2 have been tabulated and are shown below in Table 2.

Table 2: North Haven Property QTY: Structure Type

North Haven Property QTY: Structure Type		
Structure Type	Number of Properties	Percentage of Properties
Revetment	11	9
Bulkhead	37	31
Revetment/Bulkhead	5	4
Living Shoreline	7	6
Naturally Vegetated	52	43
Other	8	7
Total	120	100

Much of the shoreline is either vegetated (naturally or through construction of a living shoreline) or a hard structure is present. Approximately 51% of the shoreline is hardened with either revetments, bulkheads, a combination of both, or sporadically placed rock. It is common to have one hard stabilization structure that extends along multiple parcels. The western shoreline has two long stretches that have been hardened with either bulkhead or rock revetment. The longest of these sections spans over 9 property parcels. Long stretches of structural solutions are also found along the eastern shoreline. Four (4) stretches of multiple property parcels have been hardened with bulkhead and/or rock revetment, each consisting of at least five (5) property parcels. The shoreline also consists of long stretches of bluffs/beaches/marshes which are naturally vegetated and account for approximately 43% of the total property parcels. These portions of the shoreline vary between good and critically eroding. Constructed soft structural solutions are not as common with only about 6% of property parcels having evidence of stabilization by use of coir logs, textiles, and new plantings.

3.3.3. Shoreline Condition

Erosional forces acting on the shore are directly related to exposure based on site specific location, and can change rapidly based on storms. Naturally, erosional forces cannot be stopped, but solutions can be put into place to mitigate the effect on the shoreline. Without some level of protection the loss of bluffs/beaches will continue to occur and will affect adjacent areas. A graphic depicting the condition of the shoreline along the peninsula can be found in Appendix A, Sheet 3. The quantity and percentage of the properties depicted in Appendix A, Sheet 3 have been tabulated and are shown below in Table 3. The condition of the shoreline has been ranked as good, fair, eroded, or critical.

Table 3: North Haven Property QTY: Shoreline Condition

North Haven Property QTY: Shoreline Condition		
Shoreline Condition	Number of Properties	Percentage of Properties
Critical	8	7
Eroded	10	8
Fair	18	15
Good	84	70
Total	120	100

Based on physical observations, approximately 85% of the shoreline is characterized by **RACE** to be in good or fair condition. Along the southwestern portion of the peninsula, only one (1) property parcel is experiencing erosion. As the shoreline proceeds north, two (2) property parcels along the western portion of the peninsula are eroded and critically eroded. The majority of parcels that are experiencing erosion are located along the northwestern shoreline, where approximately eight (8) property parcels are currently eroded or are experiencing critical erosion. The northeastern and eastern sections of the peninsula have five (5) parcels that have been eroded and the southeastern portion has two (2) parcels which are critically eroded. Most of the erosion taking place on the peninsula is occurring along the northwestern and western shoreline.

3.4 Summary of Findings

The type of shoreline, condition of shoreline and the structural solutions present along the shore are all directly linked with one another. The northwestern shoreline is a series of high bluffs that are either naturally vegetated or have a soft solution present. This location has the highest number of property parcels that are either eroded or are critically eroding. However, the soft or "living shoreline" solution that has been constructed on a high bluff along the southeastern portion of the peninsula is in good condition but was also noted to be newly installed and perhaps had not seen a significant storm yet. Along the western and eastern shore, a long stretch of the shoreline is armored with bulkheads. In this area, the shoreline is in good/fair condition. However, naturally vegetated locations at the terminus of the bulkheads are experiencing erosion due to flanking which takes place when wave energy reflects off a hard structure and erodes sections of adjacent shoreline. All locations where marsh lands are present are in good condition. There are no structural solutions present in these areas.

Understanding how the dynamic physical system works as a whole is crucial to protect against current and future erosion along the North Haven peninsula. The type and the condition of the shoreline is dependent upon the wave climate which impacts the site and wave climate is also critical in the determination of viable solutions and their design. This can be seen when comparing the living shoreline solution that was constructed along the northwestern shoreline verses the southeastern shoreline. Both solutions were constructed along a high bluff however the existing condition of the bluffs in each location vary drastically. A coastal engineering analysis of the North Haven peninsula was performed to determine how the wave climate varies along the shoreline.

4. Coastal Analysis

RACE prepared a coastal analysis including numerical wave modeling and simulations of beach accretion/erosion along the shoreline of the peninsula. A desktop coastal engineering analysis was performed for the study to determine the starting (offshore) wave parameters for the 50-year storm event. These parameters were used as inputs into the wave models described below.

4.1 Stillwater Elevation

Stillwater elevation is defined as the elevation of the water surface without the presence of wave action but including storm surge and astronomical tides. The stillwater elevation reflects storm surge and astronomical tides typical of the Atlantic Ocean and, specifically, Shelter Island Sound. All elevations are referenced to the North American Vertical Datum of 1988 (NAVD 88) unless otherwise noted. The 100-yr, 50-yr, and 10-yr tidal flood frequency information provided in Table 4 below is referenced from Transect 152 from the Federal Emergency Management Agency (FEMA), Flood Insurance Study (FIS) No. 36103CV000A and dated September 25, 2009. The 50-year stillwater elevation was used to determine water depths used to model the shoreline surrounding North Haven peninsula.

Table 4: Stillwater Elevations

Return Period	Stillwater Elevation (ft)
100-yr	5.9
50-yr	5.2
10-yr	4.0

The modeling study was extended from the open water offshore of the site in a section of the reach where wave setup does not occur. Wave setup occurs within the surf zone as waves continuously break along the shoreline. The momentum of waves continuously breaking results in an increase in water elevation in the surf zone. As such, waves were transformed from offshore, utilizing the applicable Storm-Induced Beach Change model (SBEACH) described in subsequent sections, based on the stillwater elevations described in Table 4 as they propagated landward.

4.2 Wind Climatology

The design wind condition for the peninsula was extracted from the coastal analysis performed by Woods Hole Group, Inc. during their evaluation to create a “Comprehensive Plan for Docks” for the Village in March 2016. Historic wind data was extracted from the East Hampton Airport over a ten-year time span beginning on January 1, 2000 and ending on December 31, 2010. A wind rose was produced over the ten-year time span and shows most of the wind originates from the southwestern direction during the summer months and from the northwestern direction during the winter months. A directional analysis of the wind rose was grouped into 30° directional bins to distinguish the mean wind speed, the maximum wind speed, and the percentage of time that winds are generated from each bin. An extremal analysis was performed to determine the wind speeds associated with various storm events of specific frequencies. Woods Hole Group, Inc. calculated wind speeds for storms with 100-yr, 25-yr, 10-yr, and 5-yr return periods and are shown below in Figure 2.

Return Period	Event Wind Speed (MPH)
5	46.8
10	54.5
25	64.3
50	71.5
100	78.7

Figure 2: Wind Speed Associated with Return Storm Events. Extracted from "The Comprehensive Plan for Docks" prepared for the Village of North Haven and prepared by Woods Hole Group, Inc. dated March 2016

RACE generally concurs with these design wind speeds and utilized the wind speed for a 50-year return period to calculate the design wave height, wave period and wavelength of the offshore waves. The design wave climate calculated for the 50-year storm event by **RACE** was then compared to the design wave heights calculated by Woods Hole Group, Inc for the 50-year storm event.

4.3 Design Wave Climate

The design wave climate is comprised of the offshore wave height and period generated by a specific design storm event. The offshore waves produced by the design storm event are dependent upon the length of water (fetch) over which the wind blows. Since the shoreline of the peninsula has fetch lengths that vary based on the section of shoreline that is being analyzed, seven (7) different wave climates were calculated to characterize the peninsula. Wave climates were calculated from the southwestern, western, northwestern, northern, northeastern, eastern, and southeastern directions. Each wave climate direction was paired to an associated property parcel that was located in the general direction vicinity. The wave climate direction, associated property parcel address, shoreline type, directional bearing, and longest associated fetch for each wave climate are listed below in Table 5.

Table 5: Wave Climate Directions – Summary of Existing Details

Wave Climate Direction	Property Parcel Address	Shoreline Type	Directional Bearing	Longest Fetch (FT)
Southwest	116 Sunset Beach Road	Low Bluff	140°-310°	33,470
West	54 Robertson Drive	High Bluff	150°-300°	32,940
Northwest	8 On the Bluff	High Bluff	200°-20°	32,320
North	42 North Drive	Low Bluff/Marsh	270°-70°	18,560
Northeast	370 Ferry Road	Medium Bluff	320°-140°	18,710
East	27 Mashomuck Drive	Low Bluff/Beach	350°-150°	17,170
Southeast	4 Forest Road	Low Bluff	10°-180°	18,080

RACE calculated the wave climate for the 50-year storm event. The direction and length of each fetch radial associated with the seven (7) wave climates were input into the U.S. Army Corps of Engineers (USACE) *Wind Speed & Wave Growth application of the Automated Coastal Engineering System (ACES)*. ACES was used to determine the 50-year design wave height and wave period based off the windspeeds described in Section 4.1. The incident design waves were assumed to propagate perpendicular to shore. Table 6 below displays the numerical ACES model results for the different wave climates around the peninsula. Figures in Appendix A provide visual representation of how the 50-year wave heights vary along the peninsula.

Table 6: 50-year Return Period - ACES Model Results for Offshore Design Wave

Wave Climate Direction	50-year Return Period	
	Wave Height (ft)	Wave Period (sec)
Southwest	4.44	3.89
West	5.59	4.58
Northwest	5.69	4.62
North	2.77	3.03
Northeast	2.67	3.00
East	4.59	3.98
Southeast	4.99	4.13

The 50-year design offshore wave climate computed by ACES for each wave climate direction was compared to the 50-year computed numerical wind and wave model, Simulating Waves Nearshore (SWAN), generated by Woods Hole Group, Inc. To find an overview of the inputs and methods of SWAN, refer to the "The Comprehensive Plan for Docks" prepared by Woods Hole Group, Inc. dated March 2016. A summary table of the ACES wave height output and the SWAN wave height output can be found below in Table 7. Wave heights provided by Woods Hole Group, Inc. were categorized in groups of 0.5 feet. Therefore, the wave heights shown below are the average of the group they were categorized in. Wave periods were not provided in the Woods Hole Group, Inc. report and therefore are not compared.

Table 7: 50-year Return Period - ACES vs. SWAN Model Results: Wave Height Output

Wave Climate Direction	Wave Height (ft)		% Difference
	ACES	SWAN	
Southwest	4.44	5.25	-15
West	5.59	5.25	6
Northwest	5.69	5.25	8
North	2.77	4.25	-35
Northeast	2.67	4.25	-37
East	4.59	4.75	-3
Southeast	4.99	4.75	5

The wave heights calculated by ACES are fairly similar to those calculated by SWAN. Wave height outputs calculated along the western, northwestern, and southeastern shoreline matched very well with the outputs calculated by SWAN. The outputs began to differ along the southwestern shoreline and the most distinct difference was found along the northern and northeastern shorelines. The capabilities of the ACES and SWAN model differ when taking into account orientation of wave propagation toward the shoreline. SWAN is more refined in that it allows waves to propagate from a swath of directions whereas ACES is configured to transpose a wave from one direction. Therefore, the wave height differences between the ACES and SWAN model could be a result of varying wave heights from a multitude of directions.

As waves travel over and through Shelter Island Sound they will be modified by the effects of reduced depths and variations in shoreline and bottom configurations. The effects of these physical constraints will transform the incoming waves and effectively change the incident wave height, wavelength, and direction at a nearshore site. These incident waves are further transformed as the waves propagate up and over the beach and encounter the bluffs. The USACE's Storm-Induced Beach Change (SBEACH) numerical model was used to simulate the wave conditions as the waves propagated inland and were impacted by the beaches and bluffs along the shoreline.

4.4 Design Storm

The SBEACH modeling was employed to depict and estimate the quantities and limits of anticipated beach and bluff erosion that will result from a 50-year simulated storm event. A synthetic storm was generated to simulate a hurricane-like event for the 50-year storm using the design wave and water levels described above. The design synthetic storm surge took the shape of a cosine squared function (COS2) and was added on to normal tide predictions expressed as a sine function (SIN). Mean high water (El. +0.83 ft NAVD 88), the mean tide level (El. – 0.37 ft NAVD 88), and mean low water (El. -1.58 ft NAVD 88) were determined using information from the NOAA's Sag Harbor, NY Tide Station and were used to generate the normal tide function. The time series of the 50-year synthetic storm events from the southwestern and western directions are displayed below in Figures 3 and 4, for reference. The time series for the remaining five (5) directions can be found in Appendix B.

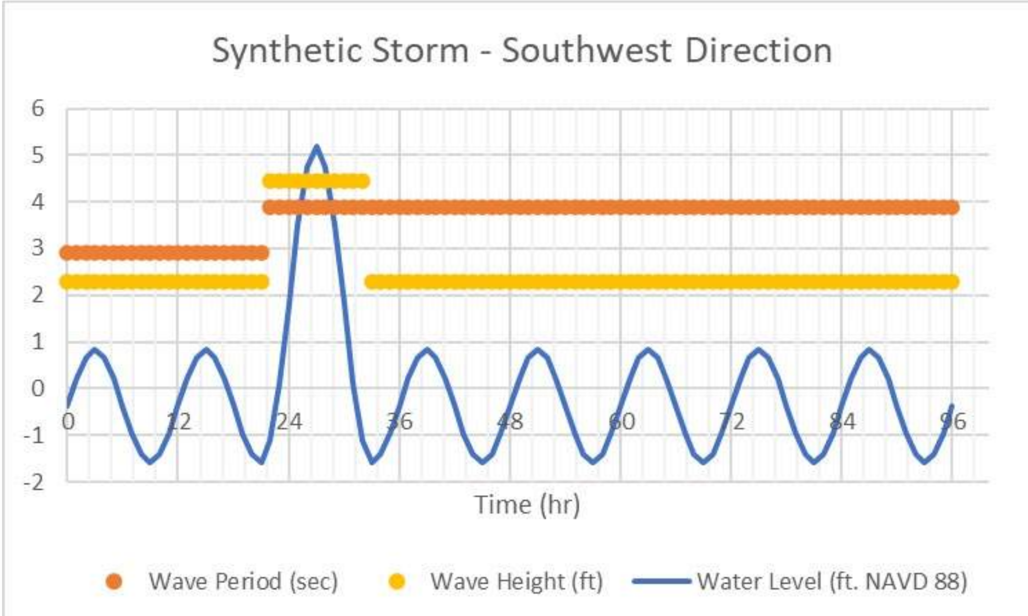

Figure 3: 50-year Synthetic Storm – Southwest Direction

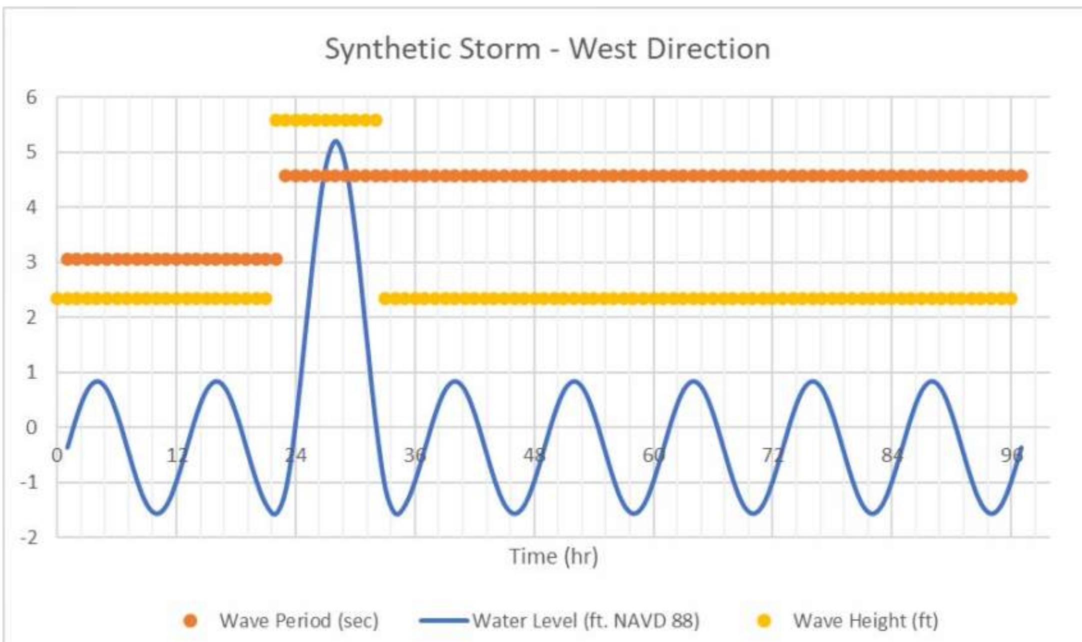

Figure 4: 50-year Synthetic Storm – West Direction

The design storm for each wave climate direction was input into SBEACH along one (1) transect at each site. The model transformed the storm waves along the profiles and the results were used to assess the impacts to the beach and bluff conditions during the 50-year event.

4.5 Discussion of SBEACH Results

The SBEACH model was run from the seven (7) different directions to further characterize the varying wave climate around the peninsula and how it may impact the shoreline. A profile was taken perpendicular to the shoreline at seven different property parcel addresses associated with the wave climate directions presented in Table 5. The seven profiles around the peninsula depict an existing shoreline type. Physical shoreline inputs such as the crest, beach face, and toe elevations can be found below in Table 8 and are accompanied by the SBEACH outputs of horizontal erosion at these key locations along the profile. Locations along the profile that are predicted to experience horizontal erosion are represented in red and are categorized by low (0 to 9'), medium (10' to 14'), and high (15' to 20'+) amounts of erosion. Similarly, locations which are predicted to experience horizontal accretion of sand are represented in green and are also categorized by low (0 to 9'), medium (10' to 14'), and high (15' to 20'+) amounts of accretion.

Table 8: SBEACH Results – Physical Inputs and Predicted Amount of Horizontal Erosion/Accretion

Direction	Description	Beach Crest Elevation (NAVD 88, ft)	Beach Face Elevation (NAVD 88, ft)	Beach Toe Elevation (NAVD 88, ft)	Horizontal Erosion along Beach Crest	Horizontal Erosion along Beach Face	Horizontal Erosion along Beach Toe
Southwest	Low Bluff	5	3	-1	High	High	Medium
West	High Bluff	15	8	1	Low	High	High
Northwest	High Bluff	27	15	3	High	Low	Medium
North	Low Bluff/Marsh	3	2	1	High	Low	Low
Northeast	Medium Bluff	5	3	0	Low	Low	Medium
East	Low Bluff/Beach	4	3	-1	High	Medium	Low
Southeast	Low Bluff	6	3	0	High	Medium	Medium

Horizontal Erosion, ft	
Low	0 to 9
Medium	10 to 14
High	15 to 20 +

Horizontal Accretion, ft	
Low	0 to 9
Medium	10 to 14
High	15 to 20 +

Visual outputs of SBEACH for wave climates propagating from the southwestern and western directions are shown below in Figures 5 and 6 for reference. The additional five (5) SBEACH runs from the remaining directions can be found in Appendix C.

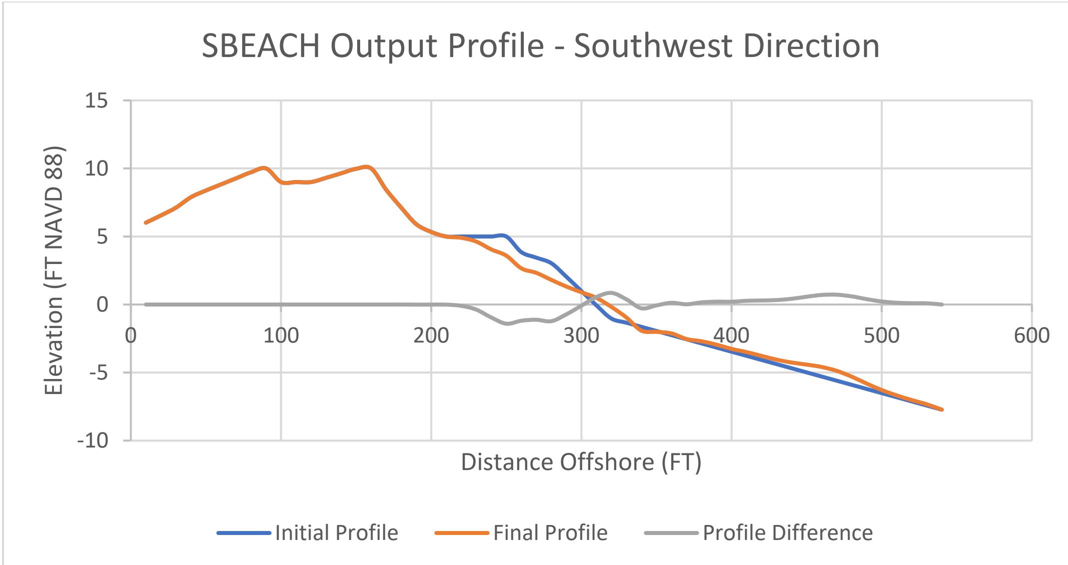

Figure 5: 50-year SBEACH Output – Initial vs. Final Profiles – Southwest Direction

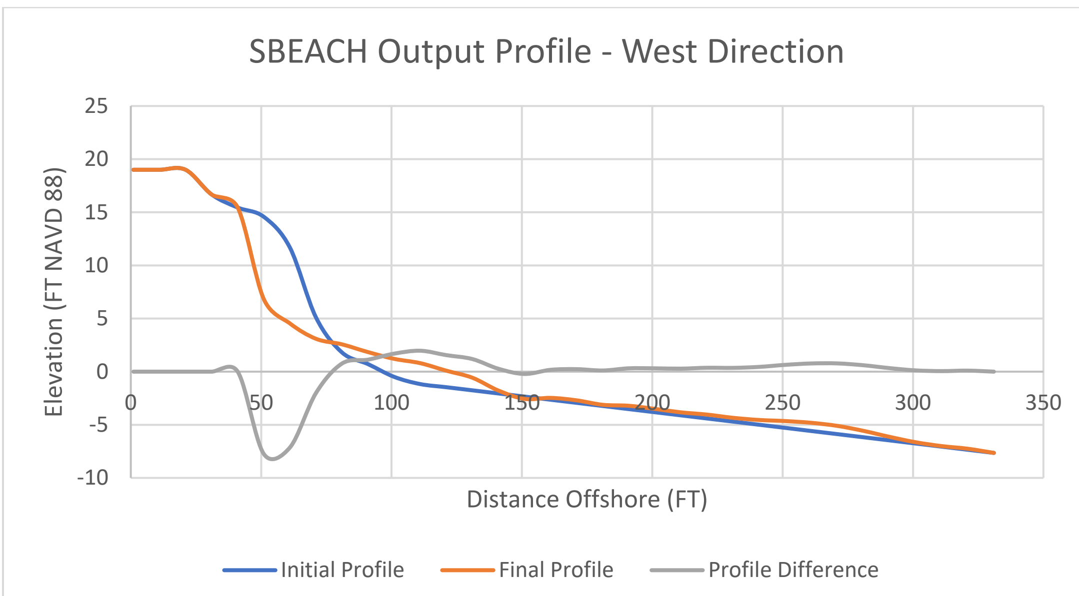

Figure 6: 50-year SBEACH Output – Initial vs. Final Profiles – Western Direction

The SBEACH output predictions for each of the seven profiles modeled along the peninsula show significant horizontal and associated vertical erosion during the 50-year storm event. Per Table 8, high amounts of horizontal erosion can be seen occurring along the crest of the existing bluffs and beaches. Similarly, medium to high amounts of horizontal erosion have been predicted to occur along the beach face of the southwest, west, east, and southeastern profiles. It is anticipated that the erosion of the beach face along the profiles directly correlates to the significant erosion occurring at the beach crest. Without the foundation support of the beach face, the crest will become unstable and ultimately fall/erode. As a result, horizontal accretion is predicted to occur along the toe of the profiles. As wave attack threatens the beach face and crest of the profiles, the sediment that erodes is deposited along the toe. This sequence of erosion and accretion along the bluff/beaches is the natural process to allow the shoreline to establish a more gradual slope along portions of bluff/beach that have become unstable.

The varying amount of horizontal erosion along the profiles is correlated with their local wave climates. The western and northwestern portions of the peninsula experience the highest wave climate with generated wave heights greater than 5.5 feet during the 50-year storm event. As seen above in Figure 6, large amounts of sediment are predicted to erode from the beach face of the western profile. Similarly, the northwestern profile is predicted to experience high amounts of erosion along its crest. Areas along the shoreline which experience a low wave climate, such as the northern and northeastern shorelines, are predicted to experience low amounts of horizontal erosion along the beach face. However, the northern profile is predicted to highly erode along its crest unlike the northeastern profile which is predicted to accrete sediment along the crest. Portions of the shoreline that experience a moderate wave climate are located in the southwestern, eastern, and southeastern quadrants. Similar to the high wave climate, these profiles are predicted to erode along the beach face and crest, while accreting sediment along the toe.

The SBEACH model predicts that a majority of the profiles will experience horizontal erosion along their crest and beach faces, while experiencing accretion along their beach toe. This is a natural process undertaken by the environment with the goal to transition an unstable bluff/beach with a steep slope into a stable bluff/beach with a gradual slope. Although a natural process, many property owners are threatened by the loss of beach or bluff and the potential impacts to infrastructure and seek ways to mitigate.

5. Shoreline Solutions

The shoreline of the peninsula has many types of existing structures to protect against erosional forces ranging from soft solutions to hard solutions. Proposed structures should be designed based on site-specific conditions of the existing shoreline, the wave climate impacting the site and with consideration of the infrastructure on the existing and adjacent property. Each solution has benefits and drawbacks that must be weighed against one another. A variety of hard and soft solutions have been evaluated and explained below. Design criteria of each are assessed and related to the existing wave climate along the North Haven shoreline.

5.1 Hard Structural Solutions

Hard structural solutions are comprised of durable material that can be designed to withstand significant storm events. They are best suited for high wave energy climates and serve to protect upland structures and property during typical and storm conditions. By hardening the shoreline, the wave energy will dissipate on the structure rather than the shoreline. Shoreline hardening must be designed appropriately for the project site while keeping in mind the shoreline of the adjacent properties. It is common for the abutting shorelines of a hard structure to erode at a faster rate than they naturally would due to flanking impacts if not accounted for in the design. This is one reason why a comprehensive plan across multiple project sites is ideal over individual scattered projects.

5.1.1 Rock Revetment

Although comprised of natural materials, rock revetments are considered a hard solution due to their hard composition, durability and inability to support an ample amount of vegetation. Rock revetments function best in moderate to high wave energy environments by allowing wave energy to dissipate along the revetment slope and in between the sections of rock. They can be designed to remain structurally sound in high wave energy climates and during large storm events such as the 100-year return period storm event. A rock revetment designed by **RACE** (not in North Haven, NY) is pictured below in Figure 7. The rock revetment was designed for a 100-year storm event to reduce wave runup and scour.

Figure 7: Rock Revetment

Rock revetments are designed to reduce the most common negative impacts associated with the design storm including wave overtopping and runup, and erosion along the toe of the revetment. The design components of the rock revetment should be determined based on detailed coastal engineering analysis of the project site. As such, it is recommended that the rock revetment design considers the following:

- The revetment shall extend above the calculated wave runup/overtopping elevation when constructed along the toe of a bluff,
- To deter undermining of the structure, the rock revetment shall extend beneath the calculated scour elevation,
- A detailed coastal engineering analysis shall be performed to determine the correct dimensions of the proposed rock to prevent movement,
- Tapered returns shall be considered at the terminus to prevent flanking and impacts to adjacent property.

5.1.2. Bulkhead/ Seawall

Bulkheads and seawalls are vertical shoreline protection measures that are constructed to provide flood and erosion control and retain upland soils. They can be comprised of various materials including steel, timber, vinyl or composite sheet piles as well as stone and/or concrete depending upon site conditions and design parameters, as well as construction and future maintenance cost considerations. They may require landside anchor system depending on the design and geotechnical characteristics of the site. This solution provides protection in locations with moderate to high wave energy climates. Unlike the rock revetment, which may have a large physical footprint, the vertical design of a bulkhead and seawall can be constructed in a comparatively small footprint while still providing protection to upland structures and land. If not designed properly, erosion caused by flanking can occur at the ends of the bulkhead or seawall and exacerbate erosion along abutting properties. An existing bulkhead constructed of vinyl sheets and timber along the North Haven shoreline is pictured below in Figure 8.

Figure 8: Vinyl Bulkhead

Since bulkheads and seawalls are vertical structures, they dissipate less energy than rock revetments and can often reflect waves away from the wall either in a vertical direction (wave runup and overtopping) and/or a horizontal direction toward deeper waters and adjacent properties. It is recommended that the design of a bulkhead/seawall incorporates the following:

- The top of the bulkhead/seawall shall be designed to an appropriate elevation to reduce or eliminate wave runup/overtopping,
- The bulkhead/seawall shall extend beneath the calculated scour elevation to prevent undermining,
- Geotechnical considerations for anchor requirements,
- Determination of wave forces to prevent sliding and overturning.

5.1.2 Rock Sill

A rock sill is a different type of structural solution, although often referred to as a “hybrid” approach or “living shoreline” because they are typically used for erosion control and to enhance marsh habitat. A rock sill is a low-profile rock structure constructed within the water column, waterward of the bluff toe and/or beach along the shoreline, to interrupt wave energy as it propagates toward the beach. It can be combined with sand fill to establish a marsh landward of the sill placement. Due to its low profile and small rock sizes, rock sills are recommended for locations with low to moderate wave energy climates. If placed in a high wave energy environment, the rocks will not remain in their designed location and the rock sill will not provide the project site with the proper protection it needs. A rock sill with an established marsh can be seen below in Figure 9.

Figure 9: Rock Sill with Established Marsh

Since the rock sill is a relatively new structural approach to wave dissipation and marsh enhancement, its design components are steadily being optimized as more sills are constructed and monitored. To successfully design a rock sill that integrates into the project site, the associated design must incorporate both objectives. According to the current literature, design of a rock sill should consist of the following:

- A detailed coastal engineering analysis shall be performed to adequately size the proposed rock. The sill is commonly comprised of small to medium sized rock,
- The crest of the sill shall have a freeboard between approximately 0 and 1 feet above Mean High Water to allow water to flow above the sill,
- The sill length shall not be greater than 100 feet and a gap is recommended between the structures to allow water circulation around the sill,
- Individual rock sills shall be staggered with an overlapping configuration such that gaps are provided between the structures for water circulation purposes,
- If applicable, marsh plantings shall be planted landward of the sill structure to encourage marsh growth.
- A monitoring plan shall be employed after the project is complete.

Water circulation patterns are imperative to consider during design to encourage marsh growth. The crest freeboard, sill length and staggered configuration play a vital role as to how water will circulate around the structure. The lower the crest freeboard and the larger the gap between sill structures, the more wave energy that will enter the site, so there needs to be a balance between energy dissipation and circulation.

By placing the rock sill within the water column, the structure serves to break waves as they propagate toward shore. By lowering the wave heights closer to shore, the associated wave energy decreases and allows planted marsh vegetation to have a higher likelihood of establishing itself during normal tidal cycles. The established vegetation in turn provides the site with a natural erosion deterrent as well as an extended area that will further dissipate wave energy. Both the rock structures and marsh area provide habitat which benefits the ecosystem in addition to adding erosion protection.

5.2 Soft Structural Solutions

Soft structural solutions are typically comprised of biodegradable components and vegetation. These solutions, although favorable, are difficult to maintain in locations with a high wave energy climate. Therefore, they perform best in low wave energy climates. The longevity and durability of the natural design also depend on length of time the solution is able to establish itself at the project site before it is impacted by storm events. Vegetation, a critical component of a soft structural design, needs approximately 24 months on average to develop a proper root system. The developed root system in turn serves as the natural erosion deterrent for the design. When placed in an environment with high wave energy, the natural components may not receive the proper amount of time to establish themselves and therefore may deteriorate, be washed away, and ultimately not meet the expected design life. Monitoring of soft structural solutions is crucial after they have been constructed. Due to their natural materials, soft solutions are less durable when compared to hard solutions and may require more frequent maintenance or adaptive management.

5.2.1. Coir Toe Protection

Coir logs or coir blocks/envelopes are comprised of coconut fibers that may be placed along the face and toe of eroding bluffs or dunes to provide toe protection. Both coir logs and blocks/envelopes function best in a low wave energy climate due to their lightweight and natural composition. Coir logs consist of densely packed coir fibers contained within either a polymer mesh log or within a woven coir mesh to produce an entirely natural log, typically 12 to 20 inches in diameter, and anchored in place with wooden stakes. The coir log is intended to provide temporary protection to the shoreline or bank while vegetation can be established landward. The coir logs are designed to biodegrade over a period of years to leave a stabilized bank of plant biomass.

Figure 10: Coir log toe protection near On the Bluff Road

Coir blocks or envelopes are constructed of coir fiber blankets or mats and filled with sand or soil. The diameters can be larger than that of a log and they can be anchored in place as well as stacked to create of more substantial "structure" similar to a rock revetment, although they are still subject to biodegradation.

An example of a coir block revetment designed by **RACE** is pictured below in Figure 11. Three (3) courses of sand and gravel wrapped in coir fiber blankets were anchored in place to create a revetment-type configuration. Once the coir block revetment was completed, it was buried with sediment to create a dune and vegetation was planted along the slope (Figure 12).

Figure 11: Coir Log Revetment Under Construction

Figure 12: Coir Log Revetment with Beach Nourishment and Plantings

A coir log revetment may be used as a nature-based erosion deterrent for toe protection during normal tide conditions and small magnitude storm events, provided the vegetation has had time to get established. To increase the stability of the coir revetment, proper design elements are recommended:

- The coir logs/blocks/envelopes of the revetment shall be properly anchored to the shoreline and installed per manufacturer's guidance. Their specifications will correspond to the diameter and length of the proposed coir log/block/envelope.

- To deter undermining of the revetment, a coir foundation log/block/envelope shall extend/be placed beneath the calculated scour elevation,
- The assembled coir revetment shall be covered with sand sediment and be planted with native coastal vegetation,
- A monitoring and maintenance plan shall be employed after the project is complete.

Coir toe protection provides stabilization for a bank by utilizing a natural design and native vegetation. However, the longevity and durability of the coir logs/blocks/envelopes depend on length of time the solution is able to establish itself at the project site before it is impacted by wave energy as well as its location relative to tides and storm surge elevations. As such, sand covering the revetment will reduce the amount of sunlight and salt water contact with the coir materials and will slow down the deterioration process of the coir.

5.2.2. Beach or Dune Nourishment

Beach or dune nourishment is a frequently used shoreline protection method which involves placing imported sediment onto a beach. During normal tidal conditions and storm events, the wider, higher beach profile causes wave energy to break further offshore and supplies a reservoir of sand to lessen the effects of erosion on upland features. However, like most soft solutions, the benefits are temporal, and success will vary based on the timing and severity of storms after placement. Maintenance nourishment is typically required on cycles.

An optimal proposed beach nourishment template is determined by performing a detailed coastal engineering analysis of the project site. It is typical to design beach nourishment templates to withstand small and moderate storm events such as the 10-year, 20-year, and 50-year storm. A **RACE** designed beach nourishment project during and after construction, is depicted in Figures 13 and 14 below.

Figure 13: Beach Nourishment During Construction

Figure 14: Beach Nourishment After Construction

Although temporal, a beach nourishment template can be designed to perform optimally during the designated design storm event. As such, beach nourishment design should be based on a detailed coastal engineering analysis with recommendations as follows:

- The width and crest elevation of the nourishment typically corresponds to the natural crest elevation of the existing beach,
- The slope of the nourishment template is typically compatible with the slope of the existing beach,
- The grain size of the imported sediment shall not exceed the spread of grain sizes of the local native sand,
- A monitoring and maintenance plan shall be employed after the project is complete.

5.2.3. Geotube or Geocube Reinforcement

A geotube is a flexible cylinder-shaped container comprised of a synthetic material casing. A geocube is similar in composition, but smaller and anchored together in units to form a line of protection. They can range in size and are commonly placed along eroding shorelines as a single unit or stacked to act as a "wall" to deter erosion from impacting upland structures or eroding bluffs. Geotubes may also be used to reinforce the core of a dune system to provide upland structures with dual protection. The first tier of protection is provided by the dune sand dissipating wave energy. The second tier of protection is the geotube core which may be exposed to wave action if the dune sand is eroded away. The geotube is filled with a water and sand slurry and the synthetic casing allows the water to escape the container while the sand remains, until the container is only filled with sand. A series of geotubes can be placed in any wave energy climate however they must be designed appropriately. An example of a geotube reinforcement solution (under construction) is depicted below in Figure 15. These tubes are typically covered with beach or dune nourishment following installation.

Figure 15: Geotube Reinforcement

As stated above, geotubes can range in a variety of sizes, shapes, and material composition. A detailed coastal engineering analysis of the project site is recommended to determine optimal type and dimensions of the geotube. Design recommendations are similar when analyzing the different geotube varieties and are as follows:

- Stacked or tiered tubes, or cubes, should be evaluated for stability against wave forces and in consideration of existing geotechnical parameters of the site,
- To deter undermining of the geotube, the bottom of the geotube shall extend beneath the calculated scour elevation,
- The geotube shall be covered in its entirety with imported sand and native vegetation to increase its longevity,
- A monitoring plan shall be employed after the project is complete.

5.3 Hybrid Solutions

Hybrid solutions are a combination of both a hard and a soft solution. They combine hard, natural materials, such as rock with natural soft materials such as beach nourishment sand and vegetation and promote environmental sustainability while being able to dissipate high wave energy and remain intact during daily and infrequent, larger storm events.

When combined with hard materials, hybrid solutions regularly consist of placing imported beach nourishment sand on top of the constructed hard solution. This sand may be sacrificial during a storm event and may need to be replaced. A **RACE** designed hybrid rock revetment is shown below in Figure 16.

Figure 16: Hybrid Rock Revetment

Since the rock revetment is durable, predictable, and reliable, it has a higher likelihood of sustaining less damage during a significant storm event. The ecological value of the project is enhanced by placing imported beach nourishment sand and vegetation on top of the rock revetment. If given the proper amount of time to establish itself, the root structure of the vegetation will help to hold the sand in place and further protect the shoreline against wave energy. In the event that the sand and plants are impacted during a storm, the revetment provides the necessary flood and erosion protection to the upland structures.

6. Design Recommendations

The North Haven peninsula is a dynamic stretch of coastline that is exposed to various wave climates. As wave forces act on the shoreline, the morphology of the shoreline changes, potentially threatening the waterfront properties. Currently, the most common shoreline types that exist along the peninsula are high bluffs, low bluffs, and marshes/beaches. Design solutions to stabilize the threatened sections of shoreline must take into consideration the shoreline type and the local wave climate. Therefore, **RACE** has developed three potential design concepts for the common shoreline types that can be altered based on the local wave climate. Eroded portions of naturally vegetated shoreline that are bounded by hard structures should be assessed separately and in coordination with the adjacent structures.

6.1 High Bluff

High bluffs along the North Haven shoreline consist of tall, steep bluffs that transition into a gradually sloped beach at the bluff toe. Some existing high bluffs have dense vegetation along their slope which acts as a natural erosion deterrent. However, other portions of high bluffs are devoid of vegetation and are significantly eroding. The majority of high bluffs exist along the western, northwestern, and southeastern shorelines. These sections of shoreline have local wave climates which range from a high wave climate in the west and northwestern quadrants to a moderate wave climate in the southeastern quadrant (See Table 6). To construct a stable shoreline solution, the local wave climate is critical and must be considered.

RACE recommends a two-tier design to stabilize eroding high bluffs. The first tier of design is a revetment constructed along the toe of the bluff and will bear the brunt of the wave action during storm events. As such, the toe of the revetment shall be buried beneath the calculated scour depth and the crest of the revetment shall be elevated above the calculated runup/overtopping elevation. As previously stated in Section 5.1.1., by extending the revetment above the wave runup/overtopping elevation and beneath the scour elevation, it is anticipated that the wave energy will dissipate along the slope of the revetment rather than the surrounding environment. A biodegradable erosion control mat can be placed beneath the revetment. The second tier of design extends above the revetment crest and along the face, and crest, of the bluff. Most high bluffs are unstable due to their overly steep slope and therefore, it is recommended to reshape the high bluff such that it has a maximum slope of 1V:1.5H or shallower. Reshaping the profile may include cutting and filling sediment along different portions of the profile. A biodegradable erosion control mat can be placed along the reshaped profile and native coastal plantings planted along the slope. If provided an ample amount of time to establish a root system, the native coastal plantings will provide the face and crest of the high bluff with a natural erosion deterrent. A typical cross section depicting the recommended design for high bluffs can be found in Appendix D.

As previously stated, the local wave climate must be considered when designing solutions to stabilize an eroding high bluff. It is recommended by **RACE** that hard materials, such as rock, shall be used to construct the revetment in areas with high wave energy (west and northwest quadrants). It is anticipated that natural materials, such as coir fibers, will not have a long lifespan under higher magnitude wave forces. However, in areas which experience a moderate wave climate (southeast quadrant), it is recommended that natural materials shall be initially used to construct the revetment. A monitoring period of the natural revetment shall be enforced to observe if bluff failure triggers occur along the subject bluff (See Section 7). If such triggers are met, hard structural solutions should be considered for the subject property.

6.2 Medium/Low Bluff

The majority of medium to low bluffs are found within the southeastern, western, and southwestern quadrants of the peninsula and experience a moderate wave energy climate. In these locations, the bluff crest can range in elevation from approximately +5’ NAVD 88 to +10’ NAVD 88 and local vegetation may be found along the bluff face and crest. However, similar to unstable sections of high bluff, portions of medium/low bluffs are devoid of vegetation and may have a steep eroding slope. Since a majority of bluffs are located in moderate wave energy climates, it is recommended by **RACE** to initially design and construct a solution comprised of natural materials along portions of the bluff which are subject to instability and erosion. A monitoring period of the natural solution shall be required to observe possible bluff failure triggers. If such triggers occur, a more robust structural solution may be warranted for the erosive bluff.

When located along a stretch of shoreline with a moderate wave energy climate, **RACE** recommends erosive portions of medium to low bluffs be stabilized using a natural solution. The design can consist of a sloped revetment comprised of natural materials, such as coir blocks/envelopes/logs. The dimensions of the natural materials shall depend on the location of the bluff and the local wave climate analyzed during a coastal engineering analysis. The natural materials shall be anchored to the earth by a series of tie down anchors in accordance with manufacturer specifications. The revetment should have a maximum slope of 1V:1.5H or shallower to provide the bluff with adequate stability. To deter undermining and destabilization of the revetment, the revetment toe shall extend beneath the calculated scour elevation and the revetment crest shall extend to at/above the calculated wave runup/overtopping elevation. If the crest of the bluff is lower than the calculated wave runup/overtopping elevation, the natural revetment shall extend to the elevation of the bluff crest and a splash zone shall extend landward of the bluff crest. The splash zone will act as a buffer along the landward portion of the proposed revetment to assist in dissipating the energy associated with runup/overtopping during significant storm events. The zone shall be supported with natural materials, such as coir blocks/envelopes/logs, and shall be planted with native coastal vegetation. As previously stated in Section 5.2.1., the assembled revetment comprised of natural materials should be covered with sand sediment, biodegradable erosion control matting, and be planted with native coastal vegetation. The ultimate goal of the sand and matting is to reduce the amount of sunlight and salt water contact with the natural revetment materials and to slow down the deterioration process of the material as well as provide natural resource enhancement. The sand cover is not intended to introduce sand sediment to the coastal system. To assist in retention of the sand covering, a coir log anchored per manufacturers specifications, can be placed along the toe of sand covering. A typical cross section depicting the recommended design for medium to low bluffs can be found in Appendix D.

6.3 Marsh/Beach Shoreline

Stretches of marsh and beach along the shoreline have similar physical features and therefore a design has been recommended that address both. Marshes and beaches are common along portions of the shoreline which experience a low to moderate wave climate and can be found in the southwestern, northern, northeastern, eastern, and southeastern quadrants. Marshes and beaches have low crest elevations that range between approximately 3' NAVD 88 to 5' NAVD 88. Since the elevation of the crest is low, the toe, face, and crest of the marshes/beaches will be inundated, and erosional forces will be acting on the profile as a whole. As such, the recommended design targets to stabilize the toe, the face, and the crest of the profile.

Most marshes and beaches along the shoreline are subject to a low to moderate wave climate which will inundate the profile during significant storm events. As such, **RACE** recommends to initially stabilize the toe, the face, and the crest of the profile with natural materials, such as coir blocks/envelopes/logs. The dimensions of the natural materials shall depend on the location of the marsh/beach and the local wave climate analyzed during a coastal engineering analysis. The natural materials shall be anchored to the earth by a series of tie down anchors in accordance with manufacturer specifications. If the profile has been eroded and an unstable slope is present, it is recommended to reshape the profile such that it has a maximum slope of 1V:1.5H or shallower. To discourage undermining of the natural materials at the toe of the profile, it is recommended a foundation coir block/envelope be constructed to extend beneath the calculated scour elevation. The low crest of the profile shall be supported with natural materials, such as coir blocks/envelopes/logs, to hinder destabilization of the crest. The natural solution, as a whole, shall be covered with biodegradable erosion control matting and planted with native coastal vegetation. If provided the proper amount of time to establish a root system, the native coastal plantings will enhance the profile by providing the marsh/beach profile with a natural erosion deterrent. A typical cross section depicting the recommended design for marsh and beach profiles can be found in Appendix D.

6.4 Natural Shoreline Bounded by Existing Hard Structures

The North Haven shoreline is comprised of long stretches of hard structures as well as those that are unprotected. It is common that the portions of shoreline that have been hardened by structures are in good/fair condition, however, many are bounded at the terminus by unimproved sections of shoreline. These naturally vegetated locations at the terminus of the hard structures are experiencing erosion due to flanking which takes place when wave energy reflects off a hard structure and erodes sections of adjacent shoreline, as well as natural recession due to erosion of the unprotected bluff. If a naturally vegetated section of shoreline is bounded by two hard structures, and is experiencing erosion, **RACE** recommends that a hard structure be constructed to continue along the unprotected shoreline such that the existing hard structures are connected with no gaps.

Currently, there are two locations where unprotected properties are bounded on both sides by hard structures. These sections are experiencing flanking and normal erosion and have been deemed eroded and critically eroded by **RACE** (See Appendix A: Drawings 2 & 3). One unprotected section exists along the northeastern shoreline in between a long stretch of existing bulkheads. The bulkhead extends across two properties to the north of the subject property and across three properties to the south The naturally vegetated property has been classified as eroded. It is recommended by **RACE** that the eroded section of shoreline be permitted to construct a bulkhead along its length. The constructed bulkhead will join the two existing bulkhead sections on either side of the property line and provide a comprehensive solution to several properties.

Similarly, two properties along the southeastern shoreline are bounded by a long stretch of rock revetment and living shoreline, which is bounded to the south by a rock revetment. As such, the subject properties have been classified as experiencing critical erosion along their shorelines (See Appendix A: Drawings 2 & 3). The adjacent rock revetment extends across eight properties to the north of the subject properties and a rock revetment extends across two properties to the south of the existing living shoreline. Since the two critically eroded properties in question are bounded by structurally supported shorelines to the north and the south, it is recommended by **RACE** to construct a rock revetment along the shoreline of both subject properties. The constructed rock revetment will stabilize the existing shoreline while connecting long stretches of structurally supported bluffs for a comprehensive solution.

7. Bluff Failure Triggers

The shoreline along the North Haven peninsula changes significantly depending on varying exposure to Shelter Island Sound. Properties along the northwestern shoreline consist of high bluffs where some are experiencing critical erosion. On the other hand, properties along the northeastern shoreline consist of bluffs with varying elevations as well as marshlands and beaches which are beginning to erode. From an environmental sustainability perspective, all shoreline protection solutions would consist of soft solutions which would ideally prevent the shoreline from continued erosion as well as enhance ecological value of the site. However, not all shorelines experience the same amount of wave energy and therefore the same type of solution may not provide adequate erosion protection. Repeated failure of non-structural solutions may require a more robust, structural solution be installed. In response, **RACE** has developed a variety of triggers that are recommended for identifying repeated failure of soft solutions and when hard structural solutions should be considered.

Failure of soft solutions should be quantitative and measurable and not subjective. The bluff failure triggers should be clearly defined and identified in the associated permit to construct the soft solution. **RACE** recommends that any one (not all) of such quantitative criteria constitute failure of the soft solution and warrants consideration of a structural solution. Following are conditions for consideration:

- One (1) foot of horizontal retreat of the top of the bluff measured from the final top of bluff position as documented in an "as-built" survey and by photographs after initial project construction. Localized retreat at discreet point(s) (e.g. tree falls) along the top shall not be considered failure. One (1) foot shall be measured as the average retreat over at least 50% of the length of the top of bluff.

- Two (2) feet of horizontal retreat of the toe of bluff measured from the final toe of bluff position as documented in an "as-built" survey and by photographs after initial project construction. Localized retreat (e.g. scarp) at single point(s) along the toe shall not be considered failure. Two (2) feet shall be measured as the average retreat over at least 50% of the length of the toe of the bluff.

- 50% damage of the slope face measured in surface area below the crest elevation of the soft structural solution as documented in an "as-built" survey and by photographs after initial project construction.

- Destabilization of components of the soft structural solution including displacement or undermining of 30% of the design after two (2) documented cases of damage and subsequent repairs as documented by before and after photographs.

RACE further recommends that "top of bluff", "toe of bluff", and "damage" of the shoreline be fully defined in the conditions as well as corresponding project plans such that characterizations are consistent between one survey/assessment to the next. Top and toe of bluff can be defined at the point where there is a distinct change from a relatively steep slope to a relatively mild slope. Damage can be defined as partial displacement or complete removal of surface treatment (coir logs, geotubes, vegetation, etc.) or removal of bluff material in the form of a scarp, which is an almost vertical slope caused by erosion.

8. Conclusion

The North Haven peninsula is home to residential, commercial, and public areas that are located along the coastal shoreline. The shoreline is a dynamic geological feature which is constantly accreting sediment in some locations and eroding sediment in others. Currently, a variety of locations are beginning to erode, and others are already considered critically eroded. As such, the Village of North Haven is trying to better understand the associated coastal processes that impact the shore as well as solutions that may be employed to mitigate erosion in the future. **RACE** completed Phase 1: Shoreline Condition Assessment, and Phase 2: Coastal Analysis, to better understand the existing condition of the North Haven shoreline and its interaction with the local wave climate.

RACE began the shoreline condition assessment by reviewing and extracting relevant information from previously written reports which were provided to the Village regarding shoreline condition, proposed dock placement and mitigation alternatives. Once complete, a **RACE** field team documented the existing conditions along the shoreline. The shoreline type, existing structures, and shoreline condition were observed and recorded. The shoreline of the peninsula varies between low to high bluffs, vegetated marshlands, and cobble/sandy beaches. A majority of the shoreline is in good condition, however there are locations that have been subject to erosion and are either steadily eroding or have been critically eroded. Some property owners have attempted to address the erosion by constructing hard and soft shoreline stabilization measures. Some of these measures have been successful at stabilizing the bluffs while others have failed and erosion continues.

RACE performed a coastal analysis of the shoreline to understand the varying characteristics of the dynamic shoreline. Seven representative stretches of shoreline with varying wave climates were determined based on orientation and fetch length. A wave climate was not calculated for the southern shoreline due to its protective location and limited fetch across Sag Harbor Cove. The wave climate around the peninsula varies depending on the amount of exposure. For instance, the northwestern portion of the shoreline has a high wave climate when compared to the low wave climate along the northern portion of the shoreline. **RACE** prepared SBEACH models to predict erosion from the "50-year" storm for each stretch of shoreline. To protect the shoreline during normal cyclic events as well as significant storm events, a series of hard and soft solutions have been presented and design conditions recommended. Specifically, for the North Haven peninsula, RACE has presented three design recommendations for portions of the shoreline that differ in geological composition and wave climate. However, recommendations must be evaluated in coordination with the existing condition and structures that are present along the shoreline.

Shoreline stabilization measures are dependent upon the geological composition, condition of the existing shoreline, and the wave climate impacting the site. Hard solutions are constructed with durable materials that can be designed to withstand significant storm events. They can be constructed along shorelines that experience a high wave energy and low wave energy climates. However, the design of hard solutions rarely incorporates features which benefit the natural environment. As such, soft solutions are used to integrate shoreline protection with environment enhancement. Since they are comprised of natural materials, soft solutions are recommended to be constructed along shorelines with a low wave energy climate. To provide the protection needed for high wave energy climates while also benefiting the environment, hybrid structural solutions can be designed and implemented. These solutions combine the hard design components which are durable during storm events and integrate them with soft design components which benefit the environment. Solutions which are comprised of soft components must be frequently monitored to better understand how the solution is integrating with the environment and if replenishment or maintenance is needed. If continued maintenance is required for soft solutions, one such solution may not be adequate for that site and structural solutions should be considered. Structural solutions should be considered as a valid approach in high wave energy areas as well as when there is a threat to life and/or infrastructure.

9. References

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APPENDIX A

Existing Shoreline Condition Drawings and Associated Photographs

GENERAL NOTES

1. PROPERTY LINES AND BASE MAPPING HAS BEEN TAKEN FROM SUFFOLK COUNTY GIS - LAND USE -2016.
2. SUPPLEMENTAL SITE INFORMATION WAS OBTAINED BY RACE COASTAL ENGINEERING, PC ON 08/06/2020. THE SUPPLEMENTAL SITE DATA CAN ONLY REPRESENT THE CONDITIONS AT THAT TIME.
3. THE SIGNIFICANT WAVE HEIGHT FOR A 50-YEAR STORM EVENT WAS CALCULATED USING USACE'S AUTOMATED COASTAL ENGINEERING SYSTEM'S (ACES) WIND SPEED & WAVE GROWTH APPLICATION.
4. PROPERTY AREAS THAT ARE FILLED WITH TWO SHORELINE TYPES HAVE BOTH TYPES OF SHORELINE FOUND WITHIN ITS PROPERTY LINE BOUNDARIES.

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Prepared for
VILLAGE OF NORTH HAVEN
335 FERRY ROAD
SAG HARBOR, NY 11963

Project
COMPREHENSIVE SHORELINE MANAGEMENT PLAN
VILLAGE OF NORTH HAVEN, NY

Drawing
EXISTING SHORELINE TYPE

Designed	Drawn	Checked
HNS	HNS	ADS
Job No. 2020061	Date 09/16/2020	Drawing No. 1 of 3

EXISTING STRUCTURE TYPE

- REVETMENT (11, 12)
- BULKHEAD (13, 14)
- LIVING SHORELINE (15, 16)
- NATURALLY VEGETATED (17, 18)
- OTHER (19, 20)

* NUMBERS CORRESPOND TO SITE PHOTOGRAPHS SHOWN ON ASSOCIATED SHEET

SIGNIFICANT WAVE HEIGHT (FEET) 50-YEAR STORM CONDITIONS

- < 2.5
- 2.5 - 3.5
- 3.5 - 4.5
- 4.5 - 5.5
- 5.5 <

GENERAL NOTES

1. PROPERTY LINES AND BASE MAPPING HAS BEEN TAKEN FROM SUFFOLK COUNTY GIS - LAND USE -2016.
2. SUPPLEMENTAL SITE INFORMATION WAS OBTAINED BY RACE COASTAL ENGINEERING, PC ON 08/06/2020. THE SUPPLEMENTAL SITE DATA CAN ONLY REPRESENT THE CONDITIONS AT THAT TIME.
3. THE SIGNIFICANT WAVE HEIGHT FOR A 50-YEAR STORM EVENT WAS CALCULATED USING USACE'S AUTOMATED COASTAL ENGINEERING SYSTEM'S (ACES) WIND SPEED & WAVE GROWTH APPLICATION.

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Project

COMPREHENSIVE SHORELINE MANAGEMENT PLAN
VILLAGE OF NORTH HAVEN, NY

Drawing

EXISTING STRUCTURE TYPE

Designed	Drawn	Checked
HNS	HNS	ADS
Job No. 2020061	Date 09/16/2020	Drawing No. 2 of 3

EXISTING STRUCTURE TYPE

SCALE: 1" = 500'–0"

EXISTING SHORELINE CONDITION

- GOOD (21, 22)
- FAIR (23, 24)
- ERODED (25, 26)
- CRITICAL (27, 28)

* NUMBERS CORRESPOND TO SITE PHOTOGRAPHS SHOWN ON ASSOCIATED SHEET

SIGNIFICANT WAVE HEIGHT (FEET) 50-YEAR STORM CONDITIONS

- < 2.5
- 2.5 - 3.5
- 3.5 - 4.5
- 4.5 - 5.5
- 5.5 <

GENERAL NOTES

1. PROPERTY LINES AND BASE MAPPING HAS BEEN TAKEN FROM SUFFOLK COUNTY GIS - LAND USE -2016.
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3. THE SIGNIFICANT WAVE HEIGHT FOR A 50-YEAR STORM EVENT WAS CALCULATED USING USACE'S AUTOMATED COASTAL ENGINEERING SYSTEM'S (ACES) WIND SPEED & WAVE GROWTH APPLICATION.

EXISTING SHORELINE CONDITION

SCALE: 1" = 500'–0"

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VILLAGE OF NORTH HAVEN, NY

Drawing

EXISTING SHORELINE CONDITION

Designed	Drawn	Checked
HNS	HNS	ADS
Job No. 2020061	**Date** 09/16/2020	**Drawing No.** 3 of 3

Photograph 1: High Bluff - Shoreline Type (Sheet 1 of 3)

Photograph 2: High Bluff - Shoreline Type (Sheet 1 of 3)

Photograph 3: Low Bluff - Shoreline Type (Sheet 1 of 3)

Photograph 4: Low Bluff - Shoreline Type (Sheet 1 of 3)

Photograph 5: Beach - Shoreline Type (Sheet 1 of 3)

Photograph 6: Beach - Shoreline Type (Sheet 1 of 3)

Photograph 7: Vegetated Marsh - Shoreline Type (Sheet 1 of 3)

Photograph 8: Vegetated Marsh - Shoreline Type (Sheet 1 of 3)

Photograph 9: Other (Water Against Bulkhead) - Shoreline Type (Sheet 1 of 3)

Photograph 10: Other (Water Against Seawall) - Shoreline Type (Sheet 1 of 3)

Photograph 11: Rock Revetment - Structure Type (Sheet 2 of 3)

Photograph 12: Rock Revetment - Structure Type (Sheet 2 of 3)

Photograph 13: Bulkhead - Structure Type (Sheet 2 of 3)

Photograph 14: Bulkhead - Structure Type (Sheet 2 of 3)

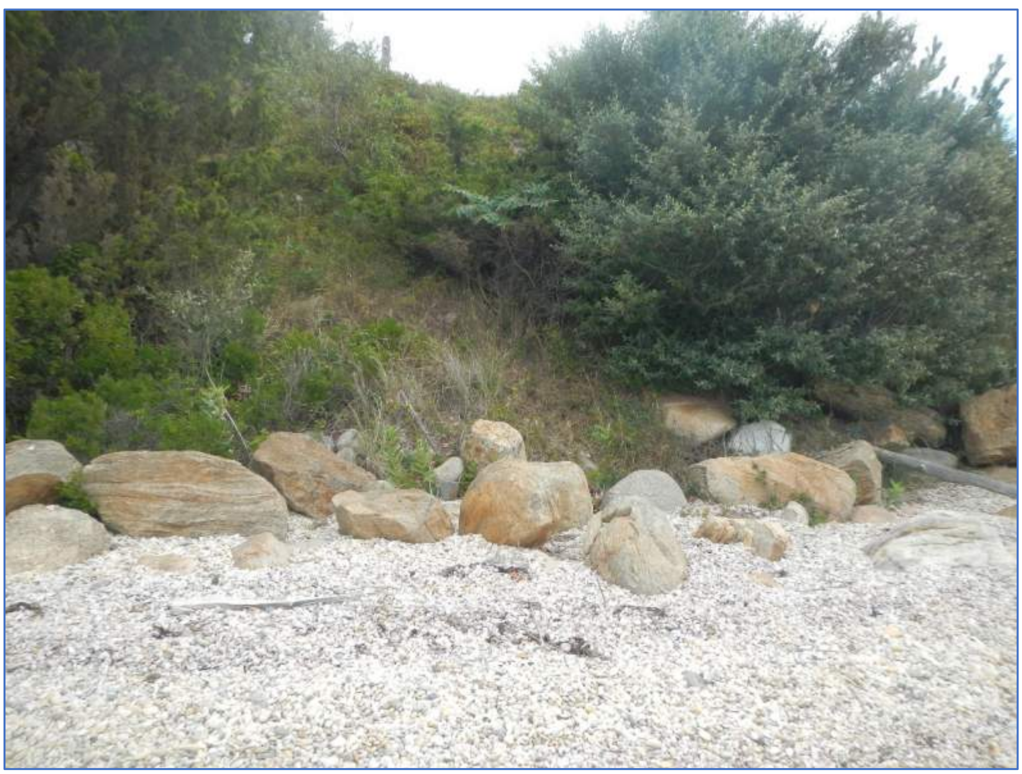
Photograph 15: Living Shoreline - Structure Type (Sheet 2 of 3)

Photograph 16: Living Shoreline - Structure Type (Sheet 2 of 3)

Photograph 17: Naturally Vegetated - Structure Type (Sheet 2 of 3)

Photograph 18: Naturally Vegetated - Structure Type (Sheet 2 of 3)

Photograph 19: Other (Random Rip Rap) - Structure Type (Sheet 2 of 3)



Photograph 20: Other (Random Rip Rap) - Structure Type (Sheet 2 of 3)

Photograph 21: Good – Shoreline Condition (Sheet 3 of 3)

Photograph 22: Good – Shoreline Condition (Sheet 3 of 3)

Photograph 23: Fair – Shoreline Condition (Sheet 3 of 3)

Photograph 24: Fair – Shoreline Condition (Sheet 3 of 3)

Photograph 25: Eroded – Shoreline Condition (Sheet 3 of 3)

Photograph 26: Eroded – Shoreline Condition (Sheet 3 of 3)

Photograph 27: Critical – Shoreline Condition (Sheet 3 of 3)

Photograph 28: Critical – Shoreline Condition (Sheet 3 of 3)

APPENDIX B

Synthetic Storm Inputs
Coastal Modeling

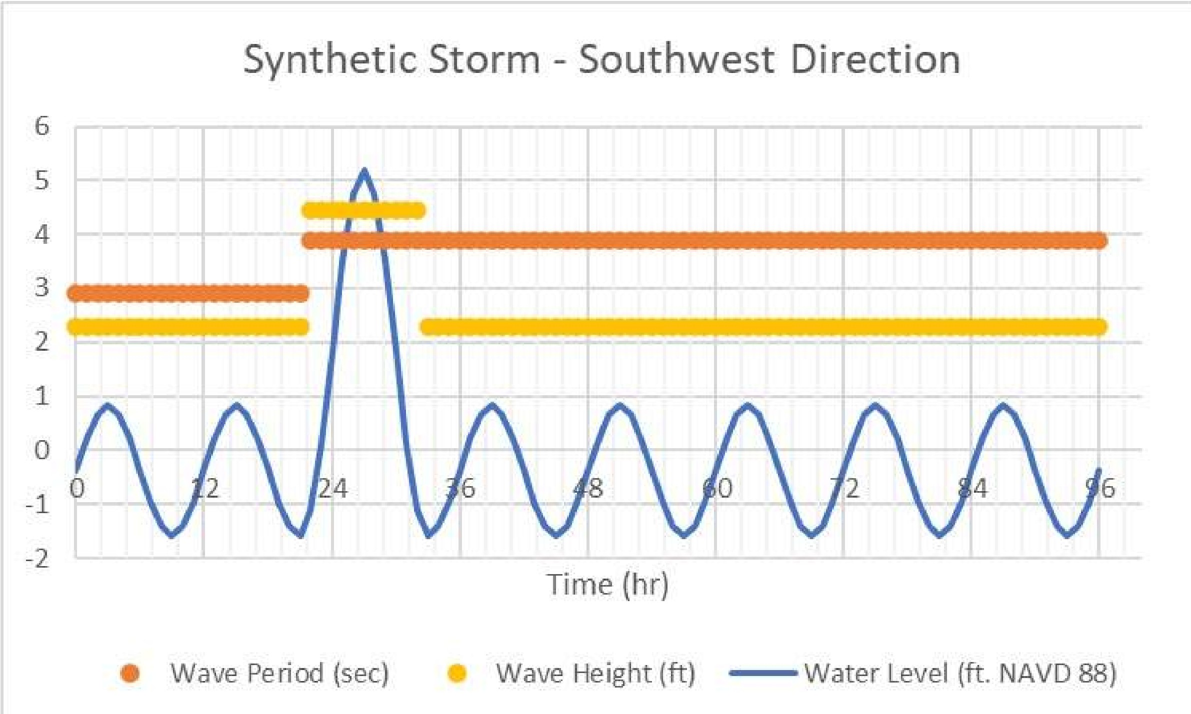


Figure 1: 50-year Synthetic Storm Input – Southwest Direction

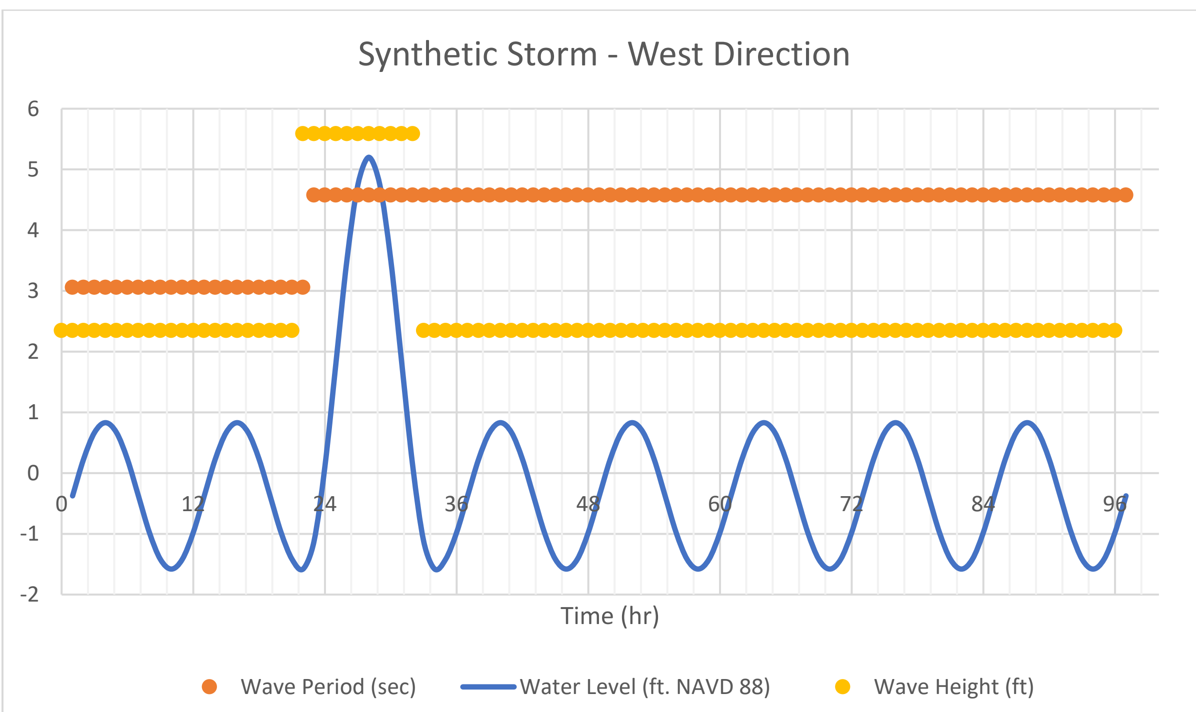


Figure 2: 50-year Synthetic Storm Input – West Direction

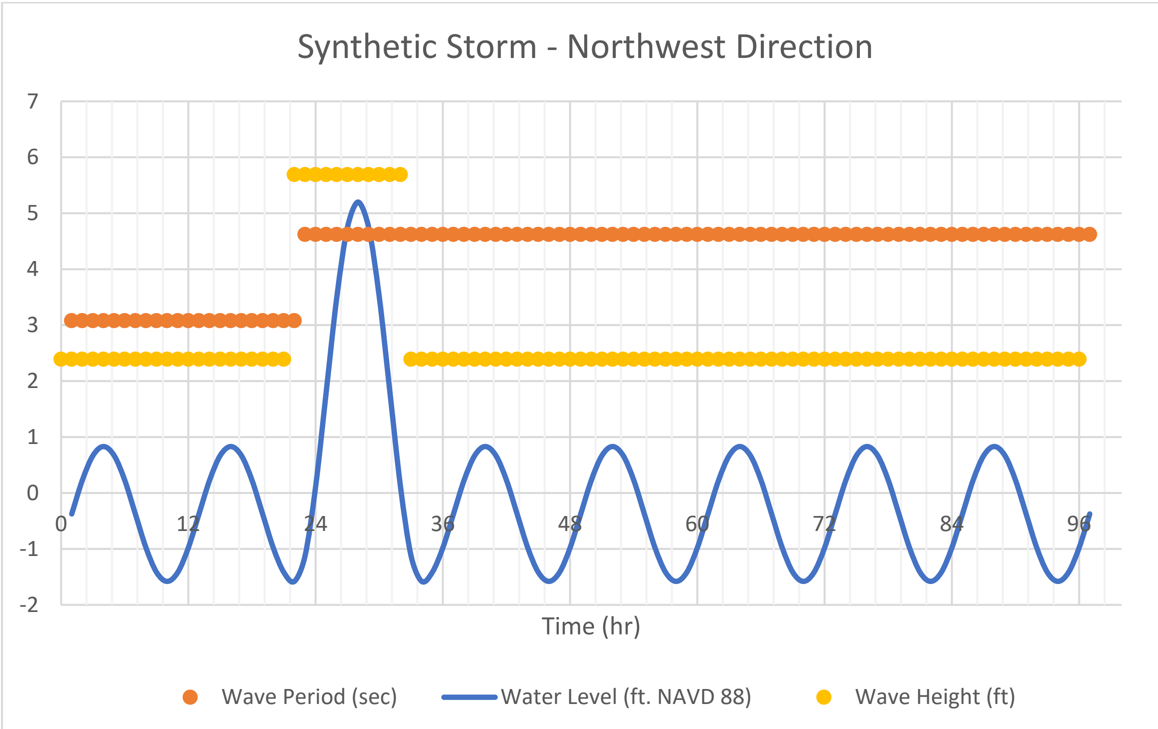


Figure 3: 50-year Synthetic Storm Input – Northwest Direction

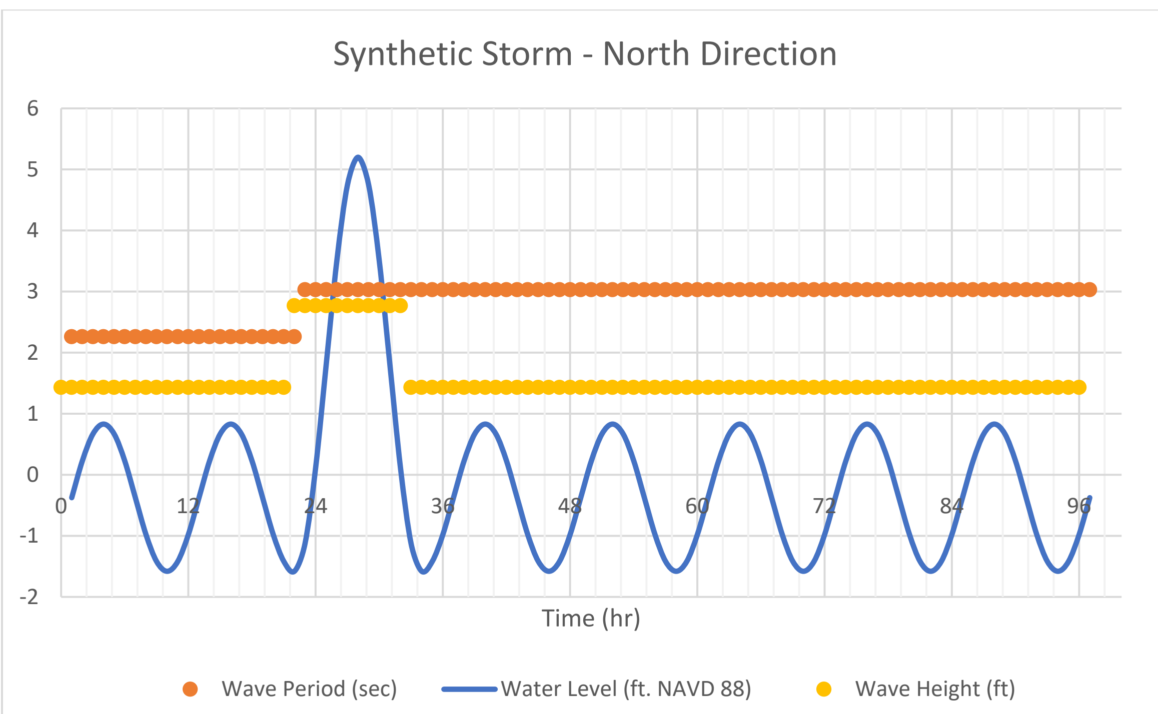


Figure 4: 50-year Synthetic Storm Input – North Direction

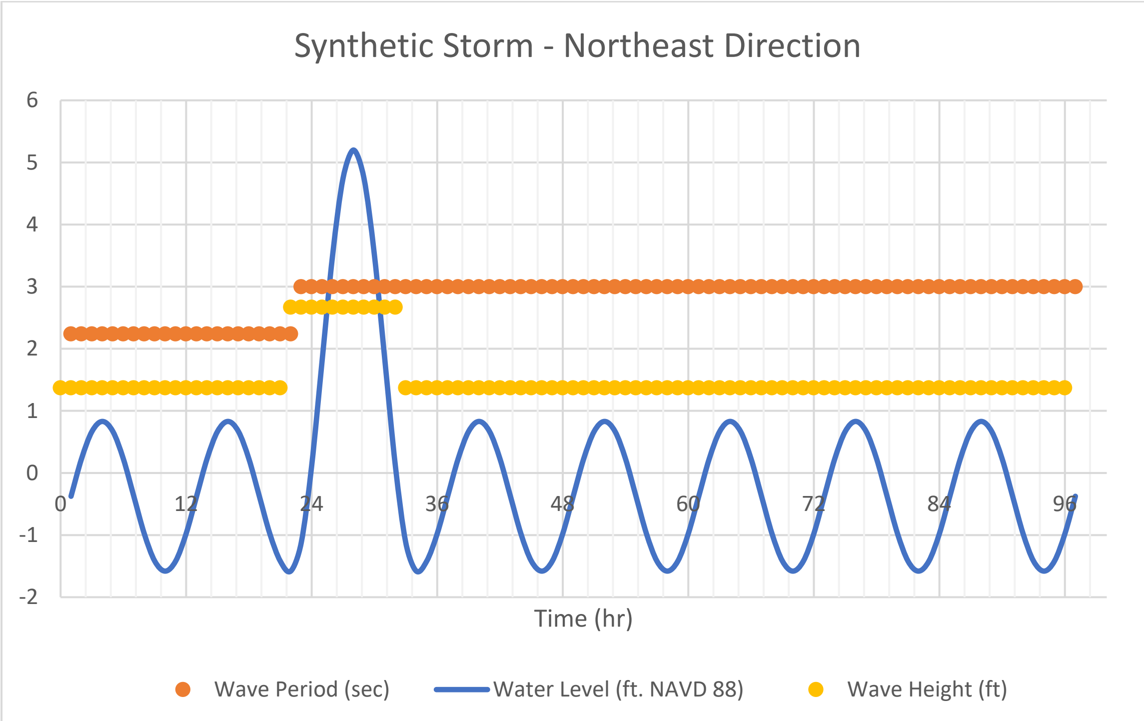


Figure 5: 50-year Synthetic Storm Input – Northeast Direction

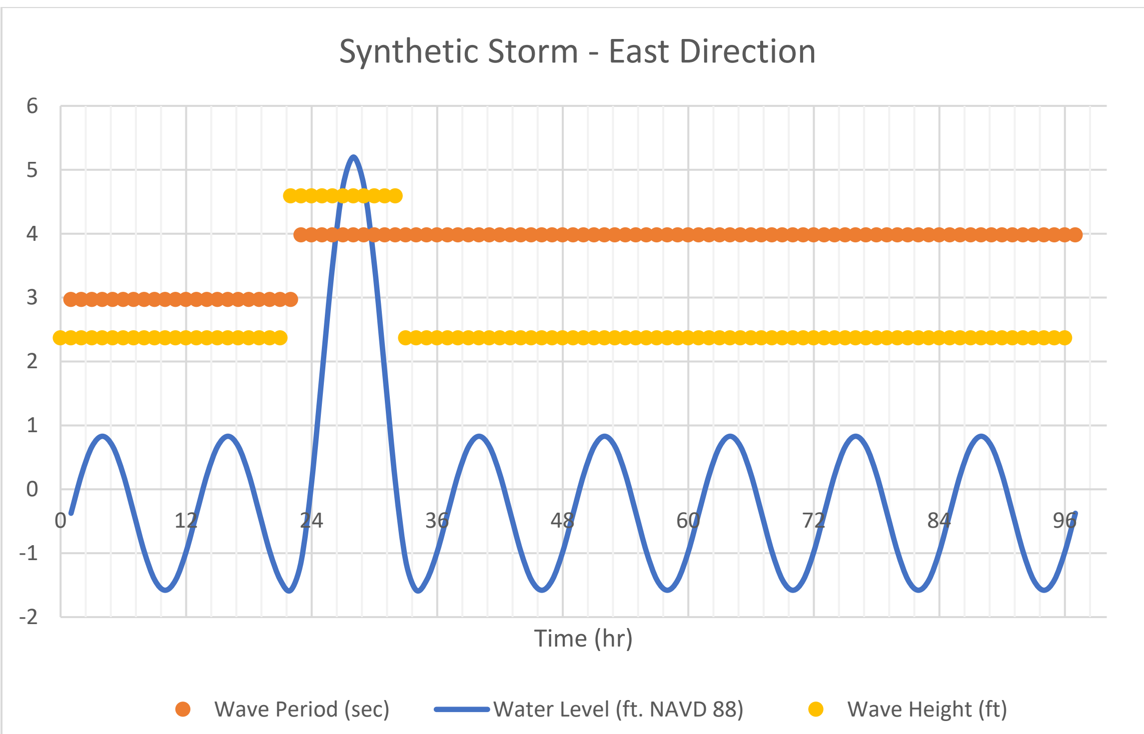


Figure 6: 50-year Synthetic Storm Input – East Direction

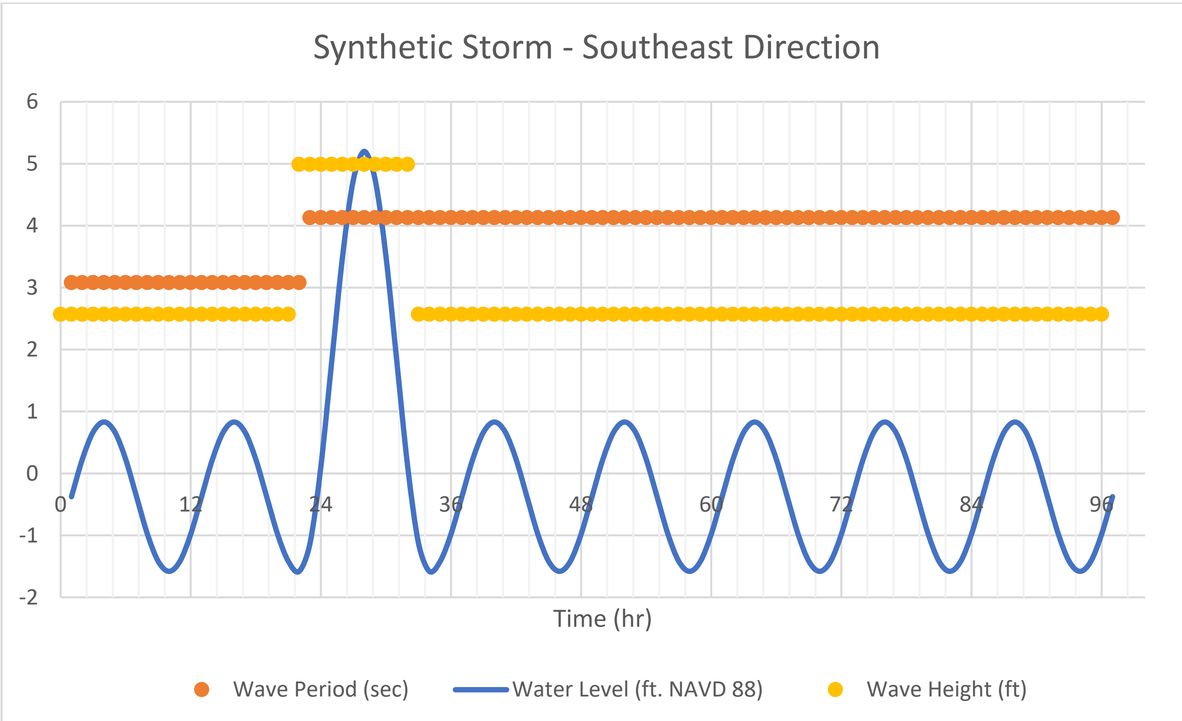


Figure 7: 50-year Synthetic Storm Input – Southeast Direction

APPENDIX C

SBEACH Outputs
Coastal Modeling

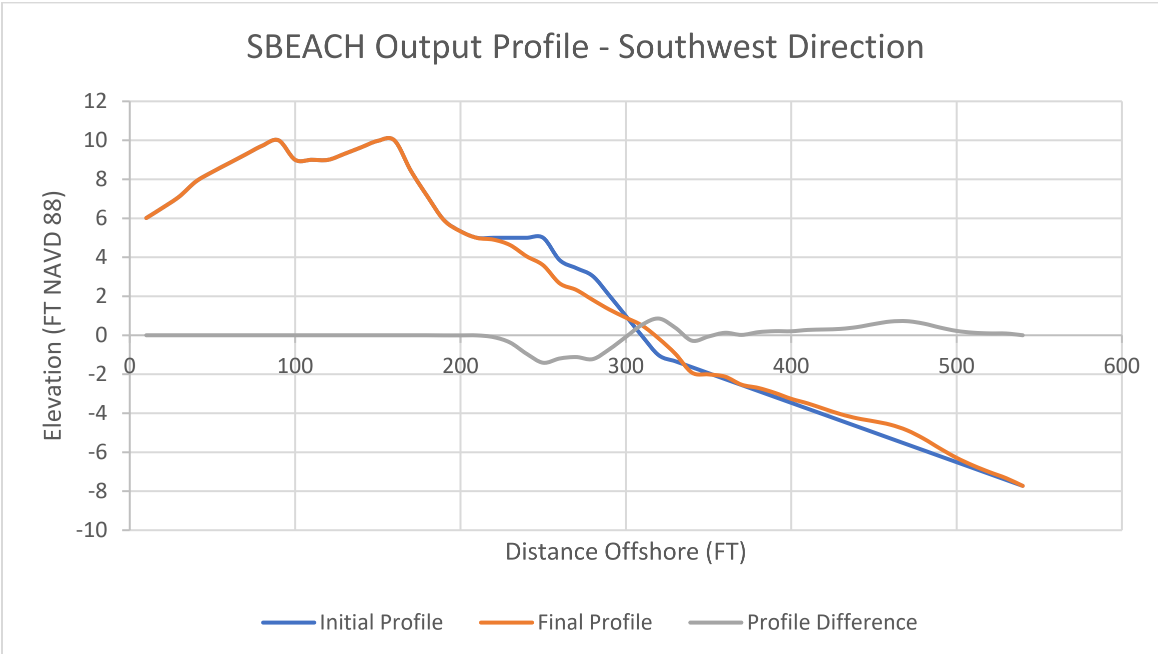


Figure 1: 50-year SBEACH Output – Initial vs. Final Profiles – Southwest Direction

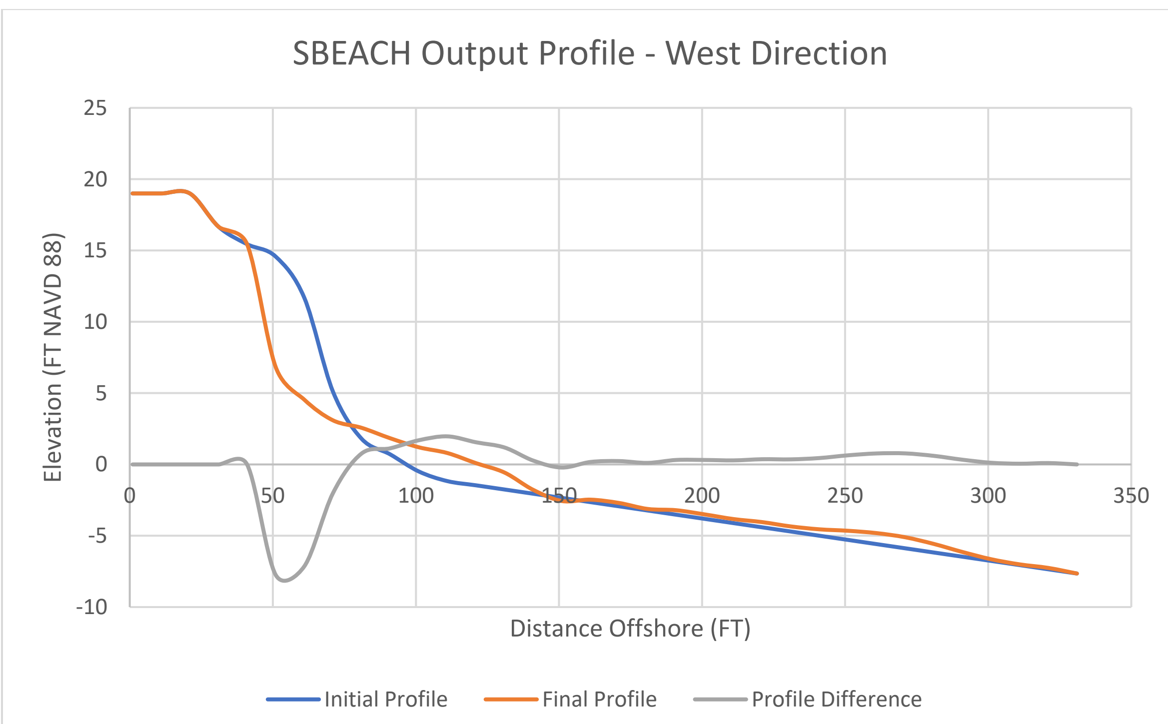


Figure 2: 50-year SBEACH Output – Initial vs. Final Profiles – West Direction

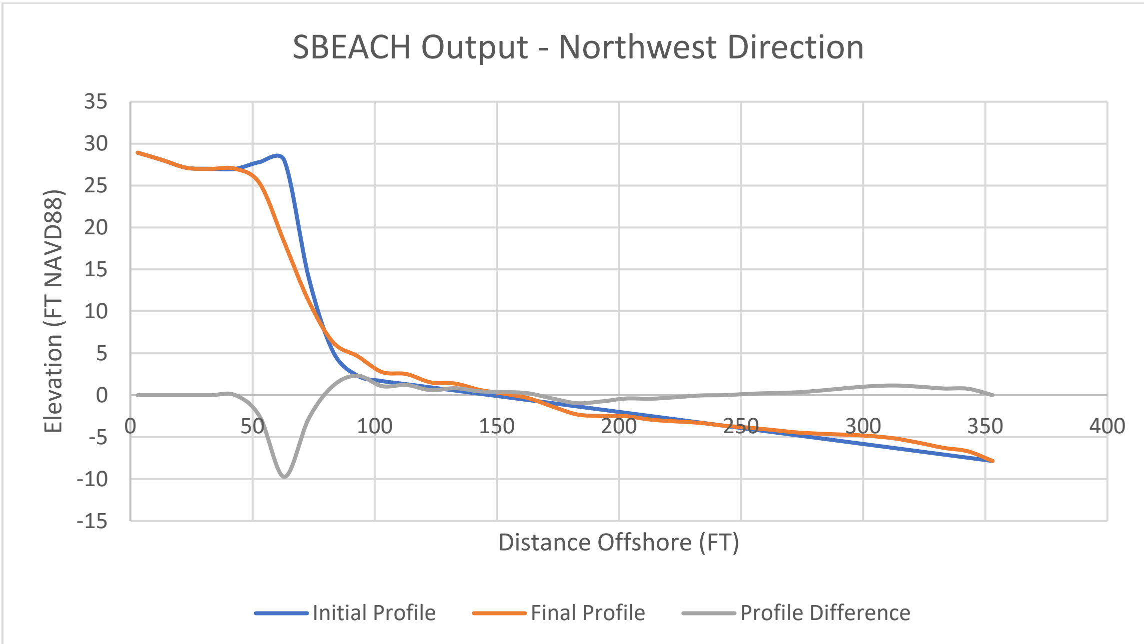


Figure 3: 50-year SBEACH Output – Initial vs. Final Profiles – Northwest Direction

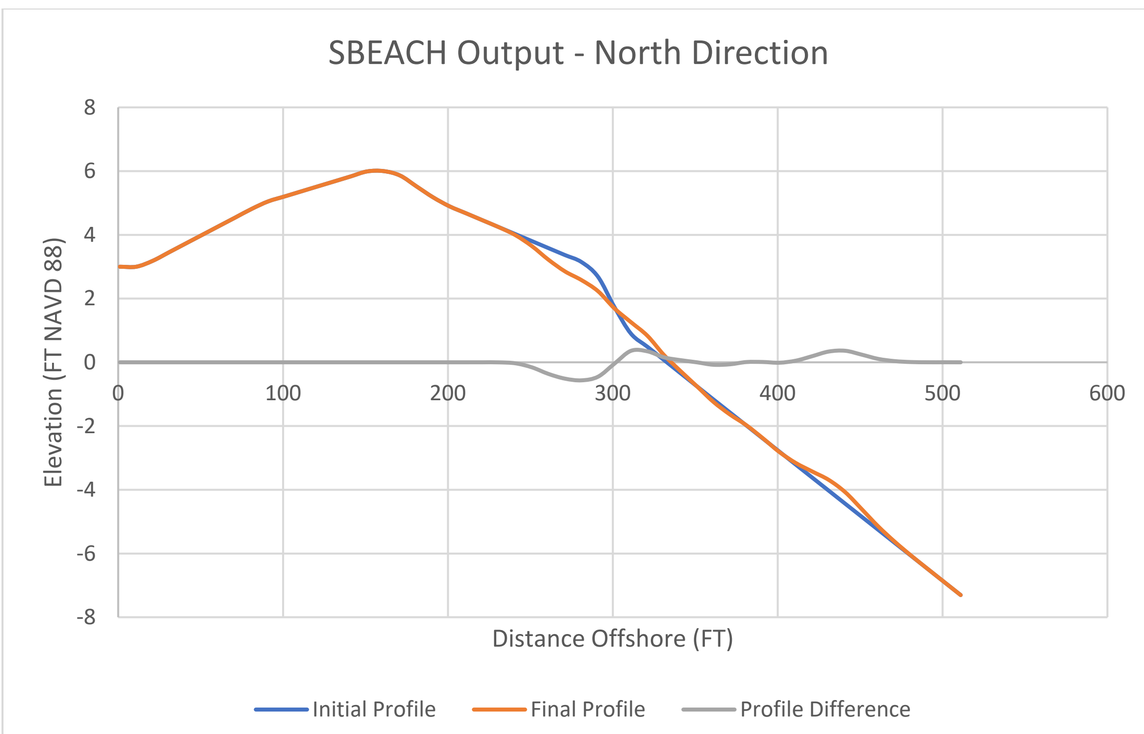


Figure 4: 50-year SBEACH Output – Initial vs. Final Profiles – North Direction

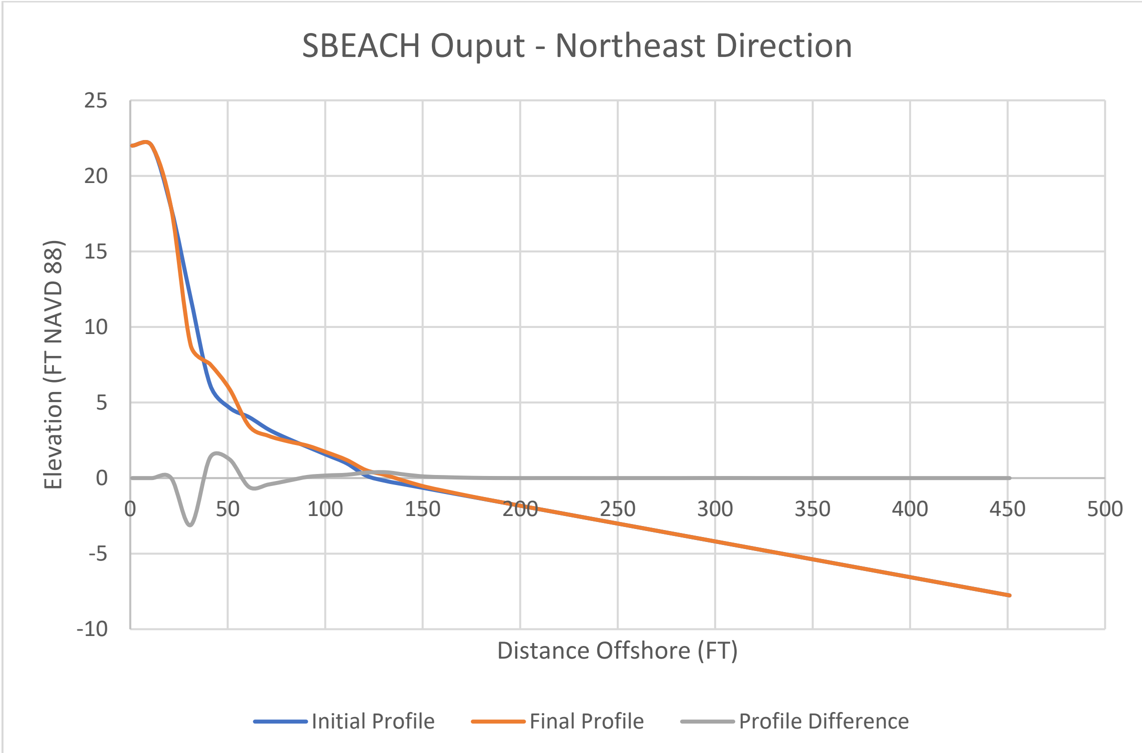


Figure 5: 50-year SBEACH Output – Initial vs. Final Profiles – Northeast Direction

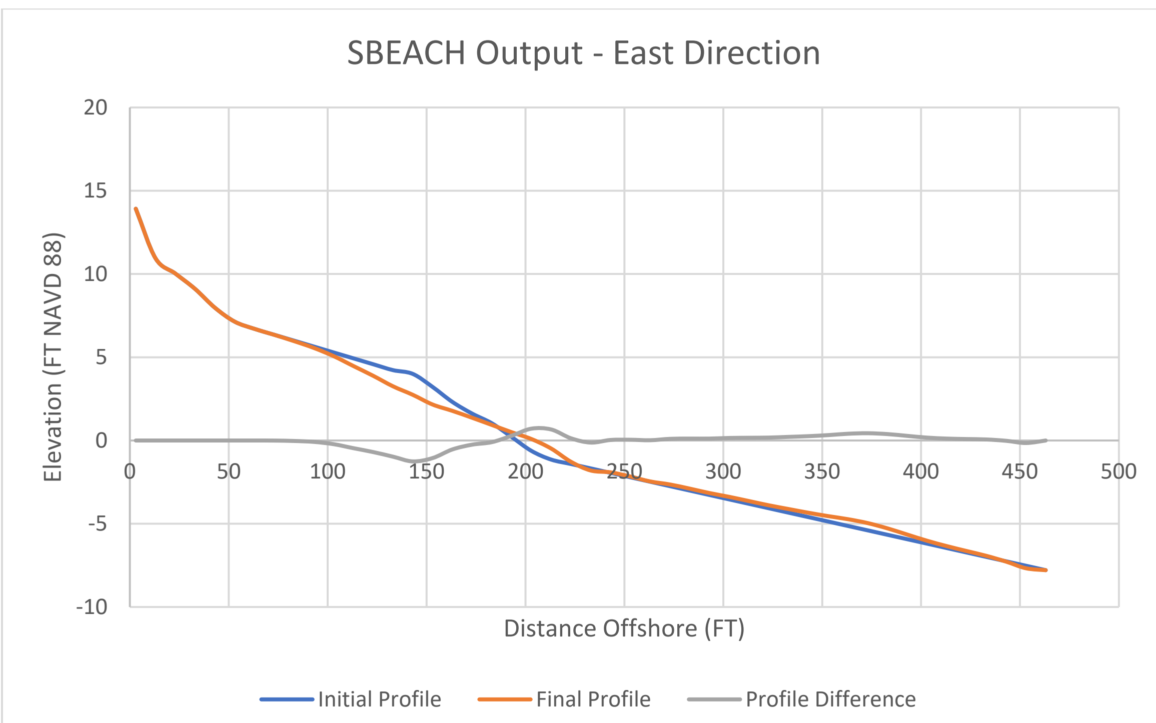


Figure 6: 50-year SBEACH Output – Initial vs. Final Profiles – East Direction

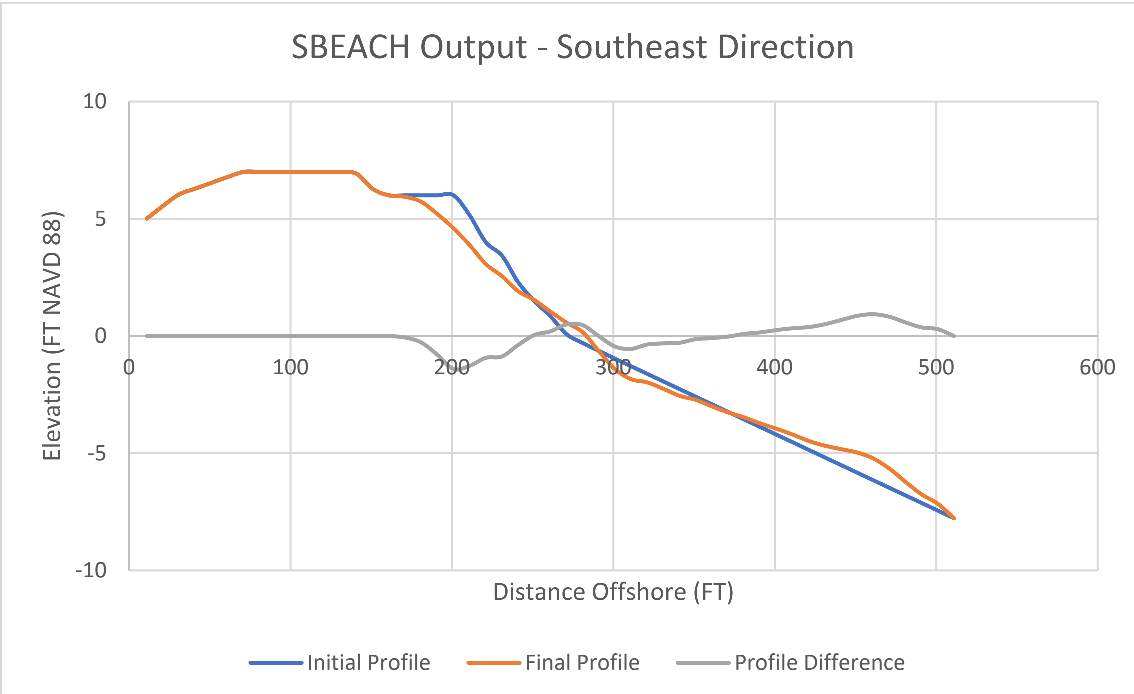
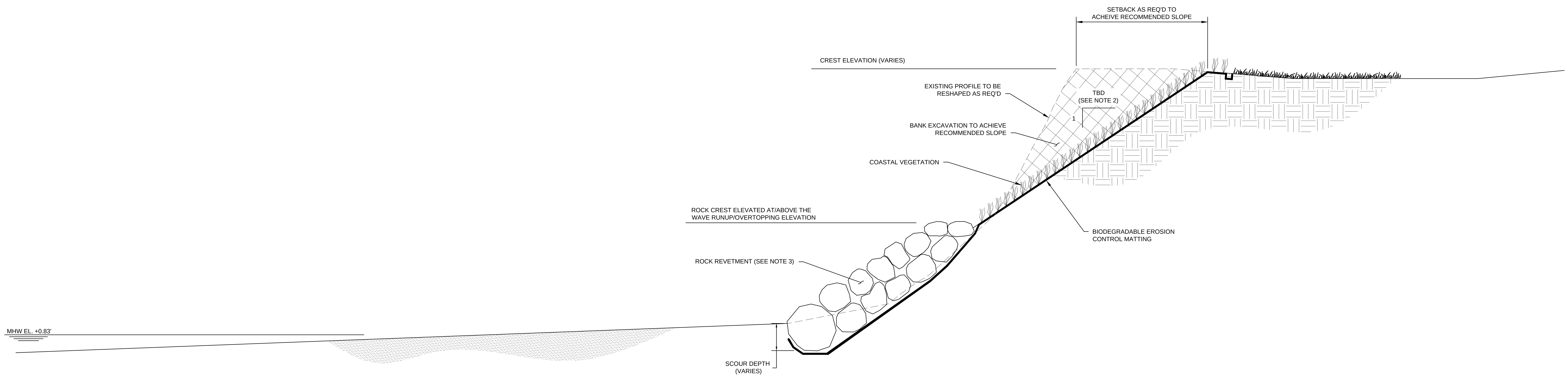


Figure 7: 50-year SBEACH Output – Initial vs. Final Profiles – Southeast Direction

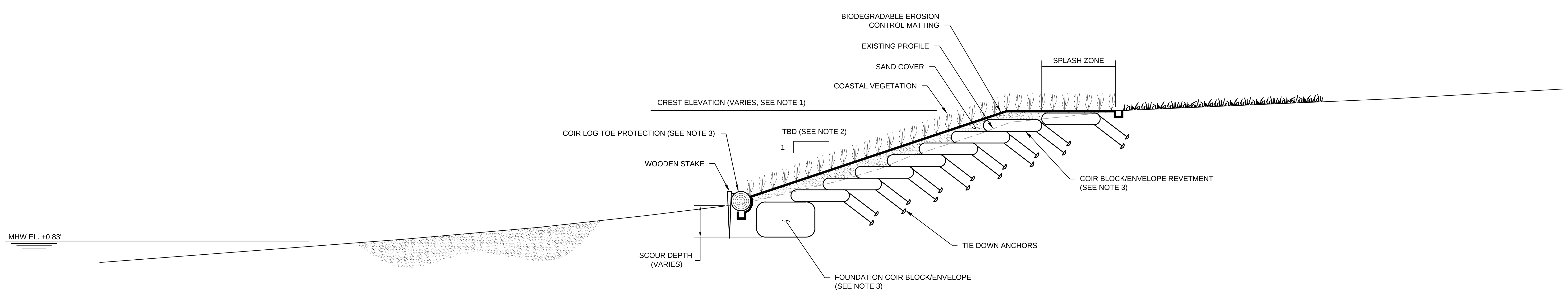
APPENDIX D

Recommended Typical Design Concepts



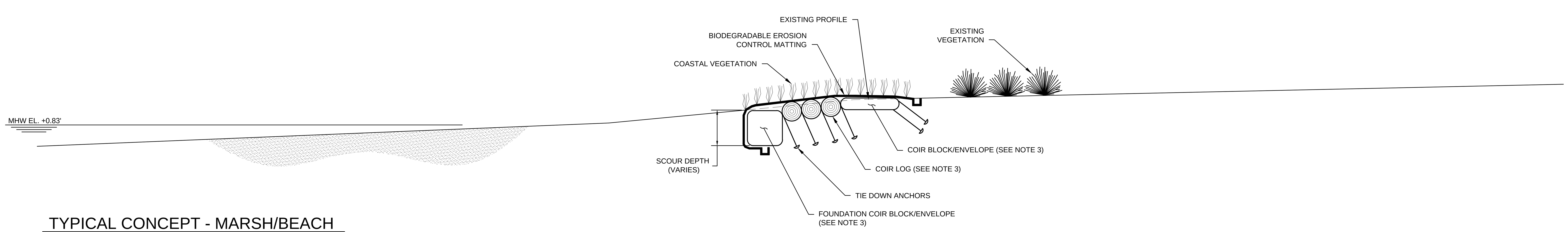
TYPICAL CONCEPT - HIGH BLUFF

SCALE: 1" = 5'-0"



TYPICAL CONCEPT - LOW BLUFF

SCALE: 1" = 5'-0"



TYPICAL CONCEPT - MARSH/BEACH

SCALE: 1" = 5'-0"

NOTE:

1. CREST ELEVATION OF STRUCTURE SHALL BE CONSTRUCTED AT/ABOVE THE WAVE RUNUP/OVERTOPPING ELEVATION OR CONSTRUCTED TO THE NATURAL CREST ELEVATION, WHICHEVER IS LOWER.
2. MAX SLOPE 1V:1.5H OR SHALLOWER.
3. DIMENSIONS DEPEND ON LOCATION & WAVE CLIMATE ANALYZED DURING COASTAL ENGINEERING ANALYSIS.
4. MEAN LOW WATER BEYOND EXTENT OF DRAWING.

REV	DATE	DESCRIPTION

NOT FOR CONSTRUCTION

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MANAGEMENT PLAN
VILLAGE OF NORTH HAVEN, NY

Drawing

RECOMMENDED TYPICAL
DESIGN CONCEPTS

Designed	Drawn	Checked
HNS	HNS	ADS

Job No.	Date	Drawing No.
2020061	12/04/2020	1 of 1

NOT VALID WITHOUT ENGINEER'S SEAL